Knowledge Update Course
for Secondary School Computer and IT Teachers

Multimedia Production and Web Authoring

Storage and I/O Technology

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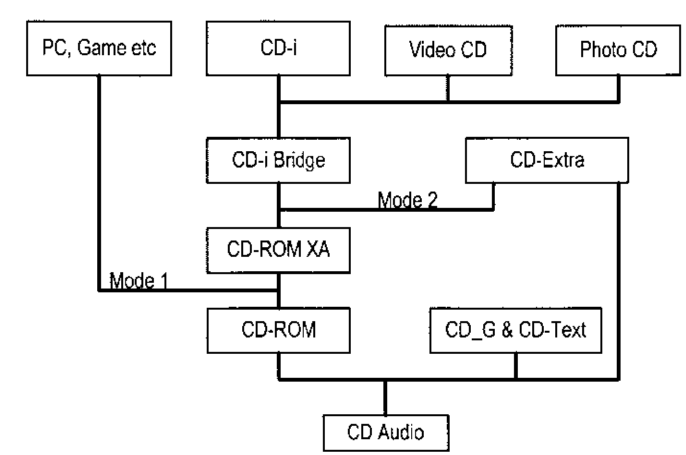
Agenda

- Storage Technology
  - Optical Media
  - Magnetic Media
  - Cache management
- I/O Technology
  - Printing Technology
  - Image Scanner
  - Display System and Device
  - Digitizing Technology

Compact Disc Technologies

- Launched in October 1982, developed jointly by Philips and Sony
- Philips contributed the laser disc experience, Sony contributed the digital audio expertise
- Up to 80 minutes high quality stereo audio1984
- 1984, CD-ROM Yellow Book was published to allow computer data storage which include CD-ROM XA, CD-I, enhanced CD and video CD
- In addition to audio, these CDs contain data, text, images, and video
- MPEG-1 video standard developed alongside with CD, allows 74 minutes high quality video stored on CD, such as on a Video CD
- Other supporting technologies
  - Pulse Code Modulation (PCM) used to digitally encode the audio on a CD
  - Error correction codes
  - Laser Technology

Compact Disc Formats



CD-ROM Specifications

- CD books are specifications for encoding and formatting of digital data on compact discs. Each specification is referred to by a color designation. The specifications detail the accepted industry foundation for inter-platform compatibility.
- Red Book for all audio CDs
- Blue Book defines the enhanced Music CDs (CD Extra) for multi-session comprising audio and data sessions. The discs can be played on any CD audio players or PCs
- Yellow Book comprises the CD-ROM specification plus an extension for CD-ROM XA. It defines the computer-based CD-ROM standard which includes file structure and sector format.

CD-ROM Specifications

- White Book defines the disc format for video CD, Karaoke CD and Super Video CD
- Green Book defines the CD-I disc format for a real-time interactive system delivering video, still image and audio together with full user interactivity
- Photo CD discs are a special type of CD-ROM/XA bridge discs that allow photographic images for play back on photo CD player or CD-I player. Images can also be read via a CD-ROM XA drive using image conversion utilities
- Multi-session Discs allow more than one recording sessions. After initial data is burned into the disc, more sessions can be added until disk full.

Digital Audio

- Compact Disc Digital Audio (CD-DA) standard was developed by Philips & Sony
- Digital technology stores samples as numbers at a particular time
- Sampling rate must be high enough for ensuring accurate reproduction of original analogue waveform
- Human ear 20kHz, min. sample rate is therefore 40KHz
- To reduce distortion and quantization noise, 16-bits resulting 65,536 levels per sample is required
- For 44,100 sampling rate, total information needed for 1 sec: 44,100 x 2 x 16 = 1,411,200 bits
- For a 74 min CD: a CD must store: 1,411,200x74x60 bits=6,6265,728 million bits

Laser Technology

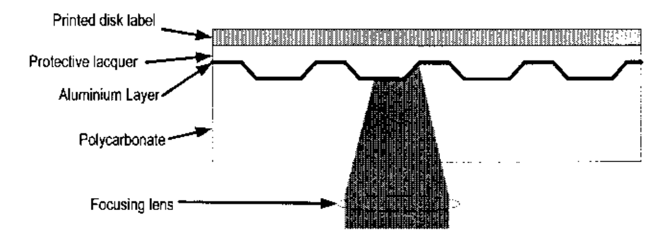
- Lasers (Light Amplification by Stimulated Emission of Radiation) generate coherent light (light comprising photons with same wavelength and in-phase.
- Light beam focuses on a very small spot size similar to the actual wavelength of the light itself
- A low power laser is used to read the information stored in pits on the disc surface
- The length of the pits varies for different sequences of 0s and 1s
- CD players use infra red light emitting diode lasers to read data in the pits
- The laser diode is mounted on a swivel arm moving in a radial direction
- An objective lens is used to focus the laser beam on the pits
- A two-way prism mirror allows the reflected light to pass back to the photo-detector
- Light is scattered and reflected, the changing pattern detected is converted into a series of zeros and ones, which is decoded by the player electronics

CD Audio Specification

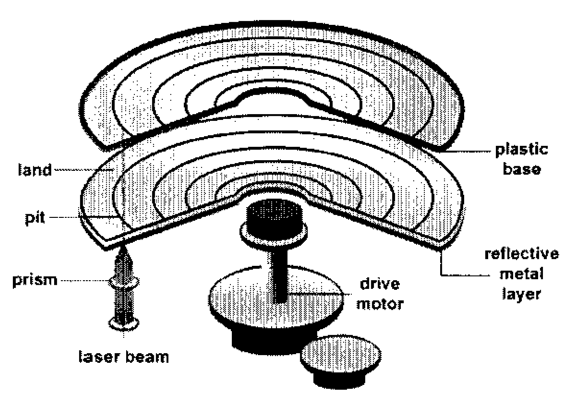
Parameter	Value	Comments
Disc diameter:	12 cm	8cm also
Disc thickness:	1.2 mm	
Sides:	1	(single side only)
Length of pits:	1 to 3 microns	
Depth of pits:	0.15 microns	
Scanning speed:	1.2 to 1.4 m/s	
Track pitch:	1.6 microns	
Laser wavelength:	780 nm	Infra red laser
Playing time:	74 minutes	Up to 80 minutes possible
Number of tracks:	99 max	Plus up to 99 indexes per track
Channel bit rate:	4.3218 Mb/s	Including modulation & error correction
Number of channels:	2	2's complement
Quantization:	16 bits/channel	8 to 14 modulation plus 3 padding bits
Modulation:	EFM	Cross interleaved Reed Solomon code
Error correction:	CIRC	For objective lens
Numerical aperture:	0.45	

CD Construction

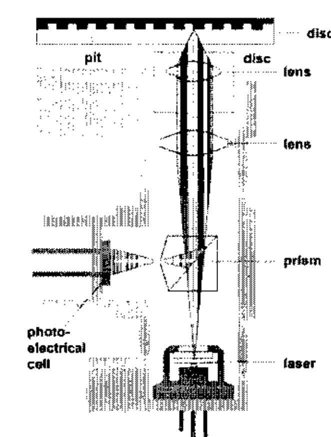
- The disc comprises a sandwich, a 1.2mm thick polycarbonate substrate containing pits molded into the upper surface is coated with aluminum, which is protected by a lacquer on which the disc label is printed
- A infrared laser beam is focused on the pits through the clear optical grade polycarbonate plastic
- Pits are embossed into the polycarbonate surface by an injection molding process
- The aluminum layer provides a reflective surface and is protected by a lacquer



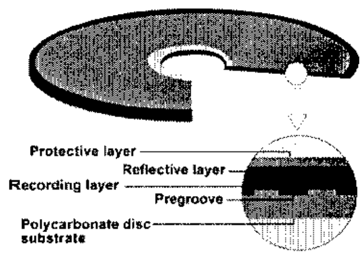
CD-ROM Drive



CD-ROM Drive

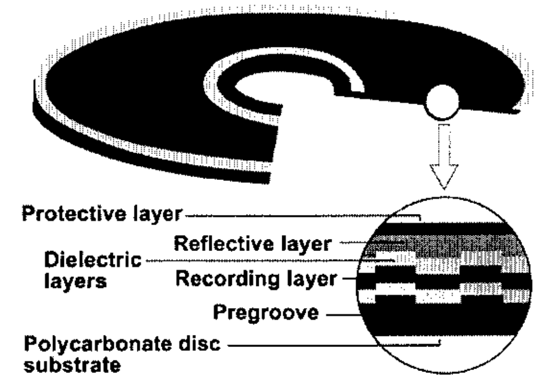


CD-Recordable



- writes data to CD-R by using a laser to physically burn pits into the recording layer
- When the layer is heated beyond a critical temperature, the area "burned" becomes opaque, subsequently reflects less light
- Data is represented by "burned" and "non-burned" area corresponding to "pit" and "land" of a normal CD

CD-Rewritable

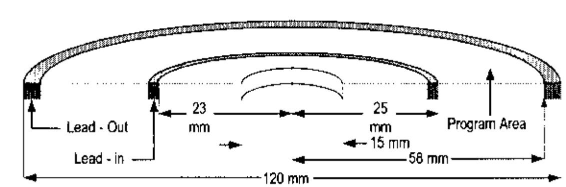


CD-Rewritable

- Technology behind CD-RW is optical phase-change
- Dielectric layers draw excessive heat from the phase-change layer during writing process
- A recording layer uses a crystalline compound made up of the mix of silver, indium, antimony and tellurium
- The mixture when it is heated to one temperature and cooled down, it become crystalline, but if it is heated to a higher temperature, when it cools down again it becomes amorphous.
- The crystalline areas allow the metalised layer to reflect the laser better while the non-crystalline portion absorbs the laser beam, so it is not reflected.
- CD-Rewritable recorder use three different laser powers to achieve the effect:
  - "Write Power" creates a non-crystalline state on recording layer
  - "Erase Power" melts the recording layer and converts it to a reflective crystalline state
  - "Read Power" not alter recording state, is used for reading data

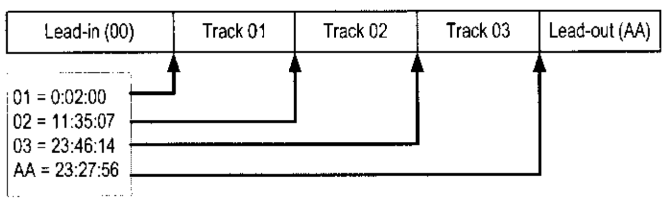
Compact Disc Layout

- The disc measure 120mm in diameter with 15mm diameter centre hole
- The audio or computer data is stored from radius 25mm after the lead-in to radius 58mm maximum where lead-out starts
- The CDs are played at constant linear velocity (CLV) of between 1.2 and 1.4 m/s. The angular velocity will reduce from lead-in to lead-out.
- Annular space is divided into three main areas:
  - Lead-in: contains audio content information, allows head synchronization to audio data
  - Program area: contains up to 74minutes audio data & divided into 99 tracks
  - Lead-out contains data silence



Tracks, Indexes & Table of contents

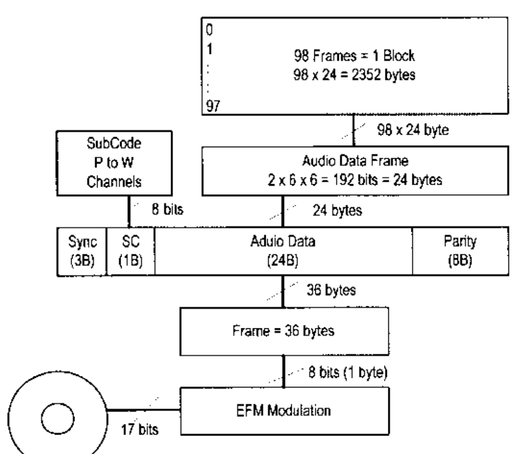
- Individual tracks are subdivided into indexes
- Usually a track contains two indexes. Index 0 marks the pause at the beginning while index 1 is for the main part of the track
- Track start times are defined in the table of contents (TOC) in the Lead-in area
- TOC comprises absolute times for the start of each track, allows fast random access
- TOC comprises time code (minutes, seconds and frames) for each track
- The last time code defined as AA gives the start of the Lead-out



Frames and Blocks

- Each frames comprises:
  - 3 bytes of sync
  - 1 byte of sub-code (SC) data
  - 24 bytes of audio data representing 6 samples for both channels
  - 8 bytes of parity for CIRC (Cross Interleaved Read-Solomon Code) error correction
- 36 bytes frame is stored on disc via an EFM (Eight to Fourteen) modulator.

Frames and Blocks

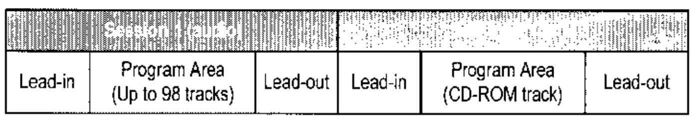


Sub-code Channels

- The eight sub-code bits represent the sub-code channels P to W
- The P-channel indicates the start and end of each track
- The Q-channel contains the time codes or the TOC in Lead-in, track type, catalogue number and ISRC (International Standard Recording Code)
- Channels R to W are for sub-code graphics (CD-G) and CD text
- CD-Graphics includes data for graphics and text for displaying graphics and text while music is being played, e.g. in Karaoke
- CD-Text in channels R to W allows disc and track related information to be added to standard audio CD for playback, can be in lead-in or program area
- Lead-in area: disc or track information of the disc
- Program area: current track title, composer or performers, repeated in track

CD Audio Enhancements

- Audio CDs can be enhanced by adding content related data (CD Extra) or by improving audio coding (in HDCD)
- CD Extra contains two sessions or multi-sessions
- Each session comprises lead-in, program and lead-out area
- For example, the first session contains 98 audio tracks; the second session contains CD-ROM XA mode 2 track
- When played on an audio player, it sees the first track session and not the data session
- CD-ROM drives see both sessions
- HDCD (High Density Compatible Digital) enhances the quality of audio
- HDCD discs contains 20-bit per channel to provide a dynamic range and natural sound



Compact Disc Read Only Memory

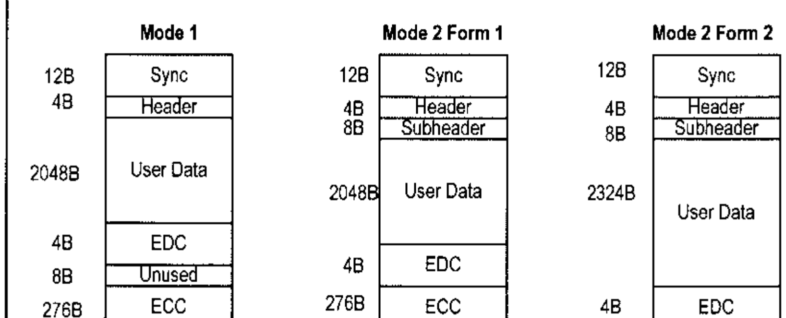
- CD-ROM discs differ from CD audio discs in :
  - CD-ROM discs are divided into sectors, contain both user data and data for control and error protection
  - CD-ROM data stored in files, and need a file system

Parameter	Value	Comments
Data capacity	682 Mbytes	Assuming 74 minutes
Raw data bit rate	1.41 Mbits/s	Includes all bytes in sector
User data rate	150kB/s	At 1x speed
Block (sector) size	2,352 bytes	
User data per sector	2048	Wit full error correction
Sector rate	75 sector/s	At 1x speed reading
Sector Modes	1 or 2	
Sector Forms	1 or 2	Mode 2 only

CD-ROM Sectors and Modes

- CD-ROM sectors are equivalent to the audio blocks, normal playback speed 75 sectors read per second. For double speed CD-ROM drives, it is 150 sectors per second
- Sectors may be either Mode 1 used for general computer or mode 2 used for CD-I, CD-ROM XA, Video CD and Enhanced CD
- Mode 1 and Mode 2, Form 1 sectors are identical in capacity and error correction.
- Difference in the presence of sub-header
- Mode 2 Form 2 sectors contains no error correction, but capacity is 2324 bytes instead of 2048 bytes, suitable for video or audio data
- Mode 2 Form 2 sectors are used for Video CD, still video or moving video
- Mode 1 and Mode 2 Form1 are used for other applications

CD-ROM Sectors and Modes



CD-ROM file Systems

- ISO 9660 file system, compatible with MSDOS, for example filenames can be 8 characters plus 3 character extension
- ISO 9660 file system has limitations so CD-ROM discs can make use of Joliet extensions and HFS file system for Macintosh applications
- Joliet extension to ISO 9660 resolves deficiencies in the ISO 9660:
  - Character set limited to upper case, numbers and underscore
  - File name length limited to 8 characters plus 3 extension
  - Directory Tree Depth limitations
  - Directory Name Format limitations
- Hierarchical File System (HFS) for Macintosh
- CD-ROM discs can have both ISO 9660/Joliet and HFS file system and are terms as hybrid discs

CD-ROM and CD-ROM XA Format

- CD-ROM XA
  - Contain Mode 2 sectors and allows audio and data to be interleaved and read simultaneously

Format name	Mode(s)	File structure	Comments
PC CD-Rom	Mode 1 or 2	ISO 9660 or Joliet	Most common format
Mac CD-Rom	Mode 1	HFS	Base on Mac operating system
CD-i	Mode 2	ISO 9660+	Superset of ISO 9660
CD-ROM XA	Mode 2	ISO 9660 or Joliet	Combines CD-ROM and CD-i
Video CD	Mode 2	ISO 9660	A CD-i Bridge format
Enhanced CD	Mode 2	ISO 9660 or Joliet	Multi-session audio + data

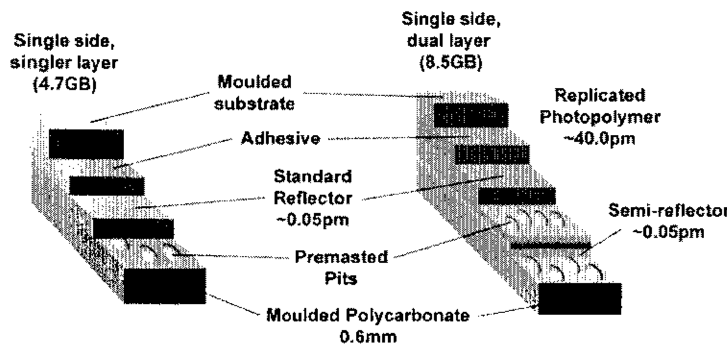
Video CD

Parameter	Video CD ver 2.0	Super Video CD
Playing time:	74 minutes	35 to 70 mins+
Data rate:	150 kBytes/s (1x speed)	300 kBytes/s (2x speed)
Video:	MPEG-1 1.15 Mb/s CBR*	MPEG-2 2.6Mb/s average VBR*
Resolution:	352x240 (NTSC) 352x280(PAL/SECAM)	480x480(NTSC) 480x576(PAL/SECAM)
Audio:	MPEG-1 stereo CBR* optional CD audio tracks	2 streams MPEG stereo VBR* optional 5.1 channel
Interaction:	Menus, Playlists	More interactivity
Subititles:	Closed captions	Overlay graphics (4 selectable channels)

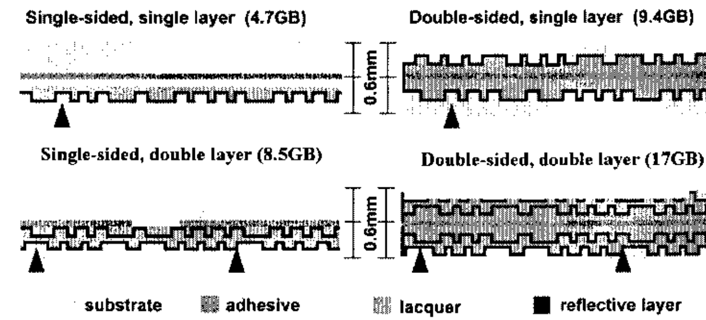
Digital Versatile Disc DVD

- DVD technology offers an optical disc with capacity 4.7GB to 17.1GB and is available as a family of pre-recorded, recordable and re-writable formats.
- DVD-video was launched in 1997
- Ideal vehicle for distributing high quality video with surround sound audio on a disc
- DVD-ROM is replacing CD-ROM, and getting popular on sophisticated and realistic games applications
- DVD-Audio was launched in 2000 for very high quality, surround sound music.
- Recordable formats such as DVD-RAM, DVD-RW and DVD-R are now being extensively used in PCs for backup and standalone products: video recorders and camcorders

Digital Versatile Disc DVD



Digital Versatile Disc DVD



DVD Specifications & Features

Book	Name	Part 1 Physical	Part 2 File System	Part 3 Application	Version
A	DVD-Rom	Read-Only	ISO9660/UDF	Undefined	1.01
B	DVD-Video	Read-Only	UDF	MPEG-2 video	1.1
C	DVD-Audio	Read-Only	UDF	MLP & PCM audio	1.2
D	DVD-R	Write once	UDF	Not defined	2.0
E	DVD-RAM/RW	Rewritable	UDF	Not defined	2.0

- Backwards compatibility with CD media
- Physical dimensions are identical to compact disc
- Single-layer/dual-layer and single/double sided options
- Up to 4.7GB read-only per layer and 8.5GB per side maximum

DVD Disc Parameters

Parameter	CD	DVD	Comment
Side	1	1 or 2	See 2.2
Layers	1	1 or 2	
Capacity (GB)	0.68	4.7 – 17	1 GB = 10^9 bytes (not 1024^3)
Track pitch (μ)	1.6	0.74	
Minimum pit length(μ)	0.83	0.4	For 13 pit
Wavelength (nm)	780	650	Of laser diode pickup
Numerical aperture	0.45	0.6	Defines angle of beam
Linear velocity (m/s)	1.3	3.49	Nominal 1x speed
Modulation	EFM	8 to 16	EFM is 8 to 14 plus 3 padding bits
Error protection	ECC	RSPC	RSPC is block protection scheme
3rd layer ECC	Yes	No	Not needed for DVD after RSPC
Subcode	Yes	No	No subcode needed
Tracks	Yes	No	DVD uses files not tracks

DVD Physical Disc Formats

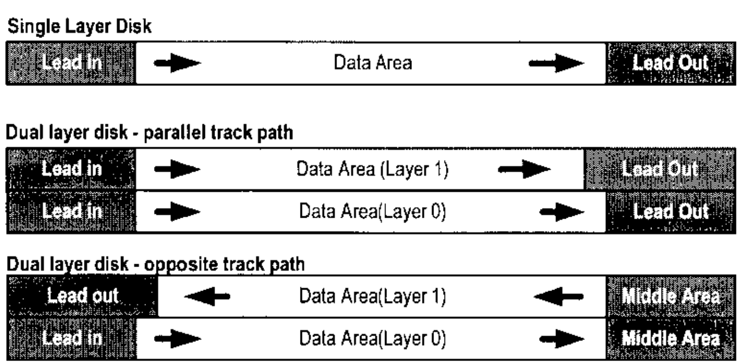
- DVD-5 discs comprise a sandwich of two 0.6mm substrates, one metallised and with data, the other blank, bonded together. Data is read from one side only
- DVD-9 discs comprise one semi-reflective substrate (layer 0) and one fully metallised substrate above it giving capacity of 4.25GB
- DVD-10 discs comprise two metallised substrates bonded together and read from both sides
- DVD-18 discs comprise two dual-layer substrates bonded together and read from both sides

	DVD-5	DVD-9	DVD-10	DVD-18	DVD-R	DVD-RW	DVD-RAM
Capacity (GB)	4.7	8.54	9.4	17.08	4.7	4.7	4.7 or 9.4
Layers/side	1	2	1	2	1	1	1
Sides	1	1	2	2	1	1	1 or 2

Recordable & Re-writable DVD Formats

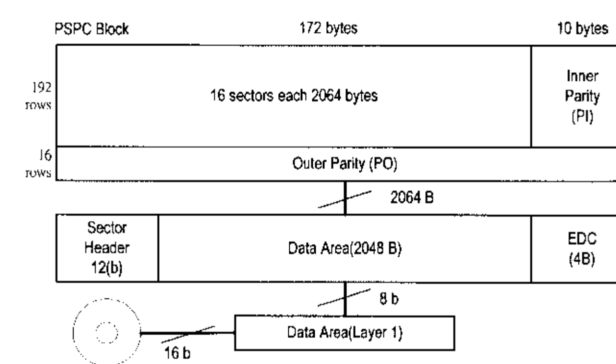
- DVD-R discs are write-once discs with a capacity 4.7GB per side
- DVD-R for authoring contain information in lead-in area for DVD-video titles while DVD-R for general use contains no titles in lead-in area
- DVD-RAM discs are re-writable discs with capacity 4.7GB per side for computer data storage
- DVD-RW discs are re-writable discs with capacity 4.7GB per side for consumer applications
- Hybrid DVD-ROM and DVD-RAM on each side of the disc
- Hybrid SACD combines SACD layer with CD layer. Both layers are read from the same side
- Hybrid DVD for a DVD-Audio/CD audio combination
- DVD Plus comprise a CD bonded to a DVD substrate resulting data cannot read from one side of a disc

Single and Dual Layer Disc Layout



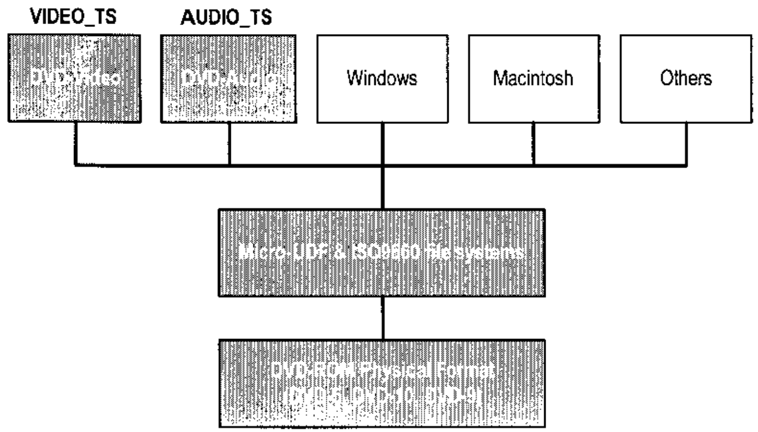
- DVD-Video discs use opposite track path so that movie can be placed across both layers and played seamless from layer 0 to layer 1

DVD Sector Structure



- Data on a DVD are organized as sectors of 2048 bytes plus 12 bytes of header data
- Blocks of 16 sectors are error protected using RSPC (Reed Solomon Product Code)

DVD Disc File Structure



DVD Disc File Structure

- All types of DVD disc contain data in files.
- For compatibility with recordable and re-writable versions the UDF Bridge Format has been chosen
- This comprises a combination of UDF plus ISO9660 for compatibility with CD-ROM
- Applications can access the data files using either ISO9660 or UFD file structures
- DVD-Video and DVD-Audio must be contained within specific directories Video_TS and Audio_TS
- DVD-Video use only UDF with all required data specified by UDF and ISO 13346 for playing in a computer system.

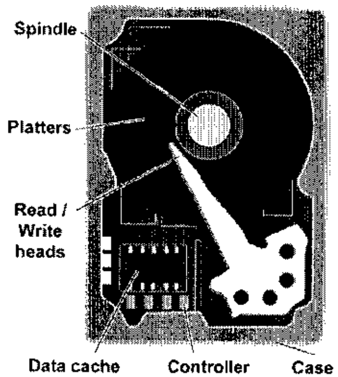
DVD-Video

- Playing time: 133 minutes for DVD-5 or each side of DVD-10 and 240 minutes for DVD-9
- Video encoding: MPEG-2 or MPEG-1
- Audio Quality and Languages: Dolby Digital, DTS, MPEG-2 or Linear PCM audio for up to 5.1 channel surround sound
- Subtitling: Sub-pictures allow subtitling for up to 32 languages
- Range of Video Formats: Pan & scan, letter box and widescreen formats
- Longer movies can make use of dual layer for continuous play
- Region Coding
  - Region 1: USA, Canada
  - Region 2: Europe, Middle East, South Africa, Japan
  - Region 3: Southeast Asia, Taiwan
  - Region 4: Central & S America, Mexico, Australia, New Zealand
  - Region 5: Russia, Africa, India, Pakistan
  - Region 6: China
- Region coded DVD discs are restricted playing to specific regions
- Non-region coded discs will play on any players

Video Discs Comparison

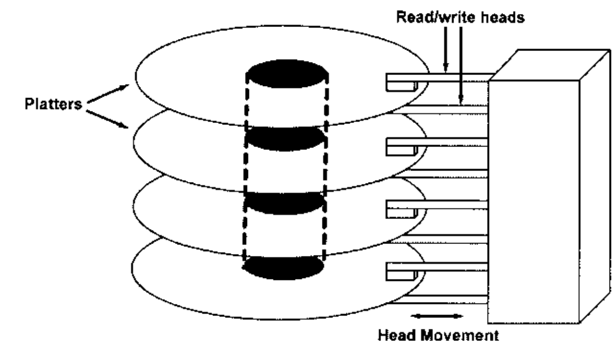
Feature	Laserdisc	Video CD	SVCD	DVD-Video
Encoding format	Analogue Composite	MPEG-1 component	MPEG-2 component	MPEG–2 component
Max image size		352 x 240/288	480 x 480/576	720 x 480/576
Video Bit Rate	-	1.15 Mb/s	2.6 Mb/s (ave)	3.5 Mb/s (ave)
Quality	Good	Fair	Good	Very good
Audio channels	2 to 5.1	2	4	5.1
Languages	1	1	2 stereo/ 4 mono	Up to 8
Playing time (mins)	60	74 max	37 at max rate	133 nominal

Hard Disk

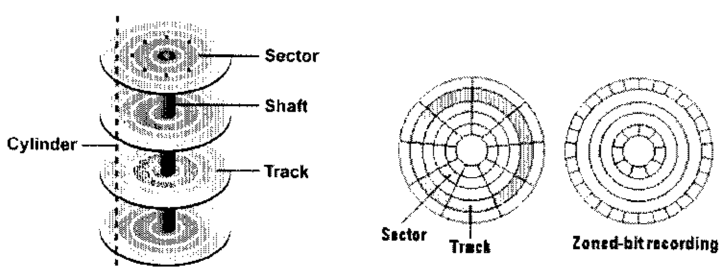


- Platters
  - make up of non-magnctic and smooth aluminum alloy or a mixture of glass coated with a magnetic medium
  - Towards glass technology, better heat resistance and thinner
  - Dust free inside a hard disk
- Read/write heads on each side of platters

Hard Disk

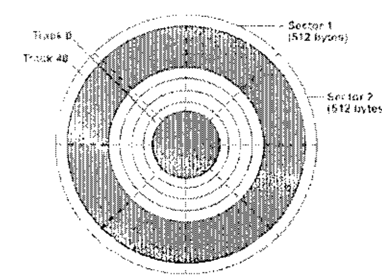


Hard Disk



- Cross-platter information in the same cylinder can be accessed without having to move the heads
- 512 bytes per sector
- Zoned-bit recording, outside tracks contain more sectors

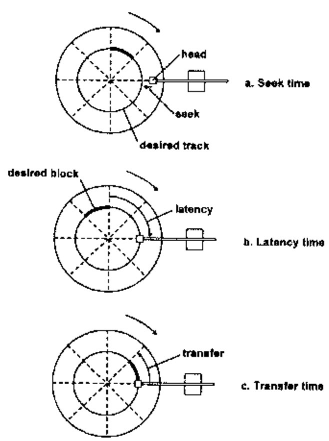
Hard Disk



- Track – A track is a concentric circle around the disk where the inmost track is track 0
- Cylinder – The track with the same track number in each surface of platter form a cylinder (i.e. the number of cylinder must equal to the number of track)
- Sector – Each track splits into number of sectors. Typically, each sector stores 512 bytes.

Hard Disk

Disk Performance Parameters



- Seek time
  - Time for a head to move to a required track
- Latency time
  - Average time for a head to rotate to a required sector
- Transfer time

Hard Disk

- **Transfer time**
  - The time required to transfer the data (which relate to the bus).
    - Internal Transfer Rate (disk transfer rate)
      - » transfer (read) occurs within the disk (Data is read from the disk platters by head and transferred to the driver's internal buffer and then it is moved from the buffer, over the interface, to the rest of the system).
    - External or Interface Transfer Rate (host transfer rate)
      - » transfer (write) from bus to the buffer of the hard disk (it is related to the interface used)
- **Rotational delay**
  - For disks – rotate at 3600 rpm, so delay will be 8.3 ms (time for half Revolution)
  - For floppy disk – rotate at 300 to 600 rpm, so delay between 100 & 200 ms

Hard Disk

- Track per inch (TPI)
  - No of tracks can be fit in a given area
- Bits per inch (BPI)
  - No of bits can be written on one inch of a track on a disk surface
- Disk Space
  = No. of Sides x Tracks x Sector per track x bytes per sector
- Example:
  A hard disk has 8 double side platters with 919 cylinders, 17 sectors per track and 512 bytes per sector.
- Disk space = 2 x 8 x 919 x 17 x 512 = 127983613 Bytes
  = 122 MB

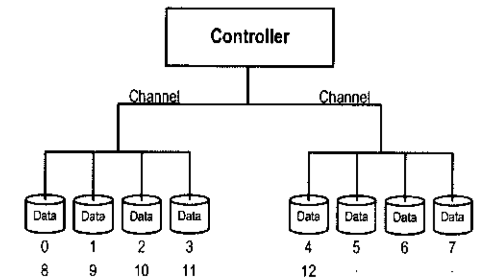
Hard Disk

- Internal Cache
  - All modern hard disks have an internal buffer or cache that is used as an intermediate repository for data being transferred between hard disk and PC.
  - Having some cache in a drive is somewhat important to overall performance; the drive will use it to buffer recent requests and to "pre-fetch" data likely to requested by the system in the future.

RAID Technology

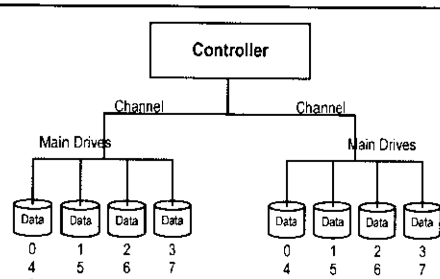
- RAID (Redundant Array of Inexpensive Disks) technology provides mass storage with high throughput and reliability
- One or more logical drives is configured from a set of disk drives
- Data is distributed across the set of drives in a pre-defined manner
- Data reconstruction capability for recovering data in case of disk failure
- Data is spread across the drives in units of 512 bytes called segments, multiple segments form a block
- The process, is called data striping, causes data to be split across multiple spindles so that different sections are served in parallel by multiple disks
- There are eight RAID levels

RAID Technology



- **RAID 0 :** disk stripping
- Data is striped across multiple disks
- High data reads, low reliability, no redundancy, no error correction

RAID Technology



- **RAID 1**: Disk Mirroring
  - Separate independent disks, all data is duplicated
  - Highest data reads and reliability, fault tolerance
  - Drives cost doubled due to total redundancy

RAID Technology

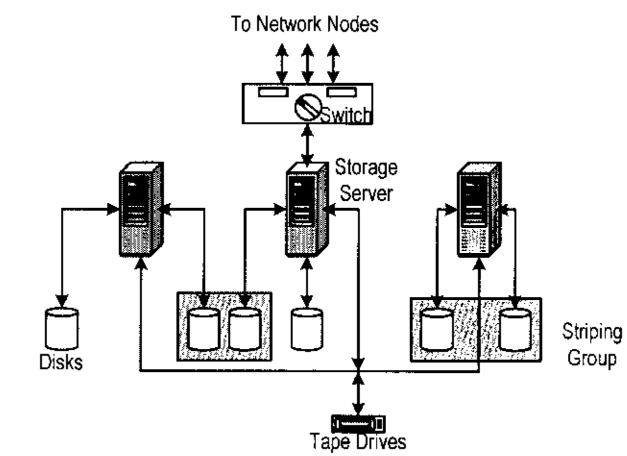
- **RAID 2:** Bit Interleaving and Hamming Code Redundancy
  - Data striped across multiple disks, errors are detected and corrected in RAM or on separate disk
  - High transfer rates, good for large data transfer
  - Not commercially available, low input/output request rates due single I/O synchronization
- **RAID 3:** Bit Interleaving and XOR parity
  - Drives operate in parallel synchronization, data is striped byte by byte across multiple disks. Separate parity-only drive which stores all redundant data
  - I/O performance good, especially for large block transfers
  - Slower read/write performance, single I/O request execution.
  - If parity drive fails, protection lost – but system still operates
- **RAID 4:** Block Interleaving with XOR parity
  - Data striped across all disks, separate parity-only drive, disks can work independently of each other
  - Good large data I/O performance

RAID Technology

- Not widely available, poor write performance
- If parity disk fails, data protection is lost

- **RAID 5**: Block Interleaving with Parity Distribution
  - Data and parity is striped across all disks
  - Data reliability equals mirroring, high read performance
  - Poor write-performance due to strip
- **RAID 6:** Fault tolerance system
  - Data and parity is striped across all disks, second parity drive is added
  - Poor write, worse than RAID 5
- **RAID 7:** Heterogeneous system
  - Allow each individual drive to access data as fast as possible, because of multiple I/O paths and embedded OS
  - Embedded OS takes care of all parity generation, checking, control and caching
  - Support up to four simultaneous disk failures
  - Easy upgrade, support heterogeneous mix drives

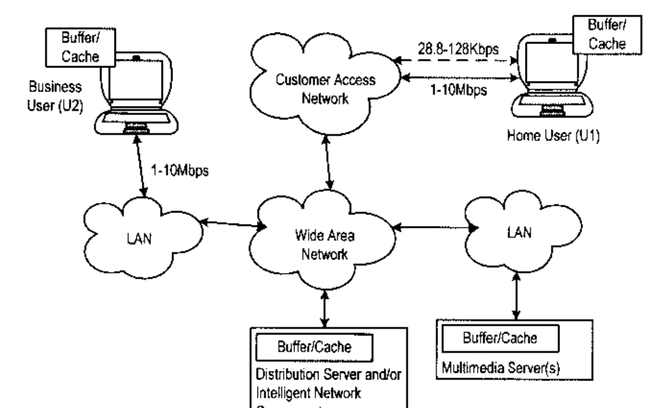
Storage System Architecture



Cache Management

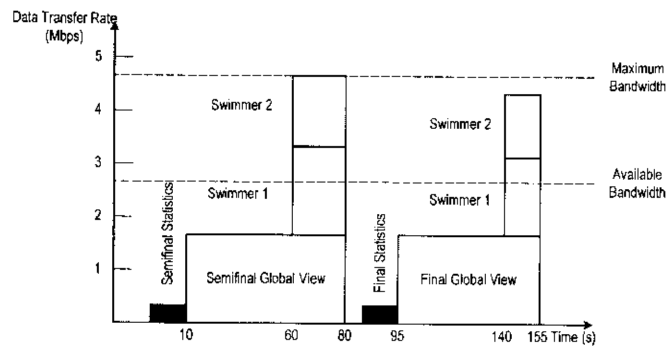
- In a multimedia system, storage and bandwidth are critical resources as it requires to deliver large volume of data in real time.
- Each multimedia object is streamed at its playback rate from the storage device to presentation device
- To guarantee quality of service, the playback bandwidth is reserved on the delivery path which consists of many system components
- Caching of multimedia documents in local storage can reduce required retrieval bandwidth
  - Storage of frequently used documents in client nodes or in intermediate distribution server nodes can reduce network bandwidth from the remote servers
  - Storage of documents shared by many users in the server memory can reduce disk retrieval bandwidth
- In a movie-on-demand application, a single long video may be last for two hours
- Small video clips may be retrieved in response to client commands

Cache Management



Multimedia end-to-end application environment

Cache Management

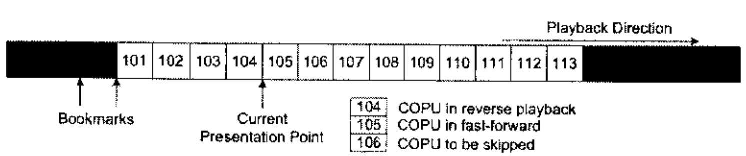


Composite Multimedia Document

Cache Management

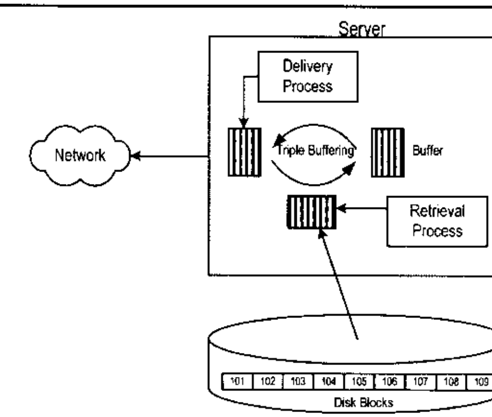
- Small media segments may be combined to form composite media documents and played back in a predefined order
- Quality and bandwidth requirements for each clip may be different
- Resulting instantaneous bandwidth for each clip in a composite document fluctuates widely
- Jitter-free playback is required for the whole playback duration
- The profile can be smoothed by prefetching the required data blocks in advance to the local or primary storage
- The access pattern within a single multimedia document may not uniform or the playback sequence may not be linear
- By caching related data clocks, the number of data blocks from secondary storage can be reduced.

Cache Management



- Data blocks are retrieved continuously in a linear fashion and are referred as a continuous object presentation unit (COPU)
- For a VCR operations, upon receiving a fast-forward command, a selected set of data blocks may be presented or a user may mark any data for playback
- Access pattern for different applications may change rapidly, need caching policies to handle different characteristics of various applications
- The policy is to guarantee continuous delivery
- It is expensive to replicate data at the locate site
- For caching to be cost-effective, only the frequently accessed data is cached

Cache Management



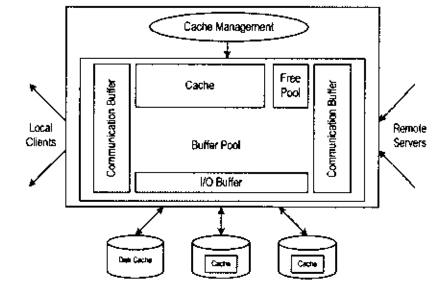
Buffering

Cache Management

- buffering and caching concern the use of primary storage to avoid delay or overhead in assessing secondary storage
- Distinction between the use of buffering and caching lies in the performance objectives, application requirements, and the usage of primary memory
- Buffering is for avoiding access delay, caching is for avoiding access overhead or delay.
- Data blocks are prefetched for consuming current data stream is referred to buffering
- Data blocks are retrieved for playback stream and retrained in the storage for future use is referred as caching
- Once enough data is retrieved to fill a buffer slot, it is passed to the delivery process
- Any mismatching in speed between the delivery and retrieval processes may result in either buffer overflow or buffer underflow
- Retrieval or delivery processes are not always smooth
- Multiple buffer slots may be used to avoid jitters in the delivery process
- Jitters possibility becomes negligible when there are more than three buffer slots
- However, multiple buffer slots introduce a large access latencies during the start of a stream

Cache Management

- Once the prefetched data blocks are consumed by the delivery process, the buffer slots become available for reuse.
- The cache manager maintains the list of currently used slots as well as free slots
- A single server may receive data from multiple sources or deliver data to multiple clients
- Cache manager employs various algorithms for retaining or turning cache blocks to free blocks
- It employs efficient prefetching algorithm for dealing with burstiness in traffic



Caching Objectives

- Increasing server capacity
  - Retrieval path from the storage devices are the bottleneck
  - Storing all or parts of frequently accessed multimedia objects in the server memory, more clients can be served, and effectively increase the capacity
- Reducing access latency
  - Servers deliver data instantly to clients whereas disks deliver in many millisecond
  - Improving interactive response time is important for video-on-demand or virtual reality applications
- Reducing network bandwidth requirements
  - based on the client request patterns, local server caches data on the local disks and memory for avoiding the communication overhead of getting from the remote sit and to improve performance

Caching Objectives

- Balancing load across storage devices
  - By employing a shared cache on the common part of the delivery paths from the servers or devices
  - By selectively caching the data from the bottleneck servers
- Supporting data migration in storage organization
  - Long-term popularity of data change with time, proper placement of data across various storage devices becomes difficult
  - Any mismatch can result in poor utilization of resources
  - Dynamic segment replication policy through copyback of playback streams is used to balance the load across striping groups

Cache Policies Characterization

- Stream-dependent caching vs. block-level caching
  - Multimedia applications required large storage space, large bandwidth and continuous delivery
  - Block-level caching policies cache unrelated sets of blocks instead of complete multimedia objects cannot guarantee continuous delivery of streams
  - Large multimedia objects need to be cached in their entirety relationships across playback streams can be established to support a following stream from the cached data by a preceding streams
- Memory vs. storage caching
  - Caching policies depend on the resource constraints of the local servers and are for improving the utilization of cache space
  - If the secondary storage device is treated as a cache, the policies need to account not only for space constraint but also for the bandwidth for reading from and writing the cache

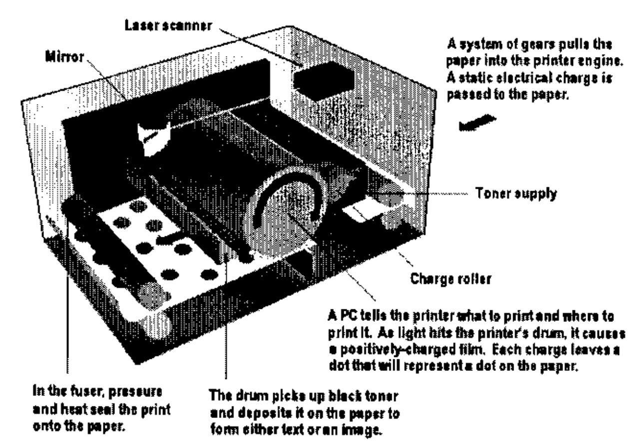
Cache Policies Characterization

- Caching vs. prefetching
  - A related aspect of caching is the prefetching of blocks to be accessed by a single stream rather than sharing of retrieved blocks across streams
  - Prefetching of blocks can mask variance in response time
  - Avoid jitters in presentation
  - Used to smooth the burstiness introduced by data compression in single, long data stream or composite multimedia documents

Cache Policies Issues

- Adaptive workload
  - Cope with dynamic changes in workload and heterogeneity arising from large and small multimedia files
  - Cope with the challenges in a large-scale distributed multimedia environment consisting of many heterogeneous servers
- Support for VCR control
  - Support for VCR control: pause, resume
  - VCR control interrupts the sequential reading of multimedia files
- Integration with other resource optimization policies
  - Multiple clients accessing the same set of documents sequentially separated by a small time intervals
  - Blocks retrieved by one client can be reused by other following clients
  - Alternatively, batch related requests and serve them using a single stream
  - Caching is integrated with merging by serving closely following streams from cache
  - Integrated with resource management policies for dealing with load balancing, data migration, and coordinated data prefetching for composite documents

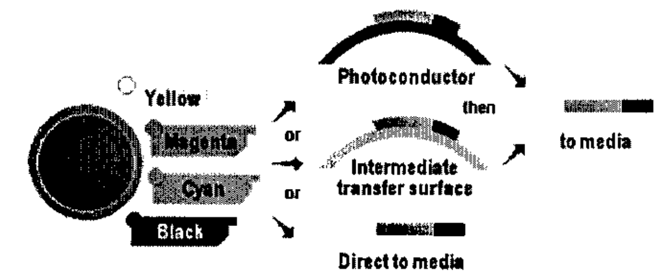
Laser Printer



Laser Printer

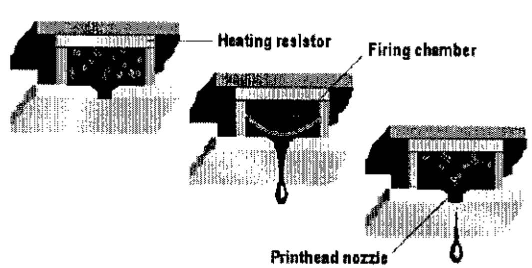
- A rotating drum – an organic photo-conducting cartridge with coating that allows it for holding charge
- Initially, the drum is positive charged, a laser beam scans across the surface of the drum, selectively impairing points of negative charge onto the drum's surface that will ultimately represent the output image
- The area of the drum is the same as that of the paper onto which the image will eventually appear
- The paper is passed through an electrically charged wire which deposits a negative charge onto it
- On true laser printers, the selective charging is done by turning the laser on and off as it scans the rotating drum, using a complex arrangement of spinning mirrors and lenses.
- As the drum rotates, the written-on area moves to laser toner, positive charge is attracted to the points of negative charge on the drum surface
- The system applies heat and pressure to the imaged paper in order to adhere the toner permanently

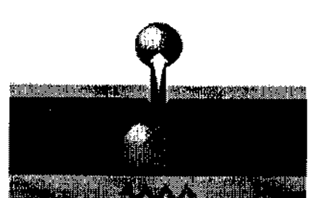
Color Laser Printer



- Laser printing can be adapted to colour using cyan, magenta and yellow in combination to produce different printable colour
- Four passes through electro-photographic process are performed by placing toners on the page one at a time or building up the four-colour image on an intermediate transfer surface

Ink Jet Printer (Thermal Technology)

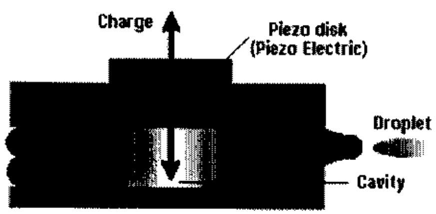


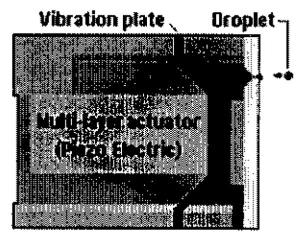


Ink Jet Printer (Thermal Technology)

- Technology used by HP and Cannon
- Heat is used to fire the ink onto paper
- 3 stages;
  - Heating ink creates a bubble, pressure forces it to burst and hit the paper
  - Bubble collapse as the element cools
  - The resulting vacuum draws ink from reservoir to replace the ejected ink
- limitations: ink must be resistant to heat, need for cooling
- Tiny heating elements are used to eject ink droplets from print-head's nozzles
- Print heads may contain between 300 and 600 nozzles, each about diameter of human hair
- Print speed is a function of frequency that nozzles firing ink drops

Ink Jet Printer (Piezo-electric Technology)

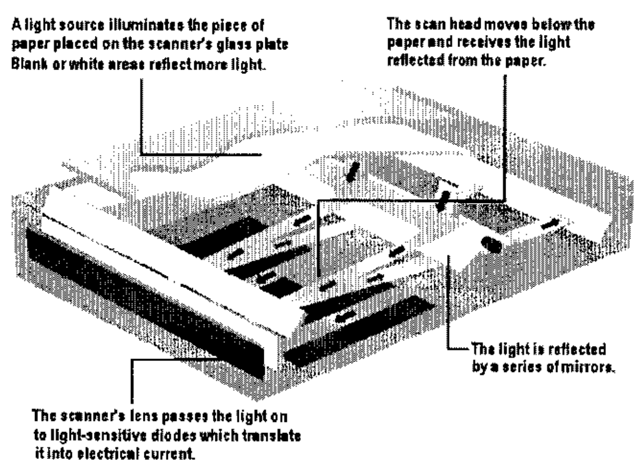




Ink Jet Printer (Piezo-electric Technology)

- Technology use by Epson
- Use a piezo crystal at the back of the ink reservoir
- When a dot is required, a current is applied to the piezo element, the element flexes and forces a drop of ink out of the nozzle
- Advantages:
  - More control on the shape and size of ink droplet
  - Tiny fluctuations in the crystal allow for smaller droplet sizes and hence higher nozzle density
  - Unlike thermal technology, no heating and cooling cycles
  - Ink is tailored for absorption properties rather than high temperature

Scanner



Scanner

- A device converts light into 0s and 1s
- All scanners work on the same principle of reflectance
  - The fraction of light incident on a surface and varies according to the wavelength distribution of the light
- The image is placed before a carriage consisting of a light source and sensor
- Light source
  - Fluorescent bulbs, two weakness: white light not consistent for a long time; emit heat that distorts other optical components
  - Cold-cathode, no filament, lower temperature
  - Late 2000, Xenon bulbs produce very stable, full spectrum light source
- To direct light from the bulb to the sensors that read the light values, CCD scanners use prisms, lenses and other optical components
- A quality scanner uses high-quality glass optics that are colour-corrected and coated for minimum diffusion

Scanner

- The amount of light reflected by or transmitted through the image and picked up by the sensor, is converted to voltage proportional to the light intensity
- The analogue to digital conversion (ADC) is a sensitive process and is susceptible to electrical interference and noise
- To protect against image degradation, the ADC is isolated from the scanner main circuitry
- Sensor components:
  - PMT (photomultiplier tube), a technology inherited from the drum scanners
  - CCD (charge-couple device), sensors used in desktop scanner
  - CIS (contact image sensor), newer technology, integrates scanning functions into fewer components, allowing scanners to be more compact in size

Display Concepts

- **Graphics Card** is an expansion card that interprets drawing instructions sent by CPU, processes them via a dedicated graphics processor and writes the resulting frame data to the frame buffer
- **3D graphics** is the display of objects and scenes with height, width, and depth information. The information is calculated in a co-ordinate system that represents three dimensions via x, y and z axes.
- **Resolution** is the number of pixels per unit area. The finer the grid defining an area, the more pixels it contains and the higher its resolution. The higher the greater its capacity for reproducing detail
- **Image Resolution** is the fineness or coarseness of an image as it was digitized, measured in Dots Per Inch (DPI), typical 200 to 400 DPI
- **Dot pitch** is the distance between adjacent sets of red, green and blue dots. For most monitors, the specification is in the range of 0.25 to 0.40mm
- The dot pitch indicates how fine the dots making up the picture, the smaller the dot pitch, the more sharp and detailed the image.

Display Concepts

- **Pixel** is the smallest unit that can be addressed and given a colour or intensity. The pixel is represented by some number of the bits (usually 8, 16, 24 or 32) in the frame buffer, and is illuminated by a collection of phosphor dots in the CRT that are struck by the beams of the electronic gun
- **Pixel clock** speed is the frequency or speed at which individual pixels in an image are written to the screen. The higher the pixel clock speed, the less likely there will be flicker
- **Aspect ratio** of the image is the ratio of the number of X pixels to the number of Y pixels. The standard aspect ratio for PCs is 4:3, but some use a ratio of 5:4 for 1280x1024

Resolution	Number of Pixels	Aspect Ratio
320 x 200	64,000	8:5
640 x 480	307,200	4:3
800 x 600	480,000	4:3
1024 x 768	786,432	4:3
1280 x 1024	1,130,720	5:4
1600 x 1200	1,920,000	4:3

Color Spaces

- **Color depth** determines the amount of information stored about the pixel.
- More memory requires to increase color depths, more data for video card to process, and hence reduce refresh rate
- **True color** requires three bytes (24bits) of information, one for each color. Some graphics cards require 32 bits of information with extra 8 bits for an alpha channel (transparencies), the underlying image can be opaque, darker or brighter
- **High color** requires two bytes (16 bits) of information, 5 bits for blue, 5 bits for red and 6 bits for green

Color Depth	Number of Displayed colors	Bytes of storage Per Pixel	Common Name for Color Depth
4- Bit	16	0.5	Standard VGA
8- Bit	256	1	256-Color Mode
16- Bit	65,536	2.0	High Color
24- Bit	16,777,216	3.0	True Color

Refresh Rate

- The **refresh rate** is the number of times per second that the RAMDAC sends a signal to the monitor for repainting the screen
- For supporting the refresh rate:
  - Video card should be fast enough to deliver the signals (Number in the table are in MHz, representing millions pixels per sec the RAMDAC must output to the monitor)
  - Monitor is capable to handle and display the video signal
- No positive effect for higher refresh rate, it will reduce the display contrast

Resolution	43.5Hz (87 interlaced)	60 Hz	72 Hz	80 Hz	85 Hz	90 Hz	100 Hz
320 x 200	3.7	5.1	6.1	6.8	7.2	7.6	8.4
640 x 480	17.6	24.3	29.2	32.4	34.5	36.5	40.6
800 x 600	27.6	38.0	45.6	50.7	53.9	57.0	63.4
1024 x 768	45.2	62.3	74.7	83.0	88.2	93.4	103.8
1280 x 1024	75.3	103.8	124.6	138.4	147.1	155.7	173.0
1600 x 1200	110.2	152.1	182.5	202.8	215.4	228.1	253.4

Monitor Size and Resolution

- Maximum resolution of a monitor is related to its size
- Higher resolution on a smaller monitor size may not be usable to the user
- Large monitor in the low resolution modes, the pixels become quite large and "blocky"
- The table shows different screen resolutions and how they appear on different monitor size

Nominal Size	14"	15"	17"	20"	21"
320 x 200	**Ideal**	Good	Blocky	Very Blocky	Very Blocky
640 x 480	Good	**Ideal**	Good	Blocky	Blocky
800 x 600	Small	Good	**Ideal**	Good	Blocky
1024 x 768	Very Small	Small	Good	**Ideal**	Good
1280 x 1024	Magnifying Glass	Very Small	Small	Good	**Ideal**
1600 x 1200	Yeah Right!	Magnifying Glass	Very Small	Good	**Ideal**

Frame Buffer Memory

- Frame Buffer Memory is the video memory used to hold the video image displayed on the screen
- The memory depends on the resolution of the screen image and also the color depth used for the pixel
- Memory in MB=(x-resolution * y-resolution * bits-per-pixel) / (8*1,048,576)

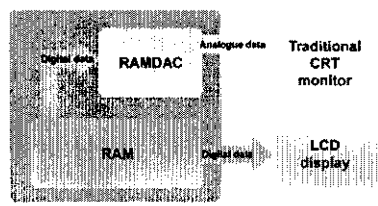
Resolution	4 Bits	8 Bits	16 Bits	24 Bits	32 Bits
320 x 200	0.03 (256KB)	0.06 (256 KB)	0.12 (256 KB)	0.18 (256KB)	--
640 x 480	0.15 (256KB)	0.29 (512 KB)	0.59(1 MB)	0.88 (1 MB)	1.17 (2 MB)
800 x 600	--	0.46 (512 KB)	0.92 (1 MB)	1.37 (2 MB)	1.83 (2 MB)
1024 x 768	--	0.75 (1 MB)	1.50 (2 MB)	2.25 (4 MB)	3.00 (4 MB)
1280 x 1024	--	1.25 (2 MB)	2.5 (4 MB)	3.75 (4 MB)	5.00 (6 MB)
1600 x 1200	--	1.83 (2 MB)	3.66 (4 MB)	5.49 (6 MB)	7.32 (8 MB)

PC Graphic Card

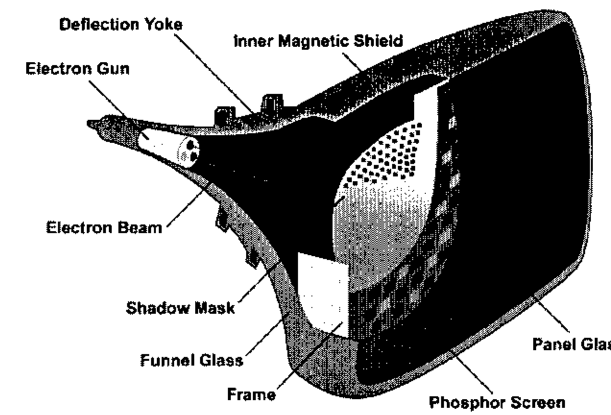
- PC graphic card consists of four components: graphics processor, video memory, RAMDAC and driver software
- **Graphics Processor:**
  - Early VGA systems were slow because CPU was heavily loaded by processing graphic data
  - It is solved by a dedicated graphics processing chips on modem graphics card
  - Instead of sending a raw screen image across to the frame buffer, the CPU sends a smaller set drawing instructions, which are interpreted and executed by the graphics card's drive
  - Operations including bitmap transfers and painting, window resizing and reposition, line drawing, font scaling and polygon drawing by writing frame data to the frame buffer
- **Video memory**
  - holds video image and is called frame buffer.
  - Information in the frame buffer is the image appeared on the screen
  - Greater number of colors, or the higher resolution, more memory is required.
- **RAMDAC** in the video card is responsible for reading the contents of the video memory, converting the digital values in memory into analog video signals, and sending them over the video cable to the monitor. It is able to control the refresh rate for the operating video mode

PC Graphic Card

- Graphic card's driver software is vitally important
- The drivers translate what the application wants to display on the screen into instructions that the graphic processor can use.
- Digital Cards
  - LCD display require digital input
  - Dedicated digital, dual digital/analogue with digital add-ons
- In 1999, Digital Display Working Group (DDWG) finalize a Digital Visual Interface (DVI) connector standard for the LCD flat-panel display



CRT Monitor

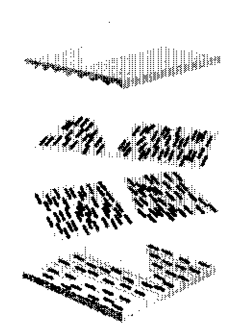


CRT Monitor

- The monitor screen is coated on inside with a matrix of thousands of tiny phosphor dots
- Phosphors are chemicals which emit light when excited by a stream of electrons
- Different phosphors emit different colored light
- Each dot consists of three blobs of colored phosphor: one red, one green and one blue.
- Three phosphors make up a single pixel
- The neck of a CRT is the electron gun, which composed of a cathode, heat source and focusing elements
- Color monitor has three separate electron guns, one for each phosphor color
- Images are created when electrons, fired from the electron guns, converge to strike their respective phosphor blobs
- Refresh rate, or vertical scanning frequency, represents the number of frames displayed on the screen per second. It is general accepted 75Hz or above for a flicker-free display
- Calculating CRT max refresh rate:

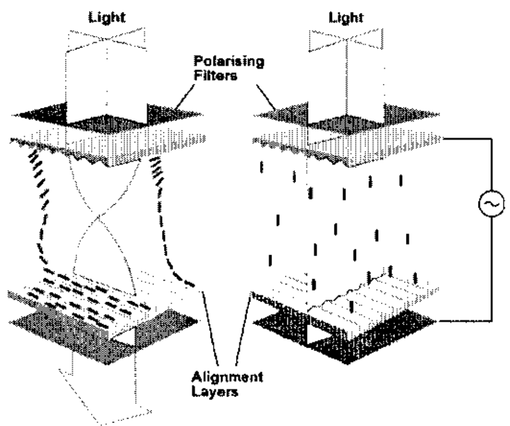
Vertical scanning freq. = horizontal scanning freq. / no. of horizontal lines x 0.95

Liquid Crystal Display (LCD)



- Liquid crystals are almost transparent substances, exhibiting the properties of both solid and liquid matter
- Light passing through liquid crystals follows the alignment of the molcculcs
- 1960, it was discovered that charging liquid crystals with electricity changed their molecular alignment, and consequently the way light passed through them
- The display works by varying amounts of a fixed-intensity white backlight through an active filter.

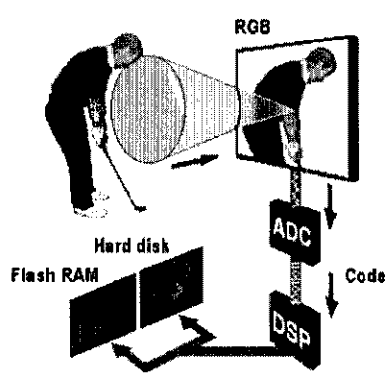
Liquid Crystal Display (LCD)



Liquid Crystal Display (LCD)

- The varying levels of brightness required to create a full color display is achieved by changing the strength of the voltage applied to the crystals.
- TFT (Thin Film Transistor) LCD displays
  - One transistor for each color (RGB) of each pixel
  - Transistors drive the pixels, eliminating problems of ghosting and slow response speed
  - Resulting response times: 25ms, contrast ratios in the region of 200:1 to 400:1 and brightness values between 200 and 250 cd/m^2
  - Liquid crystal elements of each pixel are arranged so that in normal state the light coming through the passive filter is "incorrectly" polarized and thus blocked
  - When a voltage is applied across the liquid crystal elements when they twist by up to 90 degrees in proportional to the voltage, changing their polarization for more light.
  - The transistors control the degree of twist and hence the intensity of the red, green and blue elements of each pixel forming the image on the display
  - TFT screens can be made much thinner than LCDs, making them lighter, and refresh rates now approach those of CRT

Digital Camera



Digital Camera

- Digital camera uses a combination of advanced image sensor technology and memory storage, which allows images to be captured in a digital format
- Imaging is performed either by a charge coupled device (CCD) or CMOS (Complementary metal-oxide semiconductor) sensors
- Each sensor element converts light into a voltage proportional to the brightness through an analogue to digital converter (ADC) and translates the fluctuations of the CCD into binary code
- The digital output of the ADC is sent to a digital signal processor (DSP) which adjusts the contrast and detail, and the compresses the image before sending it to storage medium

Digitizer Technology

- Two basic types of digitizers
  - Active digitizers
  - Passive digitizers
- Digitizer components
  - A pen, stylus or human finger to generate input data
  - A sensor device to generate x, y analog coordinates from the input data
  - A micro controller to convert the x, y coordinates into digital data
  - Driver software
- Passive digitizing technology
  - Used in all PDA and vertical tablet applications
  - Electronic components are contained on or beneath the surface of the contact surface
  - Input device contains no electronics
  - Voltage is applied to the top sheet, as user touches the screen, it compresses the spacer dots in between the top and bottom layers. Current flows in proportion to the distance from the edge. X & Y is calculated based on the changes of current flows

Digitizer Technology

- Capacitive technology
  - Voltage is applied to the four corner of screen
  - Electrodes spread out the voltage creating a uniform field
  - The touch of finger draws current from each side in proportion to the distance from the edge and position is calculated
  - Used in video game, kiosks and point of sale devices
- Acoustic wave technology
  - Ultrasonic transducers are mounted on two edge of the display, setting up a pattern of sound waves
  - A finger disturbs the pattern and the position is calculated based on the changes in the sound
  - Used in monitoring applications and Kiosks

Digitizer Technology

- Infrared technology
  - Similar to acoustic wave except infrared light is utilized
  - Used in large displays, banking machines and military applications
- Active Digitizing Technology
  - Input device, e.g. a pen, contains electronics external to the touch surface of the digitizing device
  - Is applied to higher resolution and higher accuracy
  - Uses electromagnetic technology to transmit information about the pen's position, via the pen, to the sensor grid located behind the LCD.
  - A controller uses information to create digital input data to the computer
  - Advantages include: supports hover capability, faster data conversion, higher resolution, higher accuracy, inking pen can be used, easier and more stable calibration, and clarity of screen.

Reference

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