CD-Recorder

CDD2000

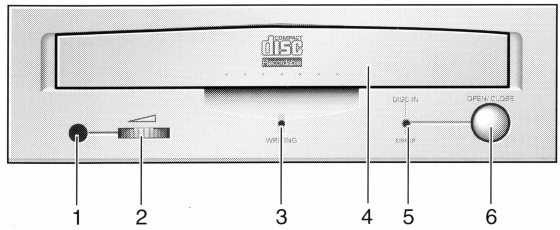
INSTALLATION INSTRUCTIONS

PHILIPS

CDD 2000 CD - Compact Disc Recorder

FIG.1

FRONT VIEW



REAR VIEW

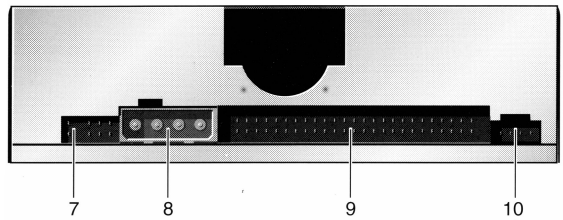


FIG.1 FRONT VIEW

1. Headphone plug
2. Headphone volume control
3. Write indicator
4. Disc Tray
5. Disc In/Read/Error indicator
6. Open/Close key

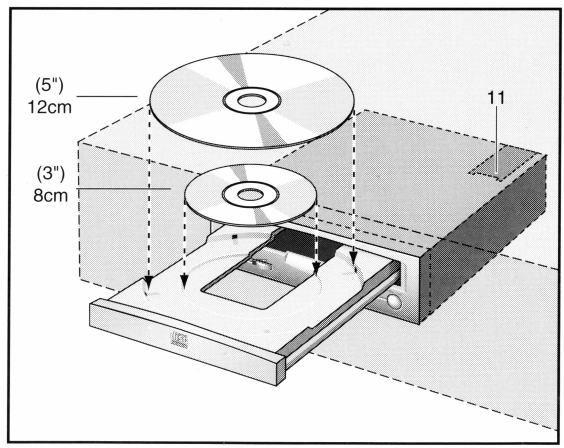
FIG.1 REAR VIEW

7. Jumperblock
8. Host DC power connector
9. SCSI connector
10. Audio Line Out connector

FIG.2 LOADER

11. Service flap

FIG.2



WARNING

This device complies with Part 15 of the FCC (U.S.A.) Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

NOTE

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can be used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning this equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

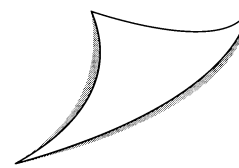
- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

IMPORTANT

Any change or modifications to the equipment by the user not expressly approved by the grantee or manufacturer could void the user's authority to operate such equipment.

FOR EUROPE

CE "The CDD2000 is in conformity with the EMC directive and low-voltage directive."



CONTENTS

LASER SAFETY

This unit employs a laser. Do not remove the cover or attempt to service this device when connected due to the possibility of eye damage.

LASER-SICHERHEIT

In das Gerät ist ein Laser eingebaut. Nehmen Sie die Abdeckung nicht ab und versuchen Sie nicht, das Gerät zu reparieren, solange es angeschlossen ist. Es besteht die Gefahr einer Augenverletzung.

CAUTION

USE OF CONTROLS OR ADJUSTMENTS OR PERFORMANCE OF PROCEDURES OTHER THAN THOSE SPECIFIED HEREIN MAY RESULT IN HAZARDOUS LASER RADIATION EXPOSURE.

WARNUNG

DIE VORNAHME VON REGELUNGEN ODER EINSTELLUNGEN ODER DIE DURCHFÜHRUNG VON VERFAHREN, DIE NICHT IN DIESEM DOKUMENT (DIESER BESCHREIBUNG; IM NACHSTEHENDEN TEXT) ANGEGEBEN SIND, KANN EINE GEFÄHRLICHE EINWIRKUNG VON LASERSTRAHLUNG ZUR FOLGE HABEN.

CAUTION INVISIBLE LASER RADIATION WHEN OPEN AVOID EXPOSURE TO BEAM

VARO! AVATTAESSA OLET ALTIINA NÄKYMÄTTÖMÄLLE LASER SÄTTEILYLLE ÄLÄ KATSO SÄTEESEN

VARNING OSYNLIG LASERSTRÅLNING NÄR DENNA DEL ÄR ÖPPNAD BETRAKTA EJ STRÅLEN

ADVERSEL USYNLIG LASERSTRÅLING VED ÅBNING. UNDGÅ UNSAETTELSE FOR STRÅLING

DANGER INVISIBLE LASER RADIATION WHEN OPEN AVOID DIRECT EXPOSURE TO BEAM

VORSICHT INSICHTBARE LASERSTRAHLUNG WENN ABDECKUNG GEÖFFNET NICHT DEM STRAHL AUSSETSEN

LASER

Type	Semiconductor laser GaAlAs
Wave lenght	775~795 nm (at 25°C)
Output Power	2,5 mW (Read)
	35 mW (Write)
Beam divergence	60 degree.

The CDD2000 allows the recording on CD of large quantities of data (up to 700 Mb) in one of the standard CD-formats : CD-ROM (XA),CD Photo, CD-I AND CD-DA. The drives of the CDD2000 family are able to write and read with double and normal transfer rate compared to standard CD-ROM (XA) and CD-DA drives. Because the CDD2000 operates conform the Orange Book standard, the recorded discs can be read in a CD-ROM (XA), CD-I, CD Photo and CD-DA player. The 12cm discs have a formatted capacity of approximately 600 Mbytes and can be inserted and removed by the operator. The 8cm discs have a formatted capacity of approximately 200 Mbytes.
The disc is read and written optically in fixed length sectors by a movable head with a diode laser. Built-in error correction ensures high data integrity. The CDD2000 is a 5,25" half height drive and is designed to be built into computer and used under office conditions. The CDD2000 and the host computer communicate via a SCSI bus.
Features of the CDD2000 CD-writer:

- Third generation design.
- Writes and reads data at two times standard CD-speed, and reads at quadruple speed.
- Capable of writing multiple logical volumes on one physical disc (multiple sessions).
- Supports Incremental Packet Writing for data storage applications.

Unpacking

If the CDD2000 package shows evidence of rough handling or damage and the drive does not function properly on initial startup: return the drive and damaged package to your supplier and request a replacement.

Lift out the CDD2000 and remove the packing pieces.
Check that the package contains following items :

- A5 user manual
- Mounting screws + jumpers

A SCSI cable and a SCSI controller board can be purchased with your supplier.

Handling Static-Sensitive devices

This CD-Recorder drives, like all electronic equipment, is static sensitive.

- Please take the proper precautions when handling the drive.

- Avoid touching the SCSI connector pins as well as the audio connector pins and the jumper pins.

- Keep the drive in its conductive wrapping until you are ready to install the drive in your computer.

Installing the drive

- In order to mount the drive inside your PC (or other type of computer), locate a free 5.25" bay and follow the instructions, as provided with your computer systems, for installing the drive.

- In order to prevent interference between the CD-Recorder drive and the computer, please make sure to mount the drive using all 4 mounting screws.

Safety Precautions

Europe: This drive shall be installed only with an EN60950 (IEC950) approved Power supply.

USA/Canada: This drive is for use only with IBM compatible UL listed Personal Computers or Macintosh UL listed workstations weighing less than 18 kg.

Host interface connections

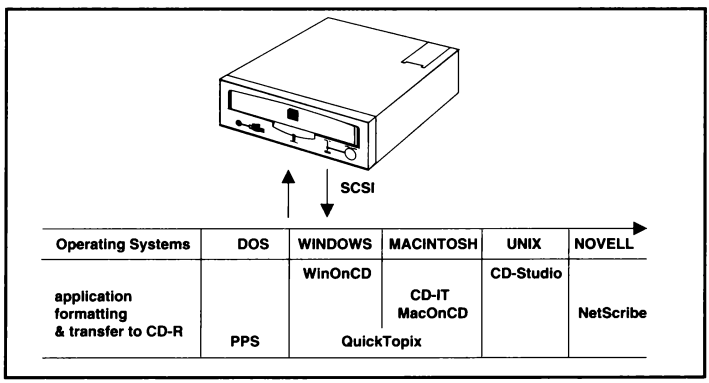
Connect the internal SCSI flatcable to the SCSI interface card of your host. Connect the other end to one of the SCSI connectors at the rear of the CDD2000 drive.

Make sure to select a free SCSI address via the jumpers on the back of the unit.(see appendix p.14 for more information on the use of the jumpers).

Then connect the power cable in your PC to the plug on the drive (see item 8 of the rear view).

Software support is available for various Operating Systems (refer to FIG.4 for an example of currently available application software packages.)

FIG.4



All trademarks acknowledged

SUMMARY OF CONTROLS AND CONNECTIONS

FRONT VIEW (See flap Fig.1)

1. HEADPHONE PLUG
Connect your headphone to listen to CD-DA discs (or tracks).

2. HEADPHONE VOLUME CONTROL
Turn the wheel to the right to increase the audio volume of your headphone.

3. WRITE INDICATOR
Lights "orange" when writing of a disc occurs.
Flashes "orange" during write emulation.

4. DISC TRAY

5. DISC IN/READ/ERROR indicator (dual color LED)
Lights "green" when a disc is present. Flashes "green" asymmetrically when data is being transferred from disc.
Flashes "green" symmetrically when starting up a disc.
Lights "red" upon error (e.g. after failed selftest).

6. OPEN/CLOSE KEY
Press the OPEN/CLOSE key to open the disc loading tray. To close the disc loading tray, push gently at the front of the tray or press the Open/Close key.

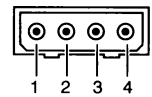
REAR VIEW (See flap Fig.1)

7. JUMPERBLOCK

With jumpers 1 to 3 the SCSI address is selected.
Jumper 4 for termination selection.

8. HOST DC POWER CONNECTOR (type AMP 00641737-1)

1: +12V
2: GND
3: GND
4: +5V

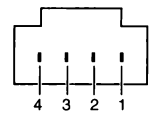


9. SCSI CONNECTOR (type MOLEX 70247-5005)

50 pin SCSI flatcable connector (for more information see p.13)

10. Audio line out connector (type: MOLEX 70555-0003)

1: Left
2: GND
3: GND
4: Right



LOADER (See flap Fig.2)

11. SERVICE FLAP

For service applications only.
Not to be opened by unauthorised people without further instructions from Philips or your supplier.

Switching on

When you have successfully installed the drive and established all connections, it is now time to switch on the host.

Loading and unloading a disc

Follow the instructions below. (see flap Fig.2)

1. To open the tray: Press the Open/Close key (6).

2. Load a (CD-R) disc, with the label facing upwards. The tray accommodates discs with 8 cm diameter (CD-Single) or the more usual 12 cm discs.

3. To close the tray, either push gently at the front of the tray or press the Open/Close key (6).

Note: for best results, use only empty discs qualified by Philips (PDO 63CDR or PDO 74CDR).
Note: don't use general purpose commercial head cleaning discs.

Switching off

Do not switch off the drive via the host after a successful write : either fixate the disc or eject it, else an incompatible disc is made.

Operating the CD-Recorder on the computer

Obviously, specific Application Software running on the computer platform in use, designed to work with the Philips CDD2000 CD-Recorder, must be used in order to be able to operate the CD-Recorder correctly. Refer to section "Host interface connections" for examples hereof.

SOFTWARE INSTALLATION

The installation and operation of the necessary software is dependent on the Host computer configuration in which the CDD2000 is to be used, e.g. PC's, Mini's, Workstations running MS-DOS, UNIX or other Operating Systems. Contact your supplier for the full list of supported host configurations and available software packages.

COMMAND DESCRIPTION

The following lists the supported SCSI commands. An extensive description of the total command set is available on request.

MESSAGES

* Following messages are implemented in the CDD2000:

Code	Description Directions
00h	command complete in
02h	save data pointer in
04h	disconnect in
06h	abort out
07h	message reject in out
08h	no operation out
0Ch	bus device reset out
80h+	identify in out

In = Target to initiator
Out = Initiator to target

* The following SCSI commands are implemented in the CDD2000:

Group 0 commands:

Opcode[a]	Command
00	Test Unit Ready
01	Rezero Unit
03	Request Sense
08	Read
0A	Write
0B	Seek
12	Inquiry
15	Mode Select
16	Reserve
17	Release
18	Copy
1A	Mode Sense
1B	Start / Stop Unit
1C	Receive Diagnostic Results
1D	Send Diagnostics
1E	Prevent/Allow medium removal

a. Opcode in Hexadecimal format

* Group 1 & 2 - ten bytes commands :

Opcode[1]	Command
25	Read Capacity
28	Read
2A	Write
2B	Seek
2F	Verify
35	Flush Cache
3B	Write Buffer
3C	Read Buffer
42	Read Sub Channel
43	Read Disc info
45	Play Audio
47	Play Audio MSF
48	Play Audio Track / Index
4B	Pause Resume
55	Mode Select
5A	Mode Sense

* Vendor Unique commands :

Opcode[1]	Command
D1	Read Disc ID
D2	Read OPC
D3	Write OPC
E2	First Writable address
E3	Format track
E4	Reserve track
E5	Read Track Info
E6	Write Track
E7	Medium Load/Unload
E8	Finish Track
E9	Fixation (write Leadin and Leadout)
EB	Send Absorption Control Errors
EC	Recover
ED	Write
EE	Read Session Info

ADDITIONAL INFORMATION

Care of discs

Whenever a disc is not in the tray or the drive, protect it from dust, ink, or other contaminant's.
Handle discs only by the outer and inner edges. When loading the disc, allow time for the door to open and then gently insert the disc.
Empty discs are separately available through your dealer.

Technical data

Performance

Capacity	
120mm disc	600 Mbytes/700 Mbytes
80mm disc	200 Mbytes
Access time average 1/3 data(1)	350 msec.
Access time max (1)	< 750 msec.

(1) After spin up, including latency and command overhead, at quadruple spead (only valid for reading).

Data-transfer-rate (recording/reading)	352,8 Kbytes/sec sustained (double speed, mode 2 data) 176,3 (single speed,mode 2 data)
Data-transfer-rate (read only)	705,6 Kbytes/sec (quadro speed, mode 2 data)
Max. burst rate	≥1,4 Mbytes/sec
Interface	SCSI 2
Form factor	5,25" Half Heigh
Data integrity from drive, assuming new discs	10^{-16}
Data buffer	1MB
Disc loading	Tray (motorised)
Dimensions	
Height	41.5 mm
Width	146 mm
Depth	206 mm
Weight max.	1 Kg
Power dissipation	max. 8 W
Environmental	
Operating temp (1)	5 to 40°C
Non operating temp	-25 to 70°C
Reliability	
MTBF (hours)	30.000 POH
Media	CD-R conf. "Orange Book" part II
Certification	FCC Compliance:Class B. UL, CSA,CEBEC. FDA-CDRH.

(1) ***Specifications for the "under pressure" case*** *(incomming air flow through the front bezel)* ***:*** *A flow of at least 2 l/sec. of air at maximum 40°, must be realised. This will be achieved by realising at least -180 Pascal of pressure difference between inside the apparatus and outside.*

Specifications for the "over pressure" case *(outgoing air flow through the front bezel)* ***:*** *A flow of at least 2 l/sec. of air at maximum 40°, must be realised. This will be achieved by realising at least +180 Pascal of pressure difference between inside the apparatus and outside. Additionally, the measured temperature of the bottom plate of the drive must not exceed 50°C.*

Remark: under an environmental temperature of the drive between 5 °to 30°C no airflow is necessary.

Electrical interface (front of drive)

- Headphone Jack
- RMS OUTPUT voltage: 3,1 V at 600 rΩ.
- Signal-to-Noise Ratio: 80 dB typ. A weighted.

Electrical interface (rear of drive)

- Audio line out: RMS OUTPUT voltage 1V at 47 K.
- Signal-to-Noise Ratio: 80 dB typ.A weighted.
- Data interface: 50 pin SCSI flatcable (see below)
- Power Supply: - voltage requirements: +12V (±5%) +5V (±5%)

- current requirements:	+12V	160 mA typ.
		200 mA max.
	+5V	1 A typ.
		1,5 A max.

Audio performance

Audio specification for line out:

	On pressed CD	On recordable CD
Output Voltage	1 V rms	1 V rms
Unbalance	max 0.25 dB	max 0.25 dB
Output Impedance	100 Ohm	100 Ohm
Amplitude Linearity	1 dB (20 Hz - 20 kHz)	2 dB (20 Hz - 16 kHz)
S/N-ratio	82 dB (87 dB A-wtg)	80 dB (85 dB A-wtg)
Total Harmonic Distortion + Noise	65 dB	55 dB
Outband attenuation	min. 50 dB above 25 kHz	min. 50 dB above 25 kHz
Channel separation	min 70 dB (20 kHz)	min 65 dB (16 kHz)
Muting level during random access	min. 90 dB (BW = 20 kHz)	min. 90 dB (BW = 20 kHz)

Audio specification for headphone:

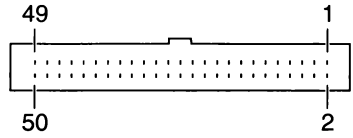
	On pressed CD	On recordable CD
Output Voltage (max volume)	3.1 V rms	1 V rms
Unbalance	max 0.25 dB	max 0.25 dB
Output Impedance	120 Ohm	120 Ohm
Amplitude Linearity	1.5 dB (20 Hz - 20 kHz)	1.5 dB (20 Hz - 16 kHz)
S/N-ratio	86 dB (88 dB A-wtg)	80 dB (85 dB A-wtg)
Total Harmonic Distortion + Noise	60 dB	45 dB
Outband attenuation	min. 50 dB above 25 kHz	min. 50 dB above 25 kHz
Channel separation	min 67 dB (20 kHz)	min 65 dB (16 kHz)
Muting level during random access	min. 90 dB (BW = 20 kHz)	min. 90 dB (BW = 20 kHz)

Note 1:
The somewhat reduced audio quality when playing back audio tracks on CD-r discs has NO RELATION to the DIGITAL QUALITY of the audio tracks as they have been recorded onto the CD-r disc.

Note 2:
This phenomena is caused by the playback decoding electronics inside the CD-r drive, when playing audio tracks on CD-r discs (caused by diffrent trackfollowing algorithm on the ATIP Absolute Time in Pregroove as exists only on a CD-r disc): the system will fall back to the lesser quality decoding known as 1-time oversampling. On pressed discs, the electronics uses the standard 4-times oversampling algorithm.

Note 3:
The analog output volume as specified above applies if the electronic attenuation in the playback circuitry inside the drive is non-operational, i.e. the electronic volumesetting is at 100%. However as is being recommended by the generic SCSI standard, the electronic attenuation is set to a default value of 25% at startup, meaning that only 25% of the maximum analog volume is supplied to the outputs. This attenuation can be changed by the appropiate software application.

Interface Pin Table



SIGNAL	PIN NUMBER
-DB(O)	2
-DB(1)	4
-DB(2)	6
-DB(3)	8
-DB(4)	10
-DB(5)	12
-DB(6)	14
-DB(7)	16
-DB(P)	18
GROUND	20
GROUND	22
GROUND	24

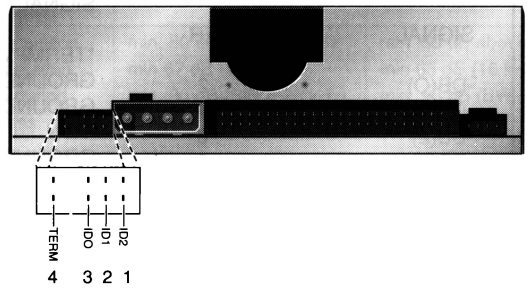
SIGNAL	PIN NUMBER
*TERMPWR	26
GROUND	28
GROUND	30
-ATN	32
GROUND	34
-BSY	36
-ACK	38
-RST	40
-MSG	42
-SEL	44
-C/D	46
-REQ	48
-I/O	50

* Note: This pin provides the terminator power (plus 5 volts).

Note: All odd pins except pin 25 shall be connected to ground.
Pin 25 should be left open but may be connected to ground.

Jumper settings

JUMPERS 1 TO 3 can be used for setting SCSI addresses.



1 = jumper installed

0 = no jumper installed

ID		0	1	2
ADDRESS	0	0	0	0
	1	1	0	0
(DEFAULT)	2	0	1	0
	3	1	1	0
	4	0	0	1
	5	1	0	1
	6	0	1	1
	7	1	1	1

TERM	1 = Termination ON (DEFAULT) 0 = Termination OFF

Remark: Jumper detection only by Power on or SCSI hand Reset.

Drive will always supply TERM POWER.

Drive will always generate parity on SCSI, and check.

Auto selftest

EXECUTION

- Selftest will be activated by pushing and holding EJECT button for one complete Open/Close cycle of tray
- At Host command : Send diagnostics.

VISIBLE EFFECTS

- At total selftest start:
  Green, orange and red will respectively light up for about 200 ms this will be repeated 3 times.

- At start of each individual test:
  The two LEDS will go on for 0.5 sec and then the test starts.

- During the test:
  The two LEDS remain on.

- At the end of an individual test: if the test was unsuccessful, the red error led will go on for 1 sec. If the test was successful, the green led will go on.

- At the end of the selftest:
  During 5 seconds, the orange and the green led will flash if the whole test was OK. In case of an error, the orange and the red light will flash during 5 seconds.

INDIVIDUAL TESTS

- Test internal processor RAM
- Test external SRAM
- Test EPROM
- Test DSP interface
- Test DRAM
- Test SCSI interface
- Test CDB2 interface
- Test datapath
- Test SRAM CDB2

CD-R: The Physical Structure

INTRODUCTION

Remark: Any unfamiliar expressions, used in this introduction, will be explained later-on.

The Compact Disk has become a widely used data-carrier.

In its most generic form it is used to hold Audio data on so-called CDDA disks (Compact Disk Digital Audio). That data is encoded onto the disk using a two-layered Error-Detection/Correction scheme (called First Layer Correction or C1 and Second Layer Correction or C2) together with data-scrambling and interleaving.

The data-encoding is done according to The Red Book, the World Standard to which ALL Compact Disks MUST comply. "ALL" means here: all CDDA disks AND all Data disks.

Above this Red Book Format, others are situated for Data disks. That disk-type is used in environments demanding an even higher data reliability. Therefore, a third Error-Detection/Correction is implemented, called Third Layer Correction or C3. Furthermore, a data-structure must be implemented to make easy data-retrieval possible.

The Data disks are described in several extra Books, each of them covering an area of data-application:

The Yellow Book: Covers CDROM and CDROM-XA Data Formats.
The Green Book: Covers CDI Data Formats and Operating System.

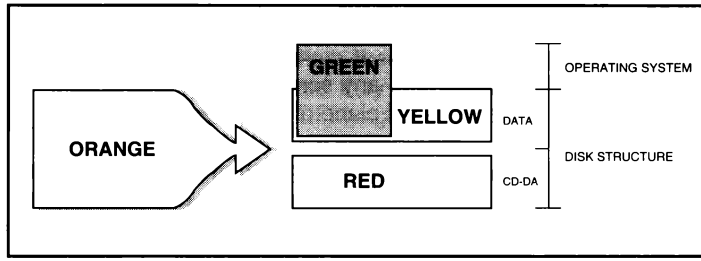
Next to the Red, Yellow and Green Books exists another one: the Orange Book. This book describes the format of the Orange Disk that is used in the Write Once systems like the CDD2000 Recorder.

This Orange Disk is NOT a disk among other Red, Yellow and Green disks. This disk initially contains no real data (except for some ATIP-code).

It doesn't even have a groove or tracks (although it does contain a pre-groove).

The reader should see this Orange disk as a "Chameleon"-disk that, when recorded onto, becomes Red, Yellow or Green after "Finalization", a special recording operation.

FIG. 5



This paper will describe the CD System, starting at the surface of the disk where the data is encoded in pits and moving up through the six layers to the carrier unit, the disk.

The complete logical data-structure above the level this paper ends with, is described in Part Two.

The six layers this paper will guide the reader through, are:

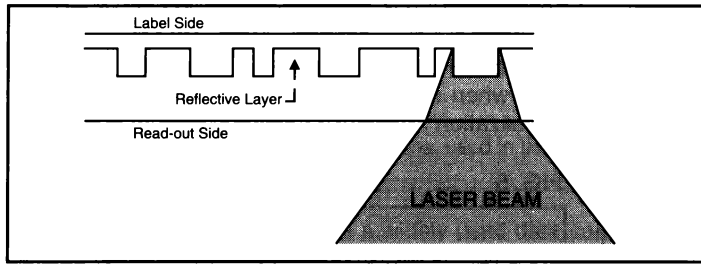
Layer One	: Physical structure.
Layer Two	: EFM Structure.
Layer Three	: Subcode Structure.
Layer Four	: Sector Structure.
Layer Five	: Track Structure.
Layer Six	: Session Structure.

Chapter 1. Layer One: The Physical Structure

All Compact Disks have the same physical structure. They are made of poly-carbonate and have a diameter of 12 cm.

The information is placed between two plastic layers. The layer at the read-out side is the thickest. This explains why, contradictorily, the side most sensitive to mechanical mistreatment is the label-side, since it has the information layer directly beneath it and is very thin.

FIG. 6

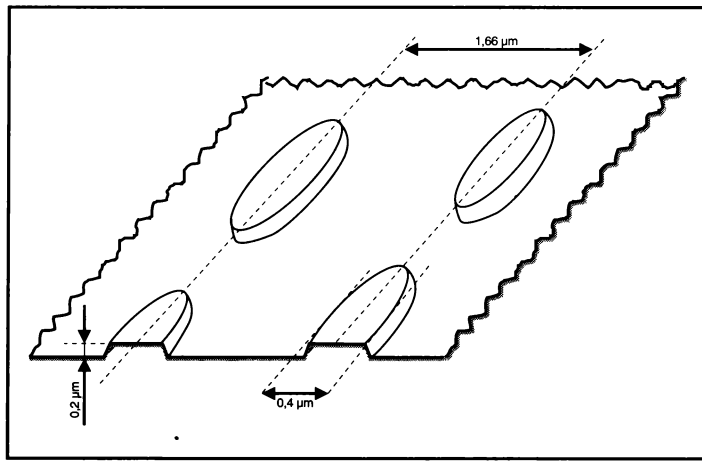


At read-out side any scratch or dirt on the surface normally lays outside the focal plane of the laserbeam.

The laser reads out the information by focussing on the reflective layer. When the laser hits a bump or pit, the laserlight is refracted and less light is reflected to the optical pickup. The reflected light is modulated by the either bumps or pits (depending on the physical structure of the disk).

This modulated light is transposed into an electrical signal that represents the string of bumps or pits read from the disk.

FIG. 7 Physical dimensions



Why bumps OR pits ?? A disk from a mass-production is stamped. Such a disk shows bumps on the tracks. With the recordable disks, the write-laser burns pits into the reflective layer. However, bumps and pits have the same optical effect on incoming laser light: it is refracted and thus less light is reflected.

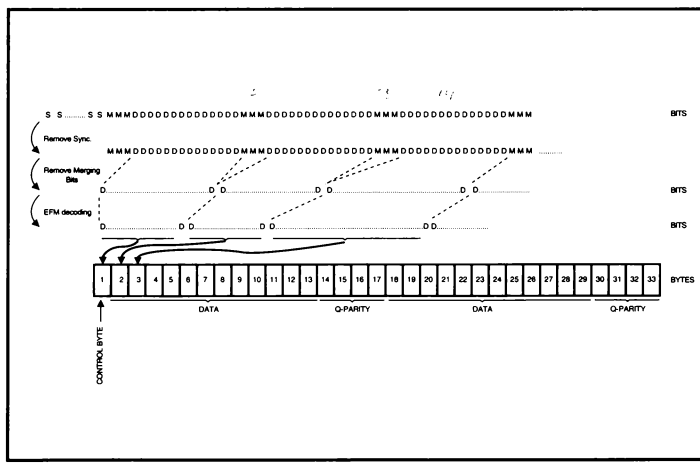
The bumps/pits are arranged in a string that is laid out in a spiral, running from near the center hole to the outer edge of the disk.

The data coming from the disk is concentrated in EFM-frames (EFM = Eight to Fourteen Modulation). One EFM-frame contains 588 bits: 24 Sync-bits, 14 bits per data-byte (there are 33 data-bytes), 3 merging bits per data-byte and 3 closing merging bits.

Sync Bits indicate the beginning of a EFM-frame. Merging bits are used to ensure that the minimum length of a bump/pit is three bits and the maximum length 11 bits. Merging bits are always inserted, even if without them the constraints, described above, would be met. In that case they are used to reduce the low-frequency contents of the EFM-signal.

After removing the EFM-Sync-bits and Merging-bits and after EFM-demodulating, the frames contain 33 Bytes: 24 databytes, 4 Q-parity bytes (for the C2 Error Correction), 4 P-parity bytes (for the C1 Error Correction) and 1 Control byte.

FIG. 8 EFM demodulating



The Control byte carries the SubCode data. Every bit of this byte represents one bit in one of the eight subcode channels (P, Q, R, S, T, U, V, W: see next chapter p 21 : The Subcode Structure).

The two sets of Parity Bits are used for error correction in two layers, C1 and C2. The Error Corrections act on the 32 data bytes, NOT on the Control Byte. That has been removed (see figure 9 p 21 in Chapter 3: The Subcode Structure).

The C1 Error Handling is used for recovery from random errors, originating from noise on the data. It restores missing databits, using redundant information in the P-Parity Bits.

The C2 Layer is used for burst errors, like scratches and dirt-spots on the disk that can disrupt whole strings of data. It depends on the data being scrambled over many frames at recording time. When read out, the data is descrambled, thus scattering the burst error. The now dispersed errors can be corrected frame by frame using the information in the Q-Parity Bits.

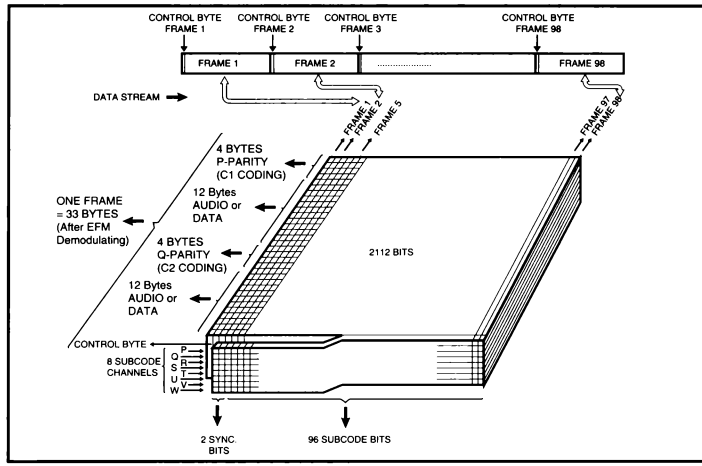
After all these actions (retrieval of the Control Byte, C1-decoding using P-parity bytes, C2-decoding using Q-parity bytes) frames of 24 bytes are obtained.

These 24-bytes-frames are the basic Audio Frames, coming at 7350 Hz rate. Every frame contains 6 Left Audio samples and 6 Right Audio samples, each 16 bits long (6 x 7350 =44100 Hz, the familiar value of the CDDA Sampling Rate)

98 of these Audio Frames form an Audio Sector, containing 2352 bytes of audio-data. The Audio Sectors come at 75 Hz rate.

The bytes of the Subcode channels P-W are formed by concatenating all bits from the corresponding position in the Control byte in the EFM-frame.

FIG. 9 3D-picture of subcode channel bits



Subcode channels also deliver data organized in frames. Each frame is built from 98 bits: 2 Subcode-Sync-bits and 96 data bits, the latter forming 12 Subcode bytes per Subcode Channel.

The Subcode frames have their own CRC-bytes, since the Subcode is added to the datastream after C1/C2 encoding while recording a disk and retrieved before C1/C2 decoding when reading a disk.

The main SubCode channels are P and Q.

The P channel indicates a pause between Audio- or data-tracks. It is a relic, called the Pause-flag, from the time that µ-processors in CD Players where not fast enough for real-time decoding of the subcode. It was used for very simple search algorithms.

The Q channel needs some more explanation. It contains all in formation regarding the organization of the disk at Red Book level.

The information in the Q channel depends on the part of the disk the laser is reading. The disk can be divided in three parts: a first part called Lead-In, a second part called Program Area and containing the user data, and a last part called the Lead-Out.

In the Program Area (the actual user data area) the Q channel carries info like Control, Address, Track No, Relative Time and Absolute Time. In total 96 bits plus 2 SubCode Sync bits.

Subcode Frame: Q channel

(S0,S1,CONTROL,ADR,<---------- Q-data ---------->,CRC)

number of bits → 1 1 4 4 72 16

S0,S1: Syncbits (form the Syncbyte together with other subcode channel Syncbits).

Control:
00X0: 2 audio channels without pre-emphasis
10X0: 4 audio channels without pre-emphasis
00X1: 2 audio channels with pre-emphasis
10X1: 4 audio channels with pre-emphasis
01X0: Data track
XX0X: Digital copy prohibited
XX1X: Digital copy permitted

These bits can only change during a pause of minimal 2 seconds or during Lead-in.

Address: Defines Q-channel Mode:
0001: Mode 1 Q-data, track/time information
0010: Mode 2 Q-data, disk unique catalogue number
0011: Mode 3 Q-data, music-track unique catalogue number

CRC: Since subcode is not subject to C1/C2 encoding, it uses its own Error Correction scheme.

The different Q-data modes allow to interleave three types of data in the Q-channel.

The Q-data Mode 1 must occupy in at least 9 out of 10 consecutive subcode frames. It is THE information needed for search actions.

The Q-data Mode 2 must, if present, occupy at least 1 out of 100 consecutive subcode frames.

The Q-data Mode 3 must, if present, occupy at least 1 out of 100 consecutive subcode frames.

Q-data format in Mode 1 (Time/Track)

	TNO	X	MIN	SEC	FRAME	ZERO	AMIN	ASEC	AFRAME
number of bits	8	8	8	8	8	8	8	8	8

TNO: Track Number, expressed in 2 digits BCD (8 bits).

During Lead-In : 00
During Program Area : 01-99
During Lead-Out : AA

X: Index to TNO, 2 digits BCD (8 bits).

During Lead-In : not available (See Chapter 4)
During Program Area : 01-99
00 during Pause encoding
During Lead-Out : 01

ZERO: 8 bits zero

MIN
SEC
FRAME: Track Relative Time, each 2 digits BCD (24 bits).
Time is ZERO at end of pause, decreases before pause and increases after pause.

There are 75 FRAMEs per second.

AMIN
ASEC
AFRAME: Disk Absolute Time, each 2 BCD digits.
Time is set to ZERO at the start of the Program Area.

The Absolute Time or Relative Time is used by the Servo µP during search actions. This is true for CDDA disks as well as Datadisks.

IMPORTANT REMARK: Some confusion may exist by the use of the FRAME-term in the Q-data. This FRAME (75 per second) is actually a Audio Sector (See end of Chapter 2 p 19 : EFM Structure) and NOT a Audio Frame, containing 24 audio data bytes.

The remaining channels R through W are free to be used for extra applications. Among possible applications are CD+G (Graphics on screen, teletext-like) and MIDI.

One of the advantages of the Compact Disk is fast access. In audio applications, only accurate positioning to the beginning of a song is required. This is done at Track level (see Chapter 5 p 28: The Track Structure).

For data applications, the data has to be accessible in much smaller blocks.

This is where the data-sectors come in. Data-sectors are data-blocks that carry extra information, e.g. sector identification number and sector type. In that extra info, we may also find EDC, Error Detection Code, and ECC, Error Correction Code, depending on the sector-type. These EDC and ECC are used in the Third Layer Correction.

The Sector Structure is placed on top of the Subcode Structure (in fact it is placed on top of the Red Book Standard). When it comes to encoding and writing to the disk, the information in a data-sector is handled just like that of an audio-sector, i.e. including EFM-coding, C1-coding, C2-coding, re-mapping and interleaving.

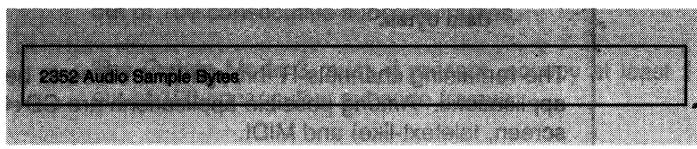
One sector contains 2352 bytes, which is precisely the size of one Audio Sector (remember, 98 Audio frames containing 24 bytes). We did encounter the number 98 somewhere else: one Subcode frame contains 98 bits per channel, being 12 bytes plus two Sync bits. This means that a Subcode frame and a Sector correspond one to one.

The basic data-sector always contains the following information:

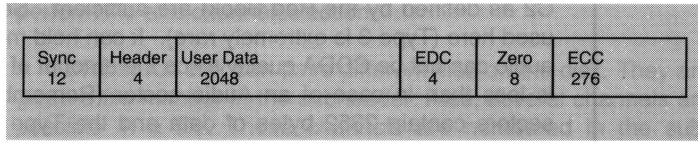
Sector Sync : 12 bytes (00 FF FF FF FF FF FF FF FF FF FF 00)
Header : 4 bytes

The remaining 2336 bytes are sector-type dependent. At this moment only five different sector-types exist (Audio sector included):

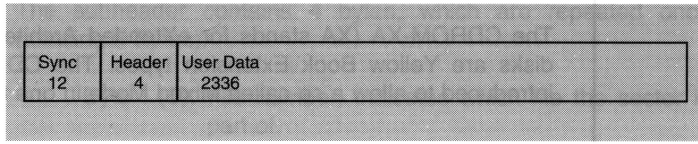
Type 1. Red Book Sector or Audio Sector:



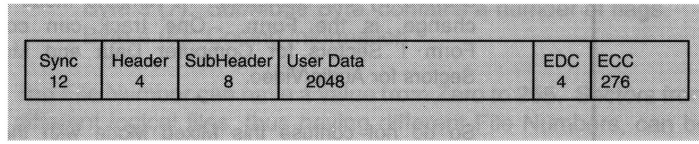
Type 2. Yellow Book Data-Sector Mode 1:



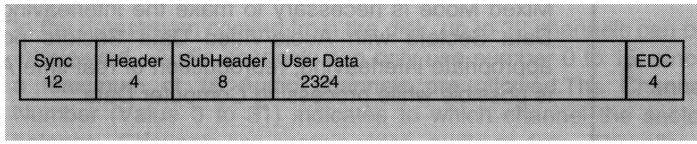
Type 3. Yellow Book Data-Sector Mode 2:



Type 4. CDROM-XA and Green Book Data-Sector Mode 2 - Form 1:



Type 5. CDROM-XA and Green Book Data-Sector Mode 2 - Form 2:



Type 1 is the Audio Sector, containing ONLY Audio samples. Type 2 through 5 are Data Sectors.

The use of the different Data Sector types can be divided in two families:

- Computer data use
- Compressed audio/video data use.

The computer data needs an extensive error-protection scheme, called the Third Layer Error Correction or C3, being on top of the C1 and C2 (described in Chapter 2 p 19: The EFM Structure) to increase the data reliability. This is performed with the EDC/ECC bytes (EDC = Error Detection Code, ECC = Error Correction Code). Sector type 2 and 4 are used here.

For video/audio data the first two error correction layers (C1 and C2 as defined by the Red Book) are sufficient. Sector type 5 is used here (Type 3 is extremely rare). It can hold more data. The audio can not be CDDA quality since the amount of data available is less than in case of an Audio sector (Remember: the audio sectors contain 2352 bytes of data and the Type 5 sector only contains 2324 bytes of data. In the first case the data rate is 176 400 bytes/sec, in the second it only is 174 300 bytes/sec).

The CDROM-XA (XA stands for eXtended Architecture) type of disks are Yellow Book Extension types. The CDROM-XA was introduced to allow a so-called Mixed Mode in one track .

> Remark: Mixed Mode is a somewhat confusing term, since the Sector Mode does not change within one track (this is not allowed by the Standard). It remains Mode 2. What does change, is the Form. One track can contain Mode 2 Form 1 Sectors for Computer Data and Mode 2 Form 2 Sectors for Audio/Video.
>
> So do not confuse this Mixed Mode with the Mixed Mode, described in Chapter 7 p 34, Disk Types.

Mixed Mode is necessary to make the interleaving of Computer Data Sectors with Audio/Video Data Sectors possible. With appropriate interleaving, reproduction of real-time Audio or Video is possible while processing Computer Data.

Although the CDROM-XA sectors have the same configuration as the Green Book sectors, the disks are not the same. CDROM-XA is a disk defined by the Yellow Book, that only defines a disk layout. The Green Book disks use the same sector layout, but the Green Book not only defines a disk but also the Operating System.

The header information is used to search a specific sector. The header contains 4 bytes:

Byte 1: Minutes (copy of the AMIN value from the Q channel)
Byte 2: Seconds (copy of the ASEC value from the Q channel)
Byte 3: Blocks (copy of the AFRAME value from the Q channel)
Byte 4: Mode (8 bits), value decimal between 0 and 2.

The CDROM-XA type of disks use the subheader information to perform file and channelselection.

A CDROM-XA disk can have different files on the disk. They are given a file number in the subheader. Also, several channels are possible in a file. These channels are numbered in the sub-header.

The subheader contains 4 bytes, which are repeated once (totalling 8 Bytes):

Byte 1 (5): File number, indicates which file the sector is part of.
Byte 2 (6): Channel number, indicates which channel the sector is part of.
Byte 3 (7): SubMode Byte, contains a number of flags.
Byte 4 (8): Coding information

The File Number can have a value from Zero to 255. Sectors from different logical files, thus having different File Numbers, can be interleaved. This is NOT true for File Zero, which is a file whose sectors must be placed consecutively on the disk.

In the datastream coming from the disk, up to 32 channels can be interleaved. Audio channels can only use number 0 to 15, since a maximum of 16 Audio channels are allowed.The Channel Number (Value 0 to 31) indicates to which channel the sector belongs. Channels can contain video, audio or data. This allows to have e.g. multiple audio/video channels in the datastream.

Lets take an example:

> The disk contains the data to reproduce a series of pictures on a TV-screen and to explain them in four, selectable languages. All this information is stored in the sectors of a file on the disk. The video data is stored in channel 0, language 1 in channel 1, language 2 in channel 2, language 3 in channel 3 and language 4 in channel 4.
>
> The data is read from the disk. The sectors with Channel Number 0 in the subheader will be directed to the video processing circuitry. Channel number 1, 2, 3 and 4 are directed to the audio processing circuitry. There, according to which language was selected by the user, one of the four channel is used to generate audio.

There are 16 audio channels, they can have channel number 0 to 15. The video and data channels can be located on numbers 0 to 31.

The Submode Byte contains flags used to indicate the properties of its sector (like Data sector, Audio sector or Video sector).

The Coding Information Byte indicates how the information in that sector is encoded. Its contents must be interpreted differently, depending on the Subcode Byte flags.There are Audio coding formats, Video coding formats and Data coding formats.

For more information about the Subheader contents, see the Green Book, Appendix A II.

Chapter 5. Layer Five: The Track Structure

Tracks are units built from sectors that have the same Mode. No Mode Mixing is allowed on any type of disk, within a track.

In CDDA, tracks contain one song. The access of the songs is done by track-jumping. This is the basic data-unit in CDDA (there is a sub-unit, called the Index and given in X in the Q-Data, See chapter 3 p 21: The Subcode Structure)

Each track can start with a optional pre-gap of 2 seconds digital silence.

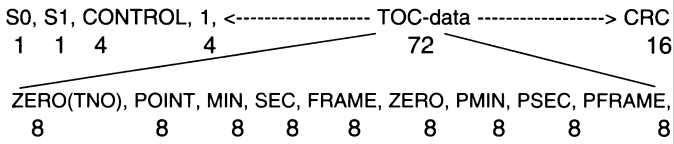
Tracks also exist on Yellow and Green disks. The color of a track may not change within the track.

Intra-track time is given in the Q channel by MIN, SEC, FRAME and is known as Relative Time. It starts at 00 seconds at the first non-silence audio sample.

Inter-track or disk time is also given in the Q channel by AMIN, ASEC, AFRAME. It is known as the Absolute Time and runs over trackboundaries.

To know where all the tracks start on the disk, a Table Of Contents, also called the TOC of the disk, is placed in the Q channel during Lead-In. The Main data contains digital silence.

TOC Q Channel Data



POINT: Gives the track number whose starting time is given in the PMIN, PSEC and PFRAME of the same subcode frame.

MIN
SEC
FRAME: Gives the relative time inside the Lead-In.

PMIN
PSEC
PFRAME: Are the starting point, in Absolute Time, of the track pointed to by POINT. Since the tracknumber in POINT is BCD encoded, a maximum of 99 tracks can be placed on a disk.

Every subcode frame is repeated three times with the same Q-data.

The complete TOC is repeated until the end of Lead-In.

POINT also has three special values in the TOC: A0, A1 and A2.

For the Red Book (CDDA):

POINT = A0	PMIN	= TNO of first piece of music
	PSEC	= Zero
	PFRAME	= Zero
POINT = A1	PMIN	= TNO of last track on disk
	PSEC	= Zero
	PFRAME	= Zero
POINT = A2	PMIN	= Abs. Time of Lead-Out
	PSEC	= Abs. Time of Lead-Out
	PFRAME	= Abs. Time of Lead-Out

For the Yellow Book (CDROM):

POINT = A0	PMIN	= TNO of first datatrack on disk
	PSEC	= Zero
	PFRAME	= Zero
POINT = A1	PMIN	= TNO of last datatrack on disk
	PSEC	= Zero
	PFRAME	= Zero
POINT = A2	PMIN	= Abs. Time of Lead-Out
	PSEC	= Abs. Time of Lead-Out
	PFRAME	= Abs. Time of Lead-Out

For the Green Book (CDI):

POINT = A0	PMIN	= Number of CDI-tracks on disk + 1
	PSEC	= 10 (BCD)
	PFRAME	= Zero
POINT = A1	PMIN	= TNO of last audiotrack on disk or idem PMIN of A0, meaning no audiotracks
	PSEC	= Zero
	PFRAME	= Zero
POINT = A2	PMIN	= Abs. Time of Lead-Out
	PSEC	= Abs. Time of Lead-Out
	PFRAME	= Abs. Time of Lead-Out

When a disk is read-in, the TOC is loaded into memory of the drive-unit. From there-on the servo-µP knows exactly where it is on the disk by reading the Subcode.

The CD reader unit does not make a distinction between all the different disk-colors. As far as the unit is concerned, the Red and the Yellow disks are the same. It knows about three disk types: Red/Yellow, Green and Bridge, which is Green combined with Red and/or Yellow. The distinction is made with the PSEC value when POINT = A0:

Red/Yellow:	PSEC	= 00 (BCD)
Green:	PSEC	= 10 (BCD)
Bridge:	PSEC	= 20 (BCD)

(For Bridge Disk, see Chapter 7 p 34: Disk Types)

The non-distinction between Red and Yellow is used with Mixed Mode Disks (see Chapter 7 p 34: Disk Types). To prevent computer data to reach the loudspeakers, the third bit in the CONTROL field of the Q channel is used: Zero for Audio, One for Data (see Chapter 3 p 21: the Subcode Structure).

All jumps and searches are done using the Subcode. This is true for all disk-types, whether Audio-disks or Data-disks. Data-disks have a special search algorithm on top of the Subcode search. We will come back to this later.

Chapter 6. Layer Six: The Session Structure

We have learned about Table Of Contents (TOC), Tracks, Sectors, Subcode. All of these elements form the block of information on the disk. The only thing needed to complete such a block is a Beginning and an Ending, which we had our first encounter with in Chapter 3 p 21: Subcode Structure.

In the Beginning there was ... the Lead-In. This is a piece of information, laying before the first track. It contains the TOC plus other miscellaneous info like the disk-label, a unique disk ID number (unique to the contents of the disk, i.e. same contents = same ID), all stored in the Subcode channels.

This Lead-In is described in the Red Book Standard. It starts at a fixed radius of the disc. The info is stored in the Subcode Channels only. The Data Sectors contain digital silence.

To indicate the end of an information block, it is closed with an Ending, called the Lead-Out. The Lead-Out contains a LO-code in its Subcode (TNO = AA).

An Information Block with its LI/TOC and LO is called a Session. Until 1990, a Session was the same as a disk, i.e. a disk could contain only one Session.

In 1992 the first CD Recordables (CD-R) arrived on the market. This is where the Orange Book was proposed by Philips (See introduction p.1). So, before we continue, let us meet this CD-R.

> Since the first years of Compact Disk Audio, many dreamed of recordable CDs. The Compact Disk was and is the perfect medium to store Audio and, later, Data. It was reliable, of high quality and very stable.

The only problem was its manufacturing process using molds to stamp the disks. Small quantities couldn't be produced, let alone piece-wise reproduction.

In 1992, Philips introduced the CD Recordable. With it came a new Standard, The Orange Book. The CD-R makes it possible to record data and audio on a special disk. It does not allow ERASURE of info. Once written, no way back.

That special disk when BLANK has none of the elements we just discussed: No Tracks, Subcode, Lead-In, Lead-Out or Sectors. It doesn't even have a groove, since there are no pits (Precisely these are to be recorded !).

Of course, it does have a structure (the CD-R has to know where it is on the disk, even when its blank). On that disk you'll find (or at least the CD-R will) a PRE-GROOVE. This Pre-groove is a small, continuous, undeep gutter, laid on the disk in a spiral form (like the original string of bumps on a stamped disk).

The spiral form of the pre-groove exhibits a small jitter that, when the disk is rotated at the correct linear velocity, has a frequency of 22.05 KHz. This Wobble, as the jitter is called, is used by the CD-R for speed control and pre-groove tracking.

The CD-R needs more than that to know were it is, so the 22.05 KHz Wobble is FM-modulated with time information, the so-called ATIP (Absolute Time In Pre-groove). This time runs continuously from the beginning to the end of the pre-groove.

For the application of the CD-R, it is clear that the user does not need to record the whole disk at once (the so-called DAO mode, for Disk At Once), as this would demand a pre-storage medium able to contain the disk's capacity. Instead, it is preferable to record track-wise, called the TAO mode for Track At Once. Another way of recording, is the Incremental Write, a mode where the recording can be done sector by sector.

Between the recording actions, it could be necessary to read back some of the data to check for errors. It might even be necessary to remove the disk from the recorder and continue recording some other time.

With an unfinished recording of the disk however, the TOC can not be written to the disk. So to keep track of all data recorded a kind of pre-TOC, called PMA (Program Memory Area), is written to the disk on an area that is only accessible by the CD-R.

When the user has finished all recording, he has to "transmute" the disk for use in a non-CD-R reader unit like a CDDA Player, CDROM/XA Drive or CDI. Those units can not cope with pre-groove, ATIP and PMA. They respectively need a Red, Yellow or Green Book disk. These standards not only require normal tracks, but a Lead-In with TOC and a Lead-Out also.

To "transmute" the disk, the user can FINAL FIXATE a disk or FIXATE a disk. When the CD-R receives this command it will write Lead-In (with TOC) and Lead-Out to the disk (for which place is reserved on the disk). From that moment on the disk conforms to the Red, Yellow or Green Book, depending on the type of information recorded on the disk.

However, it is important to note that the FINAL FIXATE command will not write a special pointer to the next session in the lead-in of this last session. This indicates to the CD-R that no more Sessions may be added after this last one.

If the user wants more information added, e.g. Photo-CD where a new load of photos from the last holiday must be added to those of previous trips, the FIXATE command must be used instead. During FIXATION, the Lead-In is written to the disk with a pointer to the start-position of the next Session (that does NOT have to actually exist). In the same action, the Lead-Out is written to the disk with a pointer to its own Session-start.

To summarize:

> The user wants to record a Session, and to leave open the possibility to record another after this one: the FIXATE command should be used to make the disk Red/Yellow/Green Book compatible.
>
> The user want to record a Session, and does not ever want to record another Session after this one: the command used should be FINAL FIXATE.

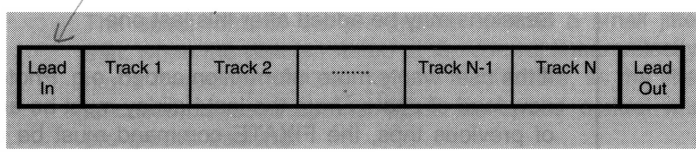
Adding a Session after the previous one is no problem for the CD-R. For the reading units (CDROM, Photo CD etc), however, something changed. Where they first had to suppose only one Session per disk, now more Sessions per disk are possible.

Philips' Multi Session CDROM drives search for all Sessions by scanning the disk until the servo electronics detects it skated right into the pre-groove area after the last Session. It returns to the last Session and uses the pointers in the Lead-Out and Lead-In to find its way in the Session Structure.

Chapter 7. Layer Seven: The Disk Types

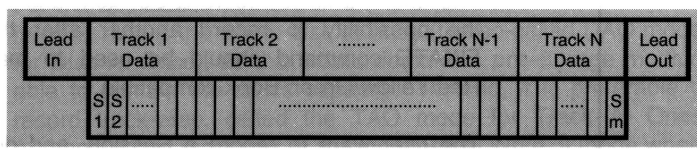
With the five sector types as described in Chapter 4 p 24: The Sector Structure, different disk types can be generated.

A. The first is the well-known CD-DA or Audio CD disk. It contains tracks with Audio sectors (Type 1) only. This is the disk defined in the Red Book.



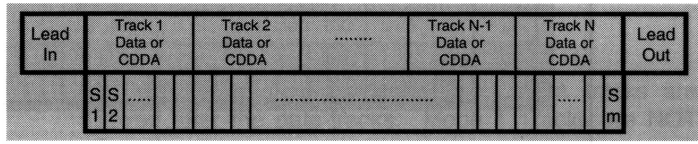
B. The second disk is the CDROM. This disk is defined in the Yellow Book. It breaks down into two subtypes: The CDROM Mode 1 and the CDROM Mode 2.

The Mode 1 disk has tracks with only Type 2 data sectors. The Mode 2 disk contains only tracks with Type 3 sectors.



NOTE: Normally Mode 2 disk are always XA disks (meaning they have Type 4 or Type 5 sectors). The Mode 2 non-XA disk (with Type 3 sectors) is extremely rare. It can be read by a normal CDROM drive, but requires special custom software to decode and interface.

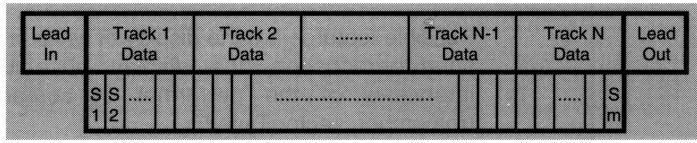
C. A disk with a combination of CD-DA tracks and CDROM tracks, is called a Mixed Mode disk. The most common Mixed Mode disk has a CDROM track as the first track and CD-DA on next tracks.



Normally, CD-DA players mute the audio output when encountering a CDROM track.

D. Newer, multimedia applications require real-time simultaneous reproduction of video and/or audio while reading computer-data. This can not be done with the Mixed Mode disk since track jumping takes to much time.

Therefore, a new disk was created: The CDROM-XA Mode 2 (see note under B). This CDROM-XA Mode 2 also Breaks up into two types: the Mode 2 Form 1 and the Mode 2 Form 2.



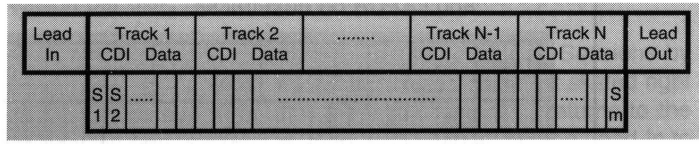
The Mode 2 Form 1 has Type 4 sectors and is used for computer data. The Mode 2 Form 2 has Type 5 sectors and is used for compressed audio/video.

These two sector types can be interleaved on one and the same track without breaking the rule that a track can only contain one Mode. This allows for multimedia applications. It does require special interface electronics to separate the different sector types in real-time.

E. Green Book or CD-I disks are disks which comply with the Green Book Standard that not only defines the disk but also the Operating System.

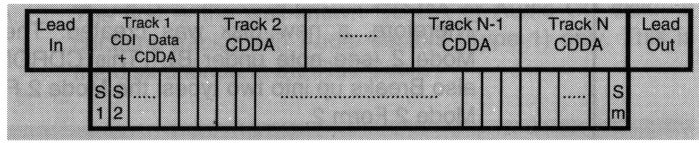
CD-I tracks are built with the same sector type as CDROM-XA, Type 4 and Type 5. These both types are interleaved for the same reason as in point D.

The only difference, at disk-level, between a CDROM-XA and a CD-I track is that the latter is not listed in the TOC of the disk.



F. CD-I Ready Type I disks are special CD-DA disks. CD-DA disks have a 2 second of audio silence in the pre-gap before the first track. Audio players skip this pre-gap.

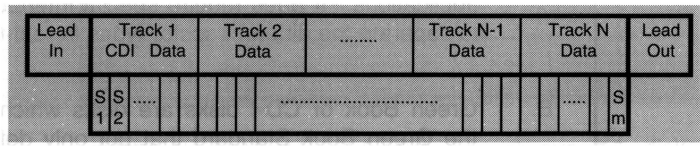
The CD-I Ready Type I disk has an extended pre-gap where CD-I information is hidden. An Audio player will normally not notice this CD-I information, but with a CD-I player extra features can be accessed this way.



Possible features are the display of lyrics or credits during song-reproduction, the display of album-covers or interviews of the performer in compressed audio (remember, sector Type 5).

Unfortunately, older CD players did not mute the pre-gap. If you ever heard CD-I data through loudspeakers, you will understand this CD-I Ready Type I was not useable.
So ....

G. In order to be able to have a disk playable on CDROM-XA unit and on CD-I player, the CD-Bridge disk was created.



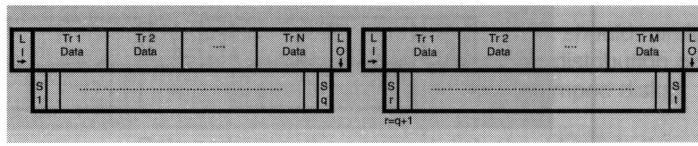
Here the first track is a CD-I track. For the CDROM-XA unit the data starts at another point than for the CD-I player. The difference is made in the disk label which points to the beginning of the computer-data.

For the CDROM-XA the label is specified to be located at 00 mins, 02 secs, 16 sectors and byte-offset 1024. For the CD-I the label is to be located at 00 mins, 02 secs, 16 sectors 0 byte offset.

Example: Photo-CD

All data tracks must be Mode 2. CD-DA tracks are allowed after the data-tracks. Mode 1 Tracks are NOT allowed.

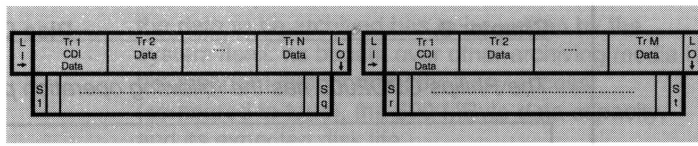
H. CDROM Multi Session.



→ is the pointer to the next Session.

↓ is the pointer to the present Session.

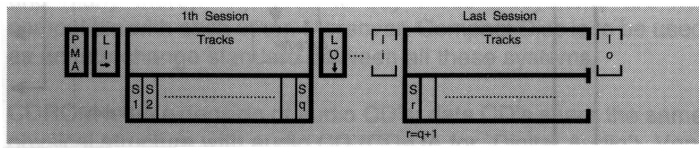
I. CD Bridge Hybrid.



→ is the pointer to the next Session.

↓ is the pointer to the present Session.

J. One Session fixated Disk (Orange Book).

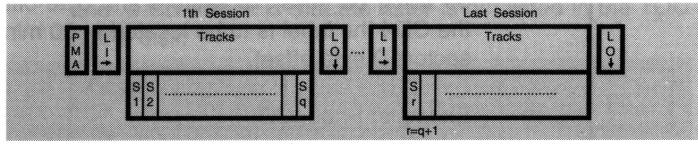


The 'li' and 'lo' indicate that Lead-In (LI) and Lead-Out (LO) have not been actually written on the disk (the disk is not Final Fixated).

→ is the pointer to the next Session.

↓ is the pointer to the present Session.

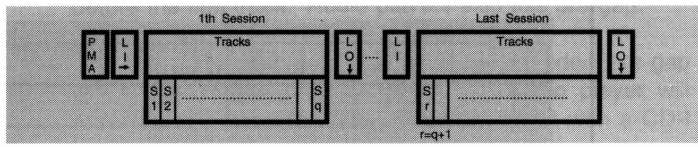
K. Fixated Disk with more Sessions (Yellow or Green Book).



→ is the pointer to the next Session.

↓ is the pointer to the present Session.

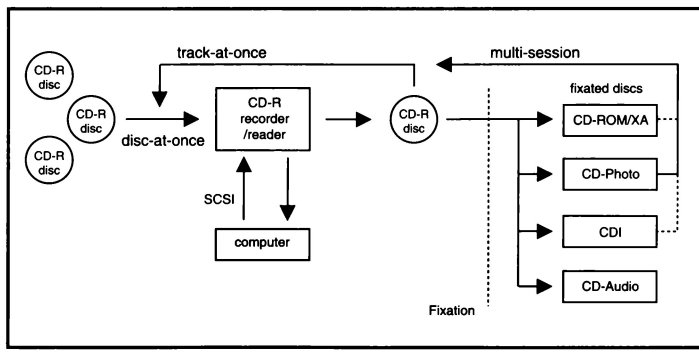
L. Final Fixated Disk (Yellow or Green Book).



A final fixated disk carries no → pointer in the last lead-in. This indicates to the CD-R that no Sessions may be recorded after the last one.

Chapter 8. Disc Overview Map

The Philips CDD2000 has the following operation possibilities



APPLICATIONS FOR CD-RECORDABLE

From the applications point of view, data is to be organized so that it can be easily accessed, either by man or machine.

There is a large variety of applications, each of them relies on specific characteristics of the medium. They all have to be covered by the same system. Some of these applications are:

- Software Distribution: the compact disc should mimic the target filesystem. The benefit over distribution on tape is the small reproduction cost (stamped disks).

- Data archiving: the compact disk should mimic the target filesystem as above, but in addition features "data appendability", i.e. the possibility of appending new data at various points of time, without loosing the previous data. This type of applications would use CD-R (Compact-Disc Recordable) discs, since the data to be archived has to be written by the system itself. Its benefit over other archiving media is the standard interchange, the easy access (compared to tape), the 600 MByte data capacity, and its expected disk life.

For these applications, a compact disc mounted on a CDROM drive to some computer system should look as the hard-disk does. The problem here is that there are lots of computer systems, each with its own filesystem structure (MS-DOS, OS/9, Unix, VAX/VMS, and many more). Needless to say these filesystems are not compatible with each other. Moreover, Compact Disc is to be used as an interchange standard between all these systems.

CDROM is an extension of audio CD's: data CD's share the same physical structure with audio CD (CD-DA for `Digital Audio'). Very soon, CDROM was extended with all kinds real-time data such as CD-DA (Real-time, since you have to process the audio as it is produced: no way to buffer). Besides "Red Audio" as found on CD-DA (standardized in the Red Book), other real-time files, such as adpcm (audio with selectable compression factor and quality level), or MPEG full motion video emerged.

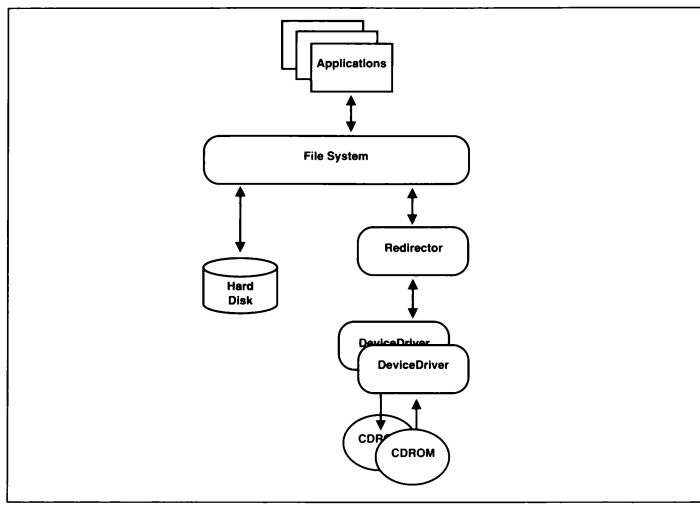
These real time files can be either accessed via the filesystem as ordinary files, or can be "played", i.e. processed to the real time output device. A standard for these real-time files is set in the CDROM XA (eXtended Architecture) spec.

This evolution ended in a new range of applications: Multi-media. CD-I. (Compact-Disc Interactive) is one of these. It is basically a device capable of playing various interleaved real time files. It assumes the program files on the disc to be written following a standard, set in the "Green Book". Other multi-media applications include MPC, with focus on the MS-DOS computer platform.
As CDROM pretends to be a interchange standard, the central issue becomes Logical Playability, i.e. the need to process any application on any platform, to the limits of its physical possibilities. Hence, a common Logical Structure is introduced, which enables the interchange from platform to platform to a certain degree.

ISO 9660 FILE SYSTEM

All computer platforms address the data on the compact disk as a file system. The file system was designed to be common to Unix, VAX/VMS and MS DOS, and their various derivates. As such, it was standardized as ISO 9660. The ISO proposal originated from a conference in the High Sierra Hotel in Nevada. It is also known as the High Sierra Filesystem.
To be accessible on the computer system, you need a platform specific redirector (see Figure 10.) MSCDEX is most famous: it interfaces the CDROM file system to MS-DOS.

FIG.10 Redirectors and device Drivers



Note also the device specific Device Driver: two different CDROM players can be attached to the redirector. In a CD-Recorder application, you may want to use a (multi-session) CDROM player and a CD-Recordable device at the same time.

ISO 9660 is meant to be compatible with various operating systems. This is done by using the common capabilities of all target systems. Some of the most constraining rules are:

- no directory trees of depth > 8
- no long filenames The filename and its extention must be less then 30 characters. However, for use in MS-DOS, this is even more limited to 8 characters for the file name, and 3 characters for the extention
- No extensions for directory names.
- Uppercase characters only
- Finally, no "odd" characters (such as % or @) are allowed.

In the table, some ISO 9660 invalid files are given, together with the reason why they are invalid.

Table 1: Invalid ISO 9660 files

File Name	Why Invalid	OK would be...
MYDATA.EXTENSION	Extension longer than 3 chars	MYDATA.EXT
MYDATA.EXT.EXT	Extension longer than 3 chars	MYDATA.EXT
mydata.ext	uppercase only	MYDATA.EXT
AVERLYLONGFILENAME.DAT	name too long (> 8)	SHORTNAM.DAT
!@#$%.dat	No "Odd" characters.	MYDATA.DAT
CD-R.DIR (for a directory)	No extension for directories	CD-R
/A/B/C/D/E/F/G/H/I/J/DATA.DAT	Directory tree >8	/A/B/C/D/E/F/G/H/ DATA.DAT

The ISO 9660 is designed for publishing data on stamped disks. For this application, you may want maximum portability from platform to platform, at the price of a careful layout of the data structure.

Although small-volume publishing on CD-Recordable is an issue, some CD-Recordable users would like the CDROM filesystem to be more "liberal": CDROM must mimic the host filesystem completely. Clearly this would reduce the possibilities to interchange between platforms (although the platform-specific redirector could fix some problems).
With this in mind, the ECMA 168 "Frankfurt Proposal" filesystem is designed to be used with CD-Recordable, and features more liberal naming (in addition to the possibility to append data — (see "Appending Data to on ISO Set" p 39).

As the Frankfurt Proposal is still in the standardization process, the only way today to mimic the file system, is to make the native filenames with ISO 9660 in mind.

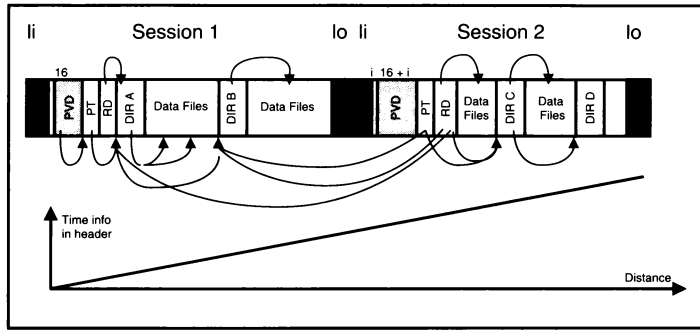
ISO SETS

On a CDROM disk, there is at least one file system. As with hard disks, there could be more than one partition of the CDROM, each of them containing one and only one file system. There are various ways to partition the CDROM. To avoid multiple (and hence incompatible) implementations of the same feature, these possibilities are limited to a very few.
Partitioning the disks into ISO Sets should always be done by using Sessions. A Session is a Leadin + a Program Area + a Leadout — (see "The Physical Structure" p 16). Although a single ISO set can be extended over more than one session, one particular session can never contain more than one ISO set.

An ISO 9660 Set is characterized by the following elements:

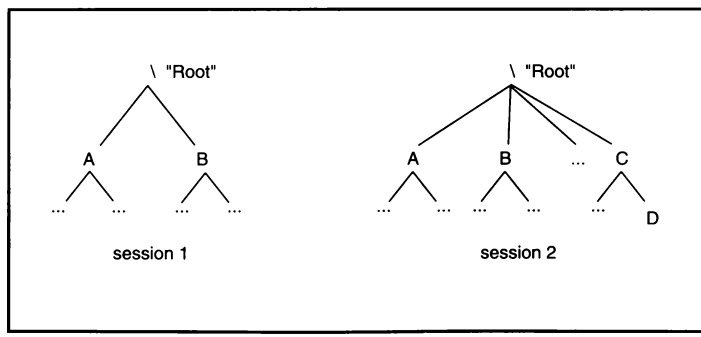
- a Primary Volume Descriptor (PVD). It can always be found at the 16th sector on the session. It is the hook of the filesystem to the medium. It refers to the Path Table, and to the Root Directory.
- The Path Table (PT). It contains the addresses for the Directory Files. As such, it is used to directly access the data files.
- The Root Directory (RD). This is a special Directory File, in that no other Directory file refer to it.
- The Directory Files (DF). It contains the addresses to its subdirectories and datafiles.As such, it is used to descend through the directory trees.
- The datafiles contain the actual data.

FIG.11 ISO 9660 set over multiple sessions



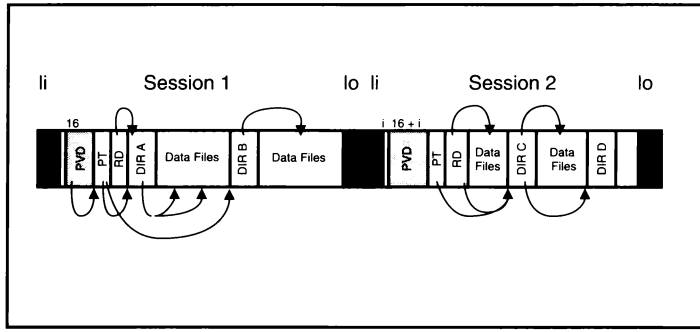
In Figure 11, there is one single ISO file system over two separate sessions: the PVD, Path Table and Directory Files are allowed to refer to data recorded in a previous session. Please note the arrow from the root directory of the second session to the directories in the first session. This makes directory "A" and "B" known as a member of the file set in the second session. In Figure 12. the file sets of session 1 and session 1+2 are given.

FIG.12 Directory trees for the above



The key in this approach is the fact that all addressing is done absolute over all sessions. Addresses of the sectors are unique: numbering of the sectors continue over the sessions, as shown in lower half of Figure 11. This allows the extension of one iso set over more session.

FIG.13 Disjunct ISO 9660 sets in multiple sessions



In Figure 11, the recorded ISO sets remained Disjunct: the ISO set in session 2 does not refer to any member of the set in session 1. Disjunct ISO sets need to be selected. To do so, one needs a selector. On MS-DOS, you may want to type "E:\", "F:\" and so on, the same way you select partitions on Hard Disks. Currently, this is not possible with MSCDEX. In the mean time, a separate selector is to be supplied which interacts with the Device Driver, both on the writing (orange) system as on receiving systems (possibly Yellow-Book readers)..

Selectors make sense for multi-session ISO sets too. Suppose we had written a directory tree in a first session, as in Figure 12 on page 39. In the next session, we want to update one of the files in directory A. Since we have a write-once medium, we cannot erase files. What we can do however, is to copy the ISO structure (PVD, PT, RD and DF's) from session 1 to session 2, with a slight modification: now DIR A contains a reference to the new data file Session 2. Now the path to the original data is lost. To the user, the data file appears to be updated. However, you can select session 1 with the selector. After this, the original data will reappear inspecting the contents of directory A.

APPENDING DATA TO AN ISO SET

One way to append data to a disk is session by session, as discussed above. However, sessions serve another purpose: they are ment to make the disk "Yellow", i.e. write Leadin and Leadout, cfr Physical Structure on page 12, thus writing the TOC for this session. This action is referred to as "finalizing". By finalizing, the CD-R disc becomes readable on standard CDROM readers. Following the orange book, finalizing takes a couple of minutes for the leadout and leadin (20 MByte!) to be written.

The entire discussion in section (ISO SETS) on page 40 is done from a "yellow" point of view: it focusses on the result, after finalizing. The process of putting the data on the disk must be discussed from an "Orange" point of view. Physically, data can be added with various degrees of "granularity". This granularity corresponds with the physical structure defined in the orange book: sectors are enclosed within tracks, tracks are enclosed within sessions, and sessions are enclosed within the disk. The coarser the granularity, the easier the write process is, but the larger the data buffer needs to be.

- Disk by disk: "Disk-at-Once". All data are available on-line, and the entire ISO-structure is prepared.
- Session by session: "Session-at-Once". The data for the session to be recorded are available on-line, and its ISO-structure is prepared.
- Track by Track: "Track-at-Once". The ISO structure is implicitly present on the disk. At the moment of finalization, it is completed with the final ISO structures, and the "hook" on sector 16 (the PVD — see ISO SETS on page 40) is written.
  Until that moment, the data on the disk is not yet standardized, and can only be accessed by the particular publishing application.
- Sector by sector: "Incremental Write". The limitations of the above are relieved, but it can't be implemented using the ISO structures, as their references change for each written sector. Incremental Write is implemented by the ECMA 168 "Frankfurt Proposal" file system, and requires a new redirector for yellow-book compatibility after finalization.

As shown above, the granularity has also compatibility implications towards yellow book players (i.e. standard CDROM readers)[1]:

- Sector by sector disks are presently incompatible, and require a ECMA 168 redirector to be installed on the yellow book player.
- It matters wether there are one or many sessions: a single session player will only "see" the first session of a multi session disk.

1. According to the yellow book, all tracks must be mode 1. Run In/ Run Out/ Link sectors do not comply with the mode 1 format. Hence, pure yellow-book readers will produce an error on these sectors. However, recent cd-rom players will process these sectors without error.

- It matters wether there are one or many tracks. If there is more than one track:
  - You have to watch for mixed-mode sessions (see Physical Structure on page 16)
  - The ISO structures are application dependent.

The "granularity vs finalized compatibility" can be summarized in the following tables:

Table 2: Sessions and Tracks

SINGLE ISO-SET	Single Session	Multi session
Single Tracks Multi Tracks	Disk-at-once (1) Netscribe (3)	Photo CD (2) CD-Write (4)

Table 3: Logical Playability of the sessions

Disk types Players	1	2	3	4	Frank - furt[a]
Yellow	All	First	All*	First*	None
Yellow Multi Session	All	All	All*	All*	None
Orange	All	All	All	All	All

a: There are currently no Frankfurt Proposal players on the market. This table however reflects the PHILIPS policy.

**: the tracks have to be recorded on an ISO 9660 compatible way: no mixed-mode, valid ISO structures.*

Basic principles of CD-R media

A blank CD-R disc is divided into the areas shown in Figure 14 p.47. This differs from a prerecorded disc by the additional CDR area, which lies in front of the lead-in area.

A cross-section through a CD-R disc is shown in Figure 15 p.48. The disc comprises four different layers.

Transparent plastics material (the same as conventional CD's) is used as the substrate. Onto this a special greenish tinged translucent layer is applied. The substrate has already been provided with a preformed track spiral into which the data will be written during recording. On top of the green recording layer is a reflective gold layer and a protective layer of plastic material.

THE ADDITIONAL CD-R AREA OF A CD-R DISC.

The additional CD-R area is divided into two areas:

1) The program Memory Area (PMA) which mainly contains, the track numbers of the titles recorded with respective start and stop points.

2) The Program calibration Area (PCA). Disc space for the CD writer to calibrate the laser energy needed for recording on the disc via a trial recording.

FIG.14

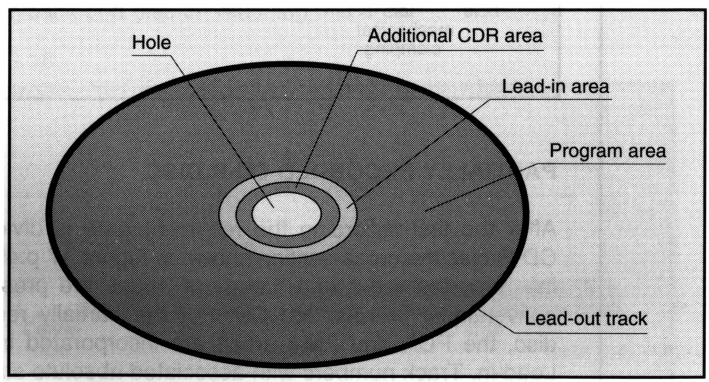
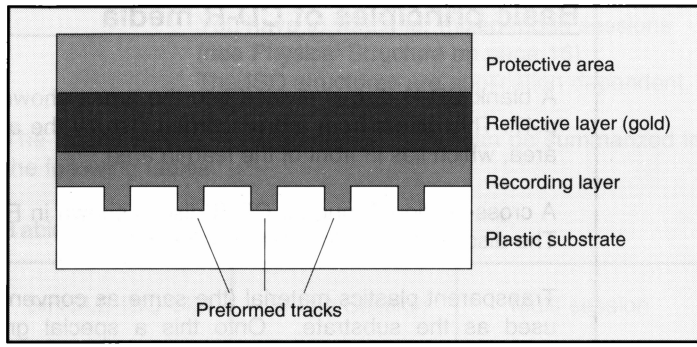


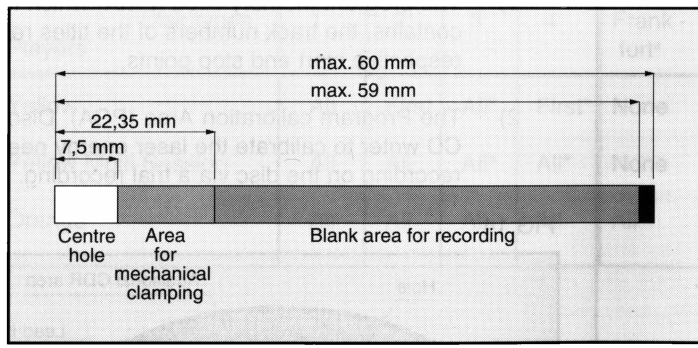
FIG.15



BLANK CD-R DISC.

Figure 16 p.48 shows the blank CD-R discs cross section. Next to the centre hole is an area for the mechanical clamping of the disc in the player. Adjacent to this is the unrecorded area of the blank CD-R disc.

FIG.16

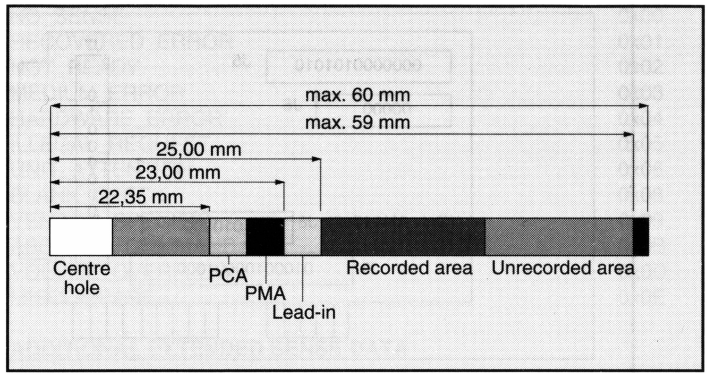


PARTIALLY RECORDED CD-R DISC.

After the first recording the recording area is divided, giving a CD-R disc the cross-section shown in Figure 17 p.49. The "Lead-in", "program area" and "Lead-out" areas are present on every conventional prerecorded CD. For the partially recorded CD-R disc, the PCA and PMA areas are incorporated in front of the Lead-in. Track numbers with associated absolute start and stop times are stored in the PMA.

The possibility exists of making further recordings later. It would also be possible to declare the disc as fully recorded. In which case, the definitive table of contents (TOC) is written into the Lead-in.

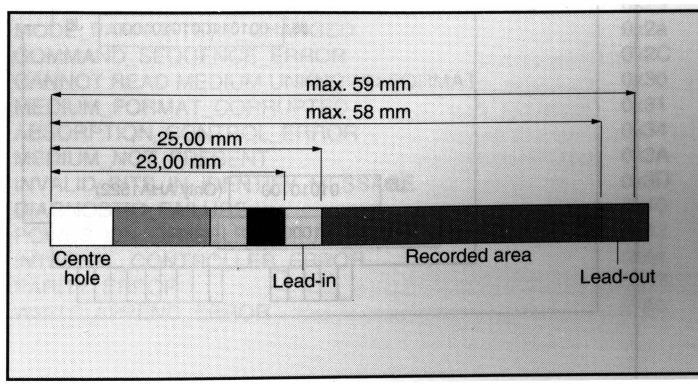
FIG.17



FULLY RECORDED CD-R DISC.

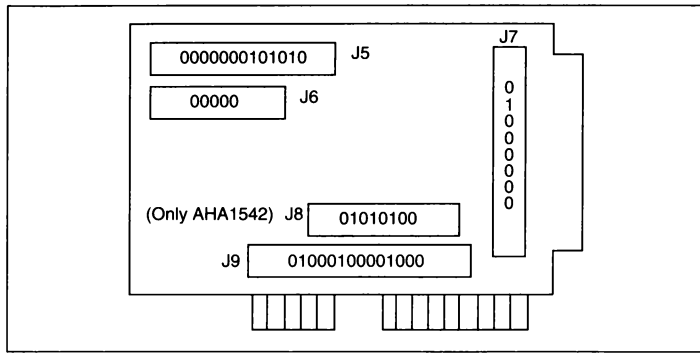
Figure 18 p.49 shows the cross-section through a fully recorded CD-R disc. The fully recorded CD-R disc has a program of 74 minutes playing time, a lead-in area with table of contents and a lead-out area. The areas specific to the CD recorder, the PCA and PMA, are still present but are simply not used by conventional CD players. When the lead-in area is provided with the table of contents, the CD recorder uses the information stored here and not the data from the PMA area. Identification of the end of the disc is stored in the Lead-out. The CD player stops playback of a disc on reaching this area.

FIG.18



Jumper settings

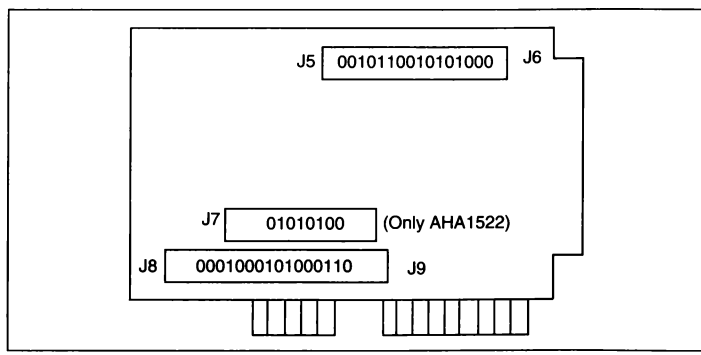
Jumper settings AHA1540/1542B



In some very fast PC environments (depending on sustained data transfer rate of harddisc system) also the Adaptec AHA1520/1522 card can also be used, although this is not recommended.

The Adaptec AHA 1540/1542B card will be replaced by the Adaptec AHA 1542C card. This card has a built-in configuration software program. The jumper settings are replaced by this configuration.

Jumper settings AHA1520/1522



List of error codes

SENSE KEY CODES

NO_SENSE	0x00
RECOVERED_ERROR	0x01
NOT_READY	0x02
MEDIUM_ERROR	0x03
HARDWARE_ERROR	0x04
ILLEGAL_REQUEST	0x05
UNIT_ATTENTION	0x06
BLANK_CHECK	0x08
VENDOR_SPECIFIC	0x09
ABORTED_COMMAND	0x0B
VOLUME_OVERFLOW	0x0D
MISCOMPARE	0x0E

ADDITIONAL EXTENDED SENSE DATA

NO_REASON	0x00
TRAY_OUT	0x03
DRIVE_NOT_READY	0x04
COMMUNICATION_FAILURE	0x08
TRACK_FOLLOWING_ERROR	0x09
UNRECOVERED_READ_ERROR	0x11
POSITIONING_ERROR	0x15
RECOVERED_READ_DATA_WITH_RETRIES	0x17
RECOVERED_READ_WITH_ECC_CORRECTION	0x18
PARAMETER_LIST_LENGTH_ERROR	0x1A
INVALID_COMMAND	0x20
INVALID_BLOCK_ADDRESS	0x21
ILLEGAL_FIELD_IN_COMMAND_DESCRIPTOR	0x24
INVALID_LUN	0x25
INVALID_FIELD_PARAMETER_LIST	0x26
MEDIA_CHANGED	0x28
POWER_ON_RESET_OR_BUS_RESET_OCCURRED	0x29
MODE_PARAMETERS_CHANGED	0x2a
COMMAND_SEQUENCE_ERROR	0x2C
CANNOT READ MEDIUM UNKNOWN FORMAT	0x30
MEDIUM_FORMAT_CORRUPTED	0x31
ABSORPTION_CONTROL_ERROR	0x34
MEDIUM_NOT_PRESENT	0x3A
INVALID_BITS_IN_IDENTIFY_MESSAGE	0x3D
DIAGNOSTIC_FAILURE	0x40
POWER_ON_OR_SELFTEST_FAILURE	0x42
INTERNAL_CONTROLLER_ERROR	0x44
PARITY_ERROR	0x47
WRITE_APPEND_ERROR	0x50

MEDIUM_LOAD_OR_EJECT_FAILURE	0x53
UNABLE_TO_READ_TABLE_OF_CONTENTS	0x57
OPERATOR_MEDIUM_REMOVAL_REQUEST	0x5A
END_OF_USER_AREA_ENCOUNTERED_ON_THIS_TRACK	0x63
ILLEGAL_MODE_FOR_THIS_TRACK	0x64
VERIFY_FAILED	0x65
ILLEGAL_TRACK_NUMBER	0x81
COMMAND_NOW_NOT_VALID	0x82
MEDIUM_REMOVAL_IS_PREVENTED	0x83
STOPPED_ON_NON_DATA_BLOCK	0xA0
INVALID_START_ADDRESS	0xA1
ATTEMPT_TO_CROSS_TRACK-BOUNDARY	0xA2
ILLEGAL_MEDIUM	0xA3
DISC_WRITE_PROTECTED	0xA4
APPLICATION_CODE_CONFLICT	0xA5
ILLEGAL_BLOCKSIZE_FOR_COMMAND	0xA6
BLOCKSIZE_CONFLICT	0xA7
ILLEGAL_TRANSFER_LENGTH	0xA8
REQUEST_FOR_FIXATION_FAILED	0xA9
END_OF_MEDIUM_REACHED	0xAA
NONE_RESERVED_RESERVED_TRACK	0xAB
DATA_TRACK_LENGTH_ERROR	0xAC
BUFFER_UNDER_RUN	0xAD
ILLEGAL_TRACK_MODE	0xAE
OPTICAL_POWER_CALIBRATION_ERROR	0xAF
CALIBRATION_AREA_ALMOST_FULL	0xB0
CURRENT_PROGRAM_AREA_EMPTY	0xB1
NO_EFM_AT_SEARCH_ADDRESS	0xB2
LINK_AREA_ENCOUNTERED	0xB3
CALIBRATION_AREA_FULL	0xB4
DUMMY_DATA_BLOCKS_ADDED	0xB5
BLOCK_SIZE_FORM_CONFLICT	0xB6
PROGRAM_AREA_NOT_EMPTY	0xB8
PARAMETER_LIST_TOO_LARGE	0xB9
NO_BARCODE_AVAILABLE	0xC0
BARCODE_READING_ERROR	0xC1
RECOVERY_NEEDED	0xD0
CANNOT_RECOVER_TRACK	0xD1
CANNOT_RECOVER_PMA	0xD2
CANNOT_RECOVER_LEADIN	0xD3
CANNOT_RECOVER_LEADOUT	0xD4
CANNOT_RECOVER_OPC	0xD5
EEPROM_FAILURE	0xD6

The following SENSE KEY CODES are defined:

00h NO SENSE
This sense key is returned following successful command.

01h RECOVERED ERROR
During it indicates that an ECC correction or retry was done. During write it indicates that the track length is longer, because not enough block where send to the device to meet the minimum track length specification of 300 blocks

02h NOT READY
Indicates that the disc cannot be accessed. Operator intervention may be required to correct this condition.

03h MEDIUM ERROR
Indicates that the command terminated with a non-recovered error condition that was probably caused by dust on the disc or an error in the recorded data.

04h HARDWARE ERROR
Indicates that the CDD2000 detected a hardware failure (e.g. controller or device failure, parity error, etc) while performing the command or during a selftest.

05h ILLEGAL REQUEST
Indicates that there was an illegal parameter in the Command Descriptor Block or in the additional parameters supplied as data for some commands (e.g. MODE SELECT).

06h UNIT ATTENTION
Indicates that either the disc or the drive operating parameters may have been changed (by a MODE SELECT command from another initiator or reset) since last command issued by this initiator.

08h BLANK CHECK
Indicates that the drive encountered blank medium or format-defined end of data indication while reading or the drive encountered a non-blank medium while writing.

09h VENDOR SPECIFIC. For reporting Vendor Specific conditions.

0Bh ABORTED COMMAND
Indicates that the CDD2000/10 device aborted the command. The host may be able to recover by trying the command again.

0Dh VOLUME OVERFLOW. Indicates that the CDD2000/10 device has reached the end-of volume during writing or reading.

0Eh MISCOMPARE. Indicates that the CDD2000/10 device detected a mismatch of settings, used to read source data on the medium.

The following ADDITIONAL SENSE CODES are defined:

03H TRAY OUT
Indicates that the drive's tray is out.
(Sense Key: NOT READY).

04H DRIVE NOT READY
Indicates that the drive is temporarily not able to perform the desired operation.
(Sense Key: NOT READY).

08H COMMUNICATION FAILURE
Indicates that a communication error between the SCSI controller and the servo prevented the command from being performed.
(Sense Key: HARDWARE ERROR)

09H TRACK FOLLOWING ERROR
Indicates that focusing or radial tracking did not succeed.
(Sense Key : HARDWARE ERROR).

11H UNRECOVERED READ ERROR
Indicates that the previous READ command failed, probably due to a flaw in the disc.
(Sense Key: MEDIUM ERROR).

15H POSITIONING ERROR
Indicates that a seek to a requested location on disc failed.
(Sense Key : HARDWARE ERROR).

17H RECOVERED READ DATA WITH RETRIES
Indicates that the previous READ command required data recovery which was accomplished by additional READ operations.
(Sense Key: RECOVERED ERROR)

18H RECOVERED READ WITH ECC CORRECTION
Indicates that the previous READ command required data recovery, which was accomplished using ECC correction.
(Sense Key: RECOVERED ERROR)

1AH PARAMETER LIST LENGTH ERROR.
Indicates that the parameter list length is too long.
(Sense key: ILLEGAL REQUEST).

20H INVALID COMMAND
The previous SCSI command is not supported by the device.
(Sense Key: ILLEGAL REQUEST).

21H INVALID BLOCK ADDRESS
Indicates that one or more of the block addresses requested by the last READ, WRITE, SEEK or VERIFY command extends beyond the end of disc.
(Sense Key: ILLEGAL REQUEST).

24H ILLEGAL FIELD IN COMMAND DESCRIPTOR
Indicates that one or more of the reserved bits in the Command Descriptor was set, or that an option was selected that is not supported by the CDD2000. The Field Pointer and possibly the Bit Pointer will indicate which field was improperly set.
(Sense Key: ILLEGAL REQUEST).

25H INVALID LUN
Indicates that the Logical Unit Field of the Command Descriptor was non-zero. The drive supports Logical Unit zero only.
(Sense Key: ILLEGAL REQUEST).

26H INVALID FIELD PARAMETER LIST
Indicates that the parameter list contained one or more reserved bits set to 1,or that an option was set not supported by the CDD2000. The Field Pointer and possible the Bit Pointer contain additional information as to which bit(s) were improperly set.
(Sense Key: ILLEGAL REQUEST).

28H MEDIUM CHANGED
Indicates that the disc may have been changed since the last command issued by this initiator.
(Sense Key: UNIT ATTENTION).

29H POWER-ON RESET OR BUS-RESET OCCURRED
Indicates that a power-on reset or a bus-reset has occurred since the last command issued by this initiator.
(Sense Key: UNIT ATTENTION).

2AH MODE PARAMETERS CHANGED
Indicates that another SCSI host changed the mode parameters of the drive by means of a MODE SELECT command.
(Sense key: UNIT ATTENTION).

2CH COMMAND SEQUENCE ERROR
Indicates that the previous command is not allowed in the sequence.
(Sense Key: ILLEGAL REQUEST).

30H CANNOT READ MEDIUM UNKNOWN FORMAT
Indicates that the drive couldn't read the information from the device or medium necessary to execute the current command.(Sense Key:NOT READY)

31H MEDIUM FORMAT CORRUPTED
Indicates that the drive couldn't read (write) the requested information from (to) disc due to a corrupted or unknown format.
(Sense Key: MEDIUM ERROR).

34H ABSORPTION CONTROL ERROR
Indicates that the laser power has clipped during reading. This is caused by dust or a scratch on the disc. This warning means: it's not necessary that the recorded data is damaged.
(Sense key: MEDIUM ERROR).

3AH MEDIUM NOT PRESENT
Indicates that no disc is mounted in the drive.
(Sense key: NOT READY).

3DH INVALID BITS IN IDENTIFY MESSAGE
Indicates that the IDENTIFY MESSAGE is corrupted.
(Sense key: ABORTED COMMAND).

40H DIAGNOSTIC FAILURE
Indicates that a device self-test failed, either as the result of a power-on self-test sequence, or as the result of the SEND DIAGNOSTICS command with the self-test bit set.
(Sense Key: UNIT ATTENTION).

42H POWER-ON OR SELF TEST FAILURE
Indicates that a power-on self-test sequence failed.
(Sense Key: UNIT ATTENTION).

44H INTERNAL CONTROLLER ERROR
Indicates that the controller detected an error which could not be otherwise explained.
(Sense Key: HARDWARE ERROR).

47H SCSI PARITY ERROR.
Indicates that the controller detected an parity error.
(Sense Key : ABORTED COMMAND).

50H WRITE APPEND ERROR
Indicates that a append by a WRITE command during writing failed.
(Sense key: ABORTED COMMAND).

53H MEDIUM LOAD OR EJECT FAILED
Indicates that loading or unloading of the disc failed.
(Sense Key: HARDWARE ERROR).

57H UNABLE TO READ TOC, PMA OR SUBCODE.
Indicates that the drive was unable to read the TOC, PMA or subcode of the current disc.
(Sense Key : MEDIUM ERROR).

5AH OPERATOR MEDIUM REMOVAL REQUEST
Indicates the operator requested to unload the disc.
(Sense key: NOT READY).

63H END OF USER AREA ENCOUNTERED ON THIS TRACK
Indicates that the requested block exceeds the current track.
(Sense Key : ILLEGAL REQUEST).

64H ILLEGAL MODE FOR THIS TRACK.
Indicates that the data on the track is not according the mode which is requested by the command. (e.g. block size < 2332 bytes for mode-2 tracks or READ DATA from audio track.)
(Sense key : ILLEGAL REQUEST).

65H VERIFY FAILED.
Reaction on the VERIFY command when the verification was not successful.
(Sense key : VENDOR SPECIFIC).

81H ILLEGAL TRACK.
Indicates that the track being accessed does not exist.
(Sense key : ILLEGAL REQUEST).

82H COMMAND NOW NOT VALID.
Indicates that the command valid for the current host.
(Sense key : ILLEGAL REQUEST).

83H MEDIUM REMOVAL IS PREVENTED.
Indicates that medium removal is prevented.
(Sense key : ILLEGAL REQUEST).

A0H STOPPED ON NON-DATA BLOCK.
During read data transfer is stopped because a non-data block was attempted to read.
(Sense key : ILLEGAL REQUEST).

A1H INVALID START-ADDRESS.
(Sense key : ILLEGAL REQUEST).

A2H ATTEMPT TO CROSS TRACK-BOUNDARY.
The transfer length by a write-track-command does not match the free space length in the track.
(Sense key : ILLEGAL REQUEST).

A3H ILLEGAL MEDIUM.
For executing current command a WO (Write Once) disc is needed.
(Sense key : ILLEGAL REQUEST).

A4H DISC WRITE-PROTECTED.
Current disc is write protected.
(Sense key : ILLEGAL REQUEST).

A5H APPLICATION CODE CONFLICT
The Disc Application Code does not match with the Host Application Code.
(Sense key : ILLEGAL REQUEST).

A6H ILLEGAL BLOCK-SIZE FOR COMMAND.
Selected block-size is not allowed for this command.
(Sense key : ILLEGAL REQUEST).

A7H BLOCK-SIZE CONFLICT.
Selected block-size caused a mode conflict.
(Sense key : MISCOMPARE).

A8H ILLEGAL TRANSFER LENGTH
Indicates that the transfer length in the command descriptor block would overflow the write buffer.
(Sense key : ILLEGAL REQUEST).

A9H REQUEST FOR FIXATION FAILED.
Because of existing of blank area on disc (=reserved tracks).
(Sense key : ILLEGAL REQUEST).

AAH END OF MEDIUM_REACHED.
Indicates that during writing the end of medium is detected or the amount of track reached the limit of 99 or the OPC area is full or PMA is full.
(Sense key : VOLUME OVERFLOW).

ABH ILLEGAL TRACK NUMBER.
Indicates a invalid Track number in command descriptor block.
(Sense key : ILLEGAL REQUEST).

ACH DATA TRACK LENGTH ERROR.
Indicates that the track length is longer, because not enough block where send to the device to meet the minimum track length specification of 300 blocks
(Sense key : RECOVERED ERROR).

ADH BUFFER UNDER RUN.
Indicates that the write action stopped because the cache buffer emptied.
(Sense key : ABORTED COMMAND).

AEH ILLEGAL TRACK MODE.
Indicates that the selected Track Mode is not valid.
(Sense key : ILLEGAL REQUEST).

AFH OPTIMUM POWER CALIBRATION (OPC) ERROR.
Indicates that power calibration failed.
This could indicate: Wrong WO medium installed, laser failure or drive failure.
(Sense key : MEDIUM ERROR).

B0H CALIBRATION AREA ALMOST FULL.
Indicates that a few Optimum Power Calibration areas are left. Its recommended to fixate after the tracks are written.
(Sense key: ABORTED COMMAND).

B1H CURRENT PROGRAM AREA EMPTY.
Indicates that the command couldn't be executed due to a empty program area.
(Sense key : ILLEGAL REQUEST).

B2H NO EFM AT SEARCH ADDRESS.
Indicates that during reading or play-back request no EFM was present. (EFM is the CD signal needed for reading)
(Sense key : BLANK CHECK).

B3H LINK AREA ENCOUNTERED.
Indicates that during reading the link area is encountered.
(Sense key : ILLEGAL REQUEST).

B4H CALIBRATION AREA FULL
Indicates that the Calibration area is full. This means that no further write can be performed on this disc.
(Sense key: VOLUME OVERFLOW).

B5H DUMMY BLOCKS ADDED.
Indicates that during writing dummy blocks are added to meet the disc specification. Dummy blocks will be added if to few (host) blocks are received for that track.
(Sense key : ILLEGAL REQUEST).

B6H BLOCK SIZE FORMAT CONFLICT.
Indicates that during writing a block (with subheader) was received and a conflict was detected between the form bit (in subheader) and the block size.
(Sense key : ILLEGAL REQUEST).

B8H PROGRAM AREA NOT EMPTY.
Indicates that the last session on disc contains tracks. Therefore the command can not be executed.
(Sense key: ILLEGAL REQUEST).

B9H PARAMETER LIST TOO LARGE
Indicates that the last command issued contained to many parameters because of specification limitations.
(Sense key: ILLEGAL REQUEST).

C0H NO BARCODE AVAILABLE.
Indicates no barcode present on disc.
(Sense key : ILLEGAL REQUEST).

C1H BARCODE READING ERROR.
Indicates that an error occurred during barcode reading.
(Sense key : MEDIUM ERROR).

D0H RECOVERY NEEDED.
Indicates that the CDD2000/10 detected during power up that the device was writing during the last power down. The medium format could be corrupted. Its recommended to issue the RECOVER command.
(Sense key : VENDOR SPECIFIC).

D1H CAN'T RECOVER FROM TRACK.
Indicates that the recovering from a corrupted track failed
(Sense Key: MEDIUM ERROR).

D2H CAN'T RECOVER FROM PROGRAM MEMORY AREA.
Indicates that the recovering from a corrupted Program Memory Area failed.
(Sense Key: MEDIUM ERROR).

D3H CAN'T RECOVER FROM LEADIN AREA.
Indicates that the recovering from a corrupted Leadin Area failed.
(Sense Key: MEDIUM ERROR).

D4H CAN'T RECOVER FROM LEADOUT AREA.
Indicates that the recovering from a corrupted Leadout Area failed.
(Sense Key: MEDIUM ERROR).

D5H CAN'T RECOVER FROM OPTICAL POWER CALIBRATION AREA.
Indicates that the recovering from a corrupted Optical Power Calibration Area failed.
(Sense Key: MEDIUM ERROR).

D6H EEPROM FAILURE.
Indicates that the non volatile memory failed.
(Sense Key: HARDWARE ERROR).

Error recovery table

DRIVE_NOT_READY	: give a START command
COMMUNICATION_FAILURE	: reset device try again else : replace hardware boards
TRACK_FOLLOWING_ERROR	: retry command again else : clean disc else : retry command again with other medium else : check vibrations of device else replace hardware boards or mechanism
UNRECOVERED_READ_ERROR	: retry again else this block is unable to read
POSITIONING_ERROR	: retry command again else : clean disc else : retry command again with other medium else : replace hardware boards or mechanism

PARAMETER_LIST_LENGTH_ERROR	: change the allocation or transfer length in command descriptor block
INVALID_COMMAND	: issue another command
INVALID_BLOCK_ADDRESS	: issue another address
ILLEGAL_FIELD_IN_COMMAND DESCRIPTOR	: read scsi command set manual for correct settings
INVALID_LUN	: set lun to zero
INVALID_FIELD_PARAMETER_LIST	: read scsi command set manual for correct settings
MEDIUM_CHANGED	: log off from medium
POWER_ON_RESET_OR_BUS_RESET OCCURRED	: initialize
COMMAND_SEQUENCE_ERROR	: read scsi command set manual for limited command set
CANNOT_READ_MEDIUM_UNKNOWN FORMAT	: fatal: could not determine block size of copy target device
MEDIUM_FORMAT_CORRUPTED	: try RECOVER COMMAND the case of a WO disc else : disc unusable
ABSORPTION_CONTROL_ERROR	: warning: the data written on disc might contain an error
MEDIUM_NOT_PRESENT	: insert a disc
INVALID_BITS_IN_IDENTIFY_MESSAGE	: read scsi command set manual for supported messages : only 80h and C0h are valid for identify messages
DIAGNOSTIC_FAILURE	: issue SEND DIAGNOSTIC command else : reset device else : replace hardware boards

POWER_ON_OR_SELFTEST_FAILURE	: issue SEND DIAGNOSTIC command else : reset device else : replace hardware boards
INTERNAL_CONTROLLER_ERROR	: no recover procedure available
PARITY_ERROR	: try command again else : check cable
WRITE_APPEND_ERROR	: check transfer rate host must be at least 500 Kbytes/sec
MEDIUM_LOAD_OR_EJECT_FAILURE	: try command again else : check loading mechanism else : replace loading mechanism
UNABLE_TO_READ_TABLE_OF CONTENTS	: try command again else : clean disc
OPERATOR_MEDIUM_REMOVAL REQUEST	: log off from medium
ILLEGAL_TRACK_NUMBER	: change track number
COMMAND_NOW_NOT_VALID	: try again with some delay
MEDIUM_REMOVAL_IS_PREVENTED	: allow medium removal (can only be done by the same which prevented) : else no recoverable
STOPPED_ON_NON_DATA_BLOCK	: check start address or transfer length
INVALID_START_ADDRESS	: change start address
ATTEMPT_TO_CROSS_TRACK-BOUNDARY	: check start address or transfer length
ILLEGAL_MEDIUM	: change medium
DISC_WRITE_PROTECTED	: check write protection reason
APPLICATION_CODE_CONFLICT	: select correct application code, or change disc
ILLEGAL_BLOCKSIZE_FOR_COMMAND	: change block size
BLOCKSIZE_CONFLICT	: change block size

ILLEGAL_TRANSFER_LENGTH	: change transfer length
REQUEST_FOR_FIXATION_FAILED	: check medium else : check amount track in program area (should greater than zero)
END_OF_MEDIUM_REACHED	: check start address or transfer length
NONE_RESERVED_RESERVED_TRACK	: check reservation of track with READ TRACK INFO command
DATA_TRACK_LENGTH_ERROR	: change length
BUFFER_UNDER_RUN	: check transfer rate host must be at least 500 Kbytes/sec
ILLEGAL_TRACK_MODE	: change track mode
OPTIMUM_POWER_CALIBRATION ERROR	: retry else : check medium : issue SEND DIAGNOSTIC
CALIBRATION_AREA_ALMOST_FULL	: write all information to disc and fixate directly afterwards
CURRENT_PROGRAM_AREA_EMPTY	: write a track or reserve a track
NO_BARCODE_AVAILABLE	: use disc with barcode
BARCODE_READING_ERROR	: try again else : clean disc
CALIBRATION_AREA_FULL	: unable to recover
RECOVERY_NEEDED	: issue the RECOVER command
CAN'T_RECOVER_FROM_TRACK	: unable to recover
CAN'T_RECOVER_FROM PROGRAM_MEMORY_AREA	: unable to recover
CAN'T_RECOVER_FROM_LEADIN	: unable to recover
CAN'T_RECOVER_FROM_LEADOUT	: unable to recover
CAN'T_RECOVER_FROM_OPTICAL POWER_CALIBRATION	: unable to recover
EEPROM_FAILURE	: no recover procedures available

Glossary of terms

CD-R : CD-Recording method according to "Orange Book" standard.

CD-ROM XA : Compact Disc Read Only Media Extended Architecture . The term used for optical storage devices designed to read digital data on 12 cm (4.72 inch) discs based on the Yellow Book standard. The CD-ROM standards were developed by N.V. Philips & Sony Corporation. The "Red Book" - CD Digital Audio and "Yellow Book" (or IEC 908) CD-ROM describe the media standards.

CD-I : Compact Disc Interactive system is designed to run discs conforming to the CD-I standard. (Green Book)

References/applicable documents

RED BOOK : Standard for CD-Audio

YELLOW BOOK : Standard for CD-ROM (incl. CD-ROM XA attachment)

GREEN BOOK : Standard for CD-I

ORANGE BOOK : Standard for CD-Recordable part II

VOLUME AND FILE STRUCTURE FOR CD-ROM ISO 9660:

Finished discs are conforming to the physical requirements as set by the Yellow, Red and Green book.

The volume and file structure for data applications can be fully ISO 9660 compatible. Note that ISO 9660 is a subset of the so called Frankfurt Group proposal as endorsed by Philips, Sony, Meridian a.o.

SCSI - II STANDARD (SUBSET)

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