Disc Manufacturing, Inc.
A QUIXOTE COMPANY

Compact Disc Terminology

Second Edition

Disc Manufacturing, Inc.
1409 Foulk Road, Suite 102
Wilmington, DE 19803
1-800-433-DISC • (302) 479-2500

WHO IS DMI?

Disc Manufacturing, Inc. (DMI) manufactures all compact disc formats (i.e., CD-Audio, CD-ROM, CD-ROM XA, CDI, PHOTO CD, 3DO, KARAOKE, etc.) at two plant sites in the U.S.; Huntsville, AL, and Anaheim, CA. To help you, DMI has one of the largest Product Engineering/Technical Support staff and sales force dedicated solely to CD-ROM in the industry.

The company has had a long term commitment to optical disc technology and has performed developmental work and manufactured (laser) optical discs of various types since 1981. In 1983, DMI manufactured the first compact disc in the United States. DMI has developed extensive mastering expertise during this time and is frequently called upon by other companies to provide special mastering services for products in development.

In August 1991, DMI purchased the U.S. CD-ROM business from the Philips and Du Pont Optical Company (PDO). PDO employees in sales, marketing and technical services were retained.

DMI is a wholly-owned subsidiary of Quixote Corporation, a publicly owned corporation whose stock is traded on the NASDAQ exchange as QUIX. Quixote is a diversified technology company composed of Energy Absorption Systems, Inc. (manufactures highway crash cushions), Stenograph Corporation (manufactures shorthand machines and computer systems for court reporting) and Disc Manufacturing, Inc.

We would be pleased to help you with your CD project or answer any questions you may have. Please give us a call at 1-800-433-DISC for pricing or further information.

We have four additional technical papers available entitled

Integrating Mixed-Mode CD-ROM

An Overview to MultiMedia CD-ROM Production

Introduction to ISO 9660

A Glossary of CD and CD-ROM Terms

These are available upon request
800-433-DISC
302-479-2500
Fax: 302-479-2527

Authors:

J. Philip Busk
Clayton Summers
C. Steven Langer
James R. Fricks

Index

COMPACT DISC T E R M I N O L O G Y

OVERVIEW

The compact disc industry has been rapidly growing since its inception back in 1980. One of the major reasons for this phenomenal growth is the standards and formats on which the compact disc industry is based. These standards and format have paved the way for CD's to become a low cost and reliable vehicle for information exchange.

The technology and standards of compact discs are growing and changing extremely fast. The opportunities and potential for information delivery are limitless. As more people and organizations consider CD technology, adherence and knowledge of the CD standards and formats will become even more important and necessary.

The following paper revises and updates Disc Manufacturing, Inc.'s 1992 Compact Disc Terminology publication which discussed compact disc standards, formats, and technology. This paper is intended to be for the readers information only. Please consult the appropriate technical information that is available from the companies listed on Page 36 before beginning any CD development project.

The four major standards and their application areas which govern almost all types of compact disc technology are as follows:

Standard:	Application:
Red Book	Audio
Yellow Book	CD-ROM
Green Book	CD-I
Orange Book	Recordable CD's

The above standards lay the foundation from which all other standards and technologies are derived. Some of the other standards and technologies discussed in this paper are as follows:

Mixed Mode Disc	KARAOKE CD
CD-ROM/XA	DVI
CD-I Ready Disc	CDTV
CD-Bridge Disc	Photo CD
CD+G	Video CD (Full-Motion Video/White Book)

A diagram of CD standards and formats can be found in Figure 1.0 on Page 7 . A diagram of CD sector layouts can be found of Page 8.

The ISO 9660 logical file format has gained acceptance as the standard file format of CD-ROM development and delivery. A general overview of this format (including extensions) is discussed on Page 30.

We hope that the reader finds the information in this paper to be beneficial. If we can provide you with any additional information, please let us know.

Disc Manufacturing, Inc. hopes to have the opportunity to work with you on your CD projects.

Please feel free to contact us at 1-800-433-DISC or 1-302-479-2500.

Figure 1.0
<u>Diagram of CD Standards and Formats</u>

Mixed Mode Disc

Example:
Audio &
Data Tracks
on
Same Disc

Red Book Includes CD+G

CD-DA (Red Book) Defines Digital Audio Format

CD-I Ready Disc

$+$

CD-ROM (Yellow Book) Defines Computer Data Format

Mode 1 (2048 Bytes) Additional EDC/ECC

Mode 2 (2336 Bytes)* No Additional EDC/ECC

ISO 9660 or High Sierra Standards

Hybrid Disc
Example:
ISO 9660 DOS
& HFS Images
On Same Disc

Non ISO 9660 or Non High Sierra Proprietary
Example:
Apple HFS

CD-ROM/XA

Bridge Disc
Examples:
Photo CD
KARAOKE CD/
Video CD
"White Book"

CD-I (Green Book)

Level 1 Inter-change

Level 2 Inter-change

Examples:
DOS
UNIX
DVI

Examples:
CDTV
Apple
UNIX

Form 1 2048 Bytes
Additional
EDC/ECC

Form 2 2324 Bytes
No Additional
EDC/ECC

Form 1 2048 Bytes
Additional
EDC/ECC

Form 2 2324 Bytes
No Additional
EDC/ECC

Orange Book Defines CD-MO & CD-WO

The Orange Book is a standard that governs the
creation of Compact Disc-Magneto Optical
(CD-MO) and Compact Disc-Write Once
(CD-WO) discs. Audio and/or data in any
of the above formats can be recorded to
a disc. Please see page 29, Figure 3.0, for
a diagram of the Orange Book standard.

Each track on a compact disc can be one and only one of the following: CD-Audio, CD-ROM Mode 1,
CD-ROM Mode 2, CD-ROM/XA, or CD-I. The whole track must be the same type. When you combine
different types of tracks on the same disc, the disc is called mixed mode disc. For example: Track 1
could be CD-ROM Mode 1 data and tracks 2 and up could be audio data. This is the most common
type of Mixed Mode Disc.

* Please note that the information located below the Mode 1 block (ISO 9660 & Non ISO 9660) can also apply to a Mode 2 disc.

<div align="center">

Figure 2.0

<u>Diagram of Sector Layouts</u>

</div>

<u>Red Book:</u>

<u>Data Layout in a CD-Audio Sector (1/75 second)</u>

User Data 2352
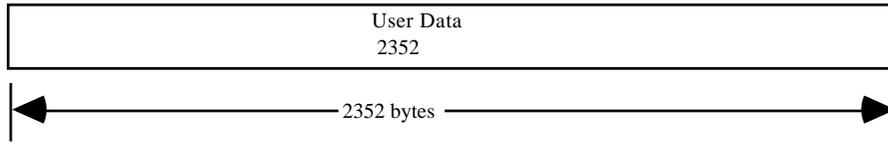
◄———————— 2352 bytes ————————►

<u>Yellow Book:</u>

<u>2352 Byte Layout for CD-ROM Mode 1</u>

Sync 12	Header 4	User Data 2048	EDC 4	blanks 8	ECC 276

◄———————— 2352 bytes ————————►

<u>2352 Byte Layout for CD-ROM Mode 2</u>

Sync 12	Header 4	User Data 2336
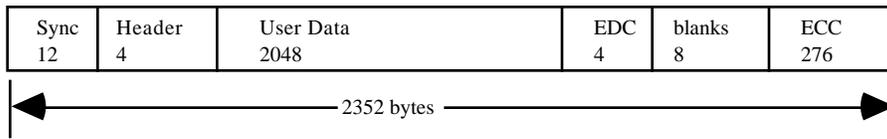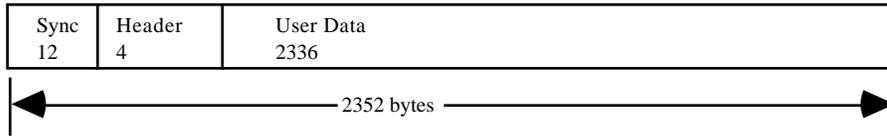
◄———————— 2352 bytes ————————►

<u>CD-ROM / XA and Green Book:</u>

<u>2352 Byte Layout for CD-ROM Mode 2 / XA Form 1</u>

Sync 12	Header 4	Sub-Header 8	User Data 2048	EDC 4	ECC 276

◄———————— 2352 bytes ————————►

<u>2352 Byte Layout for CD-ROM Mode 2 / XA Form 2</u>

Sync 12	Header 4	Sub-Header 8	User Data 2324	EDC 4
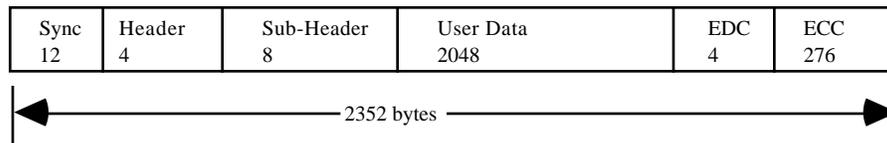
◄———————— 2352 bytes ————————►
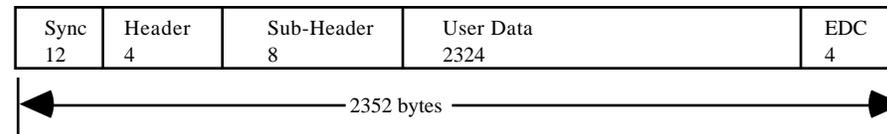
Red Book - CD Audio Standard

The compact disc industry started in 1980 when Philips and Sony introduced the Compact Disc Digital Audio Standard. This is commonly called the Red Book. The Red Book describes the Audio Compact Disc (CD) that you find in music stores today. It is the foundation on which all other CD standards are built. Because audio discs are manufactured per the Red Book Standard, all audio compact discs will play in any audio compact disc player. This interchangeability has been a major factor in the growth of the CD music industry.

The track type defined in the Red Book is: CD-Digital-Audio (CD-DA), for audio music. The Red Book specifies that the audio data is on the CD in one or more tracks. Each track is normally one song. These tracks are further subdivided into sectors that are 1/75th of a second in length and contain 2352 bytes of audio data in digital form. A maximum of 99 audio tracks may be placed on a standard Red Book disc.

In addition to the 2352 bytes of audio data, the Red Book specifies the addition of 2 layers of error detection and error correction code (EDC/ECC). The compact disc utilizes the Cross Interleave Reed-Solomon Code (CIRC) in its first two layers of error protection. If a disc gets scratched or dirty and a laser can not read the data, the CD player uses the CIRC to recreate the music.

The Red Book not only defines how to put audio on a CD, it also defines a way to add graphics information to the CD. This type of disc is commonly referred to as a CD+G disc, or "CD plus graphics" disc. Approximately 16MB worth of graphics (user data) can be stored in the subcode (channels R through W) of a 74 minute Red Book disc. More information on a CD+G disc can be found in Appendix A on Page 37.

Data Layout in a CD-Audio Sector (1/75 second)

User Data 2352

◀──────────── 2352 bytes ────────────▶
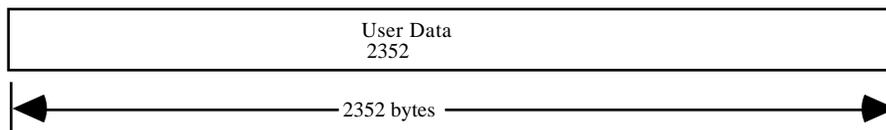
Yellow Book - CD-ROM Standard

In 1984 Philips and Sony introduced the CD-ROM (Compact Disc Read Only Memory) Standard. This standard is commonly known as the Yellow Book (Refer to Diagram of Standards, Figure 1.0, Page 7). The Yellow Book further defines the Red Book by adding two new types of tracks.

The track type defined in the Red Book is:

   * CD-Audio,   for audio music.

The two new track types defined in the Yellow Book are:

   * CD-ROM Mode 1,   usually used for computer data.
   * CD-ROM Mode 2,   usually used for compressed audio data, and video/picture
                             data. Also, usually further defined as XA.

The CD-ROM Mode 1 and Mode 2 tracks use the Red Book specifications as a foundation. This includes the Red Book 1st and 2nd layer CIRC error correction and control bytes (see Appendix A). The difference between the Red Book and the Yellow Book is a redefinition of the 2352 byte Red Book data area.

Yellow Book - CD-ROM Mode 1

CD-ROM Mode 1 redefines the Red Book 2352 byte data area as:

12 bytes of synchronization
4 bytes of header information
2048 bytes of user data
288 bytes of error correction and detection codes
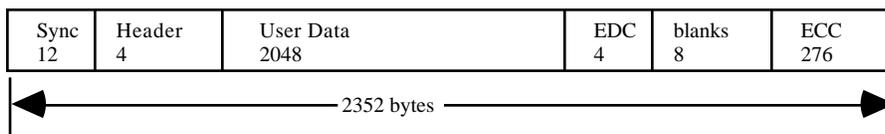
2352 Byte Layout for CD-ROM Mode 1

Sync 12	Header 4	User Data 2048	EDC 4	blanks 8	ECC 276

◄──────────────── 2352 bytes ────────────────►

The first 16 bytes contain the Synchronization and Header Information. The computer uses this information to identify which sector it is reading.

The next 2048 bytes contain the **Users Data**.

The last 288 bytes contain an additional layer (3rd layer) of error detection and error correction code, that is included in a Mode 1 sector to provide the increased reliability needed for computer data.

Yellow Book - CD-ROM Mode 2

CD-ROM Mode 2 redefines the 2352 byte area as:

12 bytes of synchronization

4 bytes of header information
2336 bytes of user data

2352 Byte Layout for CD-ROM Mode 2
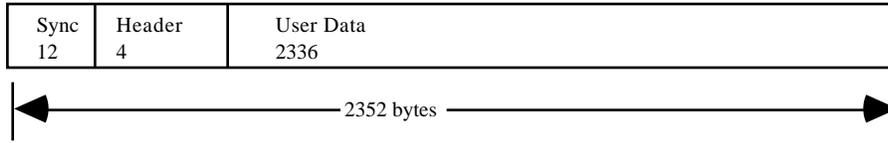
Sync 12	Header 4	User Data 2336

←——————————— 2352 bytes ———————————→

The first 16 bytes contain the Synchronization and Header Information. The computer uses this information to determine which sector it is reading.

The next 2336 bytes contain the **Users Data**.   Mode 2 does not have the additional EDC/ECC that Mode 1 has. Mode 2 allows the user to have 14% more data than Mode 1, but with less error correction capability.

CD-ROM Mode 2 as shown, which is not in XA format, is an extremely rare form. Normally, Mode 2 discs are always in the XA format. (See section on XA, Page 14.) Although Mode 2 non XA discs can be read by a normal CD-ROM drive, they require special custom software to decode and interface.

Even though CD-ROM Mode 2 does not have the additional layer (3rd layer) of error detection and correction like Mode 1, it does have the 2 layers (CIRC) of error detection and correction defined in the Red Book.

Mixed Mode Disc

When a CD has data (CD-ROM) and audio (CD-DA) tracks, it is referred to as a Mixed Mode disc.

The most common type of Mixed Mode disc is one where the 1st track on the disc is Mode 1 data, and the remaining tracks on the disc are audio tracks. Refer to Diagram of Standards, Figure 1.0, Page 7. The maximum number of tracks (data and audio) on a mixed mode disc is 99.

CAUTION: The above type of Mixed Mode disc can be played in a audio CD player. If you play the CD-ROM track (or track 1), it will sound like **FULL VOLUME STATIC** on some CD players and may damage your speakers as well as your ear drums. (Most newer audio players will mute the CD-ROM track.)

When planning to make a Mixed Mode Disc, remember the CD-ROM Player can only read one track at a time.

The two most common methods used in playing Mixed Mode applications are:

a)   To copy the program and data onto the computer and run the program from the computer memory while playing audio tracks on the CD-ROM drive. This allows the program to have continuous access to the audio. The limitation is that you must have enough memory in the computer to load the program and data before starting the application.

b)   To alternately read in a portion of the program and data. While running the portion of the program that was read in, the CD-ROM drive can play audio as needed. The limitation occurs when you need to read the next program segment. At this time, the audio must be stopped, in order to enable the CD-ROM drive to read the next portion of data.

Sample Track Layout for a Mixed Mode Disc:

Track 1	Mode 1	Data
Track 2	Audio	Audio track
Track 3	Audio	Audio track
Track 4	Audio	Audio track

Mixed Mode Disc Technical Note:

Disc times are given as minutes, seconds, and frames: example 05:27:03 means 5 minutes, 27 seconds, and 3 frames.

Note: 1 frame = 1 sector
        1 second = 75 sectors.

There are three common methods used to access the audio on a mixed mode disc: Track Relative Time, Absolute Time (ATime), or Track. Track Relative Time is measured from the start of the track, while ATime is measured from the start of the disc. The Track method involves sending a command to play a track. For example: play track 3. The CD player would then start playing track 3 from the beginning of the track.

Many mixed-mode CD-ROM's rely on track relative time addressing so if the size of the data track changes, it does not effect the audio access times. Audio accessed by ATime will require recalculating and reprogramming the audio access points when the size of the data track changes.

For example, if a program wants to play the audio section shown in Part A of the diagram below, it would play the following times:

using Track Relative Times: Start at 05:27:00 and End at 10:13:07
using ATimes: Start at 19:27:05 and End at 24:13:12

If the size of the data track increases by 4 minutes as shown in Part B of the diagram below, and the program wants to play the same audio section in track #3, then it would play the following times:

using Track Relative Times: Start at 05:27:00 and End at 10:13:07
using Absolute Times: Start at 23:27:05 and End at 28:13:12

Notice that the program using Track Relative Times for accessing the audio does not have to be changed when the size of the data track changes. However, a program that uses ATime for accessing the audio has to be recalculated and reprogrammed when the size of the data track changes.

A thorough discussion of Mixed Mode discs can be found in the Disc Manufacturing, Inc. paper <u>Integrating Mixed-Mode CD-ROM</u> by J. Philip Busk.

Track Layout for Mixed Mode Disc
Before Data Size Increases:
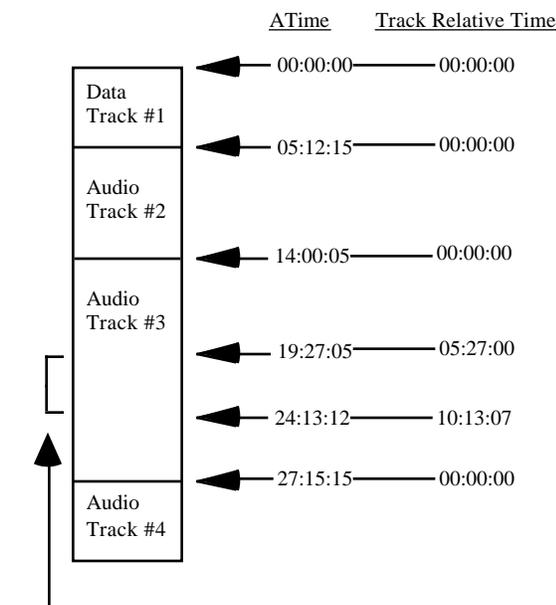
Track Layout for Mixed Mode Disc
After Data Size Increases:

	ATime	Track Relative Time
	00:00:00	00:00:00
Data Track #1		
	05:12:15	00:00:00
Audio Track #2		
	14:00:05	00:00:00
Audio Track #3		
	19:27:05	05:27:00
	24:13:12	10:13:07
	27:15:15	00:00:00
Audio Track #4		

Section of track #3 we want to play.

Part A

	ATime	Track Relative Time
	00:00:00	00:00:00
Data Track #1		
	09:12:15	00:00:00
Audio Track #2		
	18:00:05	00:00:00
Audio Track #3		
	23:27:05	05:27:00
	28:13:12	10:13:07
	31:15:15	00:00:00
Audio Track #4		
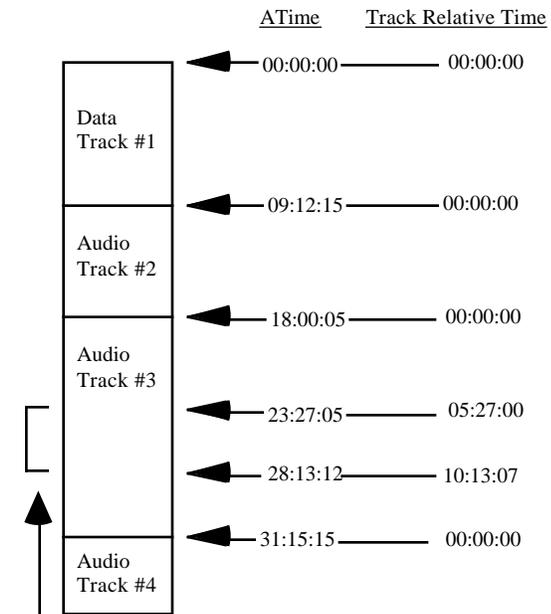
Section of track #3 we want to play.

Part B

Please note that track pregap, postgap, and pause are not shown in the above diagram to simplify the illustration. Information on track pregap, postgap, and pause can be found in Appendix F on Page 45.

CD-ROM/XA (Extension to CD-ROM Standard)

In 1989, the CD-ROM/XA standard was issued by Philips, Microsoft, and Sony (Refer to Diagram of Standards, Figure 1.0, Page 7). This standard is an <u>extension</u> to the Yellow Book and defines a new type of track.

XA allows computer data and Adaptive Pulse Code Modulation (ADPCM) audio data to be put on the same track. Computer data can be put on the track as Form 1 and ADPCM audio and/or video/picture data can be put on the track as Form 2 data. Because both Form 1 and Form 2 are "CD-ROM Mode 2, XA Format", they can both be on the same track. With the proper <u>interleaving</u> of Form 1 and Form 2, a track can play back audio, video, and computer data <u>at what appears to be the same time.</u>

Compare this to the Mixed Mode disc defined on Page 12. A mixed mode disc has computer data on one track and Red Book audio data on another track. A CD-ROM drive reading a Mixed Mode disc <u>CAN NOT read computer data while it is playing audio.</u> The XA disc has compressed ADPCM audio and computer data interleaved on the same track, so it can read the computer data and play the ADPCM audio at what appears to be the same time. This is the advantage of the XA standard.

In CD-ROM/XA Mode 2, Form 2, the audio must be in a compressed format to allow space for the Sync, Header, and Subheader in the sector and for the interleaved computer data on the track. Adaptive Pulse Code Modulation (ADPCM) is a compression scheme used by the CD-ROM/XA (and CD-I) format. In the simplest terms, the audio file structure is interleaved with the data. This compressed audio is not as high quality as the full stereo quality on a normal audio track as defined by the Red Book. The Red Book defines 16 bit samples at a 44.1 KHz sampling rate. ADPCM defines several audio compression levels, ranging from a voice quality level C defined as 4 bit samples at a 18.9 KHz sampling rate; up to a music quality level B defined as 4 bit samples at a 37.8 KHz sampling rate. (See section on Audio Compression Levels for CD-ROM/XA, located on Page 17.)

More information on sampling rates can be found in the Disc Manufacturing, Inc. paper <u>Integrating Mixed-Mode CD-ROM</u> by J. Philip Busk.

The track type defined in the Red Book is:

  * CD-Digital Audio, for audio music. (<u>not compressed</u>)

The track types defined in the Yellow Book are:

  * CD-ROM Mode 1, usually used for computer data.
  * CD-ROM Mode 2, usually used for compressed audio data, and video/picture data. Also, usually further defined as XA.

The new track type defined by CD-ROM / XA is:

  * CD-ROM Mode 2, XA Format, usually used for computer data, <u>compressed audio</u> data, and/or video/picture data.

A CD-ROM / XA track interleaves Mode 2 compressed ADPCM audio and Mode 2 data sectors. Additional hardware is needed to separate these when playing the disc. The hardware is programmed to separate the audio from the data (The Coding Information contained in the Sub-Header tells the computer which sectors are audio and which sectors are data.), decompress the

audio and play it out through the audio jacks. At the same time, the hardware passes the data to the computer. The above two processes appear to be happening simultaneously to the user.

Audio Sector Interleaving:

The table below illustrates the necessary interleaving patterns using B level and C level ADPCM encoding. The ratio of data sectors that may be interleaved between each ADPCM audio sector is also shown. The interleaved data sectors may contain data, video, or empty sectors.

Level	Sectors															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B Stereo Ratio 1:3	A	d	d	d	A	d	d	d	A	d	d	d	A	d	d	d
B Mono Ratio 1:7	A	d	d	d	d	d	d	d	A	d	d	d	d	d	d	d
C Stereo Ratio 1:7	A	d	d	d	d	d	d	d	A	d	d	d	d	d	d	d
C Mono Ratio 1:15	A	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d

A= ADPCM audio sectors, tagged with the same File & Channel Number in the Sub-header field.

d= Data sectors (data, video, or ADPCM audio with other File Numbers and Channel Numbers assignments).

Notice in the above table that as the quality of the ADPCM audio increases the amount of data interleaved between decreases.

Current CD-ROM players need additional hardware to play XA discs.   Several drive manufacturers are offering XA interface cards as well as drives that have integrated XA support. The XA interface card plugs into your computer and connects to the CD-ROM drive with a cable. The card decompresses the audio data and outputs it to the speaker system while it passes the computer data to the computer for processing.

CD-ROM / XA defines 8 bytes of the 2352 byte area as a "Sub-Header". The Sub-Header contains the following information:

File Number:	The File Number identifies all the sectors that belong to the same file.
Channel Number:	The Channel Number helps in the real-time selection of the different pieces of information that need to be chosen from an interleaved file.
Submode:	The global attributes of a sector as required for the initial selection and allocation of a sector in the system is defined by the Submode.

Coding Information: The details of the type of data located in the user area of the sector is defined by the Coding Information.

The coding information in the sub-header defines two types of CD-ROM / XA sectors:

  * CD-ROM Mode 2, XA Format, Form 1 --   usually used for computer data.
  * CD-ROM Mode 2, XA Format, Form 2 --   usually used for compressed audio data and/or video/picture data.

CD-ROM /XA Mode 2, Form 1 redefines the 2352 byte area as:

      12 bytes of synchronization
      4 bytes of header information
      8 bytes of sub-header information
      2048 bytes of user data
      280 bytes of error correction and detection codes
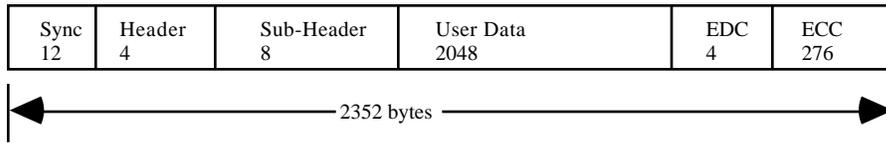
2352 Byte Layout for CD-ROM Mode 2 / XA Form 1

Sync 12	Header 4	Sub-Header 8	User Data 2048	EDC 4	ECC 276

◄————————————————— 2352 bytes —————————————————►

The first 16 bytes contain the Synchronization and Header Information. The computer uses this information to determine which sector it is reading.

The next 8 bytes contain the Sub-Header (defined above).

The next 2048 bytes contain the **Users Data**.

The last 280 bytes contain the additional layer (3rd layer) of error detection and correction which provides the increased accuracy needed for computer data.

CD-ROM /XA Mode 2, Form 2 redefines the 2352 byte area as:

      12 bytes of synchronization
      4 bytes of header information
      8 bytes of sub-header information
      2324 bytes of user data
      4 bytes of Optional EDC

2352 Byte Layout for CD-ROM Mode 2 / XA Form 2
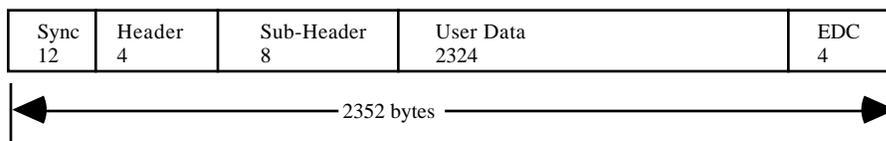
Sync 12	Header 4	Sub-Header 8	User Data 2324	EDC 4

◄————————————————— 2352 bytes —————————————————►

The first 16 bytes contain the Synchronization and Header Information. The computer uses this information to determine which sector it is reading.

The next 8 bytes contain the Sub-Header (defined above).

The next 2324 bytes contain the **Users Data**.   Form 2 does not have the additional EDC/ECC that Form 1 has. Form 2 allows the user to have 13% more data than Form 1, but with less error correction capability.

Developers need additional software and/or hardware to compress the audio and video data to this format. They also need pre-mastering software to interleave the files.

As mentioned before unless the CD-ROM drive is a purely XA drive an additional board will need to be added to play CD-ROM/XA discs. This board facilitates the separation and decoding of ADPCM audio from the data.

Audio Compression Levels for CD-ROM / XA:

(Based on a disc capacity of 75 minutes.)

In the following table, CD-DA is included as a comparison. CD-DA (Red Book Audio) can NOT be put on a CD-ROM / XA track. However, it is possible to put CD-ROM/XA and CD-DA tracks on the same disc. This disc would be a type of "mixed mode" disc. Also note that the CD-I audio level A is not defined in the CD-ROM/XA specification.

	Maximum Playing Time	Sampling size and rate		Bytes Needed to Store 1 Minute of Stereo Audio (MB)
CD-DA	1.25 hours (stereo)	16 bit samples	44,100 samples per second	10.09
Level B	5 hours (stereo) 10 hours (mono)	4 bit samples	37,800 samples per second	2.16
Level C	10 hours (stereo) 20 hours (mono)	4 bit samples	18,900 samples per second	1.08

The above playing times are "Maximum" playing times which assume you only have the compressed audio on the disc. If you add any form of data (data and/or video data) the amount of compressed audio must be reduced to make room for this data.

Example: (Based on a disc capacity of 75 minutes)

If you have 10 hours of Level B compressed mono sound on the disc, there will be no room for data. If you have 5 hours of Level B compressed mono sound on the disc, there will be room for 330 MBytes of data in CD-ROM / XA form 1 sector format. The following table provides additional times and capacities:

| Amount of Level B Mono on Disc	Amount of room for Form 1 data on Disc
10 hours	0 MBytes
7.5 hours	165 MBytes
5 hours	330 MBytes
2.5 hours	495 MBytes
0 hours	660 MBytes

Green Book (CD-I Standard)

The Compact Disc Interactive (CD-I) Media standard was released in 1987 by Philips. This standard specifies the CD-I disc layout and an operating system called CD-RTOS. This specification is known as the Green Book Standard (Refer to Diagram of Standards, Figure 1.0, Page 7). Like CD-ROM/XA (see Page 14), this standard allows for the interleaving of computer data and compressed audio on the same track. The CD-I track is not shown in the table of contents on the disc. This prevents audio players from playing the CD-I track. A CD-I system consists of a stand alone CD-I player connected to a TV set.

The sector layouts for CD-I are identical to CD-ROM / XA. Please refer to the CD-ROM/XA section (Page 14) for a more detailed discussion of the sector layouts.

Sector Layout for CD-I and CD-ROM / XA:

2352 Byte Layout for CD-ROM Mode 2 / XA Form 1

Sync 12	Header 4	Sub-Header 8	User Data 2048	EDC 4	ECC 276

←———————————————— 2352 bytes ————————————————→

2352 Byte Layout for CD-ROM Mode 2 / XA Form 2

Sync 12	Header 4	Sub-Header 8	User Data 2324	EDC 4
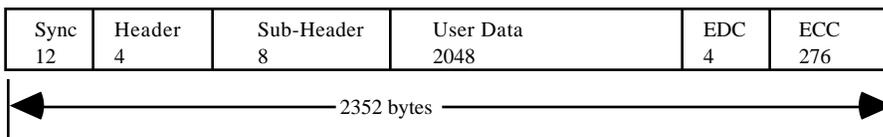
←———————————————— 2352 bytes ————————————————→
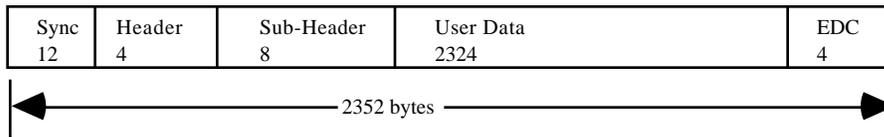
Audio Compression Levels for CD-I:

(Based on a disc capacity of 75 minutes.)

Adaptive Pulse Code Modulation (ADPCM) is a compression scheme used by the CD-I (and CD-ROM/XA) format. In the simplest terms, the audio file structure is interleaved with the data. This compressed audio is not as high quality as the full stereo quality on a normal audio track as defined by the Red Book. Levels A, B, and C, ADPCM are defined for CD-I audio.

In the following table, CD-DA is included as a comparison. CD-DA (Red Book Audio) can NOT be put on a CD-I track. However, it is possible to put CD-I and CD-DA tracks on the same disc. This disc would be a type of "mixed mode" disc.   CD-I players are capable of playing CD-DA tracks as well as Photo CD's (See Page 23).

	Maximum Playing Time	Sampling size and rate		Bytes Needed to Store 1 Minute of Stereo Audio (MB)
CD-DA	1.25 hours (stereo)	16 bit samples	44,100 samples per second	10.09
Level A	2.50 hours (stereo) 5 hours (mono)	8 bit samples	37,800 samples per second	4.33
Level B	5 hours (stereo) 10 hours (mono)	4 bit samples	37,800 samples per second	2.16
Level C	10 hours (stereo) 20 hours (mono)	4 bit samples	18,900 samples per second	1.08

The above playing times are "Maximum" playing times which assume you only have the compressed audio on the disc. If you add any form of data (data and/or video data) the amount of compressed audio must be reduced to make room for this data.

CD-I MPEG 1 Full-Motion Video (FMV)/Video CD:

It is possible to display Full-Motion Video on a television screen using a CD-I player that has an optional or integrated Full-Motion Video adapter installed. A Full-Motion Video adapter must be installed on the CD-I player to decompress MPEG data. Full-Motion Video on a CD is also referred to as Video CD. Full-Motion Video or Video CD is based on the White Book standard. More information on this standard can be found in Appendix H on Page 47.

The CD-I format adopted the MPEG 1 (Moving Picture Experts Group 1) standard (ISO 11172) for representation of video and audio data. MPEG technology can compress the data of images or audio down to 1/50 of the original size or smaller. MPEG reduces data by taking out information that is not needed, or doesn't change between frames.   MPEG specific hardware and software is required for compression as well as decompression of data during playback. MPEG 1 is designed for the coding of moving pictures and associated audio on digital storage media (compact disc & drive) that can supply data at rates up to about 1.5 Mbits/sec. As compression technologies improve along with disc storage capacities the length of Full-Motion Video that can be stored on a disc will also increase.

MPEG 2 is a compatible extension of MPEG 1. MPEG 2 supports higher transmission rates along with higher resolution applications. MPEG 2 is designed for the coding of moving pictures and associated audio on digital storage media that can supply data at rates between 4 to 10 Mbits/sec.

There are three different types of full-motion data defined:

MPEG Video data
MPEG SP (Still Picture) data
MPEG Audio data

All CD-I sectors with full-motion data are Form 2 sectors.

Several different audio and video quality levels can be supported depending on the application. The CD-I FMV format can support video source materiel with frame rates up to 30 frames/sec.

As compression technology and disc storage capacities improve FMV will become more readily applicable and practical for home, educational, and office use.

CD-I Ready Format

CD-I Ready disc is a standard audio disc with additional features.   These additional features can be accessed when the disc is played in a CD-I player.

The Red Book defines the ability to put index points in a track. This allows the user to skip to specific points in an audio track if the audio player is equipped with this capability. There are only two index points that are normally utilized, index point #0 and index point #1. Index point #0 is used to mark the beginning of a track. Index point #1 is used to mark the beginning of the audio in the track. The silence between index point #0 and index point #1 is called the track pause. (Refer to Appendix C, Page 42)

Standard audio discs have at least a 2 second pause of audio silence in front of the first track (song) on the disc. Audio players skip over this section and never play the track #1 pause. A CD-I Ready disc increases the track #1 pause to at least 182 seconds and hides the CD-I information in this area. Because audio players skip the track #1 pause, audio players will ignore the hidden CD-I information and will play only the audio part of the disc.

CD-I Ready discs play in a standard audio player as well as a CD-I player. The CD-I player reads the pause where the CD-I data is stored and displays this information to the user. CD-I Ready can be used to feature lyrics or credits of a song, and/or interviews with the performer, a discography showing the various titles and information about each title, or biographies about the performers and/or authors.

The CD-I Ready disc features three different methods of play:

The first is standard audio playback.

The second is displaying information as the audio is playing. This method is run in the same manner as a mixed mode disc. The CD-I information (pictures and text) is loaded into the CD-I players RAM memory before the audio starts playing. The CD-I player then plays the audio track and gets all the extra features for that track from the RAM memory.

The third method is playing the disc in the same manner as a standard CD-I disc. This method allows the compressed audio and data to be read from the hidden pause at <u>what appears to be</u> the same time.

<u>CD-I Ready Technical Details:</u>

See CD-I Ready Disc Layout in Appendix C (Page 42).

CD-Bridge Disc

The CD-Bridge Disc specification defines a way to put additional information in a CD-ROM / XA track in order to allow the track to be played on a CD-I player. The result is a disc that can be played on both a CD-I player connected to a TV set and on a CD-ROM / XA player connected to a computer. Bridge Discs may also be played on other XA compatible devices (KARAOKE player, Photo CD player, 3DO, etc.) if the data contains the necessary application software.

An example of the above is the Photo-CD disc (Bridge Disc) described on Page 23. The Photo-CD disc is playable on CD-I players, computers using a CD-ROM / XA drive or driver, and on Kodak Photo CD Players.

It should be noted that being able to play a Bridge Disc on an application specific device does not necessarily mean that you can play all types of Bridge Discs on this device. For example a Photo CD player can play Photo CD's which are Bridge Discs. However, a Photo CD player can not play KARAOKE CD's which are also Bridge Discs. Both of these types of discs are Bridge Discs by definition. They just can't be played on each others application specific device.

A CD-Bridge Disc must conform to all the requirements of both the CD-I and CD-ROM / XA specifications.

Technical Information about the CD-Bridge Disc:

The CD-I and CD-ROM / XA standards define volume descriptors that point to where the directory structure starts. The volume descriptors for CD-I and CD-ROM / XA are different and both need to be included on a CD-Bridge disc. The CD-I standard (Green Book) specifies a volume descriptor located at ATime 00 minutes, 02 seconds, 16 frames, and 0 byte offset. The CD-ROM / XA standard specifies a volume descriptor located at ATime 00 minutes, 02 seconds, 16 frames and a 1024 byte offset. Because of the offset, both volume descriptors can be written in the sector (at 00 minutes, 02 seconds, 16 frames) and not interfere with each other.

On a CD-I disc (not a Bridge disc) the CD-I track is NOT included in the disc Table of Contents (TOC). This was done to protect some audio players from playing the CD-I data as audio and possibly damaging the speakers. The Bridge Disc track is included in the TOC and is listed as a CD-ROM / XA track. This was done so that XA drives as well as CD-I players can access the data.

The sector layouts for the CD-Bridge disc are identical to CD-ROM / XA and CD/I.

Sector Layout for CD-I, CD-ROM / XA, and CD-Bridge Discs:

2352 Byte Layout for CD-ROM Mode 2 / XA Form 1

Sync 12	Header 4	Sub-Header 8	User Data 2048	EDC 4	ECC 276

◄──────────────── 2352 bytes ────────────────►

2352 Byte Layout for CD-ROM Mode 2 / XA Form 2

Sync 12	Header 4	Sub-Header 8	User Data 2324	EDC 4
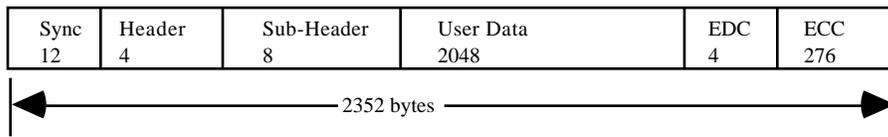
◄──────────────── 2352 bytes ────────────────►
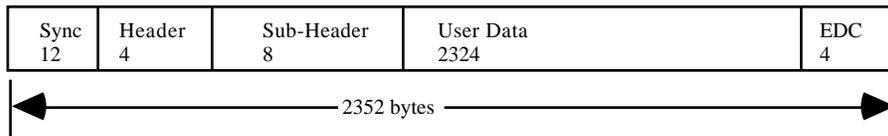
Photo CD

Eastman Kodak Company and N.V. Philips have developed a Photo CD System technology. The following is some of the information about this technology.

The Photo CD System will scan photographs into electronic form and store these pictures on CD's. The CD's can then be viewed with any of the following: (1) Photo CD Players, (2) CD-I Players, (3) CD-ROM/XA Players, and (4) 3DO Players.

Photo CD's data structure is Mode 2 Form 1 sectors per the CD-ROM / XA specifications. The disc is written in accordance to the Orange Book (see Page 26) Part II "Hybrid Disc" specifications. Therefore, photographs can be added to a Photo CD disc in several different sessions. Photo CD's can also be mastered and replicated like ordinary CD's if desired. Photo-CD discs use the CD-Bridge disc format to allow the disc to be readable by both CD-I and CD-ROM / XA players.

Photographs are readable with existing CD-ROM/XA drives connected to a computer running software written for the Photo CD picture structure. The photographs are also readable on CD-I Players and Photo CD Players connected to a TV set.

Photographs written to the disc during the first session are readable on any Photo CD compatible player. Photographs written to the disc in later sessions are only readable by multi-session capable players or devices that support the Orange Book Part II Hybrid specifications. Software and/or firmware is needed to read these additional photographs with existing CD-ROM/XA drives.

There are five Photo-CD formats:

Master: The Photo CD Master disc can hold around 100 high resolution images. Color prints can be made from these images by taking the disc to a photofinisher. This Photo CD format should not be confused with the glass or metal masters created during CD manufacturing.

Portfolio: The Portfolio disc can hold up to 800 images at video resolution, or they can hold up to one hour of stereo sound. Images and sounds can be combined on the same disc.

Catalog: The catalog disc can contain up to 6000 images and can provide programmed branching from screen menus.

Pro: The Pro format accommodates 35mm, 120, 4x5-inch, and 8x10-inch images, and is used by professional photographers.

Medical: The Medical format allows X-rays and digital data from CT or MR scanners to be stored on Photo-CD.

All information about a single (Master format) Photo CD image is stored on the disc in an Image Pac file. The Image Pac is a collection of five interdependent digital files containing both compressed and uncompressed picture data. The five Image Pac formats and their dimensions in pixels for the Master format Photo CD are as follows:

Image Pac Formats and Their Dimensions in Pixels for the Master Format Photo CD

Name	Height	Width	General Description	Approximate File Size (Truecolor, Uncompressed)	
Base/16	128	192	Thumbnail	48KB	78KB
Base/4	256	384	Low Res. TV	171KB	294KB
Base	512	768	High Res. or Zoomed TV Image or VGA Monitor	732KB	1,158KB
Base*4	1,024	768	HD-TV	3,078KB	4,614KB
Base*16	2,048	3,072	High Res. HD-TV or 35mm Quality	13,533KB	18,438KB

For more information about Photo-CD, please call Eastman Kodak at 1-800-242-2424 extension 51.

KARAOKE CD

The KARAOKE CD is used in applications where the combination of Full-Motion Video and audio is needed. The KARAOKE CD specification was written by Philips in conjunction with the Victor Company of Japan, Ltd. (JVC). Full-Motion Video on a CD is also referred to as Video CD. Full-Motion Video or Video CD is based on the White Book standard. More information on this standard can be found in Appendix H on Page 47.

The KARAOKE CD format is based on the CD Bridge disc format. Therefore, KARAOKE compact discs can be played on CD-I, CD-ROM/XA, and KARAOKE CD players. A CD-I player and KARAOKE CD player can be hooked directly to a TV.

KARAOKE technology implements ISO MPEG 1 (Motion Picture Expert Group 1) standard procedures to compress video and audio data. MPEG technology can compress the data of images or audio down to 1/50 their original size or smaller. MPEG reduces data by taking out information that is not needed, or doesn't change between frames. MPEG specific hardware and software is required for compression as well as decompression of data during playback. MPEG 1 is designed for the coding of moving pictures and associated audio on digital storage media (compact disc & drive) that can supply data at rates up to about 1.5 Mbits/sec. As compression technologies improve along with disc storage capacities the length of Full-Motion Video that can be stored on a disc will also increase.

MPEG 2 is a compatible extension of MPEG 1. MPEG 2 supports higher transmission rates along with higher resolution applications. MPEG 2 is designed for the coding of moving pictures and associated audio on digital storage media that can supply data at rates between 4 to 10 Mbits/sec.

A KARAOKE CD includes as the first track a "special KARAOKE data track". This track has a track number of one and contains an ISO 9660 logical file format and a CD-I application program. Also, the first track of a KARAOKE CD is followed by one or more MPEG video/audio tracks.

MPEG video and MPEG audio sectors must be interleaved in such a way that the appropriate decoders (audio/video) receive the proper data flowrates.

Orange Book (Recordable Compact Disc Standard)

Most CD's that are made today are READ ONLY. The information on read only discs is manufactured into the disc and can NOT be changed by the user. The Orange Book defines a new type of CD that allows the *user* to write Audio and/or Data to the disc. Part I of the Orange book describes a **CD-MO** (Compact Disc - Magneto Optical) disc where data can be written, erased, and re-written. Part II of the Orange book describes a **CD-WO** (Compact Disc - Write Once) disc where the data can be written but not erased. (See Diagram of Orange Book Standard, Figure 3.0., Page 29.)

Orange Book Part I - CD-MO

The Orange Book Standard Part I describes the information area of a CD-MO (Compact Disc-Magneto Optical) disc. For a detailed discussion on this technology please refer to the Orange Book Part I. This technology should not be confused with the Magneto-Optical 5 1/4" cartridge which is fairly common in the marketplace.

Orange Book Part II - CD-WO

The Orange Book Standard Part II defines a CD-WO (Compact Disc - Write Once) disc which is also known as a CD-R (Compact Disc - Recordable) disc or as a "one-off". The disc is manufactured with grooves indicating where the tracks exist; but, there is no user data on the disc at this time. The user can then record Audio and/or Data tracks on the disc. Once recorded, the information can not be changed. Once all of the information the user wants to record has been recorded on the disc, the Table of Contents (TOC) is written to the disc. Before the TOC is written, the disc can only be accessed by the recorder. Once the TOC has been written, the disc can be played on a normal CD player. (Today's players must read the TOC in order to play the disc.)

The CD-WO can exist in three different forms. It can be unrecorded, recorded, or partially recorded.

An unrecorded or blank disc has an information area that contains a pregroove (a groove that the laser follows while writing) with information the recorder uses.

A recorded single session disc contains a completed lead-in, program area, and lead-out. Most single session CD-WO discs are recorded in one continuous recording session.

Recording a complete single session disc, lead-in, program area, and lead-out in one uninterrupted single writing action is called "uninterrupted writing". The data layout on this type of disc is as specified by the Red, Yellow, and/or Green Books. This type of CD-WO disc will play on all CD players and depending on the recorder, may or may not include link blocks (blocks of data that do the physical linking of data between two different writing actions). However, recording a CD-WO disc in several different writing actions (possibly on different recorders and at different times) is call "incremental writing". Incremental writing can occur on a single-session or multi-session disc. When incremental writing occurs the linking rules as defined in the Orange Book must be followed. In this case link blocks will be found on the CD-WO disc. Recording a CD-WO disc using incremental writing results in a partially recorded disc. The CD-WO disc remains partially recorded (and unplayable on most systems) until you <u>finish</u> the disc (for a single session disc) or session (for a multi-session disc). Finishing a single session disc involves writing the lead-in, lead-out, and table of contents.

The following two diagrams illustrate the difference between "uninterrupted writing" and "incremental writing" for a single-session disc:

"Uninterrupted Writing" without link blocks
Single-Session Disc

Lead-in	Program Area	Lead-out
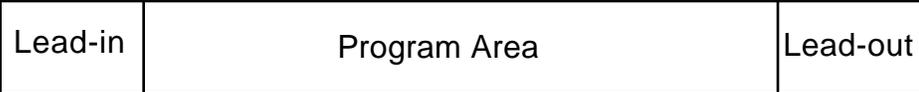
"Incremental Writing" with link blocks (finished)
Single-Session Disc

←——————— Program Area ———————→

Lead-in	Writing Action One	▐	Writing Action Two	▐	Writing Action Three	Lead-out

Link Blocks
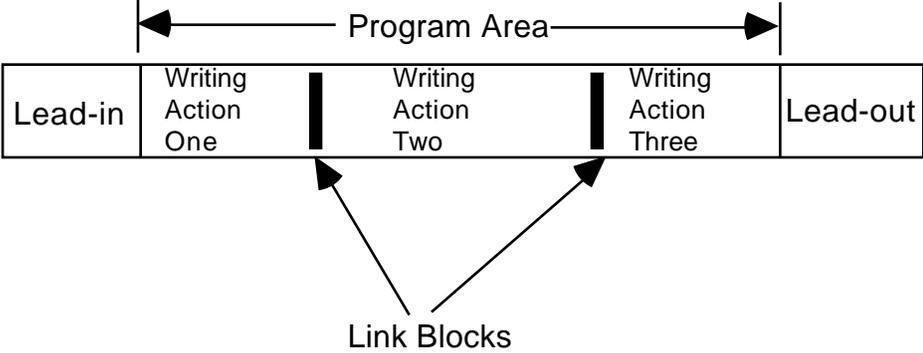
There are basically two different types of recorders on the market today:

Yellow Book Recorder: This recorder can only record discs using uninterrupted or continuous writing. This recorder can not record a multi-session disc. Therefore, this recorder can only record a single session disc. Also, this recorder does not generate link blocks.

Orange Book Recorder: This recorder has additional hardware and software that allows for the recording of discs using either uninterrupted *or* interrupted writing. Therefore, this recorder can record a single-session *or* multi-session disc. Also, this recorder generates link blocks.

A single-session disc has only one lead-in area, program area, and lead-out area. The program area on this type of disc can either be written all at once (uninterrupted writing) or it can be written at different times (incremental writing) during different writing actions. Writing at different times within a single program area does not make the disc a multi-session disc. A diagram of a single-session disc is shown below:

Single-Session Disc

Lead In	Program Area (Incremental or Uninterrupted writing)	Lead Out
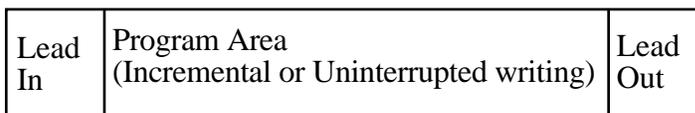
A multi-session disc has more than one lead-in area, program area, and lead-out area. The program areas on this type of disc can either be written all at once (uninterrupted writing) or they can be written at different times (incremental writing) during different writing actions. One of the advantages of this type of disc is that additional sessions/data can be added at different times when needed. A good example of this is adding more photo's to a Photo CD disc.

Having multiple lead-in, program, and lead-out areas is what makes a disc a multi-session disc. A diagram of a multi-session disc is shown below.

Multi-Session or Hybrid Disc

Lead In	Program Area (Incremental or Uninterrupted writing)	Lead Out	Lead In	Program Area (Incremental or Uninterrupted writing)	Lead Out	....

◄————— Session 1 —————►   ◄————— Session 2 —————►

Pre-mastered Area
or
Pre-Recorded Area   Recordable Area
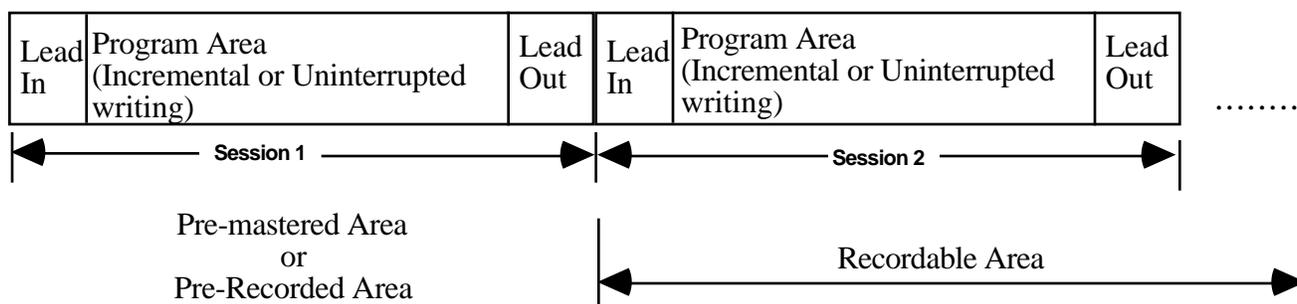
Note: Each session writes a TOC in the Lead In area for that session.
Link Blocks are not shown in the above diagram to simplify
the illustration.

The multi-session disc is defined in the Orange Book Part II. This type of disc is also known as a "Hybrid Disc". This disc contains two types of areas: (1) Pre-recorded Area and (2) Recordable Areas. The Pre-recorded area is a READ ONLY area where the information has been manufactured or recorded into the disc. (This area is written per the Red, Yellow, and/or Green book specifications, and can be played on any CD-Player.) The Recordable Areas are where additional recordings can be made in one or more sessions. Each recording session will write a three part area consisting of Lead In, Program Area, and Lead Out. Once information is written to the disc, it can NOT be changed. Only the first session on the disc is readable by today's CD-Players, additional software will be needed to read the additional sessions.

When a hybrid disc has a pre-recorded area with user information, it is basically a finalized or finished, recorded disc as described for a single-session disc above. However, a hybrid disc has additional recording possibility outside of the pre-recorded area of the disc.

CD-ROM players are read only players and can NOT record a CD-WO disc.

Figure 3.0

Diagram of Orange Book Standard

```
                        ┌─────────────────────┐
                        │    Orange Book      │
                        └─────────────────────┘
                         ╱                    ╲
       Rewriteable      ╱                      ╲      Write Once
                       ▼                        ▼
        ┌─────────────────────┐      ┌─────────────────────┐
        │      Part I         │      │      Part II        │
        │      CD-MO          │      │      CD-WO          │
        └─────────────────────┘      └─────────────────────┘
           ╱          ╲                  ╱           ╲
          ▼            ▼                ▼             ▼
```

Premastered CD-ROM Area + Rewriteable Area	100% Rewriteable Area	Regular CD-WO	Hybrid CD-WO

Regular CD-Player can only read the Premastered area on this disc.

Regular CD-Player can NOT read this disc.

Regular CD-Player can read this disc after the last recording is made and the TOC has been written to the disc.

Write TOC after last recording. Disc has one TOC.

Regular CD-Player can ONLY read the first recording session on this disc. With new software should be able to read additional recorded sessions.

A TOC is written during each recording session. Disc will have multiple TOC's, one for each recording session.

MO = Magneto Optical
TOC = Table of Contents

CD-Audio, CD-ROM, and CD-WO discs are read by changes in reflectivity. However, CD-MO discs are read by the changes in the polarization direction of the reflected laser beam. The Optional Premastered area on a CD-MO is read by changes in reflectivity.

▲

Photo-CD

ISO 9660

ISO 9660 is a standard which describes the file structure for putting computer files on a compact disc. This universal file structure can be read by a variety of different operating systems running on different computers. A more detailed discussion of ISO 9660 can be found in the Disc Manufacturing, Inc. paper Introduction to ISO 9660 by Clayton Summers.

For IBM compatible PC's, a file structure called MS-DOS is used when writing to hard disks or floppy disks. Likewise, the Apple Macintosh computer uses a file structure called HFS. If a floppy disk has files written by an IBM compatible computer in MS-DOS format, it can not be read by an Apple Macintosh computer. Conversely, if a floppy disk has files written by an Apple Macintosh computer in HFS format, it can not be read by an IBM computer. (Exceptions do exist where special programs can be loaded to allow the reading of other file structures, but in general a computer can only read information written in the file structure of the operating system it is running.)

Since CD-ROM standards do not designate which file structure to use, developers initially had to create their own file structures. This required extra time on the developers part and confusion for the user. Quite often, the user would have to restart his computer when changing applications in order to load the software for the new file structure.

In order to resolve this problem, a group of industry representatives met at Del Webb's High Sierra Hotel & Casino in Nevada and drafted a proposal for a CD-ROM file structure. This proposal is commonly called the "High Sierra" file structure. The proposal was submitted to the International Standards Organization, and with a few enhancements, it became the "ISO 9660" standard. ISO 9660 is neither MS-DOS nor HFS; but is a file structure designed for the CD-ROM.

In order for a computer operating system to read an ISO 9660 disc, the operating system must have software to allow it to read the ISO 9660 file structure. This software is normally an Extension to the operating system software.

Microsoft, the originator of MS-DOS, wrote extension software to allow the MS-DOS operating system to read ISO 9660 files. The extension software, MSCDEX.EXE, must be added to an IBM compatible PC to allow it to read ISO 9660. The extension software works with the device driver software that comes with the CD-ROM drive. The extension and drive software come in two files which are included when you purchase a CD-ROM drive for the IBM compatible PC. One file will be the device driver for the CD-ROM drive, and the second file will be a copy of the Microsoft Extensions. The computer needs both of these files to access a CD-ROM drive.

To inform the IBM compatible PC to load the device driver for the CD-ROM drive, a command must be added to a file called "CONFIG.SYS". When a PC powers up, it uses the file CONFIG.SYS to determine which additional device drivers to load.

An additional command, MSCDEX, must be run to load the Microsoft Extensions, this command is normally put in the AUTOEXEC.BAT file.

Once the above two things happen, any ISO 9660 CD-ROM can be put in any CD-ROM drive and the computer will be able to read the file directory and the files. This allows the computers operating system to read the file directory of the disc, and read the files from the disc. If the file is executable code (even though multiple systems can read the file) it will only run on the system it was written for.

Similarly, Apple has written the software to allow ISO 9660 discs to be read from an Apple Computer, and UNIX vendors have written the software to allow ISO 9660 discs to be read from UNIX systems.

By writing applications designed to work with ISO 9660 discs, the applications developer does not have to write the software to access the CD-ROM, he can use the software written to access the ISO 9660 file structure. Because each application is using the same software, the computer does not have to be restarted when the user changes applications.

In addition to the above benefit, the ISO 9660 standard allows multiple types of computers to access the same files.

Files on a CD-ROM disc in the ISO 9660 format can be read on IBM compatible computers, Apple Computers, and UNIX Systems. This allows a software company to make one disc that can be run on all three systems. For example, a disc could be made with the following 5 files (these are fictitious filenames):

IBMPROG	(executable program for MS-DOS)
MACPROG	(executable program for Apple)
UNIXPROG	(executable program for UNIX)
DATA1	(Data for above executable programs)
DATA2	(Data for above executable programs)

Assuming the file IBMPROG is a program for the IBM PC that uses the data files DATA1 and DATA2; the file MACPROG is a program for the Apple MAC that uses the data files DATA1 and DATA2; and the file UNIXPROG is a program for a UNIX based machine that uses the data files DATA1 and DATA2.

A PC running MS-DOS with Microsoft Extensions will be able to access all 5 files on this disc. The PC can execute the program IBMPROG and access the two data files, DATA1 and DATA2. This allows the PC to run the application. Even though the user can access the programs, MACPROG and UNIXPROG; the user would not be able to run these two programs because they are written to execute under a different operating system.

An Apple computer can also access all 5 of the files. The Apple computer can run the program MACPROG, giving the user access to the application and the two data files. Notice that the Apple program MACPROG is accessing the same two data files, so the data only has to be written on the disc once. The files, IBMPROG and UNIXPROG are written to be executed on other computers and will not run correctly on the Apple.

Likewise, a user running UNIX can execute the UNIXPROG and have access to the application and the two data files.

In order to allow the file structure to be usable by IBM, Apple, and UNIX computers, ISO 9660 specifies (for all three interchange levels) that all filenames and directory names must meet the following conditions:

Capital letters	**"A-Z"**
Digits	**"0-9"**
Underscore	**"_"**

The number of characters in the filename plus the extension can not exceed 30.

The directory name can not have extensions, or exceed 30 characters.

ISO 9660 level 1 interchange adds the following restrictions:

Filenames	**Maximum of 8 characters**
Filename Extensions	**Maximum of 3 characters**
Directory Names	**Maximum of 8 characters (no extension).**

Each file shall consist of only one file section. This means that the files must be contiguous, or can not be recorded in interleave mode.

ISO 9660 level 2 interchange has only the following additional restriction:

Each file shall consist of only one file section. This means that the files must be contiguous, or can not be recorded in interleave mode.

ISO 9660 level 3 interchange has no additional restrictions.

Apple ISO 9660 Extensions:

The Macintosh's native file system, HFS, has many features to support its graphical user interface that are not included in the ISO 9660 standard. By defining the Apple Extensions to ISO 9660, Apple is able to define a way to add some of the above features using the system use field of the ISO 9660 directory record. Therefore by using the Apple Extensions to ISO 9660 one is able to retain some of the Macintosh look and feel; while keeping a disc in compliance with the ISO 9660 standard.

Rock Ridge Interchange Protocol (RRIP):

The Rock Ridge Interchange Protocol was designed to allow users of POSIX and other UNIX like systems to retain much of the directory information that is in the native file system. This is important because these systems use directory entries for much more than just pointing to files. Directory entries can point to other entries (symbolic links) or to device drivers that are linked to peripheral devices such as hard disks, tape drives and CD-ROM drives (device files). The directory entry includes information that lets the system know what type of file it is dealing with, whether it is a regular file, directory, symbolic link, or device file. It also has information regarding who has permission to read, write and execute each file. Most of these systems are multi-user systems, and you would not want just anyone to be able to write to the device file that contains your operating system, because they could accidentally (or purposely?) erase the entire operating system.

The Frankfurt Group Proposal:

The Frankfurt Group Proposal is a volume and file structure proposal that expands upon ISO 9660. It is a superset of the ISO 9660 standard. In particular it is a volume and file structure that not only supports ISO 9660 CD-ROMS but also CD-WO (compact disc-write once) and CD-WO Hybrid discs. CD-WO and CD-WO Hybrid are both part of the Orange Book (Page 26). The Frankfurt Group Proposal helps to address the differences that arise due to an incrementally recorded disc.

The proposal defines two types of volume and file structures:

Type I:

Type I is the original ISO 9660 volume and file structure discussed at the beginning of this section (ISO 9660). Type I is readable by any ISO 9660 compliant system.

Type II:

Type II is a superset follow-on of Type I. It allows for incremental recording of CD-WO as well as updates to an existing CD-WO volume.

Non ISO 9660

Although ISO 9660 discs provide universal access and a standard file structure for the files, not all CD-ROMS are in the ISO 9660 format.

Example 1: High Sierra

When the High Sierra proposal was issued, it took a period of time before the ISO committee issued the ISO 9660 standard. In the meantime, several applications came out in the High Sierra proposal format. To date, some applications have still not converted over to ISO 9660.

Microsoft Extensions Version 1.0 was written to work with the High Sierra proposal. When the ISO 9660 standard was issued, Microsoft updated the software to Version 2.0. Anyone who still has a copy of Microsoft Extensions Version 1.0 or 1.1 should upgrade to version 2.0 or higher, because version 1.0 CAN NOT read ISO 9660 discs. (To get an updated copy of Microsoft Extensions, contact the company you purchased your CD-ROM drive from.)

Example 2: HFS

Apple has written drivers to allow the Apple Macintosh computer to read CD-ROM in any of three formats: ISO 9660, High Sierra, and HFS. When the CD-ROMS is being produced to run only on Macintosh computers, some developers prefer to use the HFS structure instead of the ISO 9660 structure. This gives them the standard Macintosh file naming characteristics and maintains the desktop "look and feel".

Example 3: Custom File Formats

Some discs are still being written in other file formats either because they have not converted to ISO 9660 or they are using other operating system formats.

In general, most discs are being made in ISO 9660.

Additional Technologies

3DO

The 3DO Company has introduced the 3DO Interactive Multiplayer which connects to a TV. The 3DO player is a advanced multimedia player that produces high level graphics and real-time interactive performance. The 3DO player is capable of playing several different digital formats including CD-Digital Audio, Kodak's Photo CD and CD+G. With an optional adapter the player will allow for the support of Full-Motion Video (FMV)/Video CD.

The 3DO company has selected a RISC 32-bit processor for its Interactive Multiplayer. The 3DO player incorporates a double speed CD-ROM (XA capable) drive.

DVI

DVI is a Compression / Decompression chip set that plays audio and video from files on a Hard Disk, Floppy Disk, and/or CD-ROM disc. If the storage medium is CD-ROM for the files, the disc should be in the ISO 9660 format.

A DVI disc is a regular Mode 1 CD-ROM as described in the first part of this paper. The computer must have DVI boards to take the data from the CD-ROM and decompress it to normal video and audio signals.

CDTV

A CDTV disc is a Mode 1 CD-ROM as described in the first part of this paper. Commodore has decided to use ISO 9660 interchange level 2 to allow filenames up to 30 characters. These discs are designed to play only on Commodore equipment.   (These long filenames can NOT be accessed by a IBM compatible computer. IBM compatible computers running Microsoft Extensions can only read ISO 9660 interchange level 1) CDTV discs are also using lower case letters, which do not conform to ISO 9660.

Where To Get Additional Information

For additional information on the Red Book, Yellow Book, or ISO 9660 standard, contact:

American National Standards Institute
1430 Broadway
New York, NY 10018
Sales Department: (212) 642-4900

Red Book :   CEI IEC 908

Yellow Book: ISO 10149:1989

ISO9660:   ISO 9660:1988

For additional information on the Green Book (CD-I), contact:

CD-I Association of North America
11111 Santa Monica, Suite 700
Los Angeles, CA 90025
Phone: (310) 444-6613
FAX: (310) 479-5937

For additional information on the Orange Book, contact:

Mr. Burt Gall
Philips Consumer Electronics
Coordination Office
Optical and Magnetic Media Systems
PO Box 80002
5600 JB
Eindhoven, The Netherlands
Phone: 011-31-40-736409
FAX: 011-31-40-732113

For additional information on mastering and replicating Compact Discs, contact:

Disc Manufacturing, Inc.
1409 Foulk Road, Suite 102
Wilmington, DE 19803
Phone: 1-800-433-DISC or 1-302-479-2500
FAX: 1-302-479-2527
Applelink: DMI.CD

Up to this point, this paper has been giving details on how the basic 2352 byte area is laid out.
In addition to the 2352 bytes of information included in each sector there is 98 bytes of data
called the Control Bytes.

These control bytes are produced by summing together 98 separate 8-bit fields. The 8-bits are
called a control byte because the first two bits contain timing information that is used by audio
players to position the drive head. The remaining 6 bits are available for User Information (see
subcode channels R-W section).

We have been talking about a 2352 byte area, where each byte contains 8 bits. In order to
discuss the subchannels that make up the control bytes, we must talk about <u>bits</u>.

The 8 bits in a control byte are named P, Q, R, S, T, U, V, W; where each bit represents a
subcode channel. For example, if you look at the first bit of every control byte, this stream of
bits is called the "P" subchannel. Likewise, all of the second bits in every control byte are called
the "Q" subchannel. (See the following sections for information regarding how the subchannels
are used.)

Breakdown of a Control Byte:
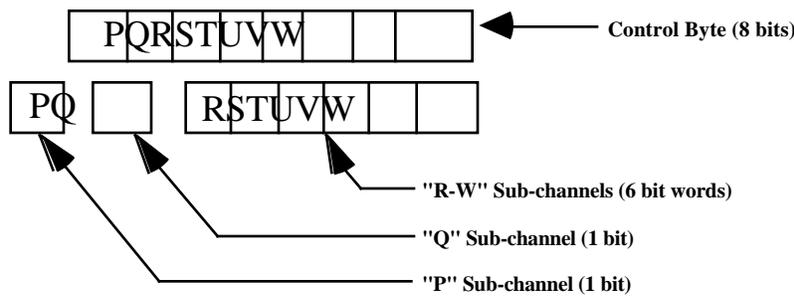
Subcode Channel P

The "P" subchannel contains a flag that signals where the music or data starts on a track

Subcode Channel Q

The "Q" subchannel contains the running times from both the beginning of the disc and from the
beginning of the current track. Audio players use this information to display the music playing
time.

98 control bytes, Layout for bit position "Q":

2	4	4	72 Bits	16 Bits

2 bits -   part of the synchronization for the Control Bytes
4 bits -   control flags defining what type of information is in this CD track.
4 bits -   control flags for the following 72 bits of data
72 bits -   Q sub-channel data
                  (During the disc Lead In, the Q channel data contains the discs Table of

contents. For the rest of the disc, the Q channel data contains the
current playing time. Both track relative time and total disc time.)

16 bits -   CRCC (Error Detection Bits) (Cyclic Redundancy Check Code)

Subcode Channels R Through W, (CD + Graphics)

The Red Book not only defines how to put audio on a CD, it also defines a way to add graphics information to the CD. The graphics information is added in the "R through W" subchannels and is commonly referred to as a CD+G disc, or "CD plus graphics" disc. Currently there are only a few of these discs in the market and very few players can play the graphics.

Today there are only a very few audio CD titles that use the "R through W" subchannels for Graphics, most audio CD's have this area empty.

About 99.9 % of the CD players today ignore the R-W subchannels, and play a CD+G disc just like a normal audio disc. The presence or absence of R-W graphics does not effect the audio, which can be played on any audio CD player.

In addition to graphics, several types of information can be stored in the R-W subchannels:

> Line Graphics
> TV-Graphics
> Extended TV-Graphics
> MIDI
> USER defined

Technical Details for R-W Subchannels:

Because R-W is only 6-bits of information, this section will discuss the number of 6-bit words. (Instead of the number of 8-bit bytes.)

There are 98 Control Bytes in each sector on the CD. The R-W bits in the 98 control bytes are laid out as follows:

> 2 words - part of the synchronization for the Control Bytes
> 4 groups of 24 words
> (Each group of 24 words is broken down as follows:)
> 1 word - defines Mode and Item
> 1 word - defines Instruction
> 2 words - EDC / ECC code
> 16 words - **User Data**
> 4 words - EDC / ECC code

98 control bytes, Layout for bit positions "R thru W":

2	24 Words	24 Words	24 Words	24 Words

1	1	2	16 Words	4
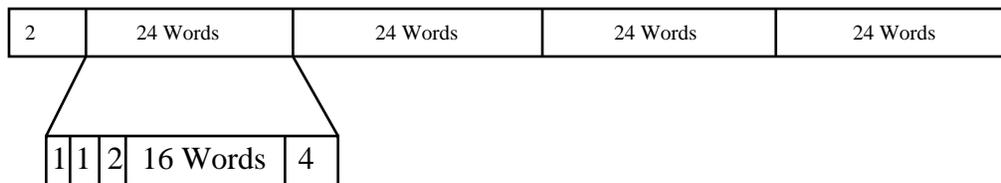
The Control Bytes are not protected by the same EDC / ECC code that protects the 2352 byte area. A separate set of EDC / ECC code is generated and placed in the R-W subchannels as shown above.

<u>R-W subcode can hold 64 6-bit words of User Data per sector</u>.
(16 words User Data per group) x (4 groups) = 64 words
(CD-ROM Mode 1 can hold 2048 8-bit words (bytes) of User Data per sector.)

User Data can only be written to R-W subcode channels for Red Book tracks, (CD-DA tracks). The Yellow Book specifies that the R-W subcode channels will be zero for data tracks.

Appendix B: CD-Encoding Overhead:

The following example is for a 74 minute Red Book CD. This example is to inform the reader about the overheads associated with CD technology.

A 74 minute CD contains approximately 1.92×10^{10} bits of information encoded on the disc. This is approximately 2.4GB. So the first question one might ask is: Why can't I store 2.4GB worth of user data on the disk? The reason you can't is due to the amount of overhead associated with certain aspects of the disc. The technologies that make a CD very reliable like the error correction code and the Eight to Fourteen Modulation also require information or data to perform their functions.

Eight to Fourteen Modulation is the process of converting every 8 bits of data to 14 bits of data for storage on the disc. This conversion helps facilitate the reading of data from the disc. When the data is read back from the disc it is converted back to 8 bits from 14 bits.

The data these technologies use reduces the overall storage capacity that remains for the user's data.

The following diagram shows the various parts of a CD and the % of the overall storage capability used by each:
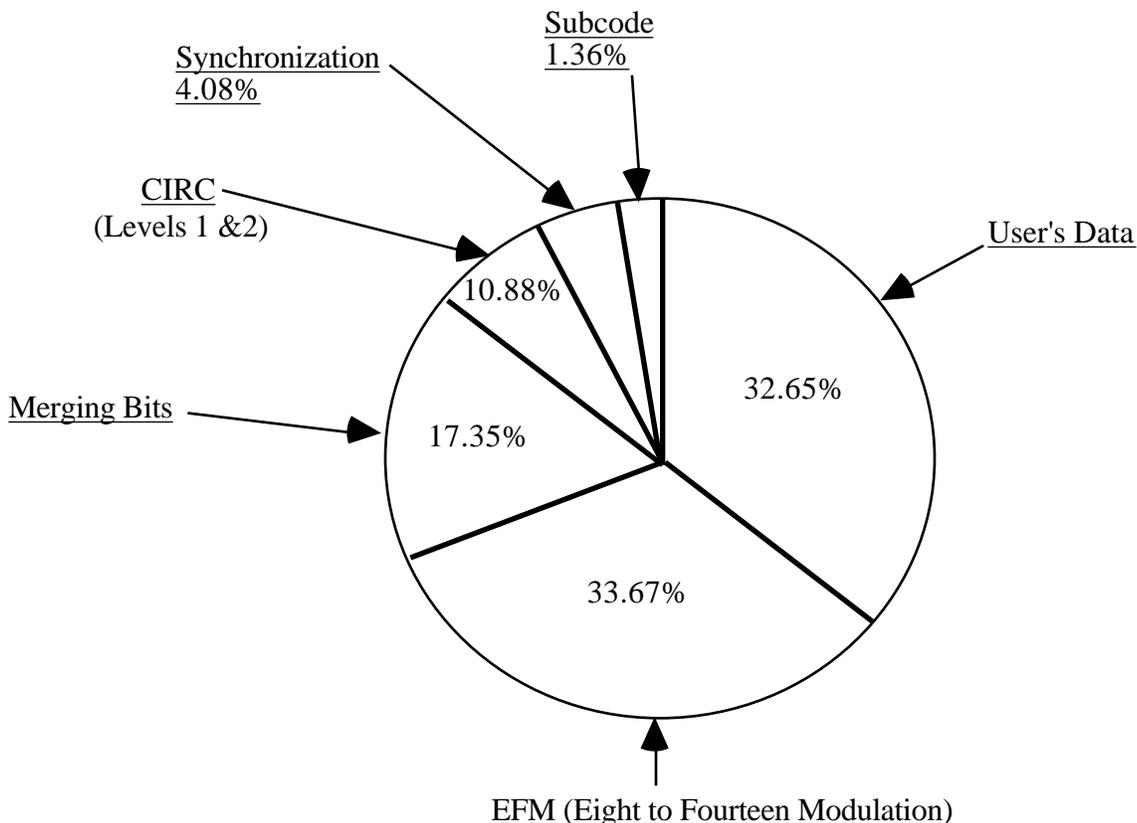
It is amazing to note that of all the actual storable information on a disc, only around 30% can be used for the actual user's data. The rest is consumed by the error correction, EFM, Merging Bits, Synchronization, and Subcode. The above example is for a Red Book CD which only has 2 layers of error correction built in. A CD-ROM Mode 1 disc with the additional (3rd layer) of error correction included would allow the user even less a percentage of the total disc for user

data. The amount of user data available on a Mode 1 disc would be around 28.43% for a 74 minute disc.

However it should be mentioned that all of the above overheads serve very important roles in making the CD a very robust and flexible technology.

Appendix C: CD-I Ready Disc Layout:

The following diagram shows the layout of a CD-I Ready Disc.

2 seconds of pre message Part A, starting at 00:00:00
sector headers show mode 2
sectors scrambled per Green Book

volume descriptors per the Green Book, starting at 00:02:16

30 seconds of pre message Part B

CD-I data sectors (per Green Book)
sector headers show mode 2
sectors scrambled per Green Book

30 seconds postgap, sector headers show mode 2
Contains scrambled Headers and Sub-headers,
but unscrambled CD-DA silence as data.

120 second pregap (per CD-I Ready Specification)
sectors of Red Book audio silence

sectors of first audio song
coded per Red Book
(recommend starting with 12 sectors of
audio silence)

Optional: 2 second audio pause (per Red Book)
sectors of audio silence

sectors of second audio song
coded per Red Book
(recommend starting with 12 sectors of
audio silence)

Optional: 2 second audio pause (per Red Book)
sectors of audio silence

sectors of third audio song
coded per Red Book
(recommend starting with 12 sectors of
audio silence)

Track #1 Index 0

Track #1 Pause

Track #1 Index 1

Track #2 Index 0
Track #2 Index 1

Track #3 Index 0
Track #3 Index 1

Track #AA Index 1

data

audio song

audio song

audio song

Appendix D: Compact Disc Layout:

Lead In Area:
This area contains the discs Table of Contents, TOC. The TOC contains a listing of where the tracks start.

Program Area:
This is the area where the tracks of information are.

Lead Out Area:
This is a buffer area in case the player reads past the last track.

The Playability Matrix below is provided for the readers information only. This matrix should be viewed as a very rough rule of thumb of "what type of disc will play on what type of player or computer". Information within this matrix should not be viewed as absolute or complete. It should be noted that almost any disc can play on any type of player if enough time is taken to write a "driver" or software to make a given disc format compatible.

Please check with the drive manufacturers and/or the companies that license the disc type or application to get the latest information concerning playability.

Playability Matrix

Types of Drives or Players

Disc Type or Application	Comment/ Examples	CD-ROM Drive & PC/DOS	CD-ROM Drive & MAC	CD-ROM Drive & UNIX	CD-I Player	3DO Player	Photo CD Player	Karaoke Player	CD-DA Player Home Stereo	CDTV Player
CD-I Disc	Greenbook				yes					
CD-I Ready Disc	CD-DA & CD-I App				yes				yes, Audio only	
Bridge Disc	Photo CD Kara. CD	yes XA drive	yes XA drive	yes XA drive	yes	yes, if PhotoCD	yes, if PhotoCD	yes, if Kara. CD		
Photo CD Disc	Bridge Disc, XA	yes XA drive	yes XA drive	yes XA drive	yes	yes	yes			
Karaoke CD	Bridge Disc	yes XA drive	yes XA drive	yes XA drive	yes			yes		
Mixed Mode Disc	Mode 1 Data & CD-DA	yes DOS Data	yes MAC Data	yes UNIX Data	yes	yes Audio Only	yes		yes Audio Only	
3DO Disc						yes				
CD-DA Disc	Red Book	yes Add. SW	yes Add. SW	yes Add. SW	yes	yes	yes		yes	
CD-ROM XA Disc		yes XA drive	yes XA drive	yes XA drive	yes, if Bridge Disc	yes, if 3DO Disc	yes, if Photo CD	yes		
ISO 9660 Interch. 1 Interch. 2 Interch. 3	Recomd. for PC&DOS App./UNIX XA Disc	yes yes XA drive	yes yes XA drive	yes yes XA drive						
HFS Disc	MAC		yes							
Hybrid Disc	ISO 9660 & HFS Image	yes	yes							
DVI Disc	Comp. must have DVI Adap.	yes								
CDTV Disc	Commodore									yes
CD-R Disc CD-WO	Orange Bk. many types	yes	yes	yes	yes	yes	yes	yes	yes	yes
CD+G Disc	Graphics & CD-DA				yes				yes Audio Only	yes
MPEG (FMV) Video CD	Full Motion Video	yes, XA drive MPEG chips	yes, XA drive MPEG chips	yes, XA drive MPEG chips	yes, needs FMV adapter	yes, with proper adapter		yes, if Karaoke CD	yes, Nimbus VideoCD W/Adptr.	

Appendix F: Transition Between Tracks (Pre-gap, Post-gap, and Pause):

The areas of a disc that help in the transition between tracks of data (same or different mode) and audio are called Pre-gap, Post-gap, and Pause. Please consult the Yellow Book specifications for details concerning Pre-gap, Post-gap, and Pause. The following information should be viewed as general rules of thumb.

Pre-gap is the area on a disc (at least 2 seconds) that separates two different types of tracks. It consists of user data that is all zeros. Pre-gap can occur between the end of lead-in and the beginning of the data track. It can also occur between two tracks of data that are different modes (mode 1 and mode 2, for example).

Post-gap is the area on a disc (at least 2 seconds) that follows a data track. It consists of user data that is all zeros. If the last track on a disc is a data track there will be a Post-gap appended to it. Also if a data track is followed by an audio track (mixed mode disc) then a Post-gap will be appended to that data track.

Pause is the area on disc (usually 2 seconds) that precedes audio tracks (between index 0 and index 1). The contents of a pause depends on the contents of the tracks on either side of it according to the Pre-gap rule. A pause may be digital audio silence or it could be a Pre-gap.

The following diagram summarizes the above discussions:

Complete Compact Disc Layout:

Lead-in	Pre-gap	Data (Tracks) (Program Area)	Post-gap	Lead-out
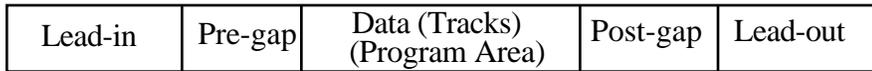
Transition Between Tracks Layouts:

Data (Track N)	Pre-gap	Data (Different Mode) (Track N+1)

Audio (Track N)	Pre-gap	Data (Track N+1)

Data (Track N)	Post-gap	Pause	Audio (Track N+1)

Audio (Track N)	Pause	Audio (Track N+1)

Data (Track N)	Data (Same Mode) (Track N+1)
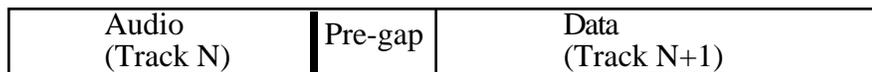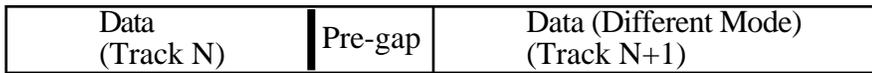
Transition Between Adjacent Tracks

Appendix G: Calculating Available User's Data:

The following is an example of how to calculate the available user's data for two different types of CD-ROMs. The first type of CD-ROM is a standard CD-ROM which is based on Mode 1 sectors. The second type of CD-ROM is a KARAOKE CD which is based on Mode 2 / XA Form 2 sectors. The following two examples are based on 74 minute discs.

### Example 1 (Mode 1 CD-ROM):

2352 Byte Layout for CD-ROM Mode 1

Sync 12	Header 4	User Data 2048	EDC 4	blanks 8	ECC 276
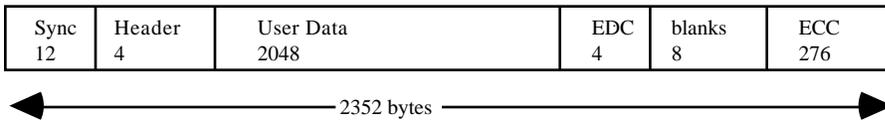
◄─────────────── 2352 bytes ───────────────►

74 min. X 60 sec./min. X 75 sectors/sec. = 333,000 sectors

Each sector for a Mode 1 CD-ROM contains 2048 bytes of user data.

Therefore, a 74 minute Mode 1 CD-ROM contains 333,000 X 2048 bytes = 681,984,000 bytes of user data.

Example 2 (CD-ROM Mode 2 / XA Form 2):

2352 Byte Layout for CD-ROM Mode 2 / XA Form 2

Sync 12	Header 4	Sub-Header 8	User Data 2324	EDC 4

◄─────────────── 2352 bytes ───────────────►
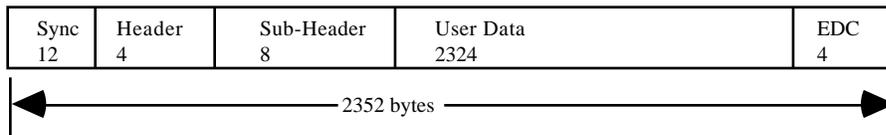
74 min. X 60 sec./min. X 75 sectors/sec. = 333,000 sectors

Each sector for a Mode 2 / XA Form 2 CD-ROM contains 2324 bytes of user data.

Therefore, a 74 minute Mode 2 / XA Form 2 CD-ROM contains 333,000 X 2324 bytes = 773,892,000 bytes of user data.

The above two examples illustrate that just because two CD-ROMs have the same number of sectors (same time length) they do not necessarily have the same amount of user data storage capacity.

Appendix H: Full-Motion Video:

White Book/Video CD

Video CD (Renamed from KARAOKE CD because of the wider application use than just KARAOKE machines of Full-Motion Video.) is used in applications where the combination of Full-Motion Video and audio is needed. The Video CD format is also known as the "White Book". This format was written by Philips in conjunction with the Victor Company of Japan, Ltd. (JVC). This format is also supported by Sony and Matsushita.

The Video CD format is based on the CD Bridge disc format. Therefore, Video CD compact discs can be played on CD-I, CD-ROM/XA, and KARAOKE CD players. A CD-I player and KARAOKE CD player can be hooked directly to a TV.

Video CD technology implements ISO MPEG 1 (Motion Picture Expert Group 1) standard procedures to compress video and audio data. MPEG technology can compress the data of images or audio down to 1/50 their original size or smaller. MPEG reduces data by taking out information that is not needed, or doesn't change between frames. MPEG specific hardware and software is required for compression as well as decompression of data during playback. MPEG 1 is designed for the coding of moving pictures and associated audio on digital storage media (compact disc & drive) that can supply data at rates up to about 1.5 Mbits/sec. As compression technologies improve along with disc storage capacities the length of Full-Motion Video that can be stored on a disc will also increase.

MPEG 2 is a compatible extension of MPEG 1. MPEG 2 supports higher transmission rates along with higher resolution applications. MPEG 2 is designed for the coding of moving pictures and associated audio on digital storage media that can supply data at rates between 4 to 10 Mbits/sec.

MPEG video and MPEG audio sectors must be interleaved in such a way that the appropriate decoders (audio/video) receive the proper data flowrates.

Nimbus Technology & Engineering/Video CD

Nimbus Technology & Engineering has also developed a Video CD technology different than the one based on the White Book discussed above.

The Nimbus Video CD and the White Book Video CD both implement the MPEG 1 technology discussed above. However, the overall technologies are different. The Nimbus Video CD conforms to the digital audio Red Book standard. Therefore, Nimbus Video CD's can be played on a standard audio CD player that has SPDIF digital output along with a special decoder (connected to the CD player and a TV) available from Nimbus.

The White Book Video CD's are encoded like CD-ROMS and incorporate XA technology. The CD-ROM specifications require a data "flag" (in the control field of the Q subchannel) that prevents (some) audio CD players from playing the data and possibly damaging the speakers.

Therefore the difference between the two technologies is whether or not the data bit is set in the Q-subchannel.

Appendix I: Technical Breakdown of how sectors are put on a CD:

The following two pages show a diagram of how sectors are put on a CD.

Expanded View of
Sector Layout.
User Data is Sent to
Manufacturer on Image Tapes.

SECTOR: 2352 Bytes (Mode 1)						
Sync 12 bytes	Header 4 bytes	User Data 2048 bytes	EDC 4 bytes	Zeros 8 bytes	P parity 172 bytes	Q parity 104 bytes

Sync | 2340 bytes

Scramble Data
NOT Sync

SCRAMBLER

Sector 95

| Sector 94 | Sync | 2340 scrambled bytes | Sector 96 | Sector 97 |
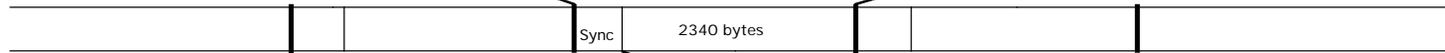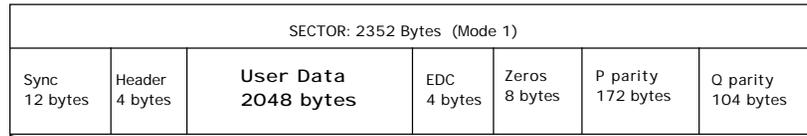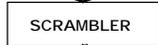
Map to 98 Frames.
24 Bytes in Each Frame.

1 f1 S95 24 f2 S95   ••• f97 S95   f98 S95   f1 S96   •••

Map to F1 Frames.
Swap MSB with LSB of
each 16 Bit Word.

1 f1 S95 24 f2 S95   1 f3 S95 24 ••• f98 S95   f1 S96   •••

Displace and Interleave
F1 Frames. Each Arrow
Associated with 2 Bytes.

1 f1 S95 24 f2 S95   1 f3 S95 24 ••• f98 S95   f1 S96   •••

Pass Through C2 Encoder.
Genrates 4 Bytes of Q Parity.

C2 ENCODER

1 f1 S95 Q Q Q Q 24 f2 S95   1 f3 S95 Q Q Q Q f4 S95   f5 S95 •••

← *4 bytes Q Parity*

Pass Through 0 to 108
Frame Delay Lines.

108 frame delay

No Delay

4 frame delay

1 f3 S95 Q Q Q Q f4 S95   f5 S95   f6 S95   1 f7 S95 •••

A

A
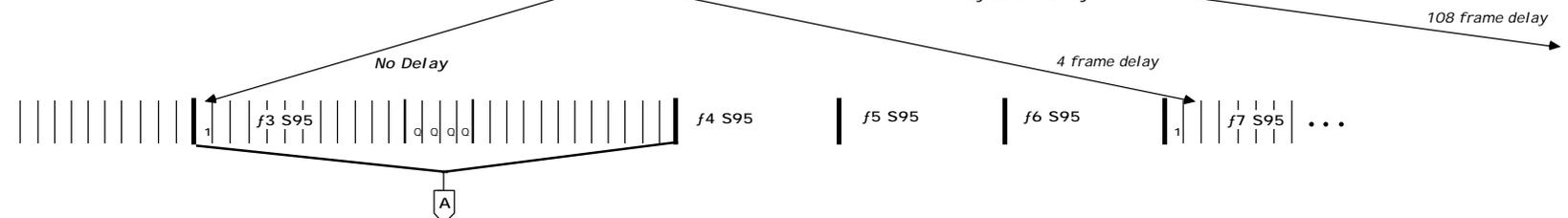
Expanded View of
ƒ3 S95 Showing
Where Each Byte
Comes From.
ƒ97 S94 = Frame 97
Sector 94.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
ƒ3 S95	ƒ97 S94	ƒ93 S94	ƒ89 S94	ƒ85 S94	ƒ81 S94	ƒ77 S94	ƒ73 S94	ƒ69 S94	ƒ65 S94	ƒ61 S94	ƒ57 S94	ƒ53 S94	ƒ49 S94	ƒ45 S94	ƒ41 S94	ƒ37 S94	ƒ33 S94	ƒ29 S94	ƒ25 S94	ƒ21 S94	ƒ17 S94	ƒ13 S94	ƒ9 S94	ƒ5 S94	ƒ1 S94	ƒ95 S93	ƒ91 S93

ƒ4 S95   ƒ5 S95   • • •
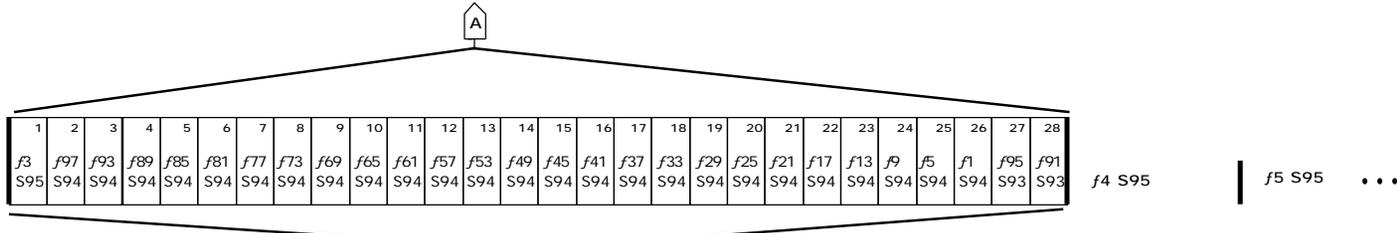
Pass Through C1 Encoder.
Genrates 4 Bytes of P Parity.
F1 Frames now F2 Frames.

C1 ENCODER

1   ƒ3 S95   Q Q Q Q   P P P P   ƒ4 S95   ƒ5 S95   • • •   ƒ98 S95 • • •

4 bytes P Parity

Delay Every Other Byte

Data from ƒ2 S95

1   ƒ3 S95   Q Q Q Q   P P P P   ƒ4 S95   ƒ5 S95   • • •   ƒ98 S95 • • •
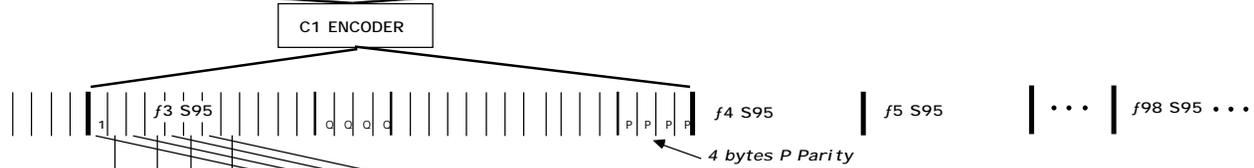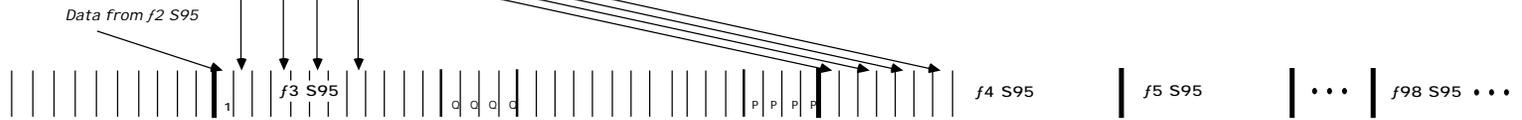
Add 1 Control Byte to
each Frame

Add Control Byte

1   ƒ3 S95   Q Q Q Q   P P P P   ƒ4 S95   ƒ5 S95   • • •   ƒ98 S95 • • •
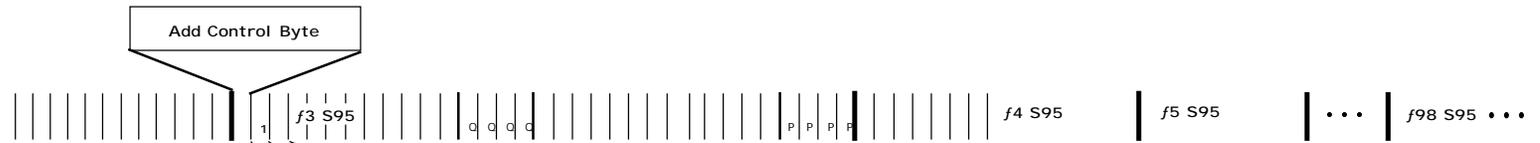
8 - Bit Data

11101000   11100010   10111010

8-to-14 Encoding

00010010000010   10010001000010   00010000100100

Add Merging Bits

010 00010010000010 000 10010001000010 001 00010000100100 100

Add Sync Header

100000000000100000000000010 010 00010010000010 000 10010001000010 001 00010000100100 100

Pit Pattern

Flow Diagram of Sector to Pits