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# **DVD-Video: Format & Features**

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# 1. Introduction

DVD-Video was originally designed to meet the requirements of the movie industry, in particular for a complete movie on a single 'compact' optical disc. The use of MPEG-2 video compression has been shown to give superlative results, far better than VHS and better than Laserdisc. DVD-Video also offers full surround sound, subtitling, a choice of display formats and user interaction for non-linear video applications.

DVD-Video players were launched in Japan in November 1996, in the USA in March 1997 and in Europe in 1998. Since then DVD-Video has grown faster than any other consumer electronics format in all these regions. Thousands of titles and millions of players are now in use around the world, with annual sales of players and discs almost doubling each year. Video recorders that use recordable DVD discs are also available to consumers.

The DVD-Video specification was written and is now maintained by the DVD Forum working group WG1, which comprises a number of task groups concerned with both read-only and recordable disc formats.

DVD-Video is now replacing VHS as the format of choice for pre-recorded movies, both retail and rental and disc sales now exceed VHS sales in many regions. With the introduction of recordable versions DVD-Video is now set to replace the VHS for home video recording and playback of pre-recorded video.

This document summarises the DVD-Video format requirements, features, specifications and applications.

## 1.1. DVD-Video Requirements

Recognising the need for a disc-based pre-recorded format for movies, in the mid 1990s the Hollywood based Motion Picture Studio Advisory Committee defined the following requirements:

- 135 minutes on one side of a single disc
- Video resolution better than Laserdisc (LD).
- CD quality surround sound, for true home cinema listening.
- 3 to 5 languages (audio) per title on one disc
- 4 to 6 subtitles per title on one disc
- Pan-scan, letterbox and widescreen formats
- Parental lockout features
- Copy protection
- Compatibility with existing CDs
- Chapter division and access (like Video CD)
- Manufacturing cost similar to current CD costs.

The Video CD format was studied, but was rejected as it could not offer the necessary combination of quality and playing time, hence the need for a new higher capacity disc format that has been realised in DVD. The above requirements have all been met in the DVD-Video specification.

## 2. DVD-Video Features and Specification

The DVD-Video specification was designed to meet the need for storing full-length movies and provides a wide range of features including the following:

- 133 or more minutes of high quality MPEG-2 encoded video with multi-channel surround-sound audio per layer of a DVD disc.
- The choice of widescreen, letter box and pan & scan video formats (though not all on the same disc).
- **Audio** in up to 8 languages
- **Subtitles** for a further 32 languages
- **Menus**, random access and navigation control for user interactivity
- Up to 9 camera angles to give the user more choice
- Digital and analogue **copy protection**

Most DVD-Videos also include extras that cannot be included on a VHS, such as biographies, director's commentary, making of the movie etc. An increasing number include DVD-ROM content, which can range from links to relevant websites to a full game based on the movie. The use of websites can allow the disc to be used in different ways with updated text and graphics information on the website complementing the video on the disc.

### 2.1. DVD Disc Formats & Playing Time

The DVD-Video specification is based on pre-recorded DVD (DVD-ROM) with the UDF Bridge file system. A DVD-Video can therefore be a DVD-5, DVD-9, DVD-10 or DVD-18 disc depending on the playing time required and other factors.

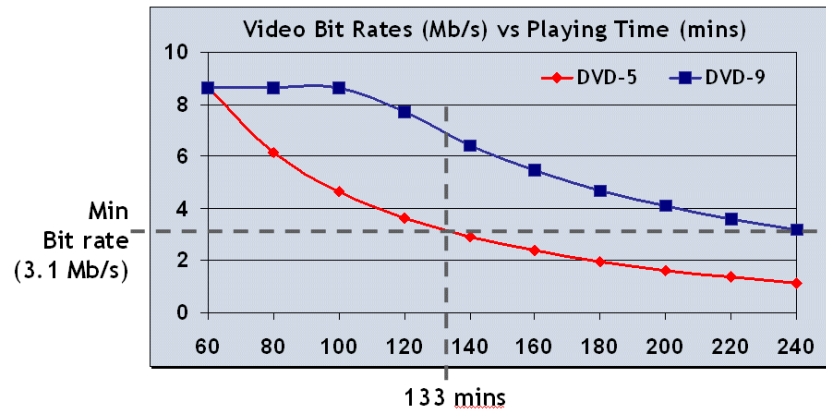
- A **DVD-5** (single sided) DVD-Video disc will hold nominally 133 minutes of high quality MPEG-2 encoded video, together with three surround-sound audio channels and four subtitle channels. (Without video compression one DVD-5 disc would hold only about 3 minutes of video).
- A **DVD-9** (dual layer) disc the playing time increases to 240 minutes of continuous video.
- A **DVD-10** (double sided) disc will hold a nominal 133 minutes on each side (ie 266 minutes in all), but the disc needs to be turned over to play the other side.
- A **DVD-18** (dual layer, doubled sided) disc can hold 240 minutes on each side, but the disc needs to be turned over to play the other side.

### Playing Times and Bit Rates

Unlike audio CDs the playing time is not fixed but can vary. Longer playing times mean lower average bit rates and lower video quality, while shorter playing times allow higher bit rates and higher quality. The use of MPEG-1 video instead of MPEG-2 allows more playing time at the expense of quality. More or fewer audio channels or different audio bit rates also affect the video bit rate and/or playing time.

The maximum bit rate is 9.8 Mb/s for video, audio and subpictures (the overall maximum, including control information, being 10.08 Mb/s). For a playing time of 133 minutes, the average bit rate is 4.7 Mb/s. The average video bit rate available depends on the number of audio streams and the encoding used, but should be at least 4 Mb/s for high quality results. Some recent titles use higher bit rates for the highest video quality.

Figure 1 shows the video bit rate for various playing times. It is assumed that the video is accompanied by 3 Dolby Digital audio streams, each at 448 kb/s and 4 sub-picture streams each at 10 kb/s. For a DVD-5 and the nominal 133 minutes playing time the video bit rate is an average of 3.1 Mb/s. 240 minutes on a DVD-9 allows the same bit rate. But DVD-9s are being used for shorter playing times, to achieve higher bit rates and so higher quality.

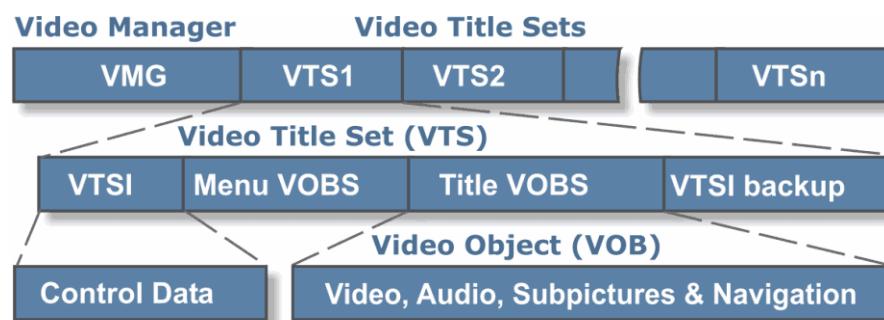


**Figure 1 DVD-Video Playing Times vs Bit Rates**

Note that the maximum video bit rate for this example is 8.4 Mb/s, the remaining 1.4 Mb/s being used for the audio and sub-pictures.

## 2.2. DVD-Video Disc Structure

DVD-Video titles consist of a hierarchical structure as illustrated in Figure 2. A DVD-Video disc is divided into Video Title Sets (or titles). As a minimum there will be one Video Manager (VMG) and one VTS. A disc containing a movie plus documentary about the making of the movie is likely to be divided into two titles. A disc containing six episodes of a TV programme would be divided into six titles. However in both cases it is possible to have only one title per disc.



**Figure 2 DVD-Video Content Hierarchy**

Each Video Title Set Information (VTSI) comprises control data and Video Objects (VOBs) for both menus (if present) and titles (stills and video). Each VOB (the fundamental file element of the disc) comprises video, audio, subpictures and navigation data. When a VOB is played the player not only plays the video sequentially but also obeys the navigation instructions for displaying menus, getting user selections etc.

Each VOB comprises individual cells linked together by Program Chains (PGCs), which provide the necessary interactivity using a simple programming language developed for DVD-Video. PGCs are used to control the playing of

video, audio and subtitles in VOBs, to display menus and input and obey user commands. There are three types of PGC: sequential play, random play and shuffle play. Individual cells may be used by more than one PGC, which can define different sequences through the video content, for example to implement seamless branching. PGCs allow a command set for simple programming including mathematical and logical operators, conditional branching, countdown timer etc. There are 16 general registers for more complex programming and 24 system registers.

### 2.3. DVD-Video Data Streams

To meet the Hollywood requirements, DVD-Video discs are designed to store audio-visual sequences each comprising data streams of four types of data (see Table 1).

**Table 1 DVD-Video Data Streams**

Data type	No. of Streams	Max data rate (Mb/s)	Coding
Video	1	9.8	MPEG-1 or MPEG-2, including stills.
Audio	8 max	6.144	Dolby Digital, MPEG, LPCM etc
Subpictures	32 max	3.36	2 bits/pixel run length encoded
Navigation	1	-	Program Chains (PGCs) for interactivity

The maximum bit rate is 9.8 Mb/s for video, audio and subpictures (the overall maximum, including control information, being 10.08 Mb/s). For a playing time of 133 minutes, the average bit rate is 4.7 Mb/s. The average video bit rate available depends on the number of audio streams and the encoding used, but should be close to 4 Mb/s for high quality results. Higher bit rates are often used to give even higher video quality.

### 2.4. Files and directories

All DVD-Video files are contained in the VIDEO\_TS directory. Table 2 gives an example of these files for a single title set disc. The audio, video and subpictures for the movie are contained in up to 9 Title VOB files per VTS, where each file is not more than 1GB in size. For a DVD-5 there will be no more than 5 VOB files, while a DVD-9 will contain up to 9 VOB files per VTS.

**Table 2 DVD-Video Files**

Filename	Description
VIDEO_TS.IFO	VMGI file (Video Manager Information)
VIDEO_TS.VOB	VOB file for VMG Menu
VIDEO_TS.BUP	VMGI backup file
VTS_01_0.IFO	VTSI file
VTS_01_0.VOB	Video Object Set for VTS Menu
VTS_01_0.BUP	VTSI backup file
VTS_01_1.VOB	First Title Video Object Set file
VTS_01_2.VOB	Second Title Video Object Set file
.....	.....
VTS_01_n.VOB	Last Title Video Object Set file (n < 10)

## 2.5. Video Recording

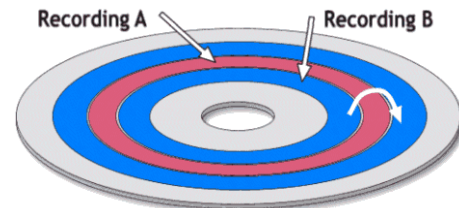
A total of five DVD recordable media formats are available for video recording. These are:

- **DVD-R**, a write-once single-sided format with a capacity of 4.7 GB. Most DVD players will read this format. There are two types: DVD-R for General is intended for consumer applications and DVD-R for Authoring is for professional application.
- **DVD-RAM**, a re-writable single of double-sided format with capacities of 4.7 and 9.4 GB. Very few players will read this format.
- **DVD-RW**, a re-writable single-sided format with a capacity of 4.7 and 9.4 GB.
- **DVD+R**, a write-once single-sided format with a capacity of 4.7 GB, developed by Philips and Sony, but not approved by the DVD Forum. Most players will read this format. About 70 per cent of players will read this format.
- **DVD+RW**, a re-writable format with a capacity of 4.7GB, developed by Philips and Sony, but not approved by the DVD Forum. About 70 per cent of players will read this format.

### DVD vs VHS

DVD offers a number of benefits compared with VHS for recording video.

- DVD offers much higher quality video and audio where the source is of a high quality.
- DVD media does not wear out
- DVD offers fast, random access to content with no rewind/wind needed
- DVD allows editing and playlists.
- DVD recording can be non-contiguous allowing over-recording even if the new recording is longer than the older one (see Figure 3).



**Figure 3 Non-contiguous DVD recording**

### Video recording modes

The DVD Forum has defined the specification for video recording for a range of applications including video camcorders, home recording and recording video on PCs. This provides more features than the DVD-Video specification but is not compatible with most DVD players. There are therefore two video recording modes available.

**Video mode** is identical to the DVD-Video specification and allows video to be recorded to a recordable DVD disc for playback on most DVD players. However editing is very limited using this format.

**DVD Video Recording (DVD-VR)** allows users to record, edit and playback video, as can be done using a VCR. In addition it allows many features that are not possible with a tape-based format. Video can be recorded on any DVD recordable or re-writable format from any suitable source. The following features are possible with DVD-VR:

- Real-time, non-sequential recording allowing spare space on the disc to be utilised and/or defective areas to be skipped.
- Partial deleting and protecting of recorded content.

- Play sequence editing, seamless transitions between sequences and audio dubbing.
- Continuous playback, play lists and trick play.

DVD-VR video is stored in video objects using MPEG-1 or MPEG-2 encoding with additional horizontal picture resolutions of 544 and 480 pixels. Audio encoding can be Dolby Digital, MPEG or LPCM but multi-channel is not possible with LPCM. Sub-pictures are as for pre-recorded DVD-Video, but with some restrictions for display control commands.

Both DVD-RAM and DVD-RW discs can be used for video recording and products are already becoming available. These include both standalone video recorders and camcorders. Prices started quite high but have already started to fall, allowing DVD to replace VHS as a recordable as well as a pre-recordable video format.

## 2.6. Regional Coding & Copy Protection

DVD-Video discs may be region coded to prevent, for example, a US disc playing on a European player and vice versa. This allows titles to be distributed in different parts of the world at different times. A total of six regions (or locales as they are called) have been defined to cover all countries (see table).

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

All players and PCs with DVD must implement region coding, but not all discs need to be region coded.

### Digital copy protection

Digital copy protection is provided by the Content Scrambling System (CSS), which is used to scramble the video data on a DVD-Video disc. Each video title set (VTS) can be selectively scrambled using a unique key. Each unique title is assigned one Disc Key and up to 99 Title Keys (one per VTS), which are stored on the disc in encrypted form.

In the decoder (see Figure 4), the original keys are obtained by decryption and used to descramble the data (see below). For DVD-ROM drives, the MPEG-2 decoder challenges the drive and receives the necessary keys for decryption. This ensures that only approved hardware/software can be used.

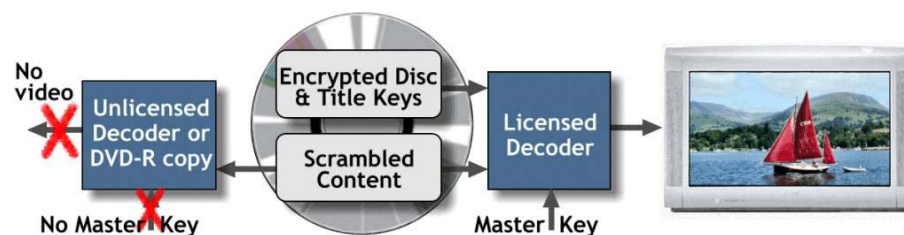


Figure 4 CSS Digital Copy Protection

The keys used should be unique for every disc title and are encrypted by the CSS Licensing Authority and, usually, the scrambling is carried out during glass mastering. Security is vital and the keys used plus the encryption

algorithms must be kept secret. Only those companies involved in designing hardware and software for CSS encoding and/or decoding need information on the algorithms and systems used.

### Analogue copy protection

The Macrovision analogue video protection system is based on Macrovision version 7.0 and is used to distort the composite video output to prevent recording and playback on VHS (see Figure 5). This does not extend to RGB or YUV outputs for which new methods are required and are currently being investigated.



**Figure 5 Macrovision Analogue Copy Protection**

Adding this copy protection to a DVD-Video disc requires the content owner to become licensed by Macrovision and the authoring studio to set a flag to enable APS in the player. This flag is stored on the disc during glass mastering and switches on the Macrovision protection circuits in the player.

### Copying to DVD

Copying to DVD can offer an exact clone. Both CSS and APS can be used to prevent such copying.

- APS, if present on an original DVD, will be detected by a DVD video recorder, which will not make a copy.
- If CSS is used to digitally protect the content, DVD players should output CGMS (copy generation management system) data in the field blanking interval on line 20 or 21 (NTSC) and with the Widescreen Signalling data (WSS) for PAL/SECAM. The result is that a DVD video recorder will not then make a copy of the disc. CSS should also prevent copying to DVD media via a PC.

It is also possible to allow single generation copying to DVD media, but prevent copies of this copy being made. CPRM (content protection for recordable media) will do this in conjunction with DVD media that contains a unique code in the BCA (burst control area) on the disc. CPRM scrambles the data and encrypts the key using the BCA code as a unique media identifier. Since it is unique any copy of this disc will contain the incorrect identifier and will not play.

### 3. Video encoding

DVD-Video uses standard broadcast video formats, which are used around the world and digitally compressed using MPEG encoding.

#### 3.1. Digital Video

Video intended for DVD-Video normally conforms to PAL/SECAM (625 line) or NTSC (525 line) video, although the number of lines may be reduced particularly for MPEG-1 encoding.

- **NTSC** stands for the *National Television Systems Committee* of the Electronic Industries Association (EIA), which prepared the TV standard for the USA, Canada, Japan, Central America, half of the Caribbean and half of South America. NTSC video is usually 525 line, 60 Hz with the number of active display lines being 480.
- **PAL** (Phase Alternation Line) is the TV format used in most of Western Europe, Australia and other countries. When referring to PAL video, what is normally meant is 625 line 50 Hz video, since PAL only refers to the way colour signals are coded for broadcast purposes. The number of active display lines is 576.
- **SECAM** ("SEquential Couleur A Memoire" or sequential colour with memory) is the TV format used in France, Eastern Europe and other countries. Like PAL, SECAM video is 625 line 50 Hz and the number of active display lines is 576.

DVD players, games consoles and other hardware that provide a video output for a TV will use one of these video standards. PCs will use other display resolutions and the video will be displayed either in a window or scaled to full screen. As a result artefacts may occur if not correctly filtered and aspect ratios may not be maintained.

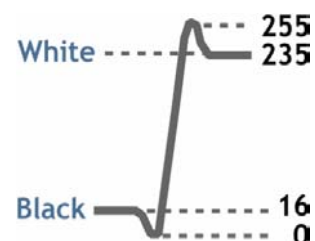
#### CCIR-601 Video Standard

CCIR (the International Radio Consultative Committee) recommendation 601 specifies the image format, and coding for digital television signals.

**Table 3 CCIR-601 Parameters**

Parameter	Value
YUV encoding	4:2:2
Sampling frequency for Y (MHz)	13.5
Sampling frequency for U and V (MHz)	6.75
No of samples per line	720
No of levels for Y component	220
No of levels for U,V components	225

The main parameters of CCIR 601 are listed in Table 3. The number of levels is less than 256 because black is defined as 16 and white as 235 to allow for overshoot in the analogue signal to be digitally coded (see Figure 6). Most digital video recording systems comply with CCIR 601 or a subset of it. CCIR 601 video can be converted to a lower resolution called SIF (Standard Interchange



**Figure 6 Video Levels**

Format) with 240 lines with 360 pixels each for NTSC, and 288 lines by 360 pixels for PAL and SECAM.

### 3.2. MPEG Compression

MPEG (Moving Picture Experts Group) is the ISO committee, which is responsible for defining the various MPEG video specifications, MPEG-1, MPEG-2 and MPEG-4.

- MPEG-1 was originally defined in 1992 and has been incorporated into the Video CD specification.
- MPEG-2 came later and was intended for digital television applications and is used for DVD-Video.
- MPEG-3 was intended for HDTV but was later incorporated into MPEG-2.
- MPEG-4 is intended for video conferencing and similar applications using low bandwidths.

Video comprises sequences of still pictures or frames, which, without compression, would require a data rate far too high even for DVD. Various methods are used to compress the video information contained in these frames.

MPEG encoding divides a video sequence into Groups of Pictures (GOPs). Each GOP comprises a number of contiguous frames. Each video frame is divided into an array of macroblocks, each 16 x 16 pixels in size and comprising four blocks of Y (luminance) and one block each of U and V (colour) information (see Figure 7). The colour information therefore has half the horizontal and vertical resolution of the luminance information. The Y, U and V information in each macroblock is compressed using Discrete Cosine Transform (DCT) encoding and Motion Compensation.

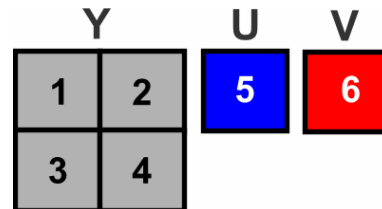


Figure 7 MPEG Macroblocks

#### Direct Cosine Transform (DCT)

Discrete Cosine Transform is used to reduce the data required to represent a single frame. Each of the 6 blocks per macroblock is encoded by carrying out a Fourier transform of the pixels in diagonal lines (see Figure 8) which maps the 8 x 8 block to 1 x 64, prior to DCT encoding. Huffman coding is used to code the DCT data. If bandwidth is limited, the higher frequency components will be missing resulting in a 'fuzzy' result. MPEG encoding can be allowed to degrade in this way to allow for lower bandwidths.

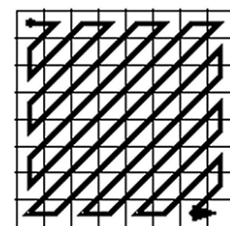


Figure 8 Pixel mapping from 8 x 8 to 1 x 64

#### Motion Compensation

Motion compensation is used to predict the values of pixels by relocating a block of pixels from the last picture. This motion is described by a 2-dimensional vector or movement from its last position. This is particularly useful for pans and other similar movement. Most prediction errors will be small since pixel values do not have large changes within a small area. The error values will therefore compress better than the values themselves. Quantization of the prediction errors further reduces the information.

## MPEG GOPs

Each GOP (Group of Pictures) comprises video frames of three different types. These are I-frames, P-frames and B-frames, which use a combination of DCT and motion prediction for their coding.

- **I-frames** (Intra coded frames) are the first frame of a GOP and use DCT encoding only to compress a single frame without reference to any other frame in the sequence. Typically I-frames are encoded with 2 bits per pixel on average. Since the initial data comprises four bytes of Y, one byte of U and one byte of V (total 6 bytes = 48 bits) per pixel, this gives a compression ratio of 24:1. For random playing of MPEG video, the decoder must start decoding from an I-frame not a P- frame. I-frames are inserted every 12 to 18 frames and are used to start a sequence, allowing video to be played from random positions and for fast forward/reverse. Decoding of video can start only at an I-frame.
- **P-frames** (Predicted frames) are coded as differences from the last I or P frame. The new P-frame is first predicted by taking the last I or P frame and 'predicting' the values of each new pixel. P-frames use Motion Prediction and DCT encoding. As a result P-frames will give a compression ratio better than I-frames but depending on the amount of motion present. The differences between the predicted and actual values are encoded. Most prediction errors will be small since pixel values do not have large changes within a small area. The error values will therefore compress better than the values themselves. Quantization of the prediction errors further reduces the information.
- **B-frames** (Bidirectional frames) are coded as differences from the last or next I or P frame. B-frames use prediction as for P-frames but for each block either the previous I or P frame is used or the next I or P frame. B-frames use Motion Prediction and DCT encoding. Because B-frames require both previous and subsequent frames for correct decoding, the order of MPEG frames as read is not the same as the displayed order. This gives improved compression compared with P-frames, because it is possible to choose whether the previous or next frame is taken for comparison.

These frames are interleaved in a GOP sequence such as **IBBPBBP...** or **IBPBPBBP...** The former is more difficult to encode but provides a higher compression ratio than the latter. For random playing of MPEG video, the decoder must start decoding from an I-frame not a P-frame.

## MPEG-1 compression

In 1992, the ISO MPEG committee published the MPEG-1 specification for compressed digital video as ISO 11172. This standard was designed for non-interlaced displays and to allow 74 minutes of digital video to be stored on a compact disc. The quality is superior to existing digital video formats and represents an international industry standard. Philips, as one of the MPEG contributing companies, adopted MPEG-1 for CD-i and it was subsequently adopted for Video CD.

Figure 9 illustrates the sequence of frames in an MPEG-1 video sequence. Note that the display order is different from the order in which they are read from the disc. Each macroblock of a B-frame is coded as a change from the previous or next P-frame or I-frame. The I-frames are repeated at approximately 0.5 second intervals, otherwise the PBBPBB.. pattern is repeated indefinitely.

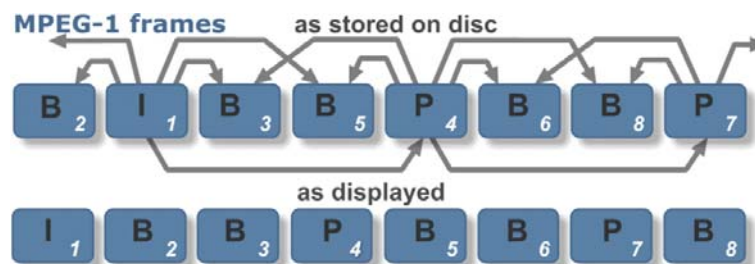


Figure 9 MPEG-1 Compression Frames

For the constrained parameter system, used for Video CD and CD-i, there are a maximum of 396 macroblocks per frame. Therefore the source PAL or NTSC video signal is encoded at SIF resolution, ie half the number of lines per video frame and half the pixels per line compared with CCIR 601.

## MPEG-2 compression

The MPEG-2 specification (ISO 13818) was designed for broadcast TV and other applications using interlaced images. It provides higher picture quality than MPEG-1 but using a higher data rate. At lower bit rates, MPEG-2 provides no advantage over MPEG-1. At higher bit rates (above about 4 Mbits/s) MPEG-2 should be used in preference to MPEG-1. Unlike MPEG-1, MPEG-2 supports interlaced TV systems and Vertical Blanking Interval (VBI) signals.

MPEG-2 also allows variable bit rate (VBR) for lower bit rates without loss of picture quality. VBR encoding uses more data to code those parts of a video sequence which are more complex and do not compress well. CBR, constant bit rate, encoding, means that the video data rate must be high enough to encode the video well. For short videos, where disc capacity is not an issue, CBR, at as high a bit rate as possible, is the better choice.

MPEG-2 uses the same frame types as MPEG-1 except that each frame comprises two interlaced fields. Also each group of pictures (GOP) is 15 (PAL) or 18 (NTSC) frames in length maximum. An example of a typical MPEG-2 sequence is shown in Figure 10. Note that there is only one B-frame between P-frames instead of two for MPEG-1.

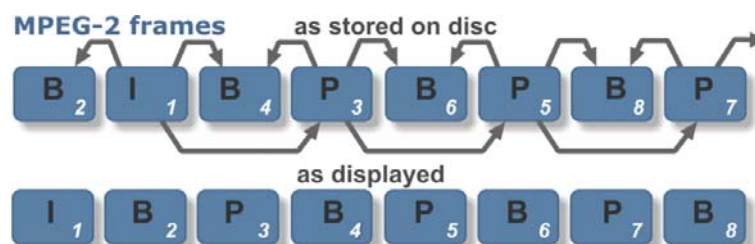


Figure 10 MPEG-2 Compression Frames

The I-frames are repeated at approximately 0.5 second intervals, otherwise the PBPBP.. pattern is repeated indefinitely.

MPEG-2 also includes higher quality audio for full surround sound with 5.1 channels. A 7.1 channel version (with additional left and right centre channels) is also possible.

### 3.3. MPEG Compression for DVD-Video

Both MPEG-1 and MPEG-2 are specified for DVD-Video, but almost all titles use MPEG-2. The image resolutions and other parameters are summarised in Table 4 for both PAL/SECAM and NTSC regions. The former is used in Europe and other areas where 625-line TV systems are used. The latter is used in the USA and Japan for 525-line systems.

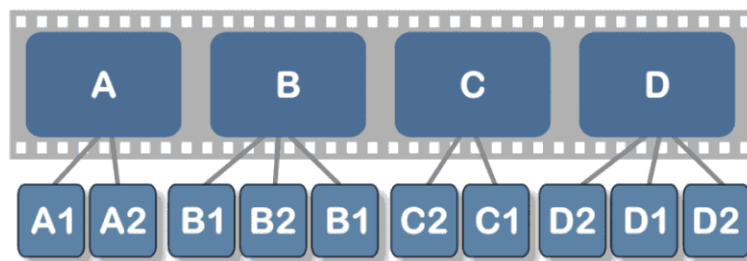
**Table 4 MPEG Parameters for DVD-Video**

Parameter	MPEG-2	MPEG-1
NTSC (525 line) Frame Size (horizontal x vertical)	720/704 x 480 352 x 480/240	352 x 480 352 x 240
PAL/SECAM (625 line) Frame Size (horizontal x vertical)	720/704x 576 352 x 576/288	352 x 576 352 x 288
Variable/Constant Bit Rate (VBR/CBR)	VBR & CBR	CBR only
PAL/SECAM frame rate	25fps	
NTSC frame rate (on disc)	24 or 29.97 fps	

#### PAL and NTSC Frame Rates

DVD-Video can comprise either PAL/SECAM or NTSC video material at frame rates of 24, 25 or 30 fps.

- **PAL/SECAM** video uses a frame rate of 25 fps (frames per second). Source video material will be at this frame rate. Film material will have a frame rate of 24 fps and played back at 25fps (to avoid frame rate conversion) and the audio is pitch corrected before the encoding begins. The result is that PAL movies on DVD-Video are 4% shorter than the equivalent NTSC movie.
- **NTSC** video uses a frame rate of 30 (actually 29.97) fps, which is identical to NTSC video material. Film material is usually converted from 24 to 30 fps by a '3/2 pulldown' whereby certain fields are repeated to convert the 24fps film to 30fps video (see Figure 11). However this is not necessary for DVD since the player can carry out the frame rate conversion. Therefore the video can be stored on disc at 24fps and displayed by the player at 30 fps. The encoder embeds MPEG-2 *repeat\_first\_field* flags into the video stream to make the decoder perform 3/2 pulldown. The two extra fields are B1 (the first field of frame B) and D2 (the second field of frame D).



**Figure 11 3/2 Pulldown**

Both PAL and NTSC versions of the same movie will therefore comprise the same number of frames but as PAL frames are larger than NTSC frames they are likely to require more data rate for the same quality.

## Picture quality

Quality and playing time of DVD-Video discs are much better than VHS and Video CD and somewhat better than Laserdisc.

- Laserdisc stores analogue video, which is composite encoded, so will suffer from noise and other defects due to imperfections on the disc, but can offer high quality video that is close to the best that can be achieved from broadcast TV. Playing time is 60 minutes maximum per side.
- Video CD is a CD-ROM format that uses MPEG-1 so is limited in playing time and video quality. Movies have been released on Video CD, but need 2 discs for a two-hour movie.
- SVCD (Super Video CD) makes use of VBR MPEG-2 to increase the video quality, but playing time is reduced to 40 minutes.

Table 5 provides a comparison between these formats and DVD-Video.

**Table 5 Comparison Between Video Formats**

Feature	Laserdisc	Video CD	SVCD	DVD-Video
Encoding format	Analogue composite	MPEG-1 (CBR) component	MPEG-2 (VBR) component	MPEG-2 (VBR) component
Max image size		352 x 240/288	480 x 480/576	720 x 480/576
Video Bit Rate	-	1.15 Mb/s	2.6 Mb/s (ave)	3.5 Mb/s (ave)
Quality	good	fair	good	very good
Audio channels	2 to 5.1	2	4	5.1
Languages	1	1	2 stereo/4 mono	up to 8
Playing time (mins)	60	74 max	37 at max rate	133 nominal

## Video Screen Formats

The aspect ratio of traditional TV pictures is 4:3 (horizontal:vertical) while movies are generally a wider aspect ratio, up to 2.35:1. A compromise format, 16:9, is now in use for widescreen TVs and, in Europe in particular, for an increasing number of television programmes.

DVD-Video discs can contain video suitable for either 4:3 or widescreen TVs. A total of three screen formats are available (see Figure 12).

- **Widescreen**, which is only suitable for a widescreen TV display, where a 16:9 image is displayed full screen as shown on the right.
- **Letterbox**, where the full widescreen image is displayed but leaving black bars at the top and bottom of the screen.
- **Pan & Scan** where a widescreen movie is displayed as a 4:3 image which is narrower than the original. Parts of the left and/or right of the original image are lost.



**Figure 12 Screen Formats for DVD-Video**

The range of on-disc and display formats are listed in Table 6 below, which shows the options for displaying different source image formats on normal and widescreen displays.

**Table 6 Disc and Display Formats**

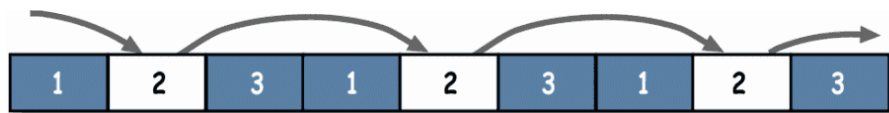
On-disc format	Resultant display	
	4:3 display	16:9 display
4:3 full frame	Full screen	4:3
4:3 letterbox	Letterbox	Widescreen
16:9 no pan & scan data	Letterbox	Widescreen
16:9 + pan & scan data	Letterbox/Pan & Scan	Widescreen

The last format requires data to define on a frame-by-frame basis which part of the image should be displayed. As yet there is probably no title available which uses this format. Instead, DVD-10 discs have been used to offer both pan & scan and widescreen versions on one disc.

Widescreen 16:9 source video is anamorphically squeezed to 4:3 prior to MPEG-2 encoding. This is because the image needs to conform to the 4:3 format on disc, there being the same number of pixels available per line for both 4:3 and 16:9 images. It is then displayed as letterbox or pan & scan on a normal TV or full size on a widescreen TV. A 16:9 image will comprise pixels that are not square, due to the anamorphic squeezing.

### Camera Angles

DVD-Video discs offer the possibility to include up to 9 different camera angles, which can be seamlessly selected by the user. The different but parallel sequences (angles) are interleaved on the disc to allow rapid seeking between them. The result is that the overall data rate available is somewhat reduced to allow for the seek time needed to allow the laser to jump to the next part of each sequence or angle. The reduction in data rate depends on the number of angles included.



**Figure 13 Example of Multiple Camera Angles**

The example in Figure 13 above shows how three angles are interleaved within the video stream (with the audio and any subpictures). Any particular angle (2 in this example) is played by jumping across the others. The need to re-seek at intervals does reduce the overall bit rate. Multiple camera angles can be seamless or non-seamless. Non-seamless transitions happen instantly but there is a break in playback. Seamless transitions are slower but there should be no break in playback.

### 3.4. Video Stills & Subpictures

MPEG-2 still images can be included such as copyright notices, menus or slide shows. These stills are encoded as single I-frames and save disc space if the image is not moving or changing.

Also video sequences can be displayed as stills using the player's still-frame control. A video sequence can also be caused to freeze automatically by

being programmed to do so. The quality of still frames depends on the video material. If a video sequence with movement is paused, any movement between the two fields will prevent the display of a perfectly still image. An example is a person walking or moving their arms. Some players allow a single field to be displayed (but repeated to give a complete frame) to avoid this problem, although the resolution is reduced.

Encoding problems can affect the display of stable still frames. For example incorrect field dominance can produce a still frame that comprises fields from two successive frames. The result will be particularly disturbing at a cut between two scenes. Video from film will not exhibit this problem as both fields of each frame were shot at the same time.

Player controls also allow the video to be played in slow motion (forward motion is relatively smooth as every frame is played but reverse motion plays only the I-frames) and fast forward or reverse (by displaying I-frames only).

## Subpictures

Subpictures are graphics images that can be overlaid on top of video stills or sequences. They can be any height and width up to full screen (720 pixels by 480 or 576 lines) with 4 colours (3 plus transparent) per pixel and are used for subtitles and menus.

- **Subtitles** provide the display of text in any of up to 32 languages per disc to complement the audio language channels. The text is stored on disc as subpictures rather than closed caption encoded characters. This is a more flexible solution that accommodates any character set. The three colours available (plus transparent) can be used to soften/anti-alias the edge of the text characters and/or to make the text more readable against a varying background.
- **Menus** comprise MPEG stills with overlaid subpictures for highlighting menu buttons or for providing additional text/graphics. Here the three available colours can be used to highlight menu buttons when selected by the user.

Subpictures can be changed each frame, may fade in/out, wipe in or scroll up and down the screen.

## Closed captions

In the USA, DVD-Video discs can also provide Closed Captions (CC), which is a feature of a standard NTSC television signal for encoding text, like a simplified version of the teletext services used in Europe. A CC button on the player's remote control is used to display closed captions.

The closed caption data is stored on the DVD disc in the user data in the GOP layer. The player will then output the data on line 21 of the analogue video signal. TVs in the USA include decoders for line 21 data and will display the closed captions on the TV screen.

## 4. Audio Features & Coding

DVD-Video discs can carry up to 8 streams of audio using a number of non-compressed and compressed audio coding methods. Each audio stream can contain from 2 (stereo) to 6 or 8 (surround sound) channels depending on the source material available. Multi-channel audio will be down-mixed to stereo in players where there is no surround-sound decoder. The number of streams available will depend on the number of channels used per stream, the coding method used and the video bit rate needed.

### 4.1. Multi-Channel Surround Sound

Both Dolby Digital and MPEG-2 allow surround sound on 5.1 channels (up to 7.1 for MPEG-2). The channels are:

- Left, Centre & Right front (L, C & R)
- Left & Right surround (Ls & Rs)
- Sub-woofer or low frequency effects (LFE)

Many movies include one or more surround-sound channels usually encoded using Dolby Digital. With the correct surround-sound amplifier and speaker set-up very realistic results can be obtained.

### 4.2. Audio Coding Formats

Normally, when used with video, a compressed format will be used. Audio coding formats available for DVD-Video include Dolby Digital, MPEG-1 & MPEG-2, LPCM and DTS. All DVD-Video discs, both for PAL and NTSC regions, must include Dolby Digital mono, stereo or multi-channel audio as a minimum requirement.

#### Dolby Digital audio

Dolby Digital (formerly known as **Dolby AC-3**) provides up to 5.1-channel surround sound and is currently used in some Laserdisc players and discs as well as DVD-Video. The coding format is lossy so some of the original audio quality will be lost. Bit rates from 64 kb/s (mono) to 448 kb/s are available. Full 5.1 channel surround sound requires at least 384 kb/s, but Dolby recommends using the maximum 448 kb/s. Stereo audio is normally encoded at 192 kb/s.

DVD-Video players will output the 5.1 channel Dolby Digital (excluding the low frequency effects channel) to Dolby Surround (ProLogic) via the analogue stereo outputs for use where there is no Dolby Digital decoder.

#### MPEG audio

The MPEG video encoding formats include audio encoding as well, using lossy compression and is an optional audio format for DVD-Video.

- MPEG-2 provides 5.1 or 7.1-channel surround sound and can be either CBR or VBR. CBR bit rates can be between 32 kb/s and 912 kb/s, typically 384 kb/s, and the sampling rate is 48 kHz. The 7.1 channel option adds left-centre and right centre speakers.
- MPEG-1 layer II stereo audio, as used for Video CD. MPEG-1 can only be CBR with bit rates up to 224 kb/s. Layer III, known as MP3, is not supported in the DVD standard but some players will play MP3 files.

MPEG-1 and MPEG-2 audio coding are identical for stereo audio, so MPEG-2 audio is backward compatible with MPEG-1 decoders.

### LPCM audio

Linear PCM (LPCM) offers an alternative uncompressed audio format that is similar to CD audio, but with higher sampling frequencies and quantisations. LPCM offers up to 8 channels of 48 kHz or 96 kHz sampling frequency and 16, 20 or 24 bits per sample but not all at the same time. These values compare with 44.1 kHz and 16 bits as used for CD audio. The maximum bit rate is 6.144 Mb/s, which is much higher than Dolby Digital or MPEG-2 coding. LPCM offers high quality but its high data rate leaves little bandwidth for video.

### DTS

DTS (Digital Theater Systems) Digital Surround is an optional 5.1 channel audio format that has become quite popular for DVD. DTS uses compression with a sampling frequency of 48 kHz at up to 20 bits per sample. The data rate can range from 64 kbps to 1.536 Mb/s, with typical rates of 768 and 1536.

### Audio for PAL and NTSC areas

The DVD-Video specification defines the use of different audio encoding methods for PAL/SECAM and NTSC areas.

**Table 7 Audio for Different Areas**

Title	Mandatory	Optional
NTSC	Linear PCM or Dolby Digital	Linear PCM, Dolby Digital, MPEG or others
PAL/SECAM	Linear PCM or MPEG-1 or MPEG-2 or Dolby Digital	Linear PCM, Dolby Digital, MPEG or others

If MPEG-2 is used it should be possible to play a stereo down-mix using an MPEG-1 decoder. Players for PAL/SECAM areas should be capable of decoding LPCM, Dolby Digital and MPEG and provide stereo outputs as a minimum.

## 4.3. Multi-language Audio

At least three surround-sound channels are possible while maintaining sufficient data for the video if either Dolby Digital or MPEG-2 encoding is used. Three examples for implementing multiple languages are shown in Table 8 with the corresponding bit rates needed.

**Table 8 Examples of Multi-language Audio**

Option	Description	Data rate
1	1 surround-sound track + 3 mono (centre) speech tracks	$448 + (3 * 128) = 832$ kb/s
2	1 surround-sound track + 3 stereo speech tracks	$448 + (3 * 256) = 1,216$ kb/s
3	3 surround-sound tracks	$3 * 448 = 1,344$ kb/s

## 5. Interactivity

DVD-Video discs offer not just higher quality audio and video than VHS but also random access to any part of the video. Like Laserdisc a DVD-Video disc can be divided into chapters or scenes each of which can be accessed almost instantly. The DVD-Video specification goes even further in providing some limited interactivity so that the user can, for example, access any scene from an on-screen menu or select language, camera angle and other options. Simple game playing is possible using DVD-Video's interactive features.

The user interacts with the disc via the player remote control, which includes some standard control functions and also allows interaction with menus. For movies, menus will be provided giving instant access to individual scenes (chapters) in the movie, to select related information such as biographies of the actors and other related video or graphic material.

The range of interactive controls for DVD-Video is not unlimited. It is not possible, for example, to program a DVD-Video application as a complex video game or interactive training program, both of which require much greater programming flexibility than is available for DVD-Video.

Some DVD-Video discs contain additional content for playing on a DVD-equipped PC, for example to access Internet websites with related content.

### 5.1. Menus & Navigation

Interactivity on a DVD-Video disc is provided as menus, which allow the user to select particular sequences or functions (see Figure 14). Each menu comprises a still image or video loop as background plus up to 36 rectangular buttons, which use subpictures for highlighting. Different versions of the menu are required for widescreen, letterbox, and pan & scan mode. In this case only 12 buttons are available for each, making 36 total.

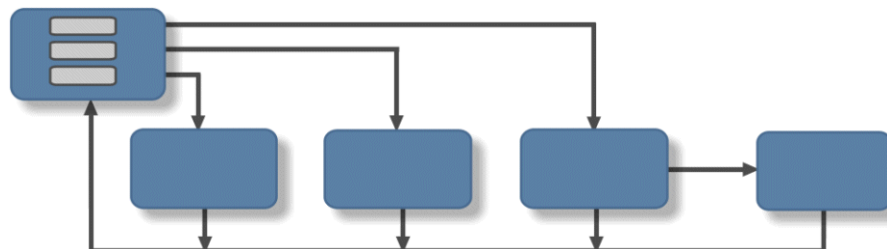


Figure 14 DVD-Video Menus and Interactivity

The user selects buttons, not by moving a cursor, but by using the **Up/Down/Left/Right** arrow keys on the remote control (see below). The three available subpicture colours (the fourth is transparent) can be used to indicate what state the button is in: unselected, highlighted and selected. This provides the necessary feedback to the user. This user interface can be cumbersome but is generally easier to use from a remote control device.

### 5.2. Program Chains

Program Chains (PGCs) are used to provide interactivity using simple program commands. Program chains are used to define menu hotspots, link hotspots to particular actions and to play the video sequences. They can also be used to add conditional branching and other programming features for more complex interactive applications.

### 5.3. Player Controls

DVD-Video players include standard controls for the following interactive features:

- Title selection where there is more than one title on a disc
- Chapter/scene selection
- Bookmarking chapters for later access
- Fast and slow forward and reverse controls
- Angle selection giving the user the choice of different views
- Soundtrack selection of up to 8 audio channels
- Subtitle selection of up to 32 subtitles
- Picture aspect ratio selection

The player remote control (see example in Figure 15) will include a number of standard buttons for controlling the player. These are summarised below and illustrated on the right. Actual players may have slightly different and/or additional buttons compared with those shown.

- 0 to 9: enter Chapter number etc
- TITLE, MENU: display on-screen menu from disc
- Up, Down, Left, Right, Select: select menu buttons
- Play, Pause, Skip, Stop: control playing of video
- Fast reverse, forward: play I-frames in forward or reverse direction at faster than normal speed.
- Slow reverse, forward: play I-frames in forward or reverse direction at slower than normal speed
- Subtitle: switch on/off and select subtitle to be displayed
- Audio: select audio stream
- Angle: select camera angle
- Set-up: set player parameters eg language, audio and display aspect ratio (normal or widescreen)

DVD-Video players can be pre-set eg for the TV/monitor used and the local language for audio and subtitles. These settings will then be used for all DVD-Video discs until changed.



Figure 15 DVD Remote Control

### 5.4. DVD-ROM Content and Internet Access

An increasing number of DVD-Video discs include additional content that can only be used when played on a DVD-equipped PC. A popular example is providing Internet access so that the user can obtain additional information relevant to the content on the disc. The result is that the high quality and bandwidth of DVD can be combined with the latest updates from the Internet. This helps to extend the life of the product, encourage additional use and offers the content owner to promote additional products to the user.

There are two ways that this can be achieved.

1. Links to websites can be used to access a website from a DVD-Video menu. These links will not be accessible when played on a DVD player.

2. HTML code can be used to play the video on the DVD-Video disc. This code can be on the disc or on the website.

Examples include unlocking and playing otherwise hidden content on the disc, playing of video with additional graphics and text from the website and re-using the video for different applications.

### 5.5. Advanced Interactive Features

The DVD Forum has been working on adding interactive features to DVD players and discs so that, for example, Internet access does not rely only on using a PC.

The additional content on DVD-Video discs to enable interactive features is called Enhanced Navigation (ENAV). This additional content must allow existing players to play the DVD-Video disc and is stored on a DVD-ROM 'zone' on the disc and, optionally, on a web server. The ENAV content can be played back by suitably equipped players as well as PCs. New DVD players will therefore be available that will play the ENAV content from the disc and from a web server via a dial-up or broadband connection.

Playability of different types of discs with and without ENAV content is shown in Table 9. The three types of player are:

- DVD-Video player    Current DVD player without ENAV capability
- ENAV player         As above with ENAV capability including a web browser to allow web pages on the disc to be viewed.
- ENAV player + Web    As above but with an Internet connection to allow web pages to be downloaded and viewed.

**Table 9 Disc/Player Compatibility for ENAV**

Disc	DVD-Video player	ENAV player	ENAV player + Web
DVD-Video	Full	Full	Full
DVD-Video + ENAV	Partial	Full	Full
DVD-Video + ENAV + Web	Partial	Partial	Full

The DVD Forum WG-1 has set up two ad hoc groups to create specifications for ENAV based on a wish list provided by working group members. The Optional (ie not mandatory) Specification (version 1.0) for ENAV is planned to be available in 2003. Appropriate guidelines for the implementation of ENAV will also be available.

## 6. DVD-Video Playback Hardware

There is now a wide range of hardware capable of playing DVD-Video titles including DVD-Video players, PCs with DVD capability and set top boxes.

### 6.1. DVD-Video Players

The first DVD-Video players appeared in Japan in November 1996 and in the USA in March 1997. Europe did not see players until a year later and it took another year before they were available in all consumer electronic stores.

All players play all physical formats, ie DVD-5, DVD-9, DVD-10, DVD-14 and DVD-18. All players will also play CD audio discs and most will play Video CD discs. Some recent players will play CDs containing MP3 files. However only high-end players with two lasers are capable of playing CD-R discs since the laser used for DVD is not compatible with the dye used for CD-R discs. Also not all players will play DVD-R discs that are often used to test titles before committing to replication and for short runs. DVD-RAM discs cannot be played on most DVD-Video players.

All players will connect to standard TV via composite video, while most have S-Video output. In Europe the SCART RGB component output is standard but in the USA component output, if present, tends to be YUV instead. Players in the USA output NTSC (525 line) video, while in Europe all players output both PAL (625 line) and NTSC. Some players may convert from PAL to NTSC or NTSC to PAL to avoid problems with TVs not being dual or multi-standard. Players should be set to play discs of only one region (see region coding above) but many now can play discs of more than one region or can be switched between regions using the remote control. This is particularly true of players manufactured in China.

Early low-end players did not include Dolby Digital 5.1 decoding. Now mid to high end players include both Dolby Digital and DTS decoding providing a 6-channel output to external amplifiers. Players without decoders will output digital audio to an external decoder.

### **DVD players don't just play DVDs.**

When DVD players first appeared in 1997/98, they were designed to play DVD-Videos, Video CDs and CDs only. But since then manufacturers have added more and more features to DVD players allowing them to play many more formats.

Some features, such as DVD-Audio, are available only in high end players, but others are available in budget players. For example MP3 audio playback first appeared in budget players from China, but now is found in many players. A more recent feature is the ability to play digital photos in JPEG format from a CD-R as slideshows. Also most players will play CD-Rs, CD-RWs and DVD-Rs, but not necessarily other DVD recordable formats.

So what features should you be looking for when buying a DVD player? The answer depends on what disc formats you want to play. Below is a list of most of the formats that some or all DVD players will accept.

- **DVD-Video:** all players play DVD-Video discs, but usually only in the relevant region. Europe is region 2 and USA region 1, but many players are available as multi-region players. In some cases the region can be changed via the remote control.

- **DVD-Audio:** an increasing number of mid to high end players now play DVD-Audio discs. However, unless you have high quality amplifier and speakers, you may not notice any loss in quality using a normal DVD-Video player as most DVD-Audio discs include DVD-Video content (ie Dolby Digital audio).
- **SACD:** SACD is not a DVD format, but some DVD players include this capability, particularly from Philips and Sony.
- **CD audio:** all DVD players play audio CDs.
- **Video CD and SVCD:** Most players will play Video CDs but not all play SVCDs. The latter offer near-DVD quality video but actual discs are difficult to obtain except in Asia.
- **DVD-R, DVD-RAM & DVD-RW:** Most modern players will play DVD-R discs without any problems, allowing, for example, home movies to be played back. Some, but not all, will play DVD-RW and a few will play DVD-RAM discs. DVD+R and DVD+RW are not DVD formats, and only some players will play these discs.
- **CD-R & CD-RW:** Most if not all modern DVD players will play recordable CDs. To do so requires the addition of a CD laser to the DVD laser pickup, as the dye used in CD-Rs prevents the discs being read by the DVD red laser. Note that such players will also read audio and Video CDs on CD-R.
- **MP3:** Many players also play MP3 compressed audio files on a CD-ROM or CD-R. In the future other formats such as Microsoft's WMA may be supported.
- **JPEG:** A few players play digital photos in JPEG format stored on a CD-R. This is particularly useful for those with a digital camera or for conventional photos that are stored on a CD-R when the film is processed, for example using the Kodak Picture CD format.
- **DVD-VR:** A few players will play recordable discs with video recorded according to the Video Recording (VR) format.

## 6.2. PCs with DVD

The number of PCs with DVD is similar to the number of DVD-Video players. Many of these are used to play DVD-Video discs, as there is a shortage of DVD-ROM titles. As mentioned above, PCs offer additional functionality including Internet access. Adding DVD to an existing PC requires a DVD drive and DVD-Video decoder. The latter can either be software or hardware.

PCs with DVD drives and DVD-Video decoders must implement region playback control (RPC) in conjunction with CSS decoding. For PC implementations, but not standalone DVD players, the DVD Copy Control Association (DVD CCA) has specified that, for drives sold since January 2000, the RPC functions must be implemented in firmware in the drive itself. The user may reset the region up to 5 times and may have this 5 times resetting capability re-established an additional 4 times.

## 6.3. Games Consoles

The first games console with DVD-Video playback capability is Sony's Playstation 2. This was launched in Japan in March 2000 and in the USA and Europe later that year. Other consoles, including Microsoft's X-Box also have DVD capability.

## 6.4. Televisions, Monitors and Sound Systems

For best results DVD movies demand the use of widescreen display monitors and a surround-sound audio system.

### Widescreen TVs

Traditional televisions (Figure 16) have a 4:3 aspect ratio, but movies are filmed in widescreen at up to about 2.35:1. TV broadcasts of movies either use pan & scan to display a part of the movie image at full screen height or display the full width of the movie with black bars above and below the picture.

Widescreen televisions (Figure 17) have a 16:9 (1.85:1) aspect ratio and allow movies to be displayed full width with no black bar or only a narrow black bar top and bottom. TV broadcasts in Europe have been gradually moving towards the 16:9 format for most new programs or the compromise 14:9. As a result widescreen TVs are quite common in Europe, but less so in the USA where screen size seems to be more important.

Widescreen TVs will display the source video in any of the following screen formats:

- 4:3 format with black bars at the side of the screen.
- 14:9 format with narrower black bars at the side, but the top and bottom of a 4:3 image is cut off.
- 16:9 format full width but the top and bottom of a 4:3 source video is cut off
- 16:9 format (sometimes called Movie Expand) where the full height and width of the source video is displayed. This is suitable for anamorphic video such as output by a DVD player from a widescreen DVD-Video disc.

A trend has recently started to integrate other hardware with the TV. Thomson, for example, has released a widescreen TV with an integrated DVD player.

### Surround Sound

A full surround-sound system requires six speakers and a surround-sound amplifier. With conventional speakers this can be both expensive and require a lot of space. Therefore there is now a range of solutions comprising very small speakers plus a sub-woofer. Some manufacturers offer DVD players with a full surround amplifier and speaker system. A few widescreen TVs include a centre speaker as well as stereo speakers and separate surround speakers. At least one model provides a wireless link to the surround speakers to avoid wires trailing across the living room floor.

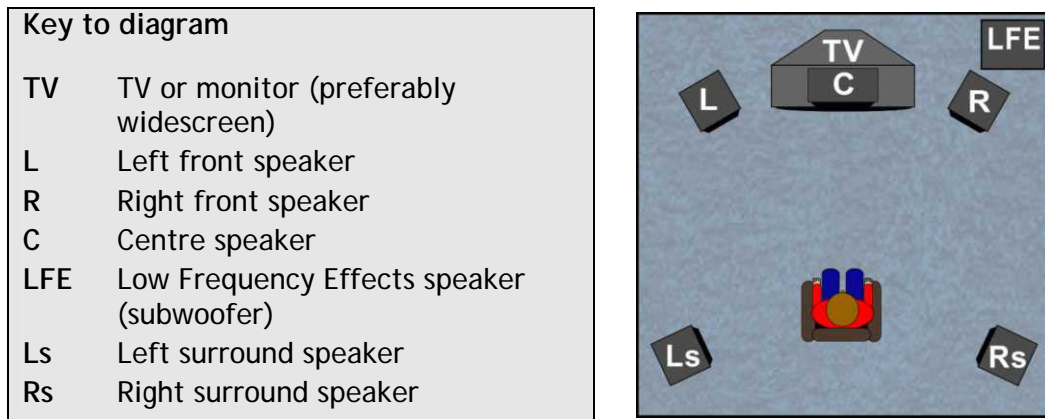
Figure 18 is a diagram of a typical surround sound home cinema set-up with 5 speakers and subwoofer (LFE).



Figure 16 Normal TV



Figure 17 Widescreen TV



**Figure 18 Surround Sound Speaker arrangement**

### Home-Theatre-in-a-Box Systems

There are now many affordable home-theatre-in-a-box systems for DVD available (see Figure 19). These comprise a DVD player, surround sound amplifier, 5 satellite speakers and a subwoofer. With the addition of a widescreen TV they offer a complete home cinema solution that can make best use of DVDs with Dolby Digital surround sound content and can reproduce most of the experience normally found in a cinema. They are also easier to setup with fewer cables needed.



**Figure 19 Home Theatre in a Box**