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APPLICATION NOTE 3768

To AC-Couple or Not to AC-Couple? That Is the Question!

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Abstract: This article explains the historic, technical, and economic reasons for choosing either an AC- or a DC-coupled video output. Maxim's DirectDrive™ video technology, which has the characteristics of an AC-coupled connection but the simplicity of a DC-coupled connection, is introduced. Using this information, a design engineer can decide better which style of video output to use in future projects.

Introduction

For analog video circuits, the question of whether or not to design an AC-coupled output depends as much on company policy and industry standards as technology and cost. An AC-coupled output includes a series capacitor (**Figure 1a**), while a DC-coupled output does not (**Figure 1b**). A designer new to video output circuits may find such a choice confusing because adding a capacitor to the output path increases cost, requires space, and distorts the video signal. However, the choice may have already been made due to historical, technical, or economic reasons.

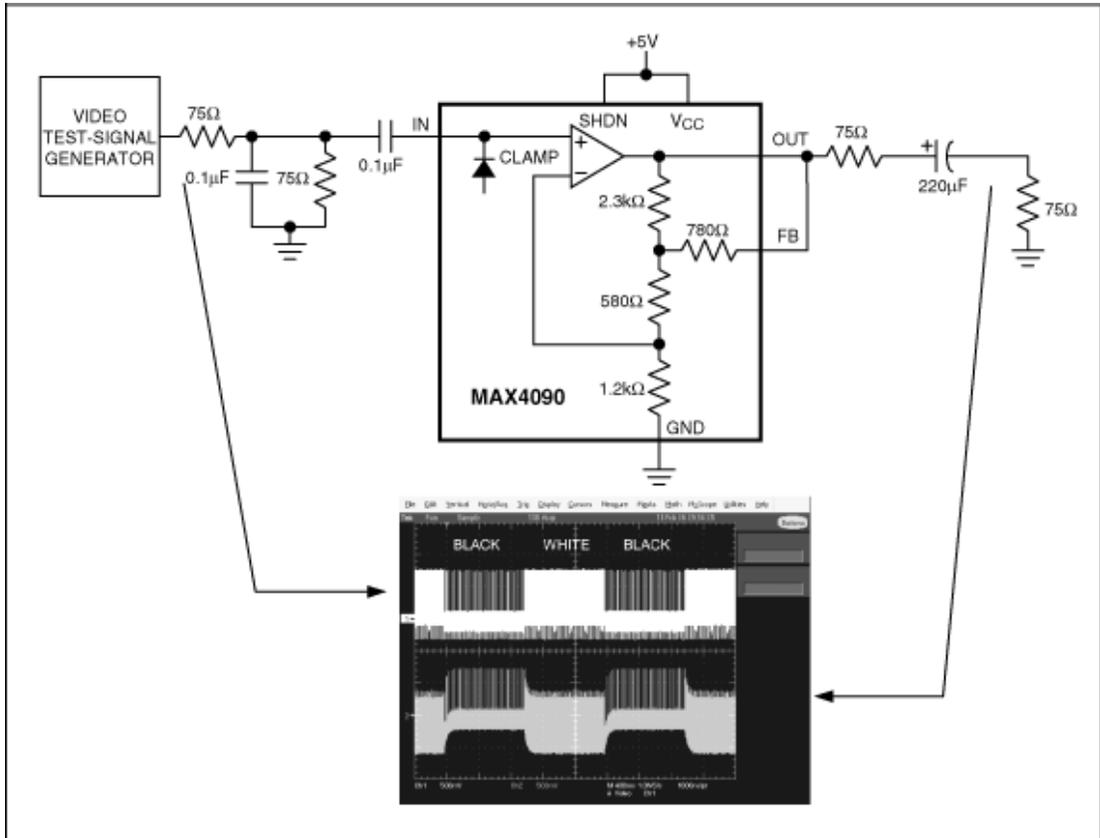


Figure 1a. AC-coupled output connection.

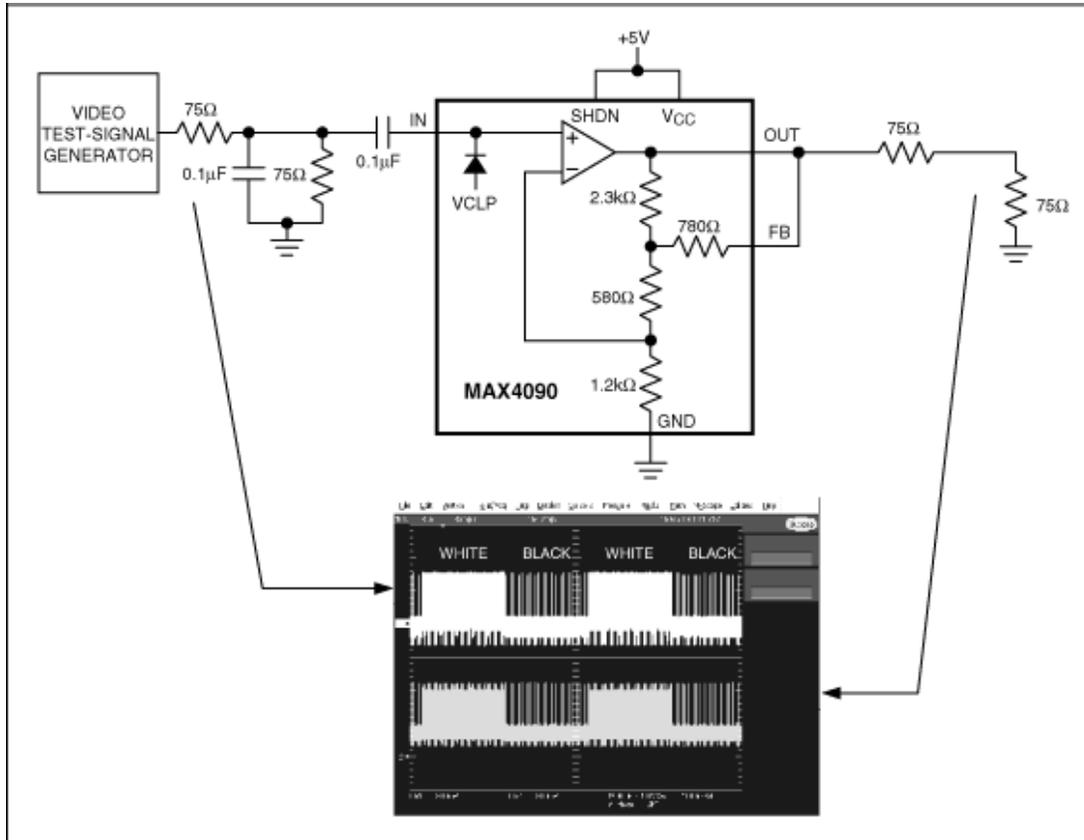


Figure 1b. DC-coupled output connection.

AC-Coupled vs. DC-Coupled Outputs

Figure 1a¹ shows the input and output waveforms for an AC-coupled output. Notice how the output waveform "tilts" up and "tilts" down with respect to the input waveform. Hence, the name of this kind of field time distortion is "field tilt." The oscilloscope trace in Figure 1b² shows a DC-coupled output. In this case, notice that there is no field tilt. The NTSC video test signal used is named "Regulate." **Figure 2a** shows what the white portion of the test signal looks like on a video monitor. **Figure 2b** shows what the black portion of the test signal looks like on a video monitor. The Regulate video test signal draws a white border on the edge of the screen during both the white portion and the black portion.

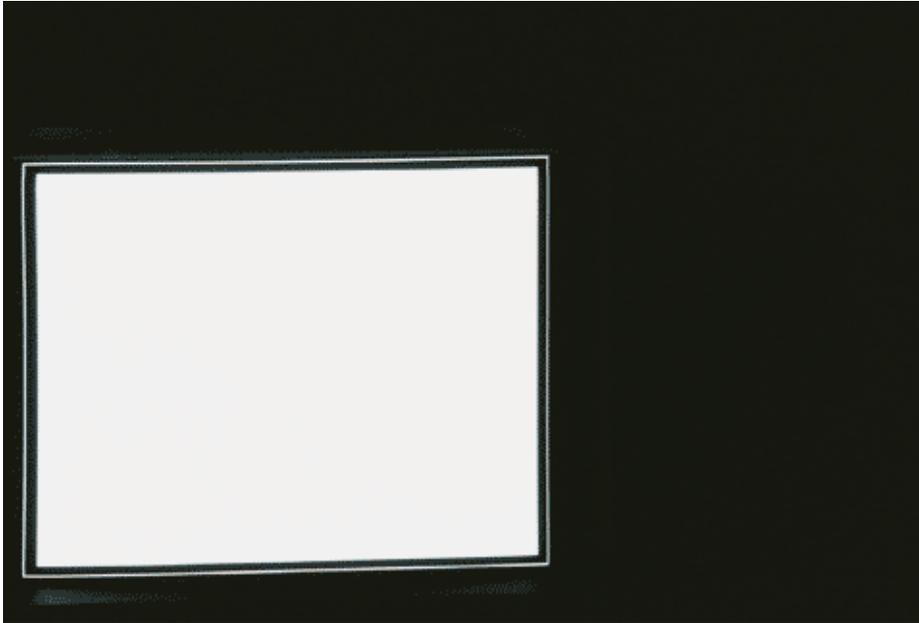


Figure 2a. White screen of Regulate video test signal.

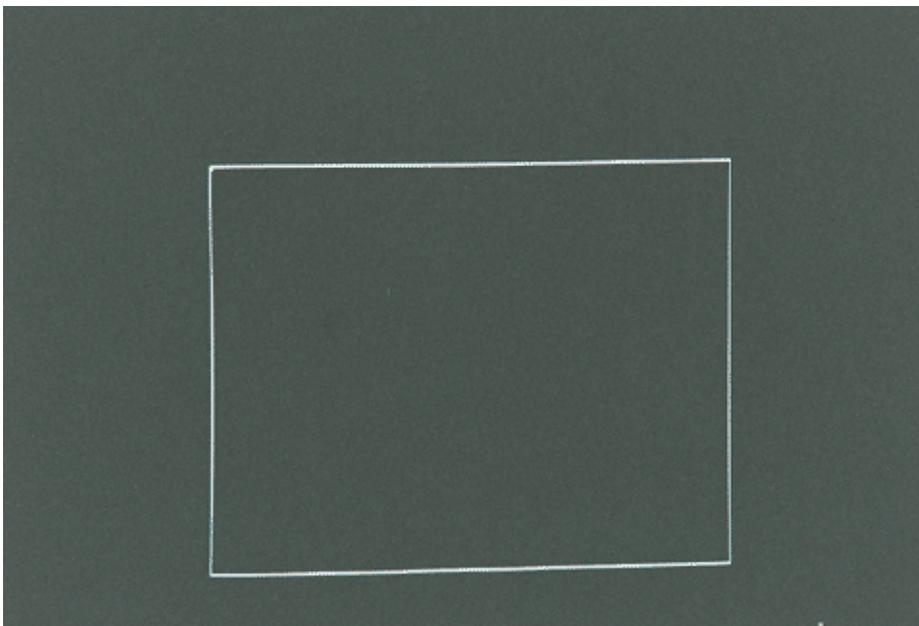


Figure 2b. Black screen of Regulate video test signal.

Historical Use of AC-Coupling

Given the drawbacks of AC-coupling, why did it ever get used? The simple answer is protection. **Figure 3** shows a simple video-output circuit that might have been created before integrated circuits were widely used. The capacitor prevents the NPN transistor from damaging itself in case the output connector is shorted to ground or a supply voltage.

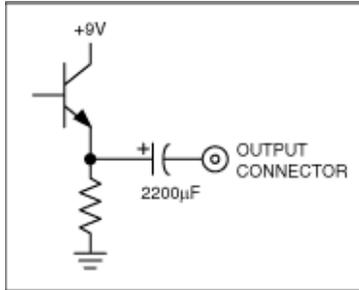


Figure 3. NPN emitter follower driving video output.

Contemporary integrated video amplifiers have robust short-circuit protection circuitry so that they are not damaged in the event of a short. Nonetheless, the use of the capacitor has become entrenched in some companies, especially those with a long history of making video equipment. Design engineers may be told that they must add a capacitor to comply with company policy.

In addition, industry standards can implicitly force the design engineer to use a capacitor. The Japan Electronics Industry Trade Association (JEITA) has a specification that requires that the voltage magnitude must be less than 100mV on an inactive video output connector (Figure 3). If the normal DC bias at the NPN emitter is 4V, then the output connector would also be approximately 4V if the capacitor and bleed resistor were not present. The easiest way to meet the JEITA specification is to add a capacitor and bleed resistor to ground.

Technical Concerns

One of the concerns about AC-coupling is that the capacitor is usually large—220µF or higher. The reason is that the frequency of the pole formed by the capacitor and 150Ω load (the total resistance of the back termination resistor and the input termination resistor) should be significantly less than the frame rate of either 25Hz or 30Hz. A 220µF capacitor forms a pole at 5Hz, which is barely adequate. Broadcast equipment typically has capacitors in the 2200µF range. **Figure 4** shows the highpass response of an AC-coupled output connection with a 220µF capacitor.

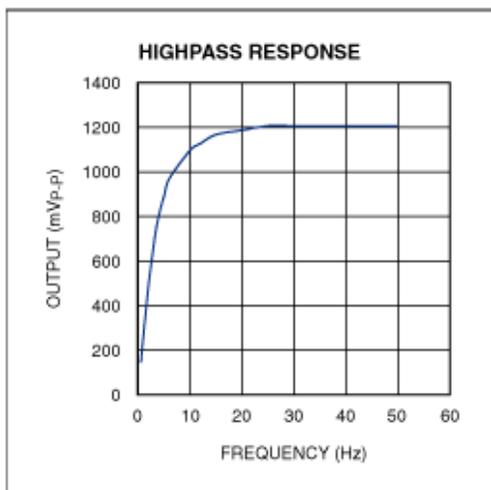


Figure 4. Frequency response of AC-coupled video connection with 220µF capacitor.

With the advent of small, portable devices that have video outputs, using a large, AC-coupling capacitor becomes prohibitive, primarily for space and cost reasons. SAG compensation, shown in **Figure 5**, can reduce space and cost while maintaining AC-coupling. The single large capacitor of the standard connection

is replaced by two, smaller capacitors. A technical analysis of SAG compensation is beyond the scope of this article, but a short, intuitive explanation can be given. The problem with a single, AC-coupling capacitor is that the signal is attenuated at frequencies below the pole frequency—the smaller the capacitor, the higher the pole frequency. SAG compensation boosts the low-frequency response in order to compensate for the low-frequency attenuation (Figure 5). At low frequencies, the capacitors can be treated as opens. The low-frequency gain is approximately 6. At high frequencies, the capacitors are essentially shorts, and the high-frequency gain is 2.

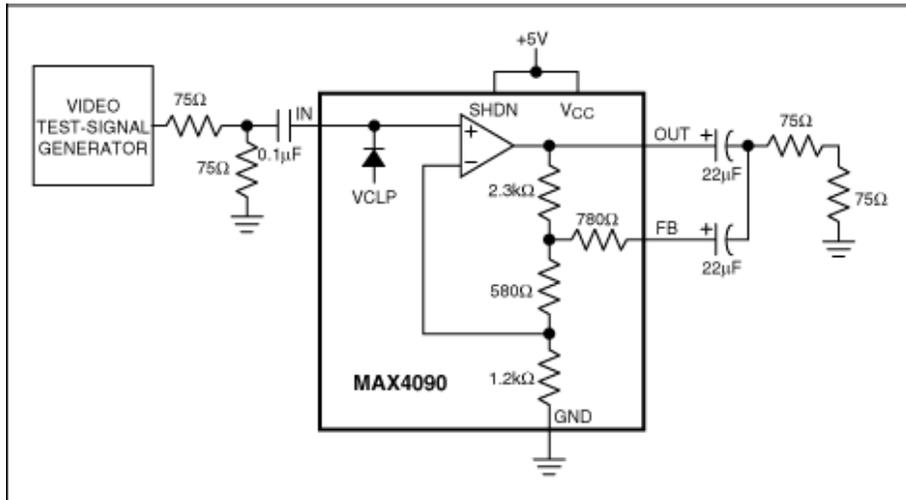


Figure 5. Video driver with SAG compensation.

In the consumer electronics industry, the pressure to reduce cost is intense, and for small devices, the pressure to miniaturize is just as intense. Companies, even some with a long history of designing video equipment, are now opting for DC-coupled video connections (Figure 1b). The main difference to note with a DC-coupled output is that the signal has a positive DC bias due to the fact that most systems have eliminated negative supplies. In order for the amplifier to remain in a linear mode of operation, the output signal must be biased between ground and the positive supply.

Design engineers who are contemplating a switch from an AC-coupled output to a DC-coupled output are concerned with compatibility. The vast majority of equipment is compatible with either style, but there is still a small percentage that is incompatible with an AC-coupled output, and yet another small percentage that is incompatible with DC-coupled outputs. **Figure 6a** shows the input stage for a modern television. The video signal is AC-coupled into a DC restoration circuit: hence, the input video signal can have any DC bias. This input circuit is compatible with both AC- and DC-coupled video sources. **Figure 6b** shows the input stage that uses a polarized capacitor. If the DC bias of the incoming video signal is too high, then the polarized capacitor could be damaged. This input stage might have problems with a signal from a DC-coupled source. **Figure 6c** shows an input stage that uses a PNP emitter follower. If the input signal is too negative, then the PNP emitter follower might saturate. Therefore, a DC-coupled video source might saturate the PNP emitter follower, especially if the local ground of the source is lower than the local ground of the receiver.

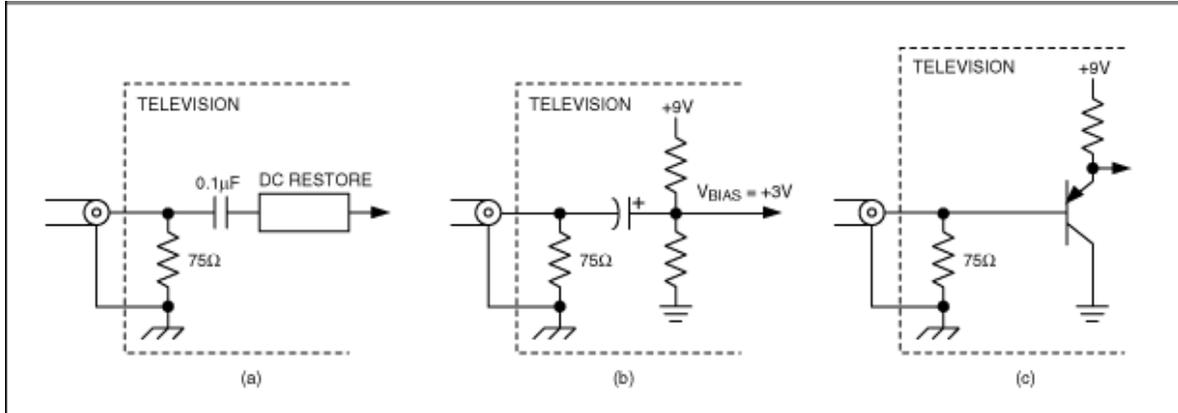


Figure 6. a) Modern TV input stage, b) polarized capacitor c) PNP emitter follower in input stage.

The problem with televisions is that there has never been a commonly accepted way of designing the input stage. Some models of the numerous televisions designed over the years have marginal input stages that could have problems with either AC- or DC-coupled sources. It is not possible to maintain universal compatibility when there are so many different kinds of receiving equipment. Most low-end video sources, which represent the greatest volume of transmitting equipment, tend to use DC-coupled outputs for cost reasons.

DirectDrive Solution

For those design engineers who still want to include an AC-coupled video output, Maxim offers DirectDrive technology, which eliminates the need for large output-coupling capacitors. The MAX9503 is the first Maxim part to incorporate DirectDrive technology for video signals (see **Figure 7**).

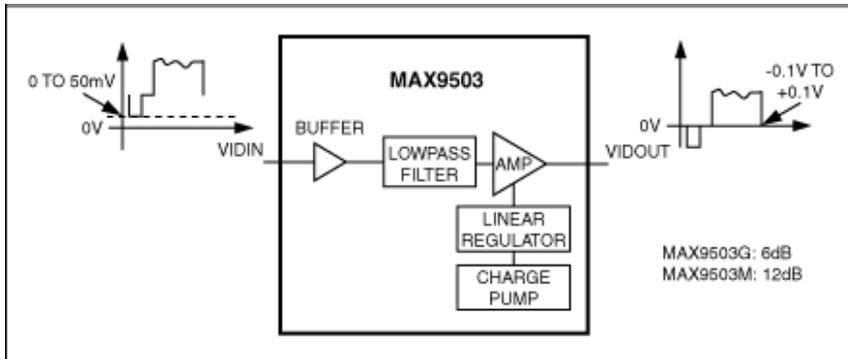


Figure 7. MAX9503 block diagram and representative input and output waveforms.

The MAX9503 filters and amplifies standard-definition video signals. The input of the MAX9503 can be directly connected to the output of a video digital-to-analog converter (DAC). An internal reconstruction filter smooths the steps and reduces the spikes on the video signal from the DAC. The MAX9503 level shifts the video signal to a lower voltage such that the blank level is approximately at ground at the output. DirectDrive requires an integrated charge pump and a linear regulator to create a clean negative power supply to drive the sync pulse below ground. The charge pump injects so little noise into the video output that the picture is seemingly flawless.

Figure 8 shows a Regulate video test signal applied to the MAX9503. Notice how the blank level of the output waveform is held near ground and that there is no field time distortion, in contrast to the normal AC-coupled waveform shown in Figure 1a. The Regulate test signal at the MAX9503 output maintains a much more well-defined output voltage range than that from an AC-coupled connection.

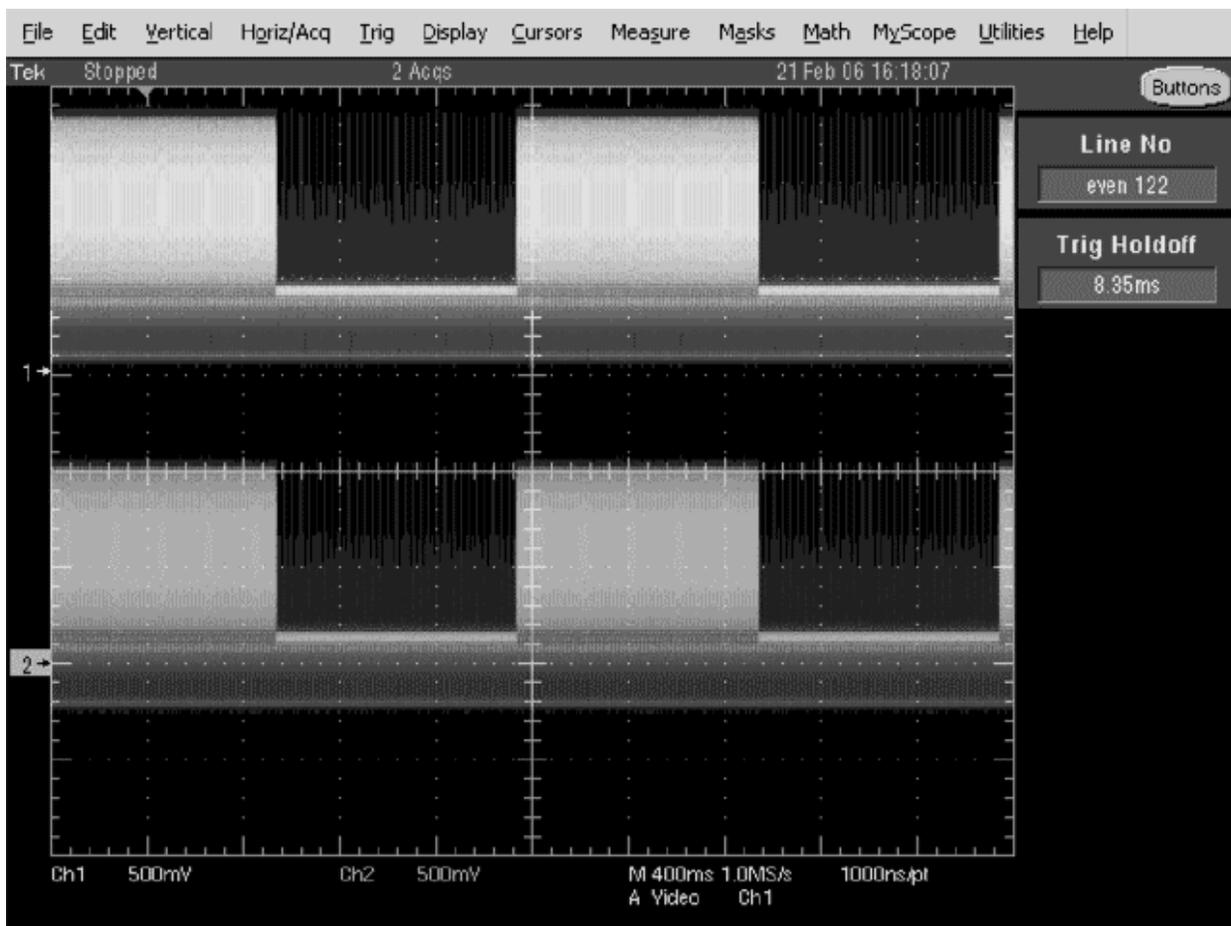


Figure 8. Regulate video test signal applied to the MAX9503—input waveform is on top, output waveform is on the bottom.

One of the reasons to use an AC-coupled video output is for protection against shorts to ground and the supply voltage. The MAX9503 typically operates from a 3.3V supply. The MAX9503 application circuit includes a 75Ω back-termination resistor that limits short-circuit current if an external short is applied to the video output. In addition, the MAX9503 features internal output short-circuit protection to prevent device damage in prototyping and applications where the amplifier output can be directly shorted. Hence, the MAX9503 is robust in the face of most common fault conditions.

The major benefit of DirectDrive is that for the addition of just two small, 1μF capacitors for the charge-pump circuit, the design engineer can eliminate the single, large, output-coupling capacitor in a standard AC-coupled video output or two medium-size, output coupling capacitors in a SAG network. Output video quality is improved because field-time distortion is eliminated.

Notes

¹The 0.1μF capacitor across the 75Ω input-termination resistor to ground filters out higher frequencies in the video waveform, removing aliasing in the black portion of the video test signal. The 400ms time scale of the oscilloscope shot is very long compared to a horizontal line time (~64μs). Without the 0.1μF capacitor, the aliasing during the black portion of the video test signal would make the black portion of the input signal nearly indistinguishable from the white portion. The black portion of the output signal would be filled in like the white portion.

²Just as in Figure 1a, there is a 0.1μF capacitor across the 75Ω input-termination resistor to ground for the

same reasons. Without the 0.1 μ F capacitor, the aliasing during the black portion of the video test signal would make the black portion look the same as the white portion.

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

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