Week 17

Computer Organization and Architecture

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Faculty

At the end of the lesson, the learner will be able to:

- Describe the basic operational concepts;
- Compare and contrast computer architecture and computer organization; and
- Solve problems using the logic gates.

What is Computer Organization and Architecture?

Computer architecture refers to the basic operational framework and conceptual design of a computer system. It covers the higher-level features of computer system architecture and operation, such as data types, addressing modes, and instruction set architecture (ISA).

What is Computer Organization and Architecture? (continuation)

Computer organization refers to the functional sections and how they are connected to each other to fulfill the architectural requirements. It covers the hardware of a computer system and how its many parts work together to accomplish different tasks.

Basic Operational Concepts

Basic operational concepts in computer systems refer to the basic ideas and procedures that specify how computers carry out commands and handle data. These ideas serve as the cornerstone for more complex subjects in computer architecture and organization and are crucial for comprehending how computer systems operate at a low level.

Key Operational Concepts

- **Instruction Cycle (Fetch-Decode-Execute Cycle)**
  - The **instruction cycle** is the method by which an instruction set is read from memory, interpreted, and carried out by a computer. The CPU performs work by repeatedly going through this cycle.

    Phases:
    - Fetch instruction from memory
    - Decode the instruction
    - Read the effective address from memory
    - Execute the instruction

Key Operational Concepts (continuation)

- **Data Path and Control Path**
  - **Data Path**: The data path includes the components that perform data processing operations, such as the ALU (Arithmetic Logic Unit), registers, and buses. It is responsible for the actual movement and transformation of data.
  - **Control Path**: The control path includes the control unit and control signals that orchestrate the operation of the data path, memory, and I/O devices. It ensures that all parts of the CPU work together harmoniously.

Key Operational Concepts (continuation)

- **Memory Hierarchy** is an organized configuration of various storage types with varying speeds and capacities to maximize efficiency and minimize expenses.
  - **Registers**: Small, fast storage locations within the CPU used to hold data temporarily during processing.
  - **Cache**: A smaller, faster type of volatile memory that provides high-speed data access to frequently used instructions and data.
  - **Main Memory (RAM):** Volatile memory used to store the currently running programs and data.

Key Operational Concepts (continuation)

- **Secondary Storage**: Non-volatile storage such as hard drives, SSDs, and optical discs used for long-term data storage.

Key Operational Concepts (continuation)

- **Instruction Set Architecture (ISA)** refers to the set of instructions that a processor can execute. It contains the instruction format, data types, registers, addressing modes, and machine language commands.
  - **RISC (Reduced Instruction Set Computer)**: Uses a small, highly optimized set of instructions.
  - **CISC (Complex Instruction Set Computer)**: Uses a larger set of instructions that can execute complex tasks in a single instruction.

Key Operational Concepts (continuation)

- **Registers** are the small, and fast storage locations inside the CPU that store data and addresses temporarily.
  - **Program Counter (PC)**: contains the address of the next instruction to be executed.
  - **Instruction Register (IR)**: contains the current instruction being executed.
  - **Accumulator (AC)**: used for arithmetic and logic operations.
  - **General Purpose Registers**: used for a variety of functions by the CPU during instruction execution.

Key Operational Concepts (continuation)

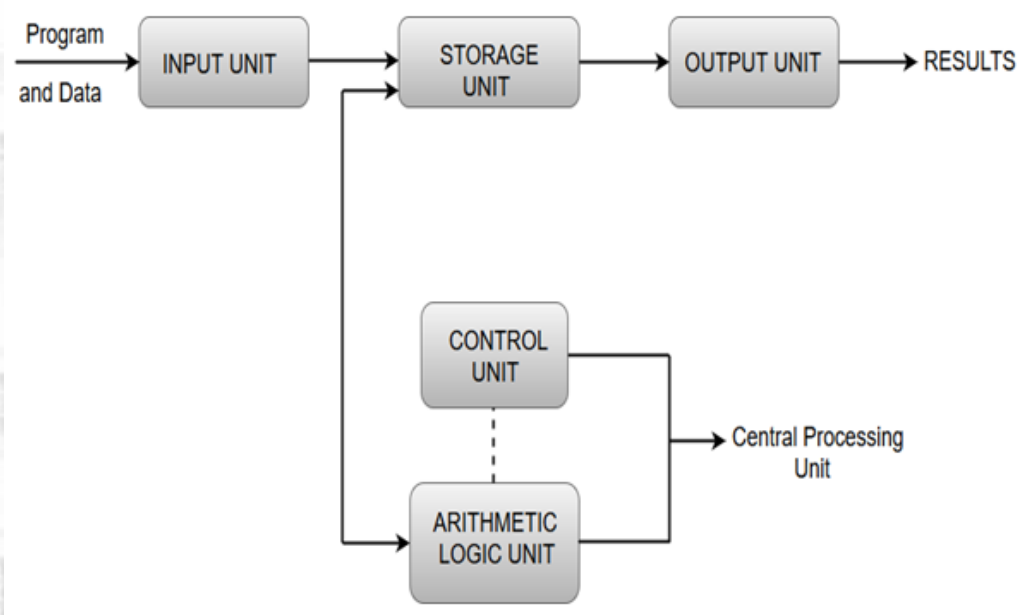
- **Bus System** is a communication channel that connects different components of the computer where it transfer data between them.
  - **Data Bus**: It transfers the data between the CPU, memory, and I/O devices.
  - **Address Bus**: It holds the addresses of data (not the data itself) to and from the memory.
  - **Control Bus**: It transmits the control signals from the CPU to other components to manage operations.

Key Operational Concepts (continuation)

- **Input/Output Operations** is permits the computer to communicate with external devices such storage devices, printers, mice, and keyboards.
- **Interrupts** are signals that temporarily halt the current operations of the CPU's to address a certain condition.
  - **Hardware Interrupts**: It is a signal generated by hardware devices (e.g., keyboard, mouse) like input availability.
  - **Software Interrupts**: It is a signal generated by programs such as a certain request by system services.

Functional Units of Digital System

A digital system, like a computer, is made up of several functional components that cooperate to carry out computing operations.



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Functional Units of Digital System (continuation)

- **Input Unit** utilized by the computer for data reading. Input devices that are most frequently used include keyboards, mice, joysticks, trackballs, microphones, etc.

- **Central Processing Unit** commonly known as CPU is the term for the electronic hardware in a computer that executes computer programs, carrying out the fundamental arithmetic, logical, control, and input/output (I/O) operations that the programs specify.

Functional Units of Digital System (continuation)

- **Memory Unit** can be thought of as the data storage area where operating programs are stored and the data such programs require to function. It categorized in two ways, the primary memory and secondary memory.
- **Arithmetic & Logical Unit** it refers to the operations of a computer that are carried out in the processor's ALU (Arithmetic and Logical Unit). It can carry out logical operations like AND, OR, and NOT operations in addition to arithmetic operations like addition, subtraction, multiplication, and division.

Functional Units of Digital System (continuation)

- **Control Unit** is a part of the central processing unit of a computer that manages how the processor operates. It instructs the computer's memory, input and output devices, and arithmetic/logic unit on how to react to commands from a program.

- **Output Unit** is to provide the user with the processed results. Devices for displaying information in an understandable manner are called output devices.

Computer Instructions

Computer instructions are a collection of instructions in machine language that a certain processor can comprehend and carry out. A computer operates according to the instructions it is given. Instructions fields:

- Mode
- Operation code (Opcode)
- Operand Address

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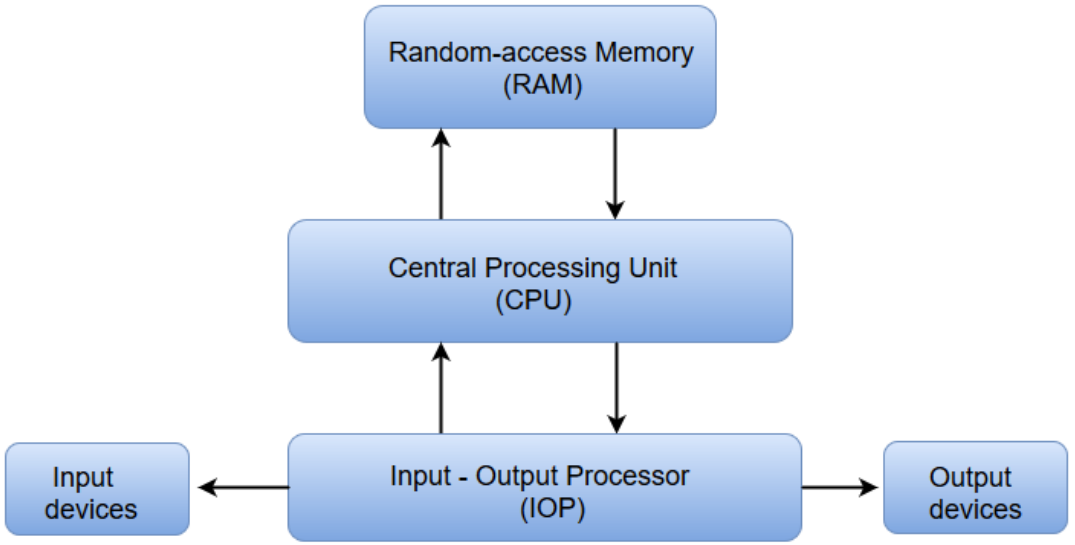
Block Diagram of Digital Computer

A digital computer's block diagram shows the main parts of the system and how they are connected, providing an overview of the system's fundamental architecture and functional flow.



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Logic Gates

Logic gates are the essential components of digital circuits and are employed to carry out simple logical operations on binary inputs. They generate a single binary output from one or more binary inputs (0 or 1). Boolean functions, which are crucial for digital systems like computers and communication devices, are implemented using these gates.

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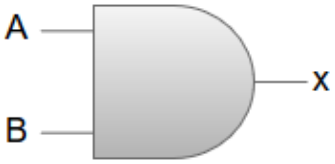
Types of Logic Gates

- **AND Gate**
  - The AND gate is an electronic circuit known as an AND gate produces a high output only when all of its inputs are high. The dot (.) symbol is used to denote the AND operation.



Algebraic Function: x = AB

Truth Table:

A	B	x
0	0	0
0	1	0
1	0	0
1	1	1

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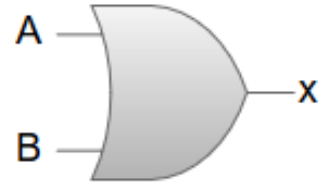
Types of Logic Gates (continuation)

- **OR Gate**
  - The OR gate is an electronic circuit that, when one or more of its inputs are high, produces a high output. A plus (+) sign denotes the operation carried out by an OR gate.



Algebraic Function: x = A + B

Truth Table:

A	B	x
0	0	0
0	1	1
1	0	1
1	1	1

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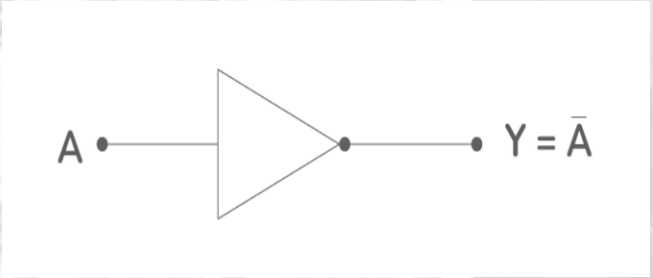
Types of Logic Gates (continuation)

- **NOT Gate**
  - The NOT gate is a type of electronic circuit that generates an output that is an inverted copy of the input. Another name for it is an inverter.



Truth Table

A (Input)	Y = Ā (Output)
0	1
1	0

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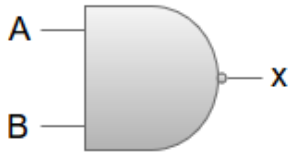
Types of Logic Gates (continuation)

- **NAND Gate**
  - The NAND gate which is equivalent to a NOT gate coming after an AND gate. If any of the inputs are low, the NAND gate outputs a high value. An AND gate with a little circle on the output serves as a representation of the NAND gate. Inversion is represented by the little circle.



Algebraic Function: x = (AB)'

Truth Table:

A	B	x
0	0	1
0	1	1
1	0	1
1	1	0

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Types of Logic Gates (continuation)

- **NOR Gate**
  - The NOR gate which is equivalent to a NOT gate coming after an OR gate. If any of the inputs are high, the NOR gate outputs a low value. An OR gate with a tiny circle on the output serves as a representation of the NOR gate. Inversion is represented by the little circle.

Algebraic Function: x = (A+B)'

Truth Table:

A	B	x
0	0	1
0	1	0
1	0	0
1	1	0

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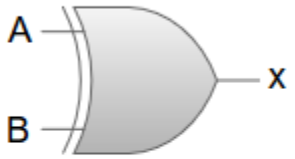
Types of Logic Gates (continuation)

- **Exclusive-OR / XOR Gate**
  - The XOR gate is a circuit that, in the event that one of its inputs is high but not both, will produce a high output. The XOR operation is shown by a plus sign that is surrounded.



Algebraic Function: $x = A \oplus B$

or

$x = A'B + AB'$

Truth Table:

A	B	x
0	0	0
0	1	1
1	0	1
1	1	0

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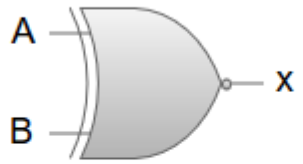
Types of Logic Gates (continuation)

- **Exclusive-NOR / Equivalence Gate**
  - The Equivalence gate is a circuit that operates on an XOR gate in the opposite way. If one of its inputs is high but not both, it will produce a low output. Inversion is represented by the little circle.



Algebraic Function: $x = (A \oplus B)'$

or

$x = A'B' + AB$

Truth Table:

A	B	x
0	0	1
0	1	0
1	0	0
1	1	1

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Try this out!

Draw a logic circuit and truth table for the following:

- $(A+B)C$
- $A + BC + \overline{D}$
- $AB + \overline{AC}$
- $\overline{(A + B)}(C + D)\overline{C}$

References:

- Holcombe, J. (2020). Operating Systems, 6e. McGraw Hill Education
- Barnes, R. (2020). Understanding Operating Systems. Lanrye International
- https://www.javatpoint.com/computer-organization-and-architecture-tutorial
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Thank you!