

# DirectDrive Video Amplifier with Short-to-Battery Protection

## General Description

The MAX9532 DirectDrive® video filter amplifier is specifically designed to work in harsh environments such as automobiles. The MAX9532 provides integrated short-to-battery protection, allowing the output of the device to survive shorts up to 18V.

Maxim's DirectDrive technology eliminates large output coupling capacitors and sets the output video black level near ground. DirectDrive requires an integrated charge pump and an internal linear regulator to create a clean negative power supply so that the amplifier can pull the sync below ground. The charge pump injects so little noise into the video output that the picture is visibly flawless.

The MAX9532 features an internal reconstruction filter that smoothes the steps and reduces the spikes on the video signal from the video digital-to-analog converter (DAC). The reconstruction filter typically provides  $\pm 1$ dB passband flatness of 9.5MHz and 42dB attenuation at 27MHz.

The input of the MAX9532 can be directly connected to the output of a video DAC. The MAX9532 also features a transparent input sync-tip clamp, allowing AC-coupling of input signals with different DC biases.

The MAX9532 features an internal fixed gain of 4V/V. The input full-scale video signal is nominally 0.5V<sub>P-P</sub>, and the output full-scale video signal is nominally 2V<sub>P-P</sub>.

The short-to-battery protection utilizes an internal switch in series with the amplifier output. When the MAX9532 detects that the output is short circuited to the battery voltage, the internal switch is disabled, protecting the MAX9532 from voltages up to 18V.

The MAX9532 is available in a 3mm x 3mm, 10-pin  $\mu$ MAX® package and is specified over the -40°C to +125°C automotive operating temperature range.

## Features

- ◆ Short-to-Battery Protection on Video Output (Up to 18V)
- ◆ DirectDrive Sets Video Output Black Level Near Ground
- ◆ DirectDrive Eliminates DC-Blocking Capacitors at the Output
- ◆ 3.3V Single-Supply Operation
- ◆ Reconstruction Filter with 9.5MHz Passband and 42dB Attenuation at 27MHz
- ◆ DC-Coupled Input/Output
- ◆ Transparent Input Sync-Tip Clamp
- ◆ 4V/V Internal Fixed Gain

## Applications

Automotive Infotainment Systems

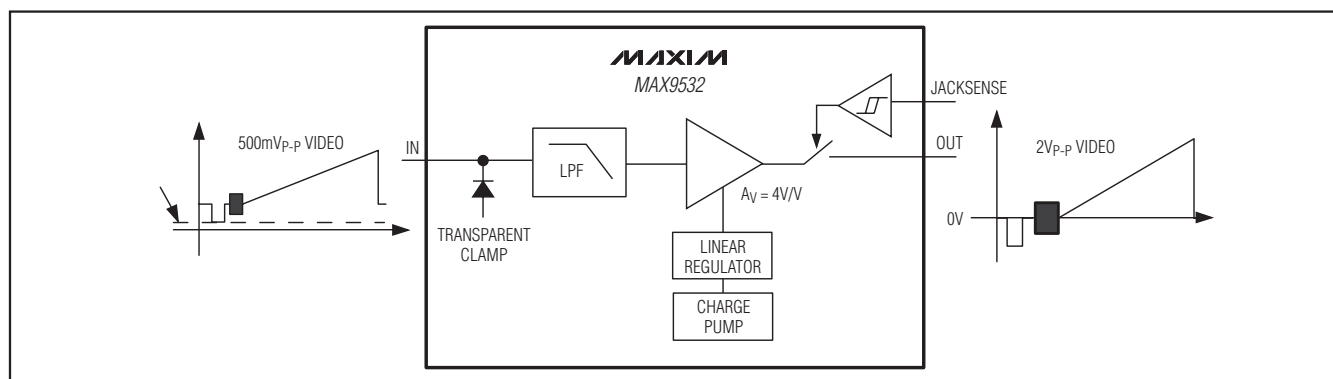
## Ordering Information

PART	PIN-PACKAGE	TEMP RANGE
MAX9532AUB+	10 $\mu$ MAX	-40°C to +125°C

+Denotes a lead(Pb)-free/RoHS-compliant package.

Pin Configuration and Functional Diagram/Typical Application Circuits appear at end of data sheet.

## Simplified Block Diagram



DirectDrive is a registered trademark of Maxim Integrated Products, Inc.

$\mu$ MAX is a registered trademark of Maxim Integrated Products, Inc.

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## ABSOLUTE MAXIMUM RATINGS

V <sub>DD</sub> to GND	-0.3V to +4V	Continuous Power Dissipation (T <sub>A</sub> = +70°C) 10-Pin μMAX (derate 8.8mW/°C above +70°C) .....707.3mW
V <sub>DD</sub> to CPGND	-0.3V to +4V	
CPGND to GND	-0.1V to +0.1V	Operating Temperature Range .....-40°C to +125°C
IN to GND	-0.3V to +4V	Junction Temperature .....+150°C
JACKSENSE to GND	The higher of V <sub>SS</sub> and -2V to (V <sub>SS</sub> + 22V)	Storage Temperature Range .....-65°C to +150°C
OUT to GND	The higher of V <sub>SS</sub> and -1.5V to (V <sub>SS</sub> + 22V)	Lead Temperature (soldering, 10s) .....+300°C
V <sub>SS</sub> to CPVSS	-0.1V to +0.1V	
Continuous Current		
IN, JACKSENSE	±20mA	
C1P, C1N, CPVSS	±50mA	
OUT	±50mA	

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

(V<sub>DD</sub> = 3.3V, GND = CPGND = 0, R<sub>L</sub> = 100Ω to GND, C<sub>1</sub> = C<sub>2</sub> = C<sub>3</sub> = 1μF, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DC-COUPLED INPUT</b>						
Input Voltage Range	V <sub>IN</sub>	Guaranteed by output voltage swing 3V < V <sub>DD</sub> < 3.135V	0		0.5	V
		Guaranteed by output voltage swing 3.135V < V <sub>DD</sub> < 3.6V	0		0.7	
Input Current	I <sub>IN</sub>	V <sub>IN</sub> = 0.5V		2	3.3	μA
Input Resistance	R <sub>IN</sub>	0.1V ≤ V <sub>IN</sub> ≤ 0.5V		5		MΩ
<b>SYNC-TIP CLAMP INPUT</b>						
Sync-Tip Clamp Level	V <sub>CCLP</sub>	Sync-tip clamp	-6.2	-1.63	+3.5	mV
Input Voltage Range		Guaranteed by output voltage swing 3V < V <sub>DD</sub> < 3.135V	0		0.5	V <sub>P-P</sub>
		Guaranteed by output voltage swing V <sub>DD</sub> > 3.135V	0		0.7	
Sync Crush		Sync-tip clamp; percentage reduction in sync pulse (0.15V <sub>P-P</sub> , 75Ω source impedance), guaranteed by input clamping current measurement			2.3	%
Input Clamping Current		Sync-tip clamp		2	3.3	μA
Max Input Source Resistance				300		Ω
<b>GENERAL</b>						
Supply Voltage Range	V <sub>DD</sub>	Guaranteed by PSRR	3.0	3.3	3.6	V
Quiescent Supply Current				15	23	mA
DC Voltage Gain	A <sub>V</sub>	Guaranteed by output voltage swing	3.92	4	4.08	V/V
Output Level		V <sub>IN</sub> = 150mV	-0.120		+0.150	V

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## ELECTRICAL CHARACTERISTICS (continued)

( $V_{DD} = 3.3V$ ,  $GND = CPGND = 0$ ,  $R_L = 100\Omega$  to  $GND$ ,  $C_1 = C_2 = C_3 = 1\mu F$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage Swing		Measured at output, $V_{DD} = 3.135V$ , $V_{IN} = V_{CLP}$ to $(V_{CLP} + 0.7V)$ , $R_L = 100\Omega$ to $-2V$ and $+2V$	2.744	2.8	2.856	V <sub>P-P</sub>
		Measured at output, $V_{DD} = 3V$ , $V_{IN} = V_{CLP}$ to $(V_{CLP} + 0.5V)$ , $R_L = 100\Omega$ to $-2V$ and $+2V$	1.96	2	2.04	
Output Short-Circuit Current				90		mA
Output Resistance	$R_{OUT}$			0.1		$\Omega$
Short Circuit to Battery Current		Short-to-battery, $V_{OUT} = 9V$ to $16V$			3	mA
Power-Supply Rejection Ratio		$3.0V \leq V_{DD} \leq 3.6V$	46	78		dB
Filter		$V_{IN} = 0.5V_{P-P}$ , reference frequency is 100kHz	Attenuation at 5.5MHz	-1.29	+1	dB
			Attenuation at $f = 27MHz$	20	42	
Differential Gain	DG	5-step modulated staircase, $f = 4.43MHz$ , $R_L = 100\Omega$ to $-2V$ and $+2V$		0.7		%
Differential Phase	DP	5-step modulated staircase, $f = 4.43MHz$ , $R_L = 100\Omega$ to $-2V$ and $+2V$		0.5		deg
2T Pulse-to-Bar K Rating		$2T = 200ns$ ; bar time is $18\mu s$ ; the beginning 2.5% and the ending 2.5% of the bar time is ignored; $R_L = 100\Omega$ to $-2V$ and $+2V$		0.5		K%
2T Pulse Response		$2T = 200ns$ , $R_L = 100\Omega$ to $-2V$ and $+2V$		0.4		K%
2T Bar Response		$2T = 200ns$ ; bar time is $18\mu s$ ; the beginning 2.5% and the ending 2.5% of the bar time is ignored; $R_L = 100\Omega$ to $-2V$ and $+2V$		0.1		K%
Nonlinearity		5-step staircase; $R_L = 100\Omega$ to $-2V$ and $+2V$		0.1		%
Group Delay Distortion		$100kHz \leq f \leq 5MHz$ , outputs are $2V_{P-P}$ ; $R_L = 100\Omega$ to $-2V$ and $+2V$		13		ns
Glitch Impulse Caused by Charge Pump Switching		Measured at outputs, $R_L = 100\Omega$ to $-2V$ and $+2V$		40		pVs
Peak Signal to RMS Noise		$100kHz \leq f \leq 5MHz$ , $R_L = 100\Omega$ to $-2V$ and $+2V$		64		dB
Power-Supply Rejection Ratio		$f = 100kHz$ , $100mV_{P-P}$ ; $R_L = 100\Omega$ to $-2V$ and $+2V$		47		dB
Output Impedance		$f = 5MHz$		2		$\Omega$
JACKSENSE Input Resistance			120	250		k $\Omega$
<b>BATTERY DETECTION</b>						
Threshold Accuracy		Referred to GND	7.3	8	8.7	V
Video Output Disconnect Time		After detection of short-to-battery		20		$\mu s$
Video Output Connect Time		After short-to-battery has been removed	4.9	10	20	ms

# DirectDrive Video Amplifier with Short-to-Battery Protection

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{DD} = 3.3V$ ,  $GND = CPGND = 0$ ,  $R_L = 100\Omega$  to  $GND$ ,  $C_1 = C_2 = C_3 = 1\mu F$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

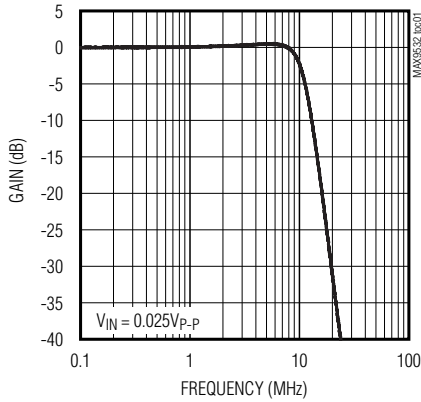
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>CHARGE PUMP</b>						
Switching Frequency	$f_{CP}$		220	440	660	kHz

**Note 1:** All devices are 100% production tested at  $T_A = +25^\circ C$ . Specifications over temperature limits are guaranteed by design.

## Typical Operating Characteristics

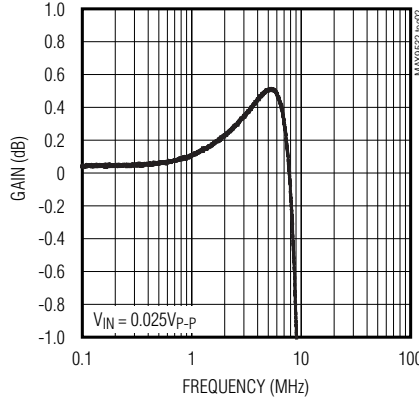
( $V_{DD} = 3.3V$ ,  $GND = CPGND = 0$ , video output has  $R_L = 100\Omega$  to  $GND$ ,  $C_1 = C_2 = C_3 = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

**SMALL-SIGNAL GAIN vs. FREQUENCY**



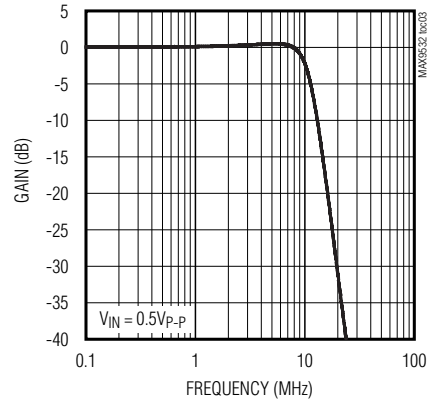
**NOTE:** GAIN VALUES (PLOTTED IN dB) ARE NORMALIZED VALUES RELATIVE TO THE EXPECTED VALUE OF 4V/V.

**SMALL-SIGNAL GAIN FLATNESS vs. FREQUENCY**



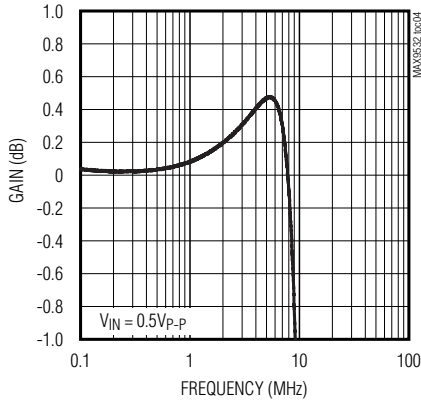
**NOTE:** GAIN VALUES (PLOTTED IN dB) ARE NORMALIZED VALUES RELATIVE TO THE EXPECTED VALUE OF 4V/V.

**LARGE-SIGNAL GAIN vs. FREQUENCY**



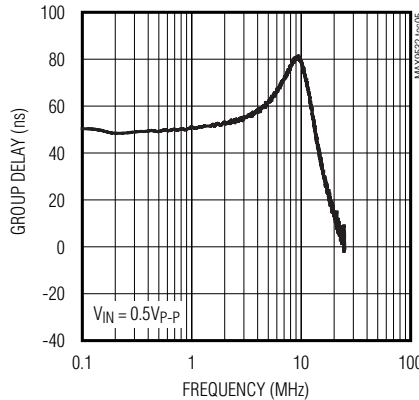
**NOTE:** GAIN VALUES (PLOTTED IN dB) ARE NORMALIZED VALUES RELATIVE TO THE EXPECTED VALUE OF 4V/V.

**LARGE-SIGNAL GAIN FLATNESS vs. FREQUENCY**

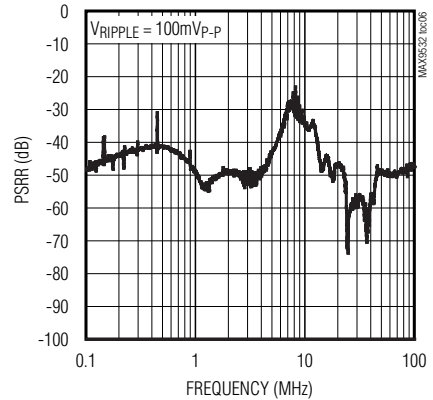


**NOTE:** GAIN VALUES (PLOTTED IN dB) ARE NORMALIZED VALUES RELATIVE TO THE EXPECTED VALUE OF 4V/V.

**GROUP DELAY vs. FREQUENCY**



**POWER-SUPPLY REJECTION RATIO vs. FREQUENCY**

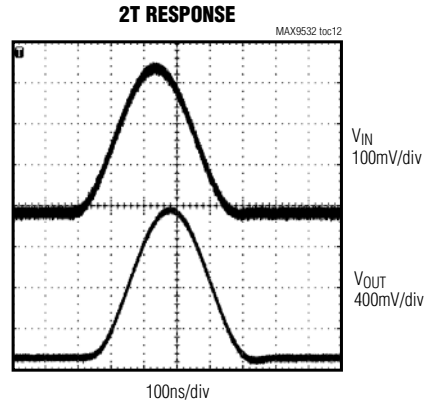
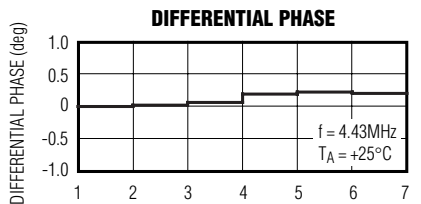
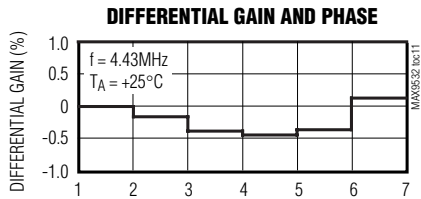
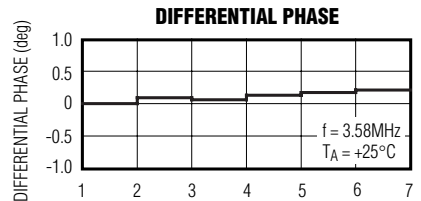
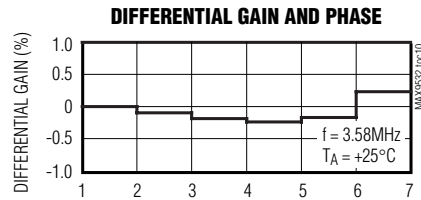
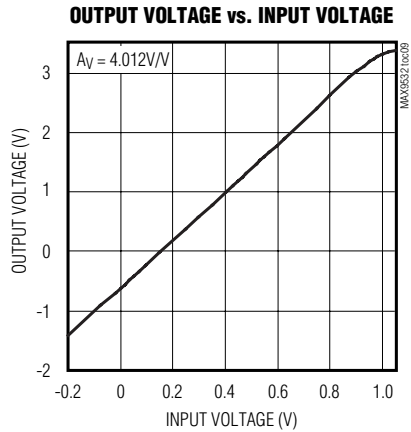
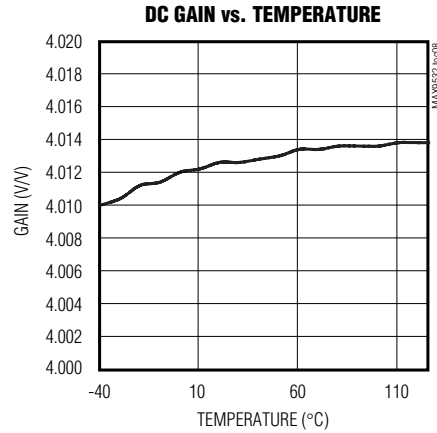
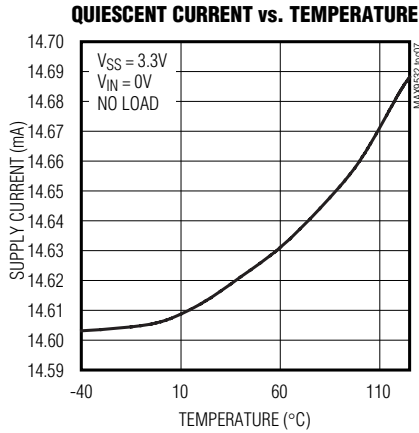


# DirectDrive Video Amplifier with Short-to-Battery Protection

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## Typical Operating Characteristics (continued)

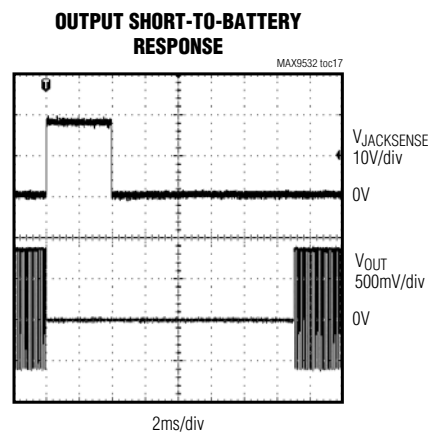
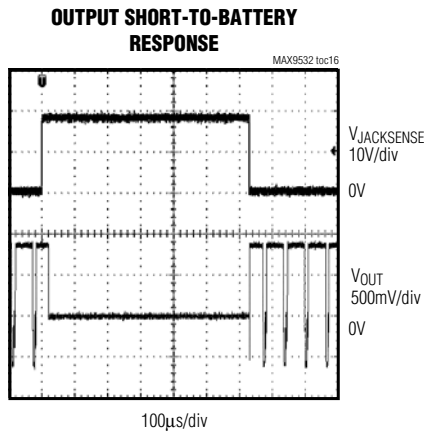
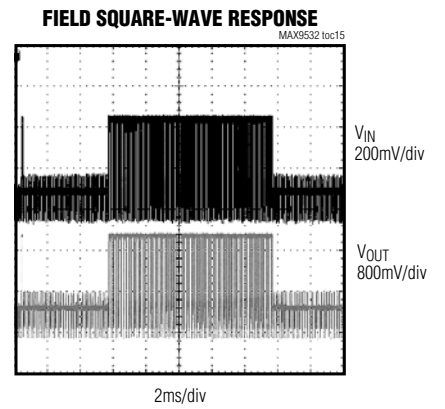
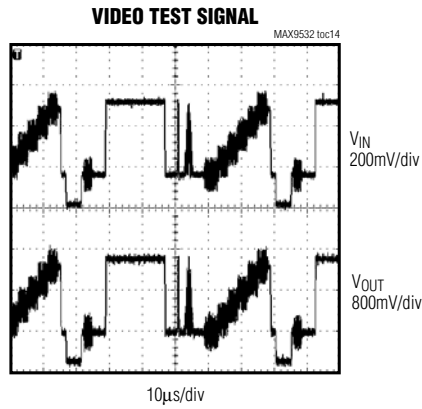
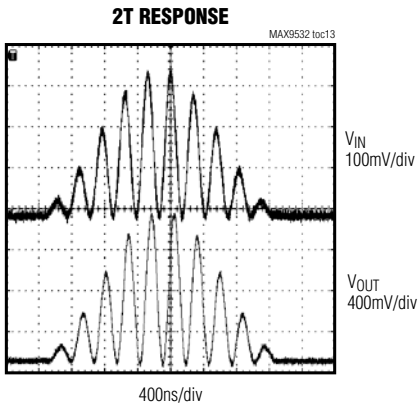
( $V_{DD} = 3.3V$ ,  $GND = CPGND = 0$ , video output has  $R_L = 100\Omega$  to  $GND$ ,  $C_1 = C_2 = C_3 = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# DirectDrive Video Amplifier with Short-to-Battery Protection

## Typical Operating Characteristics (continued)

( $V_{DD} = 3.3V$ ,  $GND = CPGND = 0$ , video output has  $R_L = 100\Omega$  to  $GND$ ,  $C_1 = C_2 = C_3 = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# DirectDrive Video Amplifier with Short-to-Battery Protection

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## Pin Description

PIN	NAME	FUNCTION
1	V <sub>DD</sub>	Positive Power Supply. Bypass V <sub>DD</sub> with a 1μF capacitor to GND.
2	C1P	Charge-Pump Flying Capacitor Positive Terminal. Connect a 1μF ceramic capacitor from C1P to C1N.
3	CPGND	Charge-Pump Ground. Connect to GND.
4	C1N	Charge-Pump Flying Capacitor Negative Terminal. Connect a 1μF ceramic capacitor from C1P to C1N.
5	CPVSS	Charge-Pump Negative Power Supply. Bypass CPVSS with a 1μF ceramic capacitor in parallel with a 10nF low ESL capacitor to GND.
6	V <sub>SS</sub>	Negative Power Supply. Connect V <sub>SS</sub> to CPVSS.
7	OUT	Video Output
8	JACKSENSE	Jack-Sense Input. Connect to the video output connector after the back-termination resistor.
9	GND	Ground
10	IN	Video Input

## Detailed Description

The MAX9532 DirectDrive video amplifier with short-to-battery protection features an internal 5-pole Butterworth lowpass filter with the amplifier configured with a gain of 4. The MAX9532 accepts DC-coupled or AC-coupled full-scale input signals of 0.5V<sub>P-P</sub>. Integrated short-to-battery protection prevents the MAX9532 from being damaged when the output is short circuited to the battery in automotive applications.

### DirectDrive Background

Integrated video filter amplifier circuits operate from a single supply. The positive power supply usually creates video output signals that are level-shifted above ground to keep the signal within the linear range of the output amplifier. For applications where the positive DC level is not acceptable, a series capacitor can be inserted in the output connection to eliminate the positive DC level shift. The series capacitor cannot truly level shift a video signal because the average level of the video varies with picture content. The series capacitor biases the video output signal around ground, but the actual level of the video signal can vary significantly depending upon the RC time constant and the picture content.

The series capacitor creates a highpass filter. Since the lowest frequency in video is the frame rate, which is between 24Hz and 30Hz, the pole of the highpass filter is ideally an order of magnitude lower in frequency than the frame rate. Therefore, the series capacitor must be very large, typically from 220μF to 3000μF. For space-constrained equipment, the series capacitor is

unacceptable. Changing from a single series capacitor to a SAG network that requires two smaller capacitors can only reduce space and cost slightly.

### Video Amplifier

When the full-scale video signal from a video DAC is 500mV, the black level of the video signal created by the video DAC is around 150mV. The MAX9532 shifts the black level to near ground at the output so that the active video is above ground and the sync is below ground. The amplifier needs a negative supply for the output stage to remain in the linear region when driving sync below ground.

The MAX9532 includes an integrated charge pump and linear regulator to create a low-noise negative supply from the positive supply voltage. The charge pump inverts the positive supply to create a raw negative voltage that is then fed into the linear regulator filtering out the charge-pump noise.

### Comparison Between DirectDrive Output and AC-Coupled Output

The actual level of the video signal varies less with a DirectDrive output than with an AC-coupled output. The average video signal level changes depending upon the picture content. With an AC-coupled output, the average level changes according to the time constant formed by the series capacitor and series resistance (usually 150Ω). For example, Figure 1 shows an AC-coupled video signal alternating between a completely black screen and a completely white screen. Notice the excursion of the video signal as the screen changes.



# DirectDrive Video Amplifier with Short-to-Battery Protection

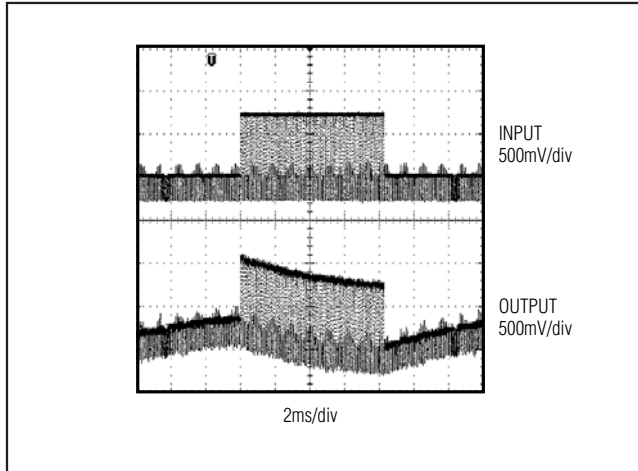


Figure 1. AC-Coupled Output

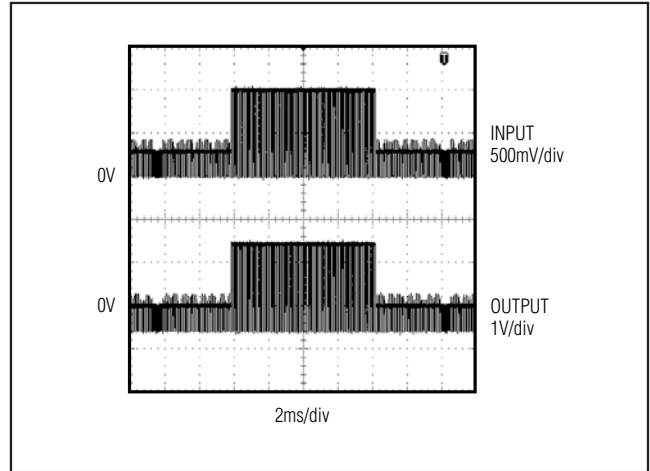


Figure 2. DirectDrive Output

With the DirectDrive amplifier, the black level is held at ground. The video signal is constrained between  $-0.3\text{V}$  to  $+0.7\text{V}$ . Figure 2 shows the video signal from a DirectDrive amplifier with the same input signal as the AC-coupled system.

### Video Reconstruction Filter

The MAX9532 features an internal five-pole, Butterworth lowpass filter to condition the video signal. The reconstruction filter smooths the steps and reduces the spikes created whenever the DAC output changes value. In the frequency domain, the steps and spikes cause images of the video signal to appear at multiples of the sampling clock frequency. The reconstruction filter typically provides  $\pm 1\text{dB}$  passband flatness of  $9.5\text{MHz}$  and  $42\text{dB}$  attenuation at  $27\text{MHz}$ .

### Transparent Sync-Tip Clamp

The MAX9532 contains an integrated, transparent sync-tip clamp. When using a DC-coupled input, the sync-tip clamp does not affect the input signal as long as the input signal remains above ground. When using an AC-coupled input, the sync-tip clamp automatically clamps the input signal to ground, preventing the input signal from going lower. A low current of  $2\mu\text{A}$  pulls down on the input to prevent an AC-coupled signal from drifting outside the input range of the device.

### Short-Circuit and Short-to-Battery Protection

The MAX9532 typical operating circuit includes a  $50\Omega$  or  $75\Omega$  back-termination resistor that limits short-circuit current when an external short is applied to the video output. The MAX9532 also features an internal output short-circuit protection to prevent device damage in

prototyping and applications where the amplifier output can be directly shorted to ground.

To protect the device from output short circuits to voltages higher than the supply voltage  $V_{DD}$ , the MAX9532 utilizes an internal switch in series with the amplifier output. When the JACKSENSE input detects that the output connector of the circuit is shorted to the battery voltage (up to  $18\text{V}$ ) higher than the internal  $8\text{V}$  threshold, an internal comparator disables the switch in  $10\mu\text{s}$  (typ) preventing the MAX9532 from being damaged.

After the output is shorted to a battery, the output immediately resumes normal operation when the short is removed within  $1\text{ms}$ . When the output is shorted to the battery for longer than  $1\text{ms}$ , the output resumes normal operation  $10\text{ms}$  after the short is removed.

## Applications

### Power Consumption

Quiescent power consumption is defined when the MAX9532 is operating without load. In this case, the MAX9532 consumes about  $47.355\text{mW}$ . Average power consumption, when the MAX9532 drives a  $100\Omega$  and  $150\Omega$  load to ground with a 50% flat field, is about  $51.596\text{mW}$  and  $49.513\text{mW}$ , respectively. Table 1 shows the power consumption with different video signals.

Notice that the two extremes in power consumption occur with a video signal that is all black and a video signal that is all white. The power consumption with 75% color bars and 50% flat field lies in between the extremes.



# DirectDrive Video Amplifier with Short-to-Battery Protection

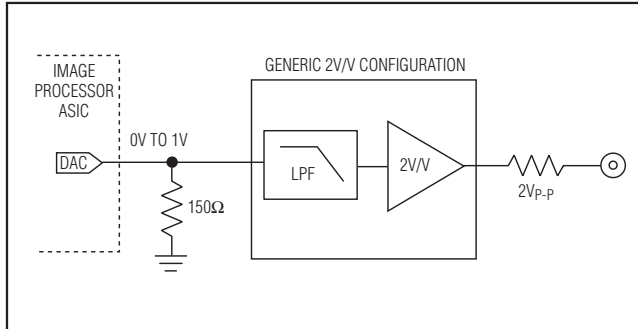


Figure 3. Typically, a Video DAC Generates a 1Vp-p Signal Across a 150Ω Resistor Connected to Ground

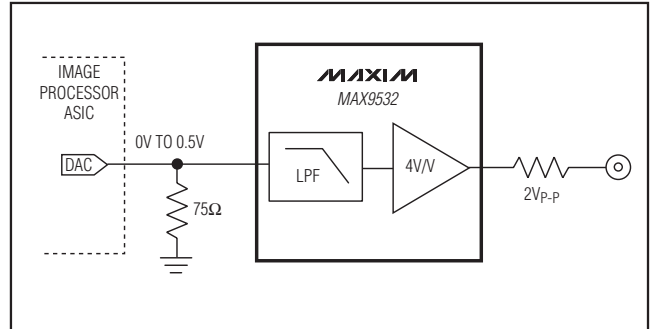


Figure 4. Video DAC Generates a 0.5Vp-p Signal Across a 75Ω Resistor Connected to Ground

**Table 1. Power Consumption of the MAX9532 with Different Video Signals**

VIDEO SIGNAL	MAX9532 POWER CONSUMPTION (mW) WITH 150Ω LOAD	MAX9532 POWER CONSUMPTION (mW) WITH 100Ω LOAD
All Black Screen	51.236	53.978
All White Screen	57.077	65.399
75% Color Bars	53.074	57.486
50% Flat Field	49.513	51.596

**Note:** The supply voltage is 3.3V.

## Interfacing to Video DACs that Produce Video Signals Higher than 0.5Vp-p

Devices designed to generate 1Vp-p video signals at the output of the video DAC can work with the MAX9532. Most video DACs source current into a ground-referenced resistor, which converts the current into a voltage. Figure 3 shows a video DAC that creates a video signal from 0V to 1V across a 150Ω resistor. With a gain of 2V/V, the following video filter produces a 2Vp-p output.

The MAX9532 accepts input signals that are 0.5Vp-p nominally. The video DAC in Figure 3 can be made to work with the MAX9532 by scaling down the 150Ω resistor to a 75Ω resistor, as shown in Figure 4. The 75Ω resistor is one-half the size of the 150Ω resistor, resulting in a video signal that is one-half the amplitude.

## Video Source with a Positive DC Bias

In some applications, the video source generates a signal with a positive DC voltage bias, i.e., the sync tip of the signal is well above ground. Figure 5 shows an example in which the outputs of the luma (Y) DAC and the chroma (C) DAC are connected together. Since the

DACs are current-mode, the output currents sum together into the resistor, which converts the resulting current into a voltage representing a composite video signal.

When the chroma DAC is connected to an independent output resistor to ground, the chroma signal, which is a carrier at 3.58MHz for NTSC or at 4.43MHz for PAL, generates a positive DC bias to keep the signal above ground at all times. When the luma DAC is connected to an independent output resistor to ground, the luma signal usually does not have a positive DC bias, and the sync tip is at approximately ground. When the chroma and luma signals are added together, the resulting composite video signal generates a positive DC bias. Therefore, the signal must be AC-coupled into the MAX9532 because the composite video signal is above the nominal 0V to 0.7V DC-coupled input range.

## Video Signal Routing

Minimize the length of the PCB trace between the output of the video DAC and the input of the MAX9532 to reduce coupling of external noise into the video signal. If possible, shield the PCB trace.

# DirectDrive Video Amplifier with Short-to-Battery Protection

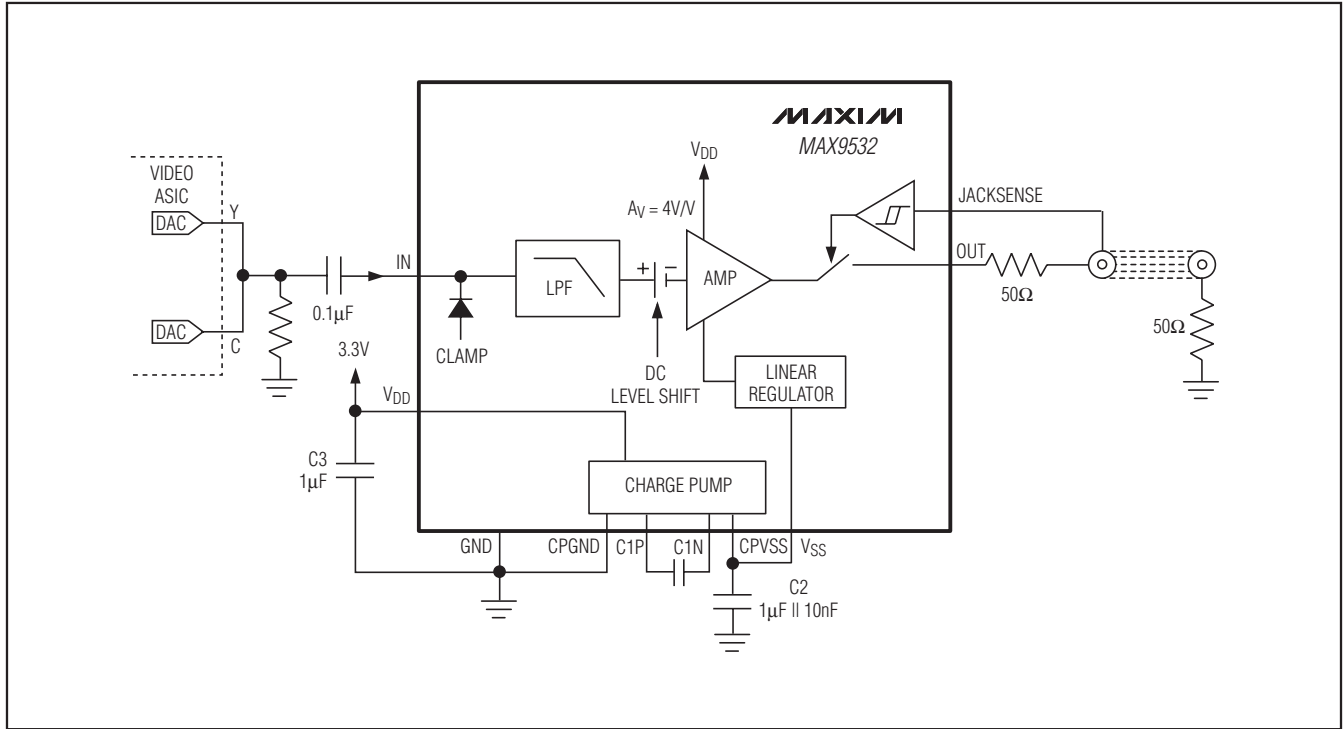


Figure 5. Luma (Y) and Chroma (C) Signals are Added Together to Create a Composite Video Signal, Which is AC-Coupled into the MAX9532

### Power-Supply Bypassing and Ground Management

The MAX9532 operates from a 3V to 3.6V single supply and requires proper layout and bypassing. For the best performance, place the components as close as possible to the device.

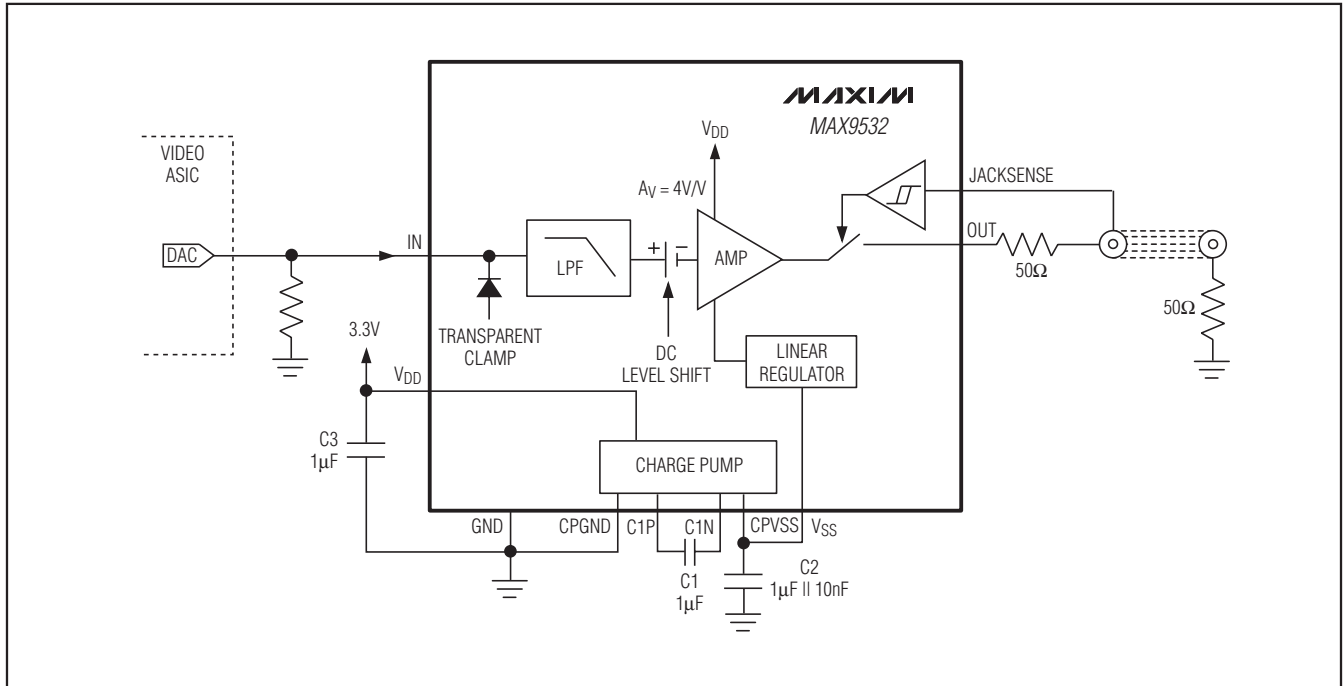
Proper grounding improves performance and prevents any switching noise from coupling into the video signal.

Bypass the analog supply ( $V_{DD}$ ) with a  $1\mu\text{F}$  capacitor to GND, placed as close as possible to the device. Bypass CPVSS to GND with a  $1\mu\text{F}$  ceramic capacitor in parallel with a  $10\text{nF}$  low-ESR capacitor. The bypass capacitors should be placed as close as possible to the device.

# DirectDrive Video Amplifier with Short-to-Battery Protection

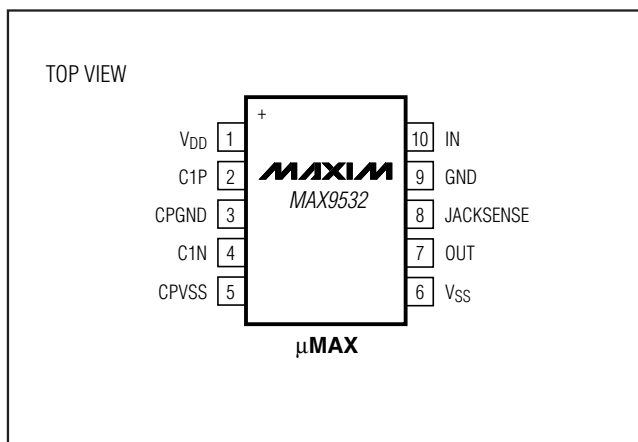
## Functional Diagram/Typical Application Circuits (DC-Coupled Input/Inactive Input Clamp)

MAX9532



### Pin Configuration

### Chip Information



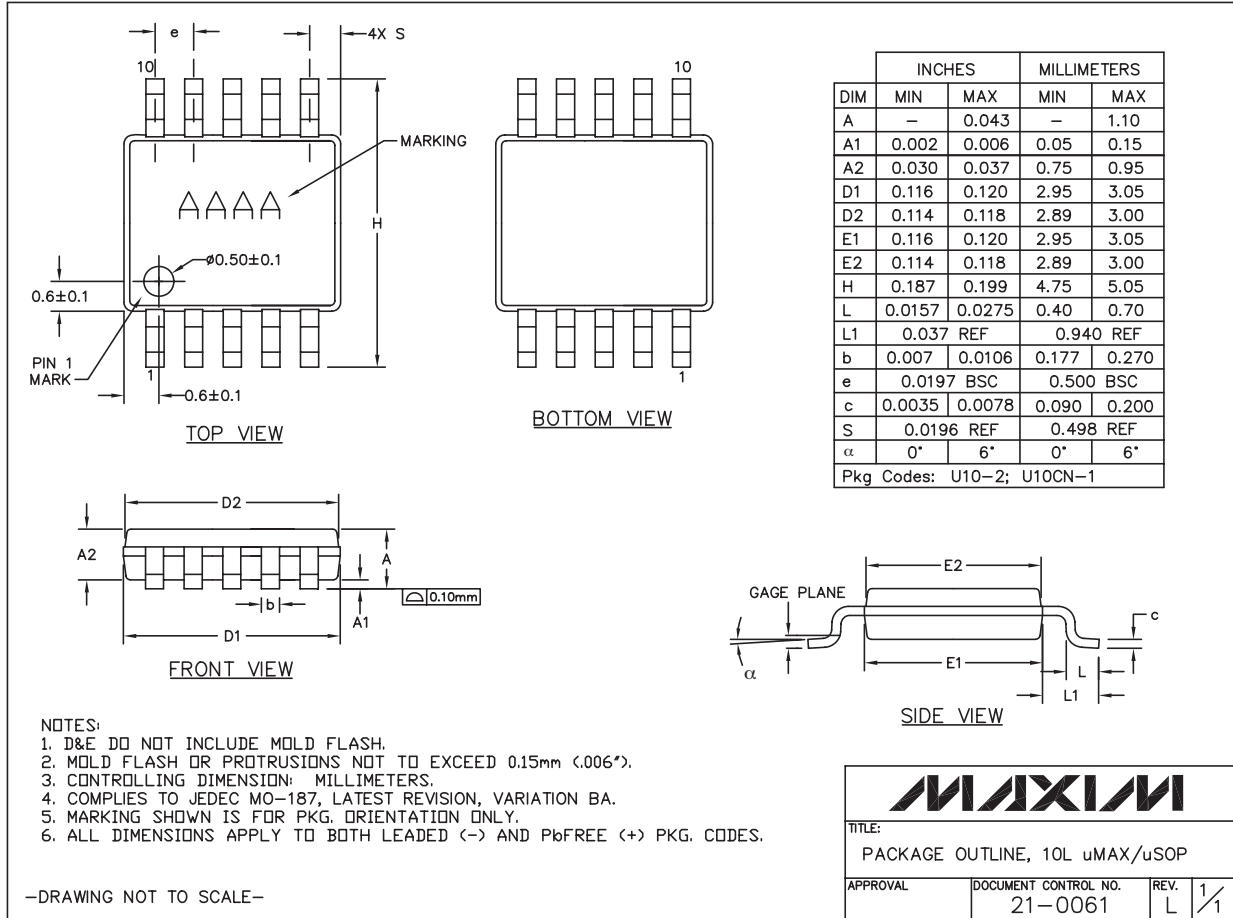
PROCESS: BiCMOS

# DirectDrive Video Amplifier with Short-to-Battery Protection

## Package Information

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
10 $\mu$ MAX	U10+2	<a href="#">21-0061</a>



**MAXIM**

TITLE:  
PACKAGE OUTLINE, 10L  $\mu$ MAX/ $\mu$ SOP

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