GCSE OCR

Computer Science
J277

1

Architecture of the CPU

Unit 1
Systems architecture

PG ONLINE

Objectives

- Understand the purpose of the CPU and the fetch-execute cycle
- Understand the following registers in the Von Neumann architecture:
  - MAR (Memory Address Register)
  - MDR (Memory Data Register)
  - Program Counter
  - Accumulator
- Understand common CPU components including:
  - ALU (Arithmetic Logic Unit)
  - CU (Control Unit)
  - Cache
  - Registers

Starter

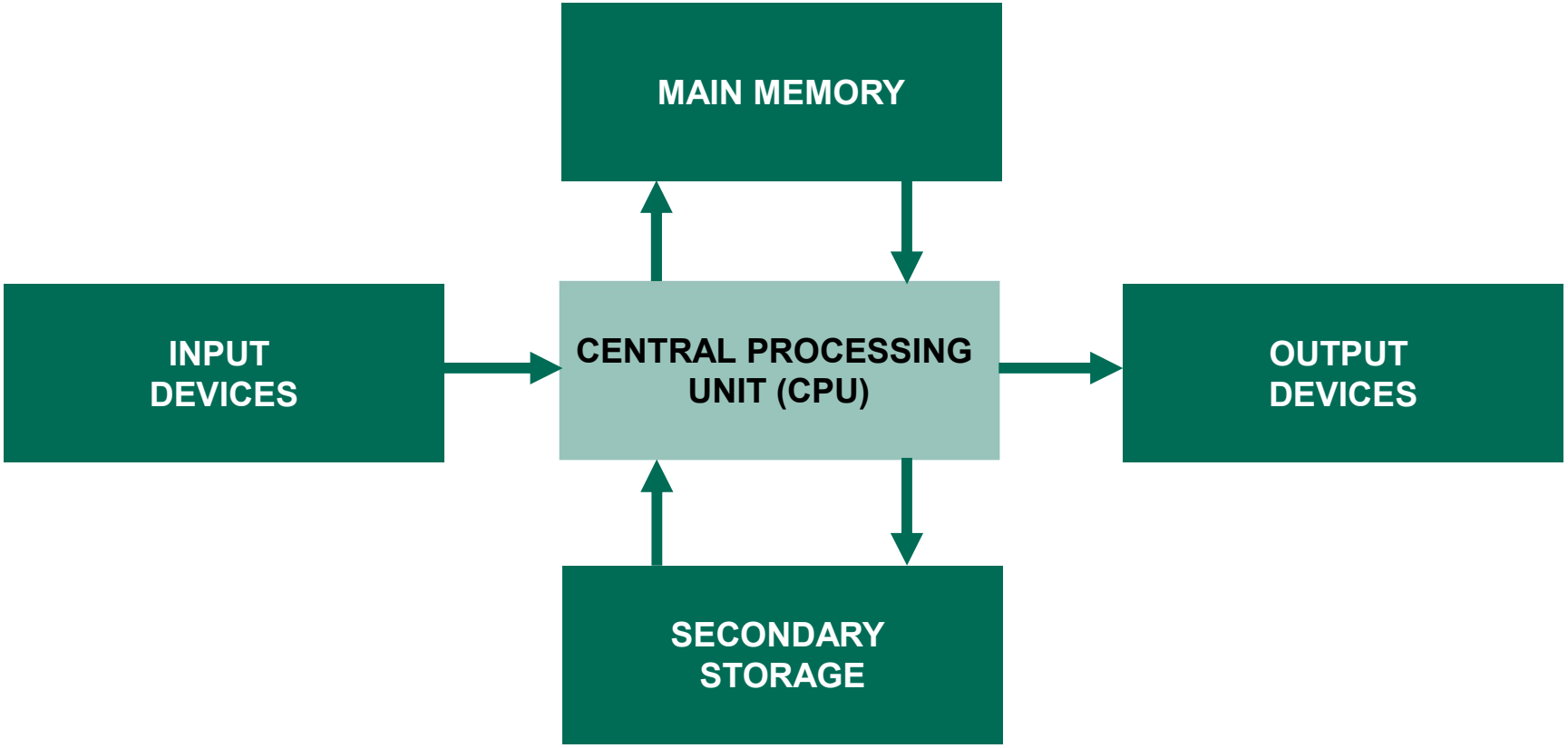
- A laptop and smartphone are both examples of computer systems
  - What are the input and output devices for these computer systems?
  - What component carries out the processing of the instructions?

Starter

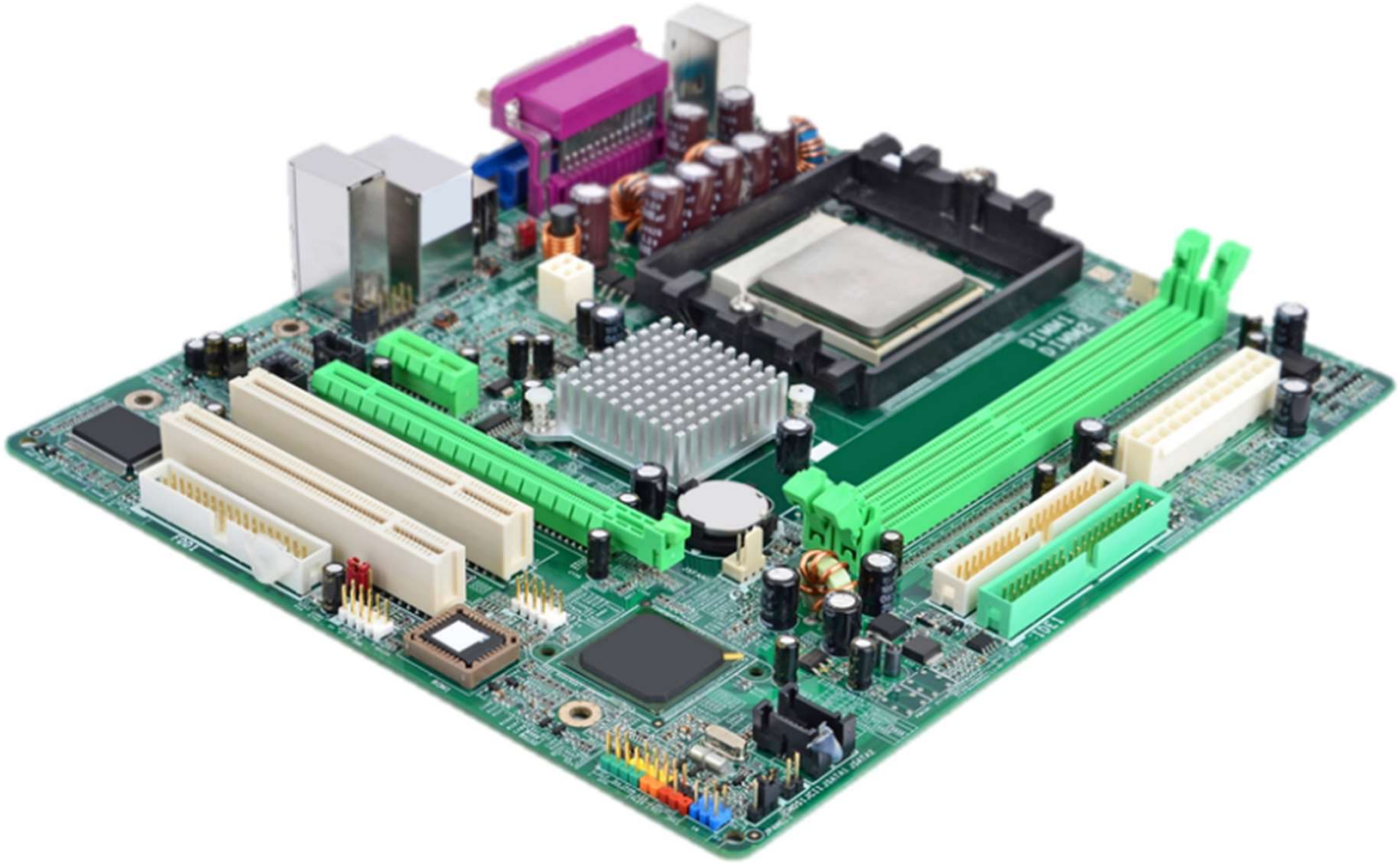
Answers

- Input devices:
  - Laptop: keyboard, buttons, trackpad, microphone
  - Smartphone: microphone, buttons, GPS sensor, gyroscopic sensor, touch part of the touchscreen
- Output devices:
  - Laptop and smartphone: speakers, display
- Processing:
  - CPU (Central Processing Unit)

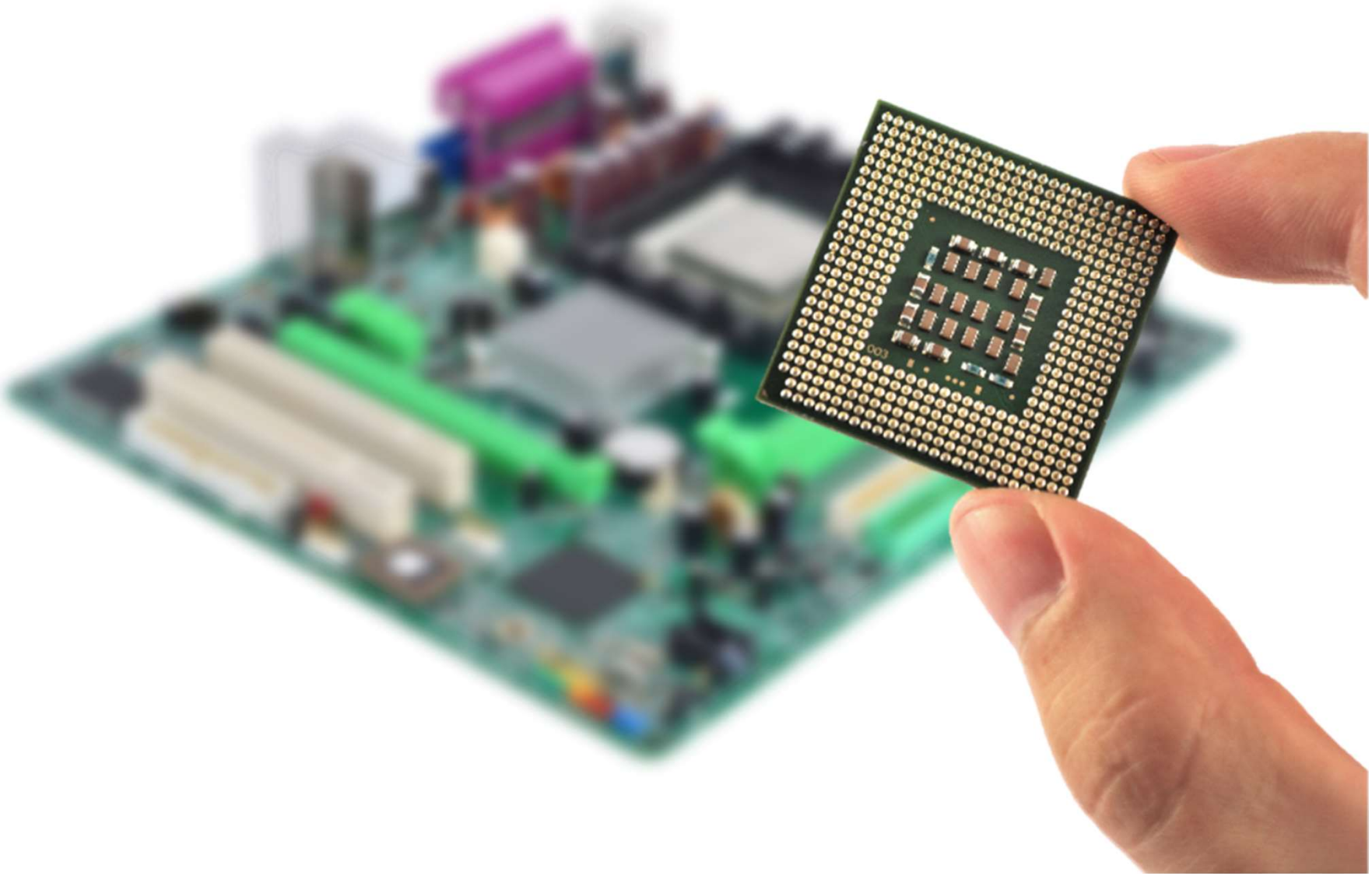
The main components of a computer



What is this?



The CPU



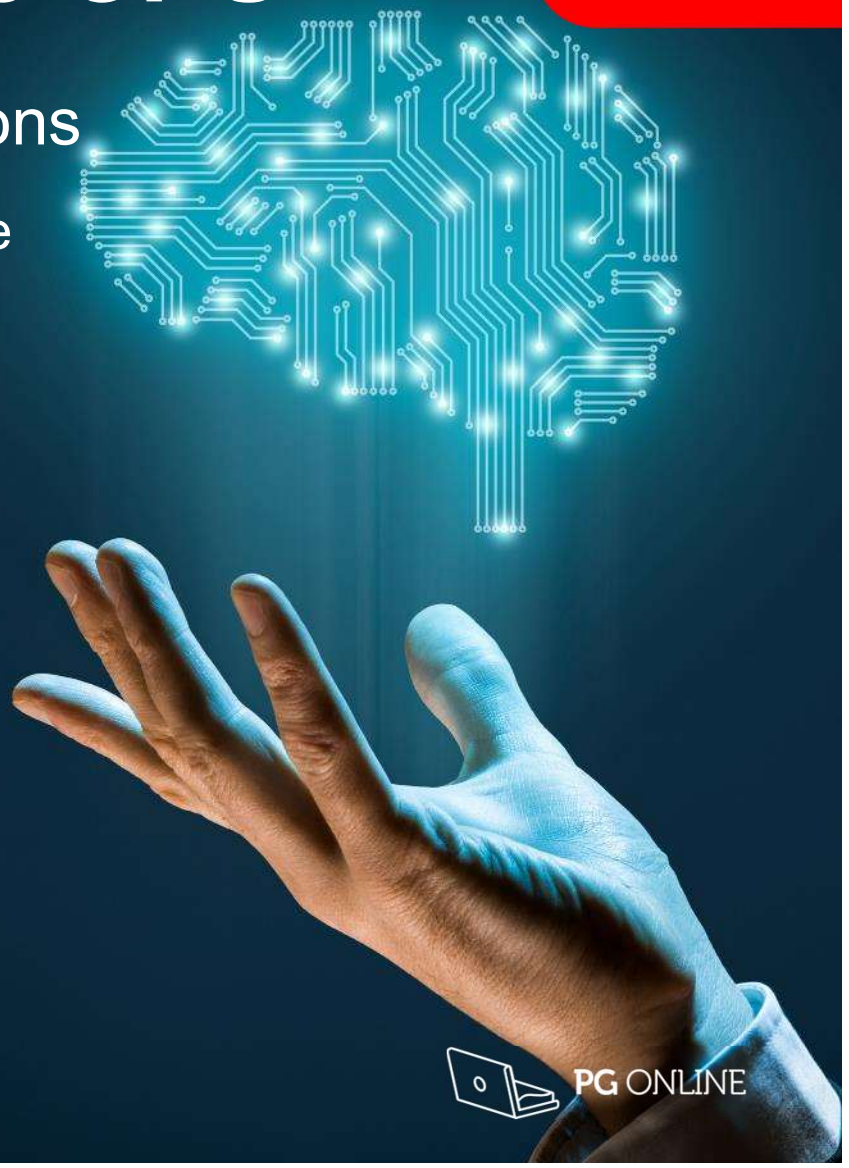
Central Processing Unit (CPU)

- The Central Processing Unit or CPU is arguably the most important component of a computer
- What does it do?
  - What organ in the human body is it often compared to?
  - What are the similarities it has to this organ?

The purpose of the CPU

Answers

- The CPU processes instructions
  - When you run a program, it is the CPU which runs the instructions
- It is often thought of as being the ‘brains’ of the computer
  - The way that a brain works is very different to a CPU
  - A CPU simply runs one simple instruction at a time
  - It carries out billions of instructions per second



Stored program concept

- Before about 1943, early computers stored the data to be worked on in memory
- The program was not stored
  - Instructions were input one at a time using switches, or read in punch cards and executed one at a time
- In 1943-44, mathematician von Neumann and his colleagues had the idea of storing the program instructions as well as the data in memory
- The **stored-program computer** was born!

Von Neumann architecture

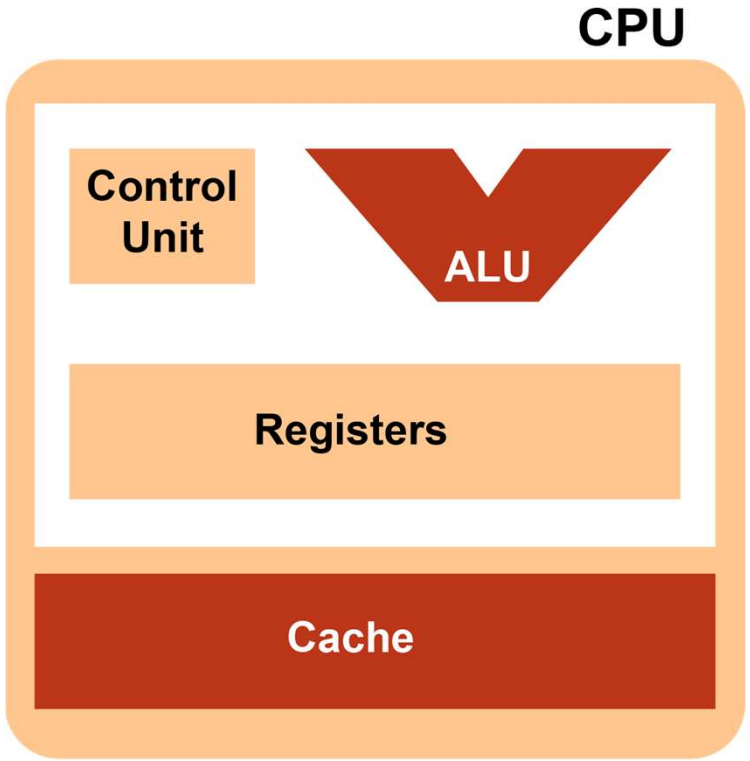
- Program **instructions** and the **data** the programs are using are both stored in the same memory
  - The CPU accesses both instructions and data from the same RAM

Memory address	Instructions and data
0	Program instruction
1	Program instruction
2	Program instruction
3	Data
4	Data
5	Data
6	Data

RAM

Components of the CPU

- The CPU has two major components called the
  - Control Unit
  - Arithmetic-Logic Unit (ALU)
- There are also registers that are used to carry out these operations
  - A register is a very fast memory location in the CPU itself



Registers in the CPU

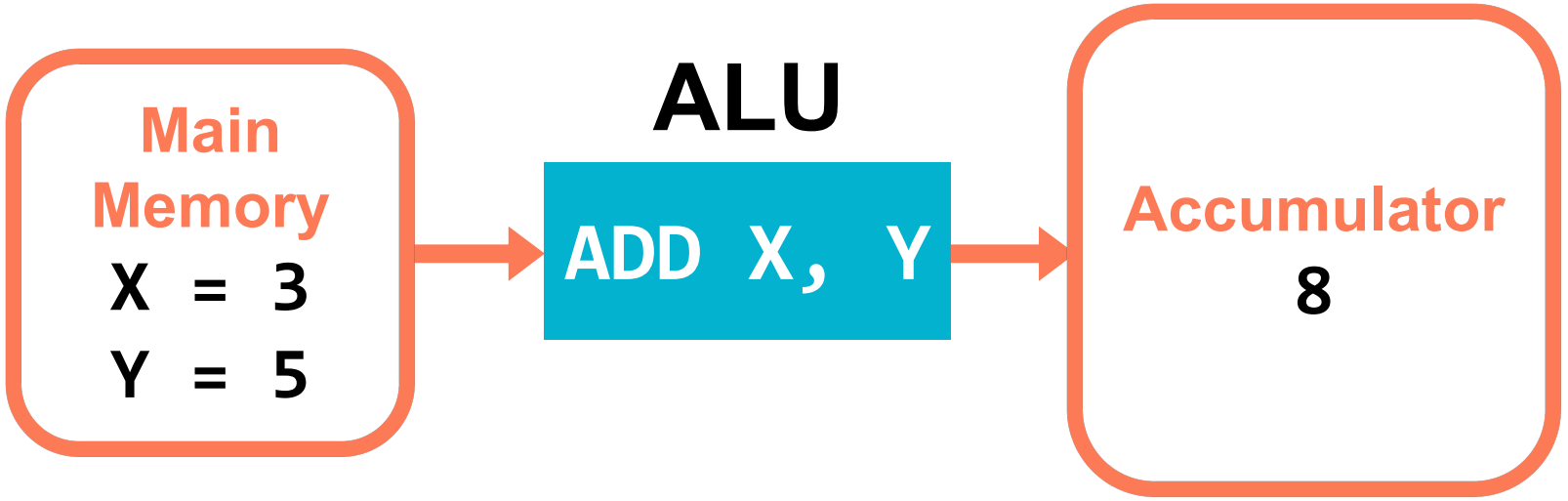
- **Program Counter (PC)**
  holds the address of the next instruction to be executed
- **Memory Address Register (MAR)**
  holds the memory address of the current instruction, and then the data that it uses, so that these can be fetched from memory
- **Memory Data Register (MDR)**
  holds the actual instruction, and then the data that has been fetched from memory
- **Accumulator**
  holds the result of an instruction before it is transferred to memory

Control Unit

- The control unit coordinates and controls all of the activities taking place within the CPU
  - It decodes instructions and executes them
  - It receives signals from the system clock
  - It directs the timing and control of other parts of the CPU, much like the conductor of an orchestra

The Arithmetic Logic Unit

- The ALU or Arithmetic Logic Unit is where the actual arithmetic operations are done
  - It also carries out logical operations such as those including AND, OR and NOT

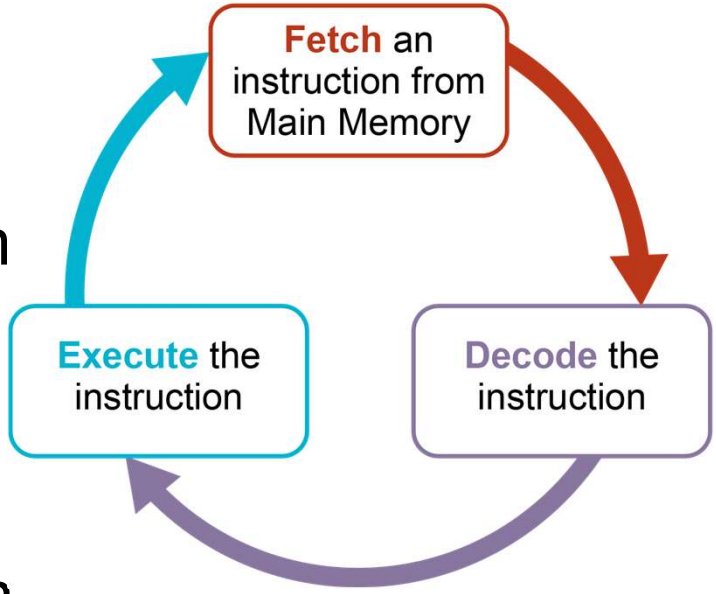


Worksheet 1

- Complete **Task 1** on **Worksheet 1**

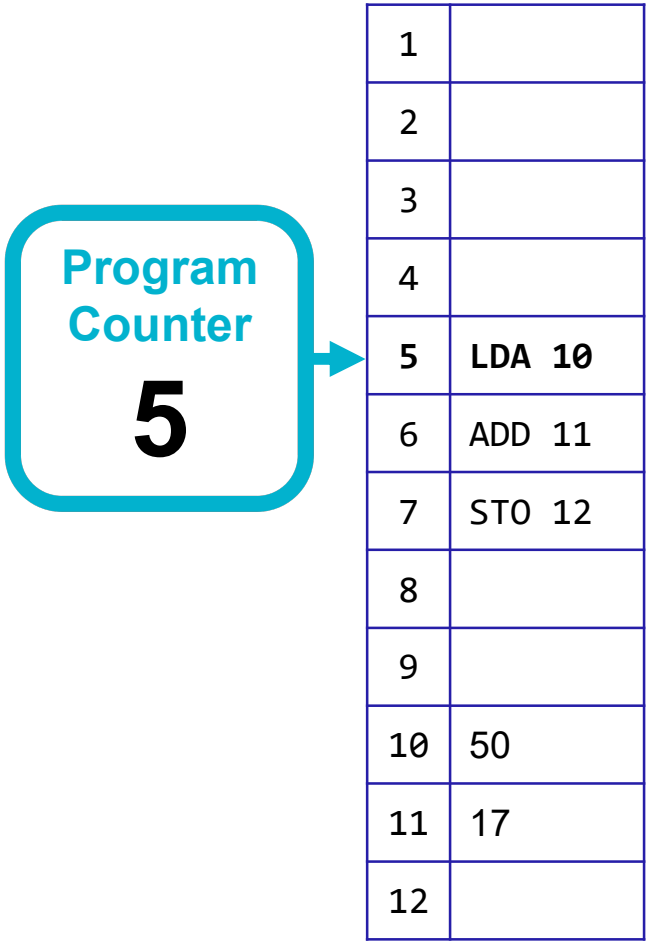
Fetch – Decode – Execute

- The CPU operates by repeating three operations:
  - **FETCH** – causes the next instruction and any data involved to be fetched from main memory
  - **DECODE** – decodes the instruction
  - **EXECUTE** – the instruction is executed
- This process is then repeated…



Program Counter (PC)

- The Program Counter holds the address of the next instruction to be executed
  - The Program Counter is incremented (increased by 1) as soon as that instruction has been fetched



Accumulator

- The accumulator (ACC) is where arithmetic and logic results are temporarily stored, much like the **M+** function on a calculator

MAR and MDR

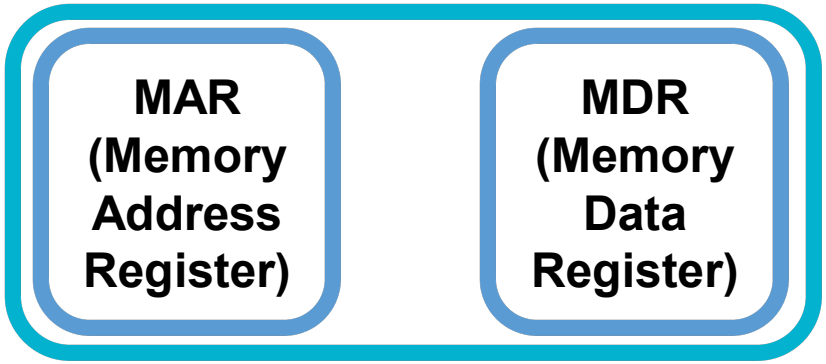
- In the FETCH stage of the F-E cycle
  - the address of the **instruction** to be executed is copied from the Program Counter (PC) to the Memory Address Register (MAR)
  - The **instruction** at that address is fetched from memory and copied to the Memory Data Register (MDR)
- The Control Unit decodes the instruction and decides if data needs to be fetched
- If so, the MAR is then used to hold the address of the **data** to be used in the instruction
- The **data** is fetched and copied to the MDR

Working together

MAR (Memory Address Register)

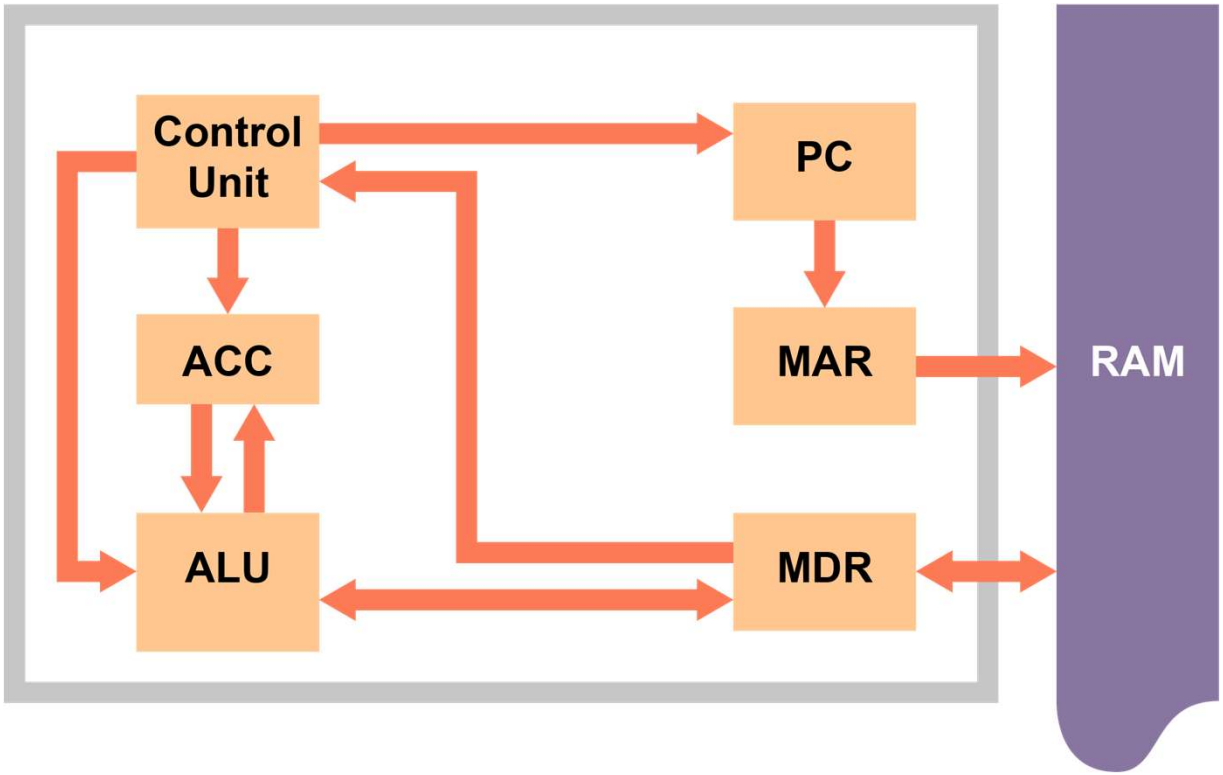
MDR (Memory Data Register)

The two work together; The MAR knows where to look for data in RAM, the MDR keeps hold of that data until it's ready to be used by the CPU



Processor architecture

- What does each acronym stand for?
  - What does each part do?



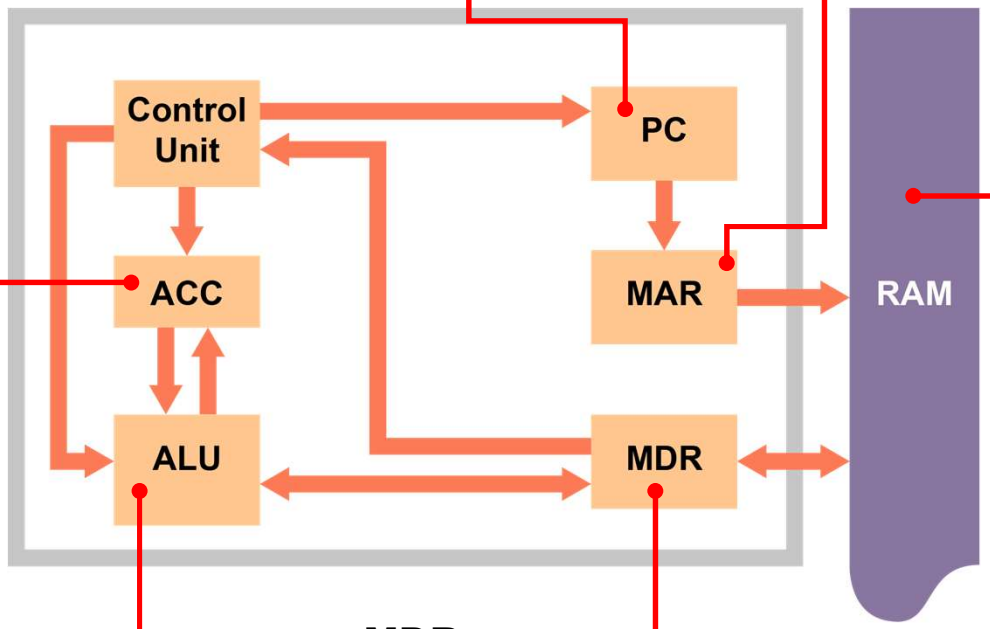
Processor architecture

Answers

PC:
Program Counter – points to the next instruction

MAR:
Memory Address Register – stores the address of the instruction to be executed

ACC:
Accumulator – Temporarily stores arithmetic results

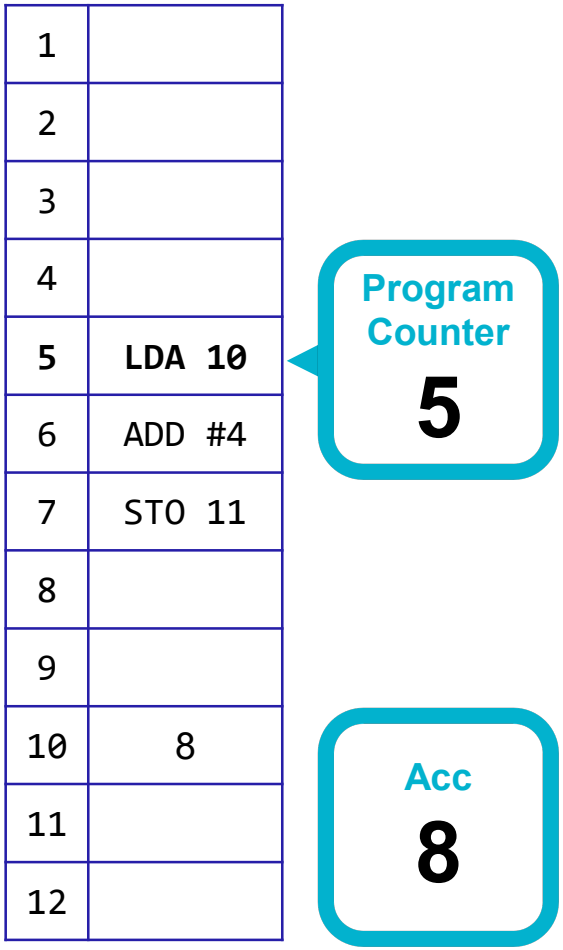


RAM:
Random Access Memory

ALU:
Arithmetic Logic Unit – performs calculations and logic expressions

MDR:
Memory data register – Stores the data to be sent/received from memory

Example – Step 1 (Add 8 + 4)



- PC points to next instruction in location 5
- Address 5 is passed to MAR and PC is incremented. It now holds 6
- Instruction at Address 5 is copied from memory to MDR
- Instruction is decoded by control unit
- Address 10 passed from MAR
- The value in location 10, i.e. 8, is passed from main memory to the MDR
- 8 is loaded into the accumulator (ACC)

Example – Step 2

1	
2	
3	
4	
5	LDA 10
6	**ADD #4**
7	STO 11
8	
9	
10	8
11	
12	

- PC now points to next instruction in location 6
- Address 6 is passed to the MAR and the PC is incremented
- Instruction at Address 6 passed to MDR
- The instruction is decoded
- No more data from memory is needed
- 4 is added to 8 in the ALU and the result is stored in the accumulator

Example – Step 3

1	
2	
3	
4	
5	LDA 10
6	ADD #4
7	**STO 11**
8	
9	
10	8
11	12
12	

Program Counter
7

Acc
12

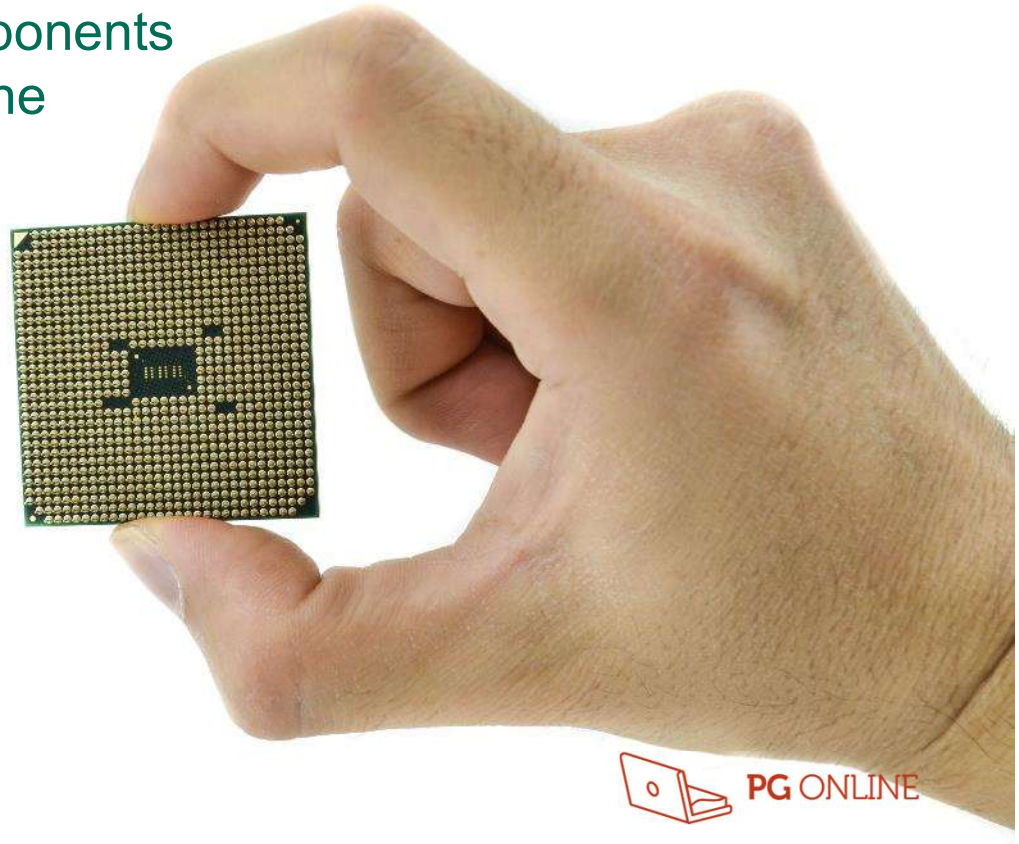
- PC points to the next instruction in location 7
- Address 7 is passed to the MAR and the PC is incremented
- Instruction at Address 7 passed to MDR
- The instruction is decoded
- The instruction is executed causing the value 12 to be transferred from the accumulator into memory location 11

Worksheet 1

- Complete **Task 2** on **Worksheet 1**

Plenary

- In pairs, answer the following:
  - What is the purpose of the CPU?
  - What are **two** major components of the CPU, and what is the purpose of each?
  - What is a register?
  - Name **four** special registers in the CPU



Plenary

Answers

- What is the purpose of the CPU?
  - To fetch and execute instructions stored in memory
- What are **two** major components of the CPU, and what is the purpose of each?
  - The ALU, which carries out arithmetic and logic instructions
  - The Control Unit, which coordinates the CPU activities
- What is a register?
  - A special fast memory location in the CPU
- Name **four** special registers in the CPU
  - PC, MAR, MDR, Accumulator

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