EL4543 CAT-5 CMV Offset Network Recovers Usable CMV Range at Receiver

Application Note | September 21, 2006 | AN1266.1

Authors: David Laing and Rudy Berneike

There are several ways to recover the common mode voltage (CMV) range of video sent from the EL4543 which has 2.5V of offset that uses most of the input CMV range of the receiver amp.

- The first way is to use AC cap coupling at the receiver, but this will lose the DC ref level for the RGB that normally has the back porch at ground. Some displays require back porch at or near ground. A DC restore can be added but it will increase cost. AC coupling can also cause droop on each horizontal line. Video YPbPr are bipolar signals and are often AC coupled, then normally DC restored in the displays. AC coupling is well known and will not be discussed in this application note.
- The second way is to use an offsetting resistor network at the receiver. This retains the DC ref level of the video with back porch near ground with only small DC offsets and no droop. The network will have some gain loss, about 30%, so the receiver has to have more gain to recover for the loss. Yet, this added gain may cause a small reduction in the maximum usable cable length, up to 5% less.

The EL4543 solves the problem of sending RGB video plus HSYNC and VSYNC down three twisted pairs of a CAT-5 cable. The RGB video is sent differentially on three twisted pairs with the HSYNC and VSYNC is encoded as differential common mode on the RGB pairs. The sync data, which is encoded on the RGB pairs, will manifest itself as a CMV on each pair. The EL4543, when used with a ± 5V supply, will have a sync data CMV (common mode voltage) offset of ±0.5V.

Yet, a typical configuration for the EL4543 is a single 5V supply operation. The single supply output has a positive DC offset of about mid supply or 2.5V with no signal applied. The problem manifests itself at the receiver when using a dual supply receiver, such as the EL9110 or EL9111, each having a wide CMV range of 7.5V. The EL4543 directly driving a cable to the EL9110 or EL9111 input, will have a positive DC offset from the EL4543. This will limit the operational common mode range for video transmission.

This document addresses the CMV problem and offers a solution to balance the EL4543 CMV output signal to take full advantage of the wide input CMV range of the EL9110 or EL9111. We will also discuss simple circuits for:

- LF and HF noise rejection,
- HSYNC jitter caused by CAT-5 cable delay difference, and
- A unique solution for circuit instability.

Even though this document discusses the CMV, LF and HF noise, HSYNC jitter, and other issues using the EL4543 and EL9110 or EL9111 for video transmission, the information in this document is applicable to any video transmission down cables.

CMV Range Computation

EL4543 – the typical output CMV for the single supply EL4543 includes the HSYNC or VSYNC data along with a DC offset. Single supply operation will offset the output to half the supply voltage range, 2.5V on a 5V supply. Embedding sync, we add ± 0.5V on this mid point. Therefore the CMV would be:

+CMV = 2.5V + 0.5V = +3V
-CMV = 2.5V - 0.5V = +2V

The EL4543 CMV, while driving a CAT-5 wire pair differentially, will be 2V to 3V above ground.

Details of the EL4543 Non-Symmetrical Impact on the EL9111

EL9110 or EL9111 — the CMV range is specified in the data sheet ‘CMIR’ from -4V to +3.5V. The usable CMV is the input CMV range minus the input signal. The input signal equals Video plus sync.

A typical video example to look at is the white RGB components. Red is by far the predominate color in white. In this case, red is about 60% of full scale or about $400mV_{p\text{-}p}$. The transmitted signal common mode voltage (EL4543), as before, would be 2V to 3V. Now, adding in the Video input and sync, the range would be the lower -CMV minus the video and the upper range would be +CMV plus the video or:

Signal min = 2V - 0.4V = 1.6V
Signal max = 3V + 0.4V = 3.4V

Since the EL9110 or EL9111 upper input CMV range is 3.5V, the CMV offset limits the input range of the EL9110 or EL9111 to about 100mV. Thus, the non-symmetrical output of the EL4543 could cause distortion at the output of the EL9110 or EL9111 if the CMV overhead of the video input is just a few 100mV. So, the issue is how to balance the 2.5V CMV offset so we can recover the usable CMV range of the EL9111.

Goals of this design are to:

1. Terminate the CAT-5 cable properly and improve HF noise rejection. See “Terminate the CAT-5 Cable” on page 2 and “Reduce the HF Common Mode Components” on page 2.
2. Balance the cable driver offsets and improve the CMV symmetry. See “Balance the CMV Cable Offsets” on page 2.

3. Reduce LF CMV noise due to long cable lengths. See "Minimize DC Loading and Reduce CMV Noise" on page 2.

Balance the Cable Driver Offset/ Recovering Usable CMV Range

The single supply EL4543 offset CMV range can be corrected by using a simple resistor network after the cable termination to offset the CMV at the cable output to level shift CMV towards ground. Offsetting the input by about -2.5V will recover the usable CMV range at the EL9110 or EL9111 receiver input.

Terminate the CAT-5 Cable

A cable input termination network is needed to properly terminate the CAT-5. This can be accomplished with two resistors, 51Ω in series across each twisted pair output (see Figure 1).

Reduce the HF Common Mode Components

The two 51Ω terminating resistors junction point has a third 51Ω resistor connected that is in series with a large capacitor to ground (0.1µF) (see Figure 1). Thus, supplying a path for cable HF common mode termination and the two series 51Ω terminates the differential pairs. The two series 51Ω match the 100Ω of the CAT-5 cable. The series RC network provides both the differential common mode termination and HF path to ground for HF rejection.

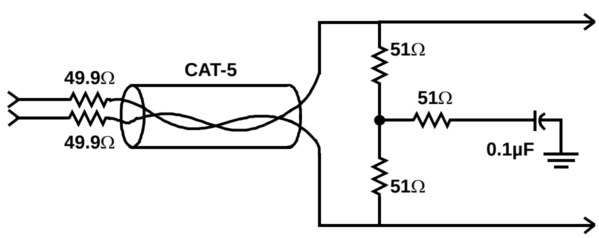

FIGURE 1. TERMINATING CAT-5 CABLE

Balance the CMV Cable Offsets

The incoming signal is offset by about +2.5V. Using a simple voltage divider to pull down the incoming signal by the same amount as the offset and thus, the input signal CMV would be about ground. You need to consider a few restrictions when selecting the resistor divider values:

- The divider should minimize the DC loading of the EL4543.
- The divider must not attenuate the signal below the useful range of the receiver.

The offset circuit consists of two matched/balanced circuits. We will discuss one half of the circuit as it is applicable to the other side as well. Let's start with the key problem, recovering the usable CMV range of the EL9111.

Minimize DC Loading and Reduce CMV Noise

A simple series 1:2 voltage divider to a negative supply would pull down the EL4543 offset on each leg to about 0V. One limit is to keep the divide impedance high enough not to draw too much DC current from the EL4543 outputs.

Series 1k with a 2k tied to -5V would bias the junction to a level removing the input offset as shown in Figure 2. The series 3k, on parallel with the 51Ω input, changes the input mpedance seen by the EL4543 by less than 2%. Yet, the EL9110 or EL9111 CMV is non-symmetrical; its mid point is -0.25V below ground. To gain back an additional 0.25mV, we need to adjust the circuit. The circuit shown in Figure 2 reflects this adjustment, the 1.05k resistor series to a 2k resistor to -5V. The series circuit is 49.9Ω source resistance from the cable source, the 1.05k, and the 2k to -5V. The overall offset at the junction will result in CMV at input to the EL9110 or EL9111 to be -0.25V, and not 0V. The EL4543 CMV offset is -2.5V. Adding -0.25V plus the original adjustment, -2.5V, the circuit compensates for the total asymmetry.

We selected -5V supply for termination because the EL9110 or EL9111 requires ±5V supply and it was readily available. Not only does this network balance the CMV DC offset, it also supplies the DC termination for low frequency rejection.

The circuit does not impact the DC loading of the EL4543, as it appears as about 1.5k impedance to the cable. That, in parallel with the 51Ω, results in a termination which appears as 49.4Ω per line. Thus, this circuit will improve the CMV symmetry and reduce LF CMV noise due to long cable.

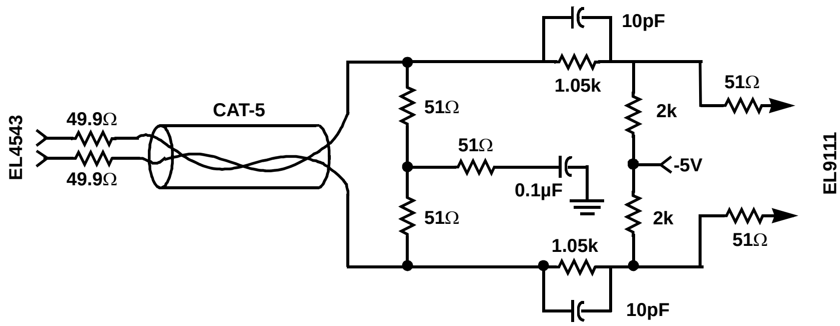

FIGURE 2. CMV OFFSET CORRECTION AND HF/LF REJECTION

Attenuating the Input Signal

The circuit does attenuate the signal by 33% (1k:2k). Yet, the EL9110 or EL9111 can cleanly reproduce the video signal of these levels using the adjustable internal gain.

Why the added 51Ω at input to the EL9110 or EL9111?

EL9110 or EL9111 gain is 1k at 100MHz at the maximum comp level. At this frequency range, the network may look like a resonance circuit. If you have feedback as little as 1/1000th of the output, the circuit may become unstable. The simplest way of lowering the 'Q' of the resonant circuit is to place the two 51Ω in series at the input to the EL9110 or EL9111 as shown in Figure 2. Thus, you will have dampened the feedback and improved the stability. This also increases ESD protection.

10pF Cable Comp

The 1.05k resistors in series from the cable pair lines to the amp inputs have 10pF caps in parallel to prevent excessive high frequency loss or color phase shift resulting in moray fringes.

The 10pF cap also helps prevent increased noise with long cables. It generates about 3.6dB peaking (33% voltage loss) that will compensate about 75 feet cables and, with short cables, the peaking effect is small enough not to impact the signal quality.

CMV Input Range

The input offset network will offset the input CMV to the EL9110 or EL9111 by -2.75V. It will also attenuate the CMV ± 0.5V sync data to ± 0.32V and the video signal from ± 0.4V to ± 0.26V so the total input signal range is -0.83V to 0.33V. The EL9110 or EL9111 CMV range is ± 3.17V. The CMV plus input signal is -4V to +3.5V and matches the EL9110's or EL9111's input amp CMV range.

ESD Protection

Long cables are subject to ESD so basic protection should be used, and under bad conductions, added protection may be needed. Basic ESD protection uses logic diodes reverse connected from the supplies to the input of the 51Ω resistor in series with the receiver amp input pin. The 51Ω are located very close to the amp input pin. This will give increased ESD protection and more stable EL9110 amps at very high cable comp levels.

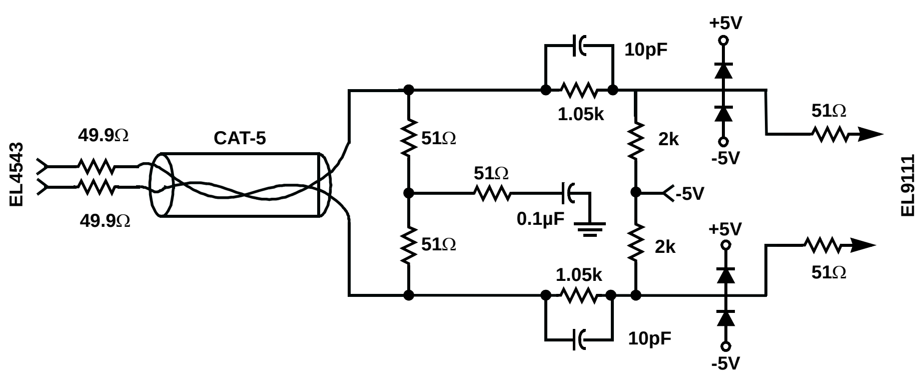

FIGURE 3. ESD PROTECTION DIODES

Sync Decode

The EL9110 or EL9111 can use the configuration in Figure 4 at their input to offset the CMV from the EL4543. They detect the CMV for HSYNC and VSYNC and are decoded in the EL9111.

Correcting for HSYNC Jitter

What is the cause of HSYNC Jitter? The HSYNC is transmitted differentially down the CAT-5 cable using three twisted wire pairs:

- RED twisted wire pairs carry Red video and -HSYNC and +VSYNC
- BLUE twisted wire pairs carry Blue video, +HSYNC inverted and +VSYNC
- GREEN twisted wire pairs carry Green video and -VSYNC inverted.

The CAT-5 cable twisted wire pairs have different twist rates resulting in up to 30nS difference between them at the receiver. The HSYNC uses the Red wire pair and HSYNC inverted is on the Blue wire pair. The HSYNC differential comparator (EL8101 seen on page 15 of the EL4543 data sheet, FN7325) could receive the HSYNC and HSYNC inverted such that both signals are at 0V for up to 30ns at the same time. The HSYNC recovery circuit could induce HSYNC jitter as the diff-comparator attempts to determine which of the HSYNCs is more positive. A simple 30mV offset imposed on one of the HSYNC differential inputs eliminates the HSYNC jitter.

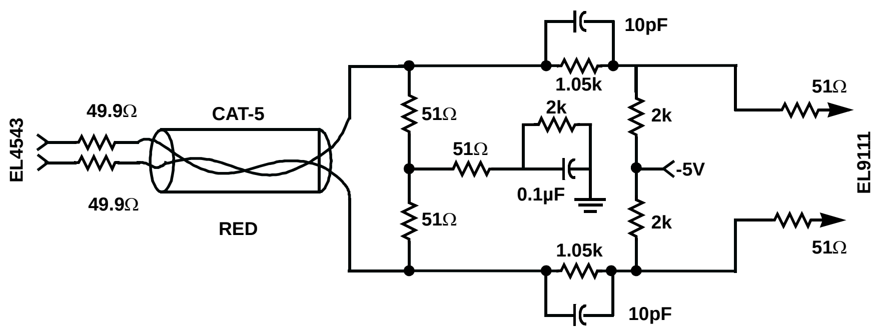

FIGURE 4. HSYNC JITTER COMPENSATION

We use the Red CMV termination circuit to add the 30mV DC offset. The input to the CMV circuit is 25Ω (the two 51Ω in parallel) through a 51Ω resistor to the 0.1µF cap. We need 1.2mA through this 25Ω equivalent resistor to generate the 30mV offset. Since the input is 2.5V (no video), we can place a resistor in parallel with the 0.1µF cap to ground for the DC path. Computing the resistor, 1.2mA through a resistor dropping 2.47V to ground would require 2kΩ. This will prevent HSYNC jitter caused by the cable skew between twisted pair.

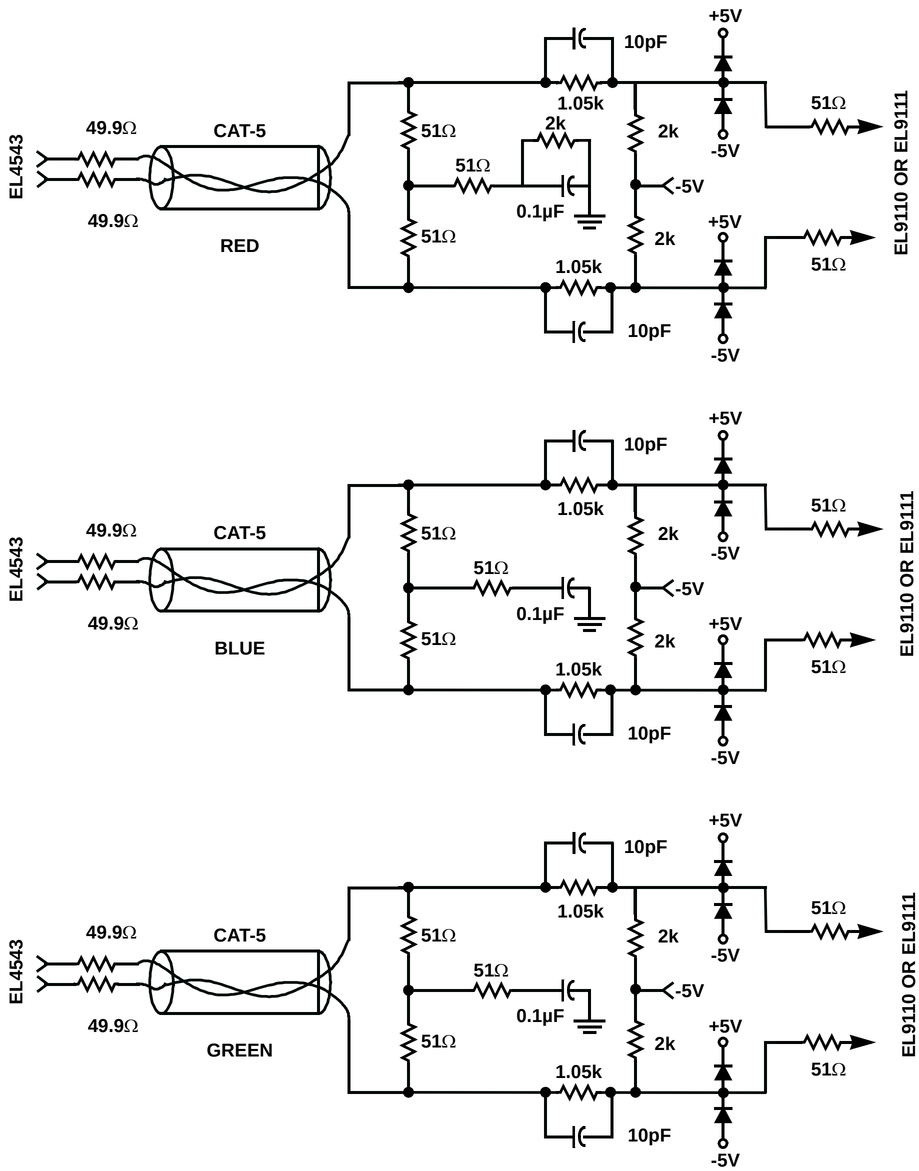

FIGURE 5. FINAL RGB BALANCE NETWORKS

Attenuation Correction

The Input offset network reduces the input video by 33.3%. To compensate for the loss, the receiver amp should have an additional gain of 1.5. The EL9110 or EL9111 has gain controls to add 1.5 gain.

Figure 6 is the implementation of the CMV restore circuit for a typical cable driver/receiver application circuit. Refer to the EL4543 data sheet, FN7325, page 15. Instead of using the EL9110 or EL9111, this circuit uses the EL5375. The EL8201 is the HSYNC recovery differential comparator circuit.

EL5375 Gain recovers the 33% loss: The EL5375 2k fixed gain resistors are replaced with 1k resistors. This changes the gain from A = 2 to A = 3, compensating for input offset circuit loss.

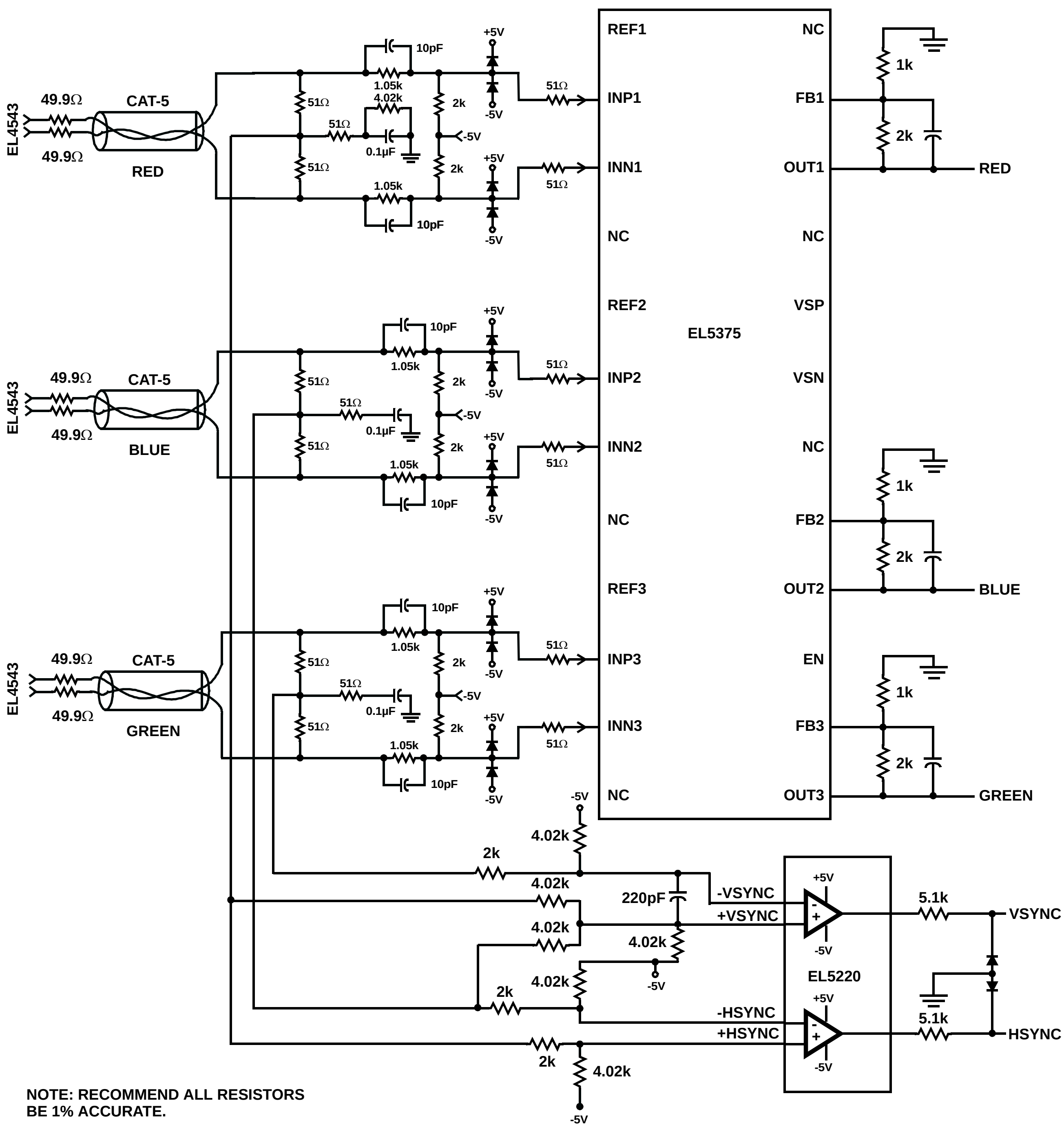

FIGURE 6. SOLUTION USING THE EL5375

Cross Talk Attenuation

The CAT-5 cable will have cross talk when transmitting digital data. A longer cable will have more cross talk. The HSYNC and VSYNC signals are basically a digital signal with fast rise and fall times causing cross talk in the CAT-5 cable. The HSYNC cross talk will appear as digital noise to the other pairs. The HSYNC is in sync with the video signal so the noise is always in a blanked part of the video signal and will not be seen on the display. The HSYNC also couples in to the VSYNC cable pairs and causes false HSYNC spikes on the VSYNC decoded data output. This will appear as failure to VSYNC. The VSYNC noise can be suppressed using a 220pF cap across the VSYNC comparator amp input to filter out the HSYNC noise spikes.

Summary

Single supply drivers interfacing into dual supply receivers may have limited CMV range due to CMV offset. Using simple balanced resistor networks, you can recover the full CMV range of the receiver. At the same time, using a few capacitors, you can improve the HF and LF rejection. We introduced two subtle issues to consider and their solutions:

- HSYNC Jitter — solved by offsetting one of the HSYNC differential signals by more than the detector's input offset voltage.
- Circuit Instability — solved by adding two 51Ω dampening resistors at the input to the differential receiver to reduce the 'Q' of the entire circuit.

Thus, you can successfully interface a single supply cable driver to a dual supply receiver.