SONY

# Technical Training

# DVD

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DVD VIDEO ™

SONY

English

# DVD TECHNICAL NOTES

DVD™

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# Welcome to the next generation in optical disc media

## Announcing the Diverse, High Performance World of DVD

The digital audio era began in the fall of 1982 with the release of the Compact Disc and the CDP-101, the Sony's first CD player. The CD represented a true breakthrough in sound reproduction. Just 12 cm in diameter, it was only a fraction of the size of vinyl analog records popular at the time. But the CD, with its highly dynamic, crystal clear sound, not to mention the sheer convenience of random access, soon eclipsed analog records to become a leading form of music software.

The CD format proved too good for music alone. In the 1980s, it was applied in the rapidly progressing computer field as a quick-retrieval data storage system called CD- ROM. Not only is CD-ROM software extremely convenient, it is also remarkably inexpensive to manufacture. The subsequent development of Video CD and Photo CD was proof that the era of optical disc media had arrived.

Interestingly enough, the CD was not the first consumer- use optical disc media. It was preceded by the LaserDisc in 1980. This 30 cm disc, roughly the same size as the analog record, was designed to hold up to one hour of high quality audio and video per disc side.

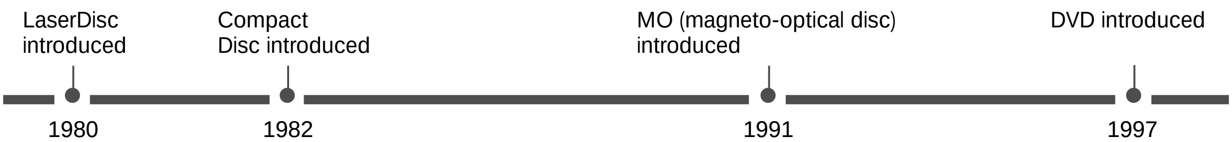
Although the LaserDisc and CD differ in size, signal recording system, and contents, they are fundamentally similar in their method of recording on micron-order pit rows and playback by laser pickup. As the first step toward practical application of optical disc media, the development of the LaserDisc began in the 1960s with the dream of creating "records which can also display images."

In the nearly two decades since the release of the LaserDisc, a broad array of technological advances in basic materials, hardware, software, and digital processing have given birth to an exciting new optical disc video format. DVD-Video is now a reality, offering superior performance in every parameter of operation.

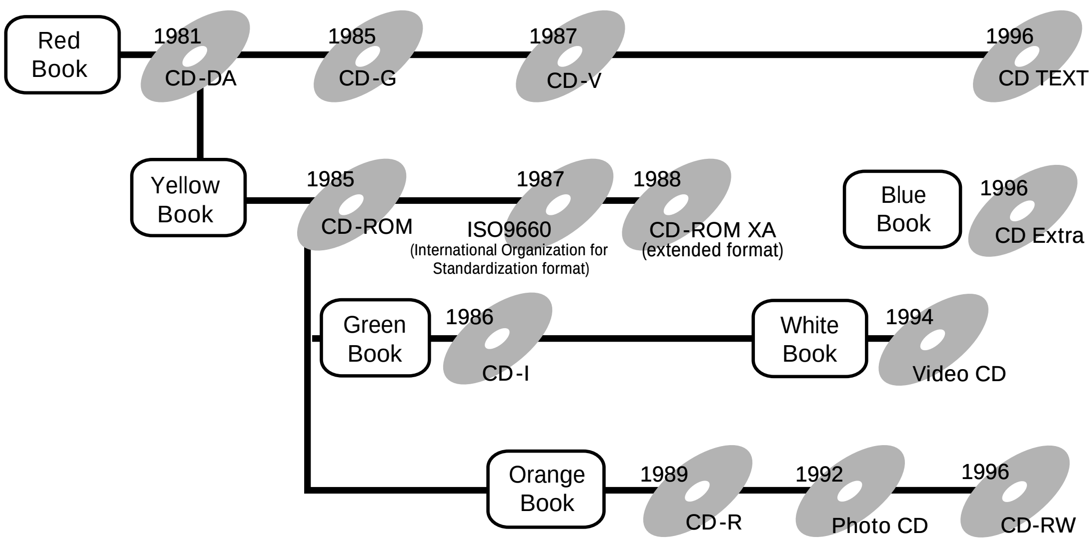
DVD-Video, just one of the many proposed forms of the DVD format, is the same size as the CD, yet boasts far higher data storage capacity. In combination with the highly advanced MPEG2 data compression technology, an entire movie — with multiple soundtracks and subtitle choices — can be recorded and played back on a single disc with full-quality image and sound reproduction.

DVD-Video was joined by DVD-ROM, which was standardized at the same time, then followed by DVD-R and DVD-RAM, which were subsequently standardized, as universal formats. DVD-Audio is currently being studied for standardization. These media are expected to play a central role in the coming age of multi-media and information technology.

■History of Optical Discs




■Evolution of the CD format



# Chapter One

## The High Capacity Optical Digital Disc for a New Era

A remarkably large storage capacity, the primary feature of DVD, has been realized by higher recording density made possible by advanced technology developed after the introduction of the CD. The storage capacity of DVD is 4.7 GB (gigabytes) by recording on a basic single sided, single layer disc. This is approximately seven times greater than that of the CD.

In addition to this basic single side, single layer disc, there are three other types of discs: 1) the single sided, dual layer disc which can store 8.5 GB of data; 2) the double sided, single layer disc; and 3) the double sided, dual layer disc. The latter two, respectively are the double-sided versions of the single side, single layer and single side, dual layer discs. At present, four types of discs have been standardized.

In addition to DVD-Video, DVD-ROM, DVD-R (write-once media) and DVD-RAM (rewritable media), for which specifications have already been published, DVD-Audio is being studied for standardization. This makes for a total of five DVD categories.

In this chapter, our discussion is focused on the physical format and fundamental signal process. DVD-Video will be taken up in Chapter 2.

### Key Points

●High density optical disc for the next generation which realizes a large capacity of 4.7 GB (single side, single layer), approximately seven times greater than that of CD.

●Four disc types: single sided, single layer (4.7 GB); single sided dual layer (8.5 GB); double sided, single layer (4.7 GBx2); double sided, dual layer (8.5 GBx2).

●Minimum pit length and track pitch are approximately one half of those of the CD. Primary technologies which made this high density storage possible are:
 (1) Short wavelength red semiconductor laser.
 (2) Improved numerical aperture (NA) of the objective lens.
 (3) Disc construction using thin 0.6 mm substrate.

●Signal processing capability for the optical disc system was improved in both modulation and error correction.

●Five disc categories have been defined: DVD-Video, DVD-ROM, DVD-Audio, DVD-R, and DVD-RAM.

●Making use of its large storage capacity and interactive characteristics, DVD is more than just a video disc. In the coming multi-media era, DVD represents a new data medium for a variety of applications in many different fields.

# DVD disc construction and high-density recording

Even a single sided, single layer DVD has about seven times the storage capacity of CD. What has made this large storage capacity possible is new technology in high density recording and reproduction.

Minimum pit length in DVD is 0.4 microns, with a track pitch of 0.74 microns. Both are approximately half of those of the CD. This has been made possible by making the laser beam spot much smaller than that of the CD. The main technical approach used to make the laser beam spot smaller is the use of a laser beam with shorter wavelength, and the adoption of a larger objective lens numerical aperture (NA). Improved signal processing of data encoding (modulation format) and error correction and reduction of data redundancy also contributed to an increase in storage capacity. In addition, the storage capacity of DVD can be greatly increased by using both dual layer and double sided configurations.

■Basic Specifications of DVD

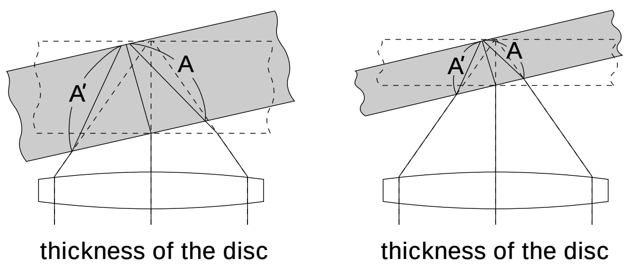
| | disc diameter | disc thickness | minimum pit length | maximum pit length | track pitch | sector alignment | reference scanning linear velocity | file system | modulation | error correction | readout wavelength of laser diode (reference) | NA of objective lens (reference) | data capacity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DVD-Video/ DVD-ROM (Single sided, single layer type) | 120mm | 1.2mm (two 0.6mm substrates bonded) | 0.4μm | 1.87μm | 0.74μm | CLV | 3.49m/s | UDF Bridge (UDF & ISO9660) | EFM plus (8-16) | RS-PC | 650/ 635nm | 0.6 | 4.7GB |
| DVD-Video/ DVD-ROM (Single sided, dual layer type) | 120mm | 1.2mm (two 0.6mm substrates bonded) | 0.44μm | 2.05μm | 0.74μm | CLV | 3.84m/s | UDF Bridge (UDF & ISO9660) | EFM plus (8-16) | RS-PC | 650/ 635nm | 0.6 | 8.5GB |
| CD-ROM | 120mm | 1.2mm | 0.83μm | 3.04μm | 1.6μm | CLV | 1.2～ 1.4m/s | ISO9660 | EFM | CIRC | 780nm | 0.45 | 0.68GB |

## ■Two 0.6 mm substrates bonded back-to-back

The DVD disc itself is 1.2 mm thick and 120 mm in diameter and is made of polycarbonate, the same as a CD. The disc consists of two 0.6 mm thick substrates bonded back-to-back, while the CD is composed of a single substrate. This has an advantage of minimizing the effects of the inclination of recorded surface against the incident laser beam (discrepancy against vertical angle) or tilt angle, thus reducing reading errors and contributing to higher storage density.

■Effects of tilt angle differ by disc thickness.

The thicker a disc is, the larger the difference in length there is between A and A'

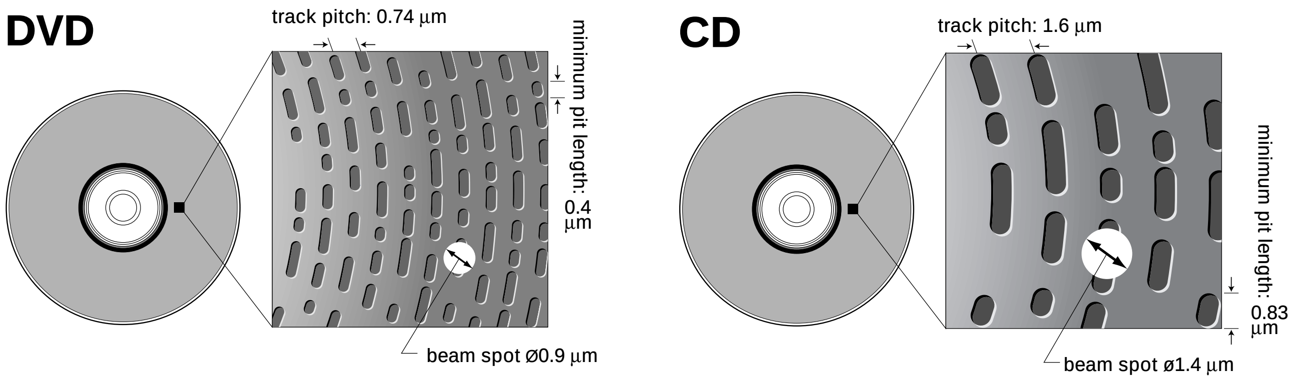



## ■Relationship between the laser beam's wavelength and the NA of the objective lens

The diameter of the laser beam spot is in proportion to the laser beam's wavelength, and is in inverse proportion to the numerical aperture of the objective lens. In DVD, a red semiconductor laser beam with a short wavelength of 650 nanometers or 635 nanometers is employed, while the CD uses a 780 nanometer laser beam. The numerical aperture (NA) of the objective lens of a DVD pickup is 0.6, larger than the 0.45 of the CD. This enables focusing the laser beam to a smaller spot than with the CD, so pit sizes and track pitch can be made smaller, resulting in higher storage density on a given disc size.

The larger the NA of the objective lens, the smaller the tolerance of the tilt angle. However, the DVD uses two 0.6 mm thick substrates bonded back-to-back, and necessary reading precision is maintained. The physical recording density of the DVD is 4.6 times as dense as that of the CD. In addition to these improvements in physical precision, improved signal processing in data encoding (modulation) and error correction also contribute to higher data capacity of the DVD.

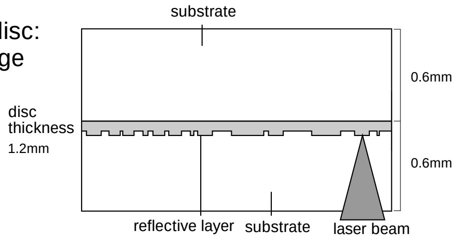
■DVD vs CD in pit length and track pitch



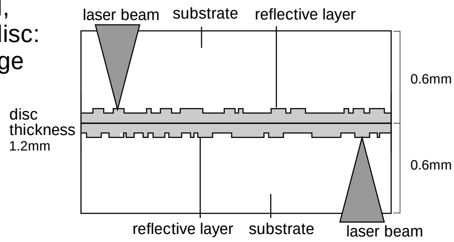
# Four types of high-capacity disc construction

Four different types of disc construction have been standardized: single sided, single layer; single sided, dual layer; double sided, single layer; double sided, dual layer disc. The single sided, single layer disc is quite similar to CD except that its substrate is 0.6 mm thick. The double sided, single layer disc is composed of two single side, single layer substrates bonded back-to-back. The single sided, dual layer disc is a single sided, single layer disc having one more storage layer beyond the first layer. To enable the pickup to read data on the second layer, the first layer is covered by semi-reflective material.

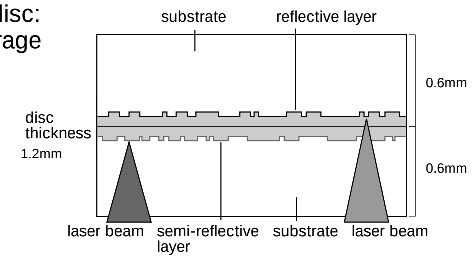
■Single sided, single layer disc: 4.7 GB storage capacity



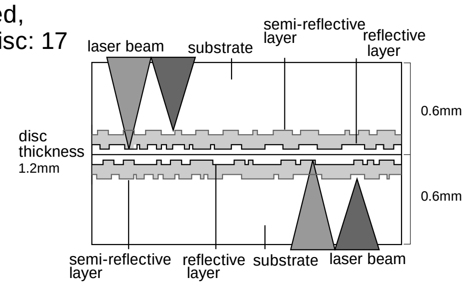

■Double sided, single layer disc: 9.4 GB storage capacity




■Single sided, dual layer disc: 8.5 GB storage capacity




■Double sided, dual layer disc: 17 GB storage capacity

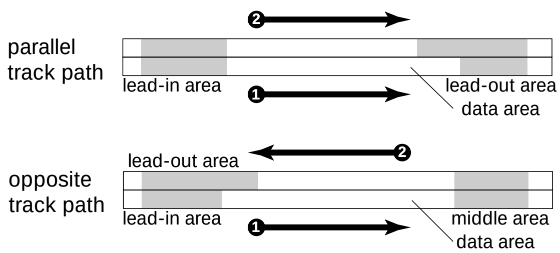



## ■Data reading and recording methods

In the case of the single sided, single layer disc and the single sided, dual layer disc, the data is read from one side of the disc as is done with CD. With the double sided, single layer disc and the double sided, dual layer disc, the data must be read from both sides of the disc. Data is recorded from the inner circumference to the outer, like with CD, except for dual layer discs (both single sided and double sided).

There are two methods of recording dual layer DVD. One method is to record data on both layers from the inner circumference to the outer (parallel track path) and the other is to record data from the inner circumference to the outer on the first layer and from the outer to the inner on the second layer (opposite track path). Data is regarded as a single volume in either method, and producers can select either method depending on the content of the software and the purpose of its expression.

■Recording method for the dual layer disc



# Modulation and error correction in the DVD system

## ■EFM PLUS Modulation

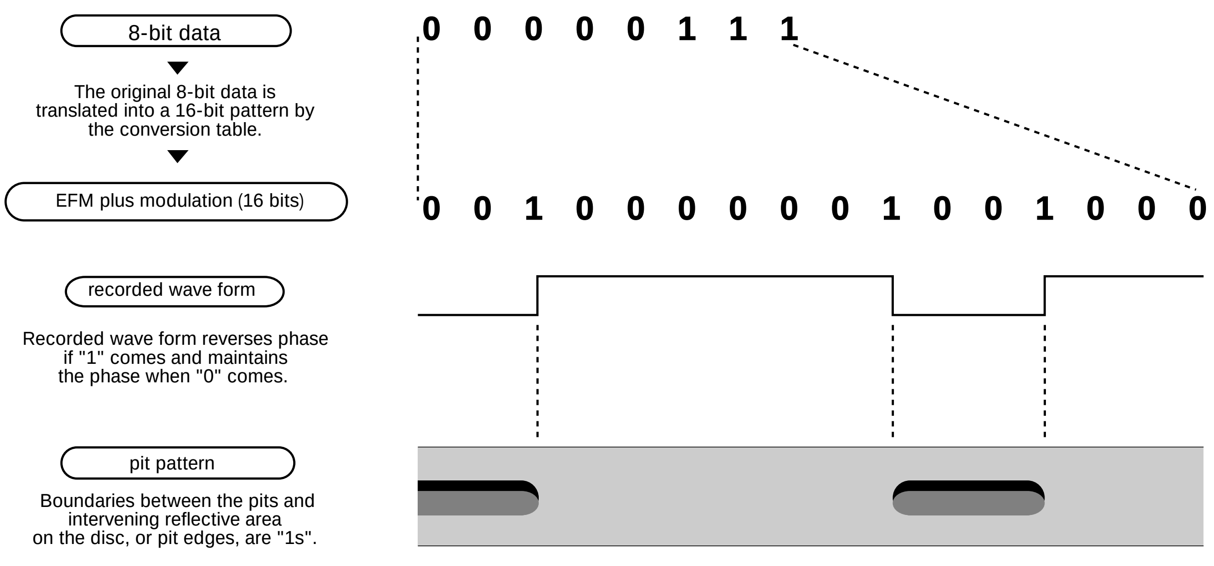
In recording data on the disc, the "EFM plus (8-16 modulation) format" is employed to encode the source data for storage on the DVD. Digital signals are normally encoded prior to recording them on the storage media instead of recording them as they are (taking the CD and DVD as examples; the "0s" and "1s" of the original data are not formed in pits as they are). By EFM the signals, a much larger volume of data can be recorded on a track of the same length. EFM is performed  to improve the efficiency (linear storage density) of the recorded wave form.

In CD and DVD, the original data constructed in 8-bit units are translated into blocks of 14-bit or 16-bit patterns using the  conversion table. (This is called 8-14 modulation or 8-16 modulation.) The edges of pits pressed on the disc indicate where "1s" appear in the successive patterns of "0s" and "1s." The principle of the modulation format called Non Return to Zero Inverse (NRZI) is used here.

The 8-16 modulation of the EFM plus format used in DVD is the improved version of the 8-14 modulation of the EFM format adopted in the CD. This 8-16 modulation may appear inefficient when compared to 8-14 modulation because 16 bits are used instead of 14 bits. In actual practice, however, it achieves a higher storage density. A total of 17 bits (14+3=17) are required because 3 merging bits are used to link the blocks of 14 bits in the EFM, while a multiple number of conversion tables are used (only one conversion table is used in EFM) to suppress indispensable DC components needed to form the optical disc system and merging bits are not required in EFM plus. The EFM plus format increases storage density by approximately 6 % when compared to the EFM format. (Note 1)

Note 1: (17-16)/16=0.0625

■8-16 modulation and pit pattern



## ■DVD error correction system

In digital data media, errors or data dropouts in recording data due to scratches on the disc, disc vibration and other causes need to be corrected. Error correction is done by adding error correcting codes. Data with those codes are modulated, and then pits are formed. By adding those codes, mistakes made in reading data are corrected.
The ratio of added codes in the total data, which includes the original data, is called data redundancy. The RS-PC (Reed-Solomon Product Code) system is used for error correction in DVD. This has more error correcting capability than the CIRC (Cross Interleave Reed-Solomon Code) used in the CD, and also boasts lower data redundancy. Burst error correction capability, which is expressed by how long a pit row on the disc can be corrected, of a DVD player is about 6 mm versus about 2 mm of a CD player.

■Error correction system for DVD

The following explains the principle of data correction in digital data recording:

original data

| | | |
|---|---|---|
| 0 | 1 | 1 |
| 1 | 1 | 0 |
| 0 | 0 | 1 |

error correcting codes are added

Digitized data are arranged in the table as shown on the left.

↓

▼ row error correcting codes

| | | | | |
|---|---|---|---|---|
| 0 | 1 | 1 | 0 | |
| 1 | 1 | 0 | 0 | |
| 0 | 0 | 1 | 1 | ◀ (a) |
| 1 | 0 | 0 | ◀ column error correcting codes | |

For example, a code is added to make the number of “1” in the row and column even.

Taking (a) as an example, a code “1” is added to make the number of "1" in the row "001" even.

↓

An error occurs when reading data on the disc.

| | | | | |
|---|---|---|---|---|
| 0 | 1 | 1 | 0 | |
| 1 | 1 | 0 | 0 | |
| 0 | 1 | 1 | 1 | ◀ (A) |
| 1 | 0 | 0 | | |
| | ▲ (B) | | | |

The number of “1” in the row and column is checked.

The number of “1” is decided to be even after a code is added, so an error must be generated somewhere in either row (A) or column (B).

↓

locating and correcting an error

| | | |
|---|---|---|
| 0 | 1 | 1 |
| 1 | 1 | 0 |
| 0 | 0 | 1 |

The data where the row (A) and column (B) cross is erroneous data. There is a “1” which is an error and we know the correct value is “0”. The data is restored to the correct value.

Naturally, the error correction system actually employed is much more complicated, and it can correct more complicated errors.

# Five diverse formats make up the DVD format group

In the DVD format group, there are five format variations: DVD-Video, DVD- ROM, DVD-R, DVD-Audio, and DVD-RAM. They can be classified by the kind of data application and whether it is read-only or read-writable. The physical and logical formats for each format are defined in published specifications; DVD-Video in Book B, DVD-ROM in Book A, DVD-R in Book D and DVD-RAM in Book E. Specifications for DVD-Audio is currently under study as Book C, respectively Looking at these five DVD categories from the standpoint of the physical format; the read-only types such as CD-ROM (Book A), DVD-Video (Book B), and DVD-Audio (Book C) use the same format, while the recordable DVD-R (Book D) and DVD-RAM (Book E) use independently separate formats. As a file system for use with personal computers, the UDF subset is employed on the read-only disc to facilitate compatibility.

■Five DVD format variations

| Designation | Type | Application | Status of specs |
|---|---|---|---|
| DVD-Video | Read only | High quality package media for movie film software with pictures and sound | Specs published in Sept. 1996 (Book B) |
| DVD-ROM | Read only | Large capacity data media that allows high quality multi-media application programs for use with computers. | Specs published in Sept. 1996 (Book A) |
| DVD-Audio | Read only | High sound quality package media specifically for music | Under study |
| DVD-R (Write Once) | Write once | Large capacity and write once data media for computers | *Specs published in July 1997 (Book D) |
| DVD-RAM (Rewritable) | Rewritable | Large capacity and rewritable data media for computers | **Specs published in July 1997 (Book E) |

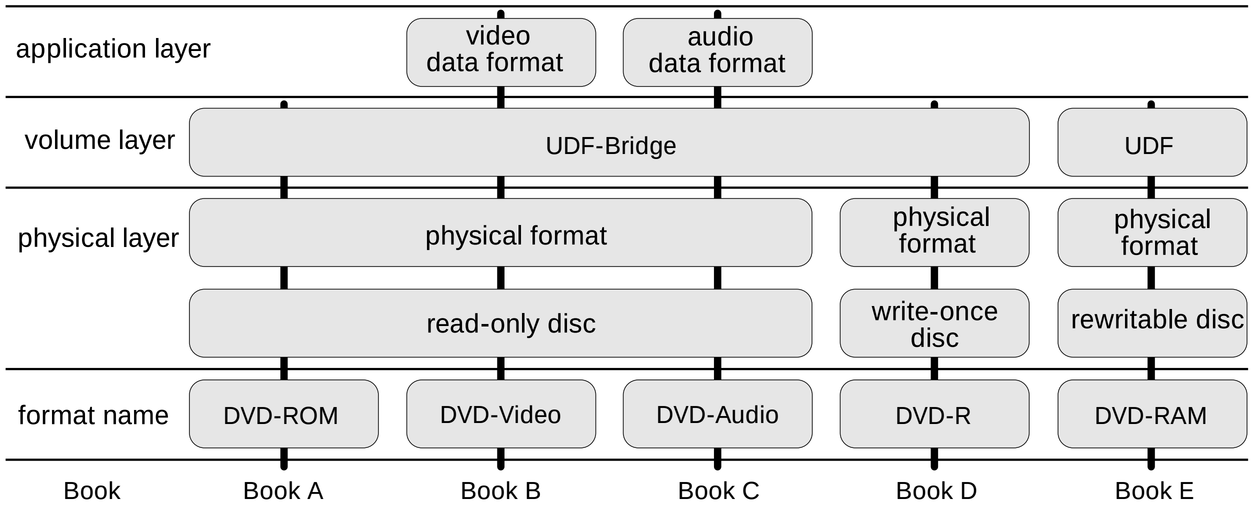
*3.95 GB/single sided **2.6 GB/single sided

As of January 1998

# DVD file systems

UDF (Universal Disc Format) is adopted as a file format in DVD. It was devised by OSTA (Optical Storage Technology Association, an international organization) which consists of some fifty optical storage media related companies. The “UDF-Bridge” shown in the figure below, which extends to DVD-ROM, DVD-Video, DVD-Audio, and DVD-R, means that the bridge format which makes the conventional ISO 9660 valid as a subset of the UDF for DVD is used. The ISO 9660, which was originally devised as the file format for CD-ROM, is used to make the DVD compatible with CD-ROM.

■Format construction and applicable books

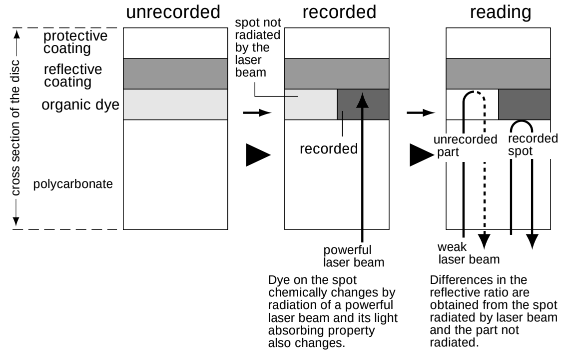


# Questions & Answers

## What is write-once DVD?

Write-once DVD, DVD-R, can be recorded only once. Its data recording layer is coated by a proprietary organic dye. Recording is performed by applying a powerful laser beam on the layer. Thermal change takes place at the spot radiated by the powerful laser beam and the light absorbing property of the spot becomes smaller than the part not radiated. In reading data, digital signals consisting of “0s” and “1s” can be retrieved by the change in reflectance of data reading laser beam like data is retrieved by existence of pits in the CD. Spots thermally changed do not change even when they are radiated by the relatively weak data-reading laser beam and data once recorded cannot be rewritten or overwritten.

Data recording and playback principle of DVD-R




## Can pictures be recorded on DVD?

We have explained that DVD-Video is a read-only format and the rewritable DVD-RAM is currently still being discussed. Will a disc that can record video and audio with quality and time duration equivalent to DVD-Video be available from other format variations in the DVD group?

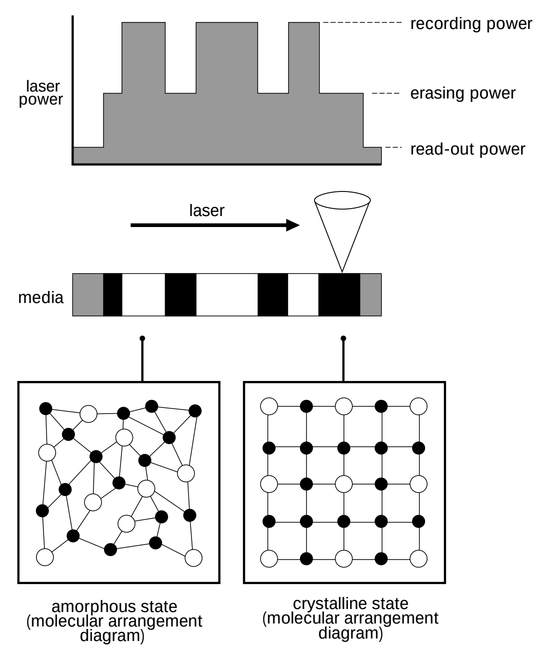
The answer is that it will be some time in the future until such a disc will be available for home use. The reasons are the lack of storage capacity (data capacity of DVD-RAM is about 2.6 GB which is still smaller than the 4.7 GB of DVD-Video) and some as-yet undiscovered technical breakthroughs such as video signal encoding LSIs. In addition to these technical obstacles, there are very important unavoidable problems in protecting the copyrights which cover various digital information, not to mention for moving pictures and sound. Sony is presently engaged in various activities to address these problems.

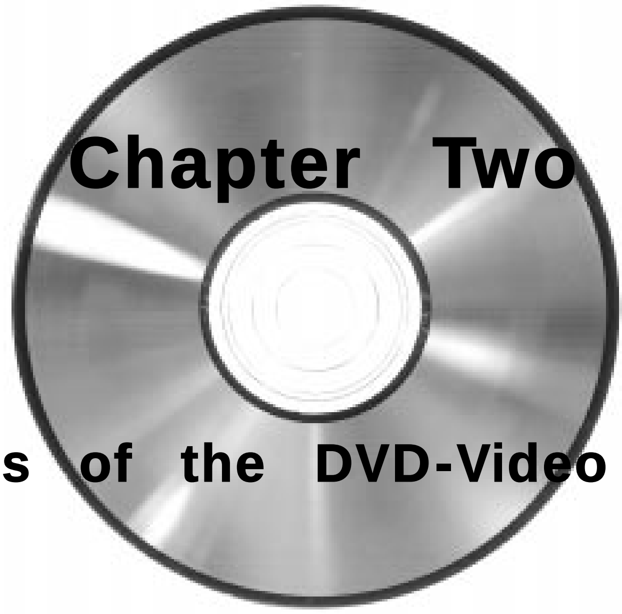
## What about Rewritable DVD?

This is called DVD-RAM, and is a rewritable type of DVD disc. For the data recording layer, it uses a metal compound that reverses its phase from a crystallized state (crystalline phase) to an amorphous state (non-crystalline phase) and vice versa by the methods used to heat and cool the compound. The compound is rapidly heated and cooled by radiating a powerful laser beam to create an amorphous state spot on the crystalline state recording layer to record data. This type of disc is generally called a “phase change optical disc” because data is read using diverse reflectance of the amorphous state spots and the crystalline state parts caused by phase transition.

Data can be written repeatedly on the disc because amorphous state spots revert to a crystalline state if a weak laser beam is radiated on them and then cooled gradually. By controlling the power of laser beam radiated on the recording layer, simultaneous erasing and writing or direct overwriting can be
performed.

phase change recording principle





# Chapter Two

## Features of the DVD-Video Format

The world of DVD begins with the advent of DVD-Video, while the world of CD began with the music CD (CD-DA).

As the storage capacity of DVD was initially aimed at enabling the recording of an entire movie on a single disc, DVD-Video is designed to make the dream of enjoying pictures and sound with theater quality in the home entertainment. As a new home entertainment media, DVD-Video has many features which have not been available from conventional package media. In this chapter, we will highlight the technology which has realized high quality video and audio from a compact 120 mm disc, and describe the many unique features

### Key

- **An entire movie can be stored on a disc the same size as a CD by making use of its large storage capacity.**
- **Picture quality close to that of the Digital Video Format D1 used for professional video masters has been realized by the adoption of MPEG2 compression.**
- **The same realistic sound and excitement as in movie theaters can be enjoyed in homes through the high-fidelity 5.1 Channel Surround of the Dolby Digital (AC-3) System, and the high-fidelity 5.1/7.1 Channel Surround of the MPEG system.**
- **Interactive software, with features such as the multi-story function which allows users to select a story and the multi-angle function for the selection of viewing angles, can be designed.**
- **The multi-language function allows dubbing of up to eight language soundtracks, and subtitles in a maximum of 32 languages. The multi-aspect function enables the reception of wide pictures on your TV screen.**

# DVD-Video technology in detail

## ■DVD-Video realizes high quality pictures, high quality sound, and multiple playback functions.

The main features of DVD-Video can be summarized as high quality pictures, high quality sound, and multiple playback functions which are made possible by its large storage capacity and digital signal processing. In terms of picture quality, high quality images have been realized with 500TV-line resolution, better than either laserdisc or CD-Video.

The most remarkable feature of DVD-Video is that it offers both the highest picture quality of home video media and the capability to record an entire movie, which requires a long recording time, all available on a single disc the same size as a CD.

The Dolby Digital (AC-3) System and the MPEG Audio System are adopted for sound in addition to the linear PCM audio. The 7.1/5.1 channel surround in the MPEG system reproduces high quality sound, while the 5.1 channel surround in the Dolby Digital (AC-3) system offers high fidelity sound with a very impressive and realistic sound field not available with Dolby Pro Logic. Using these high quality pictures and high quality sound as a basis, interactive functions such as the multi-story, multi-angle, and multi- language functions are also achieved.

■Video and sound specifications for DVD-Video

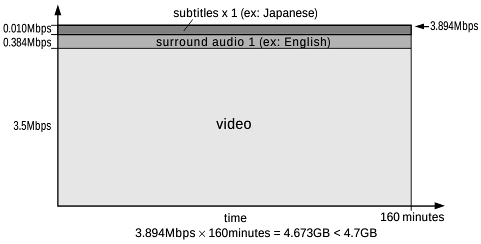
| | | DVD-Video | | | Video CD | Laserdisc |
|---|---|---|---|---|---|---|
| video | video compression system | MPEG2 (MP@ML) | | | MPEG1 | analog |
| | resolution (pixels) | 720 x 576 pixels (Note 1.) | | | 352 x 286 pixels (Note 1) | |
| | horizontal resolution | approx. 500 TV lines | | | approx. 250 TV lines (same as VHS) | approx. 420 TV lines |
| | compression ratio | approx. 1/40 | | | approx. 1/140 | analog |
| | video bit rate | 9.8 Mbps, max. (variable) | | | 1.15 Mbps (fixed) | |
| | field/frame | field/frame | | | frame | |
| | aspect ratio | 4:3/16:9 (pan scan/letter box) | | | 4:3 | 4:3 |
| audio | audio | 8 streams, max. (Note 2) | | | 2 channel (stereo) | analog 2 channel, digital 2 channel (16-bit/44.1 kHz) or analog 1 channel, Dolby Digital (AC-3): 1 stream, digital 2 channel (16-bit/44.1 kHz) |
| | audio system | MPEG | Dolby Digital (AC-3) | Linear PCM | MPEG1 layer 2 | |
| | audio bit rate | max. 912 kbps (per stream) | max. 448 kbps (per stream) | max. 6.144 Mbps (per stream) | 224kbps (fixed) | |
| | number of channels | max 7.1 ch. / stream | max 5.1 ch. / stream | max 8 ch. / stream | 2 ch only | |
| | quantization bit sampling frequency | 48 kHz | 48 kHz | 16-bit, 20-bit, 24-bit 48 kHz, 96 kHz | 16-bit 44.1kHz | |
| others | subtitles | 2 bits, run length bit map system, 32 streams, max. | | | open caption only | open caption, closed caption |

Note 1: In the case of PAL, DVD-Video is not compatible with the high definition system. Note 2: Either Dolby Digital, MPEG or Linear PCM can be selected for each audio system.

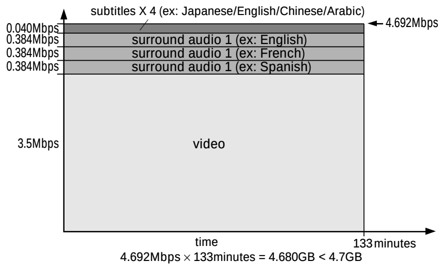
## ■Data volume can be distributed according to contents to be recorded.

DVD may be regarded as a large container of digital data and DVD-Video stores pictures and sounds in it as the main contents. DVD-Video features superior flexibility in accommodating the source, including subtitles and dubbing in multiple languages. Data is appropriately distributed depending on contents of the source within the framework of the total storage capacity. For example, when recording a movie, whether subtitles and dubbing are recorded in several languages, or just in a single language, will make the recording time much different for the same title of software. When recording a music clip which does not require as much recording time as a movie, its sound can be recorded by the linear PCM format without compressing the sound since there is a plenty of room in terms of total storage capacity.

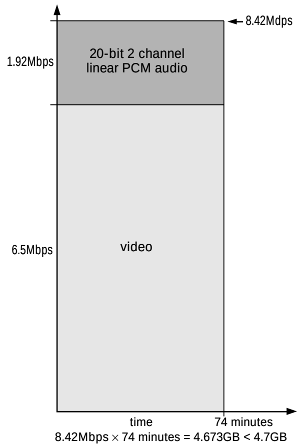
■One movie (av. 3.5 Mbps) + subtitle in one language + surround soundtrack in one language = about 160 minutes of recording time = 4.673 GB data volume




■One movie (av. 3.5 Mbps) + subtitles in 4 languages +surround soundtracks in 3 languages = about 133 minutes of recording time = 4.680 GB data volume




■One music clip (av. 6.5 Mbps) + 48 kHz 20-bit 2 channel linear PCM audio = about 74 minutes of recording time = 4.673 GB




**Recordable data volume is the same in all examples.**

# The high image quality technology of DVD-Video (1) MPEG2 picture compression system

## ■Why is data compressed?

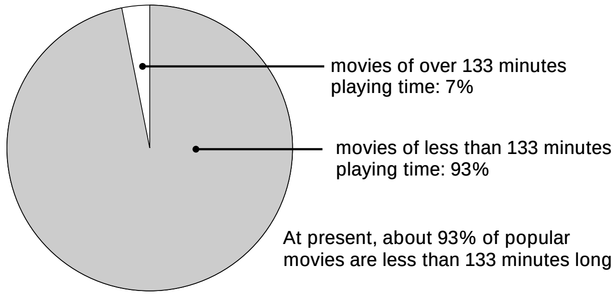
The data volume which can be stored on a CD is 5440 Mbits [Note 1] (680 MB). In the case of a music CD, digital audio data equivalent to 74 minutes of playing time can be stored on one disc. If picture signals in the PAL format are digitized, data volume for one minute will be more than 160 Mbits [Note 2] without compression and the data volume which can be stored on one disc will be less than 4 minutes of recording time even if a 4.7 GB DVD disc is used, and less than 34 seconds if stored on a conventional CD.

Storing 74 minutes worth of picture data on a Video CD was made possible by reducing the number of picture elements by half in both the vertical and horizontal directions to 352 x 286 pixels, and then finally reducing the data to 1/140 by using the MPEG1 compression system.

What made it possible to store picture data for 133 minutes (note that most popular movies are within 133 minutes) with a resolution of 720 x 576 pixels (corresponding to PAL) on a DVD-Video disc (single side, single layer) was the adoption of the efficient data compression [Note 3] of the MPEG2 system in addition to tremendous improvements in disc storage capacity.

Note 1: 5440 Mbits is a simply converted figure of 680 MB based on 1 byte = 8 bits.
Note 2: Calculated on 25 pictures with 720 x 576 pixels a second providing 8 bits to luminance and 8 bits to color per pixel.
Note 3: The compression ratio is about 1/40, lower than that of Video CD.

■Playing time of movies




## ■Profile and level of MPEG2

MPEG2 was originally designed as a universal encoding system which can also be used in transmission media for communication applications. The “profile (five types)” is used to indicate combinations of functions suitable to a number of applications to maintain compatibility between media, while the “level (four types)” is used, and both are prescribed in the MPEG2 format specifications. Of the eleven currently proposed profiles and levels, what was adopted for DVD-Video is “MP@ML (Main Profile/ Main Level ).” Until digital HDTV formats become popular in the future, many different applications other than DVD-Video may be put into practical application using the MP@ML standards.

■Currently prescribed profiles/

| Profile / Level | Simple | Main | SNR Scalable Note 2 | Spatial Scalable | High |
|---|---|---|---|---|---|
| High<br>1920 × 1080 × 30<br>or 1920 × 1152 × 25 Note 1 | | MP@HL<br>US digital HDTV | | | HP@HL |
| High-1440<br>1440 × 1080 × 30<br>or 1440 × 1152 × 25 Note 1 | | MP@H1440 | | SSP@H1440<br>European digital HDTV | HP@H1440 |
| Main<br>720 × 480 × 29.97<br>or 720 × 576 × 25 Note 1 | SP@ML<br>Digital transmission cable TV | MP@ML Note 3<br>DVD-Video, Digital satellite broadcasting<br>(PerfecTV and others) | SNP@MP | | HP@ML |
| Low 352 × 288 × 29.97 Note 1 | | MP@LL | SNP@LL | | |

Note 1: Shows the standard number of horizontal pixels x vertical pixels x frame frequency
Note 2: SNR = Signal Noise Ratio
Note 3: MP@ML = Main Profile at Main Level

## ■Hybrid coding by combining three main methods

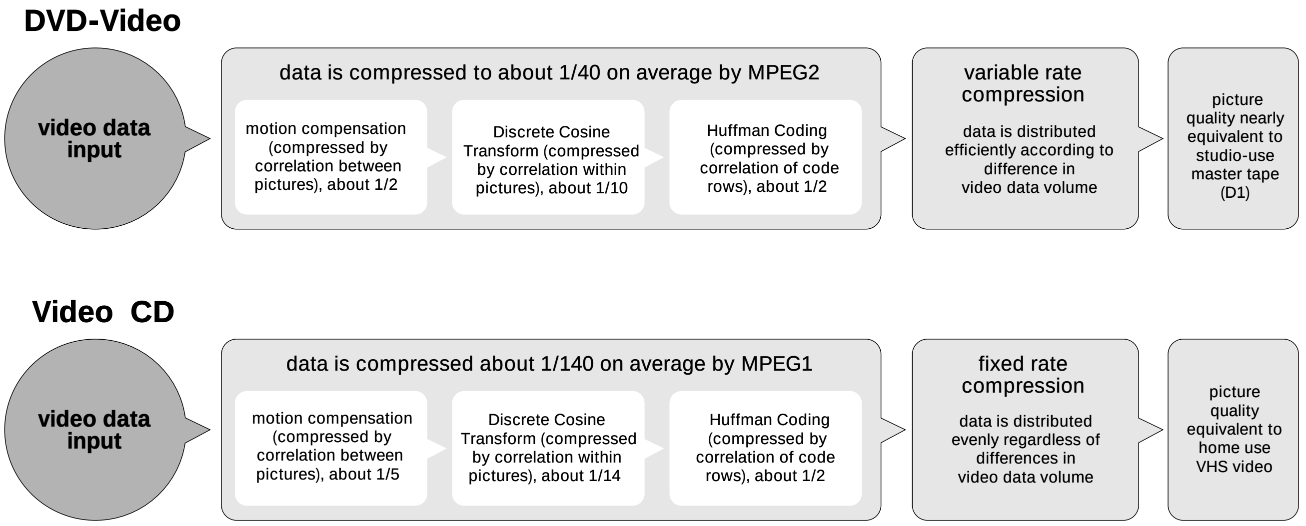
Roughly speaking, the MPEG2 (MPEG1 is also the same in basic concept terms) motion picture compression method is a combination of three main methods; “DCT (Discrete Cosine Transform)” which uses correlation in moving pictures to compress data, “Motion Compensation” which uses correlation between pictures to compress data, and “Huffman Code Processing” which employs correlation of code rows.

DCT uses the correlation of the spatial direction of pictures to remove the redundancy of data in the spatial axis, and Motion Compensation uses the correlation of the time direction in pictures to remove the redundancy of data in the time axis. In Motion Compensation, data is compressed to about 1/2; by DCT, 1/10 to 1/20; and by Huffman Code Processing, 2/3 to 1/2. Data is compressed to roughly 1/40 of the original volume in total. Reducing data to 1/40 means that picture signals of 240 Mbps can be sent at the rate of 6 Mbps, or 160 Mbps at 4 Mbps.

Compressing and decompressing motion pictures by these methods require an enormous amount of complicated calculation. The LSI of MPEG2 decoder circuits performing these calculation at high speed has made commercialization of the DVD-Video player possible.

The superior features of DVD-Video (employing MPEG2) over the video CD (which uses MPEG1) are: 4 times the number of picture elements (2 times each the in horizontal and vertical directions) and pictures are interlaced at 60 fields/second (MPEG1 is non-interlaced with 30 frames/sec.). MPEG2, the higher standard, is compatible with MPEG1.

■Picture compression in DVD-Video




# Questions & Answers

### What is MPEG?

MPEG stands for the Moving Picture Experts Group. This is the popular name of the working committee of experts who worked on encoding motion pictures as a sub-group (WG11) to JTC1/ SC29 of ISO/ IEC. The MPEG name is also used for the standard agreed on in this committee and approved as the international standard by ISO/IEC.

MPEG2 is a more sophisticated, more powerful standard of MPEG1, which was adopted in 1991 as the standard for CD-ROM. MPEG2 was adopted in 1994 as the universal coding system for various transmission media including broadcasting and communication as well as for storage media such as optical disc.

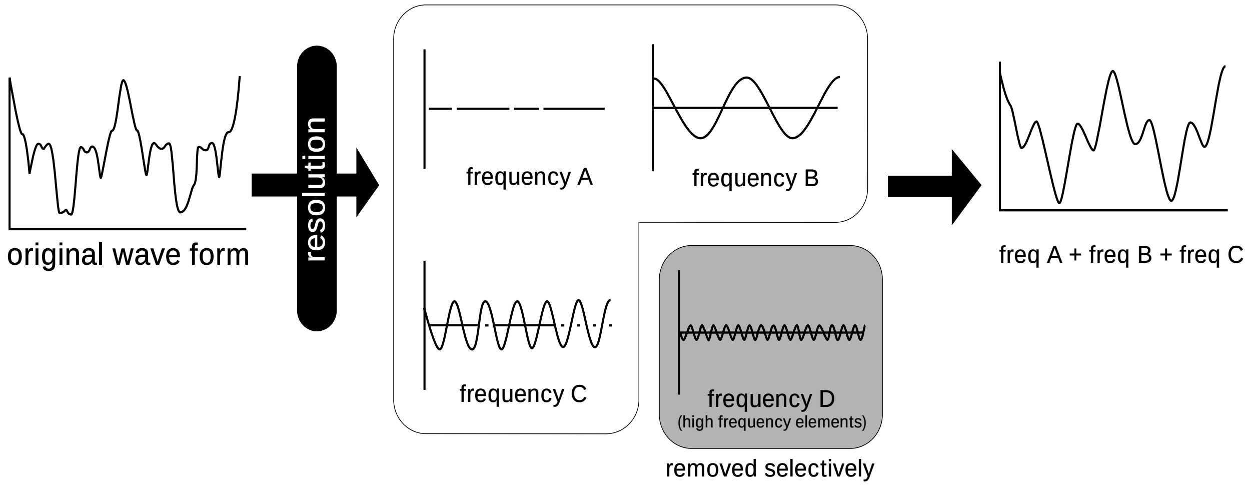
The formal names of standards are ISO/IEC CD11172 for MPEG1 and ISO/IEC 13818 for MPEG2.

# Spatial axis compression - discrete cosine transform

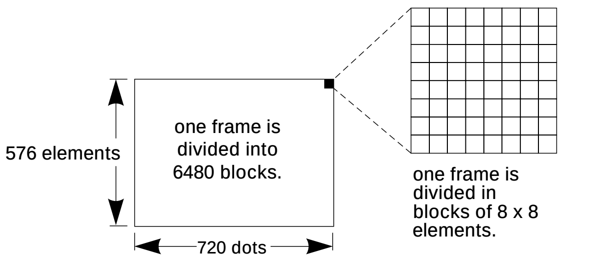
## ■DCT removes unnoticeable frequency elements.

The nature of human perception is deeply considered in the compression of data for both video and audio. Human vision perceives pictures with some of high frequency elements omitted the same as pictures without any omissions. The total data is reduced by omitting unnoticeable frequency elements selectively after picture signals are resolved in several frequency element groups. The frequency element resolving process of MPEG2 (and MPEG1 is basically the same) is called the "Discrete Cosine Transform" method and selective omission of specified frequency elements taking advantage of limitations in human perception is called the "Quantize Matrix" method. These processes are done with dividing a frame of the picture in blocks of 8 x 8 elements (6480 blocks in total) and the luminance levels of the elements in each block are converted into values, and then are converted into frequency element data.

### ■Basic concept of spatial axis compression




### ■Encoding process for spatial axis compression




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10 | 5 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Changes in luminance and color are small in some parts of a frame (low frequency) while changes are large in other parts (high frequency) and a frame can be considered as an overlaid composite picture comprised of a very low frequency picture, a low frequency picture, a high frequency picture, and a very high frequency picture.

▶ One frame is divided into small blocks, and luminance and color values of picture elements in each block are converted into numerical data. Then, the data is converted by DCT into an 8 x 8 block of frequency data.

▶ Larger picture element values, distributed at random before the DCT conversion, tend to gather in low frequencies region (upper left area of the block) by the DCT conversion.

▶ Values after conversion are divided by a specific number and the remainders are rounded (quantization step) to get many 0s line up in higher frequency regions (lower right area of the block). Removing these zeros (higher frequencies region) compresses the total data.

# Time axis compression - predictive coding with motion compensation

## ■Predictive cording constructs image by predicting motion from preceding and succeeding pictures

An image in PAL television and video is composed of 25 frames/second (a frame consists of 625 scanning lines) and the display equipment reproduces a picture of 50 fields/second since it is scanned by interlacing to eliminate flickering. A large part of each picture is made of the same elements if continuous 25 pictures per second are compared with each other. And, they do not change much in a short time.

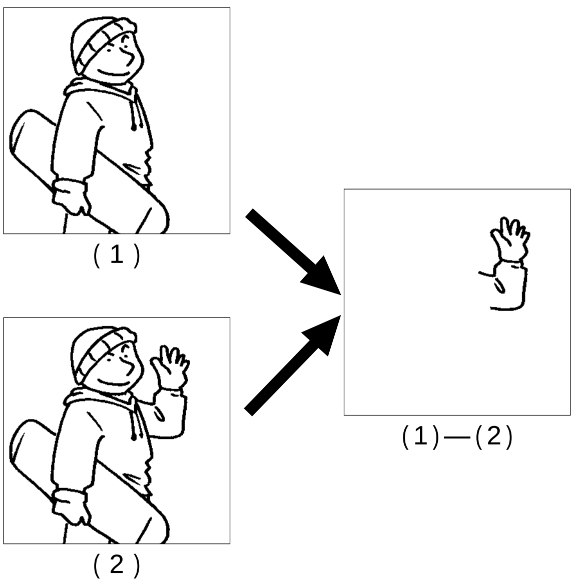
If there is a changing part in 25 pictures, the data volume necessary to store and reproduce the picture will be much smaller if only the changed part (differential) is stored and the other part is stored for one picture for synthesizing with the differential to reproduce pictures.

The method to reconstruct the original picture by extracting and coding the differential between continuous pictures is called “Predictive Coding” because the current picture is predicted from the picture immediately preceding it. As described in detail in the following section, “Time axis compression, GOP construction and bi-directional prediction, ”MPEG provides the coding to predict the current picture from the immediately preceding and succeeding pictures on a bi-directional prediction.

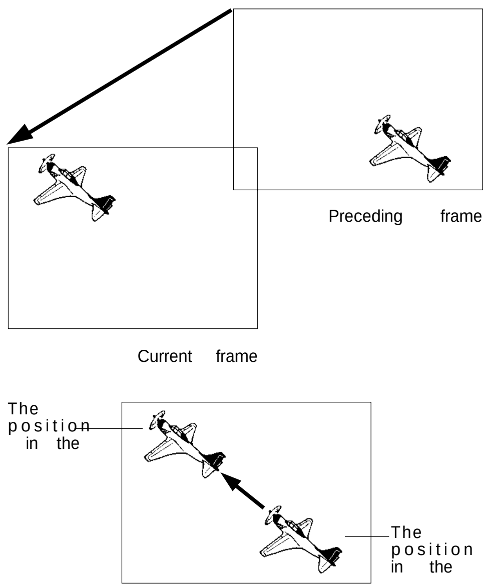
## ■Motion Compensation extracts only motion changes

There are two types of changing parts or parts with motion in pictures: one does not change its shape but changes its position as time elapses, while the other changes its shape as time elapses. Data of the shape should be used as it is for the former. The amount of position change without changing shape which takes place with time, or the amount of movement, is called the “motion vector.” The original picture can be reconstructed when reproduced (in the decoding process) with smaller data volume by coding only the movement. This method which uses the motion vector is

### ■Predictive coding and motion compensation




1. Pictures (1) and (2) to be reproduced as time elapses have many elements common to each other. Differential or (1) minus (2) is extracted and (2) is reproduced by synthesizing the differential with (1).




2. In the motion compensation process, pictures are divided into blocks and the motion vector which indicates the amount of movement is extracted and coded for the part whose position changes, without changing its shape. By combining this motion compensation with predictive coding, data is more efficiently compressed.

# Time axis compression - GOP construction and bi-directional prediction

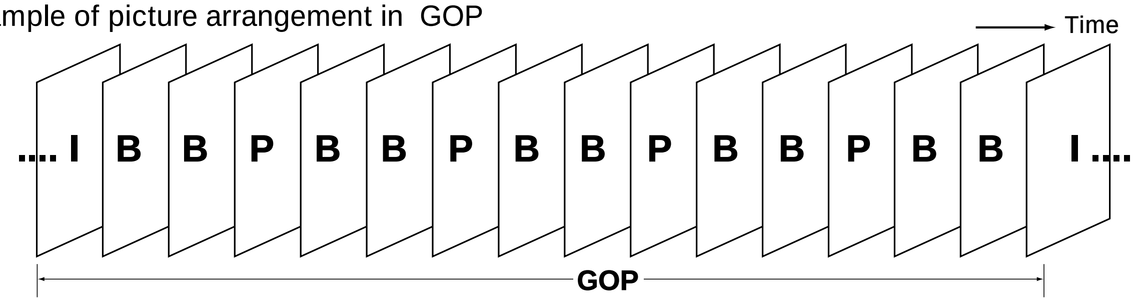
## ■GOP construction by I picture, P picture, and B picture

To perform predictive coding employing motion compensation, MPEG2 uses GOP (group of pictures) construction made of three elements called the I picture, P picture, and B picture and MPEG2 organizes roughly 15 consecutive video frames into GOPs. The I picture (Intracoded picture) is compressed by DCT using information within the frame only without predicting the motion from the preceding frame.

If pictures constructed by the predictive coding are successively lined up, pictures cannot be displayed instantly when accessed at random. Then, the standard for access is made periodically to respond to random accessing. The I picture is for maintaining independence from the GOP, so to speak.

The frequency of the I picture is normally 1-I picture/ 15 frames it is decided based upon the random access capability required for applications. The data volume of an I picture is 2 to 3 times that of the P picture and 5 to 6 times that of the B picture. The GOP is the group of pictures from one I picture to the next I picture. Thus, in simple terms, picture prediction is performed within pictures in the same group.

■An example of picture arrangement in GOP



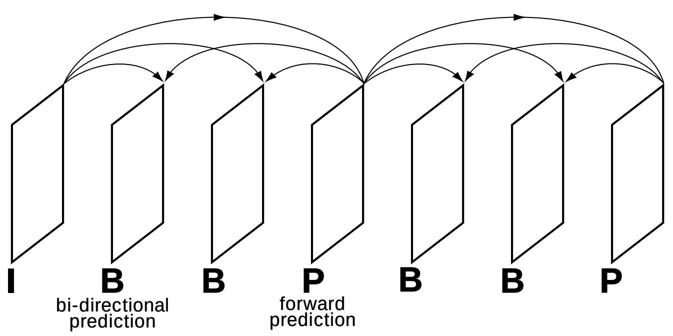

I picture = Intracoded picture P picture = Predictive coded picture B picture = Bi-directionally predictive coded picture

## ■The P picture and B picture

The P picture (predictive coded picture) is made on the basis of the I picture by predictively encoding the immediately preceding picture. The P picture may be defined as an “interframe forward direction predictive coded picture” in relation to the I picture, which itself is an “intraframe coded picture.” The B picture is a “bi-directional predictive coded picture” and is made by predicting two P pictures, the preceding and the succeeding. Taking a close look at the relationship between the I picture, P picture, and B picture in a GOP, the first step prediction made from the I picture located at the beginning of the GOP is performed in the forward direction and the P pictures are made. At that time, the P pictures are positioned jumping over a multiple number of B pictures to be constructed later.

A multiple number of B pictures are made by the second step prediction from the first I picture and the P picture coded at the first step prediction (bi-directional prediction) and they are positioned between the I picture and the P picture. Another set of B pictures is made between the first P picture and the second P picture. The B picture when decoded compensates motion using two motion vectors and two reference pictures, preceding and succeeding. Bi-directional prediction, a feature of MPEG, uses two pictures, the past and future pictures timewise, for prediction to achieve highly efficient prediction.

■Forward and bi-directional




The P picture is constructed by forward predicting the immediately preceding I picture or P picture while the B picture is made by bi-directional prediction using the immediately preceding and succeeding pictures.

# Huffman coding

## ■Huffman coding: a statistical method for data compression

In addition to motion compensation, which removes data redundancy using correlations of the time axis in pictures, and DCT which removes data redundancy employing correlations of spatial axis in pictures, MPEG2 (MPEG1 is basically the same) uses a method called Huffman coding to achieve a further reduction in data redundancy.

Huffman coding uses correlation in the code row made by MPEG processing to compress data (for example, five consecutive 0s are expressed as 0 x 5 instead of lining up five 0s). This may be called a "statistical" method if the motion compensation is called a "time" method and DCT a "spatial" method. Picture data is compressed spatially, statistically, and chronologically in MPEG2 and the total volume of codes generated is controlled by the quantization step for efficient data transmission.

# Questions & Answers

### What is 4:2:0 coding in MP@ML?

In MP@ML (Main Profile at Main Level) of MPEG2, a component system called "4:2:0" is adopted for encoding video signals. Numbers 4, 2, and 0 indicate the sampling frequency ratio of the luminance signal (Y) and two color differential signals (Cb and Cr) included in the horizontal scanning lines of video pictures, or the resolution ratio. For one picture element [Note 1], 8 bits are used for luminance and 8 bits each are used for color differential. The eye is not so sensitive to color as it is to luminance, and because the human eye is unable to perceive the reduction of color information as picture quality degradation in relation to luminance information, data can be compressed with no perceivable visual difference.

Pictures without color information reduction are called "4:4:4," pictures reduced to half in the horizontal direction called "4:2:2," and pictures reduced to half in both the horizontal and vertical directions are called "4:2:0." In the "4:2:0"system, color information is one fourth of luminance information. The DV system, which has achieved excellent color reproduction for home use digital video, employs a "4:1:1" type component signal system that reduces color information to one fourth of luminance information and its data volume is the same as the "4:2:0" of the MP@ML of MPEG2. The "4:2:0" [Note 2] coding system is normally processed and output as "4:2:2" after lines are supplemented by processing within the LSI.

Note 1: In MPEG2, 8 bits are used for each of luminance Y, and color differential Cb and Cr in one picture element (3 X 8 = 24 bits).

Note 2: The sampling frequency for all of Y, Cb, and Cr is 13.5 MHz in "4:4:4." In "4:2:2", 13.5 MHz for Y, 6.75 MHz for Cb and Cr. In "4:1:1", 13.5 MHz for Y, 3.375 MHz for Cb and Cr. In "4:2:0", 2 lines with different sampling rates are alternatively repeated. One is 13.5 MHz for Y, 6.75 MHz for Cb and Cr is not sampled, while the other is 13.5 MHz for Y, Cb

## Are there any differences between DV and DVD data compression?

The DV format of digital video recording is available as home use video media. It is quite different from DVD-Video in terms of compression because of the basic physical difference between the two forms of media, magnetic tape and optical disc. Moreover, the DV format uses only “within picture correlation’’ compression while DVD employs both ”within picture correlation” and “time axis correlation” compression.

What is the reason for this? DV was designed from the very beginning as a means to provide video recording and playback in the home, so tape editing at any point is as an important requisite as recording and playback. Data compressed on the time axis has to be decompressed each time it is played back or edited and data must be re-compressed on the time axis to keep the data on the tape. This requires tremendous signal processing power, and is very inefficient.

For this reason, taking advantage of the far larger storage capacity of tape over disc,“ within picture compression” is used in DV for compressing data on the tape while DVD must also rely on “time axis compression” because of capacity limitations.

In addition to DVD, MPEG2 can also be applied in digital TV broadcasting, and is expected to be advantageous in multi-channel broadcasting. To make this possible, the bandwidth per channel must be kept as narrow as possible, so time axis compression will be employed.

# Bit rate technology in DVD-Video (2) variable transmission rate

## ■Variable bit rate allows highly efficient image storage

The bit rate is the data volume which can be sent in a unit of time and is expressed by the number of bits sent in a second (bps=bits per second). The larger the rate is, the greater amount of data can be transmitted, and this (generally) results in higher image and sound quality. In compressing pictures by MPEG2, a bit rate of about 6 Mbps is required to maintain the same picture quality as PAL television broadcasting.

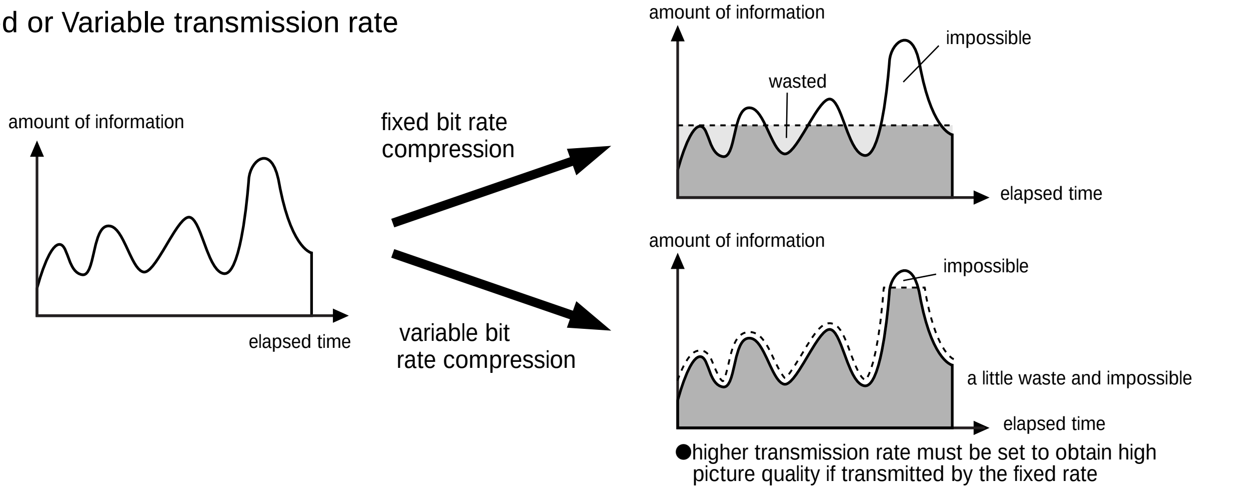
However, quick-motion parts of pictures require more data, so a higher bit rate is required to maintain high picture quality. On the other hand, parts of pictures with virtually no motion or almost still pictures require much less data, so high picture quality can be maintained with a lower bit rate.

The problem which arises here is the relationship between the bit rate and recording time. To maintain high picture quality regardless of the condition of the pictures, the highest bit rate fitted for picture parts which require the largest data volume may be used. Since the data capacity of the disc equals the bit rate times the recording time, the higher the bit rate, the shorter the recording time. A lot of data is wasted if the actual data volume needed for pictures is small.

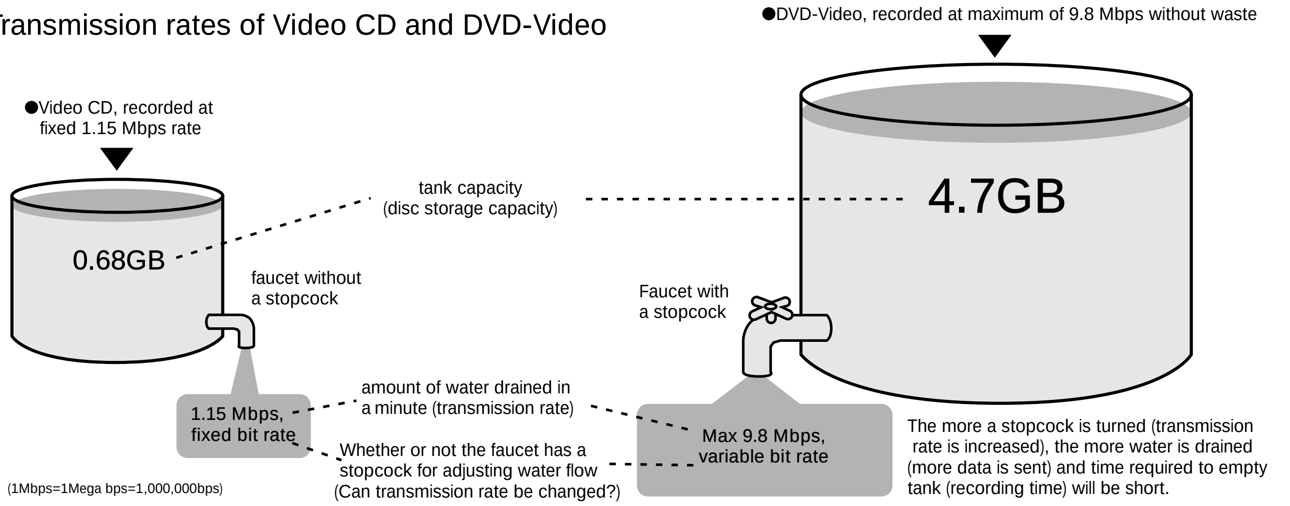
A variable bit rate technology with a maximum speed of 9.8 Mbps is employed in DVD-Video to eliminate wasteful data allocation. The bit rate is varied according to conditions of pictures; a high bit rate is used for parts of pictures which require a large data volume, while a lower rate is used for parts which require small data volume in order to make more efficient use of data capacity. With a variable bit rate, an average bit rate of 3.5 Mbps is accomplished in DVD-Video. If a fixed bit rate were to be used, the rate will need to be two times the variable bit rate just to maintain the same picture quality.

Incidentally, Video CD which compresses images with MPEG1 technology uses a fixed rate of 1.15 Mbps. This is one of the most significant technical differences between it and DVD-Video.

### ■Fixed or Variable transmission rate




### ■Transmission rates of Video CD and DVD-Video



# DVD-Video's superb audio capabilities

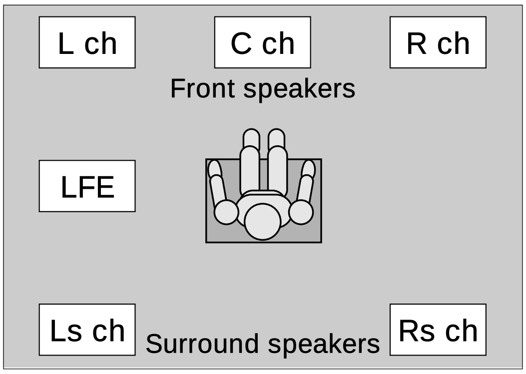
Non-compressed linear PCM audio, Dolby Digital, and MPEG Audio are adopted (along with other systems) for their superb audio quality to match the high image quality of the DVD-Video system. In DVD-Video, a maximum of eight streams (refer to page 31) are available for soundtrack recording.

It is mandatory that a mono or stereo soundtrack is used as either one pair of linear PCM audio tracks, or as Dolby Digital or MPEG Audio for discs and players in connection with a 625/50 (PAL/ SECAM) TV system. For 525/60 (NTSC) TV systems, Linear PCM or Dolby Digital is used. In addition, either Dolby Digital or MPEG multi-channel soundtracks can be used as an option with PAL/SECAM TV systems, while MPEG is an option with 525/60 NTSC TV systems. Furthermore, Dts and the SDDS 7.1 channel digital surround system developed by Sony are standardized in the format, and are available as options.

The number and quality of these audio tracks, which are variously applied in DVD software, is left to the discretion of the producers, who should retain the right to determine the contents of their software. Accordingly, this multiple track potential makes it possible to dub movie software with several different languages.

Compressed multi-channel audio formats, such as Dolby Digital and MPEG-2, can carry a multi-channel soundtrack compressed into a single stream of digital data. There are various configurations of multi-channel audio to go with moving video images. The most common is 5.1, which supplies separate sound channels to the left (L), center (C) and right (R) front speakers, as well as the left and right (Ls and Rs) surround speakers, along with low-frequency effects (LFE) to the subwoofer, which is known as the ".1" channel.

■Speaker layout for 5.1 channel



# DVD-Video's high fidelity (1) - Dolby Digital

■Various Dolby Digital (AC-3) modes

| audio coding mode | channel format | | | | | |
|---|---|---|---|---|---|---|
| | front | | | surround | | |
| | L | C | R | L | R | |
| 1/0 | | ○ | | | | monaural |
| 2/0 | ○ | | ○ | | | stereo |
| 3/0 | ○ | ○ | ○ | | | |
| 2/1 | ○ | | ○ | monaural | | surround |
| 3/1 | ○ | ○ | ○ | monaural | | |
| 2/2 | ○ | | ○ | ○ | ○ | |
| 3/2 | ○ | ○ | ○ | ○ | ○ | |

Surround modes other than 2 channel are available.

## ■Bringing the appealing power of the theater home with Dolby

The Dolby Digital (AC-3) system, already popular in some Laserdisc software, makes 5.1 channel high quality surround reproduction with its theater-like presence possible in the home. It is considered the main audio system for the DVD-Video pre-recorded movie software.

Dolby Digital (AC-3) was initially put into use in 1992 as a digital surround system called the Dolby SR-D system for theaters, and is used in major movies produced in Hollywood. Using the Dolby Digital (AC-3) system, sound of DVD-Video can be recorded in many selectable channel modes depending on the contents of the software. Monaural, 2-channel stereo, 3-channel surround, and 4-channel surround, and even 5.1-channel surround can be selected. Dolby Digital (AC-3) is equipped with dynamic range control which controls sound peaks in order to maintain the dialog at an audible level when watching a movie very late at night or in other

## ■Full-band 5.1 channel surround

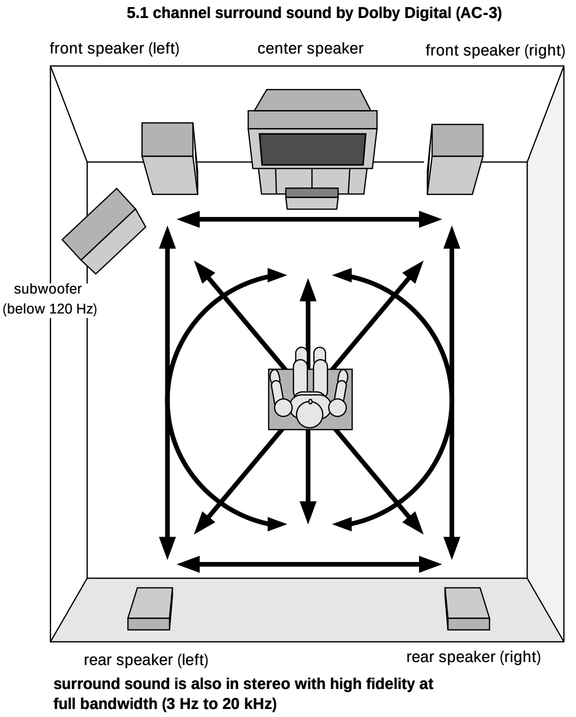
The Dolby Digital (AC-3) system is a high quality digital sound system equipped with a channel dedicated to subwoofer output (LFE=Low Frequency Effect) in order to reproduce low frequencies below 120 Hz in addition to the front left, front right, front center, surround left, and surround right channels. The conventional Dolby Pro Logic system converts two track signals into four channels (front left, right, center, and surround) at the decoding stage by using an analog matrix process. In the Dolby Digital system, each channel is discretely and digitally processed from the beginning, so they are independent and contribute to excellent channel separation. Even surround sound comes in stereo and all five channels are reproduced at full bandwidth (3 Hz - 20 kHz).

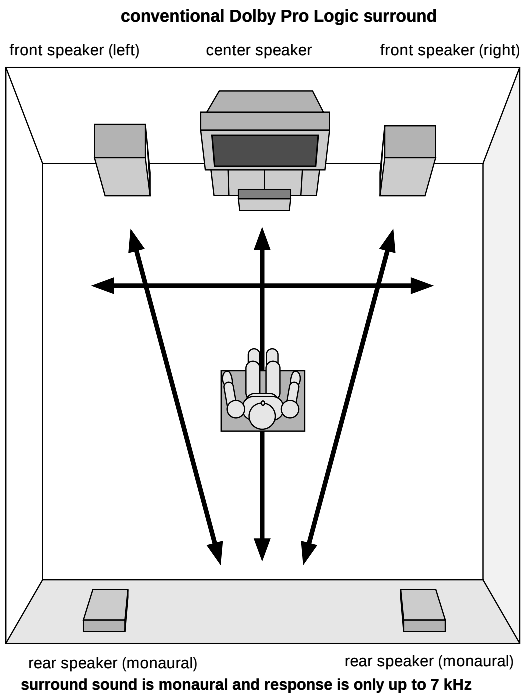
With these features, movie producers are able to reproduce sound accurately in the home theater context with the intended positioning of the sound image and the feeling of soundstage movement, along with surround reproduction with presence and power comparable to the movie theater experience.
DVD-Video players equipped with Dolby Digital have decoders capable of performing the sound mix-down for playback by decoding the 5.1 channel surround sound in the Dolby Pro Logic signals and two channel stereo signals. In players without Dolby Digital, conventional surround and stereo playback are performed upon playback of DVD-Video software.

■Home surround system comparison

| surround system | Dolby Digital (AC-3) | Dolby Pro Logic |
|---|---|---|
| number of recording channels (source) | 5.1ch | 2ch |
| number of playback channels | 5.1ch | 4ch |
| playback channel configuration | front L/C/R, surround L/R, subwoofer | front L/C/R, surround (mono), subwoofer recommended |
| sound processing | digital discrete processing | analog matrix processing |
| bandwidth of surround sound | 3Hz~20kHz | ~7kHz |

## ■Effect of 5.1 channel surround sound




## ■High efficiency coding method of Dolby Digital AC-3

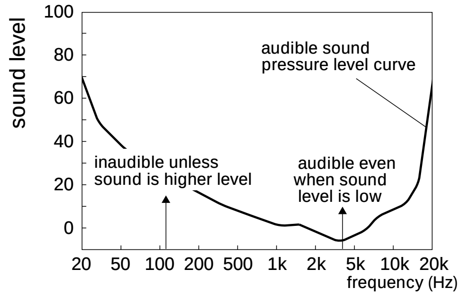
The “AC” in the name Dolby Digital AC-3 stands for Audio Coding and AC-3 is the highly efficient third-generation coding system following AC-1 and AC-2. One of its major features is the unified coding of multi-channel sound. This is made possible by processing multi-channel data together through a unique program called “Global Bit Distribution.”

In coding the data; (1) low level low frequency sound and low level high frequency sounds not audible by the human ear owing to its frequency limitations, (2) low level sound not audible by the masking effect due to differences in sound level, and (3) low level sound not audible by the masking effect between channels, are all deleted and the data is sampled after it is divided into 50 uneven bandwidths configured based on the “logarithmic” nature of human auditory sensitivity.

The method used to delete (1) and (2) is similar to that used in ATRAC (Adaptive Transform Acoustic Coding), a compression system employed in the MiniDisc format. Deleting unnecessary details of information by taking advantage of the characteristics of human audio perception is called “perceptive coding.” For your reference, the 5.1 channel surround sound transmission rate in DVD-Video is 384 kbps in total.

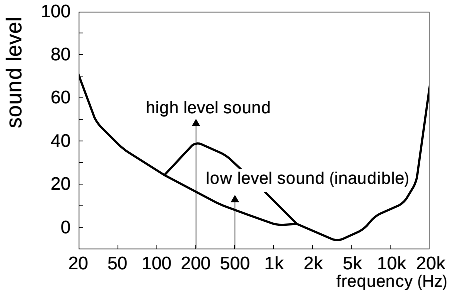
## ■Examples of inaudible sound contained in audio data

●low level sound in the inaudible range




Human hearing is most sensitive at or around 4 kHz and sound, as its frequency goes above or below 4 kHz, becomes harder to perceive.

●sound masked by higher level sounds

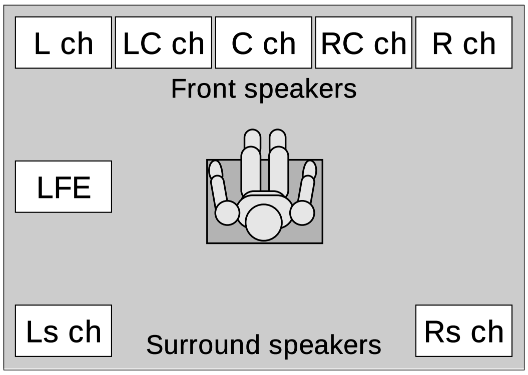



Low level sound near high level sound becomes inaudible

# DVD-Video's high fidelity (2) - MPEG Audio

When a DVD-Video disc in the PAL/SECAM format has audio content, it must have at least one stream of either MPEG Audio, Dolby Digital or linear PCM audio.

■Speaker layout for 7.1 channel MPEG-2




## ■Multi-channel surround system

MPEG Audio is compressed digital audio supporting from one to eight channel combinations, and shown in the accompanying chart. The LFE channel is optional in all combinations. For wider viewing angles, the optional 7.1 channel sound coding adds left-center and right-center channels.

■MPEG Audio Modes

| **MPEG-1 modes** | **Multi-channel output** |
|---|---|
| 1/0 | mono |
| 2/0 | stereo |
| **MPEG-2 modes** | |
| 3/0 | stereo with center channel |
| 2/1 | surround - two front channels and mono surround |
| 3/1 | surround - three front channels and mono surround |
| 2/2 | surround - two front channels and stereo surround |
| 3/2 | surround - three front channels and stereo surround |
| 5/2 | surround - five front channels and stereo surround |

## ■Features of the MPEG Audio System

MPEG-2 is a compatible surround system, and an extension of the MPEG-1 audio format. For reproduction of 5.1 multi-channel sound, additional information is necessary in the first extension part of the MPEG bit stream. And, for reproduction of full 7.1 multi-channel sound, more additional information is necessary in the second extension part of the MPEG bit stream. A DVD player having only stereo MPEG playback capability can extract the MPEG-1 compatible stereo audio content from the MPEG-2 audio stream on the disc.

Another feature of MPEG Audio is that it can be recorded on the disc at a constant or a variable bit rate. Constant bit rates can be set between 64 k and 912 k bits per second. For the variable bit rate option in MPEG Audio, an average bit rate can be selected to meet the quality, capacity and transfer rate requirements for sound encoding. When the audio material is less complex, the actual bit rate necessary to maintain the required level of audio quality can be specified. Compared with constant rate encoding, variable bit rate MPEG-2 encoding can offer audio data capacity and transfer rate savings of between 25 to 33%.

In this way, the advantages of MPEG Audio can be applied in a number of digital audio and video distribution applications, such as DVB, DAB, CATV, CD-ROM, Video CD, telecommunications uses, and more.

## ■MPEG Audio's high efficiency coding method

MPEG Audio is a high quality and highly efficient form of audio coding to ISO/IEC standards. In MPEG Audio compression, perceptual coding plays an important role. Studies in psychoacoustics have shown that low level sounds and the low and high frequency ranges are not audible due to the perceptory limitations of the human ear. This concept, along with the concept of “masking” are used to take full advantage of psychoacoustic principles. A total of 32 bands of sub-band coding, along with Modified Discrete Cosine Transform operation, is used along with other forms of coding. As a result, highly efficient compression is achieved with

# DVD-Video's high fidelity (3) - Linear PCM

## ■Linear PCM delivers the highest level of sound quality

The most important feature of linear PCM is that it delivers the highest level of sound quality since it does not employ data compression. Accordingly, it has been adopted in the DVD-Video system. Either 16-bit, 20 bit or 24-bit quantization rates can be used with 48 kHz or 96 kHz sampling rates, in any combination, can be used in linear PCM. The maximum bit rate is set at 6.75 Mbps per stream, and within this range up to eight channels of audio can be recorded, as a standard option. When using higher bit rates and the higher sampling frequency, of course, the number of channels which can be used are reduced, but at 16-bits/48 kHz, a full eight channels can be used. Music video software can be enjoyed with high-fidelity surround sound reproduction, a feature

■Linear PCM audio specifications

| sampling frequency | quantization bit | max. number of channels (and bit rate)* |
|---|---|---|
| 48KHz | 16-bit | 8ch (6.144 Mbps) |
| | 20-bit | 6ch (5.760 Mbps) |
| | 24-bit | 5ch (5.760 Mbps) |
| 96KHz | 16-bit | 4ch (6.144 Mbps) |
| | 20-bit | 3ch (5.760 Mbps) |
| | 24-bit | 2ch (4.608 Mbps) |

***Per stream; maximum bit rate per stream is 6.75 Mbps.**

# Multiple-language function

## ■Multiple-language dubbing of up to eight languages

DVD-Video is capable of recording up to eight streams of sound, with either the Dolby Digital system, the MPEG Audio system or the linear PCM system selectable for each stream within data capacity limitations. As in some movie software, each stream is used for dubbing a different language, and a particular stream can be selected from the menu upon playback. This multi-language dubbing feature allows the creation of up to eight different soundtracks. Needless to say, playback through the Dolby Digital or the MPEG Audio 5.1 channel surround sound is also possible. Using the same movie software, one language may be selected when viewing alone, while another can be selected when viewing with others.

## ■Multiple-language subtitling of up to 32 languages

DVD-Video is also capable of storing subtitles in up to 32 different languages, and any language can be selected from the menu for display upon playback. Any combination with a soundtrack language selected in the multiple-language dubbing function is possible. The remote controller of a DVD-Video player controls the display of subtitles, so subtitles may be displayed or removed from the screen at any time and software can be used in the same way as the software with closed captions which was not only used by the hearing impaired, but also popular for language learning. The "sub-picture" function of DVD-Video is used for the multiple-language subtitle function, and DVD-Video has 32 streams for these sub-pictures. Besides subtitles for movie software, the sub-pictures can be applied in many different and interesting ways, as the accompanying chart shows.

■Examples of sub-picture applications

| | |
|---|---|
| menu | may be combined with main pictures<br>(moving pictures and still pictures)<br>used with highlight commands |
| movies | subtitles (multiple-language, scrolling) |
| karaoke | text (changing displayed color, fade in, fade out) |
| games | timing display<br>(changing displayed position, flashing)<br>used with highlight commands |

# Stream and packet transmission

## ■"Stream" data flow

When speaking of data to be stored, there is the basic concept called the "stream" in DVD-Video. Literally, this means a data flow and it may be imagined as something similar to a track on a tape recorder.

Audio data or video data is stored on a stream and the data is retrieved from the stream for playback. The number of streams available in DVD-Video are one stream for the video (main pictures), eight streams for audio, and 32 streams for sub-pictures. Tracks on tape used for analog recording are arranged parallel to each other lengthwise, while data stored on a DVD disc are a tremendous number of pits stretched in a row. Picture data, audio data, and other data are included in this pit row. Let's take a look at how these forms of data are retrieved from the pit row.

■Outline of the DVD-Video data stream

| | | |
|---|---|---|
| video data | 1 stream | MPEG2 system |
| audio data | 8 streams, max | linear PCM, Dolby Digital (AC-3), or MPEG Audio |
| subpicture data (subtitles, etc.) | 32 streams, max | run length coded bit map |

## ■Transmission by packet multiplexing

Data is stored by the "packet multiplexing" system on the DVD disc. Packet multiplexing is a system in which video data and audio data are arranged into a number of blocks called "packets" and they are tagged with packet headers which indicate data type, stream number, and time axis information in a multiplexed (time division multiplexing) method.

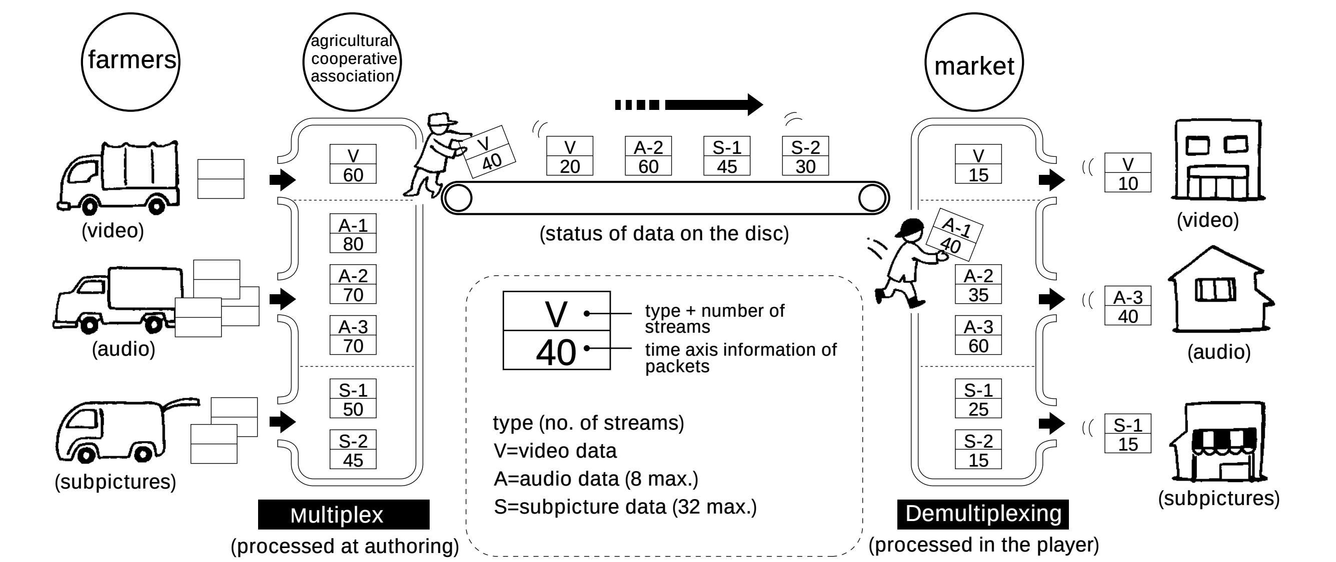
The time division multiplexing is much like what happens to packaging and shipping fruits in a warehouse. Various kinds of fruit (data) which farmers have brought in are classified by type and packed in the standard-sized cartons (packets) in the center. Tags are put on cartons to indicate contents and destinations and all cartons are placed and carried by a conveyor belt system. This can be compared to the row of many pits recorded on a disc.

The market receives and classifies cartons by tags and delivers them to stores and to consumers. Multiplexing various coded data rows corresponds to the placing of cartons containing different kinds of fruit on a conveyor belt and moved one after another. A circuit which performs a similar process is called the "Multiplexer (MUX)".

Separating multiplexed data (multiplexed streams) in original data rows may be regarded as equivalent to separating cartons by the kind of fruit at the market, and a circuit which performs this task is called the "Demultiplexer (DMUX)".

The volume of coded picture data in DVD-Video varies by frame, so video and audio cannot be synchronized by simple separation and compounding. Actually, a very complex process is performed to synchronize picture data and audio data in DVD-Video packet transmission.

■Data transmission of streams by packet multiplexing



# DVD-Video interactive operation

Random access functioning is a feature common to optical disc media. DVD-Video makes full use of this feature and new functions for the new generation of video media such as multi-story and multi-angle functioning are incorporated in the DVD-Video, enabling the creation of highly interactive software. Instead of passively watching discs straight through, viewers can get involved, engrossed with multiple story lines, multiple camera angles and more.

## ■Title menu and DVD menu

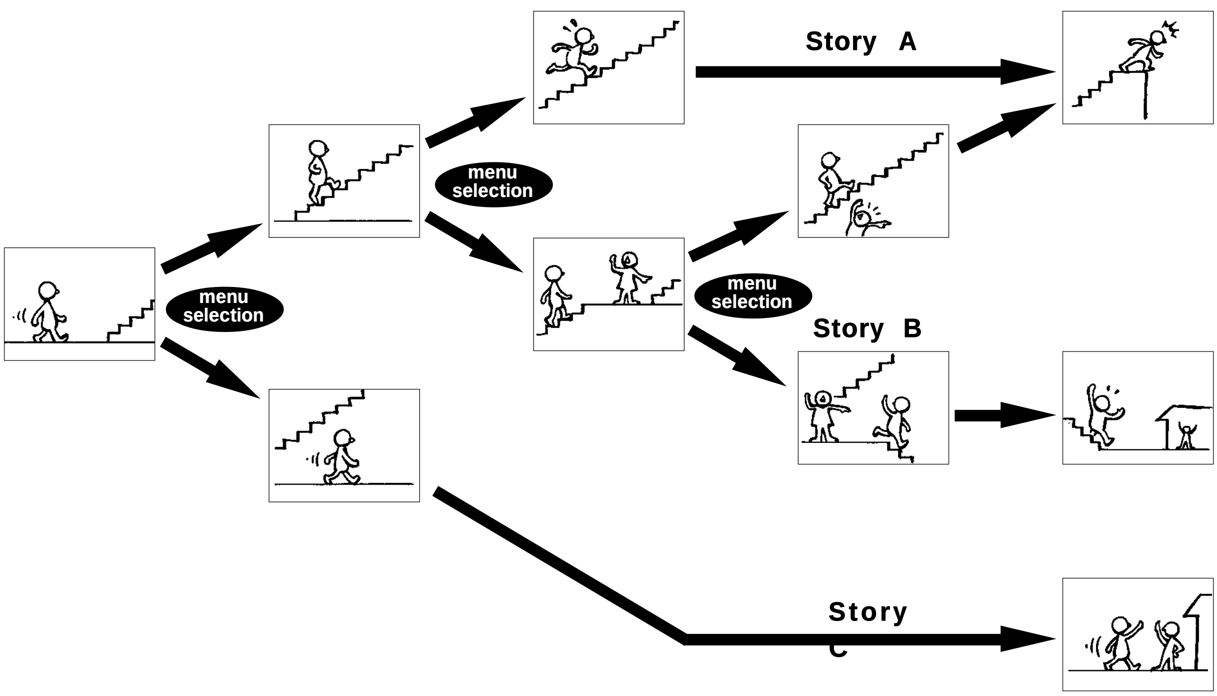
The DVD-Video can contain the title menu coupled with DVD “sub-picture” function. So producers can create a “Visual table of contents”, enabling viewers to choose sections and access them directly. For example, a music video disc might have a little menu of songs. A movie disc might have a menu of chapters, identified by representative pictures. DVD menu allows a choice of audio formats, sound tracks and subtitle languages, can also be programmed onto a disc. Disc producers are free to design their own menus, according to the type of software.

## ■Multi-story function

The multi-story function allows the recording of a number of different story sequences on the disc. Viewers can select story development during playback from the displayed menu. Highly interactive software can be created depending on software producers’ ideas by making use of the large storage capacity of DVD.

The multi-story function allows the recording of a number of program chains composed of picture and audio data matched to story configurations with control commands on the disc. The desired playback sequence is achieved by linking information in response to the menu or the viewers’ operation.

■Multi-story function (concept)

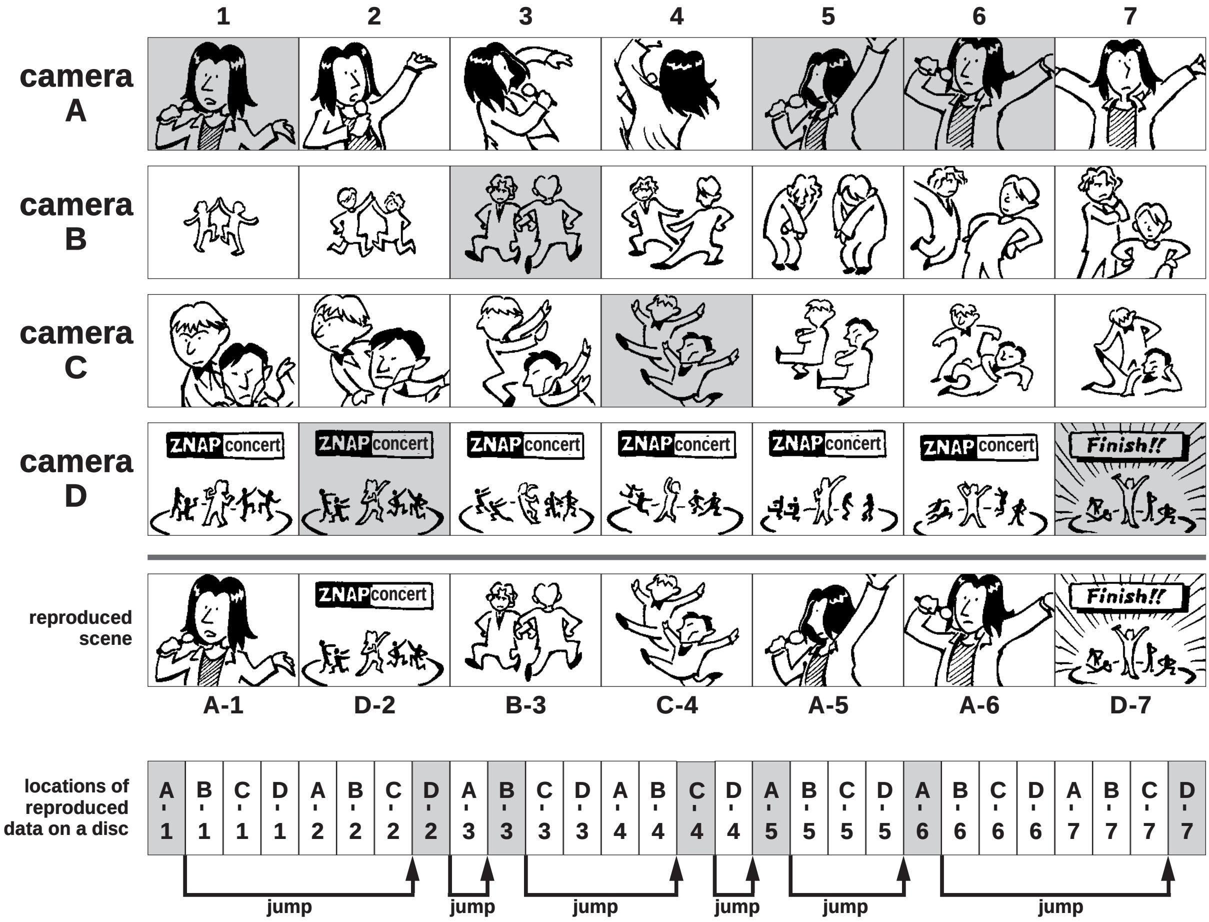


## ■Multi-angle functioning up to nine angles

Video scenes taken from up to nine different camera angles can be stored on a disc in DVD-Video, and during playback the desired angles can be selected instantly by the multi-angle function. For example, in live concert software, an individual member such as a vocalist or a guitarist may be taken by a camera in addition to the entire stage picture.

A level of “custom” software enjoyment not possible with conventional media is easily achieved with DVD Video if so created at the software production stage.
A remarkable feature of the multi-angle function is its ability to reproduce a scene without a break from a number of scenes which are progressing simultaneously. This capability is called “seamless playback.”

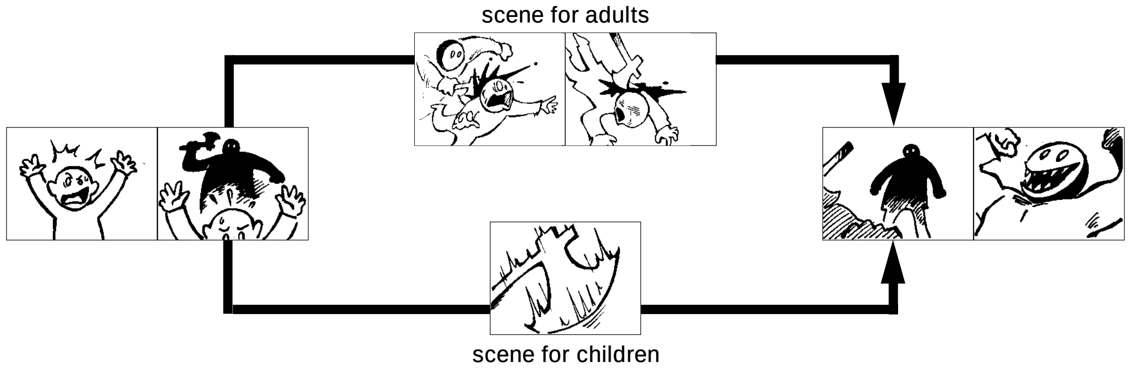
■The multi-angle function (concept)




## ■Parental lock function (optional standard)

A function called “parental lock” allows the “locking” of software at the discretion of parents to prevent undesired viewing by children depending on contents of software. Normal reproduction of the disc with this type of software requires a registered identification code and otherwise undesirable (from an educational or other standpoint) scenes such as violence are automatically skipped or switched to an alternate scene recorded on the disc. The parental lock function is an optional standard using the seamless playback capability.

■The parental lock function (concept)

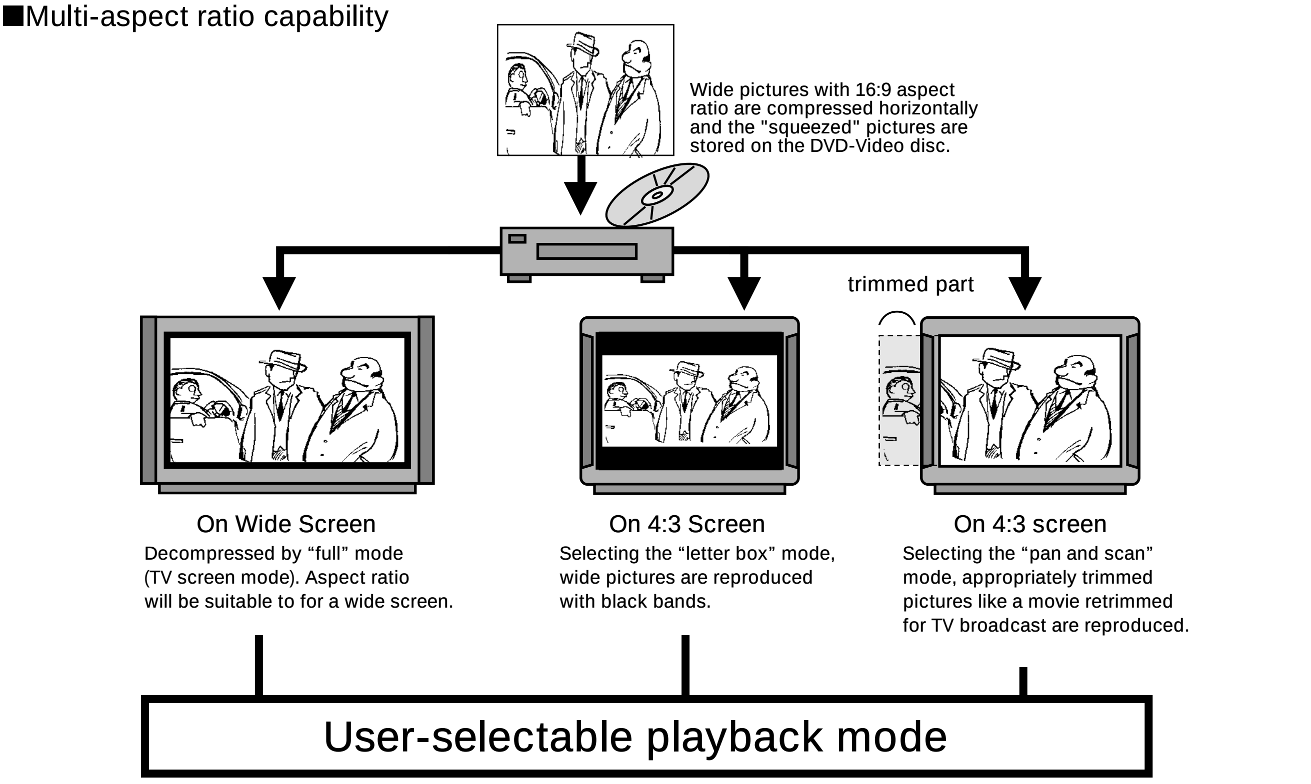


## ■Multi-aspect ratio capability

Software that allows the effective display of wide pictures with a 16:9 aspect ratio on the TV screen of a different aspect ratio can be created in the DVD-Video format. Pictures with a 16:9 aspect ratio are compressed horizontally for recording on a disc capable of the multiple aspect ratios. When playing them back on a TV or monitor with a 16:9 aspect ratio, the pictures are decompressed horizontally by the “full” mode, one of several TV screen modes, without deterioration of the horizontal resolution. The pictures are reproduced in the 16:9 aspect ratio, completely filling the wide screen.

For viewing 16:9 pictures on a 4:3 screen, a disc can be produced with the “pan and scan” mode in addition to the basic “letter box” mode. In the letter box mode, pictures are reproduced with black bands above and below the picture. In this case, scanning lines of the picture portion are reduced from 580 to 430. In the “pan and scan” mode, 16:9 pictures are reproduced by trimming the left and right portions of the playback picture itself for viewing on a 4:3 screen. Information regarding what parts are to be trimmed at what time are stored on the disc, and upon playback the player outputs the picture trimmed in the desired fashion. Functions included in MPEG2 are used in the “pan and scan” mode. Data specifying display regions of coded pictures in units of  fields can be output by MPEG2.

■Multi-aspect ratio capability




# Questions & Answers

### How does seamless playback work?

A 4 Mbit memory called a track buffer is mounted in a DVD player for variable rate playback. The seamless playback function makes good use of this track buffer memory. The time required for the pickup to read the necessary data by jumping tracks on a disc recorded with multi-angle function to play back selected pictures and audio is absorbed by this memory, and pictures are played back continuously without a break. The operation of seamless playback is basically the same as that of ESP (electronic shock protection) buffer memory in portable CD and MD players.

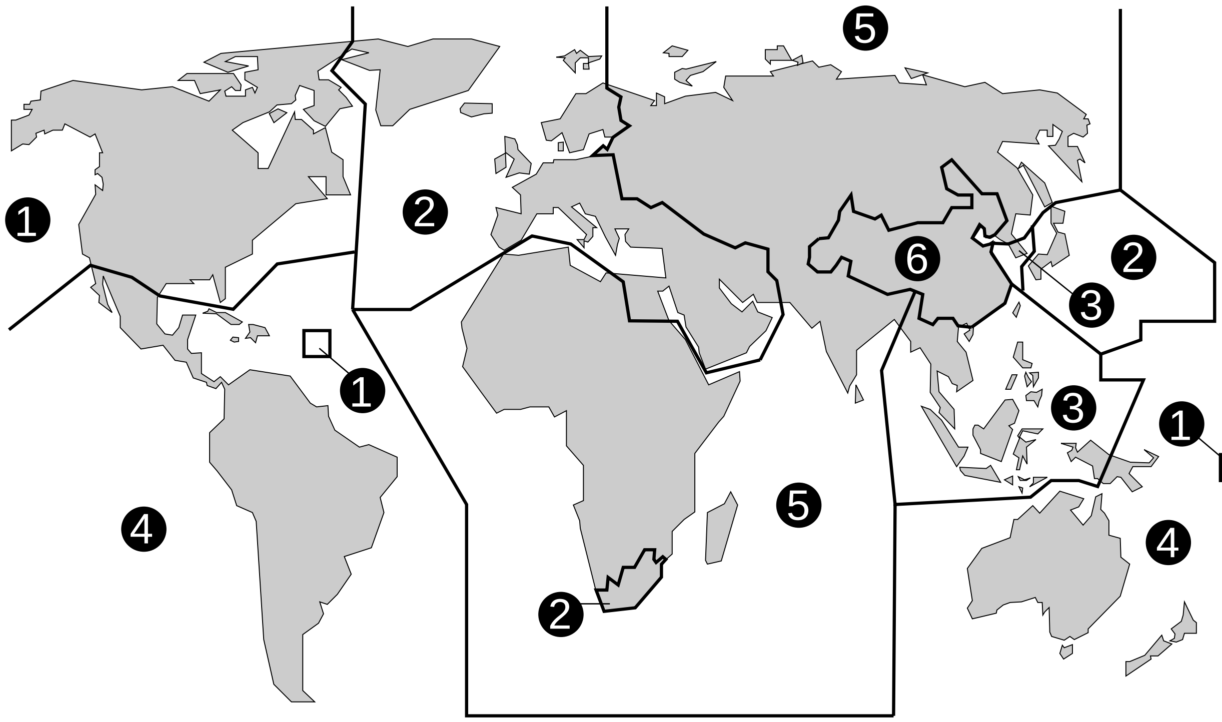
# Copyright protection system in DVD-Video

## ■"Regional Code" controls playback in six regions of the world

A new movie released in the U.S. is normally released overseas several months later, and the schedule for movie releases can differ greatly by region. If the DVD-Video software of a movie is released in the U.S. before the movie itself is released in a certain region, and if the U.S. version software is imported into that region, it will possibly affect the movie business in that region.

The playback management system introduced with DVD Video divides the world into six sales regions and sets a region ID for each region on both players and discs. This functions to allow playback of discs only in their applicable region. The ID applicable to a sales region is registered on players , and unless the ID on a disc and the ID on a player match, the software cannot be played back if the ID is recorded on the disc by intention of the copyright holder. Reproduction in more than one region may be made possible by how the ID is set, so once-famous movies may be available for playback in all regions.

■The six ID regions of the world




## ■"Copy Protection System" links software and hardware

A system designed to protect copyrighted works from illegal copying by the intention of copyright holders in either the analog interface or a future digital interface is incorporated into DVD-Video. Particularly in the case of digital copying, digital data reproduction will be controlled by linking software and hardware (including the computer field) with highly advanced scrambling technology. Although a DVD player is not equipped with digital picture output capability, if the analog copy protection is added to picture signals to protect the copyright, the analog picture output cannot be recorded with the proper quality. A disc free of the copyright protection, however, can be copied.

# DVD-Video software production

The DVD-Video software production process can be summarized as the planning and production of video and audio sources, authoring, and then disc production. Telecine conversion is required before authoring in producing movie software and this process plays an important role, along with authoring, in deciding the final picture quality of DVD-Video software.

Video and audio sources must be of high quality to make full use of the high image and sound quality of DVD-Video. Using films such as inter positives, which are very close to the original films in quality, are being considered in Hollywood for use in converting movies by telecine processing.

## ■Telecine

In producing movie software, pictures and audio recorded on film must be converted into video and audio signals before storing them on video tape. This process is called “telecine” and the converted signals are stored by a D1-format digital VTR as the studio master in producing DVD-Video software.

There are a several types of telecine conversion systems. To convert picture information on film into video signals, the difference in characteristics of films and video tapes as media should be taken into consideration, and some calibration in the reproduction of hue and gradation is necessary. Sometimes, color is calibrated closely for each cut (scene by scene) by actually viewing the scenes, and this requires deep knowledge and expertise in movie making as well as video production.

When converting movie images into video signals by the telecine process, conversion without degrading both image and sound quality is made possible since all processes, from calibrations and signal processing to recording by digital VTR, are performed digitally.

## ■Authoring-the process

“Authoring” is the entire process from encoding pictures, audio, and subtitles by applicable data compression systems to combining them into recordable digital data. The MPEG2 real-time video encoder using sophisticated, special-purpose high-speed digital processors is employed in picture data compression.

When encoding pictures by the MPEG2 video encoder, data volume is distributed by the variable bit rate (9.8 Mbps max.) according to the condition of the images. It is important to maintain high and even picture quality throughout the entire content using available capacity. Surround audio is encoded by the Dolby Digital (AC-3) encoder, while subtitles and the operation menu are encoded as subpicture data. After encoding, all video, audio, and subpicture bit streams are added with control commands for interactive functions, such as the multi-story function, and multiplexed according to the DVD logic format into one data entity. Error correction codes are added and 8-16 modulation is performed on the data before recording on the glass master disc as the original data.

## ■Authoring - MPEG2 video encoding

The “two pass coding” method which reads digital image data recorded in the digital VTR twice is used in the DVD MPEG2 real-time video encoder which employs a variable bit rate. At the first pass, the whole volume of images to be recorded is analyzed as to how much data volume is required as to when and what parts of pictures, and this information is recorded statistically.

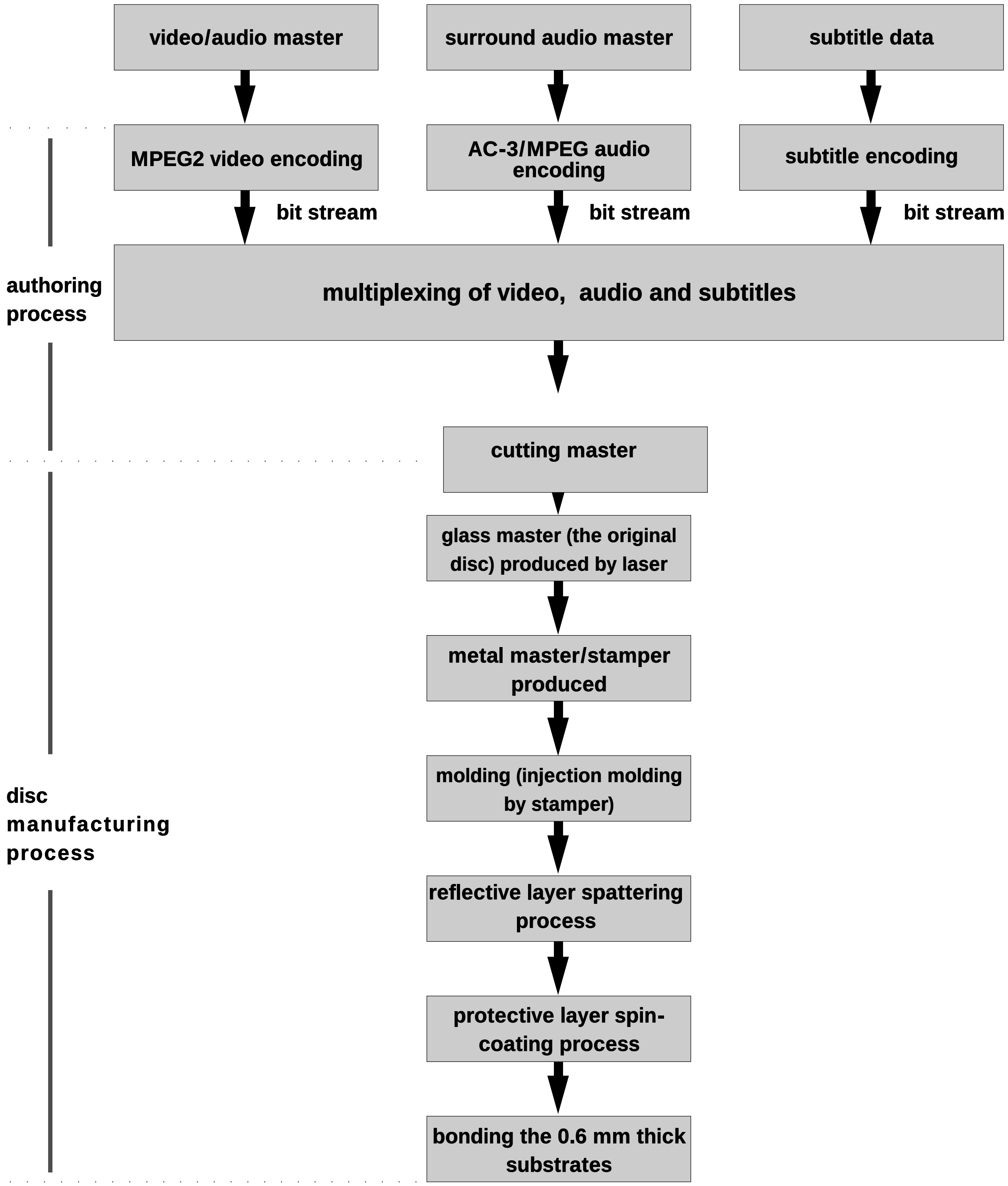
Software for picture data volume analysis and distribution contains the algorithm representing the expertise of software companies, and differences in expertise are reflected as differences in picture quality even though the same source is used to produce the software. Actual data compression is performed at the second pass according to data produced at the first pass. The subjective micro adjustment in data volume distribution is also done visually after computer-based encoding is completed. Prefiltering to process appropriate noise reduction to R, G, and B before encoding is also an important process requiring the extensive knowledge and expertise in high quality image production.

## ■Disc manufacturing

The DVD-Video disc is made of two 0.6 mm thick substrates bonded back-to back, though the material and manufacturing process of the DVD-Video disc almost the same as with CD. The process of bonding the two substrates is the last required process in disc manufacturing, and this represents the addition of one process to manufacturing when compared to the single-construction CD.

When considering productivity, DVD-Video is suitable for large scale production of software in comparison with video tape media which theoretically requires a one-to-one copying process although a high speed magnetic copying system is available. This is another excellent feature of optical disc media.

■Authoring and disc manufacturing process



# OPU, RF amplifier and servo processing

## 1. Optical pick-up unit (OPU)

### 1.1. Overview

Sony’s DVD Players DVP-S315 and DVP-715 which are available on the European market, are constructed for playing CD & DVD discs. Therefore the OPU of these DVD Players contain two different optical systems in one housing. One is used for reading out the DVD, the other one is used for reading the CD.

Figure 1-1 shows the view on the mecha deck; you can observe the two lenses of the different optical systems.

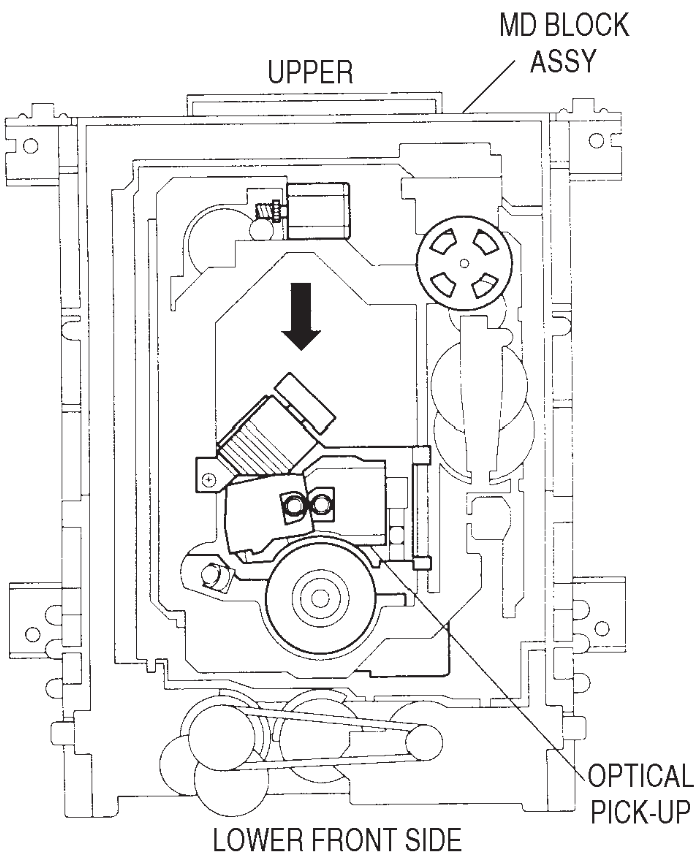



*Fig. 1-1*

## 1.2. Differences between CD & DVD optical pick-ups

The DVD part of the OPU uses a different laser diode which produces another wavelength; according to this also the NA is different (higher).

Please note that the laser diode used in the DVD side is approx. 4 times more sensitive to electrical shocks than the one used for CD. As it is well known from other laser pick-ups there are also short lands for protecting the laser diodes. As we have two laser diodes inside the pick-up we have also two short lands, one for each diode.

The 2-axis device used in the DVD part is much smaller than the one of the CD side, it is a so-called "μ-2-axis device".

Also for detecting the focus and tracking error voltages different principles are used for the DVD and CD side. Explanations for this you will find on the next pages.

Figure 1-2 shows the main differences.

***Numeric aperture (NA)***

As mentioned in the table before the value of the NA for DVD use is higher than the one for CD use. A higher NA means the focussing depth is narrower, even the tilt tolerance and the disc thickness become lower.

Figure 1-3 shows the relation of the NA value and the angle θ which influences the focussing.

| Specifications | DVD | CD |
|---|---|---|
| Optical system | Non-polarized infinite type | Non-polarized laser coupler type |
| Actuator | μ-2-axis device | 2-axis device |
| Objective lens | Glass | Plastic |
| NA (numeric aperture) | 0.6 | 0.45 |
| Focus error | Astigmatic method | Differential 3-divided focusing |
| Tracking error | DPD (differential phase detection) method | TPP (top hold push pull) method |
| Wavelength (λ) | 650 nm | 780 nm |

***Fig. 1-2***

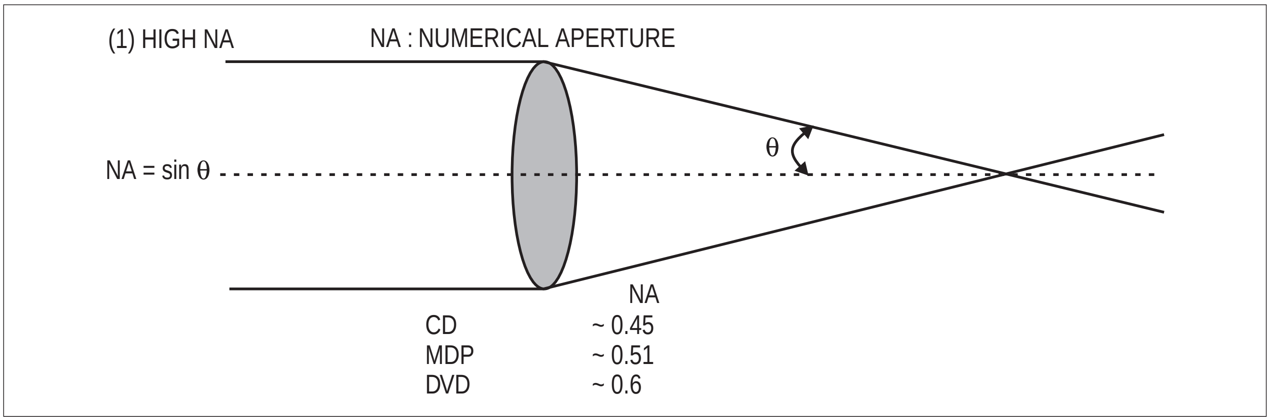



***Fig. 1-3***

As you already may know from other OPUs (e.g. from CD or MD): avoid direct view to the laser light!

The used laser light power for reading out a DVD is between 180 µW for a single-layer disc and 300 µW for a dual-layer disc (CD is approx. 120 µW).

***Lens cleaning***

As the minaturized µ-2-axis device can easily be bent be careful while cleaning the lens of the DVD part. First try to remove the dust with a hand blower; if it is necessary use a cleaning cotton swab (P/N 7−740−900−65) and wipe very carefully in a spiral way from the inner to the outer circumference. The Sony cleaning liquid can be used.

After cleaning it is important to check the jitter value, if the jitter is too high and cannot be adjusted by using the tangential screw the µ-2-axis device may be broken! (see Jitter Adjustment).

***OPU label***

There is an identification label mounted at the OPU. In the following figure you will find the explanation of the used characters.

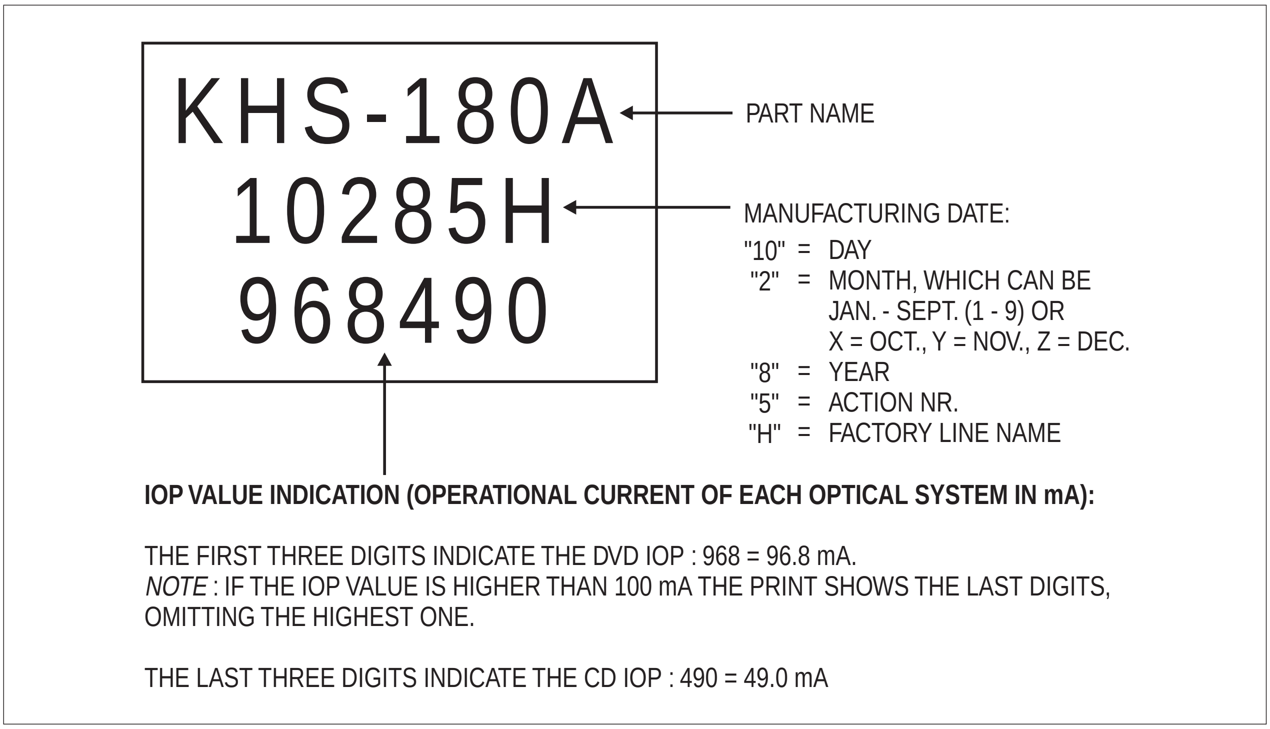



***Fig. 1-4***

### *Effect of tilt angle*

A DVD is built by two parts, each one has a thickness of 0.6 mm. They are glued together. This construction prevents disc bend caused by temperature and humidity changes. But on the other hand a disc wrapping may occur at the outer circumference of the disc caused by the higher thickness of 2 x 0.6mm. The wrapping can be described by the value of the tilt angle which differs in relation to the disc's thickness. During readout a changing tilt angle will cause a skew error, which will disturb the read-out disc signal. To detect this tilt effect a so-called SKEW sensor is mounted on the surface of the OPU. By using the skew error voltage the OPU lens is moved in parallel to the disc surface.

Figure 1-5 shows the relation between disc thickness and tilt angle.

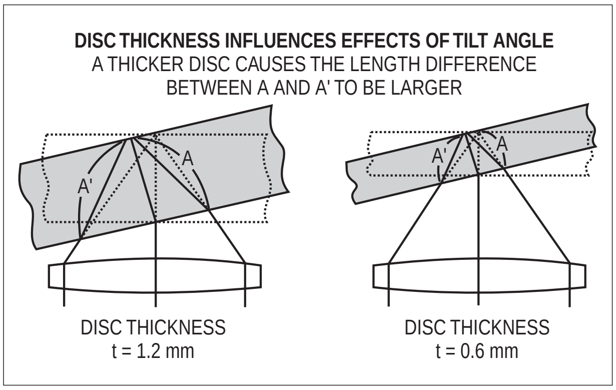



***Fig. 1-5***

Figure 1-6 shows the position of the skew sensor.

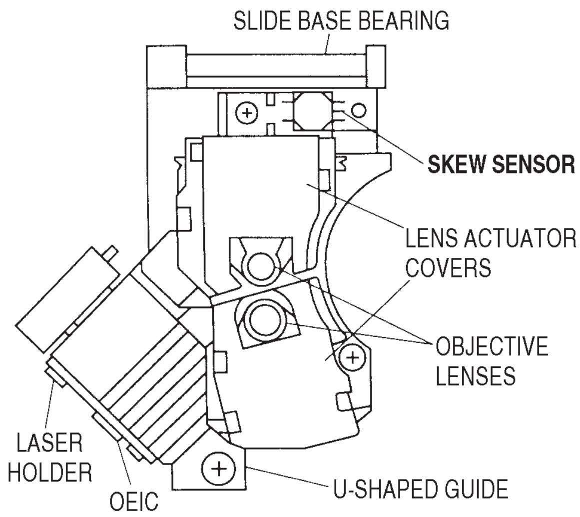



***Fig. 1-6***

**Physical parameters for readout**

| Parameter | | CD-ROM mode 1 (74 min.) | DVD-ROM (single layer) |
|---|---|---|---|
| Spot diameter | $W = \lambda / (2 \times NA)$ | 0.87 mm | 0.54 mm |
| Track pitch | p | 1.6 µm | 0.74 µm |
| Minimum pith length (3T) | = 3 x c | 0.84 µm | 0.40 µm |
| Linear velocity | v | 1.21 m/sec | 3.49 m/sec |
| Optical cut-off frequency | $f_{CO} = v / W = v \times 2 \times NA / \lambda$ | 1.4 MHz | 6.44 MHz |
| Channel bit rate | f = v / c | 4.3218 MHz | 26.16 MHz |
| Highest EFM frequency | $f_{I3} = f / 6$ | 0.72 MHz | 4.36 MHz |
| Size of program area on disc | $a = \pi \times (R_{max}^2 - R_{min}^2)$ | 8600 $mm^2$ | 8760 $mm^2$ |

*Fig. 1-7*

**Remarks**

The smaller spot size increases the optical resolution, without sacrifying system margins.

### 1.3. The optical systems inside the OPU

Before it was mentioned that inside a DVD-OPU there are two different optical systems, one for DVD, one for CD.

#### 1.3.1. The CD optical system

It works as a LASER COUPLER system. This means the laser diode itself, the monitor diode for controlling the light output and the detector unit for readout are included in one block. Even the half mirror function, which is used for splitting between incoming and outgoing beam, is done by the laser coupler block

Figure 1-8 shows the laser coupler from its outside.

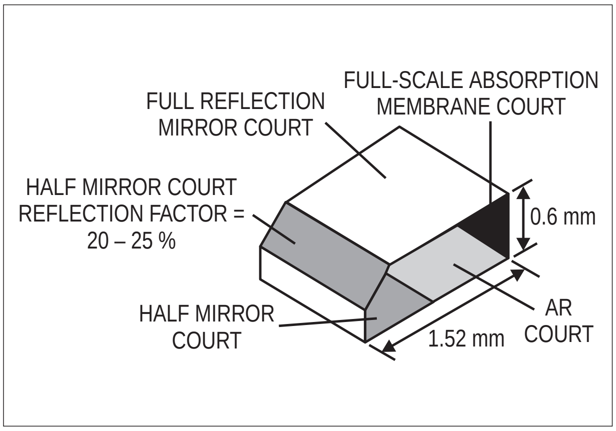



*Fig. 1-8*

Figure 1-9 shows the optical components which are included.

Figure 1-10 gives you an idea of the size.

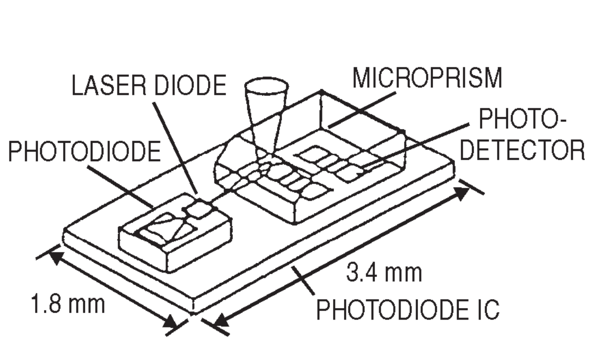



*Fig. 1-9*

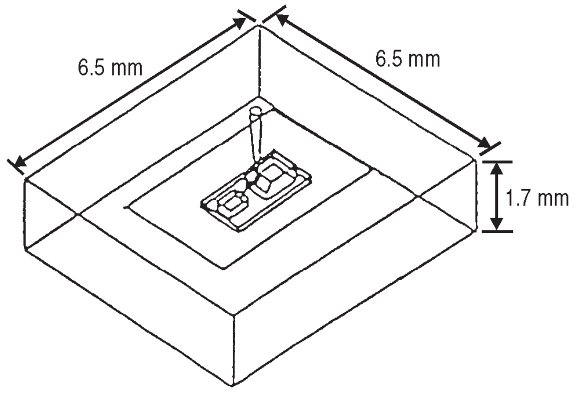



*Fig. 1-10*

### *Tracking error detection*

Tracking error detection for CD is done with the TOP PUSH PULL principle. This method is a modified PUSH PULL principle and cancels the DC offset, which is the weak point of the normal PUSH PULL system. For the TPP principle, two detectors each with four detector fields are used. The error voltage is calculated by the following formula:

$$TE = (A2 + B1 + A4 + B3) - (A1 + B2 + A3 + B4)$$

$$TE = E - F$$

Figure 1-11 shows the arrangement of the detectors PD1 and PD2. They are located on top of each other. PD1 is next to the objective lens.

Figure 1-12 shows the light spots on PD1 and PD2 in relation to the beam position on the disc. The distance from PD1 to PD2 is calculated in that way that the spot position at the surface of PD1 is opposite to the one of PD2, when the beam on the disc is in “off track” position. “On track” results in the same light amount on each detector.

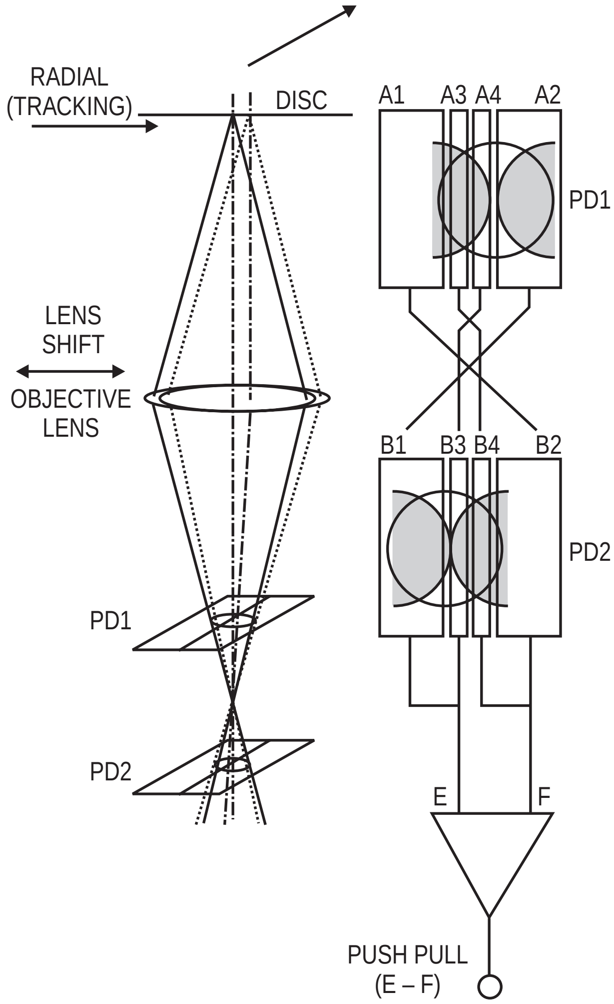

RADIAL
(TRACKING)
DISC
A1
A3 A4
A2
PD1
LENS
SHIFT
OBJECTIVE
LENS
B1
B3 B4
B2
PD2
PD1
PD2
E
F
PUSH PULL
(E – F)

*Fig. 1-11*

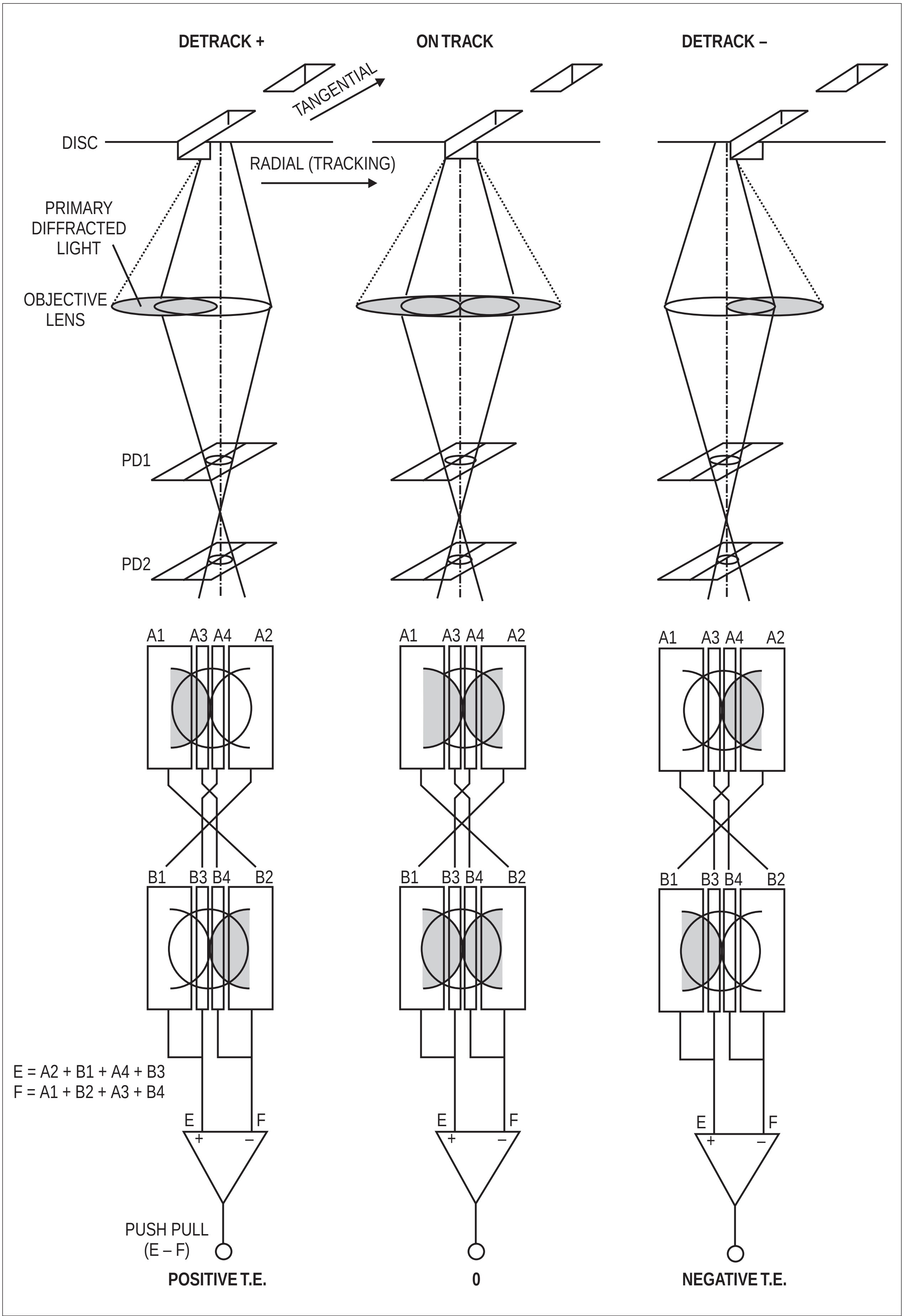

DETRACK +
ON TRACK
DETRACK –
TANGENTIAL
DISC
RADIAL (TRACKING)
PRIMARY
DIFFRACTED
LIGHT
OBJECTIVE
LENS
PD1
PD2
A1 A3 A4 A2
B1 B3 B4 B2
E = A2 + B1 + A4 + B3
F = A1 + B2 + A3 + B4
E F
+ –
PUSH PULL
(E – F)
POSITIVE T.E.
0
NEGATIVE T.E.

*Fig. 1-12*

As told shortly before, the advantage of the TPP principle is the cancelling of the DC offset. This is done with TOP HOLD circuits switched in the E and F signal path. This means: The tracking error signal is detected via low-pass-filtering of the RF envelope signal. Next the offset varation of the RF envelope has to be separated and held. In order to cancel the DC offset, occurred by lens shift, now the offset variation will be substracted from the RF envelope signal. The figures 1-13 and 1-14 show the block diagram and the signals respectively.

To cancel the DC offset the formula A Signal – b is used. In the block diagram shown in figure 1-13 the factor “K” which is a fixed value (< 1) calculated by the designer is multiplied to the “TOP HOLD” value which is calculated by the “a” peak signal shown in figure 1-14. The figure shows the RF envelope of the “E” signal. “a” shows the change of the RF envelope peak level. The “A Signal” is the low-pass-filtered RF envelope. “b” shows the offset change of the “A Signal”.

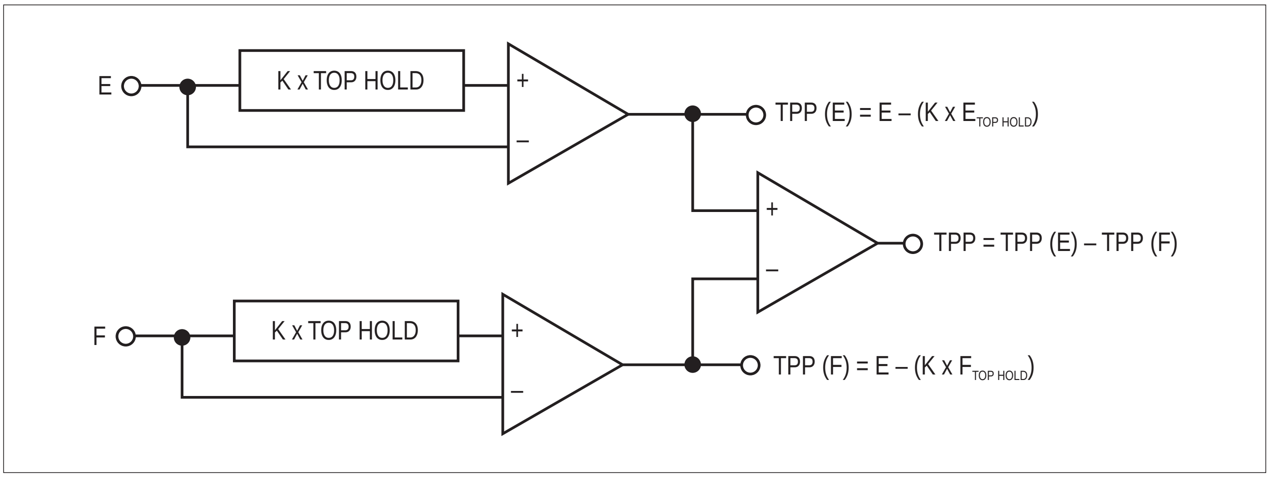



*Fig. 1-13*

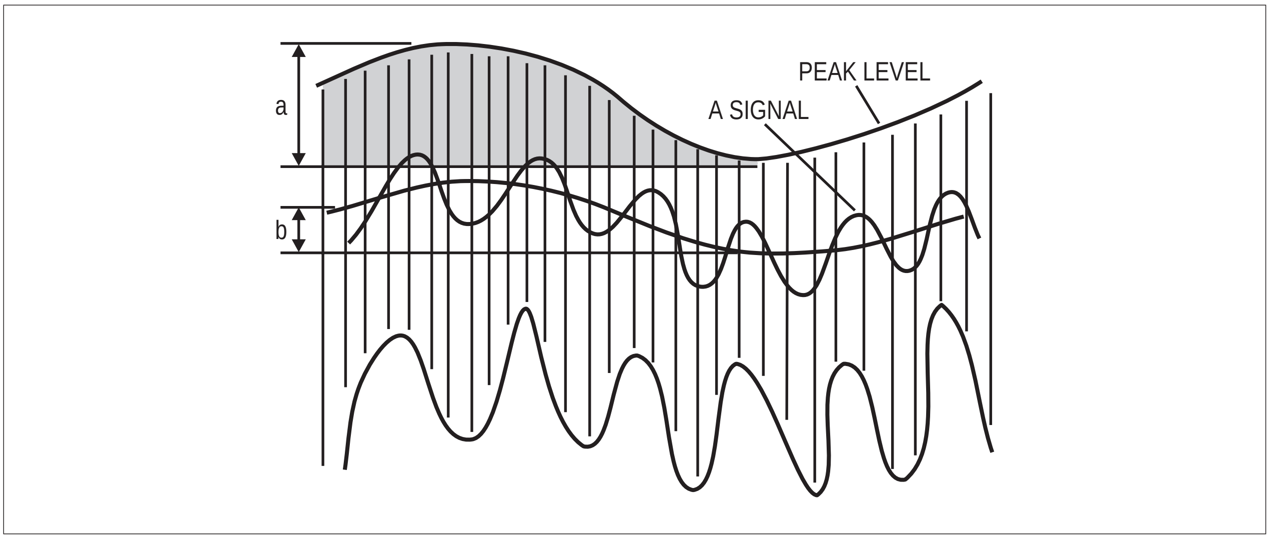



*Fig. 1-14*

*Therefore envelope of “E” signal*

### *Focus error detection*

Focur error detection for CD is done with the D - 3DF principle, which means "Differential 3-Devided Focussing". Two photodetectors (PD1 & PD2), each with three detector fields, are used for this kind of focussing. Figure 1-15 shows the alignment of the photodetectors. These detector fields are named "A" up to "C" (with and without mark). When the laser beam on the disc surface is well focussed the output of PD1 and PD2 is as follows:

$$A + C = B \text{ or } A' + C' = B'$$

With respect to this the following formulas are used for detecting the error voltage of PD1 and PD2:

$$PD1 = B - (A + C)$$
$$PD2 = B' - (A' + C')$$

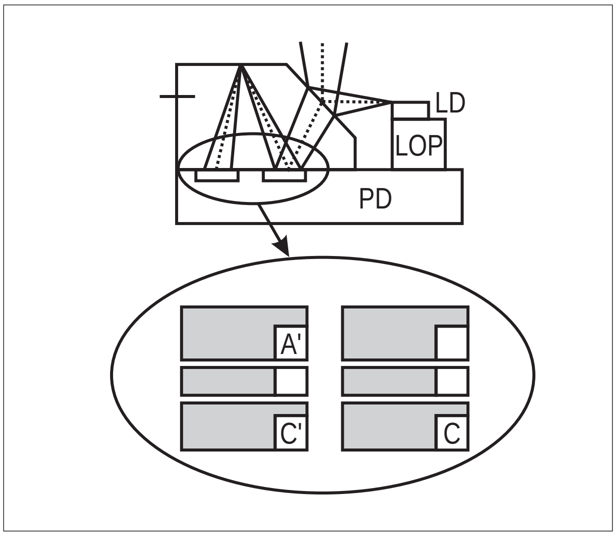



*Fig. 1-15*

For detecting the focus error the built-in microprism of the laser coupler block is very important. The light beam reflected from the disc's surface is coming back to the surface of the microprism. If the beam is well focussed at the information layer of the disc it is also well focussed on the surface of the microprism. Only when the focal point is on the surface of the prism, will the light touch both photodetectors (PD1 & PD2) evenly, so that the size of both light spots becomes equal. See figure 1-16.

The formula for FE is follows:

$$[B - (A + C)] - [B' - (A' + C')] = FE$$

$$PD1 - PD2 = FE$$

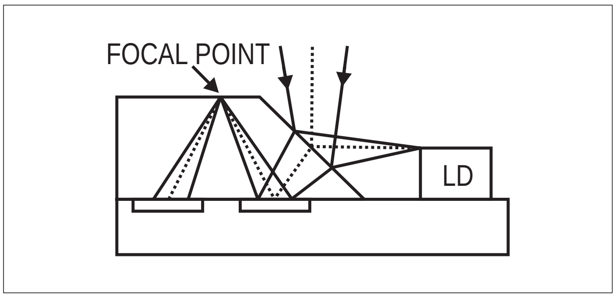



*Fig. 1-16*

Figure 1-17 shows the spots on PD1 and PD2 when the focussing is well done.

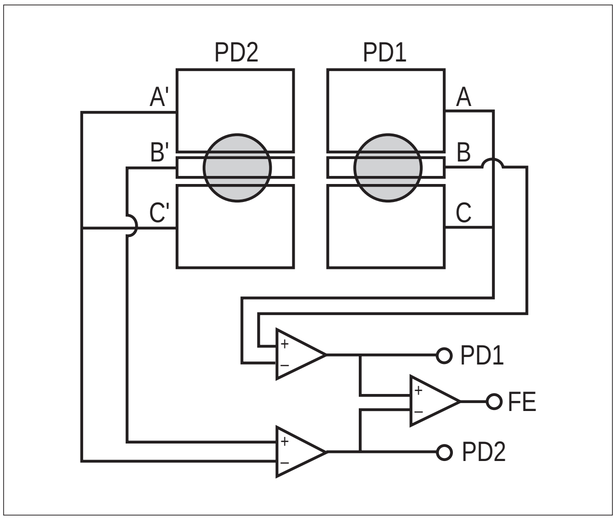



*Fig. 1-17*

Figure 1-18 shows the spots on the PD's surface if the focus adjustment is too close.

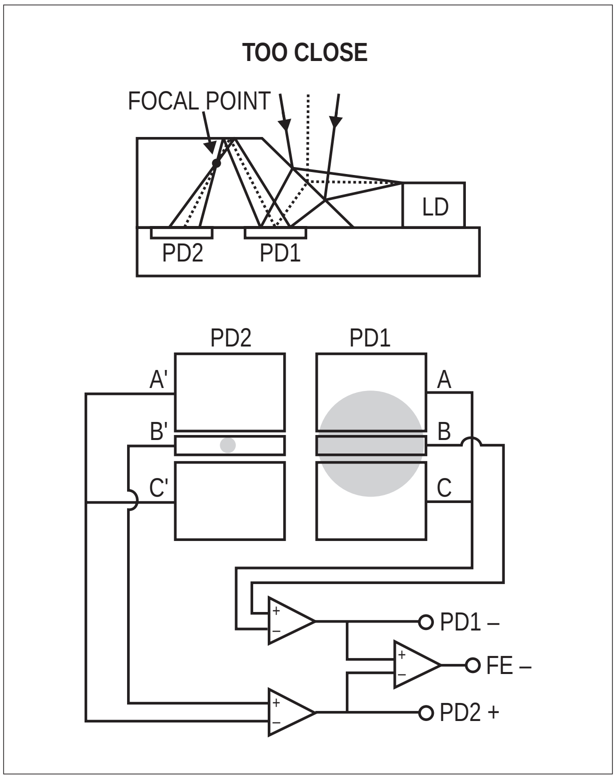



*Fig. 1-18*

Figure 1-19 shows the spots on the PD's surface if the focus adjustment is too far.

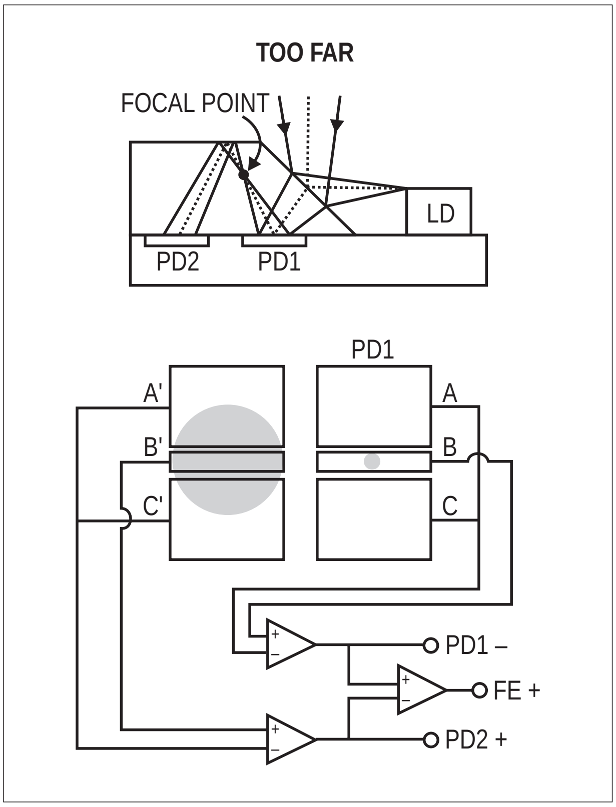



*Fig. 1-19*

### *Conclusion on the OPU's CD part*

The CD part of the OPU is mainly built up by the LC (Laser Coupler). It includes the LD (Laser Diode), the PDs (Photodetector) for tracking and focussing and the monitor diode, which controls the light ouput. The microprism of the LC works as a beamsplitter. Further a separate mirror is used for guiding the light in the direction of the disc. It sends also the reflected light back to the LC. For moving the lens the well-known 2-axis device is used. The CD optical part is a one-beam laser system. It uses the CD typical wave-length ($\lambda$) of 780 nm.

### 1.3.2. The DVD optical system

The DVD optical system works as a one-beam-infinite-type optical system. This means there is no integration of the important optical parts, as we have it in the LC. In this system there is a separate LD; it sends out the laser light ($\lambda$ = 650 nm) to a beam splitter which works as a half mirror. Next the light, on its way to the disc, is passing a collimation lens; after that a mirror reflects it in the disc's direction. The collimation lens corrects the light to a parallel form. It also sets up a defined beam diameter. Then the light passes the lens, a µ-2-axis device can move this lens in the horizontal and in the vertical direction for correcting tracking and focussing.

The reflected light of the disc is passing again the objective lens, the mirror and the collimation lens. The beam splitter sends the light to the photodetector. In the DVD part of the OPU a photodetector built by four detector fields is used. The detector fields of this photodetctor are named from “A” up to “D”. They are used for detecting the focus and tracking error signal and the RF readout, too. Another signal, which is named “PI”, is extracted also from “A, B, C, D”. The “PI” signal is used for detecting whether a single- or a dual-layer DVD is used. See also figure 1–23.

***Tracking error detection***

Tracking error detection for DVD is done with the **D**ifferential **P**hase **D**etection method (DPD). One PD with four detector fields is used. The principle is as follows:

The pit edges are detected by the four detector fields during normal playback. The signals “A, B, C, D” of the detectors are equalized and sent to separate comparators. An internal reference voltage determines the threshold level of the comparators. The output of each one is squarewave-modified. The output timing is in relation to the signal level, coming from the detectors. Next the comparators’ output signals “A” and “B” are sent to one phase detector; the phase difference signal of “A” and “B” is output. The same is done with the comparators’ ouput signals “C” and “D”. As a result a second phase difference output signal from “C” and “D” is available. To get the actual TE signal the phase difference signals “A/B” and “C/D” are added and low-pass-filtered. See figure 1–21.

$$TE = \Delta \text{ phase } A/B + \Delta \text{ phase } C/D$$

Figure 1-20 shows the PD and the spot in ideal position and shape.

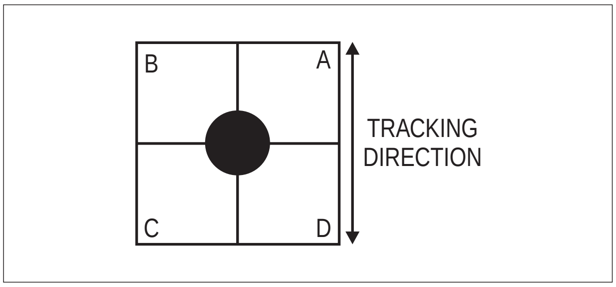



***Fig. 1-20***

Figure 1-21 shows the block diagram of the tracking error circuit.

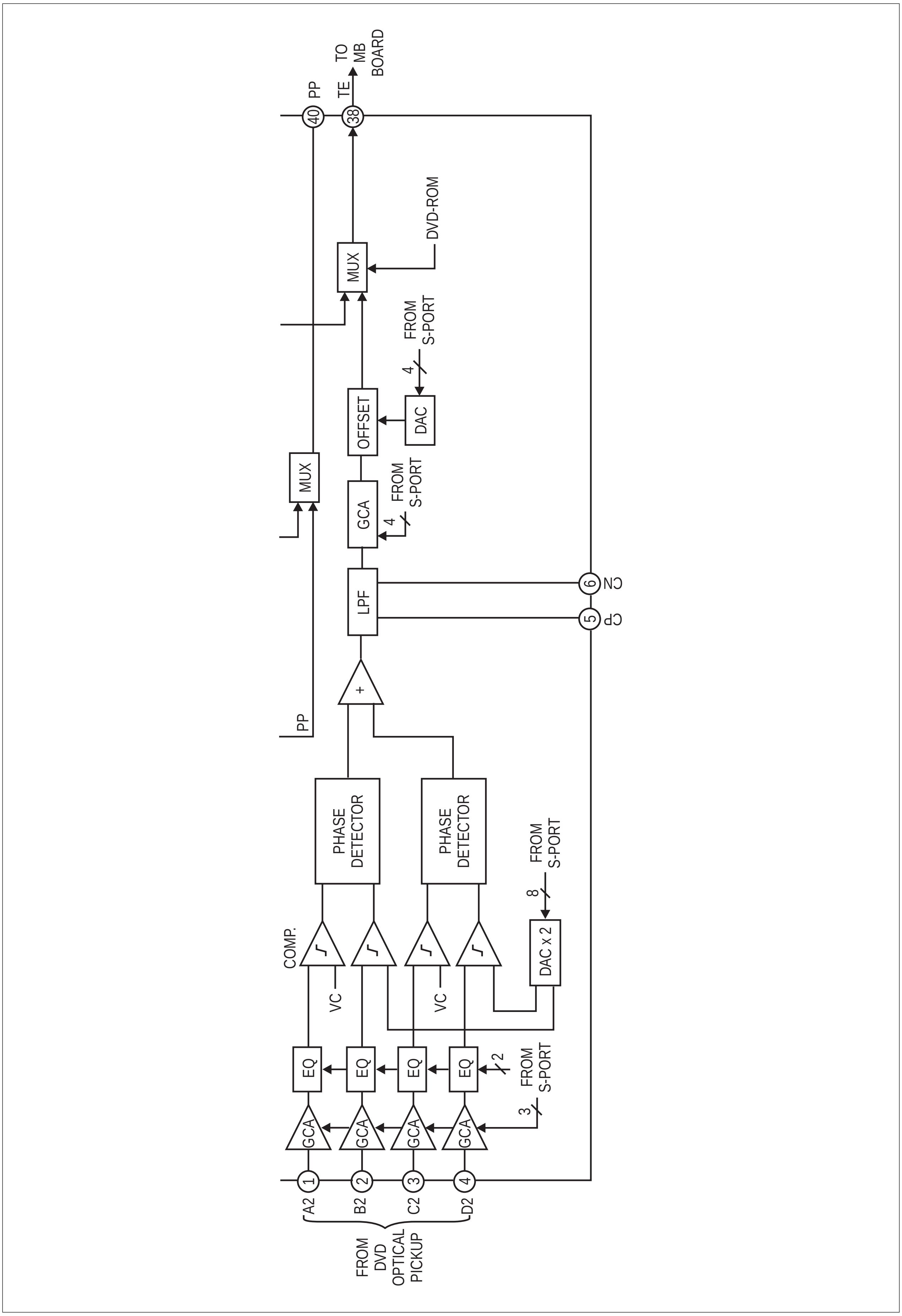

TO
MB
BOARD
PP
TE
40
38
DVD-ROM
MUX
FROM
S-PORT
4
OFFSET
DAC
MUX
GCA
LPF
CN
CP
6
5
PP
PHASE
DETECTOR
PHASE
DETECTOR
FROM
S-PORT
8
COMP.
VC
VC
DAC x 2
EQ
EQ
EQ
EQ
2
GCA
GCA
GCA
GCA
3
1
2
3
4
A2
B2
C2
D2
FROM
DVD
OPTICAL
PICKUP

*Fig. 1-21*

### *Focus error detection*

Focus error detection for DVD is done with the astigmatic method, which we know in general from CD and MD Players. From infinite OPU types used in former times for CD we know that an additional astigmatic (cylindric) lens is used for detecting the focus error. This is the difference to the optical part which is used for DVD. There is no separate astigmatic lens, instead of this the beam splitter is used for creating the astigmatic effect.

This optical system is calculated in the way that if the spot is well focussed on the information layer of the disc, the reflected light spot is also well focussed on the surface of the beam splitter. If it is well focussed on the surface of the beam splitter the spot at the PD will be in a round shape in the centre of the four detector fields. If the focus adjustment is not well done the shape of the light spot on the PD changes from round to elliptic caused by the astigmatism. Depending on the shape on the detector's surface it is possible to calculate the focus error by the following formula:

$$(A + C) - (B + D)$$

For using dual-layer discs the system is able to do a focus jump from layer 0 to layer 1 controlled by the syscon via the focus servo circuit. There is no difference in detecting the focus error itself on layer 0 or 1.

Figure 1-22 shows the different shapes of the spot on the surface of the PD in relation of the focus state.

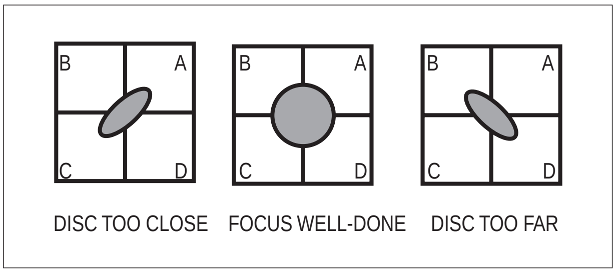



***Fig. 1-22***

Figure 1-23 shows the structures of the CD and DVD optical part of the OPU.

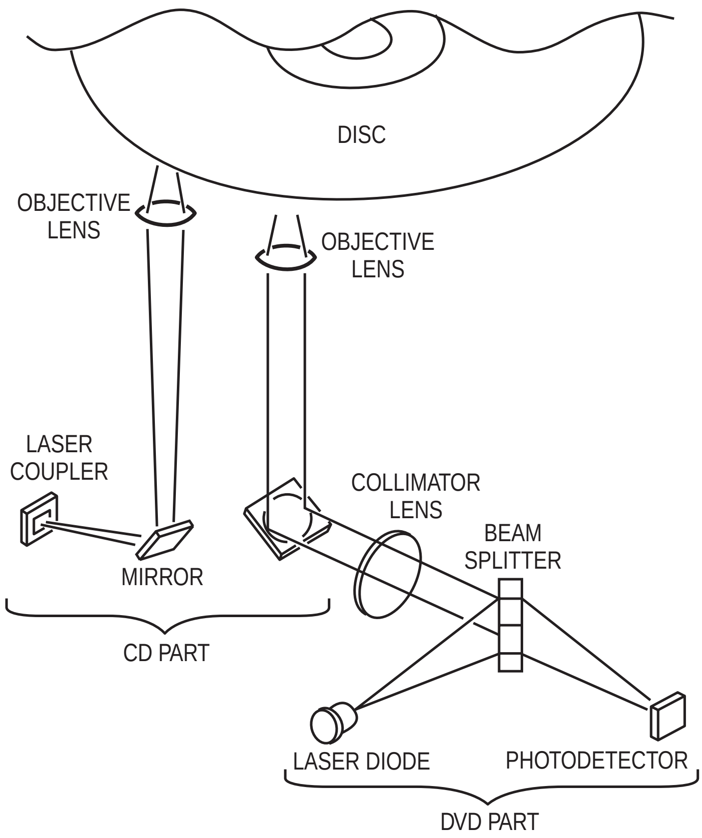



***Fig. 1-23***

***DVD optical systems built in one OPU***

## 1.3.3. Disc detection

At the beginning of the playback function the set has to decide whether a CD or a DVD is inserted. When a DVD is used it can be a single-layer or a dual-layer disc, so a separate detection for this has to be done.

***CD or DVD judgement***

When the PB starts, the sled motor will move the whole OPU several times from the inner to the outer circumference, also the focus search function starts at the CD and at the DVD part of the OPU. After focussing during this first movements the tracking error voltage level of the CD optical system is controlled. If a DVD is inserted the T.E. voltage coming from the CD part is below 0.4 $V_{PP}$ caused by the smaller pits and track pitch of the DVD. If a CD is inserted the T.E. voltage of the CD optical system is around 2 $V_{PP}$.

Therefore the disc judgement is done by controlling the T.E. voltage of the CD optical system. See figure 1-24.

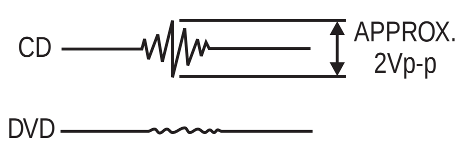



***Fig. 1-24***

***Tracking error votlage***

***Single- or dual-layer DVD (SL / DL)***

The difference between a single- and a dual-layer DVD is the intensity of the reflected light. For this the sum level PI of the DVD optical system is checked. It is built by the formula “A + B + C + D”.

The reflectivity of an SL disc should be between 45 - 80%; mostly we calculate with 70% (this is also the value of the test disc). The reflectivity of a DL disc should be between 18 - 30%; mostly we caculate with 25%.

As mentioned before the judgement between SL and DL discs is done by checking the PI voltage level, which is approx. 1V for an SL and 0.5 V for a DL disc.

See figure 1-25.

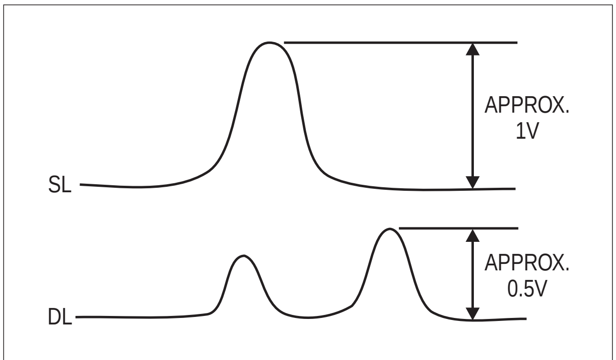



***Fig. 1-25***

***SL/DL judgement by checking PI level***

### 1.3.4. Skew sensor

The skew sensor is mounted on the surface of the housing of the OPU. It is used for detecting the tilt angle of a disc wrapping. See figure 1-5. So it will avoid a skew error at the landing spot on the surface of the main PDs, which should disturb the RF readout.

The skew sensor itself is also built with two PDs ($PD_S1$ and $PD_S2$) and one infrared LED. If the disc is parallel to the OPU the reflected light amount on each skew photodetector is the same. If the light beam is not perpendicular to the disc, the light amount on the surface of the PDs will be different. In principle the error voltage is calculated with the formula “$PD_S1 - PD_S2$”. This error voltage is sent to the tilt servo circuit which is controlling the movement of the OPU’s base unit.  For calculating an average level which avoids too heavy reactions of the tilt servo the formula is modified as follows:

$$\frac{PD_S 1 - PD_S 2}{PD_S 1 + PD_S 2}$$

# 2. Servo circuits

## 2.1. Overview

The servo circuits of a DVD Player are devided into several functions. Most of them we know from CD sets. Roughly we can devide the servo-related functions as follows:

- RF front end for DVD & CD
- Focus servo DVD/CD
- Tracking servo DVD/CD
- Sled servo DVD/CD
- Spindle servo DVD/CD
- Tilt servo

The processing of all servo circuits is totally separate from the one which is used for audio and video signal processing.

The following block diagram shows a rough overview of the whole set. You can reconize the servo-related parts as follows:

The OPU is connected to the DVD and CD front ends. They are located on the TK-47 board (see Service Manual, page 3-1). IC 006 works as the DVD RF amp, IC005 is the CD RF amp. These RF amplifiers are generating the various error voltages which are sent to the servo DSP, which is IC506 (SM/ 7-3). Also the RF signal is generated by the front ends, but these signals are not requested for the servo circuits (only the spindle servo needs the RF sync), they are processed at the RF processor IC806. The servo DSP and the RF processor are located on the MB-78 board.

Separate driver ICs for forcing the focus and tracking coils, sled motor, spindle motor and tilt motor are used.

The syscon of the set is controlling the servo DSP, the RF processor and all other important circuits like the AV decoder, video encoder and others. A data bus is connecting the processing ICs with the syscon. See figure 1-26.

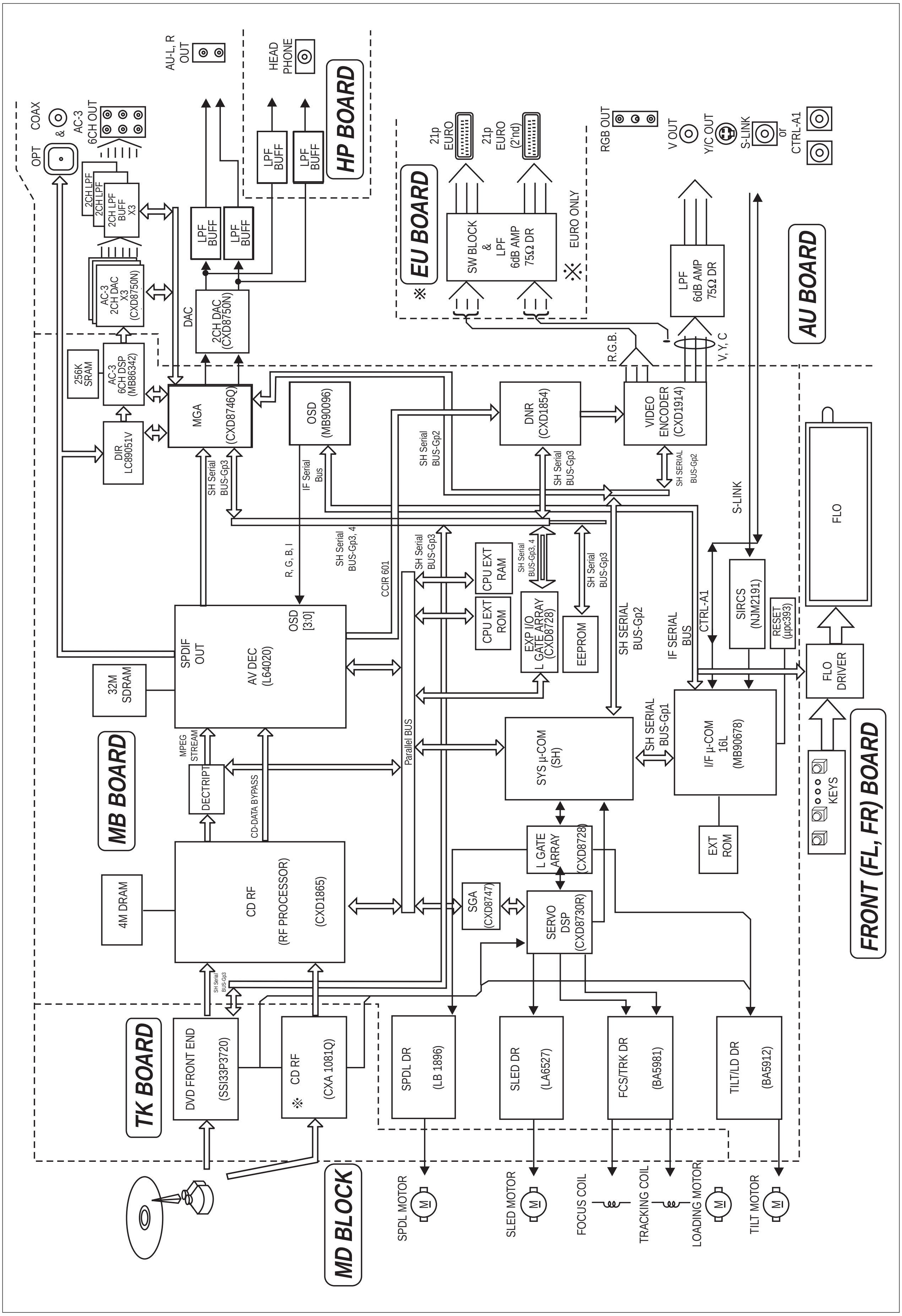



***Fig. 1-26***

***Block diagram DVP-S715***

## 2.2. DVD & CD RF amplifier ICs (IC006 & IC005)

The **DVD RF block** is built by IC006 (SS133P3720A) on the TK-47 board. The signals A, B, C, D of the DVD optical system are sent to this IC. The inputs of the four PDs are used for generating the DVD F.E. and T.E. signal. Input pin 7 - 10 is used for generating F.E., pin 1 - 4 receives the A, B, C, D signals via capacitors for generating the T.E. voltage. At pin 30 a MIRR out signal and at pin 37 the PI signal is available.

For creating the RF signal the A+B+C+D sum is input to IC006 pins 63 and 64

IC006 is controlled by the syscon via the serial interface. Various values are adjustable via this interface which connects the RF amp with the syscon via the large gate array IC804. An 8-bit address identification and an 8-bit job order are used. Figure 1-27 shows the arrangement of the interface data by a timing diagram.

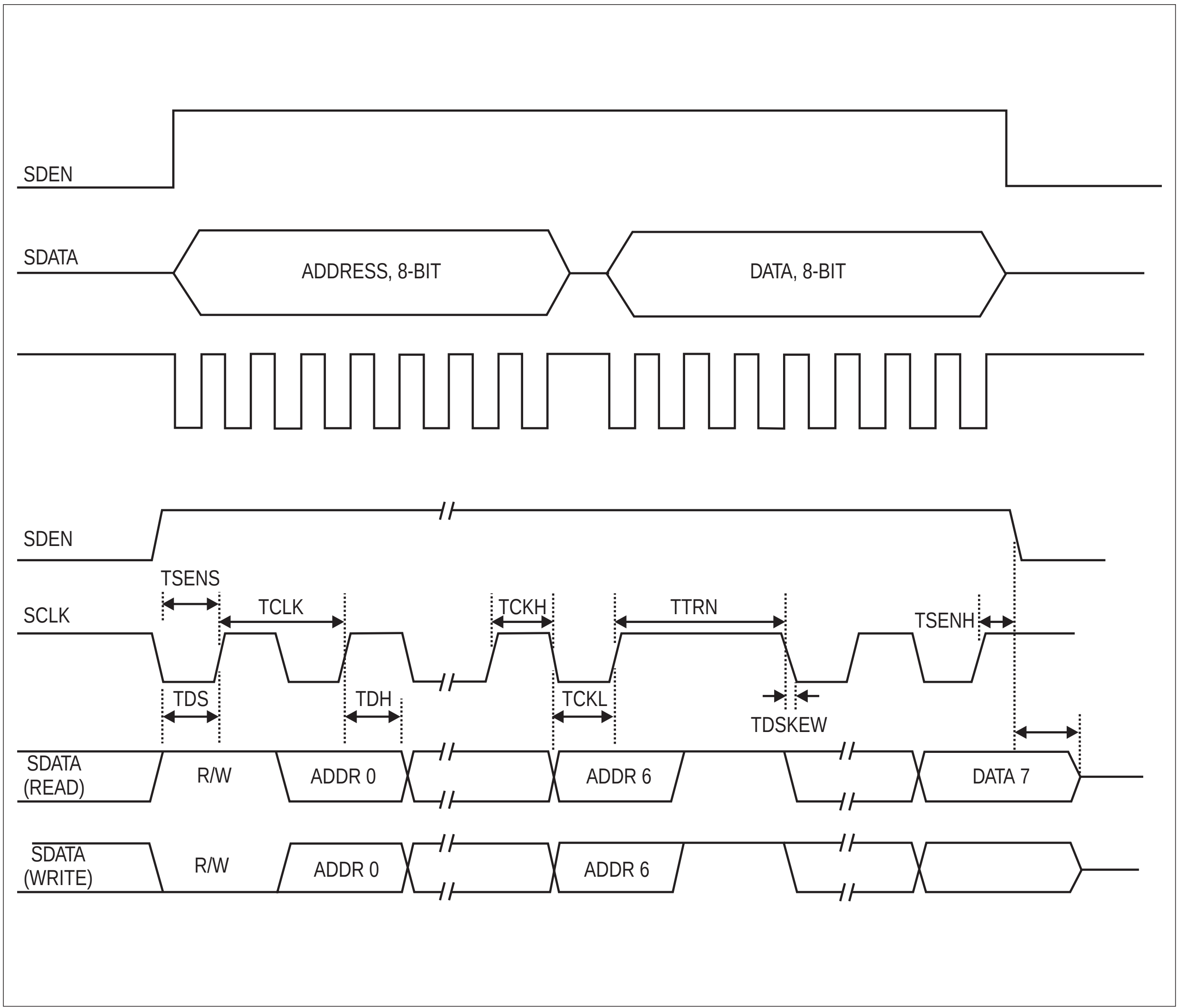



*Fig. 1-27*

The interface inputs and outputs are pin 45 (SDEN = serial data enable), pin 44 (SDATA = serial data), pin 43 (SCLK = serial clock) of IC006.

The **RF amp of the CD section** (IC005) is a well-known CXA-2550Q type which is also used in common CD Players. It is mounted on the TK-47 board, too. The signals PD1, PD2, E and F are sent from the LASER COUPLER of the CD optical system to the inputs pin 3, 4, 5 & 6 of IC005. F.E. and T.E. voltages are available at the outputs pin 15 & 13 of IC005. The MIRR signal is available at pin 19, the RF signal output is pin 32. CD-RF (AC-coupled) is available at pins 21 and 22. From pin 16 the reference voltage for all RF amplifiers is coming out. This reference voltage is also used for the DVD RF amp IC006.

The CD RF amp IC005 cannot be controlled by the syscon, this means there is no interface input/output.

### 2.2.1. Creating the DVD RF signal

First the RF signal (RFP, RFM) is attenuated by R066 and R064; next, low-frequency components are removed by using C046 and C047. The cut-off frequency is 3.16 kHz. Inside IC006 an ATT block is used for adjusting the different levels of SL and DL discs. For SL discs a ratio of 3/16 and for DL discs a ratio of 5/16 is used. The ratio values are set by the syscon via the serial interface. The RF is now AC-coupled by C050 & C051 and sent from the output pins 61 & 62 to the input pins 59 & 60. An internal AGC controls the level when the signal is input to the pogrammable EQ block. The EQ block is a programmable equalizer filter block. This block equalizes the RF signal by combining LPF and EQ functions to get an optimum RF signal. The LPF function is defined as a –3dB bandwidth without boost function.

If a low level problem occurs, a boost function is required. The gain at the cut-off frequency is as follows:

Gain at cut-off frequency = –3 dB + boost amount (dB)

See figure 1-28. The cut-off frequency and the gain are operated by the command register which is set by the serial interface.

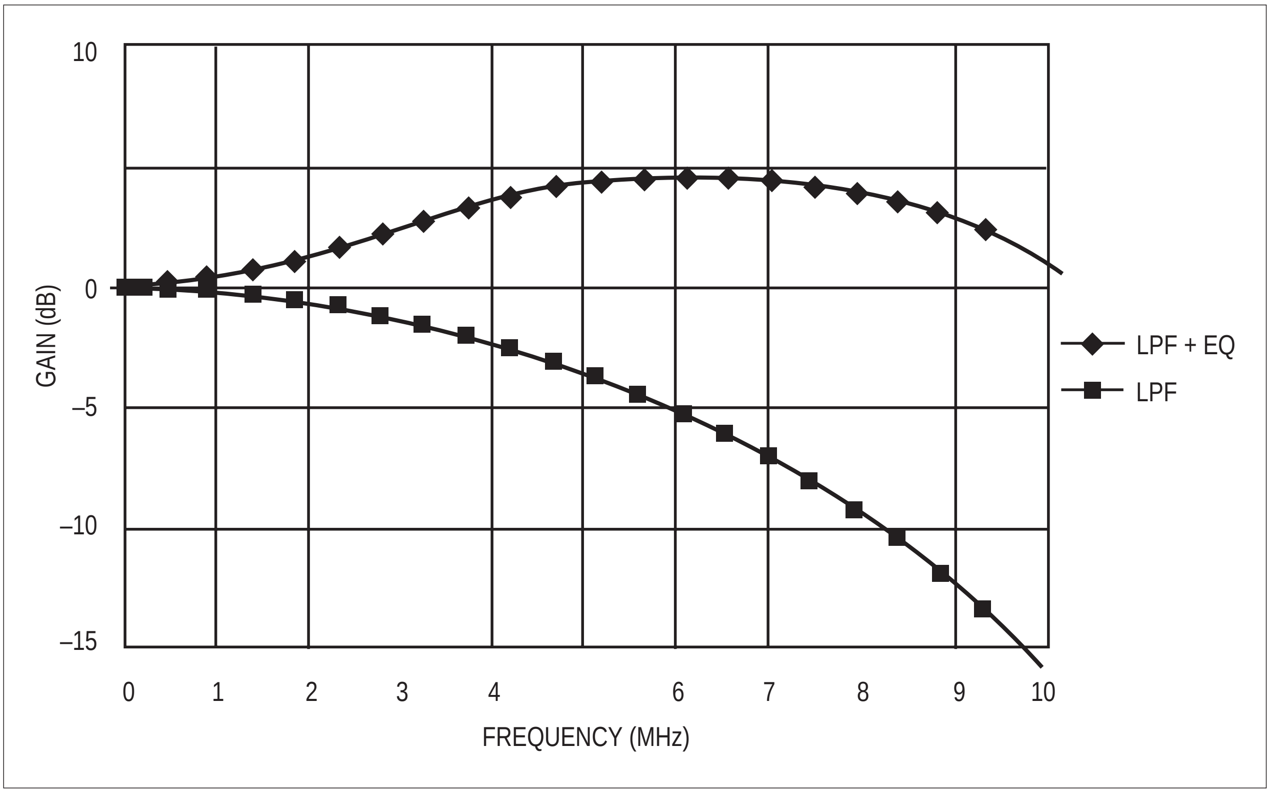



*Fig. 1-28*

The equalized signal is output at the pins 51 & 52 and via C053 & C054 sent to the inputs of a full-wave rectifier (pin 53 & 54). There the signal is used for controlling the AGC level. The RF signal for data processing is available at pin 57, from where it is sent to the processing IC806 on the MB-78 board. Figure 1-29 shows the DVD RF eye pattern. More informations are available in the "Operational Manual".

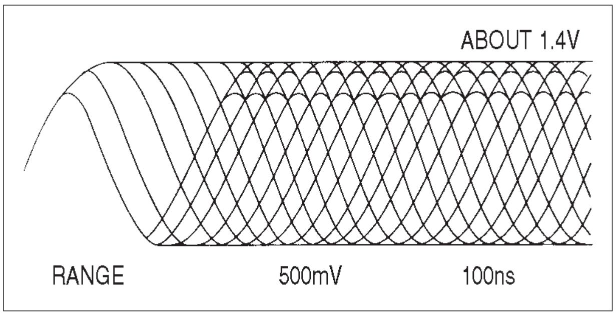



***Fig. 1-29***

***RF (eye pattern) waveform at DVD disc TK-47 board CN005 pin 26***

### 2.2.2. Creating the CD RF signal

The principle of generating the CD RF signal is the same as we know from each CD Player; the sum value of all detector fields gives the RF level. For this the PD1 and PD2 inputs at pin 3 & 4 is used. Inside IC005 amplifying and equalization is peformed. In this case the equalization is more like a bandpath filtering as a read out CD RF signal needs a bandwidth ranging from approx. 196 kHz to 780 kHz. The RF signal is available at IC005 pins 21 and 22; it is sent to IC806 on the MB-78 board. Figure 1-30 shows the CD RF signal.

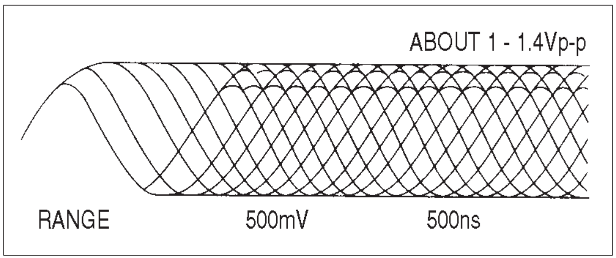



***Fig. 1-30***

### 2.3. The DVD focus servo

The **focus error signal** is calculated inside the RF amp IC006 (TK-47 board) and sent via the F.E. output IC006 pin 39, CN005, CN452 (MB-78-4/8 board) to the switch IC452 pin 3. This IC is switching between the DVD or the CD function. Next the F.E. signal is sent from IC452 pin 4 to the buffer amp input pin 10 of IC 503. After level adjusting, the F.E. signal is input to the servo processor IC 506 pin 26.

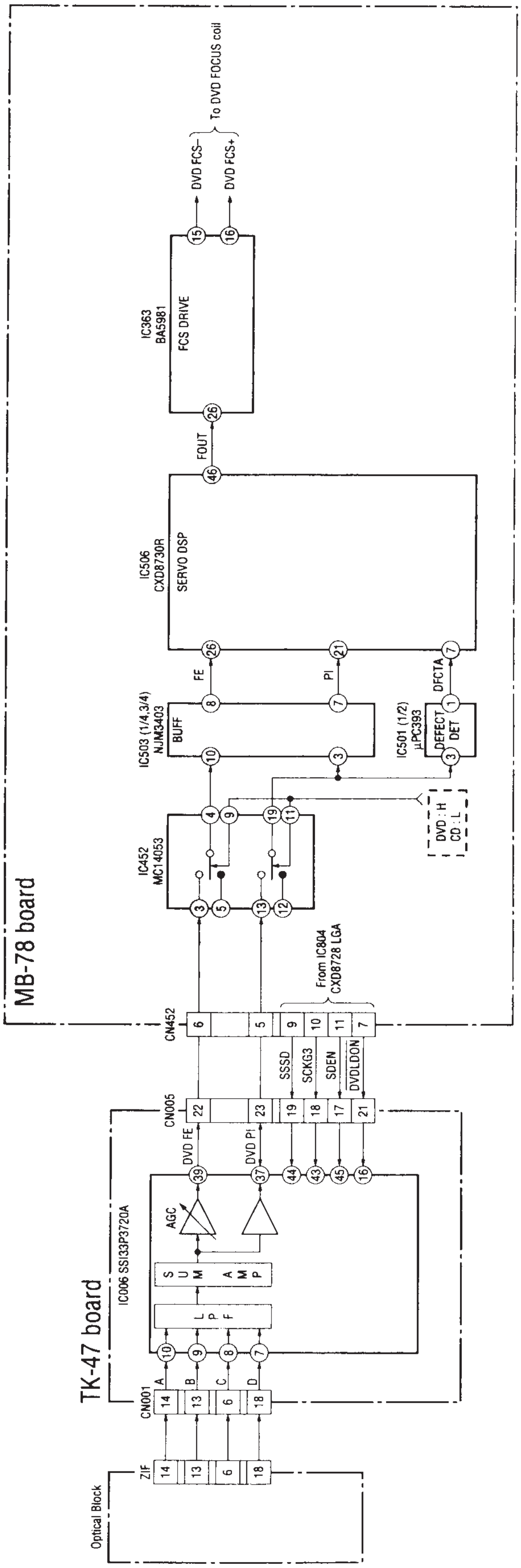
The focus error output, named FOUT at pin 46 of IC 506 is sent to the driver IC 363 (MB78-3/8 board) input pin 26. The output pins 15 & 16 are controlling the movement of the focus coil inside the DVD optical system.

The **IP signal** which is used for the SL / DL decision is sent from pin37 of IC006 (TK-47 board) via CN005, CN452 (MB-78-4/8 board) to IC452 pin 13. The output pin 14 of the switch IC sends the PI signal to pin 3 of IC 503 which is a buffer. Next the PI signal is forwarded to the input pin 21 of the servo processor IC506. For calculating a DEFECT signal the IP level is also available at the defect detector IC501 input pin 3, which gives a feedback via the output pin 1 and Q 501 to the input pin 7 of the servo processor IC506.

IC locations:

- IC 006: TK-47 board
- IC 452: MB-78 -4/8 board
- IC 503: MB-78 -4/8 board
- IC 506: MB-78 -4/8 board
- IC 363: MB-78 -3/8 board

Figure 1-31 shows a rough block diagram of the focus servo.



MB-78 board
TK-47 board
Optical Block
ZIF
CN001
CN005
CN452
IC006 SSI33P3720A
LPF
SUM AMP
AGC
DVD FE
DVD PI
SSSD
SCKG3
SDEN
DVDLDON
From IC804 CXD8728 LGA
IC452 MC14053
DVD : H
CD : L
IC503 (1/4,3/4) NJM3403
BUFF
IC501 (1/2) µPC393
DEFECT DET
FE
PI
DFCTA
IC506 CXD8730R
SERVO DSP
FOUT
IC363 BA5981
FCS DRIVE
DVD FCS–
DVD FCS+
To DVD FOCUS coil


*Fig. 1-31*

IC506 which includes the focus servo is a digital servo processor. This means that every incoming error voltage or detected level like F.E. or PI will be converted by an 8-bit A/D converter before it is input to the servo circuit inside. The servo IC itself is working as a 16-bit processor. The output signal of the focus servo circuit at pin 46 of IC506 is a PWM signal.

Every function such as FOCUS SEARCH, FOCUS JUMP or AUTO ADJUSTMENT and/or reference value switchings are controlled by the syscon IC805. The syscon commands are interfaced by the IC 807 (S GATE ARRAY) which sends the commands with a data bus (ID 0 - ID 7) to the pins 56 - 63 of IC 506. Adjustment data are stored by the syscon's memory. The syscon is working with one 1MB S-RAM (IC802), one 8MB Flash Memory and one EPROM (IC802, IC803 & IC801 / MB-78-8/8 board).

Figure 1-32 shows in a block diagram of the focus servo part of IC506.

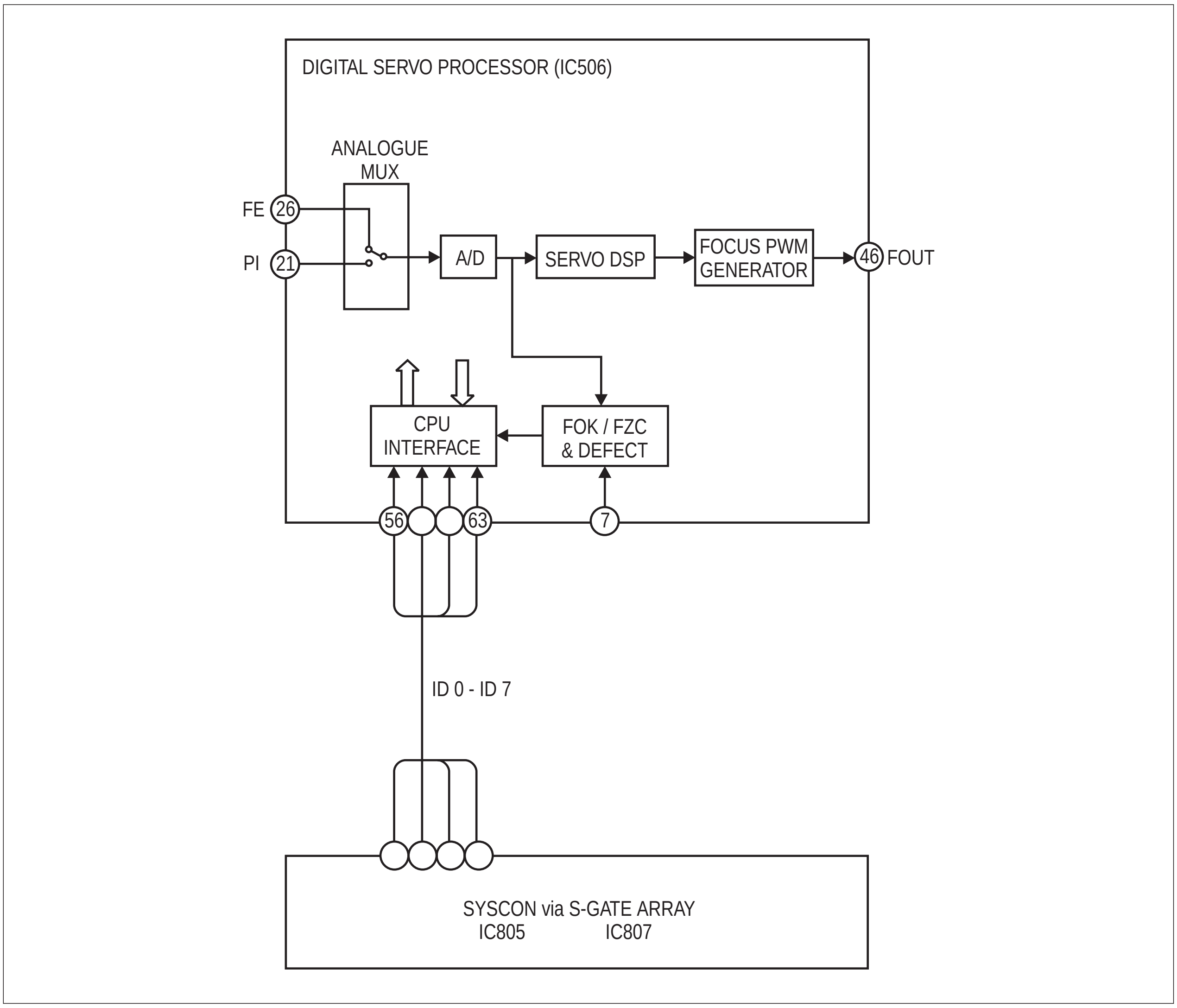



*Fig. 1-32*

### 2.3.1. Focus search

The lens of the DVD optical system is moved up and down in order to find the focussing point. The principle is the same like we know from CD. The focus servo is switched from the search function to the servo function when FOK & FZC is detected.

**FOK detection** is done by checking the level of the PI signal, which should exceed a level of 2.75 V.

**FZC** is detected when the F.E. voltage is going through zero.

The timing for switching ON the focus servo is detected by the servo logic which is checking the relation between FOK and FZC.

Figure 1-33 shows the S-curve and the levels which are coming up from the F.E. signal during focus search done with an SL disc. This is a real diagram taken with a scope during focus search. You can observe that the focus search function stops when the F.E. voltage is going through zero during FOK is at “H”.

Figure 1-34 shows the timing between FOK and FZC when focus search is continued.

When a DL disc is used you will have two S-curves; the reason for this is the reflected light of the two layers during the search movement of the optical lens.

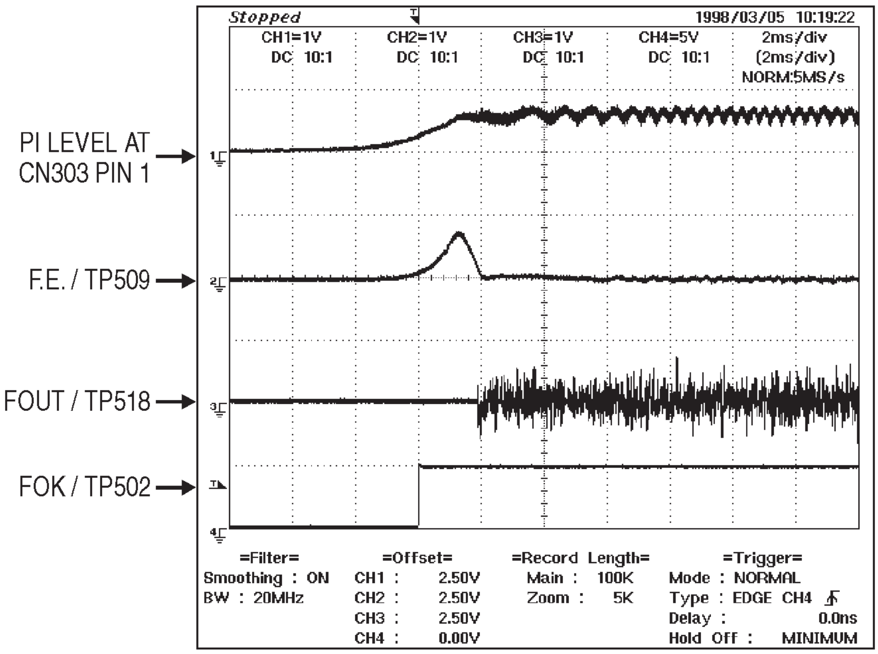



*Fig. 1-33*

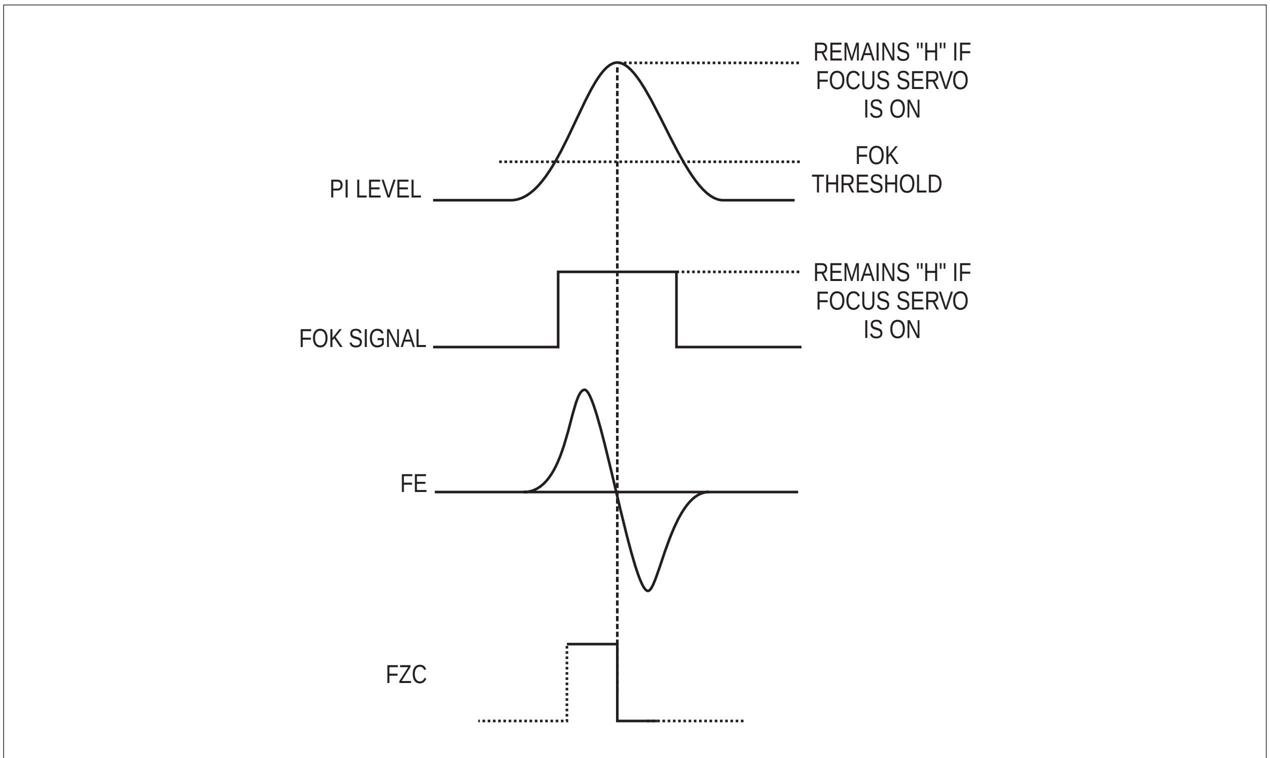



*Fig. 1-34*

### 2.3.2. Automatic focus servo adjustment

The **gain** of the servo loop is automatically adjusted every time when a disc is inserted. So the optimum gain and EQ adjustment is available for each disc; even if variations of the optical system occur they will be corrected in this way.

A **focus bias** is added to the servo filter in order to minimize offset problems caused by mechanical variations of the µ-2-axis device. Also a **voltage offset compensation** based on a digital average measurement is available. All this is done automatically, so that electrical and mechanical variations can be corrected.

### 2.3.3. Focus (layer) jump

A focus jump is carried out when a DL disc is played back. The focus jump is done between layer 0 and layer 1 (= far end layer). See figure 1-35. At the beginning of a focus jump the servo loop is turned OFF, a kick voltage is applied to the focus coil of the µ-2-axis device. The lens is moved higher to come in the focus area of the second layer (which is layer 1, the far end layer). During the jump the F.E. signal is monitored; when a focus error voltage is available a deceleration pulse is generated for stopping the lens movement and the focus servo loop is turned ON again and focussing is done. All these operations are controlled by the servo DSP IC506. Figures 1-36 and 1-37 show the PI, F.E. and FOUT signals during focus jump.

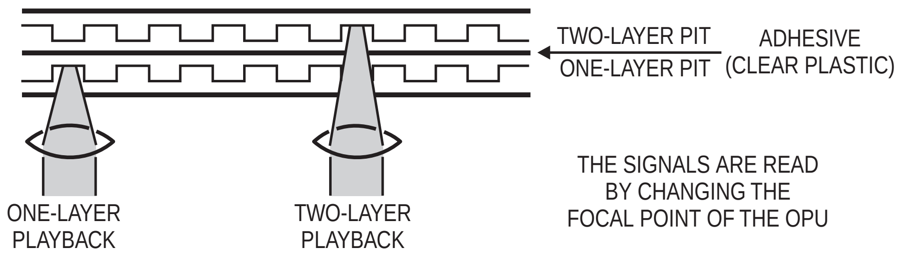



***Fig. 1-35***

***2-layer disc readout method***

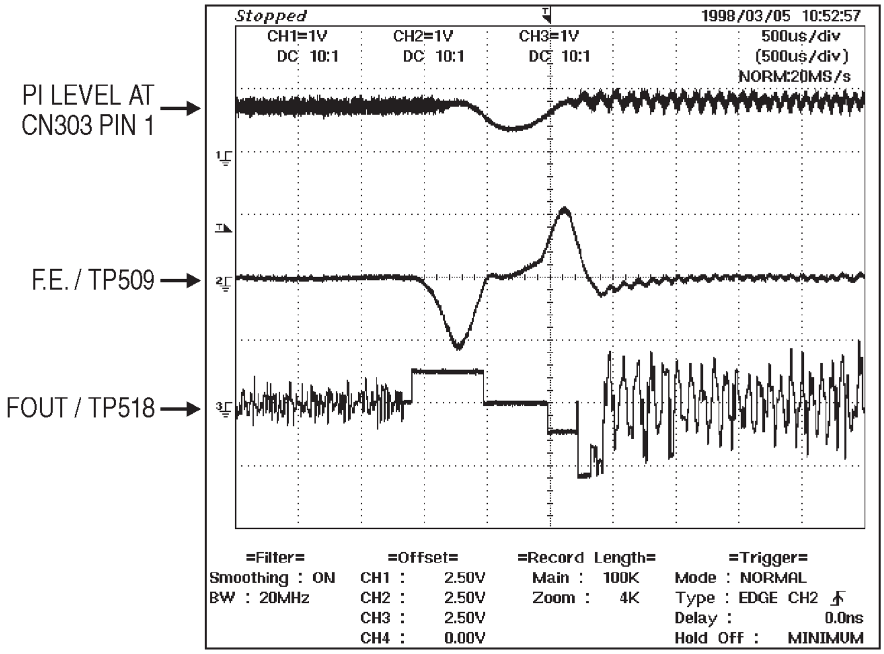



***Fig. 1-36***

***Focus jump from layer 0 to layer 1***

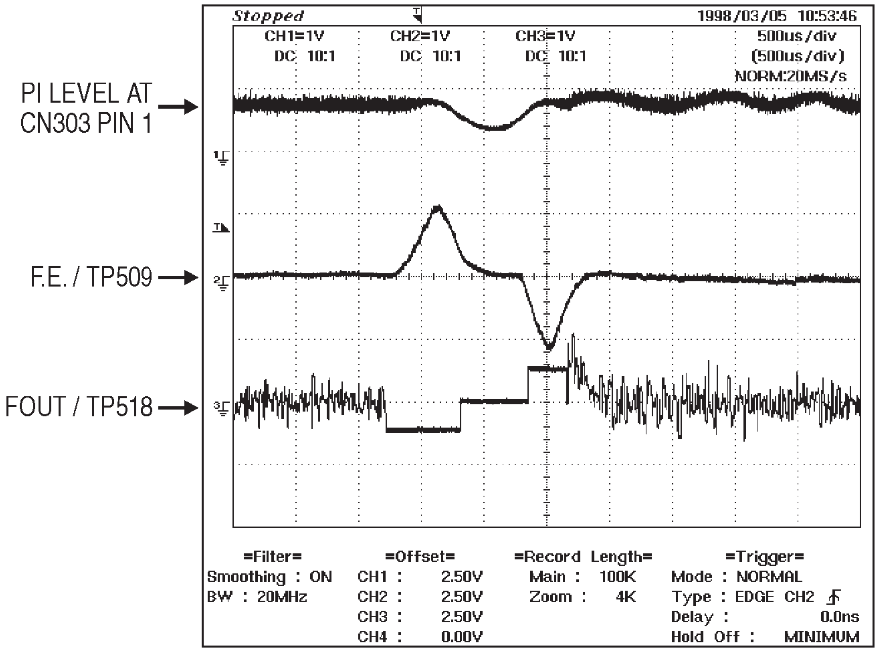



***Fig. 1-37***

***Focus jump from layer 1 to layer 0***

## 2.4. CD focus servo

The focus error signal is calculated in the CD RF amp IC005. Next it is sent from pin15 of IC005 to the switch IC452 pin 5. During CD playback it is passed through to the output pin 4 of IC452 via the buffer IC503 (in pin 10 / out pin 8) to the input of the servo DSP pin 26 of IC506.

The focus error signal is gain-, focus-bias and offset-adjusted as it is done during DVD playback.

The focus drive signal at the output pin 46 of IC506 (FOUT) is sent to the driver input pin 26 of IC363. This driver IC is a 4-channel driver which is used for driving the DVD and the CD focus coils. The CD focus coil is connected to pins 13 & 14 of IC363.

IC locations:

- IC006: TK-47 board
- IC452: MB-78-4/8 board
- IC503: MB-78-4/8 board
- IC506: MB-78-4/8 board
- IC363: MB-78-3/8 board

In the following you will find a diagram taken with a scope during CD focus search. As a CD will not have a second layer a focus jump is not necessary.

The PI signal shown in the diagram above is extracted from the RF-DC level, which is available at the RF amp IC005 pins 31 & 32. It is sent via CN005 from the TK-47 board to the MB-78-4/8 board where it is input to the switch IC452 pin 12. For CD playback it is output at pin 14 of IC452 as the PI signal. Now it is connected to IC503 pin 3 and finally it reaches the DSP input pin 21 of IC506 like we know it from DVD playback.

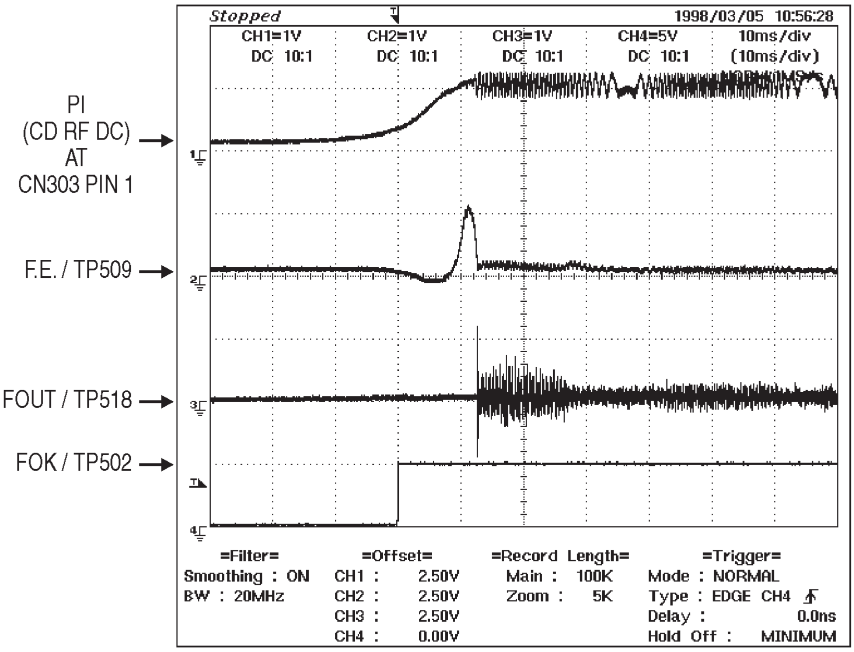



***Fig. 1-38***

***CD focus search***

## 2.5. DVD / CD switching

Partly the same ICs are used for DVD & CD focussing and tracking. Therefore a switching has to be done. The switch IC452 is controlled by the CD / DVD voltage at pins 9 & 10 for switching the DVD/CD-F.E. and T.E. voltages. At pin 11 of IC452 is a voltage for controlling whether DVD/CD-PI switching available.

The distinction for the driver IC363 is done in relation to the MUTE signal at the input pins 9 & 20 of IC363. See the following table.

| IC363 | Pin 9 | Pin 20 |
|---|---|---|
| DVD | “H” | “L” |
| CD & Video D | “L” | “H” |

## 2.6. DVD tracking & sled servo

### 2.6.1. DVD tracking servo

The tracking error voltage is detected inside the RF amp IC006. The gain and offset values are set by the internal register of IC006. The settings are controlled by the syscon IC805 via IC804 (LGA).

The T.E. signal is output from pin 38 of IC006; then it enters the switch IC011 at pin 3. The switch is set to output the T.E. signal at pin 4 when the set is in a normal PB function. The output is switched OFF when the DVD-RF level is below approx. 200 $mV_{PP}$ (AC component).

Next the T.E. voltage is sent to the MB-78-4/8 board via CN005 and CN452, where it is input to the switch IC452 at pin 1. When a DVD is played back it passes through to the output pin 15 of IC452. Now the signal is fed to the input pin 6 of the buffer IC503. The output pin 7 of IC503 is connected to the DSP’s T.E. input pin 24 of IC506.

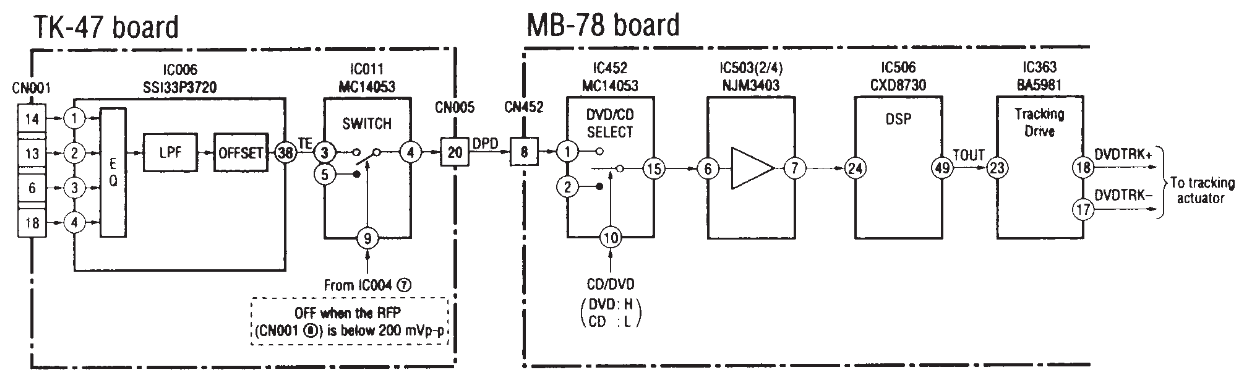



*Fig. 1-39*

The tracking drive signal at the output pin 49 of IC506 (TOUT) is sent to the driver input pin 23 of IC363. This driver IC is a 4-channel driver which is used for driving the DVD and the CD tracking coils. The DVD tracking coil is connected to pins 17 & 18 of IC363. The switching is done in the same way like it is mentioned in section "2.5. DVD / CD switching".

IC locations:

- IC006: TK-47 board
- IC011: TK-47 board
- IC452: MB-78 -4/8 board
- IC503: MB-78 -4/8 board
- IC506: MB-78 -4/8 board
- IC363: MB-78 -3/8 board

Figure 1-39 shows the block diagram.

IC506 which includes the tracking servo is a digital servo processor. This means that every incoming error voltage or detected level like T.E. will be converted by an 8-bit D/A converter before it is input to the servo circuit inside. The servo DSP is a 16-bit processor. The output signal of the focus servo circuit at pin 49 of IC506 is a PWM signal.

Every function such as TRACK JUMP or AUTO ADJUSTMENT and/or reference value switchings are controlled by the syscon IC805. The syscon commands are interfaced by the IC807 (S GATE ARRAY) which sends the commands with a data bus (ID 0 - ID 7) to pins 56 - 63 of IC506. Adjustment data are stored by the syscon's memory. The syscon is working with one 1MB S-RAM (IC802), one 8MB Flash Memory and one EPROM (IC802, IC803 & IC801 / MB-78-8/8 board). See the block diagram in figure 1–40.

***Automatic gain adjustment***

The gain of the servo loop is automatically adjusted every time when a disc is inserted. So the optimum gain and EQ adjustment is available for each disc; even if variations of the optical system occur they will be corrected in this way.

Figure 1-40 shows the block diagram of the tracking and sled servo of IC506. The sled servo will be discussed later.

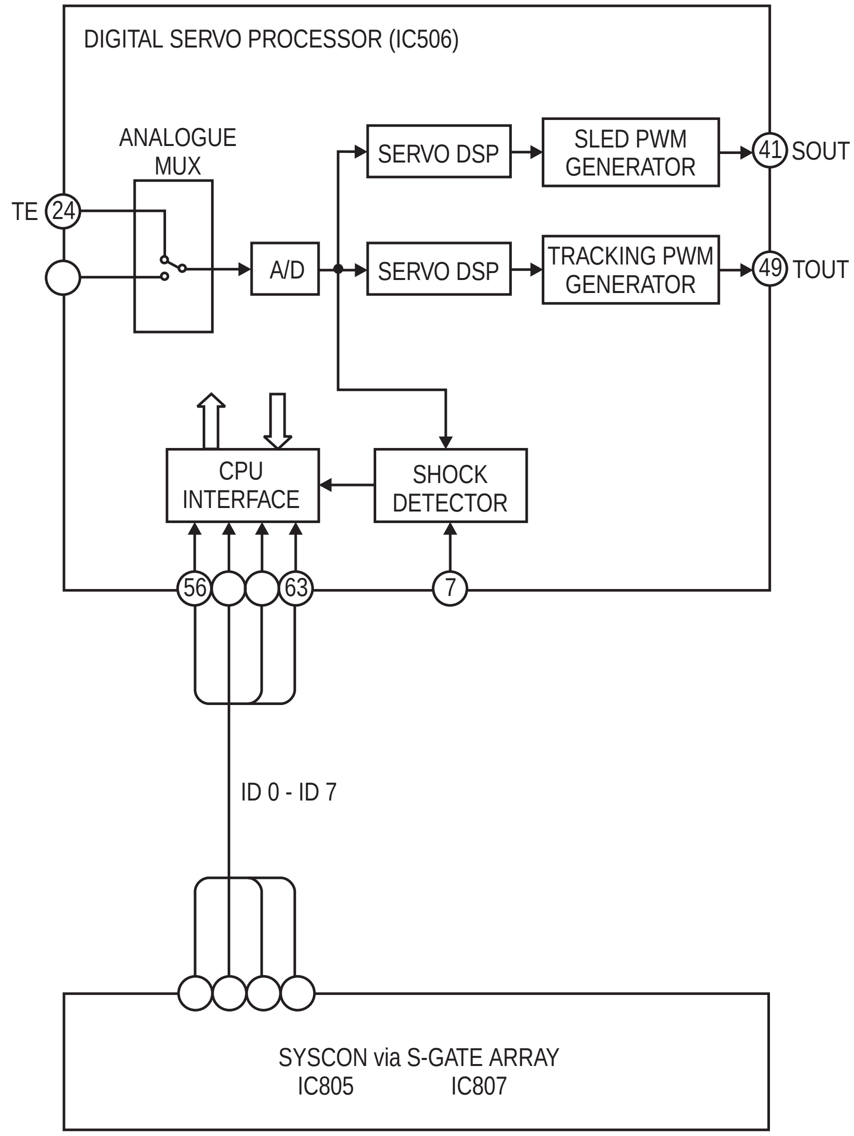

DIGITAL SERVO PROCESSOR (IC506)
ANALOGUE MUX
TE 24
A/D
SERVO DSP
SLED PWM GENERATOR
41 SOUT
SERVO DSP
TRACKING PWM GENERATOR
49 TOUT
CPU INTERFACE
SHOCK DETECTOR
56
63
7
ID 0 - ID 7
SYSCON via S-GATE ARRAY
IC805
IC807

*Fig. 1-40*

### 2.6.2. DVD sled servo in playback mode

During normal PB, when the focus and tracking servo are switched ON, the sled servo controls the sled motor so that the objective lens of the DVD optical system always works approx. in the middle of the movable range of the tracking actuator. The sled error voltage (S.E.) is calculated inside the DSP IC506. The principle is to equalize the T.E. signal so that only the low-frequency AC components are used for generating the SOUT driving voltage. It is available at pin 41 of IC506. Next it is fed to the input of the sled motor driver IC302 at pin 12. The sled motor is controlled via the outputs pin 2 & 5 of IC302. The sled ON / OFF switching is also done inside IC506. See also figure 1-40.

A switching between DVD or CD is not necessary as this is done for the T.E. voltage which is the base for the S.E. calculation.

The sled motor drive IC302 incorporates a speed feedback control (motor rotational speed). For this two Hall elements are used (HA and HB). The output is obtained from the sled motor board (FG-43 board) as the differential output. The sled drive IC detects the sled motor rotation with the Hall elements output waveforms to form the speed feedback.

In playback mode the output drive voltage at pins 2 & 5 of IC302 is generated with respect to the sled error signal (SOUT) at pin 12 and the sled motor rotational speed feedback composed by the inputs of the pins 29 & 30, 33 & 34.

### 2.6.3. Sled forced operation control

For all other sled functions except playback (speed search, etc.) a speed target signal (SDCNT) is input from pin 38 of IC506 to the driver IC302 pin 8. This is controlled by the syscon IC805 via IC804.

For stopping the sled motor immediately an offset adjustment signal (SLOFS) is sent out from pin 74 of IC506 to the input pin 11 of IC302 in order to adjust the 0 voltage at the motor terminals for stopping. Figure 1-41 shows a block diagram of the DVD sled servo.

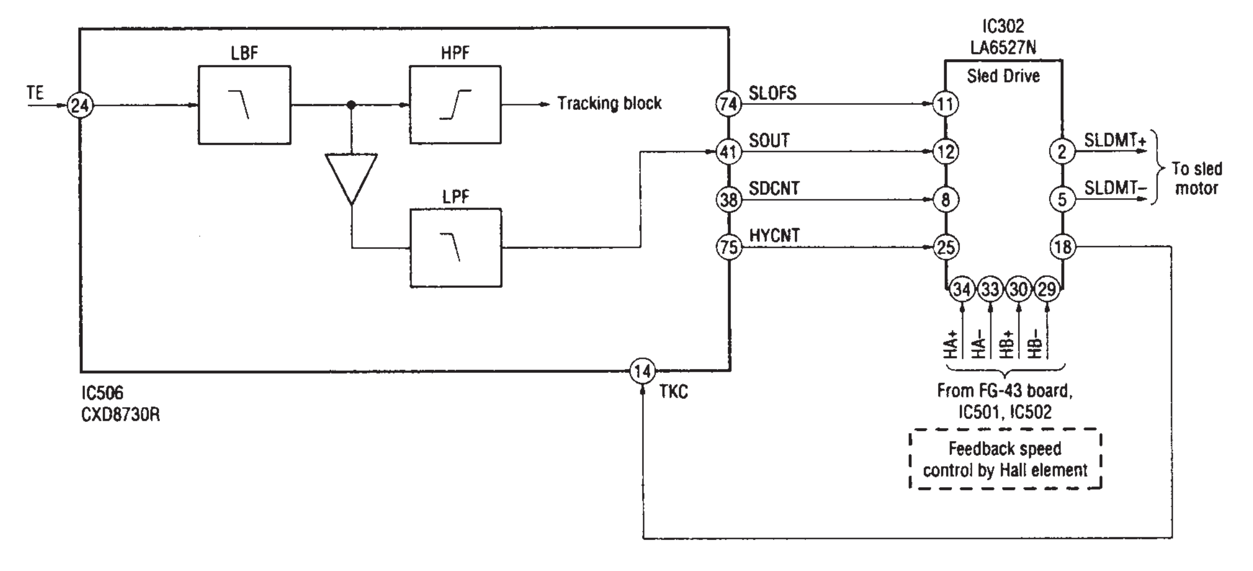



*Fig. 1-41*

### 2.6.4. Tracking jump control

For carrying out one or more track jumps several functions have do be done, special jump and brake pulses have to be created and an exact timing is necessary. The DSP IC506 is controlling the track jumps length between 1 - 1000 tracks per jump. Track jumps up to a length of 32 tracks are controlled by counting the number of tracks. For this the TZC pulses are used. These track jumps are done with the µ-2-axis device of the DVD optical system.

Track jumps with a length of more than 32 tracks are done with the sled servo. The DSP controls the timing of the jump pulses. A 100-track jump needs a pulse length of approx. 100 ms, which is controlled by the DSP.

Figure 1-42 shows a DVD 1-track jump (FWD &REV).

In figure 1-42 you can observe the TZC signal and the acceleration / deceleration pulses in the driving voltage TOUT. This 1-track jump is performed with the µ-2-axis device only.

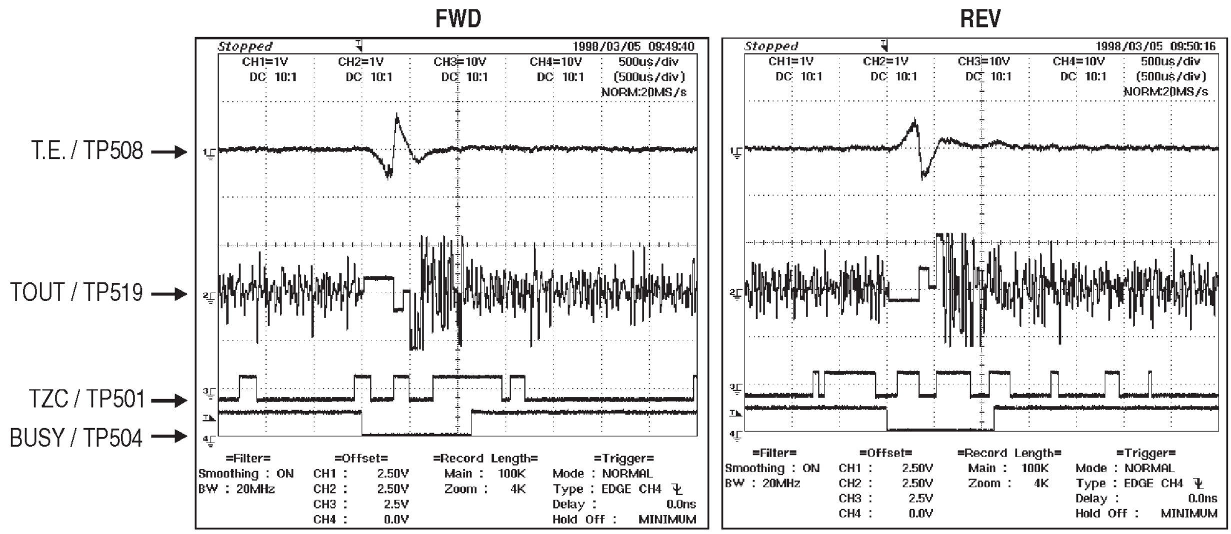



*Fig. 1-42*

Figure 1-43 shows a 500-track jump done with the sled motor mainly.

If a track jump is done with more than 1000 tracks the IC506 sends out an SDCNT pulse to force the sled operation. Neither the number of tracks nor the timing is controlled. This means a 10000-track jump will force the sled motor to cover approx. 10000 tracks; nothing checks this exactly on the servo side. See figure 1-44.

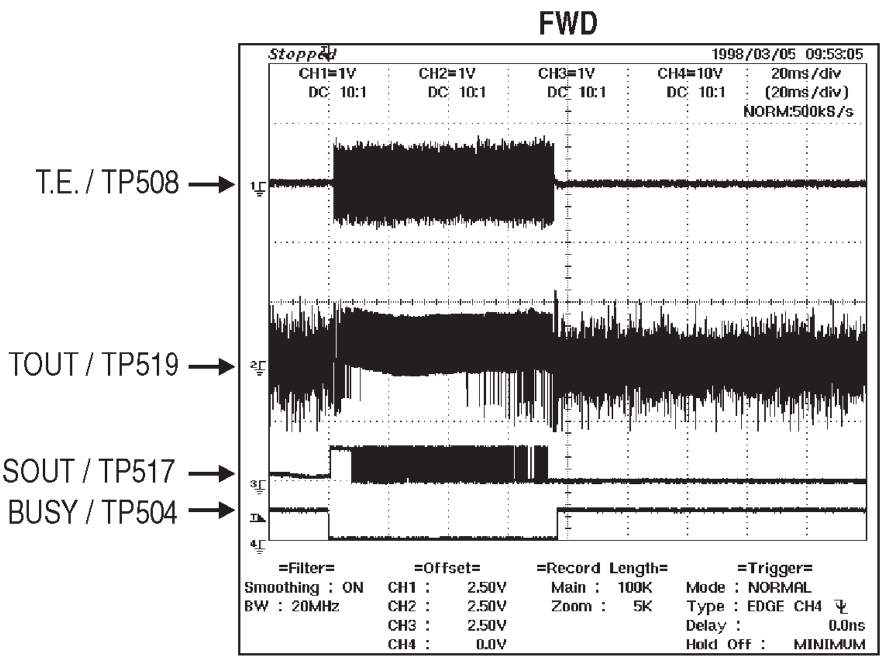



*Fig. 1-43*

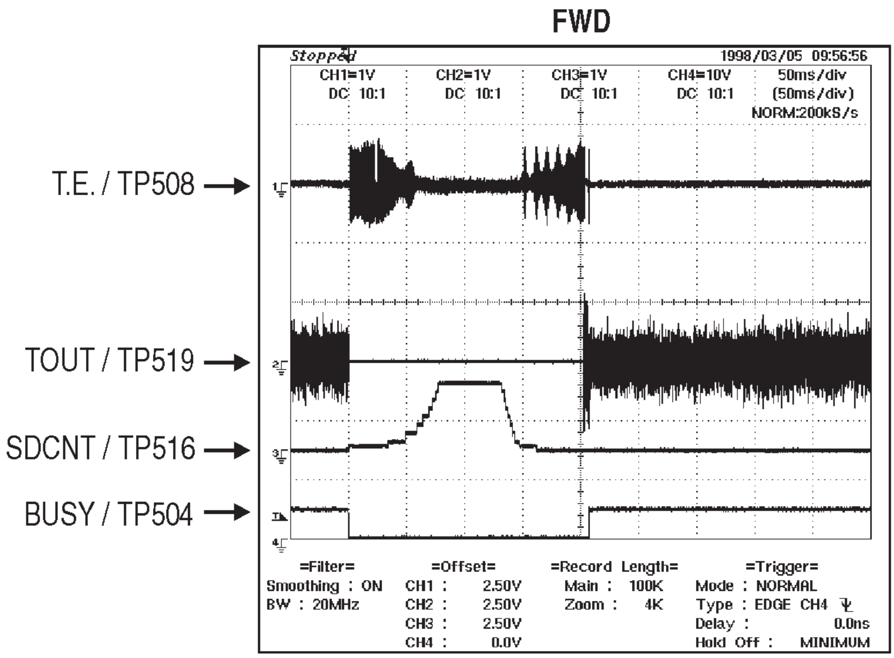



*Fig. 1-44*

### 2.6.5. CD tracking servo

The tracking error voltage is detected inside the RF amp IC005. The T.E. signal is output from pin 13 of IC005. Next the T.E. voltage is sent to the MB-78-4/8 board via CN005 and CN452, where it is input to the switch IC452 at pin 2. When a CD is played back it passes through to the output pin 15 of IC452. Now the signal is fed to the input pin 6 of the buffer IC503. The output pin 7 of IC503 is connected to the DSP's T.E. input pin 24 of IC506.

The tracking drive signal at the output pin 49 of IC506 (TOUT) is sent to the driver input pin 23 of IC363. This driver IC is a 4-channel driver which is used for driving the DVD and the CD tracking coils. The CD tracking coil is connected to the pins 11 & 12 of IC363. The switching is done in the same way like it is mentioned in section "2.5. DVD / CD switching".

IC506 which includes the tracking servo is a digital servo processor. This means that every incoming error voltage or detected level like T.E. will be converted by an 8-bit D/A converter before it is input to the servo circuit inside. The servo DSP is a 16-bit processor. The principle for generating the SOUT signal is to equalize the T.E. signal so that only the low-frequency AC components are used for generating the SOUT driving voltage. Every function such as TRACK JUMP or AUTO ADJUSTMENT and/or reference value switchings are controlled by the syscon IC805. The principles are the same like before mentioned in the DVD description. See the block diagram in figure 1-40.

***Automatic gain adjustment***

The gain of the servo loop is automatically adjusted every time when a disc is inserted. So the optimum gain and EQ adjustment is available for each disc; even if variations of the optical system occur they will be corrected in this way.

***Tracking auto level adjustment***

This function operates only during CD and V CD playback. When the T.E. level is too small due to poor reflectivity of the disc the level will be increased by changing the input gain at IC005. The principle is as follows.

After the dis is rotating and the focus servo is turned ON the peak-to-peak value of the T.E. traverse signal is measured by IC506. The results are sent to the syscon IC805 which determines the variable gain amount and sends it back again to IC506. Next the output pins 11 & 12 of IC506 send gain voltage levels (PWM) which are formed to an analogue TEATT voltage via IC503 (input pin 13, output pin 14). The TEATT signal is now sent to pin 12 of IC005 to adjust the input gain. The adjustment range is 3 dB.

### 2.6.6. CD sled servo & jump control

The principle of the sled servo and jump controlling is similar to the DVD servo and jump functions explained before. Only the internal settings for IC506 are different. Also the track jump length for CD is different : track jumps from 1 - 500 tracks are controlled. From 1 - 32 tracks the jumps are done with the 2-axis device. The others are mainly done with the sled motor. From 33 - 500 tracks the controlling is done with the timing of the track jump pulse width. If a track jump with more than 500 tracks is done IC506 sends out the SDCNT pulse to force the operation. See the DVD explanation.

## 2.7. DVD spindle servo

The spindle servo generates two error signals: one CLV speed error signal named “MDSO” and one CLV phase error signal named “MDPO”. The spindle servo circuit is integrated in signal processor IC806 (MD-78-7/8 board) and the error signals are available at pin 43 (MDSO) and pin 47 (MDPO). They are added and LPF-filtered in IC301 pins 2 & 5 (MD-78-3/8 board). The spindle error signal SPERR is coming out at pin7 of IC301. The driver IC303 receives the error signal at pin 13. The spindle motor is a BSL motor with three poles; it receives from IC303 the U, V, W drive signals (output pins 1 & 34 - 30); as is usual for a BSL motor also an FG feedback is sent from the motor’s Hall elements to the driver IC.

Pins 8 & 9 of IC303 are used for controlling the acceleration and deceleration as follows:

| Control mode | Input signals | |
|---|---|---|
| | Pin 9 | Pin 8 |
| Acceleration | “H” | “L” |
| Deceleration | “H” | “H” |
| No control | “L” | “H” |

Gain switching in relation to the disc size (8 or 12 centimeters) is done via the input pin 11 of IC303.

## 2.8. CD spindle servo

As the RF signal is processed inside IC806 the outline of the CD spindle servo is the same as the one for DVD. Figure 1-45 shows the block diagram of the spindle servo.

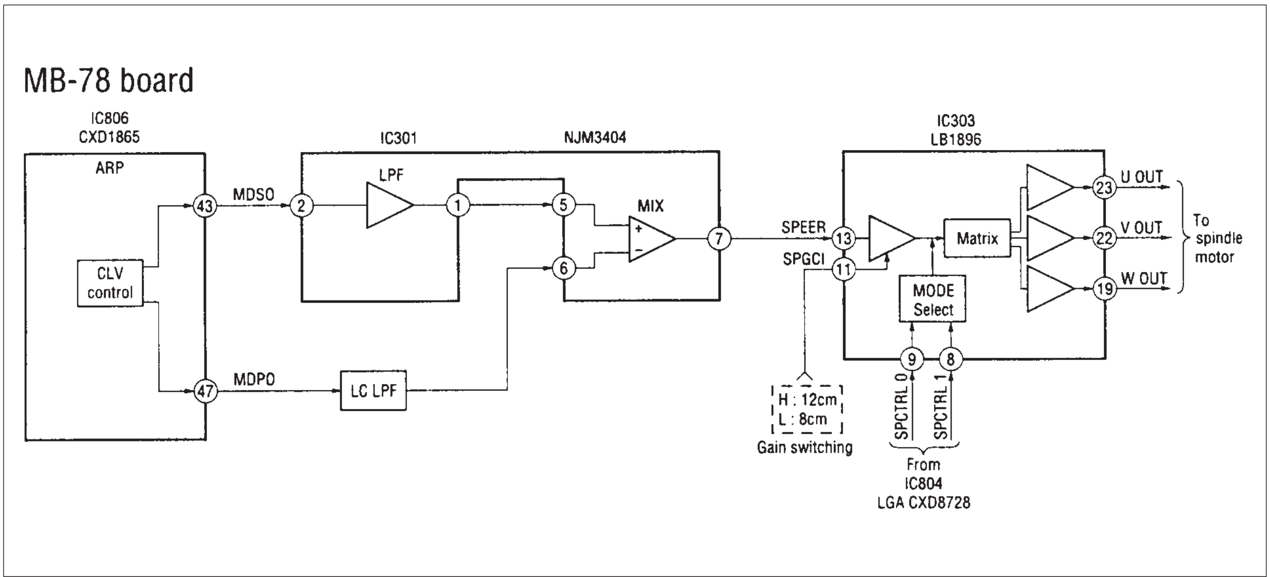



*Fig. 1-45*

### 2.9. Tilt control / tilt servo

The tilt servo is using the SKEW sensor mounted on the OPU. The tilt control is performed at the start of a DVD or CD playback.

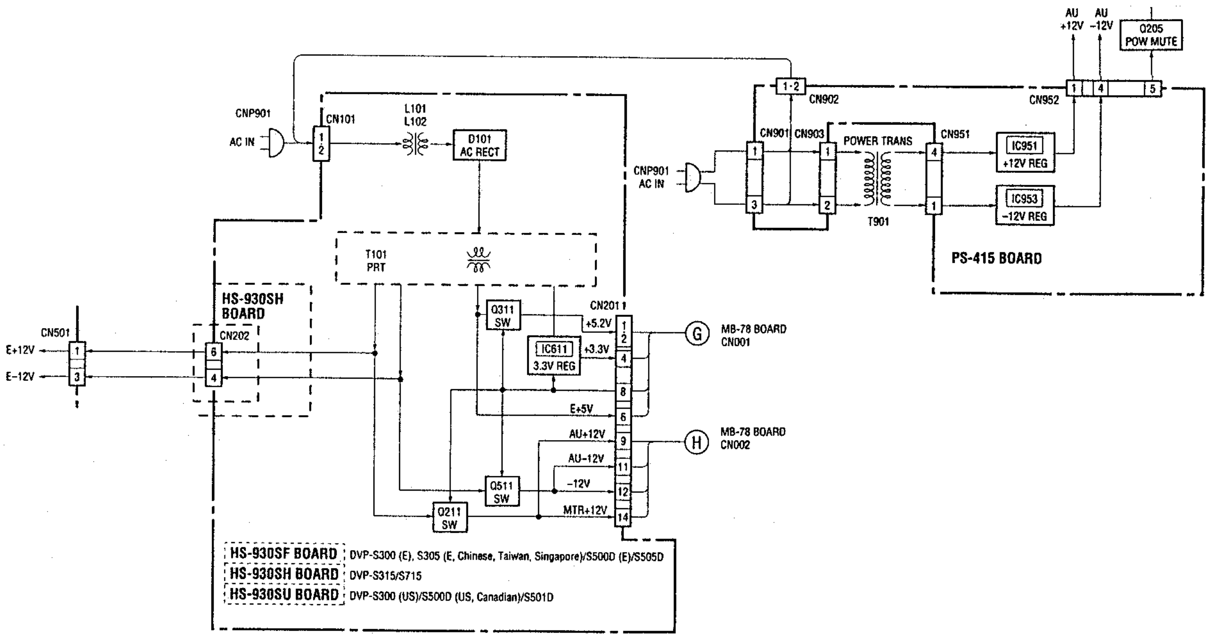
The SKEW sensor output of the OPU is input at pins 20 & 21 of IC006 (DVD-RF amp / TK-47 board). After amplification and integration the tilt error signal is output at pin 26 of IC006, named TIERR. A second tilt error signal is output at pin 23; it is named TIE.

From the TC-K47 board the signals are sent via the MD-78-4/8 board to the MD-78-3/8 board.

IC455 is working as window comparator; for this it receives the TIE voltage at pin 6. Pin 7 of IC455 is controlling Q452. When the transistor is switched OFF the tilt servo goes OFF to form a dead band. This is done when the TIE voltage drops below 2.5 V ± 50 mV.

When Q452 is ON the tilt error voltage (TIERR) is input to pin 21 of IC361. The tilt motor is connected to the driver output pins 5 & 6 of IC361. The tilt motor is a normal DC brush motor type.

# Power supply system




**PS415 and HS930SH boards**

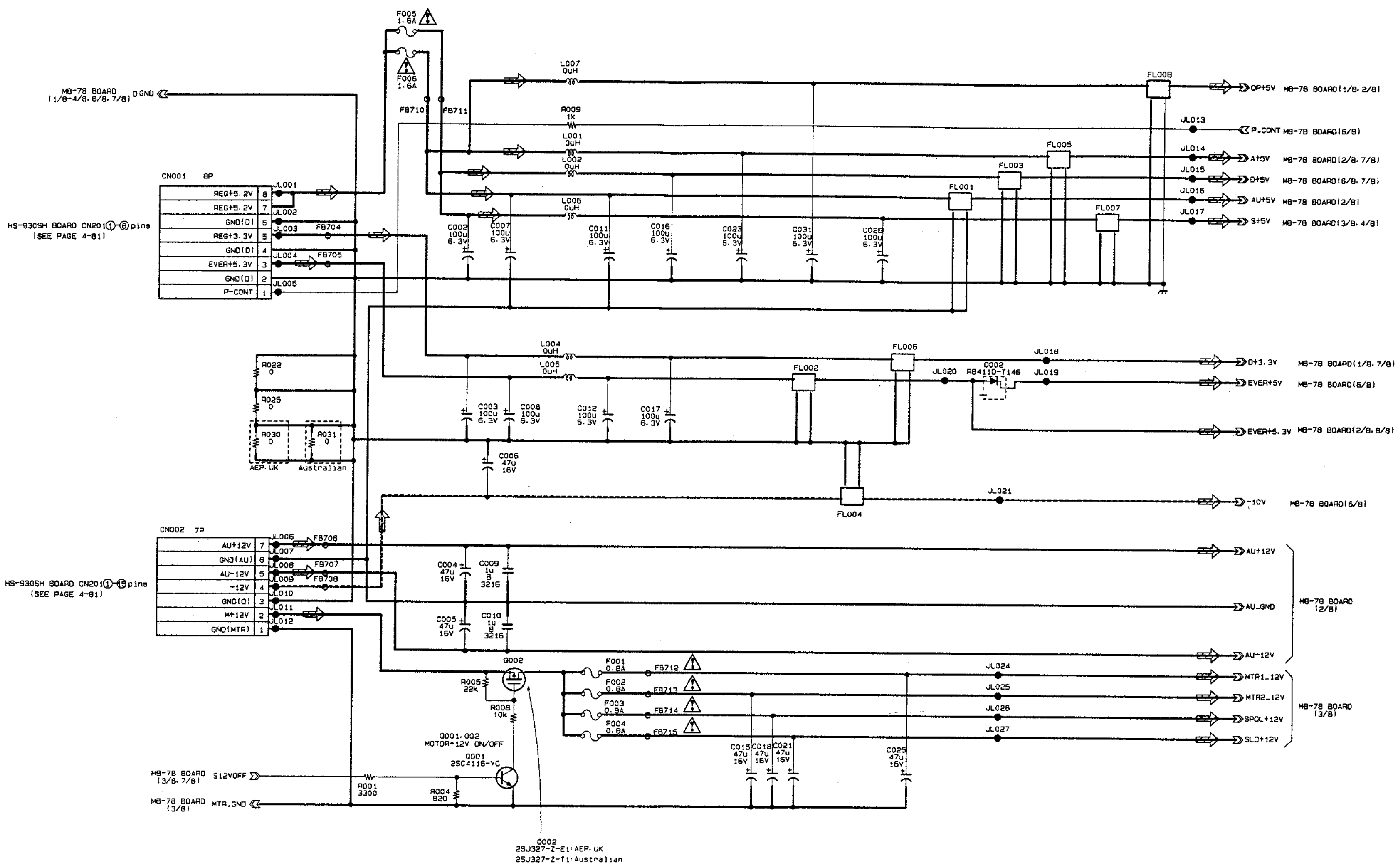
The figure above gives an easy overview of the power supply lines. This figure shows the different input/output power supply lines between the PS415 and HS930SH .
PS415 board is used only in DVP-S715 model. In order to improve the audio features, this model uses the PS415 board to supply two separately power lines AU+12V and AU–12V for the analog output section of the AU205 board.

**There can be various causes that are displayed by the different ways of the power Led illumination**

- Normal operation is as follow:

When AC power plug is connected to the wall outlet the ON/STANDBY led D401 on the frontal board FR133 must turn ON in next order: RED/GREEN/RED and then the set enters in Standby mode. When the Power switch is pressed the led appear in green colour.

Double diodo led D401 is firstly supplied by the EVER 5V and blinks red colour, then the IFμCOM IC604 send the P.CON order to the power supply board HS930SH trought CN201 pin 8 and all the power lines are switched on, at this moment the REG 5V tension supply the transistor Q401 on FR133 board and it switches off the red led and blinks green colour.
When IC604 swith off the P.CONT order, the REG 5V tension is switched off D401 returns to red colour and the set enters into Standby mode.



**Power circuitery on MB75 board**

Next, the main power supplies on the MB-75 board are indicated, with the IC's that every line supplies.

*EVER+5V/EVER+5.3V*
Latch IC601, NAND gate IC602, **ROM ICS603, IF µCOM IC604**, Reset IC605, S-Link comp IC606, ER2 board, Remote control receiver IC401/FR133 board, **1M RAM IC802**

*D+3.3V*
**16Mb SDRAM IC201/IC202, AV Decoder IC203, ARP IC806, 4Mb DRAM IC810**

*D+5V*
**EEPROM IC801, L Gate array IC804, Decrypt IC811**, LPF IC812, **8Mb Flash ROM ICS803, System µCOM IC805, S Gate array IC807,** Display driver IC101, Inverter IC211, FR133 board

*DP+5V*
Inverter IC204, Bus buffer IC205/206, **OSD IC207,** AND gate IC208, **PLL IC209, DNR IC251, Video Encoder IC252**

*S+5V*
**CD RFamp IC005, DVD RF amp IC006**, Switch IC001/IC452, Comparator IC004/IC455/IC501, Sperr amp IC301, Sled motor driver IC302, Spindle motor driver IC303, Buffer IC502/502/507, **DSP IC506**, Filter IC508

*A+5V*
**Video encoder IC252,** Video buffer IC209, ER2 board

*AU+5V/AU+12V/AU-12V*
AU205 Board

*-10V*
DC-DC Fluorescent indicator tube

*MTR1_12V/MTR2_12V*
Focus and tracking coil drivers/ Tilt and Loading motor drivers

*SPDL+12V/SLD+12V*
Spindle/ Sleed motor driver

## Troubleshooting

As you can see in the Test mode chapter, DVP-S315 and DVP-S715 have a very good test mode including a Checking method which allow to check and detect problems in all DVD sections.
Nevertheless some problems may cause the set to be completly dead, or its initialization is not ok, therefore depending on the section affected by the problem, the test mode cannot be used.
The next section includes some different symptoms and their possible solutions that the technician can use as reference in order to solve some problems.

| SYMPTOM | POSSIBLE CAUSE/POINTS TO CHECK |
|---|---|
| When Playback button is pressed, spindle motor turns on, focus and tracking coils do not work and error C:13:10 blinks on the display. | F001 of the MTR_12V on the MB-75 board open.<br>Check driver IC363 and optical pick-up. |
| No Eject, disc compartment blocked. | F002 of the MTR2_12V on the MB-75 board open. |
| When Playback button is pressed, the spindle motor does not work and error C:31:40 blinks on the display. | F003 of the SPDL+12V on the MB-75 board open. |
| When the set is AC powered, the power LED changea from Red/Green/ (set is not initialized correctly), blue background picture appears and the set is blocked.<br>The commands selected on the front panel appear on the screen, but the set does not accept them. | F004 of the MB-75 board open. |
| When the set is AC powered, the power LED remains in colour Red. | F005 of the MB-75 board which supplies the D+5 and S+5V lines is open. |
| When the set is AC powered, the power LED changes from Red to Green and the set is completly blocked.<br>The set does not accept any command. | F006 of the MB-75 board which supplies the DP+5V, A+5V and AU+5V is open. |
| The set is dead.<br>Power LED does not blink | Check the power line EVER+5V/ EVER+5.3, and the circuitry connected to this line. |

| SYMPTOM | POSSIBLE CAUSE/POINTS TO CHECK |
|---|---|
| When the set is AC powered the initialization is correct (power LED blinks: Red/Green/Red).<br>When power button is pushed the set is blocked. | Check the power line D+3.3V and the circuitry connected to this line. |
| When CD is played back, the spindle motor turns on, focus or tracking does not work and error C:13:10 blinks on the display.<br>When DVD is played the set works OK. | Problem with CD focus (CDFCS) or CD tracking (CDTRK) signals.<br>Check CF+ and CT+ lines, IC363 and optical pick-up. |
| When DVD is played, the spindle motor turns on, focus or tracking does not work and error C:13:10 blinks on the display.<br>When CD is played the set works OK. | Problem with DVD focus (DVDF) or DVD tracking (DVDT) signals.<br>Check DF+ and DT+ lines, IC 363 and optical pick-up. |
| When the set is AC powered, the power LED remains in red colour.<br>IFµCOM IC604 pin 33 does not send the P.CONT 5.1V signal to the power supply, therefore the initialization is not OK. | Check EVER5V is present in IFµCOM IC 604 pins 23, 34, 35, 84.<br>Check 4MHz signal is correct on pin 82.<br>Check that the reset input signal is correct on pin 77.<br>Check that the addresses and data communication with Latch IC601/ROM IC603 are correct.<br>Check the SI, SO, SCK , RESET OUT and CS lines are correct. |
| On-Screen Display function does not work. | Check DP5V is present on IC207 pins 6, 14, 22, 27.<br>Check whether the reset input signal on pin 5 is correct.<br>Check whether 13.5MHz signal on pin 8 is correct.<br>Check whether Hsync and Vsync signals on pins 12 and 13 are correct.<br>Check serial Clock, serial Data input and chip selector signals are being received. |
| On-Screen Display background does not appear or appears with low level. | Check if the signal IOUT on OSD IC207 pin 17 is correct. |
| On-Screen Display characters appear with different colours. | Check if R, G, B output signals on IC207 pins 18, 19, 20 are correct. |

| | |
|---|---|
| When playback button is pushed, black picture appears, with horizontal lines in the centre of the screen, and the set is blocked. | X201 which supplies the 27MHz reference for PLL circuit IC209 on the MB-75 board is defective. |
| No audio output when CD is played.<br>When DVD is played, the first DVD picture appears on the screen, the picture freezes, then the set blocks. | Problems with the 384FS signal, generated in the PLL IC209 pin 20. |

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