Appendix A - Standards Overview

Background Information

The discussions in this application note are limited to CAV interconnect schemes using three parallel wires. Digital component and the various multiplexing methods are outside the present scope.

The SMPTE and EBU have agreed on standards for a CAV color difference format that is based on the +700 mV video and -300 mV sync levels used in non-NTSC regions.

Those of us working in NTSC-related environments, however, are unfortunately faced with a confusing array of component interconnect schemes that have evolved from precedents set in the early days of monochrome and composite color video technology. The following paragraphs provide some background information to show how we got where we are today.

At one time, video and sync were distributed in the studio on separate lines. The video signal, ranging from black to peak white, was scaled to 1.0 V peak-to-peak. The sync signal amplitude was 4.0 V p-p. Usually both of these signals were clamped to establish the black (blanking) level at 0 V, peak white at +1.0 V, and sync tip at -4.0 V. (See Figure 46.)

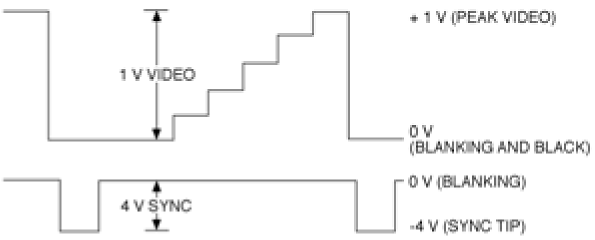

Figure 46. Early non-composite video and sync.

When sync and video were combined on one line to produce monochrome composite video for transmission, the amplitude of sync was reduced by a factor of 10. The composite signal became 1.4 V p-p, with black at 0 V, white at +1.0 V, and sync tip at -0.4 V. This set the precedent for a 10:4 ratio between video and sync amplitudes. (See Figure 47.)

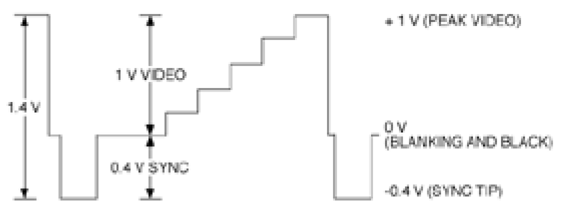

Figure 47. Early composite video.

The specified amplitude for composite video was later reduced to 1.0 V p-p, but the 10:4 video-to-sync ratio was maintained. This established the now familiar NTSC levels: blanking at 0 V, white at +714 mV, and sync tip at -286 mV. (See Figure 48.) These levels were carried over to the NTSC color standard.

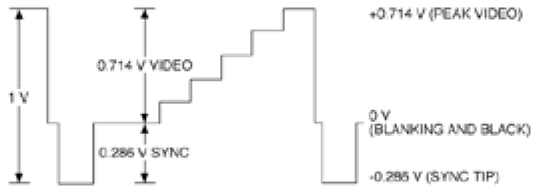

Figure 48. Modern composite video voltage levels (without setup).

Eventually the IRE (later to be the IEEE) established a unit of measure for video signals. This "IRE unit'' was defined as 1% of the video range from blanking to peak white, without reference to the actual signal voltage. Although defined as a ratio, it became common practice to refer to an IRE unit as "equal to 7.14 mV,'' because it was usually applied to the standard 1 V composite signal. (See Figure 49.)

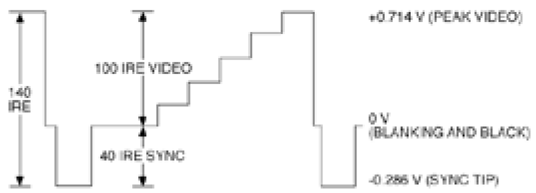

Figure 49. Modern composite video IRE levels (without setup).

Numbers like 714, 286, and 7.14 are not very convenient for measurement and calculation. Europe and elsewhere avoided this difficulty by adopting a 7:3 video-to-sync ratio while main-taining the 1 V p-p amplitude for the composite signal. The resulting levels are: blanking at 0 V, white at +700 mV, and sync tip at -300 mV. (See Figure 50.) With these levels, video measurements can be made in terms of convenient numbers using millivolts as the unit.

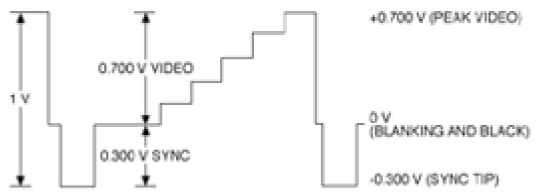

Figure 50. Non-NTSC composite video voltage levels.

So far we've described two basic standards: the NTSC-related standard with +714 mV peak video and -286 mV sync; and another (almost universal outside NTSC regions) with +700 mV video and -300 mV sync.

A further distinction is introduced by using ''black-level setup'' in NTSC and NTSC-related signals. By raising video black somewhat above the blanking level, setup provides a transmitted vertical-retrace blanking signal for TV sets. Because television displays are adjusted to produce very little light when the video is black, the blanking level (which is below black) is rendered invisible.

The black-level setup or "pedestal'' was originally anywhere from +5 to +10 IRE, but eventually the EIA RS-170A specified it at +7.5 IRE. (See Figure 51.) Consequently, since the peak white voltage is not increased with setup, the black-to-white amplitude range is reduced by 7.5%. Also, since the video is usually clamped at the blanking level, the video signal with setup does not include a reference black.

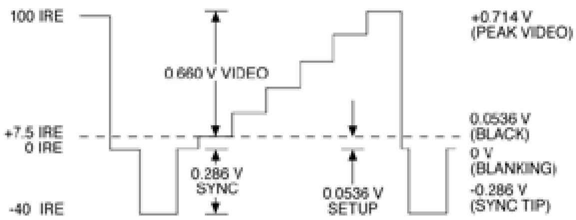

Figure 51. NTSC video voltage levels (with setup).

Modern component interconnect standards show the influence of many of the precedents described in the foregoing paragraphs. Some of these standards were initiated by professional groups (SMPTE), some by government related organizations (EBU), and some by manufacturers of hardware (Panasonic, Sony, etc.).

In this appendix, seven component standards will be described: four RGB and three color difference. Strictly speaking, these interconnect schemes are not compatible, but they have enough in common that familiarity with one method gives a sound basis for understanding the others.

With the exception of RGB, all use the idea of one luminance and two color difference signals carrying all the information for a color image.

At the present state of development, many facilities use more than one component standard and may also use component and composite signals in the same facility. A knowledge of the levels associated with the various standards is needed to ensure that each signal input is appropriate for the particular equipment involved.

Color Bar Basics

The signal levels in each standard will be described using the color bar signal. This signal is often used because it exercises the extreme range of signal values allowed in each channel by any of the interconnect schemes.

In NTSC regions, it has been common practice to use a 75% amplitude color bar signal as a test stimulus and reference. In non-NTSC regions, the 100% amplitude color bar is preferred. But in both cases, the saturation of the color bars is kept at 100%.

Note: *Sometimes the white bar of a 75% signal is raised to full amplitude as an aid in setting levels. It's important to keep in mind that a 75% color bar signal with a full-amplitude white is different from a 100% color bar signal. It has become fairly common, although incorrect and confusing, to refer to a 75% color bar signal with full-amplitude white as a "100% color bar.''*

The RGB Standards

An RGB component signal consists of three monochrome video signals, each representing the image for one of the primary colors. Combining these three monochrome images in a display results in a full color image. Possible sources of RGB video include cameras, telecine machines, composite decoders, character generators, graphics systems, color correctors, and others.

In general, RGB signals use the same peak-to-peak amplitude as the luminance signal in the local composite standard. This explains why there are several RGB standards in use today and why it's important to determine the characteristics of your equipment and calibrate for the appropriate levels (including setup, if required).

The following paragraphs describe the four RGB interconnect standards you might encounter:

- 700 mV RGB (SMPTE/EBU N10)
- 714 mV RGB (NTSC-related)
- 714 mV RGB with setup (NTSC-related)
- 700 mV RGB with setup (MII)

SMPTE/EBU N10

Since the non-NTSC regions have standardized on +700 mV video and -300 mV sync, this is the component interconnect standard in use in most non-NTSC regions. (See Figure 52.)

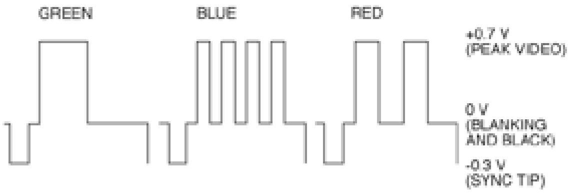

Figure 52. SMPTE/EBU N10 100% amplitude GBR color bar signal.

The SMPTE/EBU component standard specifies that the Y (luminance) signal is on channel one, the blue color difference signal is on channel two, and the red color difference signal is on channel three. Since luminance carries the sync information in color difference formats, and green carries the sync information in RGB, hardware compatibility is achieved by putting the green signal on channel one. Sync will thus always be on the same channel. (Although SMPTE RGB has sync on all channels, this is not always the case in other RGB formats.)

For similar reasons, the blue signal is put on channel two like the blue color difference signal, and the red signal is put on channel three like the red color difference signal. It therefore seems appropriate to call the SMPTE format "GBR'' rather than "RGB.'' In the rest of this appendix, we will use the term GBR. Time will tell which term remains in common usage.

NTSC-RELATED

The NTSC system has two characteristics that may lead to differences in the related GBR interconnect: the 10:4 video-to-sync ratio and black-level setup. Setup is usually added as part of the encoding process, so GBR signals coming directly from a camera generally do not have setup. In this case, the non-composite GBR is at 714 mV peak. If sync is added in this system, it will be at -286 mV. (Sync is usually taken from the green channel, although it may be added to all three.) Prior to the advent of component video, this was the common GBR interconnect in NTSC regions. (See Figure 53.)

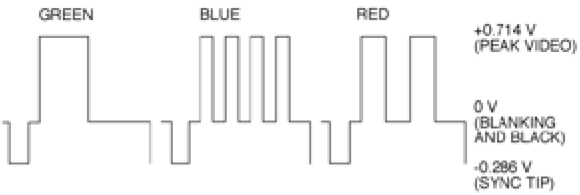

Figure 53. NTSC-related 100% amplitude GBR color bar signal (without setup).

If an NTSC signal is decoded, and the resulting GBR is normalized to 714 mV peak, setup is included on GBR. Setup may also be added on non-decoded feeds to gain compatibility among various GBR sources. In this case, each of the GBR signals will have the same levels as luminance in NTSC. Another source of 714 mV GBR with setup is translated Betacam® format component signals. (See Figure 54.)

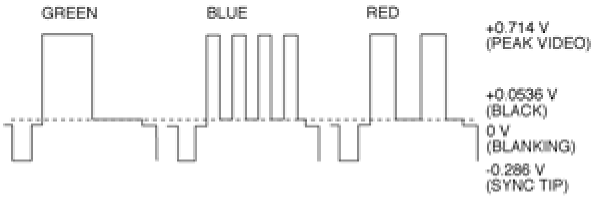

Figure 54. NTSC-related 100% amplitude GBR color bar signal (with setup).

MII

Simple transcoding of an MII format signal that has setup will yield GBR with 700 mV peak and 52.5 mV setup. This is essentially the SMPTE/EBU N10 component signal with setup added. (See Figure 55.)

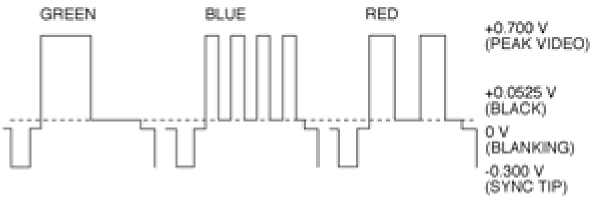

Figure 55. MII 100% amplitude color bar signal (with setup), simply translated to GBR.

The specifications for these four GBR standards are summarized in Table I.

Table I. Specifications for the Four GBR Standards

	SMPTE/EBU N10	**NTSC (no setup)**	**NTSC (setup)**	**MII**
Max	700 mV	714 mV	714 mV	700 mV
Min	0 mV	0 mV	54 mV	53 mV
Range	700 mV	714 mV	660 mV	647 mV
Sync	-300 mV	-286 mV	-286 mV	-300 mV

P-P	1 V	1 V	1 V	1 V

While the different standards described in this section are quite similar, they are not strictly compatible. The differences in peak level (700 mV vs. 714 mV) will not, in themselves, make very noticeable errors in displayed light levels, but incompatibility in setup will make quite noticeable differences in the displayed images. (An error of 7.5% at black will be very apparent.) In addition, the change in peak-to-peak video amplitude (voltage range from black to peak white) required to accommodate setup is noticeable in peak white areas of the image.

For example: a picture monitor calibrated for a no-setup signal will display peak whites at about 83% relative light output if driven with a 7.5% setup signal. The opposite case (monitor calibrated for a setup signal, but used with a no-setup signal) will have display highlights about 21% higher than normal. (These numbers apply if the displayed black level has been appropriately readjusted, but the monitor gain has not been recalibrated.)

Until such time as GBR interconnect levels are really standardized, it's important to make certain that each GBR feed is appropriate for the input specifications of the equipment it drives.

The Color Difference Standards

The three color difference CAV interconnect standards you're likely to encounter are:

- SMPTE/EBU N10
- Betacam®
- MII

SMPTE/EBU. The SMPTE/EBU standards for color difference format component analog video is much like its GBR counterpart. Each of the signal wires carries a 700 mV video signal, there is no black-level setup, and sync tip is at -300 mV.

Sync is only on the Y (luminance) channel, which is channel one. The blue color difference signal, P_B, is on channel two, and the red color difference signal, P_R, is on channel three. (See Figure 56.)

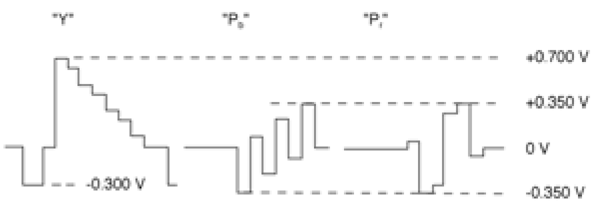

Figure 56. SMPTE/EBU N10 100% amplitude component color bar signal.

It's often convenient to display the P_B and P_R signals with the reference level offset to +350 mV on the display so all signals occupy the same range on the waveform display. (See Figure 57.)

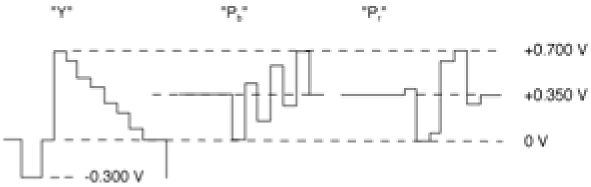

Figure 57. The SMPTE/EBU N10 color bar signal in Figure 56 with the color difference signals offset by +350 mV to match the luminance range.

The color difference signals are the familiar B-Y and R-Y, normalized for 700 mV peak-to-peak on a 100% amplitude color bar signal. Except for gain differences, these signals are identical to the U and V signals in PAL.

Betacam®. The NTSC-related Betacam® format uses 714.3 mV peak video and includes 7.5% setup in the luminance channel. To maintain the 1 V p-p amplitude of the composite format, sync tip on luminance is -286 mV. The color difference channels, however, have a range of 933.3 mV (4/3 times the 700 mV range of SMPTE/EBU N10). (See Figure 58.)

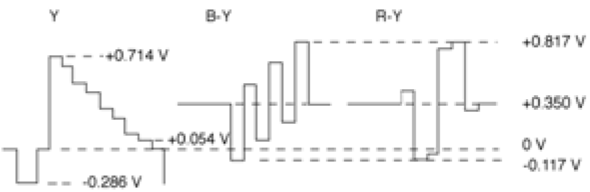

Figure 58. NTSC-related (60 Hz) Betacam® 100% amplitude component color bar signal.

In some cases, Betacam® equipment must be calibrated using 75% amplitude color bars. In the 75% luminance signal, the black-to-white video range is reduced from 660 mV to 495 mV.

(The 54 mV setup brings peak white to 549 mV.) The color difference signals are reduced from 933 mV to 700 mV. (See Figure 59.) Please refer to the manufacturer's documentation to determine proper calibration levels and test signals.

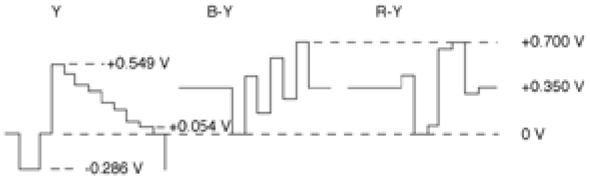

Figure 59. NTSC-related (60 Hz) Betacam® 75% amplitude component color bar signal.

The Betacam® SP format is compatible with Betacam® and has extended capabilities. The 12-pin "dub'' cable three-wire inter-connect is compatible with standard Betacam®. In addition, BNC connectors provide a three-wire component output that is compatible with the SMPTE CAV standard.

MII. The three signals in MII are luminance, scaled B-Y, and scaled R-Y. In 50 Hz regions, MII three-wire interconnect complies with SMPTE/EBU N10 standards (700 mV p-p in each channel for a 100% color bar signal).

In 60 Hz (NTSC) markets, black-level setup will be recorded and played back if it exists on the input signals. In this NTSC-related component standard, the luminance peak is limited to 700 mV (not 714 mV). When setup is included on luminance, the black-to-white range is restricted to 647.5 mV (700 mV minus the setup), and the color difference signals are also rescaled to 647.5 mV, giving them the same range as the active luminance channel. (See Figure 60.)

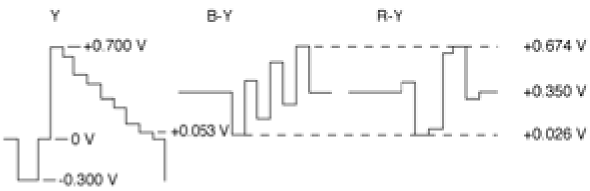

Figure 60. MII 100% amplitude component color bar signal (with setup).

The alignment tape for MII uses a 75% amplitude color bar with a 100% white reference level. (See Figure 61.)

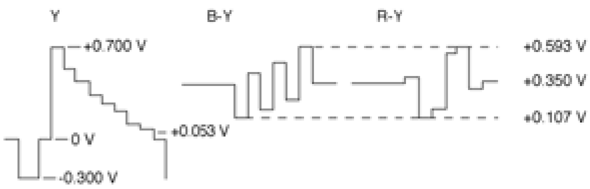

Figure 61. MII 75% amplitude, 100% white bar component color bar signal (with setup).

The recorded MII signal includes 2.25 MHz timing bursts. Because these timing bursts are generated in the CTCM (Chrominance Time Compressed Multiplex) circuitry, they are included in the two-wire dub interconnect but are not part of the three-wire input or output signals.

The specifications for these three CAV standards are summarized in Tables II and III.

Table II. Specifications for 100% Color Bars in the Three CAV Standards

	SMPTE/EBU N10	Betacam®	MII®
Luminance			
100%	700 mV	714 mV	700 mV
Max	700 mV	714 mV	700 mV
Min	0 mV	54 mV	53 mV
Range	700 mV	660 mV	648 mV
Chrominance			
Max	350 mV	467 mV	324 mV
Min	-350 mV	-467 mV	-324 mV
Range	700 mV	934 mV	648 mV
Sync	-300 mV	-286 mV	-300 mV
P-P	1 V	1 V	1 V

Table III. Specifications for 75% Color Bars in the Three CAV Standards

	SMPTE/EBU N10	Betacam ®	MII®
Luminance			
100%	700 mV	714 mV	700 mV
Max	525 mV	549 mV	539 mV[a]

	Min	0 mV	54 mV	53 mV
	Range	525 mV	495 mV	486 mV
Chrominance				
	Max	262.5 mV	350 mV	243 mV
	Min	-262.5 mV	-350 mV	-243 mV
	Range	525 mV	700 mV	486 mV
Sync		-300 mV	-286 mV	-300 mV
P-P		1 V	1 V	1 V

[a] *As shown in Figure 61, the 75% color bars include a 100% (700 mV) white level.*