

COMPACT DISK STANDARDS & SPECIFICATIONS

History:

- At the end of 1982, the Compact Disc Digital Audio (CD-DA) was introduced.
- This optical disc digitally stores audio data in high quality stereo.
- The CD-DA specification was drawn up by N.V.Philips and the Sony Corporation, was summarized in the so-called **RED BOOK**. All subsequent CD formats are based on this description.
- The extension of CD to storage of computer data was announced by N.V.Philips and Sony Corporation in 1983, and introduced to public in Nov 1985.
- This CD-ROM is described in **YELLOW BOOK**, which later led to the ECMA-119 standard, which specifies the physical format of a compact disc.
- In 1986, N.V.Philips and the Sony Corporation announced CD-I, which is described in **GREEN BOOK**.
- In 1987, Digital Video Interactive (DVI) was presented to public. The primary emphasis in DVI is on algorithms for compression and decompression of audio and video data stored on a CD-ROM.
- In 1988, the CDROM-XA was announced. Since the beginning of 1990, CD-WO and CD-MO are specified in **ORANGE BOOK**. Since the beginning of 1995, CD-RW is also specified in **ORANGE BOOK**.
- At the beginning of 1997, Digital Versatile Disc (DVD) was introduced.

BASIC TECHNOLOGY:

- In optical storage media, the underlying principle is that information is represented by using the **intensity of laser light reflected during reading**.

- A laser beam having a wave length of about 780 nm can be focused to a resolution of approximately 1 μ m. In polycarbonate substrate layer, there are depressions, called **pits**, corresponding to the data to be encoded.
- The areas between the pits are called **lands**.
- The substrate layer is smooth and coated with a thin, reflected layer. The reflected beam has a strong intensity at the lands.
- The pits have a depth of 0.12 μ m from the substrate layer. Laser light hitting pits will be lightly scattered, that is, it will be reflected with weaker intensity.
- An optical disc consists of a sequential arrangement of pits and lands within a track. The pits and lands represent data on the surface.

COMPACT DISK - DIGITAL AUDIO (CD-DA):

- The CD-DA was developed jointly by N.V.Philips and the Sony Corporation for **storing audio data**.
- CDs have a diameter of 12cm, and are played at a Constant Linear Velocity (CLV).
- Information is stored in such a way that the length of the pits is always a multiple of **0.3 μ m**. A change from pit to land or from land to pit corresponds to the coding of **1** in the data stream. If there is no change, a **0** is coded.
- It stores up to 74 minutes of high quality stereophonic sound using 16-bit linear PCM at a sampling rate of 44.1 KHz.
- Analog long playing records and cassette tapes have a SNR of approximately 50 to 60 dB. The SNR of the CD-DA is exactly **96 dB**.
- The audio data rate from a CD-DA is

$$= 16 \text{ bits} \times 2 \text{ channels} \times 44100 = 1.4112 \times 10^6 \text{ bit/s.}$$

Eight to Fourteen Modulation:

- Each change from pit to land or land to pit corresponds to a channel bit of **1**. If no change, **0** takes place.
- Pit and land may not follow each other too closely on a CD, since the resolution of the laser would not suffice to read direct pit-land-pit-land-pit.....
- At least two lands and two pits must always occur consecutively. Between every **1s** as channel bits, there will thus be at least two **0s**.
- On the other hand, pits and lands cannot be too long, otherwise a phase correct synchronization signal (clock) cannot be derived. The maximum length of pits and lands was thus limited such that there can be at most 10 consecutive **0s** as channel bits.
- For these reasons, the bit written on a CD-DA in the form of pits and lands do not corresponds directly to the actual information. Before writing, **Eight to Fourteen Modulation is applied**.
- Eight bit words are coded as 14 bit values. For example:

| Audio Bits | Modulated Bits |
|-------------------|-----------------------|
| 00000000 | 01001000100000 |
| 00000001 | 10000100000000 |

- 8 user data bits are mapped into 14 bits using 8-to-14 modulation. Also 3 additional merge or fill bits are used for each user byte. Thus one user byte gives rise to 17 bits.
- Filler bits for the above modulated bits are **010 and 100 and the channel bits are:**

01001001000100000 10010000100000000
on CD-DA lpppl l lppppllllll pppllllpppppppppp

- Each frame in a CD contains 24 bytes of user data or 192 bits of user data.
- Since 8-to-14 modulation is used before recording, 24 user data bytes lead to $24 \times (14+3)$ or 408 channel bits.
- Besides data, each frame also contains sync pattern info., Control and display info., Error detection/correction info.

- Each frame contains a total of 588 channel bits with the following break-down:

| | |
|---------------------------------|-----------------|
| sync pattern | 24+3 |
| control & display | 1*(14+3) |
| error correction | 8*(14+3) |
| user data (or application data) | 24*(14+3) |
| Frame Total | 588 bits |

Sequence: Sync + Control & Display + 12 Data + 4 Error Handling + 12 Data + 4 Error handling

Error Handling:

- The goal of error handling on a CD-DA is the detection and correction of typical error patterns. An error is usually the result of scratches or dirt.
- The first level of error handling implements two-stage error correction according to the **Reed-Solomon** algorithm. For every 24 audio bytes, there are two groups of correction data bytes, each of four bytes.
- The first group corrects single-byte errors while the second group corrects double-byte errors.
- In the second level, real consecutive data bytes (24 bytes) are distributed over multiple frames. The audio data are stored interleaved on the CD-DA. In this way, burst errors will always damage only parts of the data.
- An error rate of 10^{-8} is achieved.

ADVANTAGES OF CD-DA

- Errors on a CD-DA can be caused by damage or dirt. For uncompressed audio, the CD-DA is very insensitive to read errors that usually occur.
- An additional advantage is that there is no mechanical wear and tear.
- The disadvantage is the achievable error rate is too high for general computer data, necessitating an extension of the technology in form of the CD-ROM.

CD-ROM

- The Compact Disc Read-Only-Memory (CD-ROM) was conceived as a storage medium for **general computer data**, in addition to **uncompressed audio data**.
- It was specified by N.V.Philips and the Sony Corporation in the **Yellow Book** and later accepted as an ECMA standard.
- CD-ROM tracks are divided into audio (corresponding to CD-DA) and data types. Each track may contain exclusively data of one type.
- In such a mixed mode disc, the data tracks are usually located at the beginning of the CD-ROM, followed by the audio tracks.
- The CD-ROM data unit is called **block**. A CD-ROM block consists of 2352 **audio bytes** of a CD-DA block.
- Of the 2352 bytes of a block, 2048 bytes (computer data) or 2336 bytes (audio data) are available for user data. The remaining bytes are used for identification for random access and for another error correction layer that further reduces the error rate.
- 75 blocks per second is played back. Each block consists of 98 frames of 73.5 bytes (588 bits) each:

$$\text{Block} = 1.4112 \times 10^6 \times 1/75 \text{ s} \times 1/8 = 2352 \text{ bytes}$$

CD-ROM MODE 1

- It serves as the actual storage of **computer data**.
- The 2352 bytes in a block are split into following groups:
 - 12 bytes for synchronization
 - 4 bytes for the header
 - 2048** bytes for user data (or application data)
 - 4 bytes for error detection
 - 8 bytes unused
 - 276 bytes for error correction.

- Given a playing time of 74 minutes, a CD-ROM can store 330,000 blocks.
- Capacity of CD-ROM with all blocks in mode-1 can be computed as:

$$\begin{aligned}
 \text{Capacity}_{\text{CD-ROM mode 1}} &= 333,000 \text{ blocks} * 2048 \text{ bytes/block} \\
 &= 681984000 \text{ bytes} \\
 &= 681984000 / (1024*1024) \text{ Mbytes} \\
 &= 650.39 \text{ Mbytes}
 \end{aligned}$$

- Data rate of CD-ROM with all blocks in mode 1 can be calculated as:

$$\begin{aligned}
 \text{Data rate}_{\text{CD-ROM mode 1}} &= (2048 \text{ bytes/block}) * (75 \text{ blocks/s}) \\
 &= 153600 \text{ bytes/s} \\
 &= 153600/1024 \text{ kbyte/s} \\
 &= 150 \text{ kbyte/s}
 \end{aligned}$$

CD-ROM MODE 2

- It does not use error detection/error correction and hence more amount of user information can be stored.
- It is useful for those applications where data integrity is not crucial. Hence it is popularly used for **audio and video applications** employing lossy compression techniques.
- The 2352 bytes in a block are split into following groups:

12 bytes for synchronization
 4 bytes for the header
 2336 bytes for user data (or application data)

- Capacity of CD-ROM with all blocks in mode-2 can be computed as:

$$\begin{aligned}
 \text{Capacity}_{\text{CD-ROM mode 2}} &= 333,000 \text{ blocks} * 2336 \text{ bytes/block} \\
 &= 777888000 \text{ bytes}
 \end{aligned}$$

- Data rate of CD-ROM with all blocks in mode 2 can be calculated as:

$$\begin{aligned}
 \text{Data rate}_{\text{CD-ROM mode 2}} &= (2336 \text{ bytes/block}) * (75 \text{ blocks/s}) \\
 &= 175200 \text{ bytes/s} \\
 &= 175200/1024 \text{ kbyte/s} \\
 &= 171.09 \text{ kbyte/s}
 \end{aligned}$$

COMPACT DISK INTERACTIVE (CD-I)

- It was developed by N.V.Philips and the Sony Corporation, and announced in 1986.
- CD-I was originally designed for consumer electronics as an addition to the TV set.
- CD-I is a complete self-contained system, and it supports text, graphics, audio, image and video. CD-I is a complete delivery platform for multimedia applications.
- CD-I hardware is called the decoder. CD-I system has its own processor unit based on Motorola 68000 family together with special video and audio chips. It also includes a CD-player with a controller and a joystick or mouse interface, and there is a provision for a connection to a RGB monitor or a TV.
- It runs a real-time multi-tasking operating system called CD-RTOS.
- Audio in CD-I (A, B, C levels) generally uses ADPCM coding.
- Generally speaking, full-screen full-motion video may not be possible in CD-I. However, it may be made possible by attaching an 'FMV cartridge' containing MPEG decoder and additional memory.
- CD-I is a consumer product, aimed at repeating the success of CD-DA, so a CD-I disk will play on any CD-I player anywhere in the world.
- CD-I gives an output which can be displayed on a home TV set.
- All CD-I players can play CD-DA disks.
- This system did not become widespread and disappeared entirely from the market by the end of 1997.

VIDEO CD

- Video CDs contain up to 74 minutes of MPEG-1 video and associated audio.
- Playback is possible on dedicated video CD players, CD-I players (using an MPEG decoder extension for CD-I players), CD-ROM-XA players (using an MPEG decoder on the host) and adapted CD-DA players equipped with digital outputs (using an MPEG decoder that connects directly to the digital outputs).
- The format of the analog video signal produced by a video CD player is determined by the player, not the disc, so any video CD can be viewed on NTSC, PAL, and SECAM displays.