Main Memory - revisited

- The CPU executes programs from main memory.
- The CPU reads data from and writes data to main memory.
- Each memory location has a unique address.
  - The number of unique addresses is determined by the size of the address bus.
- Typically main memory used RAM (Random Access Memory).
  - This means you can access any memory location in any order.
  - In sequential memory systems (like tape) in order to read the 100th item, you must read the previous 99!

Main Memory – revisited (2)

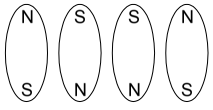
- The CPU only executes programs from main memory.
- Since capacity of main memory is usually much smaller than the capacity of other storage devices, such as the hard disk, only a fraction of the program or the data may be in main memory at any given time.
  - One of the tasks of an operating system is to efficiently manage main memory.

Hard Disk

- Nearly every computer has a hard disk.
  - Some computers have several.
- Hard disks have one major task.
  - Hard disks store data in a permanent form. Even when the power is not applied the hard disk retains the information stored on it.
- Hard disks date from the 1950's and were called fixed disks or Winchester disk (IBM codename for a fixed disk product).

Hard Disk (2)

- Hard disks have a hard platter that is coated with a magnetic material (2.5µm thickness).
  - The magnetic material is composed of little magnetic dipoles, which you can think of as little magnets.
  - Each dipole has a magnetic north and a magnetic south.
  - We can align the dipoles in two ways; one for a binary '1' bit and the other for a binary '0' bit.



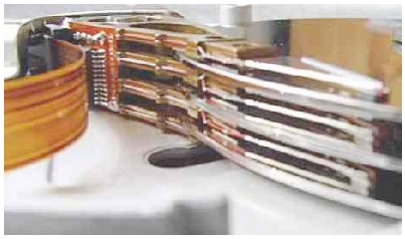
Might represent 1001

Hard Disk (3)

A hard disk is a sealed unit and opening it (like above) will ruin it.
Inside the unit is the control electronics, the platters and the read/write heads.

Hard Disk (4)

Hard Disk (5)

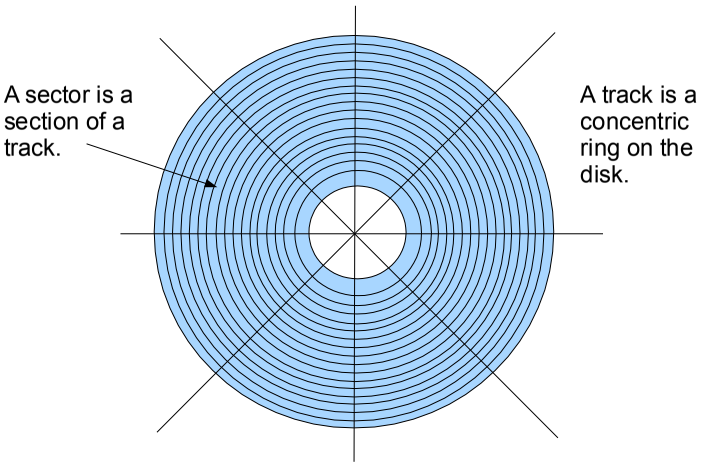


- The platters spin at 3600 rpm or 7200 rpm.
- Most disks have several platters.
- The read/write heads 'fly' over the platters.
  - The flying height is 0.5µm.
  - Finger print smear is 3µm thick and a smoke particle is 5µm in size.

Hard Disk (6)

- The arm can move from the edge of the platter to the central hub and back up to 50 times a second.
  - The arm motor is a linear motor not unlike a speaker coil in a stereo system.
- Data on a hard disk is arranged into tracks and sectors.
  - Tracks are concentric rings on the disk.
  - Sectors are sections of a track. Each sector holds a fixed number of bytes.

Hard Disk (7)



Hard Disk (8)

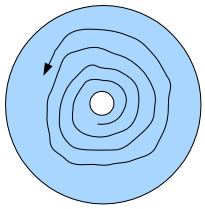
- In some operating systems sectors are grouped together into clusters.
- The **low-level formatting** of a drive establishes the tracks and sectors on the platter.
  - The start and end patterns of each sector are written onto the platter. This process prepares the drive to hold blocks of bytes.
- **High-level formatting** writes the file-storage structures, like the file allocation table, into the sectors. The file allocation table says which sectors belong to a given file.

Hard Disk (9)

- To read a file from the hard disk:
    1. The file allocation table is checked to see which sectors (track number and sector number) are being used to hold the file.
        1. The file allocation table (FAT) is usually preloaded in to main memory since it will be used a lot.
    2. Each sector is read in turn.
        1. The arm with the read/write heads is moved to the track containing the sector.
        2. Drive waits until the sector on the spinning platter passes under the read/write head.
        3. The time to reach a track is called the **seek time**.
- Performance of a hard drive is characterised by its seek time and revolution speed.

CD Disk

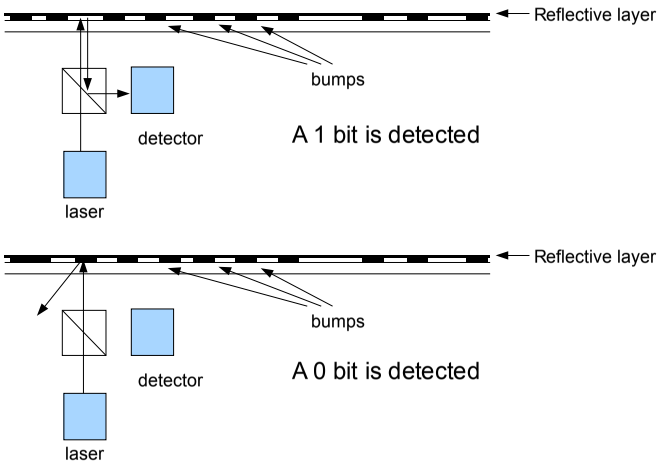
- CDs store music and other files in digital form.
- In a CD, the 1s and 0s are represented by millions of tiny bumps and flat areas on the disc's reflective surface.
    - The bumps and flats are arranged in a continuous track that measures about 0.5 microns (millionths of a meter) across and 3.5 miles (5 km) long.



CD Disk (2)

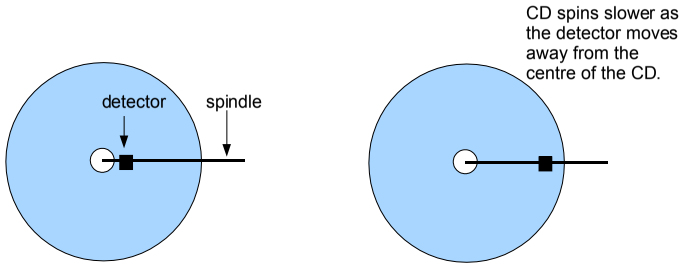
- To read this information, the CD player passes a laser beam over the track.
- When the laser passes over a flat area in the track, the beam is reflected directly to an optical sensor on the laser assembly. The CD player interprets this as a 1.
- When the beam passes over a bump, the light is bounced away from the optical sensor. The CD player recognizes this as a 0.

CD Disk (3)



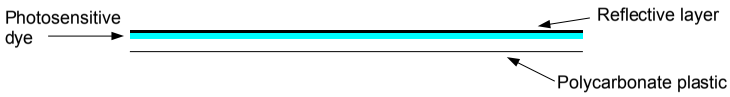
CD Disk (4)

- Since the track spirals out from the centre, in order to have the 1s and 0s pass the detector at the same rate, the CD spins slower as the laser/detector assembly moves out towards the edge.



CD-R

- CD-Rs, don't have any bumps or flat areas at all. Instead, they have a smooth reflective metal layer, covered by a layer of photosensitive dye.
- When the disc is blank, the dye is transparent, 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 and light can't pass through.



CD-R (2)

- The CD burner has a moving laser assembly, just like an ordinary CD player. But in addition to the standard "read laser," it has a "write laser."
- The write laser is more powerful than the read laser, so it interacts with the disc differently. It alters the dye.
- 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.

CD-R (3)

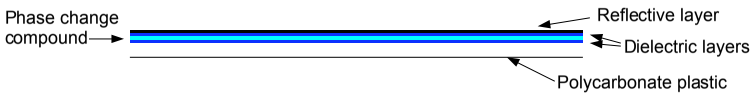
- Most CD burners can create CDs at multiple speeds.
  - At 1x speed, the CD spins at about the same rate as it does when the player is reading it. It would take about 90 minutes to record 90 minutes of music.
  - At 8x speed, it would take just over 11 minutes to record 90 minutes.
- For faster burning speeds, you need more advanced laser-control systems and a faster connection between the computer and the burner.
  - You also need a blank disc that is designed to record information at this speed.

CD-R (4)

- The main advantage of CD-R discs is that they work in almost all CD players and CD-ROMS.
  - In addition to this wide compatibility, CD-Rs are relatively inexpensive.
- The main drawback of CD-Rs is that you can't reuse them. Once you've burned in the digital pattern, it can't be erased and re-written.

CD-RW

- CD-RW discs have built in an erase function so you can record over old data you don't need anymore.
- These discs are based on phase-change technology. In CD-RW discs, 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.



CD-RW (2)

- In phase-change compounds, these changes is phase can be "locked into place": They persist even after the material cools down again.
  - If you heat the compound in CD-RW discs to the melting temperature and let it cool rapidly, it will remain in a fluid, amorphous state, even though it is below the crystallization temperature.
  - In order to crystallize the compound, you have to keep it at the crystallization temperature for a certain length of time so that it turns into a solid before it cools down again.

CD-RW (3)

- The crystalline form is transparent while the amorphous fluid form will absorb most light.
- To write information on the disc, the CD burner uses its write laser, which is powerful enough to heat the compound to its melting temperature.
  - These "melted" spots serve the same purpose as the bumps on a conventional CD and the opaque spots on a CD-R: They block the "read" laser so it won't reflect off the metal layer.
    - Each non-reflective area indicates a 0 in the digital code.
    - Every area that remains crystalline is still reflective, indicating a 1.

CD-RW (4)

- The read laser is weaker than the write laser and does not have enough power to change the state of the material in the recording layer.
- The erase laser is somewhere between the read and write lasers in strength. While it isn't strong enough to melt the material, it can 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 disc so new data can be written.
- CD-RW discs do not reflect as much light as older CD formats and cannot be read by older CD players and CD-ROM drives.

DVD Disk

- DVD stands for Digital Versatile Disk
  - DVD-ROM has data that can only be read and not written.
  - DVD-R and DVD+R can record data only once and then function as a DVD-ROM.
  - DVD-RW, DVD+RW and DVD-RAM can both record and erase data multiple times.
- DVD has a much larger data capacity than a CD.
  - A standard DVD holds about seven times more data than a CD does.

DVD (2)

- DVDs are of the same diameter and thickness as CDs.
- Similar a CD, the data on a DVD is encoded in the form of small bumps in the track of the disc arranged as a single, continuous and extremely long spiral track of data.
- The data track is tiny, just 740 nanometers separate one track from the next. And the elongated bumps that make up the track are each 320 nanometers wide, a minimum of 400 nanometers long and 120 nanometers high.

DVD (3)

- The microscopic dimensions of the bumps make the spiral track on a DVD extremely long. As a straight line, it would be almost 7.5 miles long! That means that a double-sided, double-layer DVD would have 30 (7.5 x 4) miles (48 km) of data!
- On a single-layer single-sided DVD the bumps are 2.08 times smaller than a CD plus the gap between the tracks is 2.16 smaller. That gives a 4.5 times increase in data density.
- DVDs uses a much more efficient error correction scheme than CDs. This reduction in overhead means that a DVD holds about 7 times more data than a CD.

DVD (4)

- To increase the storage capacity even more, a DVD can have up to four layers, two on each side. The laser that reads the disc can actually focus on the second layer through the semitransparent first layer.

Type	Capacity
Single sided single layer	4.38 GB
Single sided double layer	7.95 GB
Double sided single layer	8.75 GB
Double sided double layer	15.9 GB

- When a disc is made with two layers, the pits have to be a little longer, on both layers, than when a single layer is used. This is to avoid interference between the layers, which would cause errors when the disc is played.

DVD (5)

- The DVD player consists of three fundamental components:
  - A drive motor to spin the disc at a precisely controlled rotation speed between 200 and 500 rpm, depending on which track is being read.
- A laser and a lens system to focus in on the bumps and read them.
  - The light from this laser has a smaller wavelength than the light from the laser in a CD player, which allows the DVD laser to focus on the smaller DVD pits.
- A tracking mechanism that can move the laser assembly at micron resolutions so the laser beam can follow the spiral track.