



DVD-Audio for High Quality Music

January 2002

by Graham Sharpless

© 2001 - 2002 Disctronics Manufacturing (UK) Ltd

All rights reserved. No part of this document may be reproduced or transmitted in any form or by any means, including photocopying and recording, without the written permission of the copyright holder.

The information contained in this document is intended to provide an overview and is not a comprehensive description of the technology or processes involved for CD or DVD. Disctronics cannot be held liable for any consequence of using this information. For more complete information the reader is advised to see the appropriate CD or DVD specifications.

Contents

Contents	2
Introduction	3
DVD-Audio Requirements	3
Why DVD-Audio is needed	4
DVD-Audio Success Factors	4
DVD-Audio Specification	5
DVD-Audio Formats	5
Structure of a DVD-Audio Disc	5
Audio coding	7
Meridian Lossless Packing	8
Content Protection.....	9
Additional Content	10
Super Audio CD.....	11
Direct Stream Digital.....	12
Hybrid disc format	12
DVD-Audio Players and Software	12
DVD-Audio Players	13
Surround-sound systems.....	13
DVD-Audio Software	14
Producing DVD-Audio Discs	14
Premastering DVD-Audio	14
Replicating DVD-Audio Discs	16
Disctronics.....	17

Introduction

DVD-Audio is the latest member of the DVD family of pre-recorded optical disc formats and is designed to be the next-generation high-quality audio format. DVD-Audio offers very high quality, surround sound, longer playing times plus additional features that are not available on CDs. DVD-Audio discs can also carry video, like DVD-Video titles, and limited interactivity. Capacity of a single layer DVD-Audio will be at least 74 minutes of high quality full surround sound audio. In addition the disc can accommodate the same audio encoded as Dolby Digital for playing on the existing DVD-Video players.

The DVD Forum working group WG4 developed the DVD-Audio specification, which was originally released in March 1999 but it took another year to add copy protection and watermarking. DVD-Audio players are now available in the USA and Europe and several of the major music companies and some independents have begun to release DVD-Audio titles. By the end of 2002 it is expected that many more DVD players will be capable of playing DVD-Audio discs and that there will be significant growth in sales of DVD-Audio players and discs.

DVD-Audio is not just a niche format for audiophiles, but could grow into a mass-market format suitable for all music genres. With the penetration of home cinema systems growing rapidly in the USA and Europe, the demand for such a format is likely to increase. Also it is believed that car manufacturers will exploit the audio-only capabilities by installing DVD-Audio systems in cars, possibly coupled with DVD-based navigation systems.

Philips and Sony are offering the alternative Super Audio CD (SACD), which also allows a hybrid disc playable on both CD audio and SACD players.

DVD-Audio Requirements

An International Steering Committee (ISC) consisting of the IFPI, RIAA and the RIAJ with the major international music companies, produced a set of recommendations in May 1996:

- Copy protection system.
- Copyright Identification must include the ISRC.
- Anti-Piracy Measures to include SID codes.
- Compatible with CD format
- DVD-Audio discs to carry audio, video and data.
- Conditional Access to additional content on the discs.
- Six audio channels of the highest possible sound quality.
- Accessibility & Disc Functions better than CD players.
- Packaging must not involve a disc caddy.
- Disc durability should be greater than CDs
- Slide show during audio playback.
- One-sided 12-cm disc is favoured.
- Minimum playing time at maximum quality 74 minutes

Since then the ISC and the DVD Forum have worked together on the DVD-Audio specification and promoted the format at a number of venues around the world.

Why DVD-Audio is needed

Some people in the industry have questioned why the DVD-Audio format is needed, since DVD-Video can provide audio, video, stills and navigation. However, while DVD-Video offers multi-channel LPCM audio, the available bit rate is only 6.144 Mb/s compared with DVD-Audio's 9.6Mb/s, which is further enhanced by MLP to offer the maximum sampling rate and quantisation with maximum playing time. DVD-Audio is also designed to play in audio-only players (such as in-car players) and offers slideshows and text that are optimised for audio. Finally DVD-Video offers no content protection for the audio (CSS only protects the video) while DVD-Audio offers CPPM, a content protection system that is much stronger than CSS. These differences are summarised in the table below.

Feature	DVD-Audio	DVD-Video	Comments
Audio bit rate (Mb/s)	9.6	6.144	DVD-Audio allows higher quality
MLP compression	YES	NO	For higher quality & playing time
For audio-only players	YES	NO	Important for mobile players
Copy protection	YES	NO	Required by content owners

For compatibility with existing players, most DVD-Audio titles being released include a DVD-Video compatible zone using Dolby Digital or DTS encoding. This means that each DVD-Audio disc will play in the tens of millions of existing DVD-Video players around the world, although for maximum quality a DVD-Audio player is required.

DVD-Audio Success Factors

For DVD-Audio to be successful the following conditions must be met.

- **Widescale adoption of universal DVD-Audio/DVD-video players.** The additional cost to provide DVD-Audio is small so high-end DVD players will tend to become universal. It will take somewhat longer before mid-range and budget players include DVD-Audio capability.
- **DVD Audio titles to be compatible with DVD-Video.** Almost all currently available titles will play on DVD-Video players, but this compatibility may not be universally adopted for future titles.
- **Wider ownership of home cinema systems.** Forecasts show that home cinema and surround sound penetration is growing rapidly in the USA and Europe.
- **Concerted promotion of the benefits of DVD-Audio.** DVD-Video has benefited from active promotion in most territories. This has increased consumer awareness and resulted in rapid growth. DVD-Audio needs to be promoted in a similar way.
- **Support from major labels.** Several major labels and a number of independents are releasing DVD-Audio titles.

Most of these conditions are being met and it is expected that, with the introduction of more hardware and software over the coming months, DVD-

Audio will become a successful format alongside the DVD-Video format.

DVD-Audio Specification

The main features of the DVD-Audio specification include:

- High quality multi-channel audio with copy protection
- DVD-Audio players will play CDs
- A wide range of quality levels and channels allowing flexibility for the content owner
- Extensible to include new technology when available
- Additional added value content including video, stills, text and menus
- User friendly navigation system
- Connection to the Internet for the latest information for that title

Details of the DVD-Audio specification are given below.

DVD-Audio Formats

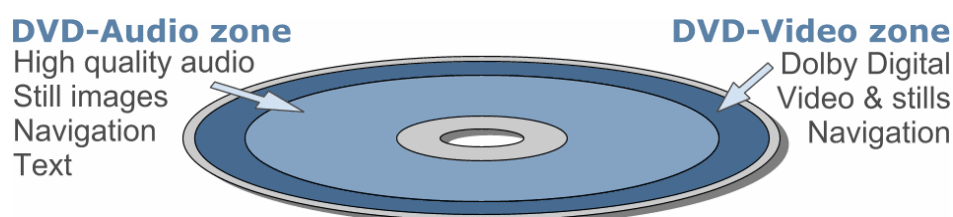
The DVD Forum's WG4 has defined two different versions of the DVD-Audio disc format, one for pure audio applications the other for audio with video. With DVD-Video this gives a total of three formats, which are listed below.

Format	Contents	Will play on
DVD-Audio (no video)	Audio disc with optional text, menus & still pictures but no video	Audio-only, DVD-Audio and Universal players
DVD-Audio (with video content)	As DVD-Audio plus video from a subset of the DVD-Video specification	Universal player and DVD-Video player (video part only)
DVD-Video	Video but no DVD-Audio content	DVD-Video & Universal player

All DVD-audio discs will also play on audio-only players (such as in-car players) with no display screen, similar to CD audio players. Note that it is recommended that all discs should include a DVD-Video section with audio in Dolby Digital format for compatibility with existing DVD players.

Structure of a DVD-Audio Disc

A DVD-Audio disc contains audio, still video and other information on the disc as files. The DVD-Audio data comprises audio objects and management information contained in the directory **AUDIO_TS**. The additional video data on a DVD-Audio disc comprises video objects contained in the directory **VIDEO_TS**. The following diagram illustrates a DVD-Audio disc with additional DVD-Video content.



The **DVD-Audio zone** comprises the following files in the AUDIO_TS directory.

- **SAMG** (Simple Audio Manager) is the equivalent of the CD Table of Contents, allowing playing of tracks on audio-only players.
- **AMG** (Audio Manager) is the table of contents for both the audio and video zones and contains the AMG information and menu.
- **ASVS** (Audio Still Video Set) containing the still images for all audio tracks
- **AOBs** (Audio Objects) containing the audio data.

The audio data comprises a single stream with no other data streams. Therefore it is not possible to interleave audio with other data such as still images. These and other data must be pre-loaded into the player's memory before the audio plays or during pauses, eg between tracks. DVD-Audio discs are not region coded so can be played on any suitable player anywhere in the world.

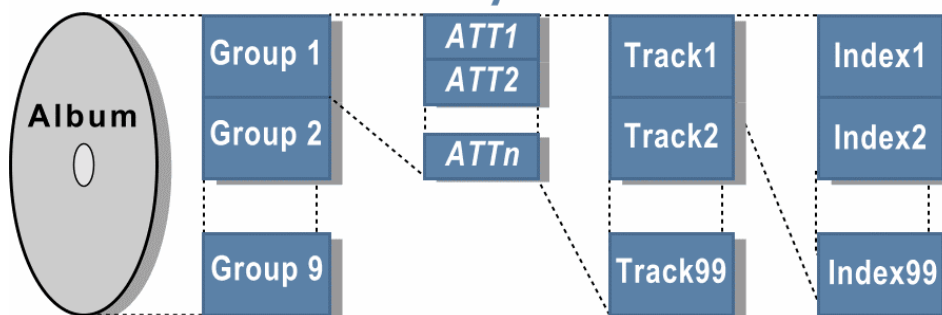
The **DVD-Video zone** can follow the audio data, and comprises video and other files, which should include the same audio as in the DVD-Audio zone but encoded as Dolby Digital. The video files comply with a subset of the DVD-Video specification, with no multi-angle or seamless branching. Due to bandwidth limitations, it is not possible to store high quality audio and video as part of the same video sequence on a DVD disc. Therefore any video on a DVD-Audio disc will use the existing audio coding specified for DVD-Video, including Dolby Digital, DTS and LPCM.

DVD-Audio discs can be any DVD physical format. DVD-5 and DVD-9 discs will contain the DVD-Audio data followed by DVD-Video data (if present) as described above. DVD-10 discs can be used with the DVD-Audio and DVD-Video data on opposite sides.

Groups and tracks

Each side of a DVD-Audio disc is called an **Album**. Each album can be subdivided into a maximum of **9 Groups**, each Group into **99 Tracks** and each track into **99 Indexes**. This structure is shown in the diagram below.

DVD-Audio Disc Hierarchy



For navigation purposes there is an additional layer between Groups and Tracks comprising Audio Titles (**ATTs**). These are logical entities that are used to allocate tracks to Groups. A Group may comprise one or more ATTs and each ATT can link to one or more Tracks. An ATT can be used to play audio tracks only or video content (for video capable players). Note that the ATTs are ignored by audio-only players, which use only the SAMG to play tracks.

Audio coding

The DVD-Audio specification makes use of a scalable linear PCM multi-channel and stereo encoding format, down-mixing control and optional audio formats. The video objects use the same audio encoding as DVD-Video discs.

Parameter	Audio Object	Video Object
Coding mode	LPCM or MLP	LPCM or Dolby Digital
Sampling frequency (kHz)	44.1 to 176.4, 48 to 192	48/96
Bits per sample	16/20/24	16/20/24
Max channels	6 (96kHz), 2 (176.4/192kHz)	6 or 8
Max bit rate (Mb/s)	9.6 (for LPCM)	6.144

As this table shows, DVD-Audio offers sampling rates up to 192kHz for stereo audio and up to 6 channels at 96kHz maximum for surround sound. Audio bandwidths of up to 96kHz are therefore possible with signal to noise ratios up to 144 dB.

Down-mixing

Down-mixing of multi-channel audio to stereo is facilitated by the inclusion of down-mix coefficients to obtain best results. This technique is called **Smart Content** (System Managed Audio Resource Technique). 16 coefficient tables can be re-defined for each Album and the appropriate coefficient table selected from these 16 for each Track. All players must implement down-mixing.

Channel Groups

The maximum data rate for the audio data is 9.6Mb/s, which means that the sampling frequency for multi-channel audio is limited to 96kHz or less. To make best use of the bandwidth available, multi-channel DVD-Audio can be encoded as two **Channel Groups** with different parameters (ie sampling frequency and quantisations) for each group.

The channel groups can be used for any number of channels from three (L, R and C) upwards. Note that the sampling frequencies and quantisations (bits per sample) used must be as shown in the table below.

	Channel Group 1	Channel Group 2
Sampling Frequency	48kHz	48kHz
	96kHz	96 or 48kHz
	44.1kHz	44.1kHz
	88.2kHz	88.2 or 44.1kHz
Bits per sample	16 bits	16 bits
	20 bits	20 or 16 bits
	24 bits	24, 20 or 16 bits

For sampling frequencies of 176.4 and 192kHz the number of channels is two or less, so only one channel group can be used. The following table shows the allowable combinations of channel groups. The meaning of the various symbols is shown below:

L and R: Left and Right channels
C: Centre channel
S: Surround channel
Ls and Rs: Left and Right surround channels
Lfe: Low frequency effects channel

	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5
1	C					
2	L	R				
3	L	R	S			
4	L	R	Ls	Rs		
5	L	R	Lfe			
6	L	R	Lfe	S		
7	L	R	C	Ls	Rs	
8	L	R	C			
9	L	R	C	S		
10	L	R	C	Ls	Rs	
11	L	R	C	Lfe		
12	L	R	C	Lfe	S	
13	L	R	C	Lfe	Ls	Rs
14	L	R	C	S		
15	L	R	C	Ls	Rs	
16	L	R	C	Lfe		
17	L	R	C	Lfe	S	
18	L	R	C	Lfe	Ls	Rs
19	L	R	Ls	Rs	Lfe	
20	L	R	Ls	Rs	C	
21	L	R	Ls	Rs	C	Lfe
	Channel Group 1				Channel Group 2	

Meridian Lossless Packing

To increase the playing time of a DVD-Audio disc to at least 74 minutes per layer for the highest quality and to allow the highest quality for stereo, WG4 has chosen Meridian Lossless Packing (MLP). MLP is easy to implement and will not alter the decoded signal in any way. Decoding MLP requires relatively little computing power even for six channels of 24-bit/96kHz audio.

But how important is MLP? DVD-Audio offers a maximum bit rate of 9.6Mb/s, higher than the 6.144Mb/s possible with DVD-Video but not high enough for 6 channels of 24-bit/96kHz audio, which would require a bit rate of 13.8 Mb/s. Using MLP reduces the bit rate to less than half this and increases the playing time from 65 minutes to at least 74 minutes and allows room for extras such as still images, menus, text and video. MLP provides many more features including the possibility to choose the quantisation in one-bit steps, to allow longer playing times without noticeably reducing quality. The possible sampling rates, quantisation and numbers of channels for both PCM and MLP audio are shown in the table below.

Sample rate	Quantisation (bits)	1 ch	2 ch	3 ch	4 ch	5 ch	6 ch
44.1 or 48 kHz	16 to 24	LPCM or MLP					
96 or 88.2 kHz	16	LPCM or MLP					
96 or 88.2 kHz	20 or 24	LPCM or MLP				MLP	
176.4 or 192 kHz	16, 20 or 24	MLP		Not possible			

Examples of typical playback times with MLP on a single layer disc are shown below for high quality stereo, high quality surround sound and CD quality stereo.

Audio combination	Configuration	Playing time Single layer	Playing time Dual layer
2 channels	192kHz, 24bits	120 mins	215 mins
6 channels	96kHz, 24bits	86 mins	156 mins
2 channels	44.1kHz, 16 bits	13 hours	23.6 hours

Alternative Coding Formats

In addition to PCM audio, other optional audio formats are possible including:

- **Dolby Digital** (AC-3), which is the audio encoding format to accompany the video on a DVD-Audio disc
- **MPEG-1** stereo or **MPEG-2** multi-channel audio
- Others such as **DTS**, **SDDS** etc

Audio using any of these coding formats must be in addition to not instead of the normal PCM audio on a DVD-Audio disc.

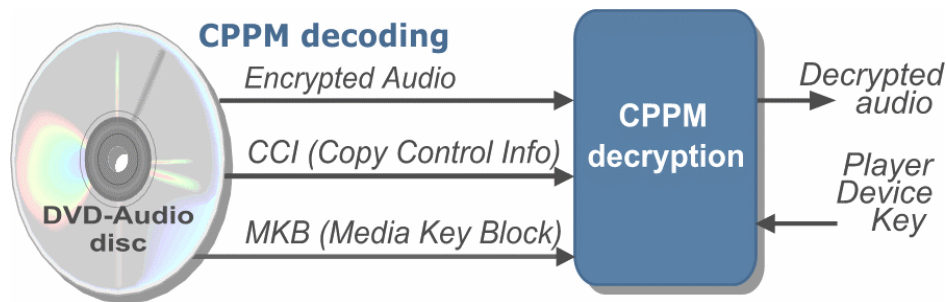
Content Protection

Digital copy protection and watermarking systems have been developed for DVD-Audio.

Digital content protection

Until December 1999, DVD-Audio digital copy protection was to be provided by CSS II. However, the existence of the DeCSS software hack for DVD-Video has meant that a better copy protection was needed for DVD-Audio to prevent a similar occurrence. Content Protection for Pre-recorded Media (CPPM) has been developed by 4C (comprising IBM, Intel, MEI and Toshiba) and uses 56-bit keys, instead of the 40-bit keys used for CSS, and the Cryptomeria Cipher (C2) for content encryption.

It allows for a hacked playback device to be revoked using a Media Key Block (MKB), which contains a very large number of keys. Each licensed decoder model has assigned to it a set of unique device keys that allow it to obtain the Media Key (used to encrypt the audio content) from the MKB stored on each DVD-Audio disc and decrypt the audio content. Any playback device can be revoked in future discs via the MKB. MKBs are unique for every DVD-Audio title and new MKBs must be used every three months to allow devices to be revoked.



CPPM was agreed in mid 2000 and is now available for use by licensees. The decoding process for CPPM protected audio data is illustrated in the diagram above. The MKB files, copy control information (CCI) and encrypted audio are all stored on the disc.

Watermarking

The copy protection scheme for DVD-Audio also includes watermarking, needed to identify music tracks and trigger copy protection systems when recording the content when supplied as an analogue input. The watermark must remain intact when the content is converted to analogue but not be noticeable in listening tests. Watermarks must provide

- Transparency (no effect on audio quality)
- Robustness (be detectable after content processing)
- Security (against forgery)

Verance has created a watermark to meet specifications from the recording industry and is regarded as the "clear winner of multiple competitive industry evaluations". It is a component of DVD-Audio security architecture and adopted for SDMI Portable Device specification. It has been used in consumer products since December 1999.

The watermark contains 72-bits of data comprising 4 CCI (Copy Control Information) bits and 8 Usage Identifier bits every 15 seconds plus 60 Content Identifier bits every 30 seconds.

Verance claims that their technology has been demonstrated to meet all industry requirements and is available for use for DVD-Audio. It is renewable for the future and audio-watermarking technologies can be expected to be appearing in other applications.

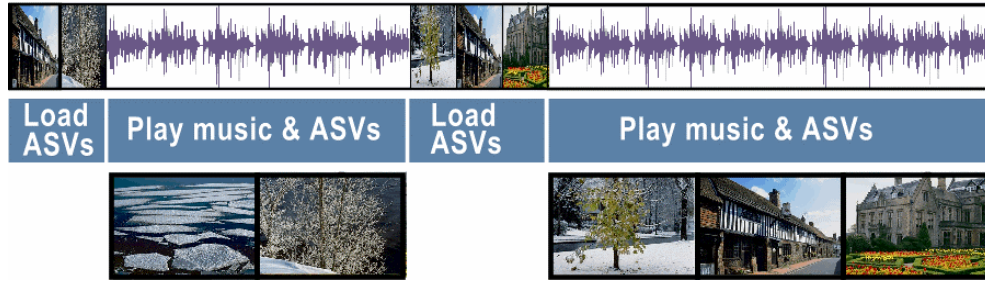
Additional Content

Additional content can include still pictures, text information, menus & navigation and (optionally) video sequences.

Still Images

Still Images, described as Audio Still Video (ASV), are recorded on disc in a separate file. Each still is an MPEG-2 Intra-frame and can, optionally, be accompanied by a subpicture for a menu. Up to about 20 still images are pre-loaded into the player's memory before the audio is played or between audio tracks where a mute is acceptable. This allows the images to be presented either as a slide show or browsable by the user. Transitions for still images include cut, fade, dissolve and wipe. Subpictures allow still images to be used as menus or for the display of lyrics etc. Loading and playing ASVs is illustrated in the diagram below.

Playing music and video stills



Images are either NTSC or PAL compatible. US players tend not to display PAL images, but most European players will probably be capable of displaying both PAL and NTSC images. Therefore titles for global use should use NTSC images. Also for compatibility with both standard (4:3) and widescreen (16:9) displays, two versions of each image will be required.

Text Information

Text is used for the contents, artists' names, Internet URLs, lyrics etc. Static text information can be used for the overall content while dynamic text is suitable for lyrics that change during the audio presentation.

Video contents

Video clips follow the DVD-Video specification but certain functions (including multi-story, parental management, region control, user operation control) are not supported. The audio part of the video may be presented without the video.

Menus and navigation

Menus and navigation can be included as on DVD-Video discs, but with restrictions. These use still images, subpictures, hotspot data and navigation data.

There are only two menu types on a DVD-Audio disc. The **main menu** (which is contained in the audio manager - AMG) provides a full set of commands and the **track level menu** that only allows scrolling forward and back.

Super Audio CD

Philips and Sony have developed an alternative specification called Super Audio CD, which uses a different audio coding method, Direct Stream Digital (DSD) and the (optional) use of a hybrid disc format.

SACD is claimed to fully meet the ISC requirements and to provide a format, which is good for another 20 years. SACD offers high quality, multi-channel audio, CD compatibility, copy protection and added features. The main parameters are shown below.

- Up to 100kHz bandwidth
- 120 dB dynamic range
- Full quality for all channels
- Hybrid disc (CD and DVD)
- Watermarking and copy protection
- Text, graphics and video

Watermarking for copy protection uses pit signal processing (PSP) which, according to Philips, cannot be copied by any known piracy process. There is also a visible watermark.

The SACD specification is contained in the Scarlet Book. SACD discs are DVD discs in that they use the same sector size, error correction and modulation as DVD discs and the same file system (UDF)

Direct Stream Digital

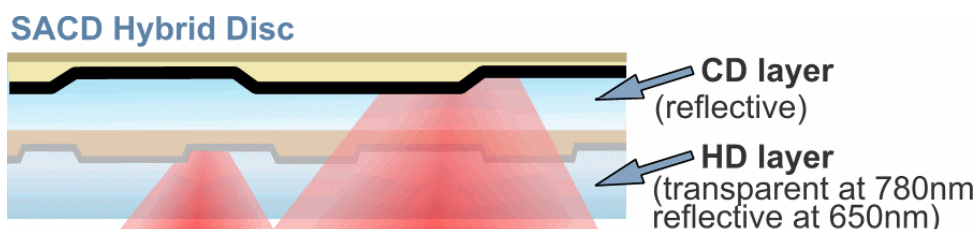
DSD was chosen as the encoding format because it avoids using PCM, which is said to be an unnecessary, intermediate format and DSD is the best format for archiving.

DSD is claimed to offer high quality audio with lossless compression and to be more future proof than PCM. Parameters include 100kHz frequency response and 120dB dynamic range on all channels. Philips and Sony recommend that recording studios use DSD and convert to CD audio using a process called Super Bit Mapping Direct.

But independent studies have concluded that DSD (also called 1-bit sigma delta) suffers from a number of problems that makes it unsuitable for archiving and, possibly, distribution. These problems include non-linearity and high frequency noise. DSD is also not easy to edit without converting to PCM. One conclusion is that DSD makes digital to analogue conversion easier and, in the past, cheaper, but PCM provides a more reliable and accurate representation of the music.

Hybrid disc format

The hybrid CD/DVD disc format allows the same disc to play on existing audio players as well as Super Audio CD players. This is possible by moulding the CD-Audio pits on the outside of the otherwise blank DVD substrate (see diagram below) and using a semi-reflective layer for the DVD metallisation, thus allowing the CD-Audio layer to be read by a conventional CD player.



The result would guarantee that DVD audio discs would be playable on existing CD players, easing consumer fears of obsolescence. However 'hybrid' discs are more difficult and therefore more expensive to manufacture than CDs. It is for this reason that few if any hybrid discs may become available when DVD-Audio and SACD discs and players are launched.

DVD-Audio Players and Software

DVD-Audio players and discs are now available after a significant delay from late 1999 until mid 2000 in the USA and late 2000 in Europe caused mainly by the need to provide strong copy protection. A significant number of players and titles are now available, but it will take some time for DVD-Audio to become a mainstream format like DVD-Video.

DVD-Audio Players

Most DVD-Audio discs will play on existing DVD players, but for best results new hardware is needed. Players of several different types are becoming available.

- **DVD-Audio, audio-only players**, such as in-car players, that have no display screen and can only play the audio track by track like a CD player.
- **DVD-Audio players**, which are designed to play audio only with simple text displays and, optionally, a video output to display slide shows and menus, but not video.
- **Universal players**, which will play both DVD-Audio (including any video) and DVD-Video discs. It is likely that many future DVD-Video players will be universal players. This is because the addition of DVD-Audio capability will not appreciably add to the complexity and cost of the hardware.
- **PCs and Macs** with DVD-ROM drives that can be upgraded

Most available DVD-Audio players are also universal players. Currently players (in Japan, USA and Europe) include the Denon, JVC, Kenwood, Panasonic, Onkyo, Pioneer and Toshiba models, all of which are universal players. The earliest players were expensive but as more models appear prices have fallen. In-car players are also becoming available and may represent an important sector of the market. All players will also play CD audio discs. Some players (eg from Pioneer) are designed to play SACD and DVD-Audio discs.

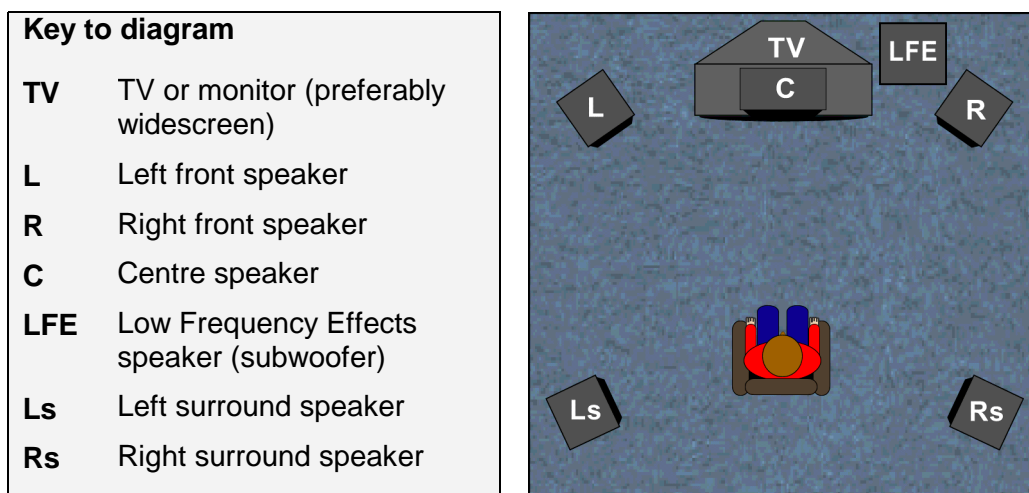
Note that DVD-Audio discs will not play on CD players. SACD discs normally include a CD layer, but the DVD Forum decided not to include this option in the DVD-Audio specification.

Surround-sound systems

Whichever hardware solution is used, DVD-Audio requires a surround-sound system using high quality amplifiers and loudspeakers to take advantage of the high resolution DVD-Audio recordings. The growth in DVD-Video has resulted in a significant penetration of surround sound systems that can also be used for DVD-Audio. A TV or monitor is also required for slideshows and for the optional video on a DVD-Audio disc.

Conventional speakers that can reproduce the full frequency range are both expensive and require a lot of space. Therefore there is now a range of surround sound solutions comprising very small speakers (satellites) plus a subwoofer. The satellite speakers reproduce audio above about 80Hz (or higher for the smallest speakers) leaving the subwoofer to reproduce all sounds below that frequency. This approach works because the low frequency sounds are non-directional. This approach is used even for some professional systems as it allows the satellite speakers and subwoofer to be positioned for best results.

The diagram below shows a possible loudspeaker placement for a surround sound set up with five satellites (or full frequency range speakers) and a subwoofer.



The speakers need a suitable surround sound amplifier that provides sufficient power and can handle both full frequency speakers and satellites/subwoofer systems. For the latter the amplifier will need to provide 'bass management' to direct the low frequency components from all five channels (and the .1 LFE channel) to the subwoofer, which is normally self-powered. The amplifier should also allow configuring each channel for position (ie distance from the listener) and balance.

Some manufacturers offer DVD players with a full surround amplifier and speaker system. Some widescreen TVs include a centre speaker as well as stereo speakers and separate surround speakers. A few models provide a wireless link to the surround speakers to avoid wires trailing across the living room floor. These solutions are compact and suitable for DVD-Video movies but not ideal for DVD-Audio.

DVD-Audio Titles

Some of the major music companies and some independents started releasing DVD-Audio software from late 2000. Warner Music anticipates that DVD-Audio growth will be faster than CD audio and launched over 60 titles in 2001. At the end of 2001 over 120 titles were available from all sources.

Most if not all titles include a DVD-Video zone allowing the audio, in a lower quality, to be played on DVD-Video players. Many titles include added extras to make them more appealing to the consumer. A typical title comprises about 70 to 80 minutes of high quality 5.1 channel music, the same audio in Dolby Digital or DTS coding format, possibly a music video and DVD-ROM content allowing access to the Internet for complementary information.

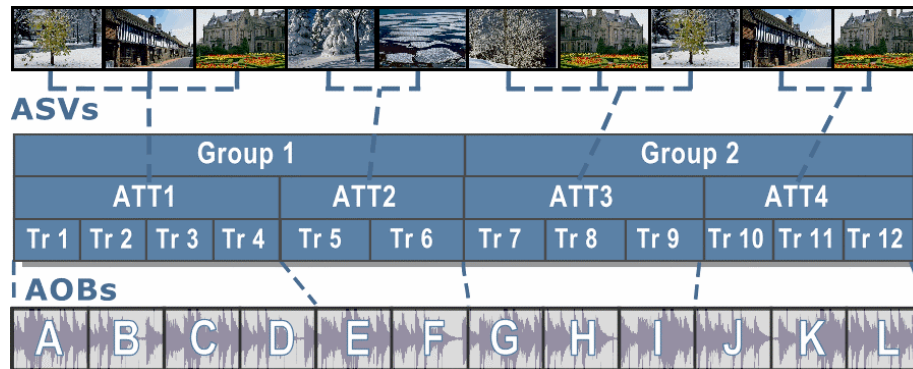
Producing DVD-Audio Discs

Producing DVD-Audio discs is a complex process, which starts with a suitably mixed multi-channel recording and requires premastering followed by disc manufacture.

Premastering DVD-Audio

To make full use of DVD-Audio's multi-channel capability and the high sampling rates available, new recording and editing systems are needed.

A DVD-Audio album can comprise one or more Groups. Each Group can comprise one or more ATT and each ATT can comprise one or more tracks. The navigation data links the tracks to specific audio objects (AOBs). Any AOB can be used more than once by the navigation. ASVs can optionally be linked to particular audio titles or all preloaded before any title plays. An example of the structure of an album comprising 2 Groups, 4 ATTs and 12 tracks plus ASVs is shown below.



The premastering process is complex and comprises the following stages:

- Review specifications with client and develop a detailed storyboard. Confirm assets required and secure legal clearance for all assets.
- Editing/mixing of source audio including creating a surround sound edit from multi-track sources. For audio material that is not in the correct format, this can be a time-consuming and expensive stage. DVD-Audio demands high quality so converting from CD sources is not usually acceptable if maximum quality is required. Ideally the audio should have been recorded for multi-channel surround sound in 96kHz/224 bit resolution.
- Define track start and end timecodes (equivalent to PQ-encoding for CD) and encode audio to MLP (if compression is required). A separate stereo source may be needed at this stage to be included within the MLP audio file. Alternatively down-mix coefficients can be used.
- Acquire and edit the images for the ASVs and convert to MPEG-2 I-frames. Note that at maximum quality a maximum of 20 ASVs can be stored in the player's memory at any time and can be loaded only while the audio is not playing. As with DVD-Video players, DVD-Audio players in the US are unlikely to display PAL images, but European players should display either. Therefore for albums intended for global distribution, the NTSC image size (720 x 480) should be used.
- Acquire and edit any text required.
- Create any DVD-ROM content including web links, simple games etc.
- Author the title to create the navigation, which links the navigation layer to the presentation layer. Since the navigation data for DVD-Audio is stored separately from the assets, which means that the same assets (AOBs and ASVs) can be used in more than one way on the same disc. Authoring includes creating menu graphics and subpictures and defining menu hotspots.
- If CPPM is required it is vital to define a unique **Album ID**, set the Copy Control Information (CCI) and ensure that empty MKB files are included. This should be handled by the authoring tools used.

- Debug and test the finished title, if necessary by writing to a DVD-R (for DVD-5 discs only).
- Write the image data with DDP file to a DLT ready to go to a replicator for glass mastering and replication. It is very important to make contact with a suitable replicator at an early stage in the project. Please contact Disctronics for more information.

These steps do not include any DVD-Video zone that is likely to be needed for compatibility with existing players. This zone must include Dolby Digital (and optionally DTS) audio plus ASVs as still video. DVD-Video allows these images to be loaded and displayed while the audio is playing. Pre-mastering the DVD-Video zone will be identical to normal DVD-Video pre-mastering, although there are restrictions such as no multiple camera angles. Both the DVD-Video and DVD-Audio zones are combined into one disc image before writing to DLT or recording to DVD-R for testing.

Until late 2001, DVD-Audio authoring tools were rudimentary and difficult to use. But there are now systems that are almost as easy to use as DVD-Video authoring systems and allow both dual layer discs to be used and CPPM copy protection.

Some titles are authored for double-sided DVD-10 discs with the DVD-Audio content on one side and the DVD-Video content on the other. This simplifies the authoring process, but is less than ideal for the consumer.

Replicating DVD-Audio Discs

DVD-Audio discs are replicated in the same way as other pre-recorded DVD discs. Any of the physical formats, DVD-5, DVD-10 and DVD-9, are suitable for DVD-Audio. Hybrid SACD discs, which include the CD audio layer, are manufactured differently and can store only 4.7 GB of audio data on one layer.

The glass mastering process is identical to DVD-ROM and DVD-Video except that the CSS copy protection is replaced by DVD-Audio copy protection (CPPM). The replicator is responsible for obtaining the necessary license and equipment for implementing CPPM copy protection.

Moulding, metallising, bonding and printing are no different from other DVDs and there is a range of packaging options available.

Disctronics

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

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

For more information on CD, CD-ROM and DVD replication email **sales@disctronics.com** or visit our website **www.disctronics.com**.

Disctronics Manufacturing (UK) Ltd Southwater Business Park, Worthing Road, Southwater, West Sussex, RH13 7YT, UK	Tel: +44 (1403) 739600 Fax: +44 (1403) 733786 FreePhone: 0800 626698 Email: sales@disctronics.com URL: www.disctronics.com
Disctronics Fulfilment Services Focal Point, Fleming Way, Crawley, West Sussex, RH10 2JY, UK.	Tel: +44 1293 590400 Fax: +44 1293 590471 E-mail: dfs@disctronics.com
Disctronics Texas Inc 2800 Summit Avenue, Plano, Dallas, Texas 75074, USA	Tel: +1 972 881 8800 Fax: +1 972 881 8500 Email: sales@discusa.com URL: www.discusa.com
Disctronics France 24, rue Evariste Galois, BP 35, F-81 001 ALBI Cedex, France 5-7, rue de l'Admiral Courbet, F-94 160 SAINT MANDE, France	Tel: +33 5 63 78 22 50 Fax: +33 5 63 78 22 55 E-mail: jgiraud@disctronics.com Tel: +33 1.53.66.15.40 Fax: +33 1.53.66.15.50 E-mail: cmadsen@disctronics.com
Disctronics Italia SpA Via Rossini, 4 20067 Tribiano, Milano, Italy	Tel: +39 02 90621.1 Fax: +39 02 90630564 Email: atricomi@disctronics.com