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Reference Circuits

Circuits from the Lab™ reference circuits are engineered and tested for quick and easy system integration to help solve today's analog, mixed-signal, and RF design challenges. For more information and/or support, visit www.analog.com/CN0264.

Devices Connected/Referenced

ADV7391/ADV7393	Low Power, Chip Scale 16-/8-Bit SD/HD Video Encoder
ADA4432-1	Single-Ended SD Video Filter Amplifier with Output Short-to-Battery Protection
ADA4433-1	Differential SD Video Filter Amplifier with Output Short-to-Battery Protection

A Robust Solution for Transmitting Composite Video with Output Short-to-Battery Protection

EVALUATION AND DESIGN SUPPORT

Circuit Evaluation Boards

[CN-0264 Circuit Evaluation Board \(EVAL-CN0264-EB1Z\)](#)

Design and Integration Files

[Schematics, Layout Files, Bill of Materials](#)

CIRCUIT FUNCTION AND BENEFITS

The circuit in Figure 1 shows a digital-to-analog video converter paired with a low cost, low power, fully integrated reconstruction video filter with output short-to-battery (STB) protection, ideal for CVBS video transmission in harsh infotainment environments such as automotive applications. Although many video encoders (video DACs), such as the [ADV7391](#), can drive a video load directly, it is often beneficial to use a video driver at the output of a video encoder for power savings, filtering, line driving, and overvoltage circuit protection. The main purpose of a video driver, typically configured as an active filter (also known as a reconstruction filter), is twofold: it blocks the higher frequency components (above the Nyquist frequency) that were introduced into the video signal as part of the sampling process, and it provides gain to drive the external 75 Ω cable to the video display.

Designers of infotainment and other video systems, such as rearview cameras and rear-seat entertainment systems, are likely to use this circuit to transmit video for the reasons previously stated. However, a third pressing design issue centers on the robustness. The [ADA4432-1](#) and [ADA4433-1](#) provide analog video designers with integrated ICs that offer crucial overvoltage protection, hardened ESD tolerance, along with excellent video specification, low power consumption, and wire diagnostic features.

The [ADA4432-1](#) and [ADA4433-1](#) are fully integrated, single-ended and differential video reconstruction filters, respectively. They combine overvoltage protection (STB protection) up to 18 V on the outputs, with low power consumption and a wire diagnostic capability. Wire diagnostics are provided by way of a logic output that is activated when a fault condition is present. The [ADA4432-1](#) and [ADA4433-1](#) feature a high-order filter with a –3 dB cutoff frequency of 10 MHz and 45 dB of rejection at 27 MHz.

The combination of STB protection and robust ESD tolerance allows the [ADA4432-1](#) and [ADA4433-1](#) to provide superior protection in the hostile environments.

The [ADV7391](#) and [ADA4432-1](#) are fully automotive qualified, which makes both products ideal for infotainment and vision-based safety systems for automotive applications. The [ADV7391](#), [ADA4432-1](#), and the [ADA4433-1](#) are available in a very small LFCSP package ideal for small footprint applications.

CIRCUIT DESCRIPTION

The [ADV7391](#) is a low power, fully integrated digital video encoder that converts digital 8-bit component video data from a CMOS imager into a standard analog baseband video signal compatible with worldwide standards. Three, 10-bit digital-to-analog video converters (operating on $V_{AA} = 2.6\text{ V to }3.46\text{ V}$) provide support for composite (CVBS), S-video (YC), or component (YPrPb/RGB) analog outputs in either standard definition (SD) or high definition (HD) video formats. The circuit in Figure 1 is configured for low output drive through DAC1 only. To conserve more power, the other DACs and phase-locked loop (PLL) are turned off. Low drive mode is defined as 4.33 mA full-scale output current. The [ADV7391](#) contains an R_{SET} pin. A resistor connected between the R_{SET} pin and AGND is used to control the full-scale output current. For low drive operation, R_{SET} must equal 4.12 kΩ, and R_L must equal 300 Ω. The resistor connected to the R_{SET} pin must have a 1% tolerance.

Rev. 0

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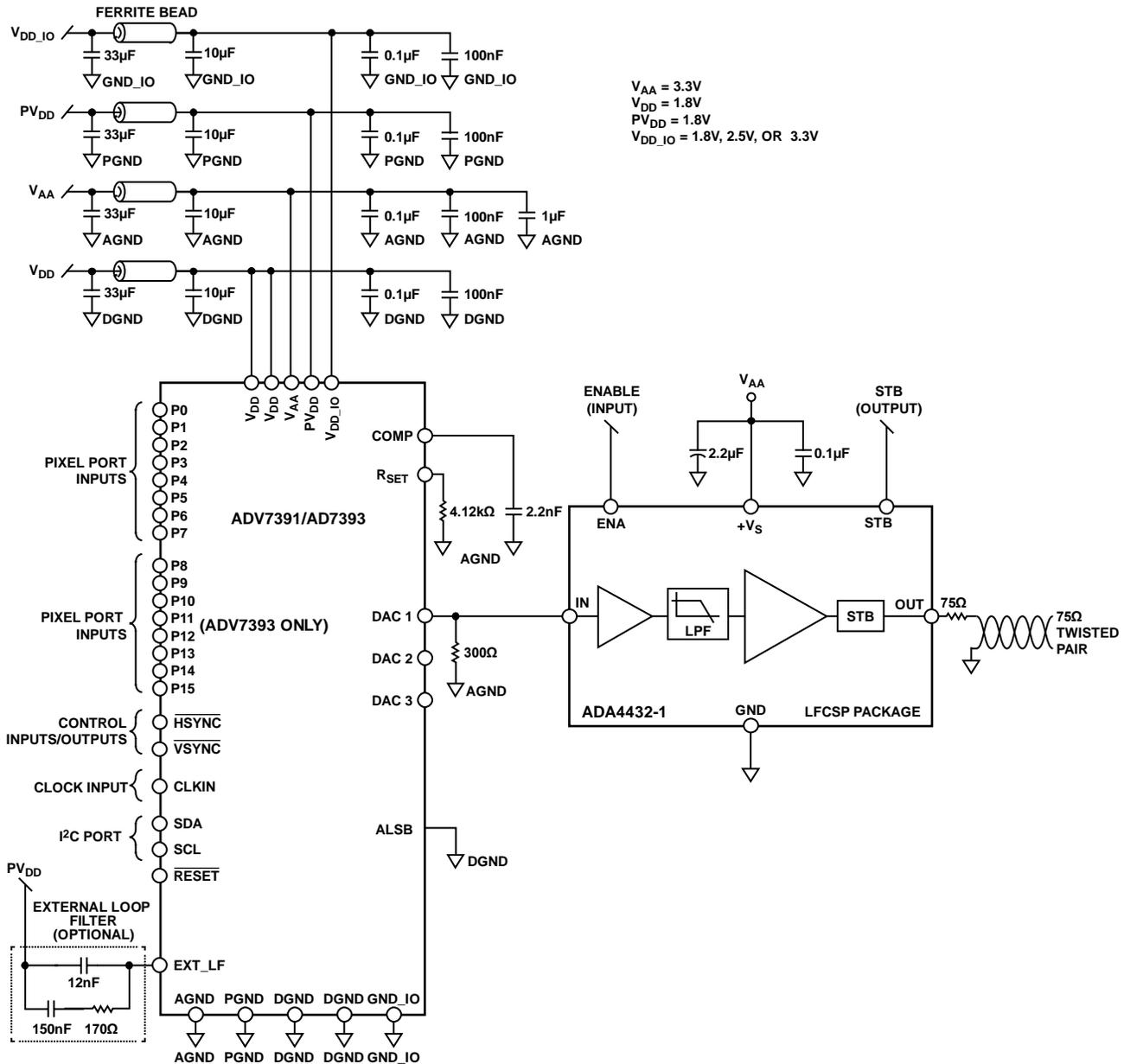


Figure 1. Low Cost, Fully Integrated Reconstruction Filter using the ADA4432-1 (All Connections and Decoupling Not Shown)

The **ADV7391** includes an on-chip, PLL that allows for over-sampling video data. As shown in Figure 1, the PLL is disabled (Subaddress 0x00, Bit 1 = 1) providing an SD oversample rate of 2x. With the PLL disabled, the external loop filter components are removed to save space and cost.

The **ADA4432-1** can be used as a pseudo differential (single-ended) driver with an unbalanced transmission line. The pseudo differential mode uses a single conductor to carry an unbalanced data signal from the driver to the receiver, while a second conductor is used as a ground reference signal.

The positive conductor connects the **ADA4432-1** output to the positive input of a differential receiver. The negative wire or ground conductor from the source circuitry connects to the negative input of the receiver. The output termination of the **ADA4432-1** should match the impedance of the input termination at the receiver. For example, in a 75 Ω system, each output of the **ADA4432-1** is back terminated with 75 Ω resistors that are connected to a resistance of 75 Ω at the receiver.

In Figure 1, the **ADA4432-1** is configured as a single-ended-to-single-ended driver that allows unbalanced transmission using twisted pair cable, untwisted cable, or coaxial cable.

Low Power Considerations

Using a series source termination and a shunt load termination on a low supply voltage with the [ADA4432-1](#) or the [ADA4433-1](#) realizes significant power savings compared to driving a video cable directly from a DAC output. Figure 2 shows a video DAC driving a cable directly. Properly terminated, a DAC driven transmission line requires two 75 Ω loads in parallel, demanding in excess of 33 mA to reach a full-scale voltage level of 1.3 V. Figure 3 shows the same video load being driven using the [ADA4432-1](#) and a series-shunt termination. This requires two times the output voltage to drive the equivalent of 150 Ω but only requires a little more than 15 mA to reach a full-scale output. When running on the same supply voltage as the DAC, this results in a 74% reduction in power consumption compared to the circuit in Figure 2. The high-order filtering provided by the [ADA4432-1](#) lowers the requirements on the DAC oversampling ratio, thereby realizing further power savings. The main source for power savings realized by the configuration shown in Figure 3 comes from the low drive mode setting for the [ADV7391](#). This along with the reduction in the requirement for oversampling (PLL turned off) and the reduced load current required results in significant power savings.

For more information on low drive mode, refer to the [ADV7391](#) data sheet.

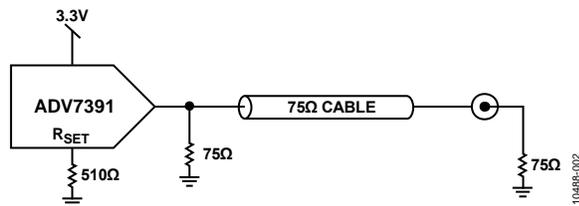


Figure 2. Driving a Video Transmission Line Directly with a DAC

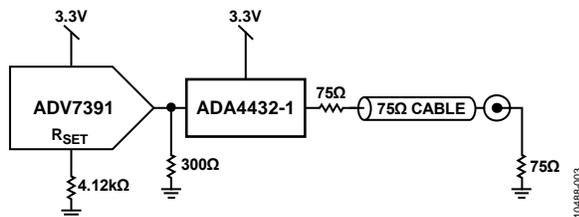


Figure 3. Driving a Video Transmission Line with the [ADA4432-1](#)

EMI and EMC Considerations

The analog output of video DACs like the [ADV7391](#) requires low-pass filtering to remove unwanted signal components at frequencies more than the sample rate or frequency sidebands. The conversion of a digital-to-analog signal creates duplicated images in the frequency domain, at multiples of the sampling frequency. Removing these frequency sideband components is the main function of the reconstruction filters. These filters significantly attenuate the sideband signals, preventing aliasing when the DAC outputs are decoded. Aliasing error can create image quality issues.

In addition, image frequency sidebands can create radiation emissions in the output traces and cabling that are potentially disruptive to adjacent circuitry and other electronic systems. To reduce the effect of radiation emissions, remove all unwanted high frequency components before transmitting along the printed circuit board (PCB) traces and transmission cables. The [ADA4432-1](#) helps reduce EMI by filtering the DAC output and removing unwanted high frequency content. Figure 4 to Figure 6 illustrate this point.

Figure 4 shows the frequency spectrum of a CVBS video signal at the output of the [ADV7391](#) without the [ADA4432-1](#). The spectrum shows a signal whose content bandwidth is 6.5 MHz, with sidebands at 27 MHz, 54 MHz, 108 MHz, and so on. The [ADV7391](#) is operating in full output drive mode with the PLL turned off at 2× oversampling.

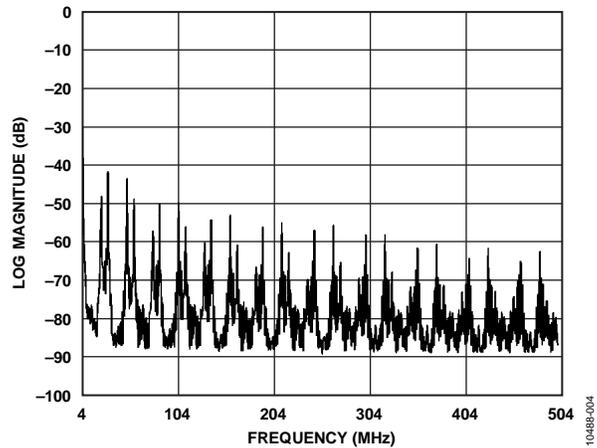


Figure 4. CVBS Measured Directly at the Output of the [ADV7391](#), PLL Off, 2× Oversampling, Full Output Drive Mode

Figure 5 show the frequency spectrum of the same CVBS signal at the output of the [ADV7391](#) without the [ADA4432-1](#). The difference here is that the [ADV7391](#) is operating in full output drive mode with the PLL turned on at 8× oversampling.

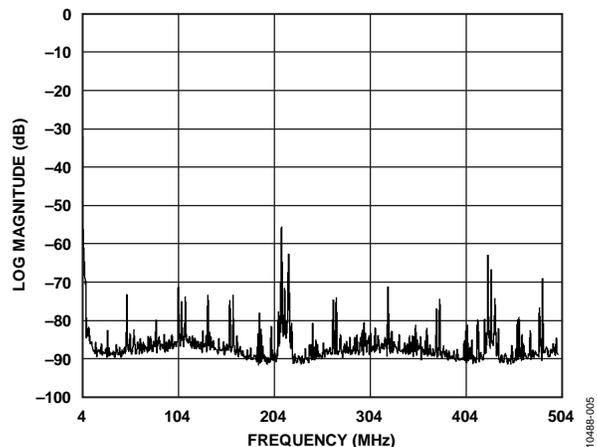


Figure 5. CVBS Measured Directly at the Output of the [ADV7391](#), PLL On, 8× Oversampling, Full Output Drive Mode

Figure 6 shows the frequency spectrum of the same CVBS signal with the ADA4432-1 filtering the output of the ADV7391. All sidebands are attenuated to less than 50 dB. The ADV7391 is operating in low output drive mode with the PLL turned off at 2× oversampling.

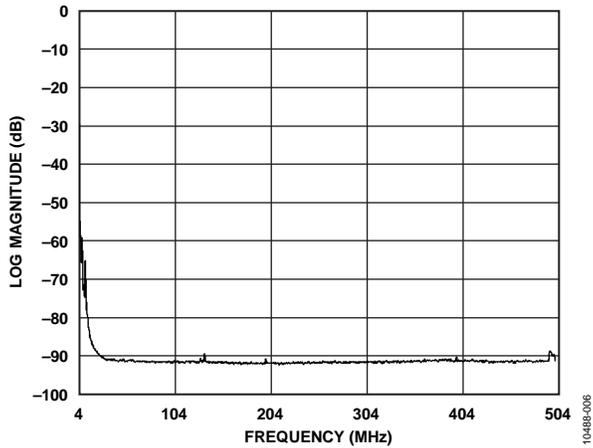


Figure 6. CVBS Measured at the Output of the ADA4432-1, PLL Off, 2× Oversampling, Low Output Drive Mode

PCB Layout Considerations

In any circuit where accuracy is crucial, it is important to consider the power supply and ground return layout on the board. Isolate the digital and analog sections of the PCB as much as possible. This PCB was constructed in a 4-layer stack up with large area ground plane layers and power plane polygons. See the MT-031 Tutorial for more discussion on layout and grounding and the MT-101 Tutorial for information on decoupling techniques.

Decouple the power supply to the ADV7391 with 10 μF and 0.1 μF capacitors. Decouple the ADA4432-1 and the ADA4433-1 output amplifiers with 0.1 μF and 22 μF capacitors to properly suppress noise and reduce ripple. Place the capacitors as close to the device as possible with the 0.1 μF capacitor having a low ESR value. Ceramic capacitors are advised for all high frequency decoupling.

It is important to keep the two ICs as close to each other as possible. Power supply lines should have as large a trace width as possible to provide low impedance paths and reduce glitch effects on the supply line. Shield clocks and other fast switching digital signals from other parts of the board by digital ground.

A complete design support package for this circuit note, including the board layouts, can be found at <http://www.analog.com/CN0264-DesignSupport>.

COMMON VARIATIONS

Many applications require differential output instead of single-ended output. For these applications, the ADA4432-1 is replaced with the ADA4433-1.

The ADA4433-1 is a fully differential filter/driver that can be used as a single-ended-to-differential amplifier or as a differential-to-differential amplifier. In Figure 7, the ADA4433-1 is configured as a single-ended-to-differential output driver. In single-ended-to-differential output applications, bias the INN input appropriately to optimize the output range. To make the most efficient use of the output range of the ADA4433-1, especially with low supply voltages, it is important to allow the differential output voltage to swing in both a positive and negative direction around the output common-mode voltage (V_{OCM}) level; the midsupply point (1.65 V).

To do this, the -IN input is biased at the midpoint of the expected input signal range, as shown in Figure 7. This is done with a voltage divider to the supply voltage (7.5 kΩ and 1.33 kΩ connected between the 3.3 V supply and GND biases -IN to 0.5 V). The 0.1 μF capacitor helps to filter high frequency supply noise. A 1 V p-p single-ended signal on +IN, with -IN biased at 0.5 V produces a differential input voltage of -0.5 V to +0.5 V. The resulting differential output swings above and below the V_{OCM} level (1.65 V). The ADA4433-1 output voltage now extends from 1.15 V to 2.15 V, requiring only 1 V of the output range to produce a 1 V p-p signal at the receiver.

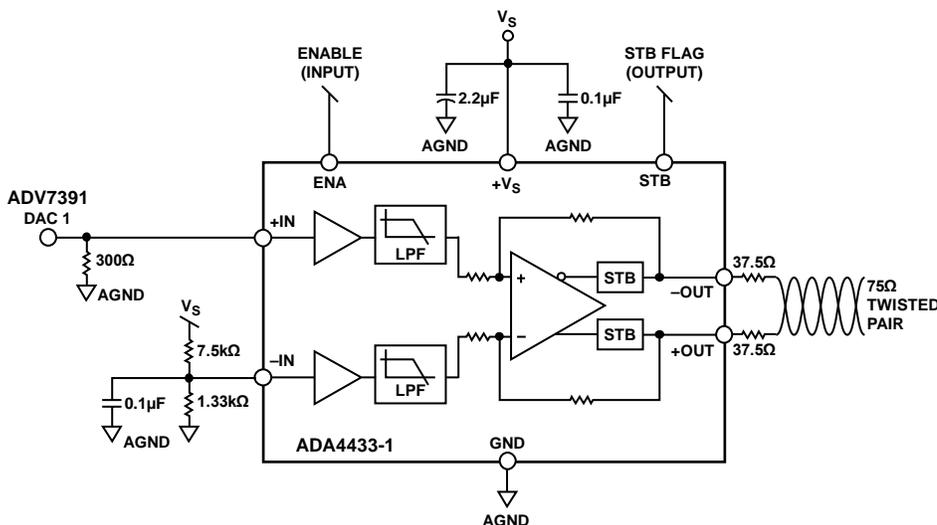


Figure 7. ADA4433-1 Typical Application Circuit

The differential outputs of the [ADA4433-1](#) allow fully balanced transmission using twisted or untwisted pair cable. In this configuration, the differential output termination consists of one source resistor on each output. Both resistors are equal to half the receiver input termination. For example, in a 75 Ω system, each output of the [ADA4433-1](#) is back terminated with 37.5 Ω resistors connected to a differential resistance of 75 Ω at the receiver.

CIRCUIT EVALUATION AND TEST

This circuit uses the [EVAL-CN0264-EB1Z](#) circuit board, which contains the circuit to be evaluated, as described in this note. The Cypress USB microcontroller is used to configure and load software to and from the [EVAL-CN0264-EB1Z](#) board.

Equipment Needed

The following equipment is needed:

- A PC with a USB port and Windows® XP or Windows Vista® (32-bit), or Windows® 7 (32-bit)
- The [EVAL-CN0264-EB1Z](#) circuit evaluation board
- The [CN-0264](#) evaluation software
- A power supply: 7.5 V wall wart
- A Spectrum Analyzer: Agilent E4440A, or equivalent

Getting Started

Load the evaluation software by placing the CN0264 evaluation CD in the CD drive of the PC. Using **My Computer**, locate the drive that contains the evaluation software CD and open the **Readme** file. Follow the instructions contained in the **Readme** file for installing and using the evaluation software.

Functional Block Diagram

See Figure 1 of this circuit note for the circuit block diagram and the [EVAL-CN0264-EB1Z-SCH.pdf](#) file for the circuit schematics. This file is contained in the [CN0264 Design Support Package](#).

Setup

With power to the supply off, connect a 7.5 V power supply to the 7.5 V terminal and the GND terminal on the board. If available, a 7.5 V wall wart can be connected to the barrel connector on the board and used in place of the 7.5 V power supply. Connect the USB cable to the USB port on the PC. Do not connect the USB cable to the mini-USB connector on the board at this time.

Test

Apply power to the 7.5 V supply (or wall wart) connected to the [EVAL-CN0264-EB1Z](#) circuit board. Launch the evaluation software and connect the USB cable from the PC to the mini-USB connector on the PCB.

Information and details regarding how to use the evaluation software for data capture can be found in the [CN-0264](#) evaluation software **Readme** file.

LEARN MORE

[CN0264 Design Support Package](#):

<http://www.analog.com/CN0264-DesignSupport>

[AN-617, Wafer Level Chip Scale Package](#), Analog Devices.

[MT-031 Tutorial, Grounding Data Converters and Solving the Mystery of "AGND" and "DGND,"](#) Analog Devices.

[MT-101 Tutorial, Decoupling Techniques](#), Analog Devices.

Data Sheets and Evaluation Boards

[CN-0264 Circuit Evaluation Board \(EVAL-CN0264-EB1Z\)](#)

[ADV7391 Data Sheet](#)

[ADV7391 Evaluation Board](#)

[ADA4432-1 Data Sheet](#)

[ADA4432-1 Evaluation Board](#)

[ADA4433-1 Data Sheet](#)

[ADA4433-1 Evaluation Board](#)

REVISION HISTORY

6/12—Revision 0: Initial Version

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