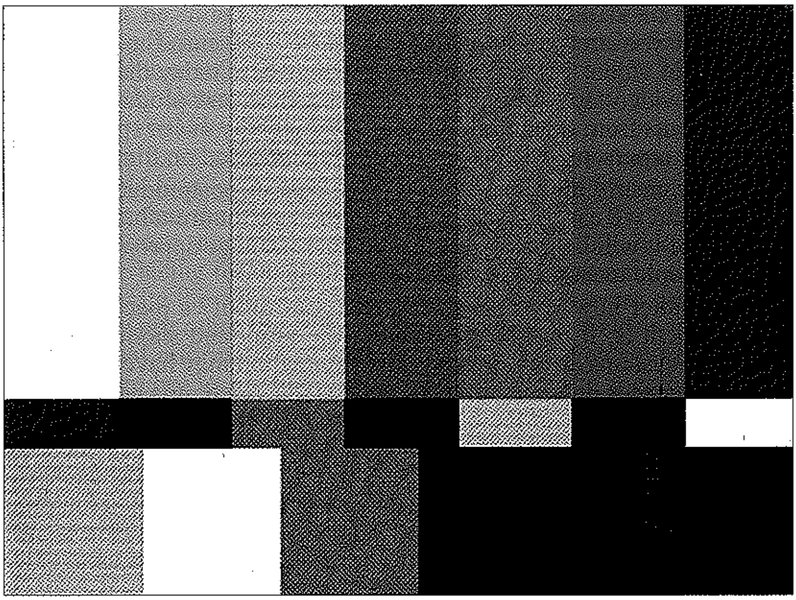


video and high def

BASICS OF VIDEO

Even if you are purely a film person, it is essential to know the basics of video. There is hardly a set anywhere today that does not have a video tap monitor and often directors and producers make judgments from that monitor even when is badly out of specs and in no way represents what is actually being recorded on film or tape.

Today, nearly all editing and a great deal of postproduction is on video and we can envision a time in the near future when virtually 100% of it will be. Moreover, as the High Def age approaches, even film people must think ahead to the changeover.

No matter how well designed and "goof proof" a piece of video equipment is, it is still not a matter of "point and shoot." Even if certain systems are automated, this automation may have unwanted consequences down the line. To understand video, it is necessary to have an overview of the basic video signal. Black-and-white television broadcasts began in 1936 in Britain and in 1939 in the U.S. Standard television had a 4:3 aspect ratio. This matched the standard film projection frame of the time — a format going back to the time of Edison and Dickson. Over 60 years later this aspect ratio is still in use today, even though film has undergone many changes. Only now is there a move toward a wider 16 x 9 format.

THE VIDEO SIGNAL

NTSC is the name for the method used to transmit television signals in North America. It is named for the name of the group that sets the broadcast television standards in North America — the National Television Standards Committee, originally formed to standardize the method for color television broadcasting. The method chosen (augmenting the existing black-and-white composite video signal) was standardized in 1953 and is still the standard for North America and Japan.

The NTSC was given the mandate to introduce color to the television system without affecting the black-and-white system then in use. It was considered essential that people who owned black-and-white televisions not have to replace them and that color signals be viewable on these black-and-white monitors. While a laudable goal (and one that probably accelerated the acceptance of color) it caused the committee to impose certain engineering standards which still cause trouble today. Because the color signal had to be more or less "crowbarred" into the black-and-white signal, some very odd things had to be done which make the color signal variable and difficult to control.

Certainly if you have ever been in a TV store and seen how nearly every set is a different color (even similar sets from the same manufacturer) you know how deeply ingrained this problem is. Many people refer to NTSC as "Never Twice The Same Color."

Originally, black-and-white television had a frame rate of 30fps, which was half of the standard 60 hertz of the national power grid. When color was introduced, this was found to be a problem; as a result, the frame rate of NTSC video is 29.97 frames per second. It is 0.1% slower than the original 30 frames per second, to avoid interference with the color subcarrier part of the signal.

The scanning electron beam starts at the top left of the picture tube and scans one horizontal line. When it reaches the right hand side of the picture, the beam drops down and writes the next line. In the early television systems, this process of writing 525 lines created a very noticeable flickering because it takes 1/30th of a second for the whole frame to be scanned. 1/30th of a second is below the threshold level of persistence of vision.

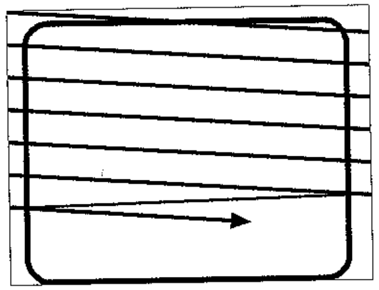
12.1. (previous page) SMPTE 75% color bars — one of the most basic references in video.

You must be thinking: "But film is 1/24th of a second and we don't notice flicker there." Almost true. Film is shot at 24 frames per second. (With a 180° shutter this makes an exposure time of 1/50th of a second.) However, it is not *shown* at 1/24th of a second. If it was, there would be a noticeable flicker.

Projectors have a blade which passes across each frame as it is shown. This breaks each projected frame into two frames as seen by the eye: thus the film is being projected at 48fps. To reduce this flicker in video, engineers developed a system of "interlaced scanning." Interlacing means that as the beam scans down the screen it does not write the whole picture; instead, it writes every other line skipping every other line. This is called a field. A field is one half of the visual information of each frame. The two fields portray the same image but as alternate lines. The two of them together compose one video frame which is 1/30th of a second. Field one consists of all of the odd-numbered lines #1, #3, etc. Field two contains the even numbered fields #2, #4, etc. (Figure 12.2).

After field one is scanned for all the odd-numbered lines, a vertical sync pulse returns the scanning beam to the top of the picture tube and then scans all of the even-numbered lines. The persistence of the CRT phosphor is long enough that the first field remains displayed while the second is being written.

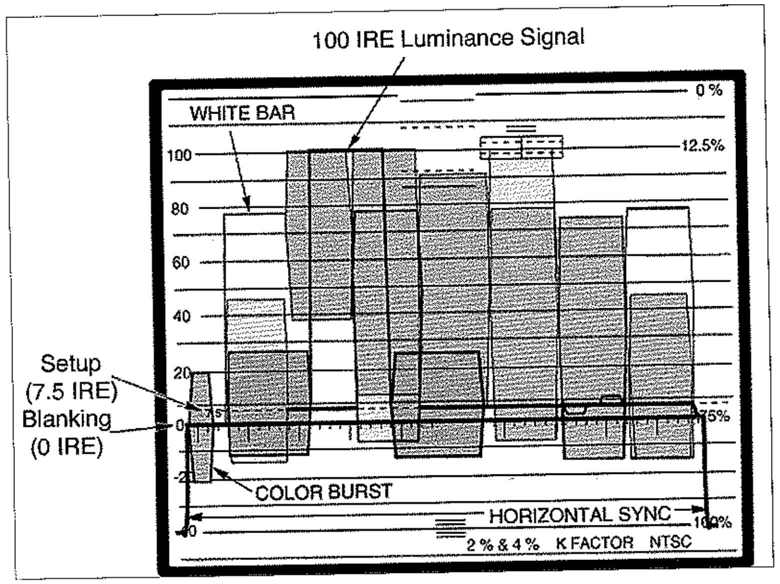
In NTSC, each frame is made up of 481 horizontal lines (240.5 lines per field) that are visible (sometimes called "active") plus another 44 lines (22 per field) that are blanked. These lines are blanked because they occur while the scanner beam is traveling back up to the starting point at the top left of the screen. If the beam was not blanked, there would be a smearing effect. This makes a total of 525 lines per frame. There are types of electronic information that come together to form a complete video image. Together they are called the television composite waveform, more commonly referred to as composite video (Figure 12.3).



12.2. Horizontal scanning on a video monitor.

THE COMPOSITE VIDEO SIGNAL

Early on the Institute of Radio Engineers divided this signal into units, called IRE units. It is now the IEEE — Institute of Electrical and Electronic Engineers, but most people in the field still call them IRE units. (IEEE is just too many syllables.) The basic signal 1 Volt Peak to Peak Video is divided up into 140 IRE units. This is done



12.3. Components of the NTSC video signal. For more information on interpreting this diagram, see the following illustrations of the waveform monitor signal.

to make numbers for luminance levels easier to communicate. The amplitude of the video signal from blanking (zero volts) to peak white is 0.714286 volts or 100 IRE units. Synchronization signals extend from blanking to -1.285714 volts or -40 IRE units. The eight elements of the composite video signal include:

- Horizontal line sync pulse
- Color reference burst
- Reference black level
- Picture luminance information
- Color saturation information
- Color hue information
- Vertical sync pulse
- Horizontal blanking

Horizontal Sync Pulse

Before each line is scanned a horizontal sync pulse sets the electron beam to a locked position so that each scan line starts at the same position during scanning. The horizontal sync pulse tells each scan line where on the screen to start, so they don't wander around from field to field (Figure 12.4).

Color Reference Burst

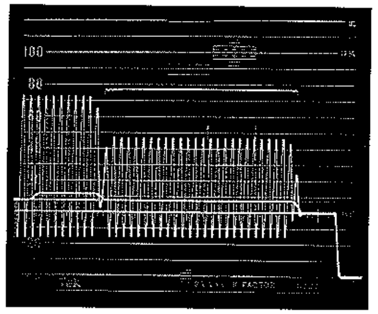
To insure standard hue and color saturation, a 3.58 megahertz color reference burst is added before the picture information on each scan line. It is a sine wave with eight to nine cycles. Its phase is set at zero.

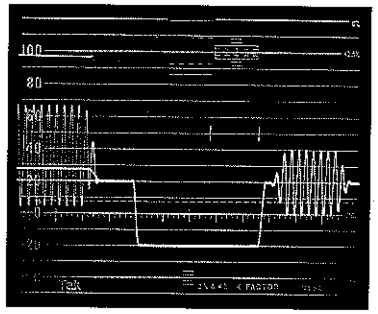
Reference Black Level

Black level is also called "setup" or "pedestal." Setup is one of the most basic adjustments we make to the video signal. It is variously called setup, pedestal or "picture" on a television set: but it's all the same thing — the lowest level of the video signal: basic black. Setup is 7.5 IRE units (Figure 12.5). For technical reasons it is not set at 0.0 units as one might expect. One critical difference between analog and digital video is that there is no setup in digital video; it is not necessary. All forms of digital video start at zero. This is because there is less chance for random variation, which the setup level is designed to protect against. Digital signals, at least at the processing level, are more controllable than analog signals. Once it gets to the display there is still variation.

12.4. (below) The sync pulse on the waveform monitor. (Photo courtesy of Tektronix.)

12.5. (bottom) The black reference level on the waveform. (Photo courtesy of Tektronix.)





Luminance

Luminance is the black to white range of the signal. It is the gray scale of the picture, without regard to color. Picture luminance ranges from 7.5 IRE units for black to 100 IRE units for peak white. This is what is called "legal video." Legal means that it is video signal that will work well on most monitors and television sets. It is important to understand that the video signal can go below 7.5 IRE and can go above 100, but this is liable to cause trouble in broadcasting or viewing.

But these limits are often exceeded, especially at the low end. "True black" that is 0 IRE units (0 volts on the signal) is a blacker black and gives a better picture. Cinematographers will often ask the telecine operator to "crush the blacks," meaning let the black end of the signal drop to near 0. This gives more contrast and a richer picture. (See the section on *Transferring Film to Video* later in this chapter for more on shooting gray scales and color bars in order to control your image in telecine.)

Color Saturation

Color information is interwoven with the black-and-white signal in the form of a 3.58 megahertz subcarrier. The saturation of the colors is determined by the amplitude of the subcarrier. The hue of the color is determined by comparing the phase of the subcarrier with the phase of the Color Reference Burst (see above).

Color Hue

As we recall from the chapter on color, hue is the spectral wavelength. It is what, in everyday language, we call "color." (See the chapter on *Color Theory.*) Color hue is also present in the 3.58 megahertz subcarrier. The accuracy of colors in the picture is determined by the phase or rotation of the color hue information.

Vertical Sync Pulse

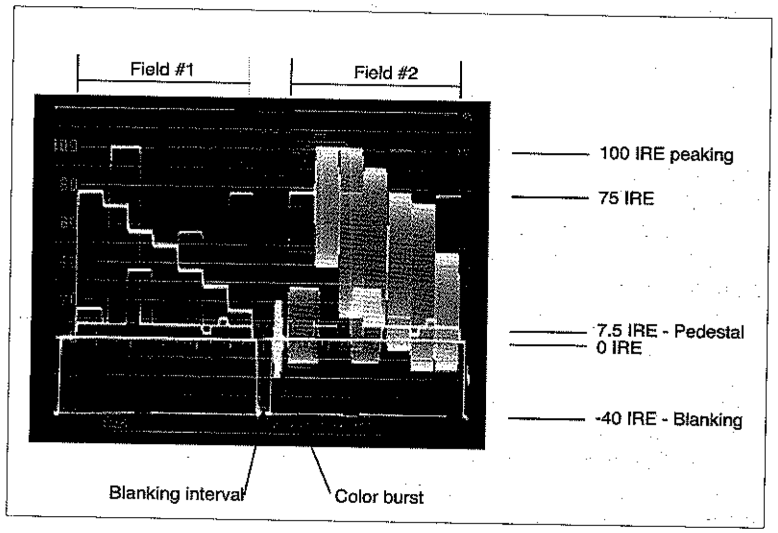
When the scanning beam reaches the end of the bottom line, it must return to the top to start the next field. If it was visible while it swung back, there would be ghosting; this was a problem in early TV. The vertical sync pulse controls the length of time of the vertical blanking interval. The vertical blanking interval is sometimes used for inserting timecode, automatic color tuning and captioning information in the video signal. Since it doesn't have to carry video information it is a good place to place other types of data.

Horizontal Blanking Interval

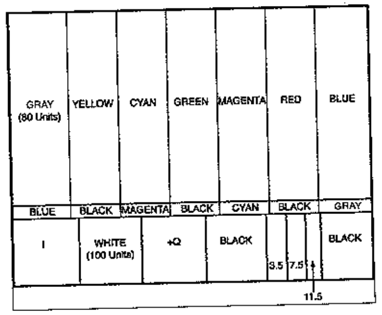
There is also a horizontal blanking interval which occurs between the end of one scan line and the beginning of the next. This blanking interval is controlled by the horizontal sync pulse. As with the vertical interval, the scanning gun is turned off while the beam swings back to the left of the screen so there is no ghosting. Contained in this interval are the horizontal sync pulse and color reference burst.

THE WAVEFORM MONITOR AND VECTORSCOPE

To see the various elements of the composite video signal two special test oscilloscopes are used — the waveform monitor and the vectorscope (Figure 12.6). On a video shoot, the waveform monitor is your light meter and the vectorscope is your color meter. Color monitors, even very sophisticated ones, can be notoriously unreliable, but information for the waveform and vectorscope can almost always be trusted. Lighting "to the monitor" can lead to disaster, even in High Def.

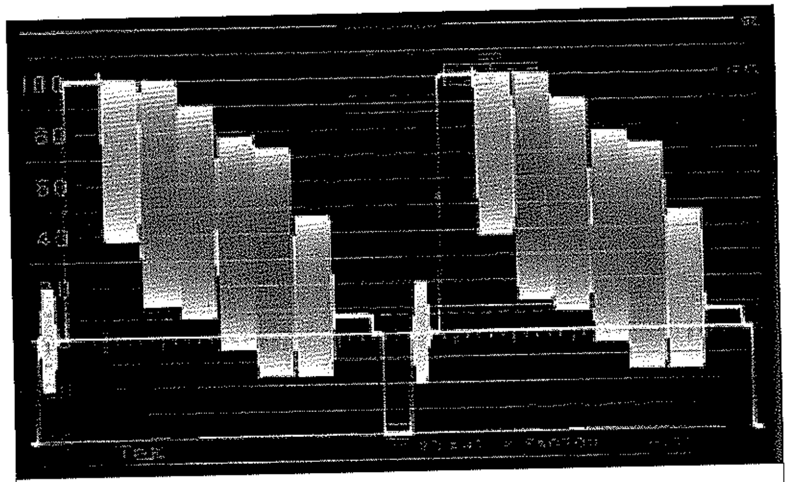


12.6. Video signal of SMPTE color bars on a waveform monitor. (Photo courtesy of Tektronix.)



12.7. (above) SMPTE 75% color bars in diagram form. See 12.1 for a full color representation of the color bars.

12.8. (right) These color bars on a waveform show both fields. They include both luminance and chrominance information, which is why they are "filled in." (Photo courtesy of Tektronix.)


This 75% color bar signal also includes a 100% white reference.

The waveform monitor displays the black-and-white video signal information. It allows you to analyze the information from an entire frame or from just one line of video. The waveform monitor displays the signal on a scale seen in Figure 12.6.

Signals that are below 7.5 units (pedestal) lose detail and those above 100 units (maximum white) are washed out and without detail. Peaking above this signal can cause other problems in the system as well. If there is skin tone in the picture and it is in the +50 to +80 range it should appear properly exposed.

SMPTE COLOR BARS

Standard reference color bars are shown in Figure 12.1. On the waveform monitor they appear as in Figure 12.8. Remember, the waveform monitor measures luminance or brightness only, not color. What is represented here is the luminance value of each section of the color bar plus chrominance (saturation).

On the set you might wonder why you couldn't just look at a standard video monitor to see if your picture is what you want. The problem is that an ordinary picture monitor is not a reliable guide to the signal you are recording or to how that picture will look in the finished videotape; for that matter, even a very expensive monitor (and high end video monitors can cost $20,000 and more) will not be a true representation if it is not set up properly.

Monitors can be manipulated in terms of brightness, contrast, color balance, even sharpness. There is just no guarantee that they represent a true image of what you are shooting or of what is on tap. (See section below on Setting Up a Color Monitor.) When used with a video camera, the waveform monitor is a reliable guide to exposure and contrast range. If the average value of important information in the picture is over 100 or under 7.5 IRE units, the exposure is off. (Note the phrase important information. Clearly deep shadows may fall near or below 7.5 and some highlights may exceed 100). This exposure can be adjusted by changing the camera's aperture and/or by adjusting the lighting or the composition of the frame (if, for example, a "hot" window is in the shot). In telecine, the waveform monitor gives an accurate picture of the signal that is going to tape.

In post production the waveform monitor works the same way only this time it measures the values of images from videotape or other online devices like character generators or special effects generators.

At this point the video signal can still be manipulated in a number of ways: we'll look at those in another section.

THE VECTORSCOPE

Used in conjunction with the waveform monitor, the vectorscope measures the chrominance (color) of the video signal (Figure 12.9). The scale of the vectorscope is a circle overlaid with the color amplitude and phase relationship of the three primary colors (red, green and blue). In the center of this circle graph is the luminance (black-and-white) value of the signal. Through this center point, three axes represent the primary colors.

The vectorscope screen for setup 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. Chroma phase error translates as "the color is off" as shown in Figure 12.10. Notice how color is conceptualized as a circle and we rotate the circle around its center to adjust the hue. This relates to the original Newton color wheel. Also, notice how not all of the target boxes are equidistant from the center reference. This is a reflection of the same principle we saw in the Munsell color system: some colors reach full saturation (full chroma) at different levels. Now you see why we had to go through all that technical color theory stuff.

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.

Proper white balance of a video camera is indicated by a fuzzy spot centered on the vectorscope display when the target or signal being displayed is a white object (Figure 12.16).

Chroma Gain

With the SMPTE color bars displayed the dots represent the peaks of chrominance. How far they are from the center indicates how much chroma gain there is; if they extend beyond the boxes, the chroma is too hot and can cause problems.

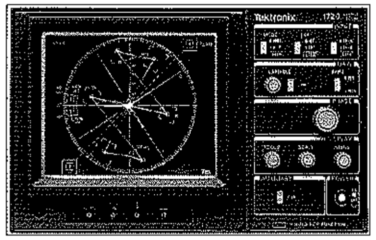
In post production, be it telecine transfer, off-line editing, on-line editing or tape duplication, the standard procedure is to record 60 seconds of color bars at the beginning of every tape. This insures that when processed and manipulated down the line, the colors will be the same from tape to tape.

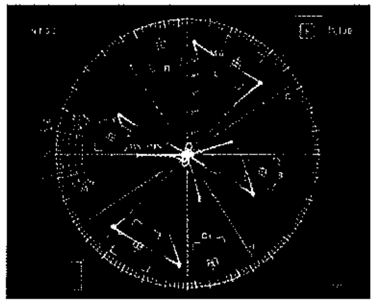
LUMINANCE AND COLOR

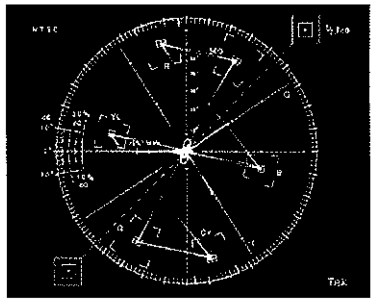
The NTSC luminance component is very much like the signal for monochrome video — containing information about the amount of light in each element of the picture. This is one of the key reasons the NTSC system is "compatible" with older monochrome equipment — monochrome sets simply ignore the color information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

Luminance is derived from RGB color signals. While the tristimulus theory requires three different colored lights, it assumes that each color contributes the same amount to our perception of brightness of an area 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







12.9. (top) The vectorscope. Think of it in terms of the color wheel. (Photo courtesy of Tektronix.)

12.10. (second from top) Hue error; notice how the color is shifted clockwise — the dots indicating the key hues are not in their proper boxes. (Photo courtesy of Tektronix.)

12.11. (third from top) Vectorscope showing correct chroma. The dots are in their boxes and also are not too far from or too near the center, indicating correct levels of chroma. (Photo courtesy of Tektronix.)

the brightness of white. As we recall from the discussion of the eye/brain perception of color — the eye is most sensitive to color in the yellow/green range, and much less sensitive in the blue range. These numbers are called the luminance coefficients of the primary colors. 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.

Color Difference Signals: B-Y And R-Y

To process all information as R, G and B is inefficient because each separate channel contains both color information and gray scale (luminance) information — this is redundant. As we recall from the chapter on color theory, black-and-white (gray scale) actually conveys the great majority of information about an image. For this reason, most video systems distill the chroma information into color difference signals. Luminance is notated as "Y," since "B" already stands for blue.

There are many systems in use, but basically, color difference is derived by taking the blue component and subtracting the luminance (gray scale) information: B-Y (blue minus luminance). Similarly, luminance is subtracted from red: R-Y. This process is fairly easy to accomplish with electronic circuits. (Sometimes, another set of color difference signals are 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

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.

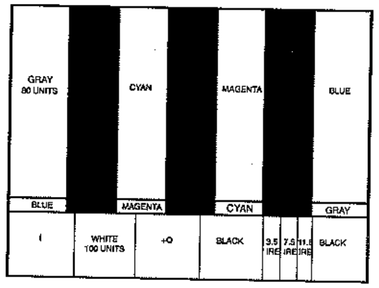
Even a full bandwidth luminance signal doesn't have very much energy in the upper end of its spectrum — the higher frequency signals are quite a bit lower amplitude almost all the time. These two facts (less bandwidth required for the color information and some "room" available in the luminance spectrum)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

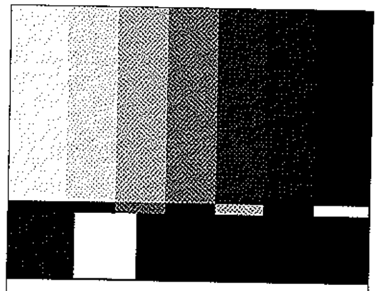
THE PROCESSING AMPLIFIER

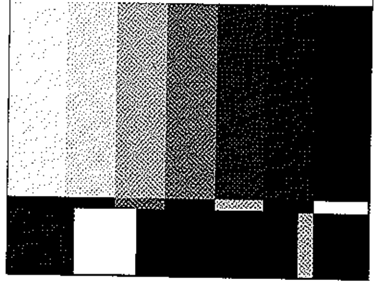
In addition to the waveform monitor and the vectorscope, the two most fundamental video tools, there is another — the processing amplifier. Commonly called a proc amp, this device can modify both the chroma and luminance values of the video signal. The proc amp should be used with both a waveform monitor and vectorscope to insure that the changes you are making are what you think you are making. As with most stages in the video system, it is just as easy to screw things up as it is to make them better.

This is similar to how you operate an ordinary household television. By adjusting color, contrast and the other controls, you can change the appearance of the picture. But you are not changing the actual signal of that picture — you are only changing the display of that signal. The proc amp lets you change the actual signal rather

than just the display. This makes it in some ways more valuable and in some ways more dangerous. The proc amp can be an invaluable tool for correcting the color and luminance elements of a video signal. However, it must be used in conjunction with a waveform monitor and vectorscope for predictable results.







12.12. (second from top) Diagram of blue only signal.

12.13. (third from top) Correct monitor setup, shown here in black-and-white.

12.14. (bottom) Incorrect luminance; notice how all three of the PLUGE bars in the lower right are visible.

SETTING UP A COLOR MONITOR

The most important thing you can learn about video is how to properly set up a color monitor. Even with other equipment such as a waveform monitor and vectorscope on hand, the monitor is still a crucial part of previewing and judging the picture. As we saw in the chapter on color theory, there is not an exact correlation between the mathematical representation of color and the human perception of it.

Color bars are an artificial electronic pattern produced by a signal generator which may be in a video camera (most professional video cameras have a "bars" setting) or a separate piece of equipment on the set or as a standard piece of equipment in any video post-production facility, be it telecine, editing or duplication. Color bars are recorded at the head of every videotape to provide a consistent reference in post production. They are also used for matching the output of two cameras in a multi-camera shoot and to set up a video monitor. On top on the left is a gray bar: it is 80 IRE units.

MONITOR SETUP PROCEDURE

To set up a monitor, start with the following steps:

- Allow the monitor to warm up.
- Shield the monitor from extraneous light.
- Display color bars on the monitor: either from the camera or a separate generator.
- Set the contrast (also called "picture") to its midpoint.
- Turn the chroma (also called "color") all the way down until the color bars are shades of black-and-white.

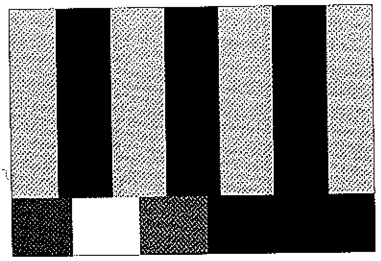
The PLUGE

Notice the three narrow bars labeled 3.5, 7.5 and 11.5 on the bottom right (Figures 12.12 and 12.14). These are the PLUGE, which stands for Picture Lineup Generating Equipment.

The PLUGE was developed at the BBC. It was generated at a central location in their facility and sent by wire to each studio. This way all of the equipment could be calibrated conveniently. This was the PLUGE alone, not combined with the color bars.

The middle black is set at 7.5 IRE black, (or in the digital realm, 16,16,16). The first chip, superblack, is set at about 2.5 IRE below black, and the third chip, dark gray is set at about 3.5 IRE above black. None of these really work to adjust a monitor to properly display 0 IRE black, so the following procedure is standard.

- Adjust the brightness control until the middle (7.5 units) PLUGE bar is not quite visible. The lightest bar on the right (11.5 units) should be barely visible. If it's not visible, turn the brightness up until it becomes visible.
- Since 7.5 units is as dark as video gets, you should not see any difference between the left bar (3.5 units) and the middle bar (7.5 units). There should be no dividing line between these two bars. The only division you should see is between 11.5 and 7.5. This same technique is used in setting the black-and-white viewfinder on a video camera.



12.15. Blue-only color bars shown in black-and-white for clarity. Notice that the bands are of equal intensity and in the upper portion the large and small bars are equally gray or black.

- The next step is to set the contrast control for a proper white level. To do so, turn the contrast all the way up. The white (100 unit) bar will bloom and flare. Now turn the contrast down until this white bar just begins to respond. The image below shows what it should look like at this point.

Adjusting Color

It is possible to "eyeball" the yellow and magenta. This is the "down and dirty" method and should only be used if other methods are not practical. The yellow should be a lemon yellow without orange or green. And the magenta should not be red or purple. This quickie method is not recommended except in emergencies; it is much better to do it the professional way.

Blue-Only Adjustment

Most professional monitors have a blue-only switch (Figure 12.15). This turns off the red and green guns, leaving only the blue. If your monitor does not have a blue-only switch, you can use a piece of blue gel (full CTB) or a Kodak Wratten #47 — the purest blue in the wratten series. View the monitor through the gel. If you see any of the red, green or yellow colors, double the blue gel over to increase the blue effect.

By using the blue-only switch or a piece of blue gel, you have removed the red and green elements of the picture. Only the blue remains. If the hue is correct, you should see alternating bars of equal intensity.

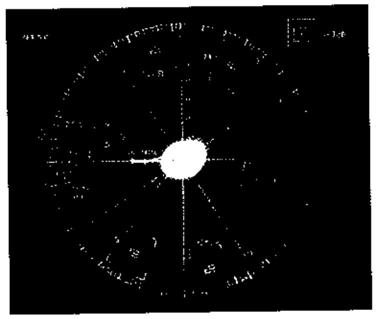
- With the blue switch on (or your blue gel in front of your eye) turn the chroma or color until the gray bar at the far left and the blue bar at the far right are of equal brightness. You can also match either the gray or blue bars with their sub-bars.
- Adjust the hue control until the cyan and magenta bars are also of equal brightness. You can also match either of them with their sub-bars. Now the four bars — gray, blue, cyan and magenta should be of equal intensity. The yellow, green and red (which are black in the diagram below) should be completely black. Here's a diagram (Figure 12.15) and in color (Figure 12.16.)

Once you have set up your monitor, leave it alone. Unless you have a waveform and vectorscope, it's the only instrument you have to see how accurate your video is. This is true of your camera viewfinder, your field monitor and your studio monitor.

CAMERA WHITE BALANCE

Just as we use film stocks of different color balance and camera filtration to adjust, in video, the white balance function compensates for variations in the color range of the source lighting. White balance is accomplished by aiming the camera at a pure white surface (usually a white card) and selecting the white balance function on the camera. The internal electronics then compensate for variations in color. Naturally, it is essential that the light illuminating the white card be the same as is in the scene, just as the light on a gray reference card in film must be the same as is on the scene.

12.16. (bottom) White balance on a vectorscope — no chroma. (Photo courtesy of Tektronix.)



Also, as in film, if you are using filters to alter the color, this must be removed for white balance or their effect will be erased by the white balance. The white balance function can also be used to "fool" the camera. If, for example, you want the overall color balance to be warm, you can put a cooling filter (blue) over the lens while doing color balance. The circuitry will then compensate and when you remove the filter over the lens, the image will then be warm. This works for any color tone you want to add and can be accomplished by placing a filter over the light illuminating the card just as well as over the lens.

EFFECT DESIRED	USE FOR WHITE BALANCE
85	Harrison Blue #5
81EF	Tiffen Cyan #2
Tiffen Coral #2	Harrison Blue #5
Harrison Coral #2	Tiffen Cyan #1 or Harrison Blue #2
Harrison Coral #3	Harrison Blue #5
Tiffen Straw .3	Tiffen 80C
Tiffen Straw .6	Tiffen 80B+80D
Fries Tobacco #1	Tiffen 82B
Fries Tobacco #2	Tiffen 82C
Fries Tobacco #3	Tiffen 80C
Fries Tobacco #4	Tiffen 80C + 82B
Fries Tobacco #5	Tiffen 80B + Cyan #1
Tiffen Sepia #1	Tiffen 82B
Tiffen Sepia #3	Tiffen 80C
Tiffen Chocolate #2	Tiffen 82C + Tiffen Cyan #1

Table 12.1. Using color gels to "fool" the white balance for desired effect. (Data courtesy of Fotokem Film and Video.)

The same technique can be used in film when shooting the gray card. Table 12.1 indicates filters which will produce a specific effect in white balance or shooting the gray card.

ANALOG AND DIGITAL COLOR SPACE - RGB, YUV, YCbCr

There are many different colorspace systems and notations used to derive and define color video, especially digital video. Color cameras analyze the image to create video signals for the three primary colors: Red, Green and Blue. Since each of these RGB signals carries part of the information in the image, and all are required to recreate a complete image, they are referred to as "components" of the color video.

ANALOG/DIGITAL CONVERSION

Conversion of the video signal from analog to digital occurs in three parts; signal preparation, sampling and quantization (digitizing). There are two types of component signals; Red, Green and Blue (RGB), and Y, R-Y, B-Y but it is the latter which is by far the most widely used in digital video. R-Y and B-Y, the color difference signals, carry the color information while Y represents the luminance. Cameras, telecine, etc., generally produce RGB signals.

Y'CBCR, YCBCR

Y'CbCr is the color space used for all digital component video formats. Y' is the luma component and the Cb and Cr components are color difference signals. Cb is B-Y and Cr is R-Y. The technically-correct notation is Y'Cb'Cr' since all three components are derived from R'G'B'. Many people use the YCbCr notation rather than Y'CbCr or Y'Cb'Cr'.

Y'IQ, YIQ

Y'IQ is a color space optionally used by the NTSC video system. The Y' component is the black-and-white portion of the image. The I and Q parts are the color difference components; these are effectively nothing more than color placed over the black-and-white, or luminance, component. Many people use the YIQ notation rather than Y'IQ or Y'I'Q'.

Y'UV, YUV

Y'UV is the colorspace used by the NTSC and PAL video systems. Y' is the luminance component while the U and V are the color difference components. In the YCbCr (or YUV) representation, Y (luminance) information occurs only once, and the color is determined by the chrominance data in Cb (U) and Cr (V). Cb and Cr are difference values, derived by subtracting the luminance value from the blue component and from the red-luminance component. When the picture is displayed, the green component is reconstructed using the Cb and Cr values to reconstruct the RGB information.

DIGITAL VIDEO ENCODING

Digital video is fundamentally different from NTSC and PAL video in the way it is encoded and processed. Various types of processing equipment manage the digital video information in different ways. These are classified by the way in which they encode the information:

4:2:2

This is a set of frequencies in the ratio 4:2:2, used to digitize the luminance and color difference components (Y, R-Y, B-Y) of a video signal. For every four luminance digital samples, there are two digital samples of each color difference channel. The human eye is not as sensitive to color as to luminance detail enabling this form of compression. RGB video is usually represented with an equal number of bits for each of the three color component channels but RGB is not normally transmitted and bandwidth is not as big a factor when dealing with a connection between the computer and display device.

The four represents 13.5 MHz, the sampling frequency of the Y channel, and the twos each 6.75 MHz for both the R-Y, B-Y channels. D-1, D-5, Digital Betacam, and most digital disk recorders use 4:2:2 digitizing. 4:2:2 is the most common format used in the United States today.

4:1:1

This is a set of frequencies in the ratio 4:1:1, used to digitize the luminance and color difference components (Y, R-Y, B-Y) of a video signal. The four represents 13.5 MHz, the sampling frequency of the Y channel and the ones each 3.75 MHz for both the R-Y, B-Y channels. When U and V are sampled at a lower rate, the color information from the last pixel is simply replicated for the next pixel (or next three pixels for 4:1:1).

4:2:0

This is a set of frequencies in the ratio 4:2:0, used to digitize the luminance and color difference components (Y, R-Y, B-Y) of a video signal. The four represents 13.5 MHz, the sampling frequency of the Y channel, while both the R-Y and B-Y are sampled at 6.75 MHz

4:4:4

YUV = four 8-bit Y samples, four 8-bit U samples, and four 8-bit V samples per unit of time. Some very high end equipment uses this encoding scheme.

IS IT BROADCAST QUALITY?

"Broadcast quality" is a term that frequently gets misused. It does not mean, as many people think, a "good quality" picture or merely a certain level of resolution. Broadcast quality is actually a complex and arcane set of standards for the timing, synchronization and levels of the video signal. It is something that can only be measured with expensive and arcane test equipment. It is purely the province of video engineers. However, even some manufacturers misuse the term to mean a "high quality" video signal or tape format.

TIMECODE AND EDGECODE

Film has long had an identifying edgecode to identify each frame (or nearly each frame) in the post production process. To provide a similar identifier for video, the Society of Motion Picture and Television Engineers (SMPTE) formalized Timecode as a method of giving each frame a unique address. This code is an eight digit number, based on the 24 hour clock and the video frame rate. Timecode measures time in Hours:Minutes:Seconds:Frames. Since most tapes are one hour or less, the first segment is often used to designate the "roll number" of the tape. This is important in post production as it prevents duplication of timecodes when using more than one tape, important since all but the shortest of productions involve multiple tapes.

The values range from 00:00:00:00, to the largest number supported by this format; 23:59:59:29, or, no more than 23 hours, no minutes or seconds greater than 59, and no frames above the highest allowed by the rate being used (29 in this case for 30 frames/sec). This format represents actual clock time — the duration of scene or program material, and makes time calculations easy and direct.

There are two ways to do timecode in the course of shooting. In the first method, each tape is cued up to the beginning and the timecode is set to start at all zeros, except for the hours, which designate tape number. In the second method, the timecode is left to run free, based on clock time. This gives each tape unique numbers, unless you shoot past midnight, in which case there is some chance of duplication.

VIDEO FRAME RATE

The frame is the smallest unit of measure within SMPTE Timecode and is a direct reference to the individual "picture" of film or video. Some timecode readers display a small blip or other symbol at the end to indicate odd or even field, but there is no number designation for it.

The rate is the number of times per second pictures are displayed to provide motion. There are four standard frame rates (frames/sec) that apply to SMPTE: 24, 25, 30, and 30 "Drop Frame."

- 24fps Frame rate based on U.S. standard motion picture film
- 25fps Frame rate based on European motion picture film and video, also known as SMPTE EBU (PAL/SECAM color and b&w)
- 30fps Frame (also called "30 frame Non-drop")
- 30fps Drop Frame

The frames figure advances one count for every frame of film or video, allowing the user to time events down to 1/24th, 1/25th, or 1/30th of a second. Unless you have an application that specifically calls out one of the above frame rates, it doesn't matter which timecode is used as long it is consistent. Most SMPTE applications outside of broadcast video use the 30 frame non-drop rate because it matches real time.

12.17. A timecode slate in use on a film set. As shown here, it can be setup to display the date for a couple of frames after slating.

DROP-FRAME AND NON DROP-FRAME

29.97 video can be written in either drop-frame or non-drop-frame format. The difference between the two is that with drop-frame format the frame address is periodically adjusted (once every minute) so that it exactly matches real time (at the 10 minute mark), while with non-drop-frame format the frame address is never adjusted and gets progressively further away from real time. See below for an explanation of drop-frame numbering.

29.97 VIDEO

Frame rate is the rate at which video records and plays back frames. As with film, it is expressed as frames per second. Before the introduction of color, video ran at a true 30 frames per second (fps). When the color portion of the signal was added, video engineers were forced to slow the rate down to 29.97fps. The reason for this is to prevent interference with the color subcarrier. This slight slowdown of video playback leads to disagreement in the measurement of video vs. real time; one second is not evenly divisible by 29.97.

A frame rate of 29.97fps is 99.9% as fast as 30fps. It is 0.1% (or one-thousandth) slower: 29.97fps / 30fps = .999 (or 99.9%). This means that a frame rate of 30fps is 0.1% (or one-thousandth) faster than 29.97: 30fps / 29.97fps = 1.001 (or 100.1%).

If it were running at precisely 30fps, one hour of video would contain exactly 108,000 frames. 30 frames x 3600 seconds = 108,000 frames total. However, since video does not actually run at 30fps, playing back 108,000 frames of video will take longer than one hour to play because: (108,000 frames) / (29.97 frames/sec) = 3,603.6 seconds = 1 hour and 3.6 seconds. In timecode this is written as 01:00:03:18. All this means that after an hour, the playback is 108 frames too long. Once again, we see the relationship of 108 frames out of 108,000, or 1/1000th. Sixty seconds of 30fps video contains 1800 frames. One-thousandth of that is 1.8. Therefore, by the end of one minute you are off by 1.8 frames. You cannot adjust by 1.8 frames per minute, because you cannot adjust by a fraction of a frame, but you can adjust by 18 full frames per 10 minutes. Two frames in 2000 accumulates 18 frames in 18,000, and there are 18,000 frames in 10 minutes.

HOW DROP FRAME SOLVES THE PROBLEM

Because 10 minutes is not evenly divisible by 18 frames, we use drop-frame timecode and drop two frame numbers every minute; by the ninth minute, you have dropped all 18 frame numbers. No frames need to be dropped the tenth minute because actual frames and timecode frames are once again in agreement.

Thus the formula for the correcting scheme is: drop frame numbers 00:00 and 00:01 at the start of every minute except the tenth. (This also translates to dropping two frame numbers every 66 2/3 seconds.) This sequence repeats after exactly ten minutes. This is a consequence of the ratios of the numbers: Two frames in 2000 accumulates 18 frames in 18,000, and there are 18,000 frames in 10 minutes (30 frames, times 60 seconds, times 10 minutes. In Table 12.2 — 00:10:00:00 in drop-frame is the same as 00:10:00:00 in real time. Also, 10 minutes of NTSC video contains an exact number of frames (17,982 frames), so every tenth minute ends on an exact frame boundary. This is how drop-frame timecode manages to get exactly one hour of video to read as exactly one hour of timecode.

TO DROP OR NOT TO DROP?

It is not necessary to use drop-frame timecode in all instances. Drop-frame is most important in applications where exact time is critical, such as broadcast television. For short pieces that are not going to be broadcast, standard timecode is acceptable, the slight mismatch will be of no consequence. In 25 Hz video (all countries that don't use NTSC), such as in 625/50 video systems, and in 24 Hz film, there is an exact number of frames in each second. As a result, drop-frame is not necessary. There is no drop frame in 24p High Def video.

Minute	Start Position	Frames Lost	Drop Frame	Adjusted Position
1		1.8 lost this minute	drop 2 to correct	0.2 ahead
2	0.2 ahead	1.8 lost this minute	drop 2 to correct	0.4 ahead
3	0.4 ahead	1.8 lost this minute	drop 2 to correct	0.6 ahead
4	0.6 ahead	1.8 lost this minute	drop 2 to correct	0.8 ahead
5	0.8 ahead	1.8 lost this minute	drop 2 to correct	1.0 ahead
6	1.0 ahead	1.8 lost this minute	drop 2 to correct	1.2 ahead
7	1.2 ahead	1.8 lost this minute	drop 2 to correct	1.4 ahead
8	1.4 ahead	1.8 lost this minute	drop 2 to correct	1.6 ahead
9	1.6 ahead	1.8 lost this minute	drop 2 to correct	1.8 ahead
10	1.8 ahead	1.8 lost this minute	drop 0	

Table 12.2. How drop-frame timecode works to correct errors.

TIMECODE SLATING TIPS

When slating with timecode, always pre-roll audio and timecode for at least five seconds. This is critical for syncing up the dailies in telecine. Timecode driven equipment (which includes the telecine and audio syncing decks, as well as playback and edit decks) takes at least five seconds to come up to speed and lock. Not having good pre-roll can definitely cause problems. Pre-roll is handled by the sound recordist. Where in the old days, the AD would call "roll sound" and the mixer would only call "speed" when the old tape decks finally lumbered up to the correct speed, the mixer now waits the appropriate time for pre-roll to lay down before calling "speed."

In telecine there is an "offset" that occurs. Sometimes the smart slate numbers and the sound don't line up. This must be dealt with at some point down the line. There is a valuable additional feature with the Denecke timecode slate. As the clap stick is help open, the timecode rolls freely so that it can be checked. As the clapper is brought down, the timecode freezes momentarily, which makes it easier for post-production people to read it without searching for the exact frame that matches the clap. But after that, the date appears momentarily. This additional feature insures that there will be no duplication of timecode and adds another identification that simplifies keeping things in order.

TIMECODE ON VIDEOTAPE

Timecode is recorded onto analog videotape in two different ways: Longitudinal Timecode (LTC) and Vertical Interval Timecode (VITC). Digital video is an entirely different matter — it is just part of the digital signal.

Longitudinal Timecode

Timecode is recorded on studio videotape and audiotape recorders in the same way as audio is recorded. LTC is interfaced in the studio as an audio signal. At normal play speed, LTC can be decoded from tape as long as the playback system. To recover timecode at the shuttle rates of a high-quality studio VTR — about 60 times play speed — requires an audio bandwidth about 60 times higher. Due to the limitations of stationary head magnetic recording, longitudinal timecode from a VTR (or ATR) cannot be read at very slow speeds or with the tape stopped.

Vertical Interval Timecode

Vertical Interval Timecode (VITC) has a key advantage over LTC: it can be read even when the tape is not running at normal speed. In the vertical interval system, scan lines in the vertical interval of the video signal contain timecode data. This can be done because during the vertical interval, when the scan is returning to the top left of the screen, information is not needed to create video — it can be used for other purposes.

SHOOTING HIGH DEF VIDEO

High definition video is similar to shooting ordinary video in some ways, but quite different in other ways. High Def cameras offer considerably more control than other types of video cameras. These controls are either accessed through menus on the camera or through remote "paint box" units which come in a variety of configurations from fairly simple ones which can be used by a trained videographer or cinematographer on the set to very complex ones which are the province of engineers. The 16x9 format is shown in Figure 12.19.

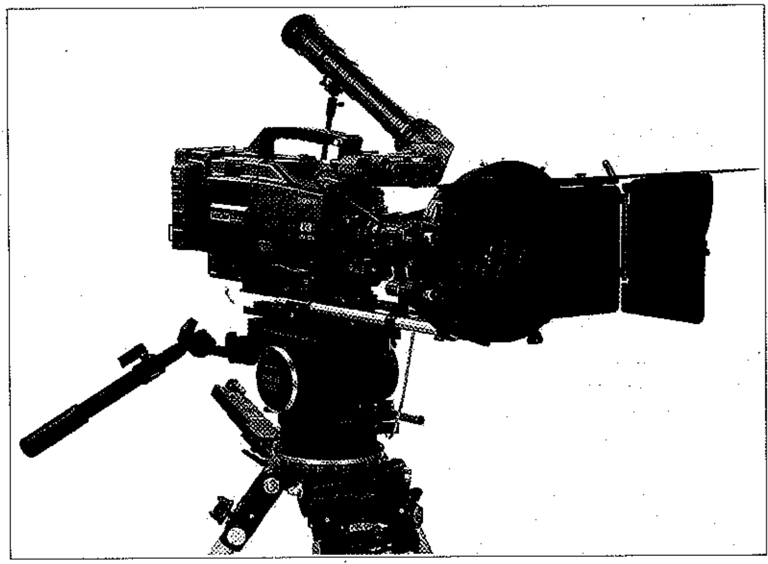
Any paintbox should be used only by people who know what they are doing as it is permanently affecting the image on tape — many effects cannot be undone in post and there is always a possibility you may be making your choices based on an improperly set up monitor or viewfinder.

High Def cameras, including the Panasonic 27V (Figure 12.21), the Sony 900 series (Figures 12.18 and 12.20) and the Panavision 24p camera based on it, use 2/3" CCD video receptors. This gives them a depth-of-field similar to 16mm. As we discussed in the chapter on *Optics*, the smaller the format, the greater the depth-of-field. This poses a problem when trying to shoot with a shallow focus or attempting a dramatic rack, especially when trying to throw the background out of focus to lessen the effect of distracting colors and objects behind the talent. You will want to avoid using regular video zooms on HD cameras — they just don't have the resolution. This doesn't appear on normal video or digital video but is very apparent in High Def. Lenses designed for HD, or better yet, film lenses, are the best choice to get maximum performance from these cameras.

There are a number of High Def formats; each one is appropriate to specific types of shooting, as shown as Tables 12.3 and 12.4. Not all High Def cameras can shoot all formats. Twenty-four frame progressive, or 24p is the format most often used for theatrical features. Progressive means that the scan lines are not interlaced as they are in normal video. This is especially important if the High Def video is going to be transferred to film for projection. There are several companies that handle this conversion to film and it is important to adhere to their varying requirements for shooting the original HD video in order to optimize the transfer to film.

Partly because the High Def cameras so closely resemble a normal video camera such as might be used for BetaSP production, it is often assumed that it is something of a "point and shoot" technology. This is definitely not the case, particularly if you are trying to get the most that the format can offer. A good deal of technical knowledge and experience are necessary to maximize the results, especially if you are trying to get a "film look."

12.18. (right) The Sony F900 Cinealta — a High Def camera that can shoot 24p and other HD formats.



12.19. (below) Comparison of standard television format and High Def standard.

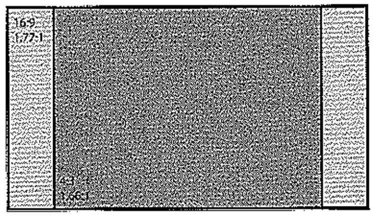


Table 12.3. High Def formats.

VERTICAL SIZE	HORIZONTAL (Pixel width)	INTERLACE or PROGRESSIVE	ASPECT RATIO	FRAME RATES
480	640	i	4:3	30
480	640	P	4:3	24, 30, 60
480	704	i	16:9	30
720	1280	P	16:9	24, 30, 60
1080	1920	i	16:9	30
1080	1920	P	16:9	24, 30
1080	1920	P	16:9	24, 30

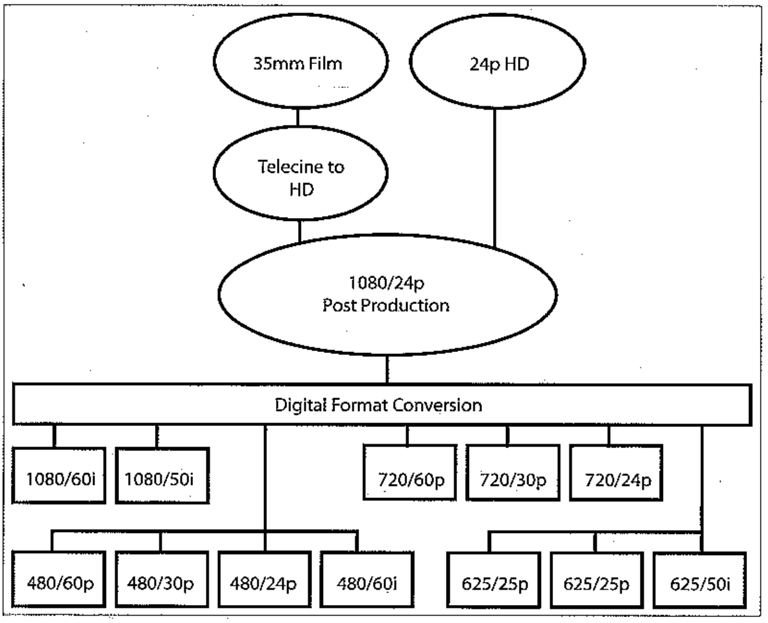
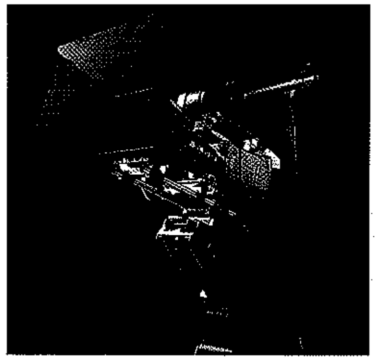
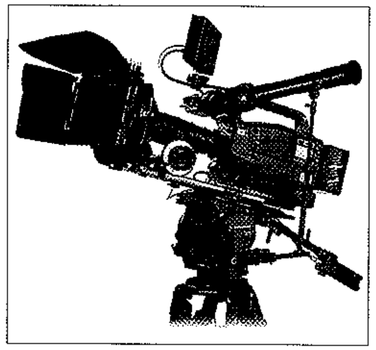


Table 12.4. (left) Typical interchanges between film and HD video formats.

12.20. (below) The Viper Filmstream camera from Thompson. Filmstream refers to its ability to record uncompressed RGB High Def data directly to a hard drive in the field. (Photo courtesy of Thompson Broadcast Solutions.)





12.21. The Panasonic AJ-HDC27V High Def camera set up for film style production. (Photo courtesy of Panasonic.)

Another myth is that you can choose to just "shoot it straight" and everything else can be done in post. This is not true; although there is more manipulation that can be done in post than might be possible in film, there are definitely some things you can do on the set that cannot be done in post and there are things you can screw up badly.

10 THINGS TO REMEMBER WHEN SHOOTING HIGH DEF

Here are some tips specific to working with High Definition cameras for narrative filming in general and particularly for digital projection or for transfer to film for standard projection:

- Control highlights: HD has trouble with them. This is similar to other types of video although not as bad.
- Don't crush the blacks. This sort of manipulation is perfectly valid, but is most likely something best left until post-production as it is irreversible.
- Nail exposure when you can, but if not, err on the side of underexposure, not overexposure (i.e., like reversal film).
- Don't turn up the detail if you are transferring to film.
- 1080 is a better choice for narrative storytelling. 720 is good for sports.
- Interlace always looks like video.
- Very wide lenses are not now available, although that may change.
- Biggest problem is too much depth of field — remember, focus is an important storytelling tool.
- Second biggest problem is seeing too much detail in things like makeup, sets and wardrobe.
- Shoot at 23.98 or 29.97, not 24 or 30. This will reduce artifacts later in the process.

LIGHTING FOR HIGH DEF VIDEO

High Def is much closer to film than non-High Def video but there are still differences. It tends to "see into the shadows" much more than film and it sees detail much more than film. This means that shadows you would expect to go black or nearly black in film are still visible in HD. This can have the effect of ruining the illusion; the same is true of HD's tendency to see more fine detail. The makeup and wardrobe departments must be especially on their toes. Tiny imperfections of sets and props can suddenly become obtrusive where on film they were more than acceptable. This is a big part of the "video look," which, while far less apparent on High Def can still be a problem if not dealt with properly. This problem is more complex than just detail resolution: it can be partially dealt with using diffusion filters but by no means entirely. Also, dealing with it in this way may mean using diffusion filters where you do not want to.

The idea that HD requires less lighting is quite simply a myth. HD cameras have a speed equivalent to around ISO 320 — not really that fast in relation to film. People who claim that HD video needs less lighting are probably just willing to settle for bad lighting.

This is much the same as happened with the advent of high speed lenses and high speed film (ISO 320, which is now more of a medium speed film, with ISO 500 and 800 being the real high speed stocks). Overenthusiastic supporters claimed that fewer people would be needed on the crew and fewer lights. None of this is true, of course. At best, you need a smaller generator and lighter gauge distribution cable and slightly smaller lights.

Think of it this way — say you light a scene beautifully with four lights: a 12K through the window, a 10K raking down the hallway, a 2K bounce for a key on the scene and a baby-junior for a backlight. Let's now assume that the speed of your video camera (or motion picture film) doubles (a very big jump in speed). Does this mean you need fewer lights? Not unless you want to do less lighting — that is, give up something important. You still need four lights — the only difference is that instead of a 12K you need a 6K, instead of a 10K you can use a 5K, and so on. Doubling the speed is a giant leap technologically, but in terms of exposure and lighting it is only one stop. Can you "get an exposure" using fewer lights? Of course you can. But as a cinematographer or director, if you are willing to say that just "getting an exposure" is your goal in lighting, then you don't need to be reading books like this one.

"Video lighting" has a bad reputation. This is not really the fault of video or of the people who shoot video. It is really a result of production circumstances: video is for the most part employed where producers don't have the money for film. Since video is perceived as not being capable of delivering the image quality of film, the producers also usually make the decision to spend less on lighting. How often have you seen a normal video production with five electricians and five grips and a 10-ton truck of lighting and grip?

The result is that video has a reputation as something you "don't light as much" as film. The great danger of High Def is not that it will replace film but that the expectations and values of the decision makers and the audience will decline and that this lower level of production value will become the accepted norm. This is not to be confused with the idea that simpler lighting can be more beautiful — it often is. Indeed, most DPs find that as they learn more about lighting and have the benefit of years of experience and experimentation that they tend to use fewer lights to get the same effect.

This is a function of a greater knowledge of what you can do with few units and the wisdom of years of doing it. This is a different issue, however. The key words are "the same effect," not "settling for less" just because it's video. Of course, there are times when you can light an entire scene with nothing but a china ball, (and it can be a thrilling experience when it really works), but there are many more times when you cannot. In terms of people and equipment you need what you need to light adequately — not to mention artistically and expressively in the service of the storytelling. Convincing a reluctant producer of this is an important skill to learn as a DP.

SHOOTING DIGITAL VIDEO

Digital video exists in many forms — DigiBeta, DV, DVCam, DVCPro and MiniDV. These differ in methods of compression, recording formats, tape speed and tape cassette size but all are similar in that they take an analog signal and convert it to digital — see the previous section on *Analog/Digital Conversion* for more on the various formats.

As with all things digital, the equipment available changes almost on a daily basis; as you decide what to use for your project side-by-side comparisons will be most helpful. Naturally the producer will be most concerned about the cost/benefit ratio of the various formats. Although video is generally much cheaper than film, shooting on video may have very serious implications for your post-productions costs and for the sales value of the finished product. These are the producer's concerns but it is your job as the cinematographer or director to make sure that the cost concerns are balanced with both the visual quality the system can produce and what its other capabilities are. For example, at the present time, no video camera, not even a top-of-the-line High Def camera can shoot true high speed. This has implications especially if you are shooting action sequences or anything else that requires a true slo-mo effect.

Certainly if you are attempting to bring to bear the entire arsenal of methods and techniques of cinematography, the lens systems will be of primary importance to you. Some cameras do offer interchangeable lenses and the quality of video lenses is improving. The size and quality of the CCD (the video receptor) is also important, not only for image quality but for focus — the smaller the CDD the greater the depth-of-field. At first glance this might seem like a good thing, but remember that depth-of-field is an important storytelling tool; too much depth-of-field restricts or even eliminates the possibility of using this important tool. This has implications beyond just the camera; for example, some cinematographers shooting projects on digital video that were formerly shot on film are finding that without the ability to restrict focus to the main subject, that distracting background set dressing or props are more obtrusive. Since the possibility of throwing them out of focus is restricted, redressing the set or changing the background is a last resort stopgap. This calls for co-operation from other departments and from the director.

Beyond this, the day-to-day operation of a digital video camera is much the same no matter what the recording format: white balancing, setting up the monitor, setting exposure and so on are essentially the same. Although much less than in the past, lighting ratios much be accommodating to the particular camera; although as we have pointed out, it is not always simply a matter of "adding more fill," indeed in some cases, negative fill may be required as you are seeing too much into the shadows.

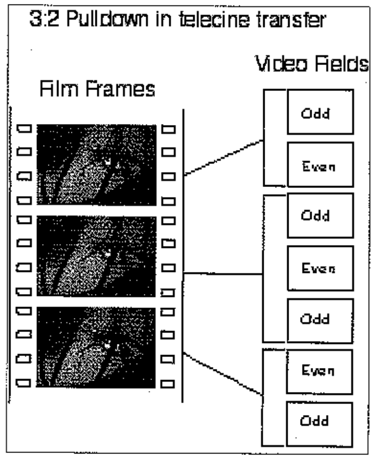
TRANSFERRING FILM TO VIDEO

NTSC AND 3:2 PULLDOWN

When transferring American system film (24fps) to NTSC video (29.97fps), there is a mismatch of speed which must be corrected. NTSC has 60 fields/second (2 fields per frame), thus five fields take 5/60 second = 1/12 second time, which is exactly the amount it takes for a film to show two frames. The solution to the problem is that each frame of film is not transferred to a corresponding frame of video.

The first film frame is transferred to 3 NTSC fields. Next the second film frame is transferred to 2 NTSC fields. The total time for the original film should be 2/24s = 1/12s, which is exactly the same it took for NTSC to transfer the same frames (3/30s+2/60s = 5/60s = 1/12s). This process alternates for successive frames. This is called 3-to-2 pulldown, usually written as 3:2 pulldown. The problem with this is that every other film frame is shown for 1/20 of a second, while every other is shown for 1/30 of a second. This makes pans look less smooth than what they did in the movie theater or in PAL video, which does not require this process (Figure 12.22).

12.22. How 3-to-2 pulldown works.



PREPPING FOR TELECINE

A great deal of film that is shot now goes from the processing lab to a telecine house where it is transferred directly to video (Figure 12.23). Even features intended for theatrical release are telecined for non-linear editing and for video dailies. It is important to follow the correct steps to prepare for telecine. Failure to do so will cost the producer considerably extra, which is not good for job security.

- If you are doing anything at all out of the ordinary: greenscreen, unusual color balances, off speed shooting, etc., it is best to confer with the telecine house before you start.

12.23. A typical telecine suite.

- Film will be transferred at 24 frames per second with standard SMPTE framing unless specifically requested otherwise. Transfer rates other than 16-30fps may not be available at all telecine houses — check before you shoot.
- Shoot a properly exposed and color balanced Gray Scale. It's a good place for the colorist to start.
- Communicate with the telecine operator. A phone call, a memo or notes on the camera reports are important. Some DPs also send audio recording with comments and also Polaroids of the scene; even pictures from a magazine that you are using as a reference or similar material.
- Full and accurate camera reports. This is especially important if you are shooting at an off-speed frame rate AND want the footage transferred at that rate.
- Write it on the slate. All slates have spaces to record if the shot is day or night, interior or exterior and frame rate. Some also have places for filtration and other key data.
- Make sure the slate is in focus and lit to be readable.
- Mark the camera reports as "Prep for telecine." When this is requested, the lab cleans the negative and joins the camera rolls into lab rolls no larger than 1200 feet with 6 feet of leader on each end. In some cases, editors may request hole punches at head and tail of each camera roll and a KeyKode log. KeyKode is a written log recording the first and last KeyKode number for each camera roll within a lab roll. It is prepared by the lab during negative assembly and used by the Editor to check the accuracy of the flex file (a computer file database).
- Use correct slating procedures (see chapter on Set Operations). This is especially important if you are doing MOS takes or tail slating. If an MOS take is not properly slated, the transfer technician can spend considerable time looking for audio that does not exist.
- Shoot a framing chart and communicate to the colorist what framing you are shooting. This is especially important with formats such as Super 35. Be sure that the framing chart agrees with your ground glass and also that all the ground glasses on your shoot agree.

AUDIO FOR TELECINE

Most transfer houses require that sync audio for telecine be recorded at 30fps not using Drop Frame timecode. Audio should never be