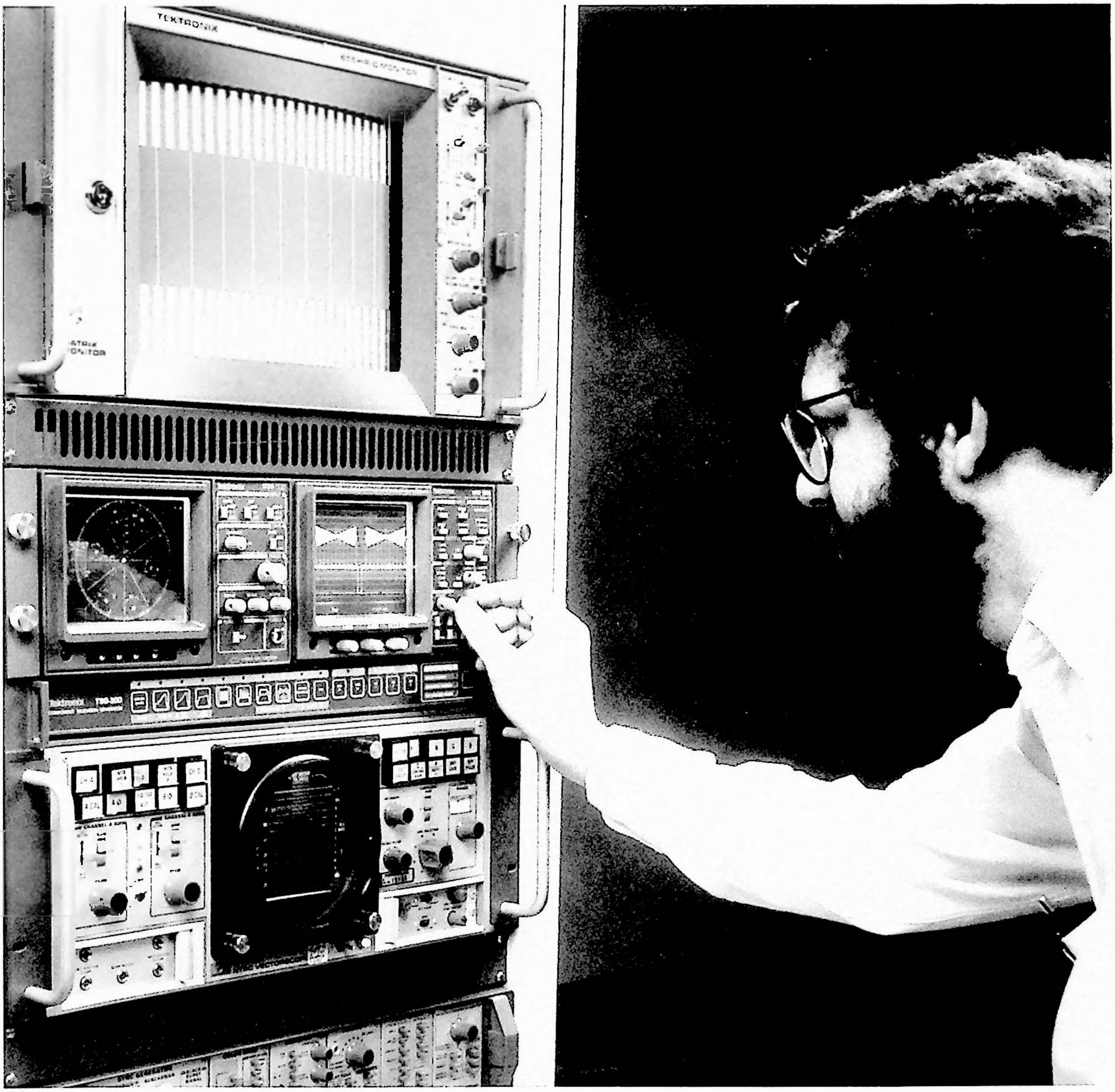
TEK TELEVISION
DIVISION

APPLICATION NOTE #45
20W-7058

TESTING COMPONENT VIDEO SYSTEMS



Tektronix
COMMITTED TO EXCELLENCE

This application note addresses one of the most critical maintenance concerns in component analog video (CAV) — namely, channel matching. Because each CAV signal is distributed on three separate, parallel paths, you need to ensure that these three channels are matched for both gain and timing.

Required Equipment

To test channel matching, you need a component signal generator such as the Tektronix TSG-370 (for the 525/60 formats), the TSG-371 (for the 625/50 formats), or the multiple-format TSG-300. You also need a component waveform monitor — for example, the Tektronix WFM-300A Component/Composite Waveform Monitor. The WFM-300A has menu selectable 525/60 or 625/50 configurations and can be ordered with either of two internal graticules (depending on the composite format you use). The graticule is marked in IRE units with supplemental millivolt markings (for NTSC formats) or in millivolts (for PAL formats).

Selecting a Test Signal

Before you can begin testing the system, you must decide what test signal to use. The choice may involve some tradeoffs. For example, a full-amplitude signal will give the highest resolution for gain testing, but unless the equipment under test has channels with well-matched linearity, a smaller signal (such as 75% amplitude color bars) will give greater accuracy.

In addition, you'll probably want to use the same test signal for the whole system. Therefore, since the system may include more than one format, you need to be sure the test signal is valid. A valid signal is one that can pass through a multiformat system without creating problems. (Refer to the inset at the end of this application note for a more detailed explanation of the terms "legal" and "valid" as they're used in the world of component analog video.)

Among the various component interconnect formats, there are three different standards for 75% amplitude color bars. You should pick the signal that corresponds to your system's interconnect format.

Matching Channel Gains — Why and How

Even small gain discrepancies (2% and less) cause visible hue changes in component systems, so you need an accurate way to check channel gains. The color bar test signal is generally preferred for gain testing because color bars are valid, and because they consist of fully saturated colors that exercise all three channels of a component system.

Three different displays are available for gain testing with color bars: parade, overlay, and Lightning. Both parade and overlay plot voltage versus time for each channel, whereas Lightning plots one signal versus another (similar to a vectorscope).

The parade display arranges the Y, P_B, and P_R signals sequentially from left to right, making it easy to compare individual signal levels with each other or with the graticule lines on the screen. (See Figure 1.) This display is therefore useful for both relative and absolute amplitude measurements.

The overlay display superimposes all three channels, making it easy to compare corresponding signal levels on different channels. (See Figure 2.) Overlay can also be used for timing evaluation by seeing how the component transitions line up. This display is therefore useful for measuring relative amplitudes and for evaluating timing relationships.

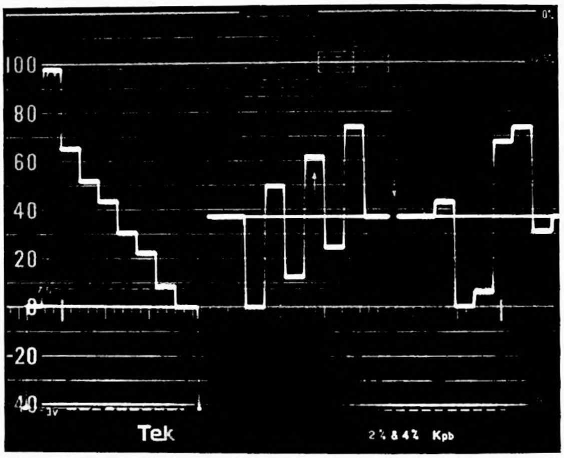


Figure 1. The parade display of SMPTE/EBU-format color bars has the Y signal on the left, P_B in the middle, and P_R on the right. The two chrominance waveforms have been vertically positioned so their minimum levels align with the "0" line.

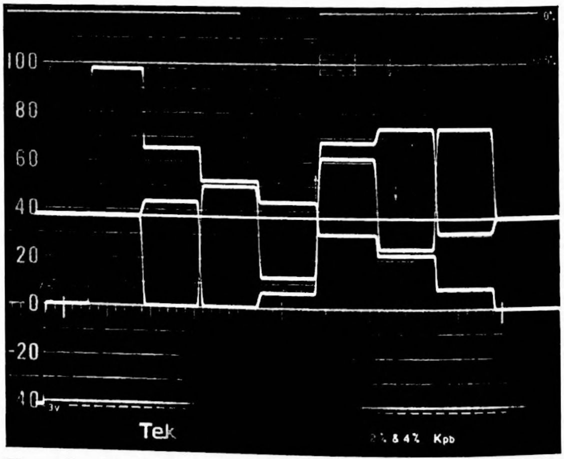


Figure 2. The overlay display superimposes the three waveforms shown in Figure 1, making it easier to compare corresponding levels on different waveforms.

The Lightning display uses an electronic graticule with boxes that correspond to color bar signal levels. Different menu-selectable graticules are provided for 75% and 100% amplitude color bars in the various formats. When the dots representing color bar voltage levels fall in the boxes as shown in Figure 3, channel gains are correct. (Be sure to select a graticule that matches your format.)

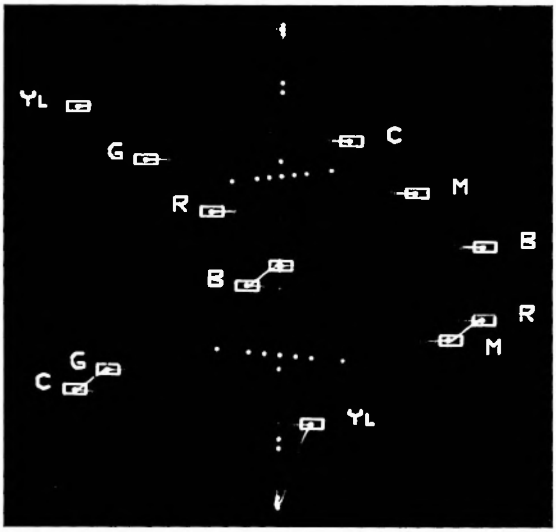


Figure 3. The unique Lightning display provides the quickest way to evaluate and adjust interchannel gain and timing of component systems using a single display and standard color bars.

Each Lightning graticule also includes markings for inter-channel timing evaluation. Lightning is therefore a powerful tool for quickly evaluating both gain and timing relationships in a component system. The Tektronix Application Note, "Monitoring and Adjusting CAV Systems Using the Lightning Display" (order #24W-7053) provides detailed information on the Lightning display — how it's formed and how to use it.

Remember there are three different signal standards in use for component analog video. Each of these standards requires a slightly different measurement method when using the parade and overlay displays. You should pick the signal that corresponds to your system's interconnect format, and then use the corresponding gain-matching technique (as described in the following sections of this application note).

SMPTE/EBU N10 Format

This format has no setup, and 75% amplitude color bars have the same voltage range in all three channels:

100% Reference Level = 700 mV
Luminance
  Minimum (Setup) = 0
  Maximum = 525 mV
  Range = 525 mV
Chrominance
  Minimum = −262.5 mV
  Maximum = 262.5 mV
  Range = 525 mV

Check gain matching by viewing the color bars in either the parade or the overlay display: First position the luminance waveform on screen so its blanking level aligns with the "0" graticule line and verify that the 100% luminance level at the left of the display aligns with the ".7 V" line. Then use the WFM-300A CH 2 & CH 3 POS knob to align the minimum chrominance levels with the "0" line and verify that their maximum levels align with each other. (See Figure 1 and Figure 2.)

The TSG-300 can, at the user's request, insert a level-reference signal on several lines of the luminance channel. This signal has steps at the 25%, 50%, 75%, and 100% levels and also includes pluge and clipping-detector peaks. (See Figure 4.) Adding this signal to the display makes it possible to verify chrominance gain relative to luminance.

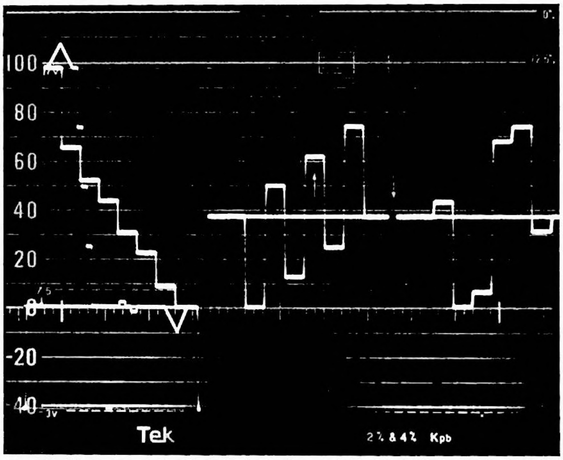


Figure 4. Including a few lines of level-reference signal on the luminance channel with the SMPTE/EBU N10 color bars makes it possible to verify chrominance gain relative to luminance.

MII Format

The 525/60 MII format has these standards:

100% Reference Level = 700 mV
Luminance
  Minimum (Setup) = 52.5 mV (7.5%)
  Maximum = 538.1 mV
  Range = 485.6 mV
Chrominance
  Minimum = −242.8 mV
  Maximum = 242.8 mV
  Range = 485.6 mV

To check channel gain using the parade or overlay display, align the *black* (not blanking) level of the luminance waveform with the "0" graticule line; then use the WFM-300A CH 2 & CH 3 POS knob to position the chrominance waveforms so their minimum levels are also at the "0" level. You can then make sure the maximum levels of all three channels line up.

If these conditions are satisfied *and* the 100% white reference flag (at the far right of the screen in the overlay display) falls on the 700 mV graticule line when the *blanking* level is at "0," you will have verified both relative and absolute channel gain. (See Figure 5.)

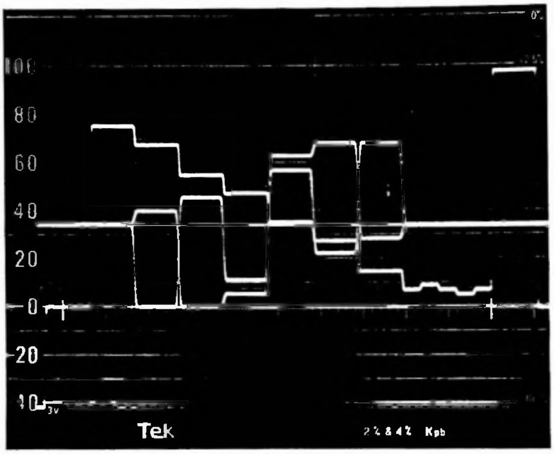


Figure 5. The 525/60 MII format color bars have a 100% white reference flag at the end of the luminance signal, making it possible to verify absolute as well as relative channel gains.

Betacam® Format

The 525/60 Betacam® format is rather like a component version of NTSC, having these standards:

100% Reference Level = 714.3 mV
Luminance
    Minimum (Setup) = 53.6 mV (7.5%)
    Maximum = 549.1 mV
    Range = 495.5 mV
Chrominance
    Minimum = −350 mV
    Maximum = 350 mV
    Range[1] = 700 mV

Because the luminance signal has a different range than the chrominance signals, you can't directly compare their gains. You can, however, verify the absolute gains of all three waveforms against the graticule in parade or overlay, and you can also compare P_B against P_R.

When the WFM-300A is configured for the 525/60 format, the "100" graticule line corresponds to 714 mV. You can therefore use this line to check the absolute gain in the luminance channel: Position the blanking level at the "0" line and compare the 100% white reference flag (at the far right of the screen in the overlay display) with the "100" line.

Next use the WFM-300A CH 2 & CH 3 POS knob to align the minimum levels of the chrominance waveforms with the "0" line and verify that their maximum levels fall on the 700 mV graticule line — the dashed line just below the "100" line. (See Figure 6.)

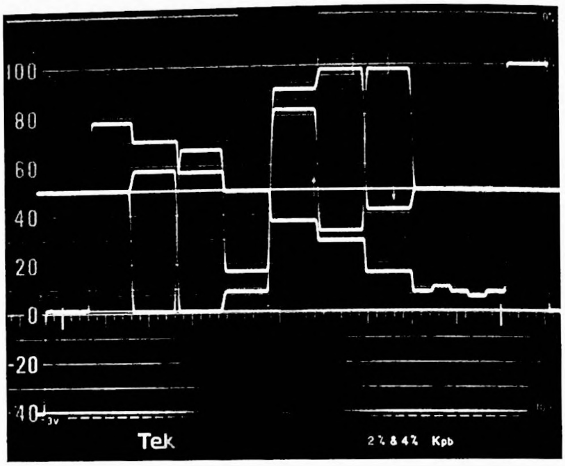


Figure 6. The Betacam® 525/60 format has a 714 mV reference white level and 700 mV peak-to-peak chrominance signals, requiring the use of two different graticule lines for verifying absolute channel gains.

Matching Channel Timing — Why and How

Timing differences between channels in a component system can cause vertical edges and fine details in the picture to be fuzzy, soft, or wrong-colored due to slight horizontal displacements. Although it's possible to make timing checks with color bars using the overlay and Lightning displays, you can make more precise timing measurements by using the Bowtie display.

The Bowtie display requires a special test signal that is formed by subtracting a 502 kHz sine-wave packet in one of the chrominance channels from a 500 kHz sine-wave packet in the luminance channel. Because the two sine-wave packets are precisely in phase at their centers and become increasingly out of phase on either side of center, the resulting waveform is shaped like a bow tie. (See Figure 7.)

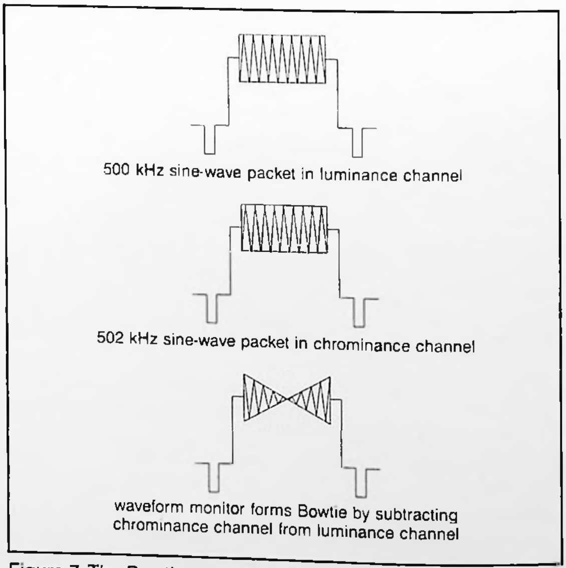


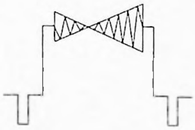
Figure 7. The Bowtie display is formed by subtracting a 502 kHz sine-wave packet in a chrominance channel from a 500 kHz sine-wave packet in the luminance channel.

---

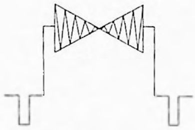
[1] Note that the 75% amplitude color bars have 100% amplitude chrominance signals.

Betacam® is a registered trademark of the Sony Corporation.

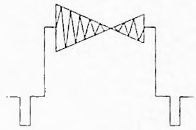
When the two sine waves that form Bowtie have perfectly matched timing, the narrowest point of the display is exactly in the center and the "bow tie" is symmetrical. But when the two sine waves have mismatched timing, the narrowest point shifts away from center and the "bow tie" is asymmetrical. (See Figure 8.)



chrominance timing advanced with respect to luminance



chrominance timing matched to luminance



chrominance timing delayed with respect to luminance

Figure 8. The position with respect to the center of the narrowest point in the Bowtie display indicates whether the chrominance signal timing is advanced, correct, or delayed relative to the luminance.

To better understand how to evaluate timing with Bowtie, let's look more closely at the way the TSG-370/371 and the WFM-300A work together to create the display: The generator provides the requisite sine-wave packets on all three channels. To ensure that the Bowtie Signal will not be distorted by VTR preemphasis circuitry, the sine-wave packet amplitudes are restricted to 350 mV peak-to-peak. (For this reason the test signal is called 50% Bowtie.) A 350 mV offset is added to the Y channel. Eleven markers that indicate timing errors in 20 ns increments and a 5 ns marker on either side of center are also provided. (See Figure 9.) The test signal and the markers are placed on different television lines, forming a time-multiplexed display.

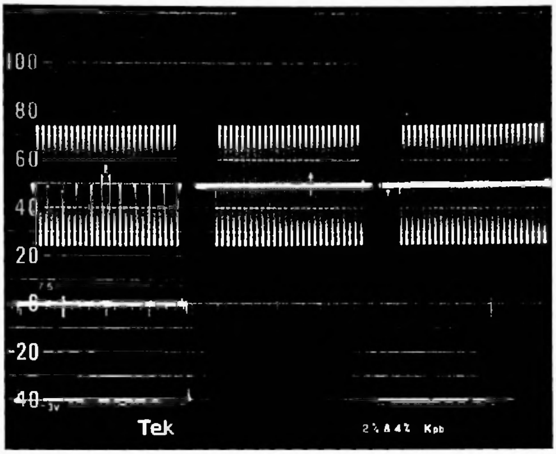


Figure 9. The WFM-300A in parade mode shows the three sine-wave packets generated by the TSG-370/371 that form the 50% Bowtie waveform. (Notice the timing markers on the reference waveform at the left.)

When you select Bowtie on the WFM-300A, the monitor produces a two-line display of CH 1 minus CH 2 followed by CH 1 minus CH 3. With properly connected inputs (Y into CH 1, B-Y into CH 2, and R-Y into CH 3), you get the Bowties shown in Figure 10. The waveform on the left shows P_B timing, and the waveform on the right shows P_R timing — both with respect to Y.

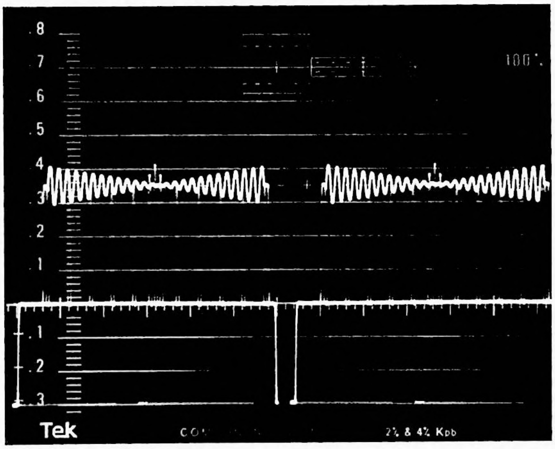


Figure 10. The WFM-300A and the TSG-370/371 produce a Bowtie display that allows you to simultaneously check the timing of both color difference channels with respect to the luminance channel. (Note the PAL graticule.)

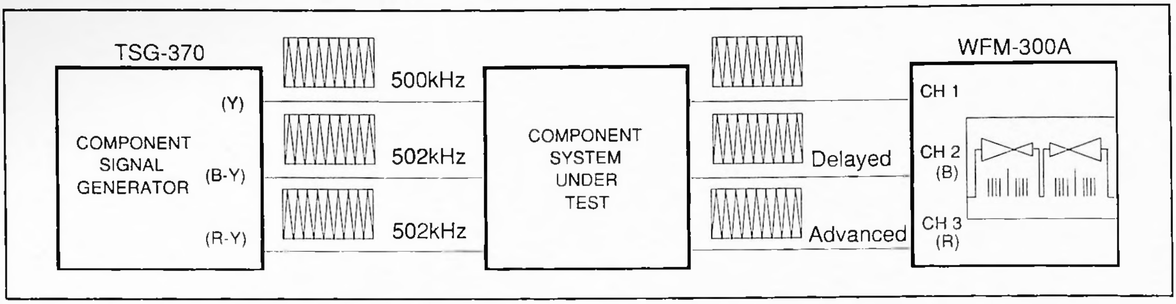


Figure 11. The Bowtie display shows both chrominance channels relative to the luminance channel, allowing quick evaluation of interchannel timing. For illustration, P_B is shown delayed *and* P_R advanced. In reality this condition would be unusual.

Therefore, by connecting the Bowtie signal from the generator to the inputs of your component system and observing the output on a WFM-300A, you'll be able to see at a glance when interchannel timing errors are present. Just look for a lopsided Bowtie! (See Figure 11.) You'll also be able to tell whether the chrominance channels are delayed or advanced with respect to luminance and by how much. (See Figure 12.)

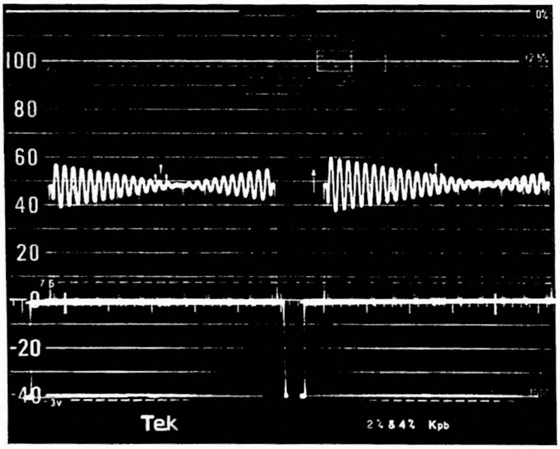


Figure 12. This Bowtie display shows that the P_B channel is delayed by a little less than 20 ns with respect to luminance, and the P_R channel is delayed by more than 40 ns.

Although Bowtie is best suited to making precise interchannel timing measurements, it can also be used to quickly detect channel gain imbalance. Ideally the Bowtie waveform should null out at its narrowest point (regardless of whether timing is correct or not). If Bowtie's narrowest point has nonzero amplitude, it means that channel gains are mismatched.

When it comes to making absolute gain adjustments, however, you'll find the Lightning display is more precise and easier to use than Bowtie. (Be sure to use the appropriate color bar test signal and Lightning graticule for your format.) And Lightning can also be used to evaluate and adjust interchannel timing. The Lightning graticule includes a series of dots crossing the green-magenta transition. When this transition passes through the center dot of the series, as in Figure 3, timing is correct. Timing errors can be seen more easily when the Lightning display is expanded. (See Figure 13.)

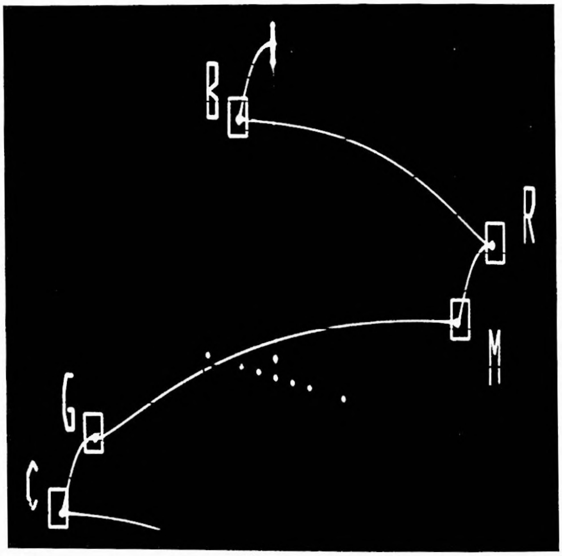


Figure 13. This expanded Lightning display shows an interchannel timing error because the green-magenta transition doesn't pass through the center dot in the series.

Summary

To get the best results from your component system, you need to pay close attention to channel matching — both gain and timing. Several methods are available and each has its advantages and disadvantages.

The parade and overlay displays, which use standard color bars, can be used for both gain and timing measurements. But parade is better for gain measurements and overlay for timing, so you have to switch back and forth between them.

The Lightning display, which also uses standard color bars, allows you to quickly evaluate both gain and timing in a single display. Lightning is especially good for making absolute gain adjustments in all three channels.

The Bowtie display, which requires a special test signal, is good for evaluating relative chrominance-to-luminance gain and is excellent for making precise timing adjustments. Bowtie also has the advantage of being easy to see from a distance.

With the TSG-370/371 or the TSG-300 and the WFM-300A you'll have all these tools to make quick work of monitoring and adjusting the interchannel gain and timing relationships in your CAV system.

Legal and Valid

The terms "legal" and "valid" take on new meanings when used to describe component analog video signals. These meanings are explained and illustrated in the next few paragraphs.

The interconnect standard for every component format specifies a voltage range called the "gamut" for each of the three video channels. The SMPTE/EBU format for example, specifies 0-700 mV for the Y channel and ±350 mV for the color difference channels, whereas the GBR format specifies 0-700 mV for all three channels. As long as a signal stays within the specified range in each channel for the system in operation, it is said to be "legal."

Problems can arise when the signal is transcoded to a different format. A signal that is legal in one format may not be legal in another. Any signal that is legal in every format is said to be "valid." A signal meets the validity test if, and only if, it is legal when transcoded to the GBR format.

Camera signals and component signals that have been either decoded from composite or transcoded from GBR are usually valid. But test signals and other signals that have been generated or modified — such as the outputs of color correctors, paint boxes, etc. — might not be valid. Furthermore, distortion can cause a signal to become invalid.

Consider, for example, transcoding standard SMPTE/EBU color bars from the YP_BP_R format to GBR. The YP_BP_R signals are as shown in Figure 14 (where a 350 mV display offset has been added to the color difference signals to bring them into the 0-700 mV range for comparison). When these signals are transcoded back to GBR, the signals shown in Figure 15 result.

Now suppose your system's luminance channel has an overall gain of 0.9, while the color difference channels have a gain of 1.0 throughout. Color bars passed through this system in YP_BP_R format would have reduced amplitude in the Y channel. (See Figure 16.)

These distorted YP_BP_R signals are legal because they fall within the specified range for each channel; but when they're transcoded to GBR, the resulting signals are illegal. (See Figure 17.) Therefore the signals in Figure 16 are *not* valid. Note that the negative portions of all three GBR signals in Figure 17 could be clipped, resulting in irrecoverable loss of information.

The example used here represents only one of several possible ways for a signal to become invalid. Other kinds of gain or timing distortion can lead to over-amplitude GBR signals. And both effects may be present in the same signal: the GBR components derived from an invalid signal could have some values below zero and others above 700 mV. In other words, clipping and other problems can be introduced on either highlights or lowlights, or on both.

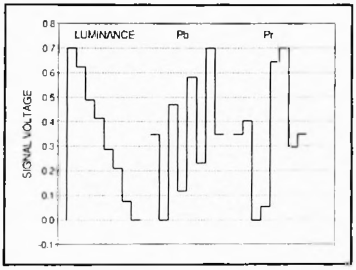


Figure 14. The standard SMPTE/EBU color bars in YP_BP_R format are both legal and valid. (A 350 mV display offset has been added to the color difference signals.)

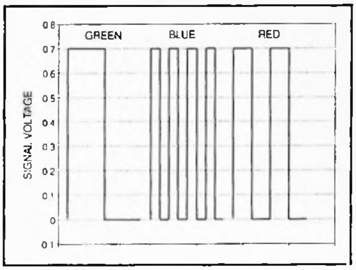


Figure 15. Transcoding the YP_BP_R format color bar signals in Figure 13 produces these legal GBR signals, which verifies that the YP_BP_R signals are valid as well as legal.

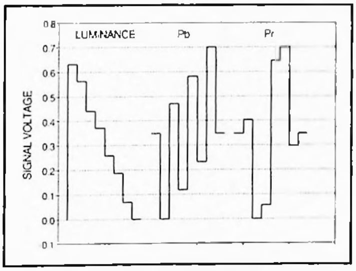


Figure 16. These SMPTE/EBU color bars have been passed through a system that has a gain of 0.9 in the luminance channel. The signals are legal, but not valid.

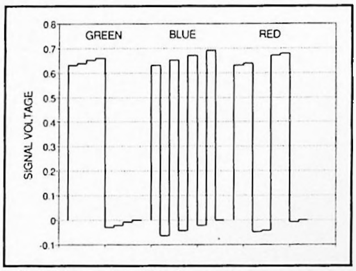


Figure 17. The GBR signals transcoded from the YP_BP_R format color bars in Figure 16 are not legal. They exceed the specified values or range in all three channels.

For further information, contact:

U.S.A., Asia, Australia, Central & South America, Japan
Tektronix, Inc.
Television Division, MS 58-699
P.O. Box 500
Beaverton, Oregon 97077
Phone: (503) 627-1555
TLX: 151754
FAX: (503) 627-4486

Canada
Tektronix Canada, Inc.
50 Alliance Blvd.
P.O. Box 6500
Barrie, Ontario L4M 4V3
Phone: (705) 737-2700
Telex: 06875672 TEKTRONIX BAR
FAX: (705) 737-5588

Federal Republic of Germany
Tektronix GmbH
P.O. Box 101544
D-5000 Cologne 1
Germany
Phone: 49 (221) 77220
Telex: (841) 8885417 ATEK D
FAX: 49 (221) 7722-362

France and Africa
Tektronix S.A.
Z.I. Courtaboeuf, Av. du Canada
BP. 13
91941 Les Ulis Cedex
France
Phone: 33 (169) 86 81 81
Telex: (842) 690332 TEKOR A
FAX: 33 (169) 07 09 37

Belgium, Denmark, Finland, Holland, Norway, Sweden and Switzerland
Tektronix Holland N.V.
P.O. Box 226
2130 AK Hoofddorp
Holland
Phone: 31 (02503) 13300
Telex: (844) 74898 TEKSO NL
FAX: 31 (02503) 37271

South Europe Area, Eastern Europe and Middle East
Tektronix Ges.m.b.H.
Doerenkampgasse 7
A-1100 Vienna
Austria
Phone: 43 (222) 68 66 02 0
Telex: (847) 111481 TEK A
FAX: 43 (222) 68 66 00

United Kingdom
Tektronix U.K. Limited
Fourth Avenue
Globe Park
Marlow
Bucks SL7 1YD
Phone: 44 (6284) 6000
Telex: (851) 847277, 847378
FAX: 44 (6284) 74799

Tektronix sales and service offices around the world:
Algeria, Argentina, Australia, Austria, Bahrain, Bangladesh, Belgium, Bolivia, Brazil, Bulgaria, Canada, Chile, Peoples Republic of China, Colombia, Costa Rica, Cyprus, Czechoslovakia, Denmark, Ecuador, Egypt, Finland, France, Federal Republic of Germany, Ghana, Greece, Hong Kong, Iceland, India, Indonesia, Ireland, Israel, Italy, Ivory Coast, Japan, Jordan, South Korea, Kuwait, Lebanon, Malaysia, Mauritius, Mexico, The Netherlands, New Zealand, Nigeria, Norway, Oman, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Qatar, Saudi Arabia, Senegal, Singapore, Republic of South Africa, Spain, Sri Lanka, Sweden, Switzerland, Syria, Taiwan, Thailand, Tunisia, Turkey, United Arab Emirates, United Kingdom, Uruguay, U.S.S.R., Venezuela, Yugoslavia, Zimbabwe.

Tektronix®
COMMITTED TO EXCELLENCE

8/90 5M FLG 20W-7058