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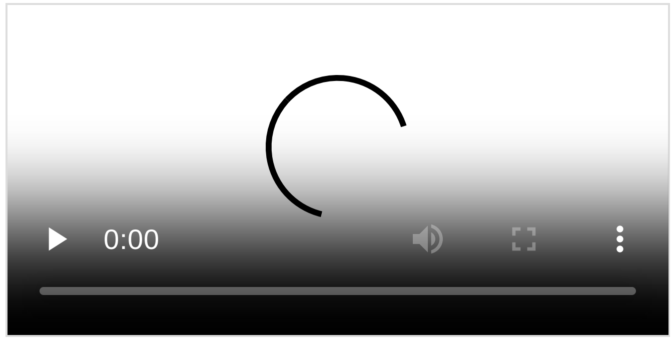
Video

Video is an electronic medium for the recording, copying, playback, broadcasting, and display of moving visual media.[1] Video was first developed for mechanical television systems, which were quickly replaced by cathode-ray tube (CRT) systems, which, in turn, were replaced by flat-panel displays of several types.



A one-minute animated video showing an example of a media production process

Video systems vary in display resolution, aspect ratio, refresh rate, color capabilities, and other qualities. Analog and digital variants exist and can be carried on a variety of media, including radio broadcasts, magnetic tape, optical discs, computer files, and network streaming.

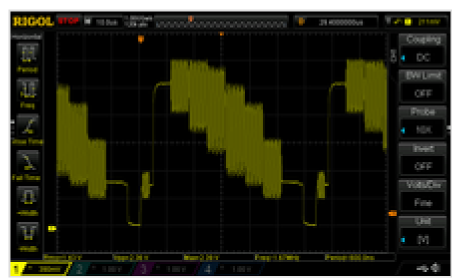
Etymology

The word *video* comes from the Latin *video* (I see).[2]

History

Analog video

Video developed from facsimile systems developed in the mid-19th century. Early mechanical video scanners, such as the Nipkow Disk were patented as early as 1884, however, it took several decades before practical video systems could be developed, many decades after film. Film records using a sequence of miniature photographic images visible to the eye when the film is physically examined. Video, by contrast, encodes images electronically, turning the images into analog or digital electronic signals for transmission or recording.[3]



NTSC composite video signal (analog)

Video technology was first developed for mechanical television systems, which were quickly replaced by cathode-ray tube (CRT) television systems. Video was originally exclusively live technology. Charles Ginsburg led an Ampex research team to develop one of the first practical video tape recorders (VTR). In 1951, the first VTR captured live images from television cameras by writing the camera's electrical signal onto magnetic videotape.

Video recorders were sold for US$50,000 in 1956, and videotapes cost US$300 per one-hour reel.[4] However, prices gradually dropped over the years; in 1971, Sony began selling videocassette recorder (VCR) decks and tapes into the consumer market.[5]

Digital video

Digital video is capable of higher quality and, eventually, a much lower cost than earlier analog technology. After the commercial introduction of the DVD in 1997 and later the Blu-ray Disc in 2006, sales of videotape and recording equipment plummeted. Advances in computer technology allow even inexpensive personal computers and smartphones to capture, store, edit, and transmit digital video, further reducing the cost of video production and allowing program-makers and broadcasters to move to tapeless production. The advent of digital broadcasting and the subsequent digital television transition are in the process of relegating analog video to the status of a legacy technology in most parts of the world. The development of high-resolution video cameras with improved dynamic range and color gamuts, along with the introduction of high-dynamic-range digital intermediate data formats with improved color depth, has caused digital video technology to converge with film technology. Since 2013, the use of digital cameras in Hollywood has surpassed the use of film cameras.[6]

Characteristics of video streams

Number of frames per second

Frame rate, the number of still pictures per unit of time of video, ranges from six or eight frames per second (*frame/s*) for old mechanical cameras to 120 or more frames per second for new professional cameras. PAL standards (Europe, Asia, Australia, etc.) and SECAM (France, Russia, parts of Africa, etc.) specify 25 frame/s, while NTSC standards (United States, Canada, Japan, etc.) specify 29.97 frame/s.[7] Film is shot at a slower frame rate of 24 frames per second, which slightly complicates the process of transferring a cinematic motion picture to video. The minimum frame rate to achieve a comfortable illusion of a moving image is about sixteen frames per second.[8]

Interlaced vs. progressive

Video can be interlaced or progressive. In progressive scan systems, each refresh period updates all scan lines in each frame in sequence. When displaying a natively progressive broadcast or recorded signal, the result is the optimum spatial resolution of both the stationary and moving parts of the image. Interlacing was invented as a way to reduce flicker in early mechanical and CRT video displays without increasing the number of complete frames per second. Interlacing retains detail while requiring lower bandwidth compared to progressive scanning.[9][10]

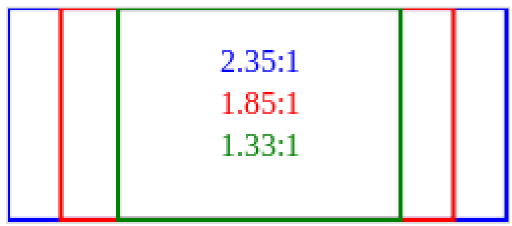
In interlaced video, the horizontal scan lines of each complete frame are treated as if numbered consecutively and captured as two *fields*: an *odd field* (upper field) consisting of the odd-numbered lines and an *even field* (lower field) consisting of the even-numbered lines. Analog display devices reproduce each frame, effectively doubling the frame rate as far as perceptible overall flicker is concerned. When the image capture device acquires the fields one at a time, rather than dividing up a complete frame after it is captured, the frame rate for motion is effectively doubled as well, resulting in smoother, more lifelike reproduction of rapidly moving parts of the image when viewed on an interlaced CRT display.[9][10]

NTSC, PAL, and SECAM are interlaced formats. Abbreviated video resolution specifications often include an *i* to indicate interlacing. For example, PAL video format is often described as *576i50*, where *576* indicates the total number of horizontal scan lines, *i* indicates interlacing, and *50* indicates 50 fields (half-frames) per second.[10][11]

When displaying a natively interlaced signal on a progressive scan device, the overall spatial resolution is degraded by simple line doubling—artifacts, such as flickering or "comb" effects in moving parts of the image that appear unless special signal processing eliminates them.[9][12] A procedure known as deinterlacing can optimize the display of an interlaced video signal from an analog, DVD, or satellite source on a progressive scan device such as an LCD television, digital video projector, or plasma panel. Deinterlacing cannot, however, produce video quality that is equivalent to true progressive scan source material.[10][11][12]

Aspect ratio

Aspect ratio describes the proportional relationship between the width and height of video screens and video picture elements. All popular video formats are rectangular, and this can be described by a ratio between width and height. The ratio of width to height for a traditional television screen is 4:3, or about 1.33:1. High-definition televisions use an aspect ratio of 16:9, or about 1.78:1. The aspect ratio of a full 35 mm film frame with soundtrack (also known as the Academy ratio) is 1.375:1.[13][14]



Comparison of common cinematography and traditional television (green) aspect ratios

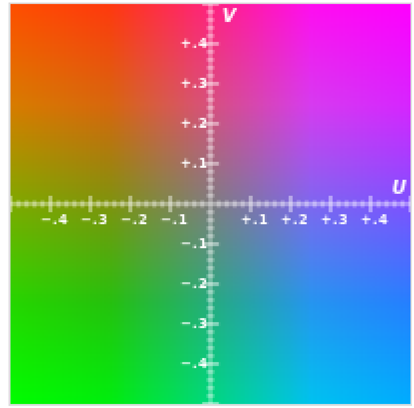
Pixels on computer monitors are usually square, but pixels used in digital video often have non-square aspect ratios, such as those used in the PAL and NTSC variants of the CCIR 601 digital video standard and the corresponding anamorphic widescreen formats. The 720 by 480 pixel raster uses thin pixels on a 4:3 aspect ratio display and fat pixels on a 16:9 display.[13][14]

The popularity of viewing video on mobile phones has led to the growth of vertical video. Mary Meeker, a partner at Silicon Valley venture capital firm Kleiner Perkins Caufield & Byers, highlighted the growth of vertical video viewing in her 2015 Internet Trends Report – growing from 5% of video viewing in 2010 to 29% in 2015. Vertical video ads like Snapchat's are watched in their entirety nine times more frequently than landscape video ads.[15]

Color model and depth

The color model uses the video color representation and maps encoded color values to visible colors reproduced by the system. There are several such representations in common use: typically, YIQ is used in NTSC television, YUV is used in PAL television, YDbDr is used by SECAM television, and YCbCr is used for digital video.[16][17]

The number of distinct colors a pixel can represent depends on the color depth expressed in the number of bits per pixel. A common way to reduce the amount of data required in digital video is by chroma subsampling (e.g., 4:4:4, 4:2:2, etc.). Because the human eye is less sensitive to details in color than brightness, the luminance data for all pixels is maintained, while the chrominance data is averaged for a number of pixels in a block, and the same value is used for all of them. For example, this results in a 50% reduction in chrominance data using 2-pixel blocks (4:2:2) or 75% using 4-pixel blocks (4:2:0). This process does not reduce the number of possible color values that can be displayed, but it reduces the number of distinct points at which the color changes.[11][16][17]



Example of U-V color plane, Y value=0.5

Video quality

Video quality can be measured with formal metrics like peak signal-to-noise ratio (PSNR) or through subjective video quality assessment using expert observation. Many subjective video quality methods are described in the ITU-T recommendation BT.500. One of the standardized methods is the *Double Stimulus Impairment Scale* (DSIS). In DSIS, each expert views an *unimpaired* reference video, followed by an *impaired* version of the same video. The expert then rates the *impaired* video using a scale ranging from "impairments are imperceptible" to "impairments are very annoying."

Video compression method (digital only)

Uncompressed video delivers maximum quality, but at a very high data rate. A variety of methods are used to compress video streams, with the most effective ones using a group of pictures (GOP) to reduce spatial and temporal redundancy. Broadly speaking, spatial redundancy is reduced by registering differences between parts of a single frame; this task is known as *intraframe compression* and is closely related to image compression. Likewise, temporal redundancy can be reduced by registering differences between frames; this task is known as *interframe compression*, including motion compensation and other techniques. The most common modern compression standards are MPEG-2, used for DVD, Blu-ray, and satellite television, and MPEG-4, used for AVCHD, mobile phones (3GP) and the Internet.[18][19]

Stereoscopic

Stereoscopic video for 3D film and other applications can be displayed using several different methods:[20][21]

- Two channels: a right channel for the right eye and a left channel for the left eye. Both channels may be viewed simultaneously by using light-polarizing filters 90 degrees off-axis from each other on two video projectors. These separately polarized channels are viewed wearing eyeglasses with matching polarization filters.
- Anaglyph 3D where one channel is overlaid with two color-coded layers. This left and right layer technique is occasionally used for network broadcasts or recent anaglyph releases of 3D movies on DVD. Simple red/cyan plastic glasses provide the means to view the images discretely to form a stereoscopic view of the content.

- One channel with alternating left and right frames for the corresponding eye, using LCD shutter glasses that synchronize to the video to alternately block the image for each eye, so the appropriate eye sees the correct frame. This method is most common in computer virtual reality applications, such as in a Cave Automatic Virtual Environment, but reduces effective video framerate by a factor of two.

Formats

Different layers of video transmission and storage each provide their own set of formats to choose from.

For transmission, there is a physical connector and signal protocol (see List of video connectors). A given physical link can carry certain display standards that specify a particular refresh rate, display resolution, and color space.

Many analog and digital recording formats are in use, and digital video clips can also be stored on a computer file system as files, which have their own formats. In addition to the physical format used by the data storage device or transmission medium, the stream of ones and zeros that is sent must be in a particular digital video coding format, for which a number is available.

Analog video

Analog video is a video signal represented by one or more analog signals. Analog color video signals include luminance, brightness (Y) and chrominance (C). When combined into one channel, as is the case among others with NTSC, PAL, and SECAM, it is called composite video. Analog video may be carried in separate channels, as in two-channel S-Video (YC) and multi-channel component video formats.

Analog video is used in both consumer and professional television production applications.

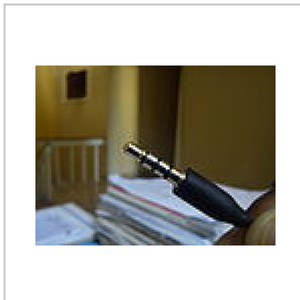
Composite video
(single channel RCA)

S-Video
(2-channel YC)

Component video
(3-channel YPbPr)

SCART

VGA



TRRS

D-Terminal

Digital video

Digital video signal formats have been adopted, including serial digital interface (SDI), Digital Visual Interface (DVI), High-Definition Multimedia Interface (HDMI) and DisplayPort Interface.

Serial digital interface
(SDI)

Digital Visual Interface
(DVI)

HDMI

DisplayPort

Transport medium

Video can be transmitted or transported in a variety of ways including wireless terrestrial television as an analog or digital signal, coaxial cable in a closed-circuit system as an analog signal. Broadcast or studio cameras use a single or dual coaxial cable system using serial digital interface (SDI). See List of video connectors for information about physical connectors and related signal standards.

Video may be transported over networks and other shared digital communications links using, for instance, MPEG transport stream, SMPTE 2022 and SMPTE 2110.

Display standards

Digital television

Digital television broadcasts use the MPEG-2 and other video coding formats and include:

- ATSC – United States, Canada, Mexico, Korea
- Digital Video Broadcasting (DVB) – Europe
- ISDB – Japan
  - ISDB-Tb – uses the MPEG-4 video coding format – Brazil, Argentina
- Digital Multimedia Broadcasting (DMB) – Korea

Analog television

Analog television broadcast standards include:

- Field-sequential color system (FCS) – US, Russia; obsolete
- Multiplexed Analogue Components (MAC) – Europe; obsolete
- Multiple sub-Nyquist sampling encoding (MUSE) – Japan
- NTSC – United States, Canada, Japan
  - EDTV-II "Clear-Vision" - NTSC extension, Japan
- PAL – Europe, Asia, Oceania
  - PAL-M – PAL variation, Brazil
  - PAL-N – PAL variation, Argentina, Paraguay and Uruguay
  - PALplus – PAL extension, Europe
- RS-343 (military)
- SECAM – France, former Soviet Union, Central Africa
- CCIR System A
- CCIR System B
- CCIR System G
- CCIR System H
- CCIR System I
- CCIR System M

An analog video format consists of more information than the visible content of the frame. Preceding and following the image are lines and pixels containing metadata and synchronization information. This surrounding margin is known as a *blanking interval* or *blanking region*; the horizontal and vertical front porch and back porch are the building blocks of the blanking interval.

Computer displays

Computer display standards specify a combination of aspect ratio, display size, display resolution, color depth, and refresh rate. A list of common resolutions is available.

Recording

Early television was almost exclusively a live medium, with some programs recorded to film for historical purposes using Kinescope. The analog video tape recorder was commercially introduced in 1951. The following list is in rough chronological order. All formats listed were sold to and used by broadcasters, video producers, or consumers; or were important historically.[22][23]

A VHS video cassette tape

- VERA (BBC experimental format ca. 1952)
- 2" Quadruplex videotape (Ampex 1956)
- 1" Type A videotape (Ampex)
- 1/2" EIAJ (1969)
- U-matic 3/4" (Sony)
- 1/2" Cartrivision (Avco)
- VCR, VCR-LP, SVR
- 1" Type B videotape (Robert Bosch GmbH)
- 1" Type C videotape (Ampex, Marconi and Sony)
- Betamax (Sony)
- VHS (JVC)
- Video 2000 (Philips)
- 2" Helical Scan Videotape (IVC)
- 1/4" CVC (Funai)
- Betacam (Sony)
- HDVS (Sony)[24]
- Betacam SP (Sony)
- Video8 (Sony) (1986)
- S-VHS (JVC) (1987)
- VHS-C (JVC)
- Pixelvision (Fisher-Price)
- UniHi 1/2" HD (Sony)[24]
- Hi8 (Sony) (mid-1990s)
- W-VHS (JVC) (1994)

Digital video tape recorders offered improved quality compared to analog recorders.[23][25]

- Betacam IMX (Sony)
- D-VHS (JVC)
- D-Theater
- D1 (Sony)
- D2 (Sony)
- D3
- D5 HD
- D6 (Philips)
- Digital-S D9 (JVC)
- Digital Betacam (Sony)
- Digital8 (Sony)
- DV (including DVC-Pro)
- HDCAM (Sony)
- HDV
- ProHD (JVC)
- MicroMV
- MiniDV

Optical storage mediums offered an alternative, especially in consumer applications, to bulky tape formats.[22][26]

- Blu-ray Disc (Sony)
- China Blue High-definition Disc (CBHD)
- DVD (was Super Density Disc, DVD Forum)
- Professional Disc
- Universal Media Disc (UMD) (Sony)
- Enhanced Versatile Disc (EVD, Chinese government-sponsored)
- HD DVD (NEC and Toshiba)
- HD-VMD
- Capacitance Electronic Disc
- Laserdisc (MCA and Philips)
- Television Electronic Disc (Teldec and Telefunken)
- VHD (JVC)
- Video CD

Digital encoding formats

A video codec is software or hardware that compresses and decompresses digital video. In the context of video compression, *codec* is a portmanteau of *encoder* and *decoder*, while a device that only compresses is typically called an *encoder*, and one that only decompresses is a *decoder*. The compressed data format usually conforms to a standard video coding format. The compression is typically lossy, meaning that the compressed video lacks some information present in the original video. A consequence of this is that decompressed video has lower quality than the original, uncompressed video because there is insufficient information to accurately reconstruct the original video.[27]

- CCIR 601 (ITU-T)
- H.261 (ITU-T)
- H.263 (ITU-T)
- H.264/MPEG-4 AVC (ITU-T + ISO)
- H.265
- M-JPEG (ISO)
- MPEG-1 (ISO)
- MPEG-2 (ITU-T + ISO)
- MPEG-4 (ISO)
- Ogg-Theora

- VP8-WebM
- VC-1 (SMPTE)

See also

General

- Index of video-related articles
- Sound recording and reproduction
- Video editing
- Videography

Video format

- 360-degree video
- Cable television
- Color television
- Telecine
- Timecode
- Volumetric video

Video usage

- Closed-circuit television
- Fulldome video
- Interactive video
- Video art
- Video feedback
- Video sender
- Video synthesizer
- Videotelephony

Video screen recording software

- Bandicam
- CamStudio
- Camtasia
- CloudApp
- Fraps

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External links

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- Video as Media Production (https://curlie.org/Business/Arts_and_Entertainment/Media_Production/Video/) at Curlie
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