COMPUTER ARCHITECTURE

HARDWARE, FIRMWARE, AND SOFTWARE

Hardware refers to the set of physical devices that make up a computer, including electronic circuit boards, integrated circuits, microprocessors, memory, peripherals, and more.

Firmware is a block of program instructions for specific purposes, stored in non-volatile memory (ROM, EEPROM, flash, etc.), which establishes the lowest-level logic that controls the electronic circuits of any type of device. Since it is integrated into the device's electronics, **it is partly hardware but also software**, as it provides logic and is written in some form of programming language. Functionally, firmware acts as the intermediary between the external commands received by the device and its electronics, as it is responsible for controlling the latter to correctly execute those external commands. We find firmware in the ROM of various peripheral devices, such as video monitors, disk drives, printers, etc., but also in microprocessors, main memory chips, and generally in any integrated circuit.

Software is the set of instructions necessary to control the hardware so that it performs the tasks assigned to it. Software includes operating systems and application programs (word processors, audio and video players, games, email clients, etc.).

The evolution of hardware and software can be summarized in the following statements:

1. - Hardware: Achieving faster machines that can process and store larger amounts of information.
2. - Software: Development of new applications or programs that make better use of existing hardware.

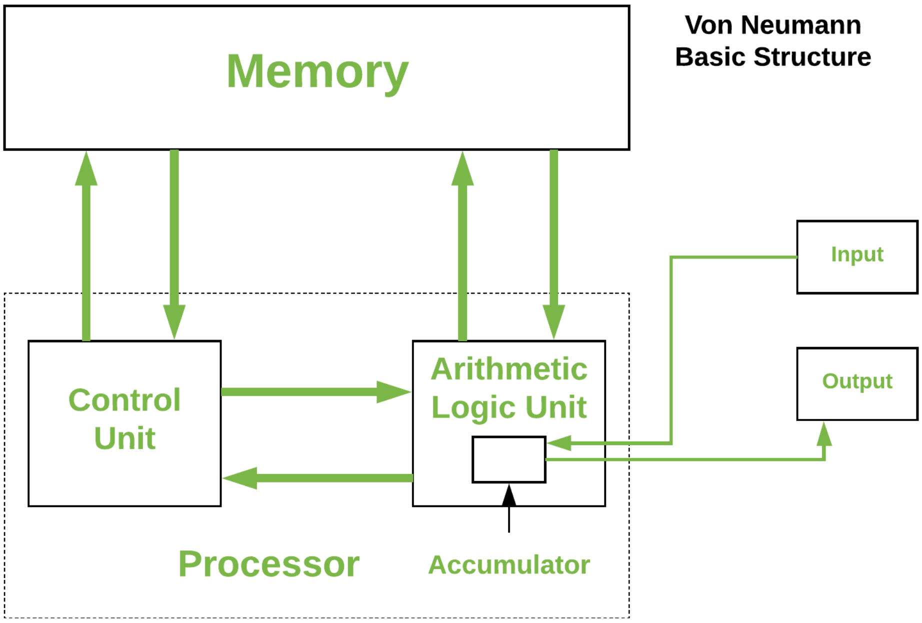
VON NEUMANN ARCHITECTURE

Von Neumann described the structure of all electronic computers. He explained how a computer could operate with its units permanently connected and how its functioning could be coordinated from the control unit (Microprocessor or CPU).

Von Neumann Architecture which is still relevant today gathers the different devices in the following blocks:

- **CPU** (Central Processing Unit or Processor in the image) which contains:
    1. **Control Unit** which is responsible for the communications between the memory and the CPU.
    2. **ALU** (Arithmetic and Logic Unit) which is responsible for the decoding and interpretation of the instructions.

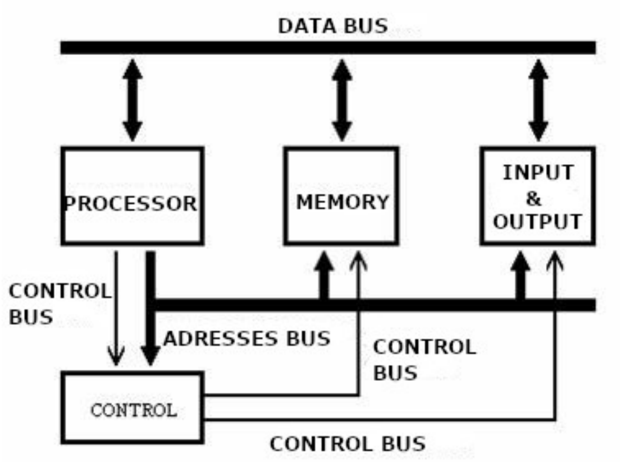
- **Main memory** (where the instructions and the data are stored)
- **Input -Output Units** which processes data from the peripherals or show data to the user.



The arrows on this diagram are representing buses. These are the channels through which all information flows in the computer allow communication between the different units, memory, and peripherals. Buses can be traces on a printed circuit board, conductive wires, integrated circuits, or electronic components such as capacitors, etc. The number of lines depends on the computer's architecture (8, 16, 32, or 64 lines), corresponding to the number of bits that can be transferred simultaneously (bus width).

Three **types of buses** are used:

- **Address bus** - carries memory addresses from the processor to other components such as primary storage and input/output devices. The address bus is *unidirectional*.
- **Data bus** - carries the data between the processor and other components. The data bus is *bidirectional*.
- **Control bus** - carries control signals from the processor to other components. The control bus also carries the clock's pulses. The control bus is unidirectional.



1.The Central Processing Unit (CPU)

- **The CPU** is the unit responsible for controlling and governing the entire system that makes a computer. The CPU consists of an integrated chip made up of millions of transistors, designed to process data and control the machine. It is a key factor in the computer's power. **The CPU has two units inside it: the control unit and the arithmetic-logic unit.**

Tabla de memoria

Dir.	Contenido
0000	00000100
0001	00000101
0010	01100111
0011	01110000
0100	00000101
0101	00001011
0110	00000000
0111	00000000

1.1 Control Unit:

- **The Control Unit** is responsible for reading the instructions (from the programs stored in memory) and sending commands to the processor components to execute those instructions.

1.2 Arithmetic-Logic Unit:

- **Arithmetic-Logic Unit (ALU).** The arithmetic-logic unit is responsible for performing all arithmetic operations (addition, multiplication, etc.) and logical operations (comparisons).

2. Main Memory:

Main Memory. A computer contains various types of memory, each of which with different functions: RAM, cache memory, ROM, etc. Additionally, it is important to notice that almost all devices in a computer come with their own built-in memory such as printers, video cards, the microprocessor itself, the hard drive, and more.

- **The RAM (Random Access Memory):**

RAM memory is quite simple compared to the CPU; it could be described as a table that contains the address (or location) where a certain piece of data is stored and the content of that data itself. The memory has an address register (AR or Dir in the picture) and a memory data register (MDR or data register or “contenido” in the picture). The address register stores the address where a piece of data will be stored or read, and the memory data register holds the data that has been read or will be stored.

The control unit contains the program counter register, which holds the memory address of the next instruction. This counter increments after executing an instruction, allowing it to traverse the memory and execute the program.

Main RAM
Its function is to have instructions and data ready so the CPU can process them, and temporarily store the results of the operations performed by the CPU.

Characteristics:

- **Random access:** Information is not stored sequentially.
- **Read and write capability:** Information can be read and written.
- **Volatile:** Its content is lost when the computer is turned off.

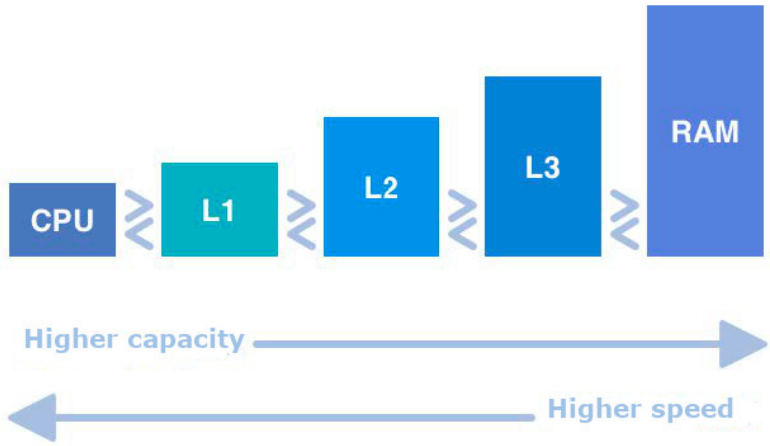
Functioning: It is like a large panel made up of a set of cells, called memory locations, where data is stored. The computer must know the exact memory location of each piece of data, so these locations are identified by a number called a memory address. Each memory location stores one byte, which highlights the vast number of locations needed to store instructions and data. Additionally, both applications and some newer operating systems require a large amount of memory, making it necessary to have at least 4 to 8 GB available.

RAM Modules: For quite some time, it has been easy to increase a computer's RAM. All you need to do is purchase memory modules and plug them in the RAM memory slots on the motherboard.
The most widely used are known as **DDR modules**. Currently, we can find DDR3 and DDR4 memory modules available. All of these are based on **SDRAM** (Synchronous Dynamic Random-Access Memory). **DDR3 modules** (Double Data Rate type 3) have 240 pins and support chips from 1 GB to 8 GB, with the potential to handle modules up to 16 GB therefore as you can deduce, the number of pins determine how powerful the RAM memory is. With 288 pins, **DDR4 chips** began to be used in computers since 2014 and were available in standard computers by 2015. **DDR4-DIMM** (Double Data Rate type four Synchronous Dynamic Random-Access Memory) speeds have improved dramatically, starting from 1,066 MHz and beyond.
Its main advantages over DDR3 are:
1.- A higher clock frequency.
2.- A higher data transfer rate (1600 to 4400 MHz compared to DDR3's 800 MHz to 2400 MHz).
3.- A lower voltage requirements (1.45 V to 1.05 V for DDR4, and 1.65 V to 1.2 V for DDR3).

Cache Memory: Cache memory is a type of RAM, much faster than conventional memory. Its function is to store information, but in this case, the cache will hold instructions or data that the microprocessor has just used or is about to use.

Types:

- **First-level internal cache (L1):** This memory is located inside the microprocessor. It is the fastest one. However, it has limited capacity.
- **Second-level internal cache (L2):** Also located inside the microprocessor, it is slightly slower but has a higher capacity than L1.
- **External or third-level cache (L3):** This memory is located between the microprocessor and the RAM to speed up the transfer of information between them.



Virtual Memory:

All operating systems use part of the hard drive to simulate RAM, thereby increasing the total memory available on the computer. This memory is generally known as virtual memory, although depending on the operating system, it may be named differently, such as **swap memory** in Linux.
Virtual memory is slower than RAM (since it is stored on the hard drive), therefore, it is preferable that the system uses it sparingly. If the computer has a large amount of RAM, the operating system will rely less on virtual memory.

ROM-BIOS Memory:

ROM (Read Only Memory) is read-only, meaning data cannot be written to it. It contains information pre-recorded by the manufacturer that does not disappear when the computer is turned off.

The **BIOS** (Basic Input Output System) is essential for starting up the computer, as it contains instructions for performing the initial system check, as well as technical data about the most basic components connected to the system.

When a computer is powered on, the BIOS checks the following components in this order:

1. The CPU
2. The system bus to verify that all peripherals are working correctly
3. The system clock
4. The RAM

5. The keyboard
6. The mouse
7. the disk drives.

The information obtained is compared with what is stored in the **CMOS** memory, detecting any changes in the components or system configuration. If the check is successful, the operating system begins to load; otherwise, the system emits a beep or series of beeps and informs of the problem.

CMOS RAM Memory:

CMOS RAM is a small amount of memory built in a chip on the motherboard whose function is to store part of the system's configuration: clock information (date and time), and configuration data for peripherals not controlled or checked by the BIOS.
Since it is RAM and contains information that must not be lost when the computer is turned off, CMOS memory is constantly powered by a battery.

MOTHERBOARD, CHIPSET, MICROPROCESSOR, AND GPU

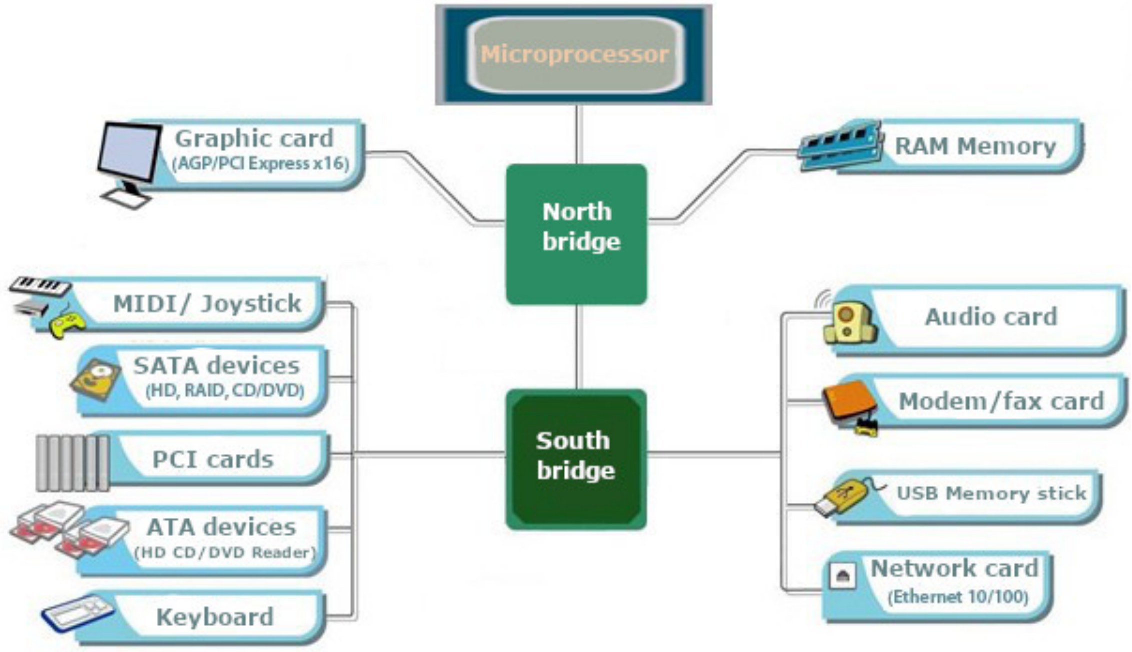
The **motherboard** (also called mainboard or system board) is a platform (printed circuit board) where all other components are connected, either directly or through expansion slots, such as the microprocessor, RAM memory, hard drives, keyboard, monitor, printer, mouse, scanner, etc.

Expansion or PCI slots are used to insert smaller boards, known as “daughter boards or expansion cards”, which allow various external peripherals to be connected to the computer. Notable examples include the video card, sound card, etc. (Most modern motherboards already have some cards integrated, typically the video card, sound card, and network card).

AGP or PCI express slots are used to insert the Graphic card which is responsible for the screen management. Graphic cards must manage a lot of information in short periods of time, this is why they usually have their own microprocessor which is even more powerful than the microprocessor of the motherboard.

Chips (integrated circuits): These are present in the motherboard, expansion cards, and all devices connected to the computer. They are made from a thin silicon wafer on which millions of electronic tracks form circuits. Externally, they are covered with a plastic casing, with metal pins exposed for connection. Depending on their circuit design, each chip performs a specific task.

Chipset: This is a set of chips located on the motherboard. It is kind of a traffic policeman trying to regulate the flow of information throughout the motherboard. The chipset is also responsible for important tasks such as managing external peripherals through communication ports and expansion slots, as well as controlling data transfer between the microprocessor and memory. It usually consists of two chips, commonly referred to as **North bridge and South bridge.** The former communicates directly with the microprocessor. Both chips also communicate with each other and with other components on the motherboard. **The quality of the motherboard largely depends on the model of the chipset it has, and the chipset also determines the type of microprocessor that can be installed on the board.**



The Microprocessor or CPU: This is the most important chip, often referred to as the brain of the computer, as it is responsible for carrying out all data processing operations and controlling the functionality of all the computer's devices.

To process data, the microprocessor needs both, the instructions for the process (provided by the program in use) and the actual data itself. Additionally, this information must be available in memory; the result of the data processing is sent by the CPU to the RAM, from where it can be distributed to the other devices in the computer. Therefore, the CPU does not execute programs or process data directly from storage devices but from the RAM only. This is why the data must first be loaded into memory. As discussed earlier in the second section of the topic, the CPU contains the Arithmetic Logic Unit (ALU), the Control Unit (CU), and registers. Many modern processors also include a Floating-Point Unit (FPU), which handles operations with decimal numbers.

An important feature of microprocessors is their bus, as it determines the number of bits that can be transmitted simultaneously. Currently, the bus width of microprocessors is 64 bits, although there are still computers with a 32-bit bus. On the other hand, the ability to maintain microprocessors working in parallel allows for multitasking without causing excessive overheating of the device. This has led to the design and production of so-called multicore processors, which contain several independent microprocessors in a single component, each with its own individual memory, and all connected to a shared memory and a bus that links to the external components.So far, processors with up to 16 cores are available for desktops and laptops.

The clock determines the operating speed of the PC. It measures the number of operations performed in one second, which is the frequency, measured in Hz (Hertz) (1 Hz is one operation per second). For instance, a CPU with a speed of 1.4 GHz processes 1.4 billion operations per second.

Note: Although people usually refer only to the speed of the microprocessor, there are other equally important speeds, such as bus speed and RAM speed.

GPU (Graphics Processing Unit): A GPU is a coprocessor dedicated to handling graphics processing or floating-point operations, relieving the central processor (CPU) of these tasks in applications such as video games or interactive 3D software. This allows the GPU to handle most of the graphics-related tasks, while the central processing unit (CPU) can focus on other types of calculations (such as artificial intelligence or mechanical calculations in video games).

The GPU implements certain graphic operations, known as primitives, that are optimized for graphic processing. One of the most common primitives in 3D graphics processing is **anti-aliasing**, which smooths the edges of objects to give them a more realistic appearance. Additionally, there are primitives for drawing rectangles, triangles, circles, and arcs. Modern GPUs feature a wide range of primitives, aiming for increased realism in effects. GPUs are found in graphic cards.

CONNECTORS AND COMMUNICATION PORTS

All the devices that make up the computer must be connected to each other to close all the buses in the computer. Many of the computer’s devices (especially internal ones) are connected to the motherboard via specific internal connectors. The Input/Output peripherals, being outside the CPU, must be connected through external connectors or ports, which are usually located at the back of the computer, though they can also be found on the front or top.

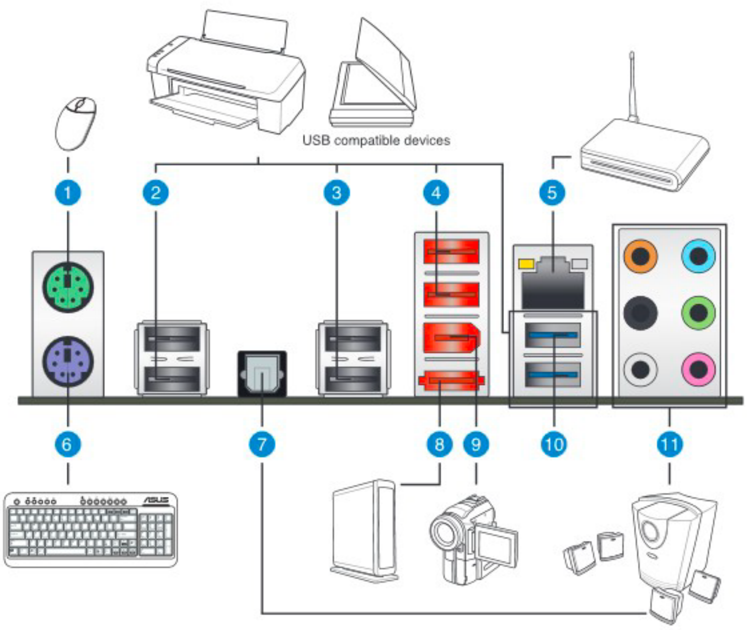
Specific connectors:

Peripherals such as the keyboard and mouse, are usually identified by a graphic symbol or different colors in the PS/2 connectors or ports. Nowadays, USB-connected keyboards and mice have become commonplace and there are wireless keyboards and mice that don't require cables to connect to the computer, as they transmit information via infrared (IR).

Communication ports:

These are a set of generic connectors that can accommodate various external devices.

- **USB ports:** These are high-speed serial ports that can connect up to 127 devices in a daisy chain. Another key feature is that they allow devices to be connected and disconnected without shutting down the computer. USB ports have evolved from USB 1.0 and 1.1 to USB 2.0 and USB 3.0. The main difference is the data transfer rate, progressing from the initial 1.5 Mbps, to 12 Mbps with USB 1.1, 480 Mbps with USB 2.0, and up to 10 Gbps with USB 3.1 (see Annex 5 of this topic).
- **IEEE 1394, FireWire (Apple computers), or i.Link ports (for Sony):** These are a standard with a data transfer speed similar to USB 2.0 ports. They also allow hot swapping of devices (connecting and disconnecting without shutting down the computer) and are commonly used for video transfer, such as from a digital camcorder.
- **Infrared ports (IrDA):** These allow devices to connect without cables. Their data transfer speed is lower than that of USB and FireWire ports, reaching a maximum of 4 Mbps. These ports are typically used for exchanging information with pocket computers, mobile phones, etc.



Rear panel connectors	
1. PS/2 mouse port (green)	7. Optical S/PDIF Out port
2. USB 2.0 ports 1 and 2	8. External SATA port
3. USB 2.0 ports 3 and 4	9. IEEE 1394a port
4. USB 2.0 ports 5 and 6	10. USB 3.0 ports 1 and 2
5. LAN (RJ-45) port*	11. Audio I/O ports**
6. PS/2 keyboard port (purple)	

3.INPUT/ OUTPUT UNITS

3.1 INPUT PERIPHERALS

Input devices allow information to be entered into the computer from external sources.

- **Mouse:** It allows information to be transmitted to the computer in two ways:
  - By moving it across a surface to cause the movement of its pointer on the screen.
  - By pressing its buttons to perform certain actions depending on where the pointer is located.
- **Keyboard:** The most common way of entering information into the computer. There are various types of keyboards, with options to connect to different ports and even wireless keyboards that use infrared data transmission.
- **Barcode readers:** Barcodes are a set of black vertical lines of varying thickness. They are commonly used in supermarkets, warehouses, stores, etc., to identify different products. A barcode reader is a device capable of reading and interpreting this sequence of bars, allowing the computer to identify the product and retrieve information such as its name, price, etc.
- **Scanner:** This device allows information from printed documents, such as images, drawings, photographs, and even text, to be input into the computer. For text, an Optical Character Recognition (OCR) system is required. The quality of a scanner is measured in dpi (dots per inch), which indicates the number of points it captures per inch (2.54 cm).
- **Joystick or game controller:** Mainly used for video games, it inputs movements made on its stick into the computer, along with specific commands (such as firing) by pressing a button. It is also used for navigating 3D environments.
- **Graphics tablets:** These boards are used for creating drawings and graphics with great precision. They are commonly used in drawing applications, particularly in professions that require detailed drawings, such as draftsmen, architects, graphic designers, and illustrators.
- **Magnetic stripe readers:** The use of magnetic stripes is increasingly widespread (credit cards, personal ID cards, etc.). Magnetic stripe readers are devices that can read the information recorded on these stripes.
- **Touchscreens:** In addition to displaying information (output device), touchscreens allow users to input information by simply touching the screen with their finger, for example, to select an option, execute a command, or retrieve information.
- **Tablet PC:** These are an evolution of laptops or PDAs, with sizes in between the two. They typically have a 10-inch screen that serves as both a display and input device, similar to how PDAs function.
- **Digital cameras:** These devices allow images and videos to be input into the computer. Notable types include:

- **Digital still cameras:** Their digital images can be downloaded to the computer for editing (special effects, photo retouching, printing, etc.).
- **Digital video cameras:** In addition to transferring their digital recordings to the computer for editing, they can be used to stream real-time video.
- **Webcam:** A small digital camera connected to a computer that can capture images and transmit them over the internet, either to a webpage or to other computers in private settings.

- **Microphone:** Used as an input device, provided the computer has a sound card. It also allows, with specific voice recognition software, the user to dictate the content of a document or give voice commands to the computer.

3.2 OUTPUT PERIFERALS

Output devices allow results to be obtained in various forms: visible on a screen, printed on paper, on transparency film, or microfilm, etc.

Monitors:
Essential for the computer, monitors allow users to visualize the results of processed information, and the computer also uses the monitor to display messages and options that help users make decisions. Currently, monitors are typically of the following types:

- **Flat LCD screens (Liquid Crystal Display):** These monitors, evolved from calculator and laptop screens, use millions of liquid crystal cells that polarize and allow the passage of certain rays, which compose the image on the screen.
- **Flat TFT screens:** Composed of a matrix of millions of points, each point is a transistor that operates independently with its color, brightness, tone, etc., forming a high-quality image.
- **Plasma screens:** Flat monitors, usually large, based on the use of gas (plasma) that, in each pixel on the screen, takes on the color, brightness, etc., necessary to form the image.
- **LED screens:**

Two important parameters for monitors are:
• **Refresh rate:** The number of times the screen is refreshed per second, measured in Hz. If the refresh rate is low, the image will flicker.
• **Resolution:** This depends on the number of pixels, which is calculated by multiplying the number of rows by the number of pixels per row (columns). The number of colors also influences image quality.
Example: 1024 x 768 means 1024 columns and 768 rows, thus 786,432 pixels.
To display an image with a certain number of colours, a specific number of bits is required to provide information for each pixel. The image creation speed depends

solely on the GPU of the video card, not on the amount of graphic RAM, which only affects the resolution and number of colours that can be activated.

Printers:
Printers allow information to be output onto physical media such as paper, transparencies, etc. Although traditionally connected via a parallel port, they now connect through USB ports. There are also wireless printers, such as Bluetooth printers, and printers with a built-in network card.
The quality of a printer is measured in dpi (dots per inch), which indicates the number of dots printed per inch. Speed is measured in cps (characters per second) or ppm (pages per minute).
Types:

- **Thermal printers:** These printers work by heating the paper to create an image. They are generally low-cost but slow and are often used for printing receipts.
- **Laser printers:** They use technology similar to photocopiers. Laser printers are faster and produce high-quality results. Color laser printers are becoming more common.
- **Inkjet printers:** Due to their good quality-to-price ratio, these are the most widely used among personal computer users. Initially, they only printed in black and white, but modern models print in color using liquid ink injected through nozzles. Newer inkjet printers can produce high-quality prints, even suitable for photographs.
- **Plotters:** These are used for computer-aided design (CAD) applications, allowing the printing of plans, technical drawings, maps, industrial designs, etc., with excellent quality. Technically, a plotter consists of a robotic arm with a pen at the end. They offer several advantages over printers:
    1. They draw continuous lines, producing high-quality figures (circles, curves, etc.).
    2. They can use large-format paper.

Speakers:
Speakers allow sound output, playing audio files, videos, and more.

3.3 INPUT AND OUTPUT PERIPHERALS

Nowadays, there are peripherals that work both as input and output devices without being storage devices. Examples include: touchscreens, multifunction devices that combine a printer, scanner, and photocopier, interactive joysticks, etc.

4.PERMANENT STORAGE DEVICES:

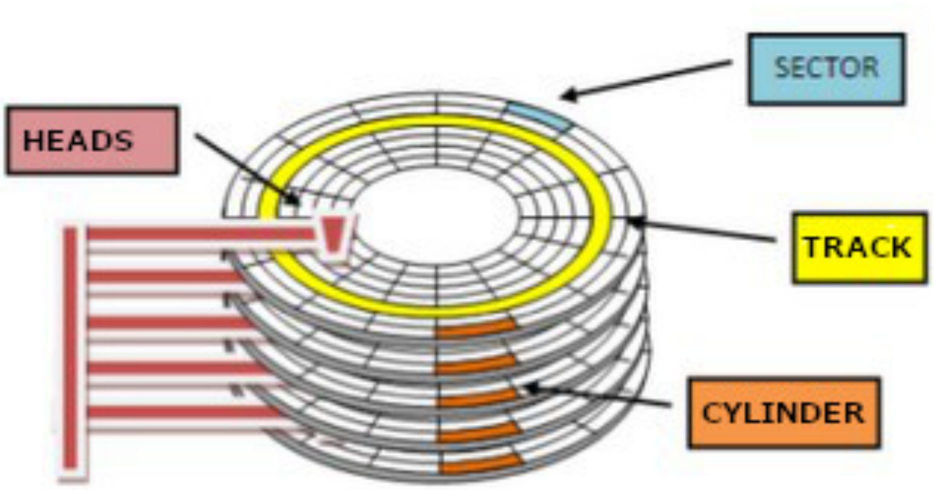
The CPU works directly with RAM, as it is through RAM that information is exchanged: the CPU retrieves the data and instructions to execute them and stores the results. Since this memory is volatile and its contents disappear when the computer is turned off, a storage system is essential to permanently save information and prevent data loss.

Types:

1. **Magnetic storage:** Uses the polarization of a magnetic material. (HDD)
2. **Optical storage:** Uses optical technology in digital form (CD/DVD are less commonly used today).
3. **Flash memory:** Uses memory chips. (SSD, SD, MMC, USB memory sticks)

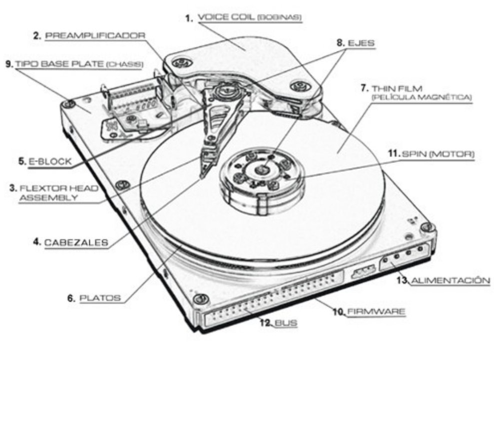
1.Magnetic Disks:

Magnetic disks store information on magnetic surfaces (disks). Before a magnetic disk can be used, it must be prepared (formatted) to receive information; this operation divides the disk into tracks and sectors where data will be stored.



1.1. Hard disk drive:

The most important representative of magnetic disks, as they are usually inside the computer. However, this is no longer entirely true, as removable hard drives and external hard drives have become common. Hard drives consist of a stack of disks with a common axis; between them are the read-write heads, positioned to read and write on both sides of each disk. The number of disks and the composition of the magnetic material determine the capacity of the hard drive, which is increasing rapidly. It's now common to talk about hard drives with capacities of 1 TB, 3 TB, 4 TB, and even up to 8 TB in RAID units.



2.Optical Disks:

The advent of optical disks (CD-ROM, DVD, and later Blu-ray) revolutionized storage systems thanks to their ability to store a huge amount of information of different types at a relatively low cost. All these disks use optical (laser) technology. Nowadays, they are almost obsolete due to the widespread use of faster, higher-capacity storage systems like memory sticks and removable drives such as **magnetic and SSD (Solid State Devices)**.

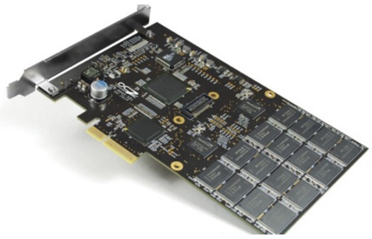
3.Flash memory-based storage devices:

Flash memories, initially used to store BIOS data on computers, have become popular and widespread, leading to an increasing number of storage devices that use this technology. SSDs are storage devices based in memory chips as well, however, a different type of microchip is used.

These are marketed under various names such as Compact Flash, Memory Stick, Smart Drive, etc. They are not just limited to computer devices; their use has extended to other electronic devices like digital cameras or video cameras. In the case of computer devices, they usually connect via a USB port or a card reader, from which they draw sufficient electrical power to operate. The most notable features of these devices are their small size and the fact that they do not require a battery or external power supply to retain the stored data. However, flash memory does have a limited lifespan, typically ranging between 100,000 and 1,000,000 write cycles.

3.1. Solid State Drives (SSD)

Currently, ultra-thin and compact laptops (between 10” and 13.5”), lightweight (around one to one and a half kilograms), and with excellent performance are being marketed. One of the factors that has allowed for the reduction in size and weight is the use of solid-state storage drives (SSD - Solid State Drives) instead of magnetic disks, as well as the removal of optical drives (CD or DVD readers).
SSD drives store data in non-volatile NAND memory chips. They don't have any moving parts, which makes them smaller, faster, and more energy-efficient than conventional magnetic hard drives. However, the number of write operations is limited. It is not correct to call them "disks" as they lack rotating internal spindles, heads, and platters (disks).

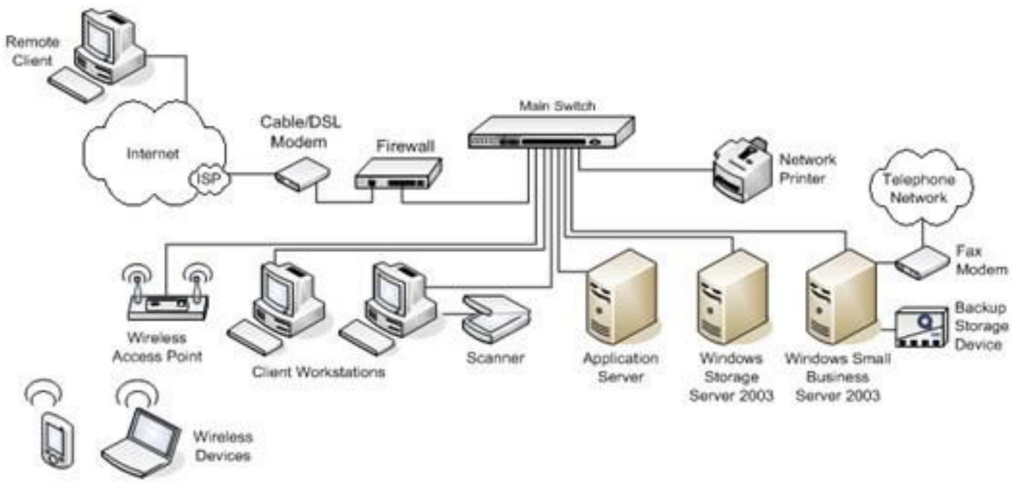


The main features of SSD drives are:

- They are more resistant to data loss from shocks and vibrations because they have no moving parts.
- They can retain stored information for up to 10 years without the need for power.
- They generate no noise, and heat is minimal, extending their lifespan since they don't operate at high temperatures.
- They are used in the market in laptops called “ultra books” or in computers designed for network use, and even in some desktop computers.
- They have a long device lifespan, with a "Mean Time Between Failure" (MTBF) of around 1,000,000 hours.
- They have very low electricity consumption, making them ideal for portable devices.
- Currently, standalone SSD units are available with similar uses to USB memory sticks or portable hard drives, with capacities reaching up to 2 TB. (Some models can be found on the following page: https://semiconductor.samsung.com/consumer-storage/portable-ssd/ by SAMSUNG).

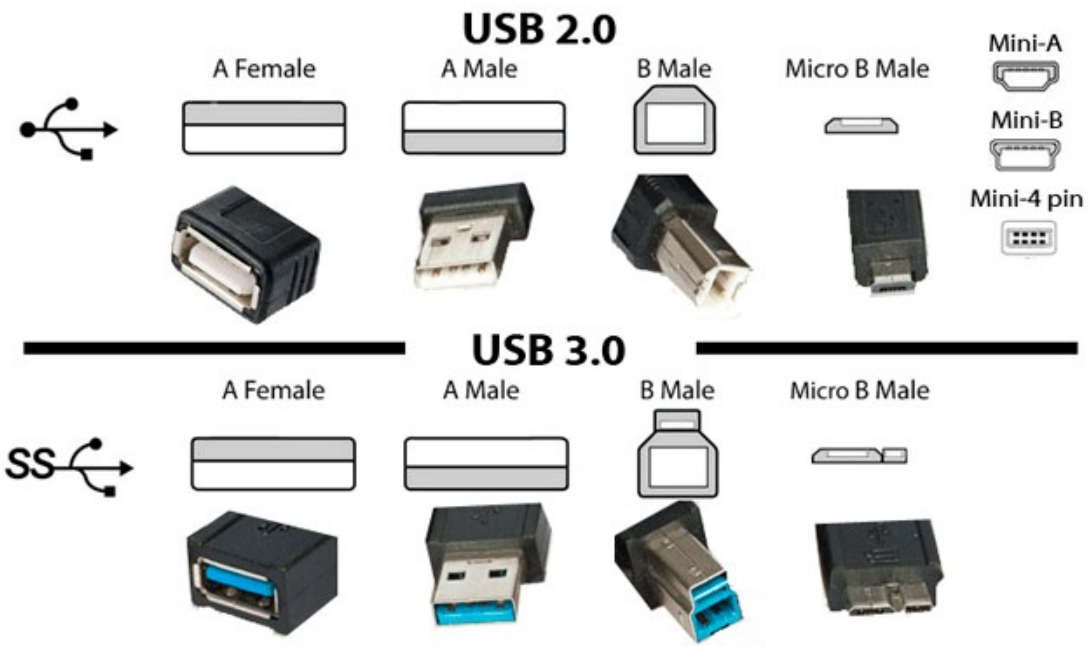
5.COMUNICATION DEVICES.

Due to their specific characteristics, although they can be considered input/output peripherals, communication devices that enable computers to connect and form networks are usually categorized separately. Examples include network cards, hubs, switches, routers, etc.



6. THE USB BUS.

The USB bus (Universal Serial Bus) has become the standard connection bus for all types of devices, thanks to its ease of use (plug and play), compatibility, and performance. The new USB 3.1 Gen 2 version with the Type-C connector offers numerous advantages compared to previous versions. Currently, USB buses from version 2 onwards are in use.



6.1 USB 2.0

The USB bus is synchronous and uses the NRZI (Non-Return-to-Zero Inverted) encoding algorithm. A USB system has an asymmetric design, consisting of a single host and multiple devices connected in a tree structure using special hubs. The standard includes the transmission of electrical power to the connected device. Some devices require minimal power, allowing several to connect without needing extra power sources. Most hubs include power supplies that provide energy to the connected devices. It uses type A and B connectors.

6.2 USB 3.1 Gen 1 and Gen 2 (USB Type-C Connector)

The USB Type-C connector is reversible, has 24 connection pins, and allows for a theoretical maximum data transfer rate of 10 Gbps (1.25 GB/s) in Super-Speed+ mode (USB 3.1 Gen 2) and 4.8 Gbps in Super-Speed mode (USB 3.1 Gen 1). It can supply a maximum power output of 100 W (20 V x 5 A with the USB Type-C Power Delivery connector).

6.3 USB 3.2 (USB Type-C Connector)

Using the USB Type-C connector, the USB 3.2 standard has been developed by the USB Implementers Forum (USB-IF), doubling the performance of USB 3.1 Gen 2. The theoretical maximum transfer rate is 20 Gbps (2.5 GB/s). The new standard, launched in September 2017 and commercially available from 2018-2019, ensures support for two 5 Gbps lanes or two 10 Gbps lanes and compatibility with

SuperSpeed USB (USB 3.1 Gen 1) or SuperSpeed+ USB 10 Gbps (USB 3.1 Gen 2). In addition to transmitting various types of signals (data, audio, and video), devices can be charged bidirectionally with up to 100 W of power.

Logo	Nombre	Versión	Velocidad teórica	Velocidad Real	Fecha Lanzamiento	Puertos
USB UNIVERSAL SERIAL BUS	Low-Speed	USB 1.0	1,5 Mbps (187,5 KB/s)	1 Mbps (125 KB/s)	Enero 1996	Type A
CERTIFIED USB	Full-Speed	USB 1.1	12 Mbps (1,5 MB/s)	7 Mbps (875 KB/s)	Agosto 1998	Type A, Type B
HI-SPEED CERTIFIED USB	Hi-Speed	USB 2.0	480 Mbps (60 MB/s)	280 Mbps (35 MB/s)	Abril 2000	Mini-A, Mini-B, Micro-A, Micro-B
SUPERSPEED USB	Super-Speed	USB 3.0	4,8 Gbps (600 MB/s)	3,2 Gbps (400 MB/s)	Septiembre 2008	A, Micro-B, B
SUPERSPEED USB	Super-Speed+	USB 3.1	10 Gbps (1,25 GB/s)	7,2 Gbps (900 MB/s)	Enero 2013	A, Type-C

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USB Technology:

USB 2.0 technology uses four copper wires (two for data, one for power, and one for grounding). USB 3.0 retains these copper wires (ensuring compatibility between USB 2.0 and 3.0) but also includes an additional five optical fiber cables. These, along with its much higher speed, allow for simultaneous data transmission and reception. Another significant difference lies in how communication with other devices is handled: while USB 2.0 operates in multicast mode (sending data to all connected devices, which must then check whether to accept or reject each data packet), USB 3.0 operates in unicast mode, sending data only to the device that is the actual recipient.