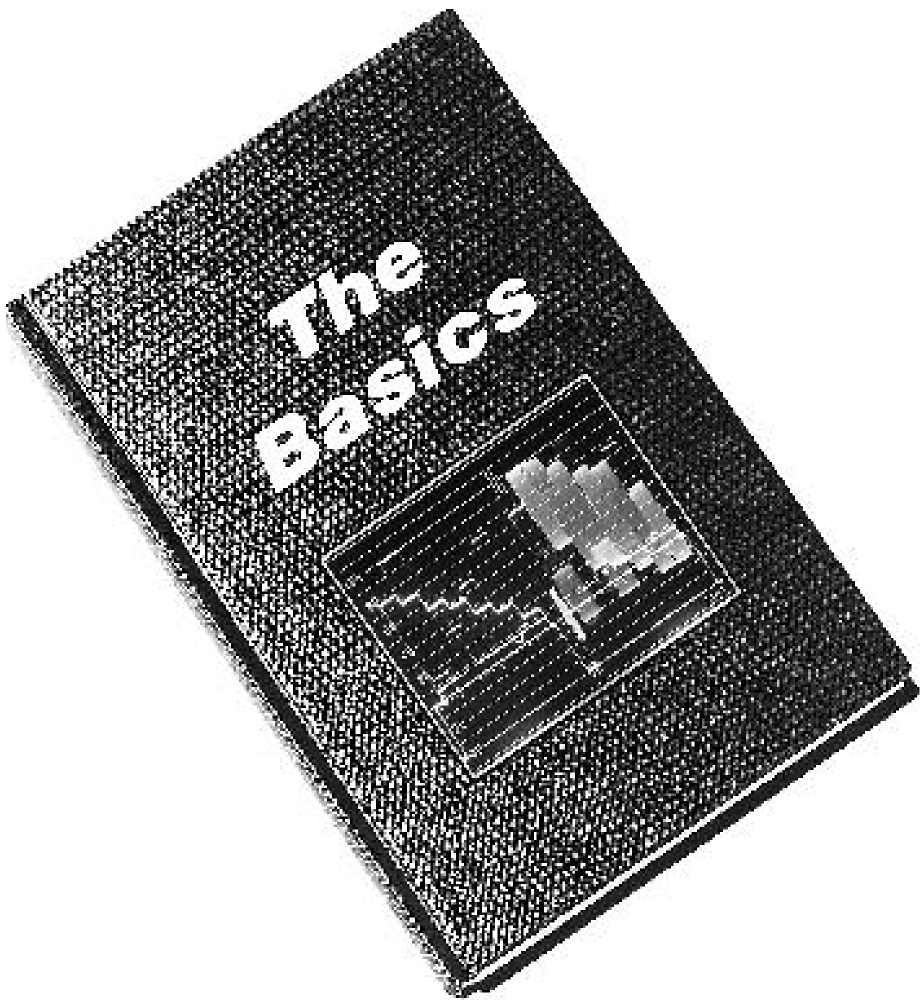
NTSC Video Measurements



About this Booklet

Over the years, Tektronix has made available many articles, application notes, booklets, video tapes, and other materials to help you, our customers, better understand the interaction of your daily activities and Tek's products. This booklet is a compilation of several shorter pieces which are (or were) offered by Tektronix' Television Division.

In this booklet we've arranged a sequence of topics which leads from relatively basic concepts toward the more advanced. The ideas involved, however, do interrelate and support each other — you may find it helpful to take the time to look through the whole booklet even if your initial interest is for a particular topic.

Page numbers and figure numbers used here indicate both the section of the booklet and the sequence within the section. For example, page 2-3 is the third page of the second section; Fig. 1-5 is the fifth figure in the first section.

As always, Tektronix is very interested in your feedback and comment and may be contacted at any of the offices listed in the back of this booklet.

Credits:

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- Government and Military Video, P.S.N. Publications, Inc., New York, NY, 1992
- Video Systems, Intertec Publishing Corp., Overland Park, KS, 1992

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General Concepts

Why Test Video Signals?

Working in video, the quality of your final product depends on many factors. Scripting, casting, directing, and many other ingredients add together to make (or break) a production. But even when all the creative efforts are perfectly balanced, poor technical quality — and the resulting poor picture quality — can obscure all the hard work and skill invested.

This holds true in any facility from the largest production house or network studio, to corporate studios, and to the smallest freelance production shop. The difference is, the larger facilities have a technical staff devoted to keeping equipment performance and picture quality in peak form. Smaller commercial, business, and industrial facilities have smaller staffs. Sometimes a staff of one!

Whether you're a video veteran or the newest intern, it behooves you to know something more about video quality than what you see on a picture monitor. The goal of this booklet is to help you acquire additional technical knowledge, and be more comfortable and capable with video testing.

You must, however, exercise caution and common sense. Be sure to heed all warnings printed on equipment covers. And never remove any equipment casings or panels unless you are qualified for internal servicing of that equipment. The information in this booklet is intended only for use in external monitoring and adjustment of user accessible controls on video equipment.

A television picture is conveyed by an electrical signal (Figure 1-1). This video signal is carried from one place to another by cables (coax) or by radio-frequency (RF) waves. Along the way, it must pass through various pieces of equipment such as video tape machines, switchers, character generators, special effects generators, and transmitters. Any of this equipment can change or distort the signal in undesirable ways.

Since picture quality is largely determined by signal quality, it's important to detect and correct any signal distortions. The signal has to be right before the picture can be right.

Many video facilities rely heavily on picture monitors for quality checks at various stages of production and distribution. A picture monitor, after all, displays the final product, the picture. It's a quick and easy means of ensuring that there are no obvious picture impairments.

But picture monitors do not tell the whole story. In fact, relying solely on picture monitors for video quality checks can be an open invitation to disaster.

First of all, not every picture impairment is obvious on a picture monitor. Minor problems are easily overlooked. Some cannot be seen at all. For example, a marginal video signal can still produce a seemingly "good" picture on a forgiving monitor. This can produce a false sense of security as signal degradations accumulate through various production stages. The end result can be a nasty surprise that can lead to costly remakes and missed deadlines.

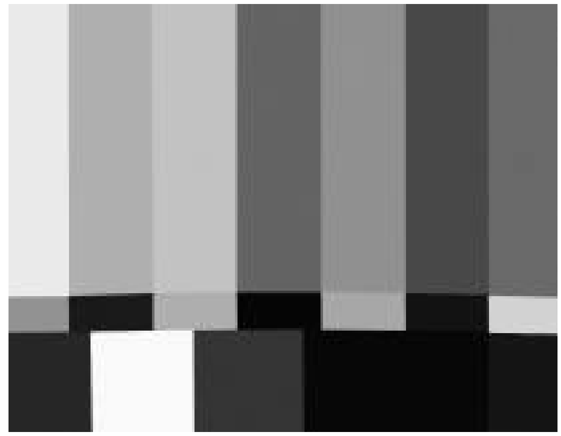


Figure 1-1. A television picture is created by an electrical video signal. In this case, the picture of color bars is created by a color bars test signal.

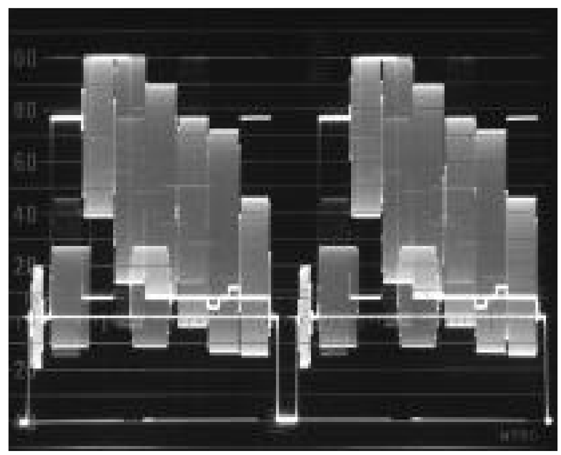


Figure 1-2. Waveform display of a color bars signal.

To avoid such surprises, you need to look at more than pictures. You need to look at the video signals that convey the picture information through the various devices and interconnecting cables of a video system. Specialized instruments have been developed to process and display these signals for analysis.

A waveform monitor is an instrument used to measure luminance or picture brightness as well as a high frequency color signal called chrominance. An instrument called a **vectorscope** is required for quality control of video chrominance, especially in more complex systems.

When properly used, these tools allow you to spot signal problems before they become picture problems. You can make certain that the signals are optimal, rather than marginal. Plus, with regular video system testing, you can catch minor degradations and performance trends that indicate a need for system maintenance. This allows you to avoid costly failures, both in equipment and in program production or distribution.

Test Methodology

There are two somewhat differing ideas used in testing video. Our approach is to test characteristics of a specific signal to ensure that it meets certain artistic or technical requirements. Or, we may test the characteristics of individual pieces of equipment or several pieces in the video signal path to determine that signal distortions introduced by this equipment are acceptable — or, at least, minimized.

An example of the first case might be monitoring the output of a video source (camera, character generator, etc.) to ensure it is not producing signals that exceed black or peak white signal limits. As an example of the second case, we may wish to ensure the overall gain of a record/playback system is correct, i.e., a recording made with a standard amplitude video signal at the machine's input will produce standard amplitude video at its output during playback.

In the first case (specific signal) we'll need test equipment that enables observation of the signal and knowledge of what the appropriate limits or characteristics are. The second case (equipment or system testing) is more general and is assumed in the following discussion.

The usual method of evaluating video equipment is with a well-defined, highly stable test signal having known characteristics, such as a color bars signal.

Video testing is based on this simple principle of applying a known test signal to the video system or equipment input and observing the signal at the output. Any distortion or impairment caused by the system is observed and measured on the output signal. If there are distortions, the equipment is adjusted to eliminate or minimize them. The point is, if the system can pass the test signal from input to output with little or no distortion, it can cleanly pass picture signals as well.

The signals necessary for such testing are obtained from a test signal generator. This instrument produces a set of precise video signals with carefully defined and controlled characteristics. Each signal is ideal for verifying one or more specific attributes of the video system under test. For all practical purposes, these test signals are "perfect" signals.

Other instruments such as waveform monitors, vectorscopes, combinations of waveform and vector monitors, or specialized video measurement sets are used to evaluate the test signal at the output of the path under test. As an example, Figure 1-2 shows a waveform monitor display of a color bars signal. This display is also called a waveform — it is actually a graph of the changing voltage of the signal (plotted vertically) and time (plotted horizontally). Calibrated scales on the waveform monitor's screen allow the various amplitude (voltage) and time parameters of the waveform to be measured. Other test signals and their related instrumentation and displays are discussed in the following sections.

Test signal generators and signal evaluation instruments are available in a wide variety of models. These can range from simple production-oriented instruments to highly sophisticated engineering instruments. Waveform monitors, vectorscopes, video test sets, and other specialized equipment to display and/or evaluate the signal are also available in a wide variety of configurations. The following sections will acquaint you with some of these tools and with methods of using them to enhance your effectiveness in maintaining video quality.

Connecting and Terminating Instruments

The Tektronix instruments discussed in this booklet, and most others, have rear panel BNC connectors. For many video tests, you only need to use one connector on each instrument. This is the connector marked TEST SIGNAL on the signal generator and the connector marked CH A INPUT on the waveform monitor or vectorscope.

Notice there are actually two "loop-through" CH A connectors on both the waveform monitor and vectorscope (Figure 1-1). If you feed the signal in one side of these inputs and out the other, the signal will pass through the instrument unaffected. This type of loop-through input lets you connect the same signal to more than one instrument.

For example, after running the test signal from the signal generator through the system under test and from there to a waveform monitor, you can then loop the signal through the waveform monitor into a vectorscope. Using the same method, you can also loop through the vectorscope to a picture monitor. This connection method allows you to look at the same test signal on all three instrument displays (Figure 1-3). The order in which the instruments are connected doesn't matter — if the connecting cables are short.

Coaxial cable does have signal loss — the signal's amplitude decreases as it progresses down the cable. For runs of a few feet, this decrease in amplitude is typically 1% or less and is usually ignored. For longer cable lengths, or when precision measurements are being made, the loss must be taken into account or corrected with a compensating distribution amplifier. Not only is coax lossy, the loss is a function of signal frequency — higher video frequencies are attenuated more than the low frequencies.

Also, not all cables are well shielded and signals may crosstalk from outside the cable into the video path inside. In other words, the interconnecting cables themselves may be introducing signal distortions.

While small, flexible cables are convenient to handle, they are not without technical cost. Consideration should be given to using larger, double-shielded cables in long or critical runs. The techniques in this booklet can be used to evaluate the distortions introduced by various lengths and/or quality of cable.

While on the subject of cables and interconnections, always remember to properly terminate each signal path. If a signal path is left "open" at the end — such as a high impedance loop-through with nothing connected on one side — several problems can result.

Most obvious will be a change in amplitude of the signal on that path. With an open termination the amplitude will be higher than expected (usually about twice amplitude, but actually depending on the signal source impedance). With a double termination, such as will result if an internally terminated loop-through and an external terminator are used on the same path, the amplitude will be decreased. A double termination will often result in a two-thirds amplitude signal, again depending on source impedances.

Amplitude is not the only effect of misterminations. Don't be tempted to make up for improper termination by adjusting the signal amplitude. Misterminations also introduce problems with frequency response (amplitude becomes a function of signal frequency) and with differing response depending on location along the signal path. Use the correct terminating resistor on the end of each coaxial path.

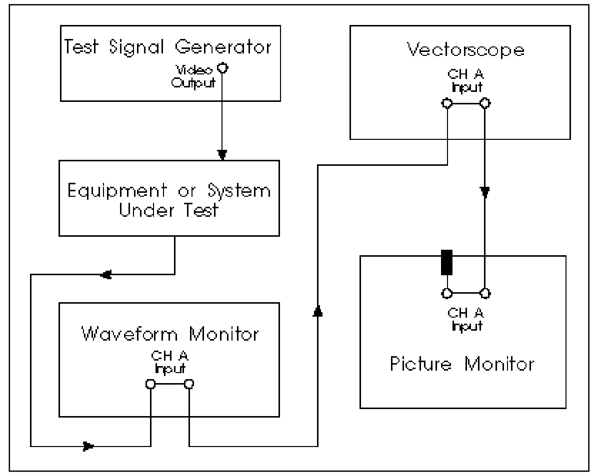


Figure 1-3. Loop-through inputs on instruments allow the same video source to be viewed simultaneously in waveform, vector and picture forms.

There are three ways a signal path can be properly terminated:

- Some instruments have a single-connector input with a built-in terminator. You can connect such an instrument "as is" at the end of a signal path, but you can't loop the signal through it.
- Some instruments have a two-connector input with a built-in terminator and a switch for selecting loop-through or terminating connection. You can connect such an instrument anywhere in the signal path, but you must set the switch correctly for the intended use (either Hi-Z for loop-through or 75 ohm for end-of-line termination).
- Some instruments, such as the 1720 and 1730, have two-connector inputs with no built-in terminators. You can connect such an instrument anywhere in the signal path. But, if you connect it at the end of the signal path, you must attach a 75 ohm terminator to the unused connector.

Basic Video Testing — Waveform Monitor Techniques

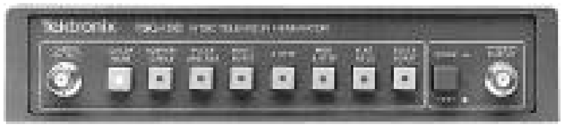


Figure 2-1. The Tektronix TSG 100 NTSC Television Generator produces a variety of special signals for testing video equipment and systems. (NTSC stands for National Television Systems Committee, the committee that developed the television system we use in the United States.)

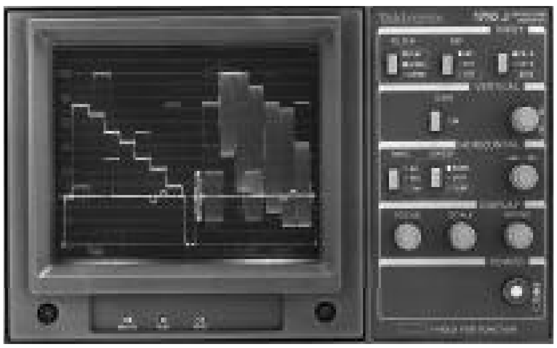


Figure 2-2. The Tektronix 1710J NTSC Waveform Monitor displays video signals for amplitude and timing measurements.

Figure 2-3. The Tektronix 1720 Vectorscope complements a waveform monitor by providing additional information about the video signal's color (chrominance) content.

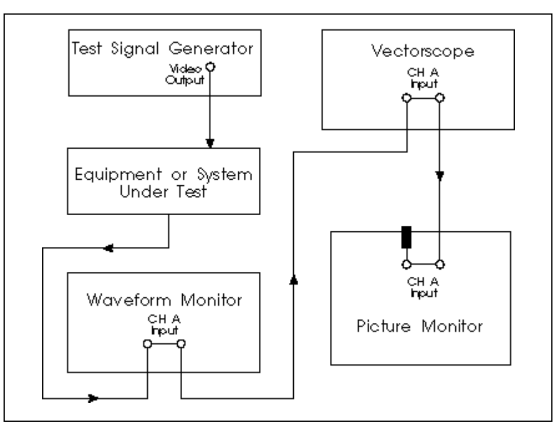


Figure 2-4. Loop-through inputs on instruments allow the same video signal to be viewed simultaneously in waveform, vector and picture forms.

The focus of this section is on tests in production facilities using a waveform monitor. It will be helpful if you have already read the first section of this booklet, *General Concepts*. The following assumes you are already familiar with that material.

To provide examples of tests in a production environment, the Tektronix TSG 100 NTSC Television Generator (Figure 2-1) and Tektronix 1710J NTSC Waveform Monitor (Figure 2-2) are used since they are models often found in the production environment. However, all waveform monitors and test signal generators, no matter how sophisticated, include the same basic functions described here. A vectorscope (Figure 2-3) is another useful instrument for video signal evaluation; its use is covered in the next section of this booklet.

Vectorscopes and waveform monitors complement one another and provide a full representation of all information about the video signal. Because of this, both instruments are often mounted side-by-side in instrument racks. In some cases, both functions may even appear in the same instrument. The rest of this section shows you how to use test signal generators and waveform monitors for basic video testing. For further details on these instruments and their additional uses, you may want to refer to: *Basic Waveform Monitoring Videotape* (24W-7029). This tape is available through your local Tektronix Sales Office or by calling 1-800-TEK-WIDE, extension TV.

Connecting the Instruments

Once you've identified the instruments to be used, the next step is to connect them to the video system to be tested. Often this has already been done for you, especially when the instruments are mounted in equipment racks. Still, it pays to know how the connections should be made so you can make sure they have been done correctly.

The Tektronix instruments discussed here have rear-panel BNC connectors. These connectors are used for connecting cables to the system under test. For basic video testing, you only need to use one connector on each instrument. Refer to *Connecting and Terminating Instruments* on page 1-3 for further information.

Ensure everything is connected as shown in Figure 2-4 (you may not be using a vectorscope or picture monitor — just be sure to terminate the end of the signal path). With all equipment turned on, a test signal also needs to be selected. For the examples in this section, a color bars signal is the only test signal that you'll need.

The TSG 100 has a series of signal selection push buttons on its front panel (Figure 2-1). Each push button is labeled to indicate the type of signal selected by that button. Select the color bars signal.

If you are using a picture monitor, you should see the familiar color bars display on that monitor. You should also see a color bars signal on the waveform monitor display. This waveform is shown in Figure 2-5. This color bars signal is called SMPTE color bars because it conforms to the signal specifications set by the Society of Motion Picture and Television Engineers (SMPTE).

Understanding the Waveform Display

Notice in Figure 2-6 that there are various lines and numbers on the front of the waveform monitor's CRT. These markings are referred to as the graticule and allow measurement of waveform amplitude and time parameters.

The nominal video signal level for television studios and production facilities is one volt (1 V) peak-to-peak. (The term peak-to-peak means from the bottom of the signal to the top. It is often abbreviated as p-p.) Without such an amplitude standard, signals from different sources might not be compatible with each other. Keep in mind that this is for a nominal signal, one that contains the brightest possible (peak white) picture information. Many test signals fit this description. Actual picture information often does not contain any peak white levels and will therefore not measure 1 V peak-to-peak.

For making peak-to-peak and other amplitude measurements, the vertical axis of the waveform monitor graticule is marked in IRE units. An IRE unit (named for the Institute of Radio Engineers) is a relative unit of measure equaling 1/140th of the peak-to-peak (p-p) video amplitude. Since a video signal should be 1 V p-p, an IRE unit is about 0.00714 V, or 7.14 mV, in this case.

Notice also that there is a horizontal scale on the waveform monitor graticule at 0 IRE. The scale is divided by tick marks into major and minor divisions. These divisions are used for measuring time intervals on the video signal. The value of each division — the time per division — is determined by the waveform monitor's horizontal control settings.

To interpret the display in Figure 2-5, you should be aware that an NTSC television picture consists of 525 horizontal lines. These lines are formed by scanning from left to right in a raster pattern. This pattern is illustrated in Figure 2-7.

Every line of a video signal contains a negative-going synchronizing pulse. This 'sync' pulse starts the next line of video and is contained in the signal's horizontal blanking interval. This blanking interval is a short period of time between the scan lines.

The 1710J displays what appears to be two lines of video side by side in what is generally called a 2H mode (two horizontal lines). This is actually a display of all 525 lines laid on top of each other, with half of the lines on the left and half of the lines on the right. It also puts a complete horizontal blanking interval near the center of the screen. This is shown in Figure 2-5. Some waveform monitors use a 1H mode which shows one line of video rather than two lines side by side. This would be like looking at just the left half of the display in Figure 2-5 expanded horizontally to fill the screen.

A Closer Look at the Color Bars Waveform

The drawing in Figure 2-6 shows one complete line of a SMPTE color bars waveform. This waveform consists primarily of a brightness signal (called luminance) and a high-frequency color signal (called chrominance). The luminance and chrominance are added together to form the overall waveform.

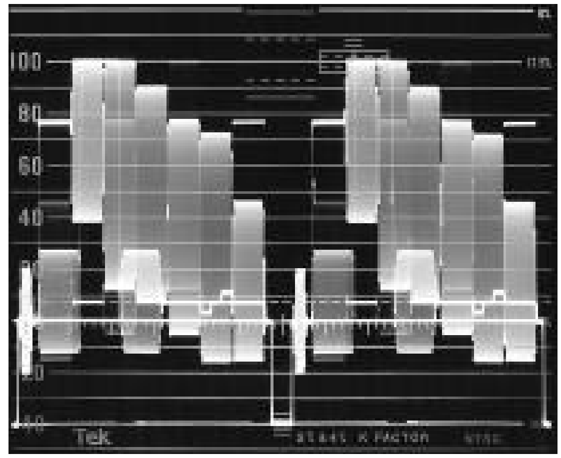


Figure 2-5. Waveform monitor display of SMPTE color bars waveform shows video signal voltage variations with time.

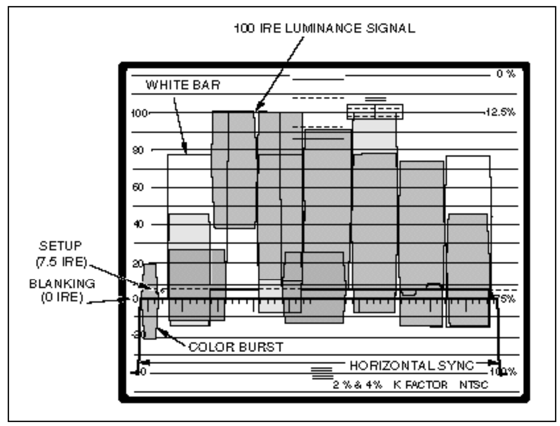


Figure 2-6. One line of a SMPTE color bars signal drawn to show key details.

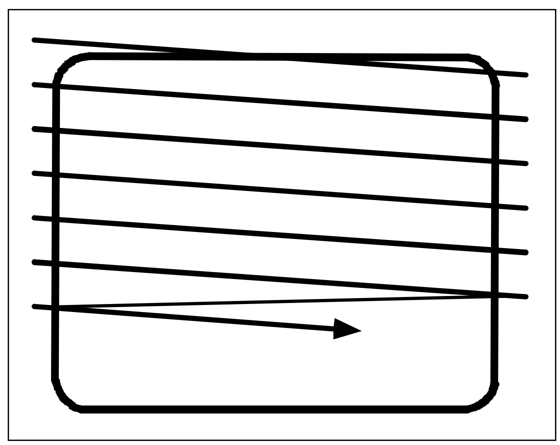


Figure 2-7. A raster pattern is followed in forming a 525-line television picture. The picture lines are scanned from left to right in a sequence from top to bottom.

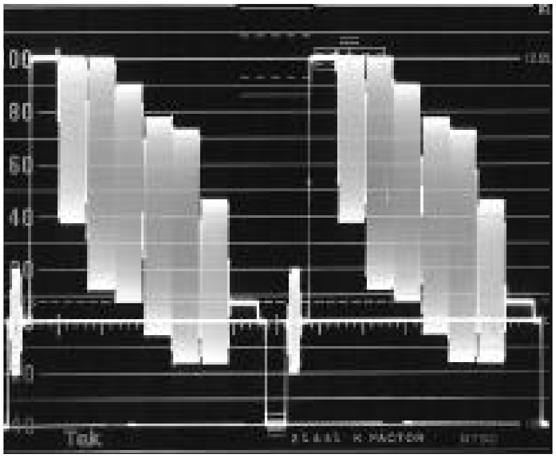


Figure 2-8. This 75% color bars signal includes a 100% white reference level. An eighth black bar is also included.

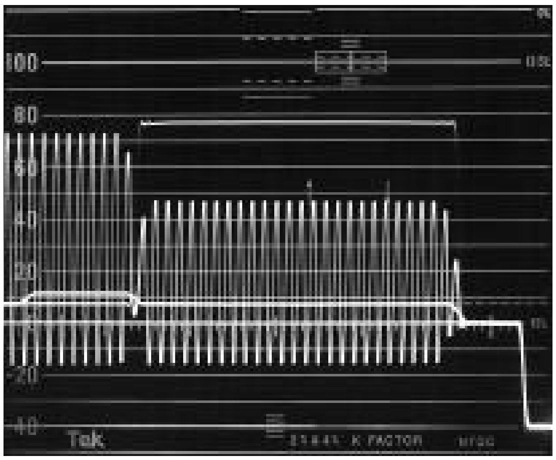


Figure 2-9. When a chrominance signal is expanded horizontally, individual cycles of the sine wave can be seen.

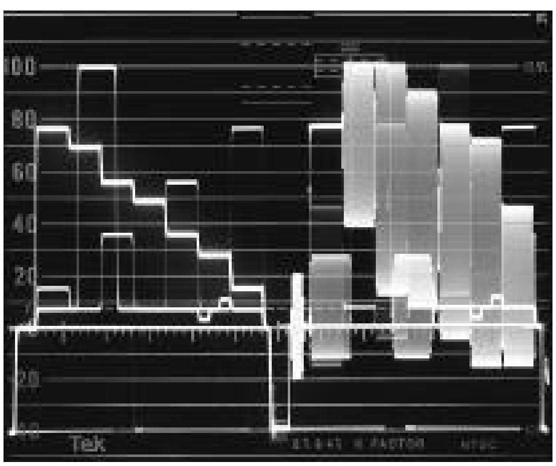


Figure 2-10. The 1710J dual-filter display is convenient for making luminance and chrominance measurements from the same display. The luminance display (L-PASS) is shown on the left, and luminance plus chrominance (FLAT) is on the right.

The luminance signal is a series of voltages or "levels" that determine brightness variations across the picture. Each of the colors in the color bars signal has a different luminance level, and the bars are arranged by level from highest to lowest (white, yellow, cyan, green, magenta, red, blue, and black).

The chrominance signal is a sine wave. Because of this signal's high frequency, the sine wave cycles appear to run together in most displays. Individual cycles can be seen, however, when the display is expanded horizontally as in Figure 2-9.

Notice in Figure 2-6 that the peak-to-peak amplitude of the chrominance signal varies from one color bar to the next. The first bar, being white, has no chrominance. All of the other bars have the correct amount of chrominance amplitude to produce a full intensity (100% saturated) color. The last bar (Black) also has no chrominance.

Color bar test signals fall into two general categories: 100% bars (full amplitude) and 75% bars (reduced amplitude). You should always use 75% bars for basic testing. This is because 100% bars contain signal levels that may be too high to pass through a system without distortion.

At some point, however, you will need a 100% white reference level for checking overall signal amplitude. Many 75% color bar test signals do provide a 100% white level for this purpose (Figure 2-8).

The SMPTE color bars signal shown in Figures 2-5 and 2-6 are 75% bars with a 75% white level. This signal also incorporates a 100% white level on some lines. This 100% white level is easiest to see on a waveform monitor used in either the low-pass or dual-filter mode (Figure 2-10).

All of the color bars test signals illustrated so far were fed directly from the test signal generator into an accurately calibrated waveform monitor. This means they are undistorted, their amplitudes and timing are correct, and they represent the ideal condition.

But suppose the signal had been passed through other equipment first, an amplifier or recorder for example. Since you know what the test signal is supposed to look like, you'll be able to quickly tell if the signal has been distorted or changed by the equipment — and by how much. That's why it's so important to use test signals with known characteristics when evaluating video systems.

Understanding the 1710J Controls

Before attempting to make any measurements, you need to know how to use the 1710J Waveform Monitor controls. It's also important to realize that when you adjust these controls, you're only changing the way the waveform looks on the monitor's display. **The waveform monitor controls do not in any way affect the video signal itself**. The same is true of picture monitors and vectorscopes. If testing reveals something wrong with the video signal, you must use the controls on the equipment under test to correct the problem.

Referring back to Figure 2-2, notice that the 1710J front-panel controls are grouped into functional blocks. The following discussion describes those controls block by block. Although this discussion is specific to the 1710J, much of it also applies in general to all waveform monitors.

INPUT block. The INPUT controls select the input signal to be displayed, which parts of it are displayed, and how it's synchronized. These controls include the FILTER, REFerence, and INPUT buttons.

FILTER Button —

FLAT displays the entire signal, such as shown in Figure 2-5.

L PASS removes the high-frequency chrominance signal from the display, leaving just the luminance signal for observation.

CHRM displays only the chrominance information.

Because you need luminance plus chrominance for some amplitude measurements, but only luminance for others, both the FLAT and L PASS displays are useful. Another option is to use the 1710J dual-filter display. This shows both waveforms at once with L PASS on one side and FLAT on the other (Figure 2-10).

To obtain a dual-filter display, simply press and hold the 1710J's FILTER button. This display allows you to check luminance and chrominance levels without switching back and forth between FLAT and L PASS.

REF Button —

INT synchronizes the waveform monitor to the displayed waveform. For the tests described in this application note, always use INT (*internal*).

EXT synchronizes the waveform monitor to an external source.

CAL displays a built-in calibration signal for adjusting the waveform monitor's gain. This will be discussed later in more detail.

INPUT Button —

A displays any signal connected to the CH A input BNC connectors on the back panel.

B displays any signal connected to the CH B input BNC connectors on the back panel.

BOTH is a press and held button for a display of both A and B inputs simultaneously.

You need to select A or B, depending on which set of connectors is being used for connection to the equipment under test (Figure 2-4).

VERTICAL block. The VERTICAL controls adjust the size and position of the displayed waveform. (Remember, changing the display doesn't change the video signal being looped through the monitor.)

GAIN Button —

GAIN magnifies the vertical size of the waveform display x5.

POSITION Knob —

POSITION moves the displayed waveform up and down on the screen.

HORIZONTAL block. The HORIZONTAL controls adjust the waveform's horizontal size and position on the display.

SWEEP Button —

SWEEP selects whether the monitor displays two lines (2H) or two fields (2FLD) of video. Press and hold for a one line display.

MAG Button —

MAG expands the display horizontally. When used with a 2H sweep, MAG provides a calibrated sweep speed of one microsecond per major division on the horizontal graticule scale. This setting is used for most timing measurements.

POSITION Knob —

POSITION moves the displayed waveform left and right on the screen.

DISPLAY block. The DISPLAY controls adjust the display for comfortable viewing.

FOCUS changes the focus of the trace.

SCALE varies the graticule illumination.

INTENS controls waveform trace brightness (intensity).

Making Measurements

Now that you understand the basic concepts of testing, test signals, and the instruments used for measurements, you are ready to make measurements.

First, feed the color bars test signal into the system you want to test. This signal can come straight from the test signal generator or it can be a color bars signal previously recorded on video tape.

Second, connect the system output to the waveform monitor CH A input. Remember to properly terminate loop-throughs. Then, set the waveform monitor controls as follows:

POWER	ON
INPUT	
FILTER	FLAT
REF	INT
INPUT	A
VERTICAL	
GAIN	x1
POSITION	Blanking level aligned with the horizontal axis as shown in Figure 2-5
HORIZONTAL	
SWEEP	2H
MAG	1µs
POSITION	Sync pulse approximately centered as shown in Figure 2-5
DISPLAY	Adjust all controls for comfortable viewing

With all controls set as described above, you should see the same display as shown in Figure 2-5 or Figure 2-8.

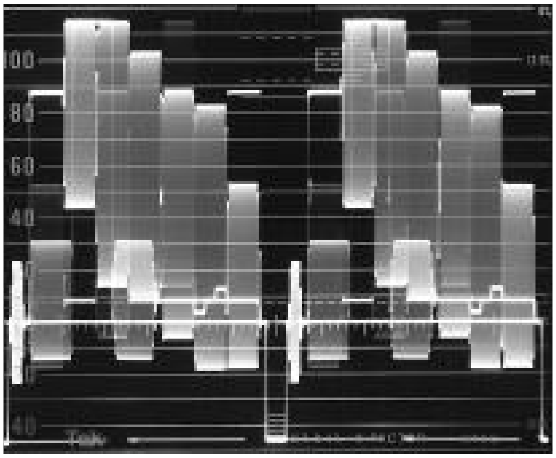


Figure 2-11. An example of a "hot" signal — notice how parts of the signal exceed 100 IRE.

Verifying monitor calibration

Before making any measurements, it is wise to make sure the waveform monitor is properly calibrated. This is an easy step to take with the 1710J's built-in calibration signal.

To view the calibration signal, press and hold the REF button located in the INPUT block. When the calibration signal is selected, the front panel CAL LED will be illuminated. The color bars signal display will disappear and the calibration signal — a 1 V p-p square wave — will appear on the screen.

To check calibration, position the calibration square wave vertically so that its flat bottoms align with the -40 IRE graticule line. The flat tops of the signal should then line up with the 100 IRE graticule line. If this is not the case, the waveform monitor is out of calibration and should be checked by a qualified technician.

Checking luminance levels

After verifying that the waveform monitor is calibrated, you can begin making video signal level measurements with confidence.

First, check the video system's overall gain. This is done by checking the amplitude of the color bars signal coming from the system. If the amplitude is too high (Figure 2-11), the picture is said to be "hot." It's like an overexposed photograph. On the other hand, an amplitude that is too low is like an underexposed photo and results in a dark picture.

All amplitude measurements are made relative to the horizontal axis at 0 IRE. To do this, make sure the blanking level (labeled in Figure 2-6) is aligned with the 0 IRE graticule line. Then make sure that the 100% white reference level coincides with the 100 IRE graticule line. Also, make sure the black level (sometimes called setup) is at 7.5 IRE. Notice there is a special dashed graticule line at 7.5 IRE for verifying black level. (Be sure you do not confuse the black level with the blanking level.)

If the video signal's 100% white level does not correspond to 100 IRE, use the gain control on the system under test to adjust the top of the signal to 100 IRE. This should also bring the black level to 7.5 IRE. However, there may be a separate black level control on the equipment under test that can be used for final adjustment of black level. If there is a separate black level control, adjust it first, then adjust the gain control for 100 IRE. Making adjustments in this order should minimize interaction between them.

Next, check the sync pulse level. The sync pulse is the narrow pulse in mid-screen in Figure 2-8 extending down from the blanking (0 IRE) level. The flat bottom of the sync pulse should be at -40 IRE. If it's more than a few IRE off, see if the equipment under test has a sync amplitude adjustment. If it does, adjust the sync amplitude to -40 IRE. The luminance level and sync level must both be correct, i.e., the 0 IRE reference level luminance must extend to 100 IRE at peak white and sync must extend to -40 IRE. If the signal cannot be adjusted to match the graticule at all three points (white at 100 IRE, blanking at 0 IRE, and sync at -40 IRE) the equipment requires servicing by a qualified technician.

A word of caution

If there is more than one piece of equipment with gain controls in the path you're testing, you must make sure that each unit is adjusted for standard input and output levels. This is done by moving the test equipment connection to the output of the first unit, then to the second, etc., and adjusting each unit in turn. Failure to do this may allow a system to have higher- or lower-than-standard levels at some points in the path, which will almost always introduce increased distortions. To put this another way, the effects of nonstandard levels at some point in the system cannot be fully corrected "downstream."

Checking chrominance gain

After verifying correct luminance gain, you need to check chrominance gain. If the chrominance amplitudes are wrong with respect to luminance, the picture's color intensity (saturation) is affected.

First, make sure the color burst ranges from -20 to +20 IRE. Then check the maximum chrominance levels of the first two color bars (yellow and cyan). Both should be at exactly 100 IRE. If they are not, adjust the chrominance gain on the equipment under test to correct the chrominance levels.

Checking sync width

Sync width should be checked after verifying correct luminance and chrominance gain. Sync width is not as critical as signal amplitude, but it still should be checked to make sure the equipment is operating within defined limits.

To accurately measure sync pulse width, you need to magnify the pulse on the waveform monitor screen. To do this, press the MAG button. If the sync pulse is at center screen when MAG is pressed, the magnified sync pulse should still appear near center screen (Figure 2-12). If it doesn't, adjust the waveform monitor's horizontal position control to bring the pulse to center screen.

Next, adjust the vertical position control to position the pulse's top (blanking level) at +20 IRE as shown in Figure 2-12. The bottom of the pulse should now be at -20 IRE. Now, the 50% level of the pulse corresponds to 0 IRE.

With the pulse displayed in this manner, you can read pulse width directly from the horizontal 0 IRE axis. In 2H MAG, each major division on the axis equals 1 µs. Using this scaling to measure pulse width at the 50% level, the sync pulse width should be 4.7 µs. If the width isn't close to 4.7 µs and there's no sync width adjustment on the equipment under test, you should have the equipment serviced.

Checking sync pulse width completes the series of basic measurements for objectively verifying video signal quality. Again, the verification relies on applying a known ideal test signal to the input of the equipment under test. The signal should pass through the equipment without any changes in luminance and chrominance amplitudes or sync pulse width. If there are changes in any of the parameters, the equipment either needs adjustment or servicing.

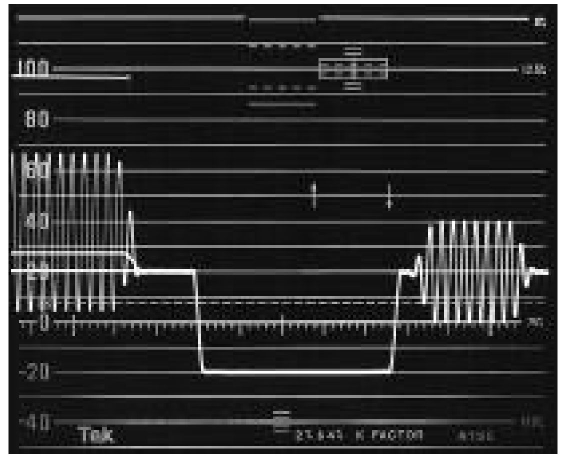


Figure 2-12. Sync pulse display horizontally magnified (MAG) and positioned vertically so the pulse's 50% levels are on the 0 IRE horizontal axis.

The next step

The instruments and techniques presented in this section can solve or avoid many picture problems often encountered in video facilities. Being able to apply these skills enhances your confidence and professional value.

You should, however, be aware that there are many other, more specialized, tests and measurements that can be made on video systems. The various test signal selection buttons on the TSG 100 (Figure 2-1), other than color bars, offer only a hint of the range of other tests and measurements possible.

Basic Video Testing — Vectorscope Techniques

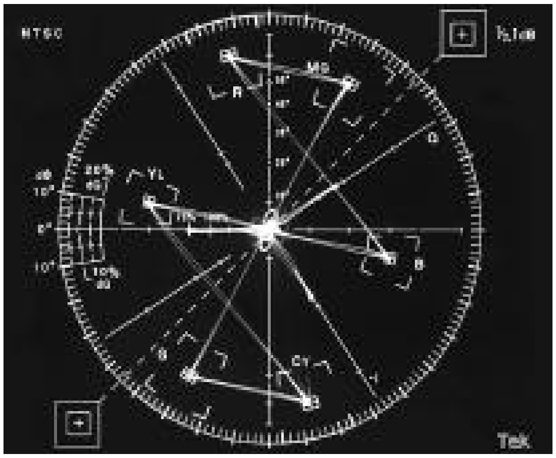


Figure 3-1a. The vectorscope screen shows a display of a SMPTE color bars test signal with all of the dots in their boxes and the color burst correctly placed on the horizontal axis.

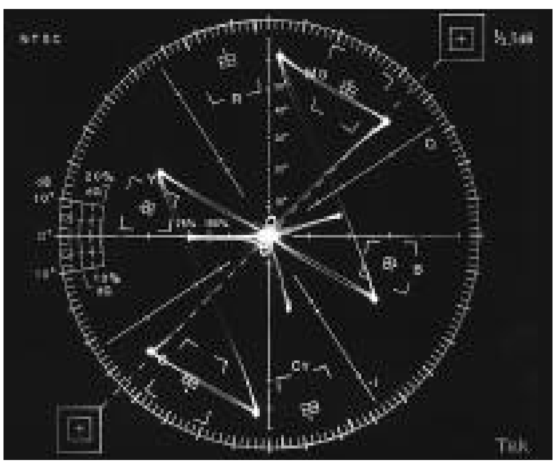


Figure 3-1b. The vector dots are rotated with respect to their boxes, indicating a chroma phase error.

In the section on waveform monitor techniques, it was explained that a waveform monitor displays a graph of the video signal — amplitude (voltage) on the vertical axis and time on the horizontal axis. A vectorscope also graphs portions of the video signal for test and measurement purposes, but the vectorscope display differs from a waveform display.

While a waveform monitor displays amplitude information about all parts of the signal, a vectorscope displays information about only the chrominance (coloring) portion of the video signal — it does not respond to other parts of the video signal.

There are two important parameters of the chrominance signal that may suffer distortions leading to noticeable picture problems. These are amplitude (gain), and phase (timing). Amplitude is an independent measurement and can actually be made with a waveform monitor. Phase is the relationship between two signals — in this case, the relationship between the chrominance signal and the reference burst on the video. The processing within a vectorscope and the display of the processed signals is designed to readily detect and evaluate both phase and gain distortions of the chrominance.

Understanding the Display

There are two parts to a vectorscope display — the graticule and the trace. The graticule is a scale that is used to quantify the parameters of the signal under examination. Graticules may be screened either onto the faceplate of the CRT itself (internal graticule) or onto a piece of glass or plastic that fits in front of the CRT (external graticule). They can also be electronically generated. The trace represents the video signal itself and is electronically generated by the demodulated chrominance signals (Figure 3-1).

All vectorscope graticules are designed to work with a color bars signal. Remember, the color bars signal consists of brightness information (luminance) and high-frequency color information (chrominance or chroma).

Each bar of the color bars signal creates a dot on the vectorscope's display. The position of these dots relative to the boxes, or targets, on the graticule and the phase of the burst vector are the major indicators of the chrominance (color) signal's health. (Burst is a reference packet of subcarrier sine waves that is sent on every line of video.)

The graticule

The graticule is usually a full circle, with markings in 2- and 10-degree increments. The cross point in the center is the reference mark for centering the trace. Within the circle you also see six target shapes each containing smaller, sectioned shapes. The smaller shapes are where each dot of the color bars signal should fall if the chroma gain and phase relationships are correct. (In practice a dot that will fall entirely within the smaller target is only created by a very low noise signal, such as directly from a color bars generator. Expect the dots to be much larger and "fuzzier" on signals from tape players or off-air receivers. Note also the camera signal in Figure 3-2.)

The horizontal line bisecting the circle at zero and 180 degrees (9 o'clock to 3 o'clock positions) is used as a reference for correctly positioning the burst display. (Burst is indicated by the portion of the trace that lies from the center part way toward the zero degree position.) The markings toward the left of the burst display indicate correct burst amplitude for 75% or 100% color bars. Note that burst does not change electrical amplitude — the gain in the vectorscope's processing is increased when it is set to display 75% amplitude bars in the targets — and that increased gain causes the display of the fixed amplitude burst signal to be longer.

At the left edge and near the outer circumference of the graticule is a grid used to measure differential gain and phase. These measurements are discussed in the later section on *Intermediate Video Testing*.

Some vectorscopes also have square boxes outside the graticule's circle in the lower-left and upper-right corners of the screen. These boxes, along with the vertical line that bisects the circle, are used for making stereo audio gain and phase measurements with a Lissajous display. While this capability is useful in certain applications, we will not discuss it in this booklet, but rather concentrate on video measurements.

The trace

The vectorscope's display is created by decoding the chrominance portion of the video signal into its two components, B-Y (blue minus luminance) and R-Y (red minus luminance). These two signals are then plotted against each other in an X-Y fashion, with B-Y on the horizontal axis and R-Y on the vertical axis. While waveform monitors lock to sync pulses in the video signal, vectorscopes lock to the 3.58 MHz color burst and use it as the phase reference for the display.

Three color bars signals are commonly used with vectorscopes — 75% and 100% full field color bars and the SMPTE color bars. The 100% and 75% labels refer to the amplitude of the signal, not the saturation of the colors; both are 100% saturated. In this application note, we will use the SMPTE color bars signal exclusively, because it is an industry standard. SMPTE bars are 75% amplitude color bars.

You should always use 75% bars for basic testing. This is because 100% bars contain signal levels too high to pass through some types of equipment undistorted, even when the equipment is operating properly. For more information on the various color bars signals, refer to pages 2-2 and 2-3 in the *Basic Video Testing — Waveform Monitor Techniques* section.

Figure 3-2. Proper white balance of a video camera is indicated by a fuzzy spot centered on the vectorscope display when the camera is viewing a white object.

Using the Vectorscope Controls

The first rule-of-thumb to remember when you begin to operate the vectorscope is that the controls do not in any way affect the video signal itself. The only way to adjust the signal, rather than just its vectorscope display, is with the controls of the equipment providing or transferring the video signal.

All the basic controls for powering up the instrument and adjusting the display for comfortable viewing (power and display: focus, scale illumination, and intensity) are self-explanatory. The gain controls provide a way to calibrate the display's gain for either 75% or 100% color bars. A variable control expands the trace to compensate for low signal levels, or so you can analyze the signal in greater detail. For white balancing cameras, use of this control also allows more visibility of the detail in the white and black information near the center of the vectorscope display.

The input controls typically consist of the input channel, reference, and mode selections. The input for channel A, for example, is likely to be video from a switcher's output (with a VTR, camera, signal generator or other equipment providing the input to the switcher). Reference may be internal, where the vectorscope locks to the color burst of the selected input channel, or external, where lock is to a second signal. In this section we are only using internal reference. **Externally referencing a vectorscope is imperative for the purpose of matching the chroma phase of various sources to eliminate color shifts at edit points**. This application is discussed in the *Setting Up a Genlocked Studio* section.

Internally referenced displays only show the phase relationship between the burst and color bars signal of the selected input signal itself — not phase relationships between different signals.

If the vectorscope has an external X,Y input for displaying audio, a mode control allows you to enable this input for display with or without the regular vector display.

The phase control is one you will use often. In the internally referenced mode it must be used to align the burst vector on the horizontal axis (pointing toward zero degrees, or 9 o'clock). If the color burst is not in this correct position, the signal is not properly aligned with the graticule and provides no really useful information. As you rotate the phase control, the whole trace rotates about the center point.

Checking the Display

When you first check the display of the color bars signal on a vectorscope, you should see:

1. A bright dot in the center of the display.
2. Color burst straight out on the horizontal axis extending to the 75% mark.

There are also a few things you should examine on the waveform monitor. The waveform monitor should indicate the following:

1. Waveform black level at 7.5 IRE. (Black level adjustments are made with the setup control on the equipment under test while viewing the waveform monitor.)
2. Waveform luminance (white bar) at 100 IRE. (Amplitude adjustments are made with the video level, or video gain control on the equipment under test while viewing the waveform monitor.) Refer to the *Waveform Monitor Techniques* section, *"A Word of Caution"* (page 2-5) if there is more than one video gain or level control in the path you're testing.

Using the test signal generator's color bars as a reference signal, you should check to make certain the signals appear on the waveform monitor and vectorscope as mentioned above. Again, use the phase control to ensure the color burst vector is properly positioned and the vector color dots are in their graticule boxes. With this reference position established, any differences in other signals you select will be obvious.

Checking Chrominance Phase

Now that you've established a reference position on the vectorscope, the next step for checking the signal from the studio VTR equipment against the reference signal is to play back a videotape with the 75% color bars recorded. Select the equipment under test on the video switcher (VTR, TBC or proc amp), or by appropriately connecting cables, and look at the vectorscope display.

If the burst phase vector lines up on the horizontal axis, but the dot pattern is rotated with respect to the boxes, there is a chroma phase problem with the equipment under test (Figure 3-1b).

This rotation of the dot pattern means that the chrominance phase is incorrect relative to the color burst. This phasing error causes hues to be wrong — people's faces appear green or purple, for example.

Correct chrominance phase is critical, even if hue errors aren't obvious on a picture monitor. To correct a chrominance phase error, perform the following steps:

1. Ensure the vectorscope's burst display is aligned with the horizontal axis (phase control on the vectorscope).
2. Adjust the hue control or chroma phase control on the equipment in the path to get the dots as close to their respective graticule boxes as possible. They may be too near the center of the display or too far away, but they will lie in the proper direction from the center when phase is correct.

If you are working with a camera in your system, the adjustments are no different. You just have to look at the cameras output, or at the output of the camera control unit (CCU) if you are using one, when you make the adjustments.

It is often best to go back and forth between the chrominance gain (discussed next) and phase adjustments to get the dots in their graticule boxes. The dots will rarely be exactly centered on the cross points in the smaller boxes. It is, however, acceptable if they fall somewhere within the small boxes rather than the larger boxes.

Remember, these tests are only checking the bar signal relative to the color burst. Not all equipment requires or makes available this adjustment. Phasing (or timing) several sources or paths so their signals may be switched or mixed requires external reference for the vectorscope and somewhat different techniques. These are discussed in the *Setting Up a Genlocked Studio* section beginning on page 4-1.

Checking Chrominance Gain (Amplitude)

Adjusting chroma phase alone may not put the dots in their boxes because they may fall short of, or extend too far outside the boxes (Figure 3-3). This indicates a chroma gain error.

For checking chroma gain on a VTR, you will again use the color bars signal recorded at the head of the tape — other equipment may require a bars signal as its input. Again, you should check luminance levels on the waveform monitor, and correct any errors, before you make any measurements with the vectorscope. (Remember the vectorscope does not display any information about luminance.)

1. Use the setup control (if provided) to position the black level at 7.5 IRE.
2. Use the video level controls on the equipment under test to adjust the white level on the waveform monitor to 100 IRE.

   While the tape is playing the recorded bars, dots will appear on the vectorscope. If the dots are beyond the boxes, the chroma amplitude is too high. If the dots fall short of the boxes, chrominance is too low.
3. Adjust the chroma gain control of the equipment under test until the dots fall into their boxes.

If adjusting the chroma gain control doesn't get the dots into their boxes, you may need to re-adjust hue or have the equipment serviced.

If you happen to run the tape past the color bars signal and into active video, you'll notice that the vector display looks very different. This is because there are typically no large areas of primary or secondary colors in the picture to create the bar dots. The display looks fuzzy or blurred because the vector shows the blend of hues within the picture.

Checking White Balance

Along with checking for chroma phase and gain, there is another studio application that uses a vectorscope in the internal reference mode — checking the white balance of video cameras.

White balance is the process of balancing the camera's red, green and blue channels. When these channels are properly balanced, the camera's output signals will reproduce whites in a scene without adding color. In order for the camera to reproduce colors correctly, it must be able to reproduce white accurately. The signals from the green, blue, and red sensing elements in the camera must be properly balanced to ensure there is no chrominance signal at the camera output when it is viewing white.

Before you can set white balance, you must first check the camera for proper black balance:

1. Connect the video camera signal to the vectorscope input, or switch to the camera on the video switcher.
2. Cap the cameras lens.

If the black balance is correct, the camera's signal will produce a fuzzy spot in the center of the vectorscope display, the same as for proper white balance (Figure 3-2). If the spot is distended away from the center in any direction, proceed as follows:

3. Adjust the black balance control on the camera until the spot returns to the center of the display.

To check white balance, uncap the camera and point it at a pure white target. If white balance is correct, the resulting signal from the camera should again produce a fuzzy spot in the center of the vectorscope display (Figure 3-2). If any color channel in the camera is out of balance, the fuzzy spot on the vectorscope will be distended or moved toward the corresponding color's graticule box. For example, too much red signal moves the spot toward the red box.

If the vectorscope display indicates incorrect color balance, it can be corrected by using the camera's white balance controls. Cameras that allow manual white balance adjustment usually have two controls (red gain and blue gain). It may help to remember the red balance control will move the spot vertically and the blue control will move it horizontally. To manually set white balance, the following steps are recommended:

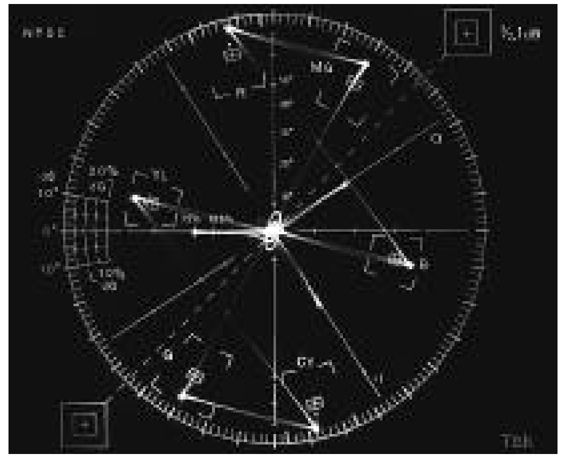


Figure 3-3. This display shows the vector dots extending beyond their boxes, indicating a chroma gain error.

1. Aim the camera at a white reference. (Before attempting to correct a white balance problem, make sure you have the correct filter selected on the camera for the type of lighting in use. The wrong filter selection will cause an apparent white balance problem on the vectorscope.)
2. Adjust the red and blue gain controls on the camera to get the fuzzy spot in the center of the graticule on the vectorscope.

Some cameras with an automatic white balance feature may not offer manual adjustment and will have to be referred to a service technician if the automatic balancing feature does not achieve the desired results.

Conclusion

This section has dealt with three basic uses of a vectorscope — evaluation of chrominance to burst phase, chrominance gain, and color balancing of a camera. There are other, more extensive, measurements that you can make with a simple vectorscope, and others that require instruments with enhanced capabilities. Several of these more advanced techniques are addressed in the following sections: *Setting Up a Genlocked Studio* and *Intermediate Video Testing*.

Setting Up A Genlocked Studio

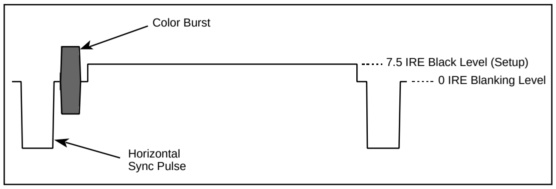


Figure 4-1. The black burst signal used in genlocking is composed of the horizontal sync pulse, subcarrier color burst, and a 7.5 IRE black signal.

Figure 4-2. The Tektronix TSG 200 provide multiple black burst signal outputs for economically genlocking small studios. Additional features on the TSG 200 can be used for basic video testing and other odd jobs around the studio, including ID generation, setting up picture monitors and blacking tapes.

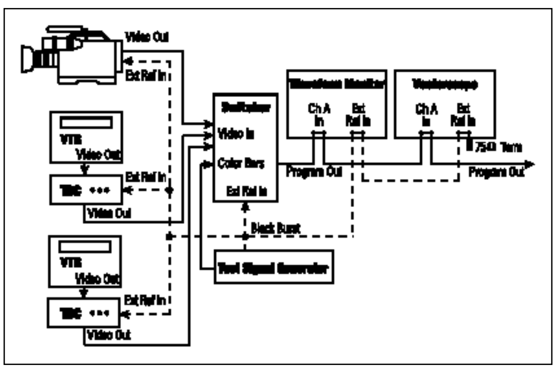


Figure 4-3. A black burst signal is distributed from the test signal generator for genlocking studio equipment. If the signal generator has multiple black burst outputs, as is the case with the TSG 200, a distribution amplifier may not be necessary since they have five black burst outputs.

Fades and dissolves are a basic part of most professional video productions. Even the smallest studios use them. Before dissolves or other editing effects can be used, though, the studio equipment must be synchronized.

Synchronization is done by locking cameras, VTRs, editors, switchers, and other video equipment to a master sync generator. Equipment that is synchronized by a master generator is often referred to as being generator locked, or “genlocked” for short.

Genlocked equipment works together in synchronization with a master sync signal. It’s much like the members of a marching band “locking” their steps to the beat of the bass drum. Without the steady beat of the drum — the synchronization pulse — the band members wouldn’t have a common reference for staying in step with each other.

Similarly, video equipment that isn’t genlocked has difficulty working together. Trying to dissolve from the output of one VTR to another results in picture tearing or roll until synchronization is reestablished. With genlocked equipment, the dissolve is smooth and “in step” with the master sync.

The black burst signal (Figure 4-1) is often used for genlocking equipment. It is a composite signal with a horizontal sync pulse and a small packet of 3.58 MHz color subcarrier (color burst). The term black burst arises from the fact that the active picture portion of the signal is at 7.5 IRE (black) and it contains color burst.

Establishing a genlocked studio is simple and need not require expensive equipment. This section will show you how to genlock your equipment with the Tektronix TSG 200 NTSC Generator (Figure 4-2). This generator is an economical source of multiple black burst signal outputs for genlocking.

Genlock Basics

There are three basic requirements for setting up a genlocked studio. You need:

- Video equipment that can be genlocked
- A genlock signal source
- Adjustment for synchronizing equipment with the genlock source.

The first of these requirements — video equipment that can be genlocked — is relatively easy to meet. Most professional video equipment is genlockable. To see if your cameras, VCRs or VTRs, and other equipment meet this requirement, check the equipment for a genlock loop-through input or an external reference input (Ext. Ref.). Also, the equipment must have some provision for adjustment of timing, whether it is a single control for adjusting both H-timing and SC-phase, or separate controls for adjusting each.

The genlock or external reference input connector is necessary for applying an external synchronization signal — typically black burst — to the equipment. The timing controls are necessary for adjusting the equipment for synchronization with the reference’s horizontal (H) sync pulse and subcarrier (SC) color burst phase.

With a genlock signal source, such as a Tektronix TSG 200, a black burst signal can be distributed to the studio equipment as shown in Figure 4-3.

There are several important things to note about this distribution diagram. First, the signal generator used for genlocking should have multiple black burst outputs. A unique black burst signal is not needed for each piece of equipment to be genlocked. Looping-through equipment in different locations within a facility is possible, but presents one major problem — too long a cable run will produce delays beyond the adjustment range of the equipment being locked.

Generally speaking, a single black burst feed for each cluster of equipment is sufficient, with that single feed being looped through just one group of equipment.

If multiple black burst outputs are not available, a multiple output signal distribution amplifier should be used with one output for each cluster of equipment to be genlocked.

Also notice in Figure 4-3 that the black burst signal is distributed to the Time Base Corrector (TBC) for each VTR, rather than the VTR itself. The reason for this is that the TBC is actually the final program output of the VTR. The TBC is where genlocking and timing adjustments need to occur.

Similarly, if you use camera control units (CCUs), connect the black burst output to the CCUs, not to the cameras. Camera timing adjustments, unlike TBC/VTR adjustments, are made at the camera, not at the CCU.

Finally, note that one of the black burst signal outputs from the test signal generator is loop-through connected to the external reference inputs of a waveform monitor and vectorscope. (Don't forget the 75 ohm terminator at the end of each chain of genlock or external reference loop-throughs.) The waveform monitor and vectorscope are also loop-through connected to the Program Output of the studio switcher.

These connections to a waveform monitor and vectorscope are necessary for the final requirement — adjusting the equipment for synchronization with the genlock source.

Adjusting TBCs

TBCs have several controls, in addition to the timing controls just mentioned, that are used to compensate for gain deficiencies and color errors on tapes. Setup (or black level), video gain, chrominance gain, and hue are commonly used adjustments on TBCs. Each of these adjustments has already been covered in this application note and will not be repeated here. The purpose of this section is to link the nearly universal inclusion of color bars on tape leaders to TBC adjustments and discuss a few guidelines to follow while making these adjustments.

Video levels and hues recorded on tape sometimes differ from facility to facility, and VTR to VTR. This is a fact of life. When differences exist they must be corrected. By recording color bars on the beginning of every tape, operators can make the necessary TBC adjustments quickly and simply with just a waveform monitor and vectorscope.

The TBC's horizontal timing and subcarrier phase controls shouldn't require checking or adjustment each time you play back a tape from a different source. Since the TBC always replaces the sync and burst of the recorded signal, playing back different tapes should not affect the TBC's system timing. Many experienced operators make TBC adjustments in the following order to minimize interaction between the adjustments: **1) setup, 2) video gain, 3) hue, and 4) chrominance gain.**

Remember that TBC adjustments must be made when the VTR connected to it is playing back a recorded color bars signal, not when the VTR is in the electrical-to-electrical (E-to-E) mode.

Adjusting for Synchronization

As mentioned before, the horizontal sync pulse and subcarrier burst of the black burst signal are like the drum beat to which members of a marching band synchronize their steps. Everyone's footsteps should strike the ground in time with the drum. Additionally, for the whole band to be in step, everyone's left foot should be striking the ground at the same time. Occasionally, however, a band member will be out of step, and you'll see them do a little "skip-step" as a timing adjustment to get in step with the rest of the band.

Similarly, each piece of video equipment must have some timing adjustments made in order for it to be "in step" with the rest of the video system. Adjusting system timing is one of the most fundamental — and critical — procedures in the studio.

System timing adjustments involve setting the H-timing and SC-phase controls on each piece of equipment. The adjustments are made so that each piece of equipment's horizontal sync pulse and color burst phase line up with the sync pulse and burst phase of the reference genlock signal (black burst).

Making sure that each piece of equipment is "in step" with the genlock signal prevents horizontal jumps and color shifts of the picture when switching between video sources. Matching the timing of the sync pulses makes sure the scanning of each picture source is in step (e.g., the images will stay in the same position, without roll, tearing or "jumps" during a cut or fade). Matching the burst phase of the various sources maintains the correct color of the images during editing transitions.

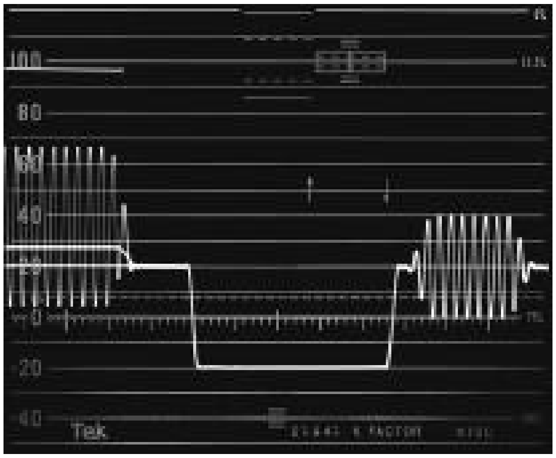


Figure 4-4. Waveform monitor display of the reference sync pulse edge adjusted to correspond to a major timing mark. This timing mark can now serve as the zero reference for individually adjusting the H-phase of each piece of video equipment in the system.

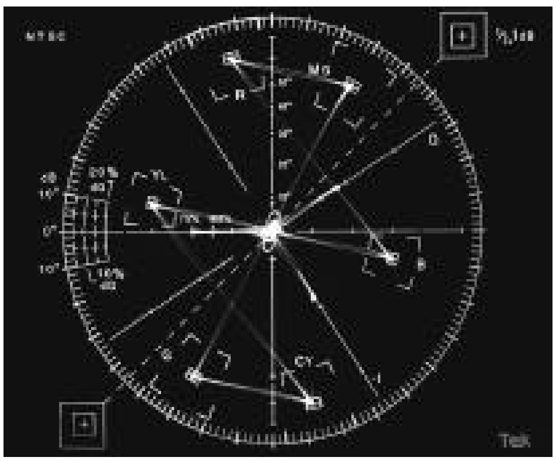


Figure 4-5. Vectorscope display of the reference color burst vector adjusted to the 9 o'clock position. All other pieces of equipment should be SC-phase adjusted to correspond to the 9 o'clock reference.

Before making timing adjustments, you should check the video gain from each piece of equipment. The SMPTE color bars signal from the TSG 200 can be used for this. If necessary, correct any video gains before going on to system timing adjustments.

System timing adjustments are made with a waveform monitor and vectorscope connected to the switcher output as shown in Figure 4-3. Make sure that both the waveform monitor and vectorscope are set to trigger on the external reference signal.

The next step is to set up zero timing references on both the waveform monitor and vectorscope. The first step in this "zeroing" process is to select the test signal generator's output as the switcher's active input. This applies the generator's test signal to the Channel A inputs of both the waveform monitor and vectorscope.

On the waveform monitor, make the necessary adjustments to expand the display on the horizontal sync pulse. Be sure the waveform monitor is in the external reference mode, i.e., displaying the program output of the switcher, but referenced to the black burst. Use the waveform monitor's horizontal positioning control to place the leading edge of sync on one of the display's major timing marks. This timing mark is now the zero-time reference for inputs from all other video equipment, and the horizontal position control should not be moved during the rest of the system timing adjustments. Figure 4-4 shows an example of the reference sync edge display with the sync edge positioned on a major timing mark.

The next step is to zero reference the vectorscope to the reference signal's color burst subcarrier phase. This is done by using the vectorscope's phase control to position the color burst vector to the 9 o'clock position. Here again, be sure the vectorscope is in the external reference mode — locking to the external black burst. This is shown in Figure 4-5. Once the reference signal's color burst is positioned to 9 o'clock, do not touch the vectorscope's phase control again during the rest of the timing adjustments.

With sync and color burst zero referencing completed, use the switcher to select the signal output from the first piece of video equipment to be adjusted.

The waveform monitor will display the horizontal sync pulse from the selected piece of equipment. If the sync edge does not line up on the previously established zero-reference mark, adjust the H-timing control on the selected piece of equipment to place the sync edge on the zero-reference marker.

Look at the color burst display on the vectorscope. Is the color burst vector aligned with the 9 o'clock position on the vectorscope display? If it isn't, use the SC-phase control on the selected piece of equipment to set color burst to the 9 o'clock zero reference.

In the case of a single timing adjustment (where SC-phase and H-timing have a fixed relationship), simply observe the vectorscope and adjust the equipment such that the color burst vector lines up with the 9 o'clock reference line on the vectorscope's graticule. Some equipment has a wide range adjustment which will continue to move the sync timing beyond the first place where the burst phase is correct — if so, continue to adjust the control in the appropriate direction. This should move the H sync pulse to the zero-reference marker as well. If it does not, there is either an internal H-timing adjustment that is set incorrectly or the equipment needs servicing. In either case, an experienced technician should attend to the problem.

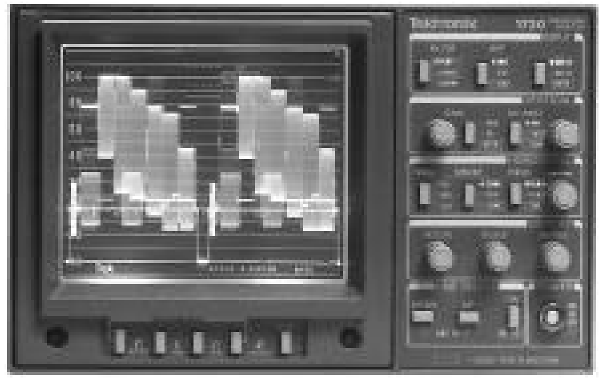
Setting sync and color burst to the established zero references completes timing alignment for the selected piece of equipment. That piece of equipment is now in step with the black burst reference signal.

Now, using the switcher, select another piece of equipment and adjust its H-timing and SC-phase controls to zero reference its sync and color burst output. Continue this equipment selection and zero-referencing process for all other pieces of video equipment in the system. Remember that for VTRs, the timing adjustments are done at the TBC.

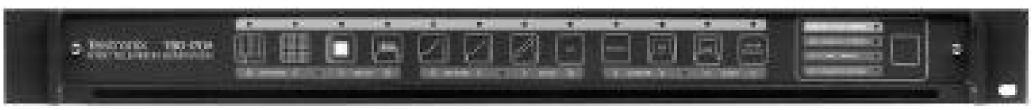
When these adjustments have been completed for all pieces of equipment in the system, each piece of equipment will be in synchronization and properly timed with all other pieces of equipment. You now will be able to switch smoothly between video sources and make clean edits without picture roll or horizontal jumps.

Intermediate NTSC Video Testing

1720 Vectorscope.



1730 Waveform Monitor.



TSG 170A NTSC Television Generator.

Figure 5-1. Video system testing requires a signal generator, a waveform monitor, and a vectorscope.

Previous sections of this booklet have discussed making basic measurements and adjustments in video systems. This section goes on to discuss intermediate level tests using three pieces of test-and-measurement equipment — a signal generator, waveform monitor, and vectorscope. This section describes how to use that test equipment to make the following tests:

- insertion gain
- frequency response
- chrominance-to-luminance gain
- luminance nonlinearity
- differential gain
- differential phase

The picture impairments caused by the distortions these tests are designed to detect are also described where appropriate.

Test equipment first

To ensure valid test results, you must use good test equipment. Essentially, there are two primary requirements for this. First, the test equipment's specified performance must exceed the expected performance of the system being tested. And second, the test equipment must be performing to its specifications.

The latter requirement is really a two-stage requirement. The test equipment must always be setup using standard operator calibration procedures. For highest confidence, the equipment should also be fully calibrated periodically at a qualified service center. (Full and precise calibration of test equipment requires special skills and laboratory instruments not normally found in a video facility.)

As for test equipment capabilities, all the tests described in this application note can easily be performed with the Tektronix instruments shown in Figure 5-1:

- 1720 Vectorscope, used to evaluate the chrominance (color) information in a video signal
- 1730 Waveform Monitor, used for video signal level and timing measurements
- TSG 170A NTSC Television Generator, used to generate the necessary standard test signals

This test equipment is excellent for all basic and intermediate testing requirements. Other similar test equipment may be available to you and can be used in essentially the same manner. In some instances, the waveform monitor and vectorscope functions

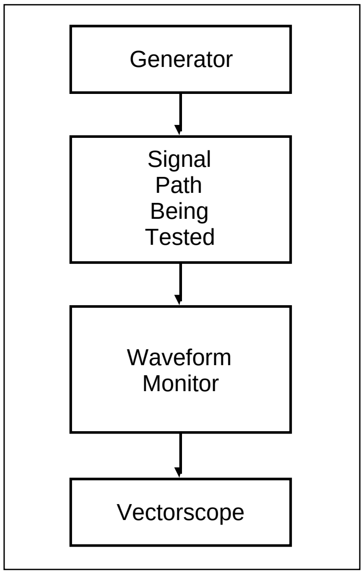


Figure 5-2. The basic test setup for any video system involves applying a standard test signal at the path input and observing or measuring the resulting signal at the path output.

will be combined in a single instrument. This is the case, for example, with the Tektronix 1740A and 1750A Series Waveform/Vector Monitors. With these instruments, you select the waveform monitor or vectorscope mode by pressing the Waveform or Vector button on the front panel.

Similarly, more advanced, multi-function instruments, such as the Tektronix 1780R or VM700T Video Measurement Sets, allow push-button selection of waveform monitor or vectorscope modes. Additionally, the 1780R and VM700T provide numerous other features that simplify the measurements described in this section as well as many other measurements. Some of these features include microprocessor-assisted or fully automatic measurements, user-programmable measurement sequences, graphic display of measurements, and brighter displays in line-select mode.

The more sophisticated capabilities and enhanced precision of these instruments makes them ideal for all measurements including applications such as complete in-service or acceptance testing. (In-service testing also requires a VITS inserter, such as the Tektronix VITS200, VITS100 or 1910, to generate and insert vertical interval test signals.)

Setting Up the Test Equipment

Regardless of the specific test equipment models used, the basic test concepts and setup remains the same. The diagram in Figure 5-2 shows the setup for testing any video system, no matter how simple or complex.

The block labeled Signal Path Being Tested can be any part of the video system. It can be a single piece of equipment such as a playback deck or a recording deck. Or the path can include a switcher along with other equipment such as cameras, VTRs, distribution amplifiers, character/title generators, special effects generators, and so forth. In any case, all testing is done in essentially the same manner — inject a signal at the start of the path (the input), and observe or measure any distortions to the signal at the end of the path (the output). For additional details, see the earlier section on *Connecting and Terminating Instruments* starting on page 1-3, and "*A Word of Caution*" on page 2-5.

Before actual testing begins, however, you should check the test equipment against its own internal calibration signal. This is typically referred to as a user calibration procedure, and it will be outlined in the instrument operator's manual.

Also, as a matter of reference, you should view an undistorted test signal on the test instrument's display. To do this, connect the test signal generator's output directly to the vectorscope or waveform monitor input terminals.

With the instruments properly connected and terminated, you'll see the test signal displayed on the vectorscope or waveform monitor. Study this display carefully. It's your reference of what the "perfect" signal should look like.

Ideally, you should see exactly the same "perfect" display after the test signal is passed through the video path being tested. However, if there are distortions in the signal path, you'll see corresponding changes in the displayed signal. Various types of distortion are described further in the following discussion of test procedures.

Insertion Gain

Insertion gain reflects the video path's ability to maintain correct signal amplitudes from input to output. The general test procedure is to apply a standard NTSC 1 volt (140 IRE) signal to the video path or equipment input. The test signal is then measured at various points along the signal path to verify its correct amplitude.

It is important to verify insertion gain before doing any other tests. If there are insertion gain errors and they are not corrected, subsequent tests will be incorrect as well. This is because most tests are based on the presumption that insertion gain is correct. Also equipment that is processing a nonstandard level signal will often introduce other distortions.

Insertion gain errors are usually expressed as a percent variation from the nominal value. Therefore, the goal is zero insertion gain.

Positive insertion gain errors indicate an increase (gain) in signal amplitude from input to output. This can lead to distortions from signal overload. Negative insertion gain indicates a decrease (loss) in signal amplitude. This causes dark pictures and also reduces the signal-to-noise ratio (SNR).

Insertion gain errors affect overall picture brightness and may also affect apparent color saturation. The human eye is very sensitive to even small brightness variations, particularly when they occur rapidly. Because of this, its especially important to make sure that all video switcher inputs are matched when different shots of the same scene are being combined. It should also be kept in mind that small gain errors in several system components can quickly cascade into big errors.

Insertion gain testing is done by applying either a SMPTE color bars signal or a full-field, 75% color bars test signal having a 100% white reference level. A waveform monitor is then used to observe the color bars signal and make insertion gain measurements.

The TSG 170A supplies the SMPTE color bars signal. Since the white reference for SMPTE color bars is at 75%, the 100 IRE Y signal that overlays the first two color bars, as shown in Figure 5-3, is more convenient for insertion gain tests. Figure 5-4 shows a full-field, 75% color bars signal with a 100% white reference. (Either of these signals can also be used to check chrominance amplitude and chrominance-to-burst phase on a vectorscope.)

The waveform monitor should be set for a one- or two-line sweep with the filter selection in flat. (Other filter positions alter the waveform monitor response and may mask a gain error.)

With the sweep and filter selected, use the vertical position control to align the trace's blanking level with 0 IRE on the graticule. As shown in Figure 5-3, the 100% white reference (Y signal) should now coincide with the 100 IRE graticule line, and the sync tips should be at 40 IRE. Insertion gain error, if any, is determined by noting the position of the white bar and subtracting 100%. For example, if the bar is at 93 IRE, insertion gain error is 93 - 100, or -7%.

When there is an insertion gain error, the equipment under test should be adjusted to remove the error. To do this, use the appropriate control on the equipment under test to align the color bars reference bar with the waveform monitor's 100 IRE graticule line. In doing this, be sure to keep the blanking level on 0 IRE by using the waveform monitor's position control if necessary. With the reference bar on 100 IRE, the sync and color burst amplitudes should both be 40 IRE peak-to-peak. You may need to make separate adjustments to make sure these levels are correct.

In making gain adjustments, it's important to start first with equipment at the beginning of the video signal path. Otherwise, you may simply mask rather than correct errors occurring earlier in the signal path.

After verifying that insertion gain is correct, you need to check chrominance amplitudes. This can be done using either a waveform monitor or a vectorscope.

On the waveform monitor, chrominance amplitude is checked by first measuring the color burst amplitude. It should extend from -20 IRE to +20 IRE (40 IRE peak-to-peak). Then check the maximum level of the first two color bars (yellow and cyan). Both should be at exactly 100 IRE. If they aren't, adjust the chrominance gain on the equipment under test to correct the chrominance levels.

Checking chrominance levels on the vectorscope is done with the display shown in Figure 5-5. The color burst vector should emanate from center screen along the horizontal axis (9 o'clock position). If it doesn't, adjust the vectorscope's phase control to put the color burst in the 9 o'clock position. Then check to see if all of the other vector dots fall into their proper boxes, as shown in Figure 5-5.

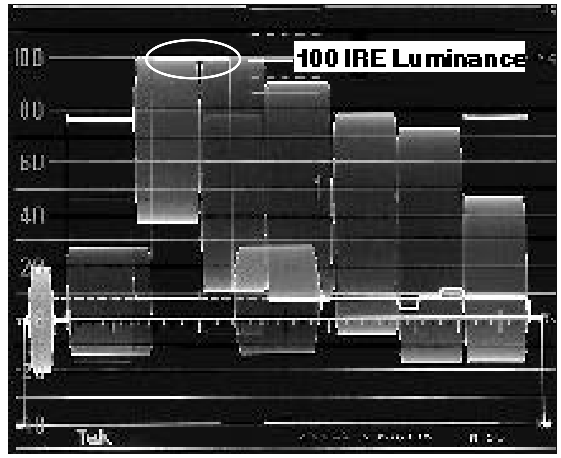


Figure 5-3. A waveform monitor, set for one-line sweep and flat response, displays a properly adjusted SMPTE color bars signal. This test signal is used for detecting insertion gain and color burst amplitude errors.

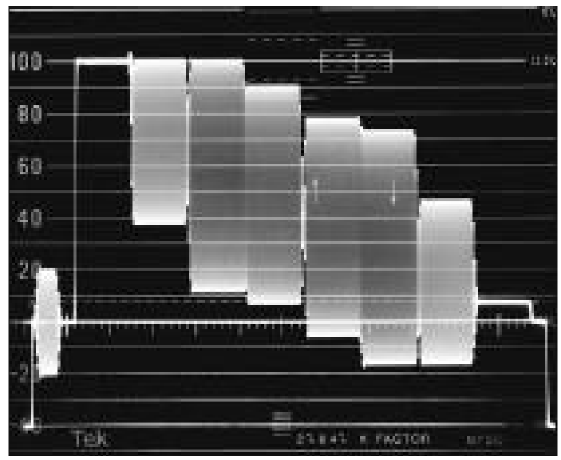


Figure 5-4. Full-field, 75% color bars signal with 100% white reference.

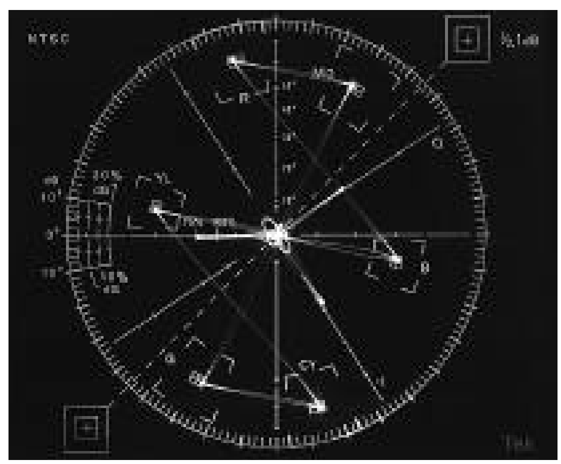


Figure 5-5. A vectorscope display of a SMPTE color bars test signal. All of the dots should be in their boxes when the color burst is aligned with the horizontal axis.

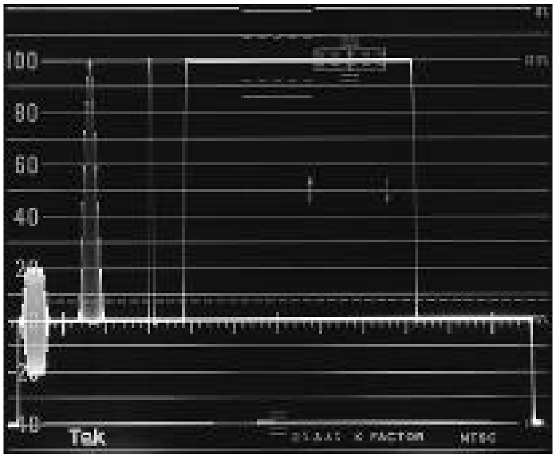


Figure 5-6. The line bar in this pulse and bar signal is used to check for low-frequency distortions at the line rate.

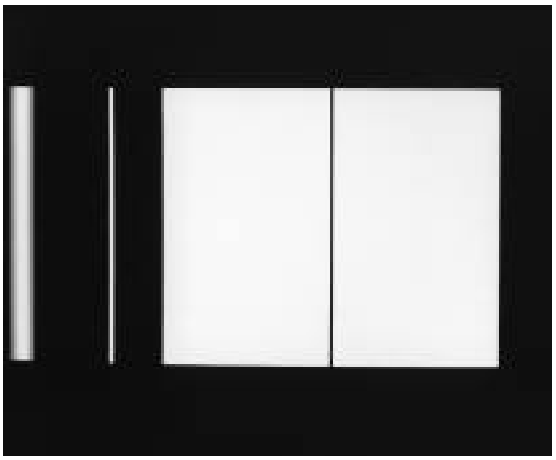


Figure 5-7. The windowed pulse and bar signal is used to check for low-frequency distortions at the field rate.

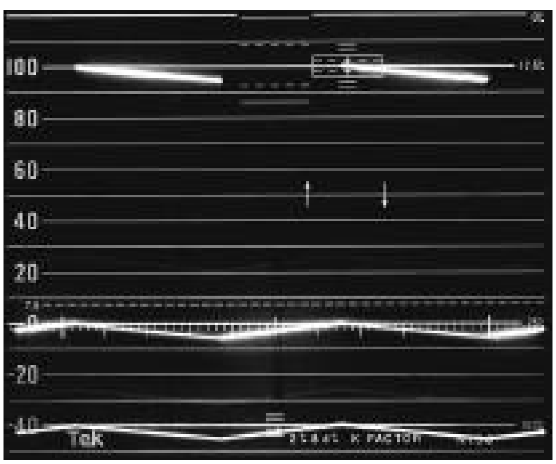


Figure 5-8. Waveform monitor display of a windowed pulse and bar signal showing about 6% field-time distortion.

If the color vector dots do not fall within their boxes, you'll need to make chrominance gain or phase adjustments on the equipment under test. When the dots are beyond the boxes, toward the display edges, chrominance amplitude is too high. If the dots fall short, toward the display center, chrominance is too low. If the dots are rotated out of their boxes, chrominance phase is incorrect relative to color burst and needs to be adjusted on the equipment under test.

If all of the dots cannot be adjusted to fall in their respective boxes, other distortion errors exist in the system. These could include frequency response errors or other gain or linearity errors. Finding and correcting these errors requires further testing and adjustments by a qualified service technician.

Frequency Response Testing

For optimum performance, the frequency response of the entire video system should be as flat as possible. Frequency response testing determines how flat the system actually is. If the system is not flat, signal amplitudes will become distorted as a function of frequency. For example, the system may attenuate higher frequency components more than lower frequency components or vice versa.

For test purposes, television signals are divided roughly at 1 MHz into low- and high-frequency ranges. Even though some of the most important signal information falls below 1 MHz — namely synchronizing pulses, general brightness level, and some active video — low-frequency testing is often neglected. This can be a troublesome and costly oversight.

You should routinely check system response in the low-frequency range. Low-frequency testing is further divided into line time and field time distortions. A line bar, such as the one found in the pulse and bar signal (Figure 5-6) is used for checking for line-time distortions. Field-time distortion testing is done with either a field square wave or a windowed bar signal.

The pulse and bar signal provided by the TSG 170A is a windowed signal, consisting of 130 lines of the pulse and bar signal in the center of the field. On a picture monitor, this creates the window effect shown in Figure 5-7. If the video path can faithfully convey this signal, you can assume that the system's low-frequency response is satisfactory.

To check field-time distortion, the waveform monitor should be set for a two-field sweep in the flat-response mode. Also, the dc restorer should be in either slow-restore mode or turned off.

If the video path's low-frequency response is correct, you should see perfectly flat horizontal lines. Any tilt in these lines, such as shown in Figure 5-8, represents a field-rate impairment. Such an impairment would cause brightness variations between the top and bottom of the picture. Provided there is no insertion gain error, the field-time distortion can be measured as the percent variation from the normal flat level, excluding the first and last 0.2 milliseconds of the bar.

Similar observations are made with the line bar signal for line-rate response problems. Any tilt in the line bar would produce brightness variations between the left and right sides of the picture. With active video, line-time distortion produces horizontal "streaking" — usually seen as light and/or dark streaks extending to the right of horizontal transitions in the picture. In quantifying this measurement, exclude the first and last microsecond of the bar, since distortions near the transition occur at frequencies above the line rate.

If your equipment exhibits line time or field time distortions beyond the limits specified by the manufacturer, it must be serviced by a qualified technician. There are no external adjustments for either low frequency response or high frequency response errors.

Response to higher frequencies, those above 1 MHz, is often checked with a multiburst test signal. Response problems above 1 MHz can cause impairments in either or both the chrominance and monochrome detail of pictures.

The multiburst signal tests response by applying packets of discrete frequencies ranging from about 500 kHz to 4.2 MHz. The Tektronix TSG 170A NTSC Television Generator provides the multiburst signal shown in Figure 5-9.

The multiburst signal is composed of six frequency packets. The second packet from the right has a frequency of 3.58 MHz and is used to check color subcarrier response characteristics. Notice also that the multiburst signal starts with a low-frequency signal (bar, sine wave, or, as is the case in Figure 5-9, a square wave). This low-frequency signal is used as an amplitude reference in measuring the relative amplitudes of the other packets.

Be aware there are many different configurations of multiburst signals — this test signal has a long history and meets many differing needs. When testing a VTR, you should use a reduced amplitude (60 IRE vs. 100 IRE) multiburst signal. This is to avoid intermodulation between the multiburst frequencies and the FM recording system in the VTR. Such intermodulation can cause signal distortions even when there actually is nothing wrong with the VTR. Also, when evaluating multiburst amplitudes, you need to take into consideration the VTR's specified bandwidth. This can be significantly less than 4.2 MHz, which means that you should expect to see attenuation of the high-frequency packets.

For multiburst measurements, the waveform monitor should be set to a one- or two-line sweep and flat response. For a perfect system response, the multiburst display would show all packets as having the same peak-to-peak amplitude. Any significant amplitude variations in packets indicate a frequency response variation — it is an error only if it is outside the equipment's specifications. Some video equipment, such as distribution amplifiers or switchers, may pass the multiburst packets with very little frequency response distortion.

The response at a specific frequency can be expressed as a percent of nominal value or in decibels. Either method of expression is based on peak-to-peak amplitude measurements.

Again, the absolute frequency response is often not the issue of greatest concern. Instead, the response relative to a particular specification or to earlier measurements is used to indicate equipment performance. A difference between past and present response measurements is a sign of equipment performance changing and may indicate a need for service.

High-frequency rolloff, such as shown in Figure 5-10, is probably the most common type of response distortion. When this occurs, luminance fine detail is degraded. Many VTRs will show a much greater rolloff and still be within specifications.

High-frequency peaking is another type of distortion. This is shown in Figure 5-11. It is usually caused by incorrect equalizer adjustment or misadjustment of some other compensating device. This problem causes noisy pictures — you see sparkles and overly emphasized edges.

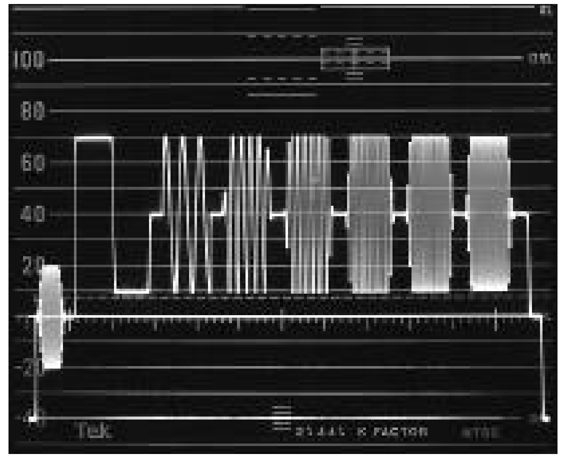


Figure 5-9. To display this multiburst signal, the waveform monitor is set for one-line sweep and flat response. This signal shows a flat response for high frequencies (500 kHz to 4.2 MHz).

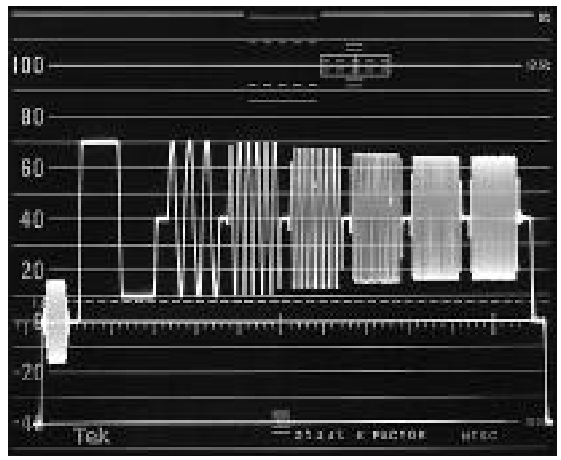


Figure 5-10. High-frequency rolloff is apparent in this multiburst signal display. The maximum error occurs where the signal is about 50 out of 60IRE, which is -1.6 dB.

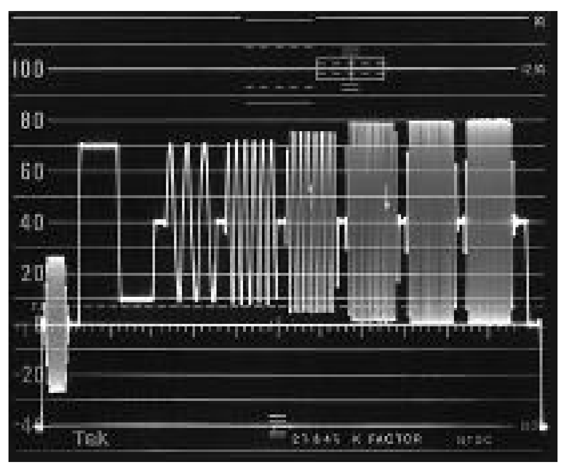


Figure 5-11. This multiburst signal suffers from high-frequency peaking. The maximum error occurs where the signal is 80 IRE instead of the nominal 60 IRE (1.3dB increase).

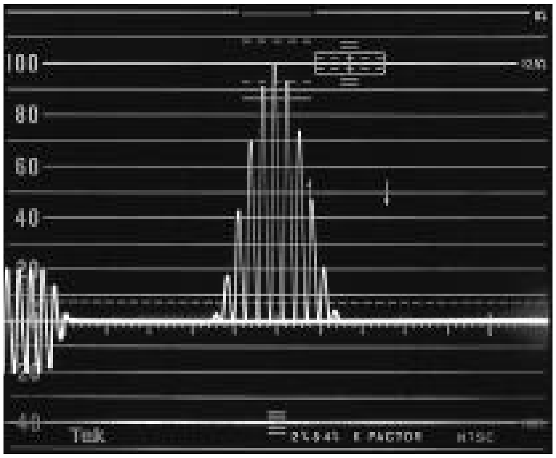


Figure 5-12. A 12.5T chrominance pulse, shown in the center of this display, is used to evaluate chrominance-to-luminance gain and delay errors. For zero gain and delay errors, the negative peaks of this modulated sine-squared pulse should line up on the pulse baseline.

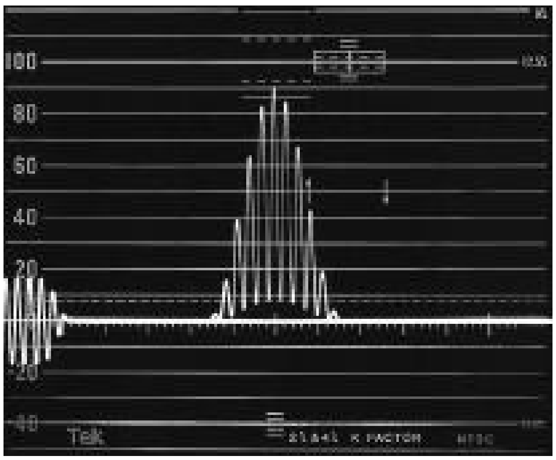


Figure 5-13. A single, symmetric peak in the chrominance pulse baseline indicates a chrominance-to-luminance gain error. This example shows an error of about 20%.

Center-frequency dipping or peaking can also occur. When this affects a broad range of frequencies, it can be detected with the multiburst signal. On the other hand, peaking or dipping may only affect a narrow range of frequencies. When this is the case and the affected frequencies occur between multiburst packets, the distortion can go undetected by this test technique.

To catch such narrowband response problems, a sweep signal or other continuous-band response measurement technique is needed. Fortunately, narrowband peaking or dipping does not occur often. And when it does occur, it can be detected as noticeable ringing on sync pulses or other sharp signal transitions. Such ringing indicates the need for more thorough response evaluation using frequency sweep, multipulse, or (sin x)/x pulse techniques. To learn more about these techniques, refer to Tektronix publications *Using the Multipulse Waveform to Measure Group Delay and Amplitude Errors* (20W-7076), and *Frequency-Response Testing Using a (Sin x)/x Signal and the VM700A Video Measurement Set* (20W-7064).

Chrominance to Luminance Gain

When a signal passes through a video system, there should be no change in the relative amplitudes of chrominance and luminance. In other words, the ratio of the chrominance and luminance gains, which is sometimes referred to as *relative chroma level,* should remain the same. If there are relative chroma level errors, the pictures color saturation will be incorrect.

Relative chroma level is checked by measuring chrominance-to-luminance gain. Measured gain-ratio errors can be expressed in IRE, percent, or dB. When chrominance components are peaked relative to luminance, the error is a positive number. When chrominance is attenuated, the error is negative.

Measurements are made using the special chrominance pulse shown in Figure 5-12. This pulse is the modulated 12.5T sine-squared pulse which is included in many combination test signals. For example, it's included in both the pulse and bar and NTC 7 Composite signals provided by the TSG 170A NTSC Television Generator. The pulse and bar signal also includes a line bar and a 2T pulse.

The chrominance pulse consists of a low-frequency, sine-squared luminance component that's been added to a chrominance packet having a sine-squared modulation envelope. These combined pulse components have characteristics that allow gain and phase errors to be seen as distortions of the pulse baseline. In the case of Figure 5-12, there are no errors and the baseline is flat.

Figure 5-13 shows what happens when there's a relative chroma level distortion. The upward bowing of the baseline (the negative waveform peaks) indicates that chrominance is reduced relative to luminance. If chrominance were increased relative to luminance, the baseline would bow downward.

Chrominance-to-luminance gain error can be measured directly on the waveform monitor graticule. This is done by comparing the peak-to-peak amplitude of the chrominance component of the 12.5T pulse to the normalized white level reference bar. In the case of Figure 5-13, the chrominance amplitude is 80 IRE, indicating a 20% error. This measurement approach is valid only if there is no low-frequency amplitude distortion and there is negligible chrominance-to-luminance delay.

A chrominance-to-luminance gain error is easy to correct if the equipment under test has an external chroma gain control. If it does, simply adjust the chroma gain control for a flat chrominance pulse baseline. If it does not, the equipment must be serviced by a qualified technician.

Chrominance-to-luminance delay, on the other hand, is a more common error. Its presence is indicated when the chrominance pulse baseline has a sinusoidal distortion such as shown in Figure 5-14. When there is delay error only, the sinusoidal lobes are symmetric and the pulse amplitude should match the white level reference bar amplitude (100 IRE). This is the case shown in Figure 5-14. Asymmetrical lobes along with peaking or attenuation of the pulse amplitude indicate the presence of combined gain and delay errors.

Since there are no user adjustments for chrominance-to-luminance delay on composite NTSC equipment, correcting this problem requires a trip to a local service center.

Measuring chrominance-to-luminance delay is beyond the scope of intermediate video system testing. However, you can learn about these more advanced measurements by referring to Tektronix publications *Television Measurements For NTSC Systems* (063-0566-00) or *Using the Multipulse Waveform to Measure Group Delay and Amplitude Errors* (20W-7076).

Nonlinear Distortions

Thus far, the focus has been on distortions having equal effects for signals of differing amplitudes. These are linear distortions because the amount of signal distortion varies linearly with signal amplitude. In other words, a linear distortion causes the same percent error on a small signal as on a large signal.

Nonlinear distortions, by contrast, are amplitude dependent. They may be affected by changes in Average Picture Level (APL) as well as instantaneous signal level. In other words, nonlinear distortion causes different percent errors depending on signal amplitude. An overdriven amplifier, for example, causes nonlinear distortion when it compresses or clips signal amplitude peaks. Since APL changes should be taken into account, more definitive measurement results can often be obtained by using a generator, such as the Tektronix TSG 170A, that provides test signals at several different APLs. When using such a generator, run the test with at least two APLs, one low and one high, and report the worst result.

The three remaining measurements to be discussed in this section fall into the category of determining the degree of signal linearity (or nonlinearity). These are the tests for luminance nonlinearity, differential gain, and differential phase. These can be conducted with test signals provided by the same signal generator used in the previous tests, the Tektronix TSG 170A NTSC Television Generator.

Luminance nonlinearity

The luminance nonlinearity test is used to determine if luminance gain is affected by luminance level. This measurement is also referred to as differential luminance.

Luminance nonlinearity errors occur when the video system fails to process luminance information consistently over the entire amplitude range. When the progression from one brightness level to another is nonlinear, the accuracy with which the picture display brightness levels in the nonlinear range is affected. For example, shades of gray that should be distinct may appear the same.

Luminance nonlinearity can be evaluated using a staircase signal having five or ten steps, with or without high-frequency modulation. However, the modulated staircase may give a different measure of luminance nonlinearity — the high-frequency signals may affect the lower-frequency processing. The TSG 170A contains both a five-step luminance staircase and a five-step modulated staircase (contained in the NTC 7 Composite signal). The five-step luminance staircase and the NTC 7 Composite signal are shown in Figures 5-15 and 5-16, respectively.

Figure 5-14. A sinusoidal distortion of the chrominance pulse baseline indicates that chrominance is either advanced or delayed relative to luminance.

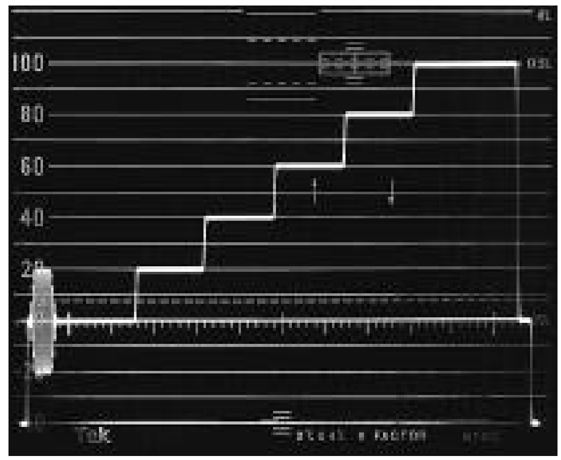


Figure 5-15. The five-step luminance staircase signal is used to measure luminance nonlinearity.

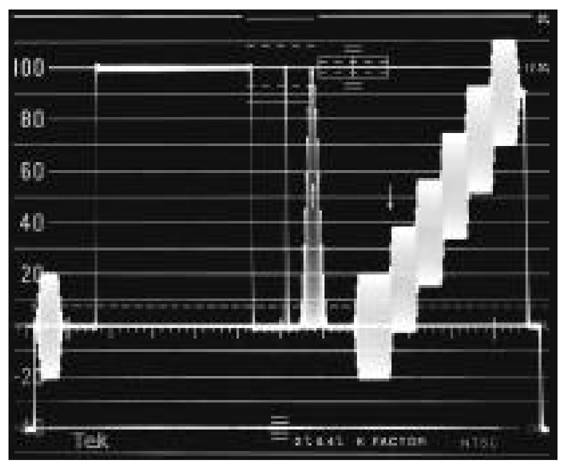


Figure 5-16. The five-step staircase of the NTC 7 Composite test signal can also be used to measure luminance nonlinearity. To make the measurement, though, the waveform monitor’s filter must be set to low-pass to remove the chrominance information.

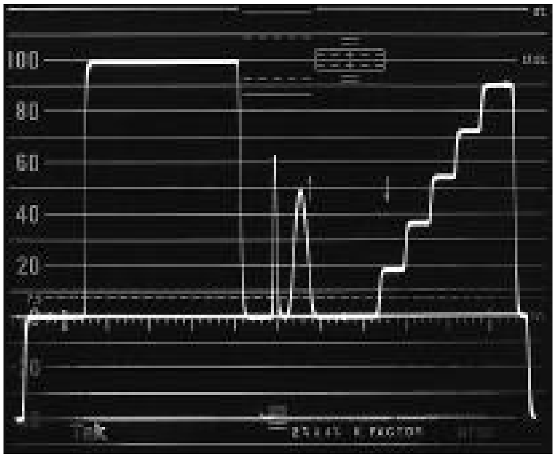


Figure 5-17. With the waveform monitor in low-pass filter mode, the undistorted modulated staircase appears as five luminance levels with equal steps.

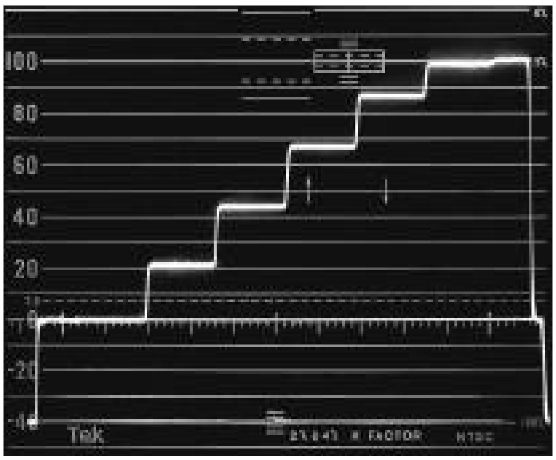


Figure 5-18. This staircase shows increased gain (taller steps) around the middle of the luminance range and decreased gain (shorter steps) at the highest luminance level. The maximum linearity error on this signal is about 30%.

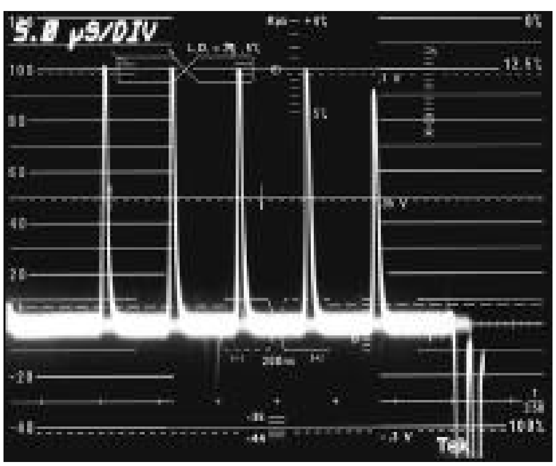


Figure 5-19. This differentiated staircase, which is displayed on the 1780R Video Measurement Set, shows a luminance nonlinearity of about 10%.

To make the luminance nonlinearity measurement on the waveform monitor using a luminance staircase, ensure the waveform monitor's filter selection is set to flat. When making the measurement on a modulated staircase, you must first engage the low-pass filter (LPASS). This eliminates the high-frequency modulation, as shown in Figure 5-17 (but remember, it does not eliminate it from the equipment under test). Then calculate the nonlinearity error as the difference in height between the largest and smallest steps. The error is then expressed as a percentage of the largest step.

In Figure 5-18, for example, the largest step covers about 23 IRE, and the smallest step covers about 16 IRE. From these two values, the luminance nonlinearity error is computed to be 30%. This is a fairly large error that was chosen simply for the purpose of illustration.

More precise measurements can be made by using the waveform monitor's X5 magnifier to expand the steps. With X5 magnification, a 20 IRE step vertically covers 100 IRE on the graticule scale. By positioning the waveform vertically, you can view each step individually over the full graticule for high-resolution measurements.

Some waveform monitors — such as the Tektronix 1780R — include a differentiated step filter. This filter can be used for luminance nonlinearity measurements on an unmodulated staircase signal.

The differentiated step filter converts each step to a spike of a height proportional to the step height (Figure 5-19). Any variations in step height become immediately apparent as changes in spike heights. By using the waveform monitor's variable gain control, the largest spike can be set to 100 IRE and the percent nonlinearity error can be read directly from the graticule.

If the amount of luminance nonlinearity measured exceeds the manufacturer's specifications, the equipment requires service or repair.

Differential gain

Differential gain testing allows you to determine when chrominance gain is being affected by luminance level. Differential gain, sometimes referred to as diff gain or dG, occurs when a video system doesn't process the chrominance signal consistently at all luminance levels. This can cause unwanted chrominance amplitude increases and decreases, all in the same signal. In other words, chrominance can be too high at one luminance level and too low at another.

Differential gain causes color saturation to have an unwarranted dependence on luminance level. This is seen in the television picture as saturation being affected by variations in brightness. When a colored object moves from sunlight to shade, for example, the color intensity will increase or decrease abnormally.

A five-step modulated staircase, found on the NTC 7 Composite signal, can be used to measure differential gain with either a waveform monitor or a vectorscope.

A modulated ramp, available in the TSG 170A, can also be used, as well as a 10-step modulated staircase.

To make measurements on a waveform monitor, set the instrument for one- or two-line sweep with the chrominance filter selected. This filter passes only the 3.58 MHz chrominance signal and eliminates the luminance steps. Also, for convenience, adjust the gain control so the maximum peak-to-peak amplitude of the signal is 100 IRE. Disregarding the color burst signal, the top and bottom of the chrominance signal should be flat, as shown in Figure 5-20. If differential gain is present, packet amplitudes will not be uniform, as shown in Figure 5-21.

To determine the amount of differential gain, find the difference in peak-to-peak values for the largest and smallest packets of the distorted signal. The difference is then expressed as a percentage of the larger number. For example, the differential gain in Figure 5-21 is about 20%. This is a fairly large distortion, used for purposes of illustration.

You can also use a vectorscope to check differential gain. On the vectorscope, the modulated staircase will appear as shown in Figure 5-22.

To evaluate differential gain, adjust the vectorscope's variable gain so that the dot representing the staircase chrominance touches the graticule circle (Figure 5-22). (If undistorted, the staircase chrominance will overlay the burst vector — they are each 40 IRE p-p at reference phase at the generator.) Any horizontal elongation of the dot is due to differential gain.

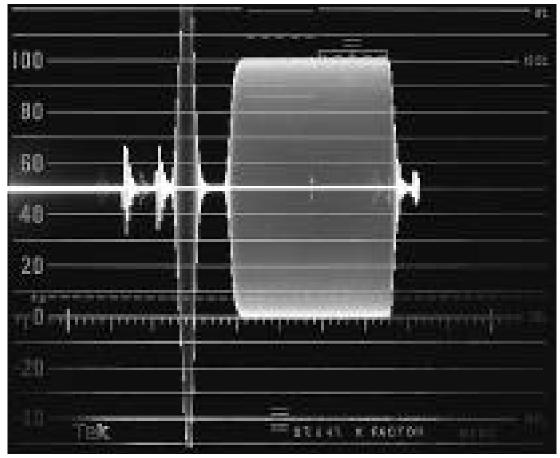


Figure 5-20. The waveform monitor's chrominance filter eliminates varying luminance levels from the modulated staircase or ramp signal. Theflat top and bottom of this chrominance signal indicate an absence of differential gain.

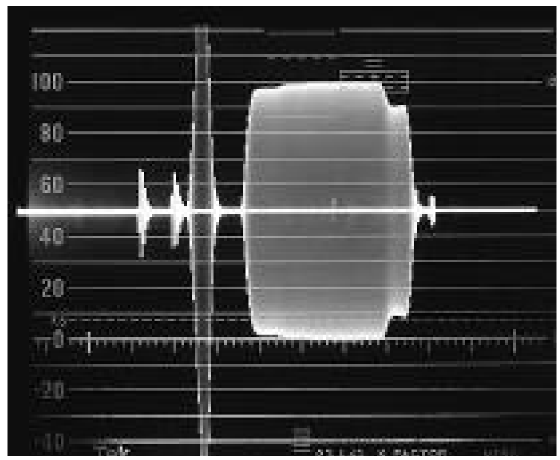


Figure 5-21. This waveform monitor display of a chrominance-filtered modulated staircase shows top and bottom distortions representing a differential gain of about 20%.

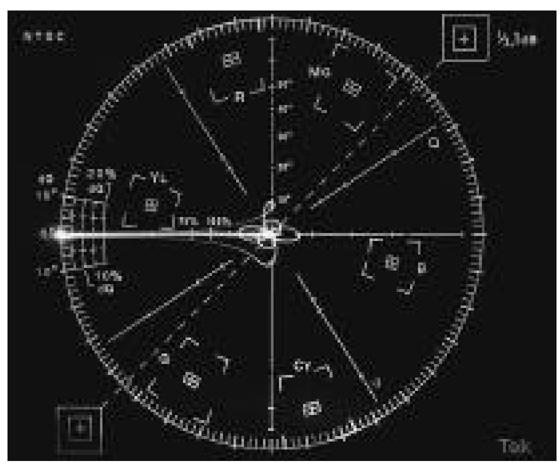


Figure 5-22. This vectorscope display of a modulated staircase test signal shows little or no differential gain. The vectorscope's variable gain has been increased for this measurement.

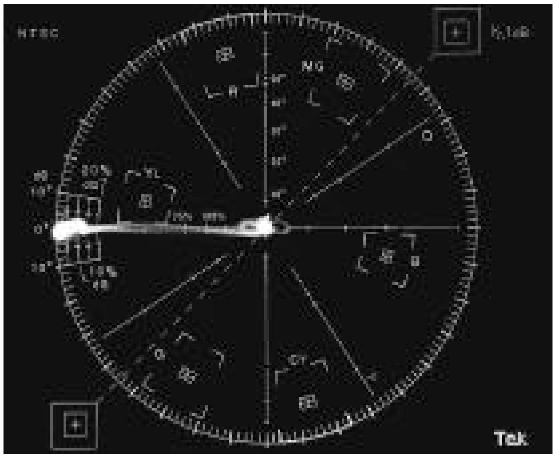


Figure 5-23. Elongation of the chrominance vector dot indicates about 15% differential gain.

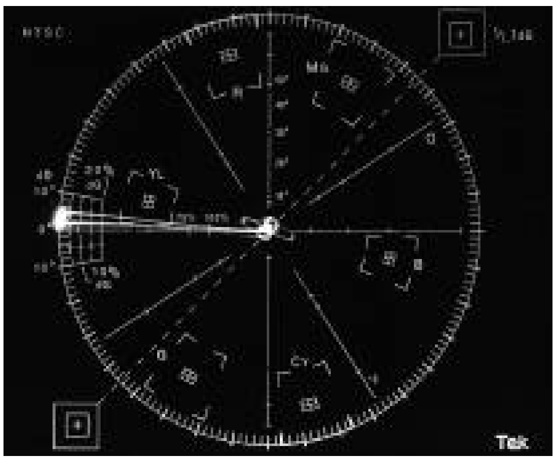


Figure 5-24. Widening of the chrominance vector dot along the graticule circumference indicates 5 degrees of differential phase.

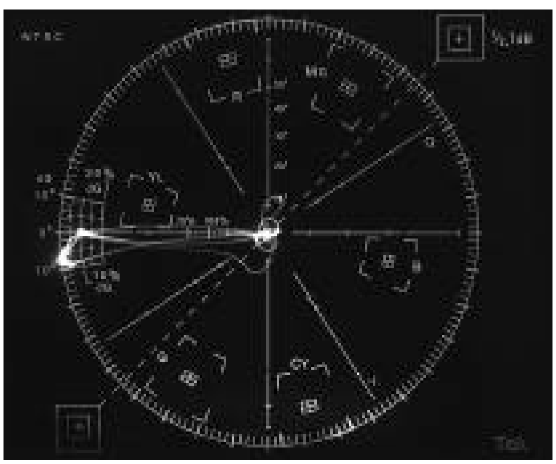


Figure 5-25. This display shows simultaneous differential gain and phase of about 10% and 9 degrees.

Most vectorscopes have special graticule marks, such as shown in Figure 5-23, to help measure the amount of differential gain. These graticule markings allow you to measure fairly large amounts of distortion. But for more precise measurements, especially on smaller amounts of distortion, you'll need a more sophisticated measurement tool with a special DIFF GAIN mode. The Tektronix 1780R Video Measurement Set, for example, provides a DIFF GAIN mode.

Differential gain, like other nonlinear distortions, cannot be corrected by a simple front panel adjustment. Internal adjustments or repairs are necessary to correct excessive amounts of diff gain.

Tektronix has produced a videotape that provides further details on differential gain and how to measure it. You can obtain this videotape by ordering *Tektronix Television Division Measurement Series #1, "Differential Gain"* (068-0330-04, NTSC VHS).

Differential phase

Measuring differential phase determines whether chrominance phase is affected by luminance level. Differential phase, also referred to as diff phase or dP, occurs when the video system fails to process chrominance consistently at all luminance levels. This is similar to differential gain, except luminance level changes affect chrominance phase rather than gain.

Differential phase causes the chrominance signal phase to either lead or lag the desired phase. Such phase errors cause colors to change hue when picture brightness changes. For example, when an object moves from sunlight to shadow, it appears to change color. The incorrect reproduction of color is most likely to occur in the high-luminance portions of the picture.

Differential phase can be tested using the same five- or ten-step modulated staircase signal used for differential gain testing. For digital systems, however, the modulated ramp signal is generally preferred.

Measurements are made using a vectorscope. As with differential gain, the vectorscope's variable gain is adjusted so the end of the modulated staircase vector touches the graticule circle. Any widening of the dot along the graticule circumference represents differential phase. This can be measured using the special graticule marks provided on most vectorscopes (Figure 5-24).

Higher resolution measurements, however, need to be done with a more sophisticated vectorscope having a DIFF PHASE mode. A DIFF PHASE mode is provided, for example, on the Tektronix 1780R Video Measurement Set. The VM700T Video Measurement Set also provides a DG DP mode for automatic measurement of differential gain and phase. This is particularly convenient since differential gain and phase often occur simultaneously, as shown in Figure 5-25.

Correcting differential phase, like differential gain, requires servicing by a qualified technician.

Tektronix has produced a videotape that provides further details on differential phase and how it is measured. To obtain this videotape, order *Tektronix Television Division Measurement Series #1, "Differential Phase"* (068-0331-04, NTSC VHS).

Conclusion

To maintain optimal signal quality, regular system testing is a must. The tests described in this booklet, while not exhaustive, do detect most of the distortions commonly responsible for picture quality problems. More importantly, these tests can warn you of impending problems that may not yet be visible as actual picture impairments.

It's wise to establish standard test procedures for each system and document the results from each test. Such test histories allow you to spot system deterioration trends even before the video signal violates acceptable limits. The reward for this effort will be video productions of consistently high technical quality while avoiding costly reshoots and reediting.

Beyond Bars — Other Tests and Test Signals

Most folks consider them obnoxious. After all, who hasn't dozed off watching late-night television only to be startled by the blare of the 400 Hz tone — you know, the one after the tranquility of "The Star Spangled Banner" — accompanying the video test signals used to check systems after programming finishes? It's hard to expect viewers to appreciate, especially at 4 a.m., that those annoying pictures and sounds are for their benefit.

Color bars are the most ubiquitous of all test signals. When not following a TV station sign-off, they are most often perceived as a preprogram place holder — something like a blank electronic film leader. But, as technical pros know, color bars provide both serious at-a-glance confirmation of signal path completion and confidence of video signal acceptability.

Merely observing bars on a TV monitor, however, is a subjective assessment. The monitor will display a signal problem, but it reveals little about the source, nature or degree of the signal impairment. To extract detailed information about video signal fitness requires careful examination of one or more test signals on a waveform monitor and/or vectorscope.

Color bars are only one of many test signals. Test signals are precisely defined electronic signals that serve as performance measurement benchmarks. The purpose of each signal is to make one or more types of video distortion easy to see and quantify.

Testing 1, 2, 3

The principles behind video signal testing are quite simple. The output of a test signal generator is applied to the input of a piece of video equipment or distribution system. The test signal, after passing through the components, is displayed on a waveform monitor and vectorscope. Any significant change in the signal becomes fairly conspicuous, and the type of change gives many clues about the possible source of the problem.

Color bars are handy for setting up such equipment as time base correctors, or TBCs. However, measuring the performance, such as the bandwidth of a TBC, requires more specific testing. Periodic measurement of overall system performance helps spot minor problems before they grow into noticeable picture problems. The result is consistently higher picture quality.

What test signals ensure video signal quality? Color bars are most obvious. They monitor or measure several amplitude, timing and color parameters. However, no one test signal defines all of the amplitude and timing relationships of the NTSC signal. Signal path impairments and system performance are often best detected with several types of test signals. You'll find the most common of these signals in the Summary of Video Test Signals chart.

The types of signals suited for an application depend mainly on two factors: the environment and the video format.

Standard values

Most studio, production and post facilities use a variety of equipment and systems. These require a broad corresponding selection of signals for setup, maintenance and calibration.

Calibrating a picture monitor requires SMPTE color bars and a crosshatch (convergence) signal. Color bars are used to set chroma, hue and brightness adjustments. The convergence signal helps align the red, green and blue beams. The multiburst signal is used to check the picture monitor's horizontal resolution.

Observing technical values within a system on a waveform monitor or vectorscope requires a generator with test signals such as pulse-and-bar, modulated staircase, multipulse or multiburst. However, evaluation with each test signal is time consuming.

Combination signals, such as NTC 7 Composite, FCC Composite and NTC 7 Combination, contain two or more test signals as elements on each video line. Each element of a combination signal is basically a narrow version of regular signals, allowing two or more to fit side by side on a single line of video.

Many generators also produce matrix test signals that combine two or more different signals in a single field of video. Different matrix signals are available for transmission and system testing and picture monitor setup applications. A matrix typically consists of 40 or more consecutive video lines of one signal followed by the same number of lines of the next signal, throughout the active video lines of a field.

Like the combination signals, matrix signals speed the process of equipment and system evaluation and adjustment. With several signal types, you can observe multiple problems (or the absence of multiple problems) without changing the test signal.

Continuous technical monitoring of a source is enhanced with Vertical Interval Test Signal (VITS) insertion. By including one or two test signals on unused lines in the vertical interval, you can make objective judgements about the extent of the signal degradation instantaneously, at any point in the program. Most TV stations and networks use VITS to monitor and evaluate technical parameters without interrupting programming.

Once you've decided which signals and formats you need, there are still more considerations for choosing a test signal generator. Space is always important; usually the smaller the generator's package size, the better, provided the unit supplies the signals you need. Depending on the complexity of the facility, other video gear in the system may need to be genlocked. Some test signal generators eliminate the need for an extra distribution amplifier (DA) by providing multiple black burst outputs.

System performance checks require only a few other signals. The NTC 7 Composite and Combination signals or a system test matrix signal can provide all components necessary for quick checks of system linearity, insertion gain, frequency response, differential phase and gain, chrominance-to-luminance gain and delay, and other short- and long-time distortions.

More than test

Other signals and functions provided by test signal generators can simplify several routine production tasks. A safe-title/safe-action-area signal helps operators position and size the critical parts of a scene so they don't appear somewhere off the edge of the presentation screen. Blacking tapes is a task that some generators can reduce to the push of two buttons. (You need only press Record on the VTR and select a countdown sequence on the generator.)

Evaluating the performance of 2-wire (Y/C) or 3-wire analog component systems requires special signals in the appropriate component form, in addition to the composite signals. Bowtie is an essential signal for 3-wire component systems designed specifically for precise amplitude and timing adjustments. An economical alternative to multiple test signal generators is a multi-format generator with signals in NTSC, Y/B-Y/R-Y and Y/C formats.

Cameras usually don't require external test signals, but in the studio they must be genlocked to the system. In smaller facilities or Electronic Field Production (EFP) applications, a generator with multiple black burst outputs might eliminate the need for a separate master sync generator or DA. A black burst input to a production switcher is commonly used as the source of black for a fade-to-black.

Distribution distortions

Distribution paths can be subject to myriad distortions. A distribution path may be as simple as a camera output looped through a monitor to a switcher and terminated, or as complicated as a 1,000-machine duplication system. That's why multipurpose combination signals, such as the FCC and NTC 7 Composite and the NTC 7 Combination, are so widely used as VITS in transmission testing.

Multiburst (which is part of the NTC 7 Combination signal), multipulse and (sinX)/X are all used extensively for frequency-response testing of various distribution systems. Multipulse and (sinX)/X indicate group delay as well, but (sinX)/X requires a spectrum analyzer or automated video measurement set for display. Big ticket items, such as spectrum analyzers or automated measurement systems, often aren't a liability, because many other standard transmission and distribution tests require these instruments. To optimize performance, particularly in this era of higher-resolution formats, good test equipment is a basic requirement, not an option.

Maintaining performance

Maintenance areas have some special requirements. Flexibility is the key, as the proliferation of interconnect and recording formats continues.

It's not uncommon to find composite NTSC gear in use with component analog or Y/C gear. Although all of this gear has NTSC inputs and outputs, equipment in each video format requires test signals in the same format to fully exercise its circuitry. In addition to the luminance and color difference signals primarily used with component analog video equipment, the time-compressed versions (CTCM or CTDM, the actual recording formats used) must also be available.

Serial digital video is finding favor as an interconnect format within many video facilities. With it comes the need for yet another test signal format and, of course, new testing issues. Serial digital requires the same analog test signals — you simply need to convert them to the new digital format and add a number of very complex digital goodies to the vertical interval.

Operational equipment in need of routine maintenance or troubleshooting can't always go to the shop. So, with the proper signals and formats, a small, lightweight package can make it a lot easier to bring the tools to the problem.

The economics of testing

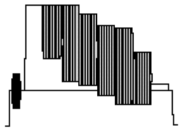
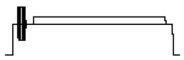
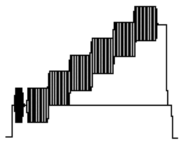
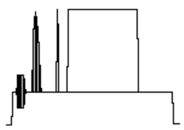
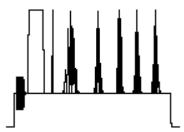
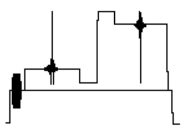
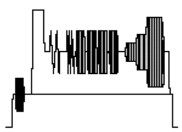
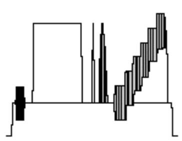
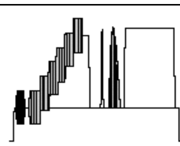
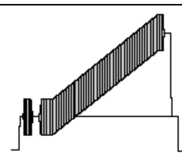
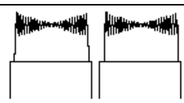
One thing is certain today — viewers expect high video quality, all the time.

Gone are the days when a single, snowy TV channel was revered as a miracle of modern technology and occasional problems from technical difficulties were tolerated. Today, home viewers fix technical difficulties on their own without leaving their armchairs by switching channels with remotes. Viewers of corporate and other nonbroadcast video have similar expectations and reactions, except instead of tuning out with a remote control, they tune out their brains.

Reliable, high-quality, uninterrupted video — the type clients pay for — requires extensive testing and preventative maintenance to catch and fix declining system performance before visible picture impairment occurs. Once quality starts to slip, so will the attention of your viewers, as well as future business from your clients.

Producing video without adequate test and measurement gear is as risky as driving a car at night without headlights. Today's digital-based test signal generators provide many high-precision signals in small, economical packages. Waveform monitors and vectorscopes come in a variety of affordable packages, and sometimes both functions are combined for even greater economy. With compact, easy-to-use gear, the serious video producer can't afford not to use test equipment every day.

Summary of Video Test Signals

Test Signal	Signal Shape	Use and Benefits
Color Bars		General amplitude and timing measurements. Most widely available test signal. Used in all aspects of system setup and testing from ENG/EFP units to the broadcast transmitter.
Black Burst		Commonly used for synchronizing video gear. Also used for noise measurements.
Multiburst		Contains packets of six different frequencies. Used for basic frequency-response checks of equipment and distribution paths in ENG/EFP and studio work.
Modulated Staircase		Available in 5- and 10-step forms. Tests differential gain/phase and luminance linearity. Used in ENG/EFP, studio and distribution.
Pulse and Bar		Used for amplitude, timing, and distortion measurements. Modulated pulse portion tests chrominance-to-luminance gain and delay. Used in ENG/EFP, studio and distribution.
Multipulse		Contains pulses modulated at different frequencies for comprehensive measurement of amplitude and group delay errors over the video baseband. Especially important for transmitter testing.
(Sin x)/x		Provides frequency-response and group-delay test coverage of all baseband frequencies. Can be used as a VIT signal, making it ideal for in-service transmitter testing.
NTC 7 Combination		Combines multiburst and modulated pedestal for frequency-response and distortion tests. Designed for distribution and transmission system testing.
NTC 7 Composite		Contains various signal elements allowing amplitude, phase and some distortion measurements. Designed for studio and distribution testing. Rise time too fast for broadcast transmitter use.
FCC Composite		Offers the same uses and benefits as the NTC 7 Composite signal. Its slower rise time makes it appropriate for VITS use with broadcast transmitters.
Modulated Ramp		Used the same as modulated staircase but provides finer-grained results.
Sweep		Provides a continuous sweep of video baseband frequencies, usually with embedded 1 MHz markers. Used for detailed frequency-response testing, but not VITS compatible.
Bowtie		Component analog video (CAV) test signal used for high-precision measurement of component channel gain and delay inequalities.

The Color Bars Signal —

Monochrome Video

The information to reconstruct a black and white image is relatively easy to understand — each point in the image is scanned in the familiar line pattern and at each point along the line the camera produces a voltage representing the amount of light at that point. The rapid succession of points scanned — and the corresponding succession of signal voltages — creates the video waveform. This waveform is "one dimensional," i.e., only one piece of information is needed for each point in the image.

Color Video — History

The situation gets quite a bit more complex with color video. The problem with color video is it's not one dimensional, but three dimensional — three pieces of information are needed for each point in the image.

There are several ways to convey information about color. Most take advantage of a characteristic of human vision known as the tristimulus theory — we can satisfactorily reproduce a wide range of color using only three colors of light mixed in certain ways. Color photography and color printing are based on these same ideas — three filters, three dyes, three inks, etc. (The four-color printing process uses black ink in addition to make dark or gray areas in the image easier to control.)

While other combinations are possible, there are some practical reasons for choosing Red, Green and Blue (RGB) as the three "primary" colors for a color video system. In fact, the earliest color television systems used three cameras, scanning in parallel, each with a Red, Green or Blue filter over the lens to produce color video. The display also used multiple images, filters and optics to combine the Red, Green and Blue images into one full-color picture.

The Color Bars Signal — RGB

Setting up a system with three cameras, three video transmission paths, and three displays is a chore! Matching the three channels to "track" from black to peak brightness is especially important. Test signals have been developed for this sole purpose. In this RGB system, each video path is normalized so the signals match at black level (zero light) and at peak level (maximum light). A good test signal consists of a square wave with black and peak levels in each of the three channels. If the square waves are timed differently in each channel, all combinations of high and low levels in the channels are exercised (Figure 7-1). Since there are three channels, each with two possible levels, there are two cubed (eight) possibilities. These eight combinations exercise the primary colors individually (Red, Green, and Blue), the secondary colors (combinations of two primaries: Yellow, Cyan, and Magenta), White, and Black. The colors (color bars) are arranged in order of decreasing total brightness: White, Yellow, Cyan, Green, Magenta, Red, Blue, Black. The color bars signal is useful in setting up a RGB-color video system, and it gives a pleasing image that also conveys some indication of the "health" of the color video system.

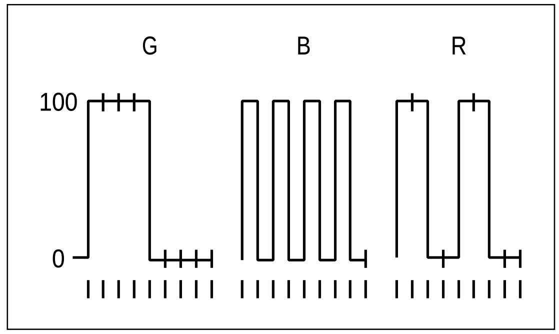


Figure 7-1. Video waveforms of the three channels for RGB-color bars (100% bars).

Encoded color — NTSC

The RGB system, with parallel full-bandwidth video in three channels, makes excellent pictures but has several practical disadvantages. Perhaps the most severe is the very wide bandwidth needed in broadcast service or over other long interconnect paths.

There have been several attempts at "compressing" color video information so it is more practical to record, interconnect, and broadcast. The winner, by far, is the NTSC system developed in the early 1950s. This "encoding" scheme manages to put the essential parts of the three-dimensional color signal into the spectrum needed for a monochrome signal — putting it all in one path. (Work is still continuing today with complex digital filters, advanced modulation techniques and "smart" compression algorithms, but these are beyond the scope of this tutorial.)

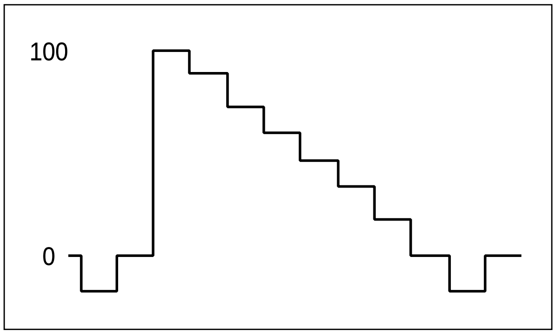


Figure 7-2. Color bars luminance signal (100% bars).

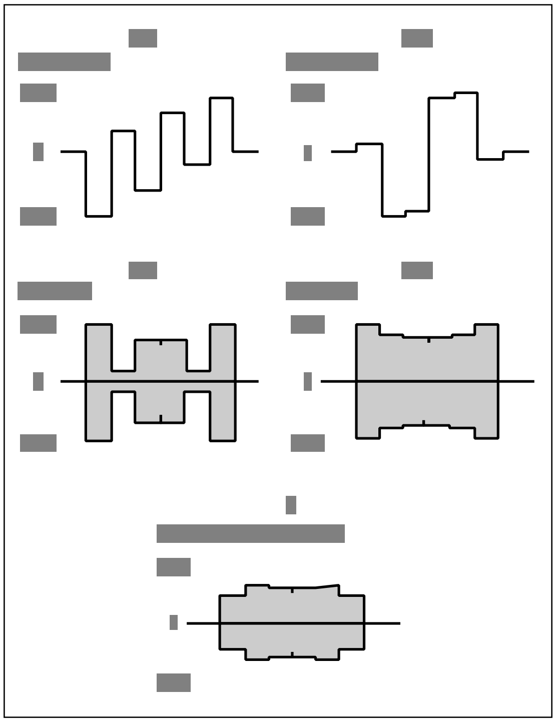


Figure 7-3. Unmodulated and modulated color difference signals and modulated chrominance for color bars.

NTSC must still maintain three information paths, inherent in the nature of color. The specific set of three signals, however, is changed from RGB to a more manageable set. The three NTSC signals are *Luminance*, and two *Color Difference* components.

The symbol used for luminance is “Y.” It is closely related to movement in the “y” direction in a common x vs y graphical representation of color. The color difference signals also contain Y and one of the primary colors — usually B-Y and R-Y. For example, B-Y is the Blue video signal minus the luminance signal.

Luminance

The NTSC luminance component is very much like the signal for monochrome video — containing information about the amount of light in each element of the picture. This is one of the key reasons the NTSC system is “compatible” with older monochrome equipment — monochrome sets simply ignore the color information and display using luminance only.

Luminance is derived from RGB color signals. While the tristimulus theory requires three different colored lights, it does *not* imply that each light contributes the same amount to our perception of brightness of a point in the image. In fact, for the particular colors chosen (a certain Green, a certain Blue, and a certain Red), Green contributes about 59% of our perception of brightness in a white part of the image. The Red light contributes about 30%, and Blue only about 11% of the brightness of white. These numbers are called the luminance coefficients of the primary colors. (A certain color of white must be chosen as well, but that and the math involved are beyond our scope here.)

The luminance signal is produced by combining (adding) the video signals from each primary color channel, taking into account the luminance coefficients of each primary, i.e., Y = 0.59G + 0.30R + 0.11B. If the input signal for this process is a RGB color bars signal, the resulting luminance video waveform is the familiar decreasing “staircase” shown in Figure 7-2.

Note the steps in this staircase are not equal amplitude — they depend on the luminance coefficients. Consider, for example, the Green to Magenta transition (in the center of the bars waveform). The luminance level for Green is 59%. Magenta consists of Blue and Red only, its luminance value is 0.11 + 0.30 = 0.41 or 41%. The amplitudes of the other levels may be similarly calculated.

Color difference signals — B-Y and R-Y

Once the luminance signal is available, it takes only a little more processing to derive the color difference signals. For example, if luminance is subtracted from the B component of the RGB video the result is B-Y. This process, and the parallel one that produces R-Y, are fairly easy to accomplish with electronic circuits. (Sometimes, another set of color difference signals were used — I and Q. We’ll discuss I and Q a little later.)

With the color information now in the form of luminance (Y) and color difference components (B-Y and R-Y) we still have three signals and the associated bandwidth and interconnect problems. A bit more processing is needed to get it all into the “‘one-wire” NTSC signal format.

Encoded color (NTSC)

Another characteristic of human vision is we can’t see fine detail nearly as well for changes in coloring as we can for changes in luminance. In other words, the picture won’t suffer very much if we reduce the bandwidth of the coloring components, provided we can maintain essentially full bandwidth of the luminance signal. In fact, this is a good reason for developing color difference components in the first place.

Even a full bandwidth luminance signal doesn't have very much energy in the upper end of its spectrum — the higher frequency signals are quite a bit lower amplitude almost all the time. These two facts (less bandwidth required for the color information and some "room" available in the luminance spectrum) allow the NTSC system to place the color components in only the upper portion of the luminance spectrum.

Color subcarriers

The technique for getting the R-Y and B-Y signals moved up in frequency is amplitude modulation — a carrier (subcarrier) is modulated by each of the color difference signals. Remember, there are two different signals, so two carriers are needed. Both signals are at the same frequency (about 3.58 MHz) but are maintained in phase quadrature (90 degrees apart) so the B-Y and R-Y information can be kept separated. This process is known as Quadrature Amplitude Modulation (QAM). Balanced modulators are also used so the carriers themselves are suppressed at the modulator output. Only the sideband energy generated in the modulation process is saved. This modulated color difference information is usually called *chrominance.*

The NTSC composite signal

When luminance and chrominance are combined, the result is the NTSC composite color signal. Figure 7-3 shows the B-Y and R-Y signals for color bars and the resultant envelope at the output of each modulator, as well as the combined chrominance envelope containing both B-Y and R-Y information.

Some adjustment of amplitudes is needed when the luminance and chrominance signals are combined. Figure 7-4 shows the result if the signals for full-amplitude bars are combined without these adjustments. Note the peak level of the chrominance is very much above 100% white luminance. This signal will be seriously distorted in passing through a video system, especially a system originally designed for handling monochrome signals. In Figure 7-5, the level of B-Y is reduced by a factor of 2.03 and R-Y level is reduced by a factor of 1.14. These specific factors are chosen to limit the peak of the waveform to 100% white level with a 75% amplitude bars signal (Figure 7-6). This 75% bars signal has become the most common for testing NTSC systems. (Refer to the discussion of various bars signals on pages 2-2 and 6-1.)

Conclusion

There are several aspects of the generation of NTSC video signals that underlie recommended monitoring and test methods.

1. Luminance and Chrominance are a "matched set" and must remain balanced in amplitude and timing in order to accurately reconstruct the RGB signal (and the color picture).
2. The color difference components are only kept separate by differences in subcarrier phase. Small phase distortions can create large color distortions in the end picture.
3. Chrominance information is all at the upper end of the video spectrum and maintaining frequency response flatness throughout the system is critical.

The color bars signal, whether in RGB or NTSC form, offers a known, accurate signal that exercises the practical limits of the color video system.

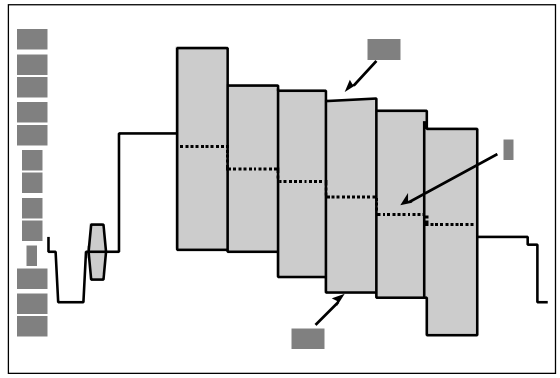


Figure 7-4. Full amplitude bars without gain adjustments.

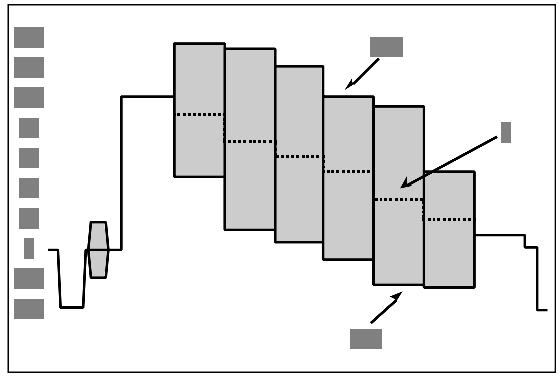


Figure 7-5. Full amplitude bars.

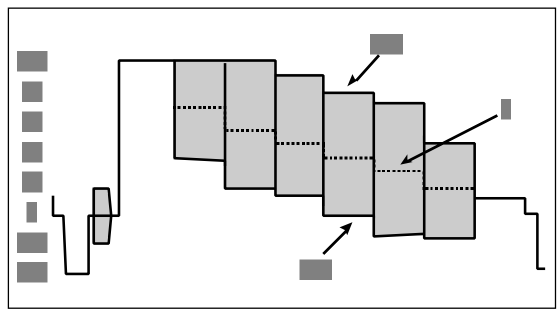


Figure 7-6. Corrected 75% bars signal (with 100% white).

Glossary

audio signals — XLR connectors provide dual-channel audio signals. The left channel can be set to click as a means of easily distinguishing the left channel from the right channel in audio tests.

average picture level (APL) — The average signal level with respect to blanking during the active picture time. APL is expressed as a percentage of the difference between the blanking and reference white levels.

chrominance — The color information in a television picture. Chrominance affects two properties of color: hue and saturation. Also called chroma.

chrominance-to-burst phase — The difference between the expected phase and the actual phase of the chrominance portion of the video signal relative to burst phase.

chrominance-to-luminance delay — The difference in time that it takes for the chrominance portion of the video signal to pass through a system relative to the time it takes for the luminance portion. Also called relative chroma time.

chrominance-to-luminance gain — The difference between the gain of the chrominance portion of the video signal and the gain of the luminance portion as they pass through a system.

color burst — The burst of color subcarrier added to the back porch of the composite video signal. It serves as a frequency and phase reference for the chrominance signal.

composite video — A single video signal containing all of the necessary information to reproduce a color picture.

convergence — Used for adjusting convergence of the green, blue and red beams on picture monitors.

decibel — A logarithmic unit that expresses the ratio between a signal and a reference signal. For voltages, dB = 20 log ($V_{measured}/V_{nominal}$).

differential gain — Variation in the gain of the chrominance signal as the luminance signal on which it rides is varied from blanking to white level.

differential phase — Variation in the phase of the chrominance subcarrier as the luminance signal on which it rides is varied from blanking to white level.

frequency response — A system's gain characteristic versus frequency. Frequency response is often stated as a range of signal frequencies over which gain varies by less than a specified amount.

graticule — The calibrated scale for quantifying information on a waveform monitor or vectorscope screen. The graticule can be silk-screened onto the CRT face plate (internal graticule), silk-screened onto a piece of glass or plastic that fits in front of the CRT (external graticule), or it can be electronically generated as part of the display.

horizontal blanking interval — (See artwork below.)

insertion gain — The gain (or loss) in overall signal amplitude introduced by a piece of equipment in the signal path. Insertion gain is expressed as a percent (V_{out} - V_{in})/V_{in} x 100.

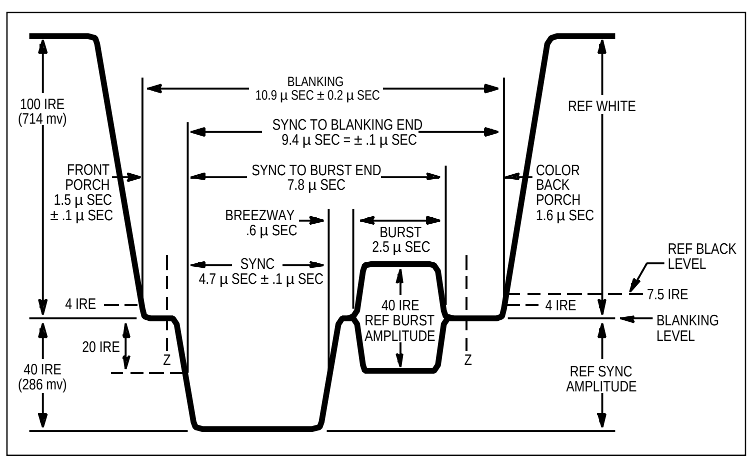


Figure 8-1. Horizontal blanking interval.

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