A DVD Primer
From DV to DVD: Enriching the Experience of High-Quality Video

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Introduction

From Stone Age to Bronze Age to Industrial Age to Information Age, humans have found new ways to communicate and to tell stories that educate, inform, and entertain. Digital technology has transformed the ways we access and use information more profoundly than any other human invention, and brought us to the dawn of the Interactive Age.

Within three years of its introduction in September 1997, DVD technology products outpaced the consumer adoption rate of any other product in history. The online resource Research and Markets predicts that worldwide DVD recorder shipments will grow from 9.4 million in 2004 to 67.7 million in 2009. This number does not even count players, set-top boxes, and computer DVD drives.

While DVD players have rapidly become a standard component of home entertainment systems, and DVD drives continue to replace CD drives in personal computers, there are also developments that are changing the way we experience and use video:

- Digital video software and hardware is readily available and affordable, so more people are producing their own videos—for work or their own entertainment.
- Nonlinear editing software has made capturing video and crafting compelling video productions affordable and easy.
- DVD allows for richer content than other media. Compact Disc (CD) technology empowered computer users of all levels to become adept at selecting, organizing, and storing their own collections of imagery and audio. Today, DVDs bring broadcast quality video to those users.

This primer introduces you to key concepts of DVD technology and shows you how easy it can be to develop and author your own DVDs. You'll learn how you can use DVD technology to make your video content more dynamic. If you're a beginner, you'll learn enough to be an informed member of a workgroup planning or producing DVD projects. If you are already creating video productions, this primer will introduce you to state-of-the-art technology you can use to repurpose your content for DVD distribution.

As you read this primer, you might encounter unfamiliar words or abbreviations. Terms in boldface are defined in the Glossary and many will also be covered in greater detail as you read on.

What is DVD?

DVD is an **optical disc** storage medium similar to CD, but capable of holding far more data. DVD stands for more than just the disc itself; it represents a whole system of standards for DVD technology—discs, drives, and players and the formats that support them. DVD technology offers the higher quality and speed needed to deliver cinema-like video and better-than-CD audio. DVD was originally an abbreviation for Digital Video Disc. To highlight the flexibility of the format, some industry leaders have suggested that DVD is an abbreviation for Digital Versatile Disc.

What are the advantages of DVD?

DVD has a number of advantages as both a delivery medium for digital media and a portable storage medium:

- **Storage capacity:** A CD stores a maximum of 650MB of data. That's enough for approximately 74 minutes of audio. A DVD stores up to 4.7GB per layer, per side. Using **MPEG-2** compression, a single-sided, single-layer DVD can easily accommodate an entire feature-length film with multichannel **digital** audio. A DVD-18 disc (currently the highest-capacity format), with two layers on each side and a capacity just over 17GB, can hold up to eight hours of broadcast-quality video.
- **Quality:** DVD provides almost twice the video **resolution** of standard VHS videotape. Because video on DVD is stored digitally, the medium itself does not create noise. As a result, DVD provides a much clearer picture than **analog** videotape.
- **Convenience and compatibility:** Unlike the larger laser disc, a DVD is the same size and thickness as a CD. Computer DVD drives support both CDs and DVDs. DVDs offer interactive menus that let users randomly navigate content. The interactive capabilities of DVDs provides unlimited possibilities for creating user experiences.
- **Durability:** While videotapes eventually wear out or break, DVDs do not suffer loss of fidelity over time, because they don't come into direct contact with the player's mechanics.

Because of its many attributes, DVD meets the demands of a number of industries:

- **Computer industry:** Recordable and rewritable DVDs provide the next generation of convenience and higher capacity for data storage and archiving. Increasingly complex multimedia applications are continually being developed and these can easily be delivered on DVD.
- **Motion picture industry:** The movie industry has embraced DVDs because they can hold a full-length feature film, while delivering excellent quality video with surround-sound audio.
- **Music industry:** The high storage capacity enables the music industry to offer products on DVD-Audio discs, which deliver higher quality sound than can be achieved on CDs.
- **Video game industry:** DVD technology delivers realistic video content with longer playing time.

Standards are set by a single association

DVD owes its phenomenal success largely to the organization that governs its standards and promotes its acceptance—the DVD Forum (www.dvdforum.org). An often uneasy alliance of hardware manufacturers, software firms, and other users of DVD technology, this international association was established in 1995 initially as the DVD Consortium by 10 companies: Hitachi, Matsushita, Mitsubishi, Philips, Pioneer, Sony, Thomson Multimedia, Time-Warner, Toshiba, and JVC (Victor Company of Japan). Today, virtually every major company involved in DVD technology is a member of the DVD Forum.

The components of DVD technology

DVD discs look much like CDs. They are the same diameter (120mm) and thickness (1.2mm). However, each layer (up to two) on each of the two sides of a DVD can hold up to seven times the data that can be stored on a single-sided, single-layer CD. While the layers on a dual-layer side of a DVD don't hold as much data as a single layer side, a double-sided, dual-layer DVD (DVD-18) can hold up to 17GB of data.

Etched into the surface of the metallic discs that are bonded within the acrylic coatings of both CDs and DVDs are microscopic marks called pits. The surface area surrounding the pits is called **land**. The pits are arranged on spiral tracks; the pitch, or space between tracks on a DVD disc is less than half the pitch between tracks on a CD, enabling more tracks to be placed on a DVD disc. The laser in the DVD drive reads the pits, and then the drive interprets the information, translating it into a signal that can, in turn, be used by a computer, television set, or audio receiver.

DVDs have greater capacity than CDs primarily because they use better laser technology. A smaller spot of laser light, operating at a shorter wavelength, enables the DVD laser to read smaller pits. The DVD laser also has the ability to change focus so it can scan and read multiple layers.

To make it easier for the laser to focus on the smaller pits, DVDs are made from a thinner plastic than what is used for CDs. A single thickness of DVD plastic, however, is too thin to withstand handling and playing, so two discs are bonded together (whether or not they are single- or double-sided), potentially doubling data storage capacity. Additionally, software used to read and decode DVDs uses a more efficient method of error correction than CDs, leaving more room on the disc for actual data.

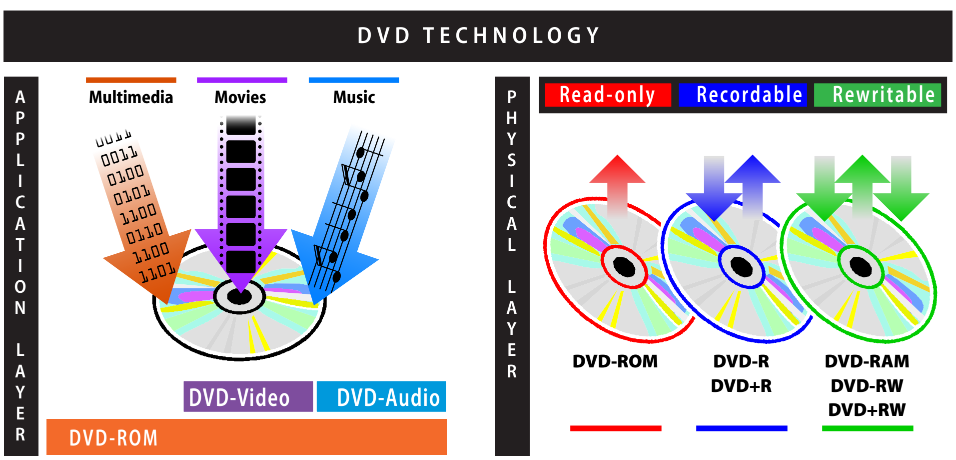
Understanding DVD formats

Just as in digital video, where the term format may be used to refer to a variety of different things, such as tape formats, broadcast formats, **aspect ratios**, or even content formats, in DVD technology the term format also refers to different sets of characteristics, sometimes known as technology layers. A technology layer is defined by a format. With DVD technology, we are primarily interested in two layers: the physical layer, which determines the recordability of a DVD, and the application layer, which governs how the data is stored on a disc and how it is played.

Physical layer

The physical layer determines recording capability:

- **Read-only format: DVD-ROM**, with its large data storage capacity, is perfect for delivering copyright-protected content such as movies and music, as well as multimedia and interactive applications like video games, and training materials.
- **Recordable formats: DVD-R** and **DVD+R** have a storage format similar to CD-R and CD+R. DVD-R and DVD+R discs can only be written to once, with the data recorded sequentially. There are two types of DVD-R:
  - **DVD-R(A)** or **DVD-R for Authoring**, is aimed at the professional market and can be used to generate masters for **production** recording.
  - **DVD-R(G)** or **DVD-R for General**, was developed for the consumer market.



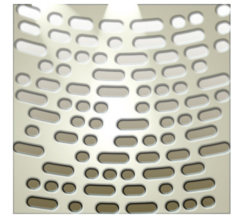
The application and physical layers of the DVD format

The authoring and general formats use different recording laser wavelengths, so they cannot be written interchangeably by the same devices. They can, however, both be read by DVD players or drives that support DVD-R media.

DVD+R uses a different technology approach and so may offer some advantages over DVD-R depending on your needs. However, DVD-R(A) is still one of the most compatible formats available and the choice of many DVD professionals.

- **Rewritable formats:** The three variations of the rewritable format—DVD-RAM, DVD-RW, and DVD+RW—can be written to, erased, and rewritten, over and over again.

CD: Wider pitch, larger pits



DVD: Narrower pitch, smaller pits

DISC STORAGE CAPACITIES DISCTYPE	NUMBER OF SIDES	LAYERS PER SIDE	STORAGE CAPACITY	HOURS OF VIDEO
CD	1	1	650MB	-
DVD-5	1	1	4.7 GB	2
DVD-9	1	2	8.5 GB	4
DVD-10	2	1	9.4GB	4.5
DVD-14	2	2, 1	12.32GB	6.5
DVD-18	2	2	17GB	8

The chart above indicates the capacity possible when using the very best equipment and methodology. **Compression** techniques and **variable bit rate (VBR)** encoding can help you fit more data on a DVD, as you'll see later in this primer.

A NOTE REGARDING THE ACTUAL STORAGE CAPACITY OF DISCS

The capacity of a single-layer DVD is often listed as 4.7GB, while the capacity of a CD is listed as 650MB. In actuality, a single layer of DVD holds 4.7 billion bytes (also known as Gbytes or GB), which is only 4.37GB. A CD-ROM holds 650 million bytes—really only 635MB.

- **DVD-RAM**, the first rewritable DVD format brought to market could, in its infancy, only be written while in a special cartridge because even a fingerprint left on the disc surface before writing would cause errors. Double-sided DVD-RAM discs came in sealed cartridges, which meant they couldn't even be inserted into standard DVD-ROM drives. But DVD-RAM technology is evolving rapidly, becoming more and more compatible. DVD-RAM writers can now also write to DVD-R and DVD-RW discs.
- **DVD-RW** (formerly known as DVD-ER and DVD-R/W) eliminated the protective cartridge that was at first required by DVD-RAM, making it compatible with the disc-loading mechanisms in DVD players and DVD-ROM drives. However, some DVD players and drives don't recognize DVD-RW discs.
- **DVD+RW** was (according to its advocates) designed to be compatible with most existing DVD drives and players but has not proven to be a perfect solution to the compatibility issue. While Minus-R (-R) and Minus-RW (-RW) are the recordable and rewritable formats supported by the DVD Forum, several manufacturers got together (including DVD Forum co-founders Philips, Sony, and Thomson) to create and manufacture the Plus RW (+RW), and later the Plus R (+R) formats. For more information, see www.dvdplusrw.org and www.dvdplusrw.org/resources/docs/howitworks.pdf.

None of the recordable or rewritable formats currently available are fully compatible with each other or with legacy players and drives. Compatibility can vary with media quality, player tolerances, and handling. For more information on the compatibility of specific devices, see:

- www.dvdmadeeasy.com
- www.vcdhelp.com/dvdplayers.php
- www.dvdplusrw.org/Compatibility.asp

The industry is working with manufacturers on these compatibility issues. The DVD Forum has developed a certification program that guarantees compatibility with DVD-R, DVD-RW, and DVD-RAM for those devices displaying the **DVD Multi** logo. A DVD Multi player (most players made today) can read all three formats; a DVD Multi writer can record all three formats.

Application layer

The application layer defines how data is stored on the disc, and how it is played in a DVD player or computer drive. Not all DVDs contain application layers—only those that must include a system for navigating and playing the content on the DVD.

The DVD-ROM format is both a physical layer format and an application layer format. The application format, based on the Universal Disc Format (UDF) file system for optical media, is the foundation of the application layer. Some portion of what is recorded on every DVD is in the pure DVD-ROM format.

DVD-Video and DVD-Audio each define a more restricted logical format made up of video or audio (or both) format specifications, interactivity, and other rules including file-naming conventions. DVD-Video and DVD-Audio files must be placed in special folders within the DVD-ROM directory, called VIDEO-TS and AUDIO-TS, respectively. You don't need to understand all the nuances of DVD file structures to create DVDs; your DVD **authoring** application will create valid DVD volume and file structures for you.

Any or all of the three application formats—DVD-ROM, DVD-Video, and DVD-Audio—can be stored on any of the three physical formats (with some variations). But, not all application formats can be played back on all devices.

- **DVD-ROM** has significantly larger capacity and achieves higher speed data retrieval than the CD-ROM application layer, making it an excellent medium for video games and other multimedia applications. For the most part, the DVD-ROM application format can only be played back by computer DVD drives. There are some proprietary DVD-ROM application formats that may only be played back by specialized devices (for example, video game platforms, like Sony PlayStation, Xbox, and Nintendo GameCube).

THE NEXT GENERATION: HIGH DEFINITION DVD

There are currently two competing standards for high definition DVD:

- **HD-DVD Disc** is promoted by the DVD Forum, which defined the DVD specification we have today. The DVD Forum has an extensive membership but the HD-DVD specification is mainly being driven by Toshiba and NEC. HD-DVDs will have a 15GB capacity per layer-per side, and an impressive 60GB capacity for a dual-layer, double-sided disc.
- **Blu-ray Disc** is the name of the **High Definition (HD)** format being developed by the Blu-ray Disc Association (BDA), whose members include LG, Panasonic, Philips, Pioneer, Hitachi, Mitsubishi, Samsung, Sharp, Sony, and Thomson. Blu-ray Disc (BD) will require significant changes to production and replication equipment. Blu-ray Discs will hold 25GB per layer (50GB for a dual-layer disc).

Will high definition DVDs make standard DVDs obsolete?

HD discs will not play on existing players, although HD-DVD discs could play on computer DVD drives with the right software upgrades. HD players will read existing DVDs in addition to HD discs, so you won't have to replace your whole collection.

Note: Don't confuse the application format with the physical format—remember that DVD-ROM discs (the physical format) can have any or all of the three application formats recorded on them, and are compatible with most any DVD device; it is the application format, DVD-ROM, that can only be played back on computers or other specialized devices.

- **DVD-Video**, often referred to as DVD, provides excellent picture and sound quality, as well as the functionality needed to support interactive entertainment. With capabilities far superior to VHS, DVD-Video offers broadcast-quality video and can provide better-than-CD-quality audio. But, the methods used in content creation and reproduction can diminish the ideal. DVD-Video uses MPEG-2 compression, a method that may result in occasionally noticeable **artifacts**. These artifacts occur when backgrounds are complex or scenes change quickly, but more often when the compression process is not performed optimally. As **MPEG** encoding technology evolves, and as technicians acquire better compression skills, generally accepted levels of quality for DVD-Video are rising.

  The quality of the audio portion of DVD-Video is similarly dependent upon the quality of the original material and how well it is processed and encoded. Capable of higher sampling sizes and rates than audio CD, DVD-Video offers the potential for superb sound quality. The audio for most prerecorded movies available on DVDs typically takes advantage of multichannel surround sound using **Dolby Digital** or **Digital Theater Systems (DTS)** audio compression similar to the cinema sound formats used in theaters.

  DVD-Video discs can be played by DVD players and computer drives, although some incompatibilities may occur depending on the physical format.

- **DVD-Audio** is a separate specification that was initially intended to replace CD as the standard distribution medium for music. DVD-Audio offers even higher quality audio than DVD-Video. However, the format is not yet widely accepted. With somewhere over 700 DVD-Audio titles available, it is at most a niche audiophile format, in part because DVD-Audio is not often found in combination with DVD-Video on major motion picture releases. For the broad consumer market, moreover, music has been moving towards portable, simple devices that store digitized music at a somewhat lower quality.

DVD-Video

The DVD-Video format accommodates all of the following features:

- **MPEG-2:** The format accommodates MPEG-2 compression for video in either constant bit rate (CBR) or variable bit rate (VBR). Audio can be uncompressed or use MPEG, Dolby Digital, DTS, or ATRAC compression.
- **Multiple audio tracks:** Up to eight tracks of digital audio may be associated with a video track to accommodate multiple languages or DVS, for example. Each audio track may have as many as eight channels and can be in one of five formats: Dolby Digital, MPEG-2 audio, PCM, DTS, or SDDS (Sony Dynamic Digital Sound).
- **A choice of aspect ratios and formats:** With fullscreen (4:3), widescreen (16:9), and pan-and-scan.
- **Multiple video tracks:** Up to nine different video tracks, also known as camera angles are typically used for different viewpoints. (For example, you can have a view of an entire concert orchestra as well as a close-up on the soloist.)
- **Subpictures:** These allow up to 32 subtitle sets for multilingual or other titling options, in addition to Closed Captioning.
- **Interactivity:** Made possible by automatic seamless branching of video for varying story lines or audience ratings (such as R or PG).
- **Menus and special features:** These facilitate interactivity such as random navigation when video is chapterized, as well as edutainment opportunities such as Q&A, multiple-choice, and true/false quizzes.

DESCRIPTIVE VIDEO SERVICE

DVS (Descriptive Video Service) is a national service (in the U.S.) that makes visual media accessible to people who are blind or visually impaired.

A DVS audio track on a DVD describes key visual elements such as action, costumes, gestures, and scene changes. Descriptive narration is carefully crafted and applied so as not to interfere with the program dialogue or original soundtrack.

- **Region coding:** Limits playback to devices purchased in the same region as a way to control distribution.
- **Built-in content protection:** A number of built-in schemes can be used to help prevent content from being copied or altered. Region coding limits playback to certain areas of the world.

Not every DVD takes advantage of all the possible features. When you create your own DVD content, you can choose which features to incorporate.

The remainder of this paper focuses primarily on the DVD-Video format and the basic information you need to produce content for and create DVDs that run in a standard DVD-Video player or computer DVD drive that supports DVD-Video. To learn more about digital video, see the Adobe Digital Video Primer from the Adobe website at www.adobe.com/motion/events/pdfs/dvprimer.pdf.

Video compression

A single layer of a DVD can hold up to 4.7GB, but it takes more than 1.5GB for just a minute of broadcast quality video at full resolution and **frame rate**. How can you fit a two-hour movie on a single-layer, single-sided disc that has only enough capacity for about three minutes? It's all accomplished with the magic of video compression, and the evolution of the technology used was so significant, it was awarded an Emmy.

What is compression?

In order to conserve storage space, as well as to make data easier to convey and process, the amount of digital information needed for video is reduced or compressed before being recorded onto DVDs. DVD players then decompress the data for playback.

Compression is a form of encoding, but not all encoding is compression. Compression and decompression is handled by a **codec** which is an acronym for compressor/decompressor or coder/decoder. The compression process is often part of the encoding process, but encoding may encompass more than just compression. For example, the process of encoding DVD-Video may also include adding Content Protection.

Codecs are found in hardware and software. A codec is a set of algorithms or computer code that is specifically designed to compress and decompress video or audio information. A codec may be hardwired into a circuit, as is the case in DVD players and on some **video capture cards**. A codec might also be entirely software-based. You may be familiar with software-based codecs available in video editing software such as Adobe® Premiere® Pro. Adobe Encore® DVD software offers integrated transcoding and can automatically convert source files to the MPEG-2 video and Dolby Digital audio formats (you can manually adjust the settings to optimize your DVD compression).

Different types of codecs have been developed to handle different types of tasks. Some codecs are better than others for compressing and decompressing video during the editing process and some are better suited than others for streaming video across networks. Some codecs are fine for use in consumer video **camcorders**, while professionals might prefer equipment based on others. Data compressed by a specific type of codec can only be decompressed by that same type of codec. The DVD specification calls for MPEG compression—currently either **MPEG-1** or MPEG-2, although MPEG-2 is typically employed.

Making video fit into less storage space isn't the only reason to compress it. At a hefty 1MB per frame, uncompressed broadcast-quality video would have to be read and processed at a rate of approximately 30MB per second, assuming the 29.97 **fps (frames per second)** rate of **NTSC (National Television Standards Committee)**, to be displayed in real time. If we convert the more familiar storage units (megabytes) into standard shipment units (megabits) by multiplying by 8 **bits** for every byte, the result is a rate of approximately 240 Mbps (megabits per second). However, DVD technology can retrieve information at a maximum rate of only 10.08 Mbps. So, in addition to economizing on storage space, compression also reduces the **data rate** so that the video can be read from the disk in real time.

If you would like to learn more about the basics of video compression, see the Adobe Digital Video Primer on the Adobe website at www.adobe.com/motion/events/pdfs/dvprimer.pdf.

MPEG

MPEG stands for the Moving Pictures Expert Group, a working group of ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission) members responsible for the development of standards related to the coded representation of digital video and audio. Among other initiatives, the film, video, and music industry professionals who make up the MPEG define the specifications for several video encoding formats that include compression and other features:

- **MPEG-1**, when used in DVD-video, is limited to a frame size of 352 x 480 pixels (NTSC) or 352 x 576 pixels (**PAL**) and a fixed data rate of 1.15 Mbps. MPEG-1 was the first MPEG standard established and is still used for CD-ROMs, video CD (VCD), and some web video. It can be (but is only occasionally) used for DVD-video.
- **MPEG-2** has gained wide acceptance in the marketplace, and is the format most often used for DVD, as well as for satellite and cable television transmission. MPEG-2 can provide extremely high-quality video with frame sizes up to 720 x 480 pixels (NTSC) or 720 x 576 pixels (PAL). Readily supporting data rates in excess of 8 Mbps (equivalent to 1MB per second), MPEG-2 is ideal for DVD.
- **MPEG-3** was abandoned as the industry moved on to complete MPEG-4. (Note that MP3—which stands for MPEG-1, Layer 3—is an audio-only compression format and should not be confused with **MPEG video** formats. MP3 audio files, or MP3s as they are popularly known, may be saved onto DVDs, but not all DVD players will play them).
- **MPEG-4** was developed to facilitate streaming video on the web and over wireless networks, as well as providing mechanisms for multimedia interactivity. However, MPEG-4 has never lived up to its expectations and has mostly been superceded by newer codecs such as H.264 and VC-1.

MPEG-2

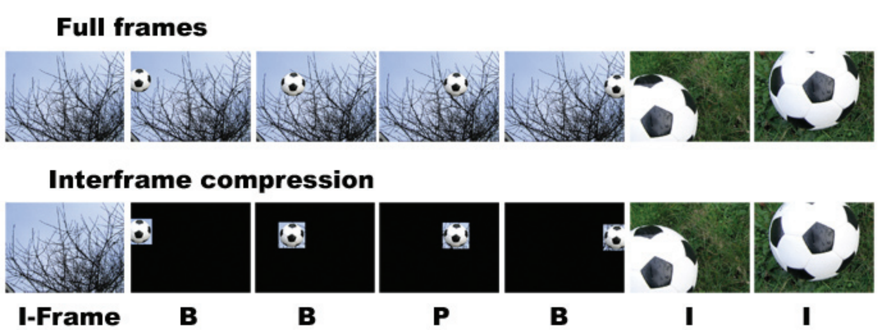
The MPEG-2 video format includes a sophisticated codec that performs both intraframe (also called spatial) compression and interframe (also called temporal) compression.

Intraframe compression basically reduces the amount of data within individual frames by removing color information that is undetectable by the human eye.

Interframe compression reduces the amount of data by replacing parts of some frames with mathematical predictions or interpolations, based on preceding and (sometimes) following frames.

MPEG-2 generates three different types of frames for interframe compression:

- **I frames** (which serve as the **keyframes** in MPEG-2) use intraframe compression to reduce the amount of image information within the frame through **color sampling**, among other means. I frames contain a complete image.
- **P frames** are predictive frames, and may require less than a tenth of the data needed for I frames, because they contain only the image information that is different from the previous frame.
- **B frames**, or bi-directional frames, contain only the image information that is different from previous and subsequent frames. B frames can be smaller than P frames.



Interframe compression (bottom) uses B and P frames, which contain only those portions of the image that are different from the adjacent frames. I frames contain complete images.

A typical MPEG-2 frame sequence might proceed like this:

I B B P B B P B B P B B P P B

Each sequence in MPEG compression is called a Group of Pictures (GOP). In the DVD-Video format, each GOP is limited to 18 frames for NTSC and 15 frames for PAL.

How each frame is compressed depends on the type of content. If the content is fairly static—for example, a talking head shot against a plain, still background—where not much changes from frame to frame, then few I frames are needed, and the video can be compressed into a relatively small amount of data. But if the content is action oriented—for example, a soccer game, where either the action or the background moves or changes rapidly or dramatically from frame to frame—then a greater amount of data is needed to maintain good quality and, therefore, the video cannot be compressed as much.

It is important to note that not all MPEG-2 codecs are the same. MPEG-2 is a set of standards or specifications that must be met for the codec to qualify as MPEG-2 and for the encoding and decoding sides of the process to work properly with other software. Codec developers are free to choose how they want to implement the standards in the codec software they create. Some implementations are better than others. If all the standards requirements are met, content encoded with a codec from one developer will render seamlessly on players using decoders from any number of different developers. When selecting an MPEG-2 codec, keep in mind the codec used for encoding has a more significant impact on the final product than the codec used to decode on the player. As long as the standard continues to be MPEG-2, the decoder chip in players will not need to change to yield better quality for video that has been compressed with better encoding technology.

CBR and VBR

MPEG-2 can be encoded in either the **CBR (Constant Bit Rate)** or **VBR (Variable Bit Rate)** mode. Which you choose depends on the length of your program and the nature of your content.

CBR yields a fixed, or constant, bit rate throughout the program. Meanwhile, the quality of the compressed video can vary. If you use CBR, it is important to select a high enough data rate to compress all of the content well. The data rate should be based on the portions of the video that are the most complex. If the data rate is too low, too much compression may be applied to portions of the program with lots of motion and change, causing the quality to degrade. Conversely, in those portions of the program without much action, the compression may not be very efficient and result in wasted **bandwidth**. CBR is fine, and often preferable, for short subjects and video that isn't action-oriented.

VBR considers quality first, adjusting the data rate to yield an appropriate amount of compression, depending on the content. VBR may yield the same average data rate as CBR, but the actual rate will vary from scene to scene. Less compression is applied (that is, more data is allocated) to the more complex portions of the program, more compression (less data) to the simpler sequences. A minimum and maximum allowable rate is specified, providing the guidelines needed to keep the entire program to an acceptable size and data rate. When trying to fit a long program onto a DVD disc, VBR can make the difference between success and having to choose a more costly alternative.

The more features you want to include on your DVD, the more closely you need to keep track of how the data is adding up. In addition to the video, you'll need to consider the data rate of the audio, at 192-448 Kbps per Dolby Digital stream, with up to eight streams supported; and the rate of subtitles, at 41 Kbps per language or other track, with up to 32 tracks allowed. The math is really easy, just take the maximum data transfer rate of 10.08 Mbps for DVD Video (that is, the video, audio, and subtitles combined) and subtract the total of the audio and subtitle tracks, as well as approximately 0.4 Mbps for **headroom**. What's left is the maximum available data rate for your most complex scenes. (Note that the maximum data transfer rate for video alone can be no greater than 9.8 Mbps.)

If you are planning a complex project, plan ahead—and understand that sometimes compromises need to be made. Even on Hollywood-produced DVDs, the featurettes are often more highly compressed than the main feature.

WHEN VBR IS CALLED FOR

If the content planned for a DVD is short relative to the disc capacity—under an hour for a DVD-5, perhaps—there is no need for VBR (Variable Bit Rate) encoding because the entire program will fit, even if it is all encoded at the peak video bit rate for DVD. If the content is long—two hours, for example—the average rate would need to be cut by half, to approximately 4 Mbps, in order to fit. But complex scenes generally require at least 6 Mbps for acceptable quality. VBR encoding allows bits to be saved in the simpler scenes, such as a conversation between two people shot against a relatively static background, that may require no more than 2Mbps. Saved bits can be reallocated to the more complex scenes, such as those with lots of action.

BANDWIDTH MATH FOR DVD

To determine the data rate available for the video in the most complex scenes on a DVD, subtract the data rate for the audio and subtitle tracks, as well as a little extra for headroom. For example:

Maximum DVD-Video transfer rate	10.08 Mbps
Headroom	- 0.4
5.1-channel (surround) English soundtrack	- 0.384
Two 2-channel (stereo) soundtracks in French and Spanish, each 0.192 Mbps	- 0.384
Peak data rate available for video	8.912 Mbps

For more information, visit http://main.wgbh.org/wgbhpages/mag/servkes/description.

Audio for DVD-Video

Digital audio for the DVD-Video format can produce extraordinary sound quality. Up to eight audio streams, or soundtracks, can be delivered on a single disc, including different language versions and DVS. DVD-Video can also deliver multiple audio coding formats on a single disc for mono, stereo, and 5.1-channel surround sound. The number and types of streams that can be combined is flexible, limited only by the disc's capacity.

Digital audio basics

Basic principles underlying digital audio are similar to those on which digital imagery and, therefore, digital video are based. Film and video work by stringing together still snapshots and relying on persistence of vision to re-create the sense of continuous motion.

Similarly, digital audio takes audio snapshots, or samples of sound, thousands of times each second. The number of samples—that is, the sampling rate—is quoted in thousands of samples per second, or kilohertz. For example, 44,100 samples per second would be represented as 44.1 kHz, which is the sampling rate of an audio CD. The higher the sampling rate you use, the greater accuracy you will get in digitally mapping the analog audio waveforms of the original sound.

The **bit depth** used for samples is also an important factor in determining the accuracy of digital audio. Bit depth is the number of bits used to describe the amplitude of each sample. Because bits are binary (that is, representing a value of 1 or 0), each bit added doubles the potential for accuracy. At 16-bit depth, there are 65,536 levels available to describe the audio sample; at 24-bit depth there are 16,777, 216 levels available.

The zones between these discrete levels are called quantizing intervals. When a sound falls between levels—that is within a quantizing interval—it cannot be accurately represented and must be approximated by rounding up or down to the nearest level. Such rounding is referred to as quantization noise.

In summary, higher resolution leads to greater dynamic range: the dynamic range of 16-bit is 96 dB (decibels) and the dynamic range of 24-bit is 144 dB. In other words, a greater bit depth yields a more accurate digital representation of the original, analog audio waveform.

When you multiply sampling rate by bit depth by the number of channels used (for example, 2 for stereo; 6 for 5.1 surround), the result is the data rate—which is equivalent to the bandwidth needed to deliver the audio. The maximum data rate of audio CD, for example, can be figured as follows:

44,100 (sampling rate) X 16 (bit depth) X 2 (stereo channels) = 1,411,200 bits per second (1.4 Mbps)

The digitized audio waveform, when uncompressed, is known as **PCM**, short for pulse code modulation. PCM may be linear or nonlinear. **Linear PCM** (LPCM), which may be used for DVD, spreads values evenly across the range from highest to lowest. **Nonlinear PCM** uses a nonlinear quantization curve to allocate values based on dynamic range.

SWEETEN YOUR AUDIO WITH ADOBE ENCORE DVD

Adobe Encore DVD makes preparing your audio **assets** for DVD projects easier with automated transcoding presets for audio formats. You can convert audio source files to 48 kHz using the integrated **sample rate** conversion capability. Adobe Encore DVD supports two channels of Dolby Digital audio encoding. If you have 5.1 audio content encoded in Dolby Digital or DTS format, Adobe Encore can use that too.

Audio compression

In addition to uncompressed digital audio, DVD-Video supports four types of audio compression: **MPEG audio** (both MPEG-1 and MPEG-2), Dolby Digital, DTS, and the ATRAC compression format used by SDDS (for descriptions of these formats, see Audio formats for DVD-Video).

Humans notice loss of detail in what we hear much more than in what we see, so when encoding for DVD, less compression is applied to the audio than to the video. Because audio requires so much less space, you might wonder why we would bother to compress it at all—but even the small amount of space gained by compressing audio provides enough room to yield a significant improvement in the quality of the video.

Video compression, as we have seen, uses two basic methods to reduce data:

- **Perceptual** (intraframe) compression removes irrelevant visual information (mostly color) from individual frames that the human eye is incapable of perceiving or unlikely to perceive.
- **Temporal** (interframe) compression removes redundant information, from frame to frame.

In digital audio compression, blocks of samples are divided into frequency bands of equal or varying widths, and these bands are analyzed to determine how the compression will be applied. Audio compression uses similar methods to video compression:

- **Perceptual coding** removes audio information the human auditory system won't perceive, either because it is out of the range of our hearing or because it is masked. Masked sound is not heard by the human auditory system because of much louder sounds occurring concurrently, just prior to, or immediately following softer sounds.

- **Channel reduction** removes redundant audio information between channels, especially when there are six or eight channels.

Audio formats for DVD-Video

MPEG-2, Dolby Digital, and linear PCM (LPCM) are the three primary audio formats supported by DVD-Video. DTS and SDDS formats are supported by some players. DVD-Video for NTSC is required to include at least one track of either Dolby Digital or LPCM audio; DVD-Video for PAL must offer at least one track of Dolby Digital, MPEG, or PCM audio. Dolby Digital is currently the format most widely used for audio on DVD-Video.

Linear PCM (LPCM) is the digital audio format used on most studio masters, as well as on audio CDs. For DVD-Video, LPCM can be sampled at 48 or 96 kHz at up to 24 bits, but some DVD players may subsample 96 kHz down to 48 and may not use all 20 or 24 bits.

Up to eight channels are available, but the number of available sample rates and bit depths may be limited when you use five or more channels. The maximum bit rate is 6.144 Mbps. LPCM is rarely used for DVD-Video because of the bandwidth needed for multichannel implementations. However, tests indicate that the average listener is unable to tell the difference between uncompressed LPCM and MPEG-2 or Dolby Digital audio for DVD, which are usually compressed at about 10:1.

MPEG-1 audio delivers either monophonic or stereophonic audio and can only be CBR. It divides samples into frequency bands of equal widths, which is easier to implement but less accurate than using variable widths. MPEG-1 offers three compression techniques, called layers. Layer II is the only one of the three MPEG-1 formats specified for DVD. (Layer III, also known as MP3, is the popular compression format for music distributed via the Internet and, although not supported in the DVD standard, some players will play MP3 files).

MPEG-2 audio allows VBR encoding to efficiently accommodate transient increases in signal complexity; although, in practice, this can prove to be problematic in passages where video and audio require simultaneous peaks, thereby pushing the combined data rate past the limit. It also adds multiple channels to produce (with the use of extensions) 5.1- or even up to 7.1-channel audio. Because MPEG-1 and -2 audio encoding for stereo is identical, MPEG-2 audio is backward compatible with MPEG-1 decoders.

Dolby Digital was designed with consumer delivery in mind and has, thereby, achieved a lead position in adoption over other multichannel systems. Most all DVDs offer a Dolby Digital soundtrack, and there's a Dolby Digital decoder built into virtually every DVD player, which turns Dolby Digital into standard analog stereo audio that can be played back by most any type of audio equipment including a standard TV. Dolby Digital audio compression, also known as **AC-3**, enables frequency bands of varying widths that match the critical bands of human hearing, resulting in smoother sound than what can be achieved by fixed-width schemes. Dolby Digital also offers other features, such as dynamic range compression (DRC) and dialog normalization (DN) that allow volume levels to be tweaked by the listener to accommodate various situations. Dolby Digital provides up to 5.1 channels of audio to create surround sound.

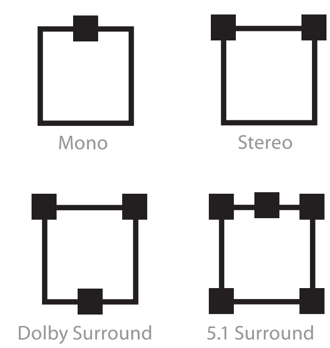
DTS is an optional format that was originally developed for theaters. A home-theater version was developed that has become popular for DVD among audiophiles. DTS for DVD is usually compressed at 6:1 or 3:1, and some listeners report that the quality is better than MPEG-2 or Dolby Digital. But differences may only be perceptible for playback on very high-end audio systems. DTS requires a special decoder, either in the DVD player or in an external receiver. Dolby Digital or PCM audio are required on NTSC discs, so all DTS DVDs also carry a Dolby Digital soundtrack because PCM and DTS together don't usually leave enough bandwidth for the video encoding of a full-length movie.

DOLBY DISTINCTIONS

Dolby Digital is the audio format most commonly employed for commercial applications of the DVD-Video format. Dolby Digital is not synonymous with 5.1 surround sound; it is a format that can be used for mono, dual-mono, stereo, **Dolby Surround** or any of eight different configurations including 5.1 surround.

Dolby Digital encodes each channel to produce discrete multichannel audio. Virtually every DVD player, worldwide, has a built-in Dolby Digital decoder. If the system does not support discrete multichannel audio, the Dolby Digital decoder in the DVD player can downmix multichannel audio to two channels.

Dolby Digital Surround EX can, with the appropriate decoder installed in the system, extract an additional matrix-encoded surround channel, known as the back surround channel, to be sent to a speaker in the center rear of the listening environment. In effect, this can yield 6.1-channel surround sound. Listeners with a 5.1 channel setup don't lose the back surround channel information; it remains mixed with the left surround and right surround channels.



Dolby sound mode icons may be used to describe the audio configurations that a product supports. The small squares show speaker placement.

Matrix encoding is the process of combining multiple channels into a standard, two-channel stereo signal.

Dolby Surround is an audio-encoding technique that uses matrix encoding to blend rear and center channels into a two-channel signal. Dolby Surround can be played on any stereo or mono system to achieve a psychoacoustic surround simulation. However, when Dolby Surround is played back on a multichannel system that has a Dolby Surround decoder, the left, right, and rear channels are separated and fed to the designated speakers. If the playback device is equipped with Dolby Pro-Logic, the center channel is also extracted. The Dolby Surround technique can be employed by analog audio, broadcast audio, PCM audio, Dolby Digital, DTS, MP3, or virtually any audio format.

Dolby Pro-Logic is the process of (and the processing circuit for) extracting the center and rear audio surround channels from matrix-encoded audio. The newer Dolby Pro-Logic II also processes the signals to generate more of a 3D audio experience.

SDDS, an optional multichannel audio format for DVD, is based on a theatrical soundtrack format that uses a type of compression called ATRAC. While SDDS is written into the DVD specification, it is a professional format intended only for motion picture theaters. Its eight-channel configuration, with five loudspeakers behind the screen, is not intended for typical 5.1 channel home systems.

AUDIO FORMAT	SAMPLE RATE	BIT DEPTH	CHANNELS	BIT RATE
Linear PCM	48 or 96 kHz	16, 20, or 24 bits	from 1 to 8	6.144 Mbps maximum
MPEG Audio	48 kHz	16 or 20 bits	from 1 to 7.1	32 to 912 kbps (384 kbps normal average)
Dolby Digital	48 kHz	up to 24 bits	from 1 to 5.1 (5.2 with new DTS-ES—Digital Surround ES)	64 to 448 kbps (384 or448 kbps recommended for 5.1 channels)
DTS (Digital Theater Sys-tems)	48 kHz	up to 24 bits	from 1 to 5.1 (5.2 with new DTS-ES—Digital Surround ES}	64 to 1536 kbps (typical rates of 754.5 and 1509.25 for 5.1 channels, and 377 or 754 for 2 channels)
SDDS (Sony Dynamic Digital Sound)	48 kHz	up to 24 bits	8 (in theaters)	up to 1280 kbps

A comparison of the audio formats available for DVD-Video

Karaoke mode

Karaoke mode allows for five channels: two for stereo left and right (L and R) that are typically instrumental only, two optional vocal channels (V1 and V2) that may be used for harmonies, and an optional melody (M) or guide (G) channel that can help the karaoke singer carry the tune. Karaoke mode can only be fully implemented by DVD players with karaoke features for mixing the recorded audio and microphone input. All five audio formats for DVD-video support karaoke mode.

Aspect ratios

The aspect ratio is the width to height ratio of an image. The 35mm still photography film frames on which motion picture film was originally based have a 4:3 (width:height) ratio, which is often expressed as 1.33:1 or, simply, a 1.33 aspect ratio (multiplying the height by 1.33 yields the width).

Standard TV matches the Academy Aperture (4:3=1.33:1 or 1.37:1)

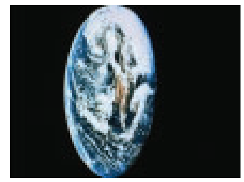
In 1927, the Academy of Motion Picture Arts and Sciences endorsed the 1.33 aspect ratio as the industry standard and it came to be known as the Academy Aperture. In 1931, the Academy Aperture was modified slightly to 1.37 to make room for a sound track. Until 1952, the 4:3 image area aspect ratio was used almost exclusively to make movies and to determine the shape of theater screens. When television was developed, existing camera lenses all used the 4:3 format, so the same aspect ratio was chosen as the standard for the new broadcast medium.

Widescreen (scope) formats (1.66:1—2.76:1)

In the early l950s, the motion picture industry began to see television as a threat. In a frenzy to ensure that audiences left their living rooms and kept going to movie theaters, all manner of gimmicks were tried, from color and sound innovations to 3D. In fact, if it weren't for the competition from black-and-white TV, it might have been much later before color was widely adopted for movies. Color technology was available as early as 1906 but, despite a few classic films like *The Phantom of the Opera* being shot in color in the 1920s, it was dismissed as too costly.

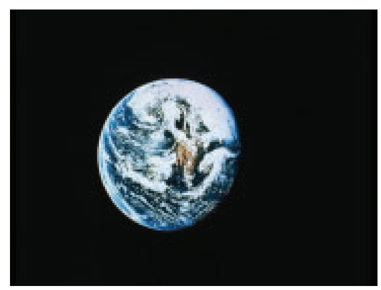
One crowd-pleaser that withstood the test of time was a wider aspect ratio. Widescreen offered audiences a you-are-there experience of panoramic cinematography. Based on a technique patented in the 1920s, Cinemascope was the first commercially successful widescreen format, making its debut in 1953 with the film *The Robe*. To produce an aspect ratio of 2.35:1 without having to manufacture special film, cameras, or projectors, special anamorphic lenses were used. The anamorphic lens used on the camera for shooting widescreen squeezed the image width to fit on standard 4:3 format film. To show the movie, another anamorphic lens, one that stretched the image back to normal, was fitted to the projector. And, of course, this new extra-wide aspect ratio required an extra-wide screen.

The yellow crop indicates the 1.33 (4:3) aspect ratio of the standard camera lens, the classic **Academy Aperture**, and TV. The red crop selects a widescreen, or **scope** view, with a 2.35 aspect ratio.



Shot with an **anamorphic** lens, the widescreen (red) crop shown above would look like this on film—remember that film frames have a 1.33 aspect ratio, so the widescreen image, with a wider aspect ratio, must be squeezed to fit.

Projected through an anamorphic lens, the image expands to look like this— exactly like the original (red) crop above.



Shot with a standard 4:3 camera lens, the scene would look like this—as indicated by the yellow crop in the top illustration—perfect for standard television viewing.

Masking either the camera lens or the projected image yields a similar widescreen look to using anamorphic lenses, but the quality is not the same—there is a loss in picture resolution.

The widest popular American film made was *Ben Hur*, with an aspect ratio of 2.76:1. A host of copycat scope formats were introduced (Warnerscope, Technicscope, Panascope, and others), but the prohibitive cost of the special anamorphic lenses needed for both shooting and projecting, as well as the exhibitor's reliance on often unreliable projectionists to remember to attach the special lens to the projector, meant anamorphic scope techniques were reserved only for the most extravagant productions.

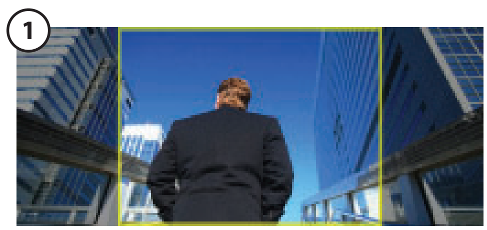
In the mid 1950s, someone realized that the scope effect could be achieved inexpensively without anamorphic lenses by shooting standard film through a viewfinder marked with the desired wide aspect ratio so the cinematographer could properly compose the shot. When the film was shown, the top and bottom of the projected image were masked off by covering the projection lens with a cheap cardboard matte. (The projector was simply slid back a few feet, so that the image would not appear too small to fill the screen.) This technique, known as soft matte, was the manner by which cost-effective scope films were made for many years, with aspect ratios ranging from 1.66 to 1.86. But exhibitors still had to rely on projectionists to attach the matte. If they forgot, the occasional microphone boom or prop-man's hand that went unnoticed by a cinematographer focused on the widescreen image area might be seen at the top or bottom of the picture.

The seemingly obvious solution was a technique known as hard matte whereby a mask is applied to the camera lens when shooting. This technique put the control back into the hands of directors.

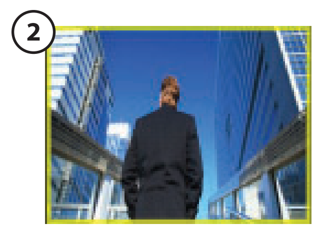
It wasn't long before the industry realized there was money to be made from repurposing film content for TV and, more significantly, videotapes for sale and rent. But something had to be done with all those films shot for widescreen, both anamorphic and hard matte, neither of which were well-suited for viewing in TV's 1.33 aspect ratio. There were four apparent choices:

1. **Slice off the sides.** Initially, the most common solution was to simply cut out a 4:3 section at the center of the frame, because that is where most of the action in a movie is. The prevailing notion was that audiences wouldn't really know what they were missing.
2. **Squeeze the image horizontally.** When the audience needed to view the complete width of the frame, the image was squeezed horizontally. Typically, this technique was done only for titles and credits of higher-budget, extra-wide, anamorphic productions.
3. **Pan-and-scan.** Rather than uniformly slicing off the sides of a frame, an editor can decide the best crop, frame by frame, using the pan-and-scan technique. Using video editing software, the editor slides a 4:3 mask around, frame-by-frame, following the action. The editor chooses where to pan (or even zoom) each frame, selecting (in the editor's opinion) the most critical portion. When presented on a standard TV, pan-and-scan fills the screen. The choices made by the editor should be an improvement over the simple slice-off-the-sides technique, but all manner of alterations to the original widescreen material may occur, such as unintended cuts where the action switches rapidly from one side of the screen to the other.
4. **Letterboxing.** By simply placing black bars above and below the widescreen image to block out the unused portions of a standard 4:3 television set, the widescreen aspect ratio is preserved, as it was originally intended to be viewed.

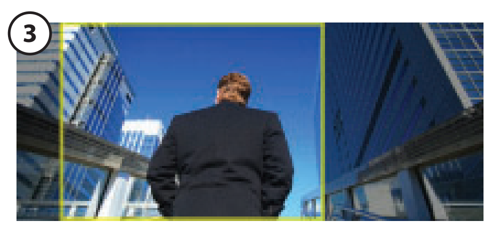
FOUR WAYS TO PRESENT WIDESCREEN ON STANDARD TV



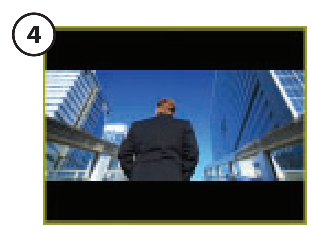
Widescreen can be made to fit 4:3 TV by slicing off the sides. The image fills the screen, but much of it is lost.



By squeezing the image horizontally, widescreen can be made to fit 4:3 TV, but the picture, if shown this way, is distorted.



With pan-and-scan, a video editor selects the "best" crop, by panning and/or zooming the widescreen, frame-by-frame.

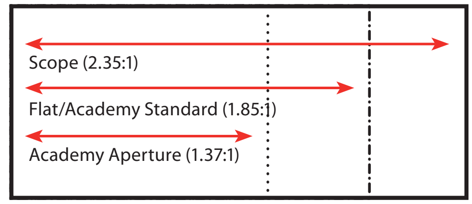


Letterbox preserves all the information in the widescreen format, placing black bars above and below the image.

Aspect ratios and today's motion pictures

Now, let's fast forward to the 21st century. Projectors have been permanently fitted with a set of mattes which, when selected, mask soft matte films for either 1.66 or the more common 1.85 widescreen aspect ratios. Most films are shot soft matte, with view-finders equipped with frame indicators for both the standard 1.37 aperture and the selected widescreen aspect ratio, to help the cinematographer design shots that will look good when displayed in either format. These are the three most common formats:

- **Flat** is the new Academy standard, with an aspect ratio of 1.85:1. It is typically shot soft matte making it easy to repurpose the production for standard TV.
- **Scope** is usually for higher budget features, with an aspect ratio of 2.35:1. It is shot anamorphically, then converted to widescreen in the lab when distribution prints are made rather than exhibited using an anamorphic lens on the projector.
- **4:3** is the classic Academy Aperture, typically used for made-for-TV features and often used for animated features with an aspect ratio of 1.37:1.



A comparison of film aspect ratios in the common production formats

Many animated features and some European films are in the 1.66 aspect ratio. Special wide-format films, requiring special cameras and projectors, have also found periods of vogue, most notably 70mm (2.20:1) and IMAX, as well as the Super 35 format used by James Cameron for *The Abyss* and Ron Howard for *Apollo 13*.

TV today

Television is going digital. But the transition is going to take some time. No one expects consumers to suddenly throw away all their old TVs and buy all new. And, despite the wide adoption of digital television delivery via cable and to satellite, the programming is still, for the most part, engineered for analog broadcast and viewing. Set-top boxes convert the digital signal back to the analog NTSC standard (in the U.S). before sending the signal to the TV. The U.S. Government has mandated a full conversion of U.S. television broadcasting to **Digital TV (DTV)** to make better use of available bandwidth.

There are two types of DTV:

- **Standard Definition Television** (SDTV) is quite similar to standard DVD. It can have a 4:3 or a 16:9 aspect ratio and has resolution roughly equivalent to a conventional analog signal (525 lines of vertical resolution for NTSC).
- **High Definition Television** (HDTV) offers the potential for approximately twice the horizontal and vertical resolution of current analog (NTSC) television. When combined with the compulsory 16:9 widescreen format, HDTV can offer about five times as much visual information as analog TV. HDTV also takes approximately five times more bandwidth to broadcast than SDTV.

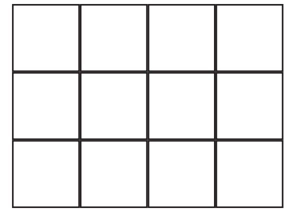
Not all TV sets available on the market today are HDTV-capable or HDTV-ready, not even the widescreen (16:9) TVs. But the sets that savvy consumers are buying today are, at least, SDTV-ready, meaning that they are equipped to accept a digital signal directly (although most also include analog inputs). So, we can connect our **DV** camcorders, digital VCRs, and our DVD players to our new TV sets via **IEEE 1394** or DVI to achieve a pristine, noiseless picture.

Aspect ratios and today's TVs

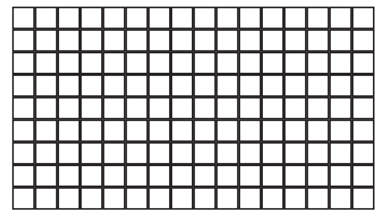
Because DTV is designed for two different aspect ratios, so are TV sets:

- **Fullscreen TV**: In the first decade of the 21st century, the standard television set still has a 4:3 (1.33) aspect ratio, also known as fullscreen. (For the rest of this primer, we'll refer to 4:3 TV as fullscreen). It's the perfect shape for viewing films shot in the classic Academy Aperture format, but not so good for scope. Scope is what widescreen films—flat, scope, or any aspect ratio wider than 4:3—have come to be called whether or not they have been shot with anamorphic techniques.

• **Widescreen TV**: Many consumers have, by now, purchased a widescreen TV, with a 16:9 (1.78) aspect ratio. (For the rest of this primer, we'll refer to 16:9 TV as widescreen). But, because most broadcast TV and much of the video recorded on VHS, laserdisc, and DVD is fullscreen, widescreen TVs can be programmed to display 4:3 in one of two ways. The first is pillarboxing (also known as windowboxing) which electronically generates black or gray vertical bars to fill the leftover space on the sides, or magnifying the picture to fill the 16:9 screen (but cutting off the top and bottom of the picture to do so). Of course, the widescreen TV aspect ratio is much better suited than fullscreen for displaying scope—its 16:9 (1.78) proportion is quite close to the Academy Standard, or Flat, proportion of 1.85 in which most of today's films are produced. With even wider scope aspect ratios, a letterboxed picture fits into the widescreen shape much better than it fits the fullscreen shape, with less vertical space above and below the image needing to be filled with black mattes. What's more, widescreen TV is specifically engineered to showcase anamorphic widescreen.



Fullscreen TV has a 4:3 (1.33) aspect ratio—4 units wide by 3 units high



Widecsreen TV has a 16:9 (1.78) aspect ratio—16 units wide by 9 units high

Aspect ratios and DVD: more choices for better or worse

With VHS and laserdisc, you got the version that was recorded. If the content was scope, it was either made to fill the fullscreen TV aspect ratio by slicing off the ends or by using pan-and-scan or it was rendered **letterbox**, with the black bars at the top and bottom of the image added in the studio. When the bars are recorded as part of the image, the picture suffers from a loss of vertical resolution—on fullscreen TVs and widescreen TVs alike—because a number of pixels must be sacrificed to accommodate the matte bars. Widescreen TVs can be set to magnify studio-letterboxed video to fill the screen, but this may reveal image defects too small to detect in the non-magnified image, thus making the enlarged picture look worse.

To get the best picture possible on widescreen TVs, digital technology borrowed the anamorphic concept from film. Digitized video stored on DVDs (or broadcast digitally, for that matter) can be anamorphically squeezed. The widescreen TV pixels have a wide aspect ratio that effectively unsqueezes anamorphic pictures. In fact, when a standard 4:3 picture is sent to a widescreen TV, if the set is not configured properly to compensate for its wide pixels, the image display is distorted, appearing to be fat.

For fullscreen TV, where the pixels have the traditional aspect ratio, anamorphically squeezed video is unsqueezed by the DVD player (or set-top box, in the case of digital broadcast) before it is sent to the display. When the DVD player unsqueezes anamorphic video for 4:3 display, it can (depending on how the viewer chooses to set it up) either add black bars to the top and bottom to letterbox the picture or it can allow the image height to fill the screen, in which case the sides of the picture will be sliced off. Some DVD players can automtically pan-and-scan of anamorphic video that includes special coding to indicate the optimal pan-and-scan center-of-interest offset. But buyer beware! Anamorphic video, when displayed as a result of automatic letterbox or auto pan-and-scan modes, can actually produce a worse-quality picture than prerecorded, studio-letterboxed or studio-pan-and-scan versions.

Many current DVDs are marked as Enhanced for Widescreen, Enhanced for 16:9 TVs, or Anamorphic, and most of these discs offer viewers two options: a studio-generated pan-and-scan version on one side of the DVD disc to give viewers with fullscreen TVs the best quality picture, and, on the other side, an anamorphic version designed to take advantage of widescreen TV. Most current DVD players have four playback modes:

➤ **Fullscreen for the prerecorded, studio pan-and-scan version.** If the viewer chooses to watch the studio-generated pan-and-scan version, the DVD player decodes the picture and delivers the signal to the display for playback. On a fullscreen TV, the picture fills the screen. A widescreen TV can be set up to either pillarbox the image by placing black bars on the sides or to magnify the image to fill the screen. But magnification results in loss of even more of the picture at top and bottom than has already been cropped for fitting into the 4:3 aspect ratio. Magnification may also reveal imperfections that might not be noticed otherwise.

THE KEY TO ANAMORPHIC VIDEO

Studio letterboxed video includes black bars in each frame of video stored on the DVD. Anamorphic video does not. Why is this so important? Each video frame stored on a DVD is made up of 720 x 480 pixels. If, as is the case for video that is letterboxed prior to being recorded, 25% of the available pixels are used up for black bars at the top and bottom of the widescreen image, there are fewer pixels available to store the actual video information.

Anamorphic video, on the other hand, uses all available pixels to store as much video information as possible. Every one of those 720 x 480 pixels carries video information. You can think of a widescreen TV as acting like an anamorphic lens. If you watch anamorphic video on a standard 4:3 TV, it will appear tall and fat but it will fill up the entire screen; which is how it is actually recorded on the DVD. If you play this same content on a widescreen (16:9) TV, the TV itself is wider and it stretches the image to the correct proportions.

When a DVD player decodes anamorphic video for fullscreen (4:3) TV, it unsqueezes the image and generates the black bars electronically. When a widescreen TV displays anamorphic video, the wide pixels effectively unsqueeze the image. In either case, more video information—which equates to higher video resolution—is available in the signal sent to the display. Thus, when anamorphic video is displayed, the picture has better resolution than studio-letterboxed video.

- **Auto letterbox for 4:3**: The DVD player stretches the anamorphic video back to its original scope aspect ratio and generates matte bars at the top and bottom of the picture. Together, the black bars at top and bottom take up nearly 25% of the usable scan lines, leaving only about 75% of them to draw the image. To compensate, a letterbox filter in the DVD player combines every four lines into three either by simply dropping out every fourth line or by using weighted averaging to combine lines. So, even though the anamorphic video has higher resolution to begin with than studio-letterboxed video, it does not make the best use of all the available information. Often, scope video letterboxed by high-end studio equipment, and prerecorded on laser-disc or DVD, produces a better picture than auto-letterboxed anamorphic video when displayed on a fullscreen TV.

- **Auto pan-and-scan**: The DVD player stretches the anamorphic video back to its original widescreen aspect ratio, but cuts off the sides according to a center of interest offset specified for each frame when the video was encoded. Unlike studio pan-and-scan, where the editor can pan from side to side, zoom, or both, to crop the very best portion of the image, auto pan-and-scan only travels laterally and must include the full height of the widescreen frame. Moreover, when studio pan-and-scan is recorded on DVD, the entire allotment of 720 x 480 pixels is dedicated to the cropped frame, while auto pan-and-scan may delete upwards of 25% of the video's width. That means that 720 pixels across might be reduced to 540 pixels, resulting in a significant loss in horizontal resolution. While the loss in resolution might not be too noticeable on a fullscreen TV, if the picture is magnified on a widescreen TV, the loss in resolution can become distinctly noticeable. And, just as when any 4:3 picture is magnified to fill the width of the widescreen TV, the image—which has already been cropped horizontally—will be cropped vertically, as well. Generally, the studio pan-and-scan version prerecorded on the other side of the DVD results in better picture quality on fullscreen and widescreen TVs. Therefore, not many DVDs are implementing auto pan-and-scan.

Academy Aperture (1.33:1) fits fullscreen TV perfectly, because television was originally based on the classic 4:3 film format.

When Academy Aperture is displayed on widescreen TV, the set generates sidebars to pillarbox (or windowbox) the picture.

Academy Standard, also called flat at (1.85) looks like this when letterboxed on fullscreen.

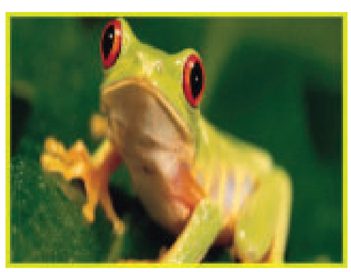
1.85 fits widescreen TV just about perfectly because the aspect ratios are very similar.

Wider Scope, for example, 2.35:1, looks like this when letterboxed on fullscreen TV.

When 2.35 is displayed on widescreen TV, the image is maximized; the matte is minimized.

Scope, when recorded for 4:3, or auto pan-and-scanned, looks like this on fullscreen.

If magnified (instead of pillarboxed), the top and bottom of 4:3 or auto pan-and-scan are cut off.



Anamorphic displayed on an improperly set up fullscreen system may look like this.

4:3 video displayed on an improperly set up widescreen system may look like this.

- **Auto widescreen**: The DVD player decodes and sends the anamorphically squeezed video to the display; the wider aspect ratio of the widescreen TV's pixels effectively unsqueezes the picture. Auto widescreen fulfills the promise of anamorphic DVD. Academy Standard films, with their near-16:9 aspect ratio, use every available pixel for image information, and every pixel recorded is displayed, resulting in a stunningly clean, clear picture. Scope pictures that have wider aspect ratios are studio-letterboxed before the anamorphic video is recorded on DVD, so, while there is some loss in vertical resolution, it is minimal—the matte bars at the top and bottom of the picture are often so narrow as to hardly be noticeable.

Pixel aspect ratios

Analog PAL and NTSC video signals have a fixed vertical resolution, which can be measured by the number of scan lines on the screen. However, the horizontal resolution of an analog video signal is really only limited by the bandwidth of the camera and recording device. Most studio cameras have very good horizontal resolution, much higher than the equivalent vertical resolution specified by the video format.

When digital video standards were standardized in the late 70s and early 80s, it was thought that, in order for a video signal to look good and to capture the true resolution of the cameras, the horizontal resolution had to be higher than the vertical resolution. A standard of 720 pixels was agreed upon for a number of reasons, but mostly because the same sample rate could be applied to both PAL and NTSC video formats. Out of the 720 pixels, only 704 are defined to be in the **active picture area**. The extra 8 pixels on each side of the image can have video in them, or they may be blanked in the camera (that is, just black is recorded).

If you compute the aspect ratio of a frame that is 704 pixels wide by 480 pixels high (the geometry of a standard video signal), you do not get 4:3. Four divided by three is 1.333 (the standard video image aspect ratio), and that figure multiplied by 480 lines high works out to a width of only 640 pixels. Digitized NTSC and PAL video squeezes in more pixels per horizontal line by using nonsquare pixels, in this case, pixels that are slightly narrower than standard square pixels. Computers typically use square pixels, and until recent years, most programs did not handle nonsquare pixels very well.

The pixel aspect ratio of video is the image aspect ratio (1.333) times the horizontal size (480 for NTSC based video) divided by the vertical size (remember to use 704, not 720), which equals a pixel aspect ratio of .909 (usually just specified as .9 in the user interface of most authoring programs, but the correct value is actually applied to the video). Since there are more pixels horizontally than there are vertically, the pixels are taller than they are wide. If you produce your video anamorphically for best image quality, the pixels are taller than they are wide, with a PAR of 1.2.

All DVDs use nonsquare pixels, and if you produce your DVD with improper settings, the image will not look right.

Aspect ratios and your DVDs

Most television viewers will move to DTV during the next decade; many videophiles have already done so. Many digital video camcorders enable you to switch between standard 4:3 aspect ratio (Academy Aperture) and 16:9 (widescreen) aspect ratio. The less expensive of these adjustable camcorders simply lop off the top and bottom of the image, using only 75% of the scan lines to create the widescreen effect, and resulting in lower vertical resolution. Some more expensive, professional-grade DV camcorders can be fitted with an anamorphic lens. But, if you don't have access to that kind of equipment, you'll find some tips for shooting the best widescreen possible—with affordable equipment—in the How do I make a DVD? section of this primer.

Progressive scan DVDs

Content shot with video cameras is typically **interlaced** content—half the image is scanned by skipping every other line (one **field**), and then the image is filled in with the second field. Content shot on film, on the other hand, uses **progressive** scanning when transferred from film to video. Unfortunately, the frame rate of film is 24 frames per second, which is different from the video frame rate of 25 frames per second for PAL and 30 (technically 29.97) frames per second for NTSC.

The process of transferring film to video and the expensive machine used to do it are both called **telecine**. The telecine is basically a projector that projects film directly onto a video sensor. When film content is transferred to PAL, the film is just run at 25 frames per second (a 4% speed increase) and each frame of film is exactly mapped to a frame of video. However, when film content is transferred to NTSC, a process known as 3:2 pulldown is used. Each frame of film is scanned so that it is mapped to three fields of video for the first frame of film, then two fields of video for the next frame of film. This sequence then repeats throughout the capture process. The result is that the video plays back with an uneven look to it.

If you encode the video with this 3:2 pattern, your results will not be optimal. The 3:2 pattern confuses the motion estimation algorithms in the codec. It sees the video as constantly speeding up and slowing down, making the encoding less efficient and increasing artifacts in the video. Secondly, you are encoding 20% more data, as the telecine process adds redundant fields that need to be encoded into the video stream. Finally, you are encoding interlace content, which does not encode as efficiently as progressive content.

The solution? Put the video through an inverse telecine algorithm before encoding the video for your DVD. This process removes the 3:2 pattern so that you can encode the 24 fps progressive frames just as the content was originally shot.

On playback, the DVD player will do one of two things: If the viewer has a DVD with a progressive scan mode and a TV that can take the progressive scan video input, the video will be shown in its native progressive format, also known as 480P (the best way to view DVDs). Otherwise, the DVD player itself will reinsert the 3:2 pattern before the video is sent out as standard NTSC or S-Video to the TV (still better than encoding the 3:2 pattern on the disc).

Almost all movies sold on DVD today are produced with progressive scan encoding.

24P video

Producing content with 24 fps progressive scan used to be the domain of film producers, but many newer high end camcorders have a 24P mode. High-definition video is also a large source of progressively scanned material that is originated on video rather than film. If you have the right equipment, shooting your material in 24P anamorphic 16:9 will produce the best results.

Multiple camera angles

The DVD-Video specification offers up to nine different camera **angles**. Angles are different views of the same scene, shot by different cameras. They are recorded as different video tracks of the same length and associated with the same audio tracks.

The promise

The multiple camera angle feature was intended to offer audiences interactive choices to enrich the entertainment experience. The video recorded simultaneously by multiple cameras can be stored on the single DVD and give the viewer choices. For example, the viewer might first watch a high-speed chase scene that is edited for dramatic effect in a film. But the second time around, the viewer might select a view shot from a different point-of-view such as that of one of the drivers. With multiple angles on a DVD, viewers could even switch back and forth between a full-stage view and assorted angles of individual performances.

The reality

Not many commercial DVDs actually take advantage of this multiangle capability because it takes more work to produce and consumes more disc space.

The possibilities

This multiangle capability offers many possibilities:

- A how-to DVD might show the construction, assembly, or maintenance of a complex piece of equipment from several different angles.
- A training DVD could instruct retail or restaurant employees about an in-store situation from the perspective of a sales associate, a store manager, or customer.

PIXEL ASPECT RATIOS

Even individual pixels have an aspect ratio! Square pixels, like those typically used in graphics programs such as Adobe Illustrator® and Adobe Photoshop®* have a 1.0 pixel aspect ratio. But video images are made up of nonsquare pixels, the aspect ratio of which varies from format to format.

Some common formats and their corresponding pixel aspect ratios:

D1/DV NTSC 0.9

D1/DV NTSC widescreen 1.2

D1/DV PAL 1.066

D1/DV PAL widescreen 1.4222

Anamorphic 2:1 (film transfer) 2.0

Adobe Encore DVD automatically scales square-pixel graphics to fit the proper nonsquare pixel aspect ratio, so your images won't look squashed when viewed in a video format.

*Photoshop 7.0 and earlier supports only square pixels, but Photoshop CS and later allow you to work directly in nonsquare pixels so no conversion is necessary.

- A wedding ceremony might be seen as viewed by the guests, through a close-up of the bride's or groom's face, or from numerous angles that have been artfully edited together.
- A sequence in a science lesson might describe a natural process, such as mitosis, with the option to view either actual time-lapse video or an animated and annotated representation in the place of an alternate camera angle.

Subpicture streams and closed captions

Subpictures laid in on top of background video or still images are typically used to provide subtitles, karaoke lyrics, instructions, or other text. But subpictures are not limited to text only. Because they are composed of **bitmap** graphics, they can include images of any shape. Subpictures are also used for highlighting menu items when they are selected or activated.

DVD-Video accommodates up to 32 discrete subpicture streams. Each subpicture stream is synchronized with the video and audio streams and multiplexed into the overall DVD-Video stream, so that it can be selectively turned on or off. Subpictures made up of of text, graphics, or a combination of both can be partial- or fullscreen size up to 720 x 480 (NTSC) or 720 x 576 (PAL). Simple motion **effects** can be applied to subpictures so they appear to change on a frame-by-frame basis, fade in and out, wipe in color or transparency, or scroll up and down.

What are subpictures made of?

While the DVD-Video format supports up to 32 simultaneous subpicture streams, the bandwidth allocation for each stream is quite limited. To meet the bandwidth restriction, subpicture text and graphics are compressed with **Run-Length Encoding (RLE)**. Run-length compression is a form of lossless compression, so the original picture can be reconstructed with no loss of detail. It is an excellent choice for subtitles and other text where legibility is critical. Run-length compression uses the principles of **spatial compression** to remove redundant areas of information from within the frame. For an area that is all the same color, run-length compression stores the color information for a single pixel, along with an instruction for how many times to repeat the pixel. So, for an area of 100 pixels that are all the same color, instead of storing 100 pieces of data, run-length compression only needs to store three pieces: a marker indicating a run of similar colored pixels, the color, and the count.

Run-length compression is not very useful for compressing photographic images or detailed illustrations that are made up of many colors because there would be little reduction of data. It does, however, work very well on simple pictures made up of a limited number of colors. So, to accommodate run-length compression, DVD limits subpictures to just four colors per frame, selected from a fixed palette of 16 colors per program. This 16-color palette may be chosen from the more than 11 million colors provided in the **24-bit color** mode. The colors chosen should also be NTSC-safe. The 16-color palette can change, from program to program or from menu to menu, on the same DVD. Each pixel is represented by 2 bits, enabling four types: background (BG); foreground (also known as pattern, P); emphasis 1 (El); and emphasis 2 (E2). Each pixel type is associated with just one color, selected from the palette of 16, as well as just one transparency level from 0 (invisible) through 15 (opaque).

Original ☒☒☒☒☒☒☒☒☒☒☒☒☒☒☒☒☒☒☒☒☒☒☒☒

Encoded 2☒ 3☒ 6☒ 2☒ 3☒ 6☒ 2☒

Run-length compression replaces redundant pixels with a value indicating the number of times the pixels are to be repeated.

While this all sounds pretty complicated, with most entry-level DVD authoring applications you don't even need to know this much to highlight menu buttons and create subtitles.

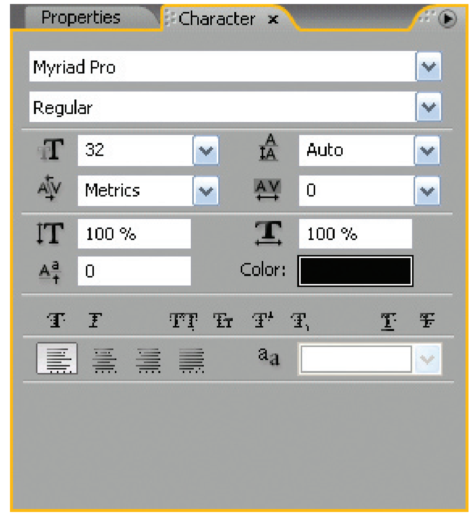
What's the difference between subtitles, captions, and Closed Captions?

- **Subtitles** are usually a foreign-language translation of dialogue, but the term can refer to any text that is superimposed over video or film, typically appearing at the bottom of the screen. Subtitles may not include every utterance—for example, if a character in an action scene simply shouts out a name ("Will Robinson!"), subtitling may be deemed unnecessary. Subtitles do not, typically, identify the speaker, as they are not specifically intended to assist the hearing impaired; subtitles are typically intended for hearing people who do not understand the language of the dialogue.

- **Captions** are almost always in the same language as the audio, although captions of a foreign language translation may be made available. Captions are intended for deaf and hearing-impaired viewers. Ideally, captions impart every utterance and identify the speaker, either by moving around the screen to appear in proximity to the speaker or by denoting, in the text, who is speaking. Captions convey tone and type of voice, where necessary (for example, [whispering], or [Russian accent]). Captions include descriptions of sound effects and other significant audio—for example, thunderclap, music rising to crescendo, or sound of breaking glass off-screen.

Captions may be supplied, like subtitles, as a subpicture stream, in which case they are called open captions. To distinguish them from subtitles or Closed Captions, open captions are usually referred to as captions for the hearing impaired. Like other subpicture streams, open captions are multiplexed into the overall DVD Video stream and extracted into a discrete stream by the decoder in the DVD player, so that they can be turned on or off at the viewer's discretion, assuming the DVD author makes this a choice.

- **Closed Captions** are not subpictures. They are made up of individual character codes carried in the MPEG-2 video stream and must be generated by a special encoder during the **post-production** process. Closed Captions are not decoded by the DVD player. The display of Closed Captions requires a special decoder chip which, by law, is built into every U.S. television set (larger than 13") sold since the mid-1990s. When the Closed Captions option is selected on the television set, Closed Captions are displayed. Closed Captioning is an NTSC standard supported by the DVD-Video format. DVD does not, however, support PAL Teletext, the European equivalent of Closed Captioning.



The Character panel in Adobe Encore DVD, where you can format text typed directly on the screen or created by running a script.

DVD-Video interactivity

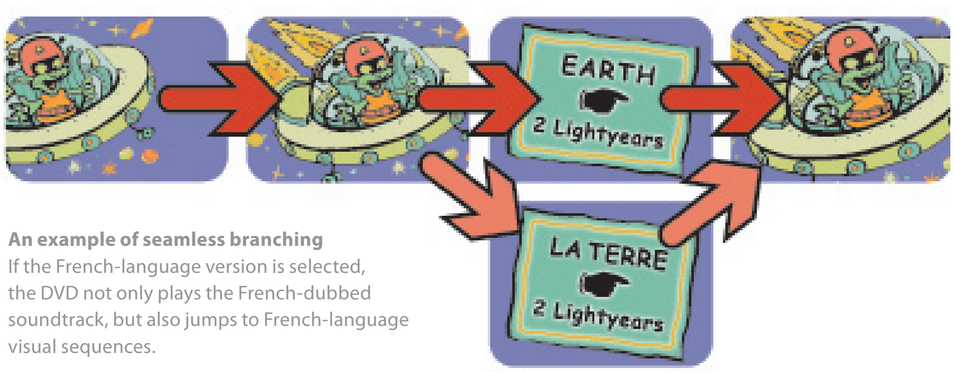
We have become used to the kind of real-time and on-demand interactivity made possible via Internet applications or application software delivered on a CD-ROM or in the DVD-ROM format—video-game play is a prime example. While DVD-Video can provide random access to all of the content stored on the disc, enabling the viewer to jump to any defined point in a video in less than one second, the interactivity afforded is comparatively limited.

DVD-Video can simulate searching and game scoring, but results cannot be generated or computed on the fly. All interactivity must be created entirely in production and stored on the DVD.

Seamless branching

A DVD-Video disc can be authored to allow the viewer to choose how a video program unfolds. The possibilities are limited only by the imagination of the DVD author.

For example, the viewer might be given choices to skip or include certain scenes, experience an alternate ending, view the director's cut, or share a specific character's point of view. Once selected by the viewer, these choices are presented *seamlessly* (that is, without a break in the perceived flow of the program). This seamless branching, also known as multistory capability, is a big improvement over the branching functionality in earlier digital video formats. With laserdiscs and videotape, the user has to interrupt the playback to jump to another part of the program.



An example of seamless branching
If the French-language version is selected, the DVD not only plays the French-dubbed soundtrack, but also jumps to French-language visual sequences.

With DVD-Video, several levels of branching can be offered to the viewer. Some examples might be long or short versions of a chase scene, or with or without a gory ending. Random branching can keep the experience fresh with each subsequent viewing.

Seamless branching functionality can also offer alternative presentations played without the viewer even realizing such a choice was made. For example, if an alternate language soundtrack is selected, scenes in which written words appear on signage might be replaced with matching language versions.

Due to the complexity of seamless branching and the difficulty in preparing content that uses the feature, seamless branching is not used frequently. No commercially-available DVD authoring systems currently offer the feature, and it has only been used on a handful of commercially-available discs.

Adobe offers all the software you need to create dynamic DVD menus: Illustrator and Photoshop for designing backgrounds and graphic elements such as buttons, Adobe After Effects® for developing motion graphics for motion menus, and Adobe Encore DVD for putting your menus together with creative authoring tools for professional DVD production.

Parental management

A special parental menu (which is accessed differently on different DVD players) allows parents to set passwords for specific rating levels (for example, any content rated R or NC-17).

There are three different implementations of parental management:

- **Lockout**: If a disc with a rating above the established level is inserted in the player, it will not play.
- **Censorship**: If the content has been rated on a scene-by-scene basis, the ratings are included in the encoding, and chapter points are set for multistory functionality, then the player can map the rating against the content and skip over those scenes that are unacceptable. While the playback will be seamless, the story line may suffer gaps in continuity.
- **Multirated**: Branching allows DVD-Video creators to create seamless playback of parentally controlled content. Objectionable scenes are replaced by alternative ones. While this feature is noteworthy for its ideals, the reality is that very few DVDs offer content variations for less mature audiences. The added production expenses are prohibitive and generally include things like: shooting extra footage, recording additional audio, editing the new sequences and submitting them for rating approvals, setting up branch points, and synchronizing the soundtrack across the jumps. Furthermore, packaging standards have not yet been established for DVDs with multirated content, so many video store chains don't carry them.

Menus and navigation

The DVD-Video specification accommodates on-screen menus; it does not require them. But, without menus, DVD is really nothing more than a storage and playback medium. Menus support the interactive features that make DVD such an appealing delivery vehicle for video. Most viewers expect at least one menu that lets them jump directly to the content they want to view.

The infrastructure of DVD navigation

Navigation is a good example of how the various components of DVD technology work together to deliver an interactive experience. The DVD-Video format stored on a DVD disc contains presentation data (video, still image, and audio content) and navigation data (information and commands that provide basic interactivity). The DVD player includes a presentation engine. This engine uses the presentation data from the disc to control the content, and to provide a user interface, including menus and other interactive features.

What is a menu?

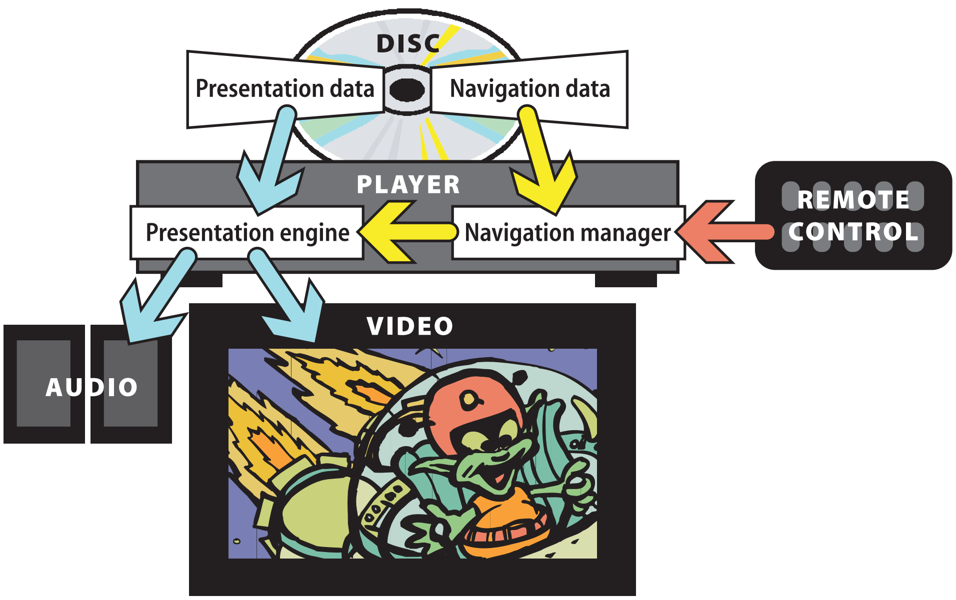
A menu is a user interface (UI) that gives the viewer the ability to navigate through DVD content. The graphical user interface (GUI) part of a menu typically consists of:

- a background that is either a still image or motion video (animation or live action). A menu may also include background audio.
- informational and sometimes instructional text.
- buttons in the form of graphics, still photos, or thumbnail-size motion video that link to points in the video content on the DVD or to other menus.

If the background or the buttons incorporate motion video or animation, the menu qualifies as a motion menu.

The user moves between buttons on the menu by pressing the up, down, left, or right buttons on the player's remote control (either a physical device if the player is a set-top box or a virtual controller if using a computer). A button can be highlighted in the GUI when selected. The user presses the select button on the controller to activate the highlighted choice. If the DVD is being played on a computer, a mouseover usually indicates a selection, causing the button to be highlighted. The user can click the mouse or press Enter to activate subpictures that may be used to provide visual feedback—that is, to highlight menu choices—when buttons are selected, and then when they are activated. Subpictures are the most common and most efficient way to highlight menus, because the 24-bit-color background graphic remains the same, while only the RLE-encoded subpictures change.

Action buttons (or action menus) are another method used to provide visual feedback (not to be confused with motion menus). A highlighted action button is really a jump to an entirely different 24-bit menu graphic—sometimes with motion. While this approach enables a full palette of colors to be used for highlighting (as contrasted to the limitations of using subpictures), and can be used for more complex motion highlighting with dynamic effects, it may not be optimal. Action buttons are more difficult to implement, the feedback may be quite slow on some players, a mouseover on a computer player will usually not cause the highlight effect, and they use more resources.



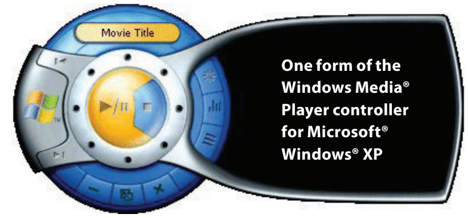
Navigation/presentation technology model

What can menus and buttons do?

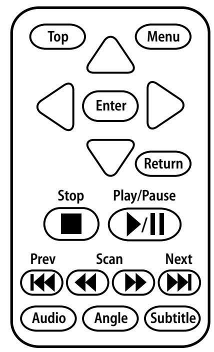
Many menus simply facilitate choices between titles or chapters on the DVD. Some menus let the user choose the way in which the content is presented. This is generally how the viewer chooses audio and language selections, whether or not to have subtitles or captions, and—if multistory options are available—which scenes will be included. A menu can masquerade as a quiz—the answer selected, once activated, will determine the next jump. Choose correctly and you've chosen to play a still or video sequence that congratulates you on your aptitude; choose incorrectly and you'll view content that may suggest you try again, or will provide more information.

Each button must be programmed to perform a desired function—in most cases, to jump to a specific point in the video content, or to another menu. So there needs to be a system for identifying desired points in the video content, as well as recognizing the menus and subpictures that need to be displayed upon command—a road map, of sorts.

DVD player controllers (both physical and virtual) provide a select button and the up, down, left, and right buttons for menu navigation. They also have buttons that let the user play, pause, and stop the video; play the video forward or backward at different rates; step through the video frame-by-frame; skip over chapters or jump to the beginning of the title; jump to the title menu or root menu; control audio volume; and choose language, subtitle, or camera angle options.



One form of the Windows Media® Player controller for Microsoft® Windows® XP



Typical layout of a DVD player remote control device

The Top button (which may alternatively be labeled; Title, Guide or Info) takes the viewer to the very top of the content hierarchy—to the most primary table of contents menu, which is known as the title menu or top menu. The Menu button invokes a jump to the most appropriate menu, based on the current state of the content display. The Return button takes the user to the next higher level of the menu hierarchy.

Some software player controllers don't include buttons that are redundant to mouse selection controls in order to minimize screen real estate. Many software players can even be configured in a variety of ways (for example, to be invisible when a video is playing).

Content hierarchy—the DVD road map

The video content saved in the DVD-Video format and stored on the disc can be parsed much like a map. In other words, it can be broken down into hierarchical units. Further, the dividing lines between these map units are indicated by specific conventions we recognize—solid or broken lines of varying weights and colors. Just as with maps, it helps to understand the nomenclature used to describe DVD-Video content, and the hierarchy of menus and buttons. And, just as with maps, the DVD-Video hierarchy is flexible, so it can be quite confusing to the newcomer. Entry-level and even quite advanced DVD authoring tools help you focus on the creative process of DVD production without having to understand the hierarchy.

A typical DVD hierarchy may look like this: volume>zone>space>domain>video title set>program chain>part of title>program>cell (smallest addressable unit).

There are two interrelated sides to the hierarchy:

- **Navigation** (or control) data is the logic that determines the order and conditions of the content playback.
- **Presentation** (or object) data is made up of the actual video, audio, and still image content, including menu backgrounds and subpictures.

The object data is combined into multiplexed streams called Video Objects (VOB). Video Objects are stored in logical containers called Video Object Sets (VOBS). Which Video Object is played back, and when, is determined by a set of instructions referred to as a Program Chain (PGC), another logical container.

But let's start at the very top of the DVD hierarchy, and move through the DVD nomenclature, looking at how the logical and presentation hierarchy is intertwined.

The top level of organization on a DVD disc is called a *volume*. A single-sided DVD contains a single volume; a double-sided disc has two volumes—one for each side. The UDF file system employed by DVD breaks the volume into zones. In this case, there are two zones: a DVD-Video zone and a DVD-Others zone. All of the video-related content and navigational data—everything that can be played back by a set-top DVD player—is in the DVD-Video zone, while the DVD-Others zone contains any non-DVD-Video data, such as desktop computer applications (which is ignored by a set-top DVD player).

Zones are made up of *spaces*; spaces are groups of *domains*—spaces and domains are fairly abstract logical constructs and beyond this overview.

The first part of the DVD-Video zone that you should be aware of is the Video Manager (VMG), a special type of Video Title Set (VTS). The Video Manager contains any first-play material, such as an introductory sequence, as well as the main table of contents menu for the entire volume. This is the top menu that is invoked when the Top button on the remote control is pressed. There can be only one Video Manager per volume, and only one top menu (although the top menu can be stored in different languages. The preferences set for the DVD player determines which is displayed).

The Video Manager may be followed by 1-99 other Video Title Sets, which fill most of the DVD. A Video Title Set is composed of one or more titles (VTTs—Video Titles) and a VTS Menu (VTSM) area, which contains a number of menus relating to the content in the VTS. Within the VTSM, one menu is designated the root menu. The root menu for the Video Title Set currently being played appears when the Menu button on the remote control is pushed.

Many DVDs have only one Video Title Set. But, because all of the video content in a given Video Title Set must be in the same aspect ratio, a DVD that offers multiple aspect ratios (for example, standard and widescreen) must have multiple Video Title Sets.

A Title (TT) is the largest unit of presentation data, or content, on a DVD—usually an entire movie, TV program, or other presentation. If a disc includes four episodes of a TV series, each episode might be presented as a separate title. A disc that offers a feature film, a theatrical trailer, and a supplement might be divided into three titles: The Movie, The Trailer, and The Making of.

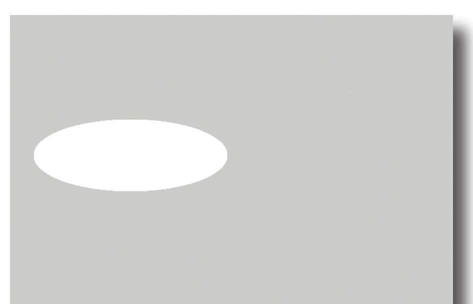
A typical DVD chapter menu

A typical DVD chapter menu. In this example, The Bride button is selected. If activated, playback will jump to The Bride content.

Button highlighting is typically done with a subpicture overlay. In this case, the subpicture overlay highlights the selection by placing a 40% opacity white oval over the selected button. Shown below are the components of this menu.

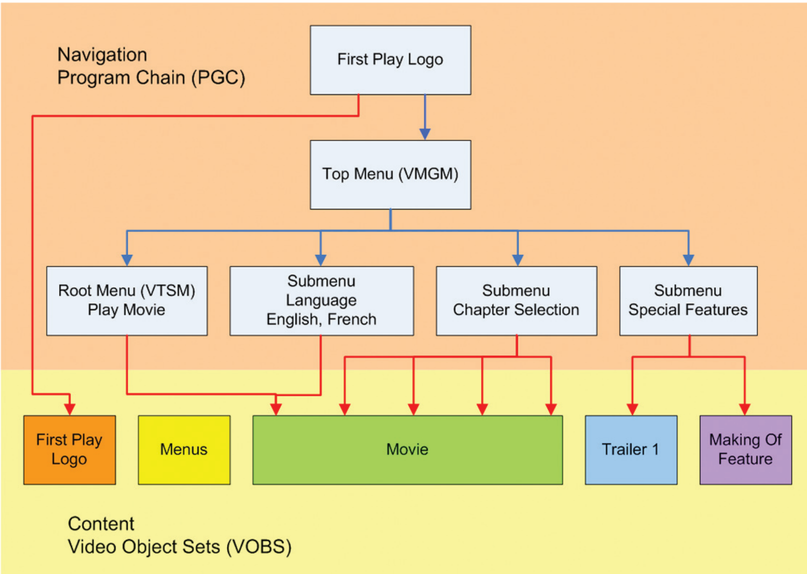
Background graphic

Buttons



Subpicture overlay (40% opacity white oval)

Optionally, a title may be broken down into parts of titles (PTTs) and/or programs (PGs), which may reflect chapters or scenes, and which may be correlated to menus. Titles, parts of titles, and programs are made up of cells. The cell is the smallest addressable unit of presentation data in the DVD hierarchy.



A video DVD is more than just movies and menus. A navigation system is necessary for the viewer to get to the content.

Don't try to equate a cell with a frame or even with a certain number of frames. A cell may be as small as an MPEG group of pictures (GOP)—that is, no more than 18 frames for NTSC, 15 frames for PAL and a fraction of a second—or as large as an entire movie.

The presentation data referenced by a title may include a single cell or multiple cells; it may be made up of cells organized into programs or directly into parts of titles, or it may be made up of cells that are organized into programs that are further organized into parts of titles. The breakdown is relevant only to the level of menu navigation that can be implemented. In any case, the presentation (or object) data is contained in logical units called Video Object Sets (VOBSs). A Video Object Set is made up of one or more Video Objects. A Video Object (VOB) includes presentation data—video, audio, subpictures, and navigation data—that is multiplexed into a stream. Because the data is multiplexed, it can be separated into its constituent parts and called upon as needed.

The VOB can be considered the basic presentation-data building block of DVD-Video, while the Program Chain (PGC) is the fundamental logical unit. Each PGC is a set of instructions telling the DVD player which VOBs should be referenced, under which conditions, and in what order. A DVD-Video title can, simply, be seen as a collection of PGC (instructions) and the Video Objects (assets) to which they refer. Different PGCs can reference the same VOBs, selecting different sets of cells and audio streams to create variations of the content (such as, versions with different ratings) . Each PGC is made up of a pre-command, a list of content residing in associated VOBs, and a post-command. The pre-command contains the instructions for playing the content. It is followed by the list of which VOB content will be played—much like an Edit Decision List (EDL) in a nonlinear editing system. The post-command contains instructions for what to do after the list of content has been played—usually to link to another PGC or jump to a menu.

WHAT'S ON THE MENU?

Because there are no details in the DVD-Video specification for menu hierarchies, the manner in which menus are presented to the end-user is up to the DVD author. A disc may have no menus or hundreds of menus. There are six basic types of menu:

Top menu

The top menu is called the **Video Manager Menu** because it resides within the Video Manager. There is only one top menu per volume (that is, only one for each side of a disc). There may be different language versions of the top menu. The top menu is often displayed automatically when the disc is first inserted in the player, but can also be invoked when the Top button on the controller is pressed (the Top button may alternatively be labeled Title, Guide, or Info). The top menu is sometimes called the title menu, but that can be misleading if there are multiple titles within the volume, each title with its own menu.

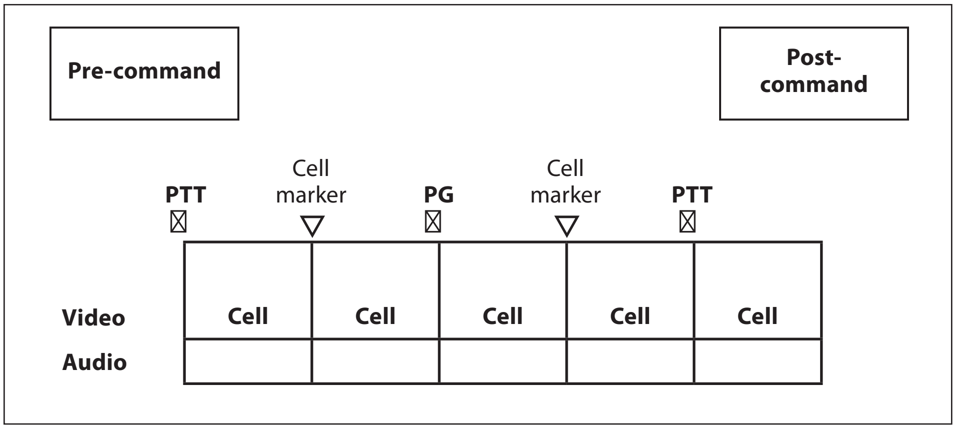
Root menu

A Video Title Set (VTS) can have a root menu area, technically called a **Video Title Set Menu**. Pressing the Menu button on the controller displays the menu that has been designated as the root for the currently active title (often a chapter menu).

Submenus

The other four kinds of menus are submenus of root menus, residing in the same Video Title Set. Many players do not provide buttons for displaying these submenus, and those that do rely on the DVD developer to have programmed the appropriate interactivity. Some players provide a Return, Back, or Go Up button that may, if the menus are programmed to take advantage of it, jump back to the parent root menu. Note that submenus can have submenus of their own. The names of the four submenu types are self-explanatory:

- **Chapter menu** (part-of-title or PTT menu): Button activation results in a jump to specified PTT (chapter) or PG (program group or scene) marker.
- **Audio menu:** Lets viewer select an audio stream (such as type of audio, language option, or narration option).
- **Angle menu:** Lets viewer select a camera angle or other alternate video stream.
- **Subpicture menu:** Usually lets viewer select a subtitle option.



The anatomy of a Program Chain (PGC)

Region Coding

The motion picture industry has a powerful voice in the DVD Forum, and that's why the controversial Region Coding feature, also known as country coding, zone lock, and, in computer drives, Regional Playback Control (RPC), was included in DVD technology. DVDs that contain Region Coding will only play on devices coded for that region. For example, if you purchase a DVD player in Canada, it will not play back most prerecorded DVDs purchased outside Region 1.

The code takes up one byte on the DVD. It is designed to search for a matching bit of code in the DVD player's firmware. If the proper code is not found, the DVD will simply not play. However, a disc without a Region Code—also known as an all-region disc—will play on any compatible DVD player or drive. And there are multiregion players available. In fact, NASA has purchased and used them on multinational space shuttle flights. But some DVDs from major motion picture studios use a system known as RCE (Region Coding Enhancement), and are unplayable in multiregion players.

Region Coding is not a requirement

The producer of a DVD—whether a major motion picture studio or you—is not required to include Region Coding. Why would it possibly be a desirable feature? Because movies aren't always released everywhere in the world simultaneously and movie studios want to control the timing of DVD releases in different geographic markets. Region coding also makes it possible to sell exclusive rights for DVDs to different foreign distributors in discrete geographic markets.

UNDERSTANDING VIDEO AND DVD HIERARCHIES

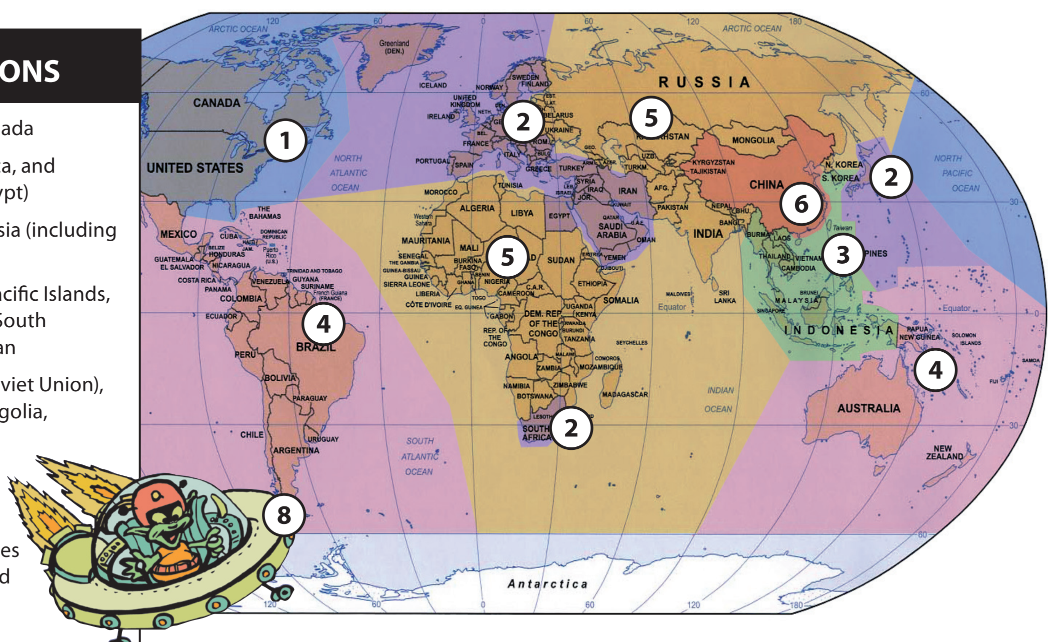
You're already familiar with the nomenclature of the video hierarchy—from largest to smallest unit: movie > chapter > scene > clip > frame > pixel. The DVD content hierarchy may sometimes seem to parallel the video hierarchy, but there isn't always a direct correspondence. In some hierarchical structures, there are clear, consistent size relationships between units. But in video and DVD, the unit relationships are not defined by size or quantity; a clip can be made up of any number of frames. Some of the larger units in the DVD content hierarchy have a capacity limit for smaller units (for example, a disc can have no more than 99 titles), but unit boundaries can typically be defined by the video editor or DVD author.

VIDEO CONTENT HIERARCHY	COMPARABLE DVD CONTENT HIERARCHY	MAXIMUM
Movie, Project, or Program	Title (TT)	99 per disc
Chapter	Part of Title (PTT) or Program Chain (PG C)	999 per title
Scene	Video Object Set (VOBS) or Program (PG)	99 per PGC
Clip	Cell	N/A

A comparison of video content hierarchy and DVD content hierarchy

THE DVD REGIONS

1. U.S.A., U.S. Territories, Canada
2. Japan, Europe, South Africa, and Middle East (including Egypt)
3. Southeast Asia and East Asia (including Hong Kong)
4. Australia, New Zealand, Pacific Islands, Central America, Mexico, South America, and the Caribbean
5. Eastern Europe (former Soviet Union), Indian subcontinent, Mongolia, Africa, and North Korea
6. China
7. Reserved
8. Special international venues (airplanes, cruise ships, and elsewhere)



The practice of Region Coding is quite controversial. Those opposed to Region Coding suggest that it may be a violation of fair trade practices. In a court case, the Australian Competition and Consumer Commission (ACCC) argued that the practical effect of Region Coding is that consumers who purchase DVD players in Australia are prevented from playing films procured overseas and, because overseas markets give Australian consumers access to a wider range of film titles with special features not available locally, the practice amounts to the creation and maintenance of artificial barriers to trade.

Can DVD Players be modified to permit multiregion playback?

Yes. Special command sequences from the remote control allow some players to switch regions or play all regions. Some players can be physically modified to play all regions; however this practice will sometimes void the warranty and may be prohibited by law in some jurisdictions.

Content Protection

Content Protection, like Region Coding, is not a requirement, but is an optional feature of DVD production. It's not very difficult to understand why content developers and copyright holders want Content Protection. So who doesn't want it, and why? The opponents of Content Protection claim that its ramifications violate our rights to benefit from open technology and to freely distribute and share information. There are complex issues involved in the Content Protection debate—issues involving not only content rights, but also the capabilities (or potential lack of them) built into the DVD recording technology available to the general public.

CPS and CPSA

Content Protection System (CPS) is the generic term for a technology designed to protect content from being misused or misappropriated—that is, altered, copied, or displayed in any unauthorized manner.

Content Protection System Architecture (CPSA) is an overall framework for DVD technology related to controlling access to content recorded on DVDs. Made up primarily of watermarking and encryption technologies and policies, CPSA includes protection measures for both digital and analog outputs. CPSA was developed jointly by IBM, Intel, Matsushita, and Toshiba, forming an alliance known as the 4C Group. The group works in cooperation with the Content Protection Technical Working Group (CPTWG), a somewhat broader consortium of consumer electronics and computer companies, as well as content producers. CPSA was designed to encompass the major Content Protection technologies currently in use, to accommodate the integration of emergent technologies, and to ensure consistency with and avoid duplication of Content Protection technologies being developed by the Secure Digital Music Initiative (SDMI).

CMI and CCI

Content Management Information (CMI) is the specific logic, or set of rules, governing protected content. Region Coding is one form of CMI. Simply stated, CMI is just digital code, recorded with the content and other data on a DVD that may modify the behavior of the DVD device in which it is played, and may restrict copying of content from protected discs. CMI often modifies playback or restricts recording attempts regardless of whether the attempt is made by digital or analog means.

Copy Control Information (CCI) is the logic governing if and how content may be copied. CCI is usually part of the CMI.

Watermarking and encryption

Digital watermarking has been in use for some years in efforts to protect still images from being used or altered without permission. Watermarking of still images is often quite obvious. Generally, an image watermark is a logo or text that partially obscures the image, and clearly identifies it as protected. Conversely, for video and audio content, watermarking refers to technologies that embed CMI in content, so that it is imperceptible to the audience. And unlike the watermarking used to protect still images, video and audio watermarking does not protect the content. The watermark simply triggers the playback device to respond in accordance with the CMI, so long as that playback device is compliant with the system being employed. A noncompliant device will generally not play back watermarked content. The watermark triggers the device to decrypt encrypted content in accordance with the CMI. Watermarking and encryption/decryption technology systems are typically made available to content producers and device manufacturers under license. The license contract specifies the CMI protocols. Watermarking technologies are standardized by an organization called the Watermarking Review Panel (WaRP).

APS, CPS, copyguard, and Macrovision

An Analog Protection System (APS), also known as an analog CPS (Content Protection System), prevents analog copies from being made from DVDs. The most widely used APS was developed by a company called Macrovision and is generally referred to by its trade name. A Macrovision circuit is built into just about every DVD player, as well as into computer video cards with S-video outputs. Macrovision-protected discs include trigger bits, encoded in the recorded data that trigger the Macrovision circuit in the player or video card to send out AGC (Automatic Gain Control) pulses to the video outputs. AGC pulses interrupt the vertical interval in the television display. The pulses usually do not affect playback on standard TVs, but do affect the AGC circuitry in VCRs, which results in noise, interference, or other undesirable artifacts on analog videotape copies.

Adobe Encore DVD supports Macrovision, CGMS, and CSS Content Protection formats.

Macrovision also uses an additional protection scheme called Colorstripe, which adds a rapidly modulated colorburst signal that results in lines or stripes appearing across the picture when analog videotape copies of protected material are viewed. Because the DVD producer pays Macrovision royalties (typically several cents per disc produced) based on how much protection is incorporated into the content, and because Macrovision protection can be applied selectively, not all the content on a Macrovision-protected disc may actually be protected. Both of the Macrovision techniques—AGC Pulsing and Colorstripe—hinge on interrupting the analog video signal, so Macrovision can be used to protect only video, not audio, content. There are some inexpensive devices available that defeat Macrovision, but only a few can be used to circumvent the Colorstripe scheme.

CGMS and SCMS

Copy Guard Management System (CGMS) is a Serial Copy Management System (SCMS). The CGMS code embedded in the outgoing video signal is based on one of three rules: copy freely, copy never, or copy once. The copy once rule allows a first-generation copy to be made, but disallows copies of copies.

CSS

Content Scrambling System (CSS) is a Content Protection solution developed primarily by Matsushita and Toshiba. It was designed to prevent the direct digital copying of video files from DVDs, which could result in virtually perfect clones. To play a protected disc, a pair of so-called keys must match to authenticate both the disc and the device as duly licensed, before allowing an encrypted MPEG-2 file to be descrambled and played back.

Here's how it works: approximately 400 master keys are stored in the lead-in area on every CSS-encrypted DVD. Each licensed hardware (device) manufacturer is given what amounts to a keyhole (in the form of computer code), matching one of the 400 master keys. This key code is included in the device's firmware.

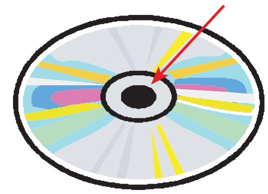
There is no charge for a CSS license, but it is difficult to obtain one, and the license is extremely restrictive, requiring among other covenants, that Region Coding be employed. If the hardware license is revoked, the matching key is simply not included on any future CSS-encrypted DVDs. In order to play a CSS-encrypted disc, the device must include a licensed CSS decryption module with a valid key code.

When a CSS-encrypted DVD is played in a CSS-enabled device, the plot thickens. In addition to decrypting the scrambled MPEG-2 file to actually play the video, the CSS decryption algorithm exchanges keys with the device to generate an incremental encryption code that prevents the further exchange of disc keys and device keys that would be needed to decrypt data from the disc.

The CSS algorithm and keys were intended to be a closely kept secret. However, these days you can learn every secret on the Internet. DeCSS is a hack that was posted on the Internet in October 1999, cracking the CSS algorithm and spawning a tangle of legal controversies. The original version of DeCSS enabled the playback of CSS-encrypted DVDs on computers running the Linux operating system (which had been excluded from CSS because of its open source approach) and another version works with the Microsoft® Windows operating system. To learn more about the DeCSS polemic, see www.opendvd.org.

CPRM and CPPM

Content Protection for Recordable Media (CPRM) has stirred up a lot of controversy because it is a technique that can be applied to a spectrum of storage media, including personal computer hard drives, where issues related to data recovery and privacy have been cause for concern. As it relates to DVD, CPRM involves a unique code, physically etched into the burst cutting area (BCA) of every blank disc. When the disc is played, a CPRM-enabled playback device reads the code from the BCA and uses it to generate a key to decrypt the content for playback. But if the encrypted digital content is copied to other media, it can't be decrypted because the code that generates the key will be missing or different. Every DVD recorder shipped after 1999 supports CPRM.



The burst cutting area (BCA) near the hub of a DVD can contain a barcode that provides CPRM Content Protection.

Content Protection for Prerecorded Media (CPPM) is designed specifically for DVD-Audio content. It is based on CSS, but uses a different algorithm developed after the appearance of DeCSS.

DCPS, DTCP, and HDCP

Devised specifically for the next generation of digital TVs and VCRs, DCPS, DTCP, and HDCP include clandestine key exchanges and encryption/decryption schemes.

Digital Copy Protection Systems (DCPS) enable the exchange of data between digital components via lossless, digital connections such as IEEE 1394 (also known as, Firewire, or i.Link), without permitting perfect digital copies to be created. Several proposals submitted to the Consumer Electronics Association (CEA) from various consumer electronics players call for devices enabled by digital keys or physical smart cards for renewable security. Such devices exchange keys and authentication certificates to establish a secure channel whereby other connected but unauthenticated devices cannot access the signal.

The DVD player itself encrypts the video signal as it sends it to the receiving device, which must decrypt it. Unauthenticated devices cannot decrypt the signal. All the proposed techniques flag content with CGMS-style copy freely, copy never, or copy once coding. Players that can authenticate that they are playback-only devices may access all protected content. Recorders can only receive data flagged as copyable and, as a copy is made, must change the flag to no more copies if the source is marked copy once.

High-bandwidth Digital Content Protection (HDCP), developed by Intel, is specifically for use with components connected with digital video monitor interfaces such as the Digital Video Interface (DVI), designed to replace the analog VGA standard. Most HDTVs are compatible with DVI. Like DCPS, HDCP uses a complex set of coded keys for device authentication. Upon authentication, the HDCP protocol encrypts each pixel as it is transferred across DVI from the DVD player to the digital display. Any unauthorized device that attempts to play back HDCP-protected content transfers only random noise to the display.

How do I make DVDs?

Because this primer isn't a how-to, you won't find step-by-step instructions. What you will find are basics to familiarize you with the tools and process. There are two principal stages to making DVDs: authoring and replication. For DVD-Video, authoring includes planning, designing, assembling, and formatting content. Depending upon the software used and individual interpretation, authoring may also include encoding or transcoding video and audio, as well as developing menus.

When authoring is complete, the DVD is replicated. In the professional production environment, the replication process consists of more than simply burning discs; it also includes premastering, proofing, quality assurance (QA), physical formatting (during which Content Protection and Region Coding may be incorporated), and glass mastering.

What tools do I need?

Much of the hardware and software you need is the same as for producing any other video-based production: tools to create, capture, and edit video. In addition, you'll need DVD-authoring software, as well as a device for recording the final content you've prepared in the DVD-Video format, either directly onto DVDs for playback or replication, or onto the half-inch digital linear tape (DLT) typically used in preparation for mass reproduction. (Most replicators also accept single-layer DVD-R for replication, but not when copy protection is to be included.)

Hardware

The speed, power, and capacity of many desktop and even laptop systems, make it possible to go from DV to DVD with a fairly minimal hardware investment, either by using the system you already own, or by enhancing it somewhat. Answers to the following questions can help you make your hardware decisions:

- What kind of video will you be incorporating into your productions?

Simple, straightforward editing of DV takes less processing power (that is, MHz) and less random access memory (RAM) than if you'll be applying complex visual effects or **compositing** uncompressed footage. Check the system requirements on your video editing software for guidelines. But because these system requirements are usually established using a clean computer, you're likely to want more than what is recommended. While you may be able to struggle along with 256MB of RAM, you'll probably be happier with at least 512MB. Many professionals opt for 2GB of RAM.

- How much video will you be working with?

Digitized video requires significant storage. Uncompressed, a single video frame is approximately 1MB and, therefore, at the NTSC frame-rate of 29.97 fps, 1.5GB is required for just one minute of video. An hour-long program can consume 90GB of disk space, without even considering all the raw footage that went into it, often five times the amount of the actual product (450GB), or, for high-end productions as much as 20-50 times (1,800-4,500GB).

To figure the amount of storage you need for DV video (compressed 5:1), allow approximately 216MB for each minute of stored video. Or, looking at it from the opposite direction, each 1GB of storage holds about 4 minutes and 45 seconds of video. For an hour of DV, therefore, you would need a 13GB disk.

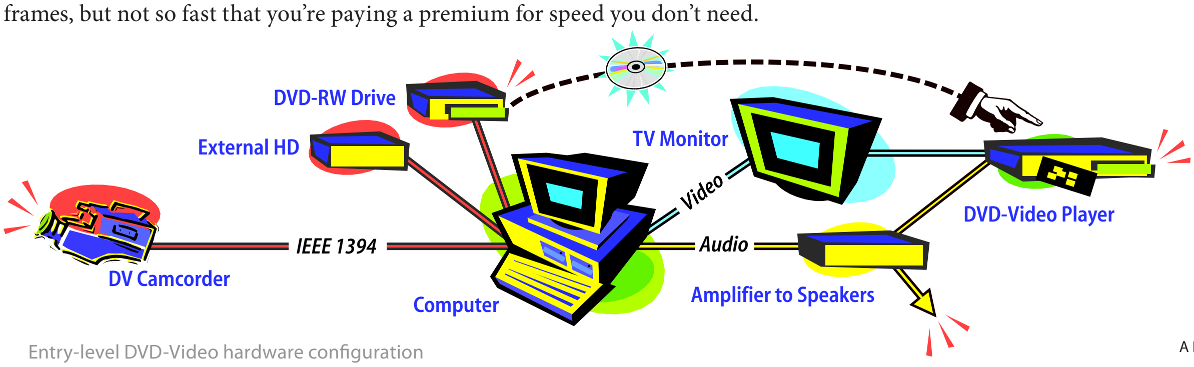
Let's say that you're an event videographer planning on creating DVDs for your clients. To figure out how much storage you would need to make a two-hour DVD, here's how you might do the math:

Start with what you need for your finished production—two hours of DV footage	26.0GB
Add a conservative amount for unused footage—at least twice the finished amount	52.0GB
Figure in some additional graphics—titles, for example—and audio tracks	2.0GB
You'll need space for the MPEG-2 files you export for your DVD	4.1GB
Minimum storage space needed	84.7GB

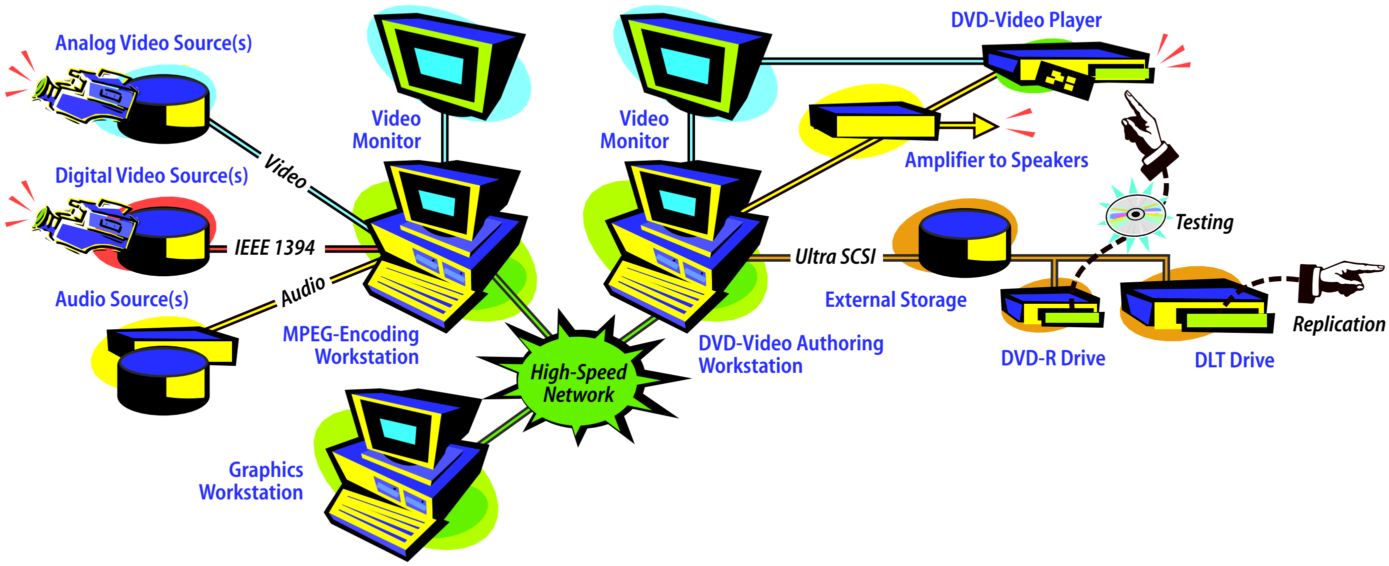
Example estimate of storage needed for a two-hour DVD

As you can see, you'll probably need offline storage, such as a large-capacity external hard drive or two at the very least, or a RAID array or storage area network (SAN) if you're running a professional operation.

When you consider an offline storage subsystem, capacity isn't the only factor—transfer rate is important, as well. To preview video in real time, the data for each frame must be transferred to and from the processor at the video frame rate—29.97 frames per second for NTSC. The transfer rate for DV is typically 3.6MB per second. If you are compositing multiple video streams in real time, that rate must be multiplied for every stream processed concurrently. And the video must move at a steady, sustained pace, too. If the transfer rate falls below what's required, frames may be dropped, resulting in poor quality video. Because faster disk subsystems typically cost more, you'll want to configure your system with disks and interfaces that are fast enough to not drop frames, but not so fast that you're paying a premium for speed you don't need.



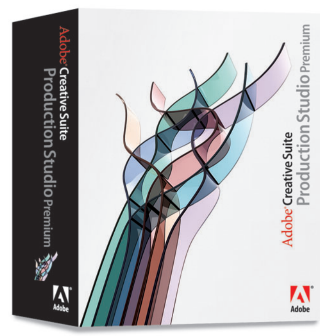
Entry-level DVD-Video hardware configuration



Mid-range DVD-Video hardware configuration

• How will you distribute your finished video?

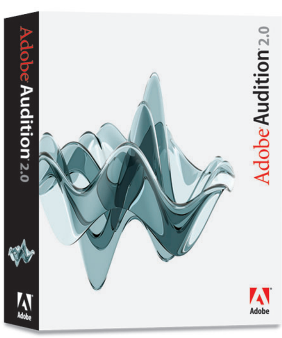
If you need only to burn a small number of final DVDs for personal use, a consumer DVD writer is all you need. If you have broader distribution plans, you may also need a DLT drive for recording to DLT, the medium often preferred by DVD-replication facilities, although these days most replicators will work from a recordable DVD.

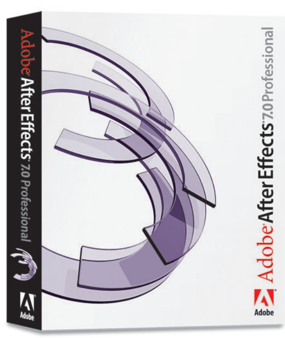


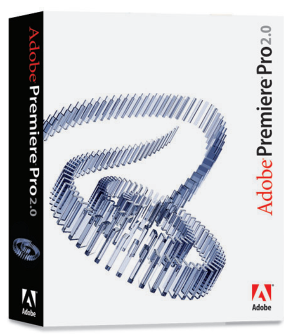
If you are upgrading any of your Adobe video products, make sure to ask about upgrading to the complete collection. The Adobe Production Studio is an incredible value.

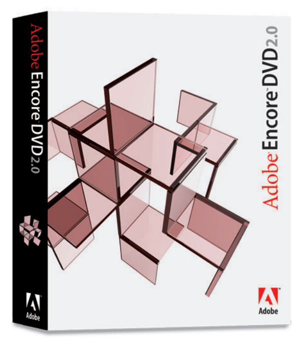
Software

Adobe Production Studio delivers the leading-edge software you need to produce professional-quality results for film, video, and DVD. This comprehensive video production toolset is well integrated, streamlining your workflow to give you more time to be creative and to maximize your productivity. Adobe applications have similar interfaces, so if you're familiar with one, you'll be able to get up to speed quickly on the others. You can even customize the interface of each Adobe application to suit your workflow needs and increase your productivity.

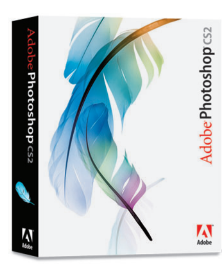


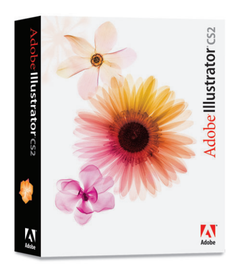






Real-time editing for professional video production: When preparing digital video for distribution, you'll need **nonlinear editing (NLE)** software such as Adobe Premiere Pro. This revolutionary editing application delivers a host of real-time video and audio editing tools, an elegantly redesigned user interface, and flexible import and export options.



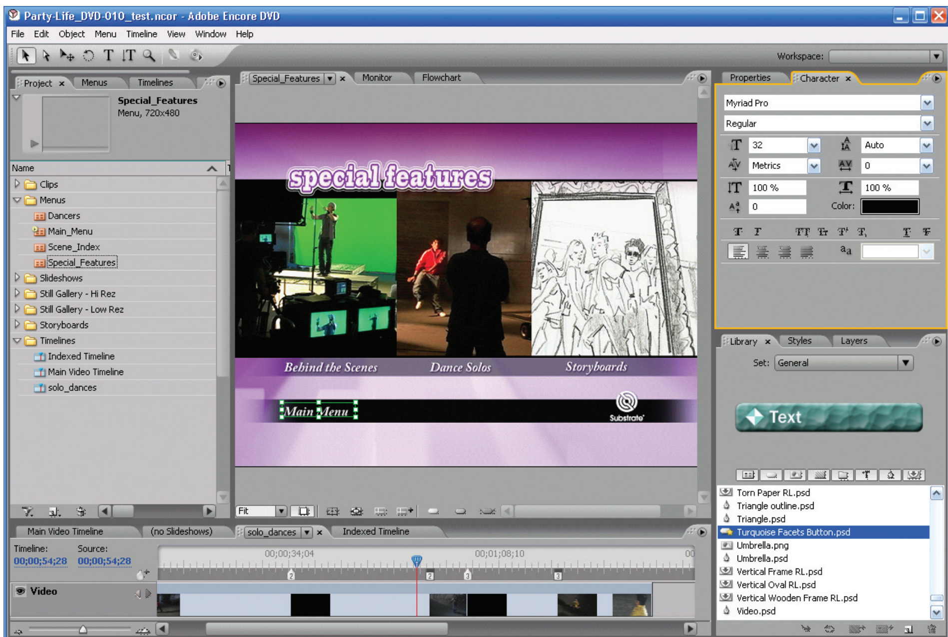


The essential tool for motion graphics and visual effects: After Effects is the industry standard for motion graphics and visual effects. Core 2D and 3D compositing tools and effects help you create eye-catching motion graphics. Sophisticated visual effects tools deliver the precision you need to produce award-winning output. Easy to learn and use, After Effects pairs a flexible workflow with exceptional creative options so you can produce professional output for any media, from film and video to DVD and the web.

The essential tool for professional digital audio: Adobe Audition® turns your computer into a professional multi-track recording studio with the tools to produce high-quality audio. DVD-Video can deliver unprecedented audio quality when the audio assets you incorporate into your DVD production are high-quality to begin with.

The world-standard image editing solution: You'll also need software for creating menu graphics: Adobe Photoshop is the industry standard for developing still graphics, including backgrounds and subpictures for DVD menus.

Creative authoring for professional DVD production: Adobe Encore DVD software gives professional videographers, DVD authors, and independent producers the power to create sophisticated, multi-language DVDs with interactive menus, multiple audio tracks, and subtitle tracks. Adobe Encore DVD provides a comprehensive set of tools for designing professional DVD titles. Unparalleled integration with Adobe Premiere Pro, After Effects, and Photoshop optimizes your efficiency. Use the convenient Edit Original command in Adobe Encore DVD to open and adjust your original files in their native applications.



The default Adobe Encore DVD workspace includes panel groups for viewing and working with project settings and content, and modifying text and graphics, as well as a timeline for laying out content.

Adobe Encore DVD includes a variety of predesigned button and menu styles that are easy to customize to create your own look.

The DVD workflow

No matter how simple or ambitious your project, the DVD workflow can basically be broken down into seven stages:

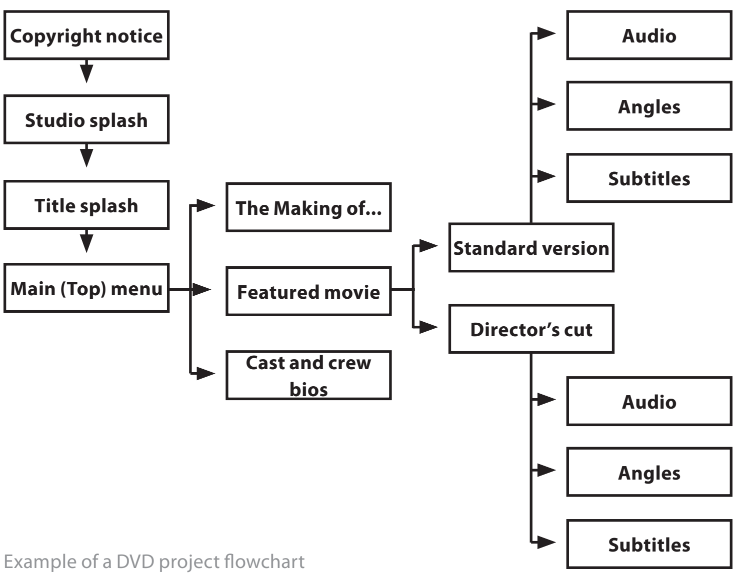
1. Planning
2. Asset preparation
3. Authoring
4. Formatting and layout
5. Emulation
6. Replication
7. Packaging and delivery

There can be as many variations to this process as there are DVD authors, and the steps that make up these stages may overlap or may be performed in different stages.

Planning

In the planning stage, you define your project, determining what content to include and how much and what kinds of interactivity to offer. If you are producing a commercial DVD, you'll develop a schedule and milestones, and prepare or confirm a budget. If you are working with others, you'll define roles and responsibilities.

If there will be a significant amount of interactivity, you should create a project flowchart, which can be used as a blueprint for building the DVD.



Example of a DVD project flowchart

You may also develop storyboards that previsualize the production, primarily showing rough menu layouts and chapter points. Storyboards also serve as important tools for sharing ideas and concepts.

Bit budgeting is a critical step in the planning stage that ensures all of your content will fit on the DVD. It's good practice to reserve some space for changes or additions as the process unfolds. Because of the possibilities inherent in DVD, it's easy to get carried away, shooting multiple angles and creating branching options or alternate endings. Don't forget that for every additional camera angle you want to include on your DVD, you increase the bits you need to budget for the scene by 100 percent.

BALANCING YOUR BIT BUDGET

In planning a bit budget, the objective is to balance the amount of content you include versus its quality. Start by making a list. In addition to your video assets (including multiple angles), list all audio streams including multiple languages and audio formats, as well as your graphic assets (such as menus, stills, and subpictures).

Consider both asset size and data rate. The combined data rates of concurrent streams cannot exceed the maximum DVD-Video data rate of 10.08 Mbps.

The data rate (in megabits per second) for each asset multiplied by the playing time (in seconds) yields the asset size (in megabits). Asset sizes, when summed, must fit within the selected disc capacity:

	CAPACITY IN BILLIONS OF BYTES	CAPACITY IN MB (MEGABITS)	LESS 4% OVERHEAD IN MB (MEGABITS)	ADJUSTED CAPACITY IN MB (MEGABITS)
DVD-5	4.70	37,600	1,504	36,096
DVD-9	8.54	68,320	2,733	65,587
DVD-10	9.40	75,200	3,008	72,192
DVD-14	13.24	105,920	4,237	101,683
DVD-18	17.08	136,640	5,466	131,174

A spreadsheet with built-in bit budget-balancing formulas is invaluable. Start by plugging in a desired level of quality. If the spreadsheet shows you have too much data to fit on your disc, you can choose to: a) reduce the amount of content, b) reduce the data rate of all or some of the assets, or c) move up to a disc with greater capacity. Option b—reducing the data rate—reduces the quality of the video when you encode it.

Some DVD-authoring applications include automatic bit-budgeting tools that perform the calculations when you arrive at the formatting (layout) stage. But if you wait until that point, you may have to go back and reencode your video to make it fit. Rather than doing work twice, it makes more sense to budget your bits during the planning stage of the process. Then, use the built-in calculator in your authoring application as a failsafe measure.

Preparation

Preparation means gathering and preparing all of the assets that will be included on your DVD—video, audio, and graphics.

The quality of your DVD is largely dependent upon the quality of your source material. Do your best to make sure that you gather the highest quality versions available for all of your assets.

For existing video, digital tape is generally better than analog, assuming that the original source was digital. If your content was originally shot as analog footage, you want the closest you can get to first generation because, with every generation copied, analog loses fidelity. If you do use videotape, test tones and color bars are valuable tools for calibrating your playback deck to match the recording deck.

If your footage was shot in 24P mode, keep your entire workflow in progressive mode for easier editing and encoding.

Video assets generated on the computer, such as motion graphics and visual effects, should be provided digitally, rather than on tape (either digital or analog)—preferably uncompressed, as AVI, MOV, or OMF files.

If you are shooting footage for your DVD, preparation includes preproduction, production, and post-production stages—planning, shooting, capturing, editing, and adding effects, as well as encoding.

After your video has been collected and edited, you may want to preprocess it using filters or **Digital Video Noise Reduction (DVNR)** processors designed to minimize any undesirable video artifacts resulting from MPEG encoding. DVNRs are available in a variety of different forms ranging from hardware to software plug-ins.

Your audio must also be recorded or collected, sweetened as necessary before encoding, and synchronized with your video. For audio assets, the higher the sample rate and the bit depth, the better your end product will be. The more information you start with, the better your results will be when you downsample and encode. Adobe Audition offers a wide variety of powerful options for sweetening and cleaning up your audio.

You then must create menu backgrounds and subpictures. Original menu design requires excellent graphic design skills and a thorough understanding of the limitations, so consider using a DVD authoring application such as Adobe Encore DVD, which comes with customizable menus.

Once your video and audio assets have been collected, edited, and preprocessed, they must be encoded for DVD: video as MPEG-2 and audio in one of the audio formats specified for DVD-Video. Encoding can be handled in Adobe Premiere Pro or right within Adobe Encore DVD.

Authoring

If your DVD-authoring software includes MPEG-encoding capabilities, you might save encoding for this stage, as long as you are willing to give up some of the fine control you have over the encoding process with more sophisticated encoding solutions. Similarly, if your authoring software provides menu templates, you may create (that is, customize) your menu graphics as part of the authoring stage, as well. Typically, however, the authoring stage involves five steps:

1. Identifying the media assets to be incorporated in the DVD project. The actual asset files are not really copied or moved anywhere in this step. Rather, their locations on the system are identified and links to those locations are generated.

2. Assembling the video and audio assets, identifying chapter points, titles, and title sets. Most DVD-authoring applications use **timelines** with drag-and-drop functionality to make this step and the next one easier.

3. Organizing the presentation groups to match the project flowchart.

4. Programming functionality and interactivity. Define the links between the various presentation groups, along with what should happen when the viewer presses the various buttons on the player remote control. Create menus by importing background graphics and subpictures into the authoring application. Then, link menu buttons to content assets and other menus.

5. Simulating the final product by testing menus and navigation. Your DVD-authoring software should let you see how your DVD will look and perform in a player. Some authoring systems will warn you of potential problems in some players. But this is only the first of several QA steps in the overall process.

Formatting and layout

After you've completed the steps of the authoring process, the various video, audio, and still picture streams must be multiplexed, or muxed. Then, the content and its associated navigation (or control) information must be formatted as special types of data files that are compliant with the DVD-Video specification: VOBs (video object files), BUPs (backup files), and IFOs (the information files that tell the player how to access the data stored in the VOBs).

Once formatting is finished, the DVD-authoring software performs the layout process, resulting in a volume image (also known as disc image).

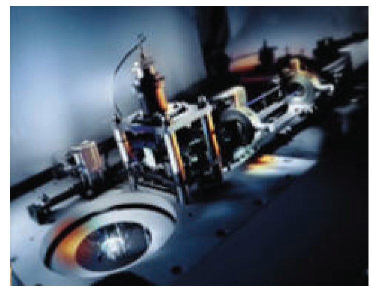
Formatting and layout take time. The amount of time depends on the processing speed and power of the computer, the type of authoring software, and the size and complexity of your DVD content. Most DVD authoring tools can perform formatting and layout in real time, meaning that if the actual playing time of your DVD content is two hours, then real-time formatting and layout take two hours. Some DVD authoring tools can also write directly to the DVD at the same time.

Emulation

Simulation tests the functionality of components of the DVD, or the DVD project as a whole, from within the DVD authoring application. Emulation, on the other hand, tests the DVD project outside the authoring tool. Most DVD authors burn a DVD-R for emulation, and then test it on as many different hardware players as possible. Emulation may catch problems that go unnoticed in the simulations run during the authoring stage. During emulation, you can test the DVD to make sure that:

- First-play material plays first.
- Video and audio are of the anticipated quality.
- Video and audio are synchronized.
- Menus look and operate as intended.
- Subpictures (that is, subtitles) appear when they are meant to and are clearly readable.
- Closed captions can be decoded by a TV set.
- Parental controls function, and user operations (that is, the functionality of player controls) behave as expected.

Dual-layer DVD burners are now available, which can be a real lifesaver for testing projects that won't fit on a single layer. If you don't have access to a dual-layer DVD burner, you can use software emulation to play the material from the disc image rather than from a DVD.



Mass DVD replication requires a number of specialized, precision machines to automate multiple processes, while maintaining quality.

Replication

If you are creating just a few final DVDs, the replication stage involves just burning the required number of discs onto DVD-R using a DVD writer. However, if you will be replicating something on the order of a thousand or more DVDs, there are a few more steps:

- If you will be implementing Content Protection or Region Coding, you'll need to flag these options using your authoring tool, and create a new disc image. The actual encryption is done in the final replication stage, as the replicator will hold the licenses and keys for these processes. (Note that not all DVD authoring applications allow this functionality.)

- Premastering is the process of writing your final disc image to the digital linear tape (DLT) or DVD-R that will be sent to the replicator. DLT is generally preferred and must be used if Content Protection or Region Coding are to be employed.

- Physical formatting converts the disc image provided on the DLT or DVD-R into the bitstream needed by the laser beam recorder (LBR). Among other processes, the data is encrypted for Content Protection and Region Coding, interleaved, and error correction added during physical formatting.

- Glass mastering is the process of creating a model of the final DVD, which is used for generating stampers. A stamper has the inverse of the pits and tracks on the glass master. Stampers wear out fairly quickly during the fabrication process, so multiple stampers may be produced from the glass master to complete the run.

- Molding, sputtering, bonding, and labeling complete the replication process. Plastic copies of the glass master are made from the stamper, using an injection-molding process. A thin metallic layer is sprayed onto the polycarbonate (plastic) substrate. The two sides of the disc are then bonded together—DVD-5 discs and some DVD-9 discs get bonded to a blank side, while two-sided discs are bonded back to back. For one-sided discs, most of the surface of the back side is available for labeling, in designs that range from one color to full-color. For two-sided discs, the print area is limited to within the burst-cutting area. Depending on the type of disc and the printing method selected, the disc may be labeled before or after bonding.

- Check discs are a limited run of proof discs created by the replicator. They should be run through the same rigorous testing process as was performed in the emulation stage. This is the DVD author's last opportunity for QA before discs are mass produced. Once check discs have been approved, it is the replicator's responsibility to make sure the final fabricated discs match the check discs.

Packaging and distribution

DVDs, once fabricated, are inserted into packages with any printed material that may be designed to house or accompany them. Commercial printers and packaging specialists can help the designer with keylines or templates to use as guides for packaging graphics. Illustrator, Photoshop, and Adobe InDesign® software are often used to develop the artwork for packaging and inserts.

Once packaged, DVDs are shrink-wrapped, boxed, and shipped.

Resources

HOW TO PURCHASE ADOBE SOFTWARE PRODUCTS

Via web:
www.adobe.com/store

Via phone:
Call the Adobe Digital Video and Audio Hotline at: (888) 724-4507

Education customers:
Find an Adobe Authorized Education Reseller at:
www.adobe.com/store/general/otherplaces/uscanada/educlist.jhtml

To find the reseller nearest you, visit:
www.adobe.com/store/customerregistration/other_places.jhtml

Glossary

Academy Aperture: Standard 4:3 aspect ratio, so called because it was adopted by the Academy of Motion Picture Arts & Sciences (in 1927) as the industry standard.

AC-3: Often used in reference to DVD because this is how the technology is referred to in the DVD standards documents.

Analog: Refers to video and audio recorded or stored nondigitally. Older video formats such as VHS and Hi 8 are analog.

Anamorphic: Refers to an image or to the technique used to create images where the visual information in a widescreen view is horizontally squeezed into the narrower proportion of a standard 4:3 image. For proper viewing, the image is expanded back to its original wide format.

Angle: Also known as a camera angle, a scene recorded from an alternate viewpoint. When used in DVD Video, angles offered as alternate video tracks must be of the same duration. Up to nine angles (total) are allowed by the DVD Video specification.

Angle menu: DVD menu used for the selection of alternate angles.

AOB: Audio Object on a DVD-Audio file.

AOBS: Audio Object Set on a DVD-Audio file.

Artifact: An undesirable distortion of the audio or video, typically a byproduct of an electronic or digital process. In digital video, artifacts usually result from color compression and are most noticeable around sharply contrasting color boundaries, such as black next to white.

Aspect ratio: The ratio of an image's width to its height. For example, a standard video display has an aspect ratio of 4:3. Pixel aspect ratio refers the shape of a nonsquare pixel.

Assets: The video and audio clips, stills, titles, and any other materials that make up the content of a video or DVD production.

Audio sweetening: Processing audio to improve sound quality or to achieve a specific effect.

Authoring: For DVD Video, the process of planning, designing, assembling, and formatting content. The authoring process may, depending upon the software being used and individual interpretation, include encoding video and audio, as well as creating menus.

Autoplay: Describes content that is programmed to start playback automatically when a DVD is inserted into a DVD player that supports automatic playback.

Bandwidth: The data-carrying capacity of a device or network. Bandwidth is the maximum amount of data that can travel a communications path in a given time, usually measured in kilobits per second (Kbps) or megabits per second (Mbps). Connections of 56 Kbps or lower (typical dial-up connection rates) are considered low bandwidth or narrowband. High bandwidth, or broadband, connections are higher than 56 Kbps (for example, ISDN, DSL, cable modem, T1).

Binary: A type of digital system used to represent computer code in which numerical places can be held only by 0 or 1 (off or on).

Bit: The smallest unit of data used by computer systems. A bit (short for binary digit) has a value of either 0 or 1. Bits are the building blocks of binary data.

Bit depth: For audio, the number of bits used to represent each sample; for video, the number of bits used to represent each channel of a sample. See Bitmap.

Bitmap: Also known as a raster, bitmap data includes a set of binary values specifying the color of individual pixels that make up an image. Bitmap data is characterized by resolution and bit depth. Resolution relates to the detail in an image, and is expressed in dots per inch (dpi) or pixels per inch (ppi). The higher the resolution (that is, the more dots used to describe the image), the more detail possible.

Bit depth defines the number of bits that are used to represent each color channel or bits per channel (bpc). The higher the bit depth, the more colors can be displayed. A high-contrast (no grey tones) black and white image is 1 bit. As bit depth increases, more colors become available:

BIT DEPTH	MAXIMUM COLORS
1	2
2	4
4	16
8	256
16	32,768
24/32	16.7 million

For image detail and quality, bit depth is as important as resolution, because the bit depth determines the available colors. When fewer colors are available, areas that may have shown a subtle shift of tones and hues are rendered as single blocks of solid color, eliminating image detail. Bitmap data is indispensable for continuous tone images, such as scanned or digital photographs, and for antialiased images. However, bitmap data is consistently larger than vector data.

Each pixel in a bitmap image has to be defined. A relatively small 150 x 150-pixel graphic requires 22,500 discrete bits of information plus the palette, or color lookup table (CLUT), which is usually included.

Blu-ray Disc: Not yet brought to market, but specified by a group of companies that make up the Blu-ray Disc Association (BDA). This 25GB capacity optical disc technology accommodates high definition (HD) feature-film length content. Based on a blue violet laser rather than the currently standard red laser, Blu-ray Disc requires industry retooling and new players for consumers.

Camcorder: A video camera that includes a device for recording audio and video.

Camera angle: See angle.

Capture: If the source footage is analog, capture refers to the act of digitization (conversion to a digital format) to make the video usable on a computer. When capturing, you may also compress the video to a manageable data rate for processing and storage. If the source video is DV, capture typically refers to the simple transfer of video from an external device, such as a digital camcorder or tape deck, to a computer hard drive.

Capture card: See video capture card.

CBR: Constant bit rate. This type of compression results in a fixed data rate. The amount of compression applied must vary to produce the selected data rate. Complex scenes that require greater compression to match the selected data rate may result in poor quality. Contrast with VBR.

Chrominance: The color portion of a video signal.

Clip: A digitized portion of video.

Codec: Short for compressor/decompressor or coder/decoder; software or hardware that encodes data for storage or transmission and decodes the data for playback. Encoding very often includes compression; decoding often includes decompression.

Color sampling: A method of compression that reduces the amount of color information (chrominance) while maintaining the amount of intensity information (luminance) in images.

Compositing: The process of combining two or more images.

Compression: Reducing the amount of digital data used to represent still image, video, audio, or other information to yield efficiencies in storage and transmission.

Compression ratio: Degree of reduction of digital data.

Data rate: Amount of data moved over a period of time, such as 10MB per second. Often used to describe a device's ability to retrieve and deliver information.

Digital: Refers to a type of signal that represents values numerically, which allows computers to manipulate and store them more easily.

Digitizing: Process of converting an analog audio or video signal to digital information.

Dolby Digital: Developed by Dolby Laboratories, Dolby Digital has become the most commonly used audio coding system for DVD-Video. The DVD-Video specification for NTSC requires at least one audio track in either Dolby Digital or PCM; DVD-Video for PAL requires at least one Dolby Digital, PCM, or MPEG 2 audio track. Dolby Digital can have from one to five full-range channels, plus an LFE (Low Frequency Effects) channel. Full surround sound Dolby Digital, utilizing all available channels, is often referred to as 5.1 sound. Also see AC-3.

Dolby Pro Logic: Developed by Dolby Laboratories, the decoding process and the circuit used to apply the process of separating discrete audio surround sound channels from a matrix-encoded Dolby Surround signal.

DTS: Digital theater systems, originally developed for use in theaters. DTS is an optional audio format for the DVD-Video specification.

DTV: Digital television.

Duration: The length of time a video or audio clip plays, or the difference in time between a clip's In point and Out point.

DV: Generally refers to digital video, but current usage suggests a number of specific definitions: 1) the type of compression used by DV systems, 2) the format that incorporates DV compression, or 3) a special type of tape cartridge used in DV camcorders and DV tape decks.

DVD: An optical storage medium that looks like a CD but has a much higher storage capacity—more than enough for a feature-length film that is compressed with MPEG-2. DVDs require special hardware for playback.

DVD Forum: International consortium of consumer electronics, computer, and entertainment industry leaders that established the initial standards for DVD technology. The DVD Forum is also responsible for HD-DVD, the standard for next generation DVDs that can hold full-length movies in high definition.

DVD Multi: A logo program overseen by the DVD Forum that identifies DVD devices (players and writers) that support all three DVD formats: DVD-RAM, DVD-R, and DVD-RW.

DVD-RAM: The first rewritable DVD format introduced; a double-sided disc requiring a special cartridge for handling and recording to avoid damage to the fragile recording surface.

DVD-ROM: A term used to refer to both the physical and application layers of the DVD formats.

DVD-R/DVD+R: Write once recordable DVD formats, often referred to as DVD minus R and DVD plus R. DVD R(A), or DVD for Authoring, is used by professionals to generate masters for replication. DVD-R(G), or DVD for General, was developed for the consumer market and incorporates content protection measures that prevent copying of specially protected entertainment titles.

DVD-RW/DVD+RW: Rewritable DVD formats, often referred to as DVD minus RW and DVD plus RW.

DVNR: Available as hardware or software plug-ins, Digital Video Noise Reduction processors can be used to minimize any undesirable video artifacts resulting from MPEG encoding.

DVS: Descriptive Video Services may be included as an alternate audio track on DVD Video, augmenting the standard soundtrack by describing the action so the program can be enjoyed by visually impaired audiences.

DV25: The most common form of DV compression, using a fixed data rate of 25 Mbps.

EDL: Edit decision list; a master list of all edit in and out points, plus any transitions, titles, and effects used in a film or video production. The EDL can be input to an edit controller, which interprets the list of edits and controls the decks or other gear in the system to re-create the program from master sources.

Effect: A process applied to a frame or frames of video to change its appearance.

Fields: The sets of odd and even lines drawn by the electron gun when illuminating the phosphors on the inside of a standard television screen, which results in the display of an interlaced image. In the NTSC standard, one complete vertical scan of the picture or field contains 262.5 lines. Two fields make up a complete television frame; the lines of field 1 are vertically interlaced with field 2 for 525 lines of resolution.

FireWire: Apple Computer trade name for IEEE 1394.

fps: Frames per second; a unit of frame rate.

Frame: A single still image in a sequence of images which, when displayed in rapid succession, creates the illusion of motion. The more frames per second (fps), the smoother the motion appears.

Frame rate: The number of images (video frames) shown within a specified time period; often represented as fps (frames per second). A complete NTSC TV image consisting of two fields, a total scanning of all 525 lines of the raster area, occurs 29.97 times a second. In countries where PAL and SECAM are the video standard, a frame consists of 625 lines, with a frame rate of 25 fps.

Fullscreen: Format that uses the entire standard aspect ratio (4:3) television screen by (a) displaying material shot in Academy Aperture, (b) lopping off the ends of widescreen material, or (c) employing the pan-and-scan technique to select the optimal 4:3 shots from widescreen.

Generation loss: Incremental reduction in image or sound quality as a result of repeated copying of analog video or audio information and usually caused by noise introduced during transmission. Generation loss does not occur when copying digital video unless it is repeatedly recompressed.

Headroom: When capturing audio, extra data acquired as a result of capturing at higher quality settings than needed for the final cut. Headroom helps preserve quality when adjusting audio gain or applying certain audio effects.

HD: Abbreviation used to refer to high-definition video.

High Definition Television (HDTV): A monitor or display offering 720p (1280 x 720 pixels progressive) or 1080i (1920 x 1080 pixels interlaced) resolution, and capable of displaying a 16:9 image and supplying high-quality, multichannel surround sound. Also, the technology used to create and deliver content meeting HDTV standards.

High Definition DVD: The next generation of DVD technology, which will provide enough storage on a single disc to deliver a feature-length film as high definition (HD) quality video.

IEEE 1394: The interface standard that enables the direct transfer of DV between devices such as a DV camcorder and a computer. Also used to describe the cables and connectors using this standard.

i.LINK: The Sony trade name for IEEE 1394.

Interframe compression: Reduces the amount of video information by storing only the differences between a frame and the frames adjacent to it. (Also known as temporal compression).

Interlaced display: System developed for early television and still in use in standard television displays. The electron gun used to illuminate the phosphors coating the inside of the screen alternately draws even, then odd horizontal lines. Each scanning of the image is called a field. To produce the approximately 30 frames per second of NTSC TV, the screen shows half the lines composing each frame (each field) about every 1/60th of a second. We perceive these interlaced fields of lines as complete pictures. The actual frame rate for NTSC video is 29.97; the field rate is 59.94.

Intraframe compression: Reduces the amount of video information in each frame, on an individual basis. (Also known as spatial compression).

JPEG: File format defined by the Joint Photographic Experts Group of the International Organization for Standardization (ISO) that sets a standard for compressing still computer images. Because video is a sequence of still computer images played one after another, JPEG compression can be used to compress video (see MJPEG).

Keyframe: A frame selected at the beginning or end of a sequence of frames, that is used as a reference for any of a variety of functions. For example, in interframe video compression, keyframes typically store complete information about the image, while the frames inbetween may store only the differences between two keyframes. Or, in applying an effect to a video clip, keyframes may contain values for all the controls in the effect and, when the values are different for the beginning and ending keyframes, the effect changes over time.

Land: The flat areas surrounding pits on the recording surface of an optical disc.

Letterbox: When the full width of a widescreen image is preserved on the screen of a standard 4:3 TV, black bars are placed above and below the image to block out the unused portions of the screen so the widescreen image can be viewed as originally intended. DVD Video players can automatically letterbox a widescreen image for viewing on a 4:3 TV.

LFE: The low frequency effects channel in 5.1 channel surround sound such as Dolby Digital or DTS is used to reproduce low frequency sounds in the 5-120 Hz range (for example an explosion, the roar of a locomotive or jet engine, or the rumble of a spacecraft). While a subwoofer may be used for the .1 channel, it can be played back through any speaker that has adequate dynamic range.

Lossless: A process that does not affect signal fidelity; for example the transfer of DV via an IEEE 1394 connection, or a lossless compression scheme such as RLE.

Lossy: Generally refers to a compression scheme or other process that strives to maintain as much quality as possible while reducing storage requirement, but does result in some degradation of signal fidelity.

Luminance: Brightness portion of a video signal.

Markers: Markers are used in the editing process to indicate important points in the timeline or in individual clips. Markers are for reference only; they do not alter the video program.

Matrix encoding: The process of combining multiple audio surround sound channels into a standard dual channel stereo signal. Also referred to as phase matrix encoding.

MPEG/MPEG-1/MPEG-2: The Moving Picture Expert Group of the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) have defined multiple standards for compressing audio and video sequences. MPEG compression uses a technique where the differences in what has changed between one frame and its predecessors are calculated and encoded. MPEG is both a type of compression and a video format. MPEG-1 was initially designed to deliver low data rate video through a standard speed CD, and is typically used for Video CDs and web video delivery. MPEG-2 provides broadcast quality video, and is most often used for DVD. MPEG-1 and MPEG-2 require a special decoder for playback.

MPEG audio: Audio compressed according to the perceptual encoding standard specified by the Moving Pictures Expert Group. MPEG-1 audio provides two channels for stereo playback, which can be in the Dolby Surround format. MPEG-2 audio offers up to 7.1 channels of audio for a true surround experience. MPEG audio is mandatory for DVD Video in the PAL format.

MPEG video: Video compressed according to the specifications of the Moving Picture Expert Group.

NLE: Nonlinear editing.

Noise: Any signal that is added to the original. That is, any distortion of the pure audio or video signal that would represent the original sounds and images recorded.

Nonlinear editing: Random access editing of video and audio on a computer, allowing for edits to be processed and reprocessed at any point in the timeline, at any time. Traditional videotape editors are linear because they require editing video sequentially, from beginning to end.

NTSC: National Television Standards Committee standard for color television transmission used in the United States, Japan, and elsewhere. NTSC incorporates an interlaced display with 59.94 fields per second, and 29.97 frames per second.

Optical disc: Removable storage medium that is written and read using laser light (for example, CDs and DVDs).

PAL: Phase-alternating line television standard used in most European and South American countries. PAL uses an interlaced display with 50 fields per second, or 25 frames per second.

Pan-and-scan: A technique for converting a widescreen image to conform to a different aspect ratio (usually 4:3 for TV) by reframing the image (that is, cropping out parts of the picture). DVD Video players can automatically create a 4:3 pan-and-scan version from widescreen video by using a horizontal offset encoded with the video.

PCM: Pulse code modulation, the uncompressed representation of audio signals in digital form. PCM is derived by sampling the analog waveform at regular intervals, quantizing the samples, and generating a series of pulses represented by digital code. PCM is one of the audio formats that may be used to fulfill the requirements of the DVD-Video specification, but is rarely used in favor of one of the compressed audio formats, typically Dolby Digital.

Phase matrix encoding: See matrix encoding.

Pitch: The amount of space between tracks on an optical disc.

Pits: Microscopic depressions in the recording layer of an optical disc that are read by a laser beam in the player and translated into a binary stream, which is then decoded for playback. Contrast with land, the flat areas surrounding pits.

Pixel: Picture element, the minimum computer display element, represented as a point with a specified color and intensity level.

Post-production: The phase of a film or video project that involves editing and assembling footage and adding effects, graphics, titles, and sound.

Preproduction: The planning phase of a film or video project usually completed prior to production.

Previsualization: A method of communicating a project concept by creating storyboards, rough animations, or edits.

Production: The phase of a film or video project including shooting or recording raw footage.

Progressive scanning display: A method for displaying video that shows all the scan lines in one pass (compare to interlaced display).

Resolution: The amount of information in each frame of video. In digital video, resolution is represented by the number of horizontal pixels times the number of vertical pixels (for example 720 x 480).

RGB: Red-Green-Blue: a way of defining a color in terms of the amounts of the three primary colors (in the additive color system) that must be combined to display that color on a computer monitor.

Sample rate: In digital audio, the number of samples per second.

Scope: Short for Cinemascope, the first commercially successful widescreen format. Scope became the generic term for film either shot or exhibited in any widescreen format.

SDDS: Short for Sony Dynamic Digital Sound. SDDS is an optional audio format for DVD-Video originally developed for theater surround sound.

Spatial compression: See intraframe compression.

Subpicture: A bitmap graphic overlay used in DVD-Video to create subtitles, menu highlights, and more.

Temporal compression: See interframe.

Time code: The time reference added to each video frame that enables accurate editing; may be thought of as the *address* where a clip starts (in point) or ends (out point).

Timeline: The graphical representation of program duration, on which video, audio, and graphics clips are arranged.

Track: (1) On the recording surface of an optical disc, a single revolution in the continuous spiral along which the pits are arranged. (2) In reference to DVD content, a discrete element such as a video, audio, or still image stream. For any given sequence, the DVD-Video specification allows up to nine different simultaneous video tracks, or angles; up to eight tracks of digital audio; and up to 32 subpicture tracks.

24-bit color: Type of color representation used by most computers. For each of the red, green, and blue components, 8 bits of information are stored (24 bits total). With these 24 bits of information, over 16 million different colors can be represented.

Uncompressed: Digitized video that has no information removed from it. Also called raw video.

VBR: Variable bit rate compression. Strives to glean the most efficient use of available bandwidth and produce consistent quality by allowing the data rate to vary between selected minimum and maximum rates. Contrast with CBR.

Video capture card (or board): A hardware component that adds the functionality needed to digitize analog video. Using a hardware or software codec, the capture card can also compress video In and decompress video Out for display on a television monitor.

Widescreen: Any aspect ratio for film and video wider than the standard 4:3 format. Widescreen previously referred to wide-aspect film formats, but is now typically used to refer to the 16:9 format that has become standard widescreen for DVD (the aspect ratio specified for HDTV).

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