Low Cost, High Speed Rail-to-Rail Output Op Amp

ADA4851-1

FEATURES

High speed
- **130 MHz −3 dB bandwidth**
- **800 V/µs slew rate**
- **85 ns settling time to 0.1%**

Fully specified at +3 V, +5 V, and ±5 V supplies
Single-supply operation
- **Output swings to within 70 mV of either rail**

Rail-to-rail output
0.1 dB flatness: 14 MHz
Differential gain: 0.04%
Differential phase: 0.06°
Low voltage offset: 0.6 mV
Wide supply range: 3 V to 10 V
Low power: 2.5 mA
Power-down mode
Available in space-saving package: SOT-23-6

APPLICATIONS

Consumer video
Professional video
Video switchers
Active filters

PIN CONFIGURATION

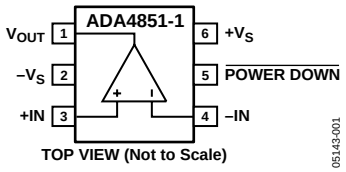

Figure 1. 6-Lead SOT-23 (RJ-6)

GENERAL DESCRIPTION

The ADA4851-1 is a low cost, high speed, voltage feedback rail-to-rail output op amp. Despite its low price, the ADA4851-1 provides excellent overall performance and versatility. The 130 MHz −3 dB bandwidth and 800 V/µs slew rate make this amplifier well-suited for many general-purpose, high speed applications.

The ADA4851-1 is designed to operate at supply voltages as low as 3 V and up to 5 V using only 2.5 mA of supply current. To further reduce power consumption, the amplifier is equipped with a power-down mode, which lowers the supply current to 0.2 mA.

The ADA4851-1 provides users with a true single-supply capability, allowing input signals to extend 200 mV below the negative rail and to within 2 V of the positive rail. On the output, the amplifier can swing within 70 mV of either supply rail.

With its combination of low price, excellent differential gain (0.04%), differential phase (0.06°), and 0.1dB flatness out to 14 MHz, this amplifier is ideal for consumer video applications.

The ADA4851-1 is available in a SOT-23-6 package and is designed to work in the extended temperature range (−40°C to +125°C).

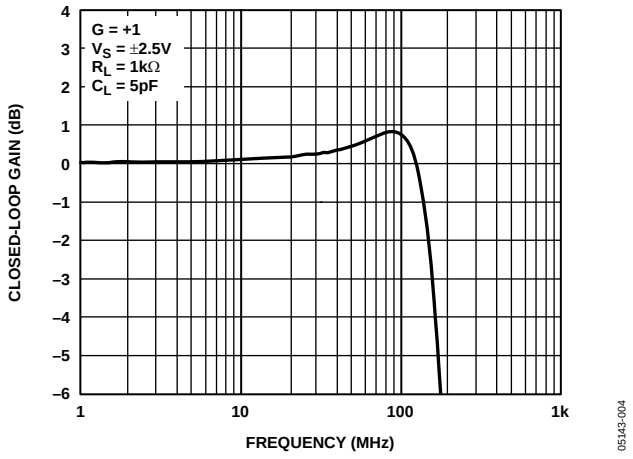

Figure 2. Small Signal Frequency Response

Rev. 0

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REVISION HISTORY

10/04—Revision 0: Initial Version

SPECIFICATIONS

SPECIFICATIONS WITH +3 V SUPPLY

T_A = 25°C, R_F = 0 Ω for G = +1, R_F = 1 kΩ for G > +1, R_L = 1 kΩ, unless otherwise noted.

Table 1.

Parameter	Conditions	Min	Typ	Max	Unit
DYNAMIC PERFORMANCE					
−3 dB Bandwidth	G = +1, V_O = 0.1 V p-p	112	130		MHz
	G = +1, V_O = 1 V p-p	54	65		MHz
Bandwidth for 0.1 dB Flatness	G = +2, V_O = 0.5 V p-p, R_L = 150 Ω		20		MHz
Slew Rate	G = +2, V_O = 2 V Step		140		V/µs
NOISE/DISTORTION PERFORMANCE					
Harmonic Distortion (dBc) HD2/HD3	f_C = 1 MHz, V_O = 0.2 V p-p, G = +2		−85/−113		dBc
Input Voltage Noise	f = 100 kHz		10		nV/√Hz
Input Current Noise	f = 100 kHz		2.5		pA/√Hz
DC PERFORMANCE					
Input Offset Voltage			0.6	3.3	mV
Input Offset Voltage Drift			4		µV/°C
Input Bias Current			1.8	3.7	µA
Input Bias Current Drift			6		nA/°C
Input Bias Offset Current			20		nA
Open-Loop Gain	V_O = 2 V to 3 V	83	102		dB
INPUT CHARACTERISTICS					
Input Resistance	Differential/common-mode		0.5/5.0		MΩ
Input Capacitance			1.2		pF
Input Common-Mode Voltage Range			−0.2 to +0.8		V
Input Overdrive Recovery Time (Rise/Fall)	V_{IN} = +3.5 V, −0.5 V, G = +1		60/60		ns
Common-Mode Rejection Ratio	V_{CM} = 0.5 V	−81	−118		dB
POWER-DOWN					
Power-Down Input Voltage	Power-down		< 1.1		V
Turn-Off Time			0.7		µs
Turn-On Time			60		ns
Power-Down Bias Current					
Enabled	Power-down = 3 V		+4	+6	µA
Power-Down	Power-down = 0 V		−14	−20	µA
OUTPUT CHARACTERISTICS					
Output Overdrive Recovery Time (Rise/Fall)	V_{IN} = +0.7 V, −0.1 V, G = +5		70/100		ns
Output Voltage Swing		0.05 to 2.92	0.02 to 2.94		V
Short-Circuit Current	Sinking/sourcing		90/70		mA
POWER SUPPLY					
Operating Range		3		12	V
Quiescent Current			2.4	2.7	mA
Quiescent Current (Power-Down)	Power-down = Low		0.2	0.3	mA
Positive Power Supply Rejection	$+V_S$ = +2.5 V to +3.5 V, $-V_S$ = −0.5 V	−84	−102		dB
Negative Power Supply Rejection	$+V_S$ = +2.5 V,$-V_S$ = −0.5 V to −1.5 V	−83	−102		dB

SPECIFICATIONS WITH +5 V SUPPLY

T_A = 25°C, R_F = 0 Ω for G = +1, R_F = 1 kΩ for G > +1, R_L = 1 kΩ, unless otherwise noted.

Table 2.

Parameter	Conditions	Min	Typ	Max	Unit
DYNAMIC PERFORMANCE					
−3 dB Bandwidth	G = +1, V_O = 0.1 V p-p	107	125		MHz
	G = +1, V_O = 1 V p-p	54	65		MHz
Bandwidth for 0.1 dB Flatness	G = +2, V_O = 2 V p-p, R_L = 150 Ω		15		MHz
Slew Rate	G = +2, V_O = 3 V Step		410		V/µs
Settling Time to 0.1%	G = +2, V_O = 1 V Step, R_L = 150 Ω		85		ns
NOISE/DISTORTION PERFORMANCE					
Harmonic Distortion (dBc) HD2/HD3	f_C = 1 MHz, V_O = 0.2 V p-p, G = +2		−98/−113		dBc
Input Voltage Noise	f = 100 kHz		10		nV/√Hz
Input Current Noise	f = 100 kHz		2.5		pA/√Hz
Differential Gain	G = +2, NTSC, R_L = 150 Ω		0.05		%
Differential Phase	G = +2, NTSC, R_L = 150 Ω		0.09		Degrees
DC PERFORMANCE					
Input Offset Voltage			0.6	3.4	mV
Input Offset Voltage Drift			4		µV/°C
Input Bias Current			1.7	3.6	µA
Input Bias Current Drift			6		nA/°C
Input Bias Offset Current			20		nA
Open-Loop Gain	V_O = 1 V to 4 V	97	111		dB
INPUT CHARACTERISTICS					
Input Resistance	Differential/common-mode		0.5/5.0		MΩ
Input Capacitance			1.2		pF
Input Common-Mode Voltage Range			−0.2 to +2.8		V
Input Overdrive Recovery Time (Rise/Fall)	V_{IN} = +5.5 V, −0.5 V, G = +1		50/45		ns
Common-Mode Rejection Ratio	V_{CM} = 2 V	−88	−130		dB
POWER-DOWN					
Power-Down Input Voltage	Power-down		< 1.1		V
Turn-Off Time			0.7		µs
Turn-On Time			50		ns
Power-Down Bias Current					
Enabled	Power-down = 5 V		33	40	µA
Power-Down	Power-down = 0 V		−22	−30	µA
OUTPUT CHARACTERISTICS					
Output Overdrive Recovery Time (Rise/Fall)	V_{IN} = +1.1 V, −0.1 V, G = +5		60/70		ns
Output Voltage Swing		0.09 to 4.92	0.05 to 4.94		V
Short-Circuit Current	Sinking/sourcing		110/90		mA
POWER SUPPLY					
Operating Range		3		12	V
Quiescent Current			2.5	2.8	mA
Quiescent Current (Power-Down)	Power-down = Low		0.2	0.3	mA
Positive Power Supply Rejection	$+V_S$ = +5 V to +6 V, $-V_S$ = 0 V	−85	−101		dB
Negative Power Supply Rejection	$+V_S$ = +5 V,$-V_S$ = −0 V to −1 V	−84	−101		dB

SPECIFICATIONS WITH ±5 V SUPPLY

T_A = 25°C, R_F = 0 Ω for G = +1, R_F = 1 kΩ for G > +1, R_L = 1 kΩ, unless otherwise noted.

Table 3.

Parameter	Conditions	Min	Typ	Max	Unit
DYNAMIC PERFORMANCE					
−3 dB Bandwidth	G = +1, V_O = 0.1 V p-p	43	105		MHz
	G = +1, V_O = 1 V p-p	64	78		MHz
Bandwidth for 0.1 dB Flatness	G = +2, V_O = 2 V p-p, R_L = 150 Ω		14		MHz
Slew Rate	G = +2, V_O = 8 V p-p Step		800		V/µs
	G = +2, V_O = 2 V p-p Step		400		V/µs
Settling Time to 0.1%	G = +2, V_O = 2 V Step, R_L = 150 Ω		90		ns
NOISE/DISTORTION PERFORMANCE					
Harmonic Distortion (dBc) HD2/HD3	f_C = 1 MHz, V_O = 1 V p-p, G = +1		−90/−117		dBc
Input Voltage Noise	f = 100 kHz		10		nV/√Hz
Input Current Noise	f = 100 kHz		2.5		pA/√Hz
Differential Gain	G = +2, NTSC, R_L = 150 Ω		0.04		%
Differential Phase	G = +2, NTSC, R_L = 150 Ω		0.06		Degrees
DC PERFORMANCE					
Input Offset Voltage			0.6	3.5	mV
Input Offset Voltage Drift			4		µV/°C
Input Bias Current			1.7	3.7	µA
Input Bias Current Drift			6		nA/°C
Input Bias Offset Current			20		nA
Open-Loop Gain	V_O = ±2.5 V	99	111		dB
INPUT CHARACTERISTICS					
Input Resistance	Differential/common-mode		0.5/5.0		MΩ
Input Capacitance			1.2		pF
Input Common-Mode Voltage Range			−5.2 to +2.8		V
Input Overdrive Recovery Time (Rise/Fall)	V_{IN} = ±6 V, G = +1		50/25		ns
Common-Mode Rejection Ratio	V_{CM} = 4 V	−91	−123		dB
POWER-DOWN					
Power-Down Input Voltage	Power-down		< −3.9		V
Turn-Off Time			0.7		µs
Turn-On Time			30		ns
Power-Down Bias Current					
Enabled	Power-down = +5 V		0.1	0.13	mA
Power-Down	Power-down = −5 V		−0.05	−0.06	mA
OUTPUT CHARACTERISTICS					
Output Overdrive Recovery Time (Rise/Fall)	V_{IN} = ±1.2 V, G = +5		80/50		ns
Output Voltage Swing		−4.9 to +4.91	−4.93 to +4.93		V
Short-Circuit Current	Sinking/sourcing		125/110		mA
POWER SUPPLY					
Operating Range		±1.5		±6	V
Quiescent Current			2.9	3.2	mA
Quiescent Current (Power-Down)	Power-down = Low		0.2	0.3	mA
Positive Power Supply Rejection	$+V_S$ = +5 V to +6 V, $-V_S$ = −5 V	−85	−102		dB
Negative Power Supply Rejection	$+V_S$ = +5 V, $-V_S$ = −5 V to −6 V	−84	−102		dB

ABSOLUTE MAXIMUM RATINGS

Table 4.

Parameter	Rating
Supply Voltage	12.6 V
Power Dissipation	See Figure 3
Common-Mode Input Voltage	$-V_S - 0.5$ V to $+V_S + 0.5$ V
Differential Input Voltage	$+V_S$ to $-V_S$
Storage Temperature	−65°C to +125°C
Operating Temperature Range	−40°C to +125°C
Lead Temperature Range (Soldering 10 sec)	300°C
Junction Temperature	150°C

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, i.e., θ_{JA} is specified for device soldered in circuit board for surface-mount packages.

Table 5. Thermal Resistance

Package Type	θ_{JA}	Unit
SOT-23-6	170	°C/W

Maximum Power Dissipation

The maximum safe power dissipation for the ADA4851-1 is limited by the associated rise in junction temperature (T_J) on the die. At approximately 150°C, which is the glass transition temperature, the plastic changes its properties. Even temporarily exceeding this temperature limit may change the stresses that the package exerts on the die, permanently shifting the parametric performance of the ADA4851-1. Exceeding a junction temperature of 150°C for an extended period of time can result in changes in silicon devices, potentially causing degradation or loss of functionality.

The power dissipated in the package (P_D) is the sum of the quiescent power dissipation and the power dissipated in the die due to the ADA4851-1 drive at the output. The quiescent power is the voltage between the supply pins (V_S) times the quiescent current (I_S).

$$P_D = \textit{Quiescent Power} + (\textit{Total Drive Power} - \textit{Load Power})$$

$$P_D = (V_S \times I_S) + \left(\frac{V_S}{2} \times \frac{V_{OUT}}{R_L}\right) - \frac{{V_{OUT}}^2}{R_L}$$

RMS output voltages should be considered. If R_L is referenced to $-V_S$, as in single-supply operation, the total drive power is $V_S \times I_{OUT}$. If the rms signal levels are indeterminate, consider the worst case, when $V_{OUT} = V_S/4$ for R_L to midsupply.

$$P_D = (V_S \times I_S) + \frac{(V_S/4)^2}{R_L}$$

In single-supply operation with R_L referenced to $-V_S$, worst case is $V_{OUT} = V_S/2$.

Airflow increases heat dissipation, effectively reducing θ_{JA}. Also, more metal directly in contact with the package leads and exposed paddle from metal traces, through holes, ground, and power planes reduce θ_{JA}.

Figure 3 shows the maximum safe power dissipation in the package vs. the ambient temperature for the SOT-23-6 (170°C/W) package on a JEDEC standard 4-layer board. θ_{JA} values are approximations.

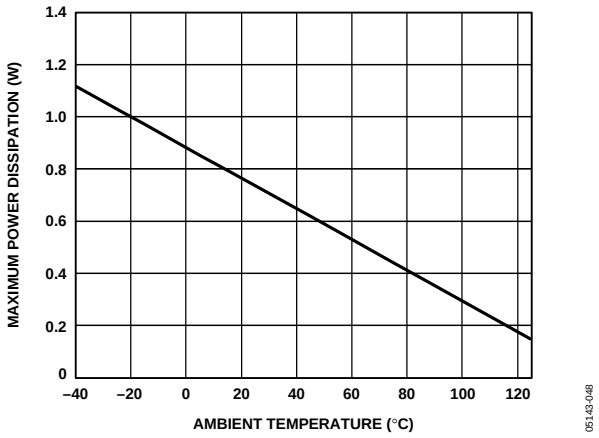

Figure 3. Maximum Power Dissipation vs. Temperature for a 4-Layer Board

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

TYPICAL PERFORMANCE CHARACTERISTICS

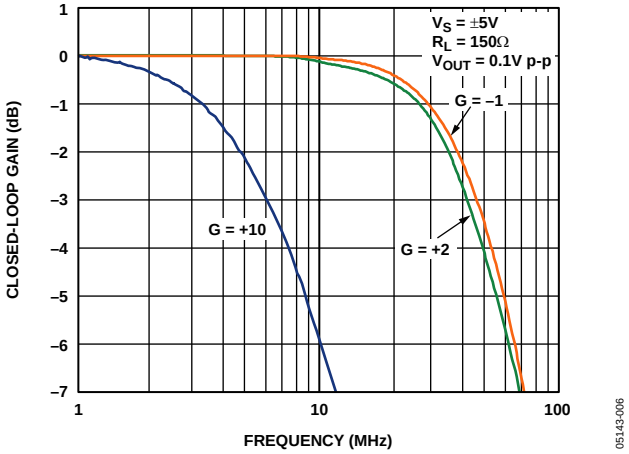

Figure 4. Small Signal Frequency Response for Various Gains

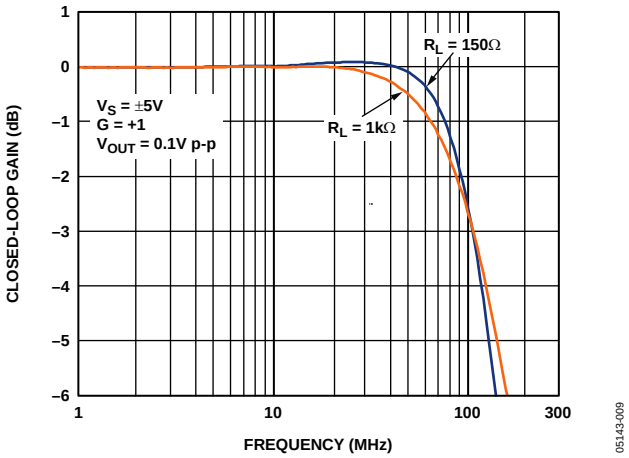

Figure 5. Small Signal Frequency Response for Various Loads

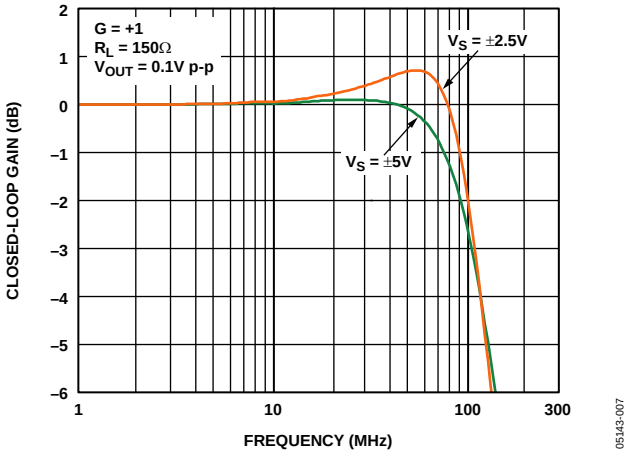

Figure 6. Small Signal Frequency Response for Various Supplies

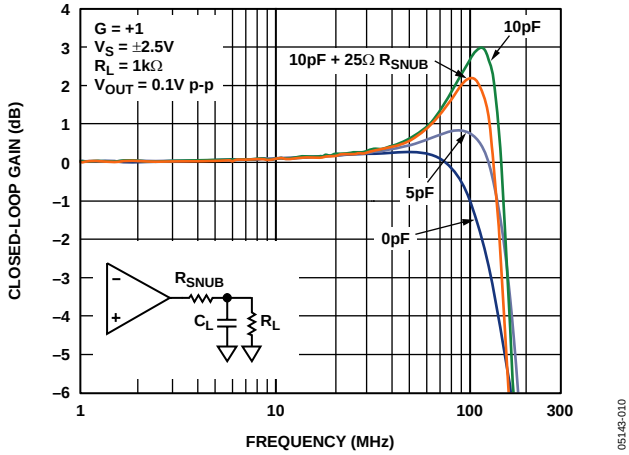

Figure 7. Small Signal Frequency Response for Various Capacitor Loads

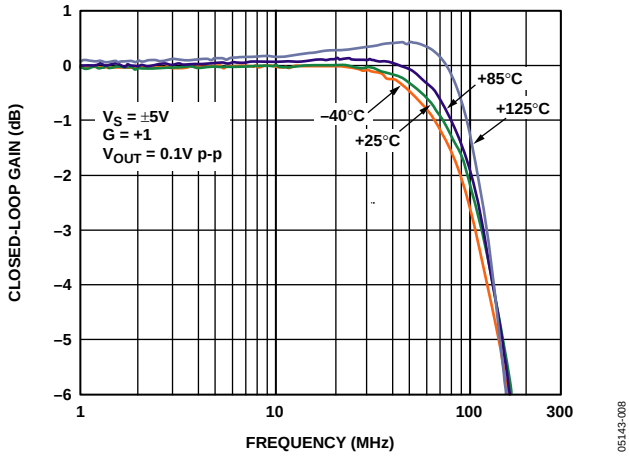

Figure 8. Small Signal Frequency Response for Various Temperatures

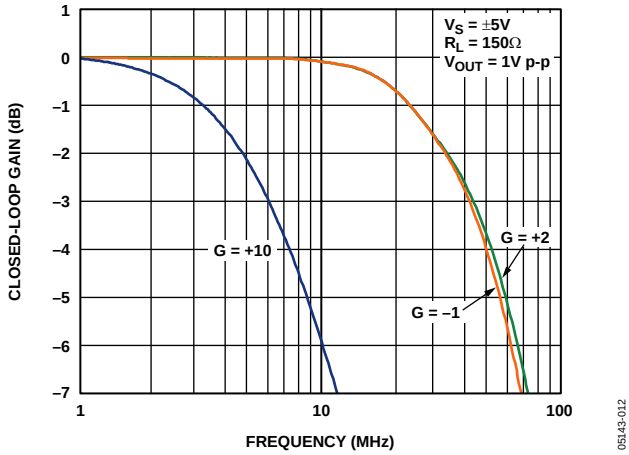

Figure 9. Large Signal Frequency Response for Various Gains

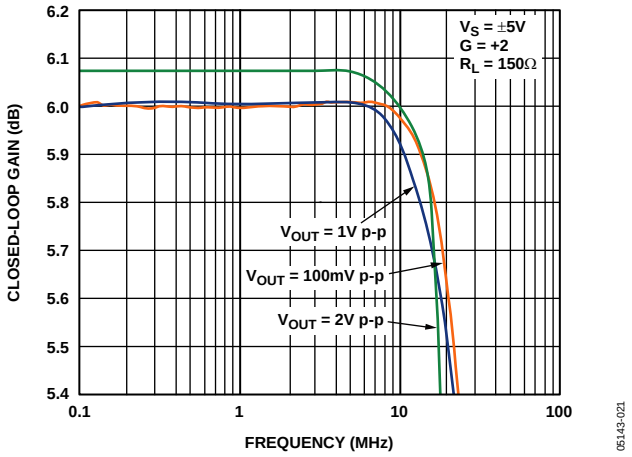

Figure 10. 0.1 dB Flatness Response

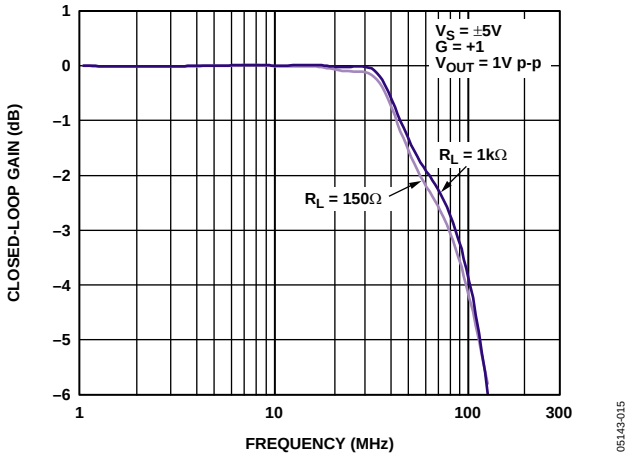

Figure 11. Large Frequency Response for Various Loads

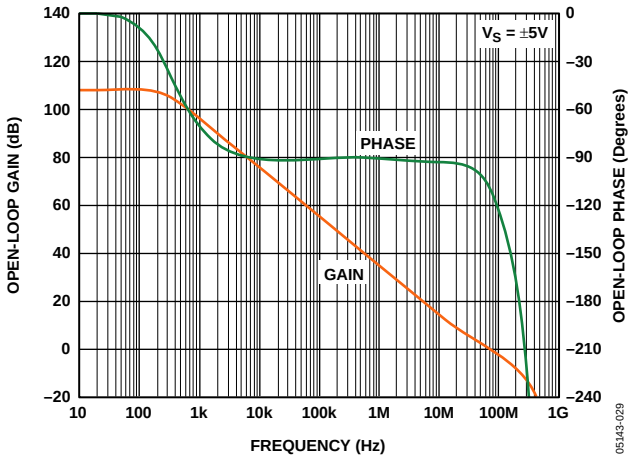

Figure 12. Open-Loop Gain and Phase vs. Frequency

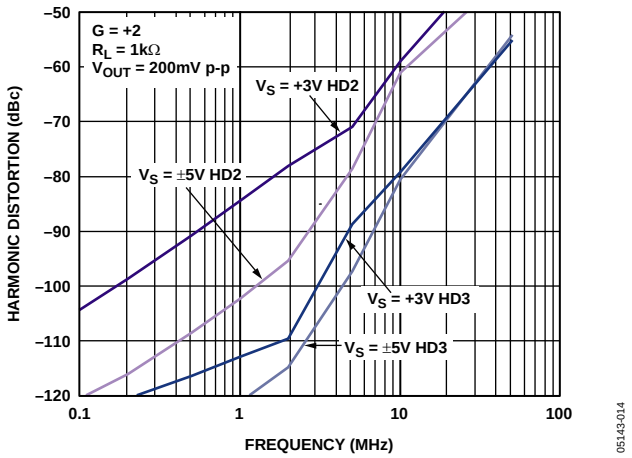

Figure 13. Harmonic Distortion vs. Frequency for Various Supplies

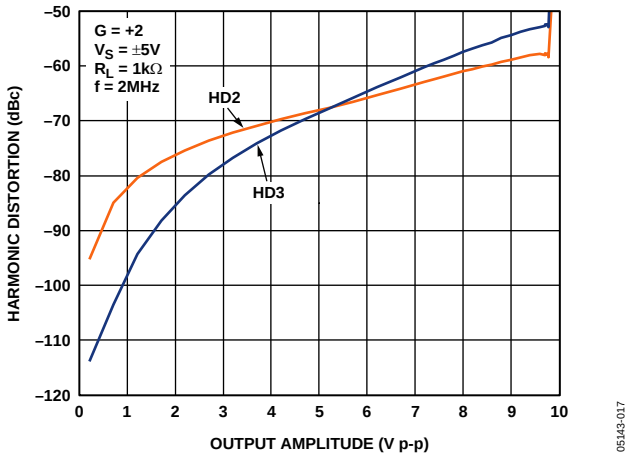

Figure 14. Harmonic Distortion vs. Output Voltage

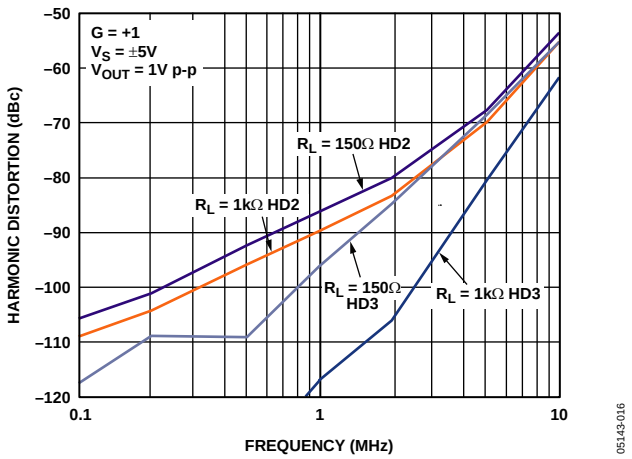

Figure 15. Harmonic Distortion vs. Frequency for Various Loads

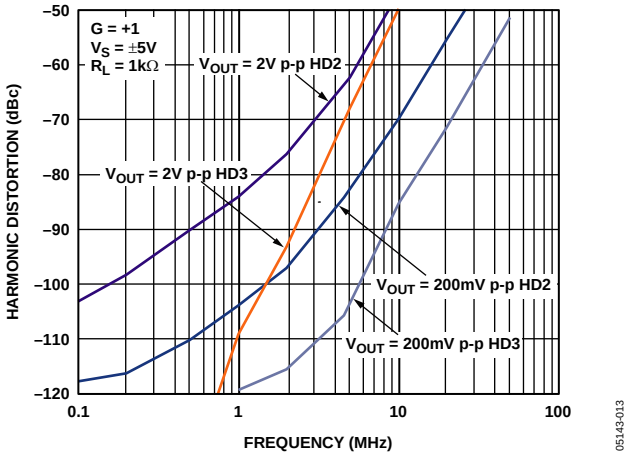

Figure 16. Harmonic Distortion vs. Frequency for Various V_{OUT}

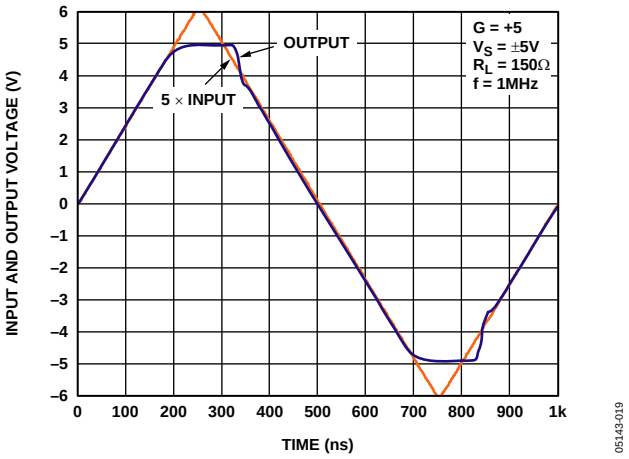

Figure 17. Output Overdrive Recovery

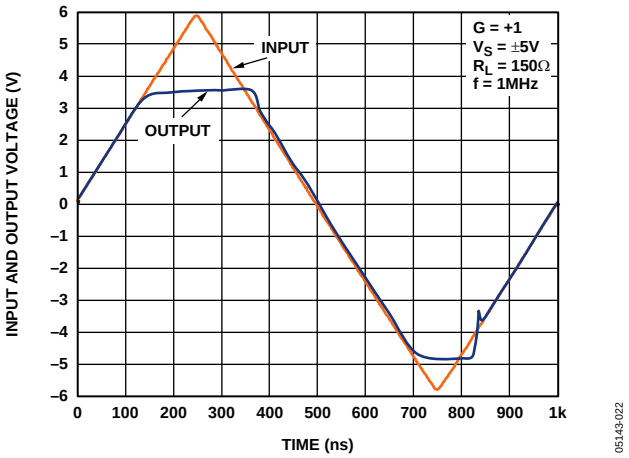

Figure 18. Input Overdrive Recovery

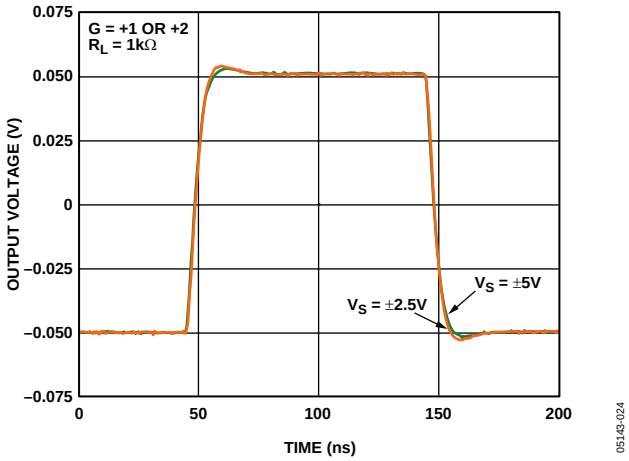

Figure 19. Small Signal Transient Response for Various Supplies

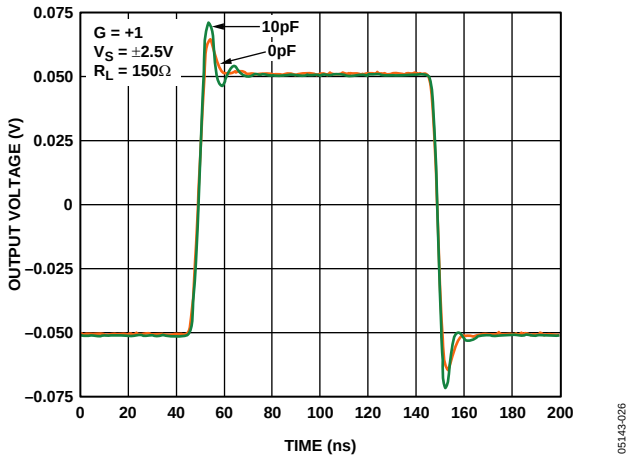

Figure 20. Small Signal Transient Response for Capacitive Load

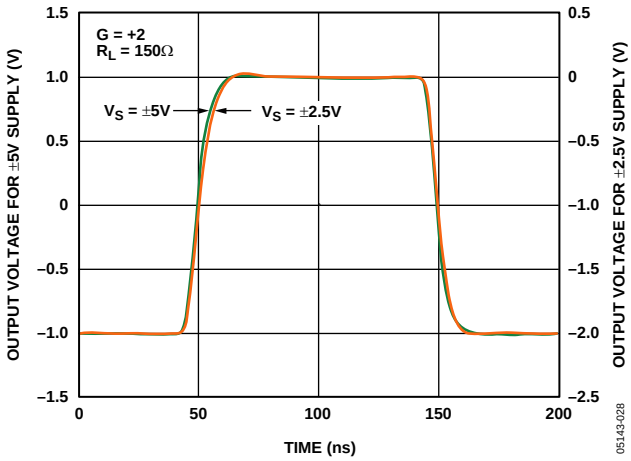

Figure 21. Large Signal Transient Response for Various Supplies

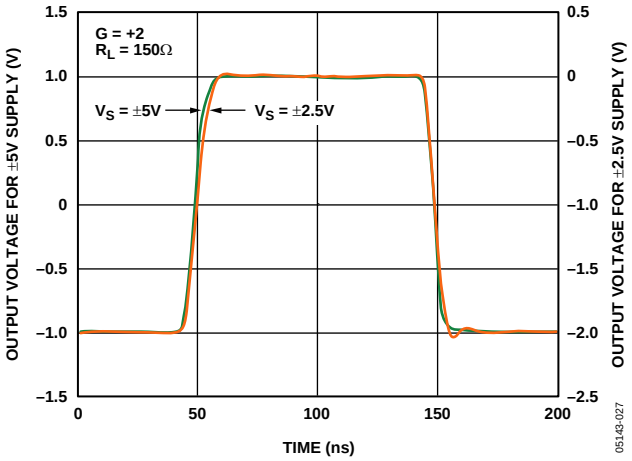

Figure 22. Large Signal Transient Response for Various Supplies

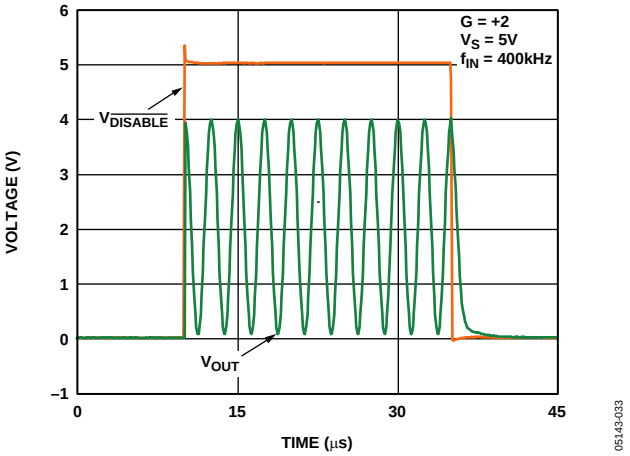

Figure 25. Enable/Disable Time

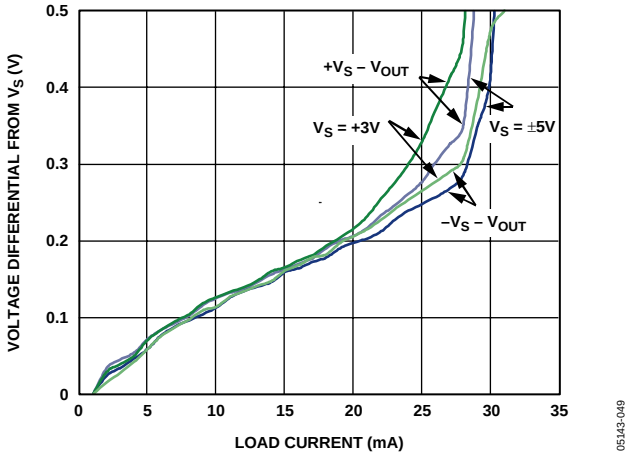

Figure 23. Output Saturation Voltage vs. Load Current

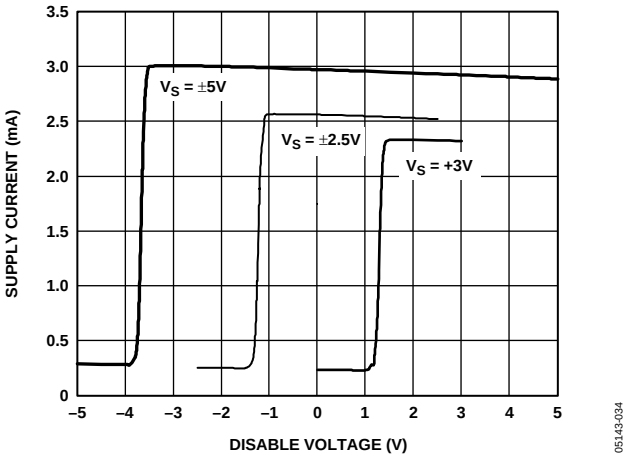

Figure 26. Supply Current vs. $\overline{POWER\ DOWN}$ Pin Voltage

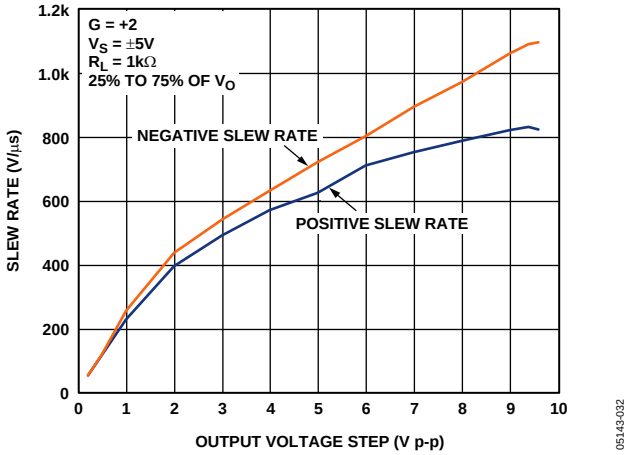

Figure 24. Slew Rate vs. Output Voltage

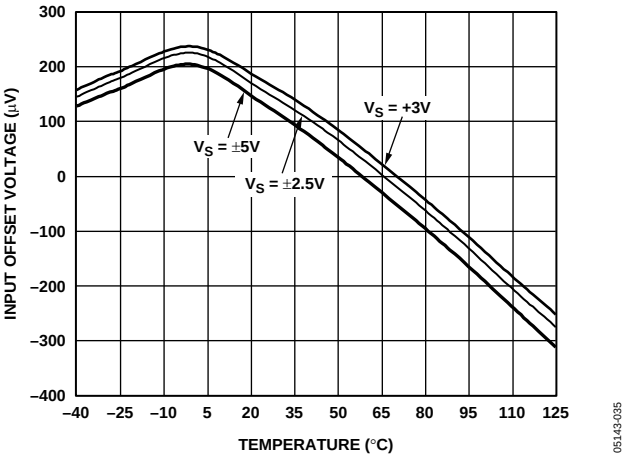

Figure 27. Input Offset Voltage vs. Temperature for Various Supplies

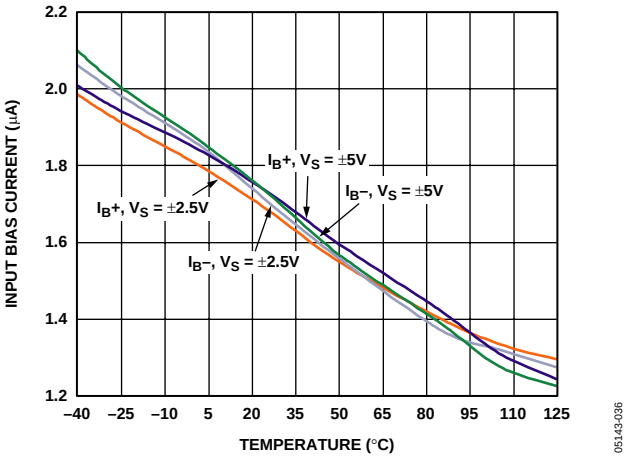

Figure 28. Input Bias Current vs. Temperature for Various Supplies

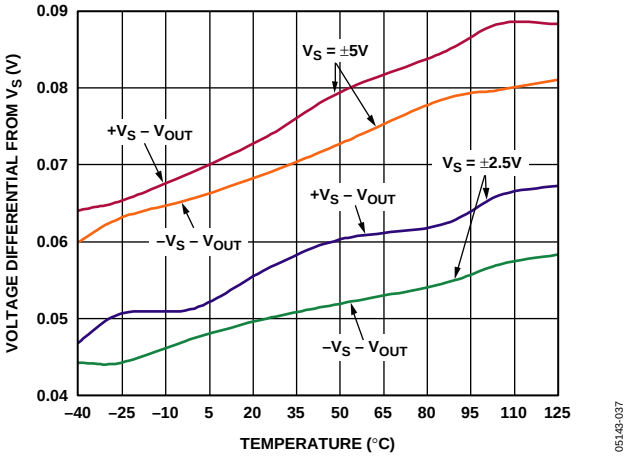

Figure 29. Output Saturation vs. Temperature for Various Supplies

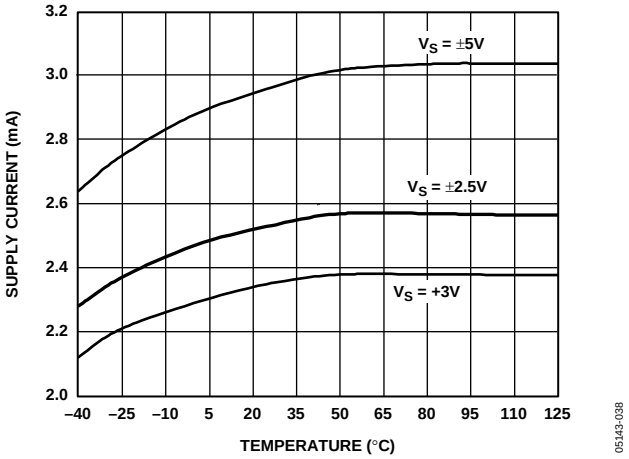

Figure 30. Supply Current vs. Temperature for Various Supplies

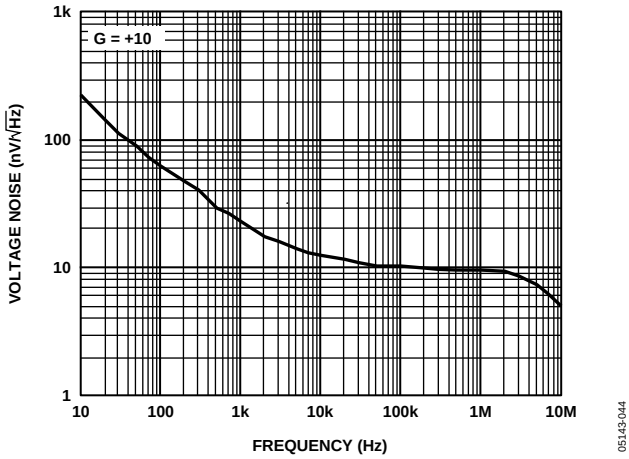

Figure 31. Voltage Noise vs. Frequency

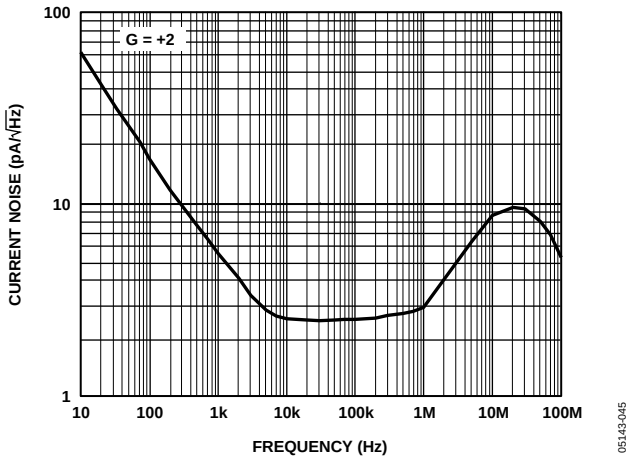

Figure 32. Current Noise vs. Frequency

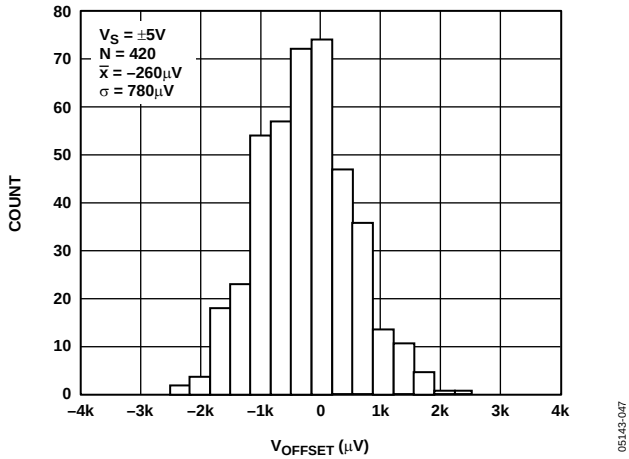

Figure 33. Input Offset Voltage Distribution

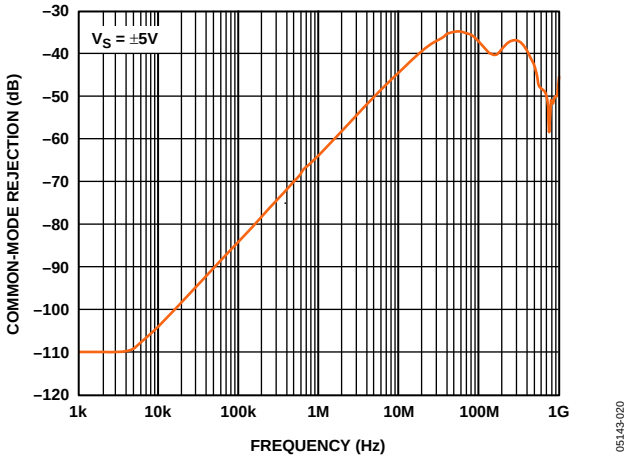

Figure 34. Common-Mode Rejection Ratio (CMRR) vs. Frequency

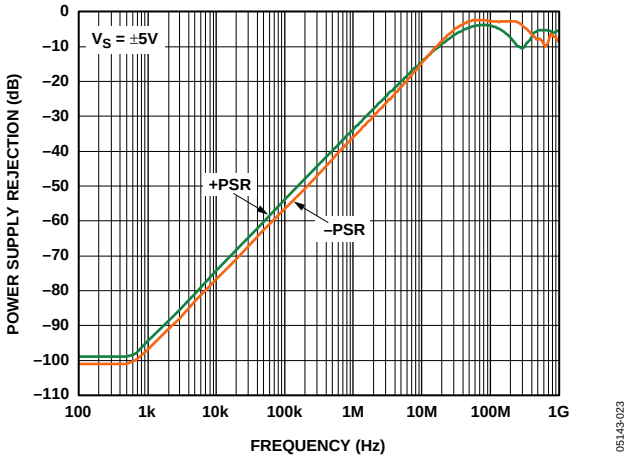

Figure 35. Power Supply Rejection (PSR) vs. Frequency

CIRCUIT DESCRIPTION

The ADA4851-1 features a high slew rate input stage that is a true single-supply topology, capable of sensing signals at or below the minus supply rail. The rail-to-rail output stage can pull within 70 mV of either supply rail when driving light loads and within 0.17 V when driving 150 Ω. High speed performance is maintained at supply voltages as low as 2.7 V.

HEADROOM CONSIDERATIONS

This amplifier is designed for use in low voltage systems. To obtain optimum performance, it is useful to understand the behavior of the amplifier as input and output signals approach the amplifier's headroom limits. The ADA4851-1's input common-mode voltage range extends from the negative supply voltage (actually 200 mV below this), or ground for single-supply operation, to within 2 V of the positive supply voltage. Therefore, at a gain of 2, the ADA4851-1 can provide full rail-to-rail output swing for supply voltage as low as 3.6 V, assuming the input signal swing is from $-V_S$ (or ground) to $+V_S/2$. At a gain of 4, the ADA4851-1 can provide a rail-to-rail output range down to 3 V total supply voltage.

Exceeding the headroom limit is not a concern for any inverting gain on any supply voltage, as long as the reference voltage at the amplifier's positive input lies within the amplifier's input common-mode range.

The input stage is the headroom limit for signals when the amplifier is used in a gain of 1 for signals approaching the positive rail. Figure 36 shows a typical offset voltage vs. the input common-mode voltage for the ADA4851-1 amplifier on a ±5 V supply. Accurate dc performance is maintained from approximately 200 mV below the minus supply to within 2 V of the positive supply. For high speed signals, however, there are other considerations. Figure 37 shows −3 dB bandwidth vs. dc input voltage for a unity-gain follower. As the common-mode voltage approaches the positive supply, the amplifier responds well, but the bandwidth begins to drop at 2 V within $+V_S$.

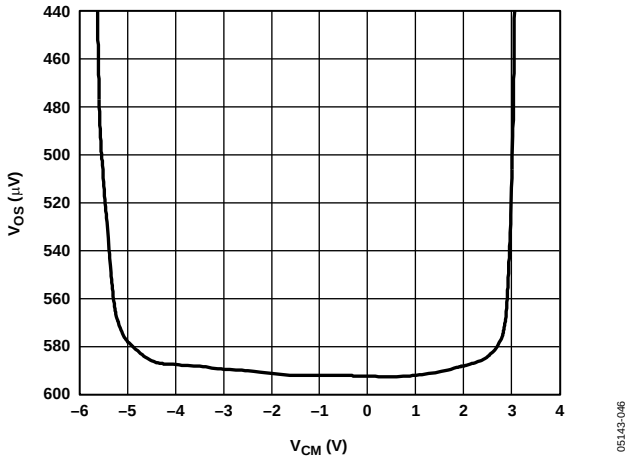

Figure 36. V_{OS} vs. Common-Mode Voltage, V_S = ±5 V

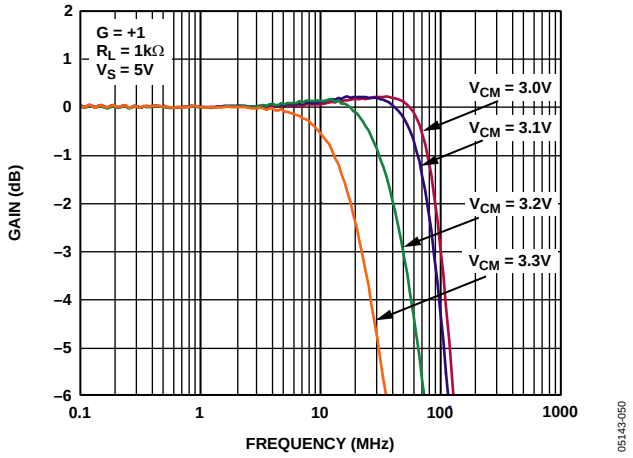

Figure 37. Unity-Gain Follower Bandwidth vs. Input Common-Mode

This can manifest itself in increased distortion or settling time. Higher frequency signals require more headroom than the lower frequencies to maintain distortion performance. Figure 38 illustrates how the rising edge settling time for the amplifier configured as a unity-gain follower stretches out as the top of a 1 V step input approaches and exceeds the specified input common-mode voltage limit.

For signals approaching the minus supply and inverting gain and high positive gain configurations, the headroom limit is the output stage. The ADA4851-1 amplifiers use a common emitter output stage. This output stage maximizes the available output range, limited by the saturation voltage of the output transistors. The saturation voltage increases with the drive current the output transistor is required to supply, due to the output transistors' collector resistance.

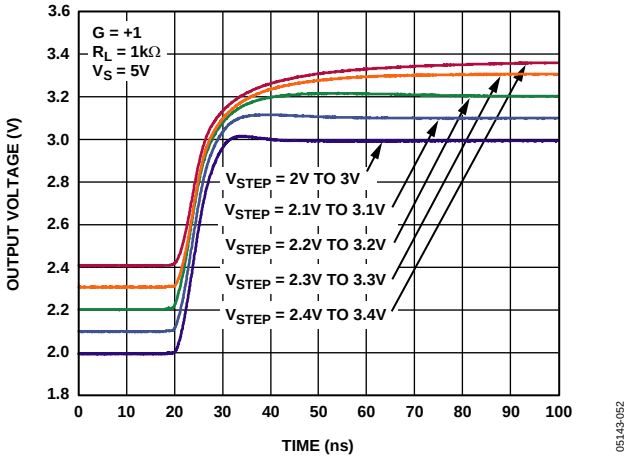

Figure 38. Output Rising Edge for 1 V Step at Input Headroom Limits

As the saturation point of the output stage is approached, the output signal shows increasing amounts of compression and clipping. As in the input headroom case, higher frequency signals require a bit more headroom than the lower frequency signals. Figure 14 illustrates this point by plotting the typical distortion vs. the output amplitude.

OVERLOAD BEHAVIOR AND RECOVERY

Input

The specified input common-mode voltage of the ADA4851-1 is 200 mV below the negative supply to within 2 V of the positive supply. Exceeding the top limit results in lower bandwidth and increased settling time, as seen in Figure 37 and Figure 38. Pushing the input voltage of a unity-gain follower less than 2 V from the positive supply leads to the behavior shown in Figure 39—an increasing amount of output error as well as much increased settling time. The recovery time from input voltages 2 V or closer to the positive supply is approximately 85 ns, which is limited by the settling artifacts caused by transistors in the input stage coming out of saturation.

The ADA4851-1 does not exhibit phase reversal, even for input voltages beyond the voltage supply rails. Going more than 0.6 V beyond the power supplies turns on protection diodes at the input stage, which greatly increase the device's current draw.

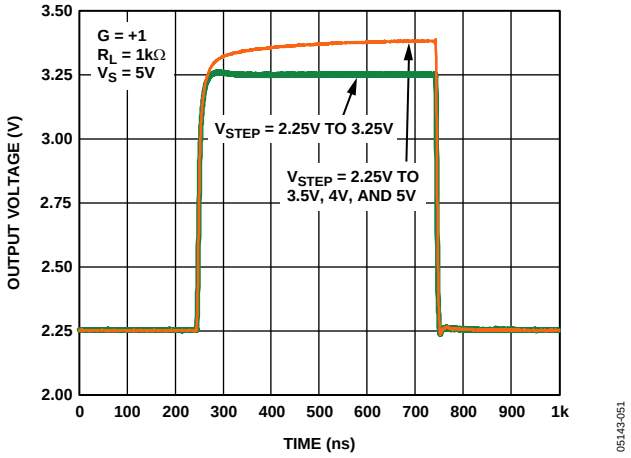

Figure 39. Pulse Response of G = 1 Follower, Input Step Overloading the Input Stage

Output

Output overload recovery is typically within 35 ns after the amplifier's input is brought to a nonoverloading value. Figure 40 shows output recovery transients for the amplifier recovering from a saturated output from the top and bottom supplies to a point at midsupply.

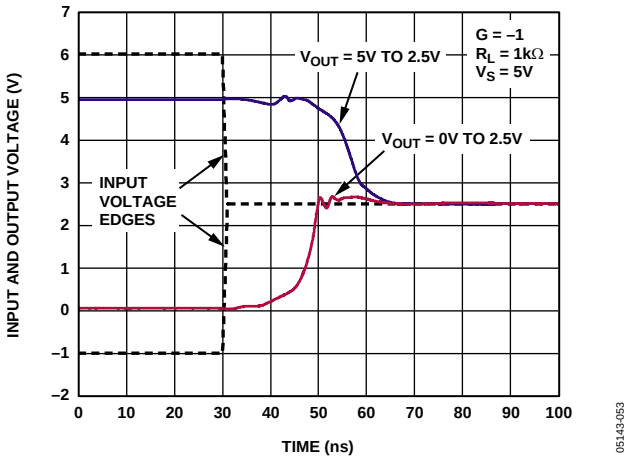

Figure 40. Overload Recovery

OUTLINE DIMENSIONS

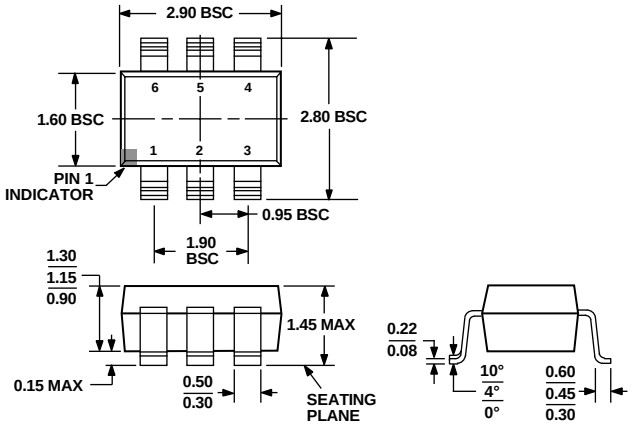

Figure 41. 6-Lead Small Outline Transistor Package [SOT-23]
(RJ-6)
Dimensions shown in millimeters

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Outline	Branding
ADA4851-1YRJZ-R2[1]	−40°C to +125°C	6-Lead Small Outline Transistor Package (SOT-23)	RJ-6	HHB
ADA4851-1YRJZ-RL[1]	−40°C to +125°C	6-Lead Small Outline Transistor Package (SOT-23)	RJ-6	HHB
ADA4851-1YRJZ-RL7[1]	−40°C to +125°C	6-Lead Small Outline Transistor Package (SOT-23)	RJ-6	HHB

[1] Z = Pb-free part.

NOTES

D05143–0–10/04(0)