Video switcher using high-speed op amps

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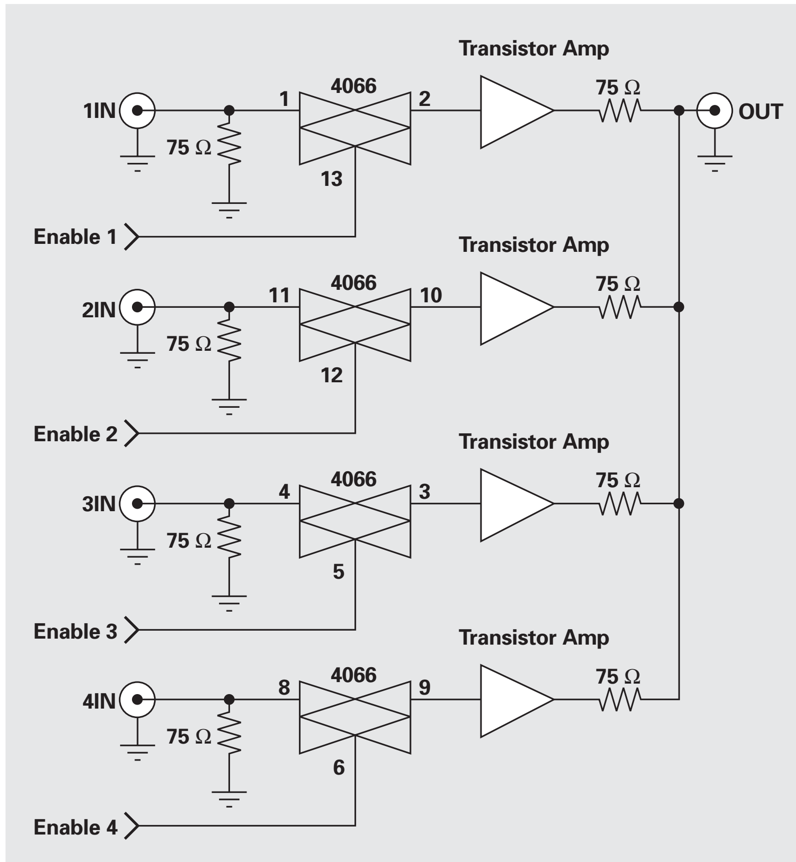
Introduction

Video switching devices are used to route video from several sources to a single channel.

Low-end consumer products use CMOS analog switches and multiplexers such as the 4066 and 4051, as shown in Figure 1. These devices have a series on resistance that ranges from just over a 100 Ω to 1 kΩ, a resistance that is not constant with video level. Unfortunately, this resistance appears in series with the signal. When combined with the 75-Ω load in the monitor, the analog switch would form a voltage divider, disastrously affecting the luminance. Consumer devices solve this problem by buffering the analog switch outputs with transistor stages. This results in video performance degraded not only by the characteristics of the CMOS switch but by those of the buffer stage as well. There should be a better way—and there is!

Figure 1. Traditional video switching solution



Video op amps with power-down inputs

Let's forget the switching action for a moment and consider just the buffer amplifier function. A transistor stage is problematic because it has several inter-related requirements. It must present high input impedance to the switch—high enough that a 1-kΩ switch resistance is inconsequential, and high enough that variation in resistance of the switch with IRE level does not produce luminance shifts. The stage has to operate with almost zero ripple and phase shift over a 6-MHz bandwidth (which translates to a very wide bandwidth stage). The transistor also has to provide enough drive for a 150-Ω load. These are tough requirements for a single transistor! Many high-end video multiplexer designs, therefore, use a FET for high input impedance and a bipolar transistor for drive.

An op amp has a lot of advantages in this application. High-speed op amps exist that have plenty of bandwidth for video applications. If an op amp with 20 or more times the video bandwidth is used, roll-off and phase shift at 6 MHz are negligible. An op amp has high input impedance, particularly in the noninverting mode. It can be terminated for 75-Ω input by a simple resistor. Two resistors create a gain of 2 in the noninverting configuration, which compensates for a 75-Ω back termination resistor on the op amp output. Overall stage gain is therefore 1.

Some new video op amps have a power-down feature that allows the output of the op amp to be disabled, producing a 0-V (0-IRE—"blacker than black") level on its output. It can therefore be connected in parallel with other op amps, because it will contribute no luminance or sync pulses. In power-down mode, its gain-setting resistors appear as a slight load on other op amps. Because the resistors have a relatively high value, they increase the load on other op amps by a negligible amount. The other op amps merely have to have enough excess drive capability to drive the extra load. This enables the op amp to operate as a video switch, as shown in Figure 2.

Figure 2. Video switcher with high-speed op amps

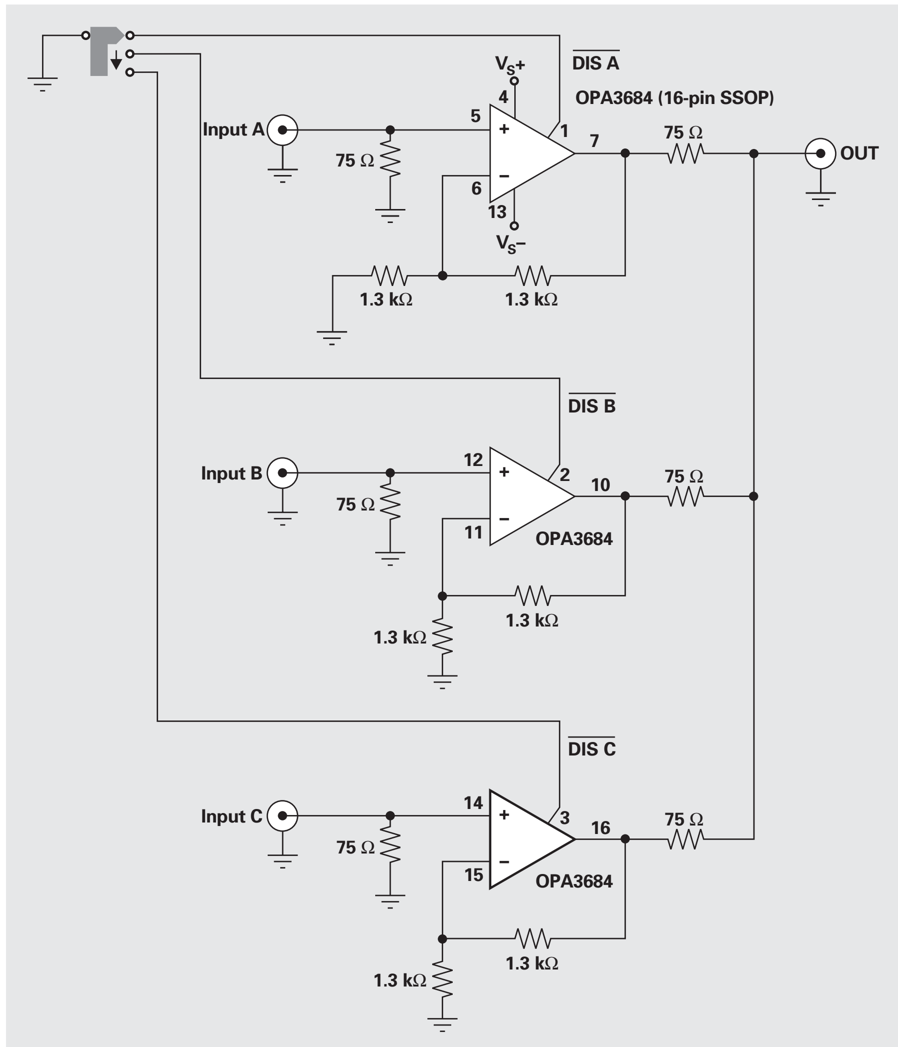


Figure 2 shows a 3:1 switcher using the OPA3684. More OPA3684 stages can be connected to add additional inputs. If only two inputs are needed, the THS4226 can be used. The limit on the number of inputs has not been tested; but the only limiting factors appear to be the additional loading on the active op amp output, the physical size of the interface, and the length of connections.

The switcher in Figure 2 shows a three-position, single-pole rotary switch—which, in practical applications, should be a "break before make" type. It can also be an electronic switching system, perhaps with an intelligent infrared interface in a consumer unit.

Tests of the video switcher

The following describes testing of a 2:1 video switcher based on the THS4226. The primary areas of concern are:

- *crosstalk*, which is the bleeding of images from inactive channels into the active channel;
- *offset errors*, which will cause a change in luminance (white and black levels);
- *gain errors*, which will expand or contract the visible 7.5- to 100-IRE portion of the video waveform; and
- *phase errors*, which will change the shades of color in the video.

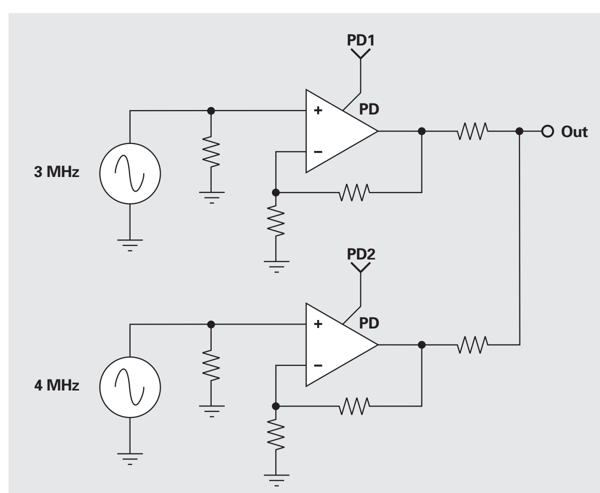
While crosstalk can be measured with conventional test equipment, the rest of the tests were performed by utilizing the Lucasfilm THX test patterns[1] (available on several consumer DVD titles). These test patterns were used on one video input, while a high-quality NTSC program source was used on another input. Although these tests were admittedly subjective, the human eye is very sensitive to shifts in brightness and color when side-by-side comparisons are made.

Crosstalk test

In the test setup in Figure 3, sinusoidal sources are input to the two channels, with 3 MHz input to one channel and 4 MHz to the other. The output is connected to a spectrum analyzer. The level of 3 MHz in the output when it is the inactive channel, and vice versa, determines how much crosstalk there will be in the video.

The level of crosstalk was close to the noise floor of the spectrum analyzer. The best estimate after 1000 samples were taken was that the crosstalk from each inactive channel was about –74 dB, referenced to the active channel.

Figure 3. Crosstalk test



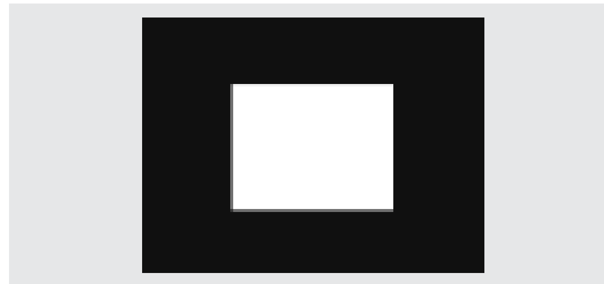
Contrast/picture test

The contrast/picture test shown in Figure 4 is a 100-IRE rectangle centered on a 0-IRE background. For proper operation, the background should appear completely black and the rectangle completely white, with no “bleeding” or “blooming” of the rectangle into the background.

When the contrast/picture test was run through the video multiplexer as the active source, black and white levels were unaffected by the presence of the op amp as a buffer. No bleeding or blooming occurred.

When the contrast/picture test was on the inactive input and program material was on the active input, any crosstalk would have resulted in a visible brightening of the center of the picture. None was observed.

Figure 4. Contrast/picture test pattern



Brightness setup test

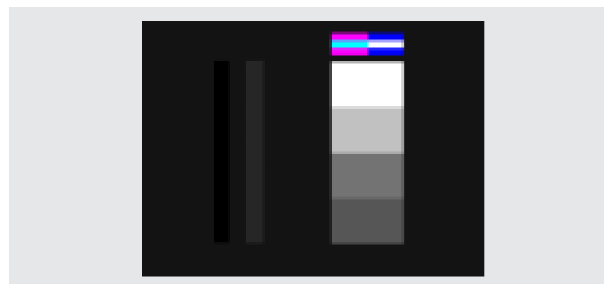
The brightness setup test pattern is shown in Figure 5. Although the right-hand side of the test pattern appears interesting, the area of interest is actually the portion on the left-hand side. Printed copies of this article almost certainly will not show anything there. On the left-hand side of the test pattern, there are two faint vertical bars—one lighter and one darker than the background. The black level is defined as 7.5 IRE, to which the background is set. The darker vertical bar is set at 11.5 IRE (slightly higher than the black level), and the lighter one is set at 3.5 IRE (slightly lower than the black level). This test pattern, called the “PLUGE bars,” is used to test the black level. Correct setting of the brightness level will allow the darker bar to be visible, but not the lighter one (because it is below the black level). Any shift in the black level due to gain-setting resistors would therefore be evident.

Please note that the purpose of this article is to describe tests performed on the video multiplexer—*not* to provide a test pattern for the adjustment of your monitor. The computer monitor on which this document is displayed is not an NTSC monitor. Colors may not display correctly in PDF format, and the color depth of the display also will affect the colors seen.

The brightness level was set without the video multiplexer being in the circuit. Then the video buffer was inserted into the signal path. No change in brightness level was observed.

The brightness setup test is also an ideal way to test for crosstalk between two video channels. Crosstalk would show up on the black background as a “ghost” image of the program material on the inactive channel. None was observed.

Figure 5. Brightness setup test



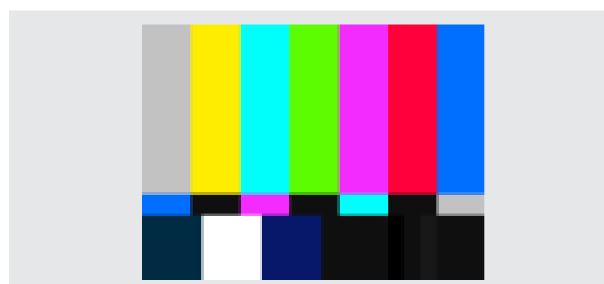
Tint and color setup using SMPTE color bars

The SMPTE color bars shown in Figure 6 have long been used in the television industry to test proper color reproduction. Their primary use here is to test for differential phase changes (and therefore color changes) in the video multiplexer.

The SMPTE bars were observed with and without the video multiplexer in the signal chain. No color shifts were observed. Although no blue filter was available to monitor the precise tint and color settings, the red color bar did not tend to bloom or get “snowy”—a sure sign that the color portion of the signal was not being significantly affected.

The color bar patterns would also produce color shifts in the other channel if crosstalk was a factor. Any broadcast technician will confirm that human skin is the toughest color to get right—and any change in skin tone due to color crosstalk will be very apparent.

Figure 6. SMPTE color bars



Conclusion

Video op amps with power-down inputs are ideal for constructing video multiplexers and switches. They improve performance by replacing problematic analog switches and transistor amplifier buffer stages. They also lower component count, raising reliability.

Reference

1. Lucasfilm THX Consumer Products: www.thx.com/mod/techLib/index.html

Related Web sites

analog.ti.com
www.ti.com/sc/device/THS4226
www.ti.com/sc/device/OPA3684

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

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