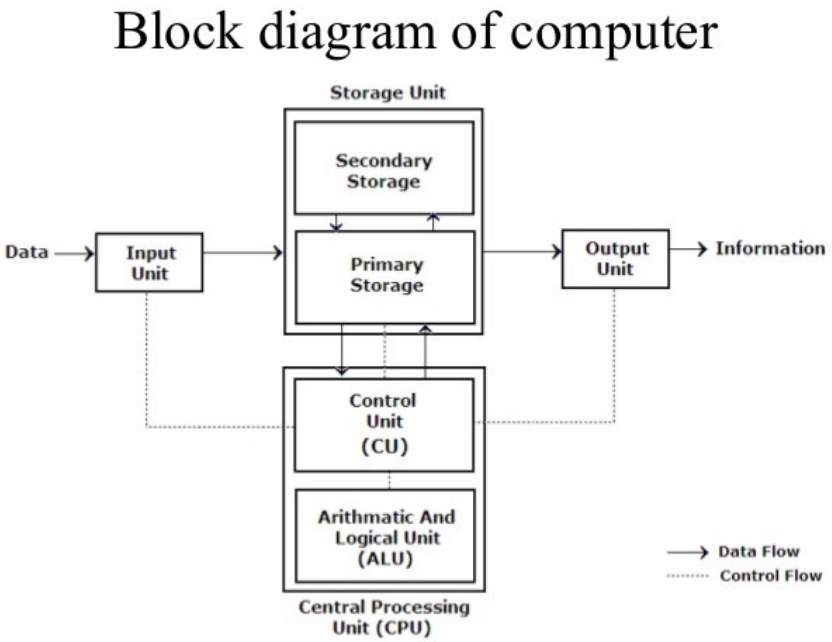
Computer:

- An electronic device which is capable of receiving data in a particular form and of performing a sequence of operations through a set of instructions (program) to produce a result in the form of information or signals and saves output for future use.



Basic Computer Terminologies

1. CPU

The Central Processing Unit (CPU) is called "the brain of computer" as it controls operation of all parts of computer. It consists of two components: Arithmetic Logic Unit (ALU) and Control Unit. It does all the data manipulation, calculations and formatting data for output.

2. RAM

Random Access Memory (RAM) is the memory or information storage in a computer that is used to store running programs and data for the programs. Data in the RAM can be read and written quickly in any order.

3. ROM

Read-only memory (ROM) is a type of storage medium that permanently stores data on personal computers (PCs) and other electronic devices. It contains the programming needed to start a PC, which is essential for boot-up; it performs major input/output tasks and holds programs or software instructions. ROM is read-only, it cannot be changed; it is permanent and non-volatile.

4. Cache

Cache memory is a small-sized type of volatile computer memory that provides high-speed data access to a processor and stores frequently used computer programs, applications and data. It is the fastest memory in a computer, and is typically integrated onto the motherboard and directly embedded in the processor or main random access memory (RAM).

5. Hardware

The physical components of the computer. They usually include the; monitor, printer, mouse, keyboard, modem etc.

6. Hard Drive

The place where programs and files are stored in a computer. Also called the Hard Disc. On PCs this is often the c:// drive.

7. Motherboard

Main board, main circuit board, system board, planar board, logic board.Hold and allows communication between many of the crucial electronic components of a system such as CPU,memory, and provide connectors for other peripherals.

8. Input Devices

An input device is any hardware device that sends data to a computer, allowing you to interact with and control it. These inputs devices converts input data and instructions into a suitable binary form which can be accepted by the computer. Input devices are necessary to enter data and instructions into a computer as input unit is the only medium through which users can interact wit the computer. Commonly used input devices are: Keyboard, Mouse, Joystick, Light pen, Camera,Scanner, Graphic Tablet, Microphone etc.

9. Output Devices

An output device is any piece of computer hardware equipment which converts information into human-readable form. It can be text,graphics,audio and video . Some of the output devices are: Monitor, Printer, Graphic Output devices, Plotters, Printers, Speakers etc.
[You can include any other terms that is related to computer.]

Data and Information

- **Data** is a collection of unorganized facts & figures and does not provide any further information. Hence data means "unstructured facts and figures" .

Also, it may be any collection of numbers, characters or other symbols that has been coded into a format that can be input into a computer and processed. Data on its own has no meaning, or context. It is only after processing by a computer that data takes on a context and becomes information. Examples of data are weights, prices, costs, numbers of items sold, employee names, student names, product names, addresses, registration marks etc.

- **Information** is a structured data. i.e. when data are processed, organized, structured or presented in a given context so as to make them useful, they are called Information. To process the data and convert into information, a computer is used. Information are pay-slips, schedules, reports, worksheet, bar charts, pie-charts, invoices and account returns etc.

- The history of temperature readings all over the world for the past 100 years is data. If this data is organized and analyzed to find that global temperature is rising, then that is information.

- The number of visitors to a website by country is an example of data. Finding out that traffic from the U.S. is increasing while that from Australia is decreasing is meaningful information.

- A day's temperature, humidity, wind and speed of recorded are **Data** While percentage of weather as ❄cold or ♨warm is an **Information.**

- Student’s name in a class are **Data** While names of students in alphabetic order are **Information.**

- A student's subject marks are **Data** While his percentage of marks, grade and position are **Information.**

Functions of Computer:

- Receiving Input

Any machine that provides data into a computer.

Data can be provided into computer through various input devices like Keyboard, Mouse, Joystick, Light pen, Camera,Scanner, Graphic Tablet, Microphone etc.

- Processing the information

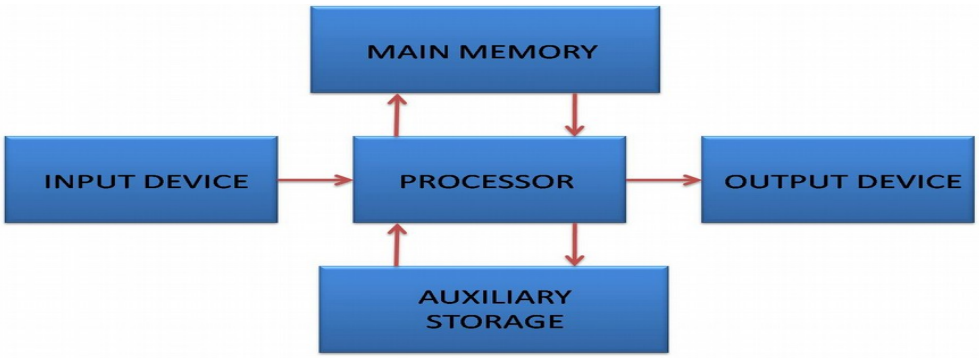
Operations on the input data are carried out based on the instructions provided in the programs.

- Storing the information

After processing, the information gets stored in the primary or secondary storage area.

- Producing output

The processed information and other details are communicated to the outside world through output devices like monitor, printer, projector, speaker, headphone etc.



Computer System

- It is a groups of CPU, memory system and peripheral devices all interconnected by a buses.
- Computer System = Hardware + Software + User
- Hardware

Hardware is a collection of Internal Devices and Peripheral Devices.

All physical parts of the computer (or everything that we can touch i.e. tangible) are known as Hardware.

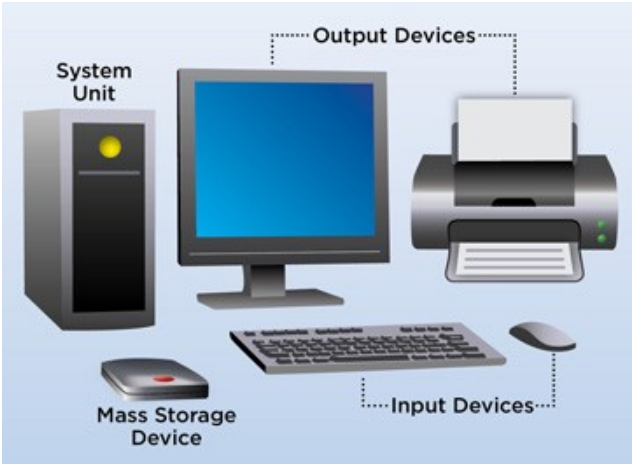
- Software = programs (set of instructions)

Software gives intelligence to the computer and it is intangible.

- User = Person, who operate computer.

Components of Computer System

Basically, Computer systems consist of components as: **Input devices, Output devices, Central Processing Unit and Memory unit**. Input devices provide data input to processor, which processes data and generates useful information that's displayed to the user through output devices. This is stored in computer's memory.



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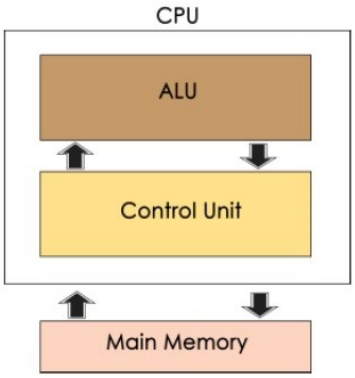


➔ Arithmetic Logic Unit (ALU)

An arithmetic logic unit (ALU) is a digital circuit used to perform arithmetic and logic operations. It represents the fundamental building block of the central processing unit (CPU) of a computer. Modern CPUs contain very powerful and complex ALUs.

➔ Control Unit

As name indicates, this part of CPU extracts instructions, performs execution, maintains and directs operations of entire system.

Functions of Control Unit

Control unit performs following functions −

- It controls all activities of computer
- Supervises flow of data within CPU
- Directs flow of data within CPU
- Transfers data to Arithmetic and Logic Unit
- Transfers results to memory
- Fetches results from memory to output devices

■ Memory Unit

This is unit in which data and instructions given to computer as well as results given by computer are stored. Unit of memory is "Byte".

1 Byte = 8 Bits

■ Output Devices

An output device is any piece of computer hardware equipment which converts information into human-readable form. It can be text, graphics,audio and video. Some of the output devices are: Monitor, Printer, Graphic Output devices, Plotters, Printers, Speakers etc.

History of Computers:

The brief history of computers is discussed below −

First Generation (1940-1956)

The first generation computers had the following features and components −

- Hardware

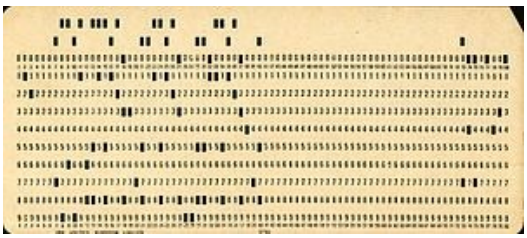
The hardware used in the first generation of computers was: **Vacuum Tubes** and **Punch Cards**.

- Features

Following are the features of first generation computers −

- It supported machine language.
- It had slow performance.
- It occupied large size due to the use of vacuum tubes.
- It had a poor storage capacity.
- It consumed a lot of electricity and generated a lot of heat.

- Memory



The memory was of 4000 bits.

- Data Input

The input was only provided through hard-wired programs in the computer, mostly through punched cards and paper tapes.

Examples

The examples of first generation computers are −

- ENIAC
- UNIVACTBM 701

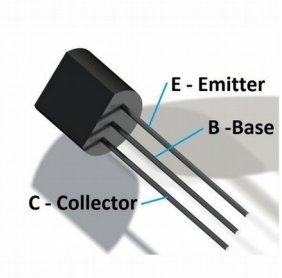
Second Generation (1956-1963)

Several advancements in the first-generation computers led to the development of second generation computers. Following are various changes in features and components of second generation computers −

- Hardware

The hardware used in the second generation of computers were −

- Transistors
- Magnetic Tapes



- Features

It had features like −

- Batch operating system
- Faster and smaller in size
- Reliable and energy efficient than the previous generation
- Less costly than the previous generation

- Memory

The capacity of the memory was 32,000 bits.

- Data Input

The input was provided through punched cards.

- Examples

The examples of second generation computers are −

- Honeywell 400
- CDC 1604
- IBM 7030

Third Generation (1964-1971)

Following are the various components and features of the third generation computers −

- Hardware

The hardware used in the third generation of computers were −

- Integrated Circuits made from semi-conductor materials
- Large capacity disks and magnetic tapes

- Features

The features of the third generation computers are −

- Supports time-sharing OS
- Faster, smaller, more reliable and cheaper than the previous generations
- Easy to access

- Memory

The capacity of the memory was 128,000 bits.

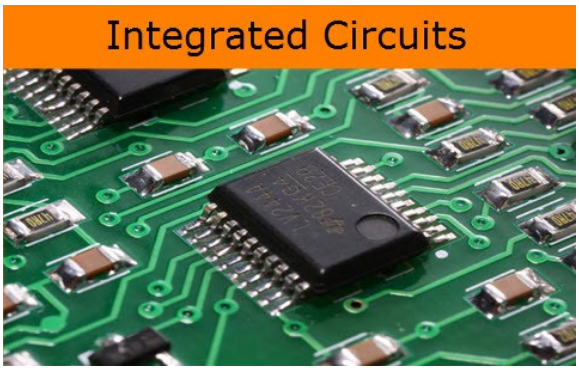
- Data Input

The input was provided through keyboard, mouse etc.

Examples

The examples of third generation computers are −

- IBM 360/370
- CDC 6600
- PDP 8/11



Fourth Generation (1972-2010)

Fourth generation computers have the following components and features −

- Hardware

The Hardware used in the fourth generation of computers were −

- ICs with Very Large Scale Integration(VLSI) technology, microprocessor
- Semiconductor memory
- Magnetic tapes and Floppy

- Features

It supports features like −

- Multiprocessing & distributed OS
- Object-oriented high level programs supported
- Small & easy to use; hand-held computers have evolved
- No external cooling required & affordable
- This generation saw the development of networks and the internet
- It saw the development of new trends in Graphical User Interface (GUI) and mouse

- Memory

The capacity of the memory was 100 million bits.

Data Input

The input was provided through improved hand held devices, keyboard and mouse.

Examples

The examples of fourth generation computers are −

- Apple II
- VAX 9000
- CRAY 1 (super computers)

Fifth Generation (2010-Present)

These are the modern and advanced computers. Significant changes in the components and operations have made fifth generation computers user-friendly and more reliable than the previous generations. Computing devices were based on artificial intelligence.

- Hardware

The Hardware used in the fifth generation of computers are −

- Integrated Circuits with ULSI and Nano technology.
- Large capacity hard disk.
- Powerful servers, Internet, Cluster computing.

- Features

It supports features like −

- Powerful, cheap, reliable and easy to use.
- Portable and faster due to use of parallel processors and Super Large Scale Integrated Circuits.
- Rapid software development is possible.

- Memory

The capacity of the memory is unlimited.

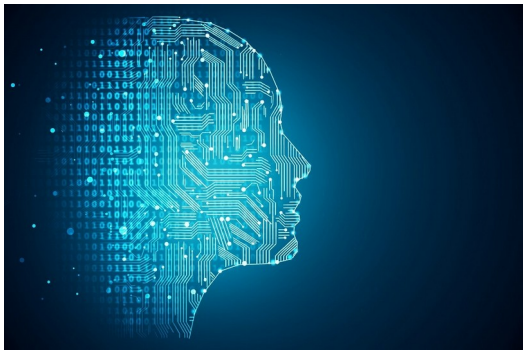
- Data Input

The input is provided through various input devices such as: Optical Disk and other touch and voice sensitive input devices.

Examples

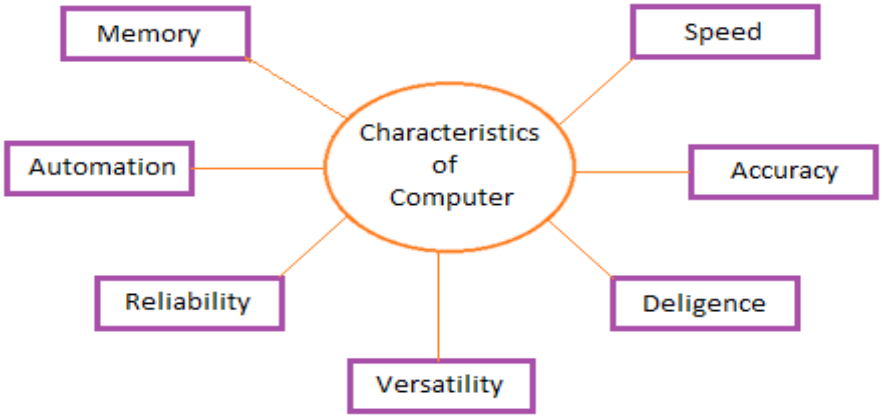
The examples of fifth generation computers are −

- IBM
- Pentium
- PARAM



Characteristics of Computer:

The characteristics of the computer system are as follows −



Speed

A computer works with much higher speed and accuracy compared to humans while performing mathematical calculations. Computers can process millions (1,000,000) of instructions per second. The time taken by computers for their operations is microseconds and nanoseconds.

Accuracy

Computers perform calculations with 100% accuracy. Errors may occur due to data inconsistency or inaccuracy.

Diligence

A computer can perform millions of tasks or calculations with the same consistency and accuracy. It doesn't feel any fatigue or lack of concentration. Its memory also makes it superior to that of human beings.

Versatility

Versatility refers to the capability of a computer to perform different kinds of works with same accuracy and efficiency.

Reliability

A computer is reliable as it gives consistent result for similar set of data i.e. if we give same set of input any number of times, we will get the same result.

Automation

Computer performs all the tasks automatically i.e. it performs tasks without manual intervention.

Memory

A computer has built-in memory called primary memory where it stores data. Secondary storage are removable devices such as CDs, pen drives, etc., which are also used to store data.

Basic Applications of Computer

Home

Computers are used at homes for several purposes like online bill payment, watching movies or shows at home, home tutoring, social media access, playing games, internet access, etc. They provide communication through electronic mail. They help to work from home for corporate employees. Computers help the student community to avail online educational support.

Medical Field

Computers are used in hospitals to maintain a database of patients' history, diagnosis, X-rays, live monitoring of patients, etc. Surgeons nowadays use robotic surgical devices to perform delicate operations, and conduct surgeries remotely. Virtual reality technologies are also used for training purposes. It also helps to monitor the fetus inside the mother's womb.

Entertainment

Computers help to watch movies online, play games online; act as a virtual entertainer in playing games, listening to music, etc. MIDI(Musical Instrument Digital Interface) instruments greatly help people in the entertainment industry in recording music with artificial instruments. Videos can be fed from computers to full screen televisions. Photo editors are available with fabulous features.

Industry

Computers are used to perform several tasks in industries like managing inventory, designing purpose, creating virtual sample products, interior designing, video conferencing, etc. Online marketing has seen a great revolution in its ability to sell various products to inaccessible corners like interior or rural areas. Stock markets have seen phenomenal participation from different levels of people through the use of computers.

Education

Computers are used in education sector through online classes, online examinations, referring e-books, online tutoring, etc. They help in increased use of audio-visual aids in the education field.

Government

In government sectors, computers are used in data processing, maintaining a database of citizens and supporting a paperless environment. The country's defense organizations have greatly benefitted from computers in their use for missile development, satellites, rocket launches, etc.

Banking

In the banking sector, computers are used to store details of customers and conduct transactions, such as withdrawal and deposit of money through ATMs. Banks have reduced manual errors and expenses to a great extent through extensive use of computers.

Business

Nowadays, computers are totally integrated into business. The main objective of business is transaction processing, which involves transactions with suppliers, employees or customers. Computers can make these transactions easy and accurate. People can analyze investments, sales, expenses, markets and other aspects of business using computers.

Training

Many organizations use computer-based training to train their employees, to save money and improve performance. Video conferencing through computers allows saving of time and travelling costs by being able to connect people in various locations.

Arts

Computers are extensively used in dance, photography, arts and culture. The fluid movement of dance can be shown live via animation. Photos can be digitized using computers.

Science and Engineering

Computers with high performance are used to stimulate dynamic process in Science and Engineering. Supercomputers have numerous applications in area of Research and Development (R&D). Topographic images can be created through computers. Scientists use computers to plot and analyze data to have a better understanding of earthquakes.

Computer Architecture

- Computer architecture describes the design or blueprint of an electronic computer with its CPU, which includes the arithmetic logic unit, control unit, registers, memory for data and instructions, an input/output interface and external storage functions.

- Computer architecture is the art of determining the needs of the user of a structure and then designing to meet those needs as effectively as possible within economic and technological constraints.

- Usually, it computer architecture is concerned with structure and behaviour of computer system and it describes what the computer does.

- It includes information, formats, instruction set and techniques for addressing memory.

- Computer architecture can last for longer times.

Computer Architecture and Computer Organization

Computer Architecture is abstract model and are those attributes that are visible to programmer like instructions sets, no of bits used for data, addressing techniques.

A **computer's organization** expresses the realization of the architecture. OR how features are implemented like these registers, those data paths or this connection to memory. Contents of computer organization are ALU, CPU and memory and memory organizations. It is also called micro architecture.

The difference lies, precisely, between the ***"What"*** and the ***"How"*** .

Computer Architecture is the ***"What"***.

Computer Organization is the ***"How"***.

Computer Architecture tells you what the system does. So, knowing about the architecture is basically knowing what functionalities will your system display. What you can expect to get out of it.

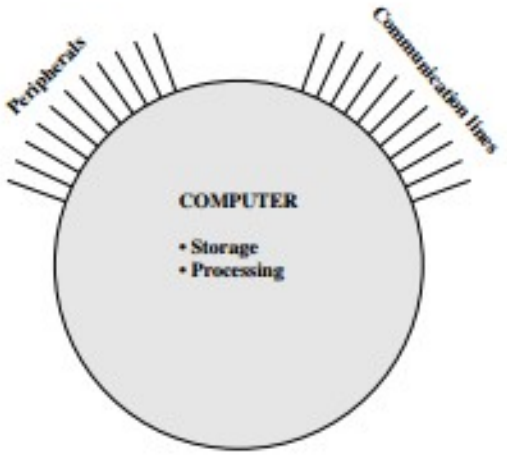
Computer Organization tells you how exactly all units in your system have been arranged and interconnected to help realize the architectural goals your system claims to have achieved.

Their differences can be tabulated as follows:

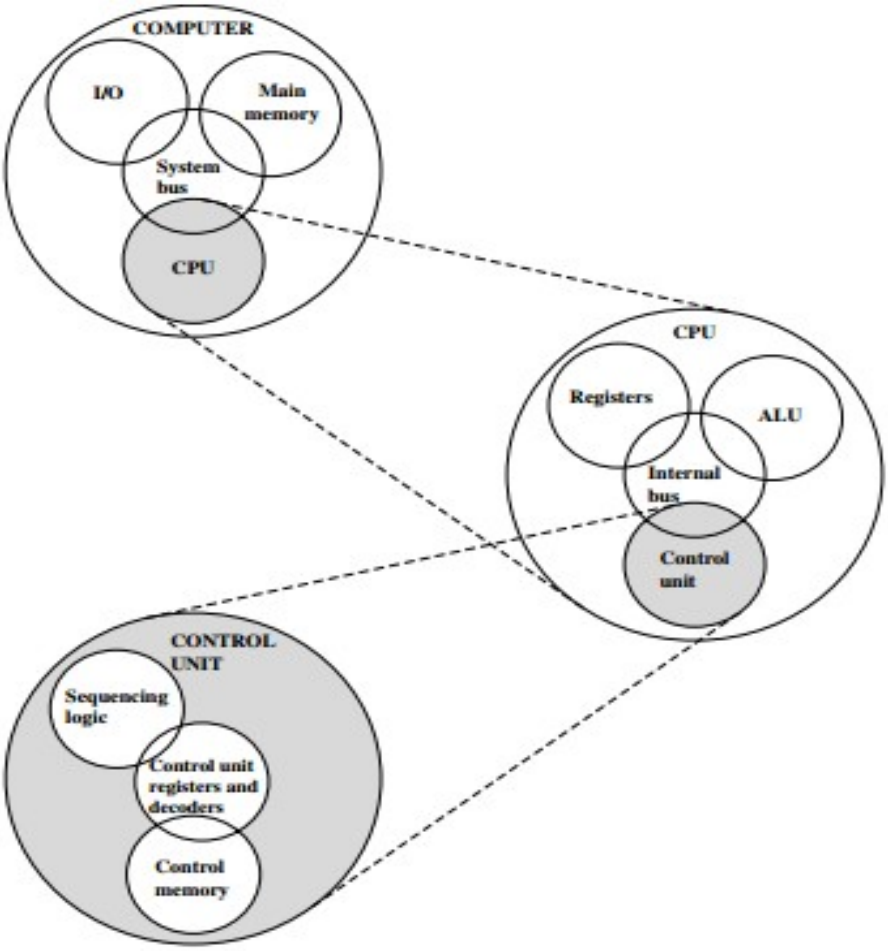
Computer Architecture	Computer Organization
1. Comp architecture is concerned with the structure and behavior of comp system as seen by the user.	**1**. Computer organization is concerned with the way the hardware components operate and the way they are connected together to form computer system.
2. It includes information, formats, instruction set and techniques for addressing memory.	**2.** It includes Hardware details transparent to the programmer such as control signal and peripheral.
3. It describes what the computer does.	**3.** It describes how the computer performs.
4.Example: instruction set, addressing modes	4.Example: circuit design, control signals, memory types this all are under computer organization.
5. Computer Architecture can last for longer times.	5. Computer Organization may changes soon and can have multiple organization for single architecture.

Structure of Computer

Structure of computer is concerned with the way in which the components are interrelated. Figure below is the simplest possible depiction of a computer. The computer interacts in some fashion with its external environment. In general, all of its linkages to the external environment can be classified as peripheral devices or communication lines.



This diagram can be further expanded as follows:



There are four main structural components:

- **Central processing unit (CPU):** Controls the operation of the computer and performs its data processing functions; often simply referred to as **processor**.
- **Main memory:** Stores data.
- **I/O:** Moves data between the computer and its external environment.
- **System interconnection:** Some mechanism that provides for communication among CPU, main memory, and I/O. A common example of system interconnection is by means of a **system bus**, consisting of a number of con-ducting wires to which all the other components attach.

Each of these components have sub components. Their major structural components are as follows:

- **Control unit:** Controls the operation of the CPU and hence the computer.
- **Arithmetic and logic unit (ALU):** Performs the computer's data processing functions.
- **Registers:** Provides storage internal to the CPU.
- **CPU interconnection:** Some mechanism that provides for communication among the control unit, ALU, and registers.

Control Unit

Control Unit is the part of the computer's central processing unit (CPU), which directs the operation of the processor. It is the responsibility of the Control Unit to tell the computer's memory, arithmetic/logic unit and input and output devices how to respond to the instructions that have been sent to the processor. It fetches internal instructions of the programs from the main memory to the processor instruction register, and based on this register contents, the control unit generates a control signal that supervises the execution of these instructions. Examples of devices that utilize control units include CPUs and GPUs.

Control signals:
Control Unit was designed to 'generate' the control signals**.** The control signals operate the functioning of the processor's hardware. It decides what operation has to be performed, what must be the sequence of the operations performed by the processor, in what time an operation must be executed and so on.

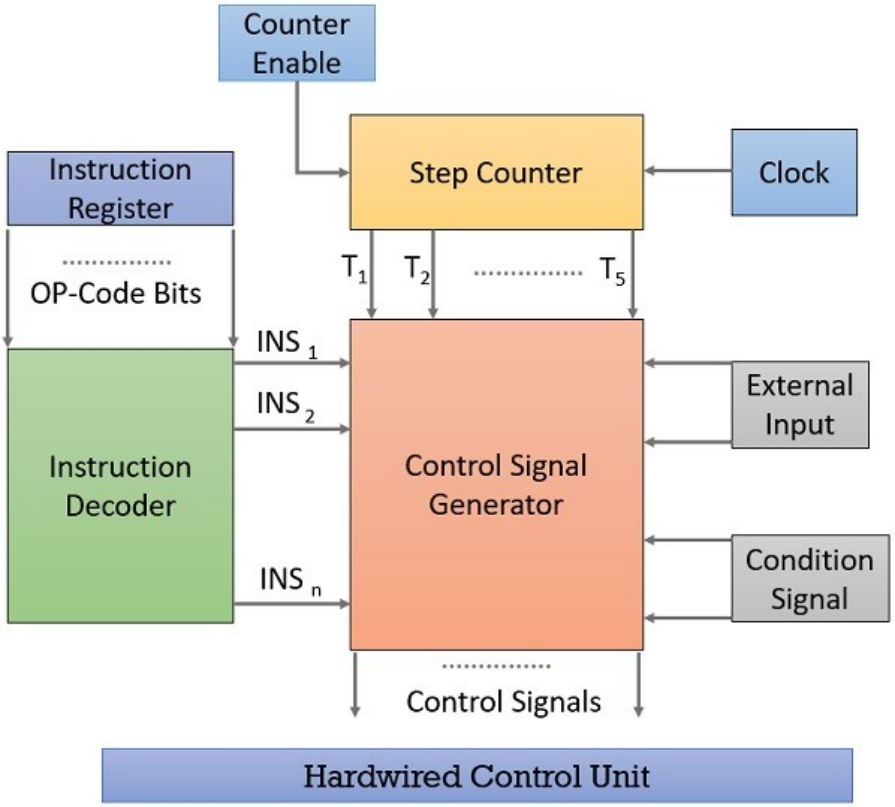
Types of control unit:

Hardwired Control Unit

Micro-programmed Control Unit

Hardwired Control Unit

The hardwired control unit generates the **control signals** to execute the instructions in a proper sequence and at the correct time. The hardwired control unit is created with the hardware; it is a **circuitry** approach. It is designed for the **RISC** style instruction set.



The **instruction register** is a processors register that has the 'instruction' which is currently in execution. The instruction register generates the OP-code bits respective of the operation and the addressing modes of the operands, mentioned in the instruction.

Instruction decoder receives the Op-code bits generated by the instruction register and interprets the operation and addressing modes of the instruction. Now, based on operation and addressing mode of the instruction in instruction register it set the corresponding Instruction signal INSi to 1.

Each instruction is executed in step-like, instruction fetch, decode, operand fetch, ALU, memory store.

Now, the control unit must be aware of the current step, the instruction is in. For this, a **Step Counter** is implemented which has signals from T1, …, T5. The step counter sets one of the signals T1 to T5 to 1 on the basis of the step, the instruction is in.

To know the current step of instruction, step counter is implemented with a **Clock**. This clock is designed such that for each step the clock must complete its one clock cycle.

for eg, if the step counter has set T3 signal 1 then after a clock cycle completes step counter will set T4 to 1.

The **Counter Enable** 'disables' the step counter to increment to the next step signal, till the execution of the current step is completed.

Now, suppose the execution of an instruction depends on some condition or if it is branch instruction. This is determined with the help of the **Condition signals**. The Condition signals generate the signals for the conditions greater than, less than, equal, greater than equal, less than equal etc.

The remaining is **External inputs**, it recognizes the control signal generator of interrupts which affects the execution of the instruction.

On an, all the Control Signal Generator generates the control signals, based on the inputs obtained by the Instruction register, Step counter, Condition signals and External inputs.

Advantages of Hardwired Control unit:

1. It is faster than the micro programmed control unit, because control signals are generated by using combinational circuit.
2. It's performance is high.

Disadvantages of Hardwired control unit:

1. Difficult to correct mistakes and adding new features in existing design of CPU.
2. Requires change in wiring if the design has to be controlled.
3. An occurrence of an error is more.
4. It requires a more chip area, therefore, it is a costlier control unit.

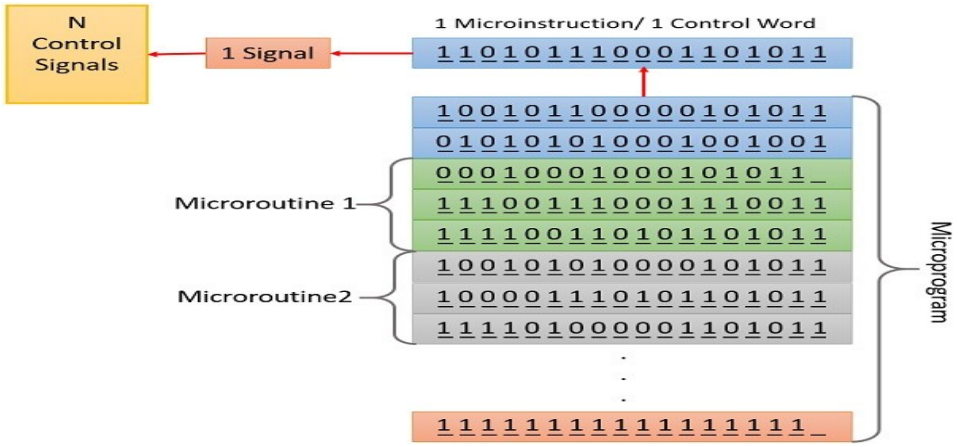
Micro-programmed Control Unit

Micro-programmed control unit also produces the control signal but using the **programs**. This approach is popular for **CISC** architecture. The program that creates the 'control signals' is called **Micro-program**. This microprogram is placed on the processor chip which is fast memory, it is also called **control memory** or **control store.**

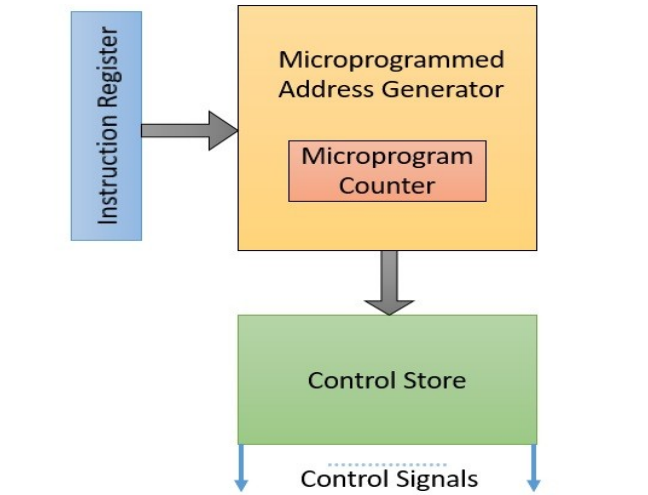
A microprogram has a set of **micro-instructions**, or it is also termed as **control word**. Each microinstruction is 'n' bit word. Each control signal differs from other control signal depending on the bit pattern of the control word. Each control word/microinstruction has a different bit pattern.

Each instruction is executed in step-like, instruction fetch, decode, operand fetch, ALU, memory store. So, for each step there is a control word/ microinstruction in the microprogram. A sequence of microinstructions required to execute a particular instruction is called **microroutine**.

In the figure below, we can understand the organization of a **control word/microinstruction, microroutine** and **microprogram**.



Now, we have **organization** of the **microprogram control unit**. We will discuss the flow of instruction execution in terms of instruction execution steps.



Microprogrammed Control Unit Organization

1. In the **first step** (instruction fetch) the **Microinstruction address generator** would **fetch** the instruction from 'instruction register' (IR).
2. In the **second step**, the microinstruction address generator **decodes** the instruction obtained from IR and retrieves the **starting address** of the **microroutine** required to perform the corresponding operation mentioned in the instruction. It loads that starting address to **microprogram counter**.
3. In the **third step**, the 'control word' corresponding to the 'starting address' of 'microprogram counter' is read and as the execution proceeds, microprogram address generator will **increment** the value of microprogram counter to read the successive control words of the microroutine.
4. In the last microinstruction of a microroutine, there is a bit which we call **end bit**. When end bit is set to 1 it denotes successful execution of that microroutine.
5. After this, the microprogram address generator would return back to **Step 1** again to fetch a new instruction. And the cycle goes on.

Control Store or Control memory is a memory used store the microprograms.

Advantages of Micro Programmed Control unit:

1.It is both cheaper and the occurrence of an error is less.
2.More flexible to accommodate with new instructions.
3.Easier decoding and sequencing can be done.
4.Easier to handle complex instruction sets.
5.It requires a less chip area.

Disadvantages of Micro programmed control unit:

1.This is slower than the hardwired control unit because the microinstructions are to be fetched from the control memory which is time-consuming.

Differences:

Basis	Hardwired Control Unit	Microprogrammed Control Unit
Basic	It is a circuitry approach.	This control unit is implemented by programming
Design	RISC style instructions	CISC style instructions
Modification	Modification is difficult as the control unit is hardwired. Modifying it will require the change in hardware.	Modifications are easy in case of microprogrammed control unit as it will require the in change in the code only.
Instructions	It works well for simple instructions.	It works well for complex instructions also.
Costing	Implementing hardwired structure requires a cost.	Implementing microprograms is not costly.
Control memory	No control memory is required	Control memory is required
Execution Speed	Faster execution	Comparatively slow

Functions of Control Unit

Control unit performs following functions −

- It controls all activities of computer
- Supervises flow of data within CPU
- Directs flow of data within CPU
- Transfers data to Arithmetic and Logic Unit
- Transfers results to memory
- Fetches results from memory to output devices

Stored Program Concept

The stored program concept means that data and instructions are both logically the same and can both be stored in memory. Before introduction of this idea, instructions and data were considered two totally different enitites and were thus stored seperately. The Von Neumann architecture is built around this principle. Instructions can be stored in memory and executed in sequence referencing the data values on which it needs to operate.

The idea behind stored-program concept was to design a computer that includes an instruction set architecture and can store in memory, then a set of instructions (a program) that details the computation. A stored-program design also allows programs to modify themselves while running.

Von Neumann Computer Architecture

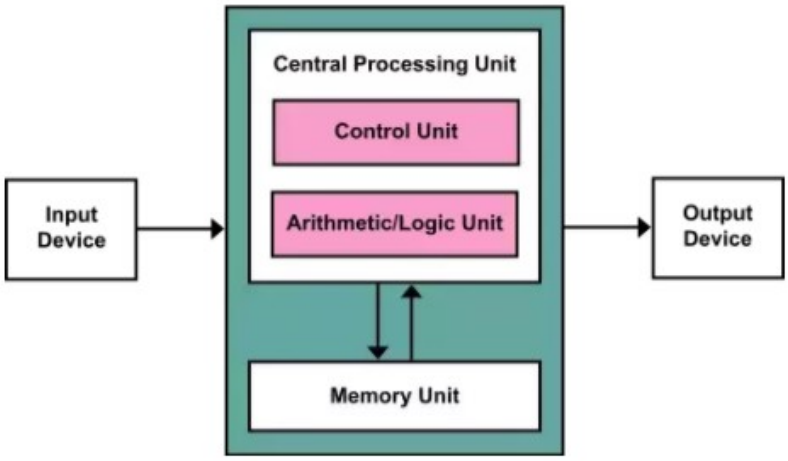
The Von Neumann architecture, is a computer architecture that was described in 1945 by the mathematician and physicist John von Neumann. This describes a design architecture for an electronic digital computer with different parts.

There are essentially three different entities, a processing unit, an i/o unit and a storage unit. The units are connected over buses.

The processing unit can be broken down into a couple of subunits, the ALU, the processing control unit and the program counter. The ALU compute the arithmetic logic needed to run programs (adding and subtracting to registers etc.) To be simple, the control unit just controls the flow of data through the processor. The program essentially points to when you are in instruction memory, it keeps track of what instruction you are running at the moment and increments when done.

The i/o unit essentially encompasses all i/o that the computer could possibly do (printing to a monitor, to paper, inputs from a mouse or keyboard, etc.)

The storage unit stores anything the computer would need to store and retrieve. This includes local hard drive storage, cache storage, and ram. It is also called stored program computer. Here, both the instructions and the data (that the instructions operate on) are stored in the computer memory itself. Thus instructions like data can be read from the memory and written to the memory by the processor.



The CPU does not distinguish in the way it deals with data or program. The read/write operations that are valid for data are valid for programming instructions as well.
Simply put the CPU addresses the memory, fetches the corresponding instruction from the memory, executes them and as per requirement addresses and then reads the data from the memory as well.
The Von Neumann Computer was the first computer to be based on the stored program concept. The architecture on which computers now are based is thus called the Von Neumann Architecture.

Von Neumann had proposed few registers in his model. They are discussed briefly below:

Registers

Registers are high speed storage areas in the CPU. All data must be stored in a register before it can be processed.

MAR	Memory Address Register	Holds the memory location of data that needs to be accessed
MDR	Memory Data Register	Holds data that is being transferred to or from memory
AC	Accumulator	Where intermediate arithmetic and logic results are stored
PC	Program Counter	Contains the address of the next instruction to be executed
CIR	Current Instruction Register	Contains the current instruction during processing

Buses

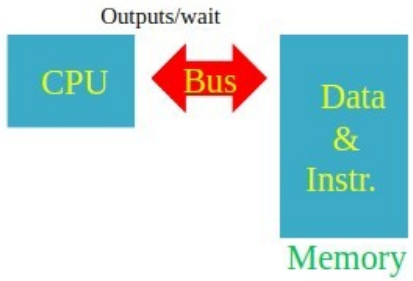
Buses are the means by which data is transmitted from one part of a computer to another, connecting all major internal components to the CPU and memory.

A standard CPU system bus is comprised of a control bus, data bus and address bus.

Address Bus	Carries the addresses of data (but not the data) between the processor and memory
Data Bus	Carries data between the processor, the memory unit and the input/output devices
Control Bus	Carries control signals/commands from the CPU (and status signals from other devices) in order to control and coordinate all the activities within the computer

The main drawback:

CPU is unable to access program memory and data memory simultaneously. This case is called the "bottleneck" that affects system performance.



Harvard Architecture

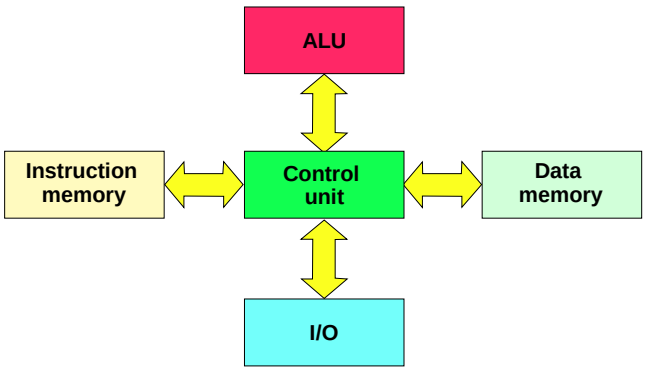


Fig: Harvard Architecture

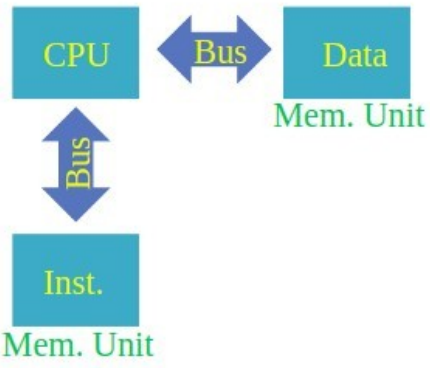
The Harvard architecture stores machine instructions and data in separate memory units using different buses.

The main advantage:

Computers designed with the Harvard architecture are able to run a program and access data independently, and therefore simultaneously.
Harvard architecture is more complicated

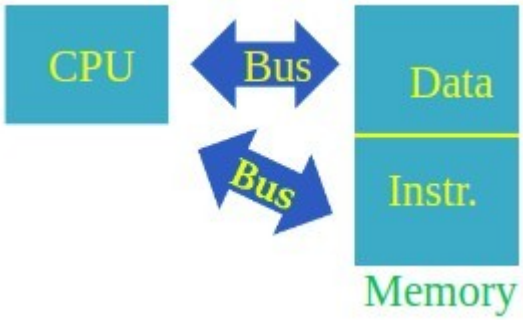
but separate pipelines remove the bottleneck

that Von-Neumann creates.



Modified Harvard Architecture

The majority of modern computers have no physical separation between the memory spaces used by both data and instructions, therefore could be described technically as Von-Neumann.



But as they have two separate address spaces, different buses and special instructions that keep data from being mistaken for code, this architecture is called "Modified Harvard Architecture".
Ex. some initial data values or constants can be accessed by the running program directly from instruction memory without taking up space in data memory.

Difference between Harvard architecture and VonNeumann architecture can be tabulated as follows:

S. N	Von Neumann Architecture	Harvard Architecture
1	This has a single common memory space where both program instructions and data are stored.	Harvard architecture computers have separate memory areas for program instructions and data.
2	There is a Single data bus which fetches data and instructions, i.e. data transfer and instruction fetch cannot be performed simultaneously.	There are two or more internal data buses which allow simultaneous access to both instructions and data.
3	Execution time taken by the CPU to fetch a program is high.	Time for execution of program is low.
4	The advantage is its simplicity and economy.	Its high-speed execution time is at the cost of more hardware complexity.