

DVD: An Introduction

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Contents

Contents	2
Introduction	3
Who Needs DVD?	3
DVD Features.....	4
DVD History	4
DVD Specifications	5
DVD Disc Parameters	5
DVD Sector Structure	6
DVD Physical Disc Formats.....	6
Burst Cutting Area	8
DVD File System	8
DVD Application Formats	9
DVD-Video	9
DVD-ROM	10
DVD-Audio	10
Copy Protection.....	11
The DVD-Forum	11
DVD Production.....	12
DVD Premastering	12
Manufacturing DVD Discs	13
Disctronics.....	13

Introduction

DVD, the Digital Versatile Disc, is a high capacity CD-size disc for video, multimedia, games and audio applications. Capacities for the read-only disc range from 4.7GB to 17GB. The high quality of video and audio is helping DVD-Video to compete effectively with VHS for pre-recorded titles, statistics showing that DVD is growing faster than any other consumer electronic format in the USA and Europe. PCs with DVD capability have been outselling DVD-Video players, but multimedia and games applications of DVD have been slow to start. The advent of new games consoles using DVD is also helping to stimulate further sales.

- **DVD-Video** was launched in 1997 in the USA and has been growing faster than any other consumer technology.
- **DVD-ROM** is forecast to grow fast but this has taken a long time to get started.
- **DVD-Audio** was launched in 2000 and promises to complement DVD-Video in offering a high quality format for surround sound music with optional extras.

Who Needs DVD?

As the compact disc has become so successful and fulfils a wide range of applications, why has a new technology been introduced and who needs it? Major companies from different industries have invested heavily in **DVD**.

The Format	Who needs it?
DVD-Video	The movie industry , which needs a CD-like disc capable of holding a full-length movie of Laserdisc quality video, or better, with surround sound audio.
DVD-ROM	The computer industry , which is including DVD-ROM drives in most new PCs instead of CD-ROM. The entertainment industry , which has developed new games consoles (eg Sony's PS2 and Microsoft's X-Box), which incorporate DVD-ROM drives for more sophisticated and realistic games applications.
DVD-Audio	The music industry , which has realised that DVD-Audio offers a higher audio quality plus surround sound and therefore a new, purer consumer experience.
DVD-RAM, DVD-RW & DVD-R	The computer and consumer electronics industries are selling PC DVD recorders and video recorders.

DVD technology offers an optical disc with a much larger capacity than the compact disc and is available as a family of pre-recorded, recordable and re-writable formats to meet the requirements of the industries mentioned above.

DVD Features

DVD started as the Digital Video Disc but now means Digital Versatile Disc or just DVD. It is a multi-application family of optical disc formats for read-only, recordable and re-writable applications. The main features of the DVD formats are:

- Backwards compatibility with current CD media. All DVD hardware will play audio CDs and CD-ROMs (although not all hardware will play CD-Rs or CD-RWs).
- Physical dimensions identical to compact disc but using two 0.6 mm thick substrates, bonded together.
- Single-layer/dual-layer and single/double sided options.
- Up to 4.7 GB read-only capacity per layer, 8.5 GB per side maximum.
- Designed from the outset for video, audio and multimedia, not just audio.
- DVD-Video for full-length movies with high quality video on one disc.
- DVD-ROM for enhanced multimedia and games applications.
- DVD-Audio for higher quality music, surround sound and optional video, graphics and other features.
- All formats use a common file system (UDF).
- Digital and analogue copy protection for DVD-Video and DVD-Audio built into the standard.
- Recordable and re-writable versions are part of the family.

DVD-Video and DVD-ROM hardware and software have been available since 1997. DVD-Audio was launched in 2000. First versions of DVD-R and DVD-RAM have been available since 1998, with consumer models available in most regions by 2001.

DVD History

DVD started in 1994 as two competing formats, Super Disc (SD) and Multimedia CD (MMCD). DVD now is the result of an agreement by both camps on a single standard to meet the requirements of all the various industries involved.

1994	Hollywood ad hoc committee defined features for movies on 'CD'.
1995	Philips/Sony announced and demonstrate MMCD
	Toshiba and Warner announce and demonstrate SD
	Agreement on a single standard format called DVD
1996	DVD-ROM and DVD-Video specifications version 1.0 published
	Digital copy protection scheme (CSS) agreed
	First DVD-Video players sold in Tokyo (November)
1997	Launch of DVD in USA (August)
	DVD Consortium becomes DVD Forum, expands membership and holds first General DVD Forum Meeting with 120 members
1998	DVD-Video version 1.1 and DVD-ROM version 1.01 specifications released
	DVD Forum adopts DVD-RW as another re-writable format
	7 new members of DVD Forum Steering Committee making 17 in all

1998	DVD Forum publishes DVD-Audio specification version 0.9
	Full launch of DVD in Europe. 1m DVD-Video players sold in USA
	4.7 GB DVD-R and DVD-RAM version 1.9 specifications released
1999	DVD-Audio specification ver 1.0 released followed later by ver 1.1
2000	CPPM copy protection for DVD-Audio agreed
	DVD-Audio players launched in USA (July)
	First DVD-Audio discs in USA (November)
2001	DVD-Audio players & discs available in Europe and elsewhere
	DVD Video Recorders launched in Europe etc

DVD Specifications

The DVD technical specifications are contained in five books A to E published by the DVD Forum.

Book	Name	Part 1 Physical	Part 2 File System	Part 3 Application	Version
A	DVD-ROM	Read-only	ISO9660/UDF	undefined	1.01
B	DVD-Video	Read-only	UDF	MPEG-2 video	1.1
C	DVD-Audio	Read-only	UDF	high quality audio	1.2
D	DVD-R	Write once	UDF	not defined	2.0
E	DVD-RAM/RW	Rewritable	UDF	not defined	2.0

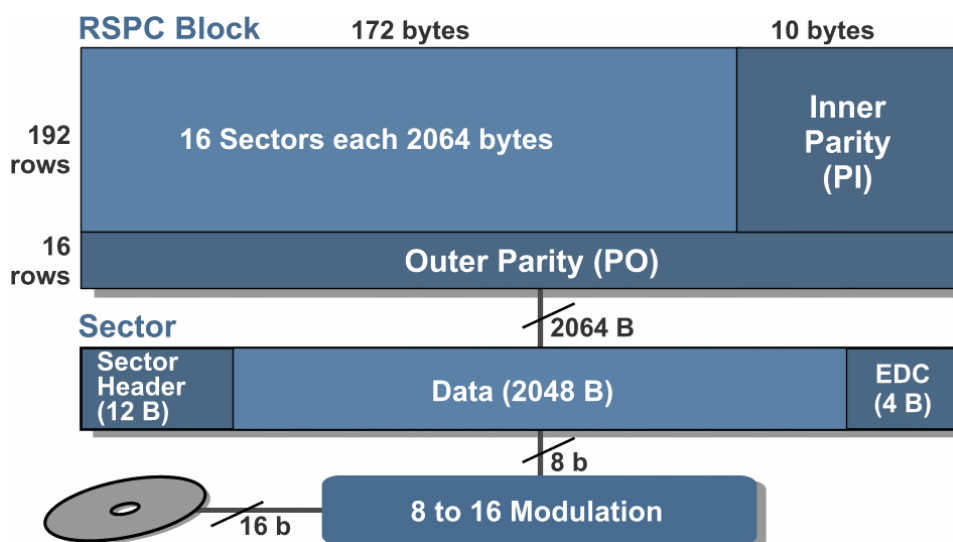
DVD Disc Parameters

The following table provides a comparison between the main physical parameters of DVD and CD discs.

Parameter	CD	DVD	Comments
Sides	1	1 or 2	<i>See below</i>
Layers	1	1 or 2	
Capacity (GB)	0.68	4.7 - 17	1 GB = 10^9 bytes (not 1024^3)
Track pitch (μ)	1.6	0.74	
Minimum pit length (μ)	0.83	0.4	
Wavelength (nm)	780	650	of laser diode pickup
Numerical aperture	0.45	0.6	
Linear velocity (m/s)	1.3	3.49	Nominal 1x speed
Modulation	EFM	8 to 16	EFM is 8 to 14 plus 3 padding bits
Error protection	ECC	RSPC	RSPC is block protection scheme
3rd layer ECC	Yes	No	Not needed for DVD after RSPC
Subcode	Yes	No	No subcode needed
Tracks	Yes	No	DVD uses files not tracks

DVD Sector Structure

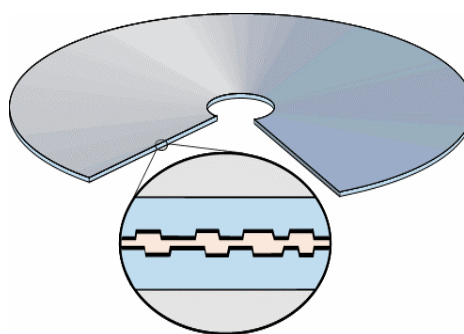
The data on a DVD disc are organised as sectors of 2048 bytes plus 12 bytes of header data (see below). Blocks of 16 sectors are error protected using RSPC RS PC (Reed Solomon Product Code), which is block oriented and is more suitable for re-writable discs (with packet writing) than CIRC, which does not use a block format. The PI and PO data are parity bytes calculated horizontally and vertically over the data bytes.



In addition DVD uses an 8 to 16 modulation scheme giving pit lengths of 3 to 14 (minimum to maximum length) compared with CD's 3 to 11 with EFM modulation. This is only a small difference but does make the jitter specification slightly tighter.

DVD Physical Disc Formats

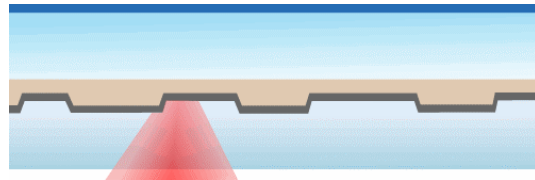
Although identical in appearance, DVDs and CDs differ in a number of key physical parameters. To meet the requirements for 133 minutes of high quality video on one side of a single disc requires the use of a thinner (0.6 mm) substrate, two of which are bonded together (see diagram). This allows a range of formats from one layer to four. In addition several recordable formats have been developed as shown below.



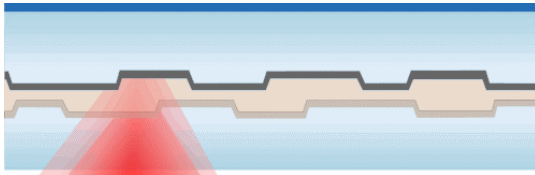
	DVD-5	DVD-9	DVD-10	DVD-18	DVD-R	DVD-RAM
Capacity (GB*)	4.7	8.54	9.4	17.08	4.7 or 9.4	4.7 or 9.4
Layers/side	1	2	1	2	1	1
Sides	1	1	2	2	1 or 2	1 or 2

* Note that for capacity purposes one GB (gigabyte) is actually a billion bytes or 10^9 bytes. This contrasts with normal computer storage capacities whereby a GB is $1024 \times 1024 \times 1024$ bytes. Therefore the capacity of a DVD-5 disc should be written as 4.337 GB using the latter definition of a GB.

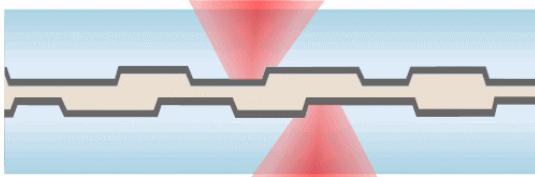
DVD-5 discs comprise a sandwich of two 0.6mm substrates, one metallised and with data, the other blank, bonded together. Labels can be printed as for CDs.



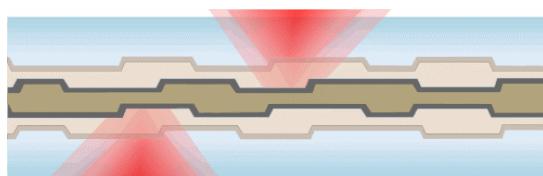
DVD-9 discs comprise one semi-reflective substrate (layer 0) and one fully metallised substrate (layer 1) bonded together with an optically transparent layer. Labels can be printed on the discs as for CDs.



DVD-10 discs comprise two metallised substrates bonded together and read from both sides. The disc label is restricted to a small annular area within the disc hub, on both sides of the disc.



DVD-18 discs, which have limited availability, comprise two dual-layer substrates bonded together and read from both sides. The disc label is restricted as for DVD-10.



DVD-R discs are write-once discs with a capacity of 3.95GB or 4.7GB per side.

DVD-RAM discs are re-writable discs with a capacity of 2.6GB or 4.7GB per side for computer data storage and archive applications.

DVD-RW discs are re-writable discs with a capacity of 4.7GB per side for consumer applications such as video recording.

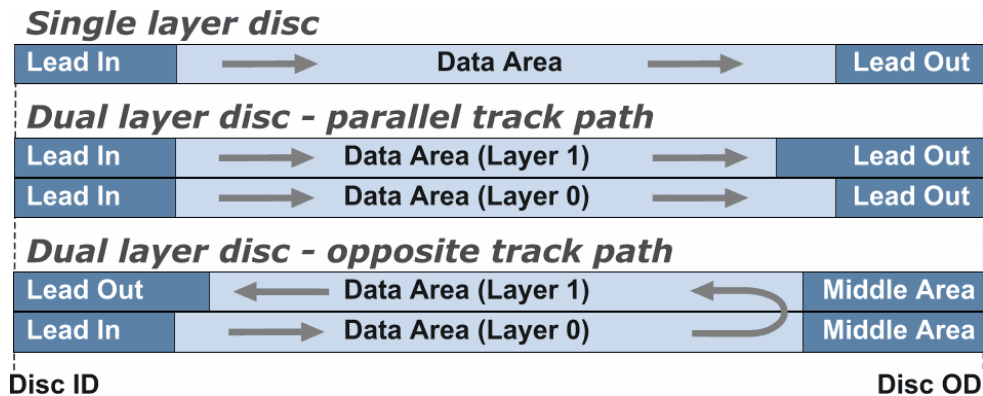
DVD+RW discs are not officially part of the DVD family.

Single and Dual Layer Disc Layout

Each layer of a DVD disc contains lead-in, data area and lead-out like a CD. A single layer disc comprises a lead-in, data area and lead-out. For dual layer discs there are two options depending on the application.

- **Parallel track path**, where the two layers are independent and both start at the inside diameter (ID) and end at the OD with the lead-out. Dual layer DVD-ROM discs are likely to use this layout allowing files on either layer to be accessed.
- **Opposite track path**, where layer 0 starts at the ID and layer 1 starts where layer 0 ends. For such discs there is one lead-in (on layer 0), one lead-out (on layer 1) and two middle areas. DVD-Video discs will use opposite track path so that a movie can be placed across both layers and played almost seamlessly from layer 0 to layer 1.

These layouts for single and dual layer discs are illustrated below. Note that the file system data (see below) will be contained in layer 0.

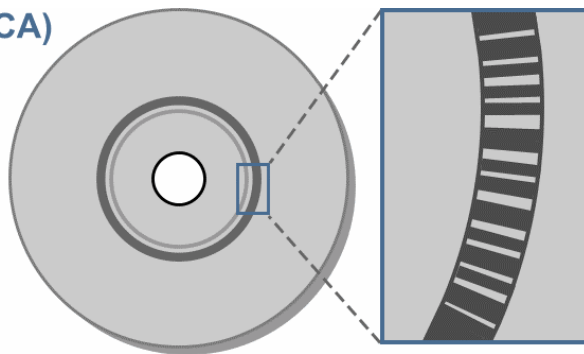


Burst Cutting Area

The Burst Cutting Area (BCA) is an annular area within the disc hub where a bar code can be written for additional information such as serial numbers. The BCA can be written during mastering and will be common for all discs from that master or, more usually, will be written using a YAG laser to 'cut' the barcode into the aluminium reflective layer of the finished disc. The data stored in the BCA can be from 12 bytes to 188 bytes in steps of 16 bytes. The ill-fated Divx format used BCA to uniquely identify every disc. New uses of this or similar technologies are being developed to use the BCA as a unique, tamper-proof means of identifying individual discs.

Burst Cutting Area (BCA)

- Radius:
22.3 to 23.5mm
- Data:
12 to 188 bytes
- Can be read by
DVD drive



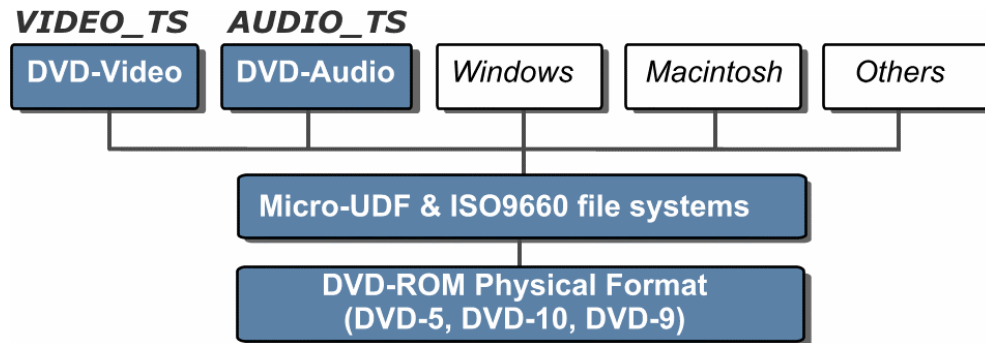
DVD File System

All types of DVD disc (DVD-Video, DVD-ROM and DVD-Audio) contain data in files. These files are accessed using a file system common to all DVD discs. For compatibility with recordable and re-writable versions the UDF Bridge Format has been chosen. This comprises a combination of Micro-UDF plus ISO 9660 for compatibility with CD-ROM. The main characteristics of UDF are:

- Robust file exchange
- System & vendor independent
- Writable & read-only media
- Based on ISO 13346

UDF is being extended to provide the necessary features for both write-once and re-writable discs. A combination of UDF and ISO 9660 (known as UDF Bridge) is used on some DVD discs to provide compatibility with existing operating systems, including Windows95. Applications can access the data files using either ISO 9660 or UDF file structures, but the use of UDF is recommended.

All discs are DVD-ROM discs, but contain any or all of the application data shown below. Only DVD-Video and DVD-Audio data must be contained within specific directories (VIDEO_TS and AUDIO_TS), as shown below.



DVD-Video discs use only UDF (not ISO 9660) with all required data specified by UDF and ISO 13346 to allow playing in computer systems. The DVD-Video files must be no larger than 1 GB in size and be recorded as a single extent (ie in one continuous sequence). The first directory on the disc must be the VIDEO_TS directory containing all the files. All filenames are 8.3 format. All other files not included in the DVD-Video specification will be ignored by DVD-Video players.

DVD-Audio discs also only use UDF and files are contained in the AUDIO_TS directory.

DVD Application Formats

Three DVD application formats have been or are being developed: DVD-Video, DVD-ROM and DVD-Audio.

DVD-Video

DVD-Video discs are intended for full-length movies and offer a range of features including the following:

- **Playing time:** a nominal 133 minutes playing time for DVD-5 or each side of a DVD-10 and 240 minutes for DVD-9 using opposite track path format.
- **Video encoding:** MPEG-2 (for better than Laserdisc quality) or MPEG-1.
- **Audio Quality and Languages:** Dolby Digital, DTS, MPEG-2 or Linear PCM audio for up to 5.1 channel surround sound.
- **Subtitling:** Subpictures allow subtitling for up to 32 languages
- **Range of Video Formats:** Pan & scan, letterbox and widescreen formats all on one disc.
- **Copy protection:** analogue and digital techniques
- **Regional coding:** so that discs can be prevented from being played in regions where they had not been released
- **Interactivity:** a range of interactive features is available including seamless transitions, menus, alternative camera angles and different routes or endings

Longer movies can make use of dual layer DVDs (DVD-9) for continuous play, where layer 1 starts where layer 0 ends to avoid seek delays.

The two sides of a DVD-10 disc can be used for two different versions of a movie. The disc must be removed and flipped to play the other side.

Some video titles contain data that can be played only on a PC. Access to websites can be achieved in this way.

DVD Players and Titles

All DVD-Video players should be capable of playing all types of DVD-Video discs (within the region specified), CD audio discs and Video CDs. DVD-Video players will output video to both wide-screen and conventional TVs. The user can choose between wide-screen, letterbox and pan & scan outputs where available. Players in the USA will generally only play NTSC video, whilst those in Europe usually play NTSC as well as PAL, but only if the monitor/TV is capable of both systems.

DVD-Video titles can also be played on PCs with DVD-ROM drives and MPEG-2 hardware or (if the processor is fast enough) software decoders.

Region coding

Many DVD-Video discs are region coded to restrict playing to specific regions as shown below.

Region 1	USA, Canada
Region 2	Europe, Middle East, South Africa, Japan
Region 3	Southeast Asia, Taiwan
Region 4	Central & S America, Mexico, Australia, New Zealand
Region 5	Russian Federation, Africa (part), India, Pakistan
Region 6	China

DVD titles do not have to be region coded, but players generally are coded for only one region. Non-region coded discs will play on any player.

DVD-ROM

DVD-ROM is essentially the pre-recorded DVD physical and logical format used for DVD-Video, DVD-Audio and a range of other applications, particularly general computer and multimedia applications, for which it can provide at least 7 times the capacity of a CD-ROM. Applications can include MPEG-2 video, as used on DVD-Video discs, to give added realism to games and richer content for multimedia applications.

DVD-ROM drives will also play CD-ROM and CD audio discs and are forecast to replace CD-ROM drives within the next few years. They are already available as add-on drives and built into new PCs. Early drives were 2x speed, but 12x drives or faster are now available.

DVD-Audio

The DVD-Audio specification was released in 1999, copy protection methods have been agreed and players and discs are now available. DVD-Audio discs use scalable multi-channel linear PCM coding with optional lossless compression. Additional content can comprise video, text and still pictures. DVD-Video like navigation is also included in the specification. DVD-Audio discs will require DVD-Audio players or universal DVD-Video/DVD-Audio

players. DVD-Audio discs can optionally include DVD-Video content for compatibility with DVD-Video players. All discs released so far include DVD-Video content so that they will play on DVD-Video players, although the audio quality is not as good as DVD-Audio can provide.

Philips and Sony have developed Super Audio CD, an alternative to DVD-Audio, which uses DSD (direct stream digital) encoding and offers a hybrid disc version containing CD and DVD audio on different layers so that the one disc will play on both SACD and CD audio players (although with a difference in quality).

Copy Protection

Copy protection for DVD is only for video and audio content and comprises both digital and analogue methods for preventing users from making perfect copies of the source material.

Digital copy protection involves scrambling the raw data using certain keys, which are stored on the disc in encrypted form. In the decoder, the original keys are obtained by inverting the encryption process and the data is then de-scrambled using the decrypted keys.

- DVD-Video titles can use **CSS** (Content Scrambling System)
- DVD-Audio titles can use **CPPM** (Content Protection for Pre-recorded Media)
- Recordable discs can use **CPRM** (Content Protection for Recordable Media).

For DVD-ROM there is no copy protection, but techniques currently used for CD-ROM are being extended to DVD.

Analogue copy protection (APS) makes use of a technique developed by Macrovision, which distorts the analogue output waveform so that the picture quality is unaffected but it cannot be successfully played back from VHS tape.

Watermarking systems have been developed for both audio and video content and are undergoing tests. These systems allow the source and ownership of the audio or video to be verified.

The DVD-Forum

The DVD specifications were originally written by the DVD Consortium, which comprised 10 companies: Hitachi, Matsushita, Mitsubishi, Philips, Pioneer, Sony, Thomson, Time Warner, Toshiba and JVC. In December 1997 the name was changed to the DVD Forum and membership opened up to other companies in the DVD industry. The original 10 members have become the Forum's Steering Committee and increased its numbers to 17 with the addition of the following companies: IBM, Industry Technology Research Institute of Taiwan, Intel, LG Electronics, NEC, Samsung and Sharp.

The DVD Forum has a total membership of over 220 and continues to produce and maintain the DVD specifications by means of eight working groups:

Working Group	Description
WG1	DVD-Video specifications.
WG2	DVD physical specification.
WG3	File systems for pre-recorded and recordable DVD formats
WG4	DVD-Audio specifications and recordable format for audio
WG5	DVD-RAM specifications
WG6	DVD-R and DVD-RW specifications
WG9	Copy protection review
WG10	Industrial/professional applications of DVD

In addition, the DVD Forum has established committees for verification of DVD discs, players etc and promotion of the DVD Format.

DVD Production

DVD discs are produced by first premastering and then manufacturing.

DVD Premastering

Premastering of DVD applications is relatively straightforward for DVD-ROM but can be very complex for DVD-Video and DVD-Audio.

DVD-Video

DVD-Video premastering comprises the following processes.

- **Video encoding to MPEG-2** using variable or constant bit rate encoding
- **Audio encoding** to Dolby Digital, MPEG or PCM
- **Subtitles** created as subpictures
- **Authoring** to add interactivity and create menus and navigation data
- **Emulation/title testing**

DVD-Audio

DVD-Audio premastering is similar to DVD-Video and can include:

- **Audio encoding** and lossless packing
- **Still image encoding** for slideshows (optional)
- **Text preparation** for audio related text
- **Authoring** for optional interactivity, menus and navigation data.
- **Emulation/title testing**

DVD-ROM

DVD-ROMs can be premastered in a similar way to CD-ROM. Premastering tools must format the data according to the DVD specifications including the UDF file system. For Windows 95, the ISO 9660 file system with Joliet extensions must be included as well. A single disc can comprise any or all of DVD-Video, DVD-Audio and DVD-ROM content each complying with the appropriate specifications. Combination discs are likely to play differently on a DVD-Video player, DVD-Audio player and DVD PC.

Manufacturing DVD Discs

Manufacturing CD and DVD discs both require similar processes. The data are stored as minute pits (which are much smaller for DVD) in the surface of the plastic disc. A stamper is created by a glass mastering process and used to mould the DVD pits in the surface of the polycarbonate disc substrate. An additional stage, bonding, is required only for DVD discs to bond two thin substrates together to produce the finished disc.

Glass mastering

Both CD and DVD discs glass mastering is needed to create stampers used to mould pits in the surface of the disc. The differences between DVD and CD means that much of the mastering process for DVD needs new equipment including improved glass master preparation, laser beam recording and developing.

Replication

Replication comprises injection moulding, using the stamper created during mastering, of two disc substrates, metallisation of one or both substrates and bonding.

Disc Finishing

Printing of single sided DVD discs can be the same as CDs, eg using screen-printing of up to six colours. Double-sided discs can only be printed within the hub area but on both sides.

New Packaging has been developed for DVD to differentiate it from CDs. There is, however, no technical reason why conventional CD packaging cannot be used.

Quality Assurance

DVD discs must meet certain stringent quality parameters, the most important of which are disc flatness, low jitter and signals within specifications. Mastering and replication equipment must be set up to ensure these specifications are met and measurement equipment is needed to check the actual parameters.

In addition, mastering and replication is the only way to ensure that a DVD title has been pre-mastered correctly. Therefore it is important to verify the replicated discs using DVD players to ensure correct functionality.

Disctronics

Disctronics is one of the largest independent CD and DVD disc manufacturers, with plants in the USA and Europe offering a total capacity of 1 million CD and 100 thousand DVD discs every day, seven days a week. The company has replication plants in the UK, France, Italy and Texas, plus sales offices in Paris and Los Angeles as well as a rapidly growing fulfilment division in the UK. We offer CD & DVD premastering, mastering, copy protection, on-line order tracking, replication, fulfilment, CD cards, custom CDs and e-commerce services for the music, software and home video industries. Disctronics is ISO 9002 registered, accredited by IRMA, ELSPA and FACT and is a founder member of IODRA.

Disctronics thrives on offering the best service to our customers. In addition to our disc replication and fulfilment services, we also provide information and advice to our customers where and when they need it. This is particularly important for new technologies such as DVD where even the most experienced are still learning.

For more information on CD, CD-ROM and other disc formats email sales@disctronics.com or visit our website www.disctronics.com.

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