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Single-Supply, High Speed, Fixed G = +2, Rail-to-Rail Output Video Amplifier

ADA4856-3

FEATURES

Voltage feedback architecture Rail-to-rail output swing: 0.1 V to 4.9 V **High speed amplifier** -3 dB bandwidth: 225 MHz 0.1 dB flatness at 2 V p-p: 74 MHz Slew rate: 800 V/µs Settling time to 0.1% with 2 V step: 5 ns High input common-mode voltage range $-V_{s} - 0.2 V$ to $+V_{s} - 1 V$ Supply range: 3 V to 5.5 V Differential gain error: 0.01% Differential phase error: 0.01° Low power 7.8 mA/amplifier typical supply current **Power-down feature** Available in 16-lead LFCSP



APPLICATIONS

Professional video Consumer video Imaging Instrumentation Base stations Active filters Buffers

GENERAL DESCRIPTION

The ADA4856-3 (triple) is a fixed gain of +2, single-supply, railto-rail output video amplifier. It provides excellent video performance with 225 MHz, -3 dB bandwidth, 800 V/µs slew rate, and 74 MHz, 0.1 dB flatness into a 150 Ω load. It has a wide input common-mode voltage range that extends 0.2 V below ground and 1 V below the positive rail. In addition, the output voltage swings within 200 mV of either supply, making this video amplifier easy to use on single-supply voltages as low as 3.3 V.

The ADA4856-3 offers a typical low power of 7.8 mA per amplifier, while being capable of delivering up to 52 mA of load current. It also features a power-down function for power sensitive applications that reduces the supply current to 1 mA.

The ADA4856-3 is available in a 16-lead LFCSP and is designed to work over the extended industrial temperature range of -40° C to $+105^{\circ}$ C.



Figure 2. Large Signal Frequency Response

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REVISION HISTORY

10/08—Revision 0: Initial Version

SPECIFICATIONS

5 V OPERATION

 $T_A = 25^{\circ}C$, $+V_S = 5$ V, $-V_S = 0$ V, G = +2, $R_L = 150 \Omega$ to midsupply, unless otherwise noted.

Table 1. Parameter **Test Conditions** Min Мах Unit Тур DYNAMIC PERFORMANCE -3 dB Bandwidth $V_0 = 0.1 V p - p$ 370 MHz MHz $V_0 = 1.4 V p - p$ 225 $V_0 = 2 V p - p$ 200 MHz Bandwidth for 0.1 dB Flatness $V_0 = 1.4 V p - p$ 90 MHz 74 MHz $V_0 = 2 V p - p$ Slew Rate $V_0 = 2 V \text{ step}$ 800 V/µs Settling Time to 0.1% (Rise/Fall) $V_0 = 2 V step$ 4.8/5.2 ns NOISE/DISTORTION PERFORMANCE dBc Harmonic Distortion (HD2/HD3) $f_c = 5 \text{ MHz}$, $V_o = 2 \text{ V p-p}$, $R_L = 1 \text{ k}\Omega$ -92/-110 dBc $f_c = 20 \text{ MHz}, V_o = 2 \text{ V p-p}, R_L = 1 \text{ k}\Omega$ -68/-71 Crosstalk, Output to Output f = 5 MHz, G = +2-80 dBc Input Voltage Noise f = 100 kHz14 nV/√Hz Input Current Noise f = 100 kHz2 pA/√Hz **Differential Gain Error** 0.01 % Differential Phase Error 0.01 Degrees DC PERFORMANCE Input Offset Voltage 3.4 1.3 m٧ Input Offset Voltage Drift 5.5 µV/°C Input Bias Current -3.8 μΑ Input Offset Current ±0.05 μΑ **Closed-Loop Gain** 1.95 2 2.05 V/V **Open-Loop Gain** 90 dB INPUT CHARACTERISTICS Input Resistance 3.2 MΩ Input Capacitance 0.5 рF Input Common-Mode Voltage Range $-V_{s} - 0.2$ $+V_{5} - 1$ V **Common-Mode Rejection Ratio** dB $V_{CM} = -0.2 V \text{ to } +4 V$ 94 **OUTPUT CHARACTERISTICS Output Voltage Swing** 0.1 to 4.9 V Linear Output Current Per Amplifier $HD2 \leq -60 \text{ dBc}, R_L = 10 \Omega$ 52 mA POWER-DOWN Turn-On Time 78 ns Turn-Off Time 950 ns Input Bias Current Enabled 0.2 μΑ Powered down -125 μΑ **Turn-On Voltage** 3.75 V POWER SUPPLY v **Operating Range** 3 5.5 Quiescent Current per Amplifier 7.8 mΑ Supply Current When Disabled 1.1 mΑ **Power Supply Rejection Ratio** $\Delta V_{s} = 4.5 V \text{ to } 5.5 V$ 96 dB

3.3 V OPERATION

 $T_{\rm A}$ = 25°C, +V_{\rm S} = 3.3 V, -V_{\rm S} = 0 V, G = +2, $R_{\rm L}$ = 150 Ω to midsupply, unless otherwise noted.

Table 2.

Parameter	Test Conditions	Min	Тур	Мах	Unit
DYNAMIC PERFORMANCE					
–3 dB Bandwidth	V _o = 0.1 V p-p		370		MHz
	$V_0 = 2 V p - p$		225		MHz
Bandwidth for 0.1 dB Flatness	$V_0 = 2 V p - p$		77		MHz
Slew Rate	$V_0 = 2 V \text{ step}$		800		V/µs
Settling Time to 0.1% (Rise/Fall)	$V_0 = 2 V step$		4.8/7		ns
NOISE/DISTORTION PERFORMANCE					
Harmonic Distortion (HD2/HD3)	$f_{C} = 5 \text{ MHz}$, $V_{O} = 2 \text{ V p-p}$, $R_{L} = 1 \text{ k}\Omega$		-95/-128		dBc
	$f_c = 20 \text{ MHz}, V_o = 2 \text{ V p-p}, R_L = 1 \text{ k}\Omega$		-74/-101		dBc
Crosstalk, Output to Output	f = 5 MHz, G = +2		-78		dBc
Input Voltage Noise	f = 100 kHz		14		nV/√Hz
Input Current Noise	f = 100 kHz		2		pA/√Hz
Differential Gain Error			0.01		%
Differential Phase Error			0.01		Degrees
DC PERFORMANCE					
Input Offset Voltage			1.2	3	mV
Input Offset Voltage Drift			5.5		μV/°C
Input Bias Current			-3.8		μΑ
Input Offset Current			±0.05		μΑ
Closed-Loop Gain		1.95	2	2.05	V/V
Open-Loop Gain			90		dB
INPUT CHARACTERISTICS					
Input Resistance			3.2		MΩ
Input Capacitance			0.5		pF
Input Common-Mode Voltage Range		$-V_{s} - 0.2$		+Vs — 1	V
Common-Mode Rejection Ratio	$V_{CM} = -0.2 \text{ V to } +2.3 \text{ V}$		94		dB
OUTPUT CHARACTERISTICS					
Output Voltage Swing, Load Resistance			0.1 to 3.22		V
Linear Output Current Per Amplifier	$HD2 \leq -60 \text{ dBc}, R_L = 10 \Omega$		49		mA
POWER-DOWN					
Turn-On Time			78		ns
Turn-Off Time			950		ns
Turn-On Voltage			2.05		V
POWER SUPPLY					
Operating Range		3		5.5	V
Quiescent Current per Amplifier			7.5		mA
Quiescent Current When Powered Down			0.98		mA
Power Supply Rejection Ratio	$\Delta V_{s} = 2.97 \text{ V} \text{ to } 3.63 \text{ V}$		94		dB

ABSOLUTE MAXIMUM RATINGS

Table 3.

Parameter	Rating
Supply Voltage	6 V
Internal Power Dissipation ¹	See Figure 3
Common-Mode Input Voltage	$(-V_{s} - 0.2 V)$ to $(+V_{s} - 1 V)$
Differential Input Voltage	±Vs
Output Short-Circuit Duration	Observe power curves
Storage Temperature Range	–65°C to +125°C
Operating Temperature Range	-40°C to +105°C
Lead Temperature (Soldering, 10 sec)	300°C

¹Specification is for device in free air.

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

Table 4.

Package Type	θ _{JA}	θ」	Unit
16-Lead LFCSP	67	17.5	°C/W

MAXIMUM POWER DISSIPATION

The maximum power that can be safely dissipated by the ADA4856-3 is limited by the associated rise in junction temperature. The maximum safe junction temperature for plastic encapsulated devices is determined by the glass transition temperature of the plastic, approximately 150°C. Temporarily exceeding this limit may cause a shift in parametric performance due to a change in the stresses exerted on the die by the package. Exceeding a junction temperature of 175°C for an extended period can result in device failure.

To ensure proper operation, it is necessary to observe the maximum power derating curves.



Figure 3. Maximum Power Dissipation vs. Ambient Temperature

ESD CAUTION



ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS



Table 5. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	NC	No Connect.
2	+IN2	Noninverting Input 2.
3	NC	No Connect.
4	PD	Power Down.
5	+IN3	Noninverting Input 3.
6	–IN3	Inverting Input 3.
7	OUT3	Output 3.
8	$-V_S$	Negative Supply.
9	+Vs	Positive Supply.
10	–IN2	Inverting Input 2.
11	OUT2	Output 2.
12	+Vs	Positive Supply.
13	-Vs	Negative Supply.
14	OUT1	Output 1.
15	–IN1	Inverting Input 1.
16	+IN1	Noninverting Input 1.
17 (EPAD)	Exposed Pad (EPAD)	The exposed pad must be connected to –Vs.

TYPICAL PERFORMANCE CHARACTERISTICS

 $T_A = 25^{\circ}C$, $+V_S = 5$ V, G = +2, $R_L = 150 \Omega$, large signal $V_{OUT} = 2$ V p-p, small signal $V_{OUT} = 100$ mV p-p, unless otherwise noted.



Figure 5. Small Signal Frequency Response vs. Supply Voltage



Figure 6. Large Signal 0.1 dB Flatness vs. Supply Voltage



Figure 7. Small Signal Frequency Response vs. Load Resistance



Figure 8. Large Signal Frequency Response vs. Supply Voltage



Figure 9. Small Signal Frequency Response vs. Temperature



Figure 10. Small Signal Frequency Response vs. Capacitive Load



Figure 13. Power Supply Rejection Ratio (PSRR) vs. Frequency









Figure 16. Settling Time



Figure 18. Small Signal Transient Response vs. Supply Voltage



Figure 19. Small Signal Transient Response vs. Capacitive Load





Figure 21. Large Signal Transient Response vs. Supply Voltage



TIME (10ns/DIV)

Figure 22. Large Signal Transient Response vs. Capacitive Load



TIME (10ns/DIV)

Figure 23. Small Signal Transient Response vs. Capacitive Load



TIME (50ns/DIV) Figure 24. Output Overdrive Recovery



Figure 25. Turn-On/Turn-Off Time



TIME (10ns/DIV)











10M

FREQUENCY (Hz) Figure 30. Output Impedance vs. Frequency

1M

1G

100M

THEORY OF OPERATION

The ADA4856-3 is a voltage feedback op amp that employs a new input stage that achieves a high slew rate while maintaining a wide common-mode input range. The input common-mode range of the ADA4856-3 extends from 200 mV below the negative rail to about 1 V from the positive rail. This feature makes the ADA4856-3 ideal for low voltage single-supply applications. In addition, this new input stage does not sacrifice noise performance for slew rate. At 14 nV/ \sqrt{Hz} , the ADA4856-3 is one of the lowest noise rail-to-rail output video amplifiers in the market.

Besides a novel input stage, the ADA4856-3 employs the Analog Devices, Inc., patented rail-to-rail output stage. This output stage makes an efficient use of the power supplies, allowing the op amp to drive up to three video loads to within 300 mV from both rails. In addition, this output stage provides the amplifier with very fast overdrive characteristics, an important property in video applications. The ADA4856-3 comes in a 16-lead LFCSP that has an exposed thermal pad for lower operating temperature. This pad is connected internally to the negative rail. To avoid printed circuit board (PCB) layout problems, the ADA4856-3 features a new pinout flow that is optimized for video applications. As shown in Figure 4, the feedback and gain resistors are on-chip, which minimizes the number of components needed and improves the design layout. The ADA4856-3 is fabricated in Analog Devices dielectrically isolated eXtra Fast Complementary Bipolar 3 (XFCB3) process, which results in the outstanding speed and dynamic range displayed by the amplifier.



Figure 32. High Level Design Schematic

APPLICATIONS INFORMATION USING THE ADA4856-3 IN GAINS EQUAL TO +1, -1

The ADA4856-3 was designed to offer outstanding video performance, simplify applications, and minimize board area.

The ADA4856-3 is a triple amplifier with on-chip feedback and gain set resistors. The gain is fixed internally at G = +2. The inclusion of the on-chip resistors not only simplifies the design of the application but also eliminates six surface-mount resistors, saving valuable board space and lowering assembly costs. Whereas the ADA4856-3 has a fixed gain of G = +2, it can be used in other gain configurations, such as G = -1 and G = +1.

Unity-Gain Operation

Option 1

There are two options for obtaining unity gain (G = +1). The first is shown in Figure 33. In this configuration, the -IN input pin is tied to the output (feedback is now provided with the two internal 402 Ω resistors in parallel), and the input is applied to the noninverting input. The noise gain for this configuration is 1.



Option 2

Another option exists for running the ADA4856-3 as a unitygain amplifier. In this configuration, the noise gain is +2, see Figure 34. The frequency response and transient response for this configuration closely match the gain of +2 plots because the noise gains are equal. This method does have twice the noise gain of Option 1; however, in applications that do not require low noise, Option 2 offers less peaking and ringing. By tying the inputs together, the net gain of the amplifier becomes 1. Equation 1 shows the transfer characteristic for the schematic shown in Figure 34.

$$V_{OUT} = V_{IN} \left(\frac{-R_F}{R_G} \right) + V_{IN} \left(\frac{R_F + R_G}{R_G} \right)$$
(1)

which simplifies to $V_{OUT} = V_{IN}$.



Figure 34. Unity Gain of Option 2

Inverting Unity-Gain Operation

In this configuration, the noninverting input is tied to ground and the input signal is applied to the inverting input. The noise gain for this configuration is +2, see Figure 35.



Figure 35. Inverting Configuration (G = -1)

Figure 36 shows the small signal frequency response for both gain of +1 (Option 1 and Option 2) and gain of -1 configurations. It is clear that G = +1, Option 2 has better flatness and no peaking compared to Option 1.



USING THE ADA4856-3 IN GAINS EQUAL TO +3, +4, AND +5

Depending on certain applications, it might be useful to have a fixed gain amplifier that can provide various gains. The advantage of having a fixed gain amplifier is the ease of layout, the reduced number of components needed, and the matching of the gain and feedback resistors.

Gain of +3 Configuration

Figure 37 shows the ADA4856-3 used as an amplifier with a fixed gain of +3. No external resistors are required, just a simple trace connecting certain inputs and outputs. Connect $V_{\rm IN}$ to U1, which is set to a gain of +2, and U2, which is set to unity. U3 then takes the output of U1 and gains it up by +2 and subtracts the output of U2 to produce $V_{\rm OUT}$. As shown in Figure 40, the large signal frequency response for G = +3 is flat out to 65 MHz, with a bandwidth of 165 MHz, a 2 V p-p output voltage, and a 100 Ω load.





Gain of +4 Configuration

To get a gain of +4, set one amplifier to a gain of +1 and set the other two amplifiers to a gain of +2. Figure 38 shows $V_{\rm IN}$ going in U2 at unity, then U1 takes the output of U2 and gains it by +2, and then feeds it to U3, which also gains it by +2 to produce $V_{\rm OUT}$.



As shown in Figure 40, the large signal frequency response for G = +4 is also flat out to 65 MHz, and it has a bandwidth of 180 MHz.

Gain of+ 5 Configuration

The gain of +5 is very similar to the G = +3 configuration but with U2 set to a gain of -1, which ends up being added to twice the output of U1 to generate V_{OUT} with G = +5.



Figure 39. Gain of +5

Figure 40 shows the large signal frequency response of the three closed-loop gain sets (+3, +4, and +5) with flatness that extends to 65 MHz and a -3 dB bandwidth of 150 MHz.



Figure 40. Large Signal Frequency Response for All Three Gains

20 MHz ACTIVE LOW-PASS FILTER

The ADA4856-3 triple amplifier lends itself to higher order active filters. Figure 41 shows a 20 MHz, 6-pole, Sallen-Key low-pass filter.



Figure 41. 20 MHz, 6-Pole Low-Pass Filter

The filter has a gain of approximately 18 dB, which is set by three fixed gain of 2 stages, and a flat frequency response out to 14 MHz. This type of filter is commonly used at the output of a video DAC as a reconstruction filter. The frequency response of the filter is shown in Figure 42.



Figure 42. 20 MHz, Low-Pass Filter Frequency Response

VIDEO LINE DRIVER

The ADA4856-3 was designed to excel in video driver applications. Figure 43 shows a typical schematic for a video driver operating on bipolar supplies.



Figure 43. Video Driver Schematic

In applications that require multiple video loads be driven simultaneously, the ADA4856-3 can deliver. Figure 44 shows the ADA4856-3 configured with triple video loads. Figure 45 shows the triple video load performance.



Figure 45. Large Signal Frequency Response for Various Loads

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SINGLE-SUPPLY OPERATION

The ADA4856-3 can operate in single-supply applications. Figure 46 shows the schematic for a single 5 V supply video driver. Resistors R2 and R4 establish the midsupply reference. Capacitor C2 is the bypass capacitor for the midsupply reference. Capacitor C1 is the input coupling capacitor, and C6 is the output coupling capacitor. Capacitor C5 prevents constant current from being drawn through the internal gain set resistor. Resistor R3 sets the ac input impedance of the circuit.

For more information on single-supply operation of op amps, see "Avoiding Op-Amp Instability Problems In Single-Supply Applications", Analog Dialogue, Volume 35, Number 2, March-May, 2001, at www.analog.com.



Figure 46. AC-Coupled, Single-Supply Video Driver Schematic

In addition, the ADA4856-3 can be configured in dc-coupled, single-supply operation. The common-mode input voltage can go about 200 mV below ground, which makes it a true single-supply part. However, in video applications, the black level is set at 0 V, which means that the output of the amplifier must go to the ground level as well. This part has a rail-to-rail output stage; it can go as close as 100 mV from either rail. Figure 47 shows the schematic for adding 50 mV dc offset to the input signal so that the output is not clipped while still properly terminating the input with 75 Ω .



Figure 47. DC-Coupled Single Supply Video Driver Schematic

POWER DOWN

The ADA4856-3 is equipped with a \overline{PD} (power-down) pin for all three amplifiers. This allows the user to reduce the quiescent supply current when an amplifier is inactive. The power-down threshold levels are derived from the voltage applied to the +V_s pin. When used in single-supply applications, this is especially useful with conventional logic levels. The amplifier is enabled when the voltage applied to the \overline{PD} pin is greater than +V_s – 1.25 V. In a 5 V single-supply application, the typical threshold voltage is +3.75 V, and in a 3.3 V dual-supply application, the typical threshold voltage is +2 V. The amplifier is also enabled when the \overline{PD} pin is left floating (not connected). However, the amplifier is powered down when the voltage on the \overline{PD} pin is lower than 2.5 V from +V_s. If the \overline{PD} pin is not used, it is best to connect it to the positive supply

PD Pin	5 V	±2.5 V	3.3 V
Not Active	>3.75 V	>1.25 V	>2.05 V
Active	<2 V	<0 V	<1.3 V

LAYOUT CONSIDERATIONS

As is the case with all high speed applications, careful attention to printed circuit board (PCB) layout details prevents associated board parasitics from becoming problematic. Proper RF design technique is mandatory. The PCB should have a ground plane covering all unused portions of the component side of the board to provide a low impedance return path. Removing the ground plane on all layers from the area near the input and output pins reduces stray capacitance. Locate termination resistors and loads as close as possible to their respective inputs and outputs. Keep input and output traces as far apart as possible to minimize coupling (crosstalk) though the board. Adherence to microstrip or stripline design techniques for long signal traces (greater than about 1 inch) is recommended.

POWER SUPPLY BYPASSING

Careful attention must be paid to bypassing the power supply pins of the ADA4856-3. Use high quality capacitors with low equivalent series resistance (ESR), such as multilayer ceramic capacitors (MLCCs), to minimize supply voltage ripple and power dissipation. A large, usually tantalum, 10 μ F to 47 μ F capacitor located in proximity to the ADA4856-3 is required to provide good decoupling for lower frequency signals. In addition, locate 0.1 μ F MLCC decoupling capacitors as close to each of the power supply pins as is physically possible, no more than 1/8 inch away. The ground returns should terminate immediately into the ground plane. Locating the bypass capacitor return close to the load return minimizes ground loops and improves performance.

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OUTLINE DIMENSIONS



ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option	Ordering Quantity
ADA4856-3YCPZ-R21	–40°C to +105°C	16-Lead LFCSP_VQ	CP-16-4	250
ADA4856-3YCPZ-R7 ¹	–40°C to +105°C	16-Lead LFCSP_VQ	CP-16-4	1,500
ADA4856-3YCPZ-RL1	–40°C to +105°C	16-Lead LFCSP_VQ	CP-16-4	5,000

¹ Z = RoHS Compliant Part.

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