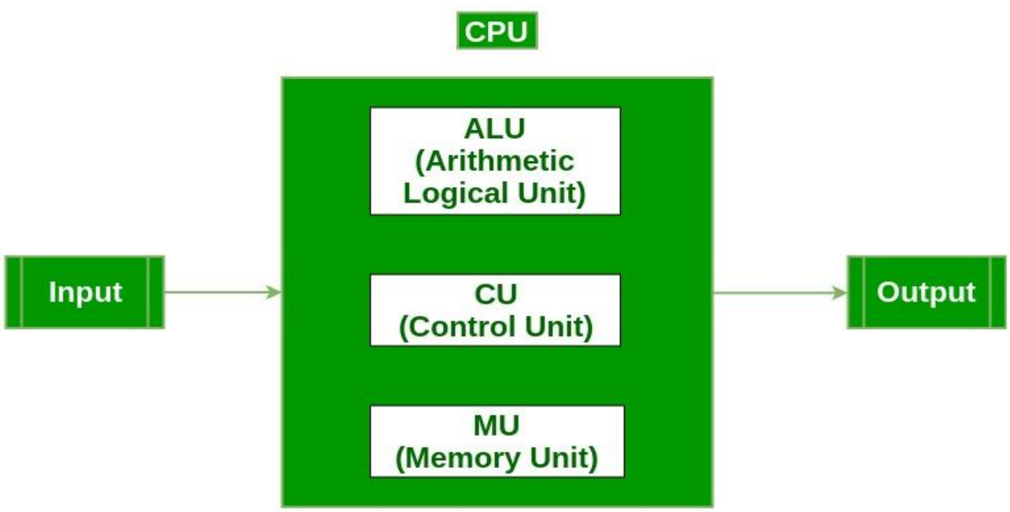
Computer Architecture (NBCA – 303)

Unit 1

Q.1 With the help of diagram explain the functional units of digital computer.

Computer: A computer is a combination of **hardware and software** resources which integrate together and provides various functionalities to the user. Hardware are the physical components of a computer like the processor, memory devices, monitor, keyboard etc. while software is the set of programs or instructions that are required by the hardware resources to function properly.
There are a few basic components that aids the working-cycle of a computer i.e. the Input- Process- Output Cycle and these are called as the functional components of a computer. It needs certain input, processes that input and produces the desired output. The input unit takes the input, the central processing unit does the processing of data and the output unit produces the output. The memory unit holds the data and instructions during the processing.
Digital Computer: A digital computer can be defined as a programmable machine which reads the binary data passed as instructions, processes this binary data, and displays a calculated digital output. Therefore, Digital computers are those that work on the digital data.

Details of Functional Components of a Digital Computer



- **Input Unit :**The input unit consists of input devices that are attached to the computer. These devices take input and convert it into binary language that the computer understands. Some of the common input devices are keyboard, mouse, joystick, scanner etc.

- **Central Processing Unit (CPU) :** Once the information is entered into the computer by the input device, the processor processes it. The CPU is called the brain of the computer because it is the control center of the computer. It first fetches instructions from memory and then interprets them so as to know what is to be done. If required, data is fetched from memory or input device. Thereafter CPU executes or performs the required computation and then either stores the output or displays on the output device. The CPU has three main components which are responsible for different functions – Arithmetic Logic Unit (ALU), Control Unit (CU) and Memory registers

- **Arithmetic and Logic Unit (ALU) :** The ALU, as its name suggests performs mathematical calculations and takes logical decisions. Arithmetic calculations include addition, subtraction, multiplication and division. Logical decisions involve comparison of two data items to see which one is larger or smaller or equal.

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Control Unit : The Control unit coordinates and controls the data flow in and out of CPU and also controls all the operations of ALU, memory registers and also input/output units. It is also responsible for carrying out all the instructions stored in the program. It decodes the fetched instruction, interprets it and sends control signals to input/output devices until the required operation is done properly by ALU and memory.

- **Memory Registers :** A register is a temporary unit of memory in the CPU. These are used to store the data which is directly used by the processor. Registers can be of different sizes(16 bit, 32 bit, 64 bit and so on) and each register inside the CPU has a specific function like storing data, storing an instruction, storing address of a location in memory etc. The user registers can be used by an assembly language programmer for storing operands, intermediate results etc. Accumulator (ACC) is the main register in the ALU and contains one of the operands of an operation to be performed in the ALU.
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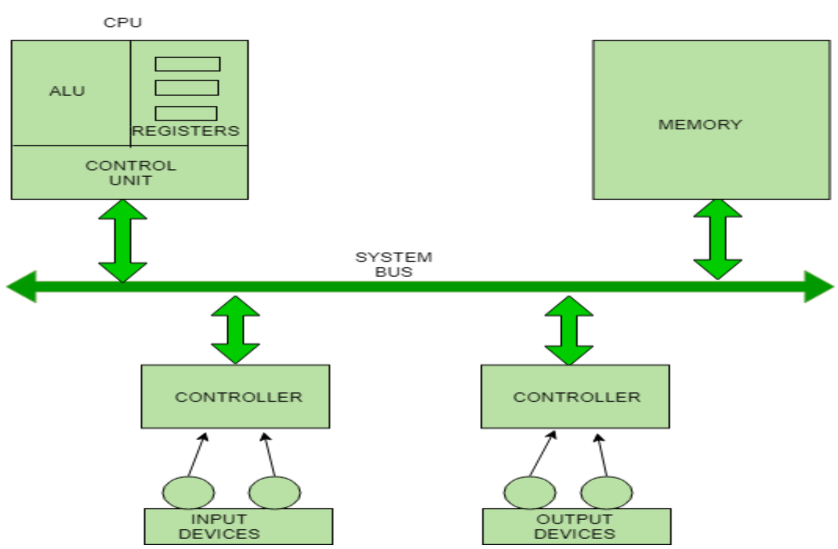
- **Memory :** Memory attached to the CPU is used for storage of data and instructions and is called internal memory The internal memory is divided into many storage locations, each of which can store data or instructions. Each memory location is of the same size and has an address. With the help of the address, the computer can read any memory location easily without having to search the entire memory. when a program is executed, it's data is copied to the internal memory and is stored in the memory till the end of the execution. The internal memory is also called the Primary memory or Main memory. This memory is also called as RAM, i.e. Random Access Memory. The time of access of data is independent of its location in memory, therefore this memory is also called Random Access memory (RAM). Read this for different types of RAMs

- **Output Unit :** The output unit consists of output devices that are attached with the computer. It converts the binary data coming from CPU to human understandable form. The common output devices are monitor, printer, plotter etc.

Interconnection between Functional Components

A computer consists of input unit that takes input, a CPU that processes the input and an output unit that produces output. All these devices communicate with each other through a common bus. A bus is a transmission path, made of a set of conducting wires over which data or information in the form of electric signals, is passed from one component to another in a computer. The bus can be of three types – Address bus, Data bus and Control Bus.

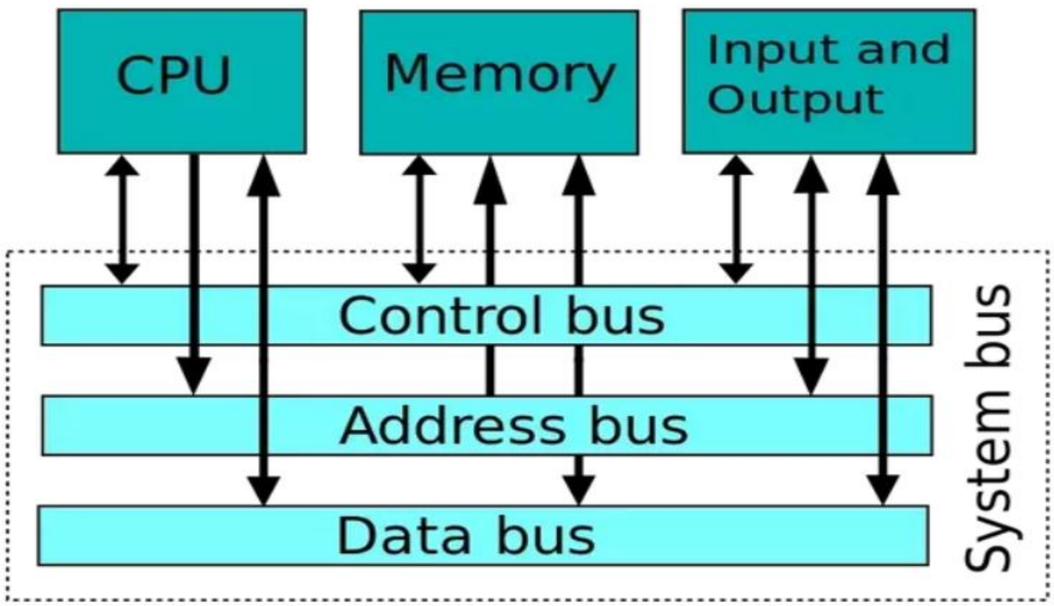
Following figure shows the connection of various functional components:



The address bus carries the address location of the data or instruction. The data bus carries data from one component to another and the control bus carries the control signals. The system bus is the common communication path that carries signals to/from CPU, main memory and input/output devices. The input/output devices communicate with the system bus through the controller circuit which helps in managing various input/output devices attached to the computer.

Q.2 What do you understand by system bus? Explain.

There are three major system bus types that can be identified based on the type of information they carry. **These include the address bus, data bus, and control bus.**



The address bus is a uni-directional pathway, which means that information can only flow one way. Its function is to carry addresses generated by the CPU to the memory and I/O elements of the computer. The number of conductors in this bus determines the size of the address bus. This, in turn, determines the number of memory locations and I/O elements that the microprocessor can address.

1. The data bus, unlike the address bus, is a bi-directional pathway for data flow, which means that information can flow in two directions. Data can flow along the data bus from the CPU to memory during a write operation, and data can move from the computer memory to the CPU during a read operation. However, should two devices attempt to use the bus at the same time, data errors will occur. Any device connected to the data bus must have the capability to temporarily put its output on hold (floating state) when it is not involved in an operation with the processor. The data bus size, measured in bits, represents the computer word size. Generally, the larger the bus size, the faster the computer system. Common data bus sizes are 8-bits or 16-bits (older systems) and 32 bits (newer systems). 64-bit data bus systems are currently being used.
2. The control bus carries the control and timing signals needed to coordinate the activities of the entire computer. Control bus signals, unlike information carried by the data and address buses, are not necessarily related to each other. Some are output signals from the CPU, and others are input signals to the CPU from I/O elements of the system. Every microprocessor type generates or responds to its own set of control signals. The most common control signals in use today are:

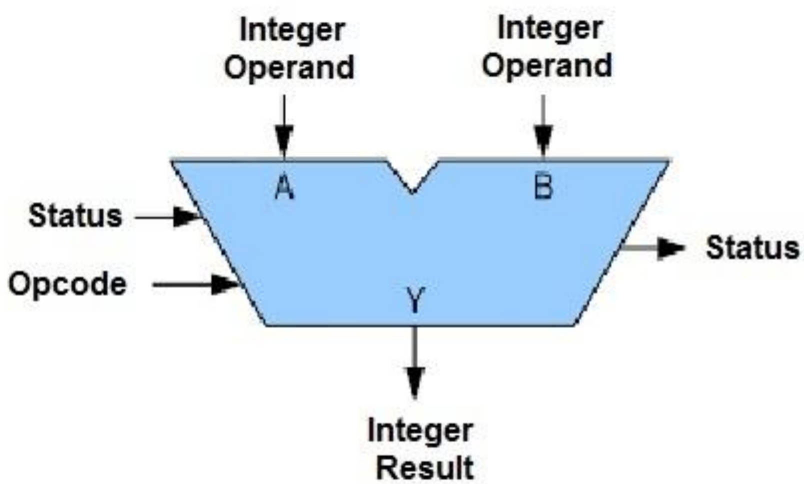
- System Clock (SYSCLK)

- Memory Read (MEMR)
- Memory Write (MEMW)
- Read/Write Line (R/W Line)
- I/O Read (IOR)
- I/O Write (IOW)

Q.3 Explain the following (a) ALU (b) Control unit

(a) ALU

Inside a computer, there is an Arithmetic Logic Unit (ALU), which is capable of performing logical operations (e.g. AND, OR, Ex-OR, Invert etc.) in addition to the arithmetic operations (e.g. Addition, Subtraction etc.). The control unit supplies the data required by the ALU from memory, or from input devices, and directs the ALU to perform a specific operation based on the instruction fetched from the memory. ALU is the "calculator" portion of the computer.



Arithmetic Logic Unit (ALU)

An arithmetic logic unit(ALU) is a major component of the central processing unit of the a computer system. It does all processes related to arithmetic and logic operations that need to be done on instruction words. In some microprocessor architectures, the ALU is divided into the arithmetic unit (AU) and the logic unit (LU).

Different operation as carried out by ALU can be categorized as follows –

- **logical operations** − These include operations like AND, OR, NOT, XOR, NOR, NAND, etc.
- **Bit-Shifting Operations** − This pertains to shifting the positions of the bits by a certain number of places either towards the right or left, which is considered a multiplication or division operations.
- **Arithmetic operations** − This refers to bit addition and subtraction. Although multiplication and division are sometimes used, these operations are more expensive to make. Multiplication and subtraction can also be done by repetitive additions and subtractions respectively.

(b) Control Unit

Introduction of Control Unit and its Design Control Unit is the part of the computer's central processing unit (CPU), which directs the operation of the processor. It was included as part of the Von Neumann Architecture by John von Neumann. 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. A control unit works by receiving input information to which it converts into control signals, which are then sent to the central processor. The computer's processor then tells the attached hardware what operations to perform. The functions that a control unit performs are dependent on the type of CPU because the architecture of CPU varies from manufacturer to manufacturer. Examples of devices that require a CU are:

- Control Processing Units(CPUs)
- Graphics Processing Units(GPUs)

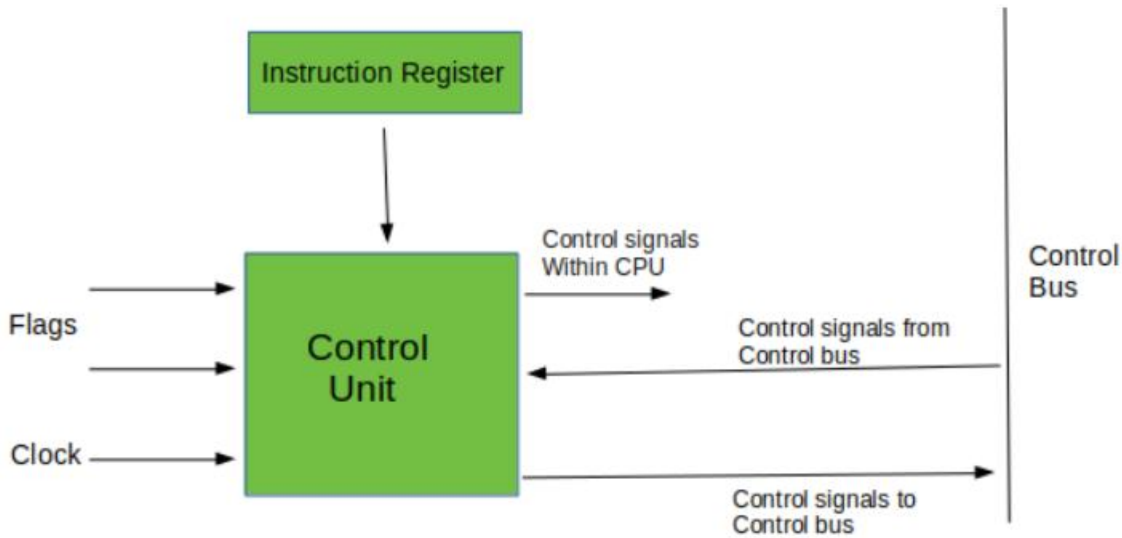


Figure 1: Block Diagram of control unit

Figure : Block Diagram of control unit Functions of the Control Unit – 1. It coordinates the sequence of data movements into, out of, and between a processor's many sub-units. 2. It interprets instructions. 3. It controls data flow inside the processor. 4. It receives external instructions or commands to which it converts to sequence of control signals. 5. It controls many execution units (i.e. ALU, data buffers and registers) contained within a CPU. 6. It also handles multiple tasks, such as fetching, decoding, execution handling and storing results.

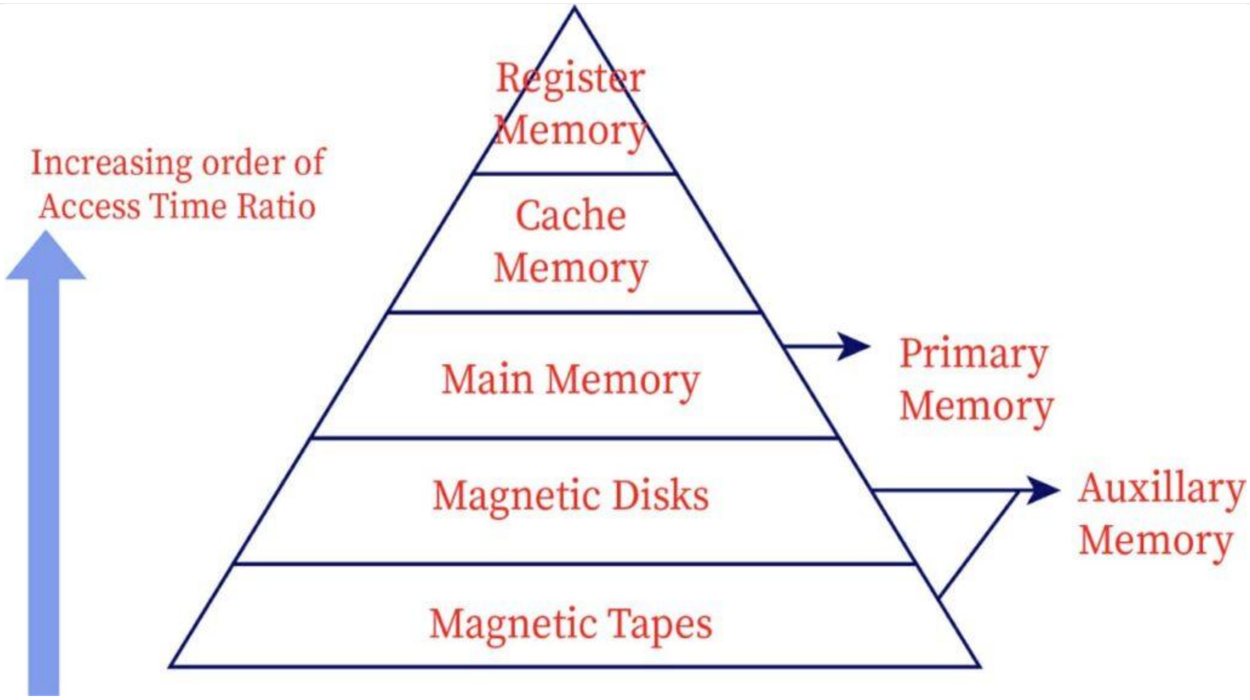
Types of Control Unit – There are two types of control units: Hardwired control unit and Micro programmable control unit.

Q.4 (a) Explain memory hierarchy. Explain the function of RAM.

A collection of connected storage devices form the memory unit. It is a space to store data and instructions required for processing. Information is stored in a memory unit in the form of bits. There are two types of memory namely:

- **Memory that is volatile:** The data is erased when the system is turned off.
- **Memory that is non-volatile:** It is permanent storage where the data remains even after the system is turned off.

Memory hierarchy



- Register memory
- Cache memory
- Main memory
- Magnetic disk
- Magnetic tapes

The memory hierarchy system is from slow auxiliary memory to fast main memory and also has a smaller cache memory. The hierarchy has auxiliary memory at the bottom. The access time of the auxiliary memory is 1000 times the main memory that is why it is at the bottom of the hierarchy system. When the central processing unit (CPU) requires a program that resides in the main memory, the program is brought to the main memory from auxiliary memory. The currently running programs are stored in the main memory. The programs which are not currently running are sent to auxiliary memory to free the space in the main memory. The data and instructions associated with the currently executing program are stored in cache memory. The ratio of the access time of cache memory and the main memory is 1 to 7~10.

Register memory

Register memory is the smallest and fastest memory located within the CPU of the computer. It is the memory associated with the registers which are directly accessed by the CPU. Since it is not a part of the main memory, it is the fastest accessible memory. It is the smallest memory that holds the data and address associated with the instruction currently executing by the CPU.

Cache memory

The data which is frequently required by the CPU from the main memory is stored in cache memory. The data is stored in cache memory for easier access of data in a shorter time. While executing a process, the CPU first checks the cache memory for the required data block. If the data block is not present in the cache memory, the block is transferred to the cache memory from the main memory and then read by the CPU. The search and fetch time of data in the cache memory is less compared to other memories. In cache memory, the old data are deleted simultaneously as the new data keeps entering the cache memory.

Main memory

Computers have a CPU for processing data and auxiliary and cache memory for storing data. These components communicate through the main memory. Main memory is also known as the central storage unit of the system. Main memory is a quite large and fast memory that stores the data and instructions corresponding to the currently executing programs. Main memory consists of RAM (random access memory) and ROM (read-only memory).

RAM

A form of computer memory that is used to store the instructions and data that can be accessed in any sequence. It is a volatile memory that stores the data temporarily. The types of RAM are listed below;

DRAM: It is a dynamic RAM. It is made up of transistors and capacitors. It refreshes every 10 ~100ms. Dynamic RAM is so cheap and slow compared to SRAM.

SRAM: It is called static RAM. It retains data in its six transistor circuits in each cell. Data gets vanished if the power cuts off.

ROM

ROM means Read-Only Memory. ROM is a non-volatile memory. It stores the data permanently. The bootstrap loader program is loaded in from the ROM. Whenever the computer system turns on or resets, ROM starts the operating system. The three common types of ROM are listed below,

PROM-Programmable ROM

EPROM-Erasable programmable ROM

EEPROM-Electrically erasable programmable ROM

Q.4 (b) What do you understand by Input/ Output devices? Explain.

Modern computers have reached the fourth stage of their evolution since the first generation of computers. The fourth generation of computers is based on microprocessors. There are five main components in modern computers.

- Input devices
- CPU
- Output devices
- Primary memory
- Secondary memory

Input and output devices are used in computers to introduce real-world problems from the user, process the problem, and return the results to the user. These devices play a very intricate role in any computer.

Numerous devices such as keyboards, computer video cameras, and microphones help the input functions of a computer. Input devices carry data to a computing device to process the received data. Output devices consist of devices like monitors, printers, and others that show or display the result found by processing the information provided by the input devices.

Input Devices and Output Devices

Various devices are used to receive data via the user or display data produced by the computer. Accordingly, they are called devices that can input or devices that can output. However, certain devices can do both and are recognised as input/output devices. These devices not only receive inputs but can also display outputs.

For instance, a keyboard can be used as an input device that sends an electrical pulse to signal the computer. A computer system receives these signals as inputs, then converts them, processes them, and produces them or displays them to the user in the form of texts and images. The computer also produces another output through the printer. The paper printed via the printer can also be recognised as an output.

Input Devices

Input devices accept commands or data from users or transfer data to other devices. After accepting the input, they convert the received data to electrical signals in the form of binary numbers that are not comprehensible by humans, and a digital computer is required to interpret these. There have been several devices that can work as input devices; a few of these are described below:

Mouse and Keyboard

A computer mouse and keyboard are devices users use to put forth their inputs towards a computer. These devices forward the accepted input (data) via the user to the computer. As the only function of these devices is to accept inputs, they can neither receive nor display output from the computer.

Microphone

A microphone is an input device that receives sound produced by an input source and permits users to transfer audio to their computers. In microphones, the accepted signal may be translated to get a digital signal and can also be an amplified analogue signal.

Webcam

A webcam is an input device that captures photos and records videos from its camera, which has a connection to the system and usually is kept facing its user. A webcam is generally used to click photographs and make videos by a computer system. It takes image files as inputs from where it is pointed and uses them for video calls and capturing selfies. However, most modern webcams are also associated with microphones built into them. These offer advanced audio quality during the making of videos. They are usually attached to computers and are also available in many laptops as they are built into them.

Output Devices

Output devices are devices that receive data through a different device and create outputs with the provided information. Although these devices cannot transfer data to a different device, they have the functionality to carry ahead data from one computer to another computer. Their main objective is to receive data from input devices and convert the electric signals into a method that can be perceived by users.

Monitor

A monitor is a computer peripheral that usually accepts data from the CPU and then outputs data on its screen through the computer's graphic card. Monitors have the functionality to output information at a very high resolution. Additionally, these devices have a functionality similar to that of televisions.

Speaker

Speakers are the most commonly-used used source of output. Speakers are devices that receive sound data from computers and output sounds for the user to hear. Although speakers can be used for any type of sound system, a few are specifically made for computers. They can neither accept sound from the user nor transfer it to another computer system. The main function is to produce output in the form of audio.

Projector

Projectors are output devices that receive data via a computer and then project that information as an image onto a flat surface or a screen. They do not have the ability to receive data as an input from the user or transfer information from one device to another. A projector is the preferred mode of display output over a conventional monitor during a large gathering to show pictures and videos because it can display data on larger surfaces than a traditional monitor, making it more visible for everyone.

Input/Output Devices

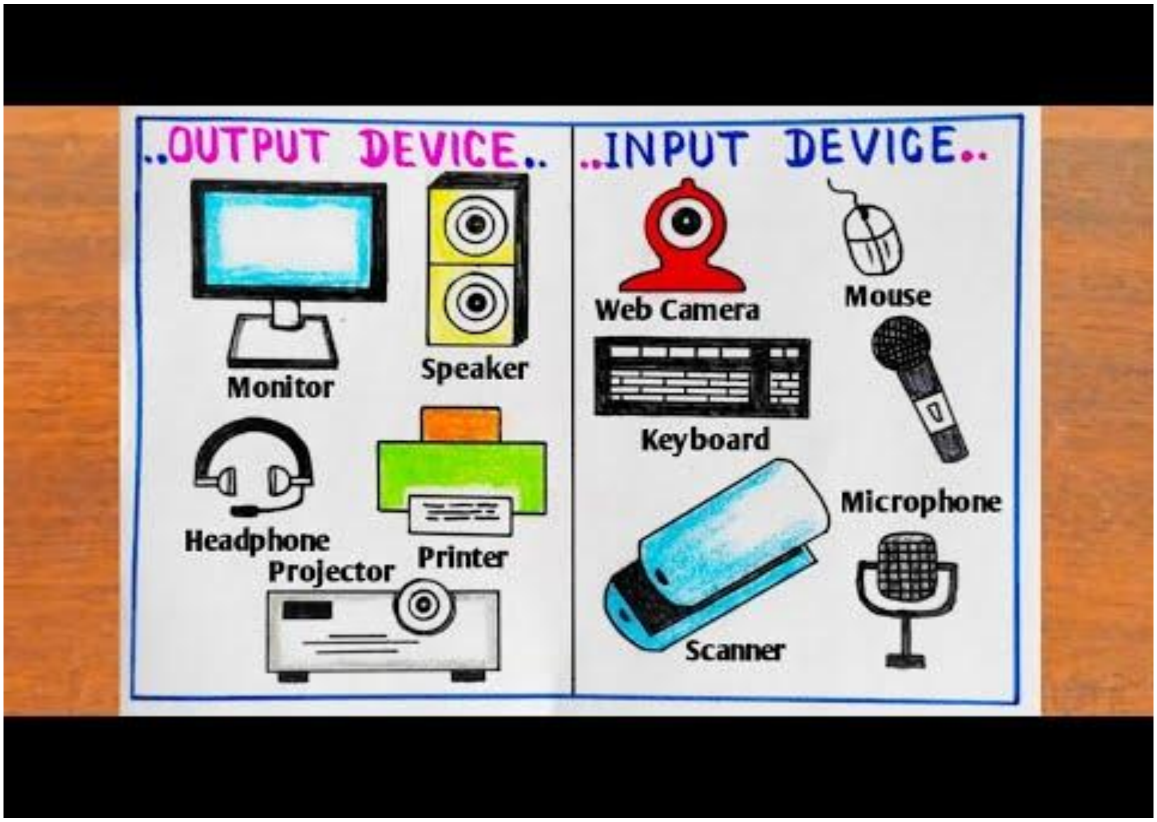
Input/output devices possess the ability to not only accept data or information from users or another input device but also transfer data to another device (output). Some devices which can function as both input and output devices are explained below:

Disk Drives

These drives have specific tasks for receiving data by a computer in the form of an input to be duplicated onto an editable drive. This information is further kept on a CD or DVD and is forwarded to the computer via these drives.

USB Flash Device

Also called a USB flash drive, thumb drive, memory unit, pen drive, these are small portable storage devices that memorise or receive data given by a computer (input). It makes a connection to the computer via a USB port and can transfer data to another computer device (output).



Q.5 What is the Difference between Computer Architecture and Computer Organization

Key differences between computer architecture and computer organization are summarized below:

Computer Architecture	Computer Organization
Computer Architecture is concerned with the way hardware components are connected to form a computer system.	Computer organization is concerned with the structure and behavior of the computer system as seen by the user.
It is a blueprint for design. So, while designing a computer system, architecture is decided first.	Computer organization is decided after the architecture.
It involves logical components such as Instruction Set, Addressing Modes etc.	It involves physical units such as circuit design, adders, signals, peripherals, etc.
It describes how a computer system is designed.	It describes how a computer system works.
It acts as an interface between hardware and software.	It deals with the components of a computer and the interconnection of components.

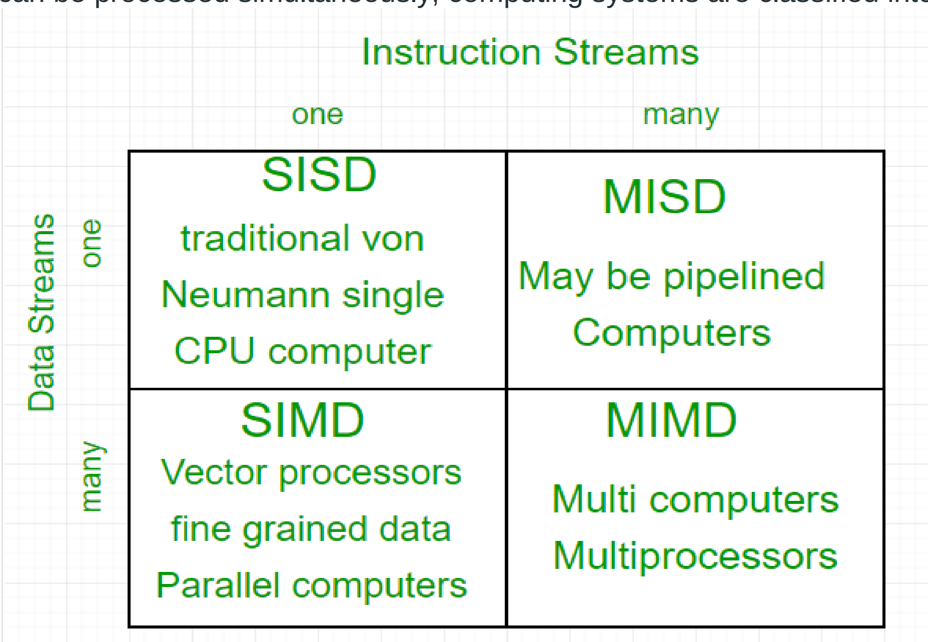
Computer architecture deals with high-level design issues.	Computer organization deals with low-level design issues.
Computer architecture defines the logical aspects of a computer system.	Computer organization defines the physical aspects of the computer system.
It deals with the functional behavior of the computer system.	It deals with the organizational structure of the computer and the various structural relationships.
It is also called an instruction set architecture.	It is also called microarchitecture.
Concerned with - What to do? (Instruction Set)	Concerned with - How to do?(implementation of the architecture)

These were some of the basic differences between computer architecture and computer organization, which will help you to understand these terms further.

Computer Architecture (NBCA 303)
UNIT- 2

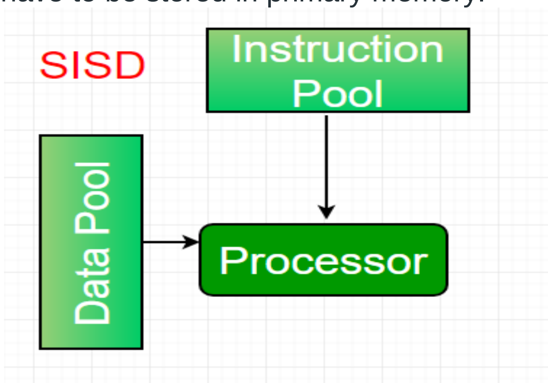
Q.1 Explain Flynn's and Feng's Classification of computers.

- **Parallel computing** is a computing where the jobs are broken into discrete parts that can be executed concurrently. Each part is further broken down to a series of instructions. Instructions from each part execute simultaneously on different CPUs. Parallel systems deal with the simultaneous use of multiple computer resources that can include a single computer with multiple processors, a number of computers connected by a network to form a parallel processing cluster or a combination of both. Parallel systems are more difficult to program than computers with a single processor because the architecture of parallel computers varies accordingly and the processes of multiple CPUs must be coordinated and synchronized.
  The crux of parallel processing are CPUs. Based on the number of **instruction and data** streams that can be processed simultaneously, computing systems are classified into four major categories:



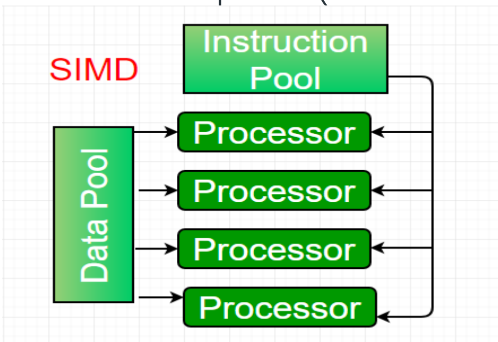
Flynn's classification –

1. **Single-instruction, single-data (SISD) systems –**
   An SISD computing system is a uniprocessor machine which is capable of executing a single instruction, operating on a single data stream. In SISD, machine instructions are processed in a sequential manner and computers adopting this model are popularly called sequential computers. Most conventional computers have SISD architecture. All the instructions and data to be processed have to be stored in primary memory.



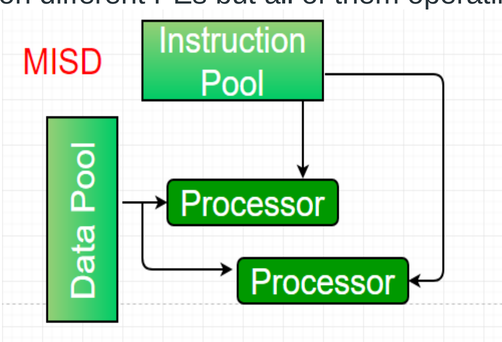
The speed of the processing element in the SISD model is limited(dependent) by the rate at which the computer can transfer information internally. Dominant representative SISD systems are IBM PC, workstations.

2. **Single-instruction, multiple-data (SIMD) systems –**
   An SIMD system is a multiprocessor machine capable of executing the same instruction on all the CPUs but operating on different data streams. Machines based on an SIMD model are well suited to scientific computing since they involve lots of vector and matrix operations. So that the information can be passed to all the processing elements (PEs) organized data elements of vectors can be divided into multiple sets(N-sets for N PE systems) and each PE can process one data set.



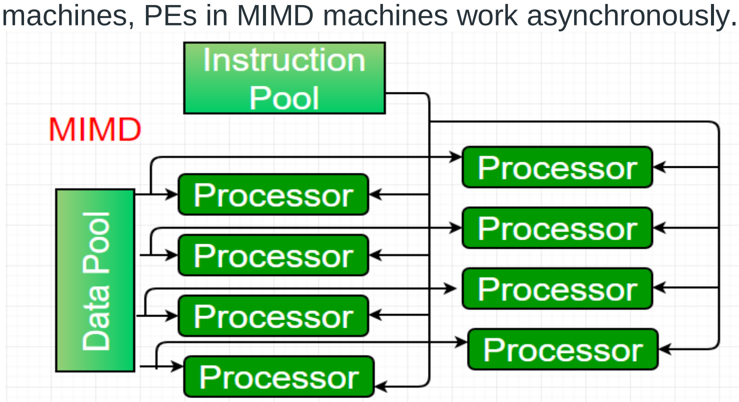
   Dominant representative SIMD systems is Cray's vector processing machine.

3. **Multiple-instruction, single-data (MISD) systems –**
   An MISD computing system is a multiprocessor machine capable of executing different instructions on different PEs but all of them operating on the same dataset .



   Example Z = sin(x)+cos(x)+tan(x)
   The system performs different operations on the same data set. Machines built using the MISD model are not useful in most of the application, a few machines are built, but none of them are available commercially.

4. **Multiple-instruction, multiple-data (MIMD) systems –**
   An MIMD system is a multiprocessor machine which is capable of executing multiple instructions on multiple data sets. Each PE in the MIMD model has separate instruction and data streams; therefore machines built using this model are capable to any kind of application. Unlike SIMD and MISD machines, PEs in MIMD machines work asynchronously.



Feng’s Classification

Parallel computing refers to the process of executing several processors or applications simultaneously. It is a kind of architecture where large problems break into smaller or usually similar parts that can be processed in one go. Parallel computing helps in faster application processing and task resolution.
There are various architectural schemes defined in order to achieve parallel computing. I.e. Flynn’s taxonomy, Feng’s Classification, Handler’s Classification, etc.

Feng’s Classification

Tse-yun Feng proposed a system for classifying the parallel processing system. This classification is based on the number of bits in a word and word length. This parallelism is based on the parallelism of bits and words. Hence we can have the bits of word processed in parallel or serially. Similarly, we can have words processed in parallel or serially. Thus resulting in the following four categories-

1. Word Serial Bit Serial (WSBS)

In this case, one bit of a selected word is processed at a time. This corresponds to serial processing and hence requires maximum processing time.

2. Word Serial Bit Parallel (WSBP)

In this case, all the bits of a selected word are processed simultaneously, but one word at a time. Hence bit parallel indicates the selection of all the bits of a word. Hence it is slightly parallel processing.

3. Word Parallel Bit Serial (WPBS)

In this case, one selected bit from all the specified words is processed at a time. Hence word parallel indicates the selection of multiple words. WSBP can be said to be row parallelism while WPBS can be said as column parallelism.

4. Word Parallel Bit Parallel (WPBP)

In this case, all the bits of all the specified words are operated on simultaneously. Hence this gives the maximum parallelism thereby minimum time for execution. The processors are classified according to Feng’s Classification can be shown in the graphical representation with a number of bits vs numbers of words in parallel.

Processors like IBM370, Cray-1, and PDP11 have words executed in parallel but the word size varies from 16 to 64 bits. Thus these processes can be said to be WSBP (Word Serial Bit Parallel) processors.

- STARAN and MPP processors have one bit of a word executed at a time but multiple words together. These processors can hence be categorized under WPBS (Word Parallel Bit Serial).
- Processors like C.mmp and PEPE are having multiple bits and multiple words being executed simultaneously and hence can be categorized under WPBP (Word Parallel Bit Parallel).

Q.2 Compare CISC and RISC architecture.

CISC vs RISC in a tabular format:

This architecture emphasizes on	Hardware	Software

Control unit used	Hardwired and microprogrammed control unit	Hardwired control unit
Types of operations that can be performed are	Register to Register, Register to Memory, and Memory to Memory	Register to Register
Size of code	Small	Large
Number of registers required	Less	More
The execution time required for an instruction	More than one clock cycle	A single clock cycle
Use of pipeline is	Difficult	Easy
Decoding instructions is	Difficult	Simple
The instruction format is	Variable	Fixed
Examples	VAX, System/360, etc.	Power Architecture, SPARC, etc.

What is CISC?

CISC Definition: ***CISC, or Complex Instruction Set Architecture, reduces the number of instructions per program while increasing the number of cycles per instruction.***

Complex Instruction Set Computer (CISC) Characteristics λMajor characteristics of a CISC architecture

»1) A large number of instructions - typically from 100 to 250 instruction

»2) Some instructions that perform specialized tasks and are used infrequently

»3) A large variety of addressing modes - typically from 5 to 20 different modes

»4) Variable-length instruction formats

»5) Instructions that manipulate operands in memory (RISC in register)

The CISC architecture reduces the number of instructions on each program while increasing the number of cycles per instruction. Because of this functionality, the instructions can take a lot of time in order to complete their execution. In CISV architecture, the instructions are directly built into hardware as hardware is faster in comparison to the software.

What is RISC?

RISC Definition: ***RISC, or Reduced Instruction Set Architecture, reduces the cycles per instruction while increasing the number of instructions per program.***

The RISC architecture reduces the cycles per instruction while increasing the number of instructions per program. Because of this functionality, the instructions take much less time to complete their execution compared to the execution of the instruction in the CISC architecture. RISC architecture emphasizes on software to optimize the instruction set.

Reduced Instruction Set Computer (RISC) λMajor characteristics of a RISC architecture

»1) Relatively few instructions

»2) Relatively few addressing modes

»3) Memory access limited to load and store instruction

»4) All operations done within the registers of the CPU

»5) Fixed-length, easily decoded instruction format

»6) Single-cycle instruction execution

»7) Hardwired rather than microprogrammed control

Q.3 What are Micro-Operations

The operations performed on the data stored in registers known as micro-operations. Example: Shift, Count Clear and Load. The micro-operations are classified as follows.

- **Register Transfer Micro-operation:** this type of micro operations are used to transfer from one register to other binary information. The term register transfer means transfer the result of the operation to the same or another register. Following are some commonly used registers:
  - Accumulator: adding a sequence of numbers.
  - General Purpose Registers: are available to store the data required by the program.
  - Special Purpose Registers: Users do not access SPR. These registers are for Computer system.
  - Memory Address Register: MAR are those registers that hold the address for memory unit.
  - Memory Buffer Register: MBR stores instruction and data received from the memory and sent from the memory.
  - Program Counter: informs the user to execute next instruction to be executed.
  - Instruction Register: IR holds the instruction being executed or decoded.
  - Information is transferred from one register to other in a symbolic form.

$$R2 \leftarrow R1$$

The data get transfer from register R1 into R2.

- **Arithmetic Micro-Operations:** A micro operation is an elementary operation performed with the data stored in the registers. It performs arithmetic operation on numeric data stored in registers.
  - Addition Micro-Operation:-It is defined by the following statement:

$$R3 \rightarrow R1 + R2$$

It states that the contents of the register R1 are added with the content of the register R2 and the result will be transferred to register R3.

- Subtract Micro-Operation:-It is defined by the following statement, Let us take an example

$$R3 \rightarrow R1 + R2' + 1$$

In subtract micro-operation, instead of using minus operator we take 1's compliment and add 1 to the register which gets subtracted, i.e. R1 – R2 is equivalent to $R3 \rightarrow R1 + R2' + 1$

-
- Increment/Decrement Micro-Operation:- In Increment the content of the register increment by 1 and In decrement the content of the register decrement by 1.

$$R1 \rightarrow R1 + 1$$

$$R1 \rightarrow R1 - 1$$

Symbolic Designation	Description
$R3 \leftarrow R1 + R2$	Contents of R1+R2 get transfer to R3.
$R3 \leftarrow R1 - R2$	Contents of R1-R2 get transfer to R3.
$R2 \leftarrow (R2)'$	Compliment the contents of R2.
$R2 \leftarrow (R2)' + 1$	2's compliment the contents of R2.
$R3 \leftarrow R1 + (R2)' + 1$	R1 + the 2's compliment of R2 (subtraction).
$R1 \leftarrow R1 + 1$	Increment the contents of R1 by 1.
$R1 \leftarrow R1 - 1$	Decrement the contents of R1 by 1.

- **Logic Micro-Operations:** individual bits of registers are operated with other corresponding register bits. Example: the XOR of R2 and R1 is symbolized by

$$P: R1 \leftarrow R1 \oplus R2$$

Example: R1 = 1010 and R2 = 1100

1010

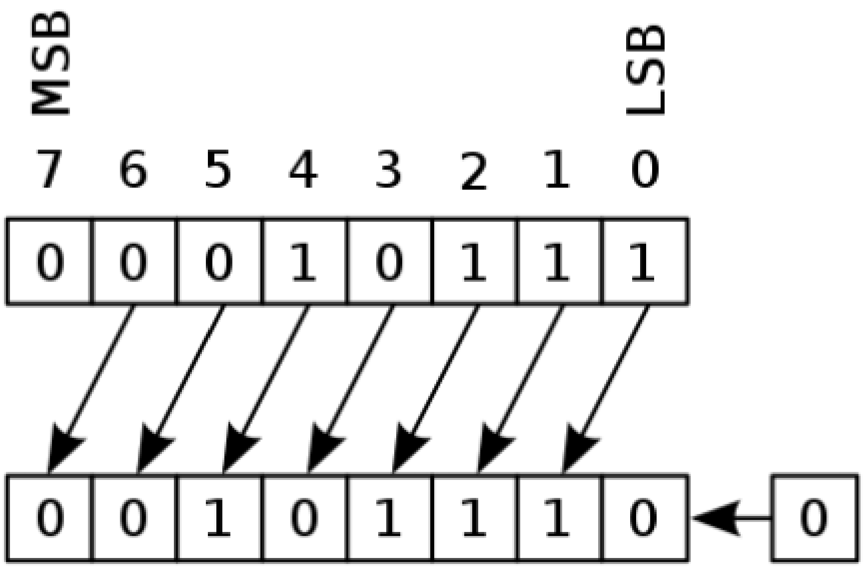
Content of R1

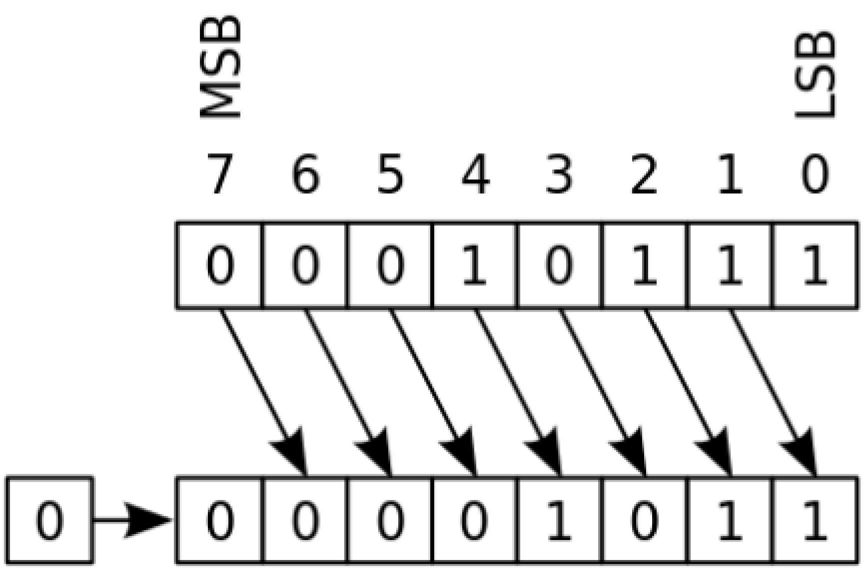
1100

Content of R2

0110

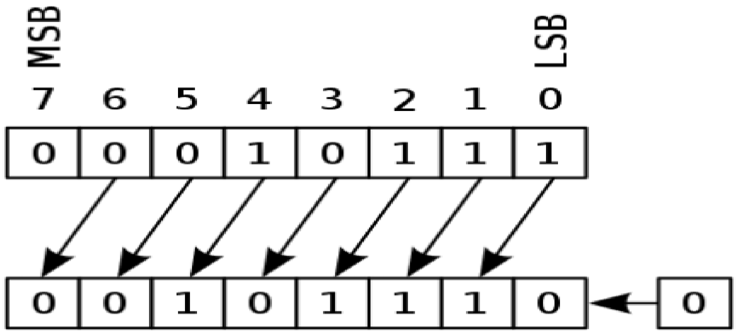
Content of R1 after P = 1

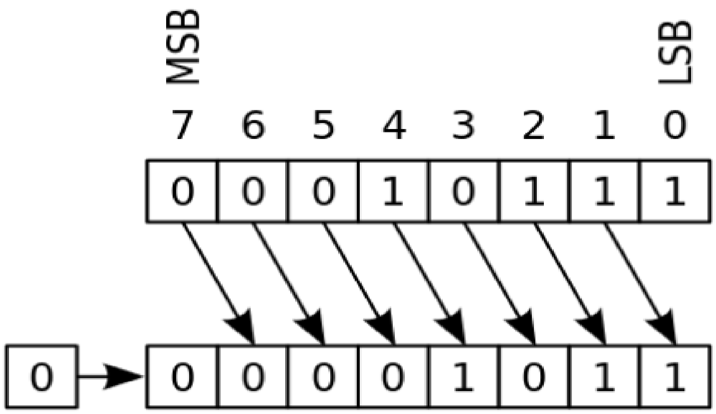




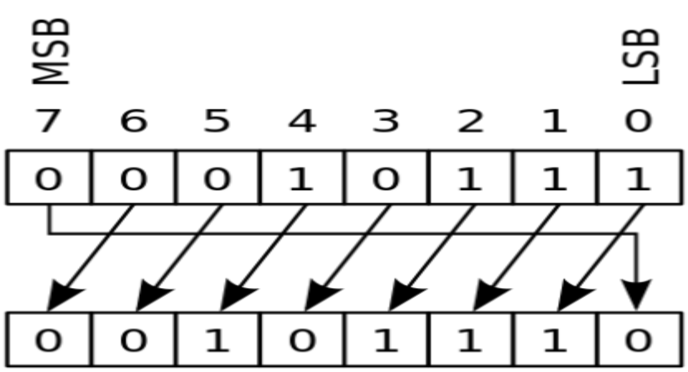
- Shift Micro-Operations: – these operations are used for serial transfer of data. They are also used in conjunction with arithmetic, logic, and other data-processing operation. The content of register can be shifted to the left or to the right. At the same time the bits are shifted, the flip flop receives the binary information from the serial input.

- Logical Shift:- The symbol “shl” is used for logical shift left and “shr” is used for logical shift right. The number got shifted to the right side if the “shr” symbol is used by one and in the same manner the number got shifted to the left side by using “shl”.

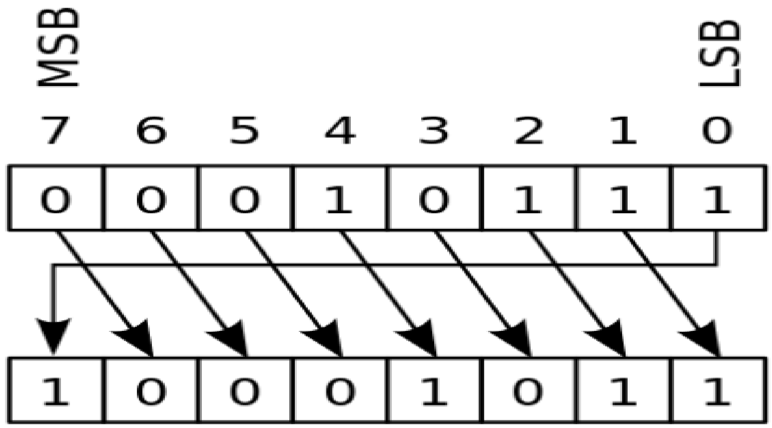




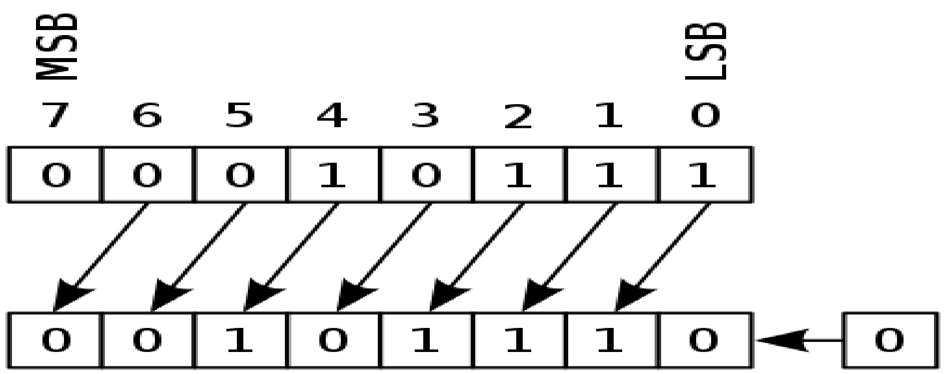
- **Circular Shift: –** is the operation of rearranging the entries in a Tuple, either by moving the final entry to the least significant bit, while shifting all other entries to the most significant bit, or by performing the inverse operation. “cil” and “cir” is used for circular shift left and circular shift right respectively.

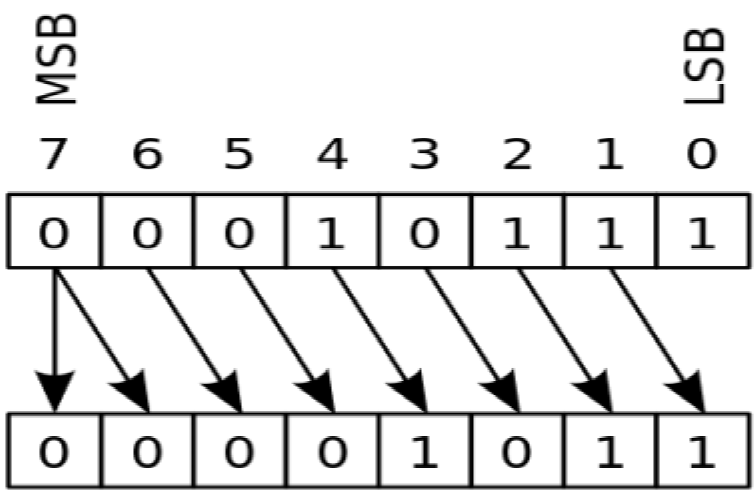


Left Circular Shift



- Arithmetic Shift:- A shift operator, sometimes termed a signed shift (though it is not restricted to signed operands). There are two types of arithmetic left shift and the arithmetic right shift.



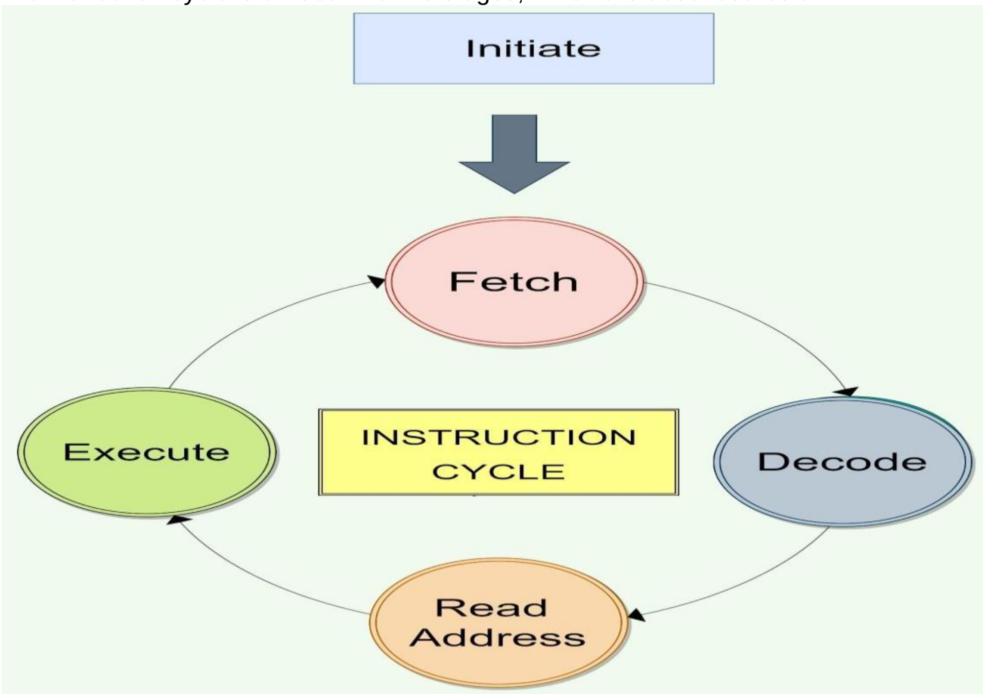


Q.4 What is the Instruction Cycle?

The instruction cycle is defined as the basic cycle in which a computer system fetches an instruction from memory, decodes it, and then executes it. Fetch-Execute-Cycle is another name for it. All instructions in a computer system are executed in the RAM of the computer system. The CPU is in charge of carrying out the instruction.
Each instruction cycle in a basic computer includes the following procedures:

- It has the ability to retrieve instructions from memory.
- It's used to decode the command.
- If the instruction has an indirect address, it can read the effective address from memory.
- It is capable of carrying out the command.

The instruction cycle is divided into five stages, which are described below:



Initiating Cycle

During this phase, the computer system boots up and the Operating System loads into the central processing unit's main memory. It begins when the computer system starts.

Fetching of Instruction

The first phase is instruction retrieval. Each instruction executed in a central processing unit uses the fetch instruction. During this phase, the central processing unit sends the PC to MAR and then the READ instruction to a control bus. After sending a read instruction on the data bus, the memory returns the instruction that was stored at that exact address in the memory. The CPU then copies data from the data bus into MBR, which it then copies to registers. The pointer is incremented to the next memory location, allowing the next instruction to be fetched from memory.

Decoding of Instruction

The second phase is instruction decoding. During this step, the CPU determines which instruction should be fetched from the instruction and what action should be taken on the instruction. The instruction's opcode is also retrieved from memory, and it decodes the related operation that must be performed for the instruction.

Read of an Effective Address

The third phase is the reading of an effective address. The operation's decision is made during this phase. Any memory type operation or non-memory type operation can be used. Direct memory instruction and indirect memory instruction are the two types of memory instruction available.

Execution of Instruction

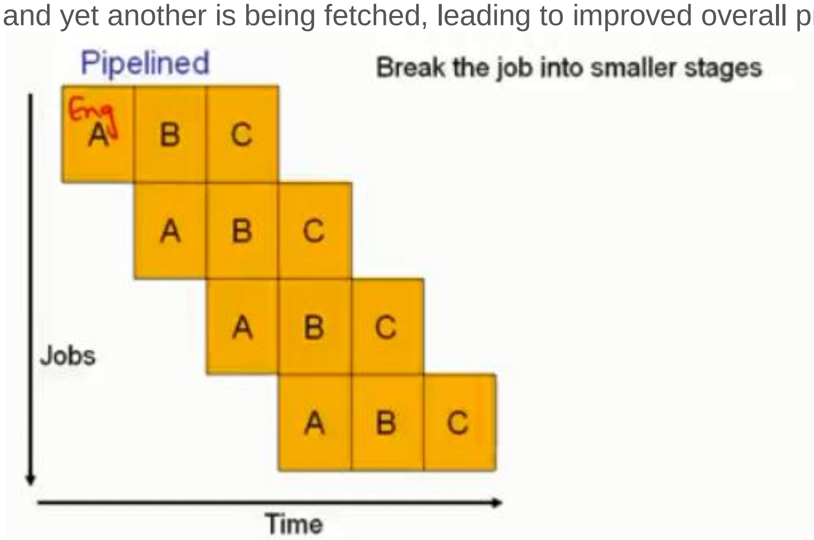
The last step is to carry out the instructions. The instruction is finally carried out at this stage. The instruction is carried out, and the result is saved in the register. The CPU gets prepared for the execution of the next instruction after the completion of each instruction. The execution time of each instruction is calculated, and this information is used to determine the processor's processing speed.

Q.5 What is difference between Pipelining and Parallel Processing

Pipeline Processing

It is a technique used in computer architecture where multiple instruction phases are overlapped to increase throughput and efficiency. The process is divided into distinct stages, such as instruction fetch, decode, execute, and write-back. As one instruction moves from one stage to the next, other instructions can enter the pipeline at different stages, allowing for continuous processing. This approach effectively maximizes the use of processor resources and reduces the time it takes to execute multiple instructions by breaking the overall process into smaller, manageable segments.

Example : In a five-stage pipeline, while one instruction is being executed, another is being decoded, and yet another is being fetched, leading to improved overall processing speed.



Parallel Processing

It involves the simultaneous execution of multiple tasks or processes to achieve faster computational performance. It utilizes multiple processors or cores to handle different tasks or parts of a task at the same time. This approach can be applied at various levels, including data-level parallelism, task-level parallelism, and instruction-level parallelism. By distributing tasks across multiple processing units, parallel processing can significantly reduce the time required to complete complex computations and improve overall system performance.

Example : In a multi-core processor system, different cores can execute separate threads of a program simultaneously, speeding up the execution of multi-threaded applications.