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MMC-2 CD MODEL

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5.0 CD Model

Data transfer can begin with any of the consecutively numbered logical blocks. Data on C/DVD devices is addressed the same as for (magnetic) direct-access devices. Some C/DVD devices support a separate information stream (e.g. audio and/or video but referred to as audio in this Section) transmitted via a connection other than the AT Bus. This specification defines commands for controlling these other information streams for C/DVD devices.

C/DVD drives are designed to work with any disc that meets IEC. Many new drives read C/DVD data discs, digital audio discs, and audio-combined discs (i.e. some tracks are audio, some tracks are data).

5.1 CD Media Organization

The formats written on the CD-ROM and CD-DA (Digital Audio) media require special interfacing considerations.

Discs may contain either audio, data or a mixture of the two. "Table 10 - Example Mixed Mode CD Disc Layout" on page 58 gives an example of an audio-combined disc to illustrate the relationship between the logical block addresses reported and the MSF address encoded on the media.

> NOTE: The term “frame” is used in two different ways in the CD media standard. The intended meaning can only be determined from the context. Whenever possible, this description replaces the larger data unit with the more familiar term sector. The primary exception to this policy is the use of frame when referring to the MSF address. In the MSF context, one frame (F field unit) equals one sector. On a typical two channel CD-DA media, each frame (F field unit) is played in 1/75th of a second.

Table 10 - Example Mixed Mode CD Disc Layout

Block Description	Logical Address (Decimal)	Absolute MSF Address[1]	Track and Index	Sector is Info or is Pause	Mode Audio or Data	CD-ROM Data Mode[2]
Lead-in area[3]	---	---	0/-	---	Audio	---
Pre-gap[3]	---	00/00/00	1/0	Pause	Data	Null
1st track data	0000[4]	00/02/00[5]	1/1	Info	Data	L-EC
2nd track data	6000[4]	01/16/00[5]	2/1	Info	Data	L-EC
	7500	01/2A/00	2/2	Info	Data	L-EC
Post-gap	9000	02/02/00	2/3	Pause	Data	Null
Pause-silence	9150	02/04/00	3/0	Pause	Audio	---
3rd track audio	9300[6]	02/04/00[7]	3/1	Info	Audio	---
	1400	02/22/00	3/2	Info	Audio	---
4th track audio	21975[6]	04/35/00[7]	4/1	Info	Audio	---
Pre-gap part1	30000	06/28/00	5/0	Pause	Audio	---
Pre-gap part2	30075	06/29/00	5/0	Pause	Data	Null
5th track data	30225	06/2B/00	5/1	Info	Data	L-EC
Last information	263999[8]	3A/27/4A	5/1	Info	Data	L-EC
Post-gap	---	3A/28/00	5/2	Pause	Data	Null
Lead-out track	264000[9]	58/42/00[10]	AA/[11]	Pause	Audio	---

1. Absolute MSF address repeated in the header field of data blocks.
2. The CD-ROM data mode is stored in the header of data tracks. This indicates that the block is part of a data pre-gap or post-gap (null), that this is a data block using the auxiliary field for L-EC symbols (ECC - CD-ROM data mode one), or that this is a data block using the auxiliary field for user data (CD-ROM data mode two).
3. Table of contents information is stored in the sub-channel of lead-in area. The lead-in area is coded as track zero. Track zero and the initial 150 sector pre-gap (or audio pause) are not accessible with logical addressing.
4. Exact value returned by READ C/DVD STRUCTURE command.
5. Value stored in table of contents with zero tolerance.
6. Value returned by READ C/DVD STRUCTURE command plus or minus 75 blocks.
7. Value stored in table of contents plus or minus 75 sectors.
8. Minimum value returned by READ C/DVD CAPACITY; exact value depends on encoding of this track and the lead out track and whether this is derived from the TOC data.
9. Value returned by READ C/DVD STRUCTURE command; exact, if lead-out track is encoded as data, or plus or minus 75 blocks if encoded as audio.
10. Value stored in table of contents; exact, if lead-out track is coded as data, or plus or minus 75 blocks if coded as audio.
11. Lead-out track number is defined as 0AAh.

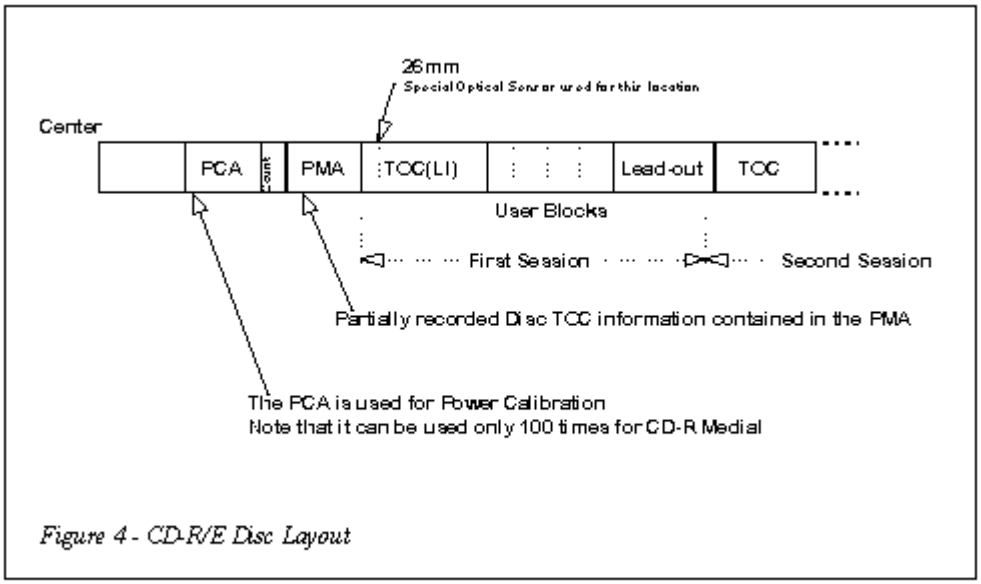

Figure 4 - CD-R/E Disc Layout

The physical format defined by the CD-ROM media standards provide 2352 bytes per sector. For usual computer data applications, 2048 byte are used for user data, 12 bytes of for a synchronization field, 4 bytes for a sector address tag field and 288 bytes - the auxiliary field - for L-EC (CD-ROM data Mode2 / Form 2).

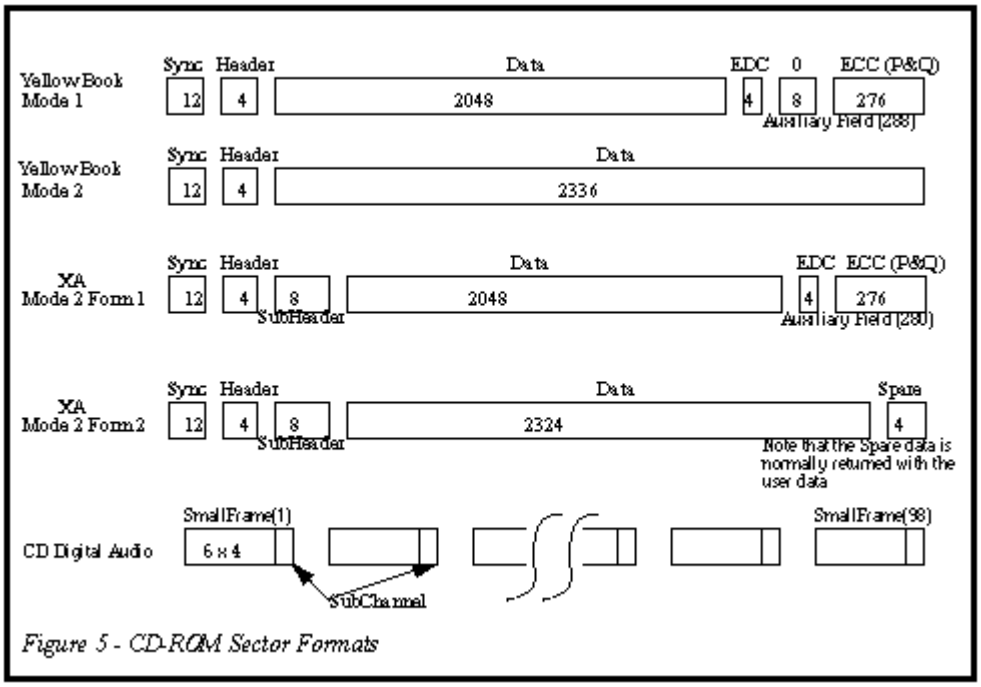

Figure 5 - CD-ROM Sector Formats

A CD logical sector size is 2048, 2052, 2056, 2324, 2332, 2336, 2340 or 2352 bytes per sector. These values correspond to the user data plus various configurations of header, sub-header and EDC/ECC.

This same area of the CD-ROM or CD audio media may store 1/75th of a second of two channel audio information formatted according to the CD-DA specification. (These audio channels are usually the left and right components of a stereo pair.) An audio only density code value can be used to declare an area of the media to be invalid for data operations.

For data and mixed mode media (those conforming to ISO/IEC 10149), logical block address ZERO shall be assigned to the block at MSF address 00/02/00. For audio media (those conforming only to IEC 908), logical block address ZERO shall be assigned to the actual starting address of track 1. This may be approximated by using the starting address of track 1 contained in the table of contents (TOC) or by assigning logical block address ZERO to the block at MSF address 00/02/00.

A track may be viewed as a partition of the CD address space. The CD media contains from one to ninety-nine tracks. All information sectors of a track are required to be of the same type (audio or data) and mode. Each change in the type of information on the disc requires a change in track number. A disc containing both audio and data would have at least two tracks, one for audio and one for data.

The tracks of a CD media are numbered consecutively with values between 1 and 99. However, the first information track may have a number greater than 1. Tracks have a minimum length of 300 sectors including any transition area that is part of a track.

The CD media standards require transition areas between tracks encoded with different types of information. In addition, transition areas may be used at the beginning or end of any track. For audio tracks the transition areas are called pause areas. For data tracks, transition areas are called pre-gap and post-gap areas. See "Table 10 - Example Mixed Mode CD Disc Layout" on page 58 for an example. The IEC 908 and ISO/IEC 10149 standards specify minimum time duration’s for these areas. Maximum time duration’s are not specified.

Transition areas are formatted and the logical address continues to increment through transition areas. Some media (i.e. discs with only one track) may not have transition areas. The means to determine the location of the transition areas is vendor or application-specific and is addressed by other standards (e.g. ISO 9660).

C/DVD is a unique Logical Unit in the respect that some logical blocks on a disc may not be accessible by all commands. SEEK commands may be issued to any logical block address within the reported capacity of the disc. READ commands cannot be issued to logical blocks that occur in some transition areas, or to logical blocks within an audio track. PLAY AUDIO commands cannot be issued to logical blocks within a data track.

CD media have lead-in and lead-out areas. These areas are outside of the user-accessible area as reported in the READ C/ DVD CAPACITY data. The lead-in area of the media is designated track zero. The lead-out area is designated track 0AAh. The sub-channel Q in the lead-in track contains a table of contents (TOC) of the disc.

> NOTE: The READ C/DVD CAPACITY command returns the logical block address of the last block prior to the lead-out area. This location may be in a transition area and therefore not a valid address for read operations.

The table of contents gives the absolute MSF location of the first information sector of each track. Control information (audio/data, method of audio encoding, etc.) for each track is also given in the TOC. However, the TOC does not distinguish between the different modes of data tracks (i.e. CD-ROM Data Mode 1 vs. CD-ROM Data Mode 2).

The MSF locations of the beginning of data tracks in the TOC are required to be accurate; however, the TOC values for audio tracks have a tolerance of plus or minus 75 sectors. Information from the TOC can be used to reply to a READ C/ DVD CAPACITY command. When this is done, the Logical Unit implementor shall consider the possible tolerances and return a value that allows access to all information sectors.

An index is a partition of a track. Pre-gap areas are encoded with an index value of zero. Pause areas at the beginning of audio tracks are also encoded with an index value of zero. The first information sector of a track has an index value of one. Consecutive values up to 99 are permitted. Index information is not contained in the TOC. Not all sectors are encoded with the index value in the Q-sub-channel data (the requirement is 9 out of 10). A sector without an index value is presumed to have the same index as the preceding sector.

Tracks and indexes are not defined to be any particular length, (except for a minimum track length of 300 sectors.) A CD disc may be created with a single information track that has a single index; or with 99 information tracks, each with 99 indexes.

The sub-channel information which is part of each sector includes a track relative MSF location value giving the distance from the first information sector of the track. On the media, this value decreases during the pre-gap area (sectors with index values of 0) and increases for the rest of the track. The data, returned by the READ SUB-CHANNEL command with MSF bit set to zero, converts this to a track relative logical block address (TRLBA). The TRLBA is continually increasing over the whole track, and pre-gap areas shall return negative values. When the MSF bit in the read sub-channel command is set to one, the MSF track relative location value from the media is reported without change.

Note: The purpose of accessing MSF addresses less than 00M 02S 00F is to retrieve information, such as packet size, from incrementally written discs. This information exists in the track descriptor block in the pre-gap area. Users can read this information by scanning the area between 00M 01S 00F to 00M 02S 00F. While the media may contain multiple redundant copies of the pre-gap data, the Logical Unit shall only return one copy. The Logical Unit may not be able to read 00M 00S 00F since there is no Sub-Q information before this frame. Refer to CD-ROM Orange book for additional de-tails.

5.2 CD Physical Data Format

The physical format of CD-ROM and CD-DA media uses a smaller unit of synchronization than the more familiar magnetic or optical recording systems. The basic data stream synchronization unit is a small frame. This is not the same large frame (sector) as referred to in the MSF unit. Each small frame consists of 588 bits. A sector on CD media consists of 98 small frames.

A CD small frame consists of:

1. 1 synchronization pattern (24+3 bits)

2. 1 byte of sub-channel data (14+3 bits)

3. 24 bytes of data (24 x (14+3) bits)

4. 8 bytes of CIRC code (8 x (14+3) bits) Total: 588 bits.

Data, sub-channel and CIRC bytes are encoded with an 8-bit to 14-bit code; then three merging bits are added. The merging bits are chosen to provide minimum low-frequency signal content and optimize phase lock loop performance.

5.2.1 Frame Format for Audio

Each small frame of an audio track on a two-channel CD-DA or CD-ROM media consists of six digitized 16-bit samples of each audio channel. These 24 bytes of data are combined with a synchronization pattern, CIRC bytes and a sub-channel byte to make a frame. Each frame takes approximately 136.05 μs to play. This gives a sampling rate of 44.1 kHz for each channel. The sub-channel information creates the higher level sector grouping for audio tracks.

5.2.2 Sector Format for Data

The data bytes of 98 small frames comprise the physical unit of data referred to as a sector. (98 small frames times 24 bytes per small frame equals 2352 bytes of data per sector.)

A sector that contains CD-ROM Data Mode 1 data has the following format:

1. 12-byte synchronization field

2. 4-byte CD-ROM data header

Absolute M field Absolute S field Absolute F field CD-ROM data mode field

3. 2048-byte user data field

4. 4-byte error detection code

5. 8 bytes zero

6. 276-byte layered error correction code

A sector that contains CD-ROM Data Mode 2 data has the following format:

1. 12-byte synchronization field

2. 4-byte CD-ROM data header

Absolute M field Absolute S field Absolute F field CD-ROM data mode field

3. 2336-byte user data field (2048 bytes of mode 1 data plus 288 bytes of auxiliary data)

NOTE: Many drives are capable of returning CD-ROM data mode one data in a CD-ROM data mode two format. This allows the user to investigate the error detection and error correction codes. However data encoded as CD-ROM data mode two cannot be read as CD-ROM data mode one data.

5.2.3 Sub-channel Information Formats

The sub-channel byte of each frame is assigned one bit for each of the 8 sub-channels, designated P, Q, R, S, T, U, V, W.

Sub-channel P is a simple flag bit that may be used for audio muting control and track boundary determination.

Sub-channel Q has a higher level of structure. All the sub-channel Q bits of a sector define the sub-channel Q information block. (For audio tracks, decoding the Q sub-channel is the only way to distinguish sector boundaries.)

The sub-channel Q block consists of 98 bits, one bit from each small frame in a sector. Three formats are defined for the sub-channel Q information block. The first format provides location information and is defined as follows:

1. 2-bit sub-channel synchronization field

2. 4-bit ADR field (defines the format)

3. 4-bit control field (defines the type of information in this sector)

4. 8-bit track number

5. 8-bit index number

6. 24-bit track relative MSF address

7. 8 bits Reserved (0)

8. 24-bit Absolute MSF address

9. 16-bit CRC error detection code

This format is required to exist in at least nine out of ten consecutive sectors.

The second and third formats are optional. If used, they shall exist in at least one out of 100 consecutive sectors. They include the absolute frame byte of the MSF address to provide location information continuity. The second format gives the catalogue number of the disc (UPC/EAN bar code number). This information is constant over the whole media.

The third format gives the International Standard Recording Code (ISRC) for each track. The ISRC is defined in ISO 3901. This format is not present on lead-in or lead-out tracks and may change only after the track number changes.

5.3 CD Audio Error Reporting

PLAY AUDIO commands with the immediate bit set in the audio control mode return status as soon as the command has been validated (which may involve a seek to the starting address). The playback operation continues and may complete without notification to the Host Computer. Error termination of audio operations shall not be reported to the Host Computer.

The status of the play operation may be determined by issuing a REQUEST SENSE command. The sense key is set to NO SENSE and the audio status is reported in the additional sense code qualifier field.

5.4 CD Ready Condition/Not Ready Condition

The ready condition occurs after a disc is inserted and the Logical Unit has performed its initialization tasks. These may include reading the Table Of Contents from the media. This “Ready” is different from and should not be confused with

the ATA Ready Status. A check condition status will be returned for the not ready condition only for commands that require or imply a disc access.

A not ready condition may occur for the following reasons:

1. There is no disc mounted, See “Removable medium” on page 52.

2. The Logical Unit is unable to load or unload the disc.

The Logical Unit shall spin up and make the disc ready for media accesses when a new disc is detected.

Any media access that occurs when the Logical Unit is not spinning shall spin the Logical Unit up and not generate an error.

Some commands are allowed to generate a “Not Ready” check condition, and others are not. See “Not Ready Error & Time-out Unit Attention Reporting (by Command)” on page 51.

5.5 CD Address Reporting Formats (MSF bit)

Several CD specific commands can return addresses either in logical or in MSF format. The READ HEADER, READ SUB-CHANNEL and READ C/DVD STRUCTURE commands have this feature.

Table 11 - MSF Address Format

Bit Byte	7	6	5	4	3	2	1	0
0	Reserved							
1	M Field							
2	S Field							
3	F Field							

An MSF bit of zero requests that the logical block address format be used for the absolute address field or for the offset from the beginning of the current track expressed as a number of logical blocks in a CD track relative address field.

An MSF bit of one requests that the MSF format be used for these fields. In certain transition areas, the relative MSF addresses are decreasing positive values. The absolute MSF addresses are always increasing positive values. The M, S, and F fields are expressed as binary numbers.

5.6 Error Reporting

If any of the following conditions occur during the execution of a command, the C/DVD Logical Unit shall return CHECK CONDITION status. The appropriate sense key and additional sense code shall be set. The following list illustrates some error conditions and the applicable sense keys. The list does not provide an exhaustive enumeration of all conditions that may cause the CHECK CONDITION status.

Table 12 - Error Conditions and Sense Keys

Condition	Sense Key
Invalid logical block address	ILLEGAL REQUEST
Unsupported option requested	ILLEGAL REQUEST
Attempt to read a blank block	ILLEGAL REQUEST
Attempt to play a data block as audio	ILLEGAL REQUEST
C/DVD device reset or medium change since last command	UNIT ATTENTION
Self diagnostic failed	HARDWARE ERROR
Unrecovered read error	MEDIUM ERROR / HARDWARE ERROR
Recovered read error	RECOVERED ERROR
Overrun or other error that might be resolved by repeating the command	ABORTED COMMAND

In the case of an invalid logical block address, the sense data information field shall be set to the logical block address of the first invalid address.

In the case of an attempt to read a blank or previously unwritten block, the sense data information field shall be set to the logical block address of the first blank block encountered. The data read up to that block shall be transferred.

There are other special error situations for C/DVD devices. In the following cases the sense key shall be set to ILLEGAL REQUEST and the additional sense code set to END OF USER AREA ENCOUNTERED ON THIS TRACK:

1. a post-gap area is encountered (i.e. a block with CD-ROM Data Mode 0);

2. a pre-gap area is encountered (i.e. a block with index equal to 0);

3. The information type (Data Mode vs. Audio etc.) changes.

When not performing audio playback, if the logical block address requested is not within a data track, the command shall be terminated with CHECK CONDITION status. The sense key shall be set to ILLEGAL REQUEST and the additional sense code set to ILLEGAL MODE FOR THIS TRACK. This applies to audio-combined and audio media.