The CPU

- The **CPU** (***C**entral **P**rocessing **U**nit)* is the 'brains' of the computer.
- The **purpose** of the CPU is to carry out program instructions *(each CPU type is designed to understand a specific group of instructions, the **instruction set**).*
- On personal computers and small workstations, the CPU is housed in a single chip called a *microprocessor*.

A typical modern CPU design showing the pins that connect it to the motherboard

What are the components of a typical CPU?

There are huge variations in CPU designs but most will share the following key components:

- An **electronic clock**
- The **control unit**
- An **instruction unit** which consists of:
  - The **arithmetic logic unit** (ALU)
  - The **floating point unit** (FPU
  - Various **registers** such as the **accumulator.**
- Various **buses**
- The **bus management unit**

typical CPU components – **the clock**

- An **electronic clock** regulates the rate at which the CPU runs and synchronizes all the various computer components.
- The higher the clock frequency, the more instructions the CPU can execute per second.
- The speed of the clock (*and therefore the speed of the CPU*) is measured in Megahertz (MHz).

typical CPU components – **the control unit**

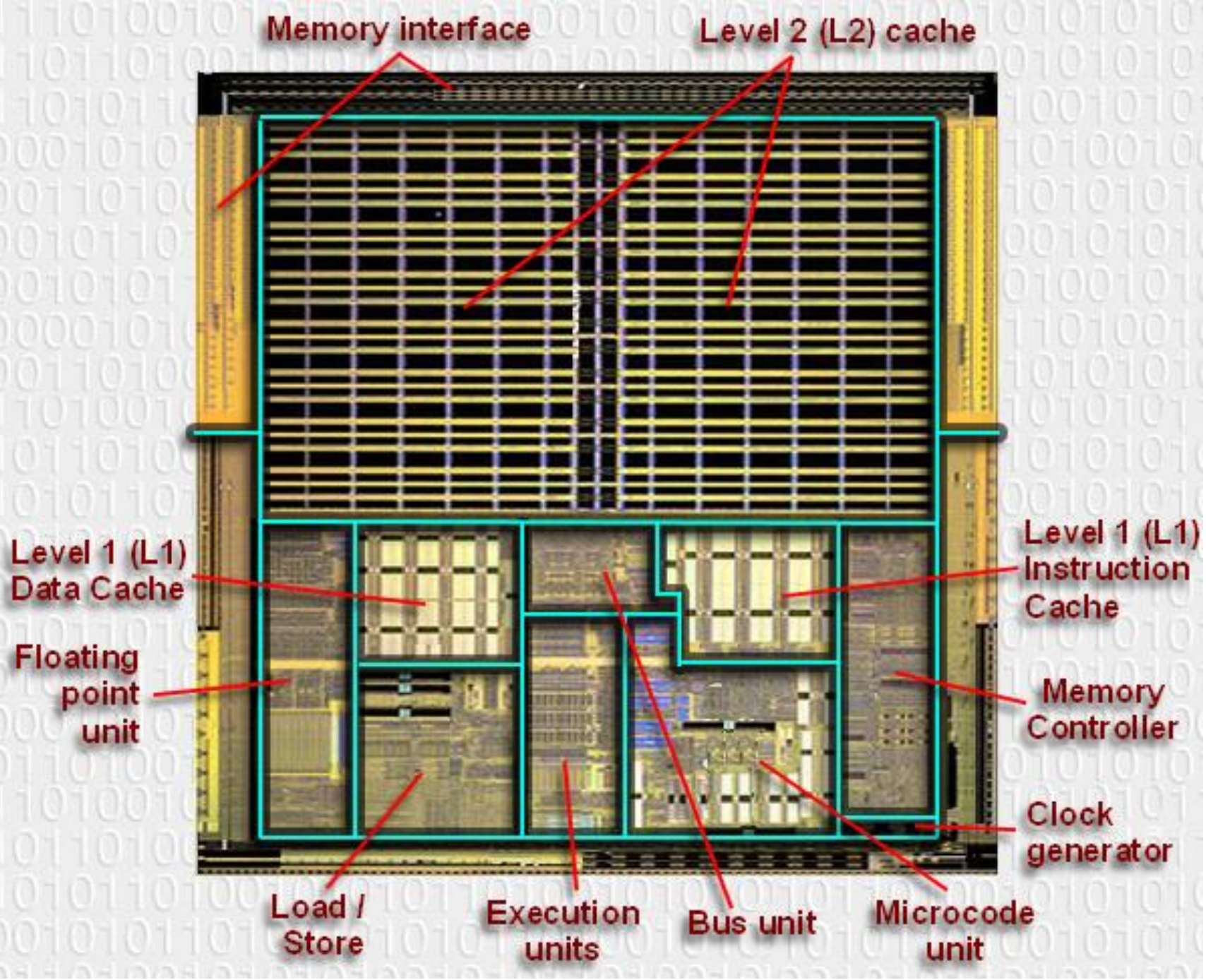
- The **control unit** performs the tasks of:
  - **Fetching** instructions from memory
  - **Decoding** the instructions
  - Managing the **execution** of instructions and the storing of the results
- It does this mainly by controlling the links between the other components of the CPU.
- It also contains various registers such as:
  - the **Program Counter** which stores the memory address of the next instruction.
  - the **Current Instruction register** which stores the instruction currently being executed.

typical CPU components – **the INSTRUCTION unit**

- An **instruction unit** consists of:
  - The **arithmetic logic unit** (ALU) which **executes** basic arithmetic and logical operations on integer data that it is linked to. Examples of such operations include:
    - Integer arithmetic operations (*addition, subtraction*)
    - Logic operations (*AND, NOT, OR, XOR*)
  - The **floating point unit** (FPU) which performs math functions on floating point numbers (*non-integer numbers*).
  - Various **registers** such as the **accumulator** that are used while instructions are being executed.

typical CPU components – **Buses**

- **Buses** are sets of tiny parallel wires that carry data between CPU components and between the CPU and external devices and RAM. The three main bus types are:
  - **address buses** - used to set which **memory address** a CPU component is linked to for a read/write operation.
  - **data buses** - used to **exchange** the **data** between a memory address and the CPU when a read/write operation is carried out.
  - **control buses** - used to **transfer command codes** and return status signals between components of the CPU and external devices.
- The **bus management unit** manages the transfer of data along the external bus connections, including the links to RAM.


Memory interface
Level 2 (L2) cache
Level 1 (L1) Data Cache
Floating point unit
Level 1 (L1) Instruction Cache
Memory Controller
Clock generator
Load / Store
Execution units
Bus unit
Microcode unit

The functions of the CPU

1 - The Fetch step:

- This involves **retrieving** a binary instruction from a memory address and storing it in the **Current Instruction** register.
- The memory address of the instruction is stored in a register called the **Program Counter** (PC) so the CPU can keep track of which instruction is next.
- After an instruction is fetched, the PC is **updated** so the CPU knows the address of the next instruction it has to fetch.

MEMORY ADDRESS						MEMORY CONTENTS							
1	0	0	1	1		1	1	0	0	0	1	1	0

The functions of the CPU

2 - The Decode step:

- This involves the CPU **identifying** the operation code (op-code) part of the instruction which tells it which operation to perform.
- If the op-code requires the CPU to act on some data then the second part of the instruction will contain either the data or the memory address where the data is stored.

MEMORY CONTENTS							
1	1	0	0	0	1	1	0

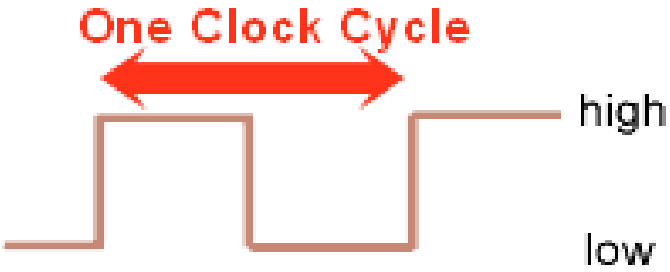
OP-CODE				ADDRESS OF DATA			
1	1	0		0	0	1	1	0

The functions of the CPU

3 - The Execute step:

- In this step the **control unit** links together the parts of the CPU that are needed to **execute the instruction**.
  - If the instruction involved integer arithmetic or logical operations then the **arithmetic logic unit** (ALU) would be connected to the relevant memory locations
  - Some types of instructions **alter the program counter** rather than produce result data. This allows programs to carry out **iteration loops** and **conditional program execution** rather than stepping through instructions in sequence.
  - Some instructions involve an additional **write-back step** if data is written back to RAM.

CPU characteristics vs. performance



The digital signal from the clock controls the rate that the CPU executes instructions

Clock speed:

- Although it might seem that a computer is carrying out many tasks simultaneously, the CPU is actually only ever processing one instruction at a time and is constantly switching between programs (*sets of instructions*).
- The speed that the processor executes instructions is controlled by the *clock speed* and is measured in MHz (***megahertz***).
- The CPU requires a fixed number of clock cycles to perform each instruction.

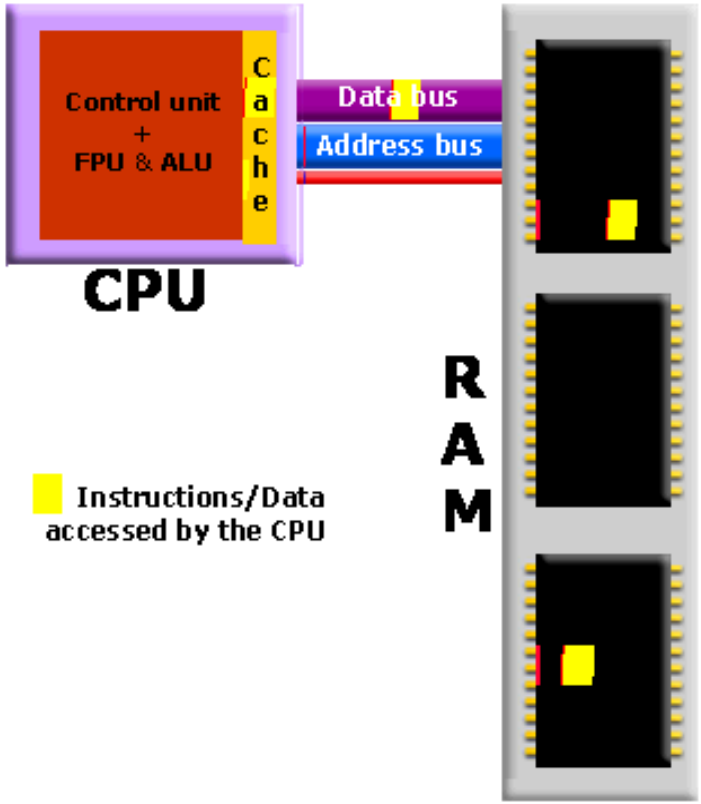
Summary:

- The **higher** the clock speed, the more instructions the CPU can execute per second, resulting in a faster running computer system.

CPU characteristics vs. performance

Cache size:

- Cache memory is a small amount of very fast memory that is built into the CPU. **Blocks** of instructions and data that are in use by the CPU are copied from RAM into cache memory, along with the associated memory addresses.
- If the CPU needs to access a memory address it first checks the cache memory to see if there is a match. If there is then it access the contents of the cache version.



Summary:

A CPU with a larger cache memory and more levels of cache memory will have a higher performance than one without cache memory.

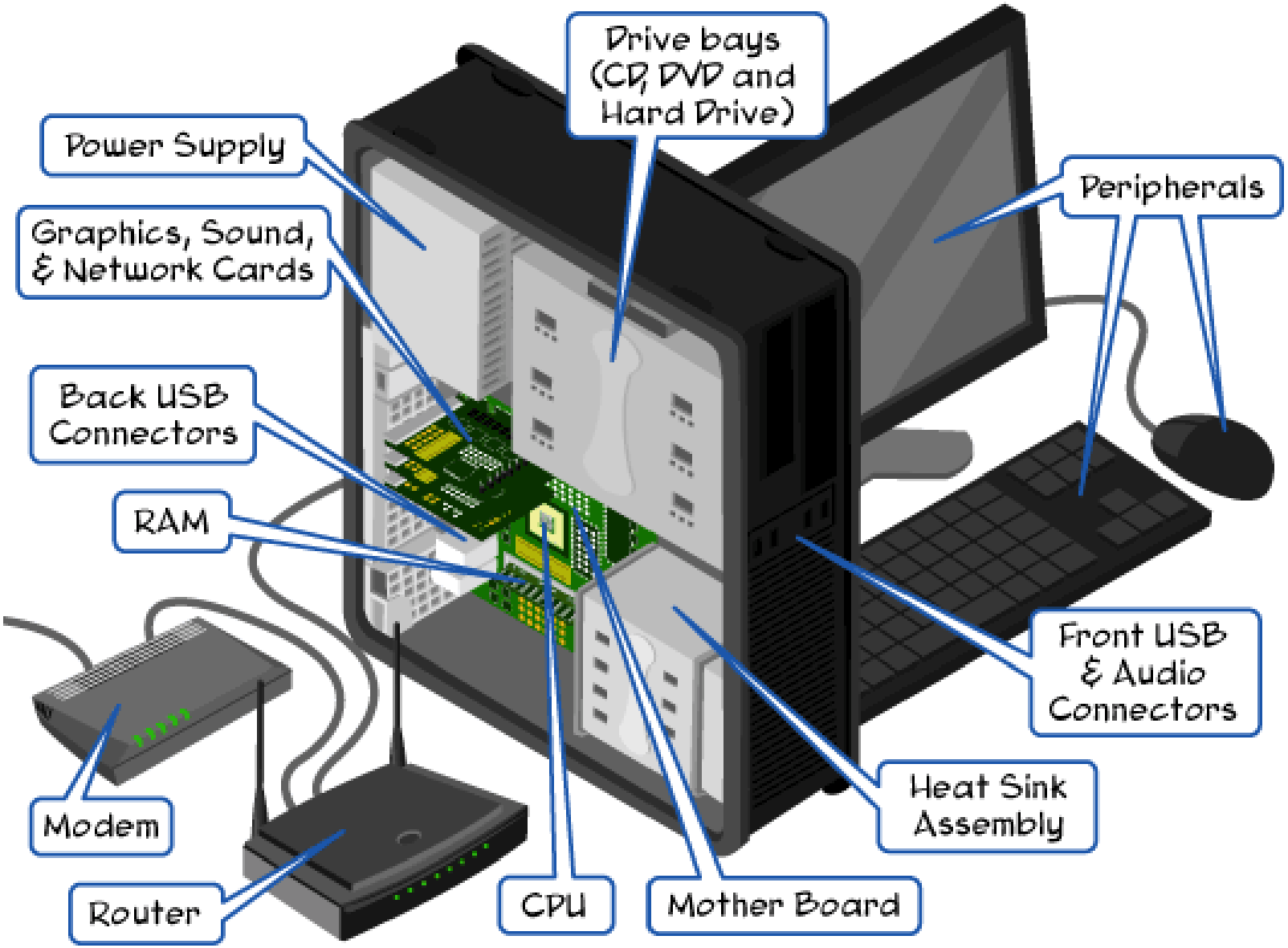
CPU characteristics vs. performance

Number of Cores:

- A multi-core processor is a single computing component with two or more independent actual processors (called "cores").
- A dual-core processor contains two cores and a quad-core processor contains four cores. Each core can process instructions independently of the other cores.
- The biggest performance gain when using a multi-core processor is when the software has been specifically written to run on multiple cores.

Summary:

- A multi-core CPU will have a higher performance than a single-core CPU with the same clock speed.


Drive bays (CD, DVD and Hard Drive)
Power Supply
Graphics, Sound, & Network Cards
Peripherals
Back USB Connectors
RAM
Front USB & Audio Connectors
Heat Sink Assembly
Modem
Router
CPU
Mother Board