DVD IN DETAIL

cinram

DVD-VIDEO • DVD-ROM • DVD-AUDIO

Table of Contents

Background of DVD

DVD seems to be everywhere these days and yet many people know very little about the power of this exciting new product. Apart from being a shiny disc that looks like a CD, what can it do? A recent definition for DVD-Video is as follows: "DVD flawlessly recreates every color of the rainbow and every sound, from the tiniest whisper to a jet engine's roar, in truly digital perfection no matter how many times it is played. With DVD the only limit is your imagination!" In this book we will explain how this media evolved, how it is created, how it is manufactured and what we can expect from DVD in the future.

In 1985, when CD-ROM was developed, it had the ability to store over 650MB worth of data. At the time, this capacity seemed almost unlimited. Most users never dreamed they would require over 650MB. Today, industry and consumers are pushing the 650MB barrier. Many of today's applications call for well over 650MB of storage. Originally, the only options available to address these needs were compression schemes or the use of multiple discs. Each one of these solutions had its drawbacks. Therefore, a second-generation disc technology was needed to address today's high data requirements for video, multimedia, databases, etc. This technology is DVD.

Early in 1995, two major groups were competing to develop the next generation of high-density compact disc. Philips and Sony partnered to develop one format and a group led by Toshiba and Time Warner were developing another. At one point, it looked like the two groups would each bring to market separate high-density compact disc solutions. This would have been analogous to the battle of Beta versus VHS in the home videotape recorder industry. Another battle of this type would not have been good for the industry or the consumer. Fortunately, in September of 1995, the two camps agreed to develop a single standard for a high-density compact disc.

The most talked about application for the new standard disc was digital video. The goal of the entertainment and compact disc industries was to put a full-length (over 2 hours) motion picture onto one side of an optical disc using the MPEG-2 video compression algorithm. Data storage on a standard compact disc allows for only 75 minutes of video using the lesser-quality MPEG-1 video compression algorithm.

In December 1995, the two groups agreed on the official name and most of the parameters governing the new high-density compact disc. The name that was agreed upon for this product was DVD (derived from "Digital Versatile Disc"). It should be noted that discs for DVD movie players are referred to as DVD; whereas the discs for computer use are referred to as DVD-ROM and for audio applications as DVD-Audio.

The agreement combined parts of both Sony/Philips' and Toshiba/Time Warner's former proposals. The "best practices" compromise included Sony/Philips' EFM-plus data storage scheme as well as backward compatibility with current CDs. In other words, DVD, DVD-ROM, and DVD-Audio players must be able to play first generation CDs.

From the Toshiba/Time Warner side, the DVD standard adopted their physical format of using two half-thickness (0.6mm) discs bonded together for a double-sided disc. Regular CDs are 1.2mm thick.

The DVD discs can store from 4.7 gigabytes (GB) to 17.0 gigabytes (GB) with the following configurations and capacities:

- 4.7 GB (Single Sided, Single Layer), referred to as **DVD-5**
- 8.5 GB (Single Sided, Dual Layer), referred to as **DVD-9**
- 9.4 GB (Double Sided, Single Layer), referred to as **DVD-10**
- 17.0 GB (Double Sided, Dual Layer), referred to as **DVD-18.**

Each layer of data on a DVD disc allows up to approximately 133 minutes of full motion MPEG-2 video. This amount of playing time allows for 95% of all movies to be contained on one disc side. DVD supports variable bit data rates, which efficiently increase digital video playback quality. DVD players and drives are capable of seamless switching between the two layers of information on each disc side.

DLT (Digital Linear Tape) is used as a "source" for DVD replication. DLT cartridges are larger than 8mm tape cartridges but smaller than VHS cartridges. DLTs have enough capacity to handle the large amounts of data that can be utilized on a DVD.

DVD brings out the best in your home entertainment system by providing very high video image quality and color purity, much better than Laserdisc or VHS. DVD-Audio allows for a truer, richer sound reproduction. DVD-ROM allows the necessary storage for creating a more satisfying multimedia experience for the customer. DVD is having a huge impact on movie-watching and computer multimedia around the world.

DVD technology offers several products including the DVD-ROM drive, the DVD-Audio player, and the DVD-Video player. Other products such as DVD-Recordable (write once) and DVD-RAM (re-writable) discs and players are also in demand.

DVD-Video players are increasingly popular in the consumer market as people realize what DVD has to offer to the home theater experience. DVD has many interactive features that over-shadow standard CD technology. These features will be constantly upgraded in the future.

Rating Control is a feature that allows the user to choose the version of a movie to watch. This is popular with the parents of young children and teenagers. Parents have the option of choosing the rating of G, PG, R, etc. If someone tries to play a movie that exceeds the rating chosen, the player will not allow it. You can choose from up to 32 different subtitles and eight different soundtracks. The choice of watching a movie in pan-and-scan mode, letterbox mode, and anamorphic format is a plus for many movie viewers. The pan-and-scan mode can be used on conventional television sets for a full screen picture. The letterbox mode is intended for a big screen TV, and the special anamorphic format provides high-resolution full screen display on widescreen televisions. Some DVD players and discs offer the option of viewing scenes from several different angles.

In late 1997, various home video companies decided to begin releasing more movie titles, causing more than a dozen hardware manufacturers to release their DVD-Video players. Today, DVD-Video players, audio players, DVD-ROM drives, and discs are plentiful in the marketplace due to overwhelming demand. Alternative players are reaching the marketplace in the form of combination VHS recorders and DVD-Video players, as well as game consoles that are DVD-Video capable.

DVD is a second-generation compact disc, which can hold more than two hours of digital video and seven times the information of a CD-ROM. DVD provides full-motion, high-resolution digital video, surround sound audio, interactive programming, and multiple language sub-titles on a single, high-density optical disc.

DVD Specifications

For DVD, the specifications are contained in a set of books, describing each DVD Format:

	Book
DVD-ROM	A
DVD-Video	B
DVD-Audio	C
DVD-Recordable	D
DVD-ReWritable	E.

The DVD-ROM Specification is the basis for the DVD-Video and DVD-Audio specifications. The Video and Audio Specifications are sub-sets of the larger ROM specification.

For purchasing the DVD Specification books and rights to use the DVD logo, contact the DVD Format/Logo Licensing Corporation at their website **http://www.dvdfllc.co.jp** or:

DVD Format/Logo Licensing Corporation
5F, Shiba Shimizu Building
2-3-11, Shibadaimon, Minato-ku
Tokyo, 105-0012 JAPAN.
Tel: +81-3-5777-2883
Fax: +81-3-5777-2884

DVD Technology

DVD is the first optical format designed to function as a multimedia storage device. The Compact Disc was primarily designed for high quality audio recording, thus limiting the types of applications which could be used on a CD-ROM. First generation CD-ROM drives were suitable for storage of databases and files; but multi-media applications found the transfer rates of 150 kilobits per second to be unacceptable. When multimedia applications began streaming audio, video, text and graphics off of the same disc at the same time, limitations in access time, seek time and data transfer rates were not adequate. Drive manufacturers compensated for some limitations by developing faster CD-ROM drives. Accessing many small files which are scattered all over the disc was still limited by how fast the objective lens could reach the desired location on the disc. This has changed little since first generation CD-ROM drives were introduced in the late 80's.

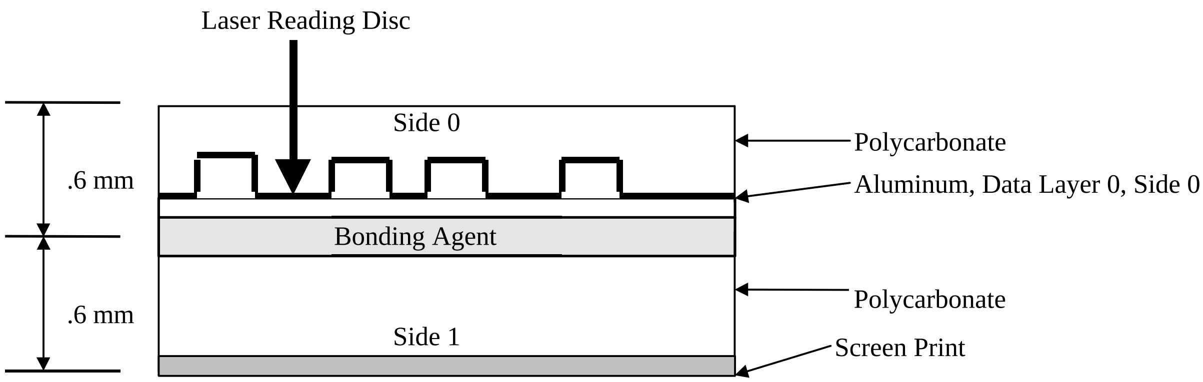
At the time of CD-ROM's introduction, 650 MB of disc space seemed more than adequate. New computers have increasingly larger hard drive storage which are fully utilized by increasingly complex software applications. These factors are driving the need for increased storage capabilities of optical media.

DVDs and CDs are the same size, but differ when you look more closely. CDs contain data on a single layer of a single substrate while DVDs can utilize multiple layers on different substrates. The table below compares the CD and the DVD:

Parameter:	**CD**	**DVD-5**	**DVD-9/18**
Track Pitch	1.6µm	0.74µm	0.74µm
Linear Velocity	1.20-1.40 M/S	3.49 M/S	3.84 M/S
Storage Capacity	650 MB	4.7 GB	8.54 GB / 18GB
Bit Rate	150 kb/s	11.06 Mbps	11.06 Mbps
Modulation	8/14	8/16	8/16
λ of Playback Laser	780nm	650nm/635nm	650nm/635nm

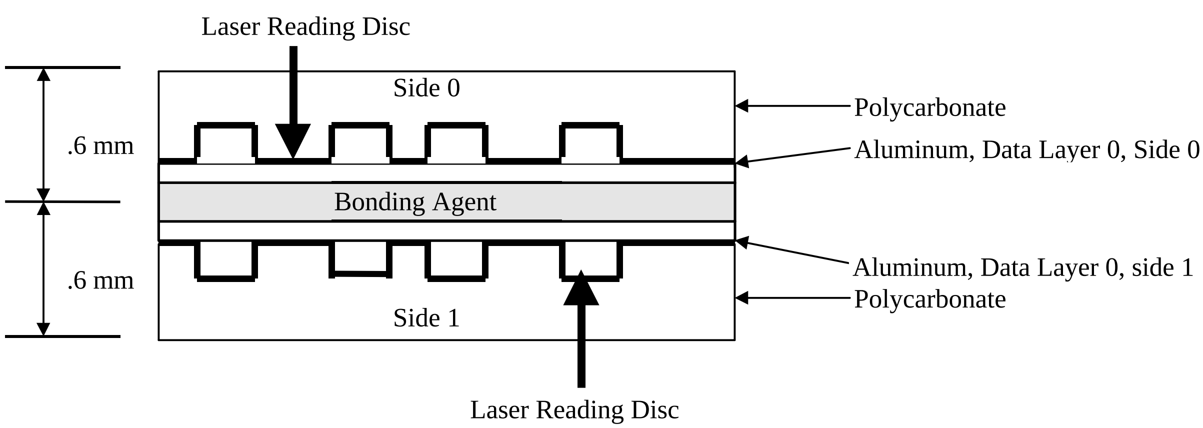
A DVD-5 disc contains user data on only one side (Data Layer 0, Side 0). The other side of a DVD-5 disc contains zero data. The zero data side of a DVD-5 disc may contain a normal printed label.

DVD-5:



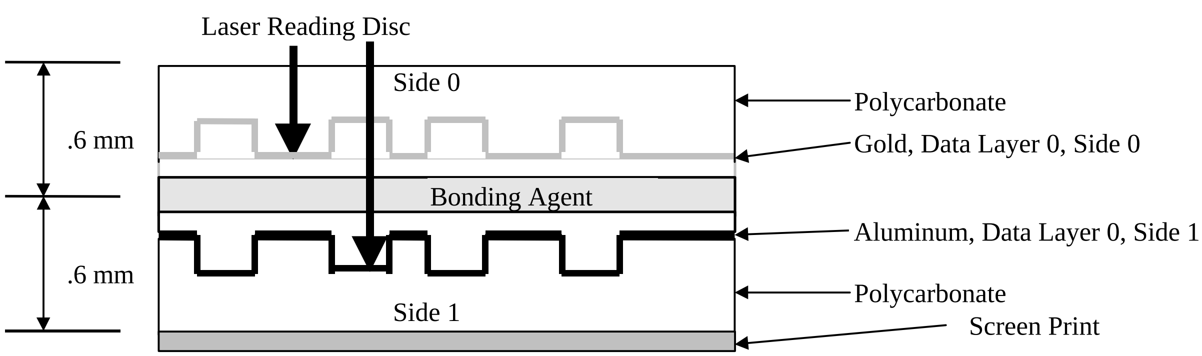
A DVD-10 disc contains user data on both sides of the disc (Data Layer 0, Side 0 and Data Layer 0, Side 1). The printed label on a DVD-10 is a very small band printed (about 2mm wide) in the mirror band area on each side of the disc.

DVD-10:



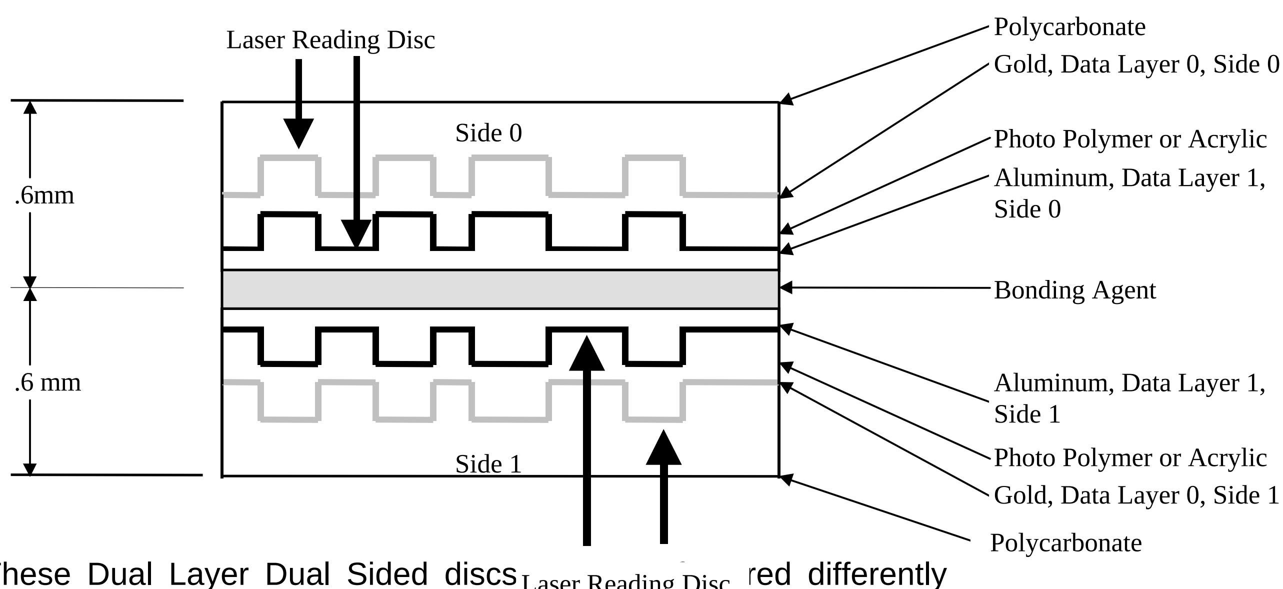
A DVD-9 disc physically contains user data on both sides of the disc, but the disc is read from only one side (Data Layer 0, Side 0 and Data Layer 0, Side 1). The side not used for reading is used for containing the printed label. DVD-9 discs are different from DVD-5s and DVD-10s in that it uses gold to form a semi-transparent layer. By changing wavelength, the laser in the player can “penetrate” the gold layer to then read the aluminum layer.

DVD-9:



The DVD-18 features two data layers per side for a total of four layers of data. The DVD-18 contains user data on all four layers. The printed label on a DVD-18 disc is a very small band printed (about 2mm wide) in the mirror band area of each side of the disc.

DVD-18:

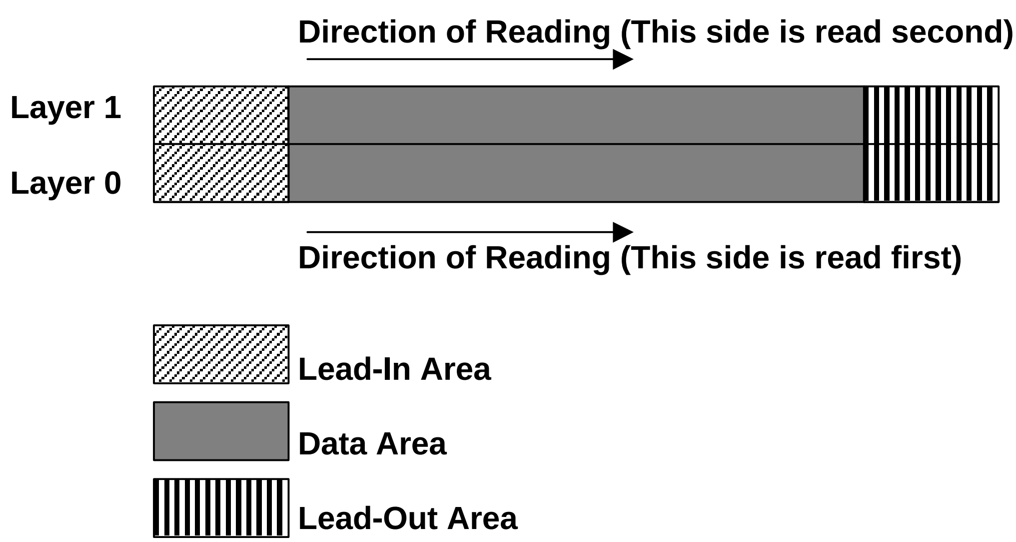


These Dual Layer Dual Sided discs red differently than the other DVD configurations. Two half thickness polycarbonate discs molded with the first layer data. Then gold is coated onto the substrates. This coating is necessary since the playback laser must be able to penetrate this layer to reach the additional layer below. On top of the gold coating, an additional UV curable layer is spincoated onto the substrate and the second layer of data is pressed into this new layer. This layer is then vacuum coated with aluminum to give it the reflectivity necessary for playback. The two substrates are bonded together.

There are two different ways of recording and playing back the data between the two layers. These two options are called "**P**arallel **T**rack **P**ath" or PTP and "**O**pposite **T**rack **P**ath" or OTP. DVD data is recorded in and played back from a long continuous track on the disc. Layer 0's track always runs from the inner most portion of the disc to the outer most portion of the disc.

When there is a second data layer (layer 1), it can be utilized in 2 different ways. The first way is called the parallel track method (PTP). PTP is where layer 0 and layer 1 run in the same direction as each other (thus "parallel"). Both layers require their own lead in and lead out areas. There is an option to allow switching between the data layers while reading.

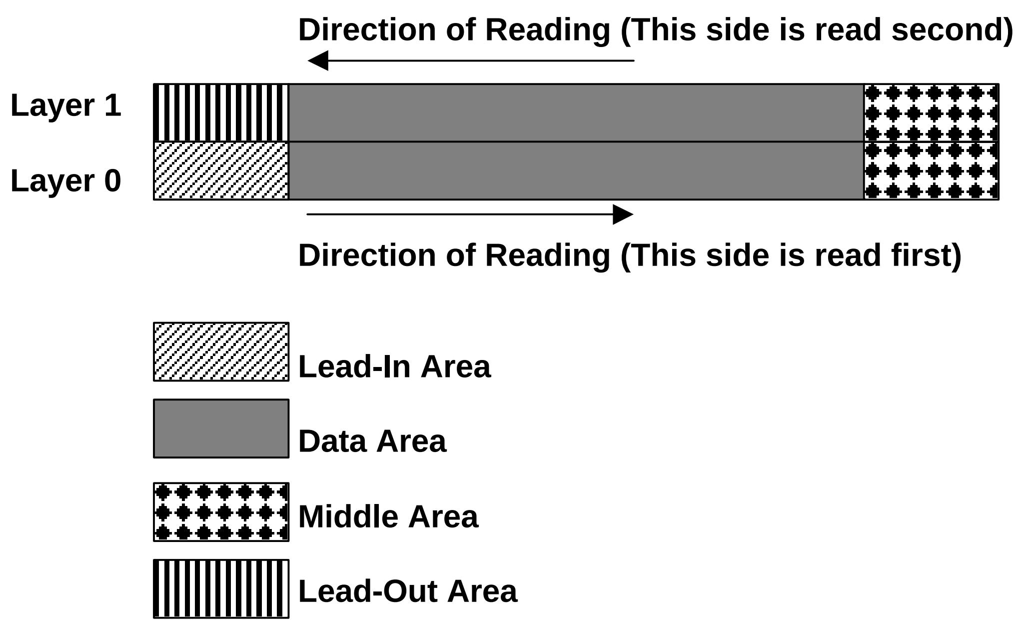
Parallel Track Path



You can notice the problem with PTP when you are watching a movie. When the player reaches the end of the first layer on one of the disc sides, there will be a noticeable pause while the player refocuses on the new layer. The player must scan back to the start of that layer and re-lock to the higher rotation speed. These steps may take several seconds to occur. It would be best if the transition between layers is totally transparent to the user.

The second method is the opposite track method (OTP) which allows for a transparent transition. As the name suggests, layer 1 runs in opposite direction of layer 0; from the outer disc edge to the inner disc edge. This is the more common approach since it allows for one long contiguous data track starting with a lead in area on layer 0 and ending with a lead out area on layer 1. The middle area exists at the end of layer 0 and the beginning of layer 1 allowing the DVD player to know there is a transition between layers.

Opposite Track Path



DVD Process Overview

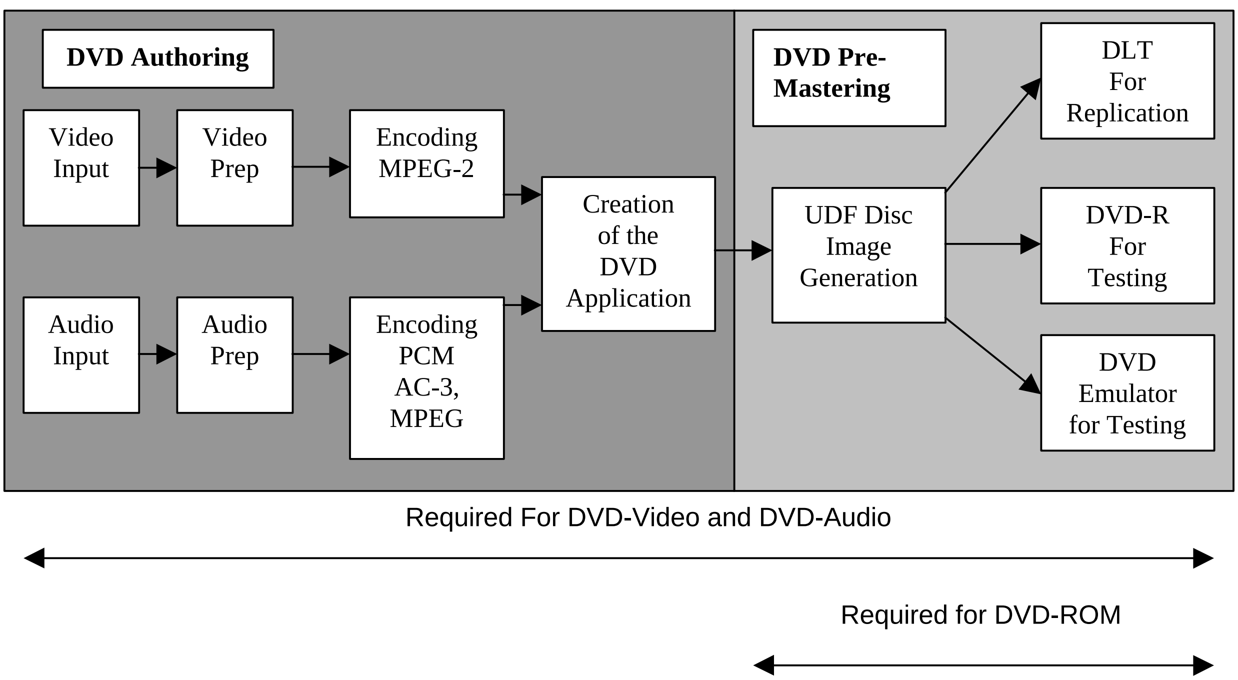
Three different general types of content can be created for a DVD:

1. Video to be played on a DVD-Video player
2. Audio to be played on a DVD-Audio player
3. Computer software or data that can be accessed by a DVD-ROM drive.

Various combinations of these three content types may be produced into a hybrid DVD. To encode DVD data and create the appropriate disc image required for replication, DVD Authoring and Pre-Mastering activities are required.

DVD Authoring is the process to encode audio and video data and then develop a DVD application. DVD Pre-Mastering is the process of creating a DVD disc image on appropriate media for replication or testing.

DVD-Video and DVD-Audio titles require Authoring and Pre-Mastering. DVD-ROM titles require Pre-Mastering. The following drawing overviews the process:



Authoring requires the gathering and creation of source materials including all video assets, audio assets, menu content, still pictures, video stills, sub-pictures, and subtitle text. Information for video title set, video management, presentation control, and data search, needs to be formulated. Functionality needs to be determined and embedded into the menus, sub-pictures, program chain information files, and video objects. To create the DVD application, all of these elements need to be assembled, synchronized, and encoded.

Once you have a DVD-Video and/or DVD-Audio application produced, a DVD disc image must be created through Pre-Mastering. Pre-Mastering is the creation of a Universal Disk Format (UDF) disc image that developers can use for testing or replicators can use for DVD manufacturing. Disc images can be created on DVD-Recordable (DVD-R) discs or Digital Linear Tape (DLT). Disc image files may also be tested through DVD player emulator software.

After Pre-Mastering, a replicator can take the DVD disc image source media and manufacture DVD disc replicas of that image. Cinram (**http://www.cinram.com**) is a DVD replicator that can provide the service of manufacturing your DVDs. Authoring and Pre-Mastering services can be provided through many US-based Authoring facilities. For a complete list, consult **http://www.macrovision.com**.

DVD-Video

The DVD-Video standard is considered to be an application or subset of the DVD-ROM standard. DVD-ROM allows for any type of information, but DVD-Video is limited to certain data types designed for television reproduction. The DVD-Video standard accommodates both the MPEG-1 fixed rate and MPEG-2 variable rate encoding algorithms. MPEG-1 (ISO/IEC 1117-2) provides video at 30 fields per second with a resolution of 352 x 240 and at fixed bit rate of 1.8 megabits per second. MPEG-2 can (ISO/IEC 13818-2) provide video up to 60 fields per second with a resolution of 720 x 480 and a variable rate of up to 9.8 megabits per second. Typical bit rates for good video sources like film require 3 to 4 megabits per second. Poor (or noisy) sources like VHS require 6 megabits per second. At average rates of 3.5 megabits per second, there may be noticeable "artifacts" (blockiness or fuzziness). At rates above 6 megabits per second, there is no perceived difference in quality.

MPEG-2 was originally established by the MPEG (Motion Picture Experts Group) organization. The goal was to establish a uniform standard in which audio and video can be encoded, placed on digital storage media, and then decoded. MPEG-2 video is used for applications requiring high quality video such as satellite broadcast, HDTV, and telephone interactive video. Not all MPEG-2 video applications fall within the DVD-Video specifications. The DVD-Video specification is considered to be a subset of the larger MPEG-2 standard.

DVD-Video Encoding

MPEG-2 encoding is a variable bit rate process requiring the individual performing the encoding to make bandwidth allocation judgements to different portions of the DVD disc. A higher video bit rate means more bits are allocated per video frame, therefore resulting in a better-looking picture. The tradeoffs for a higher video bit rate are that there is more data storage required for the encoded video and less available bandwidth for encoded audio. The tradeoffs between video quality, storage, and bandwidth must be continually monitored during the encoding process. A "bit budget" is used to show how much bandwidth is available as encoding progresses.

MPEG-2 not only encodes video into a digital format for DVD discs, but also compresses the digital information into a smaller file. MPEG-2 is a "lossy" algorithm meaning that it removes redundant information so that the encoded file does not require as much storage space. Information that does not change from frame to frame and any information that is not perceptible to the human eye can be removed.

MPEG-2 variable bit rate encoding is more labor intensive than MPEG-1 because it requires multiple encoding passes on the video stream, individual passes on each audio stream, the storing of each data stream, the editing of the streams for synchronization, and then the multiplexing of all streams. These activities must be performed as an iterative process allowing the encoder to make tradeoffs and make an impact on the overall bit budget. MPEG-1 only requires one full pass to perform encoding and multiplexing.

1. Capturing Video

The first step to producing an MPEG-2 video stream is to capture the original video and convert it to a digital form that can be compressed. The original images can be either analog or digital. This is a "digitization" of the video source, meaning that a digital value is assigned to each pixel in every video frame.

Before describing this process, an understanding of some terminology is required. A video frame is one "still" picture from a video stream. A video's frame rate is how fast frames are displayed on a screen. For motion picture film, one frame is displayed every 1/24th of a second (24 frames per second). For a NTSC (National Television Standards Committee) videotape, one frame is displayed every 1/30th of a second (30 frames per second).

In the early days of television, there was not enough bandwidth to send a complete frame at rate of 30 frames per second and still prevent flickering. Flickering results from an image on the screen that would fade away before the next image was drawn. To address this problem, frames were broken up into two fields each. Each field would contain half of the frame's information with one field containing the odd numbered scan lines and the other field containing the even numbered scan lines. With each field being drawn consecutively, thus having a rate of 60 fields per second (rate for a NTSC video), the images blend together into a smooth, continuous motion. This method is called interlacing.

For capturing images to video, film is considered to be best because it provides high resolution images with low noise and is not interlaced. Film, which is usually 24 frames per second, allows more bits to be encoded per frame as opposed to 30 frames per second digital video sources. Digital video sources may have used their own encoding or compression algorithms during recording and editing which could create changes that are not visible, but would adversely affect MPEG-2 encoding.

The film scanning process to convert film to video is called "telecine". The telecine process takes the 24 frames per second film without interlacing, scans it, and then encapsulates the resulting images into a NTSC video format of 30 frames per second with interlacing. Telecine duplicates each film frame utilizing the 3:2 pulldown method. This method alternates creating 2 fields then 3 fields for each alternating film frame. The resulting sequence is 3 fields, 2 fields, 3 fields, 2 fields, etc. The resulting video stream is a rate of 60 fields per second, which is the NTSC video rate, thus creating the NTSC 30 frames per second video. The telecine process requires significant subjective creative skills on the part of the operator. The resulting NTSC video is then used in the next step, preprocessing.

2. Preprocessing Video Data

The next step in creating a MPEG-2 video stream is the preprocessing of the digitally captured NTSC video. The purpose of preprocessing is to make it easier for the MPEG-2 algorithms to perform encoding compression.

Errors tend to be introduced during video capture because when a video is digitized, approximated values are assigned to the pixels in each frame allowing for slight variation between frames. This creates "noise" which can create two effects. First, digital variations between the frames make it more difficult for the MPEG-2 algorithm to eliminate data redundancies. Second, the MPEG-2 algorithm can potentially see random noise items as actual object motion, thus allowing the noise to be seen when the final compressed MPEG-2 file is decoded. Noise can also be attributed to grainy film, dust, snow, or detailed textures (like a waterfall).

The first step of preprocessing is to filter out the noise in the captured video. There are several filtering techniques with some being proprietary. Below are descriptions of the filter types that are available.

Anti-aliasing filters remove the effects of scaling down the original video's 720x480 television resolution to a smaller 352 x 240 resolution for the resulting MPEG-2 video stream. MPEG-2 is capable of a variable higher resolution depending upon the available bit rate. The filter measures variance between each frame's two fields. If the variance between the frame's fields is small enough, the filter averages both fields to form a frame macroblock. Otherwise, the filter will choose an area from one of the fields to use as the macroblock.

Anti-noise filters are used if an analysis indicates that serious artifacts will arise if the video stream was to be encoded in its current condition. There are three types of anti-noise filter types. These types are as follows: 1)An interframe determines thresholds between frame changes so that real motion can be distinguished from noise. 2)A softening (low pass) filter eliminates noise and increases redundancies by averaging pixel values in adjacent regions on a field. 3)A median filter removes data spikes in a frame that can be attributed to artifacts or analog drop-out.

Once the filtering has been completed, the creation of redundant fields from the original telecine process can be addressed. Because the original 24 frames per second film was converted to a 30 frames per second NTSC video using the telecine process, extra fields were inserted into the video stream at a rate of one for every four original fields. Since MPEG-2 decoders are capable of converting 24 frames per second video streams to 30 frames per second output, an "inverse telecine" process can now remove the additional fields inserted through the telecine process. Removing these redundant fields increases video quality by allowing more bits to be allocated to the remaining unique frames. After the inverse telecine process is complete, the video stream will be at a new rate of 24 frames per second and ready for encoding. The video stream preprocessing is essential for more efficient encoding since data storage and bit rates are at a premium.

3. Encoding the Video Data

Before encoding, some configuration decisions must be made. First, a list of all components to be included on the DVD disc (video, audio, still images, sub-pictures, graphics, and animation) are inventoried. Data stream breakpoints must be identified for DVD control, like parental lockouts, scene changes, and user interactivity. Audio channel issues should be answered like how many audio streams and language translations are to be used. An encoding decision list should be determined. Next, the total storage requirements and the maximum average bit rates for the DVD disc components should be calculated. The bit rates will be affected by the type of content, the required video quality, the size of the DVD disc components, the quality of the encoding equipment to be used, and the skill of the individual performing the encoding.

When estimating the average bit rates for the different encoded data streams on a DVD disc, it is important that all bit rates fit within the disc's "bit budget". DVD disc standards were determined based upon the estimated bit rates for placing a 133 minute feature film on one single-sided, single-layered DVD disc. The estimate was that an average bit rate of 4.69 megabits per second is required to achieve this goal. The average rate breaks down to 3.5 megabits per second for video, .384 megabits per second for each of three audio tracks, and .040 megabits per second for sub-picture information. These numbers are used as budgeting guidelines for the bit rates of the different data streams. As each data stream is individually encoded, the bit budget must be re-examined to see if any trade-offs are required between the different data streams.

MPEG-2 encoding uses two different types of compression. The first is interframe compression which takes advantage of redundant information in a video. When looking at a video's frames (or pictures), most of the images in a particular picture are very similar to the images in previous and subsequent frames. Interframe compression designates a particular frame as a reference frame and records only the changes to that reference frame that are needed to reproduce any preceding or subsequent frames. For this method, there are three different types of frames. First, there is the Intra Frame (I-frame) which is coded with only the video information that is contained within itself. I-frames are not coded with any information from other frames, therefore they are used as a reference to code other frames. Second, there is the Predicted Frame (P-frame) which is coded in reference to the nearest previous I-frame or P-frame. And third, there is the Bi-directional Frame (B-frame) which is coded in reference to both past and future frames.

I-frames are the building blocks for the encoded data stream. I-frames provide random access points in the video data. The MPEG encoder will choose the frequency and location of the I-frames based upon scene changes or wherever a random access point is required. The frames located between a pair of I-frames is called a Group of Pictures (GOP). The number of frames in a GOP usually ranges between 12 to 30 frames. The lower the GOP, the higher the bit rate. When random access is very important, I-frames are placed usually at a rate of 2 I-frames per second.

P-frames are placed in the data stream based upon the nearest previous I-frame or P-frame. Because P-frames are determined from calculations and used as a reference for determining other frames, P-frames can propagate encoding errors. P-frames can be used like I-frames as a reference point for determining other P-frames and B-frames. P-frames can be compressed more than I-frames using motion compensation. Motion compensation takes the images from the preceding frames and predicts the continued motion of the objects. By predicting the motion instead of encoding the entire frame, less data storage is required.

B-frames are placed in the data stream using past and future I-frames and P-frames for reference in their calculation. B-frames cannot be used as a reference for calculating other frames, thus B-frames cannot propagate encoding errors. B-frames reduce the effect of noise since they are determined by averaging the past and future frames. The MPEG-2 encoder chooses the number B-frames to insert between any pair of I-frames and P-frames. This is based upon the amount of memory available to the encoder and the aspects of the video stream being encoded. After determining the I-frames, P-frames, and B-frames, the MPEG-2 encoder will then reorder the frame sequence into a manner that would be most efficient for decoding.

After interframe compression is completed, the stand-alone I-frames can be further compressed using intraframe compression. This is a technique to compress frames that do not rely on other frames for their calculation. Intraframe compression utilizes the Discrete Cosine Transform (DCT) algorithm. DCT breaks up the images into many square blocks and codes each block separately while looking for similarities between adjacent blocks. This is a “lossy” compression method, meaning that it discards data and degrades the image quality of the I-frame. Because this method degrades image quality, it is usually the goal of the encoder to maximize the efficiency of the encoded video with the interframe compression method first.

Encoding is an iterative process that requires all data streams to be encoded, multiplexed, and then decoded for review. Close attention must be paid to the bit budget, and the effects the bit budget has on the performance of the different data streams. Tradeoffs must be considered and parameters may need to be tweaked during each iteration to attain the best quality for every scene with the least amount of bits.

DVD-Video Soundtrack Encoding

Depending on the DVD player you purchase, the audio package you receive will be significantly better than any type of Laserdisc or VHS player currently in use. Multichannel digital audio has been made increasingly popular with the overwhelming interest in DVD.

The DVD specification allows for up to eight streams of digital audio to be stored on the disc.

Although there are several different audio encoding and decoding methods, DVD supports two forms as the standards. Dolby Digital (Surround AC-3) is the audio compression standard for the DVD in the United States and Japan. MPEG-2 is the standard for DVD-Audio in Europe. Both audio compression techniques are similar in certain ways such as supporting more channels/speakers than the other methods, yet they also have several differences.

1. Dolby Digital (Surround AC-3)

Dolby Digital AC-3 is the first perceptual coding designed to specifically code multichannel digital audio. Perceptual coding reduces coding noise where there are no audio signals to mask; yet it allows strong audio signals to cover it at other times. The purpose of this coding system is to eliminate the data not heard by the human ear, while maintaining the information that can be heard. Dolby Digital AC-3 also compares the channels of a surround and stereo mix and stores the difference between the channels while eliminating the repetitive information. Dolby Digital AC-3 coding uses this auditory masking technique to the fullest extent. To ensure that noise is completely covered, this technique also lets the coder selectively alter its frequency to assure that a sufficient number of bits are used to describe the audio signal in each band.

Dolby Digital AC-3 also takes a common bit pool and decides how the bits are distributed among each of the channels. By using this technique, channels with greater frequency content are allowed to use more data than sparsely occupied channels. Dolby Digital AC-3's shared bit pool arrangement and advanced masking model are key factors in its spectrum efficiency. Since Dolby Digital AC-3 does not have to use data to carry instructions for their decoders like other systems do, it can use more of the data to represent audio to produce higher sound quality.

Dolby Digital AC-3 is a combination of data rate efficiency and high audio quality with exceptional resistance to wear and tear. Dolby Digital AC-3 is able to fit multichannel surround sound into less space than what is needed for a single channel on Compact Disc. By using Dolby Digital AC-3 compression, the DVD format has enough space to allow several different AC-3 streams to be placed on the disc.

Dolby Digital AC-3 provides six separate full bandwidth channels of sound. Full bandwidth means the five main channels range from 3 Hz to 20,000 Hz in comparison to Dolby Surround Pro Logic's bandwidth range of 100 Hz to 7,000 Hz. Dolby Digital AC-3 is composed of the left, right, and center channels across the front of the room, and the left surround and right surround channels in the back of the room. The left and right surround channels provide a more realistic ambiance and better localization and sense of depth. The sixth channel, also referred to as the .1 channel, is called the low frequency effects or the subwoofer channel, which has a limited bandwidth of 3 Hz to 120 Hz. This channel adds bass information to intensify loud or explosive scenes. When this channel is added to the other five main channels, Dolby Digital AC-3 is referred to as having 5.1 channels. Dolby Digital AC-3 also gives each channel its own data stream. Dolby Digital AC-3 for DVD has a sampling frequency of 48 kHz and has at least 20 bit dynamic range digital audio signals. The DVD standard specifies audio sectors which have an average data rate of 384 kilobits per second for each one.

This number will vary depending on the size of audio data in each channel at a given time.

2. MPEG-2 Audio

The MPEG-2 audio standard has the same six channel setup as Dolby Digital AC-3, but it also has the capability of using a left-center speaker and a right-center speaker which make up a 7.1 channel configuration to facilitate a wider screen. Much like Dolby Digital AC-3, MPEG-2 supports all channels in a digital format and provides compatibility with multichannel audio in systems with less channels.

The MPEG-2 bit-stream has been designed with compatibility in mind. MPEG-2 audio is forward and backward compatible with MPEG-1 with the basis of an MPEG-2 bitstream being an MPEG-1 bitstream. During encoding and decoding, the compatibility of MPEG-1 and MPEG-2 is achieved by employing matrix techniques. An MPEG-2 decoder will decode an MPEG-1 bitstream, and an MPEG-1 decoder will decode the stereo information from a multi-channel MPEG-2 signal. The biggest difference in the two is the number of channels each one can support and the new features that MPEG-2 offers. MPEG-1 supports 2 channels compared to MPEG-2's ability to support 5.1 to 7.1 channels. MPEG-2 also has a low sample rate to deal with low bitrate applications with limited bandwidth requirements.

Similar to Dolby Digital AC-3, MPEG-2 uses a system of perceptual coding. MPEG-2 has a family of three audio coding schemes called Layer-1, -2, and -3. These layers increase encoder sound quality per bitrate from 1 to 3 and all layers use the same basic coding scheme. The perceptual coding scheme used by MPEG-2 audio is much like MPEG-2 video in that it uses variable bit rate coding. The number of bits needed to encode the audio varies with the audio program data. The encoding process allows bits from simple sections to be saved and uses them to encode more complex ones. This process has an advantage over fixed bit rate encoding because it does not limit the bits needed for a larger set of audio information. Although the bitrate of 384 kb/s is sufficient to code the 5.1 channels, the peak bit rate sometimes needs to extend to 576 kb/s for more complex scenes. MPEG-2 has a sampling frequency of 48 kHz and at least 20 compressed bits per sample.

MPEG-2 is an advanced multichannel audio system. MPEG-2 not only supports MPEG-1 and 7.1 channel compatibility and variable bit rate coding, but it also provides processing complexity in the encoder instead of the decoder and excellent playback on the DVD.

DVD-Audio

DVD has not only created a revolution in the home video industry, but is doing so in the audio disc market as well. With its larger data capacity and multimedia possibilities, DVD-Audio discs afford a much more enriching multimedia experience for the audiophile and audio disc consumer than traditional audio Compact Discs. DVD-Audio was developed after the establishment of the DVD-ROM and Video specifications. Like the Video specification, the Audio specification is considered a subset of the DVD-ROM specification. Version 1.0 of the Audio specification was approved in February, 1999.

The goal of DVD-Audio was defined to provide very high quality audio, six sound channels, multimedia capabilities of video and data, backward compatibility with standard audio CDs, copy protection, and menu navigation functions.

Original CD technology provided 16 bit digital sound with a sampling rate of 44.1 kHz. Some audiophiles claim that CD performance did not do justice to the reproduction of analog recordings. DVD-Audio addresses this area by providing higher sampling rates resulting in truer sound reproduction. Various sampling rates are supported from 44.1 kHz to 192 kHz, as well as various word lengths of 16 bit (like CD), 20 bit, and 24 bit. Taking these parameters, as well as 1 to 6 sound channels and several different audio data encoding methods, DVD-Audio disc authors can find the optimum combination for their production.

DVD-Audio disc authors can choose from various audio data encoding methods, which are supported by the Audio specification. Some of the supported methods include:

Linear Pulse Code Modulation (LPCM)
Meridian Lossless Packing (MLP)
Dolby Digital AC-3
Digital Theater Systems (DTS)
MPEG
Sony Dynamic Digital Sound.

The chosen encoding method with the specified parameters above will affect the total playing time of the disc. For example, LPCM encoded data at a sampling rate of 96 kHz, word length of 20 bits, and a 6 channel utilization will yield a playing time capacity of 52 minutes on a 1 layer DVD-Audio disc. Another extreme would be Dolby Digital encoding at a sampling rate of 48 kHz, word length of 24 bits, and 6 channel utilization yielding a playing time capacity of 1,550 minutes (over 25 hours!) on a 1 layer DVD-Audio disc.
Meridian Lossless Packing (MLP) was chosen as the default, standard encoding method for DVD-Audio, thus MLP decoding is required on all DVD-Audio players. This is in contrast to the required Dolby Digital (AC-3) decoding capabilities of

DVD-Video players. MLP is a "lossless" encoding method because it keeps 100% of the original audio data. Even with maintaining all of the data, MLP stores the information in a more efficient manner, sometimes resulting in a 50% reduction of required storage.

From an Authoring point of view, there are two general types of DVD-Audio discs: audio-only and audio-with-video. Audio-only discs may contain not only the audio data but also still pictures (one per track), real-time text data (like lyrics in a Karaoke-type application), and static information (web links). Audio-with-video can consist of audio-only disc contents with additional video content per the DVD-Video specification.

Audio content on DVD-Audio discs has the following structure:

Album - 1 per disc side
Groups - 1 to 9 per album
Tracks - 1 to 99 per group
Indexes - 1 to 99 per track.

The disc author can utilize this hierarchy to the benefit of their work. Different encoding methods can be implemented from track to track. MLP encoded tracks are required for DVD-Audio players. Dolby Digital (AC-3) encoded tracks are playable on DVD-Video players. Other encoding methods may be used on the tracks with playback dependent upon player support.

In September 2000, Version 1.2 of the DVD-Audio specification was approved. This new version included allowances for copy protection. Two general methods were made available: Content Protection for Prerecorded Media (CPPM) and watermarking. The copy protection method allows for the author to control what type of copying, if any, is allowed by the consumer. The disc author can control what quality level of the audio track that can be copied. Watermarks can also be implemented. A watermark is additional information that is embedded in the audio signal. It can contain information on copy permissions, as well as detailed discography information about the disc and track (copyright, artist, etc.).

DVD-ROM

DVD-ROM is another application of DVD technology. DVD-ROM can be considered as a super-sized CD-ROM that is used for data storage or application development. Where standard CD-ROM capacity is 650 megabytes, a DVD-5 allows for 4.7 gigabytes or 4,813 megabytes. That means you can put over 7 CDs of information on a DVD-5, the smallest DVD disc configuration. A DVD-18, the largest DVD disc configuration, will hold the equivalent of over 26 CDs of information!

DVD-ROM drives are now standard on most computers purchased today. Most DVD-ROM drives are multi-read capable, meaning that they can read older CD-ROM discs, audio CDs, and CD-Recordables.

DVD-Audio and DVD-Video are specific applications and sub-sets of the larger DVD-ROM Specification. Because of this unique arrangement, a DVD-ROM software developer has access to DVD-Audio and DVD-Video capabilities, allowing for incredible multi-media products to be created. Not only can discs be created for computers, but hybrid discs of DVD-Audio, Video, and software content can be developed for use in all three types of players/drives.

Creating a DVD-ROM disc image that does not include DVD-Audio and DVD-Video data requires only Pre-Mastering prior to manufacturing. To include DVD-Audio and DVD-Video components with a DVD-ROM application requires encoding and Authoring.

UDF, The Filing System for DVD

The basis for the DVD filesystem is the Universal Disk Format specification (UDF). UDF (ISO/IEC 13346) was created by the OSTA (Optical Storage Technology Association) as a file system standard for use across multiple computing platforms. UDF allows for the characteristics of the different major computer operating systems (Macintosh, Win95, UNIX, etc.) so that the filesystem can appear to be native to that particular platform. UDF defines data structures such as volumes, files, blocks, sectors, CRCs, paths, records, allocation tables, partitions, character sets and time stamps. It also provides methods for reading and writing information. The UDF data structure provides a flexible, multi-application, multi-language, multi-user and most important, multi-platform format.

Initially, DVD-ROMs use a combination of the UDF and ISO-9660 formats called the UDF/ISO Bridge format. The ISO-9660 format was made popular with CD-ROM (Yellow Book) applications. Because of the bridge with ISO-9660, DVD-ROM drives can read existing CD-ROM (Yellow Book) applications and be compatible with operating systems that utilize the ISO-9660 file structure. To accommodate the enormous file sizes that can exist with UDF, operating systems have to provide compatible driver software. Eventually, ISO-9660 support will be phased out and UDF will become the industry standard on all computing platforms.

DVD-Video discs require a modified UDF file system format due to the computing limitations of a basic DVD-Video player. A subset of the UDF standard that is implemented in DVD-Video players is called Micro-UDF. The constraints of Micro-UDF for DVD-Video are listed in Section 6.9.1 of the *OSTA UDF Specification*. DVD-Video players play discs that are mastered with the full UDF specification, but only recognize those aspects of Micro-UDF. Remaining information on a DVD disc that does not satisfy the Micro-UDF format would be ignored by the DVD-Video player. This allows DVD-Video and DVD-ROM information to reside on the same side of the same DVD disc.

DVD Source Media for Replication

Digital Linear Tape (DLT) is the preferred format for sending in a finished DVD image for replication. DLT became the de facto standard for a DVD replication source because storage capacity can accommodate a full DVD image and the data throughput was fast enough for existing mastering systems. The following table lists some of the DLT drives and cartridges available and their capacities:

DLT Drive Model	DLTtape III Cartridge	DLTtape IIIXT Cartridge	DLTtape IV Cartridge
DLT 2000	10 GB	Invalid Media	Invalid Media
DLT 2000XT	10 GB	15 GB	Invalid Media
DLT 4000	10 GB	15 GB	20 GB
DLT 7000	10 GB	15 GB	35 GB

A DLT Type III cartridge can hold up to 10 Gbytes of data (uncompressed) at a transfer rate of 1.25 Mbytes/second. To transfer a 135 minute DVD application from the computer to a DLT would take approximately 60 minutes. The DLT must be formatted according to ANSI label tape specifications. A separate DLT is required for each physical layer per disc side.

To simplify setup for producing a DVD glass master, additional information must be specified on the DLT. Files containing the Disc Description Protocol (DDP version 2) information must be on the DLT or accompany the DLT on a floppy disc. The DDP files may be created by the DVD Pre-Mastering system that created the DLT or by a stand-alone program called DDP Builder from Doug Carson & Associates. The control data for the lead in area of the DVD disc must also be specified in a separate file. The lead in control data is not a part of DDP, but can be created with DDP Builder program as well. Like the DDP files, the lead-in control data file must reside with the DDP files, either on the DLT or accompany the DLT on a separate floppy disc.

DVD-Recordable discs (DVD-R) are accepted as source media for replication. There are limitations with the type of information and allowed data storage on DVD-Rs as opposed to DLTs. Future advancements in DVD-R may eliminate these differences. DVD-R is a different type of media from replicated DVDs, and this must be considered when performing disc testing. DVD-Rs may behave differently in some drives than corresponding DVD replicas. The developer should be aware of these differences if a DVD-R is to be used as source media for replication.

DVD Manufacturing

DVD manufacturing is similar to CD manufacturing in that mastering, electroforming (stamper making), molding, metalizing, printing, and testing are required. But, there are also significant differences that include bonding two ½ thickness (.6mm) substrates together, additional testing, and the handling of much smaller physical features and specifications. The following sections will review CD manufacturing while pointing out the differences and additional steps required for DVD manufacturing.

Mastering

Mastering for CD manufacturers is the process of creating the pit and land structures on a glass substrate. This substrate is the starting point for creating a stamper, the integral part of the CD mold. Mastering includes taking the disc image from the source media then formatting, encoding, and processing it into a modulated data signal.

Mastering begins with a 240mm diameter 5.9 mm thick glass plate. This plate is polished and washed. Photo-resist is spin coated and then baked on to the glass. When the glass is loaded on the mastering equipment it is then exposed or "cut" with a laser. The signal from the encoder modulates the laser, which in turn exposes a pit and land pattern onto the photo-resist. The glass substrate spins and the signal is laid out from the center of the disc in a spiral pattern.

When the master is completely exposed, it is then developed. The exposed areas are etched away with a developing solution creating the pits in the photo-resist surface. The glass master is then vacuum coated with silver. The silver layer provides an electrically conductive ”seed layer” needed for the next process, electroforming.

To master DVD versus CD, changes are made in the mastering optics and laser to create a smaller exposed area. This smaller area is needed to create smaller pit geometry that is almost half the size of the CD pit geometry.

Tighter jitter specifications (a measure of the consistency of spacings between pits and lands) makes mastering more difficult. At this time only a limited number of replicators are able to meet the stringent jitter requirements and testing needed for DVD.

Electroforming

Electroforming is the process where stampers are made. Because a stamper becomes an integral part of a mold, actually holding the information, it needs to be very robust to withstand the stresses involved in the molding process.

Once the glass master is silver coated, it is electrically conductive. The silvered glass master is placed in a galvanic tank with Nickel Sulphamate, a nickel electrolyte solution. The glass master is connected to a cathode (negative terminal) of an electrical circuit and from the anode (positive terminal) a relatively thick nickel layer is electroplated onto the glass master. The nickel is then separated from the glass, cleaned, punched, trimmed and inserted in a mold. This piece of nickel is called a stamper. This process is repeated as necessary.

DVD electroforming is conceptually the same as CD electroforming, but there is a significant need for tighter controls.

Molding

Once the electroformed stamper is loaded into a molding machine, CDs are molded/replicated approximately every four to five seconds. Hot molten polycarbonate is injected into the mold cavity which is comprised of the stamper, with all the information, on one side and a mirror block on the other side. The molten polycarbonate is injected under several tons of pressure to cause the resin to conform to the pit and land geometry of the stamper. The idea is to create a perfect replica, in reverse image, of the stamper. There are many challenges to molding the polycarbonate into flat, optically and geometrically faithful replicas of the stamper. These challenges are magnified considerably with the small DVD geometry versus CD geometry.

DVD pit geometry is smaller and narrower and closer together than those of CDs. This makes replicating discs more difficult because of the restricted flow of polycarbonate through the smaller mold structure. This reason alone may require higher tonnage molding machines and longer cycle times. To reduce some of the molding strains, half thickness discs will be molded and bonded together.

DVD requires that two disc substrates, half the thickness of regular CDs, be molded. These discs are 0.6mm thick versus 1.2mm. These thinner discs are later bonded together to form the specified 1.2mm thick disc. The thinner sides help to minimize jitter.

The tilt specification (a measure of warpage or disc flatness) for DVD cannot be easily met with current player technology for an affordable price. Players equipped to overcome the complexities associated with tilt would require a tilt correcting servo. These are available in some test equipment, but are far too expensive for commercial or consumer players. Tests have shown that performance margins of discs with 0.6mm thickness are wider than that of discs with a thickness of 1.2mm.

Double Layer discs can be created from two different processes. The first is creating a second layer by applying a photo-polymer coating over the existing semi-reflective layer. Then a second stamper embosses a second layer of pits into this photo-polymer layer. This layer is then UV cured, metalized and protective coated. The second process is molding the second layer into a separate acrylic substrate. The acrylic is then metalized and bonded to the first substrate.

Metalizing

DVD-5 discs have the same metalizing requirements as a CD. Metalizing equipment currently installed is capable of this job. DVD-10 has the same metalizing requirements as DVD-5 except metalizing is required on both 0.6mm substrates.

DVD-9 and DVD-18 require a more complex application of a semi-reflective metal layer. DVD-9 and DVD-18 require a twenty-five to forty percent semi-transparent/reflective metal layer applied to the inner layer of the dual substrate. These discs also contain fully reflective metal layers on the outermost layers. The readout laser will read these discs by focusing through the semi-reflective layer to read the second layer of information. DVD-9 and DVD-18 have the same metalization requirements as DVD-5 and DVD-10 except that a semi-transparent/reflective layer must be added when two layers of information are on one side of the disc.

Bonding

The bonding step is required to put together the two 0.6 mm thick substrates into one 1.2 mm thick DVD. Bonding can currently be accomplished with a hotmelt adhesive or an Ultra Violet (UV) cured adhesive. Bonding is the most sensitive step of the DVD manufacturing process.

The importance of this step can not be over emphasized. Correct bonding produces a very flat disc, thus reducing individual substrate tilt. Improper bonding can create discs that are warped, unbalanced, improperly aligned, have bubbles, etc., all leading to out-of-specification discs that will not play. At the very least, trouble in this area could lead to lower production yields and ultimately higher costs and slower delivery.

Label Printing

Label printing for DVD-5 and DVD-9 can be the same as for CDs. For DVD-10 and DVD-18, the print area is limited to the inner hub of the discs (approx. 2mm wide annular ring) and possibly any unused data areas in the outer diameter areas of the discs.

The dual substrate nature of DVD leads to the possibility of other printing formats. These include reverse printing, "Pit Art", and colored polycarbonate. Reverse printing is on the inner side of the blank substrate leading to a high gloss finished look. Pit Art is a design created by the master laser during the mastering process; this is the same or similar to the Cinram "Image Disc". These mastered designs are molded into the discs and then bonded. Because the blank substrate is not used in DVD-5, colored polycarbonate can be used for a decorative effect.

Testing

Cinram offers a "test disc" for all replication orders at no additional charge. The purpose of the test disc process is to allow the customer to view and verify the content, navigation and play-ability of a DVD product prior to pressing the complete order. Test discs are highly recommended for all DVD products.

Copy Protection

As with all mass distributed media, piracy prevention must always be considered. There are several DVD copy protection schemes offered to help battle this problem. All of the schemes described in this document are optional to the DVD developer.

Macrovision 7.0

This proprietary technology is based on the premise that all VCRs have certain built-in anti-copy circuitry that televisions do not have. If someone tries to copy video from a DVD player to a VCR (Digital to Analog), certain copy protection trigger bits would activate a Macrovision chip within the player. The chip applies copy protection to the analog output of the DVD player.

At the front end of the production process, the producer of a disc decides what amount of copy protection (which is digitally encoded) to enable and pays Macrovision accordingly. When an attempt is made to copy video to a VCR, the copy will receive a somewhat distorted and degraded picture.

Macrovision Corporation develops and markets technologies that protect video, audio, and data in both prerecorded and electronically transmitted formats from unauthorized viewing and unauthorized recording, For more information on Macrovision, visit http://www.macrovision.com.

CGMS - Copy Generation Management System

The Copy Generation Management System is designed to prevent file copying and guard against making iterative copies of copies. The CGMS data is encoded into the analog video signal so that digital recorders with analog inputs can recognize it. The embedded CGMS signal can determine how may copies can be made. If one copy is allowed, the signal is altered on the new copy so that additional copies are not allowed to be made from it. If copying is allowed on the original, making numerous copies of the original cannot be prevented

Regional Coding

Regional coding can be implemented with new titles to prevent users from playing the title before it is actually released in his or her country. For instance, a new title or movie may be available in six to nine months in Europe after its debut in the US. To control the release of titles, motion picture studios have required that standard “regional codes” be included within a disc that would prevent DVD’s from being played outside the area in which they were bought. This system supposedly would not effect titles that are available worldwide. Users then would be allowed to transport discs to and from different regions with no problem playing them. The DVD players sold in the different regions will include a built-in code and will not play a disc without the same code. Regional codes are optional, and discs without a code at all will play on any player in any country.

The following summary represents the codes and corresponding region:

Code	Region
1	North America, Canada
2	Japan, Europe, The Middle East, Egypt, South Africa, Greenland
3	Southeast Asia (including Hong Kong)
4	Central/South America, Australia, New Zealand, Carribean
5	Africa, Northwest Asia (including Korea), Soviet Union
6	China

It should be noted that discs may have multiple codes inserted, in which they will be able to play in those respective regions. Region coding is not implemented on DVD-Audio discs.

CSS - Content Scrambling System

Content Scrambling System (CSS) is a form of data encryption that prevents one from making digital-to-digital copies of a disc on a computer. The CSS algorithm was developed by Matsushita and Toshiba. The algorithm compresses the data files on a sector-by-sector basis and then scrambles them. CSS compliant computers will have a decryption circuit that will decode/descramble the information prior to displaying it. A secret "key" will be applied while mastering the disc. A DVD-ROM drive and video display/decoder (utilizing special hardware or software) will exchange encryption keys so that the video is decrypted for viewing. Consequently, industry front-runners IBM and Intel added a modification to the CSS algorithm, refining it so that the CPU isn't using as much processing power for descrambling content. The latter decision would allow descrambling to take place in software on a PC, or with an add-in card as opposed to a separate descrambling chip. CSS is designed for audio and video, but is used for computer data since DVD-ROM is capable of storing any form of computer data. This method is expected to be the scheme of choice amongst the computer, consumer-electronic and movie industries.

Burst Cutting Area

The DVD specification allows for an area on the disc's hub called the Burst Cutting Area (BCA). The BCA allows for a unique number to be physically burned onto each replicated DVD by a laser. The BCA creates the option of true disc serialization. When the information is burned on the DVD, the BCA is similar to a barcode and can hold up to 188 bytes of information. When the DVD is mastered, there is a flag placed in the lead in area identifying that the BCA is being used. The DVD drive/player will slow down in speed and read the information in the BCA. The firmware of the drive/player or the software application on the DVD disc itself can utilize the BCA information. Having this capability can allow the application developer to implement their own form of protection. BCA was added to the DVD specification to accommodate DIVX and other unique efforts in electronic commerce with DVD discs.

DVD is HERE!

The future for DVD is now! After years of development, the specifications are set for these exciting applications. The home entertainment and computer industries are being revolutionized by this technology. Creative artists now have an additional range of resources to use in displaying their art forms. Computer technologists now have a new way to deliver data, applications, and content to the consumer. DVD is widely accepted all over the world and is the fastest growing consumer product ever created.

How Cinram Can Help You

Cinram is the proven leader in DVD mastering and manufacturing. Cinram has been involved with DVD from the beginning, through the development of prototypes and manufacturing production lines.

Cinram is the largest independent manufacturer of compact discs and DVD discs in the world. Cinram also offers Packaging, Fulfillment, Distribution, and E-Commerce Solutions. Please contact Cinram if you would like pricing or technical assistance on your CD or DVD project. We have an online technical library at our web site, **http://www.cinram.com**. Cinram also offers full service audio and videotape duplication. We can be reached at:

Cinram
Phone: 1-800-433-DISC
Fax: 1-256-852-8706
Email: sales@cinram.com
http://www.cinram.com