OCR GCSE Computer Science

Your notes

CPU Architecture, Performance & Embedded Systems

Contents

The Purpose of the CPU

Your notes

The CPU

What is the 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

The Fetch-Execute Cycle

What is the Fetch-Execute cycle?

- The **Fetch-Execute Cycle** is the cycle that the central processing unit (CPU) runs through billions of times per second to make a computer work
- The CPU is 'the brain' of a computer and is made up of components and registers
- A computer takes an input, processes the input and then delivers an output for the user
  - **Input:** Clicking a button on the gamepad
  - **Process:** The CPU inside the console follows a set of instructions to carry out the task
  - **Output:** The player moving on screen

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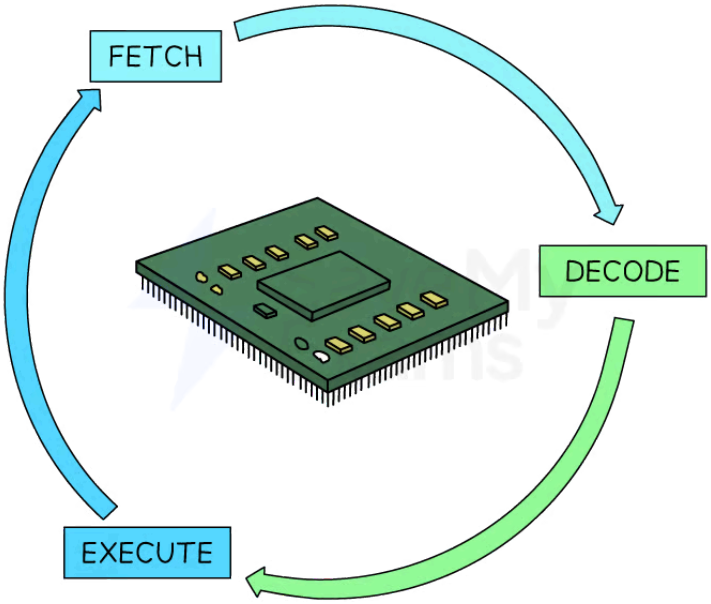

The Fetch-Execute cycle stages

Fetch stage

- During the fetch stage of the cycle, the next instruction or data must be fetched from the computer's memory (**RAM**)
- The instruction or data is brought back to the CPU

Decode stage

- During the decode stage of the cycle, the CPU needs to work out what is required from the instruction
- This could be a range of tasks depending on what the instruction or data included

Execute stage

- During the execute stage of the cycle, the CPU will carry out the instruction that was fetched
- Some examples that would take place at this stage are
  - Performing a calculation
  - Storing a result or data back in main memory (RAM)
  - Going to main memory to fetch data from a different location

The important things to remember are:

- An instruction or data is fetched from memory
- The instruction is decoded
- The instruction is executed
- The cycle repeats billions of times per second

Worked Example

Identify **two** events that take place during the fetch-execute cycle.

[2]

Answer

Any two of the following

- An instruction is fetched from memory
- The instruction is decoded
- The decoded instruction is executed
- The instruction is transferred to the MDR

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CPU Components & Their Function

What are the components of the CPU?

- The CPU is made up of 4 key components
  - **Arithmetic Logic Unit (ALU)**
  - **Control Unit (CU)**
  - **Cache**
  - **Registers**
- Each of the components sits within the CPU

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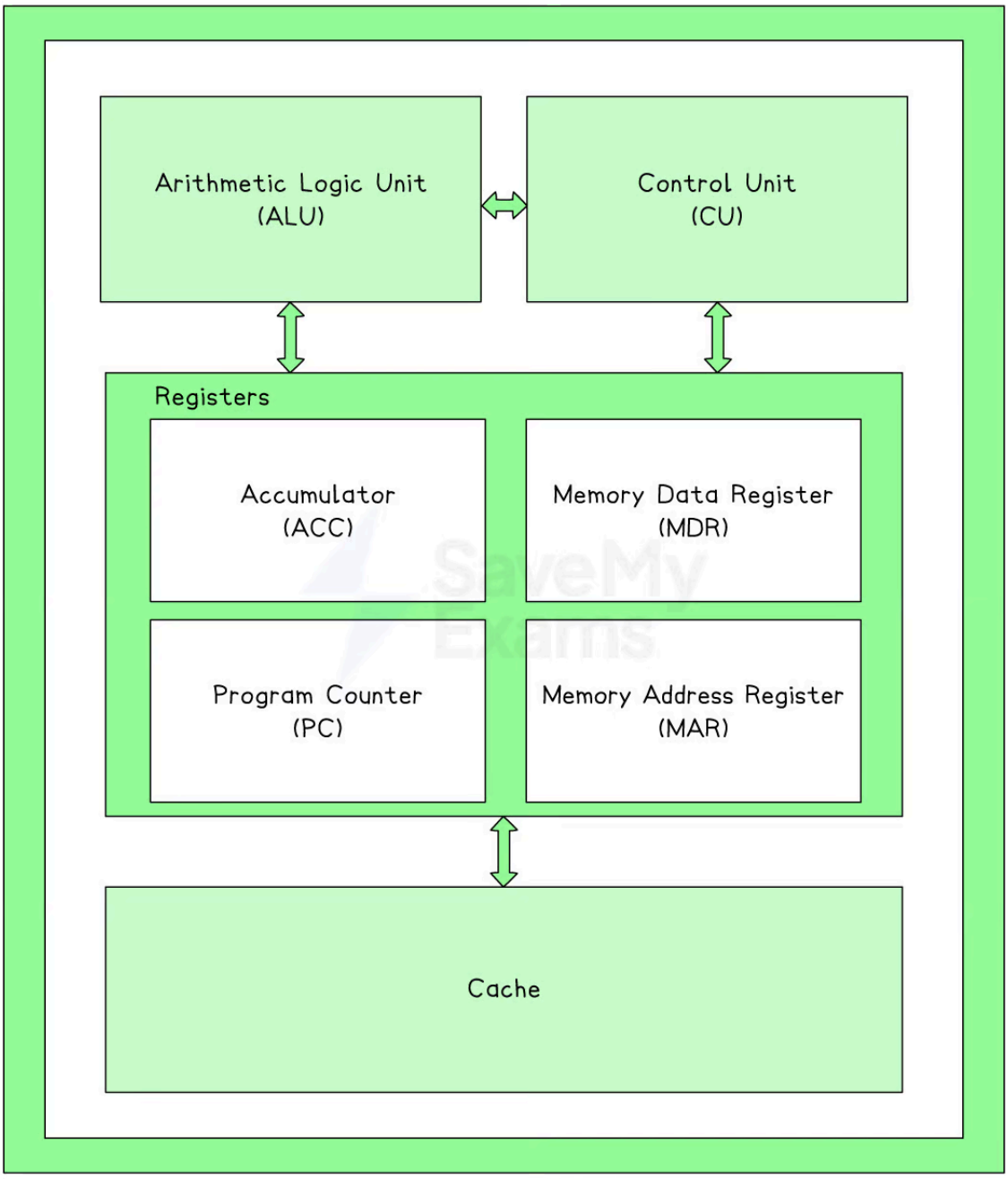

What is the function of each component?

Arithmetic logic unit (ALU)

- Performs **arithmetic** operations
- Performs **logical** decisions
    - IF X > 5 THEN
      DO …….


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Control unit (CU)

- **Coordinates** how data moves around the CPU by **sending signals** to **control the flow of the data**
- **Decodes the instructions** fetched from memory

Cache

- **Very small, very fast memory** located in the CPU which is used to provide **quick access** to **frequently used instructions and data**
- The **more cache** there is, the **more data can be stored**, which **speeds up** the performance of the CPU
- It **prevents the CPU** from having to **repeatedly fetch frequently used** instructions from RAM

Registers

- **Extremely small, extremely fast memory** located in the CPU
- Each register has its very own **specific purpose**
- More details about the individual registers can be found **here**

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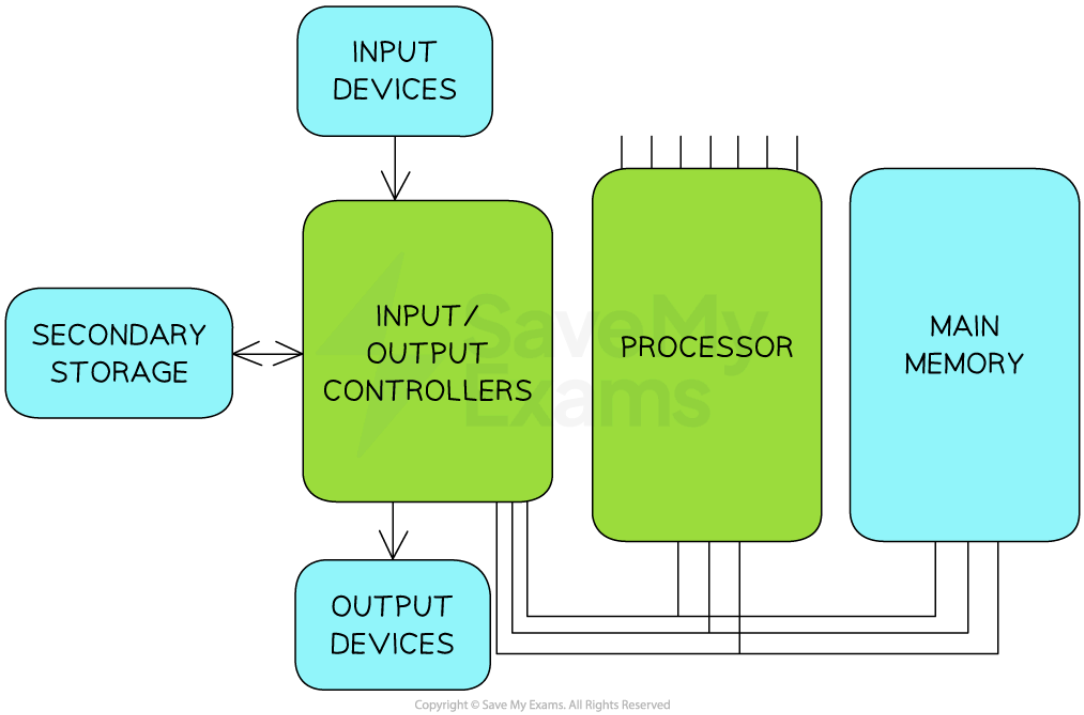
Von Neumann Architecture

What is the Von Neumann architecture?

- The Von Neumann Architecture is a design of the CPU which was proposed by Mathematician John Von Neumann in the 1940s, which most general-purpose computers are built upon
- The Von Neumann Architecture outlines how the computer memory, input / output devices and processor all work together



The Von-Neumann-architecture

- It consists of 4 main registers
  - **The Program Counter (PC)**
  - **The Memory Address Register (MAR)**
  - **The Memory Data Register (MDR)**

- **The Accumulator (ACC)**

- For each of the registers you must know
  - The name of the register
  - Its acronym
  - The purpose of the register

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What do each of the registers do?

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 Data Register (MDR)

- **Stores the data or instruction** which has been fetched from memory

Accumulator (ACC)

- Stores the **results** of any calculations that have taken place in the Arithmetic Logic Unit (ALU)

Worked Example

Complete the table by writing the missing definition or name of each of the common CPU components and registers.

CPU Component or Register	Definition
CU (Control Unit)	
	Stores the address of the data to be fetched from or the address where the data is to be stored.
	Stores the address of the next instruction to be fetched from memory. Increments during each fetch-execute cycle.

Arithmetic Logic Unit // ALU	

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Answer

CPU Component or Register	Definition
Control Unit // CU	Sends signals to synchronise / control / coordinate the processor Decode instructions to run the F-E cycle
Memory Address Register // MAR	Stores the address of the data to be fetched from or the address where the data is to be stored.
Program Counter // PC	Stores the address of the next instruction to be fetched from memory. Increments during each fetch-execute cycle.
Arithmetic Logic Unit // ALU	Performs mathematical calculations and logical operations

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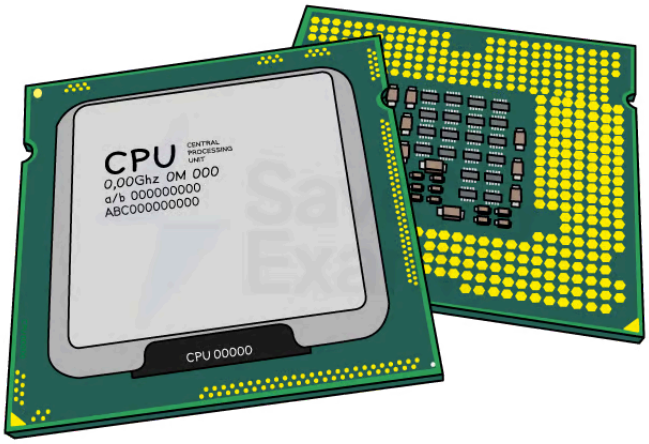
Characteristics of the CPU

What are the common characteristics of the CPU?

- There are 3 common characteristics
  - **Clock Speed**
  - **Cache Size**
  - **Number of Cores**
- Each of these characteristics has a significant impact on the performance of the CPU



How do the characteristics of the CPU affect performance?

Clock speed

- The clock speed is **measured in Hertz** (Hz)
- The clock speed measures the number of fetch-decode-execute cycles that can take place in 1 second

- The faster the clock speed, the more instructions can be fetched and executed per second
- Modern computers have a clock speed in Gigahertz (GHz), meaning billion
- A clock speed of 3.5GHz can perform up to **3.5 billion instructions per second**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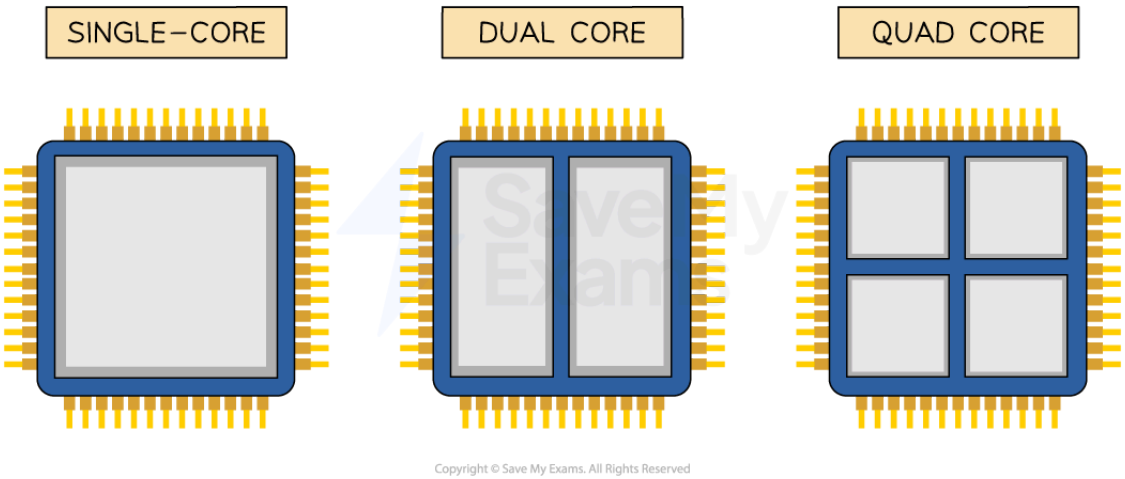
Cache size

- Cache is very small, **very fast memory** on or close to the CPU
- Cache is used as temporary storage to provide quick access to **a copy of** frequently used instructions and data
- The larger the cache size, the more frequently used instructions or data can be stored
- This results in the CPU having to complete fewer fetch cycles from memory (RAM), speeding up the performance
- 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

- A core **works like it is its own CPU**
- Multiple core processors mean they have multiple separate processing units that can fetch, decode and execute instructions at the same time
- For example, a dual-core processor would have 2 processing units, each with their own
  - **Control Unit (CU)**
  - **Arithmetic Logic Unit (ALU)**
  - **Accumulator (ACC)**
  - **Registers**
- Multi-core processors can run more powerful programs with greater ease
- Multiple cores increase the performance of the CPU by working with the clock speed
  - Example: A quad-core CPU (4 cores), running at a clock speed of 3Ghz
    - **4** cores x **3**GHz
    - 4 x 3 billion instructions
    - 12 billion instructions per second



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Worked Example

1. State the purpose of the CPU	[1]
2. State what is meant by a dual-core 2.5Ghz processor	[2]
3. Von Neumann architecture contains registers. Identify two registers used in the Von Neumann architecture	[2]

Answer

1. State the purpose of the CPU	[1]
▪ The CPU performs the FDE cycle ▪ Process instructions	
2. State what is meant by a dual-core 2.5Ghz processor	[2]
▪ Dual-core means there are two cores processing instructions ▪ 2.5GHs means it can run 2.5 billion FDE cycles per second	

3. Von Neumann architecture contains registers. Identify two registers used in the Von Neumann architecture	[2]
▪ Program Counter (PC) ▪ Memory Address Register (MAR) ▪ Memory Data Register (MDR) ▪ Accumulator (ACC)	


Your notes

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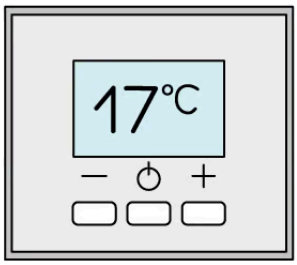
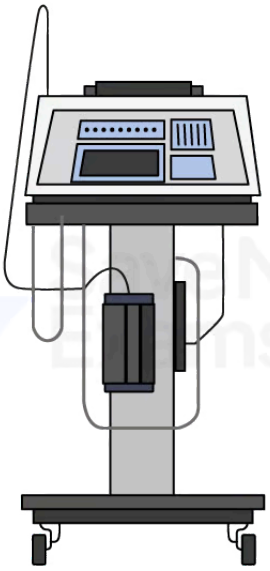
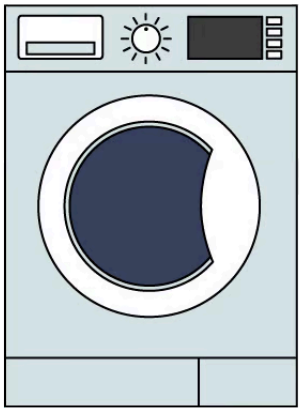
Embedded Systems

What is an embedded system?

- An embedded system is a computer system with a single function, inside a larger mechanical unit
- Examples of embedded systems include
  - **Heating thermostats**
  - **Hospital equipment**
  - **Washing machines**
  - **Dishwashers**
  - **Coffee machines**
  - **Satellite navigation systems**
  - **Factory Equipment**
  - **Traffic lights**







What are the properties of an embedded system?

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- They are **small** in size
- They **use less power** than a general-purpose computer
- They have a **lower cost**

Examiner Tips and Tricks

Always use key examples from the list above and don't try to use different examples such as a fridge or kettle as these will not appear on mark schemes because although they have a single purpose, most fridges and kettles do not have a CPU.

Worked Example

1) Tick **two** boxes below to show which are an example of an embedded system **[2]**

	Is it an example of an embedded system
Laptop	
Washing Machine	
Mobile Phone	
Car Engine Management System	

2) Justify your choice to question 1 **[2]**

Answer

1) Tick **two** boxes below to show which are an example of an embedded system. **[2]**

	Is it an example of an embedded system
Laptop	
Washing Machine	✓

Mobile Phone	
Car Engine Management System	✓

Your notes

2) Justify your choice to question 1 **[2]**
Any two of: ▪ A washing machine and car engine management system are not general-purpose computers **[1]** ▪ A washing machine and car engine management system have a single purpose and are both housed inside a larger mechanical unit **[1]** ▪ A washing machine and car engine management system have a microprocessor **[1]**