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Chapter 3

Hardware

3.1 What is computer hardware?

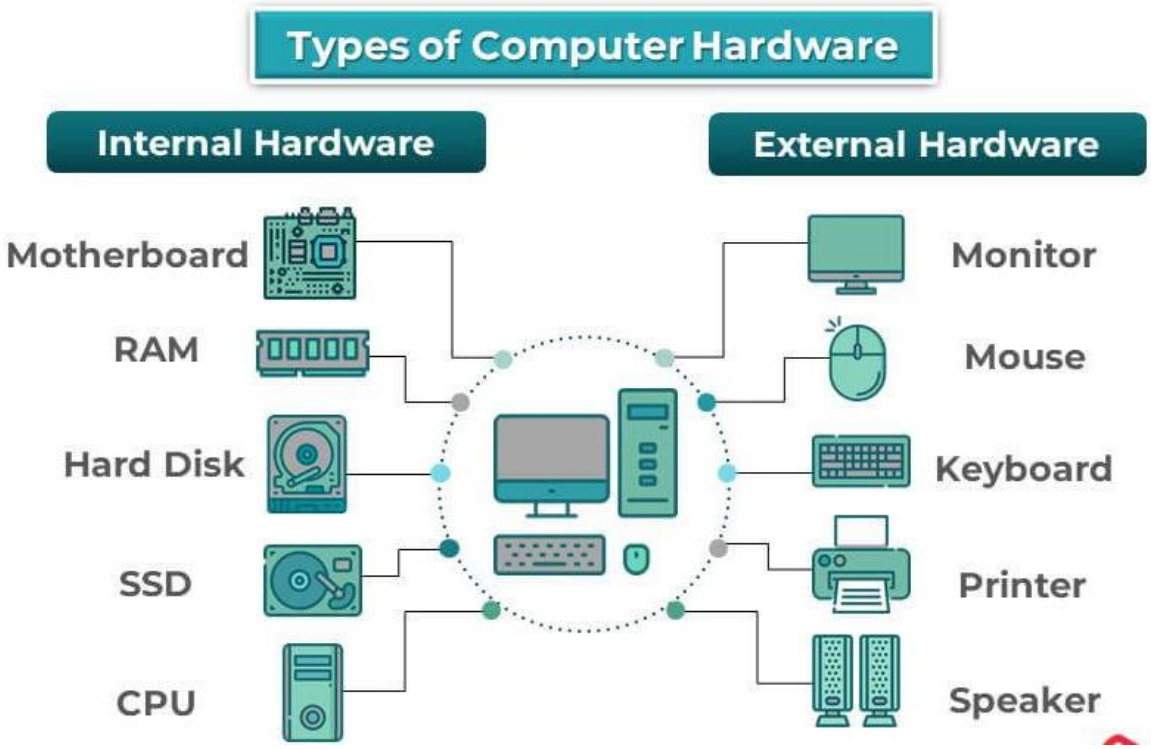
Computer hardware comprises the physical parts of a computer, such as the central processing unit (CPU), random access memory (RAM), motherboard, computer data storage, graphics card, sound card, and computer case.

It includes external devices such as a monitor, mouse, keyboard, and speakers.

3.2 Types of computer hardware

Internal hardware: An internal hardware component is any physical part that resides inside a computer and contributes to its core functionality.

External hardware: External hardware components, are those items that are often externally connected to the computer to control either input or output functions.



3.3 Computer Architecture

3.3.1 The Central Processing Unit (CPU)

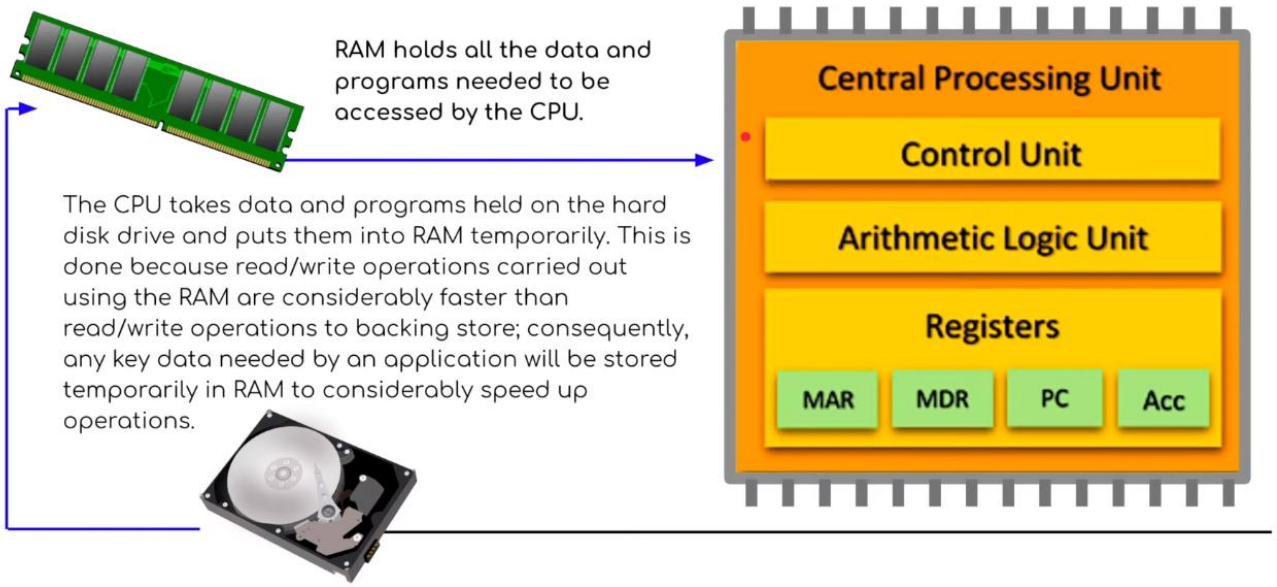
The **central processing unit (CPU)** (also known as a microprocessor or processor) has the responsibility for the execution or processing of all the **instructions** and **data** in a computer application.

A **microprocessor** is a type of **integrated circuit** on a single **chip.**

Purpose of the CPU

- The purpose of the Central Processing Unit (CPU) is to **fetch**, **decode** and **execute** instructions
- The CPU is the brain of the computer and its job is to take an input, process data and produce an output

Components of the CPU



- **Arithmetic & Logic Unit (ALU)**
  - Performs arithmetic operations

    Eg: Add, Multiply
  - Performs logical decisions

    Eg: IF X > 5 THEN

    DO ……
  - It is possible for a computer to have more than one ALU to carry out specific functions.

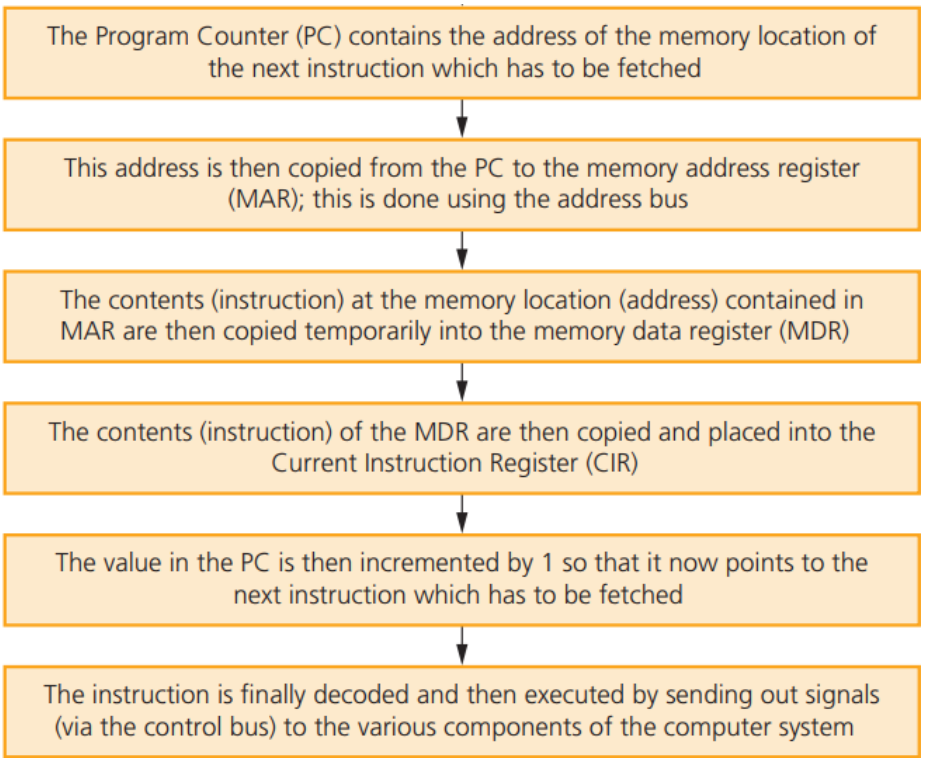
- **Control Unit (CU)**
  - **Coordinates how data moves around the CPU** by sending a signal to control the movement of the data
  - **Decodes the instructions** fetched from memory

- **Registers**
  - **Program Counter (PC)**
    - **Holds the memory address** of the **next instructions** to be executed
    - **Increments by 1** as the fetch-decode-execute cycle runs
  - **Memory Address Register (MAR)**
    - Holds the memory address of where data or instructions are to be fetched from memory
  - **Memory Data Register (MDR)**
    - **Stores the data or instruction** which has been fetched from memory
  - **Current Instruction Register (CIR)**
    - **Stores the instruction** the CPU is currently decoding or executing
  - **Accumulator (ACC)**
    - **Stores the results** of any calculations that have taken place in the Arithmetic Logic Unit (ALU)
- **Buses**
  - **Address Bus**
    - **Unidirectional**, transmits addresses from the **CPU** to **memory**
  - **Data Bus**
    - **Bidirectional**, transmits data from the **CPU** to **memory** or **input/output devices**
  - **Control Bus**
    - **Bidirectional**, transmits control signals from the **CU** to **memory** or **input/output devices**

3.3.2 Fetch-Decode-Execute Cycle (FDE)

- The **Fetch-Decode-Execute Cycle** is the cycle that the central processing unit (CPU) runs through billions of times per second to make a computer work

Fetch Stage	1. The **PC** holds the **address** of the next **instruction** to be fetched 2. The **address** held in PC is sent to **MAR** using the **address bus** 3. The **instruction** at the address stored in **MAR** is sent to the **MDR** 4. The **instruction** is copied to **CIR** 5. The **PC** is incremented
Decode Stage	6. The instruction in the CIR is decoded by the **CU** This is done as the instruction is split into two parts: • **Opcode** - what the instruction is • **Operand** - what to do it to • This could be either data or an address where the data is stored
Execute Stage	7. The instruction is executed by the **ALU** 8. The result is stored in the **ACC** or written to a memory location within memory



3.3.3 Factors that determine the performance of a CPU

➢ **Clock Speed**

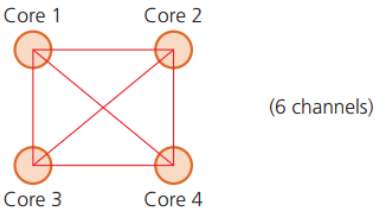
- The clock speed is **measured in Hertz (Hz)**
- Produces **timing signals** to synchronise computer operations
- The **faster** the clock speed, the better the **performance**, as more instructions can be executed per second
  - ***Overclocking*** *may lead to operations to be* ***unsynchronised*** *& CPU to* ***overheat***

➢ **Cache Size**

- A **temporary memory location** to hold **frequently used data/instructions**
- The **larger the cache**, the better the performance, as **more data can be stored & accessed faster**
- Cache also has a significantly faster read/write speed than RAM, making it much quicker to retrieve instructions from there instead of from memory (RAM)

➢ **Number of Cores**

- Each core is made up of an ALU, a control unit and the registers.
- Each core runs separate **FDE cycles** independent of each other simultaneously
- The more cores a CPU has (dual/quad), the better the performance, as more instructions can be executed per second
  - *Doubling the cores does not double the performance all the time, as the CPU needs to communicate with each core, this will consume more times.*



3.3.4 Instruction Set

- An **instruction set** is a **list of all commands** that can be processed by a CPU and are **machine code**
- An instruction is decoded into an **opcode & operand**
- The CPU finds the **opcode** in the processor's **instruction set** and knows what **operation to perform** on the **operand**

3.3.5 Embedded System

- An **embedded system** is a computer system (a combination of hardware & software) used to perform a **dedicated function**
- Characteristics
  - **Low power** consumption
  - **Small** physical size
  - **Low cost** to manufacture
  - Can be **controlled remotely**
  - Dedicated to a single task which allows for a **simple interface and OS**
- Devices e.g. security systems (use sensors to check for intruders and send a warning signal if an intruder is detected), lighting systems (automatic control of lighting using light sensors), vending machines (use a keypad, sensors, and actuators to automatically supply customers with an item)
  - Different to general purpose computers e.g. a personal computer (PC), laptop

Advantages and disadvantages of embedded system

Advantages	Disadvantages
Fast and efficient because designed for specific task	Only designed to do one or few specific task
Low power consumption	Difficult to upgrade
Small and lightweight, making them easy to fit into devices	Hard to troubleshoot due to lack of user interfaces
Can be controlled remotely using a mobile phone	Lack string protection, making them open to hacking

3.4 Input and Output devices

Input Devices

An **input device** is a piece of hardware used to **enter data or control signals** into a **computer system**.

Input Devices	Uses	Benefits	Drawbacks
Barcode Scanner	- Checkout - Parcel delivery	- Faster checkouts - Automated stock control (stock is up to date, staff can reorder when stock is low) - Less chance of error due to no manual entry - No need to price each item individually	- If the barcode scratched, the scanner may fail to read it. - Installation cost is high - No security as barcode can easily copied
QR Code Scanner	- Advertising products - Linking to websites - E-tickets - Show contact information	- Holds more information than a barcode - Can be scanned using a camera on a mobile device - Easy to transmit using images	- QR codes may be used to transmit malicious codes - If the URL changes or is deleted, the QR code becomes useless. Need to print again.
2D Scanners	- Scan documents, photos and objects	- Simple and easy to use - Low cost - Fast for flat documents	- Cannot capture depth or physical dimensions - Limited to flat surfaces only
3D Scanners	- Medical imaging - Gaming and animation - Product design	- Captures depth and full 3D shape of objects - High accuracy - Automatically creates the 3D models	- High cost - Complex to use - Slower process
Digital Camera	- Smartphones (read QR code, video call) - Security systems	- Instant preview image - No film need - Reusable storage	- Battery dependent - High initial cost - Can be complex for beginners
Keyboard	- Entering text e.g. smartphones, laptops	- Universal, easy to use - Fast text input - Common and familiar	- Not suitable for all inputs - Takes up desk space - Prone to dirt and damage
Mouse	- Navigating a GUI & making selections	- User friendly - Supports multiple functions - Simple to move pointer	- Requires flat surface - Not suitable for text entry - Need maintenance
Microphone	- Record real-world sound - Record music - Telephone calls - Voice dictation	- Enables voice input - Supports hands-free use	- Picks up background noise - Not suitable for all environments
Capacitive Touch Screen	- Entering text & commands on mobile devices - Cash machines - Interactive advertisements - Information screens	(**e.g. commercial displays**) - Good image quality - Durable glass surface - allows multi-touch	- Only allow use of bare finger / stylus - sensitive to water & light - More expensive than resistive screens

Infrared Touch Screen	- Entering text & commands on mobile devices - Cash machines - Interactive advertisements - Information screens	(**e.g. tablets**) - Good image quality - Durable and long lasting - Allows multi-touch	- Only allow use of bare finger / stylus - sensitive to water & light - Typically more expensive
Resistive Touch Screen	- Entering text & commands on mobile devices - Cash machines - Interactive advertisements - Information screens	(**e.g. cash machines**) - Good resistance to dust/water - Can be used with fingers/gloves/stylus - cheap	- Low touch sensitivity - no multi-touch - poor visibility in sunlight

Output Devices

An **output device** shows the **results of the processing** in a way humans can understand

Input Device	Uses	Benefits	Drawbacks
Actuator	- Translate energy into real-world movement of a physical object	- Enable automatic control of systems - Reduced Human Effort	- High cost - Malfunction Risk
DLP Projector (digital light processing)	- Project computer outputs onto a **large screen** - Give **presentations** in business & education settings	- Higher **contrast ratios** - Longer **life span → reliable** - Smaller and lighter → **portable**	- Lower **colour contrast** - Lower **resolution** - Image has **shadows** if it is moving
LCD Projector (liquid crystal display)		- Higher **colour contrast** - Higher **resolution** - **Low power** consumption	- Lower **contrast ratios** - Shorter **life span** → less **reliable** - Less **portable**
Inkjet Printer *(thermal bubble & piezoelectric technology)*	- Printing **one-off** photos - Useful for **high volume** printing (flyers/magazines)	- Produce **high quality** images - No need to **warm up** - Small **footprint (**less physical space**)**	- Small **ink cartridges & paper trays** - Ink **smudges** (liquid ink) - Print head **not durable**
Laser Printer *(charged drum & powdered toner)*		- **Fast** at printing **high volume** - Low **cost** per page - Large **toner cartridges & paper trays**	- **Expensive** toner cartridges - More time to **warm up** - Larger **footprint**
3D Printer	- Produce **solid 3D objects**	- Create **prototype**/**model** (e.g. prosthetics - Models can be **transmitted digitally**	- Installation cost is high - Slow production speed - Requires technical skills

LCD Screen (liquid crystal display)	Used in TVs, monitors, tablets and phones	- **Low power** consumption - Runs at a **cool temperature** - **Bright** image/colours - No **image burn** - High **resolution** - **Cheaper** than LED screen	- Limited viewing angles - Lower contrast - Slower response time
LED Screen (light emitting diode)		- **Low power** consumption - High **resolution** - Longer **life span** - **Thinner** display	- Higher cost - Heat generation in large displays
Speaker	Output **sound waves** which can be heard by humans	- Audio output - Wide usage	- Noise disturbance - Power consumption

3.4.1 Sensors

Sensors are **input devices** that measure a physical property of their environment & are used for **monitoring & control systems.**

Sensor	Type of Data Captured	Uses
Acoustic/ Sound	Sound levels	• Burglar alarm / security systems • Monitor noise pollution • Leak detection system
Accelerometer	Acceleration rate, tilt, vibration	• Detect sudden changes in vehicle movement (deploy safety features if needed) • Detect orientation of device in mobile phones
Flow	Rate of gas, liquid, or powder flow	• Detect changes in the flow through pipes in water system • Used in respiratory devices and inhalers in hospitals
Gas	Presence of a gas e.g. oxygen, carbon dioxide	• Gas levels in confined spaces • Pollution levels • Oxygen and carbon dioxide levels in greenhouse environment
Infra-red	Detecting motion (using beam) or a heat source	• Burglar alarm / security systems (intruder breaks beam) • Automatic doors (person entering breaks beam)
Level	Liquid levels	• Levels of petrol in a car tank • Levels of water in a water tank
Light	Light levels	• Street lights (switch on/off lights)
Magnetic field	Presence Strength	• In anti-lock braking systems (checks rotation speed of wheels for braking) • Mobile phones
Moisture	Presence Levels of moisture	• Moisture in soil of greenhouse environment
Humidity	Levels of water vapour	• Greenhouse environment

pH	Acidity / alkaline	• pH of soil in greenhouse environment • Chemical processes
Pressure	Gas / liquid / physical pressure	• Burglar alarm / security systems (detects weight of intruder) • Chemical processes
Proximity	Distance	• Monitor position of objects in robotics • Prevents objects colliding in safety systems
Temperature	Temperature	• Central heating / air con system • Chemical processes • Greenhouse environment

Points need to be included in your answers for Monitoring and Controlling.

1. Sensor *(name of the sensor)* continuously takes signal/data and sends to microprocessor
2. Analogue signal is converted into digital signal using ADC (Analogue to digital Convertor)
3. Microprocessor compares sensor data with already stored data in the computer
4. If sensor data is greater than stored data, microprocessor sends signal to actuator to close the door or set off the alarm *(this point need to change according to the question).*
5. If the data is within the range, there is no change *(opposite of 4th point).*
6. Monitoring Continues until the system is switched off.

3.5 Data Storage

Memory and storage devices can be split up into two distinct groups:

» primary storage

» secondary storage.

Primary Storage

- Primary storage is directly accessed by the CPU
- Primary memory allows the CPU to access applications and services temporarily stored in memory locations.
- Volatile memory (with exception of ROM)
- Small capacity
- It includes **RAM** & **ROM**

Why do you need primary storage?

- A computer needs primary storage because **access times** are considerably **faster than secondary.**
- This means the **time taken** to complete operations such as the **Fetch-Execute Cycle** is **dramatically reduced**.
- Primary storage holds the **data** and **instructions** that the CPU needs to access whilst the computer is turned on.
- Keeps the operating system, running applications, and current files active for quick use.

Random Access Memory (RAM)

» Used to store **the data and instructions that are currently in use**

» It is **volatile**, which means memory contents are lost when powering off the computer.

» Can be read from and written to

» RAM is very fast working memory, much faster than secondary storage.

» Smaller capacity

There are currently two types of RAM technology:

» Dynamic RAM (DRAM)

» Static RAM (SRAM).

Dynamic RAM (DRAM)

» It has capacitors – store the bits of information (0 or 1)

» It has transistors – Acts like a **switch** to control access to the capacitor.

» Needs to be refreshed constantly (every 15 microseconds)

DRAMs have a number of advantages over SRAMs:

» they are much less expensive to manufacture than SRAM

» they consume less power than SRAM

» they have a higher memory capacity than SRAM.

Static RAM (SRAM)

» It makes use of **flip flops circuits** (made of transistors) to store each bit of data.

» Doesn't need to be constantly refreshed.

SRAMs have a number of advantages over DRAMs:

» SRAM is much faster than DRAM

» Used in cache memory. (Cache memory helps the CPU access frequently used data **faster** than accessing main memory (DRAM)).

Read-Only Memory (ROM)

» ROM (Read Only Memory) is **primary storage** that holds the **first instructions** a computer needs to **start up** (Bootstrap)

» ROM contains the **BIOS** (Basic Input Output System)

» ROM is a small **memory chip** located on the computers **motherboard**

» ROM is **fast** memory, much faster than secondary storage but **slower than RAM**

» ROM is **non-volatile** which means the contents of ROM are not lost when the power is turned off

» ROM is **read only** which means data can only be read from

» In comparison to RAM, it has a much **smaller capacity**

Worked Example

Quinn has 512 kilobytes of ROM and 16 gigabytes of RAM in her computer

1. Describe the purpose of the ROM in Quinn's computer [2]
2. Describe the purpose of the RAM in Quinn's computer [2]

Answer

1. ROM

- Store start-up instructions/bootstrap
- Used to start the computer

2. RAM

- Stores the parts of the OS / programs that are running
- Stores data currently in use
- ...for access by the CPU

Guidance

- Do not confuse the purpose with characteristics, describe **what it does**, not **what it is**

Secondary and off-line storage

➔ Known as off-line storage as well

➔ Not directly accessed by the CPU

➔ Non-volatile

➔ Stores more data than primary memory, but the data access time is longer than that for primary memory

➔ Three types of secondary storage technologies: **magnetic, solid state, optical**

Why do you need secondary storage?

» **Stores data long-term** when not in use.

» **ROM is read-only** and **RAM is volatile** (loses data when power is off).

» **Secondary storage is non-volatile** and keeps data when the computer is turned off.

» **Slower but higher capacity** than primary storage, ideal for **backups and archives**.

Worked Example

A games console has secondary storage.

State, using an example, why the games console needs secondary storage [2]

How to answer this question

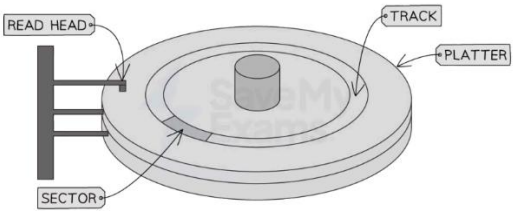
- They keyword is '**why**', why does a games console need secondary storage? give an example, do not just describe what secondary storage is!

Answer

- To store data once the power is turned oy / permanently // for non-volatile storage
- Examples could include:
  - Storing games
  - Save games
  - User data/profiles
  - Downloaded content/applications/updates

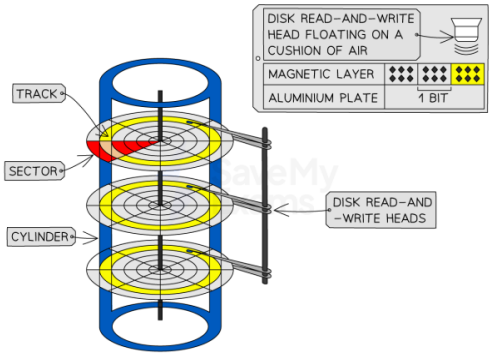
Magnetic Storage

- Magnetic storage is a type of non-volatile media that uses magnets (polarity) to store binary 0s and 1s
- Example: **Hard Disk Drives (HDD)**



How does a magnetic storage / HDD store data?

- Stores data using electromagnets and magnetic fields.
- It have platters that are divided into tracks and sectors to organize data.
- A read/write head moves across the platters to access data.
- Magnetic fields control tiny magnetic dots representing data.
- The direction of the magnetic field represents binary values (0 or 1).



Advantages and disadvantages of magnetic storage / HDD

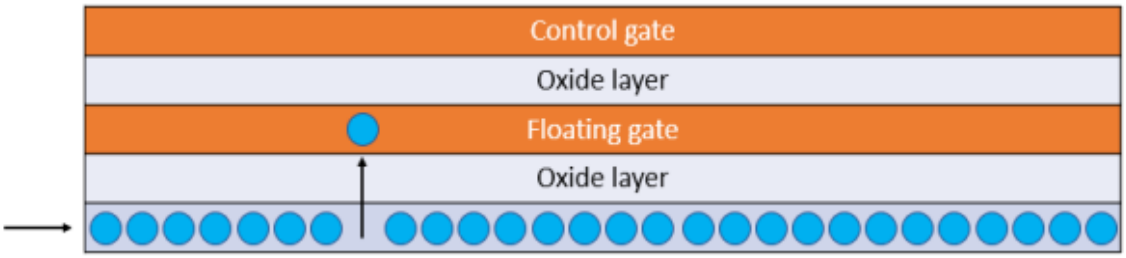
Advantages	Disadvantages
Large capacity storage	Slower data access compared to solid-state drives (SSD).
Lower cost	Moving parts make it fragile and more prone to physical damage.
Reliable for long-term storage of large amounts of data	Consumes more power than solid-state storage.
Can be rewritten many times	Noisy operation due to moving mechanical parts.

Solid State Storage

- Solid-state (flash memory) storage is a type of non-volatile media that uses electronic circuits to store binary 0s and 1s
- Examples of solid-state storage devices include:
  - **Solid state drives (SSD**) - replacing magnetic hard drives as a computers primary secondary storage device as capacity increases and cost decreases
  - **USB flash memory** - most common form of portable storage device

How does Solid-state storages / SSDs store data?

- ↳ Data is flashed onto silicon chips
- ↳ Use transistors as floating and control gates
- ↳ Use NAND/NOR gates
- ↳ Store data by controlling the flow of electrons
- ↳ The electric current reaches the control gate and flows through the floating gate to be stored
- ↳ When data is stored, the transistor is converted from 1 to 0



Advantages and disadvantages of solid-state storage / SSD

Advantages	Disadvantages
Higher storage compared to optical storages	More expensive per GB compared to HDD
Very fast read/write access	Limited read/write cycles
No moving parts which makes silent operations	Limited lifespan due to limited number of read/write cycles.
Use less power	Lower storage than HDD
Smaller and lighter than HDD	

Optical Storage/Media

- Optical storage is a type of non-volatile media that uses lasers to burn the surface of a disk, creating pits and lands suitable for storing binary 0s and 1s
- Examples of optical storage include:
  - CD
  - DVD
  - Blu-Ray

1. CD/DVD disks

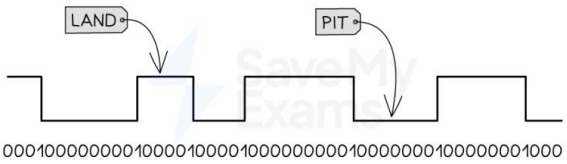
➔ CDs and DVDs are optical storage devices that use laser light to read and write data from their surfaces

➔ Data is stored in pits and lands on the spiral track, and a red laser is used to read and write data

➔ DVDs have a larger storage capacity than CDs, due to smaller pit size and track width, and can be dual-layered

How is data stored in a CD/DVD?

- Both use a red laser to write and read data
- A laser is shone on the disc
- A read/write head moves the laser across the disc
- The laser burns pits onto the surface to write data
- The laser is also used to read pits and lands
- The reflected light is captured by sensors and converted into digital



2. Blu-Ray discs

➔ Blu-ray discs use a blue laser for read-write operations, compared to CDs/DVDs, that use a red laser

➔ Blu-ray can store more data than a normal DVD

➔ A single Blu-ray can hold up to 25GB of data and dual-layer Blu-ray can store up to 50GB of data

➔ Blu-ray discs come with a secure encryption system to prevent privacy and copyright infringement

How is data stored in a Blu-ray?

- Use a blue laser to write and read data
- A laser is shone on the disc
- A read/write head moves the laser across the disc
- The laser burns smaller pits onto the surface to write data
- The laser is also used to read pits and lands
- The reflected light is captured by sensors and converted into digital

The main differences between Blu-ray and DVD

➔ A blue laser is used in Blu-ray but DVD uses a red laser to read and write operations

➔ Blu-ray can store more data than DVD

➔ The data transfer rate for a Blu-ray disc is 36 Mbps, compared to 10 Mbps for a DVD, allowing for faster transfer of data

➔ Blu-ray discs can come in single or dual-layer format, while DVDs are always dual-layer

➔ Blu-ray offer more quality than DVD

Advantages and disadvantages of optical storage:

Advantages	Disadvantages
Low cost per gigabyte	Limited storage capacity
Its durability as no moving parts	Very slow read/write access
Light weight and easy to carry	Easily scratched or damaged
Can store data for years without power	Requires an optical drive

Worked Example

Zarmeen has purchased a new tablet computer. The tablet has an internal secondary storage device.

The storage device is a solid state device.

1. Give three benefits of the tablet having a solid state device instead of a magnetic device [3]
2. Give two drawbacks of the tablet having a solid state device instead of a magnetic device [2]

Answers

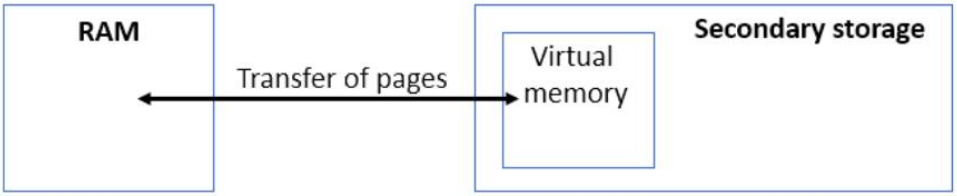
- Benefits
  - Faster access / read/write speeds
  - Smaller in physical size
  - More durable due to no moving parts
  - Portability - Small and no moving parts

- Drawbacks
  - More expensive (per gigabyte)
  - Smaller capacity (usually)
  - Limited number of read/write cycles

Guidance

- Portable is not enough on its own
- No moving parts is not enough on its own

3.5.1 Virtual Memory



- Virtual memory is an **extension of primary storage** (RAM) located on **secondary storage**
- In situations where RAM is close to being **full**, virtual memory can be used so that the computer **remains operational**
- Virtual memory is much **slower** than RAM and its use will impact negatively on system performance
- To avoid the use of virtual memory, **increase** the size of the **RAM**

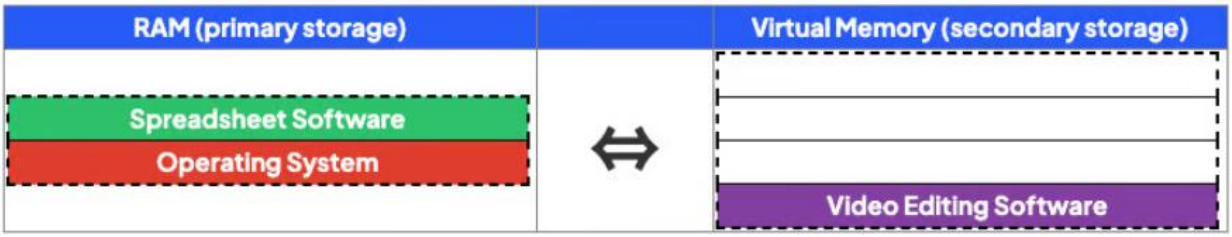
Purpose of Virtual Memory

- Prevents the computer system crashing when RAM is full
- To extends RAM capacity
- Allows CPU to process large amounts of data

How Virtual Memory works

- The **hard drive** is **given a allocated space** to create **virtual memory** (swap space)
- When RAM is full, programs and data **not currently** being **required** are transferred to virtual memory
- Programs are stored as **pages of data**
- Pages of data that needs to be **accessed** can be **transferred into** RAM
- When the **data is required again**, the pages can be transferred back to RAM Programs are stored as **pages of data**

Example



Worked Example

A computer only has 4GB of RAM, Fynn says that virtual memory can be used instead of adding more RAM.

1. Explain how virtual memory can compensate for the lack of RAM in Fynn's computer **[3]**
2. Explain why it would be beneficial for Fynn to get more RAM instead of relying on virtual memory **[2]**

How to answer these questions

1. What is the definition of virtual memory? How does it work?
2. What is the downside of using virtual memory? Turn this into an advantage of adding more RAM

Answers

- How can Virtual Memory compensate
  - Virtual Memory is used when RAM is full
  - ...part of the secondary storage used as (temporary) RAM
  - Data from RAM is moved to the secondary storage/Virtual Memory (to make space in RAM)
  - RAM can then be filled with new data
  - When data in Virtual Memory is needed it is moved back to RAM

- Benefit of more RAM
  - More RAM will improve the performance of the computer // More RAM will speed up the access to data
  - Virtual Memory is slower to access than RAM direct (because it has to go back to RAM first)
  - Moving data between RAM and VM takes processor time

3.5.2 Cloud Storage

- A collection of **physical servers** that allows data to be **access remotely** using an **internet connection**
- Data is stored on **remote servers**, typically using magnetic storage (**HDD**), but increasingly using solid state (**SSD**)

There are three common systems:

» Public cloud – this is a storage environment where the customer/client and cloud storage provider are different companies

» Private cloud – this is storage provided by a dedicated environment behind a company firewall; customer/client and cloud storage provider are integrated and operate as a single entity

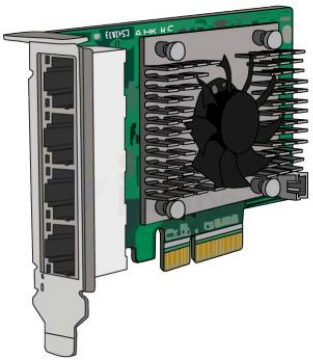
» Hybrid cloud – this is a combination of the two above environments; some data resides in the private cloud and less sensitive/less commercial data can be accessed from a public cloud storage provider.

Advantages and disadvantages of using cloud storage instead of storing data locally

Advantages	Disadvantages
Can be accessed from anywhere in the world using a network, typically the internet	If the user has a slow/unstable internet connection, they may have problems accessing their files
The user will not need to buy off-line storage devices and keep them in safe places	A large storage capacity can be expensive
Allow for almost unlimited data storage	Data being sent over the internet may be intercepted/hacked
The user does not have to worry about damage to storage devices (both internal and off-line)	If the provider goes offline or shuts down, access to data may be lost temporarily or permanently.
Multiple servers are used to backup data, reducing the risk of data loss due to hardware failure	

3.6 Network Hardware

3.6.1 Network interface card (NIC)



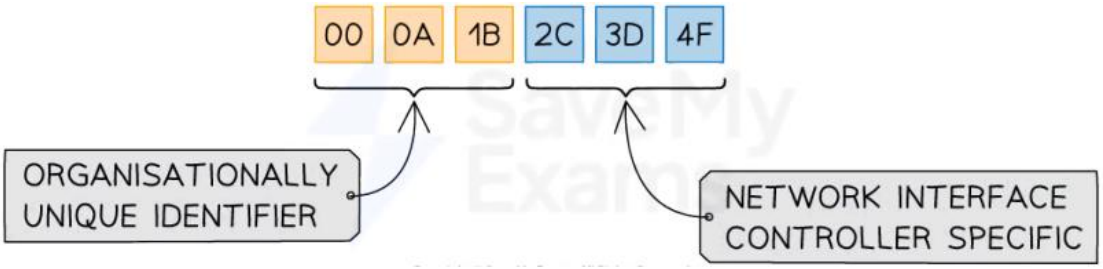
- The Network Interface Card (**NIC**) is required for a computer to connect to a network
- A NIC can be both **wired** and **wireless** and allows your computer to send and receive data over a network

3.6.2 MAC Address and IP Address

- Devices on a network send and receive data, a device needs an address to ensure it sends data to the correct place
- There are two types of network address systems:
  - **MAC Address**
  - **IP Address**

1. MAC Addresses

- A MAC (Media Access Control) address is a **unique identifier** given to devices which communicate over a local area network **(LAN**)
- A network interface card is given a MAC address at the point of manufacture
- MAC addresses are **static**, meaning they can never change
- A device connecting to a local network already has a MAC address, if it moves to a different network then the MAC address will stay the same
- A MAC address is represented **as 6 pairs of hexadecimal digits** (48 bits), separated by colon
- The **first three pairs** are the **manufacturer ID number** and the **last three pairs** are the **serial number** of the network interface card **(NIC)**



Types of MAC addresses

1. **Universally Administered MAC Address (UAA)**

   The UAA is by far the most common type of MAC address and this is the one set by the manufacturer at the factory. It is rare for a user to want to change this MAC address.

2. **Locally Administered MAC Address (LAA)**.

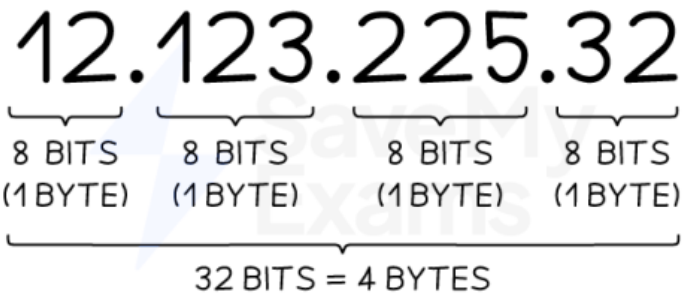
   There are some occasions when a user or organisation wishes to change their MAC address is called LAA.

2. Internet Protocol (IP) Address

- An IP (Internet Protocol) address is a **unique identifier** given to devices which communicate over the Internet (**WAN**)
- IP addresses can be **static**, meaning they stay the same or **dynamic**, meaning they can change
- IP addresses make it possible to **deliver data to the right device**
- A device connecting to a network will be given an IP address, if it moves to a different network then the **IP address will change**

IPv4

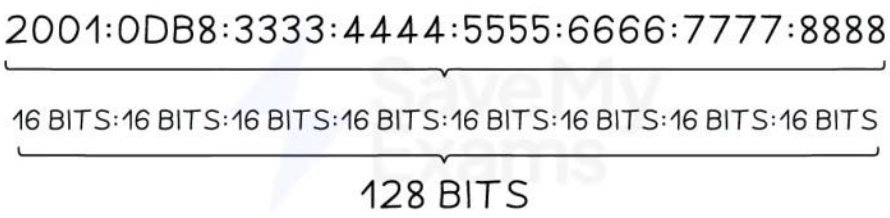
- Internet Protocol version 4 is represented as **4 blocks of denary numbers** between **0** and **255**, separated by **full stops**
- Each block is **eight bits**, each address is **32 bits**



- IPv4 provides over **4 billion unique addresses** (2^{32}), however, with over **7 billion** people and **countless devices per person**, a solution was needed

IPv6

- Internet Protocol version 6 is represented as **8 blocks of 4 hexadecimal digits**, separated by **colons**
- Each block is **16 bits**, each address is **128 bits**
- IPv6 could provide over **one billion unique addresses** for **every person** on the planet (2^{128})



Static IP addresses

- Static IP addresses are permanently assigned to a device by the internet service provider (ISP);
- These IP addresses, as the name dictates, never change
- Suitable for websites, online databases, etc

Dynamic IP addresses

- These addresses change whenever the device logs on to the internet
- A new IP address is assigned to the device by a DHCP (Dynamic Host Configuration Protocol) server each time
- Suitable for users of the internet (dynamic IP addresses help maintain privacy)

Differences		**Similarities**
MAC Address	**IP address**	—
Has 48 bits	Has either 32 or 128 bits	Both use hexadecimal
Has a serial code and a manufacturer code	Does not have a manufacturer or serial code	Both are unique
Rarely changes (can be UAA or LAA)	Can be static or dynamic	Both are used to identify devices on a network

Worked Example

Computers in a network can be identified using both IP addresses and MAC addresses.

Describe two differences between IP addresses and MAC addresses [2]

Answers

- IP address is dynamic/can change // MAC address is static/cannot change
- IP address is used to communicate on a WAN/Internet // MAC address is used to communicate on a LAN

Routers

➔ Routers are devices that are a part of a network and perform many different functions

➔ They assign IP addresses

➔ They send data to a specific destination on a network using the IP address in the data packet

➔ Routers also allow networks to communicate by taking data in one format from a network and converting it to a format understood by another network

➔ They can connect a local network to the internet (a LAN to a WAN)

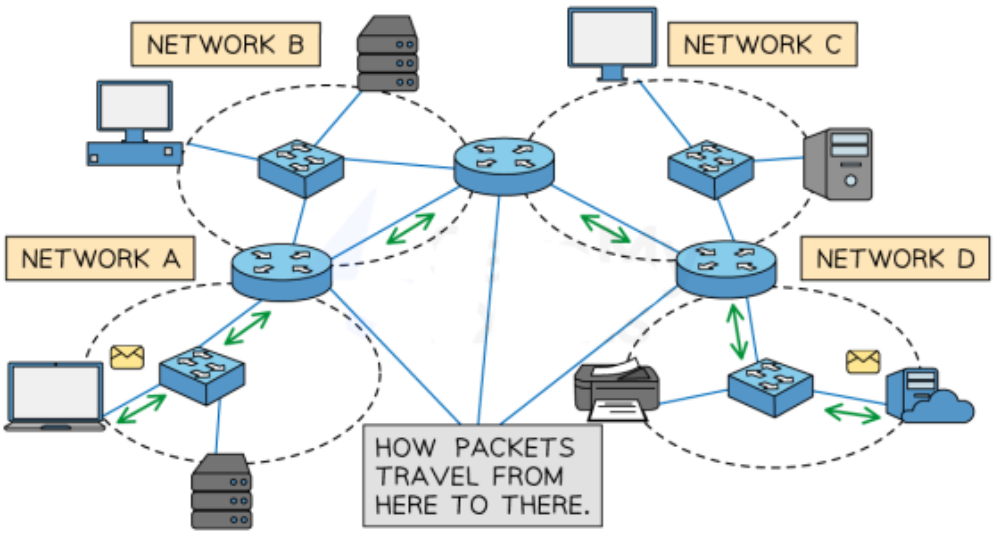


Image of how a router connects LANs to other networks

Worked Example

State 3 tasks carried out by a router [3]

Answers

- Send and Receive packets of data
- Connect a local network to the internet
- Assign IP addresses to nodes/devices
- Converts packets from one protocol to another