Introduction to computer science

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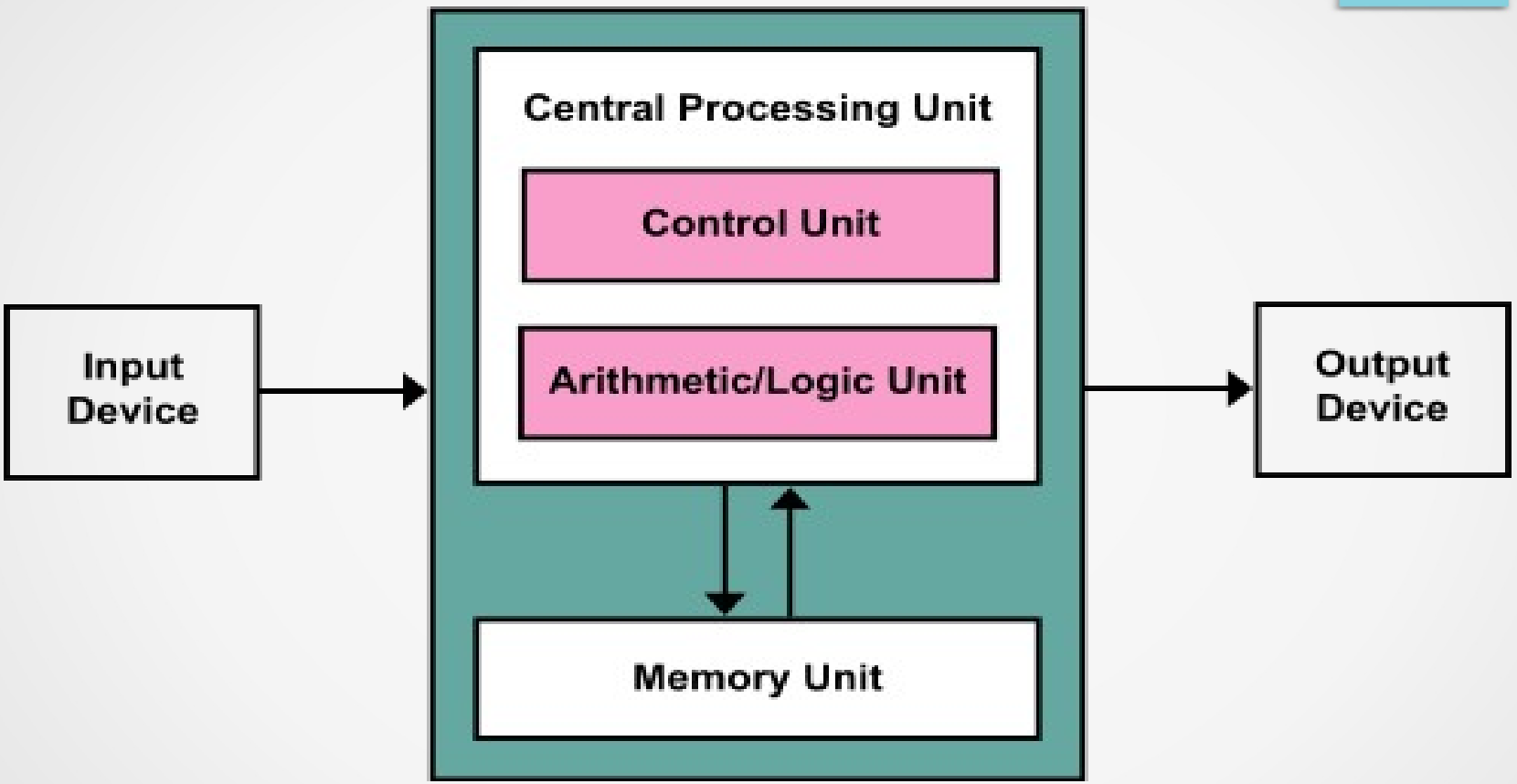
Computer Science

- We can use different definitions such as: computer science is the science of representation and information processing, paraphrasing the study of algorithms that describe and transform information

HARDWARE

Von Neumann (Zuse) Architecture



SYSTEM BUS, connection (Harvard architecture separation between data memory and memory containing the program)

Von Neumann (Zuse)

The architecture described by Von Neumann (Zuse) therefore consists of:

- The CPU and therefore a central processing unit
- A memory device which serves precisely to store the data which are then identifiable by their address
- The various Input Output (I/O) devices that are used to interact with the external user or other systems
- An interconnection line that connects the various subsystems, the bus

Von Neumann (Zuse)

Such a computer is an extremely flexible machine. The hardware provides basic functionality and the software will then specialize the machine so as to perform specific tasks.

We will present the various basic components of the calculator with a "modern" perspective

CPU

C.P.U.

C.P.U. Central Processing Unit, or Central Processing Unit, coordinates and manages all the various hardware devices to acquire, interpret and execute program instructions. Today it consists of a single chip and like each chip it communicates with the outside through the pins. Using the pins it receives signals and sends electrical signals (information consisting of bit sequences)

- Control unit (also known as CU) reads data from the instruction memory and data executes the instructions and copies the results to memory or registers

C.P.U. - A.L.U.

A.L.U. (logical-arithmetic unit) performs the logical and arithmetic operations.

- Closely connected to the ALU is the shifter which performs the shift to the right or left of the ALU result, corresponding to divisions or multiplications by powers of two

C.P.U. - Registers

Registers, in practice internal memory of the CPU that allows you to access data in motion much faster

- Registers: In all CPUs there are always at least two registers:
- IP (Instruction Pointer or Program Counter PC) which contains the pointer to the next instruction to execute.
- Register of Flags. This register is essentially a series of bits that represent a particular state of the CPU, for example the Overflow flag is set to 1 in the event that the result of the operation just performed is too large for the results field

C.P.U. - CLOCK

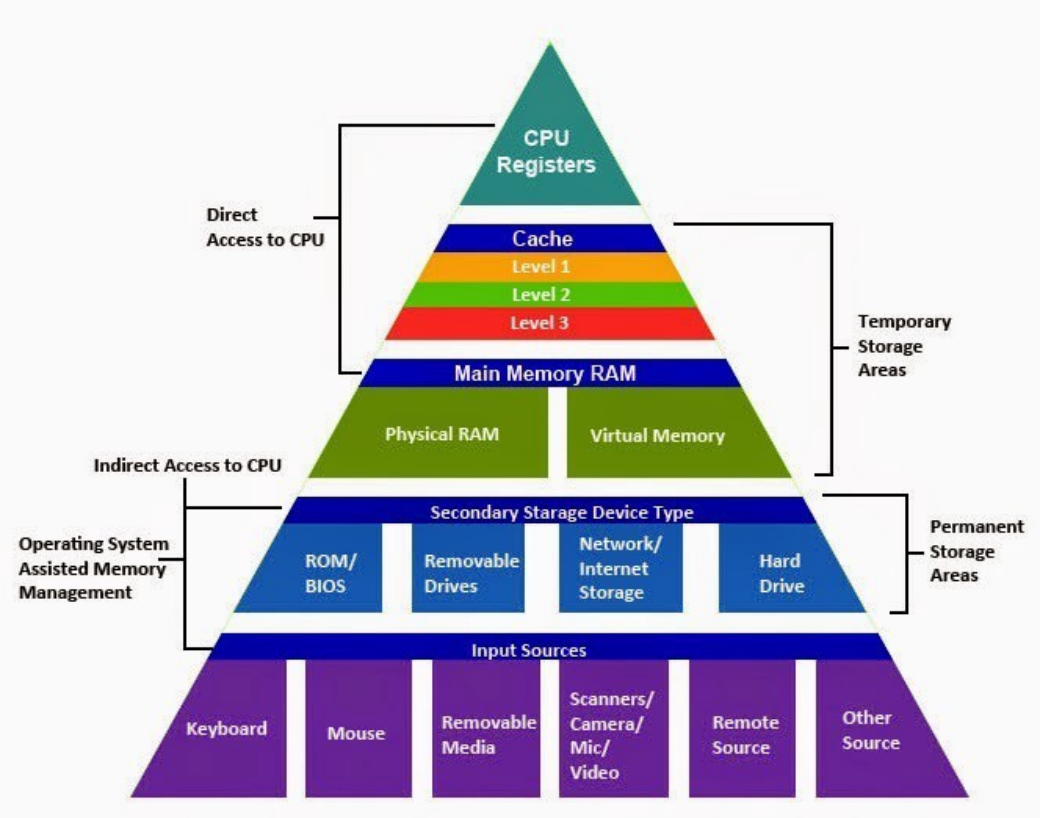
CLOCK: marks the time intervals in which the internal devices of the CPU act. It determines the speed expressed as the number of intervals in the unit of time.

- The state of the CPU changes every time a pulse is sent. So the execution time of a given operation is measured in number of clock cycles.
- An important part of the CPUs is precisely the series of "circuits" that serve to propagate this impulse among all the components of the CPU.
- No CPU can operate faster than the time taken by the clock signal to travel the longest path of this "circuit" of signal distribution, critical path

MEMORY

Memory hierarchy

The memory hierarchy in current processors is made up of different levels, each characterized by data access speed inversely proportional to the size: the larger these areas are, the greater the time required to retrieve the data contained in them.



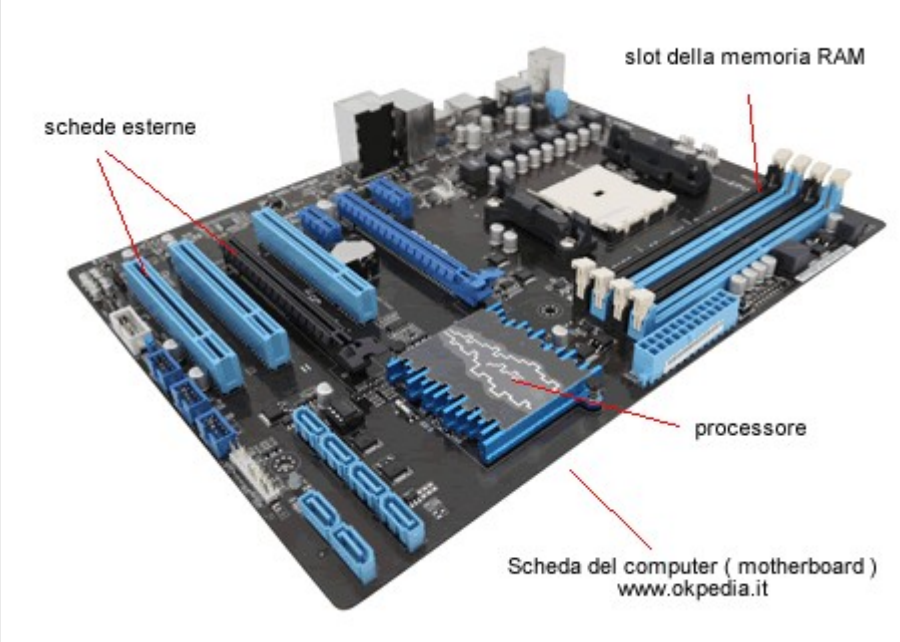
Main Memory

- It is the memory that is directly interfaced with the CPU, for example it is directly connected to the computer motherboard. This allows for a continuous flow of data to and from the CPU.
- This type of memory is characterized by an extremely fast data access speed
- The central memory (also Primary Storage) can be read-only like ROM or read and write like RAM
- N.B. CPU registers are also classified in this category

Main Memory - RAM

- RAM (Random Access Memory). It is divided into memory cells and each cell is identified at an address that is used to read and write access to the data it contains
- The RAM also contains the instructions (opcode) that will be executed and the data on which these instructions will operate
- Features:
  - Volatile: content is lost when the computer is turned off
  - Fast: Approx. 100 clock cycles. Fast therefore expensive
  - Small size compared to the mass memory of the order of a few GiB

Main Memory - RAM



There are several RAM technologies, the most used modernly is **DRAM (Dynamic RAM)**
In practice, each bit is stored in a capacitor (bit 1 or 0 depends on the charge of the capacitor), each capacitor must be recharged periodically otherwise there would be a loss of charge and therefore of information. There are also several technologically different variants of DRAM.

SRAM Static RAM, on the other hand, is memory with a technology that does not require continuous refresh, but is able to keep information for a very long time. Low consumption and short access times, but high construction costs. They are generally used for cache memory

Main Memory - ROM

- R.O.M. (Read Only Memory) high access speed read only memory compared to mass memory
- Allow to store data permanently. This type of memory is used to store the data and the code necessary for the start-up procedure of computers and other programs / procedures (Firmware)
- **BIOS Basic Input / Output System**, in modern systems replaced by **UEFI Unified Extensible Firmware Interface**
- **EPROM Erasable Programmable Read Only Memory,** i.e. programmable and erasable read only memory, They can be erased and rewritten for a generally limited number of times

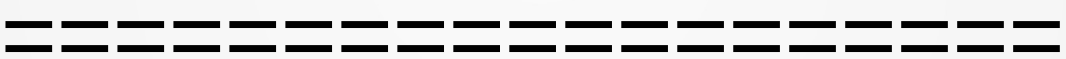
BOOTUP process

BOOTUP process

- **Power-on**: Obviously, the first phase of the process is switching on, which is usually initiated by the user.
  - More recently the ability to allow a "wake on LAN" setting has been added, which makes it easier to switch on over the network, so no physical presence or action of the user is required.
  - As soon as it is powered up, the **CPU executes the code found in the read-only memory ROM** on the motherboard

BOOTUP process

- **POST**: The system then performs a procedure called POST (**Power-On Self Test**), which ensures that all hardware is operational and ready to use. This includes checking memory and hard drives and .... Once POST is finished, the system looks for the first device in the boot order list.
- At this point after the **BIOS or UEFI** Load is completed, the system looks for an active device in the boot device list. When the **BIOS / UEFI** finds an available device, it provides information on basic communications with peripherals and communications on the motherboard itself



Main Memory - Cache

- Cache Generally 1 to 3 levels of cache memory are installed. The cache memory is characterized by different access times and sizes, depending on whether it is inside the chip (on chip) or outside the chip (offchip), and by the technology with which the memory cells are made. (**cat /proc/cpuinfo to see the cache size**)
- The use and advantage of a cache is based on the locality principle that is that a program tends to reuse recently used data and instructions A consequence and a rule of thumb which says that generally 90% of the total time is spent running 10% of the instructions. To be more precise, the use of the cache is advantageous when both the **spatial location and the temporal location of the data are exploited.**

Secondary Storage

- **Unlike the central memory, it is not directly accessible from the CPU, but the CPU communicates with a controller (I/O bus)**
- The data is transferred from the secondary memory to an area in the main memory and read from there directly by the CPU
- Physically these devices are connected to the motherboard with a high speed cable or by cables connected to external interfaces

They can be made with magnetic, optical or solid state technology

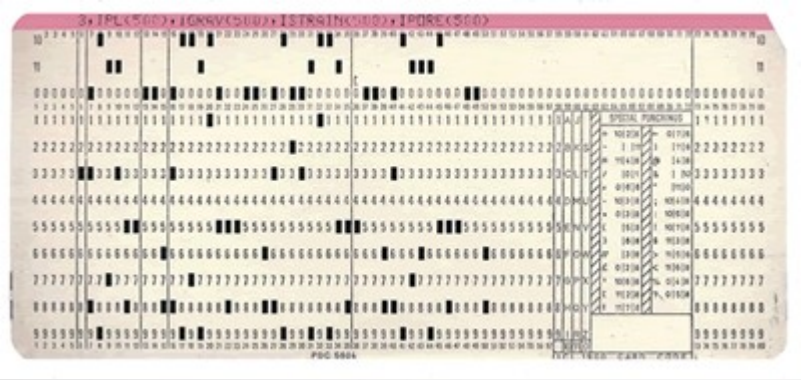
Secondary storage

Consisting of hard drives, CDs, DVDs, solid state drives, tapes

- Non-volatile, so the data remains stored when the computer is restarted
- Slow compared to RAM (> 10000 cycles), obviously very variable depending on the type of media
- On average cheaper or in any case cheaper than DRAM or SRAM
- Large (now hundreds of GiB or some TiB)
- They can be both read-only and read and write (think of HARD-Disk and DVD-ROM)

Secondary storage – Long time ago

- Punch cards, is the first secondary memory in the history of computers. The data is stored on cardboard and recorded by perforation, and subsequently read by the computer
- Punch tapes similar to punch cards



Secondary storage – magnetic tapes

- In this case the data is stored on a tape in magnetic form. These were historically used in mainframes (large computers capable of processing very quickly and storing large amounts of data) of the 70-80s, but also used today for data backup

Secondary Storage – Hard-Disk

- Composed of several magnetic plates superimposed on each other and **rotating**
  - The data is stored on both sides of the individual platters and is organized into tracks and sectors
  - The heads serve and read and write data
  - The rotation speed of the platters (rpm revolutions per minute) is one of the determining factors in the speed of reading and writing
- **SSD solid state drives** lower latencies less susceptible to breakage due to mechanical shocks

Secondary Storage – Removable

- It can be removed and separated from the computer
- **CDs and DVDs**, both read-only and read and write, data are stored and read using a laser light (the basic idea is simple reflection or non-reflection to identify 1 or 0 bits)
- **USB flash drive**
- **Foppy-disks** no longer used

USB

- 3.0 light blue or dark blue
- 2.0 black, white, gray
- 3.0 backwards compatible
- 3.0 150 mA (4.5 w)
- 2.0 100 mA (2.5 W)

- **There is also a noticeable difference in the data transfer speed which goes from 480 Mbit / s to 5 Gbit / s in the case of USB 3**
- **USB Type-C (3.1) powers devices up to 100W and allows a data transfer rate of 10 Gbit / s (different connector)**