Digital Computers

Introduction

A **digital computer** is an electronic device that processes information in **digital form**, meaning all data is represented using **binary digits (0 and 1)**. It can take input, store data, process information according to instructions, and give the required output. Unlike analog computers, which work on continuous signals, digital computers are more accurate, reliable, and versatile, which is why they are used in almost every field today.

Key Characteristics of Digital Computers

1. **Binary Operation:** All information is converted into binary codes (0s and 1s).
2. **Speed:** Modern digital computers can perform billions of operations per second.
3. **Accuracy:** They give error-free results if the program and data are correct.

4. **Automation:** Once the program is loaded, the computer executes instructions automatically without human help.

5. **Storage Capacity:** Large volumes of data can be stored in memory units for later use.

6. **Programmability:** A single machine can be programmed to perform different tasks.

7. **Versatility:** They are used in scientific, commercial, industrial, educational, and personal applications.

- **Input Unit:** Accepts data and instructions (e.g., keyboard, mouse, scanner).
- **Memory Unit:** Stores data, instructions, and intermediate results.
- **Central Processing Unit (CPU):** Called the brain of the computer. It has:
    - **Control Unit (CU):** Directs the flow of data and instructions.
    - **Arithmetic & Logic Unit (ALU):** Performs calculations and logical operations.
- **Output Unit:** Displays results to the user (e.g., monitor, printer).

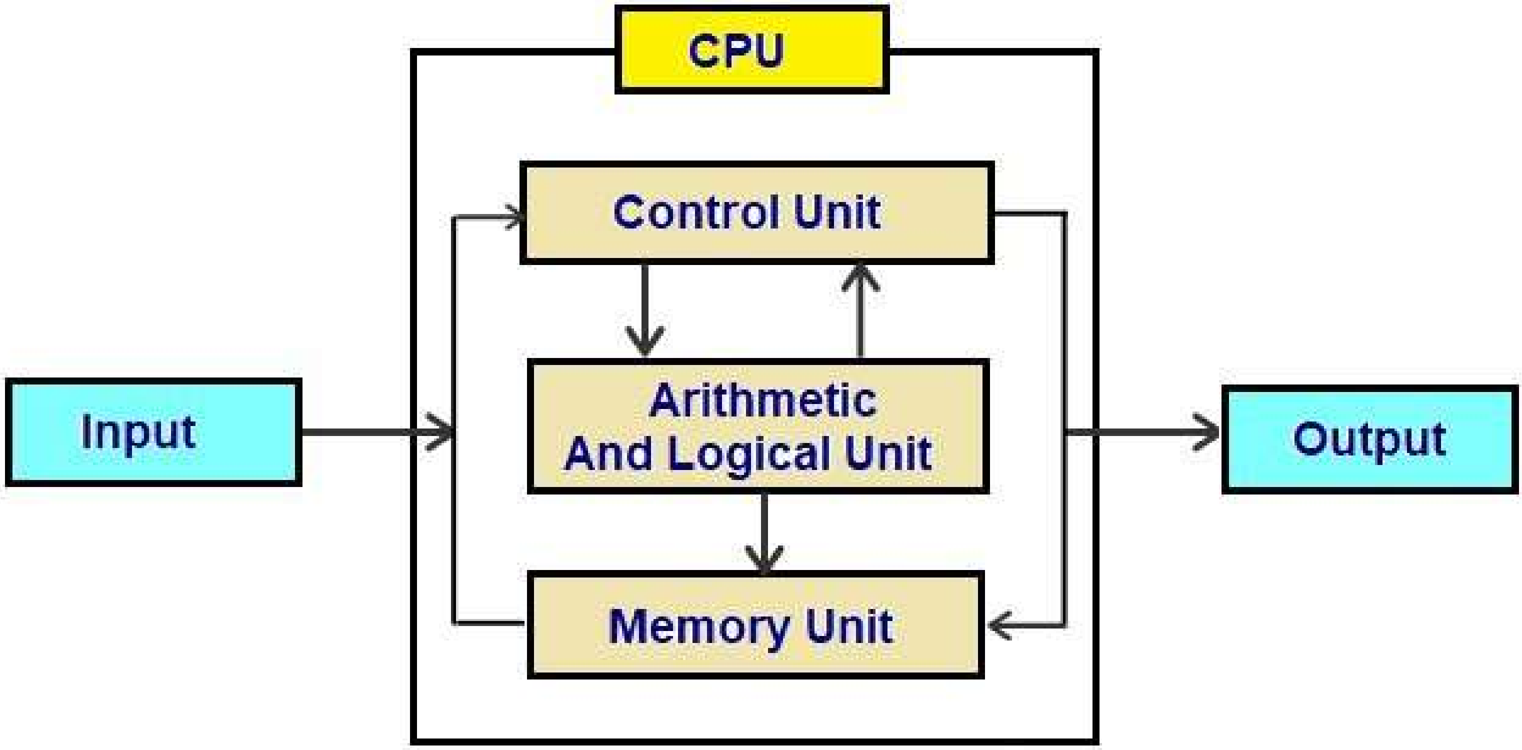
Applications of Digital Computers

1. **Scientific Research:** Weather forecasting, simulations, space research, nuclear research.
2. **Engineering & Technology:** CAD/CAM design, robotics, electronics, circuit design.

3. **Business & Finance:** Banking systems, e-commerce, stock market, payroll, billing.
4. **Education:** Digital classrooms, e-learning, online exams, virtual labs.
5. **Healthcare:** Patient monitoring, medical imaging (X-ray, MRI, CT scans), hospital management.
6. **Personal Use:** Communication, internet, gaming, multimedia, social networking.

Conclusion

In short, **digital computers** are powerful electronic devices that operate on binary digits and can perform a wide range of tasks with speed, accuracy, and reliability. They are made up of input, memory, CPU, and output units, and their programmability makes them suitable for applications in almost every field such as science, business, education, healthcare, and personal use.



Block Diagram of a Computer

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Bus System for Four Registers

Introduction

In a digital computer, different units such as registers, memory, and CPU components need to exchange data. If each register were connected to every other register separately, the hardware would become very complex and costly. To solve this, computers use a **bus system**, which is a common communication pathway. A **bus** is a set of parallel lines (wires) that carry data, control, and address signals between components.

When we design a bus system for **four registers (R1, R2, R3, R4)**, the bus allows data to be transferred between them efficiently without requiring separate connections for each pair.

Working of Bus System with Four Registers

Working of Bus System with Four Registers

1. Each register is of n bits (e.g., 16 bits).
2. The outputs of all four registers are connected to the bus through **4×1 multiplexers**.
   - A separate 4×1 MUX is required for each bus line.
   - Thus, if each register is 16-bit, 16 multiplexers are required.
3. The multiplexers are controlled by **selection lines S0 and S1**, which decide which register's data will appear on the bus.
4. Any register can be loaded with data from the bus if its **Load input** is activated.
   - Example: To transfer R1 → R3: Select R1 onto the bus using S0S1 = 00, then activate Load signal of R3.

Selection Table

Selection Table

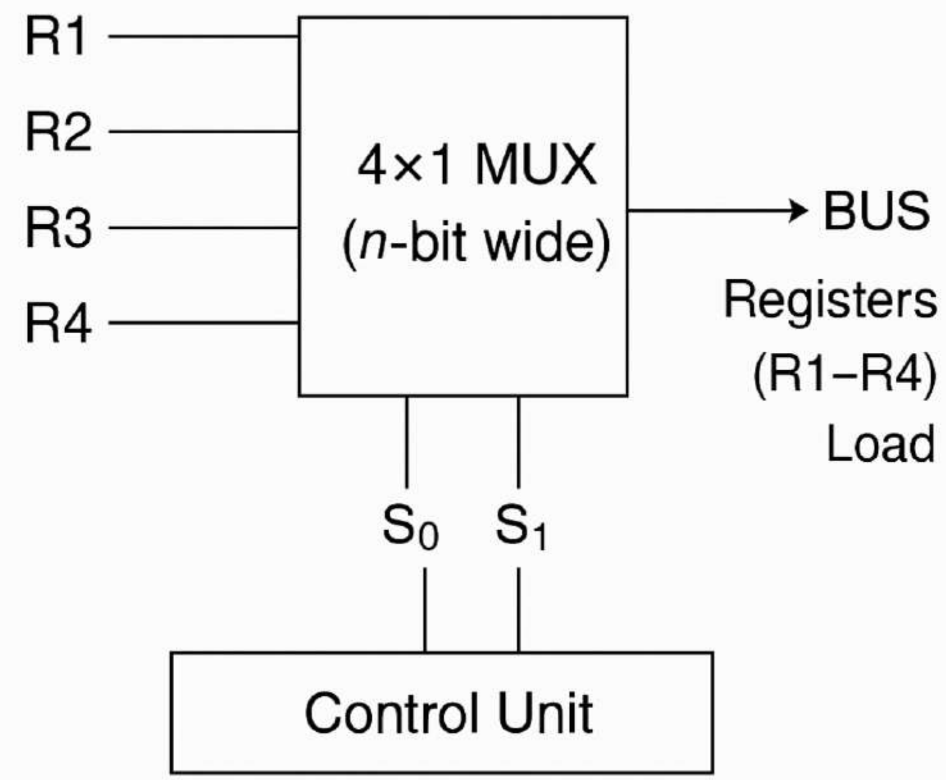
S1	S0	Register Placed on Bus
0	0	R1
0	1	R2
1	0	R3
1	1	R4

Advantages of Bus System

- Reduces hardware complexity by using a single communication path.
- Cost-effective compared to direct connections.
- Flexible and scalable; more registers can be added with larger multiplexers.
- Provides systematic and controlled data transfer.

Conclusion

The **bus system for four registers** allows communication among registers using a common set of lines and multiplexers. Control signals determine which register sends data to the bus, and the required register can load data from the bus. This reduces wiring, simplifies design, and forms the basis of register transfer in computer organisation.


R1
R2
R3
R4
4×1 MUX
(n-bit wide)
BUS
Registers
(R1–R4)
Load
S0
S1
Control Unit

3

Q) Explain the following Terms

(a) Design of Control Unit.

⇒ The Control Unit is a Critical Component of the C.P.U that manages instruction execution. Its design involves

- Instruction Decoding :- Interpreting instruction and generating control signals.
- Timing and Control :- Managing the sequence of operation and ensuring proper timings.
- Control Signal Generation :- Producing signal to execute instructions.

∴ The Control unit's design determines the CPU's efficiency and performance.

(7)

(b) Compare between hardwired Control unit and micro program Control Unit?

Feature	Hardwired Control Unit	Microprogrammed Control Unit
Basic Principle	Control signal are generated by fixed logic circuit made of gates, flip-flop, decoders, etc. It is a hardware-based approach.	Control signal are generated by executing a "microprogram" stored in a special Control memory (ROM). It is a software-based approach.
Speed	Very high speed. signals are generated directly by hardware, with no memory access delay.	Slower. Speed is limited by the access time of the Control memory where the microprogram is stored.
flexibility	Inflexibility. The Control logic is fixed in hardware.	Highly flexible. The instruction set can be modified or updated easily by changing the microcode in the control memory.
Complexity	Complex to Design	Easier to Design
Used in	RISC processors	CISC processors

📌 Floating Point Representation

1. Introduction

Floating Point Representation is a method used in digital computers to represent **real numbers (fractions, very large values, or very small values)** which cannot be efficiently stored using simple integer or fixed-point representation.
It allows a wide range of numbers to be represented in binary by dividing the number into three parts: **Sign, Exponent, and Mantissa**.

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2. General Form of Floating Point

A floating-point number is expressed mathematically as:

$$N = (-1)^S \times M \times 2^E$$

Where:

Where:

- **S (Sign bit):** 0 for positive, 1 for negative.
- **M (Mantissa or Significand):** Represents the precision/fractional digits of the number.
- **E (Exponent):** Adjusts the position of the binary (decimal) point, controlling the range.
- **Base = 2** (binary system).

This form allows both very small and very large numbers to be represented compactly.

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3. IEEE 754 Standard (Single Precision – 32 bit)

The **IEEE 754 standard** is the most widely used for representing floating-point numbers.

Structure of 32-bit single precision:

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Structure of 32-bit single precision:

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```
---------------------------------------------------
| Sign (1 bit) | Exponent (8 bits) | Mantissa (23 bits)
|
---------------------------------------------------
```

- **Sign (1 bit):** Indicates **+** or **–** of the number.
- **Exponent (8 bits):** Stored in **biased form**. (Bias = 127 for single precision).
- **Mantissa (23 bits):** Stores fractional part of normalized binary number. The leading "1" is assumed (not stored explicitly).

⚡ Thus, effectively we get 24-bit precision.

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4. Normalization

Floating point numbers are usually stored in **normalized form**, where:

$$1.\text{fraction} \times 2^E$$

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This ensures maximum precision by shifting the binary point so that only one non-zero digit remains to the left of the point.

Example:
Decimal 5.75 → Binary = 101.11
Normalized = 1.0111×2^2

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5. Example (IEEE 754 representation of −5.75)

1. Convert decimal to binary: 5.75 → 101.11 (binary).
2. Normalize: $101.11 = 1.0111 \times 2^2$.
3. Sign bit = **1** (negative).
4. Exponent = 2 + 127 = 129 → 10000001 (binary).
5. Mantissa = 0111000... (fill to 23 bits).

Final 32-bit Representation:

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```
Sign = 1
Exponent = 10000001
Mantissa = 01110000000000000000000
```

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6. Advantages

✓ Can represent **very large** and **very small** numbers.
✓ Supports fractional values (not possible with pure integer representation).
✓ Provides balance between **range and precision**.
✓ Used universally in scientific and engineering applications.

7. Disadvantages

✗ Requires **complex hardware** for arithmetic operations.
✗ Rounding and approximation errors may occur.
✗ Not suitable for pr[illegible] financial calculations (fixed-po[illegible] is preferred there).

✘ Not suitable for precise financial calculations (fixed-point is preferred there).

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8. Applications

- **Scientific calculations** (physics, engineering, simulations).
- **Computer graphics** (3D rendering, image processing).
- **Machine learning** and **AI computations**.
- Any system needing **high precision + large range**.

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9. Summary

Floating Point Representation is a powerful method of storing real numbers in digital computers using **Sign, Exponent, and Mantissa**.
The IEEE 754 standard (32-bit single precision) ensures uniformity across systems. It allows

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9. Summary

Floating Point Representation is a powerful method of storing real numbers in digital computers using **Sign, Exponent, and Mantissa**.
The IEEE 754 standard (32-bit single precision) ensures uniformity across systems. It allows efficient storage and processing of **fractions, very large, and very small numbers**, which makes it indispensable in modern computing.