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TUTORIAL 734

Video Basics

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Abstract: This article covers many of the fundamentals of analog video. It is divided into four sections: "Picture Basics" covers how a video picture is generated; "Resolution: Visual versus Format" discusses the different resolution formats and how resolution is specified and measured; "Formats and Interfaces" includes different types of video signals, waveforms, and interfaces; and the glossary at the end defines terms specific to video.

This article covers many of the fundamentals of analog video. Video is defined for our purposes here as "moving pictures." Still imaging, like what is found in digital still cameras or scanners, is not covered. The requirements for still imaging do have a lot in common with those for video, but the differences are significant enough to be dealt with as a separate discipline.

This article is divided into four sections: "Picture Basics" covers how a video picture is generated; "Resolution: Visual versus Format" discusses the different resolution formats and how resolution is specified and measured; "Formats and Interfaces" includes different types of video signals, waveforms, and interfaces; and the glossary at the end defines terms specific to video.

Picture Basics

A picture is "drawn" on a television or computer display screen by sweeping an electrical signal horizontally across the display one line at a time. The amplitude of this signal versus time represents the instantaneous brightness at that physical point on the display. **Figure 1** shows the signal amplitude relationship to the brightness on the display.
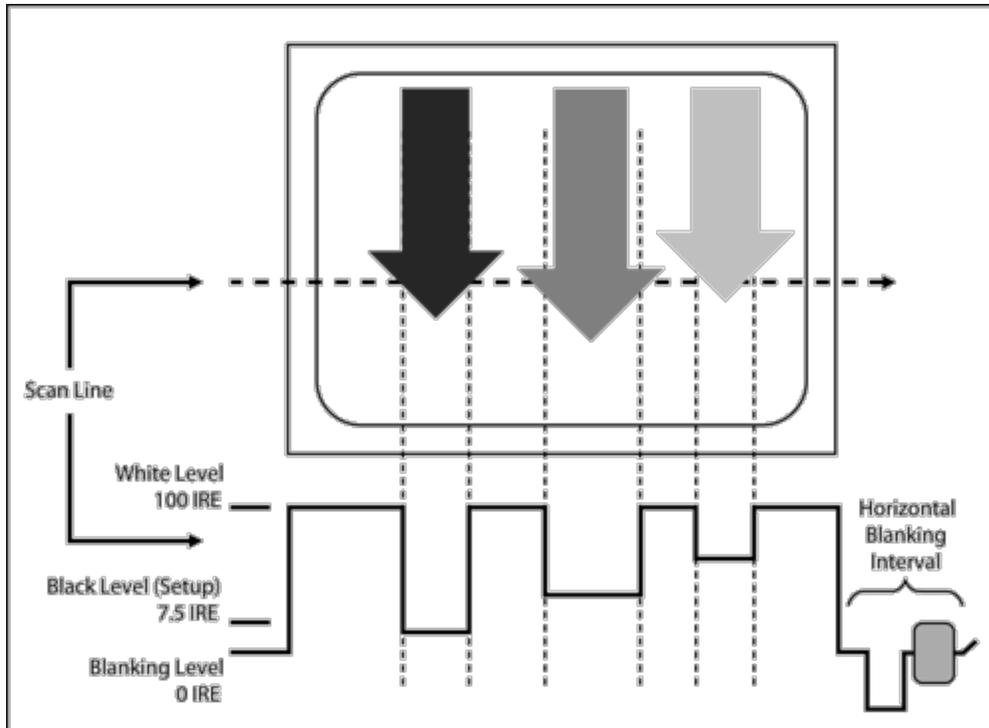
Figure 1. Horizontal scan versus display brightness.

At the end of each line, there is a portion of the waveform (horizontal blanking interval) that tells the scanning circuit in the display to retrace to the left edge of the display and then start scanning the next line. Starting at the top, all of the lines on the display are scanned in this way. One complete set of lines makes a picture. This is called a frame. Once the first complete picture is scanned, there is another portion of the waveform (vertical blanking interval, not shown) that tells the scanning circuit to retrace to the top of the display and start scanning the next frame, or picture. This sequence is repeated at a fast enough rate so that the displayed images are perceived to have continuous motion. This is the same principle as that behind the "flip books" that you rapidly flip through to see a moving picture or cartoons that are drawn and rapidly displayed one picture at a time.

Interlaced versus Progressive Scans

These are two different types of scanning systems. They differ in the technique used to "paint" the picture on the screen. Television signals and compatible displays are typically interlaced, and computer signals and compatible displays are typically progressive (non-interlaced). These two formats are incompatible with each other; one would need to be converted to the other before any common processing could be done. Interlaced scanning is where each picture, referred to as a frame, is divided into two separate sub-pictures, referred to as fields. Two fields make up a frame. An interlaced picture is painted on the screen in two passes, by first scanning the horizontal lines of the first field and then retracing to the top of the screen and then scanning the horizontal lines for the second field in-between the first set. Field 1 consists of lines 1 through 262 1/2, and field 2 consists of lines 262 1/2 through 525. The interlaced principle is illustrated in **Figure 2**. Only a few lines at the top and the bottom of each field are shown.
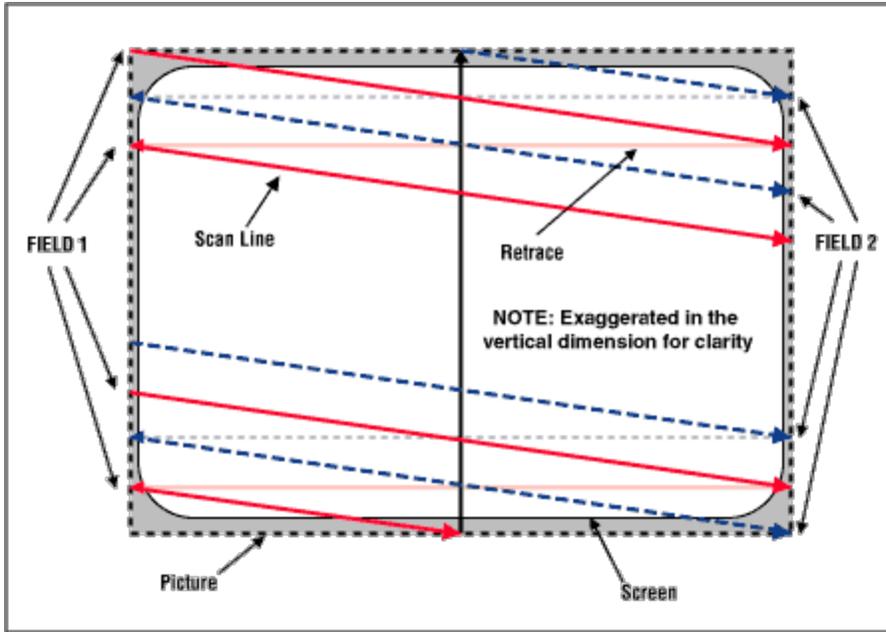
Figure 2. Interlaced scanning system.

A progressive, or non-interlaced, picture is painted on the screen by scanning all of the horizontal lines of the picture in one pass from the top to the bottom. This is illustrated in **Figure 3**.
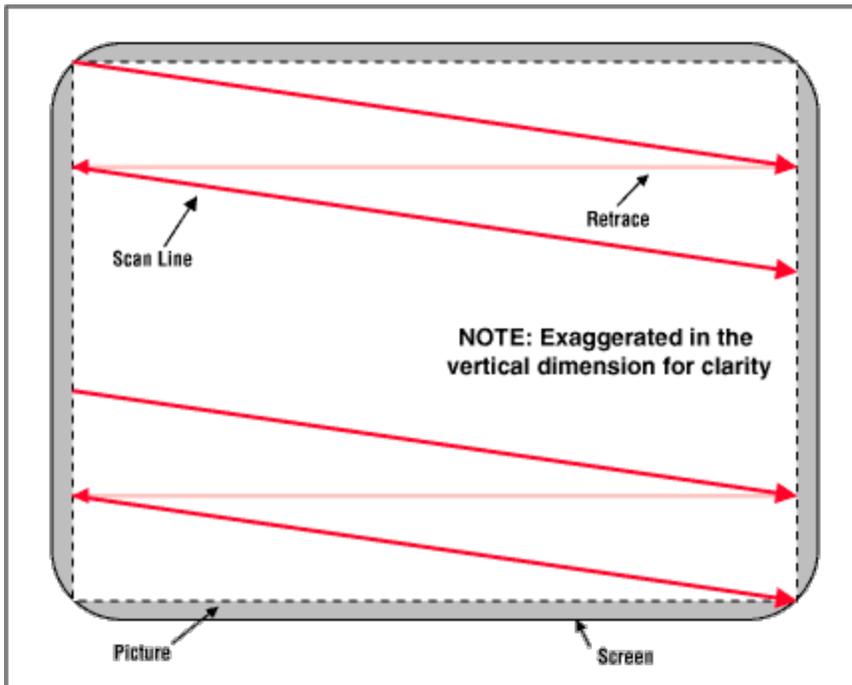

Figure 3. Progressive (non-interlaced) scanning system.

Resolution:Visual versus Format

The visual resolution of a video signal or display is the amount of detail that can be seen. This is

different from the resolution format of a signal or display. For example, in a computer application, a XGA signal has a format resolution of 1024 horizontal pixels and 768 vertical pixels (lines), and is the implied visual resolution. However, if the signal or display has any limitations that can degrade the performance, it may not be possible to actually view all of this detail.

Visual Resolution in Television Systems

Visual resolution in television systems is accurately specified in terms of a parameter called "TV lines." This parameter is typically used to indicate horizontal resolution, but the same technique can be used for vertical resolution. TV lines are determined by viewing a test pattern consisting of alternating black and white lines that are placed closer and closer together. The pair of lines with the closest spacing that can be distinguished as separate lines determines the resolution. The lines that can be extrapolated across the screen to a width equal to one picture height are the TV lines of resolution. **Figure 4** shows a representative picture for determining resolution.
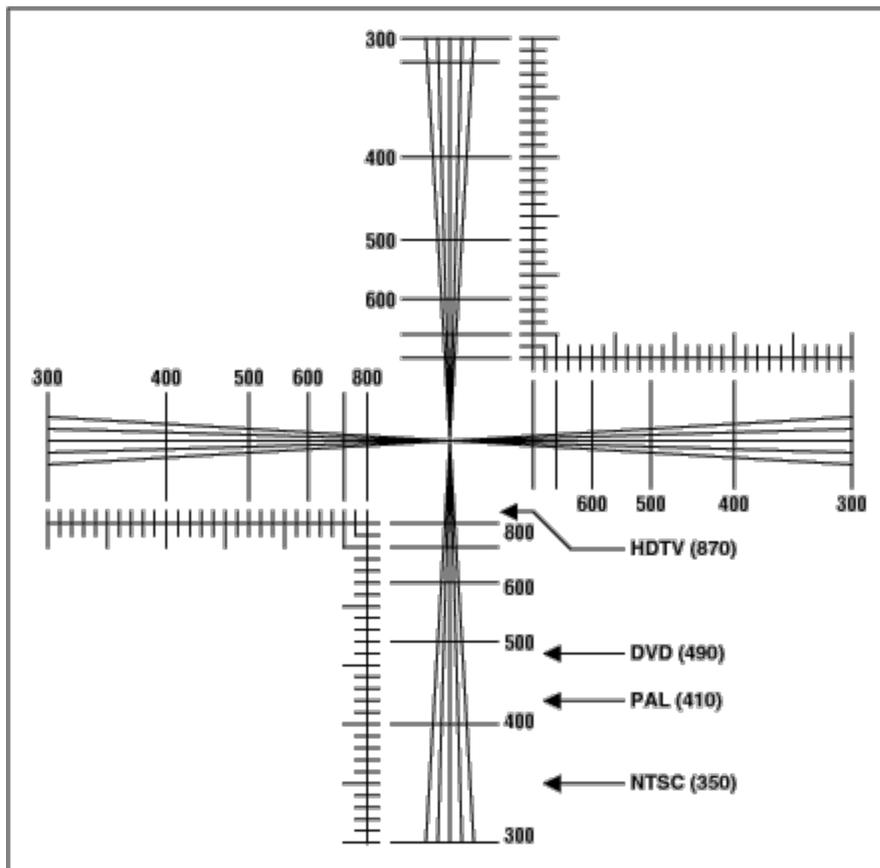

Figure 4. Representative visual resolution test pattern.

Visual Resolution in Computer Systems

Computer resolution formats are typically specified by the visible number of pixels in the horizontal and vertical dimensions. For example, a VGA format signal has 640 visible pixels in the horizontal direction and 480 visible pixels in the vertical direction. An XGA format signal has 1024 visible pixels in the horizontal direction and 768 visible pixels in the vertical direction. In a well-designed computer system that is specified to reach a given maximum format resolution, all of the signal processing would be designed such that the visual resolution would be at least as good as the format resolution. If any circuit in the chain does not have the required performance, the visual resolution will be less than the format

resolution.

Formats and Interfaces

There are many different kinds of video signals, which can be divided into either television or computer types. The format of television signals varies from country to country. In the United States and Japan, the NTSC format is used. NTSC stands for National Television Systems Committee, which is the name of the organization that developed the standard. In Europe, the PAL format is common. PAL (phase alternating line), developed after NTSC, is an improvement over NTSC. SECAM is used in France and stands for sequential coleur avec memoire (with memory). It should be noted that there is a total of about 15 different sub-formats contained within these three general formats. Each of the formats is generally not compatible with the others. Although they all utilize the same basic scanning system and represent color with a type of phase modulation, they differ in specific scanning frequencies, number of scan lines, and color modulation techniques, among others. The various computer formats (such as VGA, XGA, and UXGA) also differ substantially, with the primary difference in the scan frequencies. These differences do not cause as much concern, because most computer equipment is now designed to handle variable scan rates. This compatibility is a major advantage for computer formats in that media, and content can be interchanged on a global basis.

Table 1. Typical Frequencies for Common TV and Computer Video Formats

Video Format	NTSC	PAL	HDTV/SDTV	VGA	XGA
Description	Television Format for North America and Japan	Television Format for Most of Europe and South America	High Definition/ Standard Definition Digital Television Format	Video Graphics Array (PC)	Extended Graphics Array (PC)
Vertical Resolution Format (visible lines per frame)	Approx 480 (525 total lines)	Approx 575 (625 total lines)	1080 or 720 or 480; 18 different formats	480	768
Horizontal Resolution Format (visible pixels per line)	Determined by bandwidth, ranges from 320 to 650	Determined by bandwidth, ranges from 320 to 720	1920 or 704 or 640; 18 different formats	640	1024
Horizontal Rate (kHz)	15.734	15.625	33.75-45	31.5	60
Vertical Frame Rate (Hz)	29.97	25	30-60	60-80	60-80
Highest Frequency (MHz)	4.2	5.5	25	15.3	40.7

There are three basic levels of baseband signal interfaces. In order of increasing quality, they are composite (or CVBS), which uses one wire pair; Y/C (or S-video), which uses two wire pairs; and

component, which uses three wire pairs. Each wire pair consists of a signal and a ground. These three interfaces differ in their level of information combination (or encoding). More encoding typically degrades the quality but allows the signal to be carried on fewer wires. Component has the least amount of encoding, and composite the most.

Composite/CVBS Interface

Composite signals are the most commonly used analog video interface. Composite video is also referred to as CVBS, which stands for color, video, blanking, and sync, or composite video baseband signal. It combines the brightness information (luma), the color information (chroma), and the synchronizing signals on just one cable. The connector is typically an RCA jack. This is the same connector as that used for standard line level audio connections. A typical waveform of an all-white NTSC composite video signal is shown in **Figure 5**.
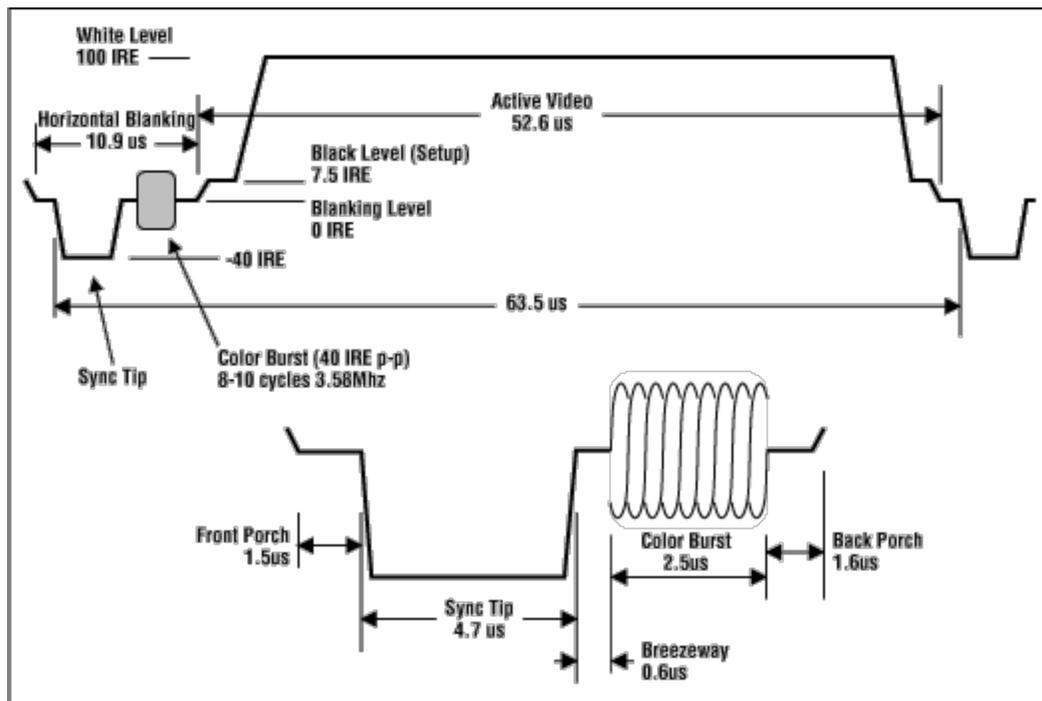

Figure 5. NTSC composite video waveform.

This figure depicts the portion of the signal that represents one horizontal scan line. Each line is made up of the active video portion and the horizontal blanking portion. The active video portion contains the picture brightness (luma) and color (chroma) information. The brightness information is the instantaneous amplitude at any point in time. The unit of measure for the amplitude is in terms of an IRE unit. IRE is an arbitrary unit where 140 IRE = 1Vp-p. From the figure, you can see that the voltage during the active video portion would yield a bright-white picture for this horizontal scan line, whereas the horizontal blanking portion would be displayed as black and therefore not seen on the screen. Please refer back to Figure 1 for a pictorial explanation. Some video systems (NTSC only) use something called "setup," which places reference black at a point equal to 7.5 IRE or about 54mV above the blanking level.

Color information is added on top of the luma signal and is a sine wave with the colors identified by a specific phase difference between it and the color-burst reference phase. This can be seen in **Figure 6**, which shows a horizontal scan line of color bars.
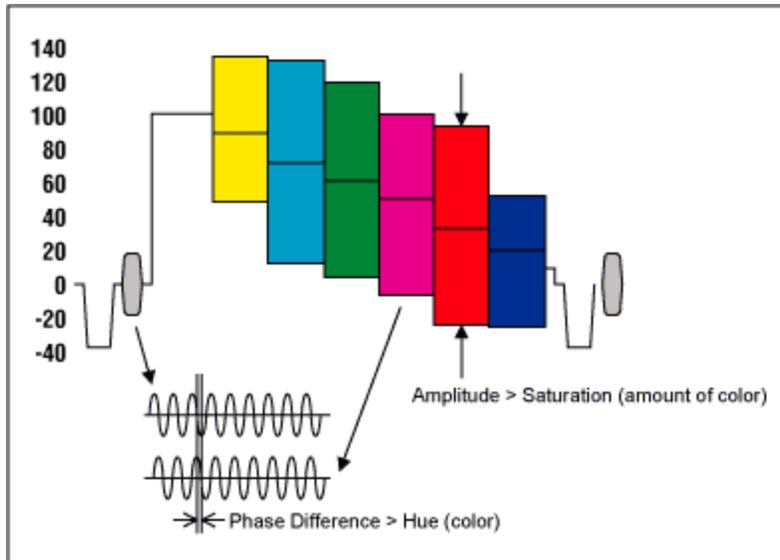
Figure 6. Composite video waveform: color bars.

The amplitude of the modulation is proportional to the amount of color (or saturation), and the phase information denotes the tint (or hue) of the color. The horizontal blanking portion contains the horizontal synchronizing pulse (sync pulse) as well as the color reference (color burst) located just after the rising edge of the sync pulse (called the "back porch"). It is important to note here that the horizontal blanking portion of the signal is positioned in time such that it is not visible on the display screen.

Y/C Interfaces

The Y/C signal is a video signal with less encoding. Brightness (luma), which is the Y signal, and the color (chroma), the C signal, are carried on two separate sets of wires. The connector is a mini-DIN type and resembles a small version of a keyboard connector.

Note: The term "S-video" stands for "separate video" and sometimes is used to refer to a Y/C signal, sometimes used in reference to recording formats. It was originally a recording format, as used for Sony Betamax, in which the luma was recorded separately from the chroma. The term is also commonly used to refer to the S-VHS (Super VHS) video recording format.

Component Interfaces

Component signal interfaces are the highest performance, because they have the least encoding. The signals exist in a nearly native format. They always utilize three pairs of wires that are typically in either a luma (Y) and two-color-difference-signals format or a red, green, blue (RGB) format. RGB formats are almost always used in computer applications, whereas color-difference formats are generally used in television applications. The Y signal contains the brightness (luma) and synchronizing information, and the color-difference signals contain the red (R) minus the Y signal and the blue (B) minus the Y signal. The theory behind this combination is that each of the base R, G, and B components can be derived from these difference signals. Common variations of these signals are as follows:

- **Y, B-Y, R-Y:** Luma and color-difference signals.
- **Y, Pr, Pb:** Pr and Pb are scaled versions of B-Y and R-Y. Commonly found in high-end consumer equipment.
- **Y, Cr, Cb:** Digital-signal equivalent to Y, Pr, Pb. Sometimes incorrectly used in place of Y, Pr, Pb.
- **Y, U, V:** Not an interface standard. These are intermediate, quadrature signals used in the

formation of composite and Y/C signals. Sometimes incorrectly referred to as a "component interface."

Computer Signal Interfaces

Virtually all computer interfaces utilize RGB format signals. The picture information is carried separately by the three base components of red, green, and blue. Synchronizing information is typically carried as separate horizontal (H) and vertical (V) signals. The five signals, R, G, B, H, and V, are carried on one cable consisting of a shielded bundle of wires. The connector is almost always a 15-pin D-type connector. Sometimes the H and V sync information is merged with one of the RGB signals, typically the green component, but this is becoming less common. This is referred to as "sync on green." In rarer cases, the sync information is on the red or the blue signal.

Glossary

Aspect Ratio

The ratio of the visible-picture width to the height. Standard television and computers have an aspect ratio of 4:3(1.33). HDTV has aspects ratios of either 4:3 or 16:9(1.78). Additional aspect ratios like 1.85:1 or 2.35:1 are used in cinema.

Back Porch

The area of a composite video signal defined as the time between the end of the color burst and the start of active video. Also loosely used to mean the total time from the rising edge of sync to the start of active video.

Blanking Interval

There are horizontal and vertical blanking intervals. Horizontal blanking interval is the time period allocated for retrace of the signal from the right edge of the display back to the left edge to start another scan line. Vertical blanking interval is the time period allocated for retrace of the signal from the bottom back to the top to start another field or frame. Synchronizing signals occupy a portion of the blanking interval.

Blanking Level

Used to describe a voltage level (blanking level). The blanking level is the nominal voltage of a video waveform during the horizontal and vertical periods, excluding the more negative voltage sync tips.

Breezeway

The area of a composite video signal defined as the time between the rising edge of the sync pulse and the start of the color burst.

Chroma

The color portion of a video signal. This term is sometimes incorrectly referred to as "chrominance," which is the actual displayed color information.

Clamp

A circuit that forces a specific portion (either the back porch or the sync tip) of the video signal to a specific DC voltage, to restore the DC level. Also called "DC restore." A black level clamp to ground circuit forces the back-porch voltage to be equal to zero volts. A peak clamp forces the sync-tip voltage to be equal to a specified voltage.

Color Bars

A standard video waveform used to test the calibration of a video system. It consists of a sequence of the six primary and secondary colors plus white with a standard amplitude and timing. The active-low color sequence is white, yellow, cyan, green, magenta, red, and blue. There are several amplitude standards, the most common being 75% amplitude (brightness) with 100% saturation (intensity of the color).

Color Burst

The color burst, also commonly called the "color subcarrier," is 8 to 10 cycles of the color reference frequency. It is positioned between the rising edge of sync and the start of active video for a composite video signal.

Color Saturation

The amplitude of the color modulation on a standard video signal. The larger the amplitude of this modulation, the more saturated (more intense) the color.

Color Subcarrier

See Color Burst.

Component Video

A three-wire video interface that carries the video information in its basic RGB components or luma (brightness) and two-color-difference signals.

Composite Video

A video signal that combines the luma (brightness), chroma (color), burst (color reference), and sync (horizontal and vertical synchronizing signals) into a single waveform carried on a single wire pair.

Differential Gain

Important measurement parameter for composite video signals. Not applicable in Y/C or component signals. Differential gain is the amount of change in the color saturation (amplitude of the color modulation) for a change in low-frequency luma (brightness) amplitude. Closely approximated by measuring the change in the amplitude of a sine wave for a change in its DC level.

Differential Phase

Important measurement parameter for composite video signals. Not applicable in Y/C or component signals. Differential phase is the change in hue (phase of the color modulation) for a change in low-frequency luma (brightness) amplitude. Closely approximated by measuring the change in the phase of a sine wave for a change in its DC level.

Fields and Frames

A frame is one complete scan of a picture. In NTSC it consists of 525 horizontal scan lines. In interlaced scanning systems, a field is half of a frame; thus, two fields make a frame.

Front Porch

The area of a composite video waveform between the end of the active video and the leading edge of sync.

Horizontal Blanking

See Blanking Level *and* Blanking Interval.

Horizontal Line Frequency

The inverse of the time (or period) for one horizontal scan line.

Interlaced Scan

The process whereby each frame of a picture is created by first scanning half of the lines and then scanning the second set of lines, which are interleaved between the first to complete the picture. Each half is referred to as a field. Two fields make a frame.

IRE

An arbitrary unit of measurement equal to 1/100 of the excursion from blanking to reference white level. In NTSC systems, 100 IRE equals 714mV and 1-volt p-p equals 140 IRE.

Luma

The monochrome or black-and-white portion of a video signal. This term is sometimes incorrectly called "luminance," which refers to the actual displayed brightness.

Monochrome

The luma (brightness) portion of a video signal without the color information. Monochrome, commonly known as black-and-white, predates current color television.

NTSC

National Television Systems Committee. A group that established black-and-white television standards in the United States in 1941 and later added color in 1953. NTSC is used to refer to the systems and signals compatible with this specific color-modulation technique. Consists of quadrature-modulated color-difference signals added to the luma with a color subcarrier reference of 455/2 times the horizontal line rate, typically 3.579545MHz with an H rate of 15.75kHz. Commonly used in 525-line, 59.94Hz scanning systems.

PAL

Phase alternate line. PAL is used to refer to systems and signals that are compatible with this specific modulation technique. Similar to NTSC but uses subcarrier phase alternation to reduce the sensitivity to phase errors that would be displayed as color errors. Commonly used with 626-line, 50Hz scanning systems with a subcarrier frequency of 4.43362MHz.

Pixel

Picture element. A pixel is the smallest piece of display detail that has a unique brightness and color. In a digital image, a pixel is an individual point in the image, represented by a certain number of bits to indicate the brightness.

Progressive Scan

The process whereby a picture is created by scanning all of the lines of a frame in one pass. *See also* Interlaced Scan. The process of converting from interlaced to progressive scan is called "line doubling."

Raster

The collection of horizontal scan lines that makes up a picture on a display. A reference to it normally assumes that the sync elements of the signal are included.

Refresh Rate

See Vertical Frame Rate.

RGB

Stands for red, green, and blue. It is a component interface typically used in computer graphics systems.

Setup

A reference black level 7.5% (7.5IRE) above blanking level in NTSC analog systems. It is not used in PAL or digital or HDTV systems. In these systems, reference black is the same level as blanking.

Subcarrier

See Color Burst.

S-Video

Commonly incorrectly used interchangeably with Y/C. *See also* Y/C. Technically, a magnetic-tape modulation format.

Sync Signals/Pulses

Sync signals, also known as sync pulses, are negative-going timing pulses in video signals that are used by video-processing or display devices to synchronize the horizontal and vertical portions of the display.

Vertical Blanking

See Blanking Level *and* Blanking Interval.

Vertical Field Frequency

The inverse of the time (or period) to produce one field of video (half of a frame). In NTSC it is 59.94Hz.

Vertical Frame Rate

The inverse of the time (or period) to produce one frame of video. Also called "refresh rate" or "vertical refresh rate."

Video Bandwidth, Minimum

The minimum analog bandwidth required to reproduce the smallest amount of detail contained in the video signal.

Y Cr Cb

A digital component video interface. Y is the luma (brightness) portion, and Cr and Cb are the color-difference portions of the signal.

Y Pr Pb

An analog-component video interface. Y is the luma (brightness) portion, and Pr and Pb are the color-difference portions of the signal. Typically used on high-end consumer video equipment.

Y/C

An analog video interface in which the chroma (color) information is carried separately from the luma (brightness) and sync information. Two wire pairs are used, denoted Y and C or Y/C. Often incorrectly referred to as "S-video."

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