DVD AUTHORING & PRODUCTION

Ralph LaBarge

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by Ralph LaBarge

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This book is dedicated to my parents,
Paul and Nanette LaBarge, who taught me that
honesty, hard work, perseverance, and respect
for others are the keys to success.

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Acknowledgments

A book of this size and complexity can't be written in a vacuum. Dorothy Cox, Paul Temme, and David Tractenberg of CMP Media convinced me to write this book. Jerry McFaul, Dana Parker, and Jim Taylor volunteered their time to review drafts, and each contributed tremendously to the final version. During the editing process I worked closely with Kimberly Reed of *DV Magazine*, and her comments and suggestions were always invaluable. Michelle O'Neal of CMP Media and Liza Niav worked diligently to turn my scribbling into a finished book, ready for the printers. Jon Wenger of Zomax worked with me to replicate the *StarGaze* DVD in the back of the book. Hundreds of others who work in the DVD business also contributed to this book, either directly by providing me with information on their companies' products or services, or indirectly by talking with me about DVD over the past six years. I can't possibly mention them all, but this book could not have been written without their help. David Goodman of DVD International has taught me a lot about the business side of DVD, and was understanding when a few projects were delayed due to the amount of time I spent writing the book (and not working on his titles). Last, but not least, I would like to thank my wife Jan and our three daughters Kim, Jenny, and Cindy who put up with me working a bunch of extra hours in order to get this book, and all my other DVD projects, done.

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Chapter 1

INTRODUCTION

DVD Authoring & Production is the result of more than six years of practical experience authoring and producing DVD-Video, DVD-ROM, and WebDVD titles. When I started developing DVD titles in early 1996 there was almost no documentation or literature available that described the process of producing a DVD title. In 1997 Jim Taylor's *DVD Demystified* was published and has since become the bible for everyone in the DVD business. *DVD Demystified* is a great book, and I strongly encourage anyone getting into DVD to buy a copy, but it is primarily a technical book. While both books cover some of the same material, *DVD Authoring & Production* provides an in-depth look at the process of authoring and producing DVD titles. Conversely, *DVD Demystified* provides an in-depth look at the technical details of the DVD specifications, the history of DVD and it's predecessors, as well as the future of the format. To sum it all up, *DVD Demystified* answers the question "Why DVD?", while *DVD Authoring & Production* answers the question "How do I make a DVD?". Although I am somewhat biased, I truly believe having both *DVD Demystified* and *DVD Production & Authoring* is worthwhile, particularly if you are directly involved with the authoring or production of DVD-Video, DVD-ROM, or WebDVD titles.

In writing *DVD Authoring & Production* I have drawn on my knowledge and experience gained in designing, authoring, and producing over 200 DVD titles. Developing a DVD title is still a fairly complicated process. A large number of issues can delay the completion of the project and result in a final product that does not meet all of your requirements. As you read *DVD Production & Authoring* you will see that there is more to producing a successful DVD title than just using a DVD authoring program to create a valid DVD disc image. In fact, the actual authoring of a DVD disc is just one of a dozen steps in the process, and is often the easiest part of the project.

During the year 2000, I completed over 25 new DVD-Video, DVD-ROM, and WebDVD titles. I am planning on releasing another 25 or so during 2001. Every time I complete a project, I feel that I have learned something new about the process of producing and authoring DVD titles. When I start a new project, I try to use a DVD feature in a new or different way, or some new combination of features that I have never used before. The DVD-Video format is an extremely rich multimedia-publishing medium. I am convinced that just about anything is possible in DVD as long as you have the desire, and patience, to make it happen.

As with skinning cats, there is more than one way to author and produce a DVD title. I will outline a process that has worked well for me over the past five years, and one that I believe will also work for you. However, as you become more proficient at developing DVD titles you'll find you need to use your own experience and knowledge to amend or modify the process I discuss in this book to suit your own specific business needs.

Who Should Read this Book?

Anyone who is involved in the production or authoring of DVD-Video, DVD-ROM, and WebDVD titles should read this book. The book covers every aspect of the DVD production and authoring process, so it may not be necessary for everyone to read every section of the book. For example, if you are only involved in the process of authoring DVD-Video titles, then you should definitely read Chapters 1–6, which discuss the process of producing DVD titles as well as the details of DVD authoring, and refer to Chapters 10 and 11, but you probably won't need to read Chapters 7–9, which cover Enhanced DVD, DVD-ROM, and the business aspects of producing DVD titles. Similarly, if your primary interest is in the production or sales of DVD titles, then you should read Chapters 1–3, covering the process of producing DVD titles, as well as Chapter 9, which covers the business of producing DVD titles.

Naturally, I would like everyone to read every chapter. Realistically, this is simply not practical in the fast-paced world of DVD title production. I have organized the book so that you can either read it from start to finish to fully understand the DVD production process, or read a chapter at a time to bone up on one specific DVD production issue. Finally, it is my hope that this book will become a useful tool for DVD producers and developers to improve their projects as they learn more about the process of developing DVD titles and bringing them to the market.

How Is this Book Organized?

DVD Authoring & Production includes eleven chapters and an index. Chapter 2 provides details on each of the DVD formats (DVD-ROM, DVD-Video, DVD-Audio, DVD-R, DVD-RAM, and DVD-RW). Chapter 2 also discusses the "unofficial" DVD formats (DVD+RW and SACD). Chapter 3 presents a step-by-step process for authoring and producing DVD titles. Chapter 4 covers entry level DVD authoring, concentrating on the use of low-end or consumer authoring tools. Chapter 5 covers mid-range DVD authoring, while Chapter 6 covers advanced DVD authoring. Chapter 7 covers enhanced DVD authoring, and Chapter 8 covers DVD-ROM authoring. Chapter 9 provides an in-depth look at the business aspects of DVD production and authoring. Chapter 10 reviews most of the major software and hardware tools

required to develop DVD titles, as well as major DVD authoring service providers. Finally, Chapter 11 provides a detailed glossary of DVD terms and acronyms with definitions.

If you turn to the back of *DVD Production & Authoring* you will see that we have included a copy of *StarGaze*, one of my recent consumer DVD releases. I am a firm believer that a picture is worth a thousand words, so I wanted to include supplemental content to illustrate the DVD authoring and production processes discussed in the book. Rather than include a custom disc, which demonstrates specific features of the DVD specifications, I thought it would be better to include an example of a real world DVD title.

Real World Example

As you read *DVD Production & Authoring* you will see *Real World Example* boxes like this. These boxes will refer to a section of *StarGaze* that illustrates a specific step in the authoring and production process, or explains a concept discussed in the book.

In the end your goal is to author and produce DVD titles that do well in the consumer, corporate, or educational market places. I think you will understand this process better with a thorough evaluation of a real world DVD project, such as *StarGaze*. If you would like to see a DVD title that demonstrates as many DVD-Video features as possible, I suggest you buy the second edition of *DVD Demystified*, which includes just such a demonstration and test disc.

Tips, Tricks & Techniques

Throughout *DVD Production & Authoring* you will also find *Tips, Tricks & Techniques* boxes, which offer some common sense advice on how to author and produce DVD titles.

A Brief History of DVD

DVD, also known as Digital Versatile Disc, was born in 1996 from a marriage of two competing optical disc technologies. DVD was developed by a group of ten consumer electronics companies, called the DVD Forum, who agreed on a set of technical specifications for each DVD format. Initially five specifications were published, including DVD-ROM, DVD-Video, DVD-Audio, DVD-R, and DVD-RAM. Recently a specification for DVD-RW has also been added to the list of "official" DVD formats. The DVD Forum has published "official" DVD formats, while "unofficial" DVD formats are those that are compatible with at least one official DVD format, but provide other features as well. DVD+RW is an example of an unofficial DVD format as it can read DVD-ROM discs, but can also read and write DVD+RW discs, which are not documented in any DVD Forum publications. The original members of the DVD Forum included Hitachi, Matsushita Electric Industrial Co. LTD (also known as Panasonic), Mitsubishi Electric Corporation, Philips Electronics, Pioneer Electronics, Sony Corporation, Thomson Multimedia, Time Warner, Toshiba Corporation, and Victor Company of Japan.

Prior to 1996 there were two competing groups of companies, one led by Sony, and the other by Toshiba. Each group was trying to develop proprietary high-density optical-disc formats to be used in the next generation of consumer electronics and personal computer products. Fortunately these two groups joined forces and agreed to form the DVD Forum. The DVD Forum actively encouraged participation from members of the entertainment and computer industries so that the DVD format had a broad base of support in both the consumer and computer electronics areas. The DVD Forum now has over 200 members representing a broad spectrum of companies offering a wide variety of DVD related products and services.

The early years of DVD were difficult and in many cases frustrating. DVD was viewed with some interest by many Hollywood studios looking to publish their content on a high quality medium, but they were concerned over copyright protection and conditional access issues. Several major motion picture studios such as Time Warner and Universal Pictures were committed to releasing their movies on DVD, while the rest of the studios remained uncommitted pending resolution of these copyright issues. The issue of how to protect content once it was distributed on a DVD-Video disc was the topic of a number of discussions between members of the DVD Forum and representatives from the motion picture and software industries. In late June of 1996 representatives from the computer, consumer-electronics and movie industries signed off on a technical working group recommendation for encrypting all data stored on DVD-Video discs and including decryption hardware in DVD Video players. During September and October of 1996 proposals from the computer industry recommending an alternative method of encrypting just the video content were considered and accepted by the Copyright Protection Technical Working Group. Finally in November 1996 all parties agreed to a specific set of analog and digital copy protection methods.

The first DVD-Video players were sold in Japan starting in November of 1996. The U.S. market for DVD-Video players and DVD-ROM drives was launched during early 1997. Initial projections for sales of DVD-Video players were quite optimistic, with many estimates as high as 2 million units or more sold during the first year. Actual sales fell far short of these initial projections due primarily to the high cost of consumer DVD-Video players as well as the limited number of DVD titles released by the major motion picture studios. When the DVD-Video format was officially launched in the U.S. on March 17, 1997 there were less than 200 titles available in only seven regional test markets. DVD went nationwide in the U.S. on August 22, 1997, although there were still several major motion picture studios not supporting the format, including Disney, Fox, and Paramount.

During 1997 a number of respected industry analysts expressed concerns over the viability of the DVD format. Some experts predicted that the DVD format would fail in its effort to become a viable home entertainment format, becoming a niche product only for high-end audio and videophiles. These predictions seemed justified by the failure of the Laser Disc format to break into the mainstream consumer market.

In September 1997 things started to look up for DVD as Disney announced that they would be releasing their non-animated movies on DVD, leaving only Fox and Paramount as major studios who were still not supporting DVD. Actual sales of DVD-Video players in the U.S. market during 1997 were only about 315,000 units, well below the industry predictions. While the future of DVD was looking brighter, total sales of DVD players and titles were below expectations, and it was not clear that DVD would become a success.

In April 1998 Paramount decided to release DVD versions of their movies, and Fox followed suit in August 1998. With all of the major motion picture studios now on board the

future looked much brighter for DVD. Over 1,000,000 DVD-Video players were sold in the U.S. market during 1998, while at the same time the European DVD market was launched. Initial sales in Europe were slow due to a lack of Region 2 titles, as well as resistance by many consumers who did not want to purchase DVD players that due to region coding prevented them from watching movies released in the US. To this day most Europeans despise the use of Region Coding by the studios, while most American consumers don't even know that their players can only play Region 1 titles. By the end of 1998 with a worldwide installed base of over 2,000,000 players and more than 1,000 titles available, most of the critics of DVD had been silenced. All of the major motion picture studios had commitments to release their entire catalogs on DVD, as well as many independent distributors and smaller studios.

By the end of 1999 DVD had become the fastest growing consumer electronics product ever. Over 4,000,000 DVD-Video players were sold in the U.S. market alone during 1999, and remarkably there were almost 4,000 DVD titles available by year-end. Perhaps the biggest news during 1999 was Circuit City's decision to abandon DIVX, its proprietary pay per view version of DVD. Circuit City had spent several years, and over $200,000,000 to develop DIVX, but in the end bowed to pressure from consumers who did not like certain technological aspects of the DIVX business model, including the ability to track consumer viewing habits and advanced copy protection features that only allowed movies to be played on DVD players registered to a specific household.

DVD solidified its claim to the most successful new consumer electronics format during 2000. In the U.S. market over 8,000,000 new DVD-Video players were sold and over 8,000 titles were available in the DVD format by the end of the year. The European market also grew significantly during 2000 with most major motion picture studios releasing specific versions of their movies for Europe, rather than simply repackaging the US versions of each release. The year 2000 was also a watershed year for DVD in several other areas. DVD branched out from the movie business to become a mainstream technology for corporate, educational, and government applications. DVD-ROM drives became common options for new consumer and corporate personal computers, and a large number of products and services were announced to help corporate, educational, and government clients move into the world of DVD. DVD-Video players were available in the U.S. for less than $100, and DVD-ROM drives became a no-cost option on many higher-end personal computers. The year 2000 ended in a bang for DVD with several recordable DVD products released worldwide, addressing the only major drawback to widespread adoption of the DVD format — the inability for the consumer to record their own content onto DVD discs.

While it is always difficult to predict how consumers will react to new technologies, it is clear that DVD will be successful for many years to come. DVD-Video is firmly entrenched as a mainstream high quality, low cost home entertainment format. Over the next few years DVD-ROM will replace CD-ROM as the standard optical disc format in all consumer and corporate personal computers. DVD-Audio products will come on the market during 2001, and it will compete directly with the new Super Audio CD format. It is too early to tell if DVD-Audio or Super Audio CD will be accepted as a mainstream replacement for CD-Audio technology, which is firmly entrenched worldwide. Finally the DVD-R, DVD-RAM, and DVD-RW formats will start to offer consumers the ability to create and record their own high quality content on recordable DVD discs. The future of DVD looks very bright; in fact, DVD is likely to be a dominant technology over the next decade.

Figure 1.1 shows the projected growth of DVD over the next ten years. (Source: DVD Intelligence, and independent market surveys.) It is easy to see from this graph that DVD has just begun its dominance as a critical component in consumer home entertainment products.

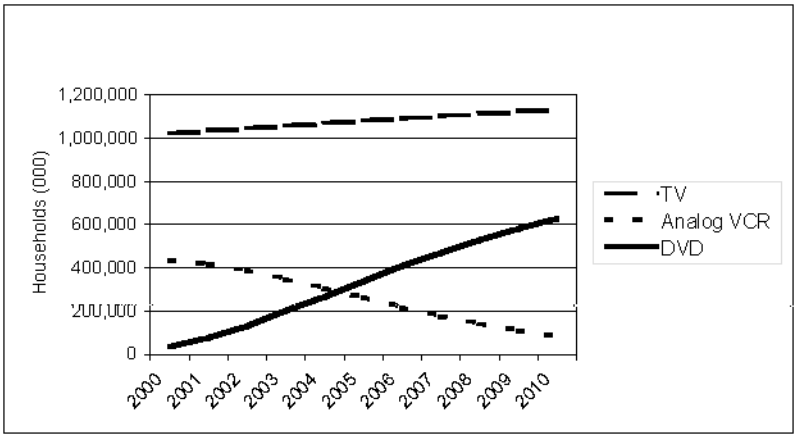

Figure 1.1 Worldwide Markets for Home Video Equipment

Chapter 2

DVD FORMAT SPECIFICATIONS

The DVD Forum has released separate books to document each of the following DVD specifications (listed with the current version at the time of this writing).

- DVD-Video v1.11
- DVD-ROM v1.02
- DVD-Audio v1.2
- DVD-R v2.0
- DVD-RAM v2.1
- DVD-RW v1.1
- DVD-Video Recording v1.1
- DVD Stream Recording v1.0

Each of the listed formats are "official" DVD formats, which means they have gone through a formal submission and review procedure and they have been approved by a vote of DVD Forum member companies. The submission, review, and approval process can take up to two years for a new DVD format. The DVD Forum is currently developing specification for advanced interactive content, also know as WebDVD, which defines an optional mechanism to include links between content stored on DVD-Video titles and content available on

the Web. The decision to develop a WebDVD specification was made in May 2001, so we may not see a formal specification approved by the DVD Forum until the end of 2002, if ever.

Sony and Philips have proposed an alternative to the recordable DVD specification called DVD+RW, which was published in 1999 and revised in 2000. Sony and Philips has also proposed an alternative to the DVD-Audio specification that is called Super Audio CD (SACD), which was published in 1999. As shown in Figure 2.1, all of the DVD format books include a physical layer section, which defines the physical properties of the disc, and a file system layer section, which defines how data will be stored on the disc. The DVD-Video and DVD-Audio format books also include an application layer section, which defines how multimedia data will be formatted and stored on the disc and read back by DVD-Video and DVD-Audio players to create high quality home entertainment devices.

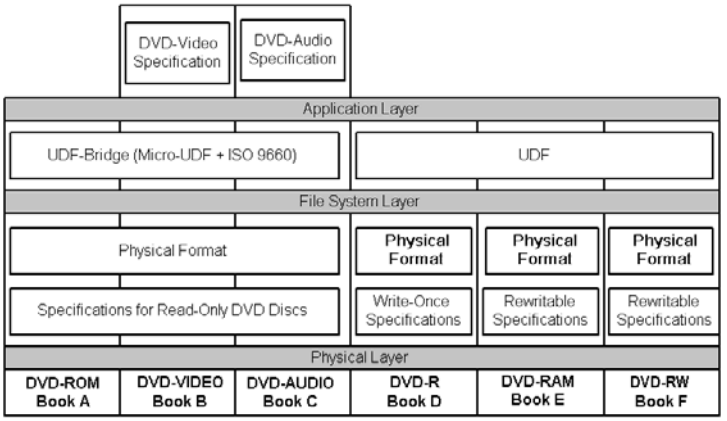

Figure 2.1 DVD Format Books Published by the DVD Forum

The physical layer section for the DVD-ROM, DVD-Video, and DVD-Audio formats are the same, and define the physical properties of a read-only DVD optical-disc. The physical layer section of the DVD-R write-once format and the DVD-RAM and DVD-RW read-write formats are different since these media types are physically different from the mass-produced DVD-ROM, DVD-Video, and DVD-Audio discs.

Each of the format books allows a micro-UDF file system to be used. Micro-UDF is a new optical disc file format specification developed by the Optical Disc Storage Association (OSTA) and is designed to allow optical discs to be compatible with all major operating system software (Windows, Mac OS, Unix, Linux, etc.). The DVD-ROM, DVD-Video, and DVD-Audio format books also allow for a standard ISO 9660 file system to be used in addition to UDF. The DVD-Video and DVD-Audio format books include an application layer section that defines how video, audio, graphic, and textual information will be digitized, compressed, and stored onto the DVD disc, and how the various interactive features of the DVD-Video and DVD-Audio formats will be implemented and used.

A copy of the DVD format books can be purchased for $5,000 from:

DVD Format/Logo Licensing Corporation
Shiba Shimizu Bldg. 5F
2-3-11 Shibadaimon, Minato-ku,
Tokyo, JAPAN, 105-0012
+81-3-5777-2883 (Voice)
+81-3-5777-2884 (Fax)
http://www.dvdfllc.co.jp (Web)

A signed confidentiality agreement and full payment must be received prior to shipment of the DVD format books. It is generally not necessary for DVD authoring or production companies to purchase a copy of the DVD format books. While the format books provide all of the low level details required to completely understand and implement the DVD-Video specification, they are typically only required for companies that are developing DVD-Video players, DVD-Video decoders, or DVD-Video authoring tools. Some advanced DVD-Video title developers may find access to these format books can be beneficial in understanding nuances of the DVD-Video format, but in general this is not required.

DVD Forum

The DVD Forum is an organization whose goal is to promote broad acceptance of DVD products on a worldwide basis. The DVD Forum has targeted the entertainment, consumer electronics, and information technology industries as potential users of DVD technology. The DVD Forum performs the following functions.

- Defines the requirements and specifications for all DVD formats including DVD-Audio, DVD-R, DVD-RAM, DVD-ROM, DVD-RW, and DVD-Video
- Publishes the various DVD format books
- Licenses the DVD Format and DVD Logo, through the DVD FLLC organization
- Administers the DVD Verification Labs throughout the world
- Holds worldwide DVD conferences, promotes DVD through public relations activities, and maintains the DVD Forum web site (http://www.dvdforum.org)

The DVD Forum currently has 64 Principal Members and 235 Associate Members. Principal Members are allowed to participate in defining the DVD formats, and can vote at the DVD Forum general meetings. The annual fee to become a Principal Member of the DVD Forum is approximately $8,000 (1,000,000 Yen). Associate Members are provided access to the DVD Forum Technical Working Group reports. The annual fee to become an Associate Member of the DVD Forum is approximately $2,500 (300,000 Yen). Current members of the DVD Forum Steering Committee include Hitachi, IBM, Intel, ITRI, JVC, LG, Matsushita, Mitsubishi, NEC, Philips, Pioneer, Samsung, Sharp, Sony, Thomson, Time Warner, and Toshiba.

The DVD Forum currently has eight Technical Working Groups.

1. DVD-Video and Video Recording
2. DVD-ROM
3. File Format
4. DVD-Audio
5. Rewriteable (DVD-RAM)
6. Write-Once (DVD-R) and Re-Recordable (DVD-RW)
7. Copy Protection
8. Pro-Use Applications

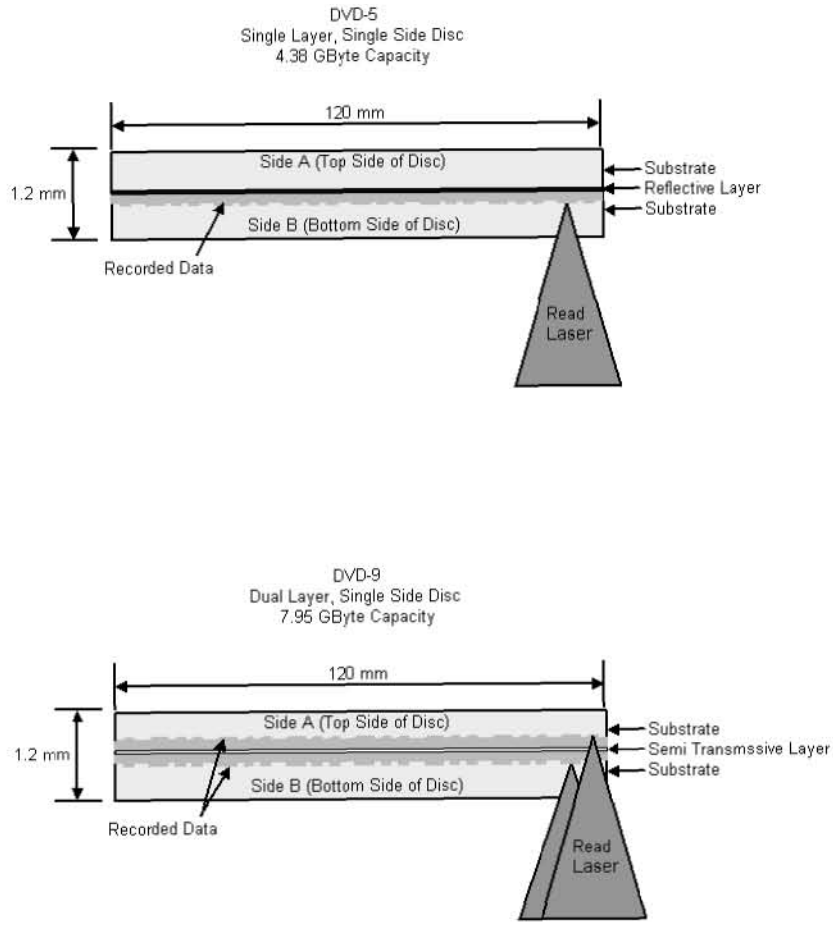

Figure 2.2 DVD Single Layer and Dual Layer Disc Construction Diagram

DVD Physical Specifications

Two of the primary technical goals of DVD are to provide both higher capacity and higher throughput than CD-ROM technology offers. All DVD formats and playback devices support a minimum throughput rate that is at least nine times faster than a conventional CD-ROM, and many DVD playback devices support even higher transfer rates. The DVD-ROM, DVD-Video, and DVD-Audio formats have storage capacities between 4.7 and 17.0 billion bytes. The variation in total storage capacity depends on the use of up to two data storage layers on each side of a DVD disc.

The DVD physical specification provides for up to four different data recording layers and two different sizes (12cm and 8cm in diameter). A single-layer, single-sided disc is referred to as a DVD-5; a dual-layer, single-sided disc is a DVD-9; a single-layer, dual-sided disc is a DVD-10; and a dual-layer, dual-sided disc is a DVD-18. It is technically possible to have a DVD disc that uses three recording layers, two on one side and one on the other. This is called a DVD-14, but is not very common.

Figure 2.2 shows how a single-layer and dual-layer DVD disc are constructed. Both single-layer and dual-layer discs are made from two distinct pieces of molded plastic that are bonded, or glued, together. For a DVD-5 disc only one recording layer is used so a reflective material is added to the middle of the disc. Then the laser can read the data stored just before the reflective material. For a dual-layer disc two data layers are recorded and separated by a semitransmissive layer. If the laser is focused on the data recorded on Layer 0, which is on the bottom of the disc, then it is reflected to the optical sensor. If the laser is focused in the data recorded on Layer 1, which in on the top part of the disc, then the semitransmissive material allows the laser to pass through and read the data on the top layer. The semitransmissive material used on most dual layer DVD discs is gold.

DVD increases capacity through the use of multiple layers and specialized lasers, which use a shorter wavelength than traditional CD-ROM devices. This means that the pits and tracks used to store data on a DVD disc can be much smaller than those used on a CD-ROM.

A traditional CD-ROM uses pits that are at least 0.83 microns long, and has tracks that are spaced 1.6 microns apart. A DVD disc uses pits that are at least 0.4 microns long, and tracks that are spaced 0.74 microns apart. The pits and tracks used in DVD are less than half the size of the pits and tracks used on CD-ROM discs.

The use of smaller pits and more closely spaced tracks on a DVD optical disc increase the total storage capacity by over 700 percent compared to a traditional CD-ROM. Figure 2.3 shows the difference between the pits and track spacing on a CD-ROM and DVD-ROM, DVD-Video, DVD-Audio, DVD-R, and DVD-RW discs.

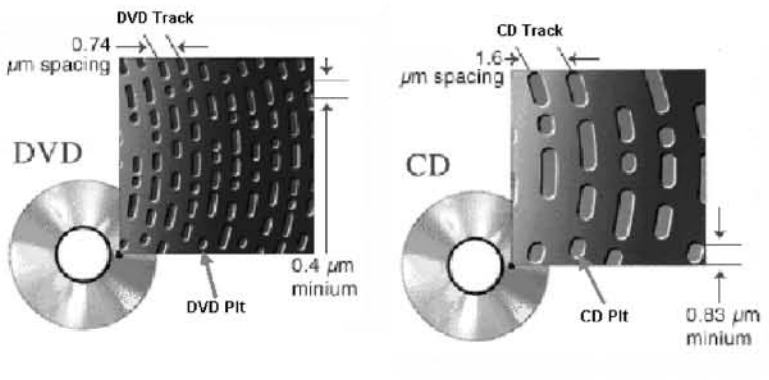

Figure 2.3 Comparison of DVD-ROM Vs CD-ROM Pit and Track Sizes

Using multiple layers and multiple sides for data storage has increased total capacity to a maximum of 15.9 Gb on a DVD optical disc compared to just 650 Mb on a standard CD-ROM — an increase of more than 25 times the capacity.

Table 2.1 provides the relevant physical properties and storage capacities for each type of DVD disc. The DVD format books refer to the storage capacity of each type of DVD disc as Gbytes, but this term has a different meaning than the classic definition for computer Gb. In the field of computer science a byte is defined as 8 bits of data, Kb as 1,024 bytes, Mb as 1,024 Kb, and Gb is 1,024 Mb. In the DVD format books a GByte is simply defined as 1 billion

bytes. This is about 7.3 percent less than a computer Gb, which is actually 1,073,741,824 bytes. When working with DVD disc storage capacities it is important to keep this difference in mind.

It is also important to note that the capacity of a dual layer (DVD-9) disc is not simply double the capacity of a single layer (DVD-5) disc. Dual layer discs have a slightly larger mark pitch than single layer discs do, so a dual layer disc can only hold about 82 percent more than a single layer disc. Table 2.2 shows some of the common physical properties of DVD discs.

Table 2.1 DVD Storage Capacity Chart

Parameters		DVD-5	DVD-9	DVD-10	DVD-14	DVD-18
User Data Capacity (Gb) *	12cm	4.37	7.95	8.75	12.3	15.9
	8cm	1.36	2.47	2.72	3.83	4.95

* Storage capacities are listed in computer Gb (2^{30})

Table 2.2 DVD Physical Parameter Chart

Parameters		DVD-5	DVD-9	DVD-10	DVD-14	DVD-18
Laser Wavelength		650/635 nm				
Disc Diameter	12cm	120 mm				
	8cm	80 mm				
Disc Thickness		1.2 mm				
Disc Center Hole		15.0 mm				
Data Area Inner Radius		24.0 mm				
Data Area Outer Radius	12cm	58.0 mm maximum				
	8cm	38.0 mm maximum				
User Data Bit Rate		11.08 Mbps				

Tips, Tricks & Techniques

Always refer to DVD storage capacities using the computer definition of Gb, rather than the DVD format book definition. DVD authoring and production tools are computer-based, so it is better to keep track of storage capacities and requirements by using the computer convention for Gb. An easy way to convert between DVD bytes and computer bytes is to multiply DVD storage sizes in billion bytes by 0.932 to get the correct computer storage size in Gb.

DVD File System Specifications

The DVD-Video format book requires the use of a general purpose volume and file layout structure so that DVD discs can be read by a variety of consumer and computer electronics devices, regardless of the specific processor or operating system used to access the disc. The DVD-Video format book requires the use of either the ISO-9660 or Micro-UDF (Universal Disc Format) file formats for storing data on a DVD disc. The ISO-9660 format has been in use for a number of years, and most CD-ROM discs that are cross-platform compatible use this format. DVD currently implements a hybrid approach, called UDF-Bridge, that provides both the newer UDF system as well as the older ISO-9660 system used by the CD-ROM format. This allows DVD discs to be used with computer operating systems that do not have any provision for UDF support.

DVD-Video requires that data stored on the disc follow the volume structure shown in Figure 2.4. Lead-in and lead-out areas are provided at the start and end of the disc to facilitate synchronization of DVD players with the data stored on the disc. An ISO-9660 and Micro-UDF file format is used to store all data. Video, audio, subpicture, menu, and still image data elements are stored in the DVD-Video zone area of the disc. The data is logically organized into the Video Manager area, which acts as the table of contents for the disc, and up to 99 Video Title Set areas, which hold individual programs, or collections of multimedia content.

All DVD discs should be mastered to include all required data as specified by ISO 13346 and UDF. This allows the playback of DVD discs on standard computer systems that support either the ISO 13346 or UDF formats. The ISO is the International Standards Organization that sets worldwide standards for a wide variety of industries, including personal computers and consumer electronics devices. Examples of such required data include the time, date, permission bits, and a free space map (indicating no free space if ROM media). While DVD player implementations may ignore these fields, a UDF computer system implementation will not. The UDF format has many features and can be complicated, however much of the information can be ignored in a dedicated DVD player environment. Due to limited computing resources within a DVD consumer player, only a subset of the UDF format is used for storing data on the DVD disc. The following restrictions apply to using the UDF format for DVD-Video discs.

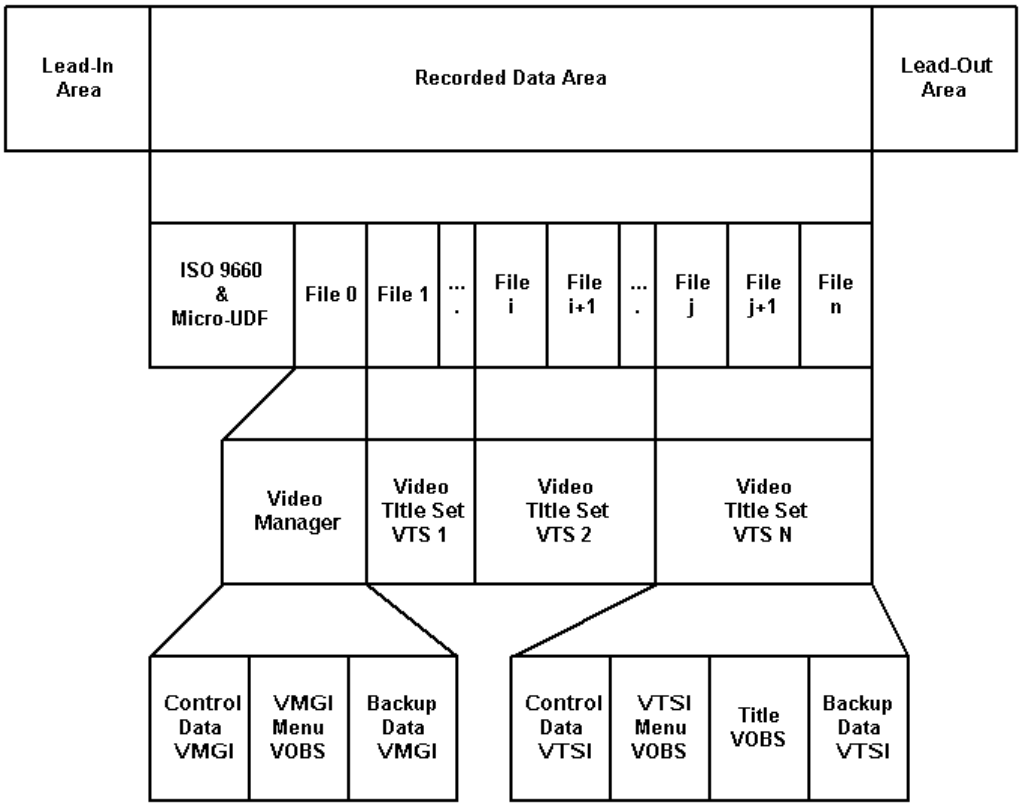

Figure 2.4 DVD-Video Volume Layout Hierarchy

- DVD-Video files should be stored in a subdirectory directly under the root directory. The directory name should be `Video_TS`.
- DVD-Video file names should consist of the characters `A-Z` (upper case), `0-9` (digits), _ (underscore), and . (period). Not more than one . should be used in a file name.
- Maximum compatibility will be ensured if the DVD-Video file names consist of no more than eight characters, optionally followed by a ., optionally followed by no more than three characters.
- There should not be any files in the DVD-Video directory that differ only by case (i.e., `Movie` and `movie` cannot coexist).
- DVD-Video authoring systems should constrain individual files to less than 1 Gb.

All these constraints apply only to the directory and files to which the DVD-Video player needs access. There may be other files and directories on the DVD disc that are not intended for the DVD-Video player and do not meet the listed constraints. Files outside the `Video_TS` directory, as well as files in the root directory, are ignored by the DVD player.

Copies of the UDF Specification can be obtained from:

Optical Storage Technology Association
311 East Carrillo Street
Santa Barbara, CA 93101
(805) 963-3853 Voice
(805) 962-1541 Fax
ray@osta.org (E-Mail)
http://www.osta.org (Web)

Most DVD authors and producers will not need to know the details of how the volume and file information is stored on a DVD disc. The authoring tools you'll use to create the DVD disc image will handle all the nuances of creating a valid DVD volume and file structure. However it is helpful if DVD authors and producers understand the file naming conventions used on DVD discs, and what each file is supposed to do.

All the files required for a DVD-Video title are stored in a directory called `Video_TS` in the root of the DVD disc volume. Within this directory there will be a number of files with three different types of extensions. Figure 2.5 shows the directory and file structure of the *StarGaze* disc.

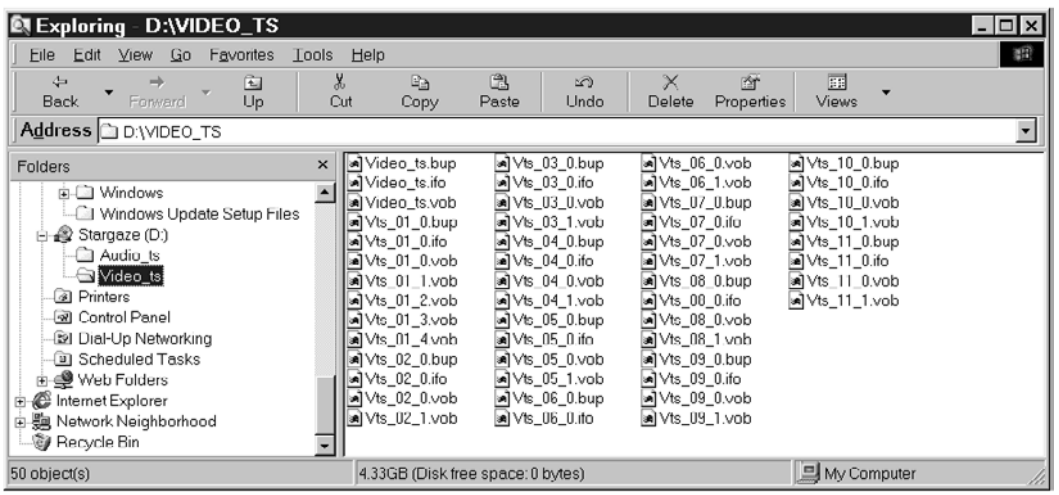

Figure 2.5 DVD-Video File Structure

Files that end with the `.ifo` extension are information files that describe the content stored in the DVD-Video zone of the disc and how that content can be accessed directly. Files that end with the `.bup` extension are backup copies of the `.ifo` files with the same name. Files that end in the `.vob` extension are Video Objects that contain all the still images, video streams, audio streams, subtitle streams, and menus that are included on the disc.

Real World Example

StarGaze is a "hybrid" DVD title with features designed for both DVD-Video players as well as personal computers with DVD-ROM drives. Place the *StarGaze* disc into a DVD-ROM drive and look at the files and directories on the disc. You will notice that most of the capacity of the disc is used by files in the `Video_TS` directory. This is where the data is stored for the DVD-Video portion of the title. There are also ten files in the root-directory used to install a Windows screen saver program. DVD-Video players ignore these files.

DVD-Video

DVD-Video is a read-only optical-disc format that can be used for the interactive playback of high quality video, audio, and graphics content. The DVD-Video format allows consumers to playback full-length motion pictures as well as interactive games with higher quality than traditional VHS, SVHS, CD-i, and Laserdisc playback systems. The DVD-Video format can deliver full screen, full motion video at a resolution of 720 480 pixels per frame and a frame rate of 30 frames per second for NTSC countries, or 720 576 pixels per frame and a frame rate of 25 frames per second for PAL countries. Video quality delivered by a DVD-Video player has the potential to be as good as the original broadcast source tape.

The DVD-Video format supports extremely high quality audio using either Dolby Digital 5.1 channel surround-sound, linear PCM encoded audio, DTS surround sound audio, or Sony SDDS surround sound audio. Each of these digital audio formats provides significantly better quality than traditional Audio-CD devices. The DVD-Video format also provides the capability of storing up to eight different audio tracks that are all synchronized to the digital video stream.

The DVD-Video format supports up to 32 subpicture streams used for subtitles, closed captioning, graphical overlays, and even simple animations. Each subpicture stream is synchronized to the video and audio streams so that a wide variety of multimedia elements (video, audio, graphics, text, and animation) can be delivered to the user in a coherent fashion. The DVD-Video format can also deliver high quality still images that can be displayed for a fixed period of time, or until a user input is received.

The DVD-Video format supports a wide range of functions that enable the user to control and interact with the DVD-Video title. Simple functions such as start, stop, pause, fast forward, and reverse are provided so the user can control the playback of a title in a manner similar to a VHS, SVHS, or Laserdisc system. In addition to these simple interactive features, DVD-Video provides random access to all of the data on the disc, allowing the user to jump to any portion of the title in less than one second. Finally the DVD-Video format provides high-level interactive functions that allow the development of titles that ask the user to respond to questions, or to provide interactive menus to determine how the user wishes to view the title.

Video, audio, subpicture, still image, and control data are all multiplexed together within a DVD-Video title to form a single bit stream that can be decoded by a DVD-Video player in a manner that provides seamless transitions between different video scenes, language tracks, or subpicture streams. DVD-Video data has the following logical structure, as shown in Figure 2.6.

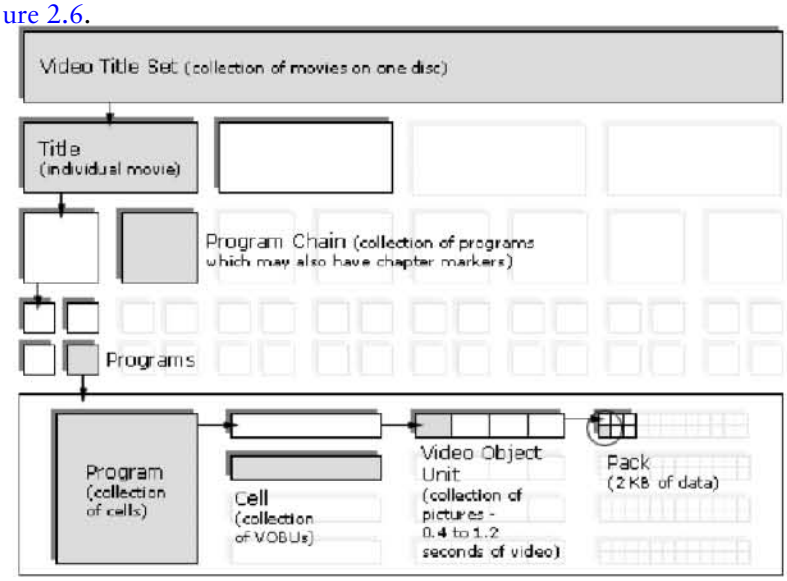

Figure 2.6 DVD-Video Logical Hierarchy

Title The Title area provides the ability to have up to 99 titles or episodes on a single disc. Titles can consist of a single program chain or multiple program chains. A title is typically used to store an entire movie or any items of content that can stand on their own.

Program Chain A collection of programs that are logically grouped together based on the content. Generally a movie is stored in a single program chain, while different episodes of a television series would be stored in separate program chains.

Part_of_Title Links to one or more programs. Part_of_Title can be used to support different versions of the title. For example if you developed a DVD for a movie that had several different endings, you would create a Part_of_Title for each unique ending. The Part_of_Title would call out the specific programs used in each variation of playback.

Program A collection of cells that are logically grouped together based on the content. Programs are usually used to identify different chapters within a movie.

Cell A collection of video or audio data packets that are logically grouped together based on the content. Cells are usually used to identify different scenes within a chapter.

VOBU Video Object Unit that is one or more MPEG Group of Pictures (GOP). A VOBU can be between 0.4 and 1.2 seconds long.

Group Of Pictures (GOP) The smallest granularity of random access to video data on the disc. A GOP typically includes compressed video data from 15 sequential frames of NTSC video, or 12 frames of PAL video.

Packet DVD-Video packets are 2048 bytes large and include only one type of data (video, audio, etc.). A packet is essentially equivalent to a single sector of data on the disc.

Navigation Packet (NAV) Contains optional commands that define the playback behavior of a cell. Navigation packs are used to control playback of the content at a very detailed level, for example you could use a navigation pack to skip over a specific Cell if it had a parental rating level higher than the player was set up to play.

DVD-Video can achieve the lofty goal of providing significantly better quality and more features than conventional VHS, SVHS, or Laserdisc players because it utilizes the latest digital techniques for encoding video, audio, still images, sub-picture information, and animation data.

MPEG Video

The DVD-Video format requires that video data be compressed in either the MPEG-1 or MPEG-2 formats. A compressed format is used to reduce the total data storage requirements for the video elements to a manageable level. "Broadcast" or "CCIR-601" quality video requires approximately 21 Mbytes/second of storage space and throughput. This means that a DVD-5 disc (4.37 GBytes) could hold only about 3.7 minutes of uncompressed, or raw, video.

MPEG-1 compressed video has a resolution of 352 240 pixels per frame and a frame rate of 30 non-interlaced frames per second (for NTSC countries). Most MPEG-1 files are compressed at a constant bit rate of approximately 1.4 Mbits/Second, which is consistent with the recommendations of the Video-CD standard. MPEG-1 compressed video provides quality roughly comparable to VHS tape, and if higher data rates are used the quality can approach SVHS tape. A standard DVD-5 (4.3 Gb) disc can hold approximately 7.5 hours of MPEG-1 video compressed at standard Video-CD rates. Video CD is an extremely popular format in Asia, but has never caught on in either the US or Europe since both areas had large installed bases of VHS players when Video CD first became available. Many DVD-Video players support the Video CD format, and some of the first titles released for DVD players were actually Video CD discs with MPEG-1 data. Despite Video CD's popularity in Asia, the vast majority of DVD-Video titles have been published using MPEG-2 compressed video in order to provide better overall video quality.

MPEG-2 compressed video has a resolution of 720 480 pixels per frame and a frame rate of 30 frames per second for NTSC countries, or a resolution of 720 576 pixels per frame and a frame rate of 25 frames per second for PAL countries. MPEG-2 files can be created using a constant-bit-rate encoding process or a variable-bit-rate encoding process. If a constant-bit-rate encoding process is used a bit rate of approximately 6 Mbits/Sec or higher is required to

provide compressed video that is as good as the original CCIR-601 source. If a variable-bit-rate encoding process is used, an average bit rate of less than 4.0 Mbits/Sec can be used to generate compressed video that looks nearly as good as the original CCIR-601 source.

Figure 2.7 shows the steps required to generate an MPEG-2 compressed digital video file. CCIR-601 component video is fed into a series of pre-filters and temporal and spatial scaling equipment to generate a high quality component digital video signal. The digital signal is then converted from RGB component format into the Y/Cr/Cb component format. Each frame of digital video is compressed using a Discrete Cosine Transform algorithm that removes redundant data (Intraframe Compression). Next each frame is compared to previous and future frames to eliminate redundant data between frames (Interframe Compression). Finally the compressed video data is formatted to comply with the MPEG-2 file format standards.

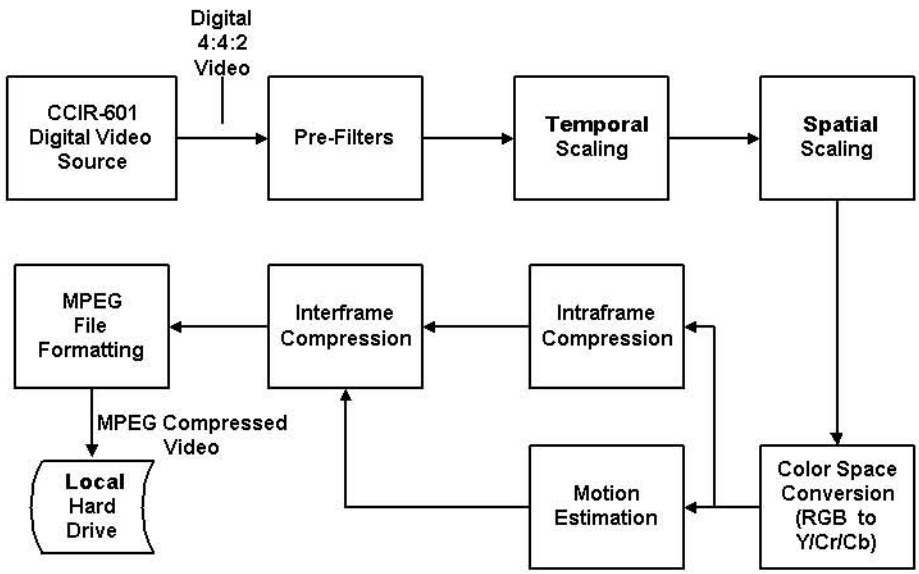

Figure 2.7 MPEG Video Compression Process Block Diagram

An MPEG-2 bit stream, as shown in Figure 2.8, is composed of a sequence of *Slices*, *Pictures*, and *Group Of Pictures*. An MPEG-2 *Picture* corresponds to a single full resolution frame, with two *Slices* that correspond to each field of the interlaced frame. There are three types of encoded frames in MPEG-2. An I frame includes all of the information required to fully reconstruct the source frame. Subsequent *Pictures* within the *Group Of Pictures* will be P or B frames. P and B frames are predictive frames, which means they only store the changes from the previous or next frame. A *Group Of Pictures* is a sequence of compressed frames that starts with a *Picture* that is an MPEG-2 I frame. The DVD-Video format book requires that the MPEG-2 compressed digital video stream include no more than 18 *Pictures* in each *Group Of Pictures*. The number of *Pictures* in a *Group Of Pictures* is also called the GOP size. The DVD-Video format book also requires that the MPEG-2 video data be multiplexed with any associated audio, sub-picture, still image, and control data.

When variable bit rate encoding is used, the actual number of bits dedicated to the MPEG encoding process is varied depending on the content of the video stream. If the video content is a scene of someone speaking, with a relatively static background, then fewer bits can be used to accurately describe the static scene. If the video content is a high action scene with both foreground and background motion, or a scene with a lot of fine detail, a higher bit rate must be used to avoid introducing digital artifacts into the compressed digital video file.

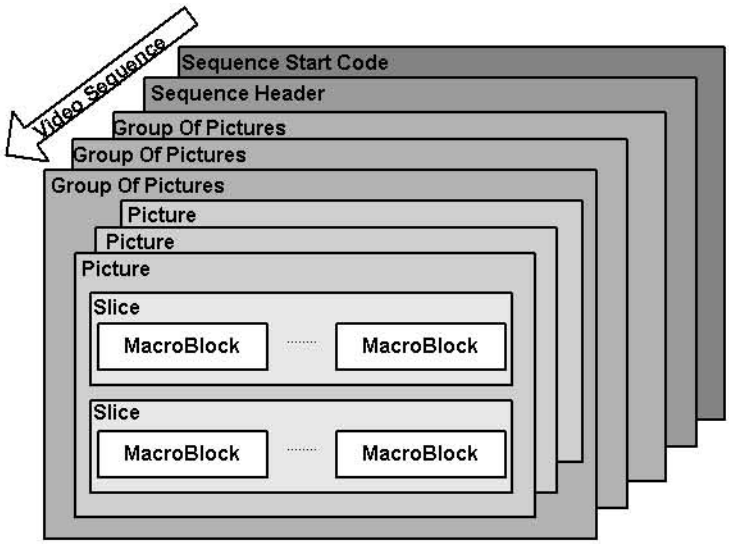

Figure 2.8 MPEG-2 Bit Stream Syntax

Lossy digital video compression techniques, including MPEG-1 and MPEG-2, can create digital artifacts during the compression process. Digital artifacts can include Color Distortion, Color Bleeding, Hue and Tint Degradation, Motion Degradation, Noise Pumping, Frame Duplication, Frame Drops, Aliasing, Blocking, Fringing, and Ringing. The most common digital artifacts generated in MPEG compressed video streams are Blocking, Color Bleeding, and Fringing. Blocking is the presence of 8 8 pixel pattern blocks in the compressed video stream that were not part of the original source. Blocking is caused by the use of the Discrete Cosine Transform algorithm, which operates on an 8 8 pixel block. Color Bleeding occurs when colors from one area of a frame migrate into neighboring areas of the same frame. Color Bleeding occurs more often with "hot" colors such as red, yellow or orange. Ringing is the presence of a blurring, or out of focus effect around the edges of an object that is moving from frame to frame. Ringing occurs more often when there is a large amount of motion between frames of the video.

Digital video artifacts can be eliminated using a variety of techniques. Most artifacts can be removed by increasing the average bit rate used to compress the content. Filtering the input video stream to eliminate high frequency noise is also a common technique for reducing artifacts. Artifacts that occur in only a single frame of the digital video can be removed by touching-up the pixels that have been distorted, although this is a very labor-intensive process.

Multiple Screen Aspect Ratios

In the early days of film all movies were shot in a 4:3 aspect ratio. As movie theatres got larger filmmakers started shooting in wide screen formats so that the movie would fill the

Tips, Tricks & Techniques

Use variable-bit-rate MPEG-2 to create broadcast quality DVD titles. For SVHS quality, use half-horizontal resolution (Half-D1) MPEG-2 compression. For VHS quality, use MPEG-1 compression at Video-CD data rates (1.4 Mbits/second).

available screen size on the stage. When television came along it was decided that all video displayed on a television would have a 4:3 aspect ratio. Today we have a number of different aspect ratios in used by filmmakers and television producers, and all of this content may eventually be transferred to DVD. Thus the DVD-Video format needs a method of handling content with different aspect ratios.

The DVD-Video Format supports the use of normal, pan-scan and letterbox formats when displayed on either 4:3 standard or 16:9 wide-screen monitors. Figure 2.9 shows how a video image created for 4:3 or 16:9 displays will look when the normal, pan-scan, letterbox, and 16:9 formats are used. Obviously a video that has been generated in the 4:3 format will look correct on a standard 4:3 monitor, and a video that has been generated in the 16:9 format will look correct on a wide-screen monitor. However, when a 4:3 formatted video is displayed on a 16:9 monitor, or a 16:9 formatted video is displayed on a 4:3 monitor, the original image will not be reproduced accurately. There are several techniques used to avoid this problem including Pan/Scan to convert a 16:9 image to a 4:3 resolution and letterboxing to display a 16:9 image on a 4:3 display in its entirety.

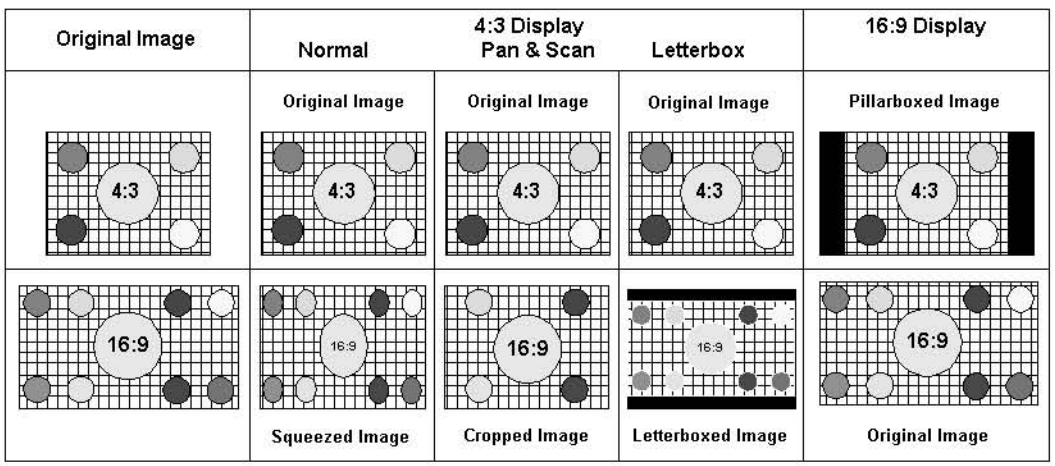

Figure 2.9 DVD-Video Multiple Aspect Ratio Comparison
(See color insert for color version of this figure.)

Multiple Camera Angles

Up to nine different camera angles are supported by the DVD-Video format. The viewer can seamlessly switch between viewing angles by using the "Angle" button on the DVD-Video

player's remote control. There are some restrictions on the use of multiple video angles, such as the length and average bit rate of each unique video angle must be approximately the same. Multiple camera angles can be used to provide different perspectives, or to provide alternative content. For example multiple camera angles have been used to provide both a finished animated video sequence as well as the wire frame animation so the viewer can understand the process used to create the video sequence, or for a sporting event where one camera angle could provide a wide angle view of the entire playing field, another could have a close up view following the soccer ball, while a third angle could provide a close up of the goal keeper.

High Quality, Multiple Channel Audio

The DVD-Video Format provides for the incorporation of high-quality, multiple channel audio using one of the following formats: Dolby Digital Stereo, Dolby Digital 5.1 Channel Surround Sound, Linear PCM Stereo, MPEG-2 Stereo, MPEG-2 Surround Sound, DTS Surround Sound and Sony SDDS Surround Sound. The Dolby Digital and Linear PCM formats are required to be supported by DVD-Video players, with MPEG-2 (stereo and surround), DTS and SDDS audio optional. The vast majority of DVD-Video players throughout the world support Linear PCM and Dolby Digital audio. Many players support the DTS audio format as well. MPEG-2 audio is supported on some European model DVD-Video players, but in general it is not supported on US player models. Most of the DVD-Video players on the market today, and sold over the past five years will not support playback of DVD-Audio discs, which generally included linear PCM or Meridian Lossless Packing (MLP) data. Consumers will need to purchase a DVD-Audio player or upgrade their DVD-Video player to a Universal player in order to play back DVD-Audio titles.

DVD-Video supports up to eight simultaneous tracks for audio, in any of the formats listed above. Each audio track is multiplexed into the overall DVD-Video bit stream so that they are synchronized with the video stream. DVD-Video players are designed so that the user can switch between the available audio tracks at any time during playback of the title. Switching audio tracks is a seamless operation that requires less than a second to complete. Video playback will continue without interruption during an audio track change.

Most DVD-Video titles include Dolby Digital stereo, or Dolby Digital 5.1 Channel Surround Sound audio tracks. Dolby Digital is a perceptual digital audio coding technique that has been used in movie theaters since 1992. Dolby Digital divides the audio spectrum of each channel into narrow frequency bands of different sizes optimized with respect to the frequency selectivity of human hearing. This makes it possible to sharply filter coding noise so that it is forced to stay very close in frequency to the frequency components of the audio signal being coded. Reducing or eliminating coding noise wherever there are no audio signals to mask it can subjectively preserve the sound quality of the original signal.

In Dolby Digital, bits are distributed among the filter bands as needed by the particular frequency spectrum or dynamic nature of the program. A built-in model of auditory masking allows the coder to alter its frequency selectivity (as well as time resolution) to make sure that a sufficient number of bits are used to describe the audio signal in each band, thus ensuring noise is fully masked. Dolby Digital also decides how the bits are distributed among the various channels from a common bit pool. This technique allows channels with greater frequency

content to demand more data than sparsely occupied channels, for example, or strong sounds in one channel to provide masking for noise in other channels.

Dolby Digital can process at least 20-bit dynamic range digital audio signals over a frequency range from 20 Hz to 20kHz x 0.5dB (-3dB at 3Hz and 20.3 kHz). The bass effects channel covers 20 to 120 Hz x0.5 dB (-3 dB at 3 and 121 Hz). For DVD-Video applications a sampling rate of 48 kHz is used. Data rates range from as low as 32 kb/s for a single mono channel to as high as 640 kb/s, thereby covering a wide range of requirements. Typical applications include 448 kb/s for 5.1-channel Dolby Digital consumer format, and 192 kb/s for two-channel audio distribution.

As shown in Figure 2.10, Dolby Digital 5.1 Channel Surround Sound delivers six totally separate (discrete) channels of sound including Left, Center and Right channels across the front of the room, and left surround and right surround channels located behind or to the side of the listener, for more precise localization of sounds. All five main channels are full range (3 Hz to 20,000 Hz) and a subwoofer can be added to each channel, if desired.

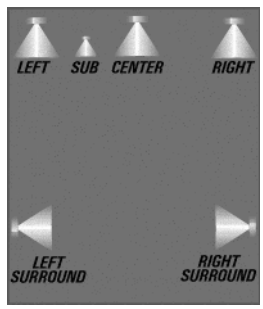

Figure 2.10 5.1 Channel Surround Sound Speaker Placement

The sixth channel, called the Low Frequency Effects Channel, will, at times, contain additional bass information to maximize the impact of scenes such as explosions, crashes, etc. Because this channel has only a limited frequency response (3 Hz to 120 Hz), it is sometimes referred to as the ".1" channel. When added to the 5 full range channels, the Dolby Digital system is usually referred to as having "5.1" channels.

For Linear PCM and DTS audio the sixth channel includes the same frequency response as the other five channels so it is capable of carrying sound other than low frequency effects. Very few DVD-Video titles have been developed using six channel Linear PCM audio as it uses over 60% of the available DVD-Video bit rate for just a single track of audio, leaving an inadequate amount of bandwidth for video, subpictures or additional audio tracks. DVD-Video titles with six channel DTS audio tracks are quite common, although in the vast majority of cases the sixth channel is used to carry low frequency effects sound.

Multiple Subpicture Streams

The DVD-Video format supports up to thirty-two (32) simultaneous subpicture streams for use as subtitles, closed captions, graphical overlays or simple animation. Each subpicture stream is multiplexed into the overall DVD-Video bit stream so that they are synchronized with the video and audio data. Subpicture streams are stored as Run Length Coded Bit Maps with 2 bits allocated per pixel of data. For countries that use the NTSC television standard Sub-Pictures have a resolution of 720 478 pixels, while in countries using the PAL standard have Sub-Pictures with a resolution of 720 573 pixels. A subpicture is created using only four colors from a 16-color palette, and four unique contrast levels. Special effects such as

scroll up, scroll down, fade in, and fade out can be applied over a sequence of video frames. The sub-picture color palette can be changed for each program chain.

The use of subpicture streams on DVD-Video titles is quite common. Subpictures are routinely used for foreign language subtitles, closed caption, and captions for the hearing impaired. Innovative uses of subpictures have included an animated director commentary where the silhouette of the directors was displayed in the bottom corner of the video display while the director's commentary is played on a supplemental audio track. Subpicture streams have even been used to provide alien language translations in the Klingon language.

High Quality Still Images

The DVD-Video format supports the use of high quality still images that can be displayed for a fixed length of time, or until a defined user input is received. Still images are stored as either MPEG-1 or MPEG-2 I frames (full reference frames). When a still image is encountered in the DVD-Video bit stream the video and sub-picture streams are frozen, and the audio is muted. MPEG-1 still images have a resolution of 352 240 pixels for NTSC, and 352 288 for PAL. MPEG-2 still images have a resolution of 720 480 pixels for NTSC, and 720 576 for PAL. The size of each compressed still image is dependent on its content, and the degree of compression that can be applied without creating digital artifacts.

Navigation & Search Functions

DVD-Video supports a wide variety of navigation and search functions that allow users to control and interact with titles. User controlled search functions include:

Title Search The user can select a specific title from the list of available titles on the DVD-Video disc.

Part_of_Title Search The user can select a specific chapter available on the DVD-Video disk.

Program Search The user can select a specific scene within a program chain.

Time Search User can select a specific time code location within a program chain.

Scan The user can scan either forward or backward in time through the current title.

GoUp The user can jump to the start of the next program chain. Many DVD-Video players include this feature as the Return button on the remote control.

The DVD-Video title author can disable the Part_of_Title, Program, Time, Scan, and GoUp search functions.

Navigation commands allow the DVD-Video author to control the playback of the Title, Part_of_Title, or Program that has been selected by the user. Navigation commands can be used in four different command areas within a DVD-Video title. These are the Button, Cell, Pre, and Post command areas. Navigation commands are all eight bytes, and include Single Instruction Commands and Composite Instruction Commands. Single Instruction Commands

include a single instruction while Composite Instruction Commands can include two or three instructions. There are six different types of Navigation Commands.

GoTo Branch between commands

Link Transfer between the same domain

Jump Transfer between different domains

Compare Recognition of parameter value

SetSystem DVD-Video player system settings

Set: Calculate DVD-Video general parameter values

Additional details on the use of Navigation Commands are provided in Chapter 6, Section "Professional DVD Authoring" on page 183.

System Parameter Registers (SPRM)

There are 24 unique player SPRM, as shown in Table 2.3 (page 26). SPRMs store a fixed length, 16-bit numerical value, and are used to keep track of user preferences as well as player capabilities information. For example if the viewer prefers to see French language subtitles if they are available, then SPRM 17 and 18 will be set up to store that information. Some SPRM registers are set up by the player manufacturer and others are configured by the viewer when the use the DVD-Video players on-screen configuration menus. All SPRM registers can be read during playback of a DVD-Video title using standard navigation commands. DVD-Video titles can be designed to read the SPRM registers and take appropriate action based on the user preferences and player capabilities.

There are also 16 general parameter registers (GPRM) that can be used by the DVD-Video title author to control playback of the title. GPRMs can be used to stored fixed length, 16-bit numerical values, which are treated as unsigned integers. There are two modes of operation for GPRMs, register mode and counter mode. In counter mode the value of a GPRM is automatically increased by one every second. All GPRMs are set to zero and placed in register mode when a DVD-Video title is first started. Chapter 6 provides an in-depth discussion on how to use SPRM and GPRM registers to create highly complex or interactive DVD-Video titles.

Regional Coding

In order to gain the support of the major motion picture studios, the DVD Forum had to modify the original DVD-Video specification to include Region Coding. Region Coding is designed to allow the major motion picture studios to control the release of their titles throughout the world. The world was broken up into eight regions and if a studio only wanted to release a title in the United States, then they would create a DVD-Video title where only Region 1 (North America) playback was enabled. Consumers in other regions of the

world would be unable to play back the title since their player's internal region code would not match the titles region code.

Table 2.3 DVD-Video SPRM Descriptions

#	System Parameter Description	#	System Parameter Description
0	Menu Description Language Code	12	Country Code for Parental Management
1	Audio Stream Number	13	Parental Level
2	Sub-Picture Stream Number	14	Player Configuration for Video
3	Angle Number	15	Player Configuration for Audio
4	Title Number	16	Initial Language Code for Audio
5	VTS Title Number	17	Initial Language Extension for Sub-Pictures
6	Title PGC Number	18	Initial Language Extension for Audio
7	Part_of_Title Number for one sequential_PGC_Title	19	Initial Language Extension for Sub-Picture
8	Highlighted Button Number	20	Player Region Code Mask
9	Navigation Timer	21	Reserved
10	Title PGC Number for Navigation Timer	22	Reserved
11	Audio Mixing Mode for Karaoke	23	Reserved

When a DVD title is manufactured one or more regional codes can be stored on the disc. Similarly, when DVD players and DVD-ROM drives are manufactured, a regional code is stored within the player hardware. The DVD player performs a comparison of its own internal regional code with the code stored on a DVD disc loaded into the player. If the regional codes match, then the DVD player will display the menu of available titles, or will start playing the default title. If the regional codes do not match the DVD player will not provide the user with access to the titles stored on the disc. Regional coding methods have been used for many years by the movie industry to control distribution of their content throughout the world.

For DVD players and titles there are 7 regions that have been defined. A region number superimposed on a world globe is used to identify players and discs. If a disc plays in more than one region it will have more than one number on the globe. DVD-Video regional codes are defined as follows:

1. North America
2. Japan, Europe, Middle East, South Africa
3. Southeast Asia (including Hong Kong)
4. Australia, New Zealand, Central/South America
5. Northwest Asia (including Korea), North Africa

6. China
7. Reserved
8. Airplanes (In-Flight Entertainment)

The use of DVD regional coding is optional for content owners, but mandatory for DVD hardware manufacturers. Content owners can publish their titles using any combination of regional codes that they choose, or none at all. DVD hardware vendors must design their equipment to support the Region Coding system.

Real World Example

StarGaze is a "region-free" DVD title that will work in all DVD-Video players and DVD-ROM enabled personal computers worldwide. There are two primary reasons for deciding to make StarGaze region free. First approximately 30% of the monthly sales volume of my titles are purchased by consumers outside the US. Since I own the world-wide rights to StarGaze, and there are likely to be a fair number of customers outside North America, it makes sense to enable the disc for playback throughout the world. Second, region coding has proved to be a failure. More than 75% of the DVD-Video players in Europe have been modified to play titles from any region, so even if I wanted to limit playback of StarGaze to just North America most Europeans could play the title anyway.

Parental Lock Out

The DVD-Video format supports up to eight levels of parental management, also called parental lockout. Viewers can configure DVD-Video players to require a password when titles above a specific rating level (G, PG, PG-13, R, etc.) are inserted into the player. DVD-Video titles include the rating levels associated with each Title stored on the disc. The player performs a comparison of the rating levels of the content stored on the disc to the parental management level programmed into its memory by the user, and will only provide access to content that is rated equal to or lower than that value. Parental management levels vary depending on the country code of the DVD-Video player.

During the DVD-Video authoring process, only the differences between the various rating levels are encoded and stored on the disc. As an example take a title that has two different ratings, G and PG, based on the presence of a single scene that has some violence. The "G" version of the title substitutes a different, non-violent scene to preserve its G rating, while the PG version will include this scene. Both versions of the scene are encoded and stored on the DVD-Video disc. The DVD-Video author constructs two unique Program Chains, one for the "G" version and the other for the "PG" version. If the user has selected to view the "G" version, the DVD-Video control stream will play the substitute scene at the correct time. If the user has selected to view the "PG" version the original scene with some violence will be displayed.

Copy Protection

The issue of how to protect content once it is distributed on a DVD-Video disc was a major topic of discussion between members of the DVD Forum and representatives from the motion picture and software industries. The launch of the DVD-Video format in the United States was delayed almost a year in order to improve the copy protection features of DVD-Video so that it would satisfy the major motion picture studios. In late June of 1996 representatives from the computer, consumer-electronics and movie industries signed off on a technical working group report that recommended encrypting all data stored on DVD-Video discs and including decryption hardware in DVD Video players. Later that year proposals from the computer industry recommending an alternative method of encrypting portions of the video content were considered and accepted by the Technical Working Group. Finally in November of 1996 all parties agreed to a specific set of analog and digital copy protection methods.

There are currently three forms of copy protection used by the DVD-Video format, Analog Copy Protection (ACP), Copy Guard Management System (CGMS), and Content Scrambling System (CSS).

Analog Copy Protection

The analog copy protection feature of DVD-Video utilizes a proprietary copy protection process developed by Macrovision. Macrovision's DVD copy protection system utilizes two separate copy protection technologies: Automatic Gain Control (AGC) and Colorstripe. The AGC technology for DVD is virtually identical to the Macrovision protection system that has been used to protect prerecorded VHS titles against consumer copying since 1985. The AGC system adds bipolar pulse pairs to the output video signal causing a recording VCR to record a weak, noisy and unstable signal level. The AGC system takes advantage of the difference in the way television and VCR automatic gain circuits work.

The Colorstripe™ technology for DVD is similar to a protection method that Macrovision has implemented in digital set top boxes and digital video networks since 1994. This technology modulates the phase of the colorburst signal in a rapid, controlled manner, which causes annoying horizontal stripes on an unauthorized copy. The Colorstripe™ technology exploits the chroma processing necessary to record and replay the color signals within the limitations of the consumer videocassette formats.

The combination of the Macrovision AGC and Colorstripe™ copy protection technologies will degrade copies made on approximately 95% of consumer VCRs in the market. These copy protection technologies are designed to stop consumers, not professional pirates. Video engineers and others with access to sophisticated professional video equipment, such as time base correctors, can make unauthorized copies of Macrovision copy protected DVD titles.

Additional information on the Macrovision ACG and Colorstripe technologies can be obtained from:

Macrovision Corporation
1341 Orleans Drive
Sunnyvale, California 94089
408-743-8600 (Voice)
408-743-8610 (Fax)
http://www.macrovision.com (Web)

Copy Guard Management System (CGMS)

Digital copying is controlled by information on each disc specifying if the data can be copied. This is a "serial" CGMS designed to prevent copies, or copies from copies. Of course, the equipment making the copy has to abide by the rules. Each sector of data on a DVD-Video disc includes CGMS data that defines how many times the data can be copied. The possible values are zero copies, one copy or infinite copies. If CGMS is set to zero copies then recording devices or computer operating systems should prevent that data from being copied. If CGMS is set to one copy then recording devices or computer operating systems will allow the data to be copied, but the CGMS values of the copied data will be set to zero copies so that additional copies can not be made from the first copy. Finally if CGMS is set to infinite copies then computer operating systems will allow the data to be copied, and the CGMS values will remain unchanged. CGMS information is also encoded into the analog video signal, on NTSC line 21, so that digital recorders with analog inputs can recognize it.

Content Scrambling System (CSS)

CSS uses data encryption techniques to prevent copying media files directly from the disc. All DVD-Video players have a decryption circuit that decodes the encrypted data before displaying it. DVD-ROM drives and MPEG-2 playback boards or software decoders that can be used to play DVD-Video titles exchange encryption keys so that the video is decrypted just before display by the encoder. During 1999 the Content Scrambling System was broken by a group of Linux programmers who wanted to watch DVD-Video titles on their personal computers. DeCSS, a simple hacking program to break CSS, has been published on the Internet, and several motion picture studios and the MPAA have sued these web sites in order to have these programs withdrawn. The MPAA has already been granted several preliminary injunctions directing various web sites to remove DeCSS from their servers. Unfortunately the MPAA and the courts can't possibly keep up with the speed of the Internet, so as soon as DeCSS is removed from one web site it then appears on several new sites. In this day an age of the Wild, Wild Web it will be virtually impossible to keep copies of DeCSS, or any other program that rips or hacks DVD-Video titles off the Internet.

The DVD Forum is currently developing more secure versions of CSS, dubbed CPPM and CPRM that will be used in DVD-Audio, Universal DVD players, and DVD recording devices. Figure 2.11 shows how the current DVD-Video Content Scrambling System works.

All three methods of copy protection are optional for the producer of a disc. These copy protection schemes are designed to guard against casual copying. Professional pirates who have access to high-end video and DVD disc replication equipment will be able to defeat each of these copy protection methods easily.

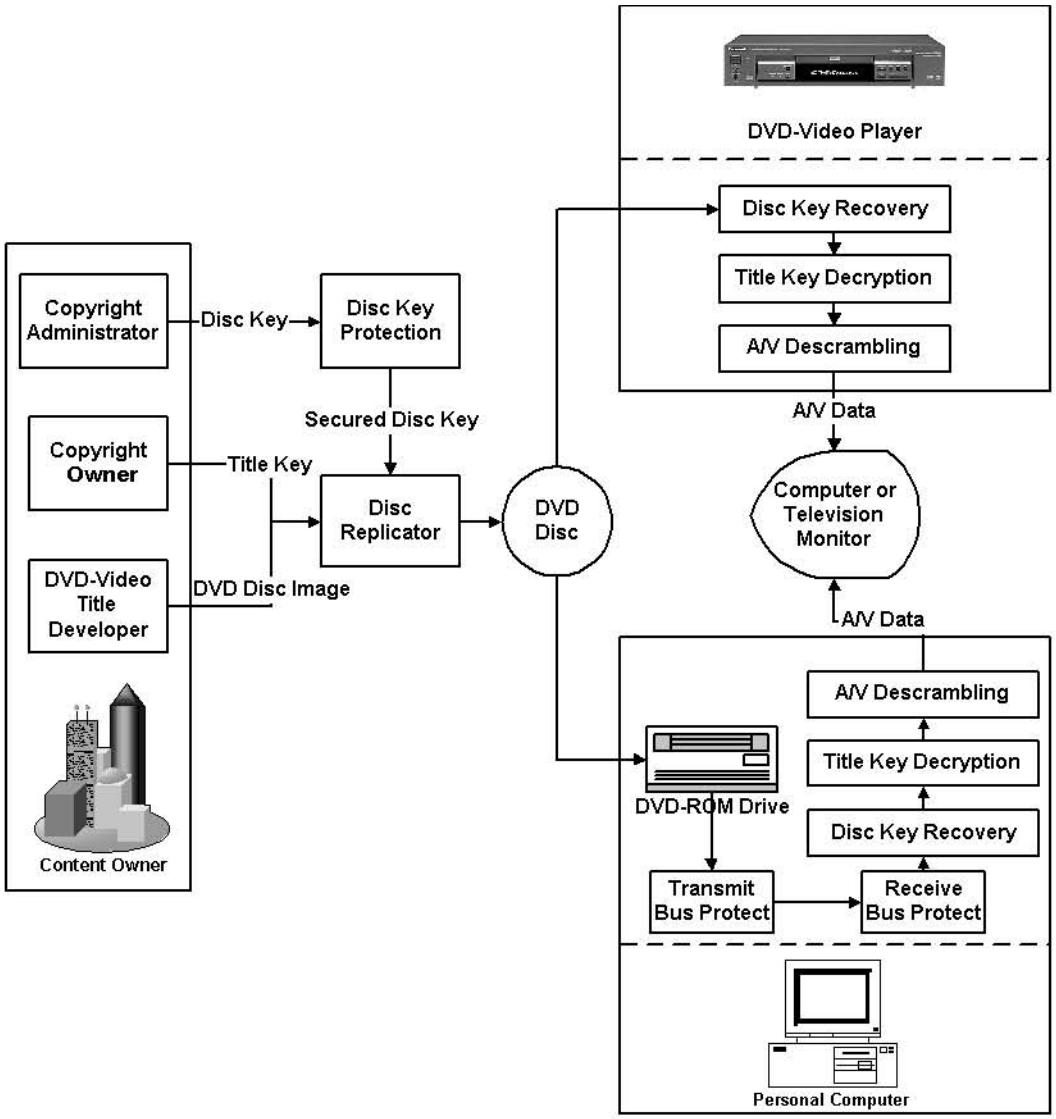

Figure 2.11 DVD-Video Content Scrambling System Block Diagram

DVD-Video Video Object Format

The DVD-Video Video Object (VOB) format is an extremely powerful publishing medium. The VOB format lets you use advanced multimedia features, such as multiple video angles, multiple audio streams, multiple subpicture streams, and seamless interactive branching. While the VOB format is an essential part of the DVD-Video specification, there is a significant potential for its use outside of DVD-Video players. A number of DVD-ROM title

developers will store their multimedia content in the VOB format even though their titles will not be designed to work in DVD-Video players. In the past year a number of DVD authoring tool vendors have released DVD-on-CD products that allow data stored in the VOB format to be transferred to CD-ROM, and then played back on any personal computer, even if it does not have a DVD-ROM drive or DVD-Video decoding software. As more and more companies create development and authoring tools for the VOB format, I predict that it will become a popular publishing format in its own right, independent of DVD-Video playback.

DVD Volume, Directory & File Structure

Figure 2.12 shows the volume, directory, and file structure of a DVD-Video disc. Note that the directory and filenames for a DVD-Video disc are defined in the specification. The `Video_TS` directory on a DVD-Video disc holds all the files that are used for the disc, and it includes three types of files. Information (`.ifo`) files provide all the details on how to access the content stored on the DVD disc. Backup (`.bup`) files are copies of an `.ifo` file stored in a different part of the disc for error recovery. Multimedia content to be delivered by the disc is stored in `.vob` files. The `video_ts.ifo` file contains information required to access content stored in the Video Manager area of the disc.

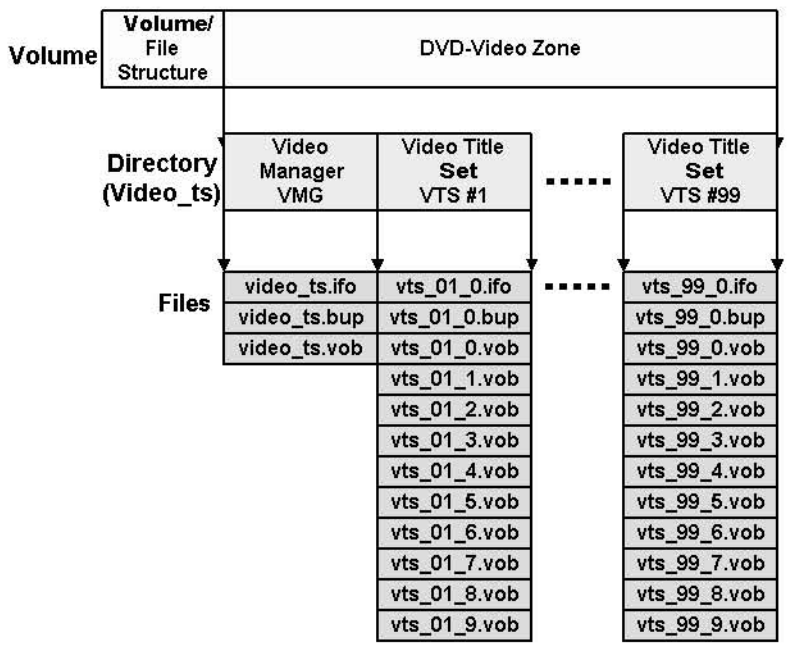

Figure 2.12 DVD-Video Volume, Directory and File Structure Hierarchy

The Video Manager area can include static menus or menus with video and audio content. This multimedia data is stored in the `video_ts.vob` file, which is accessed on a DVD-Video player through the TITLE MENU button on the remote control. A DVD-Video disc can hold up to 99 titles, each of which has its own information file. The information file for the first

title on a DVD-Video disc is vts01_0.ifo, thus vts_99_0.ifo is the information file for the ninety-ninth title. Each title can include static menus or menus with video and/or audio content. This multimedia data is stored in the vts_xx_0.vob file, where xx is the title number. These title menus are usually accessed on a DVD-Video player through the MENU button on the remote control.

The main video, audio, and graphics used in a DVD-Video title are stored in the vts_xx_y.vob files, where xx is the title number and y is a number between one and nine. .vob files are limited to 1 Gb or less in size, so a title with a lot of video and audio content will require a number of .vob files. For example, a full-length movie published on a DVD-5 disc will typically have five .vob files within the main title — vts_01_1.vob, vts_01_2.vob, vts_01_3.vob, vts_01_4.vob, and vts_01_5.vob. The first four .vob files would each be 1Gb, while the last file would be less than 1Gb. If the title developer includes additional content or trailers these are normally stored in a separate video title set and thus would have require a different set of .vob files.

DVD Video Manager

The Video Manager, shown in Figure 2.13, acts like a table of contents for all the data stored in the DVD-Video area of the disc. It includes up to eight different data tables stored in the video_ts.ifo file. Three of these tables are mandatory, two are optional, and three are required only if the Video Manager area includes a static or dynamic menu. The order of the data in the tables is typically as shown in Figure 2.13. Each table in the Video Manager file performs the following function.

1. The Video Manager Information Management Table (VMGI_MAT) provides information on the size of the video manager file, the start address of each table in the Video Manager file, and information about the DVD-Video title such as the number of titles, a volume set identifier, etc.
2. The Title Search Pointer Table (TT_SRPT) provides information on each title included on the DVD disc, such as the type of title (sequential or random), the number of video angles, the number of chapters, the parental ID code, and the start address of the video title set.
3. The Video Manager Menu Program Chain Information Unit Table (VMGM_PGCI_UT) provides information on the different menu languages used in the title menu (if it exists).
4. The Parental Management Information Table (PTL_MAIT) provides information on the parental levels defined for the Video Manager and each title (if parental levels are used).
5. The Video Title Set Attribute Table (VTS_ATRT) provides information on the attributes and start address of each video title set.
6. The Text Data Manager (TXTDT_MG) provides information such as volume name, title name, producer's name, and textual descriptions for each title.
7. The Video Manager Menu Cell Address Table (VMGM_C_ADT) provides the start and ending address of all cells used in the video manager .vob files, if they exist.
8. The Video Manager Menu Video Object Unit Address map (VMGM_VOBU_ADMAP) provides the start address of all video object units used in the video manager VOB files, if they exist.

Video Title Set Information

The Video Title Set Information (`vts_xx_y.ifo`) file contains information required to access and play each of the video titles stored on the disc. This file includes up to nine tables, as shown in Figure 2.14. The order of the data in the tables is typically as shown in Figure 2.14. Each table in the Video Title Set Information file performs the following function.

1. The Video Title Set Information Management Table (`VTSI_MAT`) provides the start address of each of the tables in the `vts_xx_y.ifo` file, as well as information about the title such as the number of audio and subpicture streams.
2. The Video Title Set Part of Tide Search Pointer Table (`VTS_PTT_SRPT`) provides the start address of each chapter within the title.
3. The Video Title Set Program Chain Information Table (`VTS_PGCIT`) provides information for each of the program chains in the title.
4. The Video Title Set Menu Program Chain Information Unit Table (`VTSM_PGCI_UT`) provides information on the existence of Root, Subpicture, Audio, Video Angle, and Chapter menus, and the start addresses, if they exist, for each title.
5. The Video Title Set Time Map Table (`VTS_TMAFT`) provides the start address for each title's timetable, the units of measurement for the time map entries, and up to 2,048 time-map entries to allow searching through the title based on time.
6. The Video Title Set Menu Cell Address Table (`VTSM_C_ADT`) provides the start and end address of each cell in the `vts_xx_0.vob` file (if it exists).
7. The Video Title Set Menu Video Object Unit Address Map (`VTSM_VOBU_ADMAP`) provides the start address of each video object unit in the `vts_xx_0.vob` file (if it exists).

Video Manager (VMG) video_ts.ifo	
Data Table Name	Required?
VMGI_MAT Video Manager Information Table	**Mandatory**
TT_SRPT Title Search Pointer Table	**Mandatory**
VMGM_PGCI_UT Video Manager Menu PGCI Unit Table	**Mandatory if video present**
PTL_MAIT Parental Management Information Table	**Optional**
VTS_ATRT Video Title Set Attribute Table	**Mandatory**
TXTDT_MG Text Data Manager	**Optional**
VMGM_C_ADT Video Manager Menu Cell Address Table	**Mandatory if video present**
VMGM_VOBU_ADMAP Video Manager Menu Video Object Unit Address Map	**Mandatory if video present**

Figure 2.13 DVD Video Manager (VMG) Structure (See color insert for color version of this figure.)

8. The Video Title Set Cell Address Table (VTS_VOBU_ADT) provides the start and end address of each cell in the vts_xx_y.vob file.
9. The video title set video object unit address map (VTS_VOBU_ADMAP) provides the start address for each video object unit in the vts_xx_y.vob file.

Video Object Set

Video Objects are the basic multimedia data type for the DVD format. A VOB includes one video stream, up to eight audio streams, up to 32 subpicture streams, and the navigation information required to connect video objects into program chains, titles, and title sets. Figure 2.15 shows the basic construction of a Video Object Set (VOBS). There are some restrictions on the data rate requirements of a Video Object Set and each of its component multimedia data types.

- The total data rate of a Video Object Set can't exceed 10.08Mbps.
- The maximum data rate of the video stream within a Video Object Set is 9.8Mbps.
- The maximum data rate for a single audio stream in a Video Object Set is 6.144Mbps.
- The maximum total data rate for all eight audio streams is 9.8Mbps.
- The maximum data rate for a single subpicture stream within a Video Object Set is 3.36Mbps
- The maximum total data rate for all subpicture streams is 9.8Mbps.

Video Title Set Information (VTSI) vts_xx_0.ifo	
Data Table Name	Required?
VTSI_MAT Video Title Set Information Management Table	**Mandatory**
VTS_PTT_SRPT Video Title Set Part_of_Title Search Pointer Table	**Mandatory**
VTS_PGCIT Video Title Set Program Chain Information Table	**Mandatory**
VTSM_PGCI_UT Video Title Set Menu PGCI Unit Table	**Mandatory if video present**
VTS_TMAPT Video Title Set Time Map Table	**Optional**
VTSM_C_ADT Video Title Set Menu Cell Address Table	**Mandatory if video present**
VTS_VOBU_ADMAP Video Title Set Menu Video Object Unit Address Map	**Mandatory if video present**
VTS_C_ADT Video Title Set Cell Address Table	**Mandatory**
VTS_VOBU_ADMAP Video Title Set Video Object Unit Address Map	**Mandatory**

Figure 2.14 DVD Video Title Set Information (VTSI) File Structure
(See color insert for color version of this figure.)

As discussed previously and shown in Figure 2.6, a Video Object Set is a collection of VOBs. Video Objects may be divided into cells, each of which is made up of a collection of Video Object units. A Video Object Unit (VOBU) is a sequence of packs, roughly equivalent to a sector on the DVD disc, and will include approximately 0.4 to 1.2 seconds of content. Video Object Units consist of a stream of navigation packs (NV PCK), video packs (V PCK), audio packs (A PCK), and subpicture packs (SP PCK). Video Object Units start with one navigation pack followed by a series of video, audio, and subpicture packs, if required. The Video Object Unit ends immediately before the next navigation pack, or at the end of the Video Object Set.

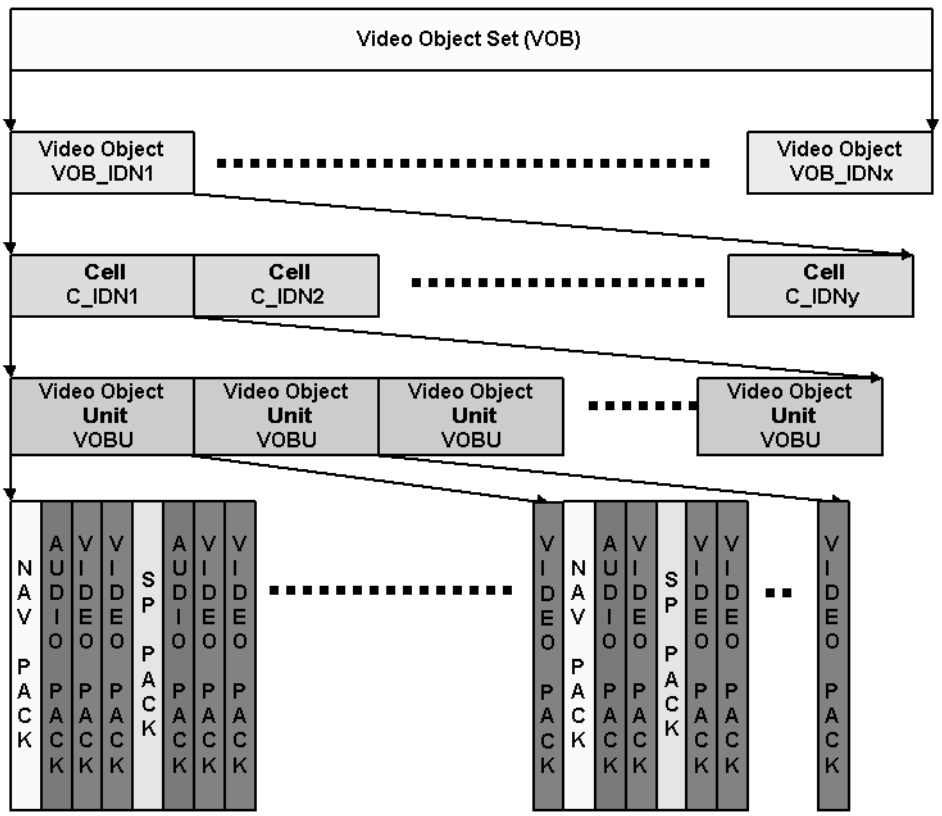

Figure 2.15 DVD Video Object Set Structure – The basic building block of DVD-Video

Why Is It So Complicated?

By now you re probably thinking that using the DVD Video Object format would be a big mistake. Why is it so complicated? Why are there so many different levels of structure, and why are there so many different terms? The DVD Video Object format is designed to deliver an unprecedented combination of video, audio, and graphics data types, at broadcast quality, with near-real-time switching between data streams. As you can see from Figure 2.15, the Video Object Unit, which is the basic building block of DVD-Video, is actually a multiplexed

combination of video, audio, subpicture, and navigation data streams. The individual data packs are small enough so that a DVD-Video player, or a DVD-ROM computer system, can switch playback streams in real time, providing seamless playback from a multitude of video, audio, and subpicture streams.

The advantages of using the VOB format are tremendous: nine broadcast-quality video streams, eight theatre-quality audio streams, 32 high-resolution graphics overlay streams, and seamless branching between any of these streams. Perhaps the biggest advantage is that every DVD-ROM computer system available today has built-in software that handles the VOB format. The disadvantages of using the VOB format are not insignificant. You're required to use directory and file naming conventions of the DVD-Video specification, a complicated hierarchy that is not easy to understand, and it costs more to create your multimedia data files in the VOB format. These disadvantages will be minimized as new, low-cost tools come to market. Authoring tools will hide the complexities of the DVD-Video specification, and the tools you use to generate DVD-Video-compliant files can be expected to drop in price.

DVD-ROM

DVD-ROM is a high capacity, high throughput read-only optical-disc format that can be used as a general-purpose computer storage device. The DVD-ROM format book does not discuss the application programs or content that may be published in the DVD-ROM format. This means that the DVD-ROM format can be used for a wide variety of purposes within a personal computer environment.

The vast majority of DVD-ROM enabled personal computers sold today include hardware or software for playback of DVD-Video titles. In general a personal computer with a 400 MHz or faster CPU can play DVD-Video titles with a "software-only" DVD decoder, while slower systems will need an add-in card to help the CPU decode the MPEG-2 video and Dolby Digital audio streams in real time. Figure 2.16 illustrates the configuration of a DVD-ROM enabled PC with an add-in card for hardware DVD decoding. Personal computers that

use software decoding will have the same basic configuration, except the add-in card will not be required to deliver acceptable playback performance.

Tips, Tricks & Techniques

DVD-Video title developers need to have several different DVD-ROM computers as part of their testing and quality assurance equipment. Many consumers play DVD-Video titles on DVD-ROM enabled personal computer systems, so these playback environments must be tested to insure title compatibility. DVD-ROM systems with hardware and software decoders should be available for testing, as well as PC and Mac systems. A good testing matrix would include the following players and computers.

DVD-ROM Testing	DVD-Video Testing
Windows 95 PC with H/W decoder	Oritron DVD-Video Player
Windows 98 PC with H/W decoder	Panasonic DVD-Video Player
Windows Me PC with S/W decoder	Pioneer DVD-Video Player
Windows NT4 PC with H/W decoder	Sony DVD-Video Player
Windows 2000 PC with S/W decoder	Toshiba DVD-Video Player
Mac OS 9 with software decoder	
Mac OS 9 with hardware decoder	

You're probably wondering why I listed an Oritron DVD-Video player in addition to the name brand players. The Oritron DVD-Video player is generally the cheapest player on the market, and has several known compatibility problems. If your title can work on the Oritron it will probably work on anything. I have not specified Mac OSX in the matrix since it does not currently support DVD-Video title playback.

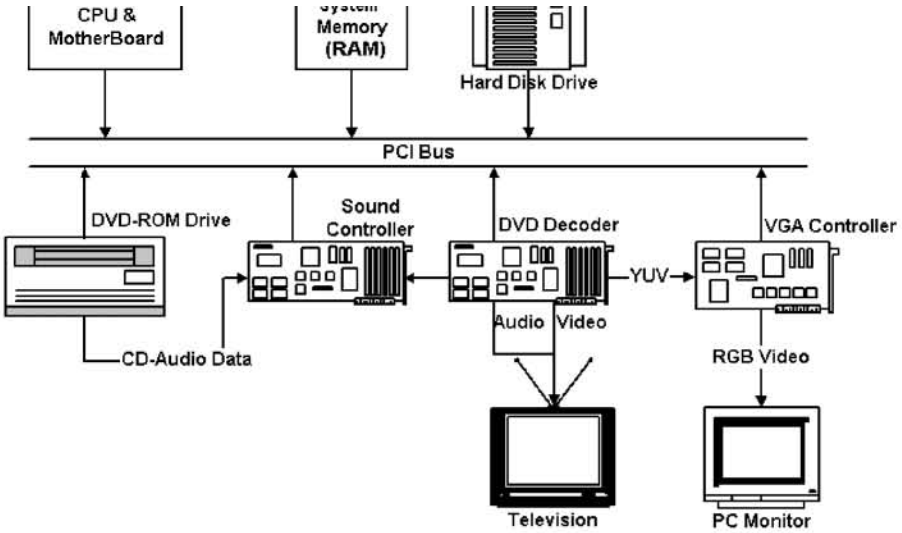

Figure 2.16 DVD-ROM Enabled Personal Computer Diagram

DVD-Audio

DVD-Audio is designed to replace CD-Audio as the primary prerecorded music format. Like DVD-Video, DVD-Audio is built on the foundation of DVD-ROM. So a DVD-Audio disc is actually a DVD-ROM that includes a zone of material supported by the DVD-Audio specification, and may or may not also contain a zone of DVD-Video material. These zones are held in the `Audio_TS` and `Video_TS` directories on the DVD disc.

DVD-Audio incorporates many DVD-Video navigational and architectural features, but it also includes several new interactive and playback features, such as still graphics slide shows. It also supports higher audio fidelity and more flexible multi-channel playback options than DVD-Video. Thus, while the two formats are closely related, DVD-Audio extends DVD-Video to create a truly distinct product tailored for audio-centric applications.

DVD-Audio Features

In developing the DVD-Audio format, the DVD Forum began with a specific set of desired features. The most important of these were:

- High Quality Audio — DVD-Audio is designed to support the very highest quality audio possible.
- Multi-Channel Audio — DVD-Audio is designed to permit extensive multi-channel capabilities, and recognizes that multi-channel programs might be played back in venues where only stereo monitoring is available.

- Additional data — DVD-Audio is designed to support synchronized text data, still images and video.
- Navigation — DVD-Audio is designed to support navigation similar to the DVD-Video format.
- Simple Interface — DVD-Audio is designed to support a simple CD player-like interface for playback settings.
- DVD-Video Compatibility — DVD-Audio is designed to be broadly compatible with DVD-Video and permits utilization of DVD-Video features, where appropriate.
- Copyright — DVD-Audio is designed to support effective anti-copying and anti-piracy measures.

DVD-Audio Players

To ensure DVD-Audio's flexibility across a wide range of applications, the DVD Forum decided not to define a mandatory set of features for all DVD-Audio players. Instead, a DVD-Audio disc can include a variety of different content types, each of which will play back on one or more of several different players. The primary distinction between different players is the availability of a video display device. For a new audio format, it is essential to support playback without a video display, such as in a car, or with a portable player.

The DVD Forum defined five player types that might possibly be used to play back content from a disc in DVD-Audio format. These include:

- A "simple" Audio-only player that has no video output, and navigates the disc linearly using a list of tracks similar to the Table of Contents on a CD.
- A "smart" Audio-only player that gives the user more choices of how to navigate the material on the disc, and may include an LCD display to show song titles and other textual information such as lyrics, but does not include a video display.
- An "Audio-with-Video" player that supports navigational choice and includes video outputs to support multimedia, including visual menus, album artwork, "slide show" graphics and motion video.
- A "Universal" player that offers the same audio and multimedia support as the Audio-with-Video DVD-Audio player, but also plays DVD-Video discs.
- A DVD-Video player, which could be used to play optional video content that has been included on a DVD-Audio disc. Note that DVD-Video players will not be able to play the content stored in the DVD-Audio zone on the disc.