Objective:

- Show understanding of need for **primary** memory, **secondary** (including removable) storage.
- Describe **principal operations** of hardware devices Including: hard disk, solid state (flash) memory, optical disc reader/writer.
- Explain differences between **RAM** and **ROM**. Including their use in a range of devices.
- Explain differences between **SRAM** and **DRAM**. Include their use in range of devices and systems and reasons for using one instead of other depending on device and its use.
- Explain difference between Programmable **ROM (PROM),** Erasable Programmable ROM **(EPROM)** and Electrically Erasable Programmable ROM **(EEPROM).**
- Show understanding of **embedded systems**, **benefits** and **drawbacks** of embedded systems.
- Show understanding of the **use of buffers**.

Computer System Hardware Functionality

A computer system has to support **three** major areas of operational capability:

- **Storage** of Data.
- **Processing** of data. Processing of data is carried out CPU.
- **Input** and **output** of data.

For data output from a computer system, following options are available:

• Screen Display • Hardcopy using printer/ plotter • virtual headset display

• speaker • writing to any data storage devices

For input of data to a computer system, following options are available:

• Keyboard • user interaction with a screen possibly using pointing device or use of touch screen • A user using a game controller • a user using a scanner

• A user using a microphone • Reading from any of the storage devices

Storage Devices

A storage device is a piece of computer equipment that is used to store information and data.

- ➤ It is an integral part of computer hardware, without which a computer would not be able to **run** or even **boot up**.
- ➤ Storage devices can hold and store information both **temporarily** and **permanently**.
- ➤ They can be **internal** or **external** to a computer, server, or computing device.
- ➤ Storage needs to be **larger** than **internal memory** since user may wish to store **large** files.
- ➤ Storage devices can be **removable** to allow data to be **transferred** between computers. **Removable devices** allow user to store important data for **back up** in different location in case of data loss.

➤ **Examples of storage devices** include hard disks, CDs, DVDs, pen/flash drives, SSDs, and cloud storage.

Types of Storage Devices

Types of computer memory: Primary memory, Secondary memory.

Primary (Main) Memory:

Primary memory is part of computer memory which can be accessed **directly** from CPU. Primary memory are used to **store** data, files, part of an application or part of operating system **currently in use.**

Example are random access memory (RAM), read-only memory (ROM) and Cache Memory.

> **Cache Memory** is external to processor, this is used to **store data** which processor will probably need to use again. **Cache** memory has **faster** access speed than that of main memory. It is built using SRAM technology

Random Access Memory

- ✓ It is '**read–write memory** because it can be read from or written to any number of times.
- ✓ It is called **RAM** because any **byte** of data stored can be accessed without affecting the other bytes stored.
- ✓ It is also called '**direct-access memory'**.
- ✓ RAM is **volatile** main memory, which means that when computer system is switched off contents of memory are lost.
- ✓ RAM is used to hold data and programs that are **currently in use**.

> Larger the RAM, faster the computer will operate. RAM never runs out of memory, it continues to operate but becomes slower and slower as more data is stored.

Two Types of RAM

⊞ Dynamic RAM (DRAM):

DRAM chip consists of a millions of **transistors** and **capacitors**. Capacitors hold the bits of information (0 or 1). Transistors act like **switch** and allow chip control circuitry to read capacitor or change capacitor's value.

DRAM needs to be constantly **refreshed** because capacitor needs to be re-charged otherwise it would lose its value. If it is not refreshed, capacitor's charge will **leak away** very **quickly**, leaving every capacitor with value 0.

⊞ Static RAM (SRAM)

SRAM does not need to be constantly **refreshed** as it makes use of **flip flops** which hold each bit of memory. SRAM is much **faster** than DRAM when it comes to data access.

DRAM is common type of RAM used in computers, but where absolute **speed** is essential, for example in processor's memory cache, SRAM is preferred technology.

Differences between DRAM and SRAM

DRAM	SRAM
Consists of number of **transistors** and **capacitors**	Uses **flip-flops** to hold each bit of memory
Needs to be constantly refreshed .	Does not need to be constantly refreshed
DRAM have less complex circuitry, use single transistor and capacitor to store a bit.	SRAM uses more than one transistor to form a memory cell and therefore has more complex circuitry.
Consumes more power than SRAM under reasonable levels of access, as it needs to be constantly refreshed.	If accessed at **high frequency** then power use can exceed than DRAM, otherwise it consume less power.
Less expensive to manufacture than SRAM	Has a faster data access time than DRAM
Has higher memory capacity than SRAM	Processor memory (cache) makes use of SRAM.
Main memory is constructed from DRAM	

Read only Memory ROM:

ROMs are

- 🞂 **Non-volatile** (contents are not lost after powering off computer)
- 🞂 **Permanent memory** devices (the contents cannot be changed)
- 🞂 Often used to **store data** which computer needs to access when powering up for first time for example, basic input/output system (**BIOS**). ROM is used to store **bootstrap** program. This is a program that runs immediately when a system is switched on.

Types of ROM:

1. Simplest type of **ROM**: Programs or data are installed as part of **manufacturing process**. If different contents are needed, chip must be **replaced**.

2. **Programmable ROM** (PROM) is type of ROM chip that can be altered **once**. Manufacturer of chip supplies chips to a **system builder**. System builder installs program or data into chips. PROM is made up of **matrix of fuses**. Programming a PROM requires use of a **PROM writer** which uses an electric **current** to alter specific cells by **'burning'** fuses in the matrix.

   PROM are used in **mobile phones** and in **RFID** tags.

3. **Erasable PROM (EPROM)** use floating gate **transistors** and **capacitors** rather than fuses. It can be re-written using ultra violet light multiple times. EPROM needs to be removed from device to erased /written again. EPROM must be entirely erased before rewriting.

   EPROM are used in **applications** which are **under development**, such as programming of new games consoles.

4. **Electrically Erasable PROM (EEPROM)**. It can be re-written and erased using electricity voltage. This has major **advantage** that chip can remain in circuit while contents are changed. However, chip is still used as **read-only**.

Differences between RAM and ROM	
RAM	**ROM**
Temporary memory device	Permanent memory device
Volatile memory	Non-volatile memory device
RAM allows you to both read and write data.	You cannot write to ROM, you can only read from it.
Used to store data, files, programs, part of OS currently in use.	Used to store BIOS and other data needed at start up.
Can be increased in size to improve operational speed of a computer.	

Secondary Storage Devices

✓ Secondary storage includes storage devices that are not **directly** accessible by CPU.

✓ They are **non-volatile** devices which allow data to be stored as long as required by user.

✓ Without secondary storage all programs and data would be lost the moment the computer is switched off.

✓ Secondary storage is **much larger** than primary memory, but **data access time** is considerably **slower** than RAM and ROM.

✓ All applications, operating system, device drivers and general files (documents, photos and music) are stored on **secondary storage**.

✓ Secondary storage devices has **three** categories:
   ➢ **Magnetic Storage** : Internal Hard Disk or External / Removable Hard Disks
   ➢ **Solid state:** SSD , USB
   ➢ **Optical Storage:** CD , DVD , DVD RAM , Blu-ray discs

Magnetic Media Storage

⊞ Hard disk drives (HDD):

Data is stored in **digital format** on **magnetic** surfaces of **disks (platters)**. Hard disk drive will have number of **platters.** Each **platter** will have **two** surfaces which can be used to store the data. **Platters** spin in unison (all together and at same speed). A number of **read-write heads** can access all of surfaces in disk drive. Read–write heads are attached to **actuator arms** which allow heads to move over surfaces of platters. Motion of each read–write head is synchronized with motion of other heads. A **cushion of air** ensures that a head does not touch a platter surface.

Data is stored on surface in **sectors** and **tracks**. A **sector** on a given track will contain a **fixed number of bytes**.

Hard disk drives have very **slow data access** when compared to RAM.

Effect of Latency:

Latency is defined as time taken by a block in a sector to rotate around to read-write head.

Many applications require **read-write heads** to constantly seek for correct blocks of data; this means a large number of head movements. Effects of latency then become very significant.

Users will notice **effect of latency** when they see messages such as, 'Please wait' or, at its worst, 'not responding'.

Hard Disk Fragmentation:

When data is stored on HDD. Required number of sectors needed to store that data will be allocated. However, sectors allocated may not be adjacent to each other. Through time, HDD will undergo numerous deletions and editing, which leads to sectors becoming increasingly **fragmented**, resulting in a gradual decline of HDD performance (it takes longer and longer to access data). **Defragmentation** software can improve on this situation by '**tidying up'** disk sectors.

> HDD is a **direct access device**; however, data in a given sector will be read sequentially.

(a) A hard disc drive   (b) A single disk
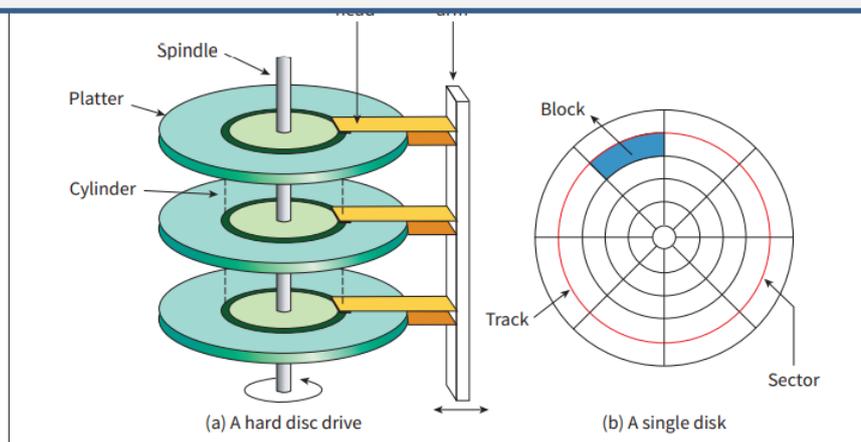
How Data is Stored in HDD?

Data is stored on each **platter**. Bits of data are arranged in **concentric**, **circular paths** called **tracks**. Each track is broken up into smaller areas called **sectors**. Hard drive stores **map** of **sectors** that have already been used up and others that are still free. When computer wants to store new information, it takes a look at the map to find some free sectors. Then it instructs **read-write head** to move across **platter** to exactly **right** location and store data there. To **read** information, same process runs in reverse.

Removable hard disk drives are **external** to computer and can be connected to computer using **USB** ports. They can be used as **back-up** devices or as another way of **transferring files** between computers.

Solid State drives SSD have **no moving parts** and all data is retrieved at **same rate**. They do not rely on **magnetic** properties. Data is stored as 0s and 1s in millions of tiny transistors within chip. SSD is **non-volatile rewritable** memory

Types of Solid State devices:

❖ **NAND base Solid State memory chips:**

This type of Solid State drives Store data by controlling movement of electrons within **NAND chips**. Millions of **transistors** are used **floating gate** and **control gate. NAND base memory chips** Read or erase **blocks of data** which means access is to a block not to individual bits.

NAND chips are used due to its **low cost**. **NAND base memory chips** is used in SSD, flash memory / pin drives, memory cards.

❖ **NOR base Solid State Memory Chips:**

It is **more expensive** and slower to read / write data but its life is more and data is accessible at **bit level**. Data can be read or erased in a **single byte** at a time. Data is accessible at bit / **byte level** so it is more useful in designing processors memory. It use electronically erasable PROM **(EEPROM)** technology. It is used in computer ROM.

Benefits of using SSD rather than HDD:

Solid state drives

- are more reliable as there is no moving parts.
- are considerably lighter (which makes them suitable for laptops)
- have a lower power consumption
- run much cooler than HDDs
- are very thin (because they have no moving parts)
- access data considerably faster

Drawback of SSD:

Main drawback of SSD is **longevity** of technology. Most solid state storage devices are conservatively rated at only **20 GB** write operations **per day** over a three-year period – this is known as **SSD endurance**. For this reason, SSD technology is not used in **servers** where huge number of **write operations** take place every day.

ESQ: How Data is Stored in Solid state (flash) memory ?

• All the data is recorded in a transistor called **Floating Gate**. • Solid state devices use NAND or NOR based flash memory which retains data without power. • NAND based memory reads **faster** than it writes • Data is stored in cells protected by **floating gates** and **Cells** are connected in series. • Other transistor used in SSD named **control Gate** controls **charges flow** from **Source** (input of current) to **Drain** (output of current).

Optical Media CDs and DVDS are **optical storage** devices.

Red Laser light is used to **read** data from, and **write** data onto, surface of a disk. Both CDs and DVDs use a **thin layer** of **metal alloy** or light-sensitive organic dye to store data. Both CD/DVD use a **single**, **spiral** track which runs from **centre of disk** to edge. When a disk spins, **optical head** moves to point where **laser beam** 'contacts' the disk surface and follows the **spiral track** from the **centre** outwards.

CD/DVD is divided into **sectors** allowing **direct access** of data. Data is stored in '**pits'** and '**Land**' on spiral track.

When laser shines on **disc surface**, **lands** (bumps) reflect light back, whereas **pits** scatter laser beam. A **sensor** looks for reflected light. Reflected light - **land** - represents a binary '1', and no reflection - **pits** - represents a binary '0'

DVD technology is different to that used in **CDs**. One of main differences is use of **dual layering** which considerably **increases storage** capacity. This means that there are two individual recording layers. **Two layers** of DVD are joined together with a transparent **polycarbonate spacer**, and a very **thin reflector** is sandwiched between two layers. Reading and writing of **second layer** is done by a **red laser**.

Single layer DVDs still have a **larger storage** capacity than CDs because **'pit' size** and **track width** are both smaller. This means that more data can be stored on DVD surface. DVDs use lasers with a wavelength of 650 nanometres; CDs use lasers with a wavelength of 780 nanometres. **Shorter** the wavelength of laser light, **Greater** the storage capacity of the medium.

Blu-ray Discs Blu-ray discs are example of **optical storage media**.

- Blu-ray uses a **blue laser**, rather than a **red laser**, to carry out read and write operations; wavelength of blue light is only 405 nanometres.
- Using blue laser light means that the **'pits'** and **'lands'** can be much smaller; consequently, a Blu-ray can store up to **five** times more data than a DVD.
- Blu-ray discs automatically come with a **secure encryption** system which helps to prevent **piracy** and **copyright** infringement.

> Optical storage media are used as **back-up** systems (for photos, music and multimedia files). This also means that CDs and DVDs can be used to **transfer files** between computers. **Manufacturers** supply their **software** (such as printer drivers) on CDs and DVDs.

Embedded Systems

Embedded systems involve installing **microprocessors** into devices to enable operations to be controlled in a more **efficient** way. Devices such as cookers, refrigerators and central heating systems can all be **activated** by a web-enabled device (such as a mobile phone). Time a central heating system switches on or off and temperature can all be set from an app on a mobile phone from anywhere.

Features of embedded systems: 9618 P12 OCT 23

- Dedicated to a single task // limited number of functions
- Built into a larger system // integrated into a larger system
- Embedded system must contain a processor, memory and an I/O capability.

Pros Of Embedded Systems	Cons Of Embedded Systems
Small in **size** and therefore easy to fit into devices	Difficult to **upgrade devices** to take advantage of new technology
Relatively **low cost** to make	Troubleshooting **faults** in the device becomes a specialist task
Usually dedicated to **one task** and no requirement of an **operating system**	Any device that can be accessed over internet is also open to hackers, viruses, and so on
Consume very **little** power	Due to difficulty in **upgrading** and **fault** finding, devices are often just thrown away rather than being repaired.

ESQ: Many modern televisions are examples of embedded systems.

(a) Explain why these televisions are embedded systems.

Ans: Embedded system is integrated into the TV • combination of hardware and software designed for a specific function • The system is not easily changed/updated by the TV owner.

(b) Embedded systems use Electrically Erasable Programmable ROM (EEPROM).

Describe one benefit of using EEPROMs in an embedded system.

Ans: No additional equipment is needed to change and enables firmware updates by non-technical users.

Can be erased and reprogrammed several times so firmware can be updated and can erase a particular byte or the whole EEPROM. Possible to reprogram / update without removing it from the device.

Buffers

It is a **temporary storage** created for **data transmitted** from one part of system to another which functions as a **queue**.

Whenever data has to be transferred from one part of a computer system to another, problem occurs if data can be sent **more quickly** than it can be received.

 Solution to the problem is to use a **buffer**. Data enters a buffer before being transmitted to its destination. Buffer functions as a **queue** so data emerges in order that it has entered buffer. Typically, buffer is created in computer memory.

Trends in factors affecting the choice of memory components

Component	Category	Access time	Capacity	Size	Cost
Register	Processor component				
Cache memory	Primary storage				
Main memory					
Hard disk	Secondary storage				
Auxiliary storage					

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