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DVD-Video: Multimedia for the Masses

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DVD—which stands for nothing, Digital Video Disc, or Digital Versatile Disc, depending on whom you ask—is the next generation of optical disc storage technology. It's essentially a bigger, faster compact disc that can hold video as well as audio and computer data. DVD aims to encompass home entertainment, computers, and business information with a single digital format, eventually replacing audio CD, videotape, laser disc, CD-ROM, and perhaps even video game cartridges. DVD has widespread—and unprecedented—support from all major electronics companies, all major computer hardware companies, and most major movie and music studios, which says much for its chances of success.

The DVD Consortium, composed of 10 companies (Hitachi, JVC, Matsushita, Mitsubishi, Philips, Pioneer, Sony, Thomson, Time Warner, and Toshiba) developed DVD. Originally two competing formats existed: the Multimedia Compact Disc (MMCD) format backed by Sony, Philips, and others; and the Super Disc (SD) format backed by Toshiba, Matsushita, Time Warner, and others. A group of computer companies led by IBM insisted that DVD proponents agree on a single standard. The combined DVD format, announced in September of 1995, avoided a confusing and costly repeat of the VHS versus Beta-Max videotape battle or the quadraphonic sound battle of the 1970s. After developing the specifications and standards, the Consortium changed its name to the DVD Forum and opened up membership. At the end of 1998 the DVD Forum had about 200 member companies.

Unlike CD-ROM, which is a data storage format kludged from a digital audio format, DVD was built, from the ground up, as a complete family of formats based on a digital data storage foundation. DVD-ROM holds computer data read by a DVD-ROM drive hooked up to a computer. DVD-Video (often simply called DVD) is an application built on top of DVD-ROM. DVD-Video holds video programs played in a DVD player hooked up to a TV. The difference between DVD-ROM and DVD-Video resembles that between CD-ROM and audio CD, including the important point that DVD-Video discs can be played in computers. In addition to DVD-Video, which was introduced with DVD-ROM in late 1996, there exists an (as yet) unreleased DVD-Audio format, finalized in February of 1999. DVD-ROM also includes recordable variations (DVD-R, DVD-RAM, DVD-RW, and DVD+RW), some not yet available, and some subject to sibling rivalry. That is, some competing formats are incompatible. See Table 1.

Most of the DVD format is proprietary to the DVD Forum. The official DVD specification books are available from Toshiba by signing a nondisclosure agreement and paying a $5,000 fee. Some portions of the DVD specification that specify physical disc characteristics were submitted to ECMA for standardization and can be downloaded for free at http://www.ecma.ch. Table 2 shows the capacities of each DVD type. The basic DVD-ROM format is covered in ECMA-267 and ECMA-268, DVD-R in ECMA-279, DVD-RAM in ECMA-272 and ECMA-273, and DVD+RW in ECMA-274. The UDF file system specification used by all DVD formats is available from the Optical Storage Technology Association at http://www.osta.org. For standards used in DVD see the sidebar (page 88).

Table 1. DVD recordable formats.

Format	Recordability	Availability Date
DVD-R 1.0	Record once	10/97
DVD-R 1.9	Record once	8/99
DVD-RAM 1.0	Rewritable	6/98
DVD-RAM 2.0	Rewritable	Estimated mid-2000
DVD-RW	Rewritable	Early 2000
DVD+RW 1.0	Rewritable	10/99
DVD+RW 2.0	Rewritable	Estimated early 2001

R=record, RAM=random access memory, RW=rewritable (or read/write).

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Table 2. DVD capacities.

Format	Sides/Layers	Gigabytes	x CD	Typical Hours	Minimum to Maximum Hours
DVD-5	Single side/single layer	4.38 (4.7)	6.9	2.2	1.0 to 9.0
DVD-9	Single side/dual layer	7.95 (8.6)	12.5	4.0	1.9 to 16.5
DVD-10	Double side/single layer	8.75 (9.4)	13.8	4.5	2.1 to 18.1
DVD-14	Double side/mixed layer*	12.3 (13.2)	19.4	6.5	2.9 to 25.6
DVD-18	Double side/dual layer	15.9 (17.1)	25.0	8.0	3.8 to 33.0
DVD-R 1.0	Single side/single layer**	3.68 (4.0)	5.8	1.8	0.9 to 7.6
DVD-R 2.0	Single side/single layer**	4.38 (4.7)	6.9	2.2	1.0 to 9.0
DVD-RAM 1.0	Single side/single layer**	2.40 (2.6)	3.8	1.2	0.6 to 4.9
DVD-RAM 2.0	Single side/single layer**	4.38 (4.7)	6.9	2.2	1.0 to 9.0
DVD-RW	Single side/single layer**	4.38 (4.7)	6.9	2.2	1.0 to 9.0
DVD+RW	Single side/single layer**	2.79 (3.0)	4.4	1.4	0.6 to 5.4

*Single layer on one side, dual layer on the other.

**All recordable formats allow dual-sided discs, effectively doubling the capacity.

More than movies

Unlike CD-ROM drives, which took hold in computers largely because of the success of CD audio format, DVD-ROM drives are quickly becoming a standard item on computers, already outselling home DVD players by a factor of ten. Ironically, the much smaller market of home DVD-Video players has a much larger selection of titles, mostly Hollywood movies, than does the computer market.

Although movies occupy the limelight of the DVD phenomenon, the DVD-Video format is capable of much more. Because the discs play on home players as well as a wide variety of DVD-equipped computers, the DVD-Video standard provides a compelling interactive multimedia format. DVD-Video was primarily designed for movies, but its feature set, though rudimentary, allows for surprisingly sophisticated products. Savvy developers, such as DVant Digital, have shown that more than 95 percent of some PC-based interactive video-game features can be duplicated on DVD-Video discs that work on the simplest home DVD-Video players.

DVD-Video

DVD-Video requires that content be authored in a specific way. The constraints of DVD-Video, as opposed to the wide-open anarchy of DVD-ROM, allow the standardization of inexpensive DVD-Video players. Specialized DVD-Video authoring systems are needed to multiplex audio, video, graphics, control data, and navigation data into custom .VOB and .IFO files that are stored in a VIDEO_TS directory at the root of the disc.

DVD-Video data structures

DVD-Video data organization structure represents the physical location of data on the disc. Since data may be shared among different titles and programs, logical data structures overlay the physical structure. The logical structures contain navigation information and determine the presentation order of information, independent of the physical order.

Physical data structure

The physical data structure determines how data is organized and placed on the disc. The standard specifies storing data sequentially, in a physically contiguous order. The primary physical block is a video title set (VTS), which contains internal information about the title, followed by video object sets. The video object set structures are broken into 1-megabyte chunks that are stored as .VOB files on the disc. The first video object set may be an optional menu, followed by video object sets that contain the actual title content. Quite often, a video title set contains only one title. A title refers to the logical construct (a movie, an episode, a collection of songs, and so on).

The main menu (the title menu) is called the video manager (VMG) and is a special case of a video title set. If present, this menu is the first thing the viewer sees after inserting the disc. Alternately, a special autoplay piece (called a first-play program chain or PGC) automatically begins playback.

Data at the video object set (VOBS) level includes attributes for video, audio, and subpicture. The language of audio and subpictures can be identified with ISO 639 codes and also as commentary, simplified audio, and so forth.

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Standards

DVD-ROM standards

- File system: OSTA Universal Disc Format Specification: 1996 (Appendix 6.9) "OSTA UDF Compliant Domain" of ISO/IEC 13346: 1995 Volume and file structure of write-once and rewritable media using nonsequential recording for information interchange. (Note: ECMA 167, 2d edition, 1994, is equivalent to ISO/IEC 13346:1995.)

- File system: ISO 9660:1988 Information processing—Volume and file structure of CD-ROM for information interchange (Note: Equivalent to ECMA 119, 2d edition, 1987.)

- Device interface: SFF 8090 ATAPI/SCSI (Mt. Fuji)

- Physical connection
  - —ANSI X3.131-1994: Information Systems: Small Computer Systems Interface-2 (SCSI-2)
  - —ANSI X3.277-1996: Information Technology: SCSI-3 Fast-20
  - —ANSI X3.221-1994: Information Systems: AT Attachment Interface for Disc Drives (EIDE/ATA)
  - —ANSI X3.279-1996: Information Technology: AT Attachment Interface with Extensions (ATA-2)

DVD-Video standards: Video content

- MPEG-1 video: ISO/IEC 11172-2: 1993 Information technology—Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbps—Part 2: Video

- MPEG-2 video: ISO/IEC 13818-2: 1996 Information technology—Generic coding of moving pictures and associated audio information: Video (ITU-T H.262)

- NTSC video
  - —SMPTE 170M-1994 Television: Composite Analog Video Signal—NTSC for Studio Applications
  - —ITU-R BT.470-4 Television Systems

- PAL video: ITU-R BT.470-4 Television Systems

- Source video: ITU-R BT.601-5 Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios

- PAL wide-screen signaling
  - —ETS 300 294 Edition 2:1995-12 Television Systems; 625-Line Television: Wide-Screen Signaling (WSS)
  - —ITU-R BT.1119-1 Wide-screen signaling for broadcasting. Signaling for wide-screen and other enhanced television parameters

- NTSC wide-screen signaling and analog copy generation management system (CGMS-A)
  - —EIAJ CPX-1204
  - —IEC 1880 (amends EIA-608)

- PAL analog copy generation management system (CGMS-A): ITU-R BT.1119-1 Wide-screen signaling for broadcasting. Signaling for wide-screen and other enhanced television parameters

- Film/camera mode: ETS 300 294 Edition 2: 1995-12

DVD-Video standards: Audio content

- Dolby Digital audio: AC-3 (ATSC A/52 1995) and ITU 11-3/25

- MPEG-1 audio: ISO/IEC 11172-3: 1993 Information technology—Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbps—Part 3: Audio

- MPEG-2 audio: ISO/IEC 13818-3: 1995 Information technology—Generic coding of moving pictures and associated audio information—Part 3: Audio

- Digital audio interface
  - —IEC 958 (1989-02) Digital audio interface (Type II: Consumer)
  - —IEC 958-2 (1994-07) Digital audio interface—Part 2: Software information delivery mode
  - —IEC 1937 (draft as of 1997) (also ATSC A/52 Annex B: AC-3 Data Stream in IEC 958 Interface)

- Optical digital audio: EIAJ CP-340

- Recording codes: ISO 3901: 1986 Documentation—International Standard Recording Code (ISRC)

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Each video object set consists of one or more video objects. The granularity of the video object level groups or interleaves blocks for seamless branching and camera angles. A video object makes up part or all of an MPEG-2 program stream.

A video object consists of one or more cells. The smallest addressable chunk, a cell is a group of pictures or audio blocks. A cell can be as short as a second or as long as a movie. Cell IDs depend on the video object in which they reside, so a cell can be uniquely identified by its cell ID and video object ID. Note that the player may need to get additional presentation information about the cell from the program chain (discussed later).

Each cell is further divided into video object units (VOBUs). In spite of its name, a video object unit doesn't always contain video. An integer number of video fields, a video object unit lasts from 0.4 to 1 second, unless last in a cell, in which case it can be up to 1.2 seconds long. Analog protection system (APS) data, stored at the video object unit level, specifies if analog protection (Macrovision) is off or if it's one of three types: AGC (automatic gain control), AGC + 2-line Colorstripe, or AGC + 4-line Colorstripe. The analog protection system data tells the Macrovision circuitry in the player when to turn on.

Finally, at the bottom of the heap, video object units break into packs of packets. The format of packs and packets complies with the MPEG standard. Packs include system clock reference information for timing and synchronization. Each packet identifies which stream it belongs to and carries a chunk of data for that stream. Packs are stored in recording order, interleaved according to the different streams multiplexed together. Different packs contain data for navigation, video, audio, and subpicture.

Logical data structure

The presentation data structure overlays the physical data structure. The top level is made up of titles. Each title contains up to 999 program chains. A program chain contains 0 to 99 programs (PGs), which are ordered collections of pointers to cells. The physical data and the logical presentation data structure converge at the cell level. The program chain links cells together and indicates the order in which to play the programs and cells. Programs within a program chain can be flagged for sequential play, random play (randomly selected and repeatable), or shuffle play (played in random order without repeats). More than one program chain may use individual cells making parental management and seamless branching possible: different program chains define different sequences through mostly the same material. The presentation data structure includes additional groupings within levels.

The groupings provide additional organization and include leading and/or trailing information, such as a set of commands to execute just before or just after displaying a video sequence. Groupings include parental blocks, used for parental management; angle blocks for multiple camera angles; interleaved blocks for seamless branching; and so on.

The part of titles (PTT) construct is commonly called a chapter. Think of a part of title as a marker or branch point, not a container. For a multi-program-chain title, the user may take different paths from program chain to program chain, so "chapter 2" via one path might include different program chains than "chapter 2" via another path.

DVD data streams also contain control information such as video display format (NTSC—National Television System Committee—or PAL—Phase-Alternate Line), aspect ratio, language, audio and subpicture selection, and moral codes for parental management. They also contain search and navigation information for random access, trick play modes (fast forward and fast reverse), menus, and so on.

DVD-Video features

The DVD-Video specification provides the following features.

- More than two hours of variable bit-rate MPEG-1 or MPEG-2 MP@ML (main profile at main level) digital video (over four hours per side when using dual layers). The average video data rate is usually 4 Mbps, with a maximum of 9.8 Mbps. DVD doesn't allow MPEG-2 progressive sequences, but frames can still be stored in progressive format. This allows interlace encoding of progressive source material, such as film, for proper display on a television monitor (including 2-3 pulldown performed by the player, where the first frame of a film frame pair is repeated as two video fields, while the second film frame repeats as three video fields). The progressive source material can also be woven back together for an improved picture on progressive displays.

- Support for wide-screen movies on standard or wide-screen TVs (4:3 and 16:9 aspect ratios).

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Video can be anamorphically compressed on a disc for improved resolution on wide-screen displays. Players can automatically letterbox—fit the full width of video to the display and cover the gaps at the top and bottom with black bars—the anamorphic video for standard 4:3 monitors.

- Up to eight tracks of multichannel PCM (pulse code modulation), Dolby Digital, MPEG, or DTS (digital theater systems) audio (for multiple languages, commentaries, simplified dialog, and so forth). Tracks can be identified with language codes and selected by the viewer.
- Up to 32 subpicture tracks. Subpictures are full-screen graphic overlays for subtitles, captions, karaoke, text effects, highlighting, pointers, and so forth.
- Automatic, seamless branching of video (for multiple story lines or multiple ratings versions of a single movie on one disc). Parental controls can be configured for up to eight levels.
- Up to nine camera angles. A unique feature that provides simultaneous, user-selectable video streams for variations of a movie, differences in time or place, views from different characters' eyes, different difficulty levels, isolation of an athlete or musician, various views of equipment in a training video, and much more.
- On-screen menus, including codes for matching the menu language to the language setting of a player.
- Interactive features based on a command language (registers, math operations, comparisons, branching, and so forth).
- Instant rewind and fast forward, including search by title, chapter, or that of timecode.
- Durability (no wear occurs from playing, only from physical damage).

Most discs don't contain all features (multiple audio/subtitle tracks, seamless branching, or parental control, for example), as each feature must be specially authored.

The appeal of DVD-Video

DVD has many advantages over other media, including videotape, print, CD-ROM, and the Internet. Even compared to CD-ROM multimedia, DVD's ability to carry large amounts of full-screen video makes it more compelling, more effective, and more entertaining. Benefits include

- Low cost. DVD-Video's production and replication costs less than that of videotape. While a single DVD costs more to replicate than a single CD, DVDs are cheaper when you consider their larger capacity. One DVD-ROM can store the same amount of data as 20 or more CD-ROMs. Businesses spending millions of dollars on videotapes can reduce the cost of duplication and inventory by at least a factor of four once DVD players become widespread.
- Simple, inexpensive, and reliable distribution. Five-inch discs are easier and cheaper to mail than tapes or books. Optical discs aren't susceptible to damage from magnetic fields, X rays, or even cosmic rays, which can damage tapes or magnetic discs in transit.
- Ubiquity. An apparent drawback to DVD—especially DVD-Video—is lack of an installed base of players. As DVD-ROM overtakes CD-ROM, it will greatly amplify the audience for DVD-based material. In the business world, the number of installations capable of playing DVD-Video will probably exceed the number of VCRs in late 1999 or early 2000.
- High capacity. A dual-layer DVD-Video disc can hold more than four hours of video—more than 15 if compressed at videotape quality. Fifteen hours of video requires three videocassettes or takes more than 25 hours to transmit over the Internet with a high-speed T1 connection. A dual-layer disc can hold almost 300 hours of stereo audio at close to CD quality.
- Self-contained ease of use. The features of DVD-Video can provide instruction, tutorials, and pop-up help. A disc can start with a menu of programs, how-to sections, and background information. The viewer can select appropriate material, instantly repeat any piece, or jump from section to section.
- Portability. A portable DVD-Video player—the size of a portable CD player—fits into a briefcase and hooks up to any television or video monitor. Future developments will include all-in-one units with an integrated LCD video

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