DAT330 – Principles of Digital Audio
Cogswell Polytechnical College
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Week 6 – Class Notes

Optical Disc Media: CD and DVD

Optical Disc Media

Design of Optical Media

Most optical storage systems store data across the surface of a flat disc. This allows random access of data, as well as ease of manufacturing replication. Because the data is written and read via optical means, there is no physical contact between the media and the pickup. This ensures long media and pickup life and minimizes damage through head crashes or other failures. In addition, a protective layer can be used to protect the data from damages or contamination. Also, multiple data layers can be places within one substrate. Nonetheless, stored data must undergo both modulation and error correction.

Data can be stored either along a spiral or concentric tracks. Most optical disc pickups shine a laser on the medium, and the reflected light is detected by a sensor and decoded to recover the carried data. The medium must have two states so that the change between them varies with the reflected light. Data can be represented as a phase change, polarization change, or change in the intensity of reflected light. The resulting variations picked up from the media can be converted into a varying electrical signal for data recovery.

Laser beams, having a short wavelength, allow for high information data density and a high SNR needed for a high bit rate. Optical media must be supported by a sophisticated servo system to provide positioning, tracking, focusing of the pickup, and accurate rotation.

Optical discs have a longer shelf life than that of magnetic media. They are less susceptible to damage from heat and are impervious to magnetic fields. Some 10-30% of the disc capacity is used for error-correction.

Nonerasable Optical Storage

In these systems, the media is considered read- or write-only. Once the data is recorded onto the media, it cannot be erased.

Read-only Optical Storage

For example: CD-Audio, CD-ROM, DVD-Video, DVD-Audio, DVD-ROM. The data is permanently formed on the medium during manufacture and is considered a playback-only format. This refractive medium, uses physical pits to store data, is widely used because it can be economically mass produced. CD's can store 680 Mbytes of formatted data, while DVD's can store up to 4.7 Gbytes on a data layer (multiple layers are possible). This medium can encode any type of data. Other formats have been developed to achieve greater data density.

Write-once Optical Recording

In this media, the user records data permanently until the disc capacity is filled. These types of disc are widely used for media distribution in the computer, audio, and video industries. Write-only discs can be implemented in a number of different ways:

1. Pit formation
2. Bubble formation
3. Dye polymer
4. Phase change
5. Texture change

Erasable Optical Storage

These optical disc systems are more versatile that write-only systems since they allow data to be written, read, erased, and rewritten again. Ideally, the number of erasures is unlimited.

Magneto-optical Recording

Combines magnetic recording with laser optics, using the benefits of magnetic media (record/erase) with those of optical media (high density). A laser beam is used and magnetic bias field is used to record and erase data, while a laser beam alone is used to read data.

The MiniDisc format is an example of this recording system.

Phase-change Optical Recording

Use a reversible change in the index of reflectivity of materials. The crystalline phase displays transparency and high reflectivity, while the amorphous phase is absorptive and has low reflectivity. These phase changes are used to record (crystalline → amorphous) and erase (amorphous → crystalline).

CD-RW, DVD-RW, and DVD-RAM are example formats for this type of system.

Dye-polymer Erasable Optical Recording

Light-absorbing dyes are placed on a bi-layer disc structure. These two layers are sensitive to different wavelengths. The physical deformation that these layers undergo result in bumps. Each layer has a dye sensitive to a different wavelength of light. When recording, one wavelength will create a bump, while another wavelength flattens it.

The Compact Disc

Overview

Each disc can store a stereo audio signal comprising of two 16-bit data words sampled at 44.1 kHz. A standard CD has a playing time of 74'33”, although by slightly changing the standard longer playing times can be achieved.

The impressed pits on one side of the discs substrate are used to contain information. The substrate is made out of polycarbonate plastic and the data surface is metalized to reflect the laser beam used to read the data from underneath the disc. Each pit edge represents a binary 1, while flat areas in between pits are coded as 0's. Pits are encoded in EFM for greater storage density, and CIRC for error correction.

The frequency response of a CD is 5 Hz to 20 kHz, with a deviation of ±0.2dB. Both the dynamic range and SNR exceed 100 dB. Wow and flutter are essentially unmeasurable. Satisfactory playing condition is indefinite and the medium does not significantly age.

Disc Design

The high density achieved by the CD results from a combination of the optical design of the disc and the method of coding data on it.

Disc Specifications

The Red Book format specifies both physical and logical characteristics of a CD. The basic specifications are:

1. Maximum playing time is 74 minutes (including pauses).
2. Minimum duration for a track is 2 seconds.
3. Maximum number of tracks is 99.
4. Maximum number of index points (subdivisions of a track) is 99 with no maximum time limit.
5. International Standard Recording Code (ISRC) should be included.

Data Encoding

Data is encoded as a 16-bit PCM signal. The data stream must undergo CIRC error correction, EFM, and should incorporate subcode and synchronization words.

Alternative CD Formats

CD-ROM: serves mainly as a mass storage format for computer application and for information distribution. Has the same physical format as a CD-Audio. The CD-ROM standard is called the Yellow Book standard.

CD-R: allows users to record their own audio/data to a CD. Recording is permanent, and can be read indefinitely, but cannot erase or overwrite new data. Can record multiple data types, including executables. The standard defining this format is called Orange Book (part II).

CD-RW: allows for data to be written, read, erased, and rewritten. Can record multiple data types. The standard defining this format is called Orange Book (part III).

CD-MO: defined by the Orange Book standard (part I). Data to be written, read, erased, and rewritten. Two types: those with a premastered area (recorded with pits) containing CD-ROM data plus a writable area, and a completely writable disc.

CD-i: devised as a product-specific application of the CD-ROM. Stores multiple data types, and defines specific data formats for these. Titles are design with real-time interactivity. Defined by the Green Book standard.

Photo CD: used to store, manipulate, and display photographic pictures. Photographs can be viewed, or reproduced as high-quality prints of images using color printers. Defined by the Beige Book.

CD+G: contains graphic data in addition to audio data. These graphics can be used to display lyrics on a television for karaoke.

CD+MIDI: used to store music-performance data which upon playback is performed by electronic instruments that synthesize the audio.

CD-3: refers to CD's that are 3 in in diameter.

Video CD (VCD): standard digital format for storing video media on a CD. Defined by the White Book standard. Full-motion video can be shown at 29.97 or 25 fps at 352 x 240 and 352 x 288 lines respectively (one-fourth the resolution of a normal DVD). Super Video CD (SVCD) is an enhanced version of VCD designed for higher-quality playback, and multi-channel audio.

Super Audio CD: introduced as a higher fidelity substitute for the CD. Supports higher sampling rates and a larger dynamic range (120 dB), as well as multi-channel audio. Defined by the Scarlet Book standard.

Copy Protection

Red Book audio specification, except for a simple 'anti-copy' bit in the subcode, does not include any serious copy protection mechanism. Starting in early 2002, attempts were made by record companies to market "copy-protected" non-standard compact discs, which cannot be ripped, or copied, to hard drives or easily converted to MP3s. One major drawback to these copy-protected discs is that most will not play on either computer CD-ROM drives, or some standalone CD players that use CD-ROM mechanisms. Numerous copy-protection systems have been countered by readily available, often free, software.

DVD

There are six DVD books: Book A (DVD-ROM, read only), Book B (DVD-Video), Book C (DVD-Audio), Book D (DVD-R, write once), Book E (DVD-RAM), Book F (DVD-RW, rewritable).

Although the physical dimensions of a DVD are similar to a CD, they differ in the DVD's larger storage capacity and its design as a universal storage medium.

Disc Design

Part 1 of the DVD specification defines the physical aspects of DVD discs, and applies to the first three format books. They share disc construction, modulation code, error correction, etc.

A DVD can store 4.7 Gbytes of data on a single layer and can increase this capacity with the addition of multiple data layers.

Disc Specification

DVD's use a double layered substrate bonded together with the data layers placed near the internal interface. Layers are embedded deeply within the disc and thus are more protected from damage. The dual substrate construction allows for the manufacture of different DVD variants with different capacities of playback-only discs: DVD-5, DVD-9, DVD-10, DVD-14, DVD-18 (the numbers express disc capacity in billions of bytes). Data is held in a spiral track.

Data Coding

Read-only DVD's have data stored in files within directories, this increases data density. Reed-Solomon product code (two RS codes) is used for error correction. EFMPlus modulation is used instead of EFM. This channel code provides an increased storage capacity, promotes timing recovery, and the suppression of low-frequency components.

UDF Bridge

Part 2 of the DVD specification specifies a file format called Universal Disc Format bridge (UDF). The UDF bridge defines data structures, as well as methods for reading, writing, and other operations. It standardizes many file and directory names to simplify operation. The UDF bridge allows for DVD's to be used in multiple computer operating systems.

The basic directory and file structure provided by UDF bridge allows for the definition of different “zones” to be organized under a common root directory. For example, the VIDEO_TS directory within the DVD-Video zone contains both menu and program data. In particular, a Video Manager defines file types and organization of both video and audio data (Video title set or VTS subdirectories).

DVD-Audio zones contain linear PCM audio data contained in an Audio title set (ATS) subdirectory, and an Audio Manager defines file types and organizes both audio and video data.

DVD Formats

DVD-Video: first DVD format launched and remains the standard for storing video data. They feature multi-channel digital audio, contain approximately 135 minutes of digital video, multiple aspect ratios, multiple language soundtracks, 32 subtitles, parental options, and copy protection. Many resolutions and formats are supported, most DVD-Video discs use either 4:3 or anamorphic 16:9 aspect ratio MPEG-2 video, stored at a resolution of 720×480 or 720×576 at 23.976, 29.97, or 25 fps.

Audio is commonly stored using the Dolby Digital (AC-3) or Digital Theater System (DTS) formats, ranging from 16-bits/48 kHz to 24-bits/96 kHz format with monaural to 7.1 channel presentation, and/or MPEG-1 Layer 2.

DVD-Audio: provides high fidelity audio with support for multiple channels, high sampling frequencies, and longer word lengths.

Many audio coding methods can be used to provide different recording parameters. The number of channels available ranges from 1-6, the word length from 16-24 bit, and the sampling frequency from 44.1-192 kHz. These options offer different ranges of playback times.

In addition, the SMART (System Managed Audio Resource Technique) feature provides automatic downmixing so that a multi-channel audio program can be mixed to stereo by the player during playback on a stereo playback system. “Value added” content, such as artist name, commentary, biography, etc., can be added.

DVD-ROM: used as an open ended and high density storage medium. Usually used for software applications.

DVD-R and DVD+R: offer write-once capability to permanently record data. The +/- refers to different specifications of the disc.

DVD-RW and DVD+RW: allow the rewriting of data. Considered an extension of DVD-R and is similar to CD-RW formats.

DVD-RAM: rewritable format. Used in computers as well as camcorders and personal video recorders.

DVD Content Protection

For DVD-Video, the Content Scramble System (CSS) copy protection system is used. Data encryption is self-protecting (software key is needed for decryption is missing in the copy) and is voluntary (discs can have or not copy protection).

DVD-Audio used a similar copy protection scheme as CSS called Content Protection for Pre-Recorded Media (CPPM). It is stronger than CSS and places a secret album identifier in a control area of the disc that cannot be read by recordable drives, thus is cannot be copied to blank media.

Recordable media is protected by the Content Protection for Recordable Media (CPRM). CPRM links content to the media it is recorded to, so that the recording is playable but copies of the recording are not. CPRM is similar to CPPM.

The Copy Generation Management System (CGMS) controls the copying of digital and analog video signals. Discs can specify whether any copying is permitted; which is conveyed in data in the output analog and digital signal and interpreted by recorders.

The High-bandwidth Digital Content Protection (HDCP) system defines a secure digital interface for players and displays. Both devices must exchange authentication keys so that the encrypted data at the transmitting device can be properly decrypted at the receiving device. If the devices are not HDCP compliant, the transmitted content will have a lower resolution.

The Digital Transmission Content Protection (DTCP) provides secure transmission over bi-directional digital lines.

Finally, watermarking can be used to intertwine data into DVD contents so that the watermark can later be retrieved to identify the contents on the disc. Watermarking does not prevent copying, rather it identifies the content. Thus, a watermark is only useful if downstream equipment can recognize it.