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AND8457

SAG Correction

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APPLICATION NOTE

Video amplifiers are typically used to drive 75 Ω coaxial cables through an AC coupling capacitor. Unfortunately, in order to maintain the quality of the video signal this output capacitor must be made extremely large. However, as portable applications become more compact there are greater size restrictions to meet. A solution is a method called SAG correction, also known as SAG compensation, which is used in AC coupled video applications to allow a smaller output capacitor. A low cost solution is the NCS2561, a single channel video driver that integrates a built−in SAG correction circuit.

Typically a 220 μF capacitor is used to couple the output of the video driver. In certain applications or to satisfy customer specifications, one may need a higher capacitance value, for example 470 μF and sometimes up to 1 mF, to improve field tilt effects. However, there are two major problems with using large output capacitors. First of all, they are large in size, so they do not fit most portable applications like cell phones or digital cameras. Secondly, they are quite costly and minimizing expenditures is a key design objective. A solution is to use SAG compensation, reducing the size of the output coupling capacitor. Changing the output capacitance affects the frequency response of the high pass filter, composed of the output coupling capacitor and the load resistor. With the introduction of the C_{sag} capacitor a peaking begins to occur at lower frequencies. As the value of the SAG capacitor is decreased the cutoff frequency increases attenuating parts of the desired signal. Therefore it is important to choose the lowest capacitance values while still maintaining a low cutoff frequency. The purpose of this application note is to determine SAG capacitances that provide a comparable solution to standard coupling without the use of large capacitors.

The goal of the SAG correction is to reduce the size of the output capacitor without degrading the video performance. The SAG correction offers a smaller and cheaper output capacitor solution by splitting the original capacitor into two smaller capacitors, which are referred to, in this text, as C_{out} and C_{sag}. When seeking the smallest values for these output capacitors, the cutoff frequency is an important parameter which should not be compromised.

Cutoff Frequency

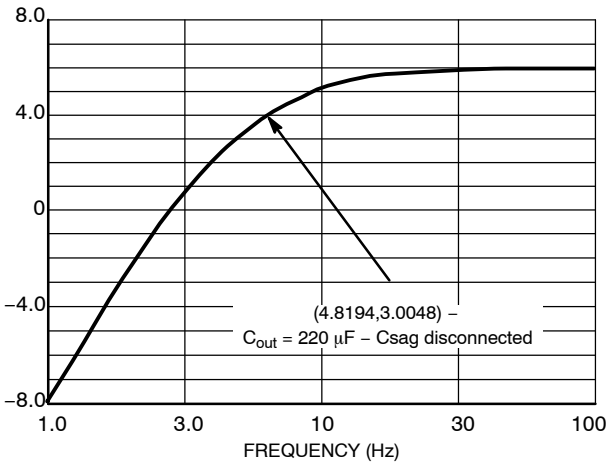

Figure 1. Gain vs. Frequency Simulation 220 μF Capacitor Configuration

The cutoff frequency as shown below is dependent on the line and load resistances, as well as the output capacitance.

$$f_C = \frac{1}{2\pi \times \left(R_{Line} + R_{Load}\right) \times C_{out}} \quad \text{(eq. 1)}$$

The 220 μF output capacitor produces a low −3 dB cutoff frequency at approximately 5 Hz with the formula:

$$f_C = \frac{1}{2\pi \times \left(75\ \Omega + 75\ \Omega\right) \times 220\ \mu F} \approx 5\ Hz \quad \text{(eq. 2)}$$

A 470 μF capacitor will also provide a low cutoff frequency around 2.3 Hz:

$$f_C = \frac{1}{2\pi \times \left(75\ \Omega + 75\ \Omega\right) \times 470\ \mu F} \approx 2.3\ Hz \quad \text{(eq. 3)}$$

In the case where SAG correction is not used, as the value of C_{out} is decreased in a standard video circuit (Figure 3), the cutoff frequency of the high pass filter approaches the critical frequency bandwidth of 24 Hz – 30 Hz. This bandwidth should not be attenuated because these are the frequencies of the slower frame rate used by standard definition television– NTCS (30 Hz), PAL & SECAM (25 Hz), and ATSC (24 Hz).

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Coupling Methods

In video amplifier applications, AC or DC coupling methods can be used. The AC coupling mode has become a standard because not all video displays contain internal DC restoration circuitry. In the AC method, a large output coupling capacitor is used to block any DC voltage from reaching the display input. However, the DC coupling method provides the most ideal video performance which will be seen later. Unfortunately, the average output is much greater in DC topologies than in AC, drastically increasing the power consumption. Beginning with the AC method, both the 220 μF configuration (Figure 3) and the SAG compensation (Figure 5) will be discussed in the following simulations.

Simulations

The below simulations were completed in Spice using an ideal operational amplifier. The resistors of the circuit have been chosen to obtain a 6 dB or 2 V/V gain on the amplifier output. Consequently, the signal is averaged by the coupling capacitor and then divided by a factor of 2 as a result of the voltage divider on the output created from two 75 Ω series resistors.

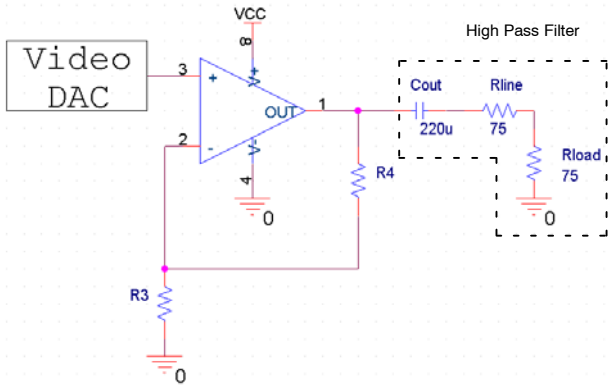

Figure 2. C_{out} = 220 μF without C_{sag}

Figure 2 shows a traditional circuit using a video amplifier and a large external 220 μF coupling capacitor in series with a 75 Ω resistor. As explained earlier this capacitor is bulky and costly. Traditionally, this coupling capacitor was acceptable for video signal transmission mainly in Set Top Box applications. However, those applications don't have the same space restrictions as smaller applications like cameras or cell phones. Due to the limited space in portable applications, the video amplifier circuit, including the external components, must be as compact as possible. In the NCS2561, the SAG correction is implemented in such a way that only two small capacitors are used.

Frequency Response

Using the traditional coupling capacitor schematic (Figure 3), it can be seen from the frequency response shown in Figure 4, that as the capacitance is increased, the cutoff frequency decreases. It can also be seen that there is no peaking effect at low frequencies, which is an advantage of the large output capacitor over SAG compensation.

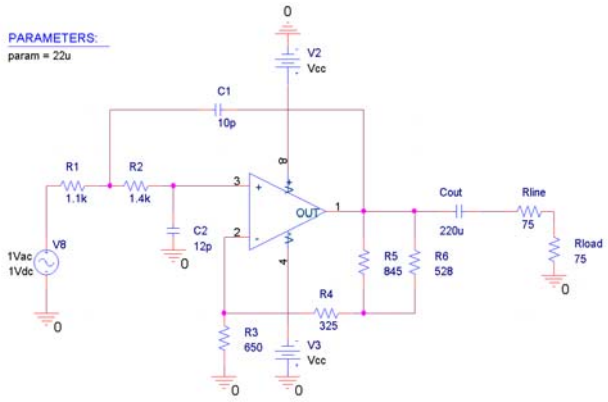

Figure 3. Standard Coupling for AC Output

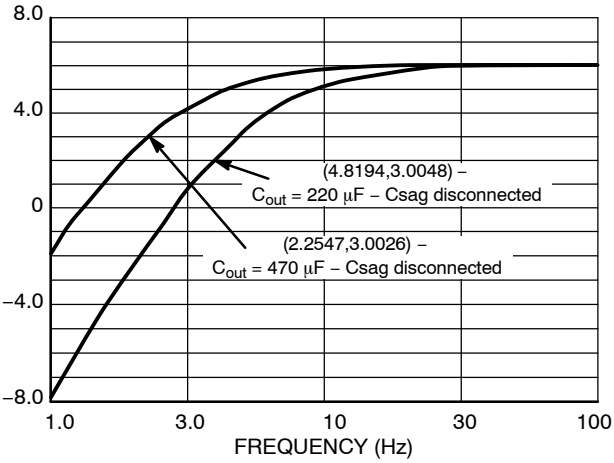

Figure 4. Gain vs. Frequency simulation without C_{sag} C_{out} = 220 μF and 470 μF

In the following simulations, SAG correction has been implemented as shown in Figure 5, fixing C_{sag} at 22 μF, and varying C_{out} using a wide range of capacitor values. Ideally, the value of C_{out} should be around 100 μF in order to obtain a cutoff frequency much lower than 25 Hz. The characteristic image frequency of a video display occurs at 25 Hz, therefore it is important to not have any attenuation at this frequency.

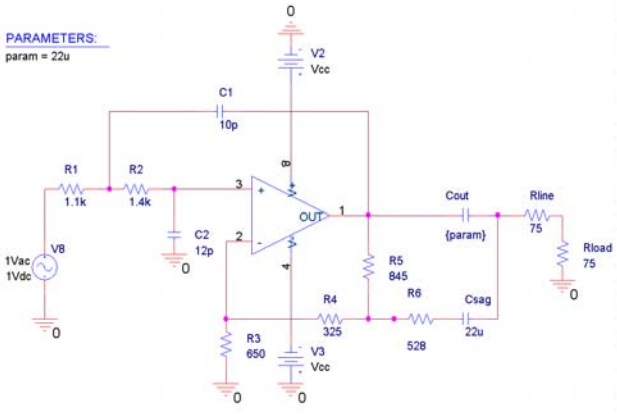

Figure 5. Simulation with C_{sag} = 22 μF and C_{out} = Variable

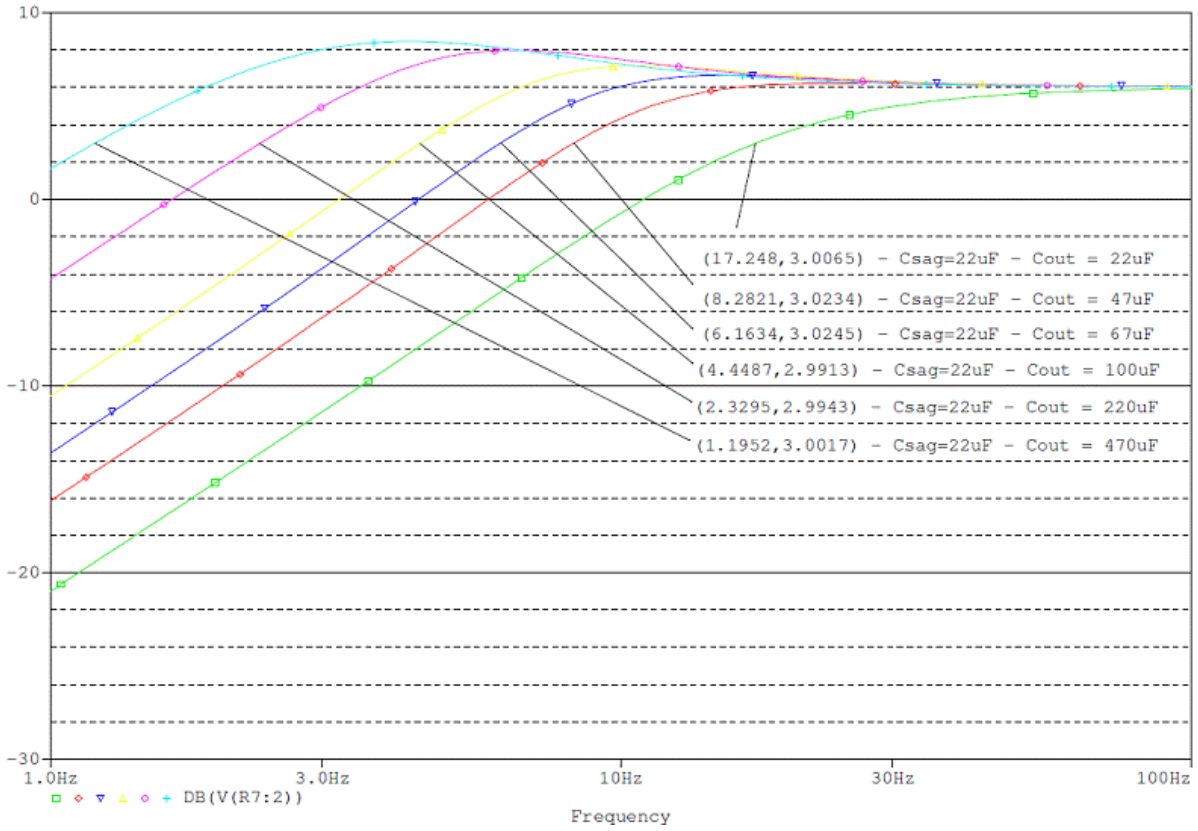

Figure 6. Gain vs. Frequency Simulation
C_{sag} = 22 μF and C_{out} = 22 μF, 47 μF, 67 μF, 100 μF, 220 μF, and 470 μF

As can be seen from Figure 6, a peaking effect occurs in the low frequency bandwidth. The peaking is a result of the addition of the SAG capacitor. As explained earlier, the output capacitor and load resistance create a high pass filter. When a new capacitor is added to the feedback loop a new filter zero is created causing a peak in the frequency response.

The objective is to obtain a frequency response similar to that of the 220 μF output capacitor without SAG compensation, as shown in Figure 4. From the frequency response shown in Figure 6, it can be seen that the behavior when C_{out} is 100 μF is very similar to the response of the 220 μF output capacitor providing a cutoff frequency around 5 Hz. Unfortunately there is more to be done to determine the best C_{sag} capacitor value. Another beneficial analysis is the black and white test.

Black and White Test

To perform the black and white experiment, a 50 Hz, half black and white signal, was injected in the input of the amplifier detailed in Figure 5.

On the output, the same signal will be seen with the amplitude multiplied by a factor of 2. Applying the same test conditions as in the previous simulations, C_{sag} was fixed to 22 μF, while C_{out} was varied using the parameters listed in Figure 6. To analyze the SAG capacitances a reference signal using the standard configuration was captured to make effective comparisons.

The first case is the standard configuration as shown in Figure 2. The schematic uses a large 220 μF output capacitor without SAG correction. As seen from the waveforms in Figure 7, there is a slight field tilt effect on the output signal. This phenomena is observed because the output signal follows the charge and discharge of the output coupling capacitor. The output capacitor forces the black level, in the black and white test, to be referenced at 0 V. The next case is the ideal situation with no output capacitors also known as DC coupled. With the exclusion of the capacitors there is no charge and discharge behavior therefore no field tilt effect. Now using the standard waveforms as a reference, each of the C_{sag} values can be evaluated to determine the capacitance needed to meet the design requirements.

Using Figures 8 to 12, it can be seen that, as the size of the capacitor is increased the field tilt effect has a smaller impact on the output signal. When C_{out} is 67 μF, as in Figure 10, the signal behaves much like the standard waveform when only the 220 μF capacitor is used. Also, it can be seen that when the output capacitor is very large the signal behaves much like the DC coupled output.

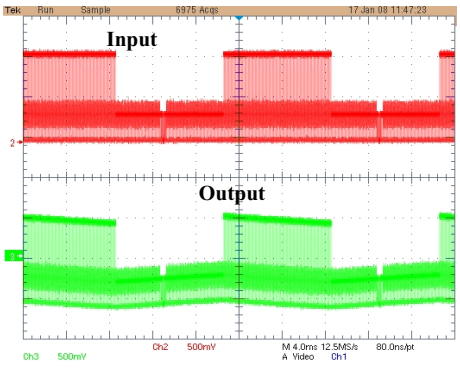

Figure 7. C_{out} = 220 μF without C_{sag}
Top curve: Input – Bottom curve: Output

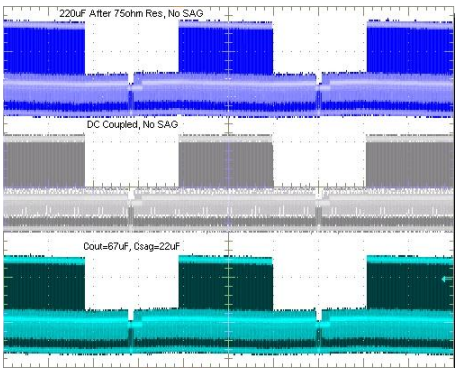

Figure 10. C_{out} = 67 μF, C_{sag} = 22 μF

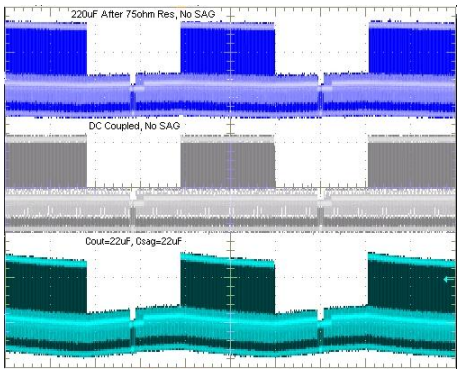

Figure 8. C_{out} = 22 μF, C_{sag} = 22 μF

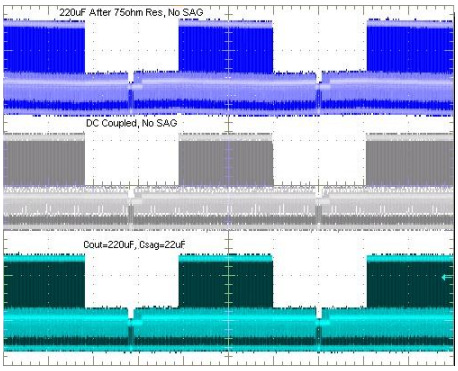

Figure 11. C_{out} = 220 μF, C_{sag} = 22 μF

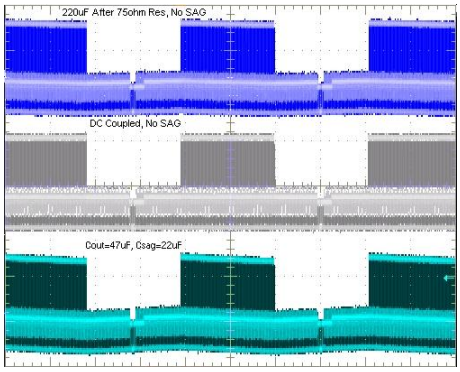

Figure 9. C_{out} = 47 μF, C_{sag} = 22 μF

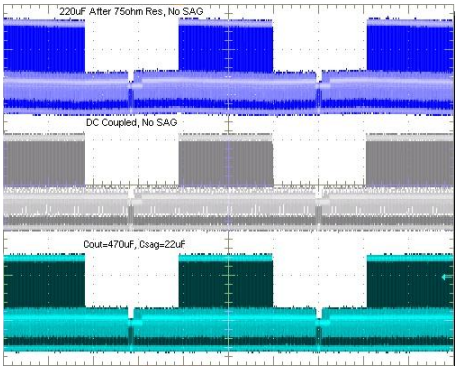

Figure 12. C_{out} = 470 μF, C_{sag} = 22 μF

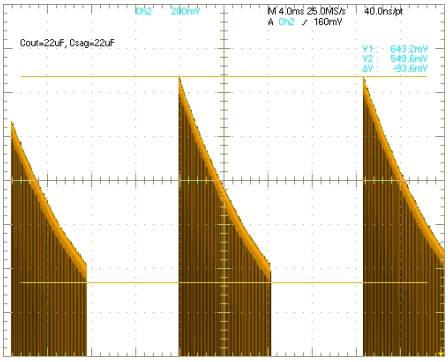

Figure 13. C_{out} = 22 μF, C_{sag} = 22 μF ΔTilt ≈ 94 mV

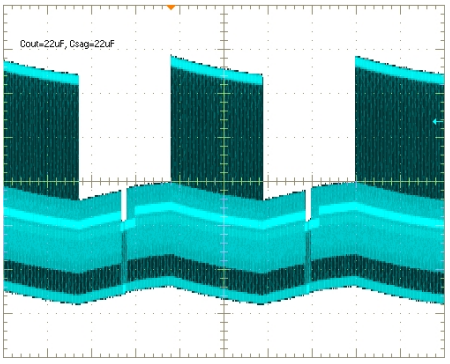

Figure 17. C_{out} = 22 μF, C_{sag} = 22 μF

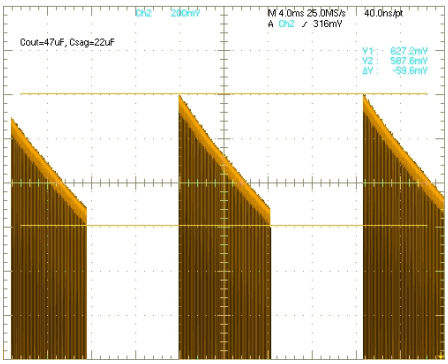

Figure 14. C_{out} = 47 μF, C_{sag} = 22 μF, ΔTilt ≈ 60 mV

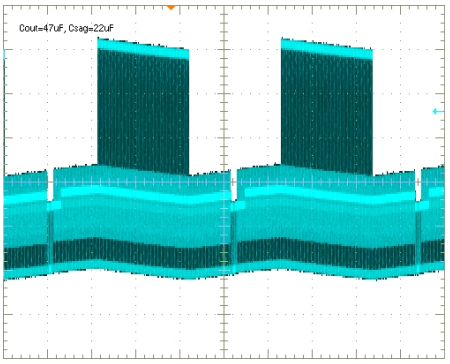

Figure 18. C_{out} = 47 μF, C_{sag} = 22 μF

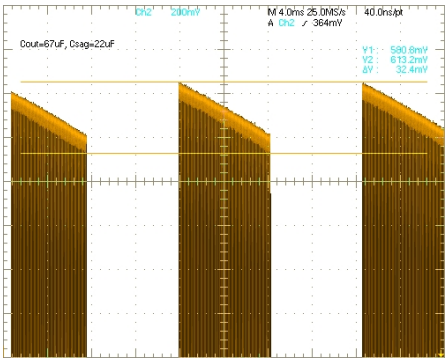

Figure 15. C_{out} = 67 μF, C_{sag} = 22 μF, ΔTilt ≈ 32 mV

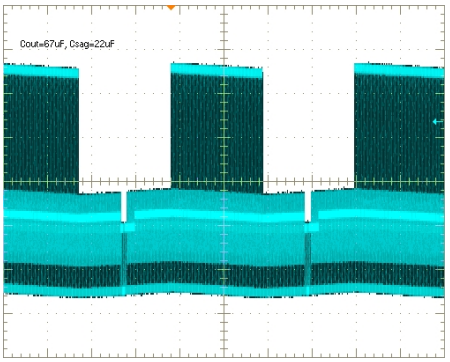

Figure 19. C_{out} = 67 μF, C_{sag} = 22 μF

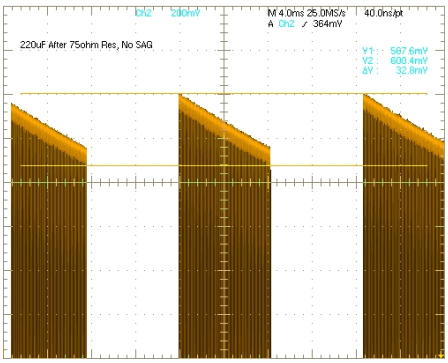

Figure 16. 220 μF after 75 Ω, No C_{sag}, ΔTilt ≈ 32 mV

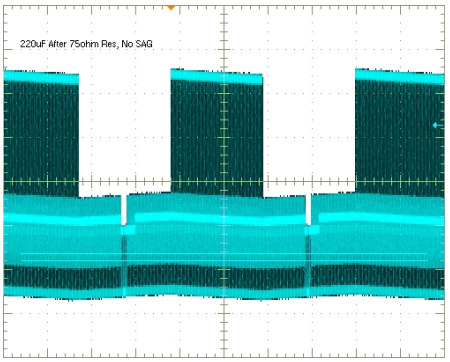

Figure 20. 220 μF after 75 Ω, No C_{sag}

To further analyze the black and white waveforms, zoom measurements were taken to show the change in tilt amplitude. As can be seen from Figures 13 through 16, by increasing the capacitance the tilt effect is reduced and is eventually negligible at very high capacitances. Again, the goal is to find the smallest capacitance that provides minimal tilt to the signal. When C_{out} was 67 μF there was only a 32 mV change in tilt as in the standard case. Therefore, out of the various capacitors used the 67 μF is the most ideal providing a comparable output to the standard coupling case.

Figure 21. TV Picture using the Standard Configuration with no C_{sag} and C_{out} = 220 μF

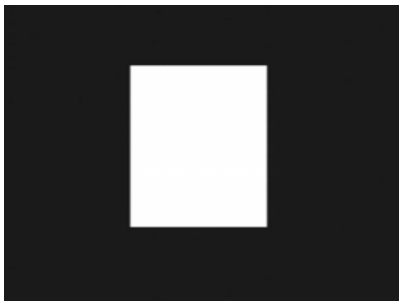

Figure 22. TV Picture with C_{sag} = 67 μF, C_{out} = 22 μF

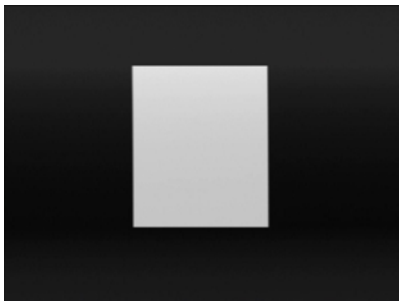

Figure 23. TV Picture with C_{sag} = 22 μF, C_{out} = 22 μF

Figures 21 to 23 show a screen capture taken from a television when injecting the black and white test pattern as used in the previous measurements. Figure 21 gives a visual appreciation of what the white window test pattern looks like in a standard configuration when C_{out} is 220 μF and no SAG capacitor is used. Comparing Figure 23 to the ideal output shown in Figure 21 there is visible loss in the black and white signal in the vertical direction. However, Figure 22 using a 67 μF capacitor shows less signal degradation than the 22 μF case in Figure 23. To understand how the tilt effect appears in the black and white output signal please refer to Figure 24.

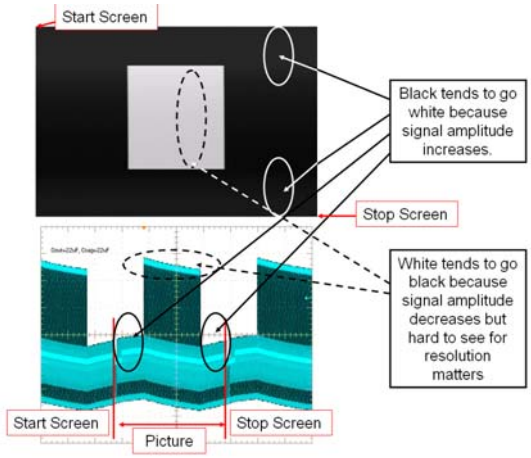

Figure 24. TV picture with C_{sag} = 22 μF, C_{out} = 22 μF

Ideally, the signal should not have a tilt effect which requires the use of a large capacitor. Unfortunately, the choice must be made between either having a clean signal and a large output capacitor, or a small output capacitor but a tilted signal. A good medium is the SAG configuration with an output capacitor of 67 μF and a SAG capacitor of 22 μF.

Summary

In video applications it is important to maintain the quality of a video signal which requires the use of large output capacitors. A good solution is the implementation of SAG correction. However, when applying SAG correction it is important to choose the most optimal capacitor to avoid attenuating the desired signal while maintaining a low cutoff frequency. ON Semiconductor provides a low cost solution, the NCS2561, a 3.3 V single channel video driver that integrates a reconstruction filter and includes a built−in SAG correction circuit.

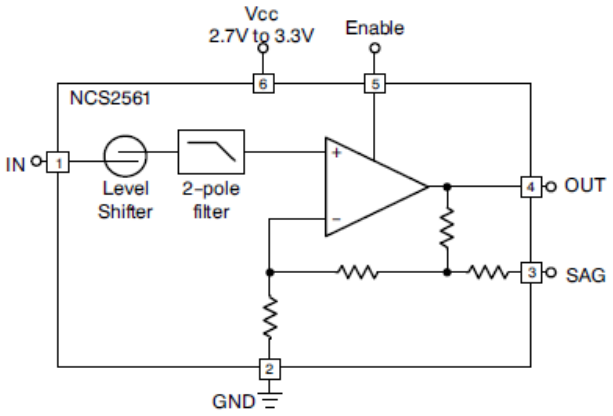

Figure 25. NCS2561 Block Diagram

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