

FEATURES

Low offset: 2.5 μ V maximum

Low offset voltage drift: 0.015 μ V/ $^{\circ}$ C maximum

Low noise

5.6 nV/ $\sqrt{\text{Hz}}$ at $f = 1$ kHz, $A_v = +100$

97 nV p-p at $f = 0.1$ Hz to 10 Hz, $A_v = +100$

Open-loop voltage gain: 130 dB minimum

CMRR: 135 dB minimum

PSRR: 130 dB minimum

Gain bandwidth product: 4 MHz

Single-supply operation: 2.2 V to 5.5 V

Dual-supply operation: ± 1.1 V to ± 2.75 V

Rail-to-rail input and output

Unity-gain stable

APPLICATIONS

Thermocouple/thermopile

Load cell and bridge transducer

Precision instrumentation

Electronic scales

Medical instrumentation

Handheld test equipment

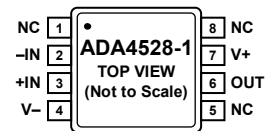
GENERAL DESCRIPTION

The ADA4528-1 is an ultralow noise, zero-drift operational amplifier featuring rail-to-rail input and output swing. With an offset voltage of 2.5 μ V, offset voltage drift of 0.015 μ V/ $^{\circ}$ C, and noise of 97 nV p-p (0.1 Hz to 10 Hz, $A_v = +100$), the ADA4528-1 is well suited for applications in which error sources cannot be tolerated.

The ADA4528-1 has a wide operating supply range of 2.2 V to 5.5 V, high gain, and excellent CMRR and PSRR specifications that make it ideal for precision amplification of low level signals, such as position and pressure sensors, strain gages, and medical instrumentation.

The ADA4528-1 is specified over the extended industrial temperature range (-40° C to $+125^{\circ}$ C) and is available in an 8-lead MSOP package.

PIN CONFIGURATION



NC = NO CONNECT. DO NOT CONNECT TO THIS PIN.

Figure 1. 8-Lead MSOP

08457-001

Table 1. Analog Devices, Inc., Zero-Drift Op Amp Portfolio¹

Type	Ultralow Noise	Micropower (<20 μ A)	Low Power (<1 mA)	16 V Operating Voltage
Single	ADA4528-1	ADA4051-1	AD8628 AD8538	AD8638
Dual		ADA4051-2	AD8629 AD8539	AD8639
Quad			AD8630	

¹ See www.analog.com for a selection of zero-drift operational amplifiers.

Rev. 0

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	ESD Caution.....	5
Applications.....	1	Typical Performance Characteristics	6
Pin Configuration.....	1	Applications Information	15
General Description	1	Input Protection	15
Revision History	2	Rail-to-Rail Input and Output.....	15
Specifications.....	3	Noise Considerations.....	15
Electrical Characteristics—2.5 V Operation	3	Printed Circuit Board Layout	17
Electrical Characteristics—5 V Operation.....	4	Outline Dimensions	18
Absolute Maximum Ratings.....	5	Ordering Guide	18
Thermal Resistance	5		

REVISION HISTORY

1/11—Revision 0: Initial Version

SPECIFICATIONS

ELECTRICAL CHARACTERISTICS—2.5 V OPERATION

$V_S = 2.5\text{ V}$, $V_{CM} = V_{SY}/2\text{ V}$, $T_A = 25^\circ\text{C}$, unless otherwise specified.

Table 2.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
INPUT CHARACTERISTICS						
Offset Voltage	V_{OS}	$V_{CM} = 0\text{ V to } 2.5\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.3	2.5	μV
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.002	0.015	$\mu\text{V}/^\circ\text{C}$
Input Bias Current	I_B	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		220	400	pA
Input Offset Current	I_{OS}	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			600	pA
Input Voltage Range			0		1	nA
Common-Mode Rejection Ratio	CMRR	$V_{CM} = 0\text{ V to } 2.5\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	135	158	2.5	V
Open-Loop Gain	A_{VO}	$R_L = 10\text{ k}\Omega$, $V_O = 0.1\text{ V to } 2.4\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	116			dB
		$R_L = 2\text{ k}\Omega$, $V_O = 0.1\text{ V to } 2.4\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	130	140		dB
			126			dB
			125	132		dB
			121			dB
Input Resistance, Differential Mode	R_{INDM}			225		k Ω
Input Resistance, Common Mode	R_{INCM}			1		G Ω
Input Capacitance, Differential Mode	C_{INDM}			15		pF
Input Capacitance, Common Mode	C_{INCM}			30		pF
OUTPUT CHARACTERISTICS						
Output Voltage High	V_{OH}	$R_L = 10\text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	2.49	2.495		V
		$R_L = 2\text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	2.485			V
			2.46	2.48		V
			2.44			V
Output Voltage Low	V_{OL}	$R_L = 10\text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		5	10	mV
		$R_L = 2\text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			15	mV
				20	40	mV
					60	mV
Short-Circuit Current	I_{SC}			± 30		mA
Closed-Loop Output Impedance	Z_{OUT}	$f = 1\text{ kHz}$, $A_V = +10$		0.1		Ω
POWER SUPPLY						
Power Supply Rejection Ratio	PSRR	$V_S = 2.2\text{ V to } 5.5\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	130	150		dB
			127			dB
Supply Current/Amplifier	I_{SY}	$I_O = 0\text{ mA}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		1.4	1.7	mA
					2.1	mA
DYNAMIC PERFORMANCE						
Slew Rate	SR	$R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, $A_V = +1$		0.45		V/ μs
Settling Time to 0.1%	t_s	$V_{IN} = 1.5\text{ V step}$, $R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$		7		μs
Gain Bandwidth Product	GBP	$R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, $A_V = +1$		4		MHz
Phase Margin	Φ_M	$R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, $A_V = +1$		57		Degrees
Overload Recovery Time		$R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, $A_V = -10$		50		μs
NOISE PERFORMANCE						
Voltage Noise	e_n p-p	$f = 0.1\text{ Hz to } 10\text{ Hz}$, $A_V = +100$		97		nV p-p
Voltage Noise Density	e_n	$f = 1\text{ kHz}$, $A_V = +100$		5.6		nV/ $\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$, $A_V = +100$, $V_{CM} = 2.0\text{ V}$		5.5		nV/ $\sqrt{\text{Hz}}$
Current Noise	i_n p-p	$f = 0.1\text{ Hz to } 10\text{ Hz}$, $A_V = +100$		2.6		pA p-p
Current Noise Density	i_n	$f = 1\text{ kHz}$, $A_V = +100$		0.7		pA/ $\sqrt{\text{Hz}}$

ADA4528-1

ELECTRICAL CHARACTERISTICS—5 V OPERATION

$V_S = 5\text{ V}$, $V_{CM} = V_{SY}/2\text{ V}$, $T_A = +25^\circ\text{C}$, unless otherwise specified.

Table 3.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
INPUT CHARACTERISTICS						
Offset Voltage	V_{OS}	$V_{CM} = 0\text{ V to }5\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.3	2.5	μV
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.002	0.015	$\mu\text{V}/^\circ\text{C}$
Input Bias Current	I_B	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		90	200	pA
Input Offset Current	I_{OS}	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		180	400	pA
Input Voltage Range			0		5	V
Common-Mode Rejection Ratio	CMRR	$V_{CM} = 0\text{ V to }5\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	137	160		dB
Open-Loop Gain	A_{VO}	$R_L = 10\text{ k}\Omega$, $V_O = 0.1\text{ V to }4.9\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	122	139		dB
		$R_L = 2\text{ k}\Omega$, $V_O = 0.1\text{ V to }4.9\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	125	131		dB
Input Resistance, Differential Mode	R_{INDM}			190		$\text{k}\Omega$
Input Resistance, Common Mode	R_{INCM}			1		$\text{G}\Omega$
Input Capacitance, Differential Mode	C_{INDM}			16.5		pF
Input Capacitance, Common Mode	C_{INCM}			33		pF
OUTPUT CHARACTERISTICS						
Output Voltage High	V_{OH}	$R_L = 10\text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	4.99	4.995		V
		$R_L = 2\text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	4.96	4.98		V
Output Voltage Low	V_{OL}	$R_L = 10\text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		5	10	mV
		$R_L = 2\text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		20	40	mV
Short-Circuit Current	I_{SC}			± 40		mA
Closed-Loop Output Impedance	Z_{OUT}	$f = 1\text{ kHz}$, $A_V = +10$		0.1		Ω
POWER SUPPLY						
Power Supply Rejection Ratio	PSRR	$V_{SY} = 2.2\text{ V to }5.5\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	130	150		dB
Supply Current/Amplifier	I_{SY}	$I_O = 0\text{ mA}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	127	1.5	1.8	mA
					2.2	mA
DYNAMIC PERFORMANCE						
Slew Rate	SR	$R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, $A_V = +1$		0.5		$\text{V}/\mu\text{s}$
Settling Time to 0.1%	t_s	$V_{IN} = 4\text{ V step}$, $R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$		10		μs
Gain Bandwidth Product	GBP	$R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, $A_V = +1$		4		MHz
Phase Margin	Φ_M	$R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, $A_V = +1$		57		Degrees
Overload Recovery Time		$R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, $A_V = -10$		50		μs
NOISE PERFORMANCE						
Voltage Noise	e_n p-p	$f = 0.1\text{ Hz to }10\text{ Hz}$, $A_V = +100$		99		nV p-p
Voltage Noise Density	e_n	$f = 1\text{ kHz}$, $A_V = +100$		5.9		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$, $A_V = +100$, $V_{CM} = 4.5\text{ V}$		5.3		$\text{nV}/\sqrt{\text{Hz}}$
Current Noise	i_n p-p	$f = 0.1\text{ Hz to }10\text{ Hz}$, $A_V = +100$		2.6		pA p-p
Current Noise Density	i_n	$f = 1\text{ kHz}$, $A_V = +100$		0.5		$\text{pA}/\sqrt{\text{Hz}}$

ABSOLUTE MAXIMUM RATINGS

Table 4.

Parameter	Rating
Supply Voltage	6 V
Input Voltage	$\pm V_{SY} \pm 0.3$ V
Input Current ¹	± 10 mA
Differential Input Voltage	$\pm V_{SY}$
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

¹ The input pins have clamp diodes to the power supply pins. Limit the input current to 10 mA or less whenever input signals exceed the power supply rail by 0.5 V.

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

THERMAL RESISTANCE

θ_{JA} is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages. This was measured using a standard 4-layer board.

Table 5. Thermal Resistance

Package Type	θ_{JA}	θ_{JC}	Unit
8-Lead MSOP (RM-8)	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.

TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, unless otherwise noted.

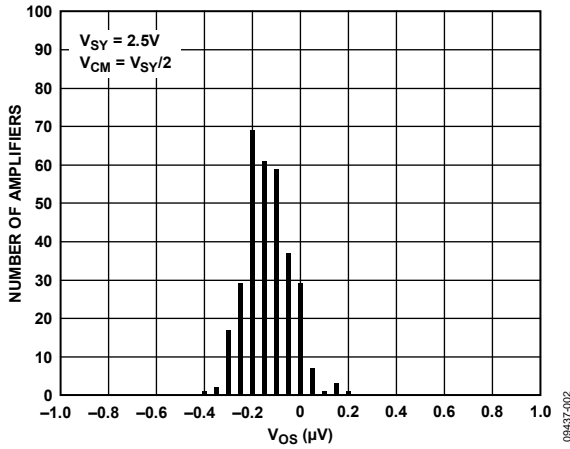


Figure 2. Input Offset Voltage Distribution

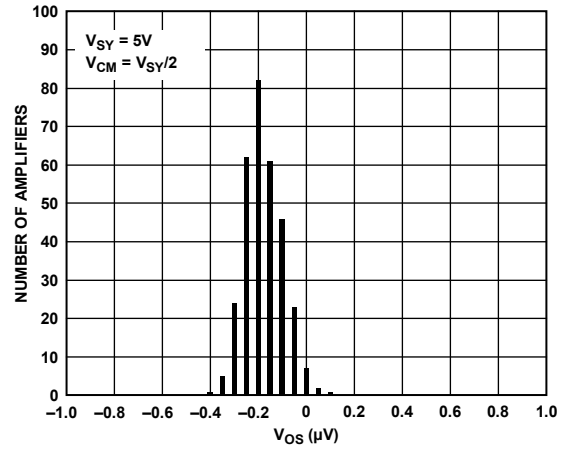


Figure 5. Input Offset Voltage Distribution

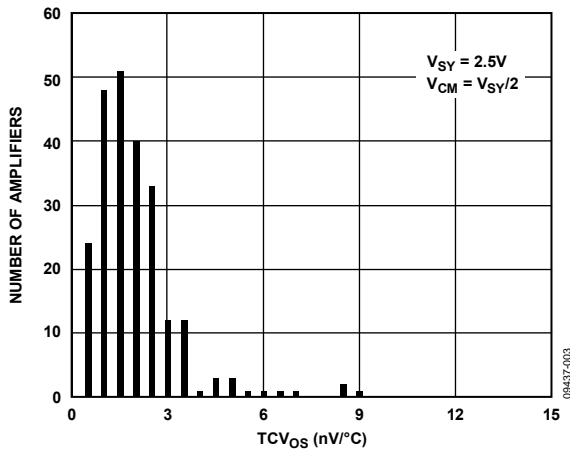


Figure 3. Input Offset Voltage Drift Distribution

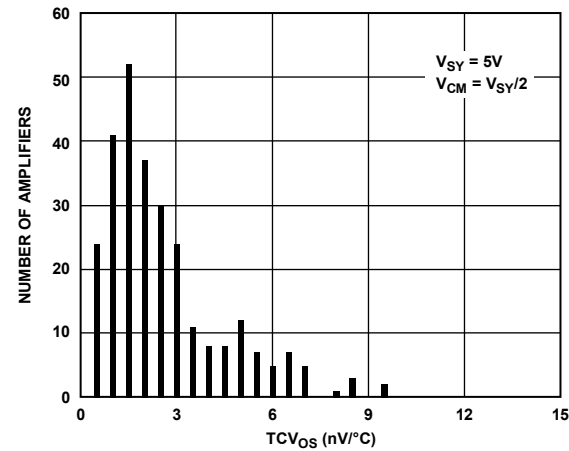


Figure 6. Input Offset Voltage Drift Distribution

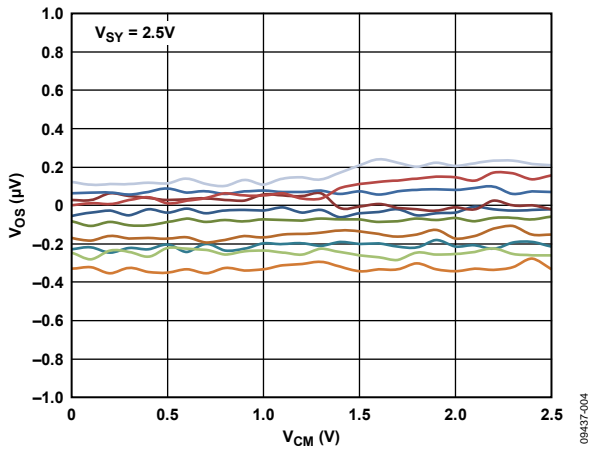


Figure 4. Input Offset Voltage vs. Common-Mode Voltage

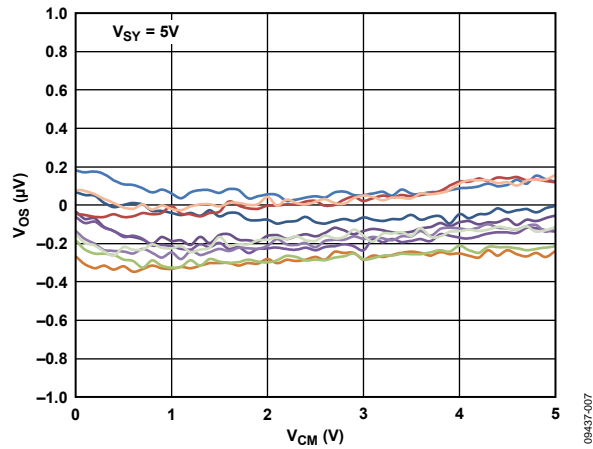


Figure 7. Input Offset Voltage vs. Common-Mode Voltage

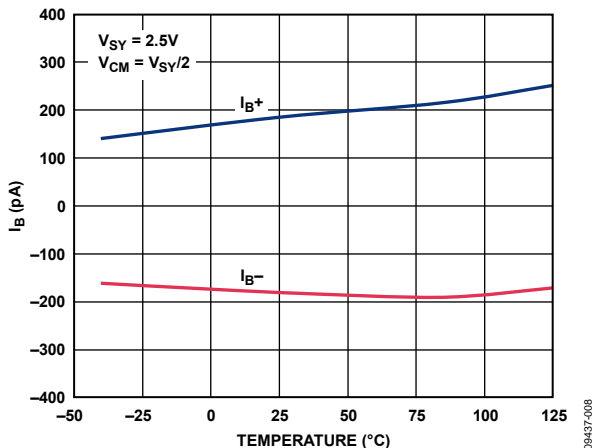


Figure 8. Input Bias Current vs. Temperature

09437-008

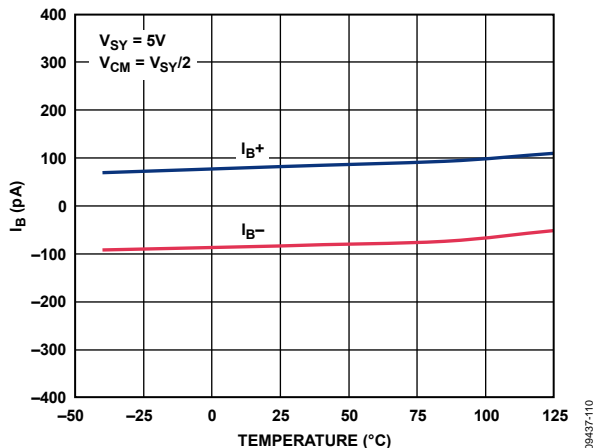


Figure 11. Input Bias Current vs. Temperature

09437-110

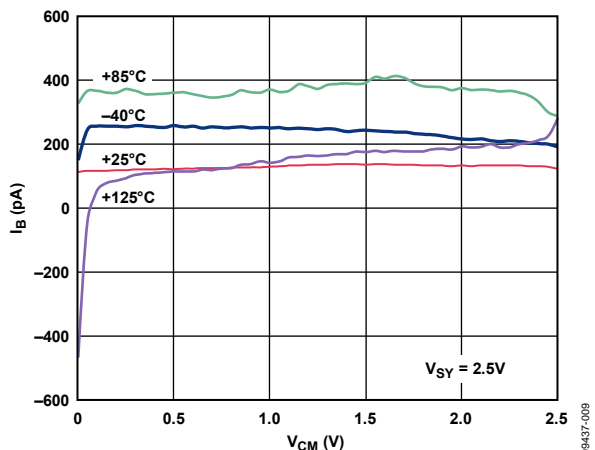


Figure 9. Input Bias Current vs. Common-Mode Voltage

09437-009

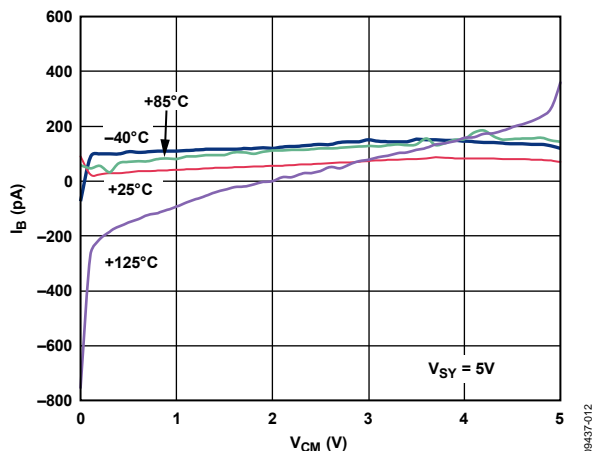


Figure 12. Input Bias Current vs. Common-Mode Voltage

09437-012

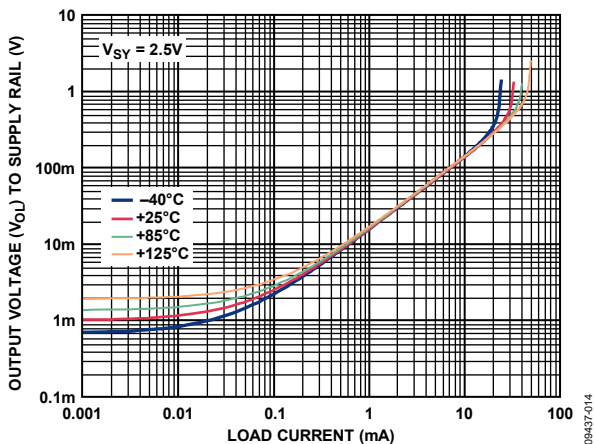


Figure 10. Output Voltage (V_{OU}) to Supply Rail vs. Load Current

09437-014

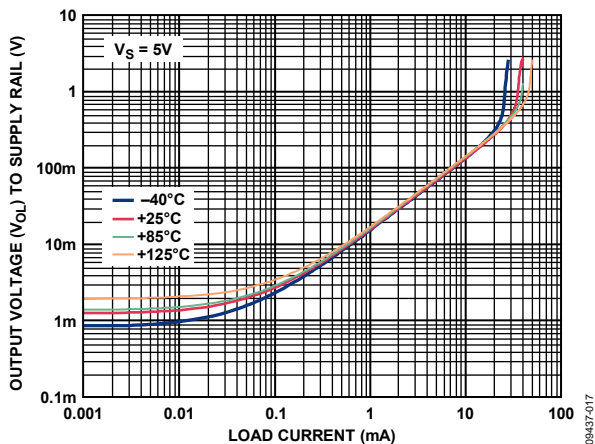


Figure 13. Output Voltage (V_{OU}) to Supply Rail vs. Load Current

09437-017

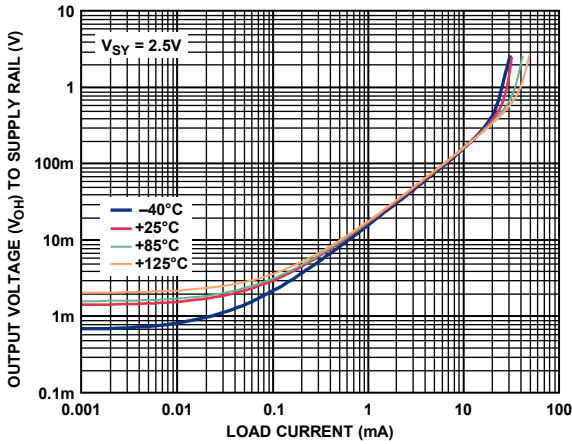


Figure 14. Output Voltage (V_{OH}) to Supply Rail vs. Load Current

09437-010

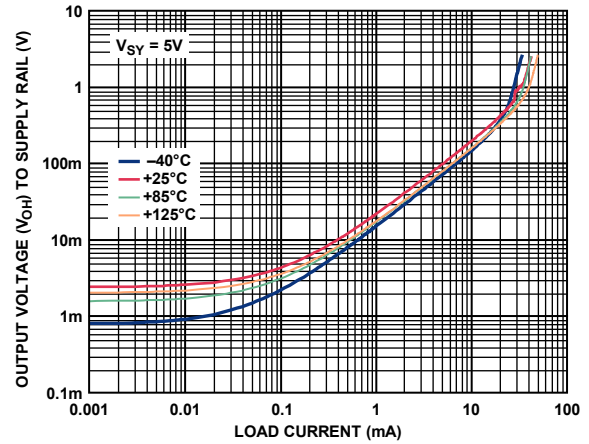


Figure 17. Output Voltage (V_{OH}) to Supply Rail vs. Load Current

09437-013

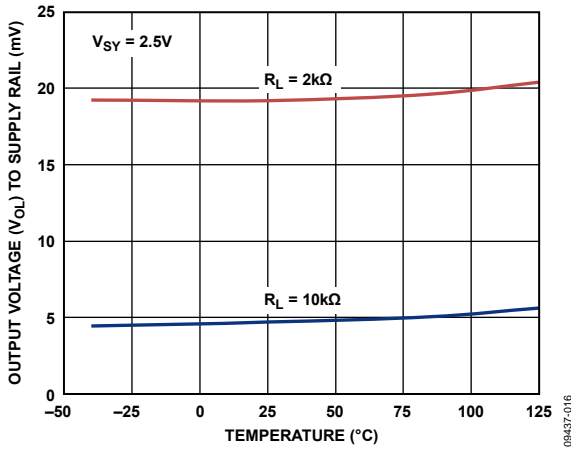


Figure 15. Output Voltage (V_{OH}) to Supply Rail vs. Temperature

09437-016

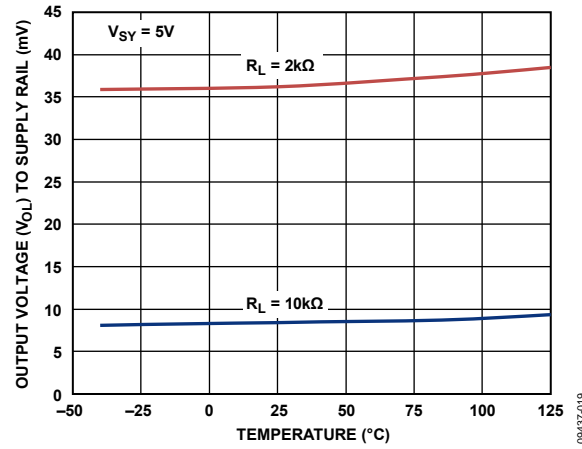


Figure 18. Output Voltage (V_{OH}) to Supply Rail vs. Temperature

09437-019

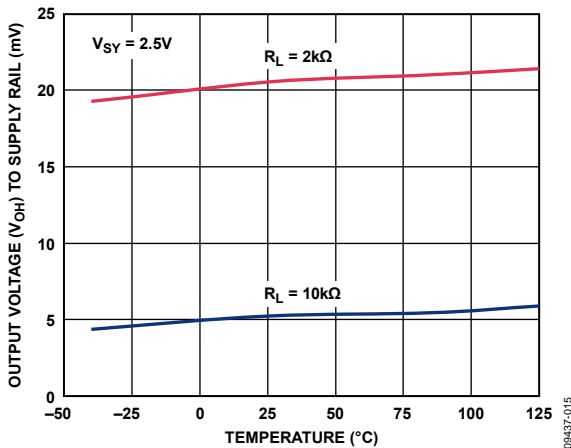


Figure 16. Output Voltage (V_{OH}) to Supply Rail vs. Temperature

09437-015

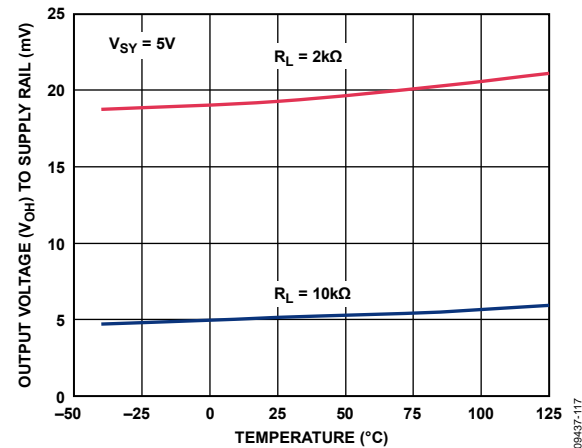


Figure 19. Output Voltage (V_{OH}) to Supply Rail vs. Temperature

09437-117

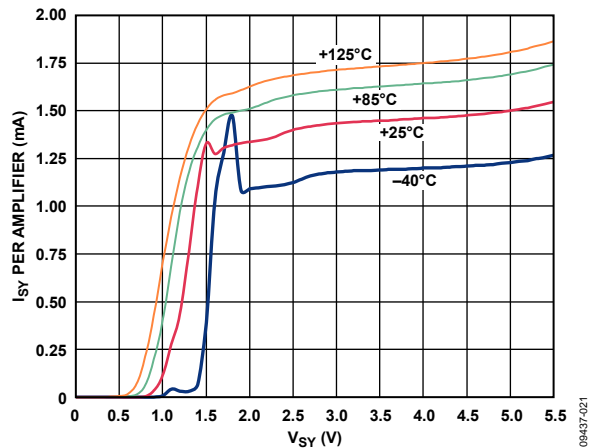


Figure 20. Supply Current vs. Supply Voltage

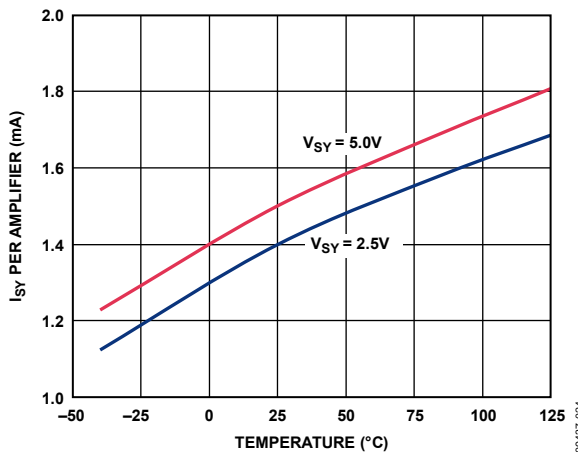


Figure 23. Supply Current vs. Temperature

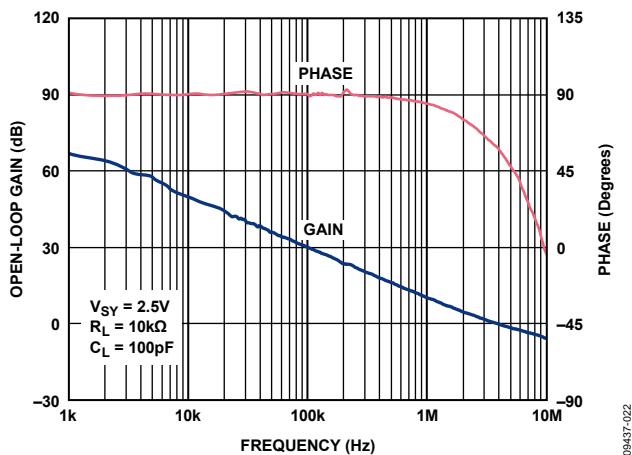


Figure 21. Open-Loop Gain and Phase vs. Frequency

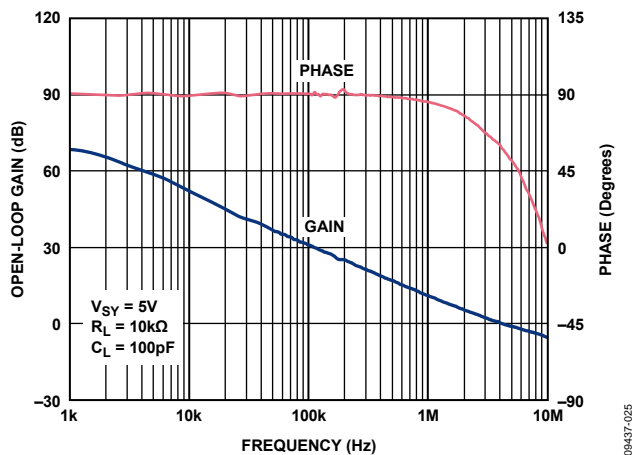


Figure 24. Open-Loop Gain and Phase vs. Frequency

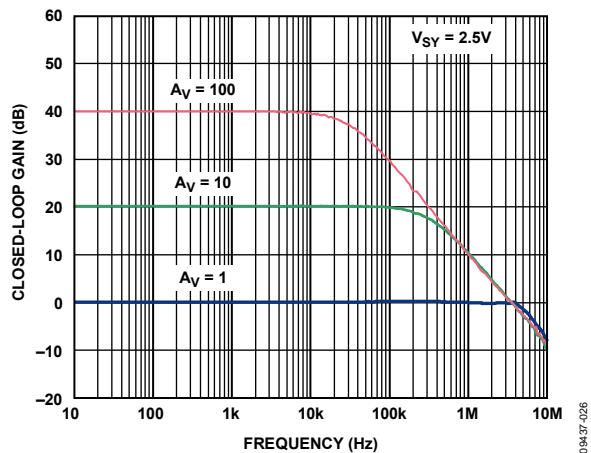


Figure 22. Closed-Loop Gain vs. Frequency

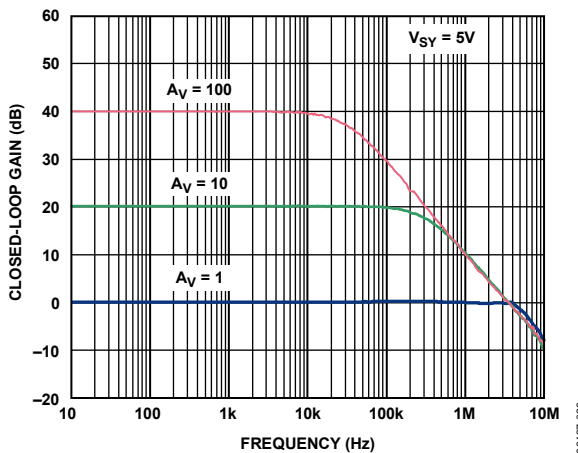


Figure 25. Closed-Loop Gain vs. Frequency

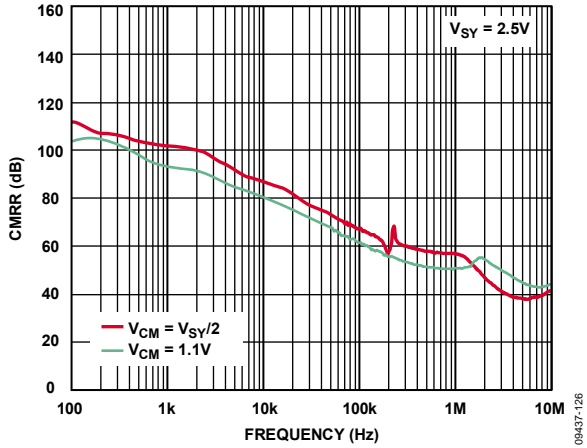


Figure 26. CMRR vs. Frequency

09437-126

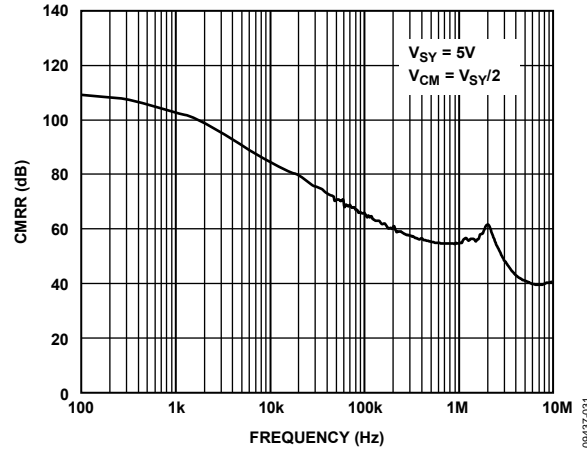


Figure 29. CMRR vs. Frequency

09437-031

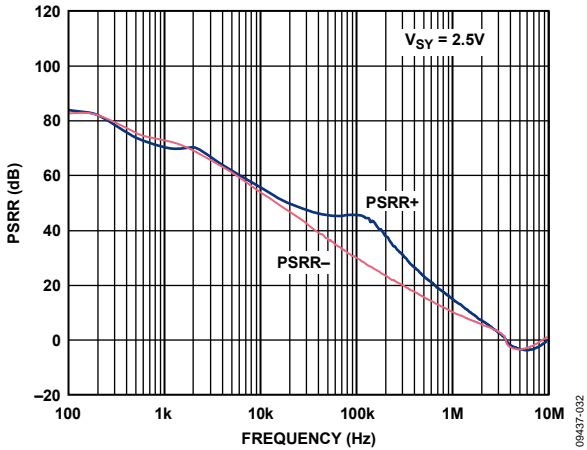


Figure 27. PSRR vs. Frequency

09437-032

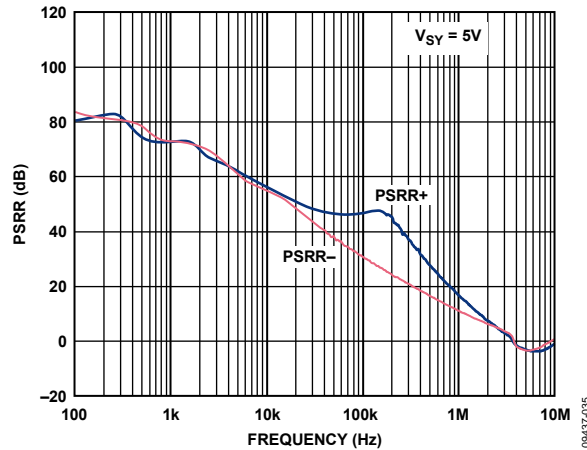


Figure 30. PSRR vs. Frequency

09437-035

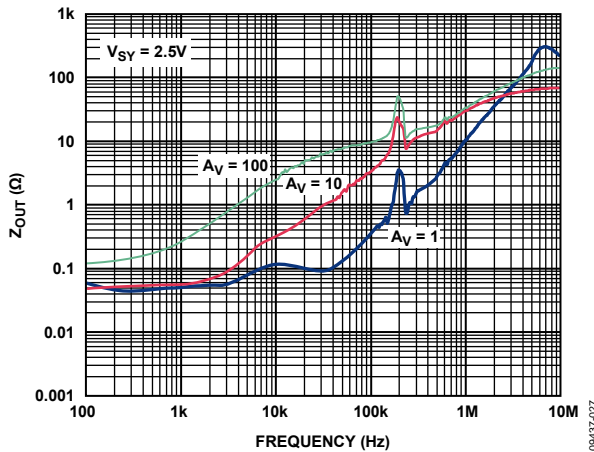


Figure 28. Output Impedance vs. Frequency

09437-027

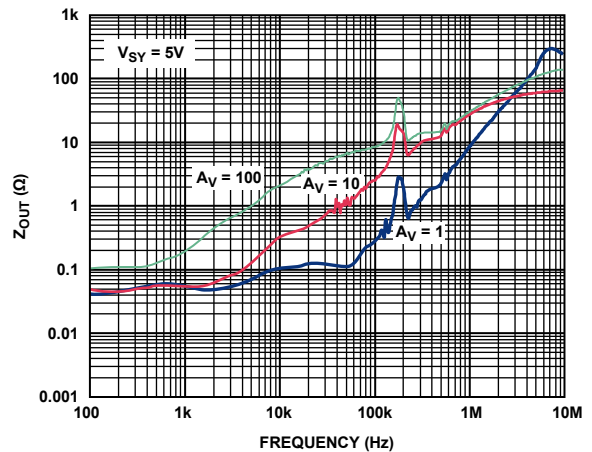


Figure 31. Output Impedance vs. Frequency

09437-030

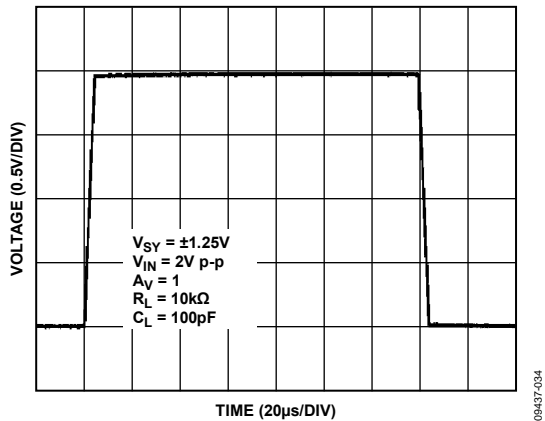


Figure 32. Large Signal Transient Response

09437-034

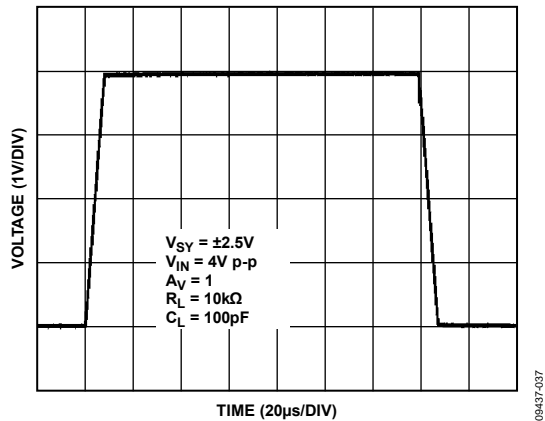


Figure 35. Large Signal Transient Response

09437-037

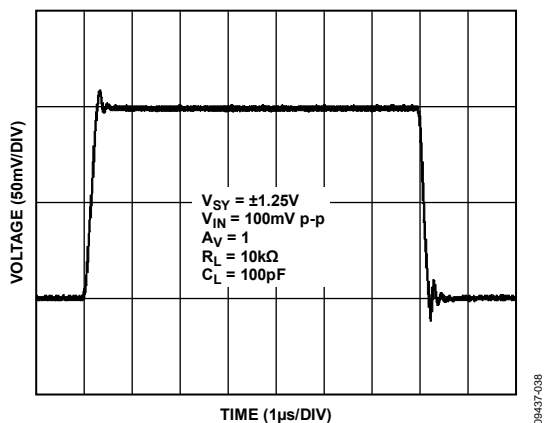


Figure 33. Small Signal Transient Response

09437-038

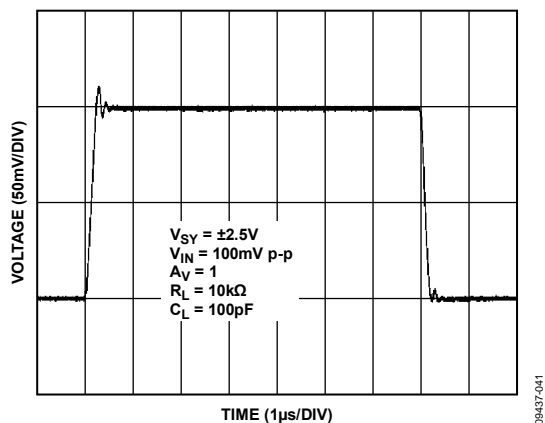


Figure 36. Small Signal Transient Response

09437-041

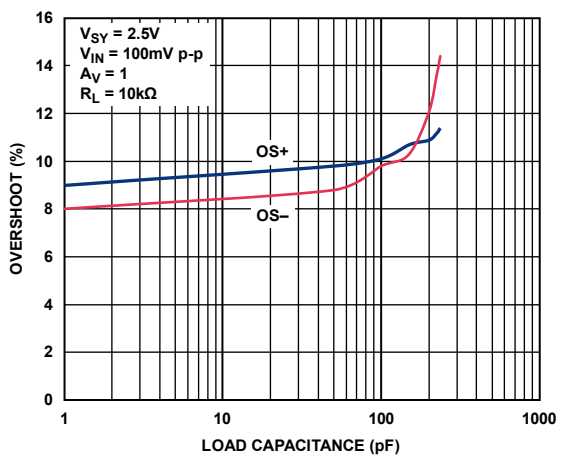


Figure 34. Small Signal Overshoot vs. Load Capacitance

09437-033

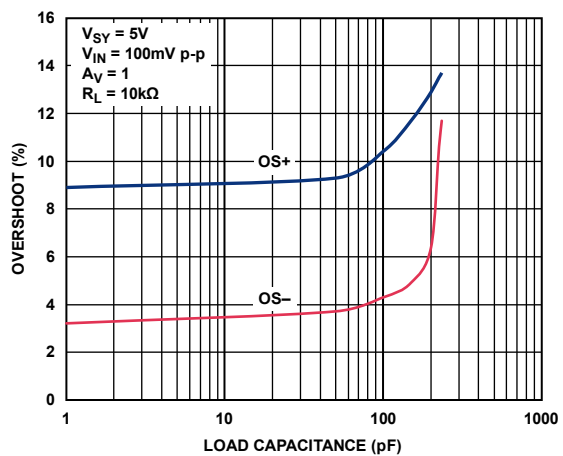


Figure 37. Small Signal Overshoot vs. Load Capacitance

09437-036

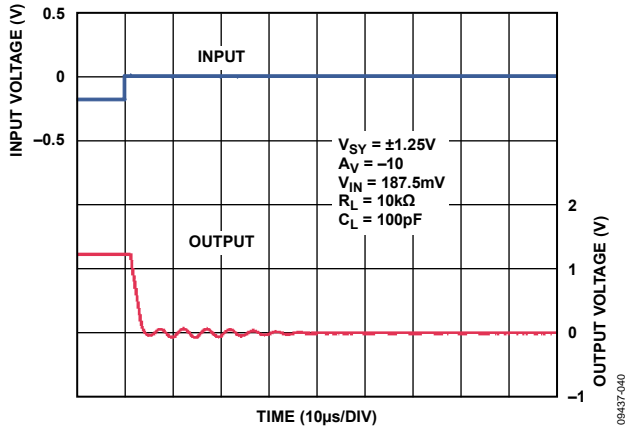


Figure 38. Positive Overload Recovery

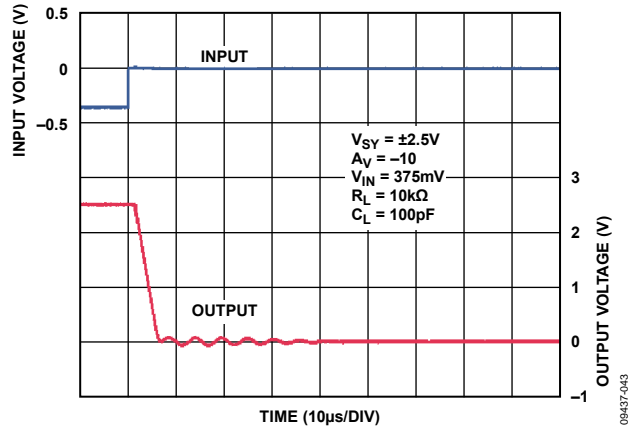


Figure 41. Positive Overload Recovery

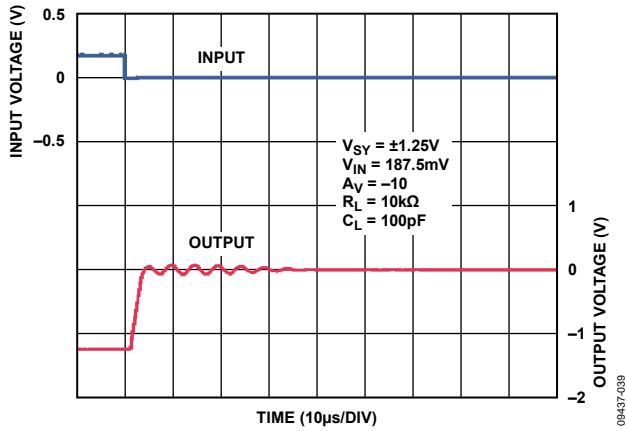


Figure 39. Negative Overload Recovery

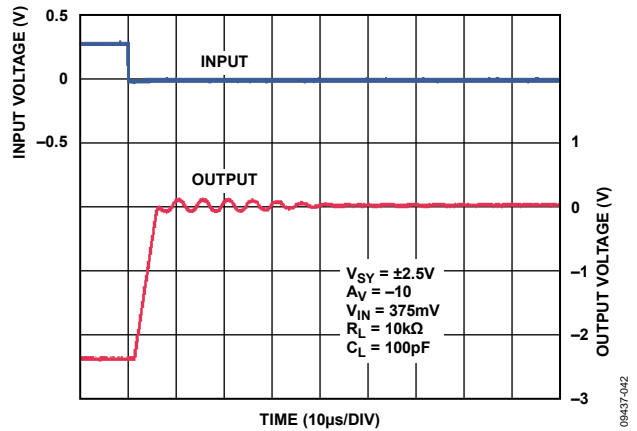


Figure 42. Negative Overload Recovery

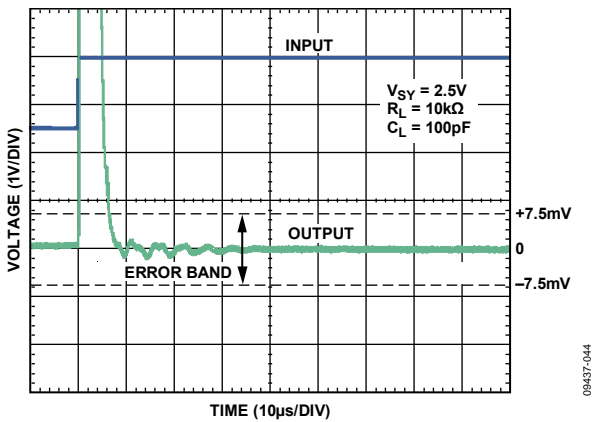


Figure 40. Positive Settling Time to 0.1%

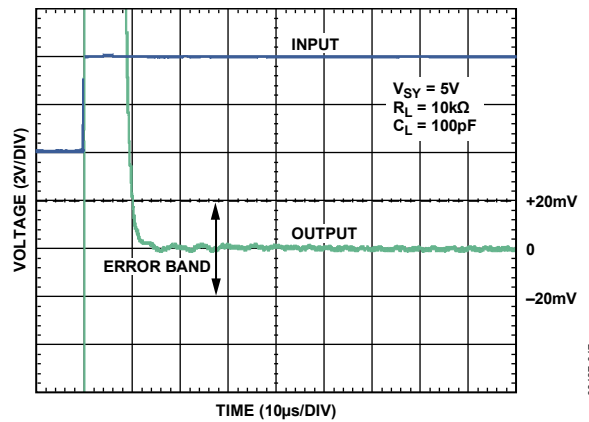


Figure 43. Positive Settling Time to 0.1%

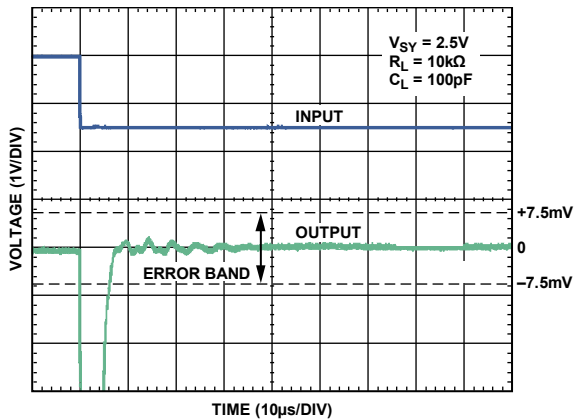


Figure 44. Negative Settling Time to 0.1%

09437-045

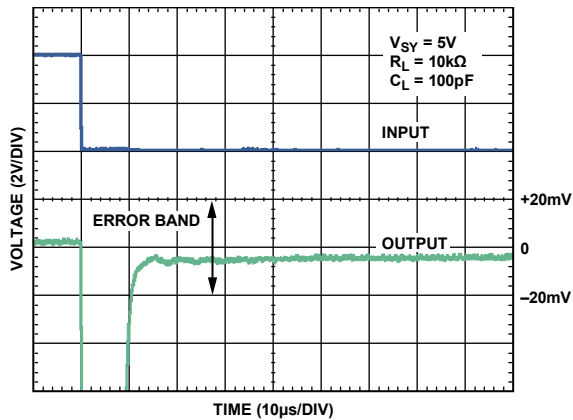


Figure 47. Negative Settling Time to 0.1%

09437-048

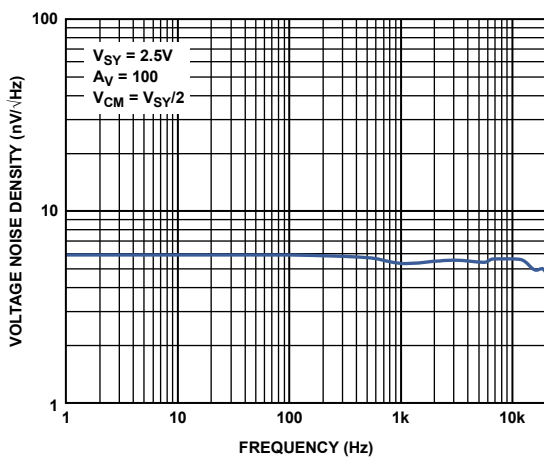


Figure 45. Voltage Noise Density vs. Frequency

09437-046

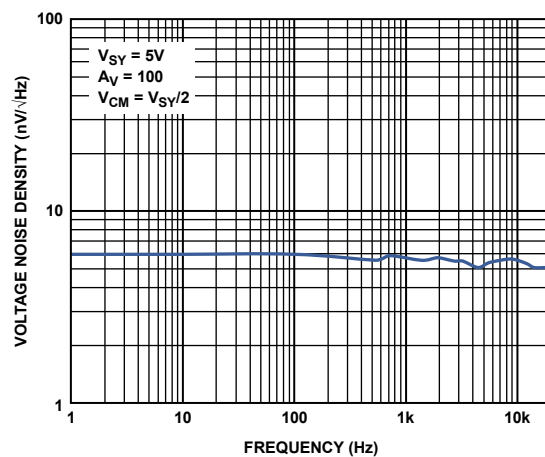


Figure 48. Voltage Noise Density vs. Frequency

09437-049

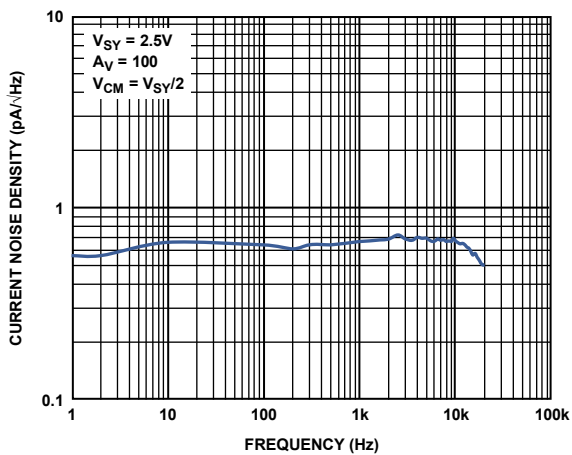


Figure 46. Current Noise Density vs. Frequency

09437-150

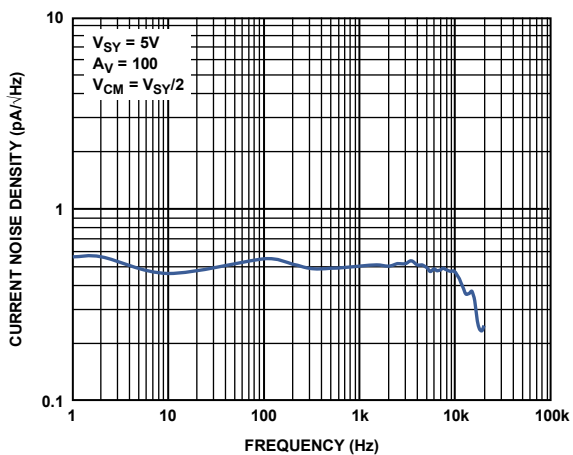


Figure 49. Current Noise Density vs. Frequency

09437-153

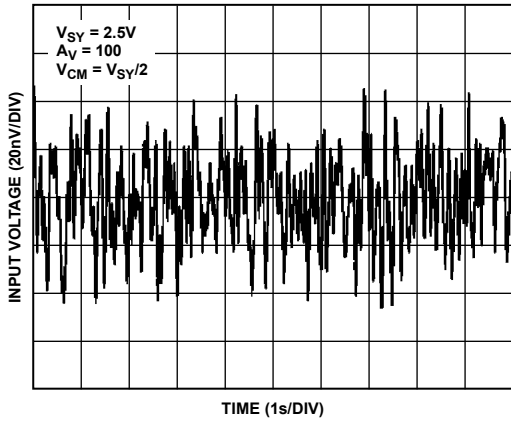


Figure 50. 0.1 Hz to 10 Hz Noise

09437-050

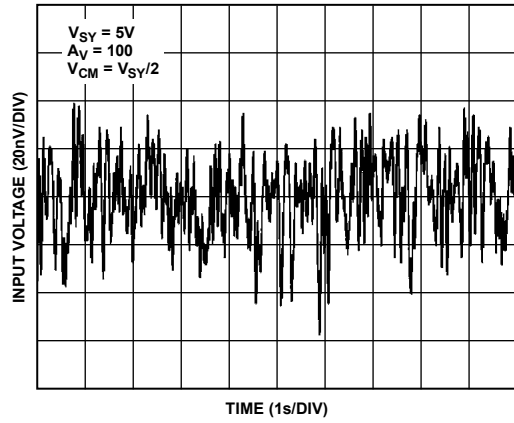


Figure 53. 0.1 Hz to 10 Hz Noise

09437-053

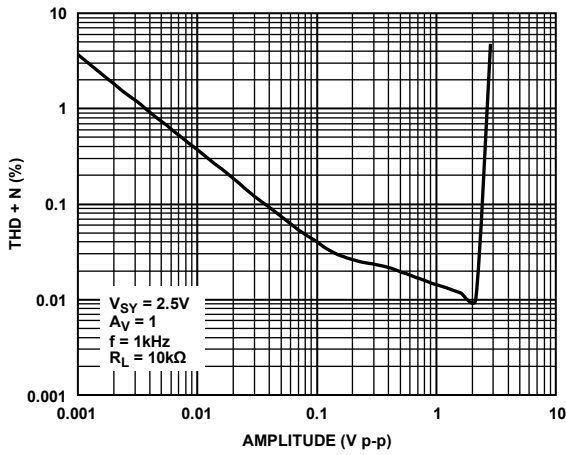


Figure 51. THD + Noise vs. Amplitude

09437-152

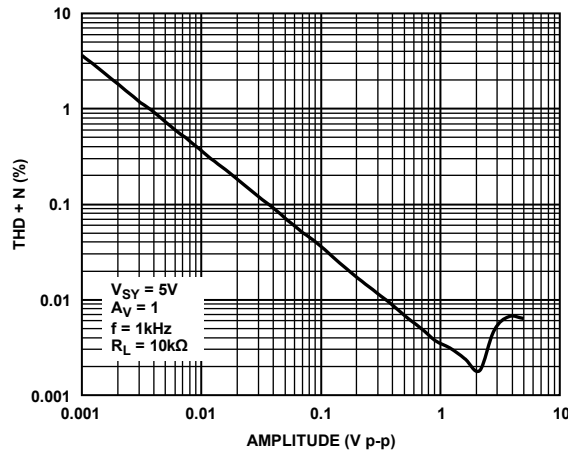


Figure 54. THD + Noise vs. Amplitude

09437-155

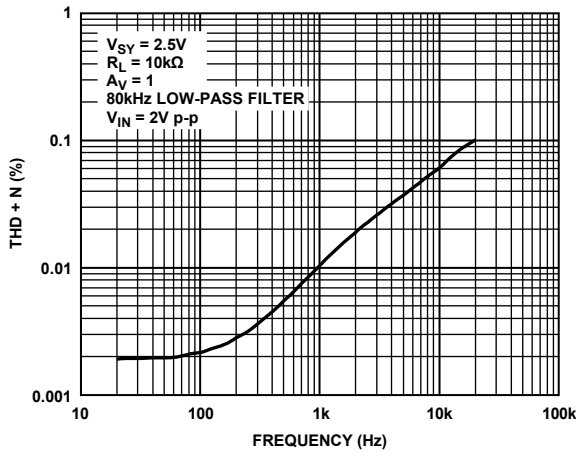


Figure 52. THD + Noise vs. Frequency

09437-056

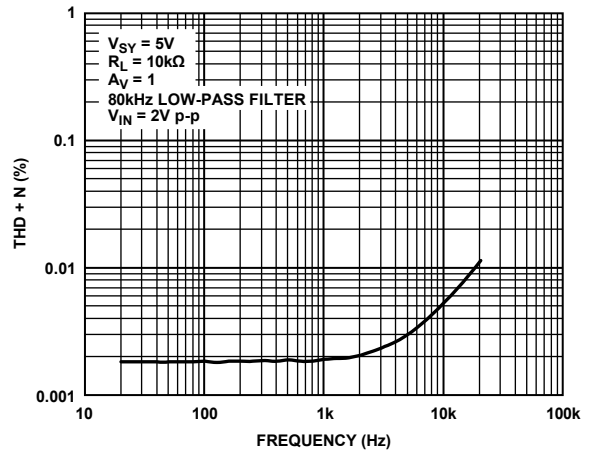


Figure 55. THD + Noise vs. Frequency

09437-057

APPLICATIONS INFORMATION

The ADA4528-1 is a precision, ultralow noise, zero-drift operational amplifier that features a patented chopping technique. This chopping technique offers ultralow input offset voltage of 0.3 μV typical and input offset voltage drift of 0.002 $\mu\text{V}/^\circ\text{C}$ typical.

Offset voltage errors due to common-mode voltage swings and power supply variations are also corrected by the chopping technique, resulting in a typical CMRR figure of 158 dB and a PSRR figure of 150 dB at 2.5 V supply voltage. The ADA4528-1 has low broadband noise of 5.6 nV/ $\sqrt{\text{Hz}}$ (at $f = 1 \text{ kHz}$, $A_V = +100$, $V_{SY} = 2.5 \text{ V}$) and no 1/f noise component. These features are ideal for amplification of low level signals in dc or subhertz high precision applications.

INPUT PROTECTION

The ADA4528-1 has internal ESD protection diodes that are connected between the inputs and each supply rail. These diodes protect the input transistors in the event of electrostatic discharge and are reverse-biased during normal operation. This protection scheme allows voltages as high as approximately 300 mV beyond the rails to be applied at the input of either terminal without causing permanent damage. Refer to Table 4 in the Absolute Maximum Ratings section.

When either input exceeds one of the supply rails by more than 300 mV, these ESD diodes become forward-biased and large amounts of current begin to flow through them. Without current limiting, this excessive fault current causes permanent damage to the device. If the inputs are expected to be subject to overvoltage conditions, insert a resistor in series with each input to limit the input current to 10 mA maximum. However, consider the resistor thermal noise effect on the entire circuit.

At a 5 V supply voltage, the broadband voltage noise of the ADA4528-1 is approximately 6 nV/ $\sqrt{\text{Hz}}$ (at unity gain), and a 1 k Ω resistor has thermal noise of 4 nV/ $\sqrt{\text{Hz}}$. Adding a 1 k Ω resistor increases the total noise by 30% root sum square (rss).

RAIL-TO-RAIL INPUT AND OUTPUT

The ADA4528-1 features rail-to-rail input and output with a supply voltage from 2.2 V to 5.5 V. Figure 56 shows the input and output waveforms of the ADA4528-1 configured as a unity-gain buffer with a supply voltage of $\pm 2.5 \text{ V}$ and a resistive load of 10 k Ω . With an input voltage of $\pm 2.5 \text{ V}$, the ADA4528-1 allows the output to swing very close to both rails. Additionally, it does not exhibit phase reversal.

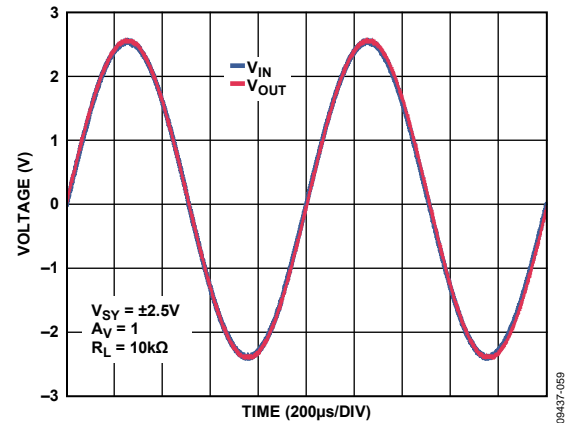


Figure 56. Rail-to-Rail Input and Output

NOISE CONSIDERATIONS

1/f noise

1/f noise, also known as pink noise or flicker noise, is inherent in semiconductor devices and increases as frequency decreases. At low frequency, 1/f noise is a major noise contributor and causes a significant output voltage offset when amplified by the noise gain of the circuit. However, the ADA4528-1 eliminates the 1/f noise internally, thus making it an excellent choice for dc or subhertz high precision applications. The 0.1 Hz to 10 Hz amplifier voltage noise is only 97 nV p-p ($A_V = +100$) at 2.5 V of supply voltage.

The low frequency 1/f noise appears as a slow varying offset to the ADA4528-1 and is greatly reduced by the chopping technique. This allows the ADA4528-1 to have a much lower noise at dc and low frequency in comparison to standard low noise amplifiers that are susceptible to 1/f noise. Figure 45 and Figure 48 show the voltage noise density of the amplifier with no 1/f noise.

Source Resistance

The ADA4528-1 is one of the lowest noise zero drift amplifiers with 5.6 nV/ $\sqrt{\text{Hz}}$ of broadband noise at 1 kHz ($V_{SY} = 2.5 \text{ V}$ and $A_V = +100$) currently available in the industry. Therefore, it is important to consider the input source resistance of choice to maintain a total low noise. The total input referred broadband noise ($e_N \text{ total}$) from any amplifier is primarily a function of three types of noise: input voltage noise, input current noise, and thermal (Johnson) noise from the external resistors. These uncorrelated noise sources can be summed up in a root sum squared (rss) manner by using the following equation:

$$e_N \text{ total} = [e_n^2 + 4 kTR_S + (i_n \times R_S)^2]^{1/2}$$

where:

e_n is the input voltage noise of the amplifier (V/ $\sqrt{\text{Hz}}$).

i_n is the input current noise of the amplifier (A/ $\sqrt{\text{Hz}}$).

R_S is the total input source resistance (Ω).

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

T is the temperature in Kelvin (K).

ADA4528-1

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

$$e_{N,RMS} = e_N \text{ total} \sqrt{BW}$$

where BW is the bandwidth in hertz.

This analysis is valid for broadband noise calculation. If the bandwidth of concern includes the chopping frequency, more complicated calculations must be made to include the effect of the noise spike at the chopping frequency (see Figure 59).

With a low source resistance of $R_S < 1 \text{ k}\Omega$, the voltage noise of the amplifier dominates. As source resistance increases, the thermal noise of R_S dominates. As the source resistance further increases, where $R_S > 100 \text{ k}\Omega$, the current noise becomes the main contributor of the total input noise. A good selection table for low noise op amps can be found in the AN-940 Application Note, *Low Noise Amplifier Selection Guide for Optimal Noise Performance*.

Voltage Noise Density with Different Gain Configurations

Figure 57 shows the voltage noise density vs. closed-loop gain of a zero-drift amplifier from Competitor A. The voltage noise density of the amplifier increases from $11 \text{ nV}/\sqrt{\text{Hz}}$ to $21 \text{ nV}/\sqrt{\text{Hz}}$ as closed-loop gain decreases from 1000 to 1. Figure 58 shows the voltage noise density vs. frequency of the ADA4528-1 for three different gain configurations. The ADA4528-1 offers lower input voltage noise density of $6 \text{ nV}/\sqrt{\text{Hz}}$ to $7 \text{ nV}/\sqrt{\text{Hz}}$ regardless of gain configurations.

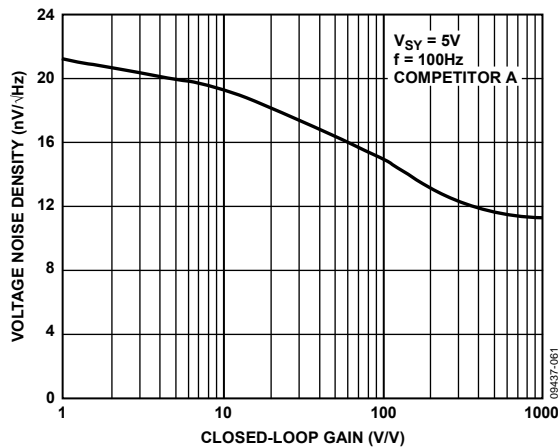


Figure 57. Competitor A: Voltage Noise Density vs. Closed-Loop Gain

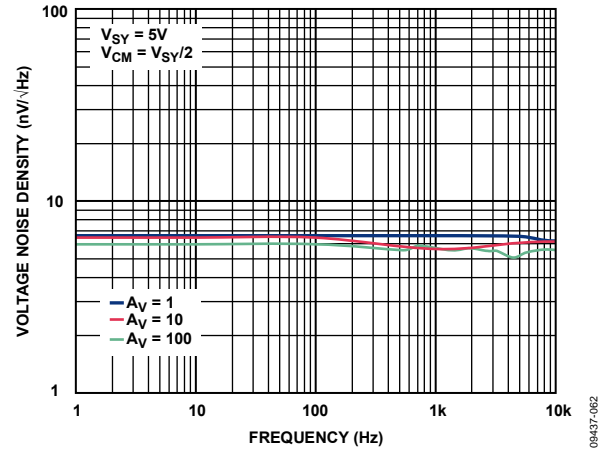


Figure 58. Voltage Noise Density vs. Frequency

Residual Ripple

Although the ACFB suppresses the chopping related ripples, there exists higher noise spectrum at the chopping frequency and its harmonics due to the remaining ripples. Figure 59 shows the voltage noise density of the ADA4528-1 configured in unity gain. A noise spike of $50 \text{ nV}/\sqrt{\text{Hz}}$ can be seen at the chopping frequency of 200 kHz . This noise spike is significant when the op amp has a closed-loop frequency that is higher than the chopping frequency. To further suppress the noise to a desired level, it is recommended to have a post filter at the output of the amplifier.

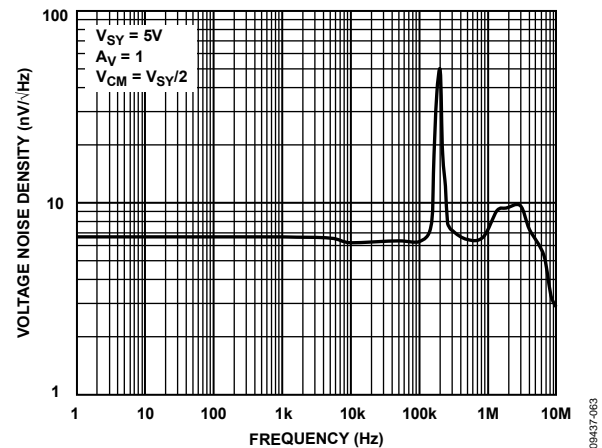


Figure 59. Voltage Noise Density

PRINTED CIRCUIT BOARD LAYOUT

The ADA4528-1 is a high precision device with ultralow offset voltage and noise. Therefore, care must be taken in the design of the printed circuit board (PCB) layout to achieve optimum performance of the ADA4528-1 at board level.

To avoid leakage currents, keep the surface of the board clean and free of moisture. Coating the board surface creates a barrier to moisture accumulation and reduces parasitic resistance on the board.

Properly bypassing the power supplies and keeping the supply traces short minimizes power supply disturbances caused by output current variation. Connect bypass capacitors as close as possible to the device supply pins. Stray capacitances are a concern at the outputs and the inputs of the amplifier. It is recommended that signal traces be kept at a distance of at least 5 mm from supply lines to minimize coupling.

A potential source of offset error is the Seebeck voltage on the circuit board. The Seebeck voltage occurs at the junction of two dissimilar metals and is a function of the temperature of the junction. The most common metallic junctions on a circuit board are solder-to-board trace and solder-to-component lead. Figure 60 shows a cross section of a surface-mount component soldered to a PCB. A variation in temperature across the board (where $T_{A1} \neq T_{A2}$) causes a mismatch in the Seebeck voltages at the solder joints, thereby resulting in thermal voltage errors that degrade the performance of the ultralow offset voltage of the ADA4528-1.

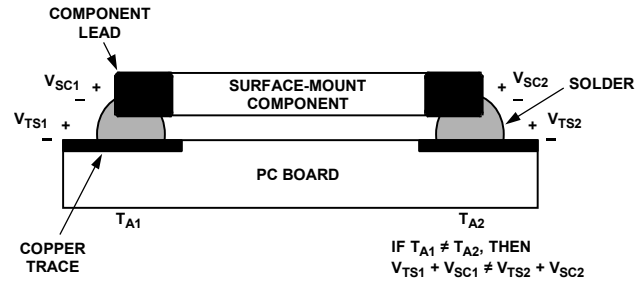


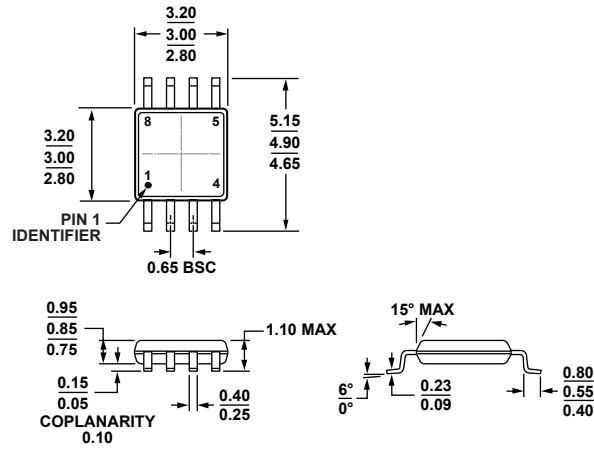
Figure 60. Mismatch in Seebeck Voltages Causes Seebeck Voltage Error

To minimize these thermocouple effects, orient resistors so that heat sources warm both ends equally. Where possible, the input signal paths should contain matching numbers and types of components to match the number and type of thermocouple junctions. For example, dummy components, such as zero value resistors, can be used to match the thermoelectric error source (real resistors in the opposite input path). Place matching components in close proximity and orient them in the same manner to ensure equal Seebeck voltages, thus cancelling thermal errors. Additionally, use leads that are of equal length to keep thermal conduction in equilibrium. Keep heat sources on the PCB as far away from amplifier input circuitry as is practical.

It is highly recommended to use a ground plane. A ground plane helps distribute heat throughout the board, maintains a constant temperature across the board, and reduces EMI noise pick up.

ADA4528-1

OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MO-187-AA

Figure 61. 8-Lead Mini Small Outline Package [MSOP] (RM-8)

Dimensions shown in millimeters

10-07-2008-B

ORDERING GUIDE

Model ¹	Temperature Range	Package Description	Package Option	Branding
ADA4528-1ARMZ	-40°C to +125°C	8-Lead Mini Small Outline Package [MSOP]	RM-8	A2R
ADA4528-1ARMZ-R7	-40°C to +125°C	8-Lead Mini Small Outline Package [MSOP]	RM-8	A2R
ADA4528-1ARMZ-RL	-40°C to +125°C	8-Lead Mini Small Outline Package [MSOP]	RM-8	A2R

¹ Z = RoHS Compliant Part.

NOTES

ADA4528-1

NOTES