Digital Audio Media

DIGITAL AUDIO MEDIA

Introduction

CD, DAT, MD, SACD and DVD formats and their operations are explained.

COMPACT DISC & PLAYER

The CD is the audio standard for optical playback systems. In addition, some optical recorders are designed to conform to its standard and format so that the recorded information maybe reproduced on a conventional Compact Disc Player (CDP).

1. The CD Message

A CD contains digitally encoded audio information in the form of pits impressed into its surface. The information on the disc is read by the player's optical pickup, decoded, processed and ultimately converted into acoustical energy. The disc is designed to allow easy access to the information by the optical system as well as provide protection for the encoded information.

The medium

The CD's dimensions are: Diameter 12cm

Thickness approx. 1.2 mm

The middle hole for the motor spindle shaft is 15 mm in diameter.

The CDP's laser beam is guided across the disc from the inside to the outside, starting from at the lead-in area moving outward through the programme area and ending at the outer edge with the lead-out area.

The lead-in and lead-out areas are designed to provide information to control the player. The lead-in area contains a Table of Content (TOC) which provides information to the CDP, such as the number of musical selections including starting points and duration of each selection.

The lead-out area informs the player that the end of the disc has been reached.

The CD spins at a fixed Constant Linear Velocity (CLV) of 1.2 m/s for CD with programme exceeding 60 minutes. A CD programme under 60 minutes has a CLV of 1.4 m/s. The angular velocity (rpm) decreases as the optical pickup moves toward the outer tracks of the disc. At linear velocity of 1.2 m/s the angular velocity varies between 486-196 rpm.

At 1.4 m/s the angular velocity varies between 568-228 rpm.

Data is stored in pit formation.

These pits vary in length from 0.833-3.054 μm depending on the encoded data and the linear velocity of the disc.

The information contain in the pit structure on the disc surface is coded so that the edge of each pit represents 0 and all space between the edges represent 0. The width and depth of the pits are approximately 0.5 and 0.11 μm respectively. The track runs circumferentially from the inside to the outside. The total number of spiral revolutions on a CD is 20 625.

The Pickup

The function of the pick up is to transfer the encoded information from the optical disc to the CDP's decoding circuit (fig. 8). The pickup is required to track the information on the disc, focus a laser beam and read the information as the disc rotates. The entire lens assembly is able to move across the disc as directed by the tracking information taken from the disc and programming information provided by the user.

The pickup must respond accurately under adverse conditions such as playing damaged and dirty disc or while experiencing vibrations or shocks.

CDP uses either a three-beam pickup or a single-beam pickup. A laser diode functions as the optical source for the pickup. The AlGaAs laser is commonly used in CDP. Its wavelength is 780 nm.

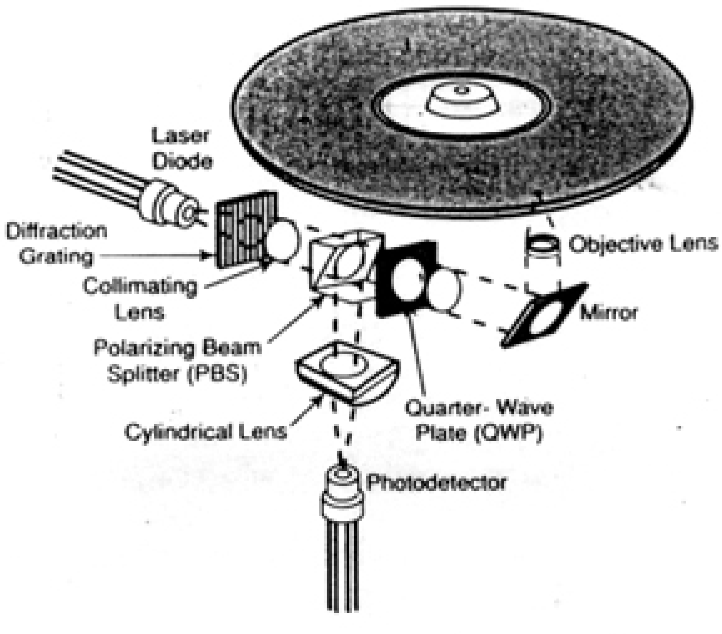
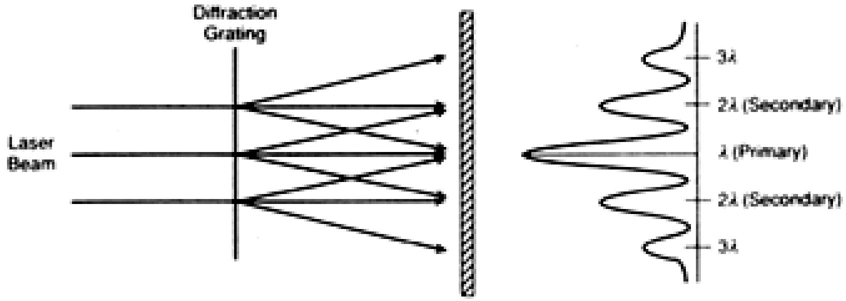


Figure 8. The compact disc three-beam optical system.

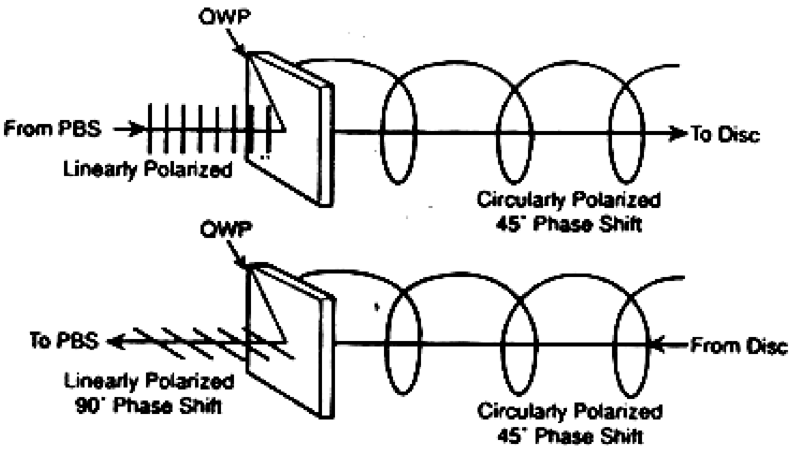
The laser beam is split by a diffraction grating into multiple beams. Diffraction gratings are plates with slits placed only a wavelength apart (fig 9a). As the beam passes through the grating it diffracts in different directions resulting in an intense main beam (primary beam) with successively less intense beams on either side. Only the primary and secondary beams are used in the optical system of a CDP. The primary beam is used for reading data and focusing the beam. The outer two beams (secondary beams) are used for tracking. The light is subjected to a collimator lens that converges the previously divergent light into a parallel path. The light is conditionally passed through a Polarization Beam Splitter (PBS). The PBS acts as a one-way mirror allowing only vertically polarized light to pass to the disc; it reflects all other light.



(a) A diffraction grating splits the laser beam into multiple beams

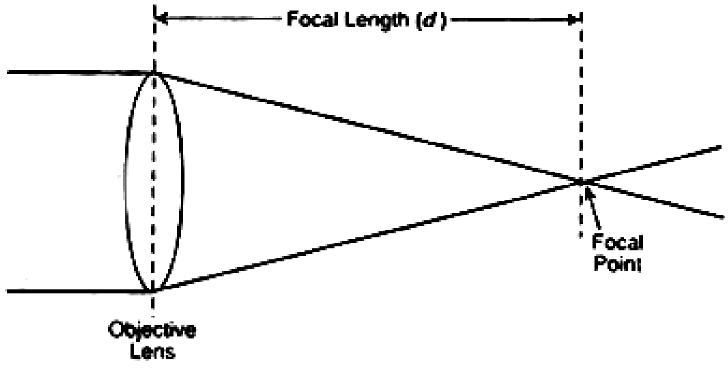
Figure 9. The optical pickup is made up of several components

The light is than directed to the toward a quarter-wave plate (QWP). The QWP is an anisotropic crystal material designed to rotate the plane of polarization of linearly polarized light by 45o (fig 9b).



(b) The quarter-wave plate rotates the plane of polarization 45°.

The laser light is then focus onto the disc by an objective lens. The objective lens converges the impinging light to the focal point at a distance (d) from the lens called the focal length (fig. 9c).



(c) The objective lens converges the light

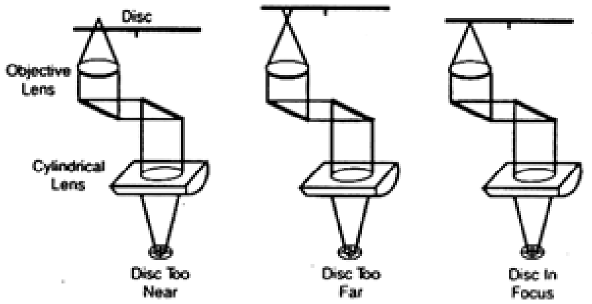
The objective lens of a CDP is mounted on a two-axis actuator that is controlled by focus and tracking servos. The spot size of the primary beam on the surface is 0.8 mm and is further reduced in size to 1.7 µm at the reflective surface of the disc. This is due to the converging effect of the objective lens.

Accurate control of the focusing system causes dust, scratches or fingerprints on the surface of the disc to appear out of focus to the reading laser.

The pits appear as bumps from underneath where the laser enters the medium. The wavelength of the laser in air is 780 nm. Upon entering the polycarbonate subtrate with a refractive index of 1.55, the wavelength is reduced to approximately 500 nm. The depth of the pits are between 110 and 130 nm and are designed to be approximately one quarter of the laser's wavelength. The pit depth of one quarter of the laser's wavelength will create a diffraction structure such that reflected light undergoes destructive interference. This interference thus decreases the intensity of light returned to the pickup lens. The presence of pits and land areas are detected in terms of changing light intensity by photodetectors.

The light signal is converted to a corresponding electrical signal by the photodetectors. Thereafter the electrical signals are sent to the decoder for processing and eventually are converted into audio signal.

As the light is reflected from the disc and it passes through the objective lens again. The light converges as it passes through the objective lens and is again phase-shifted 45^o by the QWP. The plane of polarization of the reflected light is now at right angle to its original state; its now horizontally polarized. Since the light is horizontally polarized it is reflected by the PBS toward a cylindrical lens. The cylindrical lens uses an astigmatic property to reveal focusing errors in the optical system (fig. 9d). Light passes through the cylindrical lens and is received by an array of photodetectors, typically a four-quadrant photodetector.



(d) Astigmatism is measured by photodetectors to determine the focusing error.

Figure 9. (cont.)

FOCUSING MECHANISM

A perfectly focused beam places the focal point of the light on the photodectors where the shape of the image on the photodetectors is correspondingly circular. When the focal point is in front of the photodetectors an elliptical image is projected on the photodectors at an angle. If the focal point moves behind the photodetectors, the elliptical image is rotated 90°. The photodetectors act as transducers converting the impinging light signals into corresponding electrical signals. The electrical signals thus contain information for both focusing and tracking the laser beam, as well as audio information.

The four-quadrant photodetectors (labeled A, B, C, D) [Fig 10] used to control the focus servo and to transfer the audio signal to the decoding circuit. The focus circuit provides control for the vertical positioning of the two-axis objective lens. The focus correction signal (A+C) - (B+D) is equal to zero when the laser is focused correctly on the disc, and the shape of the photodetector is correspondingly circular. When the optical correction system is out of focus the focus correction signal is a non-zero value. The focus correction signal provides feedback to the focus servo circuit, which moves the objective lens up or down according until the laser is focused and the shape of the image on the photodetectors becomes circular

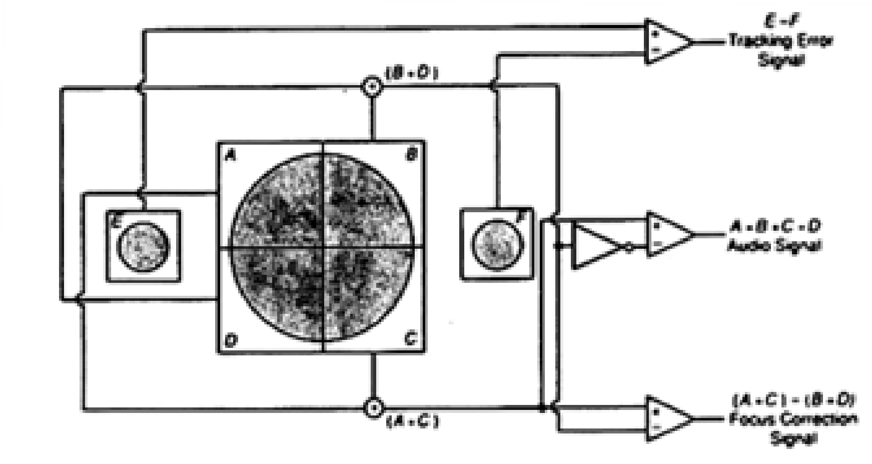
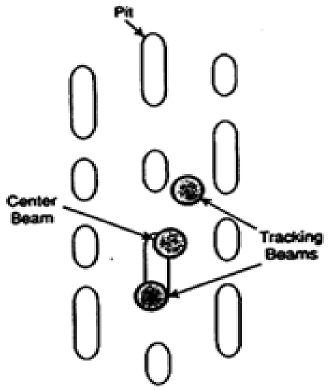


Figure 10. The signal from the four-quadrant photodetector controls focus and carries the audio signal. The signal at the outer detectors controls tracking.

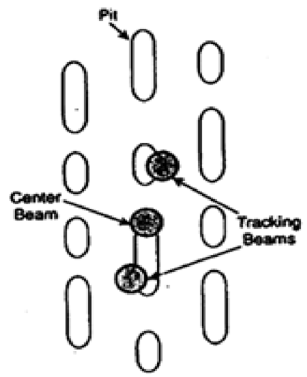
The audio information is collected by summing the signals from the four photodiodes (A+B+C+D). The audio signal must exceed a threshold level prior to activation of the focus servo. When the disc is first placed in the player the distance between the objective lens and the disc is large, and therefore the audio signal is below the threshold and the focus servo is inactive. A focus search circuit initially moves the lens closer to the disc, causing the audio signal to increase. When the audio signal exceeds the threshold the focus servo is activated.

TRACKING

The tracking servo is controlled by the signals received at two outer photodetectors E and F (Fig. 10). The secondary beams are directed to these photodetectors. The two outer photodetectors generate a tracking error signal (E-F) [fig. 11]. The tracking system detects mistracking to the left or right and returns a tracking error signal to the tracking servo.

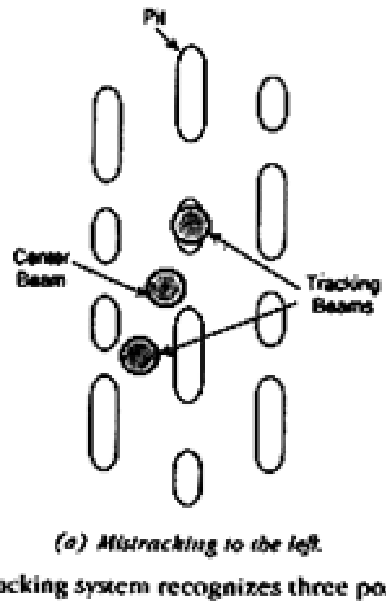


(b) Mistracking to the right.



(c) Correct tracking.

Figure 11. (cont.)



(a) Mistracking to the left.

Figure 11. The tracking system recognizes three possible conditions.

The servo moves the pickup accordingly to correct the tracking error. The tracking error signal controls the horizontal movement of the two-axis objective lens actuator. The tracking servo continually moves the objective lens in the appropriate direction to reduce the tracking error.

PICKUP CONTROL

Three-beam pickups are mounted on a sled that moves radially across the disc, providing coarse tracking capabilities. Tracking signals are derived from the signal used to control the two-axis objective lens actuator. The sled servo operation is contingent upon the level of the primary beam exceeding the threshold.

Precise tracking is always provided by the tracking servo and corresponding control circuit. During fast forward or reverse a microprocessor takes control of the tracking servo to increase locating speed.

2. SPARS CODE

Found on CDs stating which recording format was used in the three stages of album production.

Recording	**Mixing**	**Mastering**
A	A	D
A	D	D
D	A	D
D	D	D

A – analogue

D - digital

Reference: Ken C. Polman,, Fundamentals of Digital Audio, Focal Press

DIGITAL AUDIO TAPE

Introduction

DAT was developed by Sony in the early 1980's as new consumer format to replace the analogue Compact Cassette.

High Fidelity Recording

There is no signal degradation during playback or recording because the audio signal is recorded digitally on a DAT.

The quality of the head, tape and transport in an analogue cassette recorder will affect the playback of a cassette tape. There is no tape hiss, noise, distortion and wow and flutter which are inherent limitations found in cassette tape.

For a DAT, both recording - Analogue-to-Digital Conversion (encoding) and playback - Digital-to-Analogue Conversion (decoding) are performed in the digital domain. As a result there is little, if not an absent, of the above problems associated with analogue recording and playback.

THE DAT ADVANTAGE

Frequency Response	20 to 20 KHz
Sampling Frequency	44.1 or 48 Khz
Dynamic Range	> 90 dB
Bit Depth	16, 24 Bit
Wow & Flutter	Unmeasurable
Tape Speed	8.15 mm/sec (1/6th of compact cassette tape @ 4.76 cm/sec)
Tape Width	3.81 mm
Tape Thickness	13 microns
Tape Size	73mm x 54mm x 10.5 (half the size of Compact Cassette)
Longest Playback Time	120 min
High-speed Search	Up to 200 times its normal layback speed 60-min programme material can be searched in < 20 sec
Subcode	Like CD a subcode can be incorporated to provide information such as track number and playing time - elapse and total programme time

Synchronisation Yes

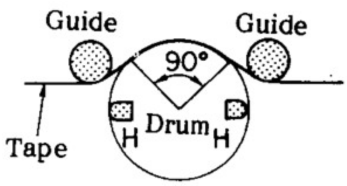
1. DAT Mechanism

Due to the extremely large amount of digital audio data involved. Highly precise, high-density recording is required. For this reason a DAT employs rotation heads like those of a VTR. The head rotates at a very high speed while the tape runs pass it, thereby increasing the relative head-to-tape speed and improving recording performance. There are two heads, Head A and B, mounted on a rotating drum which is set at a 6^{o} 23" angle against the tape. Signals are recorded diagonally on the tape, using a helical scan system, in the same way as in a VTR.

The tape wraps around only 90^{o} of a 30mm drum's circumference (see diagram below) which is remarkably little when compared to 180^{o} to a VTR. Because of this, the stress on the tape is minimised allowing high-speed rewinding, fast-search and cueing without having to "unwrap" the tape from the drum.

This is a big advantage of DAT.

The drum of the DAT rotates at 2000 rpm (1800 rpm for VTR), for a relative tape speed of 3.13 meter per sec or 66 times that of an analogue cassette at 4.76 cm/s.



2. DAT RECORDING SYSTEM

The DAT recording system is like that of a VTR. Diagonal tracks are created on the tape in the area used for recording, which 2.163 mm wide. These tracks are only about 13.6 microns wide or less then 1/5th the diameter of a human hair.

While rotating, the two heads, A and B, record alternatively, overlapping slightly to leave no space between tracks because the azimuth angles of the two heads are different, crosstalk between tracks is minimised. The A head azimuth is angled at 20° called the plus (+) azimuth head. The B head, on the other hand, records at an angle of 20° clockwise from the perpendicular track, and is called the minus (-) azimuth head.

Digital AudioTape (DAT) Format 201

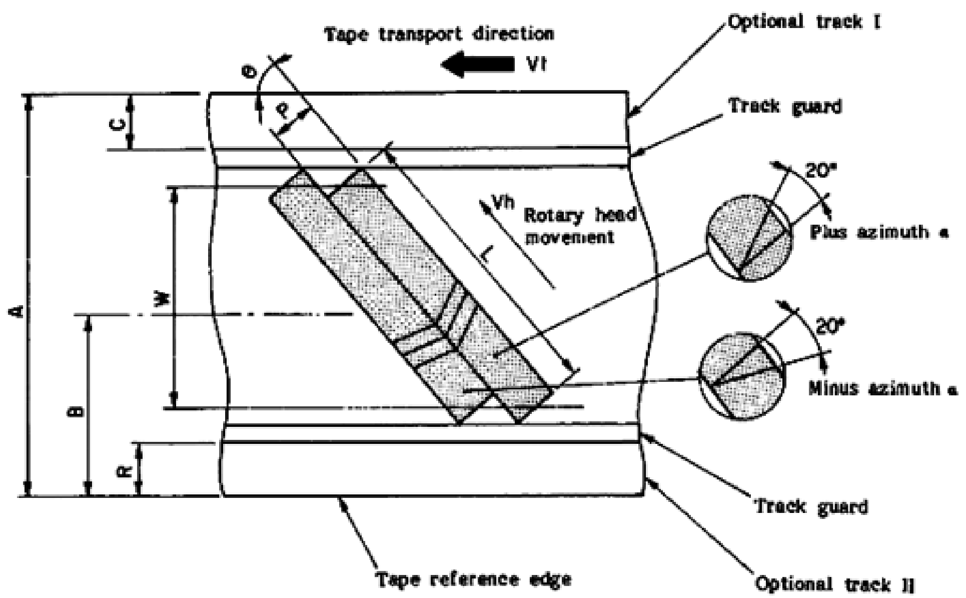


Figure 17.2 *Simplified R-DAT track pattern*

In this way the two heads play and record in an interleaved pattern. DAT heads are used for both recording and playback, and any unwanted audio data is erased by writing over it.

Heads A and B alternately record on 13.591 micron wide tracks as they rotate, but there is practically no space between the tracks. This is because they slightly overlap as shown in the drawing. During playback the heads do not read information from adjacent tracks due to their different azimuth angles.

On both edges of the tape there are auxiliary tracks for fixed head access in as-yet-undecided future systems. At present, they can be looked at as being nothing more than blank areas that contribute to tracking stability.

3. <u>WHAT IS RECORDED ON A DAT</u>

The different types of data that is written on a DAT tape can be divided into three following areas:

MAIN AREA

In the main area, PCM digital audio data (main data) is recorded here. The control signal called the Main ID (Identification Code) is also embedded in this area. This records, among other things, such information as sampling frequency, the number of bits, anti-piracy status known as Serial Copy Management System (SCMS), the number of channels in the recorded signal format and the presence or absence of emphasis. Due to the important role Main ID plays as control signal in playback, the main ID is repeated 16 times per track to ensure no mistakes occur when the DAT recorder reads the data.

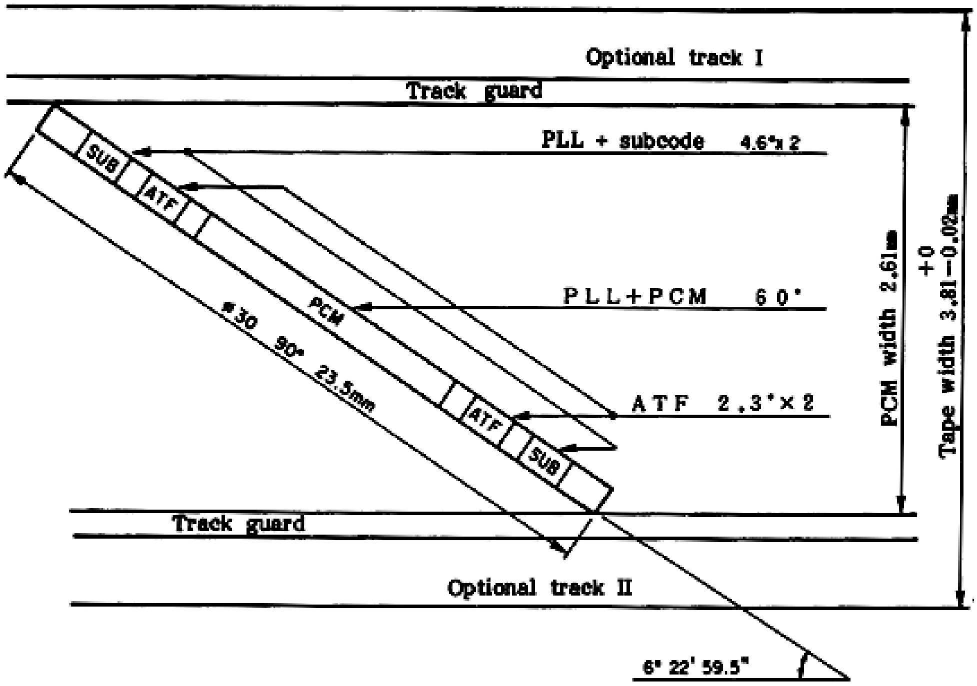


Figure 17.4 *R-DAT tape track format*

SUB AREA

Start IDs, address, absolute time and programme numbers are recorded in this area. A similar sub area exists in CDs but DAT has four times the recording capacity. This sub area is designed to give the user the convenience of editing programme numbers, start and skip IDs.

ATF AREA

Automatic Track Finding (ATF) data is recorded here. These signals are recorded on one track when the head is touching the tape at a 90° angle.

The ATF is found both on home VCR and DAT alike. During the playback of a DAT, the playback head must be correctly positioned on the recorded track. Even a slight drift from the track will impair the playback due to the head inability to read data correctly.

The ATF signal is recorded to make sure heads stay correctly positioned on the right track during recording and playback. ATF in DAT helps to do away with control head or tracking control knob found in VCRs.

Thus the order of recording on a DAT is SUB, ATF, MAIN, ATF and SUB again.

START ID and SKIP ID

These signals recorded in the subcode are, the Start ID – which is of one of the most important. It is a special mark recorded to indicate the beginning of a song. In the normal mode it is recorded from the start of a song up through to the ninth second. During playback it is used by the search function to locate the start of a song. The Start ID is recorded automatically and it can set to record manually as well. Automatic recording occurs at the first rise in signal level after a space of about two-second or more of silence.

Programme Numbers are recorded automatically at the same time as IDs to separate songs. With programme numbers it is also possible to go directly to the song of one's choice by using the direct song function, by selecting the appropriate number on the 10-key pad.

Editing of recorded music programme is possible by adding or deleting Start and Programme Numbers.

Absolute Time

Absolute Time (ABS) is another example of data that is recorded automatically. It represents the total time that has elapsed since the beginning of the tape, and it serves a useful role in high-speed searching. It cannot normally be added after recording although it is possible with certain high-grade models. This is essential if synchronization is needed subsequently.

Skip Ids

Skip IDs is useful, enabling the user to mark songs or the recorded material that one does not want to hear. During playback when the DAT deck comes to a Skip ID, it skips over at high speed to the next Start ID. For example one is listening to a recorded digital radio broadcast, Skip Ids can be used to exclude commercials and talk leaving just the music for one's enjoyment.

Skip IDs can be inserted or erased at will during recording and playback.

4. Error Correction System

On a DAT even if one of the heads is clogged almost perfect playback is possible from the other head. This is because data is interleaved across the two tracks during recording. The DAT error correction system can restore all of the original PCM data because odd number data and even number date is split between the A and B head tracks during recording. This data is then rearranged during playback. This means that even if playback from the B head is impossible because of clogging provided, there is sufficient data on the A head track. The error correction system will be able to provide approximate correction by interpolating an average value based on division by two of the neighbouring data values from both sides of the missing value.

When the tape is dirty or damaged. The DAT system is designed to suppress noise from dirty or damaged tape in all but the worst cases, thanks to powerful error correction and compensation function.

1. Other Features
   Random Programming

   This function allows one to select the order in which songs are played back with fast access time.

   Various Repeat Functions

   As with a CD, a number of repeat functions are possible. A single song, all the songs on the tape, a programmed sequence, or songs between any two points can be repeated at will.

   Music Scan

   This function enables rapid checking of everything recorded on the tape by automatically playing the first few seconds of all the songs.

   End Search

   This fast-forwards the recorded DAT to the end of the last song where new programme can be recorded on it.

   Informative Display

   Display of subcode information such as the number of songs, time and programming information is possible.

   Construction

   A lid covers the tape and a slider covers the reel hub holes when not loaded. This protects the tape from fingerprints, dirt, dust and damage that could affect the recorded data. When loading the cassette, the slider pin is depressed to release the hub brakes and retract the slider which uncovers the tape reel hub holes. At the same time, the front lid opens so the tape can be drawn out and wrapped across the periphery of the rotary head drum.

   Longer Recording Time

   At the slower secondary speed the total tape time can be increased up to 4 hours. Some DAT will use a slightly thinner tape for up to 3 hours of recording time at the normal speed and up to 6 hours at the secondary speed.

   All recordings on a DAT is done on one side only.

There is no “Side B” on a DAT unlike compact analogue cassette.

Material of Tape

DAT tape uses metal particles of unoxidised iron and cobalt alloy particles suspended in a binder. This is similar to the metal particle tape used in analogue cassettes and 8mm (Hi-8) video cassette.

Identification Holes

There are five identification holes on the bottom of the tape, one of which is an erasure prevention hole. Unlike on ordinary cassette tapes, this can be opened or closed by a sliding tab.

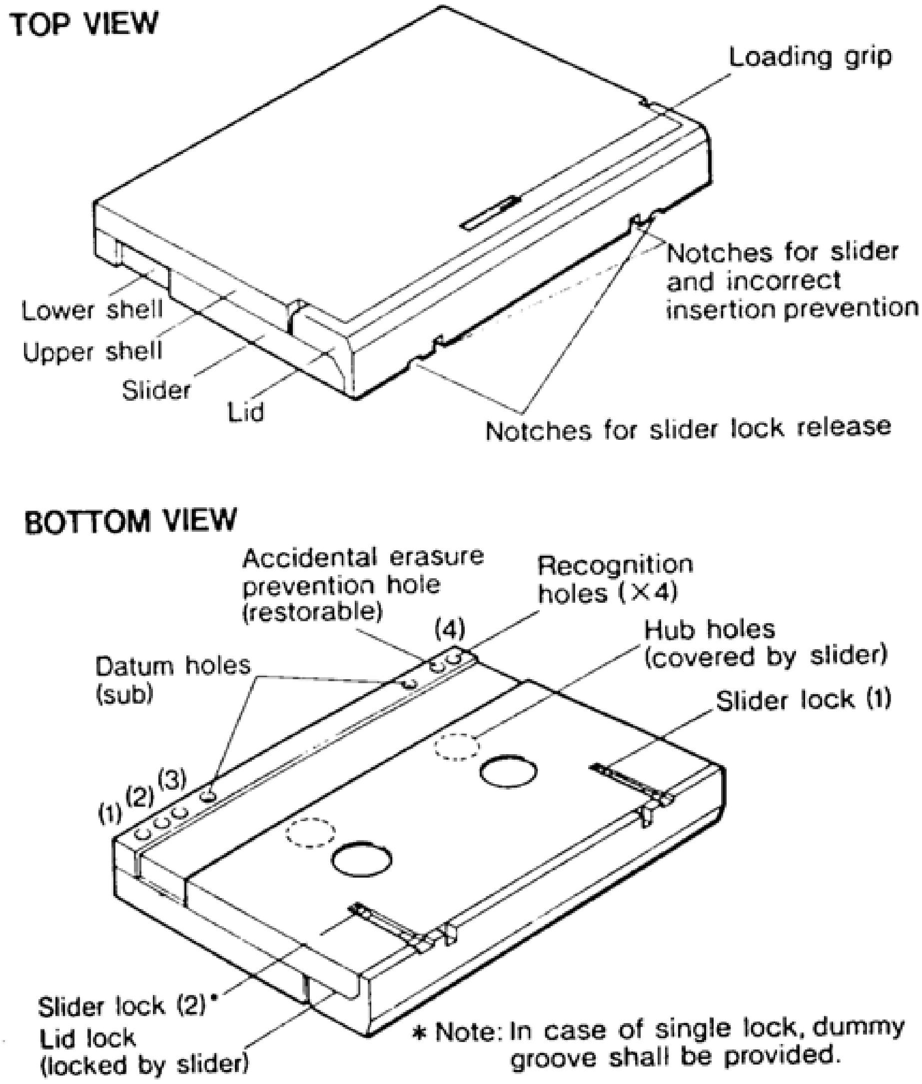


Figure 17.18a

MINI DISC

Introduction

The MD was developed in the early 1990's as new consumer format to replace the analogue Compact Cassette.

1. General Features
   Quick Random Access

   Total Durability - never gets stretched, broken or tangled. The optical pickup never physically touches the surfaces of the MD. Hence no scratches, no wear and tear. The disc is house in a casing for further protection.

   Superb compactness - ø 64mm disc

   Casing dimension - 68 x 72 x 5mm

   Recordable Disc

   Unsurpassed digital sound based on CD technology.

   Shock-proof portability-uses an advanced semiconductor memory to provide almost total shock resistant operation. No skips whilst jogging or driving.

2. The Disc
   PRE-REcorded MD

   Pre-recorded Mini Disc for music software. The audio signals are recorded in the form of pits on the MINI DISC. The casing helps to protect the pits. The casing has a read window shutter only on the bottom of the surface of the cartridge, leaving the top free for the label. The disc is made of polycarbonate like the CD.

   Recordable MD

   Can be recorded and re-recorded up to a million times without signal loss or degradation and has a life time to that of a CD. This recordable disc is based on the *Magneto Optical* (MO) disc technology.

   During the recording on MO disc a laser shines from the back of the MO disc while a magnetic field is applied to the front. MO disc casing has a read and write window on both sides of it.

3. The Laser Pickup

Ability to read both types of MD for MO discs, the pickup reads the polarity of the disc.

For pre-recorded discs, the laser pickup reads the amount of reflected light.

The pickup system is based on a standard CD pickup with the addition of a MO signal readout analyzer and two photo diodes. (See diagramme)

4. <u>Playback On A Magneto Optical (Mo) Disc</u>

A 0.5 mW laser is focused onto the magnetic layer.

The magnetic signal on the disc affects the polarization of the effect. The direction of the polarization is converted into light intensity by the MO signal readout analyzer. Depending on the direction of polarization. One of the two photo diodes will receive more light.

The electrical signal from the photo diodes are subtracted and depending on whether the difference is positive or negative, a “1” or “0” is read.

The same laser is used for the playback of pre-recorded discs. The amount of light reflected depends on whether or not a pit exists.

The pits are covered with a thin layer of aluminum which improves its reflectivity like that of a CD.

242 Digital Audio Recording Systems

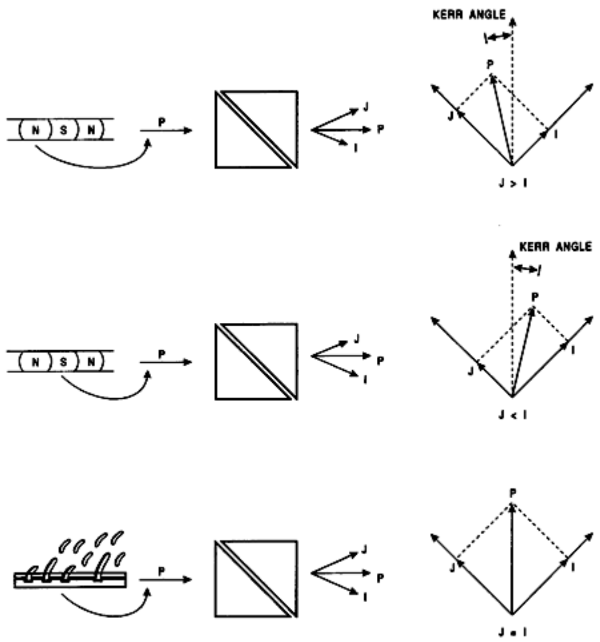


Figure 19.6 *Wollaston principles*

If no pits exist, most of the light is reflected back through the beam splitter into the analyzer and eventually into the photo diodes.

If a pit does exist, some of the light is diffracted and less light reaches the photo diodes. The electrical signals are summed up depending on the sum, a “1” or “0” is read.

5. Recording

Requires the use of a laser and a polarizing magnetic field.

When the magnetic layer in the disc is heated by the laser to a temperature of

400°F, it temporarily looses its coercive force (becomes neutral and loses its magnetism). As the disc rotates and the irradiated domain (the exposed domain) returns to its normal temperature, its magnetic orientation is determined by an external magnetic field produced by the write head.

Polarities of N & S can be recorded, corresponding to “1” or “0”.

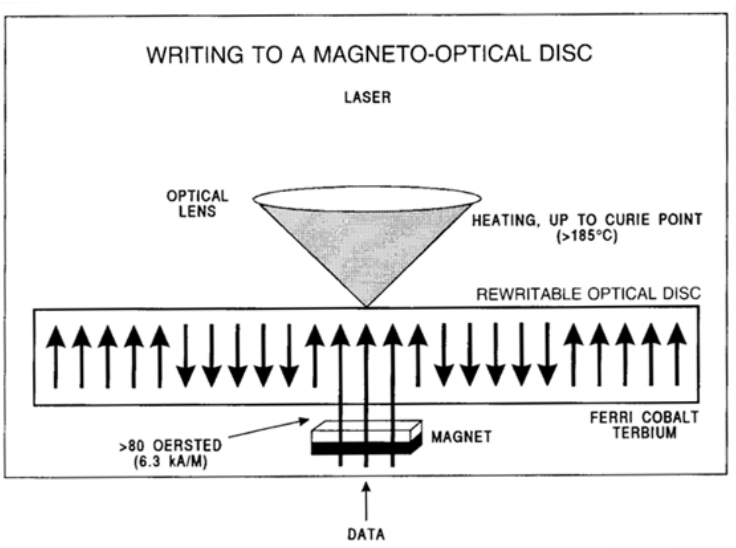


Figure 19.3 *Recording on MD*

The magnetic head is positioned directly across from the laser source on the opposite across from the laser source on the opposite side of the disc.

A magnetic field corresponding to the input signal is generated over the laser spot. The rotation of the disc then displaces the area to be recorded, allowing the temperature at the spot to drop below the Curie point. At that point the spot takes on a polarity of the applied magnetic field.

6. Quick Random Access

MD has a ‘pre-groove’ which is formed during manufacture.

This groove helps the tracking servo and spindle servo during recording and playback.

Addressed information is recorded at intervals of 13.3 ms using technology that puts small zigzags on the pre-groove. Therefore the disc has all the addresses (timing) already notched along the groove even on a blank MD.

There is a User Table of Content Area (UTOC) located around the inner edge of the disc before the programme which only contains the order of the music.

Start and end addresses for all music tracks recorded on the disc are stored in this area enabling easy programming just by rewriting the addresses.

7. Adaptive Transform Acoustic Coding (Atrac)

Digital audio data compression compresses information down to a fifth (20%) enabling 74 minutes of recording time on MD. A MD stores approximately 130 MB data or 1.756 MB/min of compressed stereo digital audio data –

16-bit, 44.1 KHz.

Unlike uncompressed digital audio data for 16-bit, 44.1 KHz stereo CD recording is approximately 10 MB/min.

ATRAC starts with 16-bit information and it analyses segments of the data for its waveform content.

ATRAC encodes only those frequency components which are audible to us.

It works on the principle of the threshold of hearing and masking effect. (see diagram)

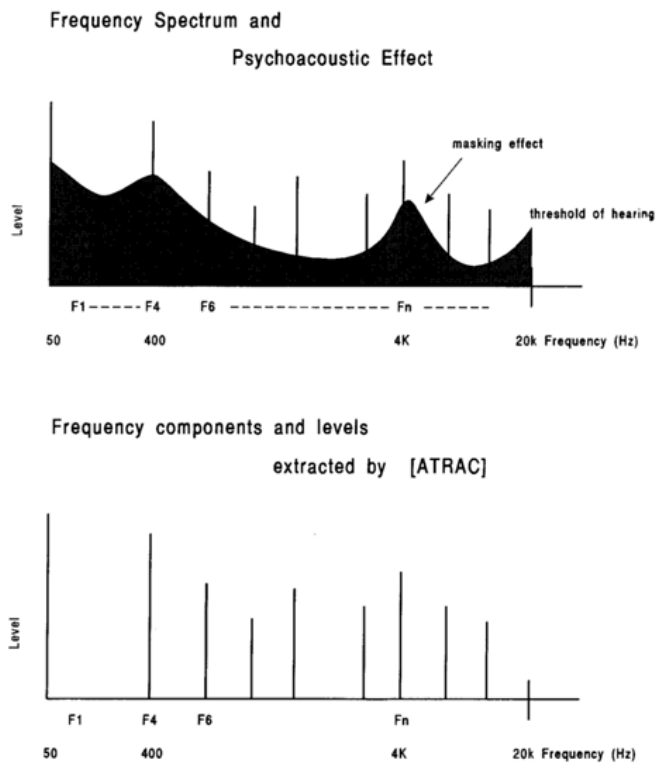


Figure 19.14 *Psychoacoustic effects : threshold*

8. Shock Proof Memory

Aim is to prevent skipping or muting while the user is moving about.

The pickup can read information off the disc at a rate of 1.4M bit per second but the ATRAC decoder requires a data rate of only 0.3M bit per second for playback.

Allows the use of a buffer memory that can store up 20 seconds of digital information. It is a read ahead buffer.

Should the pickup be jarred out of position and stop supplying information. The correct information continues to be supplied to the ATRAC decoder from the buffer memory. As long as the pickup returns to the correct position within 3 – 20 seconds, depending on buffer memory size, the listener will never experience mistracking.

238 Digital Audio Recording Systems

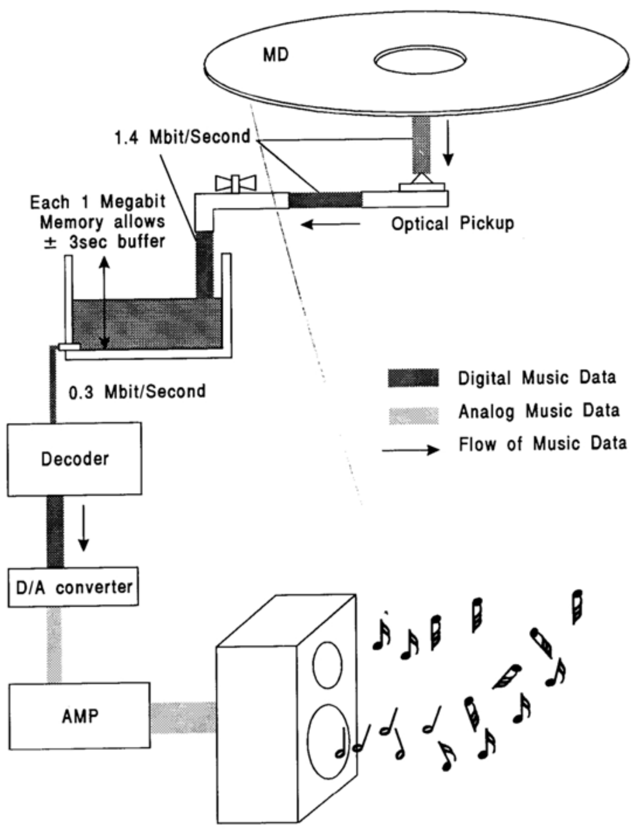


Figure 19.1 *Shock-proof capacity*

Since signals enter the buffer faster than they leave it, the buffer will eventually become full. At that point the pickup stops reading information from the disc. It resumes as soon as there is room in the memory.

This memory can also be applied to the conventional CD but will require a much larger memory.

Using a concept called sector repositioning the pickup has the ability to resume reading from the correct point after being displaced. It simply memorizes the address every 13.3 ms where it was displaced and returns the pickup to the correct position.

9. Mini Disc Specifications

Frequency range: 5 Hz to 20 KHz

Dynamic range: 105 dB

Sampling Resolution: 16-bit

Sampling Frequency: 44.1 KHz

Disc speed: 1.2 - 1.4 m/sec (CLV) centrifugal linear velocity

User Table of Content (UTOC) programmable

A MD that has some pre-recorded and recordable areas in one disc.

Useful for language learning and music study, where the student could repeat and record what is already on the disc.

10. Manufacture and Mastering
K-1216 MD Format Converter

The original 16 bit digital signal is compressed using ATRAC encoder.

A hard disc is built into the K-1216 for saving the compressed signal data.

Simultaneously with ATRAC compression, the signal is restored back to the 16-bit audio for monitoring the MD audio sound.

A keyboard is supplied with the format converter so that character and text information can be applied.

Subcode info is read from the original CD master and converted to MD format sub code and saved on the hard disc.

K-1217 Address generator

Used in producing the final MO glass master and only required at actual disc cutting facilities. It interfaces directly with the cutting machine, supplying the necessary audio, error correction and address codes via Sony CDX-I code pro.

DVD

Introduction

DVD format was design to replace the Laser Disc boosting a higher storage capacity then LD.

1. DVD-Audio

Even though DVD is of the same size and shape of a CD, DVD can hold up to 4.7GB of data on a single sided, single layer disc in comparison to CD's storage capacity of 650 MB only. This is achieved by tightening tolerances to squeeze more data pits closer together.

Like a vinyl record it needs to be flipped over when side A has finished playing on current DVD player. Where multilayer technology is used on the DVD, more data can be packed into the disc. Here two layers of different data are to be found on one or both sides of the disc. Though one layer lies in front of the other, the separate layer can be read by changing the focal point of the laser. This is very similar to us looking through a rain-spattered windowpane and focusing on the landscape, the rain-splattered windowpane would now become out of focus.

Storage Capacity

CD 650 - 700 MB

DVD

A single sided, single layer	4.7GB
A doubled-sided	9.40 GB
A dual-layer (DVD-9), single-sided	8.54 GB
A double-layer, double-sided	17.08 GB

DVD player requires new heads using shorter-wavelength lasers and more refined focusing mechanisms, other then that, it is identical to a CD player's transport.

RS-PC (Reed Solomon Product Code) error correction system is approximately 10 times more robust than the current CD system.

2. Multi Channels

LPCM is mandatory, with up to 6 channels at sample rates of 48/96/192 kHz (also 44.1/88.2/176.4 kHz) and sample sizes of 16/20/24 bits. Yielding frequency response of up to 96 kHz and dynamic range of up to 144 dB. Multichannel PCM will be downmixable by the player, although at 192 and 176.4 kHz only two channels are available. Sampling rates and sizes can vary for different channels by using a predefined set of groups. The maximum data rate is 9.6 Mbps.

3. Meridian Lossless Packing

Meridian's MLP (Meridian Lossless Packing) scheme licensed by Dolby. MLP removes redundancy from the signal to achieve a compression ratio of about 2:1 while allowing the PCM signal to be completely recreated by the MLP decoder (required in all DVD-Audio players). MLP allows playing times of about 74 to 135 minutes of 6-channel 96kHz/24-bit audio on a single layer (compared to 45 minutes without packing). Two-channel 192kHz/24-bit playing times are about 120 to 140 minutes (compared to 67 minutes without packing).

4. Various Audio Formats

Other audio formats of DVD-Video (Dolby Digital, MPEG audio, and DTS, described below) are optional on DVD-Audio discs, although Dolby Digital is required for audio content that has associated video. A subset of DVD-Video features (no angles, no seamless branching, etc.) is allowed. It's expected that shortly after DVD-Audio players appear, new universal DVD players will also support all DVD-Audio features.

DVD-Audio includes specialized downmixing features. Unlike DVD-Video, where the decoder controls mixing from 6 channels down to 2, DVD-Audio includes coefficient tables called SMART (system-managed audio resource technique) to control mixdown and avoid volume buildup from channel aggregation. Up to 16 tables can be defined by each Audio Title Set (album), and each track can be identified with a table. Coefficients range from 0dB to 60dB.

DVD-Audio allows up to 16 still graphics per track, with a set of limited transitions. On-screen displays can be used for synchronized lyrics and navigation menus. A special simplified navigation mode can be used on players without a video display.

Matsushita announced that its new Panasonic and Technics universal DVD-Audio/DVD-Video players will be available in fall 1999 and will cost $700 to $1,200. Yamaha may also release DVD-Audio players at the same time. BMG, EMI, Universal, and Warner have all announced that they will have about 10 to 15 DVD-Audio titles available at launch.

5. Audio details of DVD-Video

The following details are for audio tracks on DVD-Video. Some DVD manufacturers such as Pioneer are developing audio-only players using the DVD-Video format. Some DVD-Video discs contain mostly audio with only video still frames.

Surround Sound Format

A DVD-Video disc can have up to 8 audio tracks (streams). Each track can be in one of three formats:

- Dolby Digital (formerly AC-3): 1 to 5.1 channels
- MPEG-2 audio: 1 to 5.1 or 7.1 channels
- PCM: 1 to 8 channels.

Two additional optional formats are provided: DTS and SDDS. Both require external decoders and are not supported by all players.

The "0.1" refers to a low-frequency effects (LFE) channel that connects to a sub low frequency driver (subwoofer).

Linear PCM

Linear PCM is uncompressed (lossless) digital audio, the same format used on CDs and most studio masters. It can be sampled at 48 or 96 kHz with 16, 20, or 24 bits/sample. (Audio CD is limited to 44.1 kHz at 16 bits.) It ranges from 1 to 8 channels depending on surround sound format. The maximum bitrate is 6.144 Mbps, which limits sample rates and bit sizes with 5 or more channels. It's generally felt that the 96 dB dynamic range of 16 bits or even the 120 dB range of 20 bits combined with a 48 kHz sampling rate is adequate for high-fidelity sound reproduction. However, additional bits and higher sampling rates are useful in studio work, noise shaping, advanced digital processing, and three-dimensional sound field reproduction. DVD players are required to support all the variations of LPCM, but some of them may subsample 96 kHz down to 48 kHz, and some may not use all 20 or 24 bits. The signal provided on the digital output for external digital-to-analog converters may be limited to less than 96 kHz and less than 24 bits.

Dolby Digital

Dolby Digital is multi-channel digital audio, using lossy AC-3 coding technology from original PCM with a sample rate of 48 kHz at up to 24 bits. The bitrate is 64 kbps to 448 kbps, with 384 being the normal rate for 5.1 channels and 192 being the normal rate for stereo (with or without surround encoding). (Most Dolby Digital decoders support up to 640 kbps.)

Dolby Digital is the format used for audio tracks on almost all DVDs.

MPEG Audio

MPEG audio is multi-channel digital audio, using lossy compression from original PCM format with sample rate of 48 kHz at 16 bits. Both MPEG-1 and MPEG-2 formats are supported. The variable bitrate is 32 kbps to 912 kbps, with 384 being the normal average rate. MPEG-1 is limited to 384 kbps. The 7.1 channel format adds left-center and right-center channels, but will probably be rare for home use. MPEG-2 surround channels are in an extension stream matrixed onto the MPEG-1 stereo channels, which makes MPEG-2 audio backwards compatible with MPEG-1 hardware (an MPEG-1 system will only see the two stereo channels.) MPEG Layer III (MP3) and MPEG-2 AAC (a.k.a. NBC, a.k.a. unmatrix) are not supported by the DVD-Video standard.

Digital Theater Systems

DTS (Digital Theater Systems) Digital Surround is an optional multi-channel (5.1) digital audio format, using lossy compression from PCM at 48 kHz at up to 20 bits. The data rate is from 64 kbps to 1536 kbps (though the DTS Coherent Acoustics format supports up to 4096 kbps as well as variable data rate for lossless compression). The DVD standard includes an audio stream format reserved for DTS, but many players ignore it. According to DTS, existing DTS decoders will work with DTS DVDs. All DVD players can play DTS audio CDs.

Sony Dynamic Digital Sound

SDDS (Sony Dynamic Digital Sound) is an optional multi-channel (5.1 or 7.1) digital audio format, compressed from PCM at 48 kHz. The data rate can go up to 1280 kbps. SDDS is a theatrical film soundtrack format based on the ATRAC compression format technology that is used in Minidisc.

Super Audio Compact Disc (SACD)

Sony and Philips are promoting SACD, a competing DVD-based format using Direct Stream Digital (DSD) encoding with sampling rates of up to 100 kHz.

SACD and DVD-audio are not design to replace the CD format.

DSD is based on the pulse-density modulation (PDM) technique that uses (1-bit) single bits to represent the incremental rise or fall of the audio waveform.

The 1 bit system encodes music at 2 822 400 samples a second. This supposedly improves quality by removing the brick wall filters required for PCM encoding. It also makes downsampling more accurate and efficient.

DSD provides frequency response from DC to over 100 kHz with a dynamic range of over 120 dB. DSD includes a lossless encoding technique that produces approximately 2:1 data reduction (50%) by predicting each sample and then run-length encoding the error signal. Maximum data rate is 2.8 Mbps.

1. Watermark – Anti Piracy Feature

SACD includes a physical watermarking feature - Pit signal processing (PSP) modulates the width of pits on the disc to store a digital watermark (data is stored in the pit length). The optical pickup must contain additional circuitry to read the PSP watermark, which is then compared to information on the disc to make sure it's legitimate – anti piracy. A downside because of the requirement for new watermarking circuitry, SACD discs are not playable in existing DVD-ROM drives.

SACD includes text and still graphics, but no video. Sony says the format is aimed at audiophiles and is not intended to replace the audio CD format – 13 billion CDs worldwide. It may be revived when yields are high enough that it no longer costs more to make a hybrid SACD disc than to press both an SACD DVD and a CD.

Future SACDs will have enough room for both a two-channel mix and a multi-channel version of the same music including text and graphics alike.

With the SACD format, music companies can offer three different types of discs. The single-layer disc can store a full album of high-resolution music. A dual-layer disc provides nearly twice the playing time.

2. Hybrid Disc

Two layers – the top layer is CD while the bottom layer is high density SACD. It is compatible with 700 million CD players worldwide.

Sony released an SACD player in Japan in May 1999 and expects the player to be available in the U.S. for $4,000 by the end of the year. Initial SACD releases will be mixed in stereo, not multichannel. A number of studios have announced that they will release SACD titles by the end of the year: Audioquest (2), DMP (5), Mobile Fidelity Labs, Sony (40), Telarc (12), Water Lily Acoustics (2).

Student Notes