Knowledge Update Course
for Secondary School Computer and IT Teachers

Computer Organisation

I/O, Buses and Peripherals

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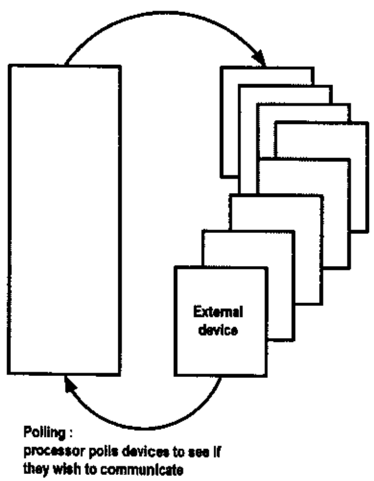
Agenda

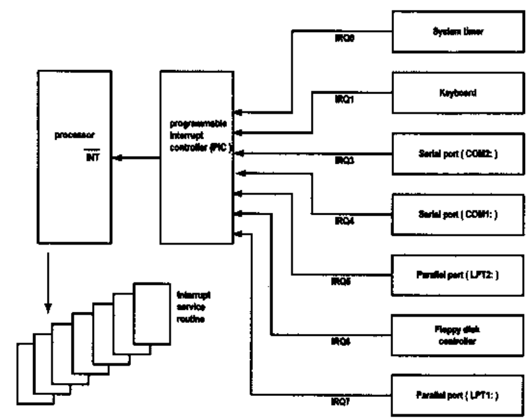
1. Computer Input and Output
2. Computer Buses
3. Computer Peripherals

Programmable I/O



- CPU interacts directly with the I/O device by sending a command to the I/O module & waiting for the I/O operation to complete
- Causes serious degradation to the computer system (since CPU is faster than the I/O devices)

Interrupt driven I/O



Interrupt driven I/O

- The I/O device & the CPU each handles its tasks
- I/O interrupts the CPU only when an I/O operation is done
- A vectored interrupt approach is used in which a no. of devices share a common interrupt line using a first-come-first-serve method

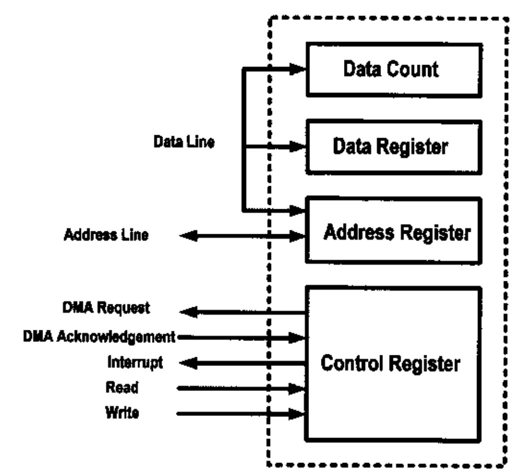
Interrupt driven I/O

- The interrupt service routine:
  - Each device have a device-specific code that handles the I/O requests
  - All service routines need first to save the processor context on entry
  - And restore them on exit of the routine
- Other issues:
  - Prevention of modifying data from interrupt routine using synchronize operations between 2 independent threads of an execution

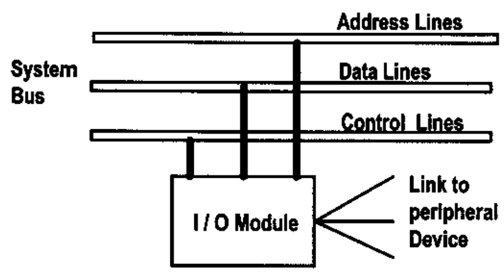
Direct Memory Access (DMA)

- Specifically designed for transferring large volumes of data
- The DMA transfers the entire block of data one word at a time directly to/from the memory without going through the CPU
- The CPU gets 2 interrupts (1st from sending request, 2nd from receiving interrupt after serviced)
- DMA module gets priority in controlling the bus (cycle-stealing)

Direct Memory Access (DMA)



Input/Output Modules

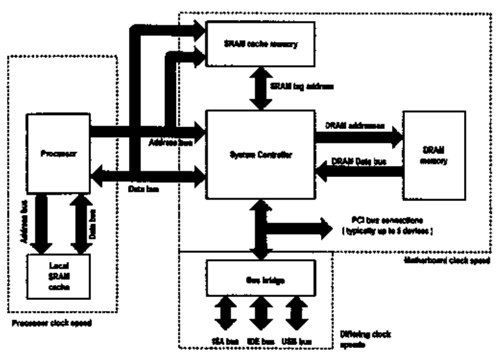


- Each module interfaces to the system bus or central switch and control one or more peripheral (e.g. mouse)
- It contains some "intelligence" (i.e. it contains logic for performing a communication function between the peripheral and the bus)

Input/Output Modules

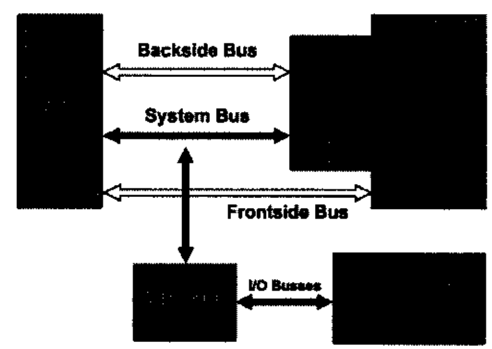
- Why one does not connect peripheral directly to the system bus
  - There are a wide variety of peripherals with various methods of operation. It is impractical to incorporate the necessary logic within the processor to control a range of devices.
  - The data transfer rate of peripheral is often much slower than that of the memory or processor. It is impractical to use the high-speed system bus to communicate directly with a peripheral.
  - Peripheral often use different data format and word lengths than the computer to which they are attached.
- An I/O module is required
  - Interface to the processor and memory via the system bus or central switch
  - Interface to one or more peripheral devices by tailored data links

Computer Busses



- Busses – connect all PC's internal components and external devices and peripherals to its CPU and memory
- Fastest bus: processor & primary cache
- Next level is system bus: processor & memory (L2 cache & main memory)
- CPU connect to main memory through a system controller chip

Computer Busses



- Dual Independent Bus (DIB) replaced the old single bus system with a frontside bus and a backside bus
- CPU access data from either of the busses independently and in parallel

Computer Busses

- Bus Terminology
  - System bus referred to main bus, processor bus or local bus
  - I/O bus referred to expansion bus, external bus or host bus

Standard	Typical uses	Burst DTR	Outlook
ISA	Sound cards, modems	2 MB/s to 8.33 MB/s	Almost entirely phased out; superseded by PCI
EISA	Network, SCSI adapters	33 MB/s	Almost entirely phased out; superseded by PCI
PCI	Graphics cards, SCSI adapters, new generation sound cards	266 MB/s	Standard add-in peripheral bus for the foreseeable future
AGP	Graphics cards	528 MB/s	Standard in all Intel-based PCs from the Pentium II; co-exists with PCI

PC Bus and VL-local Bus

- PC Bus
  - 8-bit data bus and 20 bit address bus
  - transfer rate is fixed in 4.77 MHz
  - data rate: 8MB/s
- VL-local Bus (Video Electronics Standard Association (VESA local Bus)
  - Local bus for video card
  - Direct access to system memory at processor speed, bus speed depends on processor
  - Positioned as an extension of ISA slot, 58pins
  - Offers 32-bit and 64 bits with max data rate 260MB/s
  - 33MHz is the speed limit

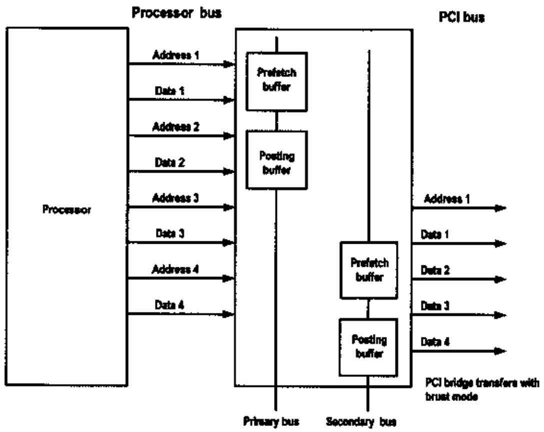
ISA Bus and EISA Bus

- Industry Standard Architecture (ISA)
  - Designed for 80286
  - Originally 8-bit data and 20-bit address, 62-way double side slot, 4.77MHz
  - The 16-bit and 24-bit address, 36-way extension added to 62-way slot, 8.33 MHz
  - Data rate: 16MB/s
  - Compatible with PC bus
- Extended ISA (EISAQ)
  - 32-bit based on ISA, runs at 8.33MHz
  - Backward compatible to ISA
  - Double ISA data width 32.32MB/s

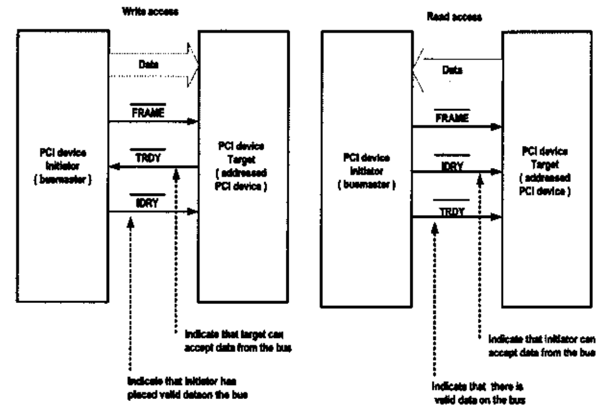
PCI Bus

- Peripheral Component Interconnect (PCI)
  - PnP, enable PC to adjust new card automatically
  - Link to PC system bus through a "bridge" circuitry and runs at fixed speed, independent of processors
  - 2 versions: 32-bit (124 ways) & 64-bits version (188-ways)
  - Support 33MHz giving data rate : 132MB/s & 264MB/s for 32 bits & 64 bit respectively
  - PCI creates an intermediary bus between CPU local bus & I/O expansion bus
  - PCI2.1 runs at 66MHz, for 64 bits, data rate is 526MB/s
- PCI-X V1.0
  - Backward compatible with PCI
  - For increased I/O requirements for Gigabit Ethernet, Fibre Channel, Ultra3 SCSI and high-performance graphics
  - Support 64-bit at 133MHz for 1GB/s
  - Application in server, workstations, embedded systems and data communication

PCI Bridge



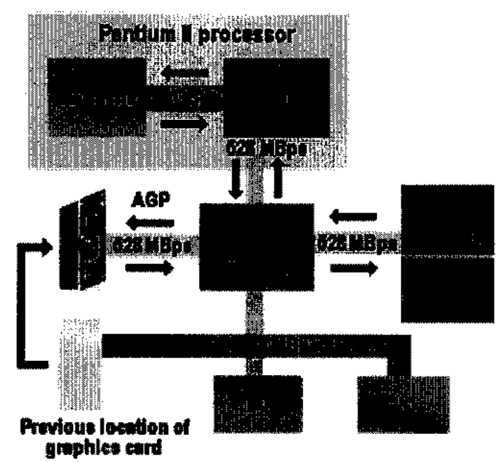
PCI Handshaking



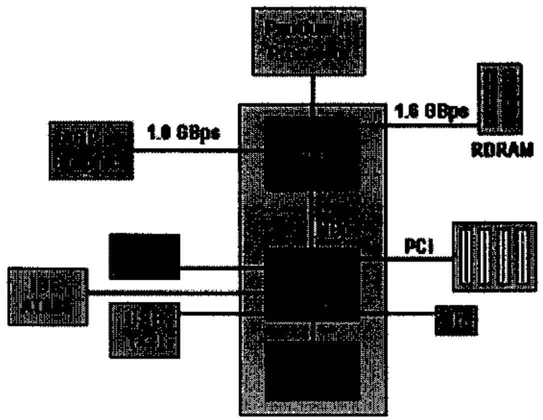
AGP Bus

- Accelerated Graphics Port (AGP)
  - 32-bit, 3.3V dedicated bus for high performance video graphics
  - Operates at processor bus "frontside bus" speed at clock rate 66MHz with data rate 266 MB/s
  - Allows data to be sent during rising & falling edges, double clock rate to 133MHz with data rate 533MB/s, this is known as AGP X 2
  - AGP can use system memory as display memory, is called Direct Memory Execute (DIME)
- AGP 2.0
  - 4X-transfer mode on 66MHz for data rate 1.066 GB/s
- AGP Pro
  - Physical spec for high end-graphics card
  - Caters for 100W AGP cards (AGP, 25W)
  - Longer AGP slot that will also take current AGP cards

Accelerated Graphics Port (AGP)



Pentium Busses



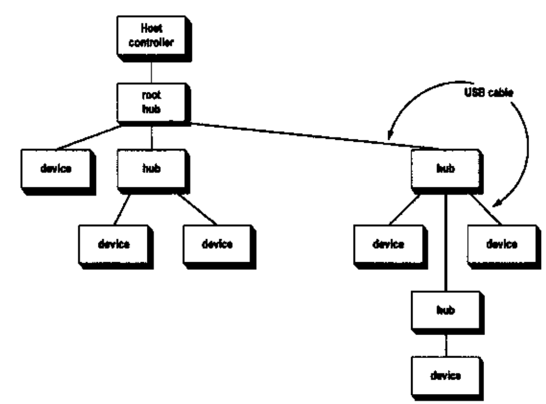
PCMCIA Card

- Personal Computer Memory Card International Association (PCMCIA)
  - Credit-card-sized expansion board with 68-way edge connector for notebook
  - Type I - 3.3 mm thick, for memory such as RAM, flash or SRAM card
  - Type II - 5.5 mm thick, for I/O devices such as modem/fax/LAN card and mass storage devices
  - Type III - 10.5 mm thick for thicker components, such as portable disk.
  - Software defines "Plug and play" capability , and is made up of Socket Services and Card Services
  - Socket Services is BIOS-level software that detect insertion and removal of PC card
  - Card Services describes an application Programming Interface (API) which allows the cards and sockets shared by multiple clients
  - Derived from PCI local bus protocol, it is 32-bit address and data, runs at 33MHz and bus master operation

Universal Serial Bus (USB)

- Hot-pluggable: I/O devices can be added while PC is running
- Ease of use: I/O device attachment is recognized by the PC and appropriate device drivers, and configuration is done automatically
- Single connector type: all devices plug into the same socket type
- Automatically match speed: 1.5 or 12 Mbps (USB1.1); 480Mbps (USB 2.0)
- Four wires, one twisted-pair lines gives differential data line (D+ & D-), two wire for power supply (+5 & GND)
- Up to 127 devices: no practical limit to I/O devices expandability
- Max length 5m between each peripheral device or hub device
- Power supplied by cable, power automatically when not use
- Error detection and recovery
- External to PC

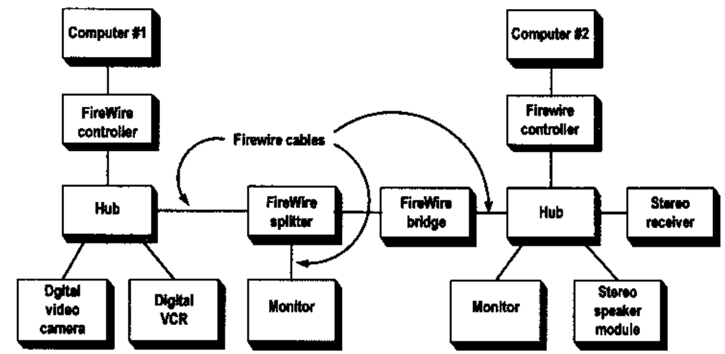
USB Hub



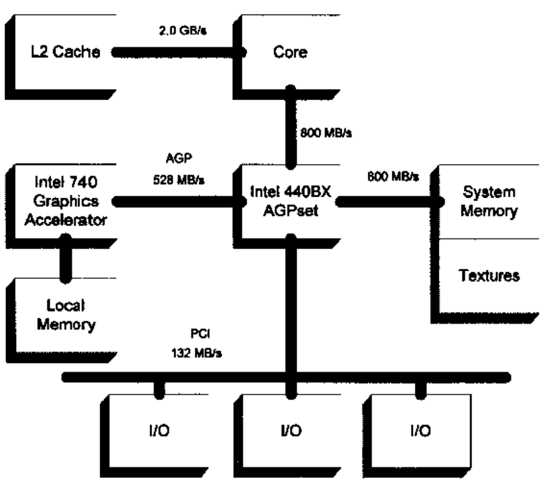
Firewire IEEE 1394

- Scalable performance
  - Speeds 100, 200 and 400Mbps
  - New version 1394.B, 800Mbps, 1.6Gbps and 3.2Gbps, and backward compatible
- Support isochronous and asynchronous transfers
  - Isochronous, fixed length, periodic and time critical
- Point to point with tree topology: support 64 node addresses on a single serial bus, and support 1024 buses
- Max cable length is 4.5m
- Automatic configuration and hot plugging
- Rate mixing, a single cable medium can carry a mix of different speed
- Inexpensive targeted at consumer devices
- Applications:
  - Mass storage
  - Video conferencing and production
  - Small networks
  - High speed printer
  - Entertainment equipment
- Devices can talk without PC

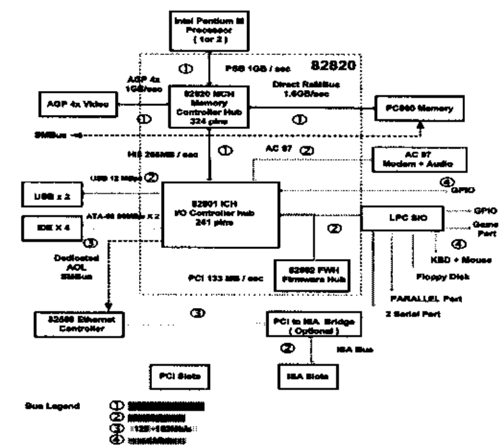
Firewire 1394



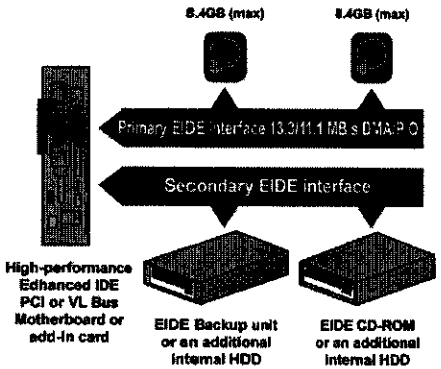
Computer Chipsets



820 Chipset Rambus Support



Integrated Drive Electronic (IDE)



- IDE itself is not a hardware standard is ATA interface
- Originally 2 hard disks, each with max capacity of 528MB
- In 1993, Western Digital brought EIDE (Enhanced IDE) onto market,
- EIDE overcomes the constraints of ATA and maintain backward compatibility, and 4 devices handled by 2 channels
- Fast ATA burst rate up to 16.6MB/s, hard disk capacity 137GB

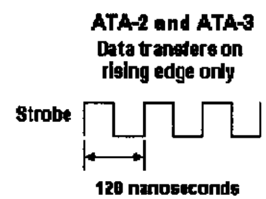
Integrated Drive Electronic (IDE)

- When host reads data, OS determines hard disk no., cylinder no. and sector no., then OS send commands to hard disk controller to position the head onto the desired sector position and read data into cache buffer in usually 4k block then to the host
- Support non-disk peripherals such as CD-ROM drives and tape drive by ATAPI (AT Attachment Packet Interface)
- ATAPI defined by Western Digital, is the ATAPI extension of the ATA protocol
- EIDE also supports transfer standards developed by ATA committee
- Programmed Input/Output (PIO) modes are a range of protocols for a drive and IDE controller to exchange data at different rates between hard drive and memory
- Many drive also support Direct Memory Access (DMA) operation as alternative protocol to PIO modes
- DMA takes over the bus master and transfers data directly to system memory

Integrated Drive Electronic (IDE)

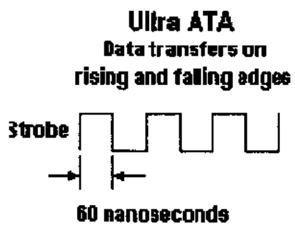
- Good for multitasking PCs as CPU can take care other tasks when data transfers occur
- Need OS device driver for DMA and BIOS support
- ATA/IDE needs upgrade to cope with the change of hard drive technology, large drive capacity, increase in track density, higher rpm drives, cache buffer algorithm
- Ultra ATA - original ATA, data rate is 2-3MB/s, then 16.6MB/s, and doubled to 33MB/s for the ATA-33 or Ultra DMA mode 2 protocol
- Original ATA is based on ISA protocol which is asynchronous data transfer method
- Both data and command signals are sent along with strobe pulse
- Data and command are sent separately
- Data request must be completed before a command can send

Integrated Drive Electronic (IDE)



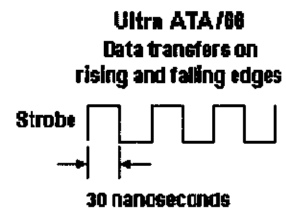
- Starting from ATA-2, synchronous data transfer is used
- Drive controls the strobe and synchronizes the data and command signals with rising edge of the pulse
- To improve data rate, logically increase the strobe rate
- ATA-2 also includes PIO mode 4, the data rate is 16.6MHz

Integrated Drive Electronic (IDE)



- ATA-4 makes most of the strobe by using the rising and falling edges
- Twice the data rate 33.3MHz
- ATA-4 adds Ultra DMA mode 2
- Adds Cyclical Redundancy Check (CRC) for the Ultra DMA

Integrated Drive Electronic (IDE)



- ATA-5 includes Ultra ATA/66 which doubles the Ultra ATA burst transfer rate by increasing the setup times and increase the strobe rate
- Increase the strobe rate, increase EMI
- Change 40-pin cable to 80-pin cable
- the cable is backward compatible to ATA/33 and DMA, EIDE/IDE, CD-ROM drive and host system
- ATA-5 introduce new CRC detection code, Ultra DMA mode 3 (44.4 MB/s) and 4 (66.6 MB/s)
- Ultra ATA/100 includes Ultra DMA mode 5, and increasing data burst rate to 100MB/s by reducing signal voltage to 3.3v

Integrated Drive Electronics (IDE)

Specification	ATA	ATA-2	ATA-3	ATA/ATAPI-4	ATA/ATAPI-5
Max Transfer Modes	PIO1	PIO4 DMA 2	PIO4 DMA 2	PIO4 DMA 2 UDMA 2	PIO4 DMA 2 UDMA 4
Max Transfer Rate	4 MBps	16 MBps	16 MBps	33 MBps	66 MBps
Max Connections	2	2	2	2 per cable	2 per cable
Cable Required	40-pin	40-pin	40-pin	40-pin	40-pin, 80-connector
CRC	No	No	No	Yes	Yes
Year Introduced	1981	1994	1996	1997	1999

Integrated Drive Electronic (IDE)

- Hard disk capacity barrier (504MB)
  - Due to BIOS, Operating system, file systems as result of bugs in hardware and software, and limitation of hard disk itself
  - IDE drive identified by BIOS: cylinders, heads and sector per heads
  - Capacity is based on CHS (cylinders, head & sectors)
  - Sectors is always 512, the BIOS allows max 1024 cylinders, 255 heads and 63 sectors
- IDE changed spec to logical block addressing (LBA) which referred as BIOS Int13h extensions
- BIOS translate CHS to 28-bit LBA, i.e 137GB max
- However, restricted to 8.4GB, due to BIOS imposed a restriction to 24-bit addressing
- Enhancement to BIOS Int13h to 64 bits, and so, max 9.4 Tera Gigabytes
- However, next EIDE protocol (ATA-6) is only 48-bit addressing

Serial ATA

- 2 alternative serial interface technologies, USB & IEEE1394 proposed. However, both cannot offer low cost and high performance serial interface
- In 1999, serial ATA working group worked on Serial Advanced Technology Attachment (ATA) storage interface for hard disk and ATA packet Interface (ATAPI) device to replace the parallel ATA interface
- Backward compatible to parallel ATA, needs serial and parallel dongles

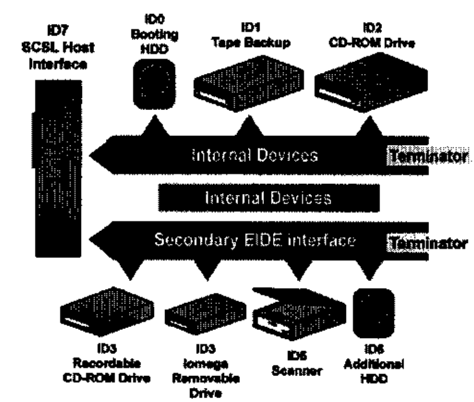
Serial ATA

- Benefits:
  - Reductions in voltage and pin counts
  - Smaller and easy-to-route cables
  - Eliminate cable length limitation, can be up to 1 m
  - Improve data robustness, Serial ATA offers more error checking capabilities
  - Data rates 150MB/s, subsequent data rate will be 300MB/s, 600MB/s

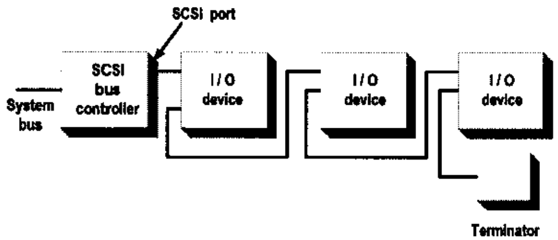
Small Computer System Interface SCSI

- A bus to control computer and its peripherals, but it requires an interface to PCI or ISA
- It is a host adapter and not a controller, the actual control is built in each SCSI device. They "chain" SCSI peripherals to SCSI bus via the host adapter
- It can control up to 8 devices including the adapter, the devices can be hard disk, CD-ROM, printer, scanner, network cards and much more
- Each device chained together, including the host, must be identified by a unique ID number
- The devices can be at any position of the cable, but both ends of the cable must be terminated.
- ID numbers from 0 to 7. Usually, the adapter is 7 and the boot device is 0
- SCSI host adapter takes one IRQ, but the devices don't
- Add additional SCSI adapter still takes one IRQ, but handles 15 devices

SCSI Interface



SCSI Bus



- For new standard - SCSI II / III
  - it allows connection up to 15 devices

Small Computer System Interface SCSI

- In 1986, SCSI-1, it used asynchronous transfer, 8bits, 3MB/s bandwidth, and up to 8 devices, one for host adapter, 7 for hard disk
- 1994, SCSI-2,
  - synchronous transfer, 5MBps, multiple-device interface
  - optional 10MBps (Fast SCSI)
  - Add a second "P" cable to the SCSI bus, allow 16-bit and 32-bit data transfers (Wide SCSI)
  - If combine two options, then it becomes Fast Wide SCSI, data rate 20MBps
  - Wide SCSI can support 16 devices on a single chain
- SCSI-3 drafted in 1996, splits SCSI into a number of standards:
  - Parallel Interface, SCSI cables
  - Architectural Model, define data transfer instructions
  - Primary Commands specification, set out commands for all SCSI devices
  - Specifications for device types

Small Computer System Interface SCSI

  - SCSI-3 eliminates the need for a second cable for Fast SCSI or Wide SCSI
  - Add support for fibre-optics
  - Addition of SCAM (SCSI configuration Auto-Magically), a subset of Plug and Play
  - Auto select their own ID number and auto termination
- Ultra SCSI (Fast-20)
  - SCSI-2 extension, double signal rate to 20MHz at cost of shorten cable length to 1.5m
- Ultra SCSI-20 (Fast-40)
  - Signal rate 40MHz, 16-bit wide & Max 80MBps bandwidth
- Ultra2 SCSI
  - 3V LVD (low voltage differential) signaling, allow cable length 3m, 16 devices
- Ultra160 SCSI in late 1999
  - Cyclic redundancy checking (CRC) on all transferred data
  - Intelligent system configuration verification
  - Double transition clocking for improving bandwidth
- Ultra320 SCSI, bandwidth 320MBps, 16-bit, 16 devices, LVD 12m
- Ultra640 SCSI, bandwidth 640MBps, 16-bit, 16 devices, LVD 12m

SCSI

SCSI Version	Signaling rate (MHZ)	Bus width (bits)	Max .DTR (MBps)	Max. devices	Max. cable length
SCSI-1	5	8	5	7	6m
SCSI-2	5	8	5	7	6m
Wide SCSI	5	16	10	15	6m
Fast SCSI	10	8	10	7	6m
Fast Wide SCSI	10	16	20	15	1.5m
Ultra SCSI	20	8	20	7	12m
Ultra SCSI-2	20	16	40	7	12m
Ultra2 SCSI	40	16	80	15	12m
Ultra160 SCSI	40	16	160	15	12m

Hard Disk

- Partition
  - In order to place the operating system in hard disk, a disk address space of blocks is divided into partitions.
  - Partitions are similar to a whole disk in the fact that they consist of adjacent block.
  - For description of a partition it is necessary to specify the beginning of a partition and its length in block
  - A hard disk can contain 4 primary partitions
  - Partition contain a file system which is a system of block marking for file storage. After creation of a file system on a partition and after files of operating system are placed , the partition becomes a boot one.
  - Information on a hard disk partitioning is kept in the first block of a hard disk called the Master Boot Record (MBR)

Hard Disk

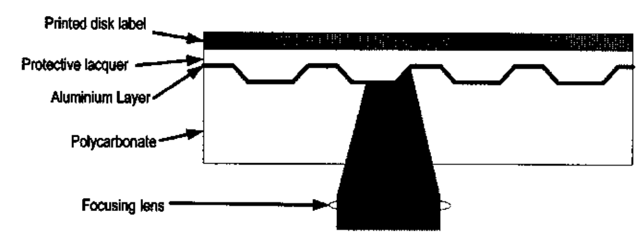
- Self-Monitoring, Analysis and Reporting Technology (S.M.A.R.T)
  - The SMART system for disk drives is designed to revolutionize overall system and data reliability.
  - The system is comprised of software that resides on both on the disk drive and on the host computer.
  - The disk drive software monitors the internal performance of the motors, media , heads and electronic of the drive, while the host software monitors the overall reliability status of the drive.
  - The reliability status is determined through the analysis of the drive's internal performance level and the comparison of internal performance levels to predetermined threshold limits.

Laser Technology

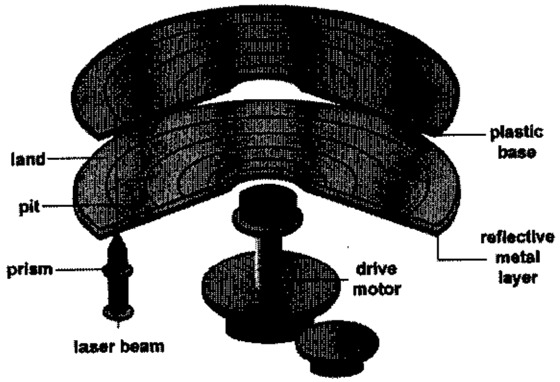
- Lasers (Light Amplification by Stimulated Emission of Radiation) generate coherent light (light comprising photons with same wavelength and in-phase.
- Light beam focuses on a very small spot size similar to the actual wavelength of the light itself
- A low power laser is used to read the information stored in pits in 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 Construction

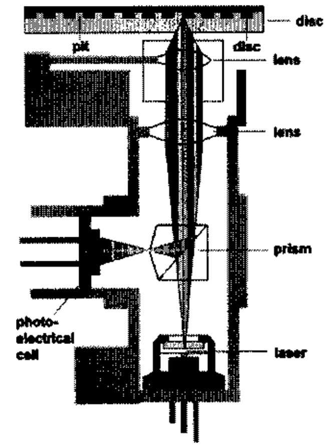
- The disc comprises a sandwich, a 1.2mm thick polycarbonate substrate containing pits molded into the upper surface is coated with aluminum, which is protected by a lacquer on which the disc label is printed
- A infrared laser beam is focused on the pits through the clear optical grade polycarbonate 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



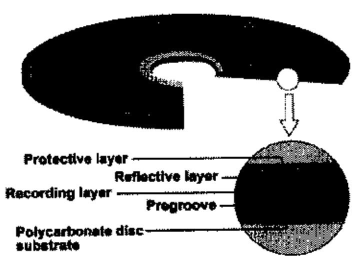
CD-ROM Drive



CD-ROM Drive

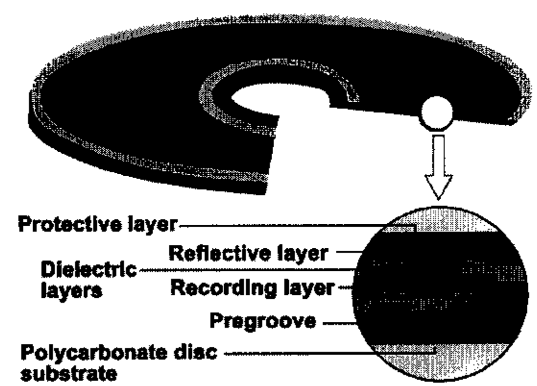


CD-Recordable



- 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

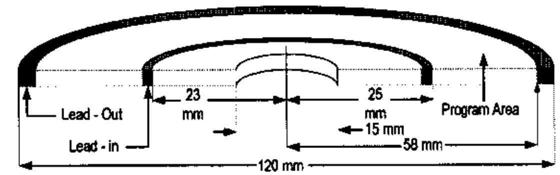


CD-Rewritable

- 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

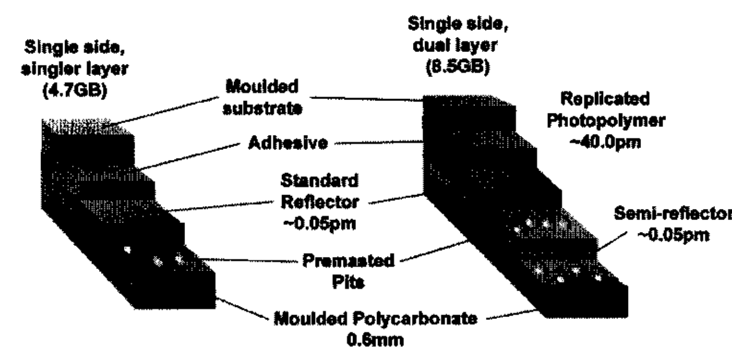
- The disc measure 120mm in diameter with 15mm diameter centre hole
- The audio or computer data is stored from radius 25mm after the lead-in to radius 58mm maximum where lead-out starts
- The CDs are played at constant linear velocity (CLV) of between 1.2 and 1.4 m/s. The angular velocity will reduce 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



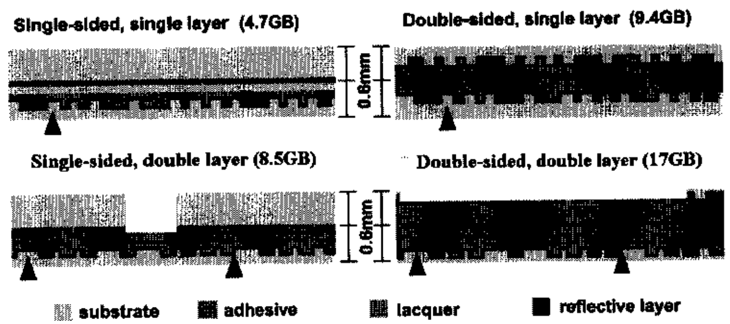
Digital Versatile Disc DVD

- 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

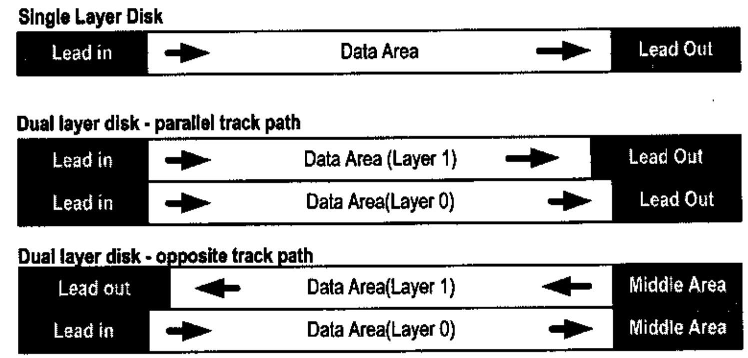
Digital Versatile Disc DVD



Digital Versatile Disc DVD

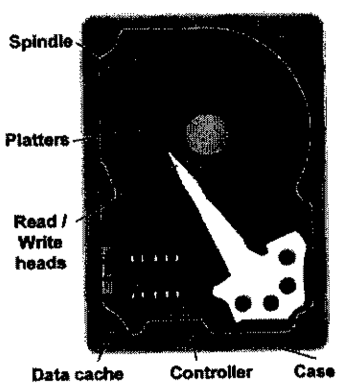


Single and Dual Layer Disc Layout



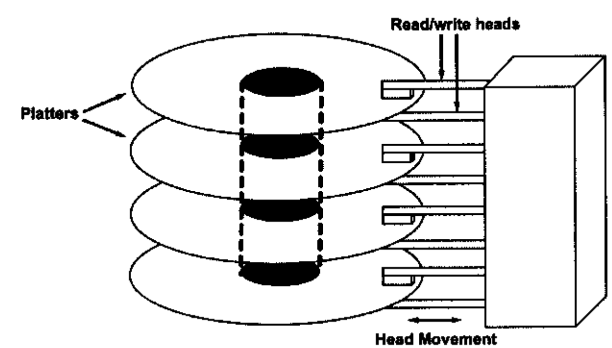
- DVD-Video discs use opposite track path so that movie can be placed across both layers and played seamless from layer 0 to layer 1

Hard Disk

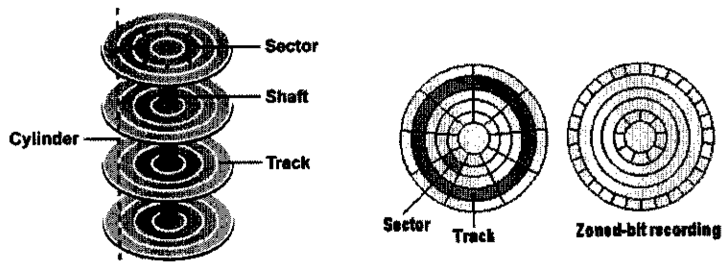


- Platters
  - make up of non-magnetic and smooth aluminum alloy or a mixture of glass coated with a magnetic medium
  - Towards glass technology, better heat resistance and thinner
  - Dust free inside a hard disk
- Read/write heads on each side of platters

Hard Disk

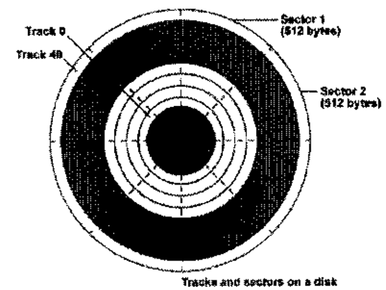


Hard Disk



- 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

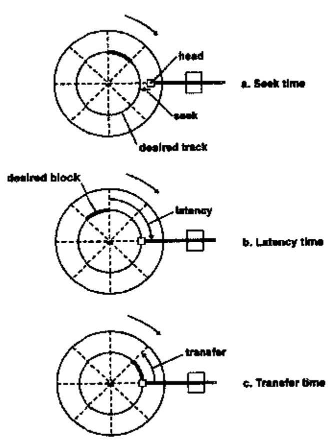
Hard Disk



- 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

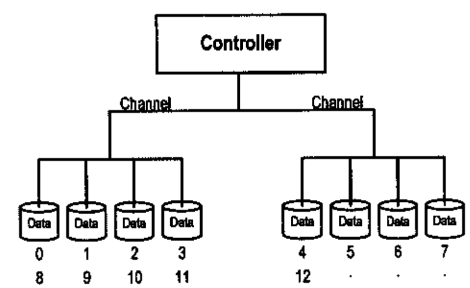
Hard Disk

- 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

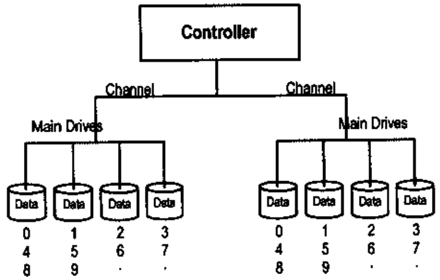
- RAID (Redundant Array of Inexpensive Disks) technology provides mass storage with high throughput and reliability
- One or more logical drives is configured from a set of disk drives
- Data is distributed across the set of drives in a pre-defined manner
- Data reconstruction capability for recovering 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

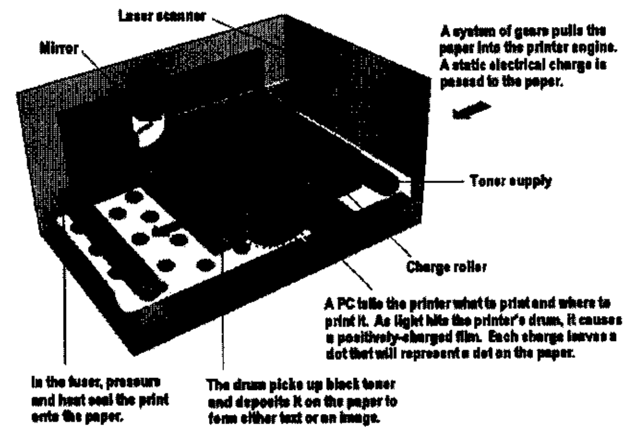
RAID Technology

- **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

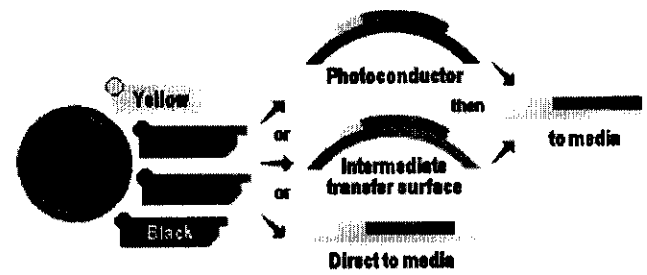
Laser Printer



Laser Printer

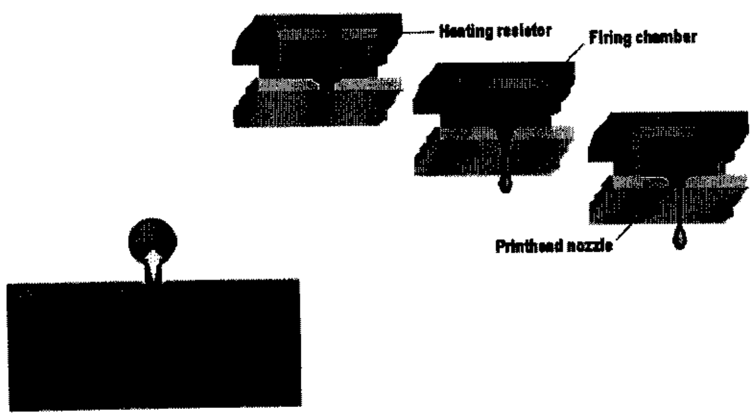
- A rotating drum – an organic photo-conducting cartridge with coating that allows it for holding charge
- Initially, the drum is positive charged, a laser beam scans across the surface of the drum, selectively impairing points of negative charge onto the drum's surface that will ultimately represent 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

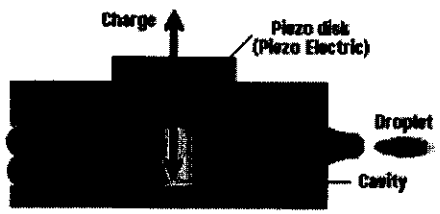
Ink Jet Printer (Thermal Technology)

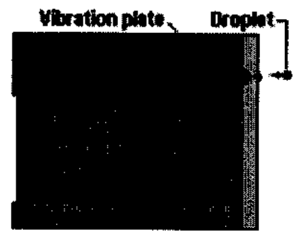


Ink Jet Printer (Thermal Technology)

- 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)

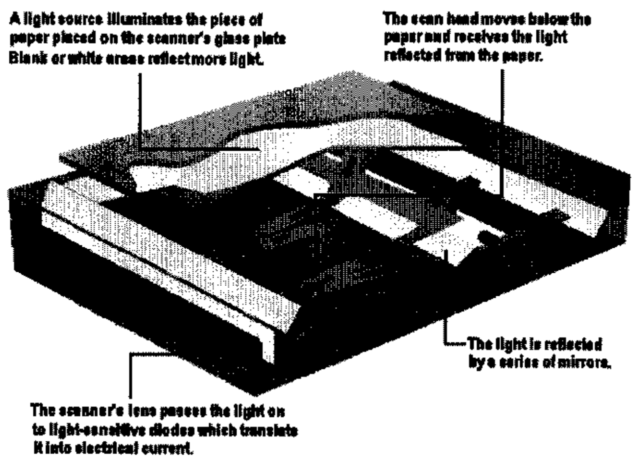




Ink Jet Printer (Piezo-electric Technology)

- 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 Depths
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)

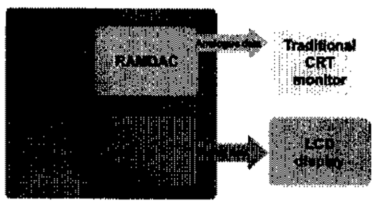
Resolution	4 Bits	8 Bits	16 Bits	24 Bits	32 Bits
320 x 200	0.03 (256KB)	0.06 (256 KB)	0.12 (256 KB)	0.18 (256KB)	--
640 x 480	0.15 (256KB)	0.29 (512 KB)	0.59(1 MB)	0.88 (1 MB)	1.17 (2 MB)
800 x 600	--	0.46 (512 KB)	0.92 (1 MB)	1.37 (2 MB)	1.83 (2 MB)
1024 x 768	--	0.75 (1 MB)	1.50 (2 MB)	2.25 (4 MB)	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

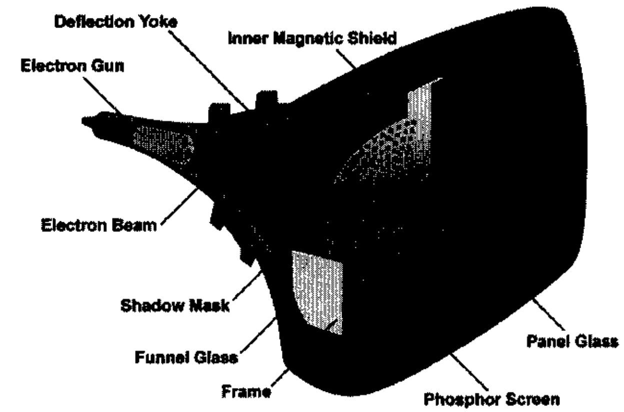
- PC graphic card consists of four components: graphics processor, video memory, RAMDAC and driver software
- **Graphics Processor:**
  - Early VGA systems were slow because CPU was heavily loaded by processing graphic data
  - It is solved by a dedicated graphics processing chips on modern graphics 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

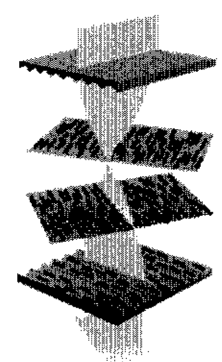


CRT Monitor

- 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 "bottle neck: of the 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

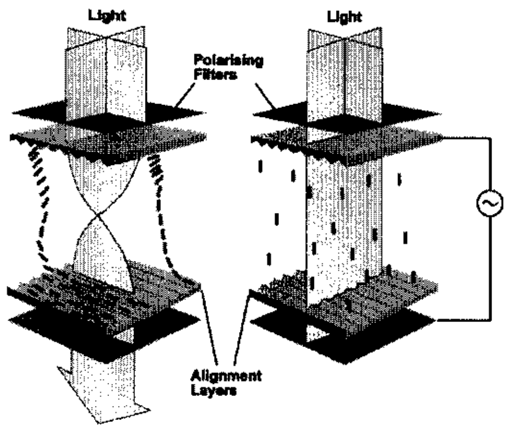
Liquid Crystal Display (LCD)



Principle (1)

- 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 molecules
- 1960, it was discovered that charging liquid crystals with electricity changed their molecular alignment, and consequently the way light passed through them
- LCD is a transmissive technology. The display works by letting varying amounts of a fixed-intensity white backlight through an active filter.

Liquid Crystal Display (LCD)

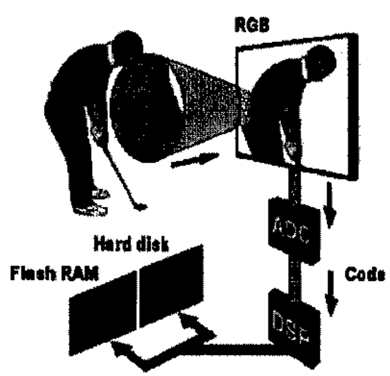


Principle (2)

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 and letting ,more light through.**
  - **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.

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