

EXHIBIT 1004



Video 4th Edition Demystified

ANALOG

NTSC/PAL
YPbPr
RGB
VBI

MPEG

-1
-2
-4
H.264

HDTV

ATSC
DVB
ISDB
OpenCable



CD-ROM included
Contains design tools, test files
and a fully searchable eBook



A Handbook for the Digital Engineer



Keith Jack

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Introduction to Video

Although there are many variations and implementation techniques, video signals are just a way of transferring visual information from one point to another. The information may be from a VCR, DVD player, a channel on the local broadcast, cable television, or satellite system, the internet or one of many other sources.

Invariably, the video information must be transferred from one device to another. It could be from a satellite set-top box or DVD player to a television. Or it could be from one chip to another inside the satellite set-top box or television. Although it seems simple, there are many different requirements, and therefore many different ways of doing it.

Analog vs. Digital

Until a few years ago, most video equipment was designed primarily for analog video. Digital video was confined to professional applications, such as video editing.

The average consumer now uses digital video every day thanks to continuing falling costs. This trend has led to the development of DVD players and recorders, digital set-top boxes, digital television (DTV), portable video players and the ability to use the Internet for transferring video data.

Video Data

Initially, video contained only gray-scale (also called black-and-white) information.

While color broadcasts were being developed, attempts were made to transmit color video using analog RGB (red, green, blue) data. However, this technique occupied 3× more bandwidth than the current gray-scale solution, so alternate methods were developed that led to using Y, R-Y and G-Y data to represent color information. A technique was then developed to transmit this Y, R-Y and G-Y information using one signal, instead of three separate signals, and in the same bandwidth as the original gray-scale video signal. This *com-*

posite video signal is what the NTSC, PAL, and SECAM video standards are still based on today. This technique is discussed in more detail in Chapters 8 and 9.

Today, even though there are many ways of representing video, they are still all related mathematically to RGB. These variations are discussed in more detail in Chapter 3.

S-Video was developed for connecting consumer equipment together (it is not used for broadcast purposes). It is a set of two analog signals, one gray-scale (Y) and one that carries the analog R-Y and B-Y color information in a specific format (also called C or chroma). Once available only for S-VHS, it is now supported on most consumer video products. This is discussed in more detail in Chapter 9.

Although always used by the professional video market, analog RGB video data has made a temporary come-back for connecting high-end consumer equipment together. Like *S-Video*, it is not used for broadcast purposes.

A variation of the Y, R-Y and G-Y video signals, called *YPbPr*, is now commonly used for connecting consumer video products together. Its primary advantage is the ability to transfer high-definition video between consumer products. Some manufacturers incorrectly label the YPbPr connectors YUV, YCbCr, or Y(B-Y) (R-Y).

Chapter 5 discusses the various analog interconnect schemes in detail.

Digital Video

The most common digital signals used are *RGB* and *YCbCr*. RGB is simply the digitized version of the analog RGB video signals. YCbCr is basically the digitized version of the analog YPbPr video signals, and is the format used by DVD and digital television.

Chapter 6 further discusses the various digital interconnect schemes.

Best Connection Method

There is always the question of “what is the best connection method for equipment?”. For DVD players and digital cable/satellite/terrestrial set-top boxes, the typical order of decreasing video quality is:

1. HDMI (digital YCbCr)
2. DVI (digital RGB)
3. Analog YPbPr
4. Analog RGB
5. Analog S-Video
6. Analog Composite

Some will disagree about the order. However, most consumer products do digital video processing in the YCbCr color space. Therefore, using YCbCr as the interconnect for equipment reduces the number of color space conversions required. Color space conversion of digital signals is still preferable to D/A (digital-to-analog) conversion followed by A/D (analog-to-digital) conversion, hence the positioning of DVI above analog YPbPr.

The computer industry has standardized on analog and digital RGB for connecting to the computer monitor.

Video Timing

Although it looks like video is continuous motion, it is actually a series of still images, changing fast enough that it looks like continuous motion, as shown in Figure 2.1. This typically occurs 50 or 60 times per second for consumer video, and 70–90 times per second for computer displays. Special timing information, called *vertical sync*, is used to indicate when a new image is starting.

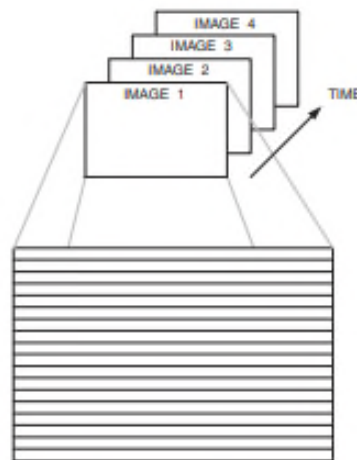


Figure 2.1. Video Is Composed of a Series of Still Images. Each image is composed of individual lines of data.

Each still image is also composed of *scan lines*, lines of data that occur sequentially one after another down the display, as shown in Figure 2.1. Additional timing information, called *horizontal sync*, is used to indicate when a new scan line is starting.

The vertical and horizontal sync information is usually transferred in one of three ways:

1. Separate horizontal and vertical sync signals
2. Separate composite sync signal
3. Composite sync signal embedded within the video signal

The composite sync signal is a combination of both vertical and horizontal sync.

Computer and consumer equipment that uses analog RGB video usually uses technique 1 or 2. Consumer equipment that supports composite video or analog YPbPr video usually uses technique 3.

For digital video, either technique 1 is commonly used or timing code words are embedded within the digital video stream. This is discussed in Chapter 6.

Interlaced vs. Progressive

Since video is a series of still images, it makes sense to simply display each full image consecutively, one after the another.

This is the basic technique of progressive, or non-interlaced, displays. For progressive displays that “paint” an image on the screen, such as a CRT, each image is displayed starting at the top left corner of the display, moving to the right edge of the display. Then scanning then moves down one line, and repeats scanning left-to-right. This process is repeated until the entire screen is refreshed, as seen in Figure 2.2.

In the early days of television, a technique called “interlacing” was used to reduce the amount of information sent for each image. By transferring the odd-numbered lines, followed by the even-numbered lines (as shown in Figure 2.3), the amount of information sent for each image was halved.

Given this advantage of interlacing, why bother to use progressive?

With interlace, each scan line is refreshed half as often as it would be if it were a progressive display. Therefore, to avoid line flicker on sharp edges due to a too-low refresh rate, the line-to-line changes are limited, essentially by vertically lowpass filtering the image. A progressive display has no limit on the line-to-line changes, so is capable of providing a higher-resolution image (vertically) without flicker.

Today, most broadcasts (including HDTV) are still transmitted as interlaced. Most CRT-based displays are still interlaced while LCD, plasma and computer displays are progressive.

Video Resolution

Video resolution is one of those “fuzzy” things in life. It is common to see video resolutions of 720×480 or 1920×1080 . However, those are just the number of horizontal samples and vertical scan lines, and do not necessarily convey the amount of useful information.

For example, an analog video signal can be sampled at 13.5 MHz to generate 720 samples per line. Sampling the same signal at 27 MHz would generate 1440 samples per line. However, only the number of samples per line has changed, not the resolution of the content.

Therefore, video is usually measured using “lines of resolution”. In essence, how many distinct black and white vertical lines can be seen across the display? This number is then normalized to a 1:1 display aspect ratio (dividing the number by $3/4$ for a 4:3 display, or by $9/16$ for a 16:9 display). Of course, this results in a lower value for widescreen (16:9) displays, which goes against intuition.

Standard Definition

Standard definition video is usually defined as having 480 or 576 interlaced active scan lines, and is commonly called “480i” and “576i” respectively.

For a fixed-pixel (non-CRT) consumer display with a 4:3 aspect ratio, this translates into an active resolution of $720 \times 480i$ or $720 \times 576i$. For a 16:9 aspect ratio, this translates into an active resolution of $960 \times 480i$ or $960 \times 576i$.

Enhanced Definition

Enhanced definition video is usually defined as having 480 or 576 progressive active scan lines, and is commonly called “480p” and “576p” respectively.

For a fixed-pixel (non-CRT) consumer display with a 4:3 aspect ratio, this translates into an active resolution of $720 \times 480p$ or $720 \times 576p$. For a 16:9 aspect ratio, this translates into an active resolution of $960 \times 480p$ or $960 \times 576p$.

The difference between standard and enhanced definition is that standard definition is interlaced, while enhanced definition is progressive.

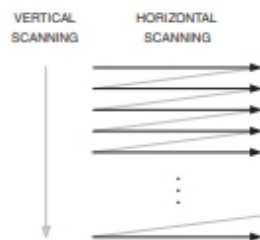


Figure 2.2. Progressive Displays “Paint” the Lines of An Image Consecutively, One After Another.

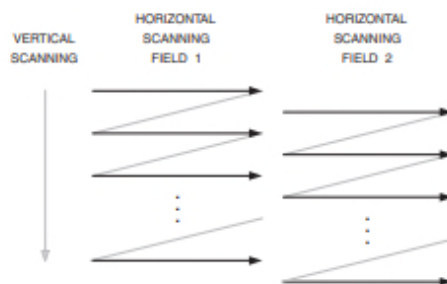


Figure 2.3. Interlaced Displays “Paint” First One-Half of the Image (Odd Lines), Then the Other Half (Even Lines).

High Definition

High definition video is usually defined as having 720 progressive (720p) or 1080 interlaced (1080i) active scan lines. For a fixed-pixel (non-CRT) consumer display with a 16:9 aspect ratio, this translates into an active resolution of 1280×720 p or 1920×1080 i, respectively.

However, HDTV displays are technically defined as being capable of displaying a minimum of 720p or 1080i active scan lines. They also must be capable of displaying 16:9 content using a minimum of 540 progressive (540p) or 810 interlaced (810i) active scan lines. This enables the manufacturing of CRT-based HDTVs with a 4:3 aspect ratio and LCD/plasma 16:9 aspect ratio displays with resolutions of 1024×1024 p, 1280×768 p, 1024×768 p, and so on, lowering costs.

Audio and Video Compression

The recent advances in consumer electronics, such as digital television, DVD players and recorders, digital video recorders, and so on, were made possible due to audio and video compression based largely on MPEG-2 video with Dolby® Digital, DTS®, MPEG-1 or MPEG-2 audio.

New audio and video codecs, such as MPEG-4 HE-AAC, H.264 and SMPTE VC-9, offer better compression than previous codecs for the same quality. These advances are enabling new ways of distributing content (both to consumers and within the home), new consumer products (such as portable video players and mobile video/cell phones) and more cable/satellite channels.

Application Block Diagrams

Looking at a few simplified block diagrams helps envision how video flows through its various operations.

DVD Players

Figure 2.4 is a simplified block diagram for a basic DVD-Video player, showing the common blocks. Today, all of this is on a single low-cost chip.

In addition to playing DVDs (which are based on MPEG-2 video compression), DVD players are now expected to handle MP3 and WMA audio, MPEG-4 video (for DivX Video), JPEG images, and so on. Special playback modes such as slow/fast forward/reverse at various speeds are also expected. Support for DVD-Audio and SACD is also increasing.

A recent enhancement to DVD players is the ability to connect to a home network for playing content (music, video, pictures, etc.) residing on the PC. These “networked DVD players” may also include the ability to play movies from the Internet and download content onto an internal hard disc drive (HDD) for later viewing. Support for playing audio, video and pictures from a variety of flash-memory cards is also growing.

In an attempt to “look different” to quickly grab buyers attention, some DVD player manufacturers “tweak” the video frequency response. Since this “feature” is usually irritating over the long term, it should be defeated or properly adjusted. For the “film look” many video enthusiasts strive for, the frequency response should be as flat as possible.

Another issue is the output levels of the analog video signals. Although it is easy to generate very accurate video levels, they vary con-

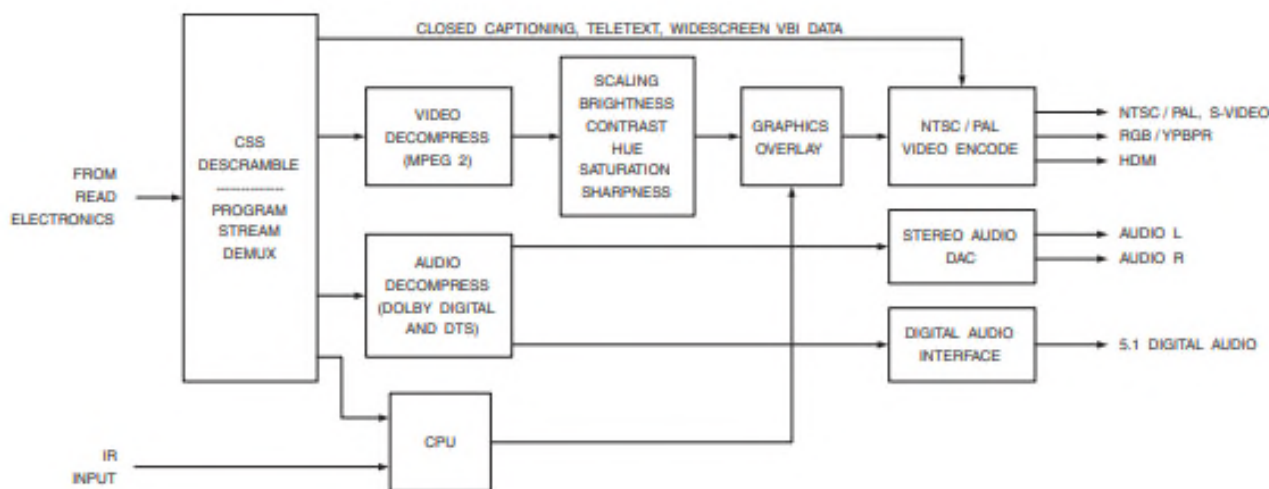


Figure 2.4. Simplified Block Diagram of a Basic DVD Player.

siderably. Reviews are now pointing out this issue since switching between sources may mean changing brightness or black levels, defeating any television calibration or personal adjustments that may have been done by the user.

Digital Media Adapters

Digital media adapters connect to a home network for playing content (music, video, pictures, and so on) residing on the PC. These small, low-cost boxes enable PC-based content to be enjoyed on any or all televisions in the home. Many support optional wireless networking, simplifying installation. Except for DVD playback, they have capabilities similar to networked DVD players.

Figure 2.5 is a simplified block diagram for a basic digital media adapter, showing the common blocks. Today, all of this is on a single low-cost chip.

Digital Television Set-top Boxes

The digital television standards fall into six major categories:

- ATSC (Advanced Television Systems Committee)

- DVB (Digital Video Broadcast)

- ARIB (Association of Radio Industries and Businesses)

- Open digital cable standards, such as OpenCable

- Proprietary digital cable standards

- Proprietary digital satellite standards

Currently based on MPEG-2 video compression, with Dolby® Digital or MPEG audio compression, work is progressing on supporting the new advanced audio and video codecs, such as HE-AAC, H.264 and VC-9.

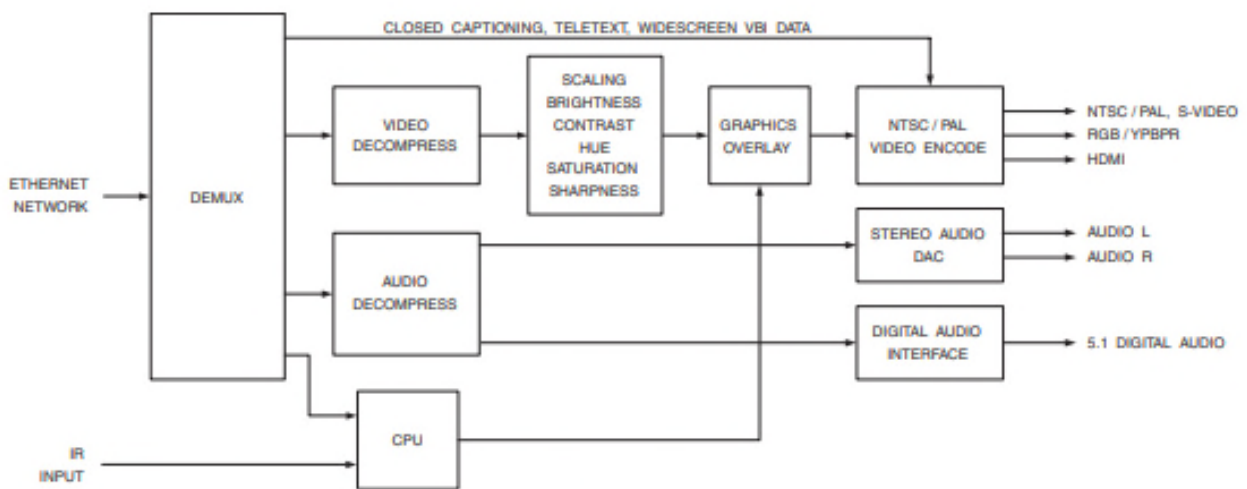


Figure 2.5. Simplified Block Diagram of a Digital Media Adapter.

Figure 2.6 is a simplified block diagram for a digital television set-top box, showing the common audio and video processing blocks. It is used to receive digital television broadcasts, from either terrestrial (over-the-air), cable, or satellite. A digital television may include this circuitry inside the television.

Many set-top boxes now include two tuners and digital video recorder (DVR) capability. This enables recording one program onto an internal HDD while watching another. Two tuners are also common in digital television receivers to support a picture-in-picture (PIP) feature.

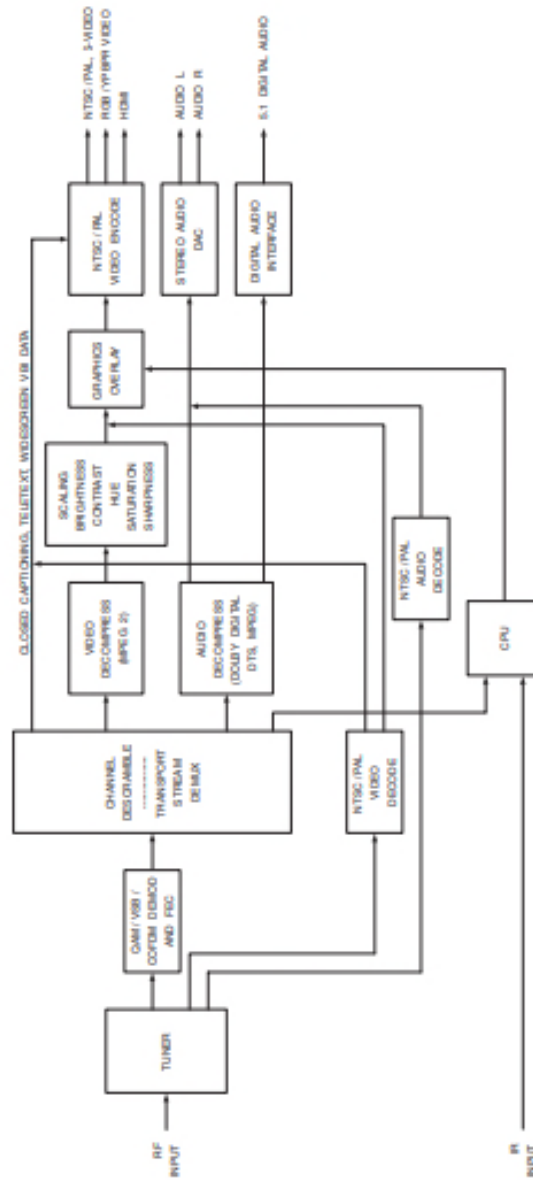


Figure 2.6. Simplified Block Diagram of a Digital Television Set-top Box.