Types of storage devices

EL3010 Arsitektur Sistem Komputer
Sekolah Teknik Elektro dan Informatika – ITB 2010

What everybody wants

- Fast processor
- More Ram
- Plenty of storage space
- Multiple storage option

Storage Media

- The materials on which data is stored
  - Magnetic
  - Optical

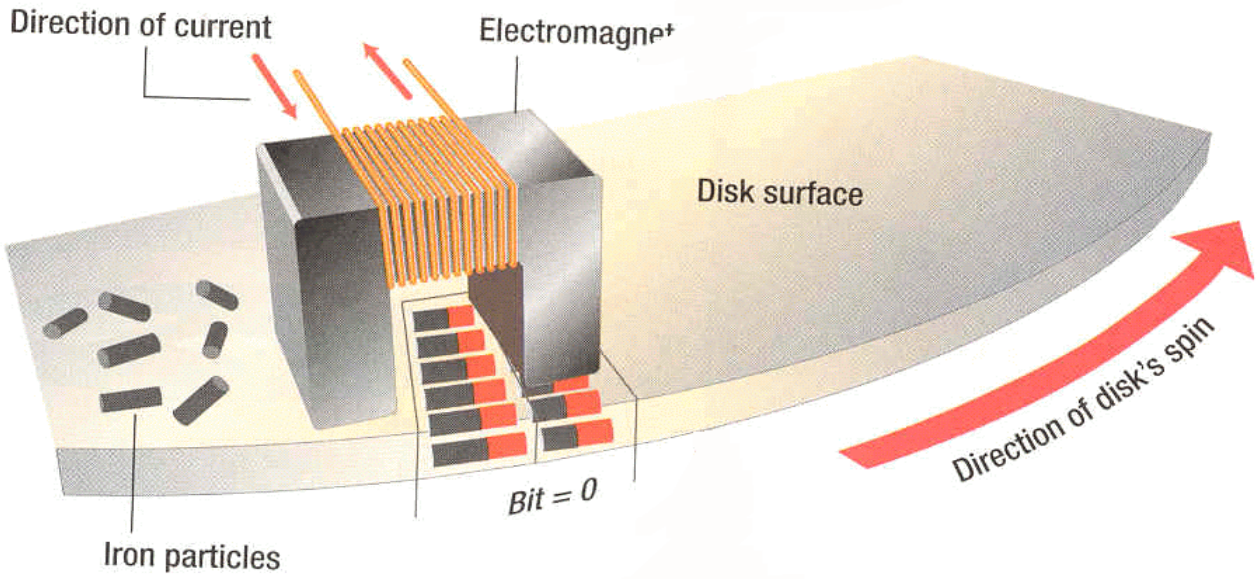
Storage devices

- The hardware components that write data to, and read data from, storage media
- The purpose of storage device is to hold data
- Storage involves two processes:
  - Reading data : retrieving data from the surface of a disk or tape and moving it into the computer's memory
  - Writing data : recording data on the surface of a disk or tape for later use
- Common storage
  - Magnetic storage
    - Diskette, Hard disk, High capacity floppy disk, disk cartridge, and magnetic tape
  - Optical storage
    - CD-ROM, CD-R/CD-RW, DVD±R, DVD±RW, DVD-RAM

Magnetic Storage Devices

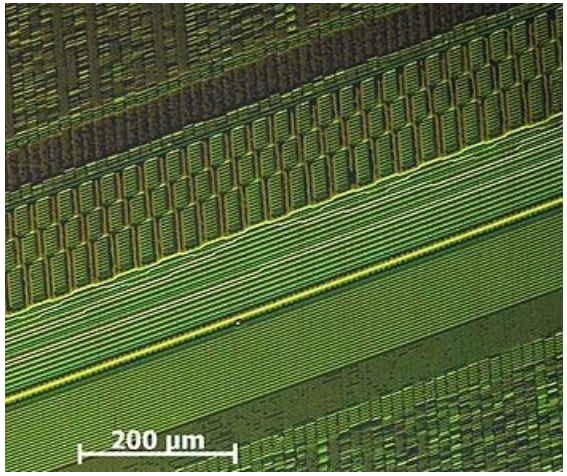
- Hard disks, diskettes, high-capacity floppy disks and tapes have a magnetic coating on their surface that enables each medium to store data
- A medium that is sensitive to magnetic fields such as iron oxide.
- Diskette made of a thin layer of plastic - floppy disk
- Hard disk made of a rigid material such as aluminum

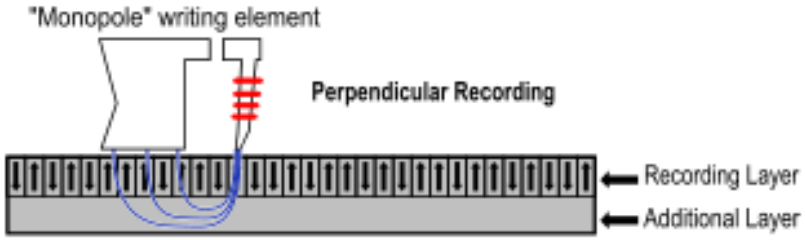
How data is stored



- Writing : current creates magnetic field so that the iron particle becomes polarized in the direction of the magnetic field
- Retain polarity without power
- Reading is the opposite process. The magnetic field of the media creates a current in the reading head in the same direction of the polarity

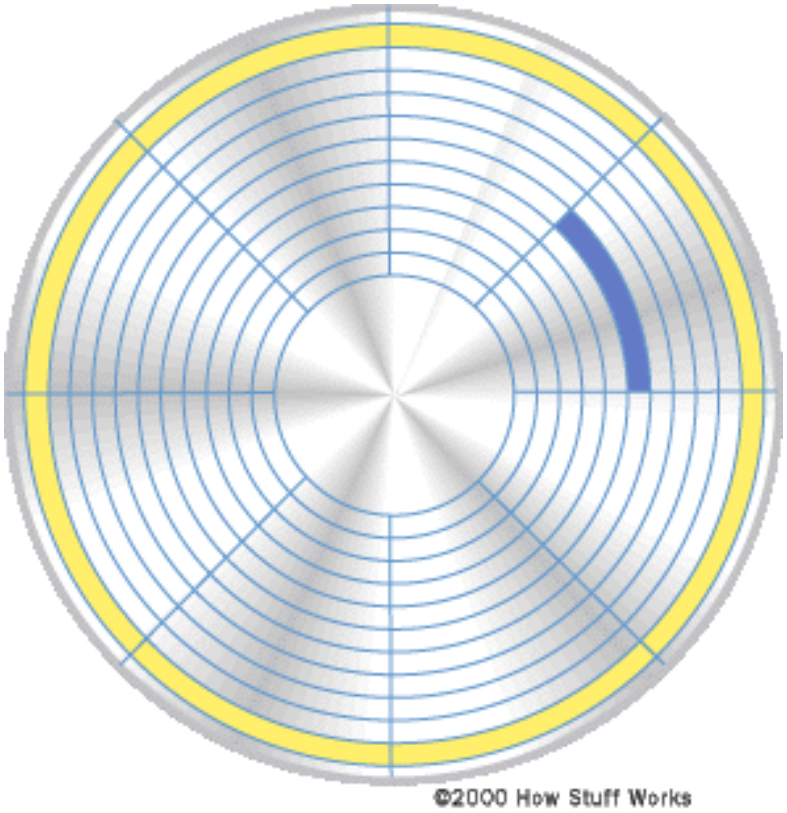
Read/Write Head and Recording





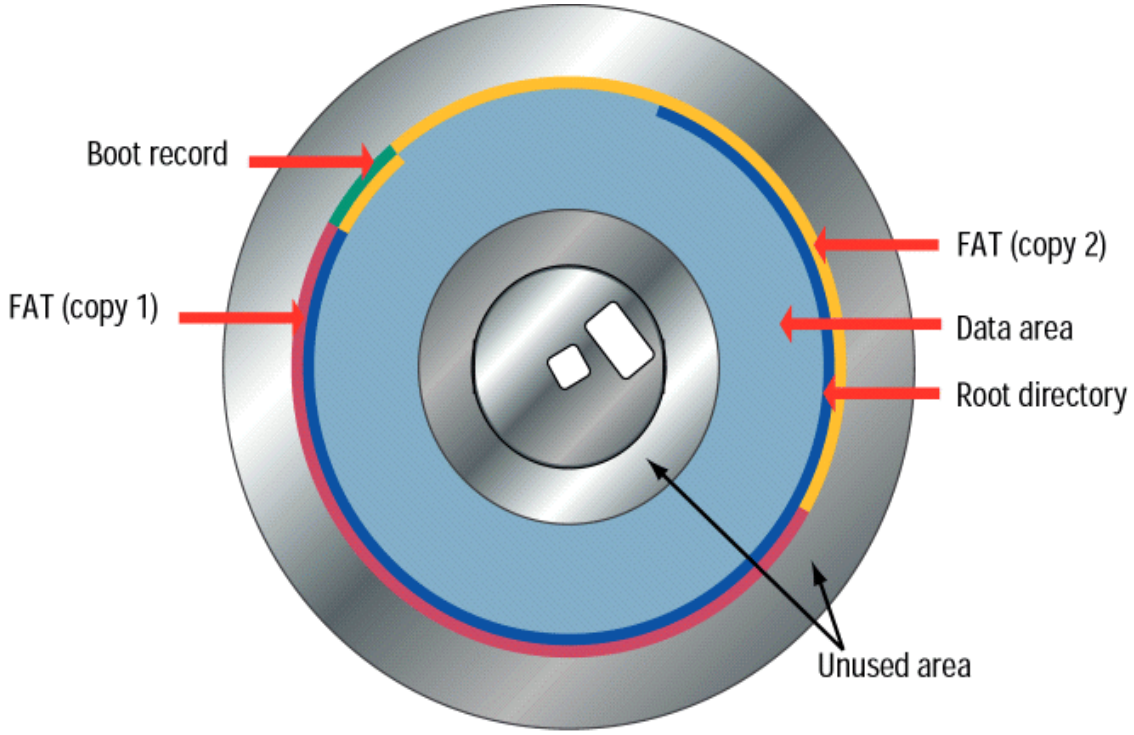
Data Organization

- Before use the magnetic disk must be mapped.
- The process of mapping is called formatting
  - Setup
    - Number of tracks
    - Number of sectors
    - Byte per sector
- Main sections, called Tracks
- Track subsections, called Sectors
- Groups of sectors, called Clusters
- Types of format
  - FAT
  - NTFS
  - LINUX
  - Others



The Logical Format has Four Disk Areas

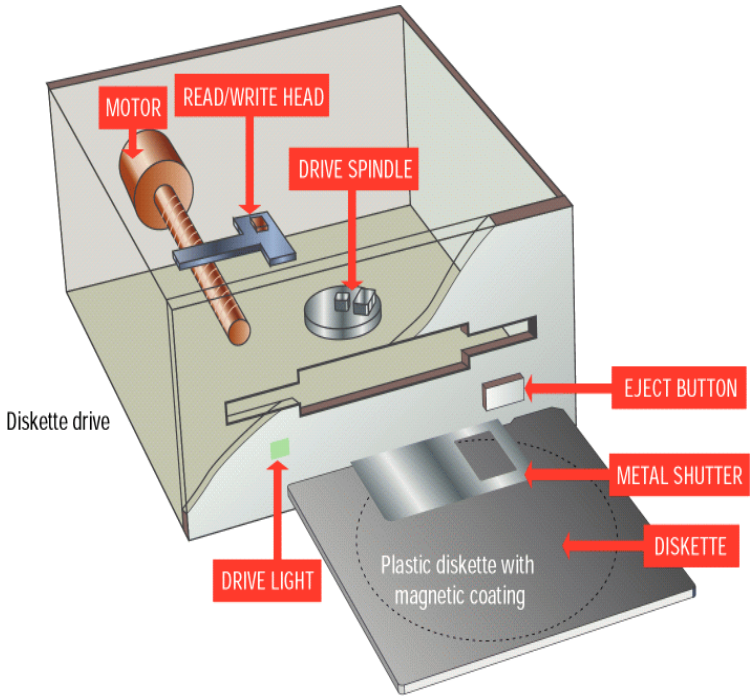
- A logical format is the labeling of tracks and sectors
- Master boot record contain a program that runs when you first start the computer
- File allocation table
- Root folder
- Data area
  - Each track & sector is labeled



The Logical Format has Four Disk Areas

- Master Boot record
  - This program determines whether the disk contains the basic components of an operating system necessary to run successfully
- FAT
  - A log created during the logical formatting process that records the location of each file and status of each sector on the disk
- Root Folder
  - The top folder or directory in the disk's folder hierarchy

3.5-inch Diskettes (Floppy Disks)



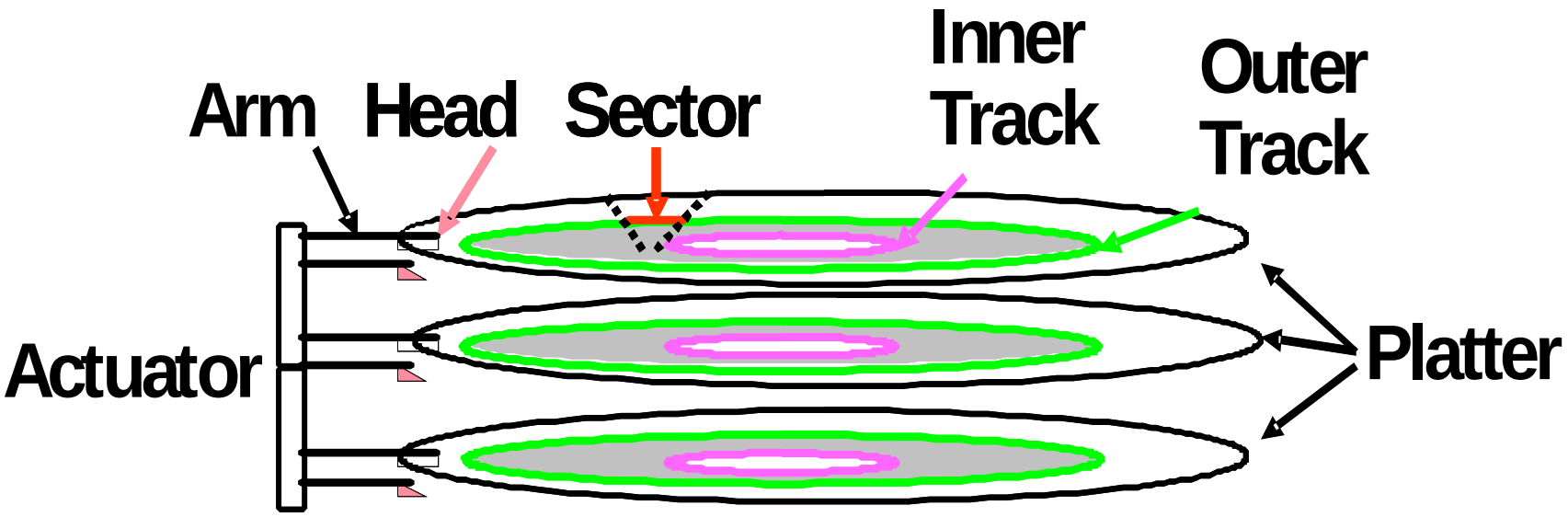
- Spin rate: 300 revolutions per minute (rpm)
- High density (HD) disks more common today than older, double density (DD) disks
- Storage Capacity of HD disks is 1.44 MB

Hard Disk

- Spin rate: from 3,600 to 15,000 rpm
- Storage capacity ranges from several hundred MB to more than 1TB
- These platters are manufactured to amazing tolerances and are mirror- smooth.
- Non-removable
  - Hard disk = Hard Drive

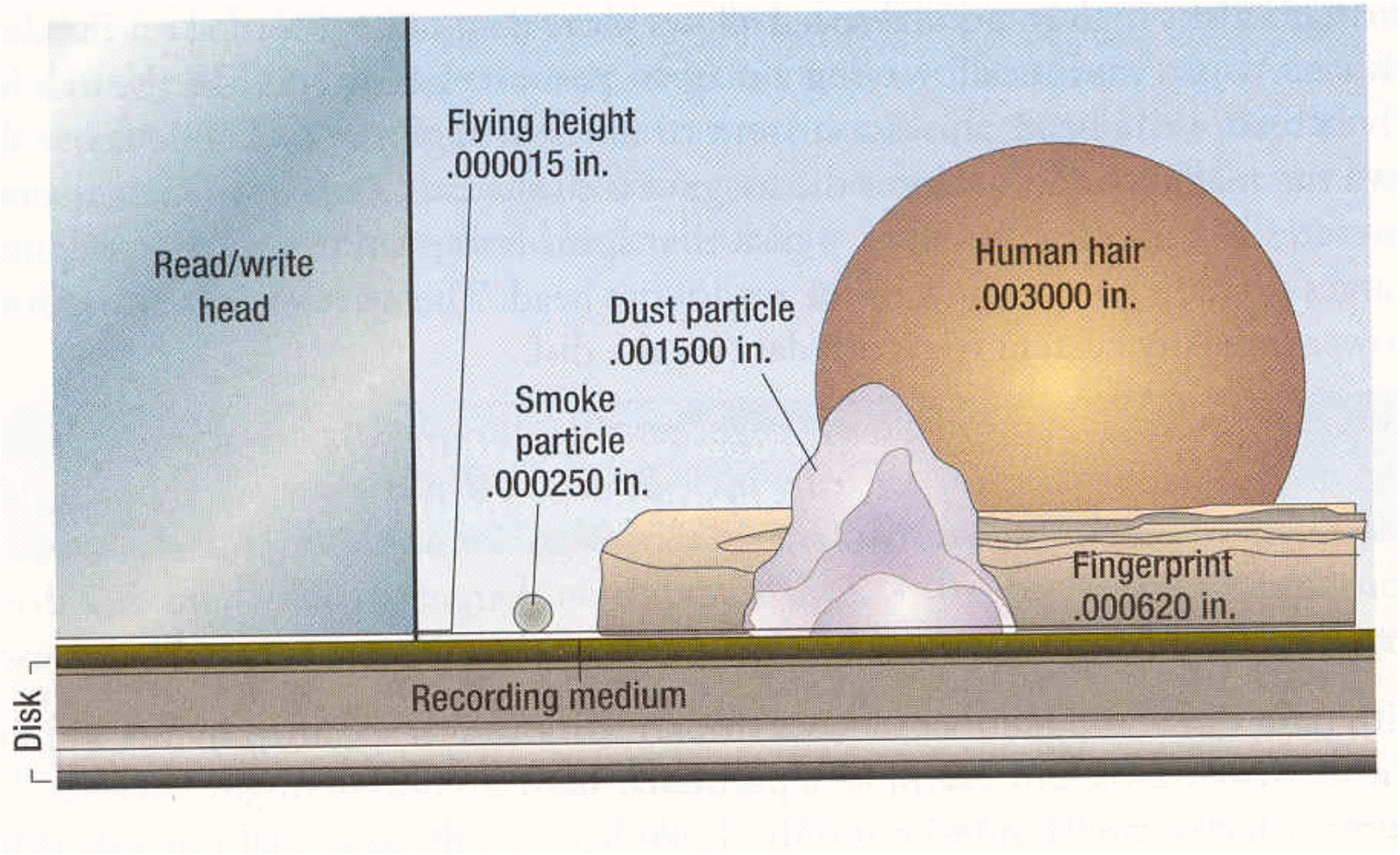
- The arm that holds the read/write heads is controlled by the mechanism in the upper-left corner, and is able to move the heads from the hub to the edge of the drive. The arm and its movement mechanism are extremely light and fast. The arm on a typical hard-disk drive can move from hub to edge and back up to 50 times per second.

Disk Device Terminology



- Several platters, with information recorded magnetically on both surfaces (usually)
- Bits recorded in tracks, which in turn divided into sectors (e.g., 512 Bytes)
- Actuator moves head (end of arm) over track (“seek”), wait for sector rotate under head, then read or write

Tolerance


Read/write head
Flying height .000015 in.
Human hair .003000 in.
Dust particle .001500 in.
Smoke particle .000250 in.
Fingerprint .000620 in.
Recording medium
Disk

Hard Disk

- Increase storage capacity by
  - Pack data more closely
  - Multiple platters -> multiple read/write heads
    - Example HD with 4 platter may have 7 heads
    - Unused bottom side of the bottom disk

- Cylinder : same track across all disk
- Head move together
- Head does not touch platter but fly across (very very close to the disk)
- Do not open Hard Drive : destroy the disk magnetic material

Typical Disk Data

- Typical numbers (depending on the disk size):
- 1 to 15 platters per disk - each with 2 surfaces
- 500 to 2,000 tracks per surface
- 64 to 200 sectors per track
- A sector is the smallest unit that can be read or written
- Typically 512 bytes per sector

Data Rate: Inner vs. Outer Tracks

- To keep things simple,
  - originally same # of sectors/track
  - Since outer track longer, lower bits per inch
- Competition decided to keep bits/inch (BPI) high for all tracks (“constant bit density”)
  - More capacity per disk
  - More sectors per track towards edge
  - Since disk spins at constant speed, outer tracks have faster data rate
- Bandwidth outer track 1.7X inner track!

Removable High Capacity Magnetic Disk

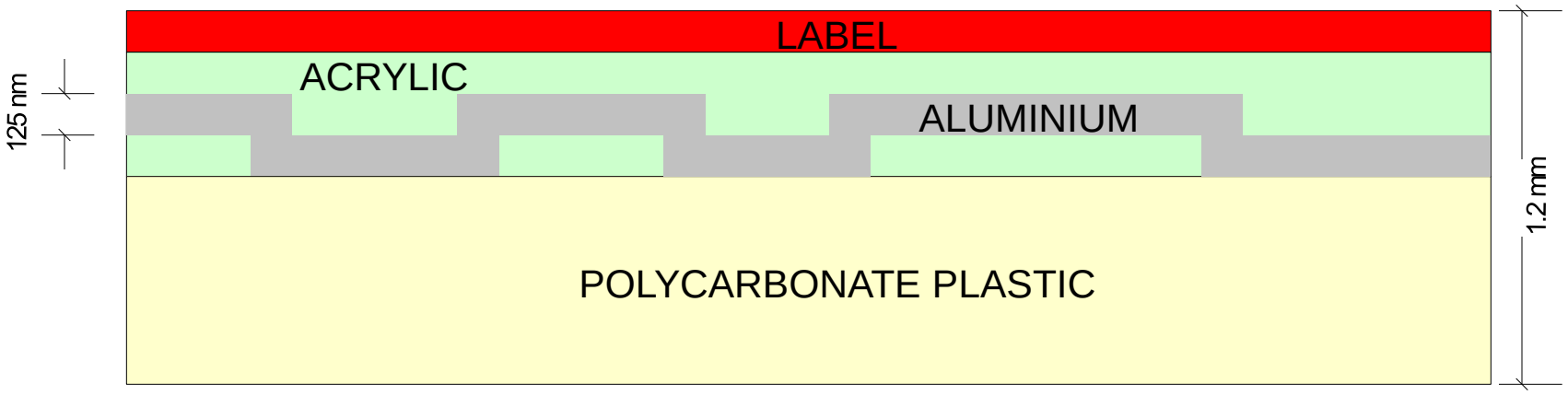
- High Capacity Floppy Disk
  - ZIP disk (100, 250 and 750 MB)
- Hot Swappable Hard Disks
  - Can be removed while the computer is on
  - Servers and workstations
- Disk Catridges
  - Backup
  - 1GB to 35 GB
- Tape Drives
  - Backup
  - 100 to 200 GB
- PC Cards
  - PCMCIA
  - Type I, II, and III miniature drives
  - Up to 2 GB

Optical Storage Devices

- Data is stored on a reflective surface so it can be read by a beam of laser light.
- Two Kinds of Optical Storage Devices
  - CD-ROM (compact disk read-only memory)
  - DVD-ROM (digital video disk read-only memory)

CD-ROM

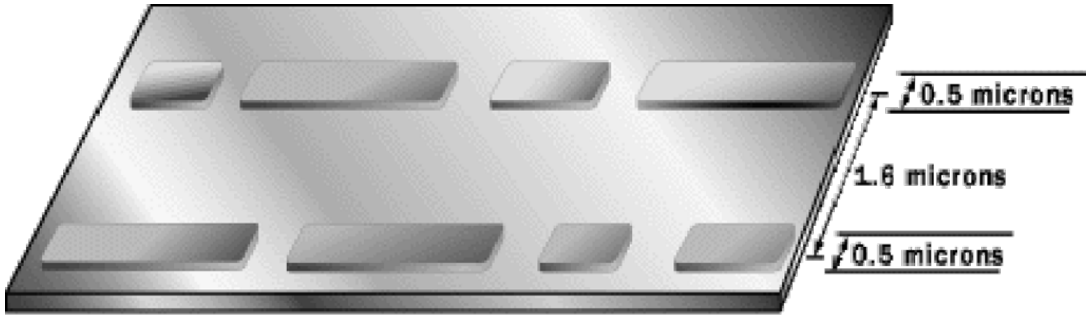
- A CD is a fairly simple piece of plastic, about four one-hundredths (4/100) of an inch (1.2 mm) thick. Most of a CD consists of an injection-molded piece of clear polycarbonate plastic.

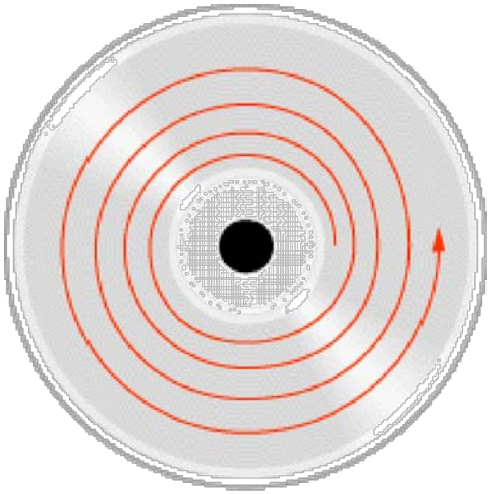


- Standard CD's store 650 MB of data or 70 minutes of audio
- New generation CD's hold 700 MB of data or 80 minutes of audio

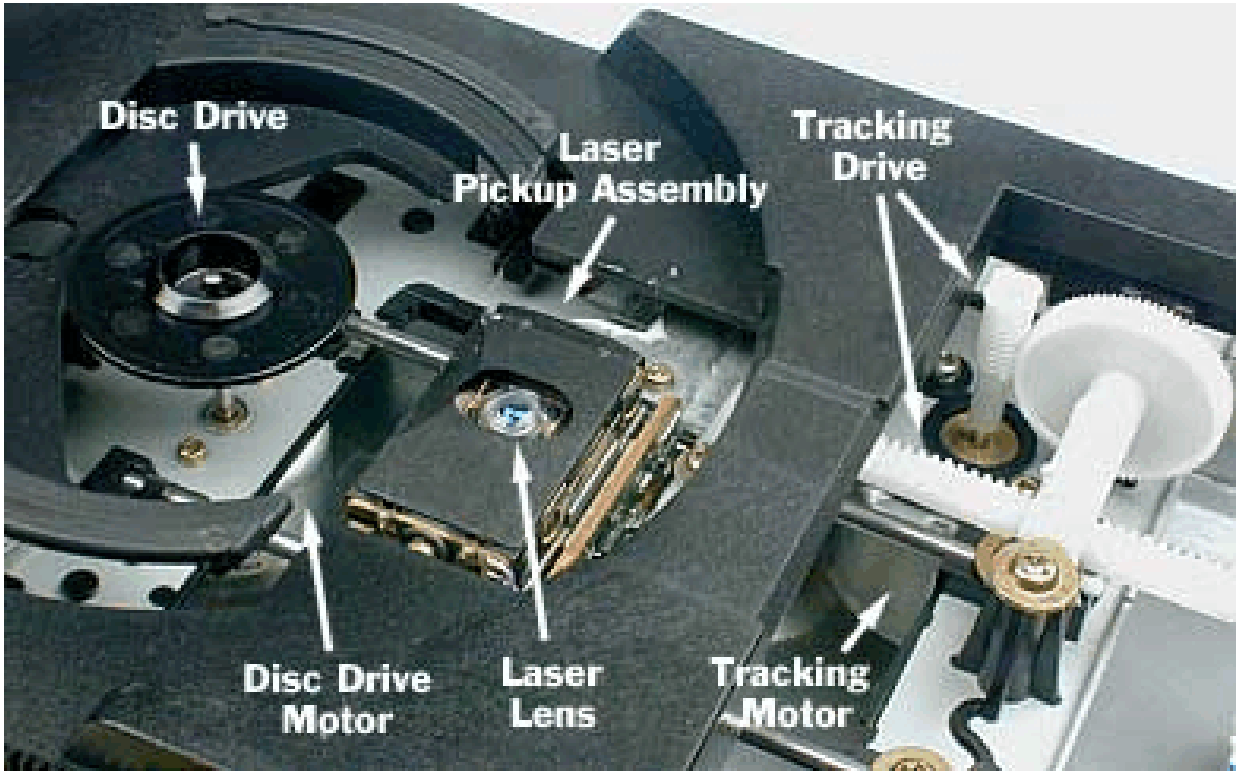
CD-ROM

- A CD has a single spiral track of data, circling from the inside of the disc to the outside. The fact that the spiral track starts at the center means that the CD can be smaller than 4.8 inches (12 cm) if desired, and in fact there are now plastic baseball cards and business cards that you can put in a CD player. CD business cards hold about 2 MB of data before the size and shape of the card cuts off the spiral.
- The elongated bumps that make up the track are each 0.5 microns wide, a minimum of 0.83 microns long and 125 nanometers high. (A nanometer is a billionth of a meter.)



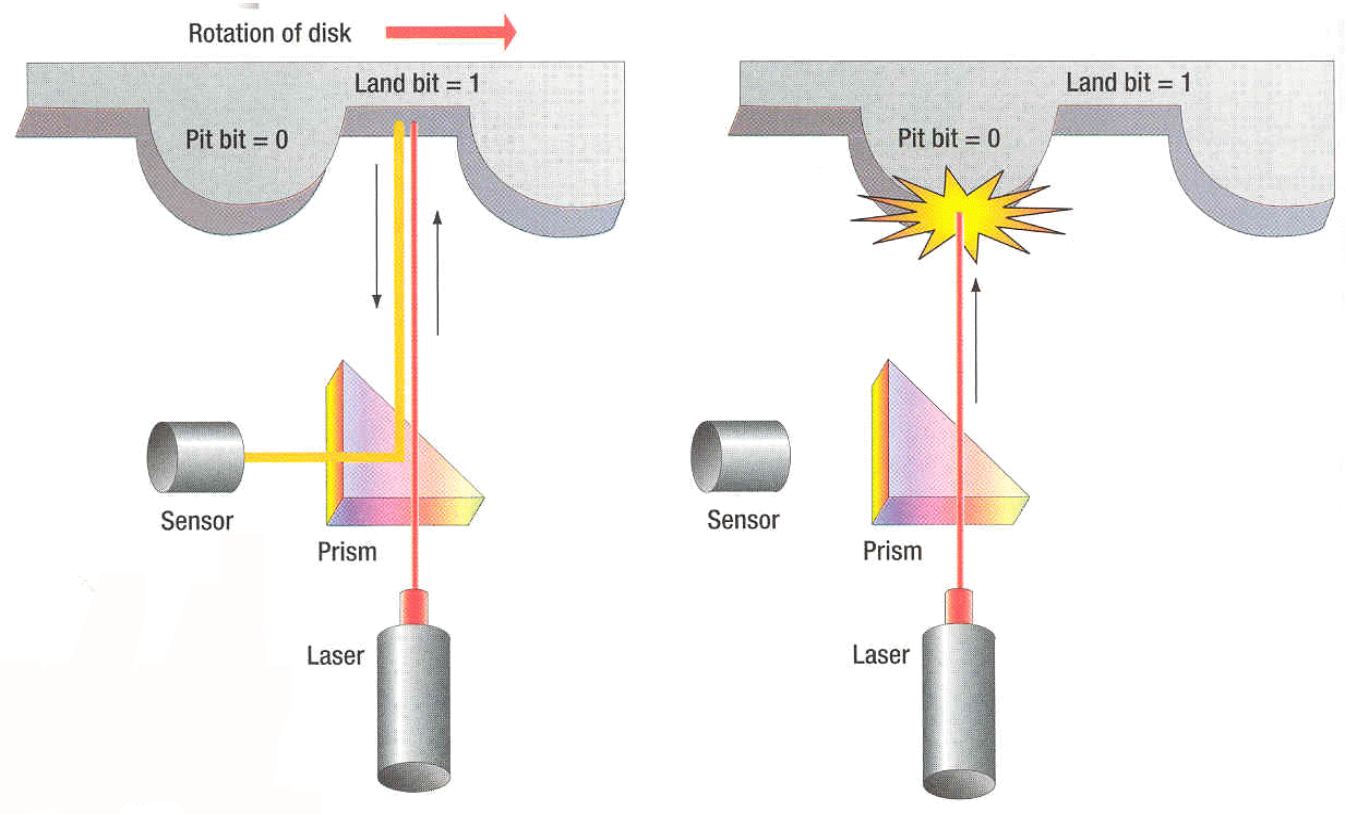


CD-ROM Drive



- CD-ROM drives are slower than hard disk drives
- CD-ROM speed is expressed in multiples and range from 2x to 75x

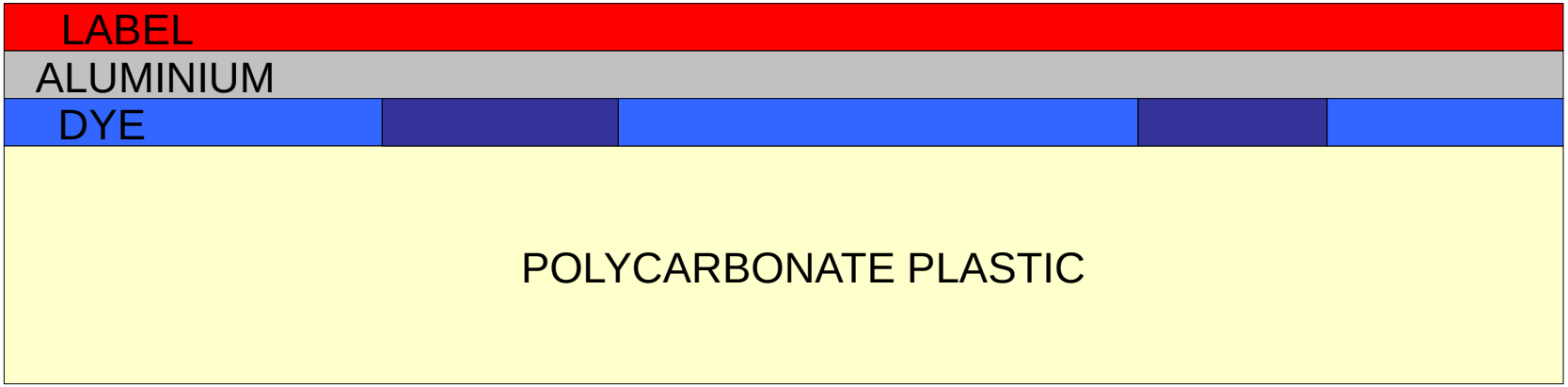
Reading CD-ROM



- Land : reflect laser
- Pit : does not reflect laser

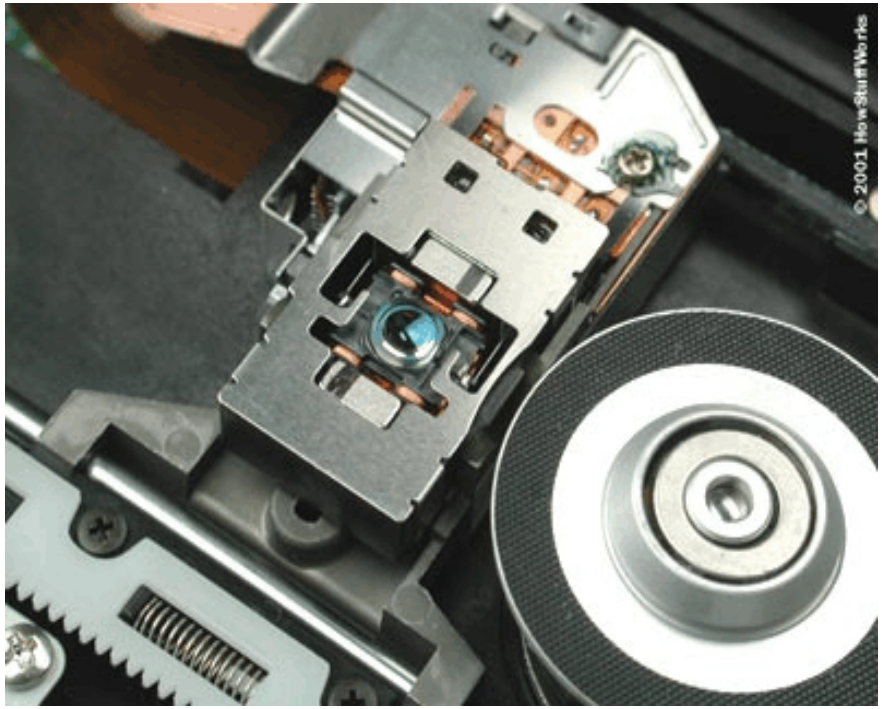
CD-R

- CD-recordable discs, or CD-Rs, don't have any bumps or flat areas at all. Instead, they have a smooth reflective metal layer, which rests on top of a layer of photosensitive dye.
- When the disc is blank, the dye is translucent: Light can shine through and reflect off the metal surface. But when you heat the dye layer with concentrated light of a particular frequency and intensity, the dye turns opaque: It darkens to the point that light can't pass through.



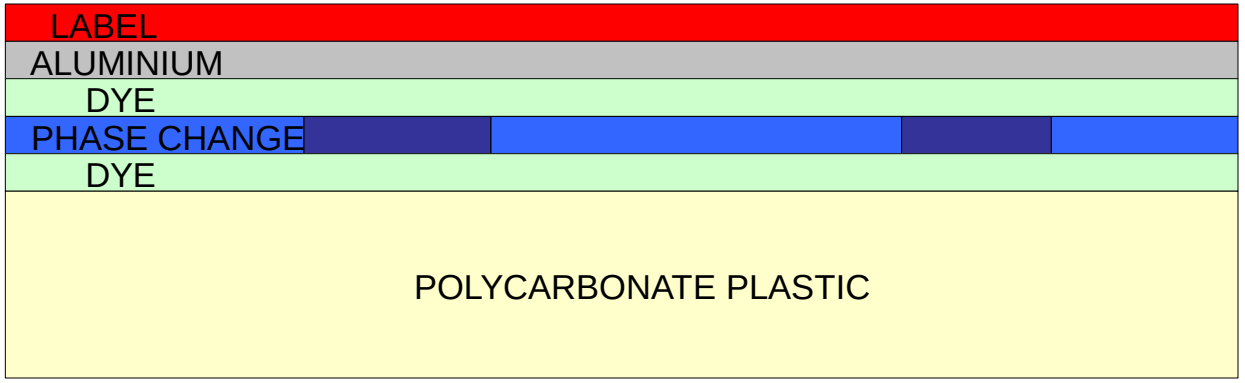
Write Laser

- The write laser is more powerful than the read laser, so it interacts with the disc differently: It alters the surface instead of just bouncing light off it. Read lasers are not intense enough to darken the dye material, so simply playing a CD-R in a CD drive will not destroy any encoded information.
- To record the data, the burner simply turns the laser writer on and off in synch with the pattern of 1s and 0s. The laser darkens the material to encode a 0 and leaves it translucent to encode a 1.



CD-RW

- CD-RW has the erase function ability so you can record over old data you don't need anymore. These discs are based on phase-change technology. The phase-change element is a chemical compound of silver, antimony, tellurium and indium
- When the compound is heated above its melting temperature (around 600 degrees Celsius), it becomes a liquid; at its crystallization temperature (around 200 degrees Celsius), it turns into a solid.
- The reflecting lands and non-reflecting bumps of a conventional CD are represented by phase shifts in a special compound.
  - When the compound is in a crystalline state, it is translucent, so light can shine through to the metal layer above and reflect back to the laser assembly (1)
  - When the compound is melted into an amorphous state, it becomes opaque, making the area non-reflective (0)



The Erase Laser

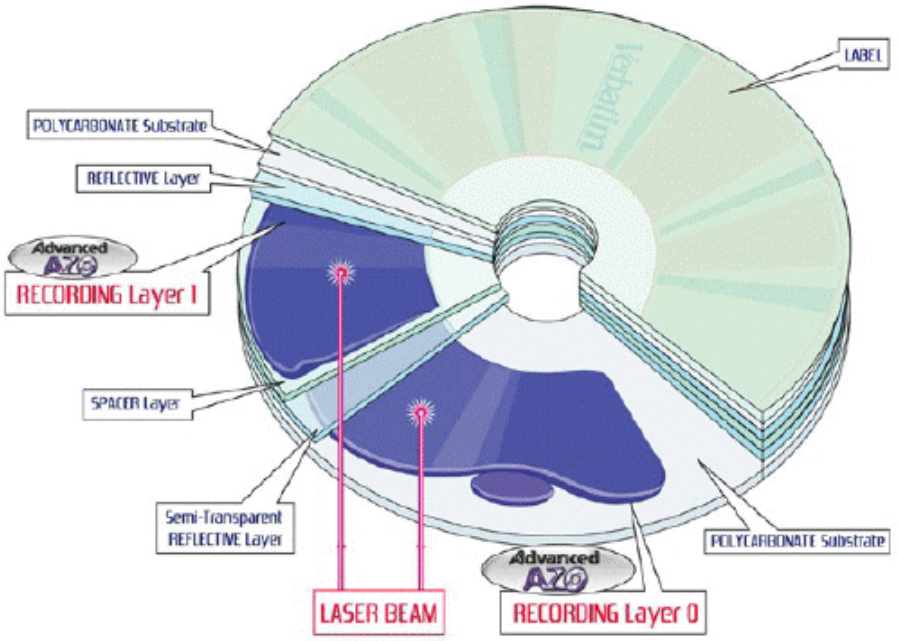
- As with CD-Rs, the read laser does not have enough power to change the state of the material in the recording layer
- It's a lot weaker than the write laser.
- The erase laser falls somewhere in between: While it isn't strong enough to melt the material, it does have the necessary intensity to heat the material to the crystallization point.
  - By holding the material at this temperature, the erase laser restores the compound to its crystalline state, effectively erasing the encoded 0.
- CD-RW discs do not reflect as much light as older CD formats, so they cannot be read by most older CD players and CD-ROM drives

DVD - Digital Versatile Dics

- Not : Digital Video Disc
- Same physical dimension as CD
- Much higher density and smaller laser (650 nm)
- Recordable Format
  - -R/RW
  - +R/RW
  - DVD-RAM

Format	Capacity	Approx. Movie Time
Single-sided/single-layer	4.38 GB	2 hours
Single-sided/double-layer	7.95 GB	4 hours
Double-sided/single-layer	8.75 GB	4.5 hours
Double-sided/double-layer	15.9 GB	Over 8 hours

Dual Layer DVD

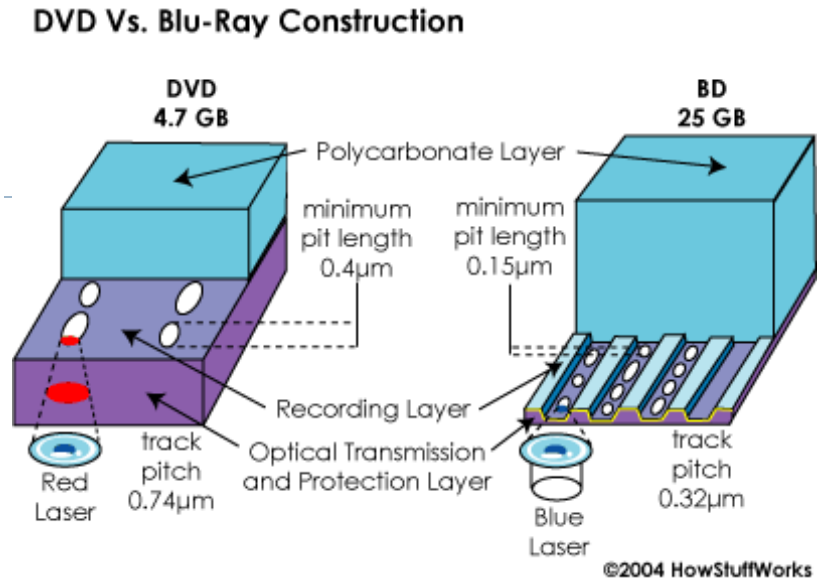


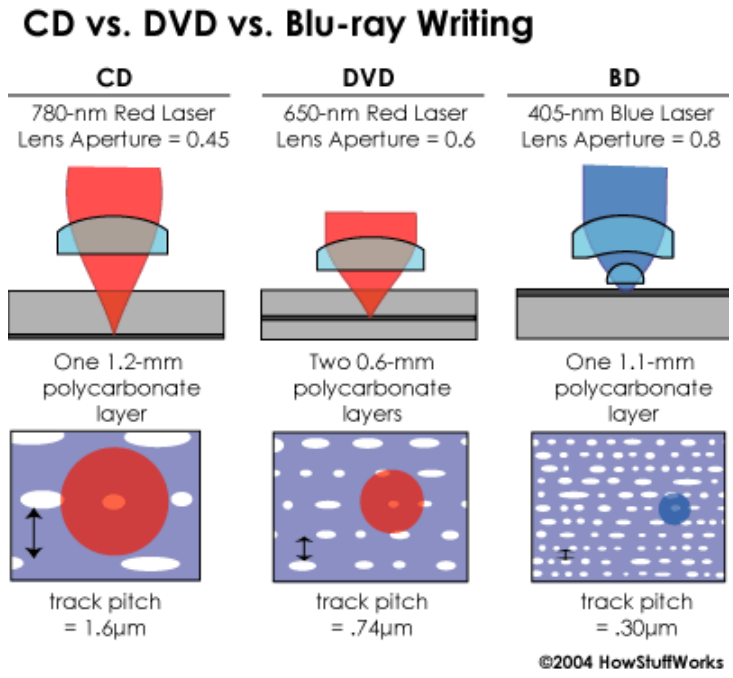
Blue Violet Ray DVD

- Competing Format
  - Blu-Ray DVD (BD)
  - HD DVD
- Laser : 405 nm
- Capacity from 25 GB - 200 GB
  - BD: currently only upto 50 GB Dual Layer
  - HD : 15 GB, 30 GB Dual Layer, 45 GB Tripple Layer
- BD:
  - About 9 hours of high-definition (HD) video can be stored on a 50 GB disc.
  - About 23 hours of standard-definition (SD) video can be stored ona 50 GB disc.
- HD:
  - Gear towards HDTV storage
  - Backward compatible with DVD±RW

Blu-Ray

- Record high-definition television (HDTV) without any quality loss
- Instantly skip to any spot on the disc
- Record one program while watching another on the disc
- Create playlists
- Edit or reorder programs recorded on the disc
- Automatically search for an empty space on the disc to avoid recording over a program
- Access the Web to download subtitles and other extra features





Blu-Ray

- Format
  - BD-ROM (read-only) - for pre-recorded content
  - BD-R (recordable) - for PC data storage
  - BD-RW (rewritable) - for PC data storage
  - BD-RE (rewritable) - for HDTV recording

Solid State Storage

- No moving parts
- Faster
- Small Capacity
- A very popular type of removable storage for small devices, such as digital cameras and PDAs
- Example
  - Flash Drives (up to 4GB)
  - Smart Media (up to 128 MB)
  - Memory Sticks
  - Secure/Digital Card
- Size is increasingly smaller

SSD - Solid State Drive

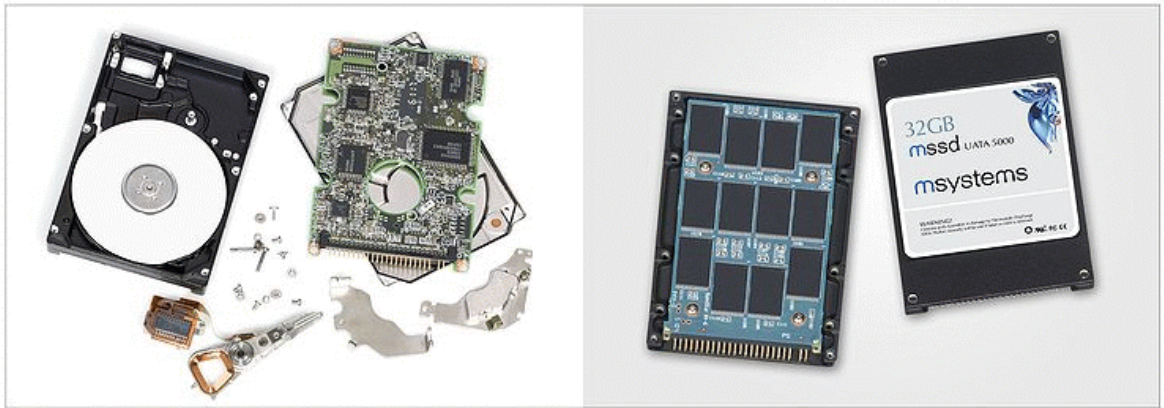
- Flash drives
  - Most SSD manufacturers use non-volatile flash memory to create more rugged and compact devices for the consumer market.
  - These flash memory-based SSDs, also known as flash drives, do not require batteries.
  - They are often packaged in standard disk drive form factors (1.8-, 2.5-, and 3.5-inch).
  - In addition, non-volatility allows flash SSDs to retain memory even during sudden power outages, ensuring data persistence

SSD - Solid State Drive

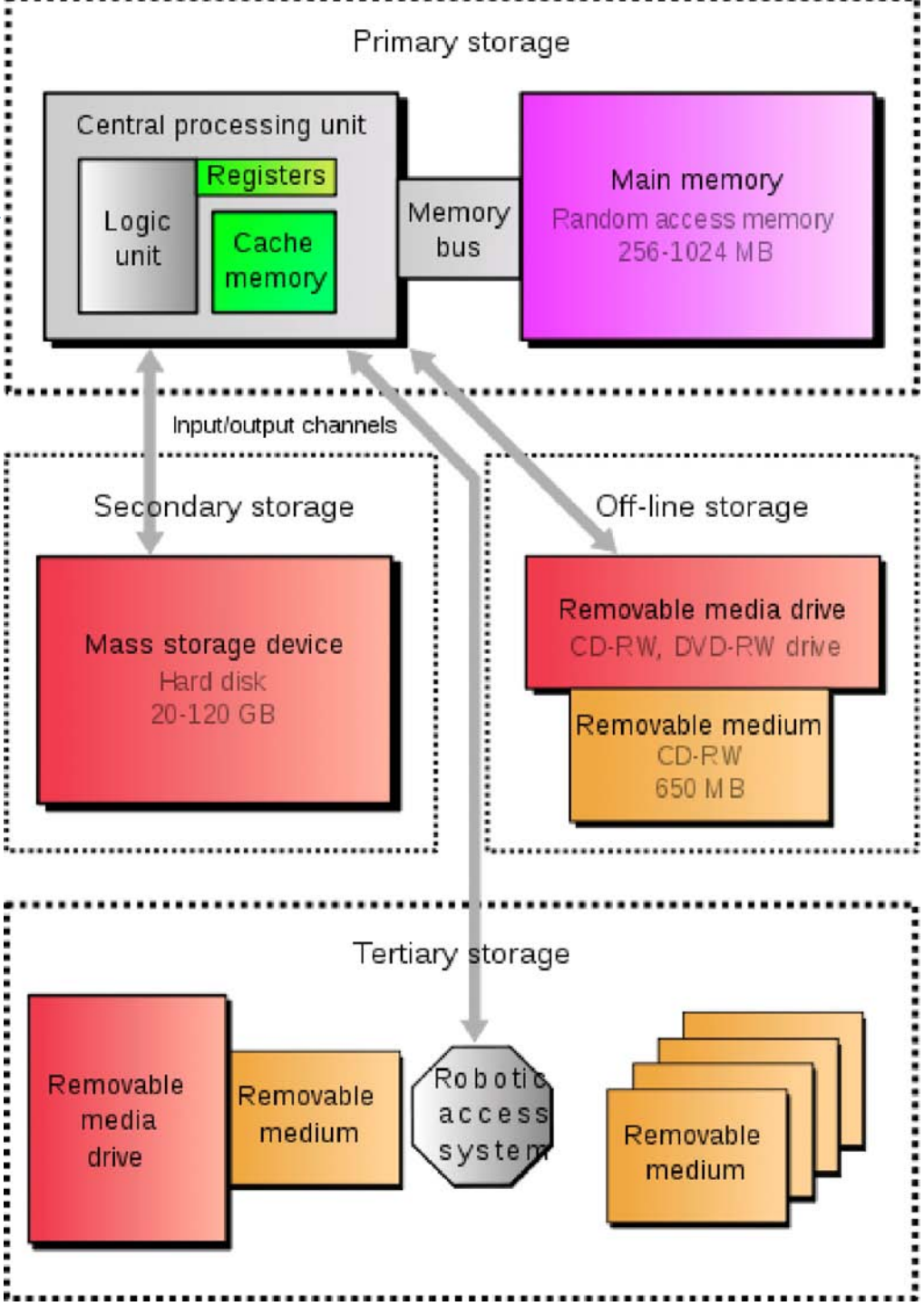
- DRAM Based
  - SSDs based on volatile memory such as DRAM are characterized by ultrafast data access, generally less than 0.01 milliseconds, and are used primarily to accelerate applications that would otherwise be held back by the latency of Flash SSDs or traditional HDDs.
  - DRAM-based SSDs usually incorporate either an internal battery or an external AC/DC adapter and backup storage systems to ensure data persistence while no power is being supplied to the drive from external sources.
  - If power is lost, the battery provides power while all information is copied from random access memory (RAM) to back-up storage.
  - When the power is restored, the information is copied back to the RAM from the back-up storage, and the SSD resumes normal operation.

SSD - Solid State Drive

- Advantages
  - Faster start-up because no spin-up is required.
  - Fast random access because there is no read/write head
    - Low read latency times for RAM drives. Consistent read performance because physical location of data is irrelevant for SSDs.
    - File fragmentation has negligible effect.
  - Silent operation due to the lack of moving parts.
  - Low capacity flash SSDs have a low power consumption and generate little heat when in use.
  - High mechanical reliability, as the lack of moving parts almost eliminates the risk of "mechanical" failure.



Computer Storage System



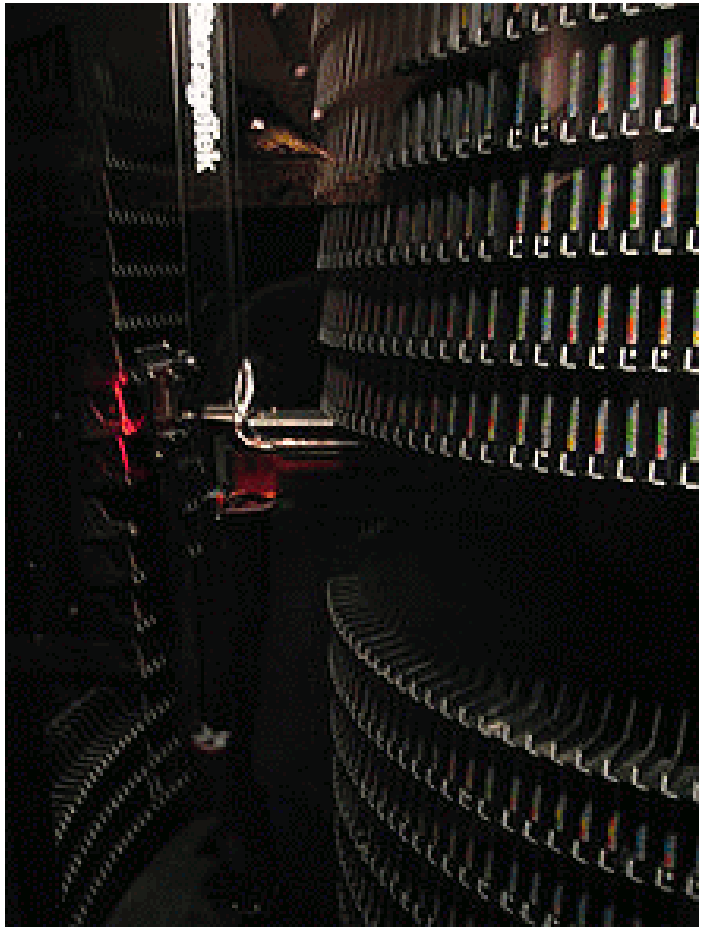
Tertiary Storage

- Tertiary storage or tertiary memory provides a third level of storage.
- Typically it involves a robotic mechanism which will mount (insert) and dismount removable mass storage media into a storage device according to the system's demands; this data is often copied to secondary storage before use.
- It is primarily used for archival of rarely accessed information since it is much slower than secondary storage (e.g. 5–60 seconds vs. 1-10 milliseconds).
- This is primarily useful for extraordinarily large data stores, accessed without human operators.
- Typical examples include tape libraries and optical jukeboxes.

Tape Library

- Tape library, sometimes called a tape silo, tape robot or tape jukebox, is a storage device which contains one or more tape drives, a number of slots to hold tape cartridges, a barcode reader to identify tape cartridges and an automated method for loading tapes (a robot)
- These devices can store immense amounts of data, currently ranging from 20 terabytes up to more than 366 petabytes of data, or about seven hundred thousand times the capacity of a typical hard drive and well in excess of capacities achievable with network attached storage.
- There are several large-scale library-management packages available commercially.
  - Open-Source support includes AMANDA, Bacula, and the minimal mtx program.

Tape Library



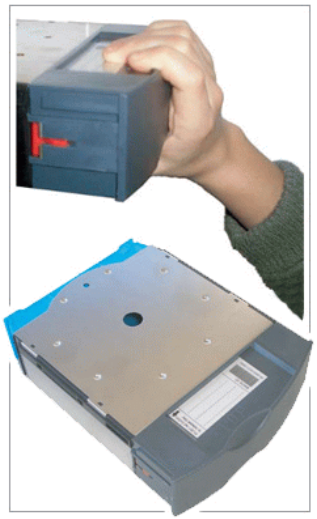
StorageTek Powderhorn tape library

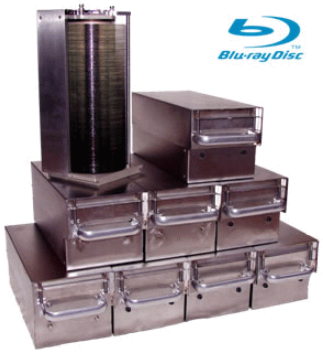
Small ADIC Scalar 100 tape library, robot visible on the bottom, two IBM LTO2 tape drives behind it.

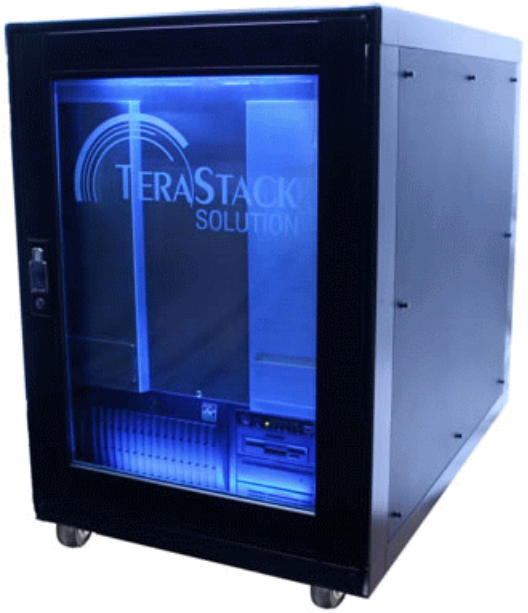
Dell PowerVault 124T Autoloader

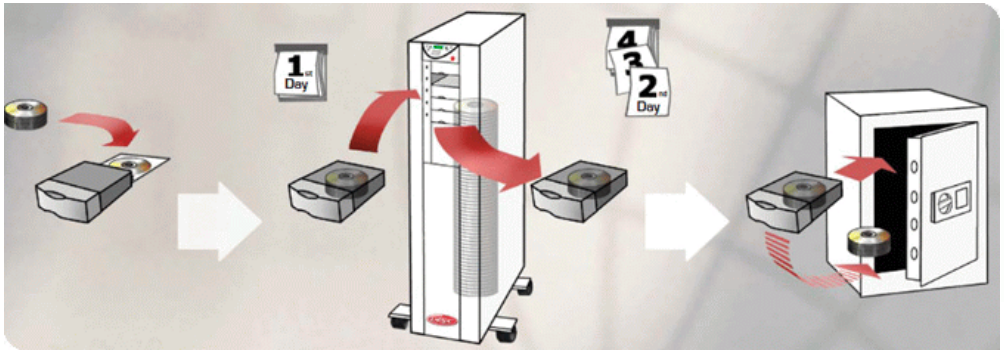
Optical JukeBox

- An optical jukebox is a robotic data storage device that can automatically load and unload optical discs, such as Compact Disc, DVD, Ultra Density Optical or Blu-ray disc and can provide terabytes and petabytes of tertiary storage.



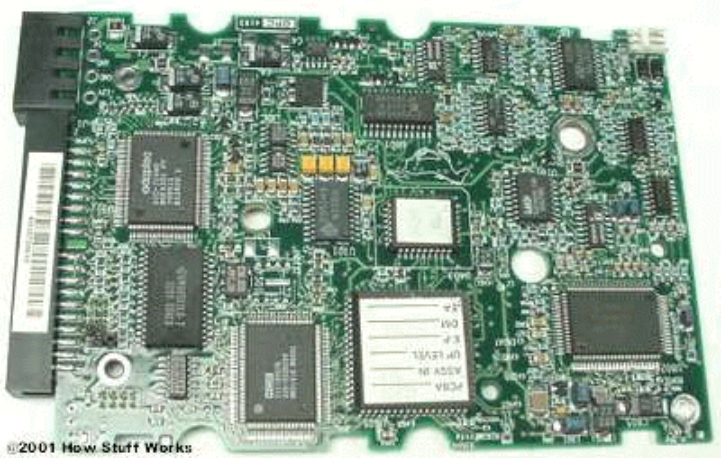






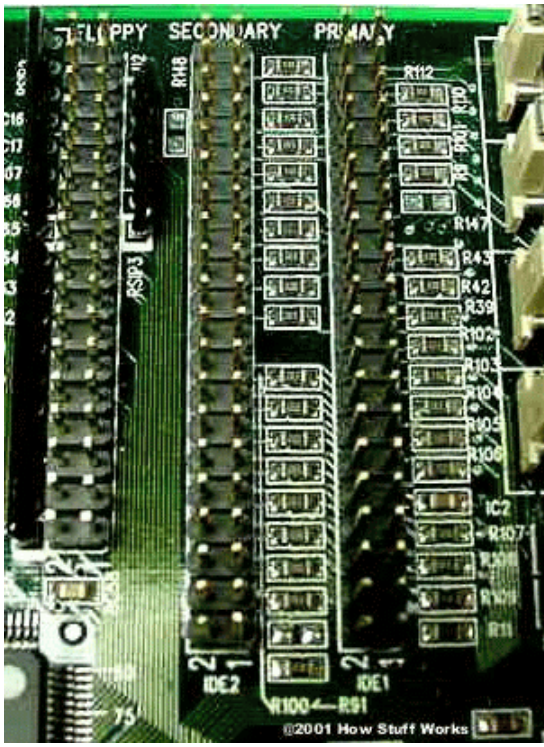
IDE : Integrated Drive Electronics

- IDE was created as a way to standardize the use of hard drives in computers.
- The basic concept behind IDE is that the hard drive and the controller should be combined.
- The controller is a small circuit board with chips that provide guidance as to exactly how the hard drive stores and accesses data. Most controllers also include some memory that acts as a buffer to enhance hard drive performance.



ATA : AT Attachment

- IBM introduced the AT computer in 1984 with a couple of key innovations.
  - The slots in the computer for adding cards used a new version of the Industry Standard Architecture (ISA) bus.
  - IBM also offered a hard drive for the AT that used a new combined drive/controller.
    - A ribbon cable from the drive/controller combination ran to an ISA card to connect to the computer, giving birth to the AT Attachment (ATA) interface.
- In 1986, Compaq introduced IDE drives in their Deskpro 386. This drive/controller combination was based on the ATA standard developed by IBM.
- IDE became the term that covered the entire range of integrated drive/controller devices. Since almost all IDE drives are ATA-based, the two terms are used interchangeably.

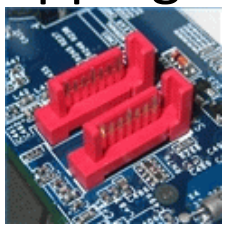


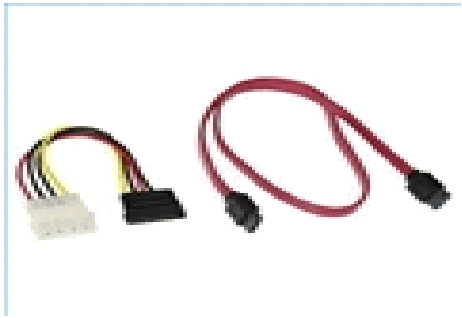
Variations of ATA

- ATA-1 - The original specification that Compaq included in the Deskpro 386.
  - It instituted the use of a master/slave configuration.
  - DMA and PIO
- ATA-2 - DMA was fully implemented beginning with the ATA-2 version.
  - Standard DMA transfer rates increased from 4.16 megabytes per second (MBps) in ATA-1 to as many as 16.67 MBps.
  - ATA-2 provides power management
- ATA-3 - With the addition of Self-Monitoring Analysis and Reporting Technology (SMART), IDE drives were made more reliable.
- ATA-4 - Probably the two biggest additions to the standard in this version are Ultra DMA support and the integration of the AT Attachment Program Interface (ATAPI) standard.
  - ATAPI provides a common interface for CD-ROM drives, tape backup drives and other removable storage devices.
- ATA-5 - The major update in ATA-5 is auto detection of which cable is used: the 40-conductor or 80-conductor version.
  - Ultra DMA is increased to 66.67 MB/sec with the use of the 80-conductor cable. ATA-5 is also called Ultra ATA/66.

Serial ATA

- Serial ATA (SATA) is a computer bus interface for connecting host bus adapters to mass storage devices such as hard disk drives and optical drives.
- Serial ATA was designed to replace the older ATA (AT Attachment) standard (also known as EIDE).
- It is able to use the same low level commands, but serial ATA host- adapters and devices communicate via a high-speed serial cable over two pairs of conductors
- SATA offers several compelling advantages over the older parallel ATA (PATA) interface: reduced cable-bulk and cost (reduced from 80 wires to seven), faster and more efficient data transfer, and hot swapping.





SATA version

- SATA Revision 1.0 (SATA 1.5Gb/s)
  - For HD OK
  - FOR Flash too slow
- SATA Revision 2.0 (SATA 3 Gb/s)
  - For mechanical hard drives, SATA 3 Gbit/s transfer rate exceeds drive throughput, and will for some time, as the fastest mechanical drives barely saturate a SATA 1.5 Gbit/s link.
  - Problem SSD drive already saturated the bandwidth
- SATA II misnomer
  - Popular usage refers to the SATA 3 Gbit/s specification as Serial ATA II (SATA II or SATA2), contrary to the wishes of the Serial ATA International Organization (SATA-IO) which defines the standard.
  - SATA II was originally the name of a committee defining updated SATA standards, of which the 3 Gbit/s standard was just one.

SATA version

- SATA Revision 3.0 (SATA 6 Gb/s)
  - A new Native Command Queuing (NCQ) streaming command to enable isochronous data transfers for bandwidth-hungry audio and video applications.
  - An NCQ Management feature that helps optimize performance by enabling host processing and management of outstanding NCQ commands.
  - Improved power management capabilities.
  - A small low insertion force (LIF) connector for more compact 1.8-inch storage devices.
  - Connector designed to accommodate 7 mm optical disk drives for thinner and lighter notebooks.
- eSATA
  - Standardized in 2004, eSATA provides a variant of SATA meant for external connectivity.
  - It has revised electrical requirements in addition to incompatible cables and connectors

SATA Data

- The SATA standard defines a data cable with seven conductors (3 grounds and 4 active data lines in two pairs) and 8 mm wide wafer connectors on each end.

Pin #	Function
1	Ground
2	A+ (transmit)
3	A− (transmit)
4	Ground
5	B− (receive)
6	B+ (receive)
7	Ground
8	Coding notch

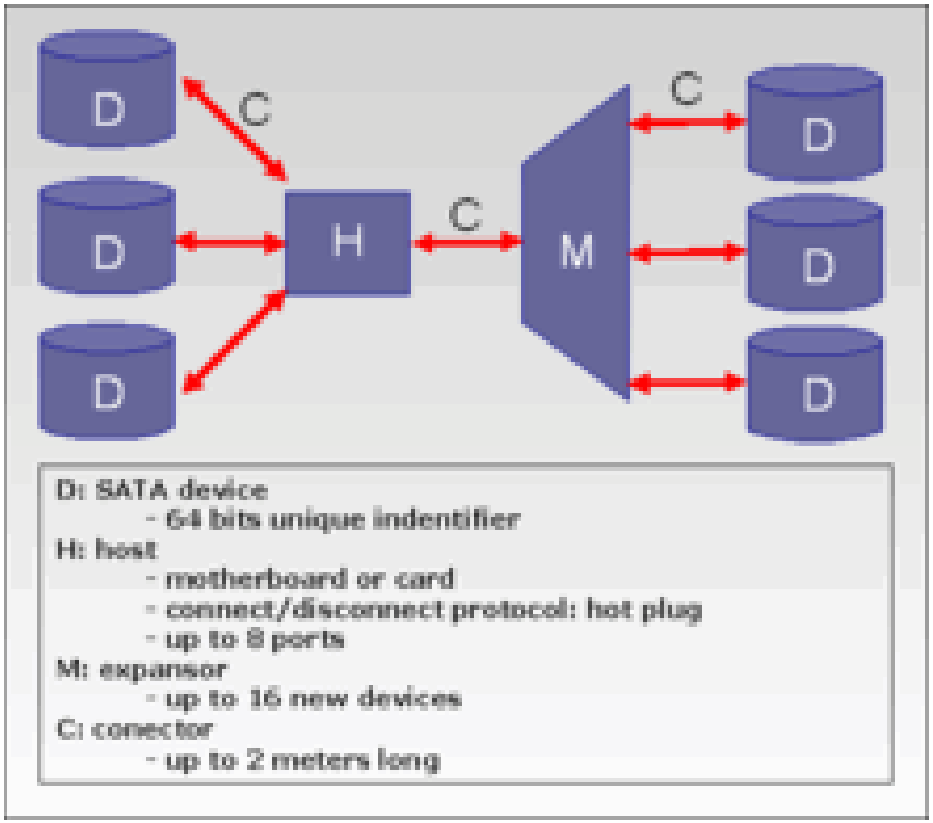
SATA Power

- The SATA standard specifies a different power connector than the decades-old four-pin Molex connector found on pre-SATA devices.

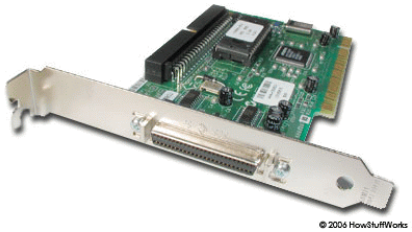
Pin #	Mating	Function
—		Coding notch
1	3rd	3.3 V
2	3rd	
3	2nd	
4	1st	Ground
5	2nd	
6	2nd	
7	2nd	5 V
8	3rd	
9	3rd	
10	2nd	Ground
11	3rd	Staggered spinup/activity (in supporting drives)
12	1st	Ground
13	2nd	12 V
14	3rd	
15	3rd	

SATA Topology

- SATA uses a point-to-point architecture. The connection between the controller and the storage device is direct.



SCSI



- SCSI originally stood for Small Computer System Interface, but it's really outgrown the "small" designation.
  - It's a fast bus that can connect lots of devices to a computer at the same time, including hard drives, scanners, CD-ROM/RW drives, printers and tape drives.
- SCSI has several benefits. It's fairly fast, up to 320 megabytes per second (MBps).
- It's been around for more than 20 years and it's been thoroughly tested, so it has a reputation for being reliable.
- Like Serial ATA and FireWire, it lets you put multiple items on one bus. SCSI also works with most computer systems.

SCSI

- SCSI has three basic specifications:
  - SCSI-1: The original specification developed in 1986, SCSI-1 is now obsolete. It featured a bus width of 8 bits and clock speed of 5 MHz.
  - SCSI-2: Adopted in 1994, this specification included the Common Command Set (CCS) -- 18 commands considered an absolute necessity for support of any SCSI device. It also had the option to double the clock speed to 10 MHz (Fast), double the bus width from to 16 bits and increase the number of devices to 15 (Wide), or do both (Fast/Wide).
  - SCSI-3: This specification debuted in 1995 and included a series of smaller standards within its overall scope. A set of standards involving the SCSI Parallel Interface (SPI), which is the way that SCSI devices communicate with each other, has continued to evolve within SCSI-3.
    - Most SCSI-3 specifications begin with the term Ultra, such as Ultra for SPI variations, Ultra2 for SPI-2 variations and Ultra3 for SPI-3 variations. The Fast and Wide designations work just like their SCSI-2 counterparts. SCSI-3 is the standard currently in use.

SCSI

Name	Specification	# of Devices	Bus Width	Bus Speed	MBps
Asynchronous SCSI	SCSI-1	8	8 bits	5 MHz	4 MBps
Synchronous SCSI	SCSI-1	8	8 bits	5 MHz	5 MBps
Wide	SCSI-2	16	16 bits	5 MHz	10 MBps
Fast	SCSI-2	8	8 bits	10 MHz	10 MBps
Fast/Wide	SCSI-2	16	16 bits	10 MHz	20 MBps
Ultra	SCSI-3 SPI	8	8 bits	20 MHz	20 MBps
Ultra/Wide	SCSI-3 SPI	8	16 bits	20 MHz	40 MBps
Ultra2	SCSI-3 SPI-2	8	8 bits	40 MHz	40 MBps
Ultra2/Wide	SCSI-3 SPI-2	16	16 bits	40 MHz	80 MBps
Ultra3	SCSI-3 SPI-3	16	16 bits	40 MHz	160 MBps
Ultra320	SCSI-3 SPI-4	16	16 bits	80 MHz	320 MBps

- All of these SCSI types are parallel -- bits of data move through the bus simultaneously rather than one at a time.
- The newest type of SCSI, called Serial Attached SCSI (SAS), uses SCSI commands but transmits data serially.
- SAS uses a point-to-point serial connection to move data at 3.0 gigabits per second, and each SAS port can support up to 128 devices or expanders.

SATA and SCSI

- SCSI uses a more complex bus, usually resulting in higher manufacturing costs.
- SCSI buses also allow connection of several drives (using multiple channels, 7 or 15 on each channel), whereas SATA allows one drive per channel, unless using a port multiplier.
- SCSI drives provide greater sustained throughput than SATA drives because of disconnect-reconnect and aggregating performance.
- SCSI, SAS and fibre-channel (FC) drives are typically more expensive so they are traditionally used in servers and disk arrays where the added cost is justifiable.
- Inexpensive ATA and SATA drives evolved in the home-computer market, hence there is a view that they are less reliable.

Name	Raw bandwidth (Mbit/s)	Transfer speed (MB/s)	Max. cable length (m)	Power provided	Devices per Channel
eSATA	3,000	300[26]	2 with eSATA HBA (1 with passive adapter)	No	1 (15 with port multiplier)
eSATAp				5 V/12 V[27]	
SATA 600	6,000	600[28]	1	No	
SATA 300	3,000	300[29]			
SATA 150	1,500	150[30]			1 per line
PATA 133	1,064	133.5	0.46 (18 in)	No	2
SAS 300	3,000	300[31]	8	No	1 (16k with expanders)
SAS 150	1,500	150[32]			
FireWire 3200	3,144	393	100 (more with special cables)	15 W, 12–25 V	63 (with hub)
FireWire 800	786	98.25	100[33]		
FireWire 400	393	49.13	4.5[33][34]		
USB 3.0*	4,000	400[35]	3[36]	4.5 W, 5 V	127 (with hub)[36]
USB 2.0	480	60	5[37]	2.5 W, 5 V	
USB 1.0	12	1.5	3	Yes	
SCSI Ultra-320	2,560	320	12	No	15 (plus the HBA)
Fibre Channel over optic fiber	10,520	2,000	2–50,000	No	126 (16,777,216 with switches)
Fibre Channel over copper cable	4,000	400	12		
InfiniBand Quad Rate	10,000	1,000	5 (copper)[38][39] <10,000 (fiber)	No	1 with point to point Many with switched fabric
Light Peak	10,000	1,250	100	No	Many