Microprocessors (3 – 1 – 2)

Evaluation:

	Theory	Practical	Total
Sessional	30	20	50
Final	50	-	50
Total	80	20	100

Course Objectives:

The Objective of this course is to provide the knowledge of

1. the architecture and organization of a Microprocessor (8085/8086).
2. the Basic operations, programming and application of Microprocessor.
3. the Interfacing I/O devices with the Microprocessor.
4. the foundation for the microprocessor based system design.

1. Introduction to Microprocessors **[4 hrs]**

1.1 Evolution of Microprocessors
1.2 Von Neumann and Harvard architecture
1.3 Microprocessor & Micro controller
1.4 Internal architecture of 8 bit Microprocessor 8085
1.5 concept of fetch, decode and execution

2. Assembly Language Programming **[10 hrs]**

2.1 Instruction Formats (Opcodes, mnemonics and operands)
2.2 8085 Instruction Sets
2.3 Functional Architecture of 8085
2.4 Addressing Modes of 8085
2.5 Data Transfer Instructions, Arithmetic and Logic Instructions, Program Control
Instructions (Jump Instructions, Subroutine Call)
2.6 Timing Diagram
2.7 RTL Instruction descriptions
2.8 Assembly language program

3. Bus Structure, Memory and I/O Interfacing **[13 hrs]**

3.1 Bus Structure: Bus structure, Synchronous and Asynchronous data bus, Address bus, Read/Write operations and bus timing (READ Cycle, WRITE Cycle).
3.2 Memory Interfacing: Types of Memory, RAM and ROM Interfacing with Timing Considerations, DRAM Interfacing, Memory mapped I/O, I/O mapped I/O.
3.3 I/O Interfacing: Concept of Interrupt, Interrupts of 8085 (Programmed I/O, Interrupt Driven I/O), DMA, Parallel I/O (8255-PPI), Serial I/O (8251/8250), 8259-Programmable Interrupt Controller, 8237-DMA Controller.

4. 16-bit Microprocessor and Programming **[13 hrs]**

4.1 Internal Organization of 8086
4.2 Bus Interface Unit & Execution Unit
4.3 Pin diagram

4.4 Instruction Set
4.5 Addressing Modes of 8086
4.6 Assembly language programming (Simple Sequence programs, jumps, flag and conditional jumps, if-then programs)
4.7 One Pass and Two Pass Assemblers
4.8 Assembler Directives
4.9 Procedures and Macros
4.10 System Timing Diagrams
4.11 Functional Chips (8284A Clock Generator, 8282 Address Latch, 8286 transceiver, 8288 Bus Controller)
4.12 Interrupt and Interrupt service procedures
4.13 Interrupt Vector Table
4.14 Introduction to Intel 80386.

5. Data Communication Basics **[5 hrs]**

5.1 Serial and Parallel Data Communication
5.2 Asynchronous Serial Data Communications
5.3 Serial data transmission methods and standards (RS232/RS-232C, RS422/423A)
5.4 Synchronous Serial Data Communication and Protocols (BISYNC).

Laboratory Works:

1. Assembly language program using 8085 microprocessor kit. Program should comprise the use of all types of instructions and addressing modes.
2. Assembly language programming with 8086 family. Program should comprise the use of all types of instructions and addressing modes.
3. The programming should include the concept of Arrays and the concept of Multiplications and Division operations on Microprocessor.
4. Assembly language programming, using any type of Assembler, which should include the different functions of Interrupt (Int 10h, and Int 21h).

Text Books:

1. R. Gaonkar, *Microprocessor Architecture, Programing & Application*, Penram International Publishing.
2. Hall D. V., *Microprocessors Interfacing*, TMH (2nd Edition)
3. Liu G. A. Gibson, *Microcomputer Systems: The 8086 / 8088 Family*, PHI 2nd Ed.

Reference Books:

1. M. Rafiquzzaman, *Microprocessors Theory & Applications*, PHI
2. Kenneth J. Ayala, *The 8051 Micro controller*, Penram International Publishing 1996
3. Kip Irvine, Maxwell Macmillan, *Assembly language for the IBM PC*
4. K. Gosh, Prentice Hall, *Introduction to 8085 Microprocessor for Engineers and Scientists*

CHAPTER-1

Introduction to Microprocessors (4 hrs)

EVOLUTION OF MICROPROCESSOR:

The microprocessor revolution began with a bold and innovative approach in logic design pioneered by Intel Engineer, Ted Hoff. He suggested for the first time, a general-purpose chip that could perform various logic functions, which could be activated by providing patterns of 0s and 1s through registers with appropriate timing.

Intel coined the term 'microprocessor' for the first time in 1971 and released the first 4-bit microprocessor as the 4004. Intel Corporation is the leading corporation in the evolution of microprocessors, so we focus on various Intel Series of microprocessors in describing the evolution of microprocessor. The various Intel series microprocessors with their essential features are as given below:

Intel 4004

- It was the first commercially available microprocessor produced in 1971.
- It was designed with LSI technology and contained 2300 PMOS transistors.
- It was 4-bit microprocessor with data bus of 4-bit and address bus of 10-bit.
- It had addressable memory of 640 bytes.
- It had initial clock speed of 108 kHz.
- It was a 4 bit device intended to be used with some other devices in making a calculator.

Intel 8008

- Intel 4004 was replaced by the 8-bit microprocessor, Intel 8008 in 1972.
- It had the data bus of 8-bit, address bus of 14-bit and the memory addressing capacity was 16K.
- It contained 3,500 transistors and had initial clock speed of 200 kHz.
- Intel 8008, however required 20 or more additional devices to form a functional CPU.

Intel 8080

- In 1974 Intel announced the 8080, which had a much larger instru and required only two additional devices to form a functional CPU.
- The 8080 used NMOS transistor, so it operated much faster than the 8008
- It had the data bus of 8-bit, address bus of 16-bit and addressable memory of 64K.
- The initial clock speed of Intel 8080 was 2 MHz.
- The 8080 is referred to as a Second generation Microprocessor.
- It was widely used in control applications, and small computers also were designed using the 8080 as the CPU.
- It required +5V,-5V and +12V supply.

Intel 8085

- In 1976, Intel produced 8085, an upgrade of 8080 that required only a +5V supply.
- In the same year Motorola 6800, the Zilog Z80 were developed.
- It was designed with upward software compatible with the 8080 i.e. it included all the instructions of the 8080 plus additional instructions.
- It was 8 bit microprocessor with data bus of 8-bit and address bus of 16-bit with memory addressing capability of 64K.
- It is widely used in the areas of industrial control, process control, instrumentation, and consumer appliances.

Intel 8086

- In 1978 Intel came out with the 8086 which is a full 16 bit Microprocessor.
- It has a 16 bit data bus and has systematic internal architecture with the implementation of segmentation and pipelining concepts.
- It has the address bus of 20-bit and can address up to 2^{20} = 1M or 1048576 memory locations.

Intel 8088

IBM.

- It has 16 bit registers and the internal data bus of 16-bit but the external data bus of 8 bit.
- It has address bus of 20-bit, so the addressable memory is of 1M.
- It includes the features of both 8085 and 8086 microprocessors so it has faster and systematic internal architecture and is much easier to interface with peripheral devices.

Intel 80186 and Intel 80188

- The Intel 80186 is an improved version of the 8086, and Intel 80188 is an improved version of the 8088 microprocessor.
- In addition to a 16-bit CPU, the 80186 and 80188 each have programmable peripheral devices integrated in the same package.
- The instruction sets of the 80186 and 80188 are the superset of the instruction set of the 8086.

Intel 80286

- It was first introduced in 1982 and had 16-bit data bus and 24-bit address bus.
- It is a 16-bit, advanced version of the 8086 which was specially designed for use as the CPU in a multiuser or multitasking microcomputer.
- Runs faster than the preceding processors, has additional capabilities and can address up to 16 million bytes.
- This processor can operate in real mode or in protected mode, which enables an operating system like windows to perform multitasking and to protect them from each other.
- The 80286 is the CPU used in the IBM PC/AT personal computer.

Intel 80386

- It was first 32-bit processor introduced in 1985.
- With the 80386 processor, Intel started the 32-bit processor architecture, known as the IA-32 architecture. This architecture extended all the address and general purpose registers to 32-bits which gave the processor the capability to handle up to 4GB of memory addressing.

Int 4004 8008 8080

system.

- The processor supports virtual mode, whereby it can swap portions of memory onto disk

Intel 80486

- It was first introduced in 1989 and contained about 1.2 millions of transistors.
- Most of the features of Intel 80486 are same as Intel 80386. The main new features included in the 80486 are a built-in 8-Kbyte code/data cache and a 32-bit floating point unit.
- Has 32 bit registers and 32 bit data bus.
- High speed cache memory connected to the processor bus enables the processor to store copies of the most recently used instructions and data.
- The processor can operate faster when using the cache directly without having to access the slower memory.

Intel PENTIUM

- The term "Pentium processor" refers to a family of microprocessors that share a common architecture and instruction set.
- The first Pentium processor (the P5 variety) was introduced in 1993.
- The microprocessors with Pentium architecture have 32 bit registers, a 64 bit data bus and separate caches for data and for memory.
- Various series of Intel Pentium processors were developed with the successive advancements in features, like clock speed, cache memory, bus speed, low power consumption, number of cores and so on.
- The Pentium has a 5 Stage pipelined structure and the Pentium II has a 12 stage super pipelined structure.
- This feature enables them to run many operations in parallel.
- Pentium, Pentium Pro, Pentium II, Pentium III, Pentium 4 are the different Pentium series of microprocessors introduced by Intel from 1993 for use in a wide variety of a computer

bus of 36-bit , and thus memory addressing capability up to 64 GB.

Intel Core Processors

- Intel introduced the Core brand in 2006 as a replacement for the Pentium M line of processors.
- Different series of modern core processors include the Core Solo, Core Duo, Core 2 Quad, Core i3, Core i5 and Core i7 processor families.
- These Core processors include every essential features of their predecessors and also include the more advanced features for high speed operation, protection from overheat and so on.
- The various core processors vary with each other in the important features like:
  - the number or cores,
  - Intel turbo boost,
  - cache-size,
  - Hyper-threading and so on.
- The strength of these features in the core processors determines the processing power and thus their ratings.
- With the availability of most advanced features, the Core processors occupy most of the world's modern market for designing computer systems.

- On the basis of methods of storing programs and data, we can categorize the computing machines as:
  1. Fixed Program Machines, and
  2. Stored Program Machines

1. Fixed Program Machines:

- The earliest computing machines had fixed programs.
- These machines were programmed by setting switches and inserting patch leads to route data and to control signals between various functional units.
- Changing the program of a fixed-program machine requires rewiring, restructuring, or redesigning the machine.
- "Reprogramming", when it was possible at all, was a laborious process, starting with flowcharts and paper notes, followed by detailed engineering designs.
- For example- ENIAC

2. Stored Program Machines:

- A stored-program machine is one which stores program instructions and data in electronic memory.
- The program stored in this machine can be easily reprogrammed.
- Von Neumann machine is one of the best example of Stored Program Machine or Stored Program Computer.

Neumann & Harvard Architecture:

Neumann Architecture:

It is also called as Stored Program Computer.

This architecture was first founded by John Von Neumann in 1945 A.D.

This describes a design architecture for an electronic digital computer with parts consisting of a processing unit containing an arithmetic logic unit and processor registers, a control unit containing an instruction register and program counter, a memory to store both data and instructions, external mass storage, and input and output mechanisms.

ntel 8085 microprocessor follows this architecture.

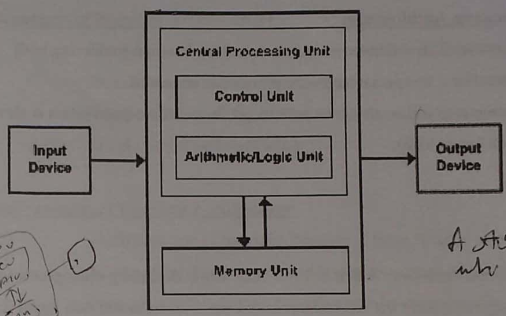


Fig. Von Neumann Architecture

Memory Unit:

- Both data and instructions are stored in single electronic memory unit , so it is easy to read/write data and instructions
- Instruction fetch and a data operation cannot occur at the same time because they share a common bus.

Control Unit (CU):

- This unit consists of Instruction Register and Program Counter.
- It helps for instruction interpretation and program execution to control the overall functioning of the whole system.

Arithmetic/Logic Unit (ALU):

- Performs various arithmetic and Logic Operations.

Input/output Devices:

- These devices help to provide external communication of the system with the user.

Advantages of Von Neumann Architecture:

- Holds instructions as easy as data.
- Efficient use of memory.
- Ease of loading program from memory.

Disadvantages of Von Neumann Architecture:

- Data can overwrite instructions as uses same memory location for storing both data and instructions, so special hardware precaution is needed.
- Data and instructions follow the same path to get the processor, so system is slow (called limited bandwidth).

Harvard Architecture:

- First founded by Harvard Hathaway Aiken in 1944 A.D. while designing microprocessor.
- It is also a stored-program system but has one dedicated set of address and data buses for reading data from and writing data to memory, and another set of address and data buses for fetching instructions.

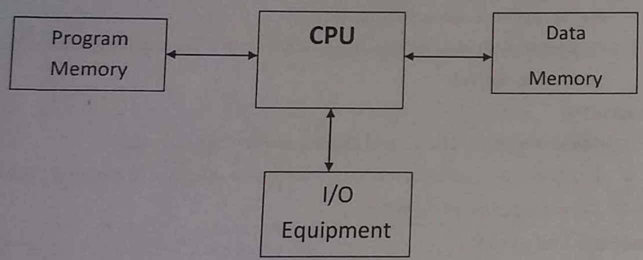


Fig. Harvard Architecture

- In this architecture, memory for storing program and data are separate, so it is faster than Von Neumann Architecture.
- For example, DSP (Digital Signal Processor) uses this architecture.
- Operations of all parts are similar to that of Von-Neumann Architecture.

Advantages of Harvard Architecture:

- The program and data memory are stored in different memory, thus preventing from overwrite.
- Separate dedicated bus system for program and data, so the data transfer is much faster (sufficient bandwidth).

Disadvantages of Harvard Architecture:

- Inefficient use of memory, because if there is large size of program and less size of data, then data memory can't store program, so overloading of one memory may occur while having enough space in other memory.
- Greater Cost because two memory are used and memory are costlier.
- Appropriate methods for storing data and program would have to be developed/.

MICROPROCESSOR

- A Microprocessor is a multipurpose, Programmable clock-driven, register based electronic device that read binary instruction from a storage device called memory, accepts binary data as input and processes data according to those instructions and provides results as outputs.
- A Microprocessor is a clock driven semiconductor device consisting of electronic circuits manufactured by using either a LSI or VLSI technique.
- A typical programmable machine can be represented with three components : MPU, Memory and I/O as shown in Figure

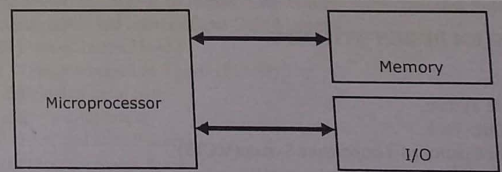


Figure: A Programmable Machine

- These three components work together or interact with each other to perform a given task; thus they comprise a system
- The machine (system) represented in above figure can be programmed to turn traffic lights on and off, compute mathematical functions, or keep trace of guidance system.
- This system may be simple or sophisticated, depending on its applications.
- The MPU applications are classified primarily in two categories : reprogrammable systems and embedded systems
- In reprogrammable systems, such as Microcomputers, the microprocessor is used for computing and data processing.
- In embedded systems, the microprocessor is a part of a final product and is not available for reprogramming to end user. A copying machine is a typical example of an embedded system.

APPLICATIONS OF MICROPROCESSOR

- Microcomputers
- Industrial Control
- Robotics
- Traffic Lights
- Washing Machines
- Microwave Oven
- Security Systems
- On Board Systems

EXAMPLE: A SYSTEM DESIGN WITH MPU

- SMART Fan
- Access Control System
- Automated Water Tank
- Microprocessor Controlled Temperature System(MCTS)

MICROCOMPUTER

- In the modern days, microprocessor is used as a primary component of a computer.
- Traditionally, the Computer System is represented by input, output, memory and Central Processing Unit (CPU).
- The CPU contains various registers to store data, the Arithmetic/Logic Unit (ALU), the instruction decoders, counters, and control lines.
- In the late 1960s, the CPU was designed with discrete components on various boards.
- With the advent of Integrated Circuit Technology, it became possible to build the CPU on a single chip, called microprocessor.
- Thus, the computer with a microprocessor as its CPU is known as Microcomputer.
- MPU implies a complete processing unit with necessary control signals.
- Examples of Microcomputers are IBM PC, Apple Macintosh computer, etc

MICRO CONTROLLER

- Single-chip Microcomputers are also known as Microcontrollers.
- They are used primarily to perform dedicated functions.
- They are used primarily to perform dedicated functions or as slaves in distributed processing.
- Generally they include all the essential elements of a computer on a single chip: MPU, R/W memory, ROM and I/O lines.
- Typical examples of the single-chip microcomputers are the Intel 8051, AT89C51, AT89C52 and Zilog Z8.
- Most of the micro controllers have an 8-bit word size, at least 64 bytes of R/W memory, and 1K byte of ROM
- I/O lines varies from 16 to 40

Typical Example: AT89C51 Microcontroller

- It is low power, high performance CMOS 8 bit microcomputer with 4K bytes of Flash programmable and erasable Read Only Memory.
- 128 bytes of Internal RAM
- 32 I/O pins arranged as 4 ports (PO-P3)
- A full duplex serial port
- 6 Hardware Interrupts
- 16 bit PC and Data Pointers.
- 8 bit Program Status Word
- Two 16 bits timers/counter TO and T1

GENERAL ARCHITECTURE OF MICROCOMPUTER SYSTEM

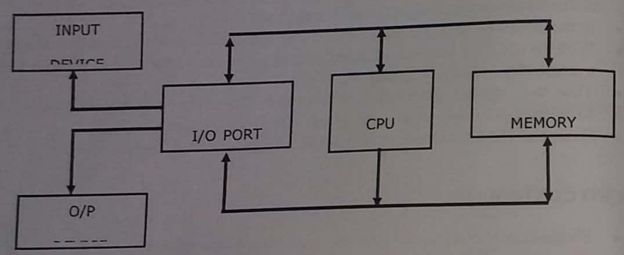


Figure: Block Diagram of a simple Microcomputer

- Figure shows a block diagram for a simple Microcomputer.`
- The major parts are the CPU, Memory and I/O.
- Connecting these parts are three sets of parallel lines called buses.
- The three buses are address bus, data bus and the control bus.

MEMORY

- It consists of RAM and ROM.
- The First Purpose of memory is to store binary codes for the sequences of instructions you want the computer to carry out.
- The second purpose of the memory is to store the binary-coded data with which the computer is going to be working

INPUT/OUTPUT

- The input/output or I/O Section allows the computer to take in data from the outside world or send data to the outside world.
- Peripherals such as keyboards, video display terminals, printers are connected to I/O Port.

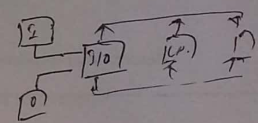
CPU

- The CPU controls the operation of the computer.
- In a microcomputer CPU is a microprocessor.
- The fetches binary coded instructions from memory, decodes the instructions into a series of simple actions and carries out these actions in a sequence of steps.
- The CPU also contains an address counter or instruction pointer register, which holds the address of the next instruction or data item to be fetched from memory.

ADDRESS BUS

- The address bus consists of 16, 20, 24 or 32 parallel signal lines.
- On these lines the CPU sends out the address of the memory location that is to be written to or read from.
- The no of memory location that the CPU can address is determined by the number of address lines.
- If the CPU has N address lines, then it can directly address 2^N memory locations i.e. CPU with 16 address lines can address 2^{16} or 65536 memory locations.

MEMORY CALCULATIONS



- 2^{10} =1K(Kilo)
- 2^{20}=1M(Mega)
- 2^{30}=1G(Giga)
- 2^{40}=1T (Tera)

- Specify Data and Address Bus size and calculate the size of Memory.

DATA BUS

- The data bus consists of 8, 16 or 32 parallel signal lines.
- The data bus lines are bi-directional.
- This means that the CPU can read data in from memory or it can send data out to memory

CONTROL BUS

- The control bus consists of 4 to 10 parallel signal lines.
- The CPU sends out signals on the control bus to enable the output of addressed memory devices or port devices.
- Typical control bus signals are Memory Read, Memory Write, I/O Read and I/O Write.

COMPONENTS OF CPU

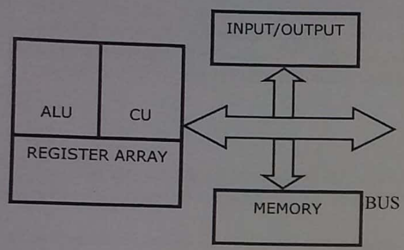


Figure: Microprocessor Based System with Bus Architecture.

- The Microprocessor is divided into three segments: ALU, Register array and Control Unit.

ARITHMETIC LOGIC UNIT

- This is the area of Microprocessor where various computing functions are performed on data.
- The ALU performs operations such as addition, subtraction and logic operations such as AND, OR and exclusive OR.

REGISTER ARRAY

- These are storage devices to store data temporarily.
- There are different types of registers depending upon the Microprocessors.
- These registers are primarily used to store data temporarily during the execution of a program and are accessible to the user through the instructions.

- General purpose Registers of 8086 includes AL, AH, BL, BH, CL, CH, DL, DH.

CONTROL UNIT

- The Control Unit Provides the necessary timing and control signals to all the operations in the Microcomputer
- It controls the flow of data between the Microprocessor and Memory and Peripherals.

- The Control unit performs 2 basic tasks
    - Sequencing
    - Execution

1. SEQUENCING

- The control unit causes the processor to step through a series of micro-operations in the proper sequence, based on the program being executed.

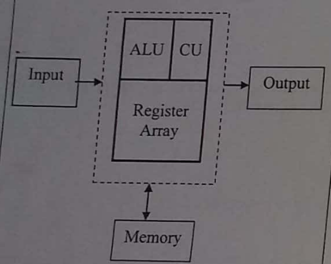
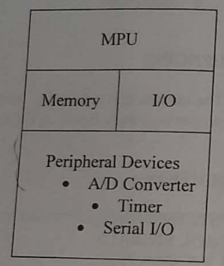
2. EXECUTION

- The control unit causes each micro operation to be performed.

CONTROL SIGNALS

- For the control unit to perform its function it must have inputs that allow it to determine the state of the system and outputs that allow it to control the behavior of the system.
- Inputs : Clock , Instruction Register, Flags
- Outputs :
    - Control signals to Memory
    - Control signals to I/O
    - Control Signals within the Processor.

Although both microprocessor and microcontrollers have been designed for real time applications and they share many common features, they have significant differences which are as follows:

Microprocessor	Microcontroller
1. Microprocessor is a silicon chip which includes ALU, register circuit and control circuits.	1. Microcontroller is a silicon chip which includes microprocessor, memory and I/O in a single package.
2. The general block diagram to show microprocessor is as shown below: 	2. The general block diagram of microcontroller is as shown below: 
3. Normally used for general purpose computers as CPU.	3. Normally microcontrollers are used for specific purposes (embedded system) e.g. traffic light controller, printer, etc.
4. The performance speed, i.e. clock speed of microprocessor is higher ranging frequency from MHz to GHz.	4. The performance speed of microcontroller is relatively slower than that of microprocessors, with clock speed from 3-33 MHz.
5. Addition of external RAM, ROM and I/O ports makes these systems bulkier and much more expensive.	5. Has fixed memory and all peripherals are embedded together on a single chip, so are not bulkier and are cheaper than microprocessors.
6. Microprocessors are more versatile than microcontrollers as the designers can decide on the amount of RAM, ROM and I/O ports needed to fit the task at hand. E.gs. Intel 8085, 8086, Motorola 68000, Intel Core i7, etc.	6. As microcontrollers have already fixed amount of RAM, ROM and I/O ports, so are not versatile as the user cannot change the amount of memory and I/O ports. E.gs. AT89C51, At mega32, AT89S52, etc.

Concept of Fetch, Decode and Execution:

Most modern processors work on fetch-decode-execute principle. The fetch-decode-execute cycle is also called as **instruction cycle.** When a set of instructions is to be executed, the instructions and data are loaded into main memory (RAM), determine what actions the instructions require and carries out those actions. This cycle is repeated continuously by Central Processing Unit (CPU) from bootup to when computer is shut down. The execution of an instruction by a processor is divided into 3 parts as explained below:

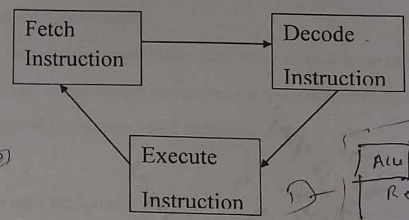


Fig. Fetch-Decode-Execute Cycle

1. **Fetch the instruction:**
   - In the first step, the processor fetches the instruction from memory and it is transferred to Instruction Register(IR)
2. **Decode the instruction:**
   - During this cycle, the encoded instruction present in the Instruction Register (IR) is interpreted by the decoder.
3. **Execute the instruction:**
   - The control unit of CPU passes the decoded information as a sequence of control signals to the relevant function units of CPU to perform the actions required by the instructions such as – reading values from the register, passing them to the ALU to perform mathematical or logical functions on them and writing the result back to the register.