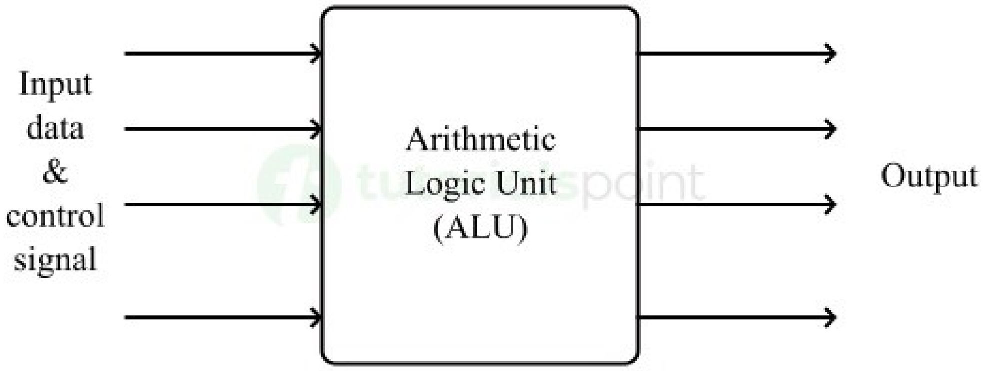
ALU (Arithmetic Logic Unit)

Arithmetic Logic Unit abbreviated as ALU is considered as the engine or heart of every central processing unit (CPU). ALU is basically a combination logic circuit that can perform arithmetic and logical operation on digital data (data in binary format). It can also execute instructions given to a computing system like a digital computer



Features of Arithmetic Logic Unit

- The ALU can perform all arithmetic and logic operations such as addition, subtraction, multiplication, division, logical comparisons, etc.
- It can also perform bitwise and mathematical operations on binary numbers.
- It contains two segments namely, AU (**arithmetic unit**) and LU (**logic unit**) to perform arithmetic operations and logical operations respectively.
- It is the computational powerhouse within a central processing unit (CPU).
- ALU is the part of every CPU where actual data processing takes place.
- ALU is responsible for interpreting the code instructions based on which operations to be performed on the input data.
- Once the data processing is completed, the ALU sends the outcomes to the memory unit or output unit.

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Main Components of Arithmetic Logic Unit

The arithmetic logic unit consists of various functional parts that are responsible for performing specific operations like addition, subtraction, multiplication, division, comparison, and more. Some of the key components of the arithmetic logic unit are explained below −

Arithmetic Unit

The main components used in the arithmetic unit (AU) segment of the arithmetic logic unit are as follows −

Adder

The adder or binary adder is one of the important components of the arithmetic logic unit. It performs the addition of two or more binary numbers. To accomplish this operation, it performs a series of logical and arithmetic operations. Some common types of adders used in the arithmetic ogic unit are half-adder, full-adder, parallel adder, and ripple carry adder. Each type of adder is designed and optimized to perform a specific computing operation.

Subtractor

The subtractor is another digital combinational circuit designed to perform subtraction of binary numbers. In most arithmetic logic unit, the subtractor uses 2s complement arithmetic to perform subtraction on binary numbers.

Multiplier and Divider

In more complex and advanced arithmetic logic units, dedicated multiplier and divider circuits are also implemented to perform multiplication and division on binary numbers. These circuits use advanced processing techniques like iterative or parallel processing to accomplish these operations.

Logic Unit

The logic unit (LU) of the ALU comprises the components responsible for performing Boolean or comparison operations. The following are some main components of the logic unit of an ALU −

Logic Gates

The logic gates like AND, OR, NOT, NAND, NOR, XOR, and XNOR are the key components of logic unit. These are standard logic circuits that can manipulate input data based on some predefined logical instructions and generate a desired output.

Each logic gate can perform a specific logical operation. However, different types of logic gates can be connected together in a specific manner to perform complex logical operations.

Type of Logic Gate

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The brief overview of each type of logic gate is explained here −

- **AND Gate** − It performs the Boolean multiplication on input binary data. Its output is logic 1 or true, only when all its inputs are logic 1 or true.
- **OR Gate** − The OR gate performs the Boolean addition of input binary data. It generates a logic 1 or true output, if any of its inputs is logic 1 or true.
- **NOR Gate** − The NOT gate performs the inversion operation. It gives a logic 1 or true output when its input is logic 0 or false and vice-versa.
- **NAND Gate** − The NAND gate performs the NOTed AND operation and produces a logic 1 or true output when both inputs or any of the inputs is logic 0 or false.
- **NOR Gate** − The NOR gate performs the NOTed OR operation and generates a logic 1 or true output when all its inputs are logic 0 or false.
- **XOR Gate** − The XOR gate performs the exclusive OR operation and produces a logic 1 or true output when its both inputs are dissimilar. Hence, it is used as inequality detector.
- **XNOR Gate** − The XNOR gate performs the exclusive NOR operation and gives a logic 1 or true output when both its inputs are similar. Thus, it is used as an equality detector.

This is all about structure and components of the arithmetic logic unit. Let us now understand what functions an ALU can perform.

Functions of Arithmetic Logic Unit

The arithmetic logic unit can perform a wide range of functions and operations in digital computing systems. Some important functions that an arithmetic logic unit perform are explained below −

Arithmetic Operations

The arithmetic operations are one of the primary functions that the arithmetic logic unit performs. This category of operations includes addition, subtraction, multiplication, and division of binary numbers. All these operations form the basis of mathematical computations that the arithmetic logic unit can perform.

Logical Operations

The arithmetic logic unit can also perform various logical operations such as AND operation, OR operation, NOT operation, etc. These logical operations form the basis of decision making and data manipulation processes.

Comparison Operations

The arithmetic logic unit also facilitates to perform various comparison operations such as equal to, not equal to, less than, greater than, etc. These comparison operations are essential in decision making processes.

Shift Operations

The arithmetic logic unit can also perform shift operations on binary numbers such as left shift and right shift. These operations are important in multiplication and division operations. The shift operations can manipulate binary data at bit level and hence optimize the arithmetic calculations.

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Working of Arithmetic Logic Unit

The working of the arithmetic logic unit depends on a combination of input data and control signals. In other words, the arithmetic logic unit receives the input data and control signals and then interpret these data and signals to perform specific operations.

Let us understand the working of the arithmetic logic unit in detail by breaking it down in sub-components.

Receiving Input Data and Control Signals

The arithmetic logic unit receives the input data from the user and a set of control signals that specifies the operation to be performed. The data is received through the input data path while the control signals are received from the control unit.

Execution of Operation

Once the arithmetic logic unit received the input data and control signals, it selects an appropriate functional component among arithmetic unit, logic unit, comparison unit, or shift unit to perform the specific operation. Once the operation completes, the ALU sends the results to the memory unit for storage or output unit.

Half-Adder

A combinational logic circuit which is designed to add two binary digits is called as a **half adder**. The half adder provides the output along with a carry value (if any). The half adder circuit is designed by connecting an EX-OR gate and one AND gate. It has two input terminals and two output terminals for sum and carry. The block diagram and circuit diagram of a half adder are shown below

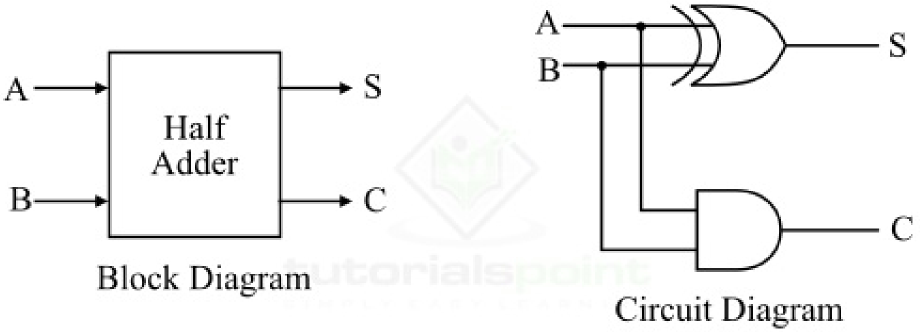

Figure 1 - Half Adder

Operation of Half Adder

Half adder adds two binary digits according to the rules of binary addition. These rules are as follows −

$0+0=0$
$0+1=1$
$1+0=1$
$1+1=10$ Sum=0 & Carry=1

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Truth Table of Half Adder

What is a Full Adder?

A combinational logic circuit that can add two binary digits (bits) and a carry bit, and produces a sum bit and a carry bit as output is known as a full-adder.

In other words, a combinational circuit which is designed to add three binary digits and produces two outputs (sum and carry) is known as a full adder. Thus, a full adder circuit adds three binary digits, where two are the inputs and one is the carry forwarded from the previous addition. The block diagram and circuit diagram of the full adder are shown in Figure-1.