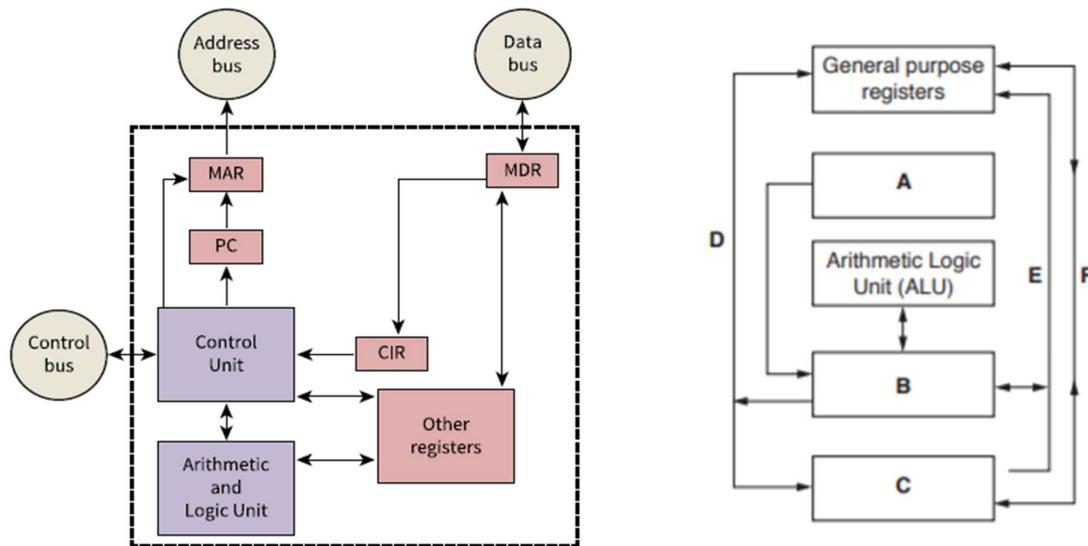## CENTRAL PROCESSING UNIT ARCHITECTURE

Von Neumann Architecture

John von Neumann was the first person to describe the basic principles of a computer system and its architecture in a publication.

- The Von Neumann model consists of:

- Central processing unit (CPU)

- Able to access memory directly

- Memory that can store programs as well as data (registers)

- Stored programs that contain instructions that can be executed in order.

REGISTERS

- Small piece of memory

- Part of the processor

- Temporary storage of data which is about to or has been processed.

Difference between general purpose and special purpose registers

- General purpose registers hold the temporary data while performing different operations.
- Special purpose registers hold the status of a program

SPECIAL PURPOSE REGISTERS

MAR Memory Address Register

Stores the address of a memory location or an I/O component which is about to have a value read from or written to.

MDR Memory Data Register

Stores data that has just been read from memory or is just about to be written to memory

CIR Current Instruction Register

Stores the current instruction while it is being decoded and executed

PC Program Counter

Stores the address of where the next instruction is to be read from

IX Index Register

Stores a value; only used for indexed addressing

ACC: (Accumulator) is the register where the data is worked on (General purpose register)

Status Register: Is interpreted as independent flags, each flag is set depending on an event.
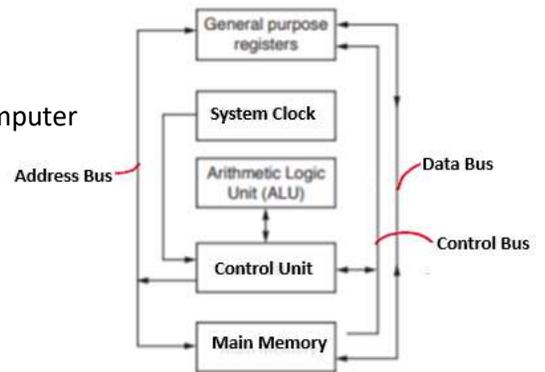
Components of the CPU
What is the CPU?
The CPU is responsible for processing all data within the computer
It is made up of a number of components including:
- Arithmetic and Logic Unit (ALU)
- Control Unit (CU)
- System clock
- Immediate Access Store (IAS)
- Buses

Component	Full name	Purpose / function
ALU	Arithmetic Logic Unit	Performs **calculations** (e.g. add, subtract) and **logic operations** (e.g. AND, OR)
CU	Control Unit	**Manages and controls** the execution of instructions and **directs data flow**
System Clock	–	Sends out **regular pulses** to **synchronize** all CPU operations
IAS	Immediate Access Store	**Main memory** where **instructions and data** needed by the CPU are **temporarily stored**

Operand: Part of the computer instructions which specifies what data is to be processed
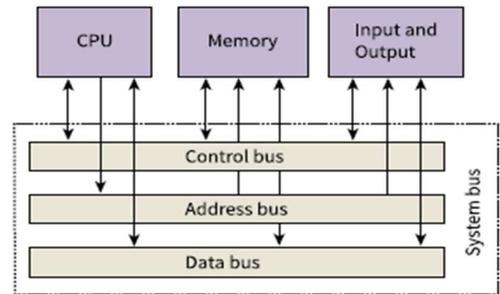**Opcode**: Is the instruction that is executed by the CPU.

Buses

A bus is a set of parallel wires through which data/signals are transmitted from one component to another.

How data are transferred between various components of the computer system?

Data Bus

- Carries data between processor and memory
- Bi- directional bus
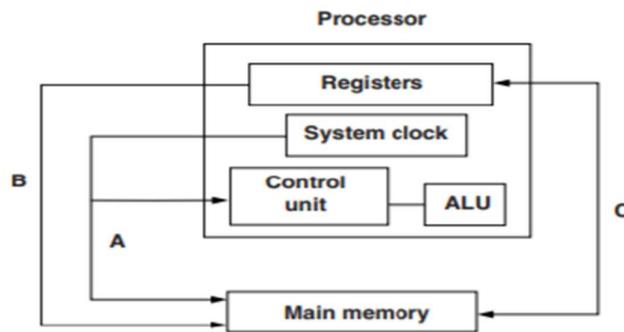- Used to exchange data.

Address Bus

- Uni- Directional bus
- That carries signal related to memory address
- Between processor and memory

Control Bus

- Transmits signals between control unit and other components
- Bi- directional.

Exam Question

2 (a)

The diagram above shows a simplified form of processor architecture.

Name the three buses labelled A, B and C.

A ....

B ....

C ....

[3]

2   (a) A = control bus

B = address bus

C = data bus

FACTORS AFFECTING THE SYSTEM PERFORMANCES

Data Bus Width

- The width of a bus determines the number of bits that can be simultaneously transferred
- Increasing the width of a data base increases the number of bits that can be transferred
- Hence improves processing speed as fewer transfers are needed.

Clock speed

- One F-E cycle runs on each clock pulse
- So, the clock speed dictates the number of instructions that can be run per second.
- The faster the clock speed, the more instructions can be run per second.

Cache Memory

- Can also improve processor performance, it is similar to RAM, cache uses SRAM so they have faster access time as there is no need to keeps refreshing.
- Cache memory stores frequently used instructions and data that needs to be accessed faster, this improves processor performance.

Number of cores

- Each core processes one instruction per clock pulse
- More cores mean that sequence of instruction can be split between them and so more than one instruction is executed per clock pulse.
- More cores decrease the time taken to complete task.

PORTS

Acts as an interface between computers and other peripheral devices

The Universal Serial Bus (USB) Port

- Fast data transfer

Useful when transferring large files such as video files

- Automatic connection/ plug and play

So usually there is no need to install separate drivers.

- USB is now an industrial standard.

All new computers will be equipped by USB port.

- Device may be powered or charged through USB.

External devices could be charged while working at the computer.

High-Definition Multimedia Interface (HDMI)

* Helps to connect more monitors

* HDMI port allows to output both audio and visual

* They support high-definition signals

* Faster data transfer.

* HDMI increases the bandwidth making it possible to supply the necessary

   data for high quality sound and visual effects.

Advantages of HDMI	Disadvantages of HDMI
Current standard for modern televisions and Monitors.	Not a very robust connection (easy to break connection when simply moving devices)
Allows for a very fast data transfer rate	Limited cable length.
Improved security, helps prevent privacy by the help of HDCP.	
Supports modern digital system.	

Video Graphic Array (VGA)

Advantages of VGA	Disadvantages of VGA
Simpler technology.	It does not support audio.
Only one standard available.	Outdated as modern laptops and computers rarely have a VGA port.
Easy to split the signals and connect a number of devices from one source.	Easy to bend the pins when making connections.
The connection is very secure.	
VGA supports a higher refresh rate.	

FETCH EXECUTE CYCLE

The full name for this is the fetch, decode and execute cycle. This is illustrated by the flowchart.
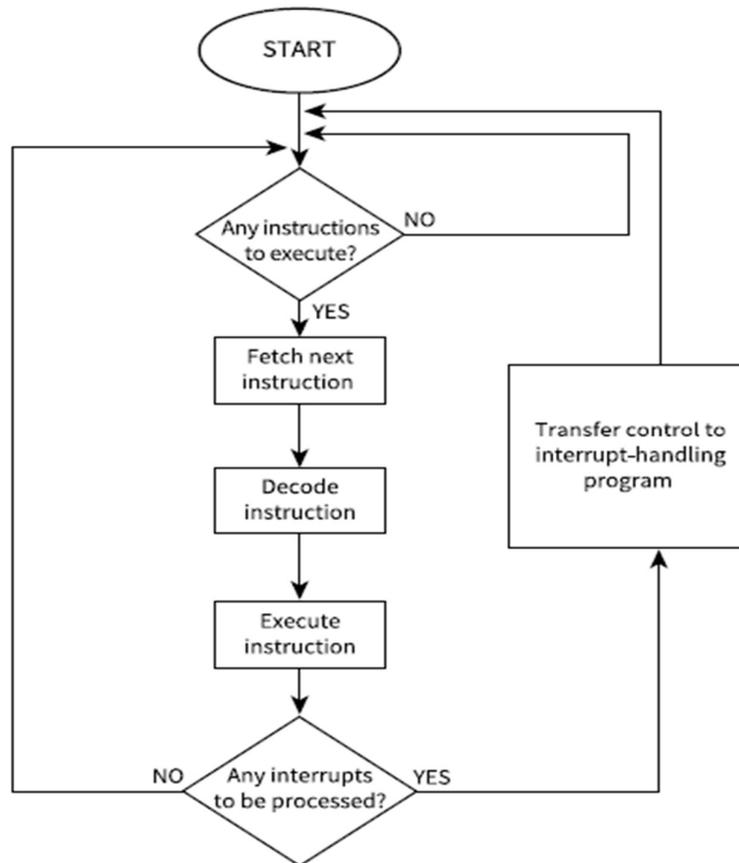
Describe how special purpose registers are used in the fetch stage of the fetch-execute cycle.

- Program Counter (PC) holds the address of the next instruction to be fetched
- The address in Program Counter (PC) is copied to Memory Address Register (MAR)
- Program Counter (PC) is incremented.
- The instruction is copied from address stored in Memory Address Register (MAR) to Memory Data Register (MDR).
- Then instruction from the MDR is copied to Current Address Register (CIR).

The stages in the FE Cycle are shown in register transfer notation.

$$MAR \leftarrow [PC]$$
$$PC \leftarrow PC + 1$$
$$MDR \leftarrow [\ [MAR]\ ]$$
$$CIR \leftarrow [MDR]$$

The third instruction [[MAR]] has double Brackets, because the content of MAR is an address, it is the contents of this address which is transferred to MDR.

CONCEPT OF INTERRUPT

What is meant by Interrupt?

- A signal from source/ device

- Telling the processor that its attention is needed.

Hardware Interrupt

- Printer out of paper

- No CD in drive

Software Interrupt

- Run- time error

- A running program needs input

Working Example

Explain how the computer handles an interrupt when a key is pressed on the keyboard. **[5]**

Answer

- An interrupt flag is raised in the interrupt register [1 mark]
- The system finishes its current fetch–execute cycle [1 mark]

- The interrupt register is checked for a higher priority interrupt [1 mark]
- If a higher priority interrupt is found, the current register contents are pushed to the stack [1 mark]
- The appropriate Interrupt Service Routine (ISR) is executed [1 mark]
- The ISR processes the key press and completes [1 mark]
- The register contents are restored from the stack [1 mark]
- Control is returned to the original process [1 mark]

What is Buffer?

It is a temporary storage area used to hold data before transferred allows for difference in working speeds (of processors and peripheral devices)

What is a core?

A core acts like a **mini CPU**, it can **fetch, decode, and execute** instructions on its own

Each core has its own:

- o **Control Unit (CU)**
- o **Arithmetic Logic Unit (ALU)**
- o **Registers**

A CPU with **more than one core** is a **multicore CPU**

Allows for **parallel processing**, multiple instructions are processed **at the same time**

Example:

- o A **dual-core** processor has **2 cores**
- o A **quad-core** processor has **4 cores**

More cores = **better performance**, especially for powerful

programs Example:

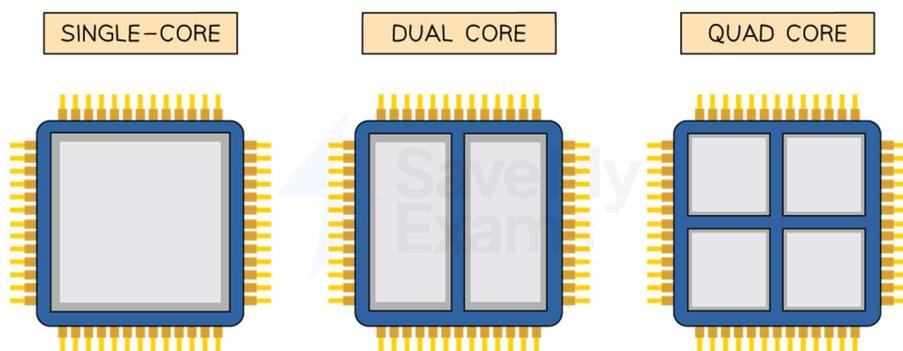A **quad-core CPU** running at **3GHz**

4 cores × 3 billion = **12 billion instructions per second**

A **dual-core** processor isn't always **twice as fast** as a single-core

Some time is used for **organizing tasks between cores**

Not all tasks can be **split across cores**

Some tasks are **sequential** and must be done **step-by-step**

What is clock speed?

The **clock** controls the **timing of operations** inside the CPU

It constantly **switches between 0 and 1**, each switch is called a **state change**

A **state change** can represent **one step** in the **fetch-decode-execute cycle.** Some instructions may take **more than one cycle**

Clock speed measures **how many state changes happen per second.**

1 cycle per second = 1 Hz

A typical clock speed is around **2.3 GHz**

> That's **2.3 billion cycles per second**

A **higher clock speed** means the CPU can **execute more instructions per second**

This helps the computer **run tasks more quickly and efficiently.**

What is cache memory?

- Cache is part of **primary storage**

- Stores **frequently used data and instructions**

- Located **closer to the CPU** than RAM, so it's **faster to access**

- Some cache is built **directly into each processor core**

- **Speeds up** the performance of the CPU

   More cache = **more data stored** nearby = **less time waiting** for data from RAM Example:

- A **website** you visit often can be stored in the cache

- Next time you visit, it **loads faster**

- If the website updates, the **cached version is updated too.**