

Data Storage Devices

PG131 - TXB

Used to store applications, data, and files.

Primary and Secondary Storage | 3.3.1, 3.3.2

Primary storage is directly accessible by the CPU, meaning data can be read very quickly. However, their capacity is typically much lower, and often volatile. This includes RAM, ROM, and cache memory.

Secondary storage cannot be directly accessed by the CPU. It can be both internal and external to the CPU. It is necessary for permanently storing data for long periods of time as primary storage is often volatile meaning that it will lose its data when power is shut off. It is also used for transferring data from one computer to another. It stores data that the CPU does not currently need. Examples of secondary storage include HDD (hard disk drives), SSD (solid state drives), and DVD (digital versatile discs).

Magnetic, Optical, and Solid-State Storage | 3.3.3

Optical storage - laser technology:

It is a form of data storage that uses light to read or write data onto an optical media. This is done via laser to read and write information onto the surface of a disc.

→ ROM - Read only memory

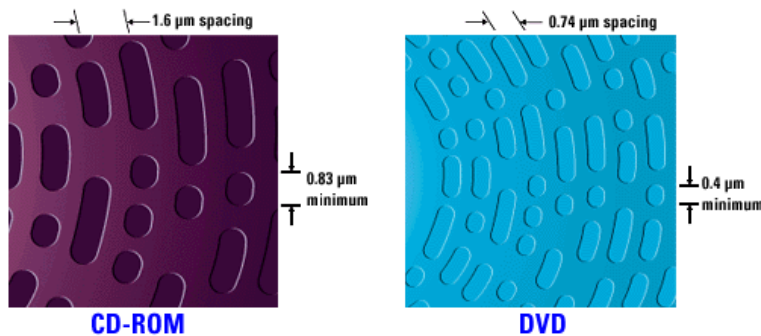
- ◆ Stores factory settings of the computer
- ◆ Stores data the computer needs to access at start-up such as BIOS and Bootstrap
- ◆ Firmware located on the BIOS chip
- ◆ Permanently stores start-up sequence and initiates the computer when turned on
- ◆ Stores set routines
- ◆ Non-volatile, **permanent memory**
- ◆ Cannot be electronically changed or written to, it is read only

Red laser/blue lasers can either read or write to DVDs, CDs, and Blu-rays. They can be set to write once only or both read and write, depending on the manufacturer.

→ DVD - Digital versatile disc, CD

- ◆ Thin layer of metal alloy that stores data
- ◆ Only a single spiral track runs throughout the disc from the centre to the outer edge
- ◆ These disc are also separated in sectors so that the head can directly access data
- ◆ When read, the **optical head** moves to the surface of the disc and reads along the spiral track as the disc spins, using a red laser
- ◆ Data is stored in pits and lands where lands represent 1 and pits represent 0

- ◆ Lands are flat, non-indented surfaces and pits are small indents in the reflective surface of the disc
- ◆ These optical discs can be written once only, or read and written to multiple times

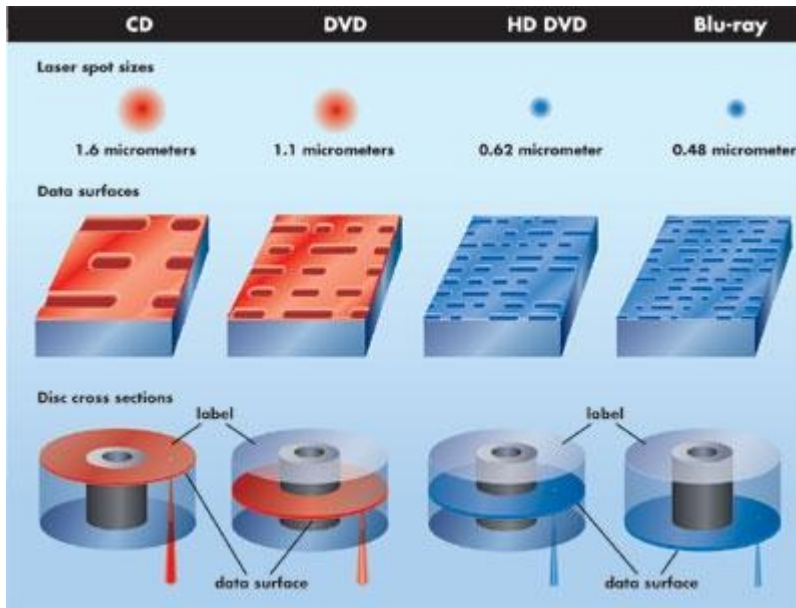


- ◆ DVDs can store more data than CDs but they can also be dual-layered, which significantly increases the storage capacity - CDs track widths are larger as well therefore it cannot fit as much data as a DVD.

In dual-layering, two disks are joined together and separated with a transparent spacer. The laser accesses the second layer through the first layer (and transparent spacer).

→ Blu-ray

- ◆ A blue laser is used instead of a red laser
- ◆ The wavelength of blue light is much smaller than red light, so that the pits and lands can be smaller, allowing for more storage capacity (5 times more than a DVD)
- ◆ Blu-rays can be dual-layered as well
- ◆ They come with secure encryption
- ◆ Can do much more than DVDs: high definition television, quickly skip to any part of the disc, create playlists off of recorded media, automatically search for empty space



Solid state storage:

→ SSD - Solid state drive

- ◆ Has no moving parts (therefore 'solid') which eliminates latency
- ◆ Instead of relying on magnets, SSDs store data by moving electrons around within NAND or NOR chips
- ◆ Data can also be read throughout the entire chip at the same time rather than one bit at a time in HDDs as the state of all the transistors can be known at the same time
- ◆ Overall SSDs are much more efficient than HDDs as they are more reliable, lighter, faster, and uses less power
- ◆ However SSDs have a relatively lower endurance and cannot perform as well when writing a lot of data
- ◆ How it works:
 - The drive is arranged in a **matrix**
 - At each intersection there are two transistors, **a floating and a control gate**
 - A **dielectric coating** acts as an **insulator** which allows the transistor to keep their charges
 - To assign charges, a voltage is applied to the control gate and attracts electrons to the corresponding floating gate
 - The insulating layer locks the charge in
 - When the floating gate is charged, its value is 1, and when it has no charge, its value is 0
 - If charges up a 'floating gate' to represent either 0 or 1. The way it does this is by attracting electrons to charge a floating gate via a 'control gate' when a voltage is applied

→ BIOS

- ◆ This is stored in EEPROM - electrically erasable programmable read only memory. This means that its contents can be changed electrically
- ◆ Flash memory technology is used allowing it to maintain its memory without power (non-volatile)

- ◆ However the settings of the BIOS is stored in a CMOS, which is battery powered
- ◆ These settings can be changed by the user
- ◆ Restarting or reconnecting the CMOS to power will reset the BIOS settings to factory defaults

TRANSISTORS

'Used to amplify or switch electrical signals'

In SSDs, floating and control gates are transistors

In RAM, they read and write to capacitors by allowing current or discharging them

→ USB Flash drive/Memory sticks

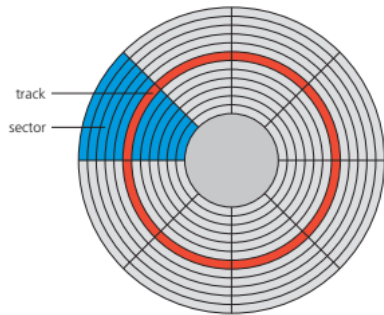
- ◆ Uses the same technology as solid state drives
- ◆ They are small, lightweight, and portable
- ◆ They can be used as backup devices, transferring files between devices, or as dongles for expensive software (additional files that a software needs to run - this is a security method that prevents unauthorised use of the software as well as copying the software)

Magnetic storage:

Data is read and written using electromagnets as bits are stored magnetically.

→ HDD - Hard disk drive | <https://www.youtube.com/watch?v=NtPc0jl21i0>

- ◆ **Data is stored magnetically as magnetic bits**
- ◆ Has spinning platters (aluminium, glass, ceramic material) thinly coated with a magnetic substance (can spin 7000 times per second)
- ◆ 'Read-write' transducers (read/write heads) have electromagnets that can read or write data to the platters
- ◆ The platter is divided into many many tracks and sectors where sectors hold a specific amount of data (bytes)
- ◆ The heads read and write individual bits off of tracks at a designated address - however they need to look for the correct track and sector which may cause latency
- ◆ It takes time for an entire block of data to rotate to a head, that is latency
- ◆ Fragmentation can occur overtime as data is not always stores in adjacent sectors. This means that the heads will have to look for scattered files which makes accessing data slower, and will damage the arms as it has to constantly move
- ◆ HDDs have a coil that generates a magnetic field by spinning
- ◆ Very slow data access compared to RAM



→ RAM - Random access memory

- ◆ Volatile, temporary memory
- ◆ Memory can be accessed at any location at any time, independent of which memory location was last used or its order
- ◆ Locating data is much faster than secondary storage
- ◆ Stores currently running applications, data, parts of the OS, instructions, utility software
- ◆ Can be directly written to or read from by the user or computer
- ◆ If RAM is full, data needs to constantly be overwritten with new data from secondary storage, which takes time. If the size of RAM is increased, computer performance increases as more data can be accessed quickly.
- ◆ Disadvantages: not as fast as the cache, expensive, lower capacity compared to secondary storage

Address	Data
0 (000)	1 0 1 0
1 (001)	0 0 1 1
2 (010)	1 1 0 1
3 (011)	1 0 1 0
4 (100)	0 1 1 1
5 (101)	0 0 0 1
6 (110)	1 0 1 1
7 (111)	0 0 1 0

◆ SRAM

- Uses flip flops (a circuit consisting of multiple transistors) to hold bits
- Faster than DRAM
- Disadvantages: expensive, higher power usage, lower storage capacity
- Advantages: doesn't need to be recharged, faster data access, CPU cache makes use of SRAM because it is faster than DRAM

◆ DRAM

- Uses transistors (switch, allows chip to read or change the value of capacitors) and capacitors (stores the bits)
- Advantages: cheaper, more memory capacity, lower power usage
- Disadvantages: needs to be constantly refreshed (recharged every 15ms to maintain its charge, otherwise the 1 charge would be lost and every capacitor would be 0), slower than SRAM

→ Cache

- ◆ This is the fastest possible access to memory the CPU has
- ◆ L1 is the fastest with a larger L2 cache underneath, and sometimes L3
- ◆ The cache is a form of RAM and does not need to be refreshed (recharged) (SRAM)
- ◆ It holds memory that the CPU uses very often
- ◆ When the CPU takes memory from the cache, it's called a cache hit. When the CPU cannot find necessary files in the cache, it's a cache miss.

→ Tape

- ◆ Data is stored on a magnetic tape
- ◆ Playback heads touch the tape and read the magnetic bits

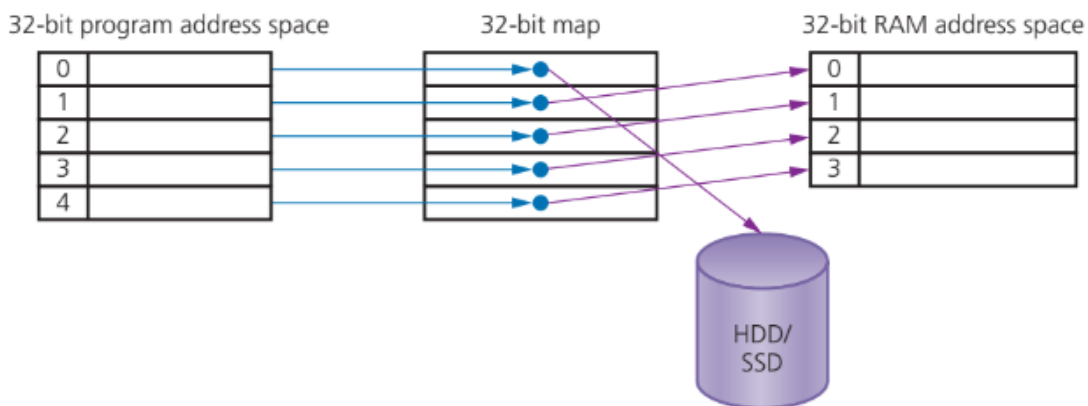
Virtual memory | 3.3.4

Virtual memory is a memory management technique that allows the computer to deal with memory shortages and creates an illusion that there is more memory capacity than physically available.

The hard drive is partitioned. When a computer runs out of space in its RAM, pages of unused data are temporarily transferred from RAM to secondary storage such as a HDD or SSD. When the data is required again, the pages are copied back into RAM.

Virtual memory is a combination of memory in the RAM and additional swappable memory in secondary storage.

Our diagram now changes to:



Maps:

All the programs requesting access to the RAM are sent to a 'map'. In the case that there is not enough space in the RAM, the map will direct the newly opened programs to the

HDD/SSD. Virtual memory will then now 'map' the oldest data in the RAM into the HDD/SSD to make space for the program previously moved to the HDD.

A process called **paging** moves data in and out of the RAM in pages. A **page** is a block of data of a fixed-size. When the RAM runs out of space, old pages of data are transferred to the HDD/SSD and are replaced with new pages.

When the RAM is full and the user opens a new application, virtual memory temporarily moves the oldest unused data in pages to swap space in secondary storage. This makes space in the RAM for the new application to be copied over. This continues until the RAM is no longer being over-utilised.

Benefits:

- Allows the user to use more memory than physically available
- Does not waste memory on unused data
- Allows computer to handle large amounts of data at a time
- Reduces the need to buy better, more expensive RAM

However virtual memory requires moving a lot of data in and out of the hard disc, constantly. Overtime, the hard disc will be damaged and break down prematurely.

Another issue is disc thrashing, where a buildup of data needs to be swapped between RAM and virtual memory. This is time consuming as there is a high rate of read/write head movements, and will eventually reach the **thrash point**, which is where more time is spent moving data rather than the execution of a program, causing it to stop. This can be avoided by using SSDs as there are no moving parts.

Cloud storage | 3.3.5, 3.3.6

Cloud storage is a collection of servers that store data in remote locations. The data can be accessed using an internet connection.

Data redundancy is where users' data is stored on multiple different servers in case of malfunctioning or maintenance so that they can be accessed at any time.

The physical servers are often managed by a hosting company such as Amazon or Google.

Systems for cloud storage

→ Private

- ◆ The client and storage provider are integrated as one single entity
- ◆ For example, Google keeping their data on their own servers

→ Public

- ◆ The client and storage provider are two different entities
- ◆ Example: a company's website using Amazon's servers

→ Hybrid

- ◆ Stores sensitive, private data on the users individual storage device(s) and less sensitive information on the cloud

Advantages:

- Negates the need to carry an external storage device
- Able to access the information from any device at anytime
- Unlimited storage capacity for users
- Cloud storage can backup lost data on local storage

Disadvantages:

- Without internet or if the internet is slow, data on the cloud cannot be accessed
- Expensive if large storage capacity is required
- External facilities may malfunction and the client's data is lost
- Questionable security - hackers may steal or read private information of public servers

Security responsibility:**Provider:**

- Encryption to protect the privacy of the user's data
- Secure infrastructure, resistance to natural disasters, resistance to break-ins
- Policies preventing insider attacks, authorisation codes
- Backup procedures
- Up to date security software to prevent malware, hacking scandals

User:

- Strong passwords
- Not leaving the computer unattended
- Not sharing credentials
- Not using automatic login