Media_Generation

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How Video Works

Video occupies no space; it is a medium of time and voltage. There is no tangible image. Light entering the camera becomes electricity, which in the monitor is converted directly back into light. Capturing an image on one end and displaying it on the other requires a complex orchestration of individually simple events.

In the beginning, a lens focuses an optical image on the target area of the camera tube. The tube itself is an electrical circuit made when electrons from the heated and negatively charged cathode travel to the positively charged anode, which in this case is the target. The target is sensitive to light and will pass electricity in proportion to the amount of light falling on it.

The electron beam is narrow and travels to the center of the target, but the image covers the whole target area. In order to read the image, the electron beam sweeps across the target in a precisely defined pattern called the raster. Deflection plates in the tube pull the beam in the desired direction. A set of sync pulses, voltages lower than picture black, key the movement of the beam.

To start a scan of one frame, a vertical sync pulse returns the beam to the top of the picture. A series of precisely timed horizontal sync pulses direct the side-to-side motion of the beam. At the end of 262.5 scans, the beam has reached the bottom of the picture and another vertical sync pulse sends it back to the top. The raster is rigidly timed, so that any position on the screen can be defined as the interval of time since the previous vertical sync pulse. For example, the center of the screen is always 1/120th second from the pulse.

The raster scans the screen 60 times per second. A video frame is technically 525 lines 30 times per second; a frame is actually two fields of 262.5 lines. The first field fills in the odd lines and the second the even lines. The frame was divided this way to prevent the screen from flickering. (The PAL system used in Europe has a field rate of 48 per second, and the flicker is quite noticeable.)

Solid-state sensors such as MOS and CCD chips work a little differently. They are arrays of discrete sensors which are read sequentially from top to bottom and side to side. The resulting stream of information is the same as from the roving electron beam.[1]

The monitor decodes this continuously varying voltage. The picture tube is like the camera tube- It has a negatively charged cathode emitting a beam of electrons that move to a positively charged anode, in this case a phosphor screen that lights up in proportion to the amount of electricity hitting it. Deflection plates sweep the beam across the face of the phosphor screen in a raster that matches that of the camera. The vertical and horizontal sync pulses that are part of the video signal keep the monitor raster in sync with the camera scan.

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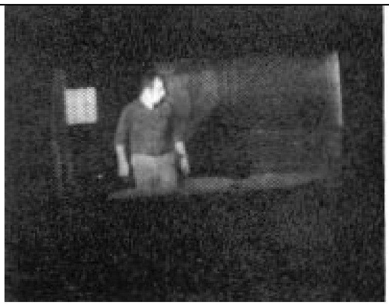
[1] A bit more about solid state sensors.

 **A 1/30-second exposure captures the entire video picture.**	 **Shorter exposures (e.g.. 1/125) capture only part of the raster.**

What we actually see on a television screen is a thin beam of modulated light crossing the screen 15,734 times a second and filling in a slice of picture with each pass. The phosphors decay slowly, so the whole screen appears to be lit. However, if you take a photograph of a TV screen at 1/125 of a second or faster, you will find much of the screen is blank.

Color complicates the picture. Video sees the world in the primaries red, green, and blue, or RGB. (Yellow is derived by subtracting blue from green—remember, colors are only voltages.) To capture a color image, the camera generates a red, a green, and a blue signal. To display a color image, the monitor uses a red, a green, and a blue electron beam. Ideally, you would transmit and record three separate video signals, but this would take up a lot of frequency space and carry an enormous amount of redundant information.

The RGB signals are combined in three ways to give a black-and-white or luminance signal (Y), a color-saturation signal (I), and a hue signal (Q). Y carries the fine picture detail. I is amplitude-modulated, and Q is phase-modulated on a separate subcarrier frequency. In essence, the black-and-white picture is one signal and the color information is a discrete complementary signal. YI/Q is the basis for component video recording such as Betacam, where the color and the black-and-white are recorded separately, as well as for the encoding used for broadcasting.

If you are algebraically inclined, the transformation equations are as follows:

The real world gives RGB.

$.30R + .59G + .1IB=Y$
$.60R - .28G - .32B = I$
$.21R - .52G + .3IB = Q$

YI/Q is recorded, transmitted, and received.

$Y + .95I + .62Q = R$
$Y - .28I - .64Q = G$
$Y - 1.11I + 1.73Q = B$

RGB gives the color picture back to the real world.

The video recorder records the stream of voltage fluctuations that comprise the video signal. Because the frequency range is so high, the speed with which the tape passes the recording head (the writing speed) must be high. This is achieved by spinning the heads rather than speeding up the tape. To keep the heads aligned with the tracks on playback, a set of control track pulses is recorded along the edge of the tape (much like sprocket holes in film). To compensate for minor fluctuations in playback, the signal is processed through a time base corrector, to adjust the duration of each horizontal line, and through a proc amp, to reset the levels of the sync pulses, before it is broadcast or re-recorded.

Reading the Instruments

Underscan and Pulse-Cross Monitor

In the early days, I recorded some reel-to-reel tape that looked great on a monitor but could not make it through a TBC because it contained errors beyond what the TBC could correct. An engineer told me that a monitor was the best TBC of all, because it could accommodate a wide range of errors without their being apparent in the picture. So we focused a camera on the monitor, played the tape, and made a new recording off the screen that was stable enough to edit.

Monitors are so forgiving that they do not make good diagnostic tools. For critical use, studio monitors are set up to display any timing errors, and they usually have features that allow you to look at the normally invisible parts of the picture.

Most monitors are set up to overscan the picture; the top, bottom, and sides bleed off the screen. If the monitor is set to under-scan, you can see if the sides are straight (indicating proper horizontal timing). If the brightness is turned up, you can see a black bar that constitutes the vertical sync pulse.

A pulse-cross monitor goes a step further and displaces the picture so that a vertical sync pulse occurs in the center of the screen, and the row of horizontal sync pulses occur about one-third of the way across the screen. A glance at the pulse-cross will tell you if improper tape tension is causing a skew error, if your color burst is missing, or if there are any other problems with the timing of the signal.

A pulse-cross monitor can be extremely useful in small editing setups where there is no TBC or proc amp. It shows problems with skew and tracking that can be corrected by adjusting the playback VCR during editing or dubbing and can be used to check completed edits.

Waveform Monitor

The waveform monitor is the most important diagnostic device in video for adjusting the initial recording, for maintaining quality during editing, for checking the signal as it is broadcast, and for diagnosing and repairing equipment. While using one to its full potential is a science unto itself, even the video novice should know what it displays and how to read it.

Like the pulse-cross monitor, the waveform monitor displays the video signal in a different way to illustrate parts of the signal that are otherwise invisible. The most common configuration displays two horizontal lines. The horizontal and vertical axes represent time and voltage, respectively, which as you will recall are the two dimensions of the video signal. The top of the scale, or 100 percent, is the maximum allowable voltage and is pure white. Three-fourths of the way down are a set of double lines that indicate the voltage for the darkest part of the picture. Lower voltages are "blacker than black," the realm of sync pulses.

Picture quality can be judged by observing the signal between picture black and 100 percent white. The brightest parts of the picture should just touch the 100 percent line. If they do not, you need either a wider f stop on the lens or more light on the set for shooting, or higher gain on the proc amp for editing and duplicating. Conversely, if the whites go over the 100 percent line you are overmodulating and have to pull back on the gain or stop down the lens. The lowest values of the picture should rest on the double line. If they are too high, the blacks will be washed out; and if they are too low, the shadow areas will all merge into one black. The black level is adjusted with the pedestal on the camera or proc amp.

The waveform also displays the sync pulse and the color burst signal. Each horizontal line lasts 63.5 microseconds (μs) and consists of the following components. A 10.45 μs horizontal blanking interval is the point in each line when the beam is turned off for 10.45 μs to fly back from the left to right side of the screen. The deep valley of zero voltage is the horizontal sync pulse. It is followed by eight cycles of the 3.579 MHz color subcarrier, or color burst, which sets up the color for the upcoming line. Next comes the actual picture information.

If you are doing your own editing at a cable station and the picture doesn't look quite right, knowing a bit about the wave form monitor can help you set it up to look better. If you are a producer getting trouble from an engineer about the technical quality of a tape, he or she will invariably point to the waveform. You will be ahead of the game if you know what that screen displays, even if you are not responsible for adjusting it.

Vectorscope

The Vectorscope is the snazziest of quality control instruments. It is a great display often incorporated into low-budget science-fiction visuals, which you will probably never need. It is used mostly when setting up cameras, video recorders, and other equipment to determine that color-bar test signals are making it through the system without phase changes or color degradation.

The vectorscope reads the phase and amplitude of the color signals (I and **Q)**. The reticule on the vectorscope is calibrated in degrees with box-shaped targets that show the correct position of all six primary and complementary colors that make up color bars. If the trace does not light up in the appropriate place, adjusting the hue or phase control on the proc amp will rotate them into place. If the traces are not the correct distance from the center of the circle, adjusting the chroma or color on the proc amp will move them in or out from the center.[2]

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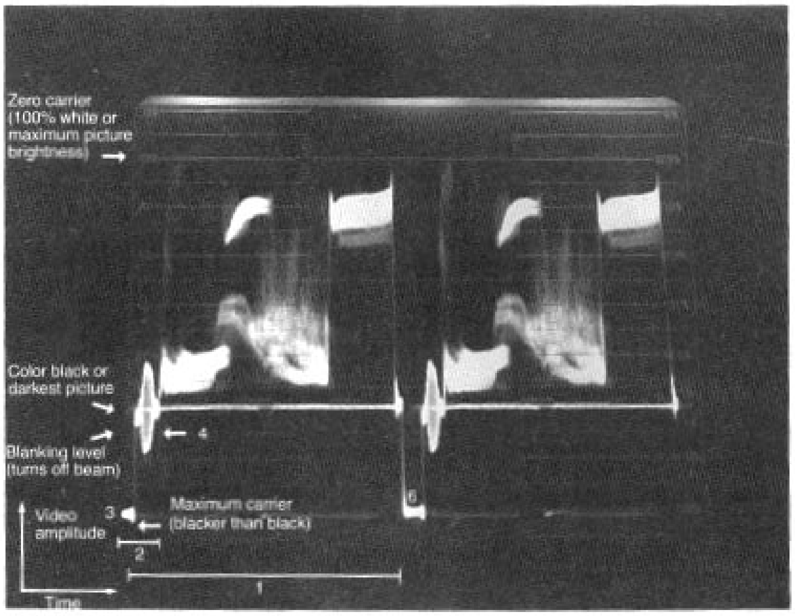
[2] The reason color bars are recorded at the beginning of a tape, both the camera tapes and the edited master tapes, is so that the proc amp can be adjusted using the waveform monitor and vectorscope. If you set the recording chain up to the bars on a source tape, you will get a close match on the record tape.



Waveform display of two horizontal lines. Voltage is displayed on the vertical axis and tine on the horizontal. 1. A single horizontal line. 2. The horizontal blanking interval. 3. The horizontal sync pulse. 4. Color burst of eight cycles of the color subcarrier. 5. The picture information. 6. Sync pulse for the next horizontal line.

Bishop, John: **MAKING IT IN VIDEO** (McGraw-Hill 1988) page 165-169