Equalization and Pre-Emphasis Enable Use of 30-Meter Cat-5 UTP Cable

By Charly El-Khoury

Over the past few years, the use of *category-5* (Cat-5) *unshielded twisted-pair* (UTP) cable has grown due to its respectable performance and low cost. This type of cable is currently used for *keyboard-video-mouse* (KVM) networking, with three out of the four twisted pairs carrying the *red, green, and blue* (RGB) video signals. With high-definition television (HDTV) becoming increasingly popular, this type of cable could provide an inexpensive solution when long-distance connectivity—up to 30 meters—is required.

Because Cat-5 UTP cable is made for economy use, its performance degrades rapidly with longer distances. This article presents two solutions that can reduce the transmission losses when using cables up to 30-m long with HDTV 1080p signals, which require a video bandwidth of about 75 MHz.

Figure 1 shows the magnitude response of a 30-m cable vs. frequency. The loss at 75 MHz is about 6 dB, so 6 dB of high-frequency gain must be applied either before transmission or after reception.

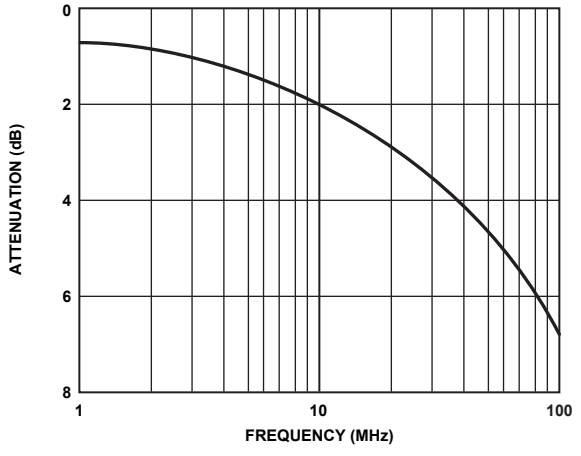

Figure 1. Cable attenuation vs. frequency (30 meters).

Table 1 lists the latest HDTV standards and requirements. High-definition Blu-ray players use 1080p 16:9 HDTV. The exact video bandwidth required is undefined, but 75 MHz should be enough to capture the experience.

Pre-Emphasis

The circuit shown in Figure 2 uses the AD8148[1] driver board with pre-emphasis to compensate for the high-frequency attenuation through a 30-m Cat-5 UTP cable. At the receiver end, the AD8145[2] board—set for a gain of 2—is used without equalization.

Table 1. Common Video Resolutions and Bandwidths

Video Standard	Horizontal Resolution (Pixels/Line)	Vertical Resolution (Lines/ Frame)	Frame Rate (Hz)	Pixel Rate (Mp/s)	Estimated Video BW (MHz)
720p, 16:9 HDTV	1280	720	60	57.6	30
1080i, 16:9 HDTV	1920	1080	30	64.8	32
1080p, 16:9 HDTV	1920	1080	24/30	51.8/ 64.8	32
1080p, 16:9 HDTV	1920	1080	60	130	75

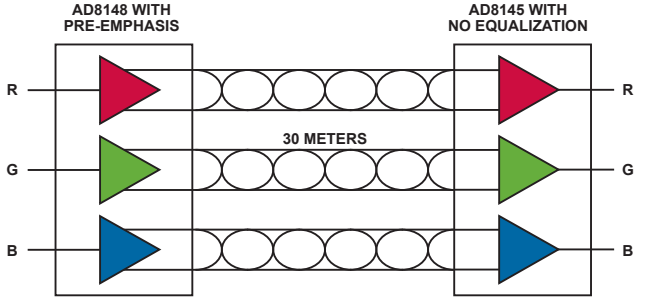

Figure 2. AD8148 with pre-emphasis.

Figure 3 shows the pre-emphasis circuit. The AD8148 differential amplifier is set internally for a gain of 4 (12 dB); the RC network controls the overall gain, which starts with a gain of 2 at low frequencies and slowly increases to a gain for 4 at higher frequencies, as shown in Figure 4.

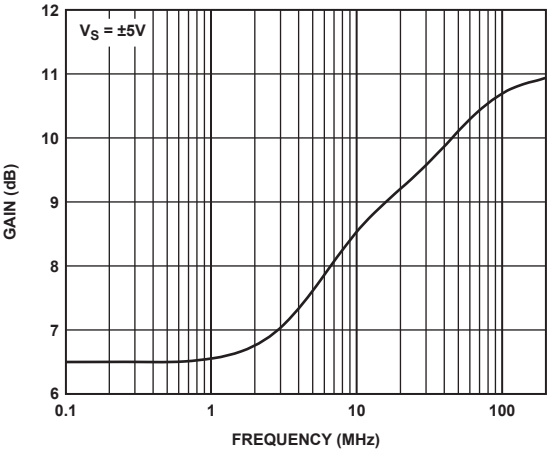

Figure 4. Pre-emphasis gain vs. frequency.

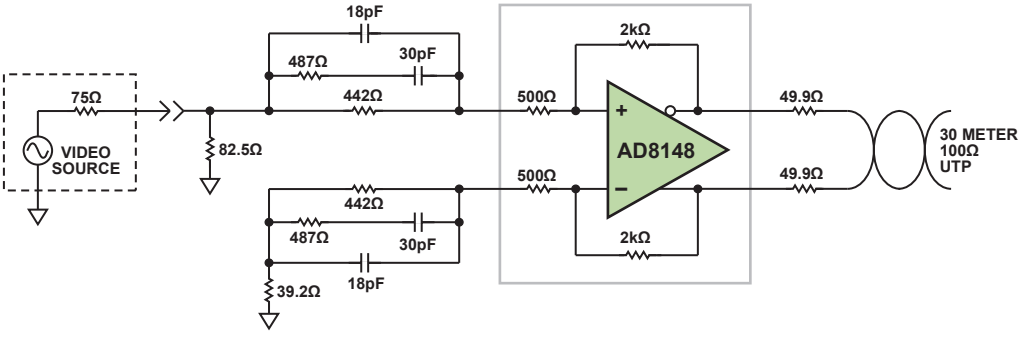

Figure 3. Pre-emphasis circuit.

The general idea is to use the driver's pre-emphasis to counteract the cable's attenuation at high frequencies. Adding the receiver to the output of the cable will not affect the bandwidth, provided the receiver has a flat bandwidth of more than 100 MHz, which is true with an AD8145 set to a gain of 2. Figure 5 shows that the gain at 6 dB is flat to within 1 dB up to 100 MHz, proving that Cat-5 cable can transmit 1080p HDTV.

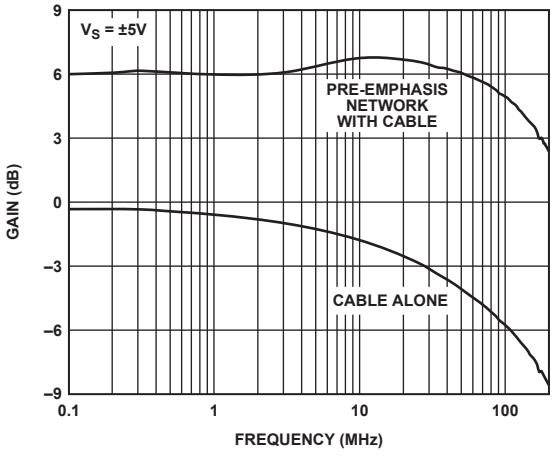

Figure 5. Pre-emphasis network and cable gain vs. frequency.

The performance of this circuit was tested for 10-m, 20-m, and 30-m cable lengths. If a shorter (<5 m) cable is needed, however, the driver can be used without pre-emphasis, as it will be able to handle the shorter distance.

Equalizer

The circuit shown in Figure 6 uses the AD8148 board without pre-emphasis and the AD8143[3] receiver board with equalization. The idea is the same: the high-frequency attenuation of the long cable must be counteracted by boosting the signal gain at higher frequencies. The AD8148 driver is set to a gain of 4; the AD8143 receiver is set to a gain of 1 for low frequencies and a gain of 2 at higher frequencies.

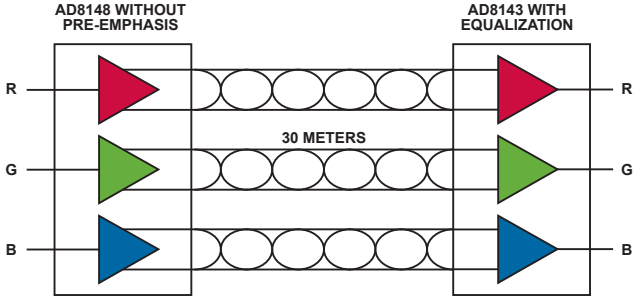

Figure 6. AD8143 with equalization.

Figure 7 shows the equalizer circuit that sets gain at low frequencies to 1 and the gain at high frequencies to 2, as shown in Figure 8. At less than 2 MHz, the gain is 0.5 dB, reaching about 6 dB at 50 MHz.

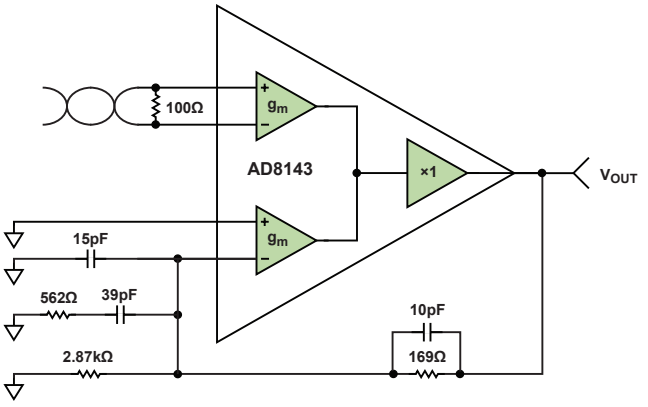

Figure 7. Equalization circuit.

After adding the 30 m cable, the magnitude stays flat to within 1 dB up to 80 MHz, well beyond what is needed for 1080p HDTV. Figure 9 shows about 2-dB peaking at 40 MHz. This will brighten the high-frequency signals a little, but its effect is not noticeable on the screen.

To account for the input and output termination, a gain of 4 is needed. The AD8143 is set at a gain of 1, so the driver must handle a gain of 4 and still have a flat band of more than 100 MHz. At a gain of 4, the AD8148 driver provides a flat response to about 500 MHz, allowing it to support the receiver in 1080p HDTV applications.

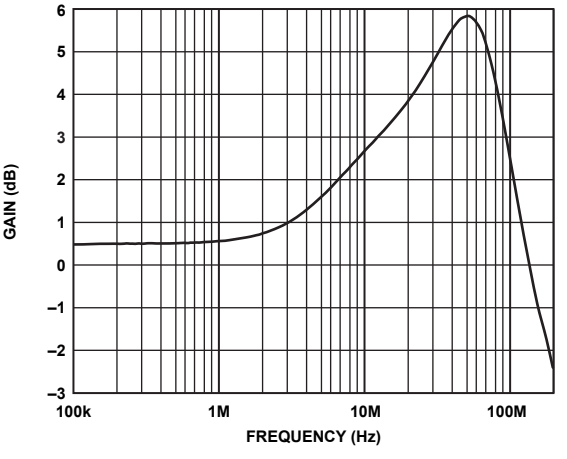

Figure 8. Equalizer magnitude response without cable.

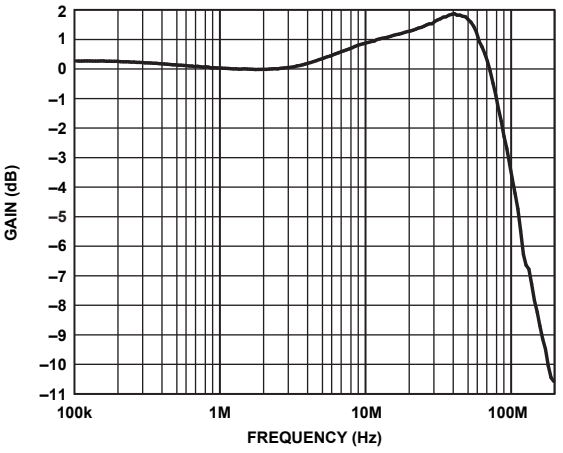

Figure 9. Equalizer magnitude response with the 30 m cable.

Conclusion

The demand for an inexpensive cable that can support HD is rising with the demand for better picture. Cat-5 UTP cable is becoming the best alternative solution. The two solutions proposed for longer distance needs can easily translate to shorter cables by using the AD8148 driver without pre-emphasis along with the AD8145 or AD8143 receivers. In all cases, the proposed solutions always preserve unity gain from the input of the driver to the output of the receiver, with all internal gains compensating for input and output termination losses. These stand-alone solutions allow inexpensive Cat-5 cable to be used for HD transmission, replacing the more expensive cables on the market today.

References

[1] www.analog.com/en/audiovideo-products/video-ampsbuffersfilters/ad8148/products/product.html

[2] www.analog.com/en/audiovideo-products/video-ampsbuffersfilters/ad8145/products/product.html

[3] www.analog.com/en/audiovideo-products/video-ampsbuffersfilters/ad8143/products/product.html

1. Pearson, Jonathan. *"Adjustable Cable Equalizer Combines Wideband Differential Receiver with Analog Switches,"* Analog Dialogue, Volume 38-07, July 2004.

2. Budak, Aram. *"Passive and Active Network Analysis and Synthesis,"* Houghton Mifflin, 1974.