# CENTRAL PROCESSING UNIT

CHAPTER 3

**After completing this lesson, you will be able to:**

- Define CPU and its components (ALU, CU, Register, Cache and Internal Buses).
- Describe the functions of general purpose and special purpose registers.
- Define bus and explain data bus, address bus and control bus.
- Define instructions and its types.
- Explain instruction formats.
- Describe instruction cycle (Fetch, Decode and Execute).
- Describe CISC and RISC architecture.
- Differentiate between Intel Pentium IV and AMD Athlon processors.

## UNIT INTRODUCTION

Central Processing Unit (CPU) is the main part of any computer system. This unit explains central processing unit and the components inside it. It describes instruction formats and their execution by the control unit. It describes how control unit cycles through fetch, decode and execute operations to carry out program instructions stored in main memory. It also discusses the role of registers and buses in programs execution.

## 3.1 INSIDE CPU

**Q.1 State the capabilities of computers.**

**Answer**

Computers have the capabilities to store and process a large amount of information at extremely high speed and produce accurate results. Computers can work for many hours uninterruptedly and can do the same jobs repeatedly that would be impossible without them.

**Q.2 Write a note on CPU.**

**Answer**

**Central Processing Unit (CPU)**

The Central Processing Unit (CPU) is the main part of the computer, which performs all its activities. It is also called the processor or microprocessor and is truly the "brain" of the computer system. It combines the circuitry that generates all the control signals needed to execute instructions. A latest CPU or microprocessor is shown in Fig.3.1.




Fig.3.1 Intel Core i7 Microprocessor

**DO YOU KNOW?**
*Intel Corporation released the Intel 4004, a 4-bit central processing unit (CPU) in 1971. It was the first microprocessor.*

### 3.1.1 COMPONENTS OF CPU

**Q.3 What are the main Components of CPU?**

**Answer**

**Main Components of CPU**

The following are main components of CPU:

- ALU
- CU
- Registers
- Cache
- Internal Buses





**Q.4 What is arithmetic logic unit? Which operations are performed by it? Explain the working of arithmetic logic unit?**

**Answer**

**Arithmetic Logic Unit (ALU)**

Arithmetic Logic Unit (ALU) is the part of the CPU where the actual processing takes place. ALU is capable of performing arithmetic, logical and data manipulation operations on data.

**Operations performed by ALU**

The ALU consists of logic circuitry that performs operations such as addition, subtraction, multiplication, division, exponentials, data manipulations (for example, shifting), comparisons and logical operations such as AND, OR, NOT, etc. on the data contained in the registers. An ALU is shown in Fig.3.2 with its associated registers.




Fig.3.2 Arithmetic Logic Unit

**Working of ALU**

Suppose we want to add two numbers 30 and 45. The ALU will perform the following steps to do this addition:

1. The first number, 30 will be stored in the Accumulator Register (AC).
2. The second number, 45 will be stored in the Data Register (DR).
3. Control unit (CU) will send the command to add the numbers through the control input.
4. Two numbers, 30 and 45 will be added by the circuitry in the ALU.
5. The result 75 will appear at the ALU output and will be transferred to AC.
6. Finally, the result 75 will be sent to the main memory from AC.

**Q.5 What is control unit? Explain its parts.**

**Answer**

**Control Unit (CU)**

Control unit directs and coordinates the activities of the entire computer system. It controls the working of all the input/output devices, all the primary and secondary storage devices and the calculations performed by the ALU. Control unit controls the operations of computer system based on the instructions in the program by executing them in a proper order.

**Parts of Control Unit**

Control Unit consists of three main components:

- Instruction Register
- Instruction Decoder
- Timing and Control Logic








Fig.3.3 Control Unit

1. **Instruction Register**
   Instruction register stores the instruction while it is being executed.
2. **Instruction Decoder**
   Instruction decoder decodes (translates) it and timing and control logic generates the signals to execute it.
3. **Timing and Control Logic**
   All sequential circuits in the Basic Computer CPU are driven by a master clock, with the exception of the INPR register.

At each clock pulse, the control unit sends control signals to control inputs of the bus, the registers, and the ALU.

**Q.6 Define Registers. Name some commonly found registers inside CPU.**

**Answer**

**Registers**

Registers are small memory devices whose function is to temporarily store data information and pass it on to the other parts of the processor or main memory during the processing. CPU contains several registers that are used to store various kinds of information needed by the microprocessor as it performs its functions.

**Commonly Found Registers**

Some commonly found registers inside the CPU are:

- Instruction Register
- Accumulator Register
- Data Register
- Program Counter
- Memory Address Register

**Q.7 Write a short note on cache memory.**

**Answer**

**Cache Memory**

Cache memory is a very small amount of memory inside the microprocessor as shown in Fig.3.4.




Fig.3.4: Cache Memory





It is faster than main memory but it is very expensive. It stores some active portion main memory, which is frequently required by the CPU.

**Q.8 Define bus and internal bus. How many types of buses are inside microprocessor?**

**Answer**

**Bus**

A bus is a group of parallel wires used for transmitting data/information from one part of the computer to another. In other words, it provides a pathway for transmitting data/information among various components of computer.

**Internal Buses**

The buses that are found inside the CPU are known as internal buses.

**Types of Buses**

There are three types of buses inside microprocessor, which are:

- Address Bus
- Data Bus
- Control Bus

Types of buses are shown in Fig.3.5.




Fig.3.5 Microprocessor bus architecture with associated registers

### 3.1.2 REGISTERS

**Q.9 State the purpose of registers. Explain the types of registers used in the computer.**

**Answer**

**Registers**

Registers are used to quickly accept, store, and transfer data and instructions that are being used immediately by the CPU.

**Types of Registers**

Registers used in the computer are divided into two types:

- General Purpose Registers
- Special Purpose Registers

**1. General Purpose Registers**

General-purpose registers are used to store data as well as addresses. These registers are used for arithmetic data movement. Typically, these are 8 to 32 bit registers.

**Commonly Used General Purpose Registers**

Following are the commonly used general purpose registers:

**i) Accumulator Register (AC) and Data Register (DR)**

These two registers hold the operands (values) that the ALU operates on during the execution of an





instruction. Operands are values on which operations such as addition or multiplication is to be performed. Operands are loaded into these registers from memory. After performing the operation, the results of ALU are transferred to the accumulator (AC). Both the accumulator and the data registers can receive data from memory over the data bus but only the accumulator can send data/information back to the memory.

**ii) Base Register (BR)**

It is used to hold a number that can be added to (or, in some cases, subtracted from) the address portion of a computer instruction to form an effective address. It is also known as Index register.

**iii) Counter Register (CR)**

It contains the address (location) of the instruction being executed at the current time. As each instruction gets fetched, the Counter register increases its stored value by 1. After each instruction is fetched, it points to the next instruction in the sequence. When the computer restarts or is reset, it normally reverts to 0.

**2. Special Purpose Registers**

These registers hold the state of a program. They include program counter, instruction register, memory address register and memory buffer registers. These are used by Control Unit to control the operations of CPU and by the Operating System programs to control the execution of me programs.

**Types of Special Purpose Registers**

Following are the types of special purpose registers:

**i) Instruction Register (IR)**

Instruction register holds program instructions that are fetched from the memory for execution. It holds the instruction while the instruction decoder circuit decodes it. After decoding, the timing and control logic generates the proper sequence of control signals to complete the execution of the instruction.

**ii) Memory Address Register (MAR)**

Memory address register hold the address of memory location from where a memory word is to be fetched or where data is to be stored.

**iii) Memory Buffer Register (MBR)**

A memory word that is to be stored in or to be fetched from memory must first be transferred into memory buffer register. MBR acts as a buffer (a small temporary memory) allowing to microprocessor and memory unit to act independently without being affected by minor differences in operation.

**iv) Program Counter (PC)**

It controls the sequence in which instructions are fetched from memory. At any given instant, the contents of PC indicate the address in memory from which the next instruction is be fetched. Contents of PC are loaded into MAR to fetch an instruction from memory. After fetching an instruction from memory, the PC is incremented by one to point to the next instruction to be fetched.

### 3.1.3 BUSES

**Q.10 What is meant by bus? Explain its types.**

**Answer**

**Bus**

A bus is an electrical pathway inside the computer system over which data/information is transferred from one part to the other. It connects the CPU to the main memory on to motherboard.

**Types of Buses**

Following are the three types of buses:

- Address Bus
- Data Bus
- Control Bus

**1. Address Bus**

The address bus is used by the CPU to select a memory word for a read or operation. It is





unidirectional bus because information flows in only one direction. Address width is from 16 to 32 bits. A system with a 32-bit address bus can address $2^{32}$ (4,294,967,296) memory locations.

**2. Data Bus**

The data bus is a bidirectional bus over which data can be sent from the microprocessor to memory (Write operation) or from the memory to the microprocessor (Read operation). Although, it is called data bus, the information carried on this will not always be data, it will often be instruction codes fetched by the microprocessor. Data bus width is from 32 to 64 bits.

**3. Control Bus**

The control bus is a group of wires that sends timing and control signals to all the parts of computer needed to carry out the instructions. Some of the control lines are outputs from the microprocessor and others are inputs to the microprocessor from I/O devices. Control bus width is in the range of 8 to 16 bits.




Fig.3.5b System Buses

### 3.2 CPU OPERATIONS

**Q.11 What are CPU operations? State the fundamental operations of most CPUs. Also state the steps that CPUs use in their operations.**

**Answer**

**CPU Operations**

CPU is the main component of a computer system, which carries out the instructions by performing the basic arithmetical, logical, and input/output operations of the system.

**Fundamental Operation of most CPUs**

The fundamental operation of most CPUs is to execute a sequence of stored instructions called a program. The program is represented by a series of instructions that are kept in some kind of computer memory.

**Steps performed in operations**

There are four steps that CPUs use in their operations, these are:

- Fetch
- Decode
- Execute
- Store

### 3.2.1 INSTRUCTIONS

**Q.12 What is meant by instruction? What are its fields?**

**Answer**

**Instruction / Instruction Code**

An instruction (or instruction code) is a group of bits that tells the computer to perform a specific operation. Instructions are stored in the main memory, waiting to be processed by the processor.





**Fields of Instruction**

An instruction has two fields.

1. **Operation code**
   Operation code, which represents the action that the processor execute.
2. **Operand code**
   Operand code, which defines the parameters of the action. The operand code depends on the operation. It can be data or a memory address.

| Operation code | Operand code |
|---|---|

**Q.13 Explain the types of instructions.**

**Answer**

**Types of Instructions**

Modern computers support many types of instructions. The following are some general types of instructions used in computers:

- Data Transfer Instructions
- Data Processing Instructions
- Program Control Instructions

**1. Data Transfer Instructions**

Data Transfer instructions transfer data from one location in the computer to another location without changing the data content. The most common transfers are between:

- Registers and memory
- Registers and I/O
- Registers to registers

**Examples of data transfer instructions**

Examples of some common data transfer instructions are as follows:

- MOV
- LOAD
- STORE

**i) MOV (MOVE) instruction**

MOV (MOVE) instruction transfers data from a memory location to a register, register to memory and register to register. This instruction is also used to store the result of a computation.

**Example:**

MOV A, B (Move the contents of register A to B)

**ii) LD (LOAD) instruction**

LD (LOAD) instruction loads particular register contents from memory.

**Example:**

LD A (Load the data to register A from memory)

**iii) STO (STORE) instruction**

STO (STORE) instruction stores information from register to memory location.

**2. Data Processing Instructions**

These instructions are related to the arithmetic and logic operations. The arithmetic or logic operations are performed on the values of two registers and the result is also placed in a register.

**Types of Data manipulation instructions**

Data manipulation instructions can be divided into three basic types:

- Arithmetic Instructions
- Logical Instructions
- Shift Instructions





**i) Arithmetic Instructions**

These instructions are used to perform arithmetic operations. The four basic arithmetic instructions are ADD (Addition), SUB (Subtraction), MUL (Multiplication) and DIV (Division).

**ii) Logical Instructions**

These instructions are used to perform logical operations like AND, OR, NOT, etc. on binary data stored in registers.

**iii) Shift Instructions**

Shift instruction is used for transfer of bits either to the left or to the right of an operand.

**3. Program Control Instructions**

Program control or transfer of control is a way of altering the order in which statements are executed. There are a number of instructions used for this purpose like JMP (Jump) and LOOP.

**i) JMP instruction**

The JMP instruction jumps to begin the execution at another location.

**ii) LOOP instruction**

The LOOP instruction is used when number of statements is to be repeated.

### 3.2.2 INSTRUCTION FORMATS

**Q.14 Define instruction format and its parts.**

**Answer**

**Instruction Format**

An instruction format defines the layout of the instruction.

**Parts of Instruction Format**

Instruction Format consists of two parts:

- Op-Code
- Operand

**1. Op-Code**

Op-Code is a group of bits that define various processor operations such as LOAD, STORE, ADD and SHIFT to be performed on some data stored in registers or memory.

**2. Operand**

Operand can be data, or can refer to data - i.e. address of data.

**Example**

The Op-code (10010) specifies the code for ADD operation to be performed on the operand at the address specified in Operand part.




**Q.15 Explain some common instruction formats.**

**Answer**

**Common Instruction Formats**

Some common instruction formats are discussed as follows:

- Zero-Address Instruction
- One-Address Instruction
- Two-Address Instruction

**1. Zero Address Instruction**

The Zero Address instruction format requires only op-code, having no operand to work with.





**Example**

Examples of the Zero Address instruction format are HALT and STOP, which do not have any address.

**Example:** STOP

**2. One Address Instruction**

One Address instruction format requires one op-code and one Operand.

**Example**

Example of the one address instruction format is LDA (Load Accumulator), JMP (Jump) etc. These instructions require one address to do the operation. Like JMP requires one address in order to jump to that specific address location.

| Op-Code | Operand |
|---|---|

**Example**: JMPAX

**3. Two Address Instruction**

Two Address instruction format requires one op-code and two operands.

**Example**

Example of such instruction format is the MOV (Move), which moves data from the memory location to the register and from register to the memory location.

| Op-Code | Operand | Operand |
|---|---|---|

**Example:** ADD A, B

### 3.2.3 INSTRUCTION CYCLE

**Q.16 Define instruction cycle.**

**Answer**

**Instruction cycle**

Instruction cycle is the basic operation cycle of a computer to execute various instructions. A computer retrieves an instruction from its memory, determines what actions the instruction requires, and carries out those actions by the process.




Fig.3.7 Instruction Cycle

**Q.17 Describe the steps of instruction cycle.**

**Answer**

**Steps of Instruction Cycle**

The following are the three instruction cycle steps:

- Fetch operations
- Decode operation
- Execute operation

**1. Fetch Operation**

In this operation, the control unit fetches an instruction from main memory by sending an address through the address bus and a read command through the control bus. The fetch operation places the instruction into the instruction register (IR) inside the microprocessor.





**2. Decode operation**

In this step, the instruction decoder decodes the instruction to determine what the instruction is intended to do.

**3. Execute Operation**

Once the instruction has been decoded, it can be executed. In this operation, the timing and control logic circuitry in the control unit generates signals needed to execute the instruction. The instruction may perform arithmetic, make a decision, simply move data from one memo location to another, etc..

### 3.2.4 CISC AND RISC ARCHITECTURE

**Q.18 Explain CISC and RISC architecture.**

**Answer**

CISC and RISC are two different competing philosophies in designing modern computer architecture.

**CISC Architecture**

CISC stands for Complex Instruction Set Computer. CISC architecture is the traditional architecture of CPU that supports a large variety of instructions. These instructions may have different length, and use all addressing modes and require complex circuitry to decode them. CISC architecture is complex because of the instructions used at the hardware level.

**Examples**

Examples of CISC processors are the Intel 486 series and Pentium series.

**RISC Architecture**

RISC stands for Reduced Instruction Set Computer. It is considered new architecture of CPUs. RISC architecture of CPU supports same size of instructions and it does not use indirect addressing mode. The instructions of a CPU that uses RISC architecture are very simple and are executed very fast. RISC CPUs require fewer transistors, which makes them cheaper to design and easy to manufacture.

**Examples**

Examples of RISC processor are:

- IBM PowerPC
- Sun SPARC
- Mobile phones
- Tablet PCs

**Q.19 Differentiate between CISC and RISC architecture.**

**Answer**

**Differences between CISC and RISC architectures**

The following are few differences between CISC and RISC architectures:

1. CISC instructions utilize more cycles than RISC.
2. CISC has way more complex instructions than RISC.
3. CISC typically has fewer instructions than RISC.
4. CISC implementations tend to be slower than RISC implementations.
5. Computers typically use CISC while tablets, smart phones and other devices use RISC.

### 3.2.5 INTEL AND AMD PROCESSOR

**Q.20 Explain Intel and AMD processor.**

**Answer**

Intel and AMD (Advanced Micro Devices) are the primary manufacturers of processors. They make processors for desktop computers, laptops, notebooks and mobile devices. Different types of processors perform different functions at different speeds, depending on what kind of system they run.





Each type of processor has different functionality, but similarities do exist among various types. Both Intel and AMD make processors for a variety of systems. Core, Pentium and Celeron families of processors belong to Intel while Phenom, Athlon and Sempron processors belong to AMD.

**Intel Pentium IV Processor**

Intel Pentium IV processors have 20 steps execution process. They have high clock speed and perform fewer operations per clock. Pentium processors generally use 478 pin sockets and use Mega Hertz (MHz) to specify processor speed.

**AMD Processor**

AMD processors have 10 steps execution process. These processors generally use 462 pin sockets. AMD processors do not use Mega Hertz (MHz) to specify processor speed. This is due to the instruction set handling that AMD uses.

**Q.21 Compare Pentium IV and AMD processors.**

**Answer**

**Comparison between Pentium IV and AMD Athlon processors**

The following is the comparison between Pentium IV and AMD Athlon processors:

| Intel Pentium IV Processor | | AMD Athlon Processor |
|---|---|---|
| **Clock Speed** | **1.7 to 3.0 GHz.** | **1.4 to 2.33 GHz.** |
| **Bus width** | **32/64 bits** | **32/64 bits** |
| **Cache** | **256 KB to 1 MB** | **256/512 KB** |
| **Architecture** | **CISC/RISC** | **RISC** |

## KEY POINTS

- Central Processing Unit (CPU) is a single unit that consists of ALU and Control Unit. It is the "brain" of a computer.
- Arithmetic Logic Unit (ALU) is the part of the computer where actual processing takes place.
- Control Unit directs and coordinates the activities of the entire computer system. It controls the working of all the input/output devices, storage devices and the calculations performed by the ALU.
- A bus is a group of parallel wires used for transmitting binary information from one part computer to another. There are three types of buses, address bus, data bus and control bus.
- The general types of instructions used in computers are data movement, operation, shift comparison, branch and input/output instructions.
- Instruction code is a group of bits that tells the computer to perform a specific operation.
- Control Unit repeatedly cycles through the FETCH, DECODE and EXECUTE steps till the last instruction of the program is executed.
- CISC stands for Complex Instruction Set Computer that supports a large variety of instructions, which may be as many as three hundred.
- RISC stands for Reduced Instruction Set Computer that supports very simple limited number of instruction.

## EXERCISE

**Q.1 Select the best answer for the following MC Qs.**

i. **Which part of computer performs Fetch, Decode and Execute cycle?**
A. ALU B. Control Unit C. Output Unit D. Registers

ii. **Where are the results of ALU operations transferred?**
A. Counter register B. Base register
C. Data register D. Accumulator register

iii. **Which of these buses selects a memory word for a read or write operation?**
A. Data bus B. Control bus C. Address bus D. System bus

iv. **Which of these registers controls the sequence in which instructions are fetched from memory for execution?**
A. Program counter B. Memory buffer register
C. Data register D. Counter register

v. **A memory word that is to be stored in or fetched from memory must first be transferred into which register?**
A. Accumulator B. Data register
C. Memory buffer register D. Program counter

vi. **Which instruction causes transfer of instruction execution to a specified address?**
A. Comparison instruction B. Branch instruction
C. Shift instruction D. Data movement instruction

vii. **Which of these instructions will perform addition of two numbers?**
A. Operation instruction B. Shift instruction
C. Comparison instruction D. Data movement instruction

viii. **Through which bus, instructions are transferred from main memory to instruction register?**
A. Control bus B. Address bus C. Instruction bus D. Data bus

ix. **How many distinct operations can be performed if op-code of a microprocessor consists of 4 bits?**
A. 4 B. 8 C. 16 D. 32

x. **Which part of computer decodes instructions?**
A. ALU B. Main memory
C. Program counter D. Control unit

**Answers**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| i. | B | ii. | D | iii. | C | iv. | A | v. | C |
| vi. | B | vii. | A | viii. | D | ix. | C | x. | D |

**Q.2. Write short answers of the following questions.**

i. **What is a microprocessor?**

**Answer**

**Microprocessor**

Microprocessor is truly the "brain" of the computer system. It combines the circuitry that generates all the control signals needed to execute instructions.

ii. **What is the function of ALU in the computer?**

**Answer**

**Function of ALU**

The ALU function is to perform operations such as addition, subtraction, multiplication, division, exponentials, data manipulations (for example, shifting), comparisons and logical operations such as AND, OR. NOT, etc. on the data contained in the registers.

iii. **What is the function of control unit in the computer?**





**Answer**

**Function of CU**

The function of control unit is to direct and coordinates the activities of the entire computer system. It controls the working of all the input/output devices, all the primary and secondary storage devices and the calculations performed by the ALU. Control unit controls the operations of computer system based on the instructions in the program by executing them in a proper order.

iv. **Define bus.**

**Answer**

**Bus**

A bus is an electrical pathway inside the computer system over which data/information transferred from one part to the other. It connects the CPU to the main memory on to motherboard.

**Define register**

**Register**

Register is small memory device whose function is to temporarily store data information and pass it on to the other parts of the processor or main memory during the processing.

v. **Define cache memory.**

**Answer**

**Cache Memory**

Cache memory is a very small amount of memory inside the microprocessor. It is faster than main memory but it is very expensive. It stores some active portion main memory, which is frequently required by the CPU.

vi. **What is meant by instruction code?**

**Answer**

**Instruction Code**

Instruction code is a group of bits that tells the computer to perform a specific operation. Instructions are stored in the main memory, waiting to be processed by the processor.

vii. **What is operation code?**

**Answer**

**Operation Code**

Operation code represents the action that the processor executes.

viii. **What is the advantage of using address mode in an instruction?**

**Answer**

**Advantage**

The advantage of using address mode in an instruction is that it indicates the way in which the operand is accessed.

ix. **Differentiate between CISC and RISC architecture.**

**Answer**

**Differences between CISC and RISC architectures**

The following are few differences between CISC and RISC architectures:

1. CISC instructions utilize more cycles than RISC.
2. CISC has way more complex instructions than RISC.
3. CISC typically has fewer instructions than RISC.
4. CISC implementations tend to be slower than RISC implementations.
5. Computers typically use CISC while tablets, smart phones and other devices use RISC.

**Q3. Write long answers of the following questions.**

i. **Describe general purpose and special purpose registers.**

**Answer**

**General Purpose Registers**

General-purpose registers are used to store data as well as addresses. These registers are used for





arithmetic data movement. Typically, these are 8 to 32 bit registers.

**Commonly Used General Purpose Registers**

Following are the commonly used general purpose registers:

1. **Accumulator Register (AC) and Data Register (DR)**
These two registers hold the operands (values) that the ALU operates on during the execution of an instruction. Operands are values on which operations such as addition or multiplication is to be performed. Operands are loaded into these registers from memory. After performing the operation, the results of ALU are transferred to the accumulator (AC). Both the accumulator and the data registers can receive data from memory over the data bus but only the accumulator can send data/information back to the memory.
2. **Base Register (BR)**
It is used to hold a number that can be added to (or, in some cases, subtracted from) the address portion of a computer instruction to form an effective address. It is also known as Index register.
3. **Counter Register (CR)**
It contains the address (location) of the instruction being executed at the current time. As each instruction gets fetched, the Counter register increases its stored value by 1. After each instruction is fetched, it points to the next instruction in the sequence. When the computer restarts or is reset, it normally reverts to 0.

**Special Purpose Registers**

These registers hold the state of a program. They include program counter, instruction register, memory address register and memory buffer registers. These are used by Control Unit control the operations of CPU and by the Operating System programs to control the execution of the programs.

**Types of Special Purpose Registers:**

Following are the types of special purpose registers:

(i) **Instruction Register (IR)**
Instruction register holds program instructions that are fetched from the memory for execution. It holds the instruction while the instruction decoder circuit decodes it. After decoding, the timing and control logic generates the proper sequence of control signals to complete the execution of the instruction.

(ii) **Memory Address Register (MAR)**
Memory address register hold the address of memory location from where a memory word is to be fetched or where data is to be stored.

(iii) **Memory Buffer Register (MBR)**
A memory word that is to be stored in or to be fetched from memory must first be transferred into MBR. MBR acts as a buffer (a small temporary memory) allowing to microprocessor and memory unit to act independently without being affected by minor differences in operation.

(iv) **Program Counter (PC)**
It controls the sequence in which instructions are fetched from memory. At any given instant, the contents of PC indicate the address in memory from which the next instruction is be fetched. Contents of PC are loaded into MAR to fetch an instruction from memory. After fetching an instruction from memory, the PC is incremented by one to point to the next instruction to be fetched.

ii. **Explain the types of buses used in computers.**

**Answer**

**Types of Buses**

Following are the three types of buses:

- Address Bus
- Data Bus
- Control Bus

1. **Address Bus**
The address bus is used by the CPU to select a memory word for a read or operation. It is unidirectional bus because information flows in only one direction. Address width is from 16 to 32 bits.





A system with a 32-bit address bus can address $2^{32}$ (4,294,967,296) memory locations.

2. **Data Bus**
The data bus is a bidirectional bus over which data can be sent from the microprocessor to memory (Write operation) or from the memory to the microprocessor (Read operation). Although, it is called data bus, the information carried on this will not always be data, it will often be instruction codes fetched by the microprocessor. Data bus width is from 32 to 64 bits.
3. **Control Bus**
The control bus is a group of wires that sends timing and control signals to all the parts of computer needed to carry out the instructions. Some of the control lines are outputs from the microprocessor and others are inputs to the microprocessor from I/O devices. Control bus width is in the range of 8 to 16 bits.




Fig. 3.5b System Buses

iii **Describe the types of CPU instructions.**

**Answer**

**Types of CPU Instructions**

Modern computers support many types of instructions. The following are some general types of instructions used in computers:

- Data Transfer Instructions
- Data Processing Instructions
- Program Control Instructions

1. **Data Transfer Instructions**
Data Transfer instructions transfer data from one location in the computer to another location without changing the data content. The most common transfers are between:
   - Registers and memory
   - Registers and I/O
   - Registers to registers

**Examples of data transfer instructions**

Examples of some common data transfer instructions are:

- MOV
- LOAD
- STORE

1. **MOV (MOVE) instruction**
MOV (MOVE) instruction transfers data from a memory location to a register, register to memory and register to register. This instruction is also used to store the result of a computation.

**Example**

MOV A, B (Move the contents of register A to B)

(ii) **LD (LOAD) instruction**
LD (LOAD) instruction loads particular register contents from memory.

**Example**

LD A (Load the data to register A from memory)

(iii) **STO (STORE) instruction**
STO (STORE) instruction stores information from register to memory location.





2. **Data Processing Instructions**
These instructions are related to the arithmetic and logic operations. The arithmetic or logic operations are performed on the values of two registers and the result is also placed in a register.

**Types of Data manipulation instructions**

Data manipulation instructions can be divided into three basic types:

- Arithmetic Instructions
- Logical Instructions
- Shift Instructions

(i) **Arithmetic Instructions**
These instructions are used to perform arithmetic operations. The four basic arithmetic instructions are ADD (Addition), SUB (Subtraction), MUL (Multiplication) and DIV (Division).

(ii) **Logical Instructions**
These instructions are used to perform logical operations like AND, OR, NOT, etc. on binary data stored in registers.

(iii) **Shift Instructions**
Shift instruction is used for transfer of bits either to the left or to the right of an operand.

3. **Program Control Instructions**
Program control or transfer of control is a way of altering the order in which statements are executed. There are a number of instructions used for this purpose like JMP (Jump) and LOOP.

(i) **JMP instruction**
The JMP instruction jumps to begin the execution at another location.

(ii) **LOOP instruction**
The LOOP instruction is used when number of statements is to be repeated.

iv. **Explain different types of instruction formats with examples.**

**Answer**

**Types of Instruction Formats**

Some types of instruction formats are as follows:

- Zero-Address Instruction
- One-Address Instruction
- Two-Address Instruction

1. **Zero Address Instruction**
The Zero Address instruction format requires only op-code, having no operand to work with.

**Example**

Examples of the Zero Address instruction format are HALT and STOP, which do not have any address.

| Op-Code | Operand |
|---|---|

**Example: STOP**

2. **One Address Instruction**
One Address instruction format requires one op-code and one Operand.

**Example**

Example of the one address instruction format is LDA (Load Accumulator), JMP (Jump) etc.. These instructions require one address to do the operation. Like JMP requires one address in order to jump to that specific address location.

**Example:** JMPAX

3. **Two Address Instruction**
Two Address instruction format requires one op-code and two operands.

**Example**

Example of such instruction format is the MOV (Move), which moves data from the memory location to the register and from register to the memory location.

| Op-Code | Operand | Operand |
|---|---|---|





**Example:** ADD A, B

v. **Explain CPU instruction cycle.**

**Answer**

**CPU Instruction cycle**

Instruction cycle is the basic operation cycle of a computer to execute various instructions. A computer retrieves an instruction from its memory, determines what actions the instruction requires, and carries out those actions by the process.




Fig.3.7 Instruction Cycle

**Steps of Instruction Cycle**

The following are the three instruction cycle steps:

- Fetch operations
- Decode operation
- Execute operation

1. **Fetch Operation**
In this operation, the control unit fetches an instruction from main memory by sending an address through the address bus and a read command through the control bus. The fetch operation places the instruction into the instruction register (IR) inside the microprocessor.
2. **Decode operation**
In this step, the instruction decoder decodes the instruction to determine what the instruction is intended to do.
3. **Execute Operation**
Once the instruction has been decoded, it can be executed. In this operation, the timing and control logic circuitry in the control unit generates signals needed to execute the instruction. The instruction may perform arithmetic, make a decision, simply move data from one memo location to another, etc..

## LAB ACTIVITIES

**Following lab activities are to be carried out during the practical periods.**

1) **Components on the motherboard including microprocessor, RAM and ROM should, be shown to the students.**

**Answer**

Practical Work

2) **Installation of microprocessor on the motherboard along with the cooling fan) should be demonstrated.**

**Answer**

Practical Work

3) **Students should be explained how data bus, control bus and address bus circuits are designed on the motherboard and they should have a clear understanding about their functions.**

**Answer**

Practical Work

4) **Students should be explained how programs are loaded into the RAM memory and executed by the microprocessor.**

**Answer**

Practical Work

5) **All the above activities should also be demonstrated through videos or animations.**

**Answer**

Practical Work

**Q.1 Select the correct choice from the following questions.**

1. **Abbreviation of CPU is:**
   A. Central Population Unit B. Central Processing Unit
   C. Central Publishing Unit D. Control Processing Unit
2. **It is also called the processor or microprocessor:**
   A. AU B. CPU C. CU D. ALU
3. **ALU stands for:**
   A. Arithmetic and Local Unit B. Align and Logic Unit
   C. Arithmetic and Legal Unit D. Arithmetic and Logic Unit
4. **It is capable of performing arithmetic, logical and data manipulation operations on data:**
   A. AU B. LU C. CU D. ALU
5. **CU stands for:**
   A. Circuit Unit B. Control Unit C. Center Unit D. Compound Unit
6. **This unit directs and coordinates the activities of the entire computer system:**
   A. AU B. CPU C. CU D. ALU
7. **Types of buses inside microprocessor are:**
   A. 3 B. 4 C. 6 D. 5
8. **It is also known as Index register:**
   A. Accumulator Register (AC) B. Data Register (DR)
   C. Base Register (BR) D. Counter Register (CR)
9. **It contains the address (location) of the instruction being executed at the current time:**
   A. Accumulator Register (AC) B. Data Register (DR)
   C. Base Register (BR) D. Counter Register (CR)
10. **This register holds program instructions that are fetched from the memory for execution:**
    A. Instruction Register (IR) B. Memory Address Register (MAR)
    C. Memory Buffer Register (MBR) D. Program Counter (PC)
11. **This register holds the address of memory location from where a memory word is to be fetched or where data is to be stored:**
    A. Instruction Register (IR) B. Memory Address Register (MAR)
    C. Memory Buffer Register (MBR) D. Program Counter (PC)
12. **This register acts as a buffer (a small temporary memory) allowing to microprocessor and memory unit to act independently without being affected by minor differences in operation:**
    A. Instruction Register (IR) B. Memory Address Register (MAR)
    C. Memory Buffer Register (MBR) D. Program Counter (PC)
13. **It controls the sequence in which instructions are fetched from memory:**
    A. Instruction Register (IR) B. Memory Address Register (MAR)
    C. Memory Buffer Register (MBR) D. Program Counter (PC)
14. **This bus is used by the CPU to select a memory word for a read or operation:**
    A. Address bus B. Control bus C. Data bus D. Information bus
15. **Address width is from:**
    A. 16 to 32 bits B. 8 to 16 bits C. 1 to 10 bits D. 16 to 100 bits
16. **A system with a 32-bit address bus can address ____ memory locations:**
    A. $2^{32}$ B. $2^{10}$ C. $2^{64}$ D. $2^{16}$
17. **It is unidirectional bus because information flows in only one direction:**
    A. Address bus B. Control bus C. Data bus D. Information bus





18. **It is a bidirectional bus over which data can be sent from the microprocessor to memory or from the memory to the microprocessor:**
    A. Address bus B. Control bus C. Data bus D. Information bus
19. **Data bus width is from:**
    A. 16 to 32 bits B. 32 to 64 bits C. 1 to 10 bits D. 16 to 100 bits
20. **It is a group of wires that sends timing and control signals to all the parts of computer needed to carry out the instructions:**
    A. Address bus B. Control bus C. Data bus D. Information bus
21. **Control bus width is in the range of:**
    A. 16 to 32 bits B. 2 to 64 bits C. 1 to 10 bits D. 8 to 16 bits
22. **These instructions transfer data from one location in the computer to another location without changing the data content:**
    A. Data Transfer Instructions B. Data Processing Instructions
    C. Program Control Instruction D. Batch Processing Instructions
23. **This instruction transfers data from a memory location to a register, register to memory and register to register:**
    A. MOV B. LOAD C. STORE D. SAVE
24. **This instruction loads particular register contents from memory:**
    A. MOV B. LOAD C. STORE D. SAVE
25. **This instruction stores information from register to memory location:**
    A. MOV B. LOAD C. STORE D. SAVE
26. **These instructions are related to the arithmetic and logic operation:**
    A. Data Transfer Instructions B. Data Processing Instructions
    C. Program Control Instruction D. Batch Processing Instructions
27. **These instructions are used to perform arithmetic operations.**
    A. Arithmetic Instructions B. Logical Instructions
    C. Shift Instructions D. Processing Instructions
28. **These instructions are used to perform logical operations like AND, OR, NOT, etc..**
    A. Arithmetic Instructions B. Logical Instructions
    C. Shift Instructions D. Processing Instructions
29. **It is used for transfer of bits either to the left or to the right of an operand:**
    A. Arithmetic Instruction B. Logical Instructions
    C. Shift Instructions D. Processing Instructions
30. **This instruction format requires only op-code, having no operand to work with:**
    A. Zero-Address Instruction B. One-Address Instruction
    C. Two-Address Instruction D. Three-Address Instruction
31. **This instruction format requires one op-code and one operand:**
    A. Zero-Address Instruction B. One-Address Instruction
    C. Two-Address Instruction D. Three-Address Instruction
32. **This instruction format requires one op-code and two operands:**
    A. Zero-Address Instruction B. One-Address Instruction
    C. Two-Address Instruction D. Three-Address Instruction

**Answers:**

| | | | |
|---|---|---|---|
| **1.** | Central Processing Unit | **2.** | CPU |
| **3.** | Arithmetic and Logic Unit | **4.** | ALU |
| **5.** | Control Unit | **6.** | CU |
| **7.** | 3 | **8.** | Base Register (BR |
| **9.** | Counter Register (CR) | **10.** | Instruction Register (IR) |
| **11.** | Memory Address Register (MAR) | **12.** | Memory Buffer Register (MBR) |





| | | | |
|---|---|---|---|
| **13.** | Program Counter (PC) | **14.** | Address bus |
| **15.** | 16 to 32 bits | **16.** | $2^{32}$ |
| **17.** | Address bus | **18.** | Data bus |
| **19.** | 32 to 64 bits | **20.** | Control bus |
| **21.** | 8 to 16 bits | **22.** | Data Transfer Instructions |
| **23.** | MOV | **24.** | LOAD |
| **25.** | STORE | **26.** | Data Processing Instructions |
| **27.** | Arithmetic Instructions | **28.** | Logical Instructions |
| **29.** | Shift Instructions | **30.** | Zero-Address Instruction |
| **31.** | One-Address Instruction | **32.** | Two-Address Instruction |

**Q.2 Give short answers of the following questions.**

**Q1: Define CPU.**

**Ans.** The Central Processing Unit (CPU) is the main part of the computer, which performs all its activities. It is also called the processor or microprocessor and is truly the "brain" of the computer system. It combines the circuitry that generates all the control signals needed to execute instructions.

**Q2: What are the main components of CPU?**

**Ans.** The following are main components of CPU:

- ⇨ ALU
- ⇨ CU
- ⇨ Registers
- ⇨ Cache
- ⇨ Internal Buses

**Q3: What is meant by ALU?**

**Ans.** Arithmetic logic unit (ALU) is the part of the CPU where the actual processing takes place. ALU is capable of performing arithmetic, logical and data manipulation operations on data.

**Q4: Which operations are performed by ALU?**

**Ans.** The ALU consists of logic circuitry that performs operations such as addition, subtraction, multiplication, division, exponentials, data manipulations (for example, shifting), comparisons and logical operations such as AND, OR, NOT, etc. on the data contained in the registers.

**Q5: What is CU?**

**Ans.** Control unit directs and coordinates the activities of the entire computer system. It controls the working of all the input/output devices, all the primary and secondary storage devices and the calculations performed by the ALU. Control unit controls the operations of computer system based on the instructions in the program by executing them in a proper order.

**Q6: What are the main components of CU?**

**Ans.** Control Unit consists of three main components, Instruction Register, Instruction Decoder and Timing & Control Logic.

**Q7: What is instruction register?**

**Ans.** Instruction register stores the instruction while it is being executed.

**Q8: What is instruction decoder?**

**Ans.** Instruction decoder decodes (translates) it and timing and control logic generates the signals to execute it.

**Q9: What are registers?**

**Ans.** Registers are small memory devices whose function is to temporarily store data information and pass it on to the other parts of the processor or main memory during the processing. CPU contains several registers that are used to store various kinds of information needed by the

| | | | |
|---|---|---|---|
| 13. | Program Counter (PC) | 14. | Address bus |
| 15. | 16 to 32 bits | 16. | $2^N$ |
| 17. | Address bus | 18. | Data bus |
| 19. | 32 to 64 bits | 20. | Control bus |
| 21. | 8 to 16 bits | 22. | Data Transfer Instructions |
| 23. | MOV | 24. | LOAD |
| 25. | STORE | 26. | Data Processing Instructions |
| 27. | Arithmetic Instructions | 28. | Logical Instructions |
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| 31. | One-Address Instruction | 32. | Two-Address Instruction |

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microprocessor as it performs its functions.

**Q11: Write some commonly found registers inside the CPU.**
**Ans.** Some commonly found registers inside the CPU are:
- ⇨ Instruction Register
- ⇨ Accumulator Register
- ⇨ Data Register
- ⇨ Program Counter
- ⇨ Memory Address Register

**Q12: What is cache memory?**
**Ans.** Cache memory is a very small amount of memory inside the microprocessor. It is faster than main memory but it is very expensive. It stores some active portion main memory, which is frequently required by the CPU.

**Q13: Define bus.**
**Ans.** A bus is a group of parallel wires used for transmitting data/information from one part of the computer to another. In other words, it provides a pathway for transmitting data/information among various components off computer.

**Q14: Define internal buses.**
**Ans.** The buses that are found inside the CPU are known as internal buses.

**Q15: Name the types of buses inside microprocessor.**
**Ans.** There are three types of buses inside microprocessor, which are:
- ⇨ Address Bus
- ⇨ Data Bus
- ⇨ Control Bus

**Q16: What are general-purpose registers?**
**Ans.** General-purpose registers are used to store data as well as addresses. These registers are used for arithmetic data movement. Typically, these are 8 to 32 bit registers.

**Q17: What are Accumulator Register (AC) and Data Register (DR)?**
**Ans.** These two registers hold the operands (values) that the ALU operates on during the execution of an instruction. Operands are values on which operations such as addition or multiplication is to be performed. Operands are loaded into these registers from memory.- After performing the operation, the results of ALU are transferred to the accumulator (AC). Both the accumulator and the data registers can receive data from memory over the data bus but only the accumulator can send data/information back to the memory.

**Q18: What is base register?**
**Ans.** Base Register is used to hold a number that can be added to (or, in some cases, subtracted from the address portion of a computer instruction to form an effective address. It is also known as Index register.

**Q19: What does counter register contain?**
**Ans.** Counter Register contains the address (location) of the instruction being executed at the current time. As each instruction gets fetched, the Counter register increases its stored value by 1. After each instruction is fetched, it points to the next instruction in the sequence. When the computer restarts or is reset, it normally reverts to 0.

**Q20: What is Instruction Register (IR)?**
**Ans.** Instruction register holds program instructions that are fetched from the memory for execution. It holds the instruction while the instruction decoder circuit decodes it. After decoding, the timing and control logic generates the proper sequence of control signals to complete the execution of the instruction.

**Q21: What is memory address registers?**
**Ans.** Memory address register hold the address of memory location from where a memory word is to be fetched or where data is to be stored.





**Q22: What is Memory Buffer Register (MBR)?**
**Ans.** A memory word that is to be stored in or to be fetched from memory must first transferred into MBR. MBR acts as a buffer (a small temporary memory) allowing to microprocessor and memory unit to act independently without being affected by minor differences in operation.

**Q23: What is the function of Program Counter (PC)?**
**Ans.** Program Counter controls the sequence in which instructions are fetched from memory. At any given instant, the contents of PC indicate the address in memory from which the next instruction is be fetched. Contents of PC are loaded into MAR to fetch an instruction from memory. After fetching an instruction from memory, the PC is incremented by one to point to the next instruction to be fetched.

**Q24: What is the fundamental operation of most CPUs?**
**Ans.** The fundamental operation of most CPUs is to execute a sequence of stored instructions called a program. The program is represented by a series of instructions that are kept in some kind of computer memory.

**Q25: Which steps CPUs use in their operations?**
**Ans.** There are four steps that CPUs use in their operations, these are:
- ⇨ Fetch
- ⇨ Decode
- ⇨ Execute
- ⇨ Store

**Q26: How many fields an instruction has?**
**Ans.** An instruction has two fields:
1. Operation code, which represents the action that the processor executes.
2. Operand code, which defines the parameters of the action. The operand code depends on the operation. It can be data or a memory address.

**Q27: How many types of instructions are used in computers?**
**Ans.** Modern computers support many types of instructions. The following are some general types of instructions used in computers:
- ⇨ Data Transfer Instructions
- ⇨ Data Processing Instructions
- ⇨ Program Control Instructions

**Q28: Into how many types, data manipulation instruction can be divided?**
**Ans.** Data manipulation instructions can be divided into three basic types:
- ⇨ Arithmetic Instructions
- ⇨ Logical Instructions
- ⇨ Shift Instructions

**Q29: Define JMP instruction.**
**Ans.** The JMP instruction jumps to begin the execution at another location.

**Q30: Define LOOP instruction.**
**Ans.** The LOOP instruction is used when number of statements is to be repeated.

**Q31: How many parts of instruction format are there?**
**Ans.** Instruction Format consists of two parts:
- ⇨ Op-Code
- ⇨ Operand

**Q32: Define Op-Code.**
**Ans.** Op-Code is a group of bits that define various processor operations such as LOAD, STORE, ADD and SHIFT to be performed on some data stored in registers or memory.





**Q33: What are the common instruction formats?**
**Ans.** Some common instruction formats are discussed as follows:
- ⇨ Zero-Address Instruction
- ⇨ One-Address Instruction
- ⇨ Two-Address Instruction

**Q34: What is the purpose of two address instruction?**
**Ans.** Two Address instruction format requires one op-code and two operands.

**Q35: Define instruction cycle.**
**Ans.** Instruction cycle is the basic operation cycle of a computer to execute various instructions. A computer retrieves an instruction from its memory, determines what actions the instruction requires, and carries out those actions by the process.

**Q36: What are the steps involved in instruction cycle?**
**Ans.** The following are the three instruction cycle steps:
- ⇨ Fetch operations
- ⇨ Decode operation
- ⇨ Execute operation

**Q37: Give some examples of CISC architectures.**
**Ans.** Examples of CISC processors are the Intel 486 series and Pentium series.

**Q38: Give some examples of RISC processor.**
**Ans.** Examples of RISC processor are:
- ⇨ IBM PowerPC
- ⇨ Sun SPARC
- ⇨ Mobile phones
- ⇨ Tablet PCs

**Q39: Write down any three between CISC and RISC architectures.**
**Ans.** The following are few differences between CISC and RISC architectures.
1. CISC instructions utilize more cycles than RISC.
2. CISC has way more complex instructions than RISC.
3. CISC typically has fewer instructions than RISC.

**Q40: State the features of Intel Pentium IV.**
**Ans.** Intel Pentium IV processors have 20 steps execution process. They have high clock speed and perform fewer operations per clock. Pentium processors generally use 478 pin sockets and use Mega Hertz (MHz) to specify processor speed.

**Q41: State the features of AMD Processor.**
**Ans.** AMD processors have 10 steps execution process. These processors generally use 462 pin sockets. AMD processors do not use Mega Hertz (MHz) to specify processor speed. This is due to the instruction set handling that AMD uses.