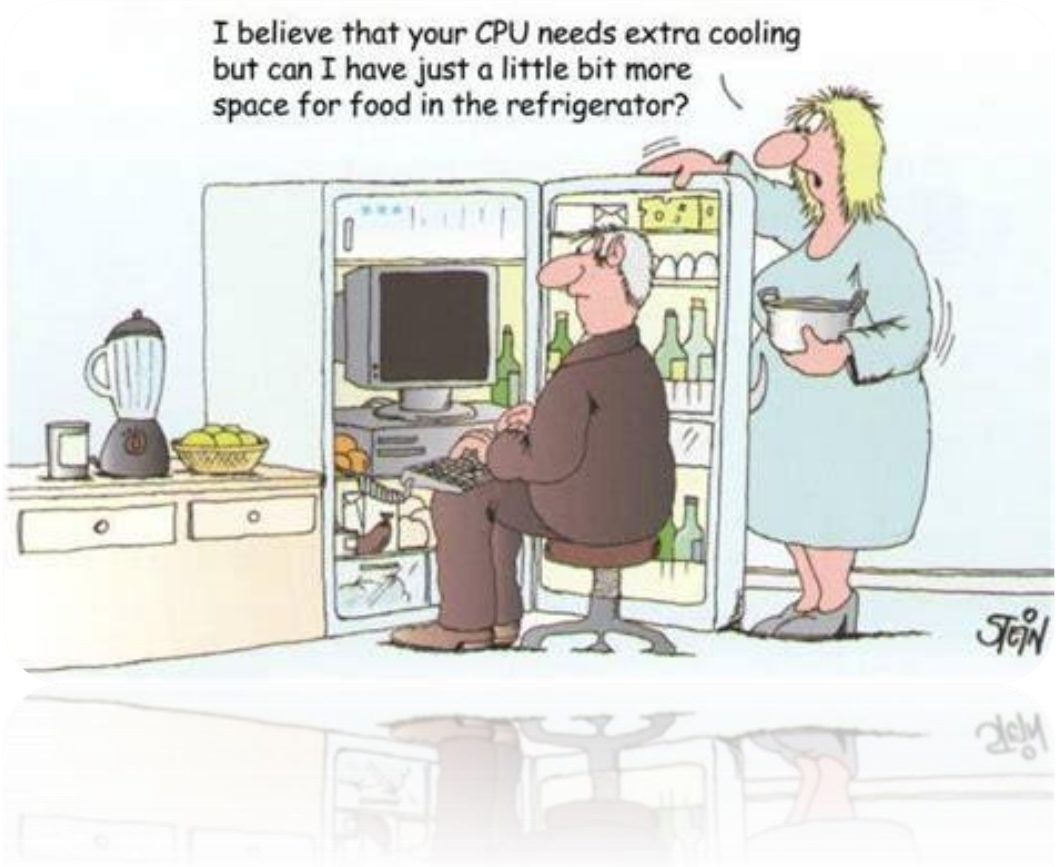
Systems Architecture



Friday, 27 April 2018
Systems Architecture

Today's Objectives:

1. To be able to **explain** the purposes and uses of embedded systems.
2. To be able to **describe** how the CPU executes instructions and the stages of the fetch-decode-execute cycle.
3. To be able to **describe** the purpose and functions of the CPU and the different components.
4. To be able to e**xplain** how the characteristics of a CPU affects their performance.

Today's Key Terms: Hardware, devices, embedded systems, processing, Firmware, microchip, U, components, functions, ALU, CU, MAR, MDR, Processor, CPU, MHz, GHz, Hertz, instruction, clock speed, cache, core, Moore's Law.

Embedded Systems

Types of Computers

All computers can be classified into two different groups:

- **General purpose systems**
- **Embedded systems**

General Purpose System

A general purpose computer **can perform many different tasks.**

Examples of General purpose systems are:

- **Personal computers**
- **Laptops**
- **Tablets**
- **Smart phones**

To perform a range of tasks they use **software applications.**

For example, a tablet can be used to listen to music, view web pages, use camera software and create documents

Embedded Systems

- An embedded system is a computer which **performs one specific task within a larger mechanical system.**
- Embedded systems do not look like a traditional computer. They do not have a monitor, keyboard or touch screen.
- They are built on a **single printed circuit board.**
- They are made up of both **hardware** and the **software** that they **specifically need to do their task.** This is known as **‘Firmware’**

The CPU

CPU

Defined…

- The purpose of the CPU is to **process data**.
- It is where all the **sorting, searching, calculating and decision** making takes place

The CPU:

- Fetches instructions from memory (RAM)
- It decodes those instructions
- It then executes (carries out) the instructions.

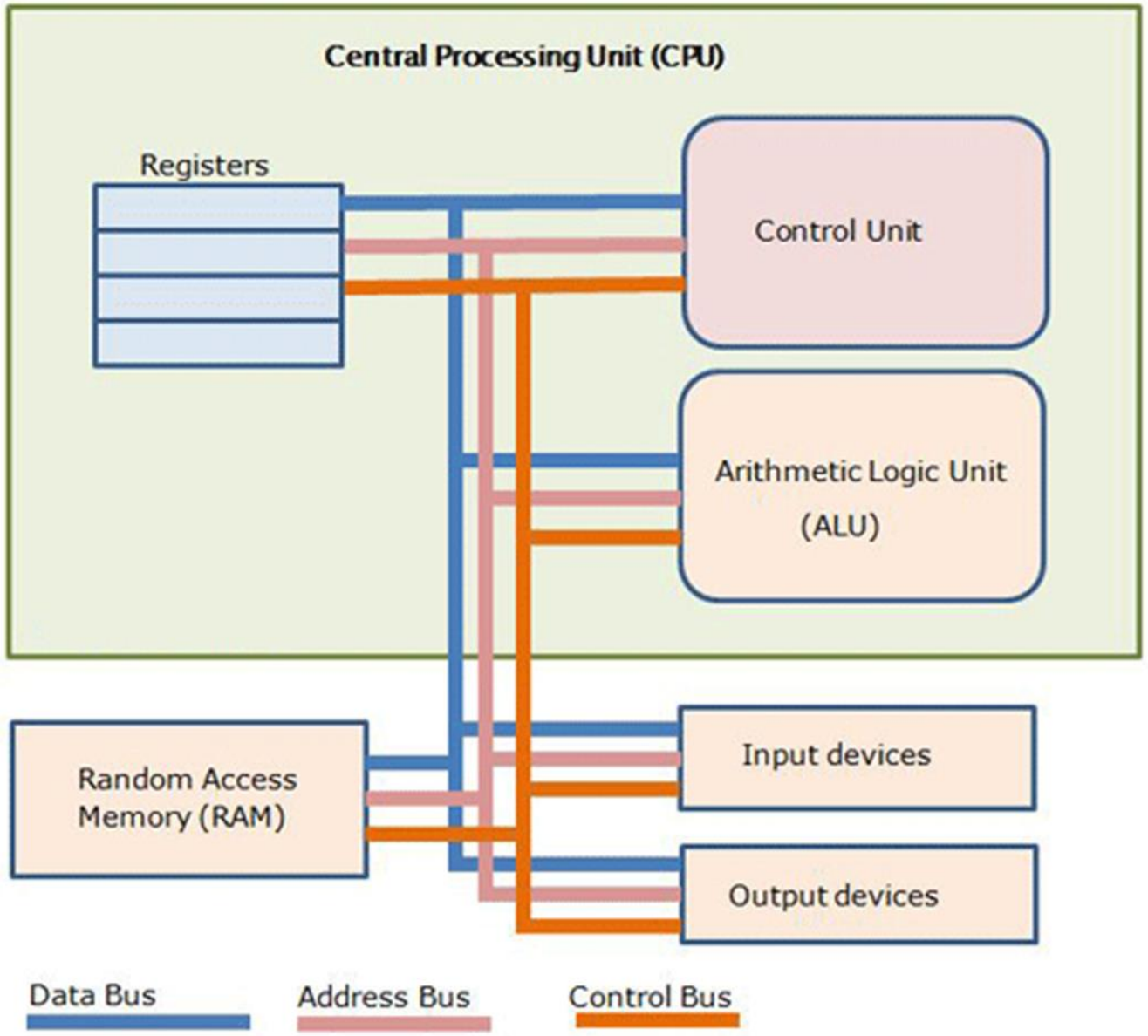
CPU

- As well as processing data, the CPU also controls the computer hardware, for example the:
  - Hard disk
  - Input/output devices
  - DVD drive
  - Sound system
  - Graphics system

This is done in conjunction with the computer's operating system.

CPU – In diagram form

Also known as the **"Von Neumann Architecture"**



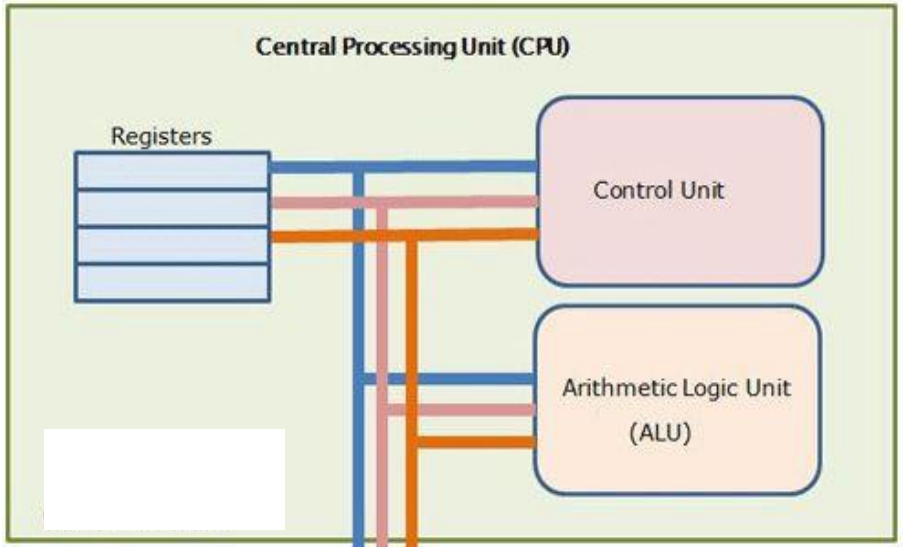
The main components of the CPU you need to know about are:

- The Control Unit (CU)
- The Arithmetic Logic Unit (ALU)
- The registers
- The cache
- The clock
- The data buses

The Control Unit (CU)

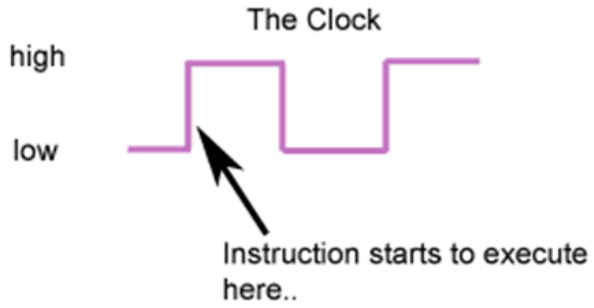
The control unit coordinates the actions of the computer. Sending out control signals to the other parts of the CPU such as the ALU and registers. It also controls the other components of the computer system such as the input and output devices.

The two main elements of the control unit are the clock and the decoder.



The Clock & Decoder

- Pulses are sent out to components to coordinated their activities The timing is controlled by a tiny vibrating quartz crystal.
- Each time the clock ticks the CPU can process one instruction (Higher the clock speed the more process that can be completed)
- Clock speed is measured in cycles per second. A typical clock has a speed of around 3GHz which means the CPU can carry out three thousand million instructions per second!

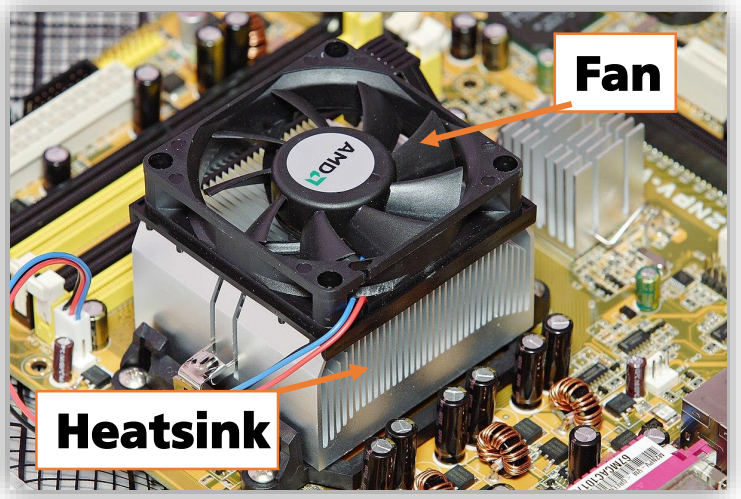


Cycles per second	Rate
1	1 Hertz
1 million	1 megahertz (MHz)
1,000,000,000	1 gigahertz (GHz)

- The decoder is the section of the control unit that decodes the program instructions brought from the memory and decides upon their action.

Clock Speed

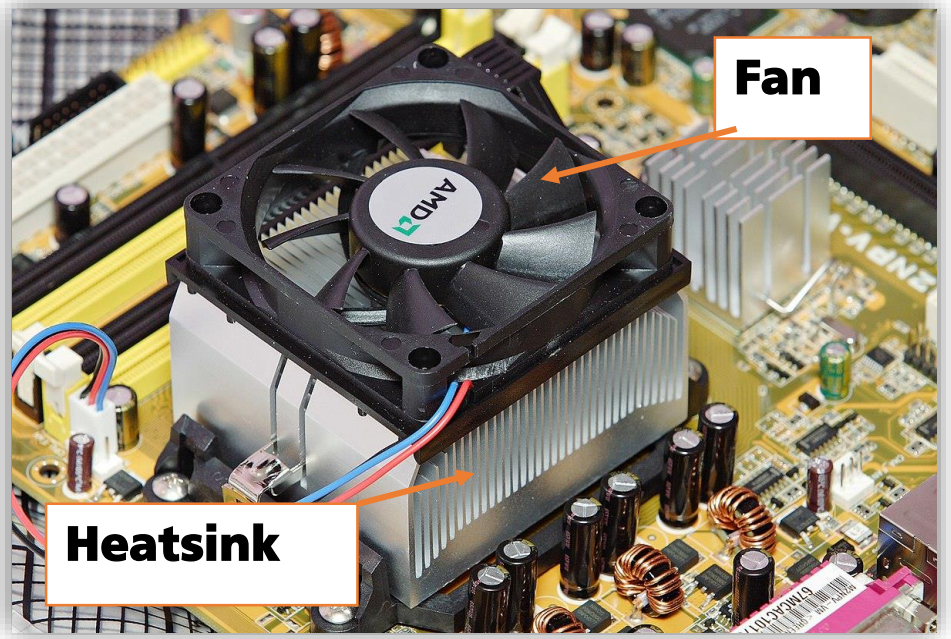
- Each time the clock ticks, one complete fetch-decode-execute cycle will take place.
  - This means that during each tick, a single instruction will be processed.
- The higher the clock frequency, the faster the CPU can run.
  - And the faster the CPU runs, the more instructions that can be processed every second.
- Increased speed has limitations:
  - Instructions are processed by transistors. The rate at which they work has not become faster.
  - Large amounts of heat are generated, increasing as the clock speed does. Heatsinks & fans are used but these have limited rates of cooling
  - Clock speeds of 9 GHz require cooling by liquid nitrogen



Overclocking

What is it?

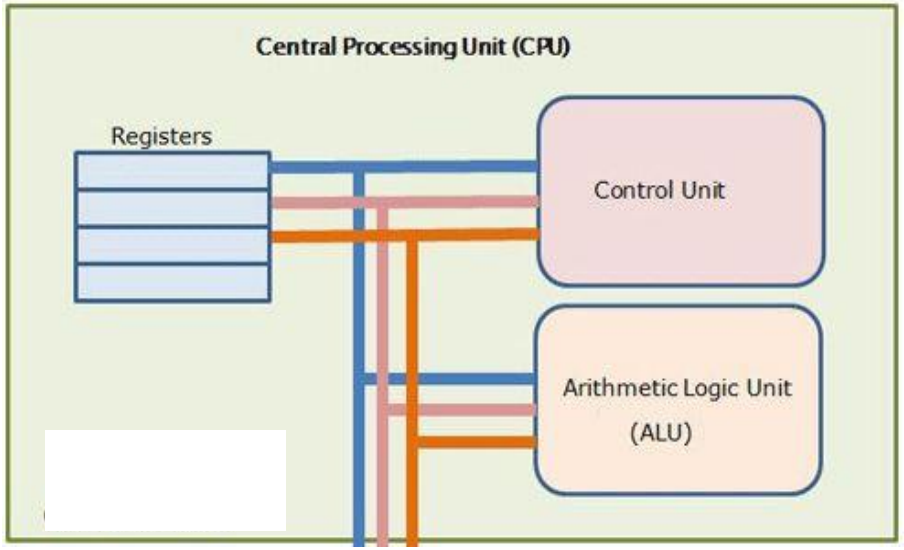
- The CPU clock speed can be increased beyond the normal design limit. This allows the CPU to process more instructions per second.
- This is called ‘overclocking’. It is something gamers like to do with their machines.
- But to overclock, you will need a very good cooling system to stop the CPU from overheating.



The Arithmetic and Logic Unit (ALU)

The ALU handles the data processing inside the CPU

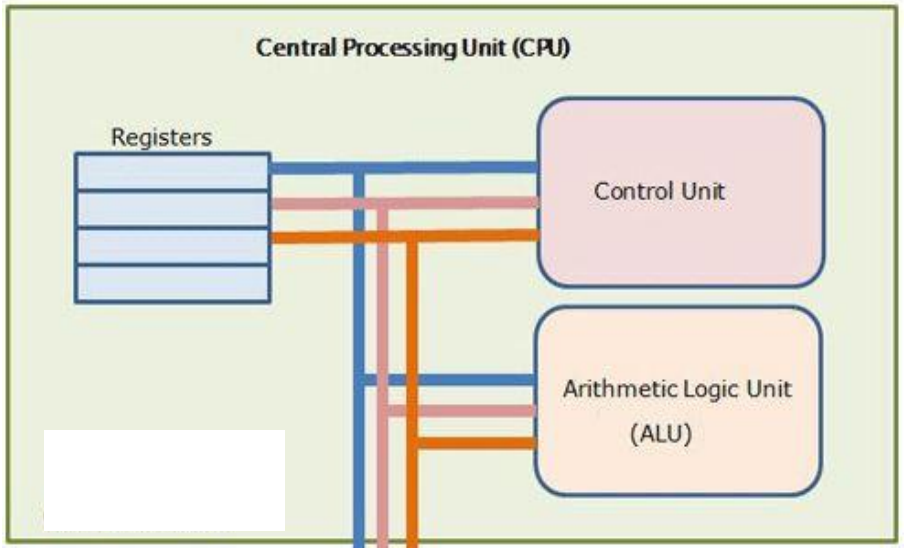
- It performs standard arithmetic operations such as:
  - addition and subtraction
  - multiplication and division
- It deals with logic – using logic gates (AND / OR / NOT)
- comparisons such as ‘is this value greater than that value?’



Registers

A register is a type of temporary memory located inside the CPU.

It is faster to shift data to and from registers rather than RAM so it speeds up processing time.



There are many registers inside the CPU

These are a few:

- The accumulator (A or ACC)
- The program counter (PC)
- The memory address register (MAR)
- The instruction register (IR)
- The memory data register (MDR) or memory buffer register (MBR)

Buses

- A bus is a set of wires or tracks laid down on a printed circuit board.
- Their role is to carry data around the system, connecting the control unit with other components of the CPU and devices in the computer system.
- The **data bus** carries data around the system
- The **address bus** carries information on the location of the data
- The **control bus** handles commands to control devices e.g. hard disk, monitor etc

Fetch –Decode - Execute

The way the CPU is designed and executes the program instructions is known as ‘von Neumann architechure’.

John von Neumann’s design was for a ‘stored program’ computer where both the program and the data are stored in memory.

Previously to this computers had to be rebuilt for each new program.

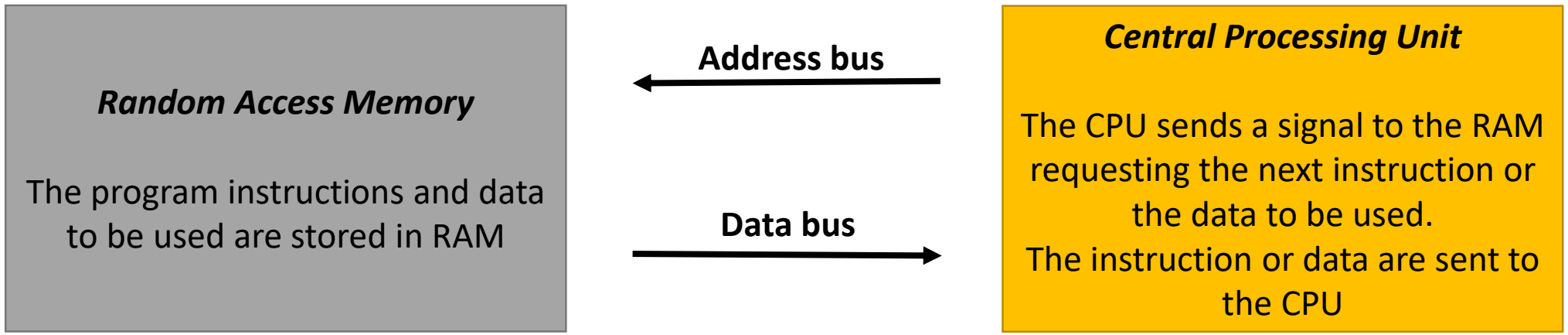
The method designed to execute the programs is known as the:

fetch-decode-execute cycle

Fetch

Draw the diagram in your notes with title

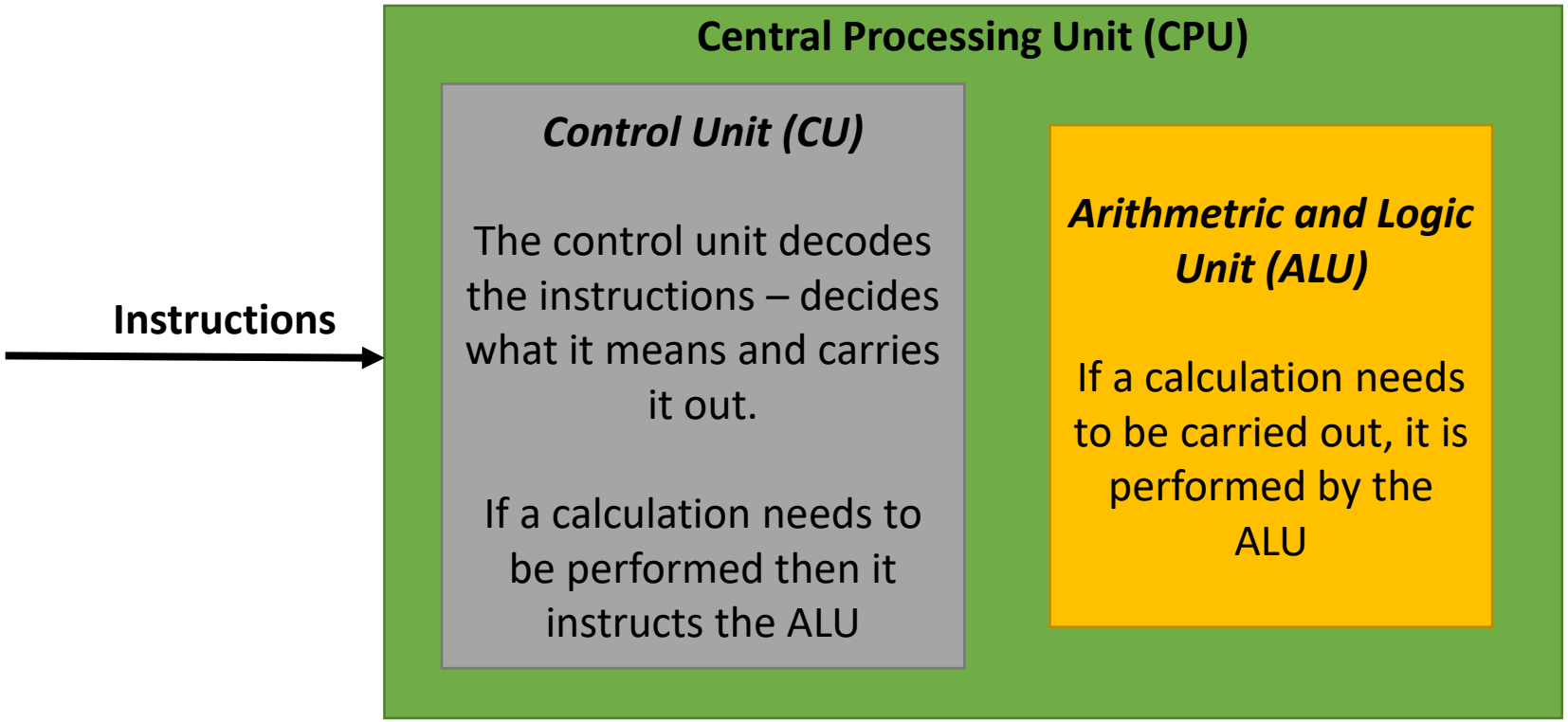
In the fetch part of the cycle, instructions and data are moved from the RAM to the CPU.



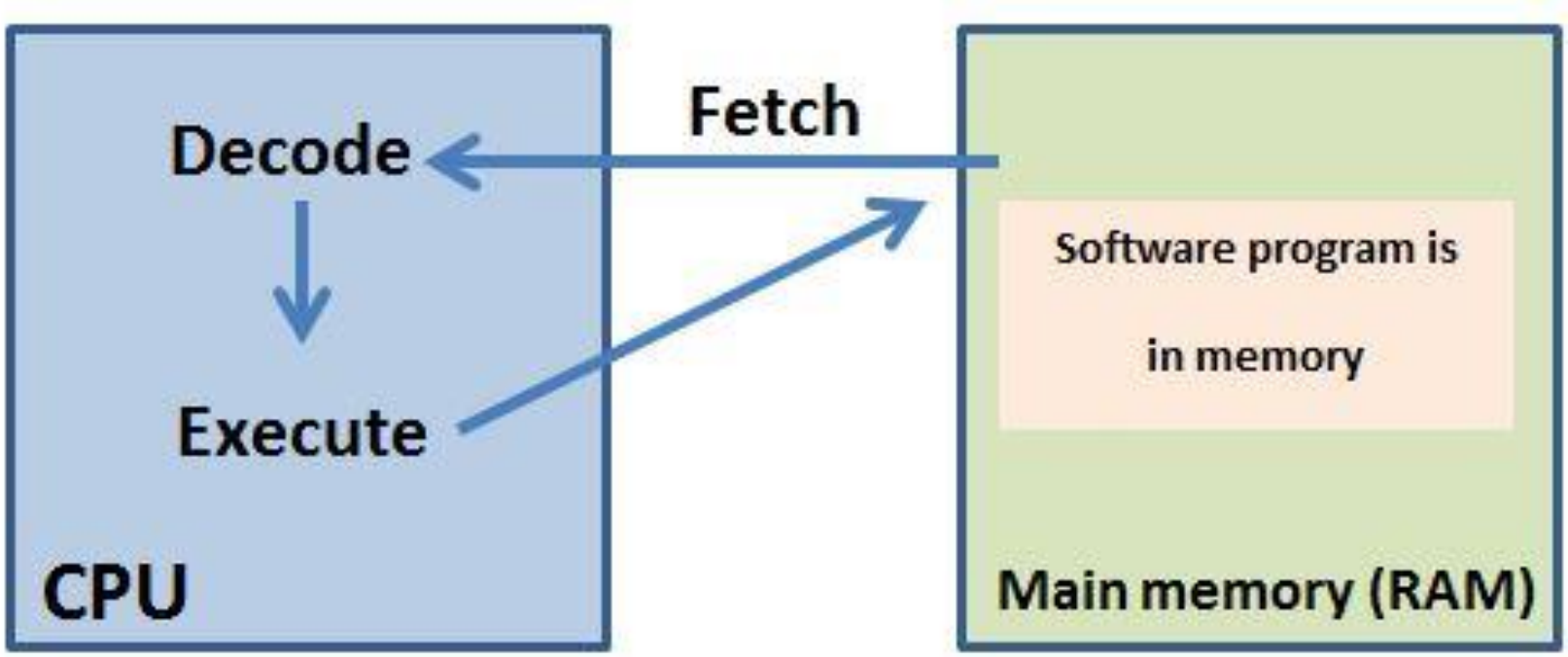
Decode and execute

Draw the diagram in your notes with title

The decode part of the cycle had the control unit interpret the instructions and decide what action to perform. During the execute phase, the instructions are then carried out.



CPU Recap – fetch-decode-execute



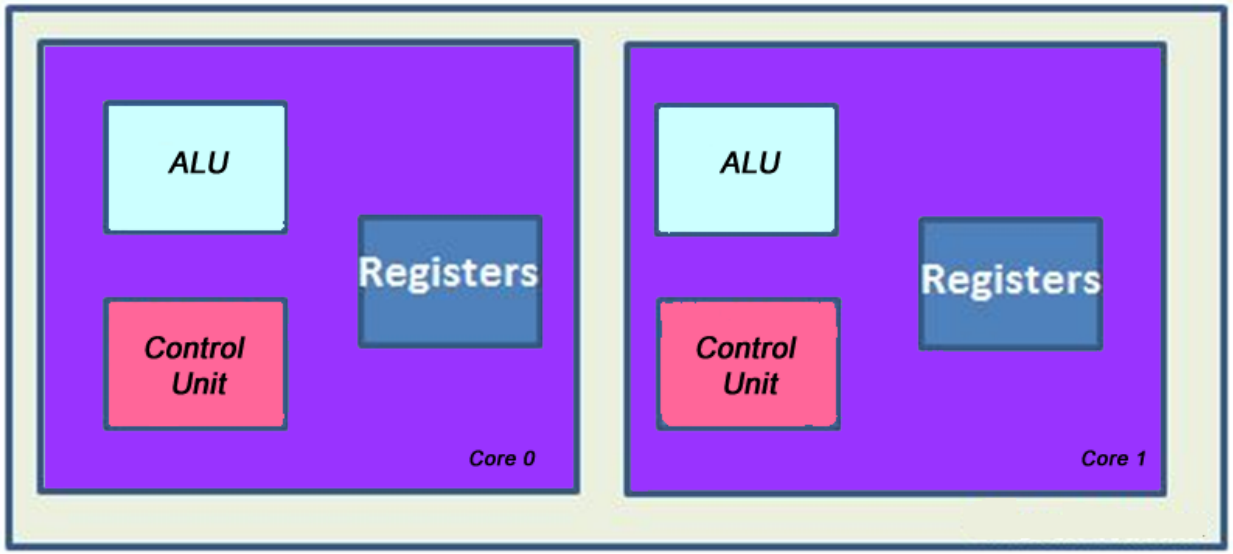
Fetch - instructions and data are moved from the RAM to the CPU.

Decode - the control unit interpret the instructions and decide what action to perform.

Execute - the instructions are then carried out.

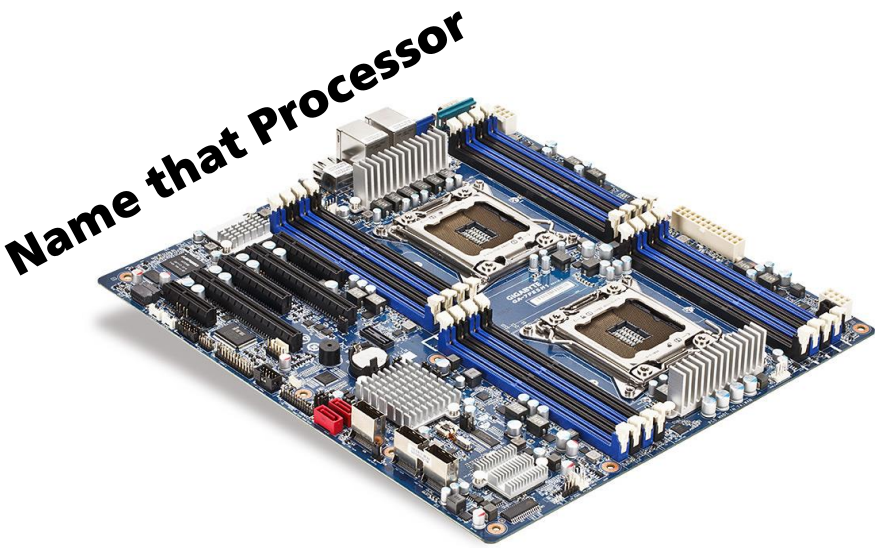
Multi-core processors

- A multi-core processor has more that one CPU
  - Each core has its own ALU, Control Unit and Registers.
- The following diagram illustrates the structure of a dual-core processor



- Having extra cores allows additional tasks to be carried out simultaneously, thus speeding up the processing time.
  - This is called ‘multi-tasking’

Multi-core processors



Number of cores	Common name
1	Single-core
2	Dual-core
4	Quad-core
5	Penta-core
8	Octa(o)-core
10	Deca-core

Advantages

- The cores can work together on the same program, known as parallel processing
- The cores can work on different programs at the same time, known as multitasking

However…

- This doesn’t always double performance as some programs are sequential and cannot easily be split into two parts. Requiring one task to finish before the next can begin

1. The three main factors which affect the performance of a CPU are:

a)

b)

c)

2. During each tick of the clock, how many instructions can be processed?

1 100 1000 1 million

3. How many instructions can a 3 GHz CPU process per second?

4. The higher the clock frequency, the faster the CPU can run

TRUE FALSE

5. There is a limit to the speed that a CPU clock can tick because:

6. To keep the temperature of the CPU down, which of the following are used?

A thermometer A motherboard A heat sink

7. Which of the following ARE part of a CPU core:

Register Heat sink Control Unit Hard disk ALU External cache

1. The three main factors which affect the performance of a CPU are:

   a) The clock b) The cores c) The cache

2. During each tick of the clock, how many instructions can be processed?

   1

3. How many instructions can a 3 GHz CPU process per second?

   3 billion instructions per second

4. The higher the clock frequency, the faster the CPU can run: ***TRUE***

5. There is a limit to the speed that a CPU clock can tick because:

   The faster the clock ticks, the more heat is generated. This can damage the CPU

6. To keep the temperature of the CPU down, which of the following are used?

   A heat sink

7. Circle which of the following ARE part of a CPU core:

   Register Control Unit ALU

9. The cache acts as a temporary buffer between the ***CPU*** and ***RAM***

10. The cache stores instructions and data that are frequently been used, ***have recently been used or are about to be used.***

11. Because instructions and data can be used directly from the cache, it ***speeds up*** processing

12. The CPU will always have its own internal cache: ***TRUE***

13. Cache memory is ***FASTER*** to access than RAM