# CS304 – Digital System Sem-3rd CSE RGPV

By:- Mr. Sonu Kumar

## Module -1 Review The Number System

### Number System

- The system can understand only the optional number system. In these systems, digits symbols are used to represent different values, depending on the index from which it settled in the number system.
- For representing the information, we use the number system in the digital system.
  - Note: When the number system represents a digit from 0 - 9, the base of the number will be 10.

**Types of Number System**

1. Binary Number System
2. Decimal Number System
3. Hexadecimal Number System
4. Octal Number System

**Binary Number System**

- A binary number system is used in the digital computers. In this number system, it carries only two digits, either 0 or 1.
- There are two types of electronic pulses present in a binary number system. The first one is the absence of an electronic pulse representing '0'and second one is the presence of electronic pulse representing '1'.
- Each digit is known as a bit. A four-bit collection (1101) is known as a **nibble**, and a collection of eight bits (11001010) is known as a **byte.**
  - The location of a digit in a binary number represents a specific power of the base (2) of the number system.

**Characteristics:**

1. It holds only two values, i.e., either 0 or 1.
2. It is also known as the base 2 number system.
3. The position of a digit represents the 0 power of the base(2). Example: $2^0$
4. The position of the last digit represents the x power of the base(2). Example: $2^x$, where x represents the last position, i.e., 1

**Examples:**

$(10100)_2$, $(11011)_2$, $(11001)_2$, $(000101)_2$, $(011010)_2$.

| Number | Octal Number |
|---|---|
| 0 | 000 |
| 1 | 001 |
| 2 | 010 |
| 3 | 011 |
| 4 | 100 |
| 5 | 101 |
| 6 | 110 |
| 7 | 111 |

**Decimal Number System**

- The decimal numbers are used in our day to day life. The decimal number system contains ten digits from 0 to 9(base 10).
- The position in the decimal number system specifies the power of the base (10).
- The 0 is the minimum value of the digit, and 9 is the maximum value of the digit.

**Example,**

(2×1000) + (5×100) + (4×10) + (1×1)
$(2\times10^3) + (5\times10^2) + (4\times10^1) + (1\times10^0)$
2000 + 500 + 40 + 1
2541

**Octal Number System**

- The octal number system has base 8(means it has only eight digits from 0 to 7). There are only eight possible digit values to represent a number. With the help of only three bits, an octal number is represented. Each set of bits has a distinct value between 0 and 7.

**Characteristics:**

1. An octal number system carries eight digits starting from 0, 1, 2, 3, 4, 5, 6, and 7.
2. It is also known as the base 8 number system.
3. The position of a digit represents the 0 power of the base(8). Example: $8^0$
4. The position of the last digit represents the x power of the base(8). Example: $8^x$, where x represents the last position, i.e., 1

**Examples:**

$(273)_8$, $(5644)_8$, $(0.5365)_8$, $(1123)_8$, $(1223)_8$.

**Hexadecimal Number System**

- It is another technique to represent the number in the digital system called the **hexadecimal number system**.
- The number system has a base of 16 means there are total 16 symbols(0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F) used for representing a number.
- The single-bit representation of decimal values10, 11, 12, 13, 14, and 15 are represented by A, B, C, D, E, and F. Only 4 bits are required for representing a number in a hexadecimal number.
- Each set of bits has a distinct value between 0 and 15. There are the following characteristics of the octal number system:

**Characteristics:**

1. It has ten digits from 0 to 9 and 6 letters from A to F.
2. The letters from A to F defines numbers from 10 to 15.
3. It is also known as the base 16number system.
4. In hexadecimal number, the position of a digit represents the 0 power of the base(16). Example: $16^0$
5. In hexadecimal number, the position of the last digit represents the x power of the base(16). Example: $16^x$, where x represents the last position, i.e., 1

**Examples:**

$(FAC2)_{16}$, $(564)_{16}$, $(0ABD5)_{16}$, $(1123)_{16}$, $(11F3)_{16}$.

**Binary to BCD code conversion**

- BCD code plays an important role in digital circuits. The BCD stands for Binary Coded Decimal Number.
- In BCD code, each digit of the decimal number is represented as its equivalent binary number. So, the LSB and MSB of the decimal numbers are represented as its binary numbers.

**There are the following steps to convert the binary number to BCD:**

1. First, we will convert the binary number into decimal.
2. We will convert the decimal number into BCD.

Let's take an example to understand the process of converting a binary number into BCD

Example 1: $(11110)_2$

**1. First, convert the given binary number into a decimal number.**

Binary Number: $(11110)_2$

Finding Decimal Equivalent of the number:

| Steps | Binary Number | Decimal Number |
|---|---|---|
| 1) | $(11110)_2$ | $((1 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (0 \times 2^0))_{10}$ |
| 2) | $(11110)_2$ | $(16 + 8 + 4 + 2 + 0)_{10}$ |
| 3) | $(11110)_2$ | $(30)_{10}$ |

Decimal number of the Binary number $(11110)_2$ is $(30)_{10}$

**2. Now, we convert the decimal to the BCD**

We convert each digit of the decimal number into groups of the four-bit binary number.

| Steps | Decimal Number | Conversion |
|---|---|---|
| Step 1 | $30_{10}$ | $(0011)_2$ $(0000)_2$ |
| Step 2 | $30_{10}$ | $(00110000)_{BCD}$ |

**Result:**

$(11110)_2 = (00110000)_{BCD}$

Below is the table that contains the BCD code of the decimal and binary number.

| Binary Code | Decimal Number | BCD Code |
|---|---|---|
| **A B C D** | | **$B_4 : B_3B_2B_1B_0$** |
| 0 0 0 0 | 0 | 0 : 0 0 0 0 |
| 0 0 0 1 | 1 | 0 : 0 0 0 1 |
| 0 0 1 0 | 2 | 0 : 0 0 1 0 |
| 0 0 1 1 | 3 | 0 : 0 0 1 1 |
| 0 1 0 0 | 4 | 0 : 0 1 0 0 |
| 0 1 0 1 | 5 | 0 : 0 1 0 1 |
| 0 1 1 0 | 6 | 0 : 0 1 1 0 |

| | | |
|---|---|---|
| 0 1 1 1 | 7 | 0 : 0 1 1 1 |
| 1 0 0 0 | 8 | 0 : 1 0 0 0 |
| 1 0 0 1 | 9 | 0 : 1 0 0 1 |
| 1 0 1 0 | 10 | 1 : 0 0 0 0 |
| 1 0 1 1 | 11 | 1 : 0 0 0 1 |
| 1 1 0 0 | 12 | 1 : 0 0 1 0 |
| 1 1 0 1 | 13 | 1 : 0 0 1 1 |
| 1 1 1 0 | 14 | 1 : 0 1 0 0 |
| 1 1 1 1 | 15 | 1 : 0 1 0 1 |

**BCD to Binary Conversion**

- The process of converting BCD code into Binary is opposite to the process of converting Binary code into BCD. There are the following steps to convert the BCD code into Binary:
  - **In the first step, we will convert** the BCD number into a decimal by making the four-bit groups and finding the equivalent decimal number for each group.
  - **In the last step, we will convert** a decimal number into Binary using the process of converting decimal to binary number.

Example 1: $(00101000)_{BCD}$

**1) Convert BCD to Decimal**

Make the groups of 4 digits and find the equivalent decimal number as:

| Steps | BCD Number | Conversion |
|---|---|---|
| Step 1 | $(00101000)_{BCD}$ | $(0010)_2$ $(1000)_2$ |
| Step 2 | $(00101000)_{BCD}$ | $(2)_{10}$ $(8)_{10}$ |

| | | |
|---|---|---|
| Step 3 | $(00101000)_{BCD}$ | $(28)_{10}$ |

The decimal number of the given BCD code is: $(28)_{10}$

**2. Convert Decimal to Binary**

Use the long division method to convert the decimal number into a binary number as:

| Steps | Operation | Result | Remainder |
|---|---|---|---|
| 1. | 28 / 2 | 14 | 0 |
| 2. | 14 / 2 | 7 | 0 |
| 3. | 7 / 2 | 3 | 1 |
| 4. | 3 / 2 | 1 | 1 |
| 5. | 1 / 2 | 0 | 1 |

- Arrange the remainders in the reverse order. So, the LSB of the binary number is the first remainder, and the MSB of the binary number is the last remainder.

The binary number of the decimal number $(18)_{10}$ is: $(11100)_2$

**Result:**

$(00101000)_{BCD} = (11100)_2$

**Boolean Functions**

- The binary variables and logic operations are used in Boolean algebra. The algebraic expression is known as **Boolean Expression**, is used to describe
- the **Boolean Function**. The Boolean expression consists of the constant value 1 and 0, logical operation symbols, and binary variables.

**Example 1: F=xy' z+p**

**Methods of simplifying the Boolean function**

- There are two methods which are used for simplifying Boolean function. These functions are as follows:

**Karnaugh-map or K-map**

- De-Morgan's law is very helpful for manipulating logical expressions. The logic gates can also realize the logical expression.
- The k-map method is used to reduce the logic gates for a minimum possible value required for the realization of a logical expression.

- The K-map method will be done in two different ways, which we will discuss later in the **Simplification of Boolean expression** section.

**NAND gates realization**

- Apart from the K-map, we can also use the NAND gate for simplifying the Boolean functions. Let's see an example:

Example 1: F(A,B,C,D)=A' C'+ABCD'+B' C' D+BCD'+A'B'

## Logic Gates

- Logic gates play an important role in circuit design and digital systems. It is a building block of a digital system and an electronic circuit that always have only one output.
- These gates can have one input or more than one input, but most of the gates have two inputs. On the basis of the relationship between the input and the output, these gates are named as AND gate, OR gate, NOT gate, etc.

**There are different types of gates which are as follows:**

**AND Gate**

- This gate works in the same way as the logical operator **"and"**. The AND gate is a circuit that performs the AND operation of the inputs.
- This gate has a minimum of 2 input values and an output value.

Y=A AND B AND C AND D......N
Y=A.B.C.D......N
Y=ABCD......N

**OR Gate**

- This gate works in the same way as the logical operator **"or"**. The OR gate is a circuit which performs the OR operation of the inputs.
- This gate also has a minimum of 2 input values and an output value.

Y=A OR B OR C OR D......N
Y=A+B+C+D......N

**NOT Gate**

- The NOT gate is also called an inverter. This gate gives the inverse value of the input value as a result. This gate has only one input and one output value.

Y=NOT A
Y=A'

**NAND Gate**

- The NAND gate is the combination of AND gate and NOT gate. This gate gives the same result as a NOT-AND operation.
- This gate can have two or more than two input values and only one output value.

Y=A NOT AND B NOT AND C NOT AND D......N
Y=A NAND B NAND C NAND D......N

**NOR Gate**

- The NOR gate is the combination of an OR gate and NOT gate. This gate gives the same result as the NOT-OR operation.
- This gate can have two or more than two input values and only one output value.

Y=A NOT OR B NOT OR C NOT OR D......N
Y=A NOR B NOR C NOR D......N

**XOR Gate**

- The XOR gate is also known as the Ex-OR gate. The XOR gate is used in half and full adder and subtractor. The exclusive-OR gate is sometimes called as EX-OR and X-OR gate.
- This gate can have two or more than two input values and only one output value.

Y=A XOR B XOR C XOR D......N
$Y=A\oplus B\oplus C\oplus D$......N
Y=AB'+A'B

**XNOR Gate**

- The XNOR gate is also known as the Ex-NOR gate. The XNOR gate is used in half and full adder and subtractor.
- The exclusive-NOR gate is sometimes called as EX-NOR and X-NOR gate. This gate can have two or more than two input values and only one output value.

Y=A XNOR B XNOR C XNOR D......N
$Y=A\ominus B\ominus C\ominus D$......N
Y=A'B'+AB

## Number Systems:

- Number systems are a way to represent and express numerical values. The most common number systems are:

- **Decimal (Base-10):** This is the system most people use daily. It uses ten digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.
- **Binary (Base-2):** It uses only two digits, 0 and 1, and is widely used in digital electronics and computing.
- **Octal (Base-8):** It uses eight digits, 0 to 7.
- **Hexadecimal (Base-16):** It uses sixteen digits, 0 to 9 and A to F, and is commonly used in computer programming.

**Number Base Conversion:**

- Converting between different number bases is a common operation. Here's how to convert from one base to another, like from decimal to binary:
- To convert from decimal to binary, you can repeatedly divide the decimal number by 2 and keep track of the remainders. Then, read the remainders in reverse order to get the binary representation.
- To convert from binary to decimal, multiply each digit by 2 to the power of its position and sum up the results.

**Binary Codes:**

- Binary codes are used to represent information in binary form. Some common binary codes include:
- **Gray Code:** A binary code where only one bit changes at a time as you count up or down. It's useful in rotary encoders.
- **BCD (Binary Coded Decimal):** It represents decimal numbers using 4-bit binary code. Each digit is separately coded.
- **ASCII (American Standard Code for Information Interchange):** A binary code that represents characters, numbers, and symbols.

**Boolean Algebra:**

- Boolean algebra is a mathematical system that deals with binary variables and logical operations. It's based on three primary operations:
- **AND:** Returns true (1) if both inputs are true, otherwise false (0).
- **OR:** Returns true if at least one input is true.
- **NOT:** Returns the opposite of the input, i.e., true becomes false and vice versa.

**Boolean Functions:**



Mr. Sonu Kumar

- Boolean functions are expressions or equations that define relationships between Boolean variables using logical operations.
- They can be represented as truth tables or algebraic expressions.
- For example, the Boolean function "A AND B" is true only when both A and B are true.

**Logic Gates:**

- Logic gates are physical or electronic devices that implement Boolean functions. Some common logic gates include:
  - **AND Gate:** Outputs true (1) if both inputs are true.
  - **OR Gate:** Outputs true if at least one input is true.
  - **NOT Gate:** Inverts the input, turning true into false and vice versa.
  - **NAND Gate:** Outputs false only if both inputs are true.
  - **NOR Gate:** Outputs true only if both inputs are false.
  - **XOR Gate (Exclusive OR):** Outputs true if only one input is true.
  - **XNOR Gate (Exclusive NOR):** Outputs true if both inputs are the same (either both true or both false).

**Simplification of Boolean Functions:**

- Boolean functions can be simplified to make them more manageable and efficient. This simplification helps reduce the complexity of digital circuits.
- Two common methods for simplification are Karnaugh maps and Sum of Products (SOP) and Product of Sums (POS) forms.

**Karnaugh Map Method:**

- The Karnaugh map (K-map) is a graphical tool for simplifying Boolean functions, especially when dealing with small to moderately sized expressions. Here are the steps to use the K-map method:
- Create a Karnaugh map grid with cells corresponding to all possible combinations of input variables.
- Fill in the values of the Boolean function in the cells.
- Group adjacent 1s in power-of-2-sized groups (1, 2, 4, 8, etc.). Each group must be a rectangle or square and should cover as many 1s as possible.
- Write the simplified Boolean expression based on these grouped terms.
- For example, consider the Boolean function F(A, B) = AB + A'B'. The K-map for this function would look like this:



Mr. Sonu Kumar

A\B | 0 | 1
---------------
0 | 0 | 1
1 | 0 | 0

- You can see that there's a single 1, and its grouping yields the simplified expression: F(A, B) = B.

**SOP (Sum of Products) and POS (Product of Sums) Simplification:**

- Boolean functions can also be simplified using the SOP and POS forms.
  - SOP (Sum of Products): In this form, you express the function as a sum (OR) of product (AND) terms. For example, F(A, B) = AB + A'B' is already in SOP form.
  - **POS (Product of Sums):** In this form, you express the function as a product (AND) of sum (OR) terms. For example, F(A, B) = (A + B)(A' + B') can be expressed in POS form.

**NAND-NOR Implementation:**

- NAND and NOR gates are universal gates, meaning that any other Boolean function can be implemented using only these gates. Here's how you can use them for implementation:

**NAND Gate Implementation:**

- Implement AND, OR, and NOT functions using NAND gates:
  - **AND:** Y = A NAND (A NAND B)
  - **OR:** Y = (A NAND A) NAND (B NAND B)
  - **NOT:** Y = A NAND A

**NOR Gate Implementation:**

- Implement AND, OR, and NOT functions using NOR gates:
  - **AND:** Y = (A NOR A) NOR (B NOR B)
  - **OR:** Y = A NOR (A NOR B)
  - **NOT:** Y = A NOR A



Mr. Sonu Kumar

# Module – 2 Combinational Logic Circuits

## Combinational Logic circuits

- A circuit in which different types of logic gates are combined is known as a **combinational logic circuit**.
- The output of the combinational circuit is determined from the present combination of inputs, regardless of the previous input. The input variables, logic gates, and output variables are the basic components of the combinational logic circuit.
- There are different types of combinational logic circuits, such as Adder, Subtractor, Decoder, Encoder, Multiplexer, and De-multiplexer.

**There are the following characteristics of the combinational logic circuit:**

- At any instant of time, the output of the combinational circuits depends only on the present input terminals.
- The combinational circuit doesn't have any backup or previous memory. The present state of the circuit is not affected by the previous state of the input.
- The n number of inputs and m number of outputs are possible in combinational logic circuits.

**Half Adder**

- The half adder is a basic building block having two inputs and two outputs.
- The adder is used to perform OR operation of two single bit binary numbers.
- The **carry** and **sum** are two output states of the half adder.

**Full Adder**

- The half adder is used to add only two numbers. To overcome this problem, the full adder was developed.
- The full adder is used to add three 1-bit binary numbers A, B, and carry C.
- The full adder has three input states and two output states i.e., sum and carry.

**Half Subtractors**

- The half subtractor is also a building block of subtracting two binary numbers. It has two inputs and two outputs.
- This circuit is used to subtract two single bit binary numbers A and B. The **'diff'** and **'borrow'** are the two output state of the half adder.

**Full Subtractors**

- The Half Subtractor is used to subtract only two numbers. To overcome this problem, full subtractor was designed.

- The full subtractor is used to subtract three 1-bit numbers A, B, and C, which are **minuend, subtrahend**, and **borrow,** respectively.
- The full subtractor has three input states and two output states i.e., diff and borrow.

**Multiplexers**

- The multiplexer is a combinational circuit that has n-data inputs and a single output. It is also known as the **data selector** which selects one input from the inputs and routes it to the output.
- With the help of the selected inputs, one input line from the n-input lines is selected. The enable input is denoted by E, which is used in cascade.

**De-multiplexers**

- A De-multiplexer performs the reverse operation of a multiplexer. The de-multiplexer has only one input, which is distributed over several outputs.
- One output line is selected at a time by selecting lines.
- The input is transmitted to the selected output line.

**Decoder**

- A decoder is a combinational circuit having n inputs and to a maximum of m = 2n outputs. The decoder is the same as the de-multiplexer.
- The only difference between de-multiplexer and decoder is that in the decoder, there is no data input.
- The decoder performs an operation that is completely opposite of an encoder.

**Encoder**

- The encoder is used to perform the reverse operation of the decoder. An encoder having n number of inputs and m number of outputs is used to produce m-bit binary code which is related to the digital input number.
- The encoder takes the digital word and converts it into another digital word.

**Multiplexer**

- A multiplexer is a combinational circuit that has $2^n$ input lines and a single output line. Simply, the multiplexer is a multi-input and single-output combinational circuit.
- The binary information is received from the input lines and directed to the output line.
- On the basis of the values of the selection lines, one of these data inputs will be connected to the output.

**De-multiplexer**

- A De-multiplexer is a combinational circuit that has only 1 input line and $2^N$ output lines. Simply, the multiplexer is a single-input and multi-output combinational circuit.
- The information is received from the single input lines and directed to the output line. On the basis of the values of the selection lines, the input will be connected to one of these outputs.
- De-multiplexer is opposite to the multiplexer.

## Combinational Logic:

- Combinational logic circuits produce output based on current input alone, disregarding previous inputs or the circuit's state.
- The outputs are determined by logical functions of the input values. Examples include logic gates, adders, subtractors, multiplexers, and demultiplexers.

**Half Adder:**

- A half adder is a basic combinational circuit used to add two single-bit binary numbers.
- It has two inputs, A and B, and produces two outputs: the sum (S) and the carry (C).
- The sum is obtained using an XOR gate, and the carry is obtained using an AND gate.

**Half Subtractor:**

- A half subtractor is a circuit that subtracts two single-bit binary numbers. It has two inputs, A and B, and produces two outputs: the difference (D) and the borrow (B). The difference is obtained using an XOR gate, and the borrow is obtained using an AND gate in conjunction with a NOT gate.

**Full Adder:**

- A full adder adds two single-bit binary numbers along with a carry input. It has three inputs: A, B, and an incoming carry (Cin).
- It produces two outputs: the sum (S) and a carry out (Cout). It can be constructed using multiple half adders and additional logic gates.

**Full Subtractor:**

- A full subtractor subtracts two single-bit binary numbers along with a borrow input. It has three inputs: A, B, and an incoming borrow (Bin).
- It produces two outputs: the difference (D) and a borrow out (Bout). It can be constructed using multiple half subtractors and additional logic gates.

**Look-Ahead Carry Generator:**



Mr. Sonu Kumar

- In arithmetic circuits, particularly in adders, the ripple carry adder suffers from delay in the carry propagation.
- Look-ahead carry generators help in producing carry signals independently of the input values, reducing the time required for the carry to propagate.

**BCD Adder:**

- Binary Coded Decimal (BCD) adders are used to add two BCD numbers. They produce a correct BCD output for the sum, handling carry between decimal digits.

**Series and Parallel Circuits:**

- In digital circuits, components can be connected in series or parallel configurations. Series connections mean components are connected end-to-end, while parallel connections mean they share common connections.

**Multiplexer-Demultiplexer:**

- **Multiplexer (MUX):** A MUX is a combinational circuit that selects one of many input lines and forwards it to a single output line based on a control signal.
- **Demultiplexer (DEMUX):** A DEMUX takes a single input and distributes it across multiple output lines based on a control signal.

**Encode - Decode:**

- **Encoder:** Encoders convert data from one format to another, often from multiple input lines to a smaller set of output lines.
- **Decoder:** Decoders perform the reverse operation of an encoder, translating coded data into a more usable format.

**Arithmetic Circuits:**

- These circuits perform arithmetic operations, including addition, subtraction, multiplication, and division.
- They are made up of adders, subtractors, and other components tailored for arithmetic tasks.

**ALU (Arithmetic Logic Unit):**

- The ALU is the part of a CPU responsible for performing arithmetic and logic operations. It performs addition, subtraction, logical AND, OR, shifting operations, and more.

Mr. Sonu Kumar

# Module – 3 Sequential Circuits & Logic

## Introduction

- The sequential circuit is a special type of circuit that has a series of inputs and outputs.
- The outputs of the sequential circuits depend on both the combination of present inputs and previous outputs. The previous output is treated as the present state.
- The sequential circuit contains the combinational circuit and its memory storage elements. A sequential circuit doesn't need to always contain a combinational circuit.
- The sequential circuit can contain only the memory element.

**Difference between the combinational circuits and sequential circuits are given below:**

| | Combinational Circuits | Sequential Circuits |
|---|---|---|
| 1) | The outputs of the combinational circuit depend only on the present inputs. | The outputs of the sequential circuits depend on both present inputs and present state(previous output). |
| 2) | The feedback path is not present in the combinational circuit. | The feedback path is present in the sequential circuits. |
| 3) | In combinational circuits, memory elements are not required. | In the sequential circuit, memory elements play an important role and require. |
| 4) | The clock signal is not required for combinational circuits. | The clock signal is required for sequential circuits. |
| 5) | The combinational circuit is simple to design. | It is not simple to design a sequential circuit. |

**Types of Sequential Circuits**

1. **Asynchronous sequential circuits**

- The clock signals are not used by the **Asynchronous sequential circuits**.
- The asynchronous circuit is operated through the pulses. So, the changes in the input can change the state of the circuit.

- The asynchronous circuits do not use clock pulses. The internal state is changed when the input variable is changed.
- The un-clocked flip-flops or time-delayed are the memory elements of asynchronous sequential circuits.
- The asynchronous sequential circuit is similar to the combinational circuits with feedback.

**Synchronous sequential circuits**

- In synchronous sequential circuits, synchronization of the memory element's state is done by the clock signal.
- The output is stored in either flip-flops or latches(memory devices). The synchronization of the outputs is done with either only negative edges of the clock signal or only positive edges.

**Clock Signal and Triggering**

- **Clock signal:-**
  - A clock signal is a periodic signal in which ON time and OFF time need not be the same. When ON time and OFF time of the clock signal are the same, a square wave is used to represent the clock signal. Below is a diagram which represents the clock signal:
  - A clock signal is considered as the square wave. Sometimes, the signal stays at logic, either high 5V or low 0V, to an equal amount of time. It repeats with a certain time period, which will be equal to twice the 'ON time' or 'OFF time'.

**Types of Triggering**

1) **Level triggering**

- The logic High and logic Low are the two levels in the clock signal. In level triggering, when the clock pulse is at a particular level, only then the circuit is activated. There are the following types of level triggering:

2) **Positive level triggering**

- In a positive level triggering, the signal with Logic High occurs. So, in this triggering, the circuit is operated with such type of clock signal. Below is the diagram of positive level triggering:

**Negative level triggering**

- In negative level triggering, the signal with Logic Low occurs. So, in this triggering, the circuit is operated with such type of clock signal. Below is the diagram of Negative level triggering:

**Edge triggering:-**

- In clock signal of edge triggering, two types of transitions occur, i.e., transition either from Logic Low to Logic High or Logic High to Logic Low.
- Based on the transitions of the clock signal, there are the following types of edge triggering:

**Positive edge triggering**

- The transition from Logic Low to Logic High occurs in the clock signal of positive edge triggering. So, in positive edge triggering, the circuit is operated with such type of clock signal. The diagram of positive edge triggering is given below.

**Negative edge triggering**

- The transition from Logic High to Logic low occurs in the clock signal of negative edge triggering. So, in negative edge triggering, the circuit is operated with such type of clock signal. The diagram of negative edge triggering is given below.

**Applications of PLA**

1. It is utilized as a counter.
2. It is utilized as a decoder.
3. It is utilized to give control over the datapath.
4. It is utilized as a BUS interface in programming Input/Output.

**What is PAL?**

- ***PAL*** is an abbreviation for ***"Programmable Array Logic"***. It is a ***PLD (Programmable Logic Device)*** circuit that functions likewise to the ***PLA***. Unlike PLA, PAL utilizes programmable ***AND*** gates but fixed ***OR*** gates.
- It uses two straightforward functions, where the amount of linked AND gates to each OR gate determines the maximum number of product terms that may be formed in the SOP representation of the function.
- Even though the AND gates are always linked to the OR gates, the resulting product term is not shared with the output functions.

**Benefits of the PAL**

1. It is highly secure.
2. It is highly flexible to design.
3. It is highly efficient.
4. It is more reliable than others.
5. It needs low power consumption to work.

| Features | PLA | PAL |
|---|---|---|
| **Full Forms** | PLA is an abbreviation for Programmable Logic Array. | DHCP is an abbreviation for Programmable Array Logic. |
| **Cost** | Its cost is high. | Its cost is low. |
| **Speed** | Its speed is low. | Its speed is high. |
| **Usable** | It is less usable. | It is more usable. |
| **Availability** | It is less available. | It is easier to produce and more easily. |
| **Function Implementation** | It has a limited amount of functions implemented. | It has a huge number of functions implemented. |
| **Complexity** | Its complexity is high than PAL. | Its complexity is less than PLA. |
| **Design** | It may be built utilizing a programmable set of AND gates and a fixed set of OR gates. | A programmable set of AND and OR gates may be utilized to build PAL. |
| **Flexibility** | It is more flexible as compared to PAL. | It is less flexible than PLA. |

**Sequential Logic:**

- Unlike combinational logic, sequential logic circuits have memory elements and depend on both the current inputs and the circuit's previous state to produce outputs.
- They are used for applications like data storage, timing, and synchronization.

**Flip-Flops:**

- Flip-flops are the fundamental memory elements used in sequential circuits. They can store one bit of information (0 or 1) and are sensitive to the clock signal.
- Common types of flip-flops include D flip-flops, T flip-flops, S-R flip-flops, and J-K flip-flops.

**D Flip-Flop:**

- The D flip-flop has a data input (D) and a clock input (C or CLK). It stores the value of the data input when the clock transitions. It's often used for storage and synchronization.

**T Flip-Flop:**

- The T flip-flop toggles its output based on its current state and the clock input. It's often used for frequency division and counting applications.

**S-R Flip-Flop:**

- The S-R flip-flop has two inputs, Set (S) and Reset (R), and a clock input. It's versatile but sensitive to input timing, leading to potential issues like the "racing condition."

**J-K Flip-Flop:**

- The J-K flip-flop has two inputs, J (set) and K (reset), along with a clock input. It can be configured to act as an S-R flip-flop, a T flip-flop, or a D flip-flop, making it highly flexible.

**Master-Slave Flip-Flops:**

- Master-slave flip-flops are composed of two flip-flops (master and slave). The master flip-flop is sensitive to the clock's rising edge, and the slave flip-flop is sensitive to the falling edge. This design helps eliminate the racing condition.

**Racing Condition:**

- A racing condition is a timing problem in sequential circuits where the output can oscillate or be undefined due to the uncertainty of signal arrival times.
- It's a common issue in S-R flip-flops but can be resolved with master-slave designs.

**Edge & Level Triggered Circuits:**

- **Edge-Triggered:** These circuits respond to a specific edge (rising or falling) of a clock signal. They are widely used in synchronous digital systems.

Mr. Sonu Kumar

- **Level-Triggered:** These circuits respond to the continuous presence of a signal at a certain level (high or low). They are used in asynchronous systems but can lead to race conditions.

**Shift Register:**

- A shift register is a sequential logic circuit that can shift data in or out in a serial fashion. It's often used for data storage, data transfer, and parallel-to-serial or serial-to-parallel conversion.

**Asynchronous and Synchronous Counters:**

- **Asynchronous Counters:** These counters change state based on the clock signal without regard for other states. They can lead to race conditions.
- **Synchronous Counters:** These counters change state simultaneously based on a common clock signal, avoiding race conditions and ensuring synchronized counting.

**State Diagrams:**

- State diagrams are graphical representations of the states and transitions in a sequential circuit.
- They help in understanding and designing sequential circuits, especially counters and finite state machines.

**Semiconductor Memories:**

- Semiconductor memories are used to store and retrieve digital data. They come in various types, including RAM (Random-Access Memory) and ROM (Read-Only Memory). Here, we will focus on specific types and trends in semiconductor memories.

**Digital ICs - 2716 and 2732:**

- **2716:** The 2716 is a popular UV-erasable EPROM (Erasable Programmable Read-Only Memory) IC.
- It has a capacity of 2KB (2048 bytes) and is organized into 8-bit words. It requires a separate erasure process using ultraviolet light before reprogramming.



Mr. Sonu Kumar

- **2732:** The 2732 is another UV-erasable EPROM IC with a capacity of 4KB (4096 bytes), also organized into 8-bit words.

**Address Decoding:**

- Address decoding is the process of determining which memory location is being accessed based on the address provided. In memory ICs like the 2716 and 2732, address lines are used to select a specific memory location.
- Decoding logic is implemented to enable the correct memory cell based on the address lines.

**Modern Trends in Semiconductor Memories:**

- **DRAM (Dynamic Random-Access Memory):** DRAM is a type of volatile memory known for high-density storage and fast access times. It's widely used as main memory (RAM) in computers and mobile devices.
- **FLASH RAM (NOR and NAND Flash):** FLASH RAM is non-volatile memory commonly used in storage devices, such as USB drives, SSDs, and memory cards. It's known for its ability to retain data even when power is removed.

**Designing with ROM and PLA:**

- **ROM (Read-Only Memory):** ROM is a type of non-volatile memory used to store fixed data. It can be custom-programmed during manufacturing with a specific data pattern.
- ROMs are used for firmware storage, look-up tables, and other applications where data doesn't change.
- **PLA (Programmable Logic Array):** PLA is a type of programmable logic device used for combinational logic functions.
- It allows designers to create custom logic functions by configuring the connections between input and output lines using programmable AND and OR gates.
- PLAs are versatile and used in various digital applications.

Mr. Sonu Kumar

# Module – 4 Introduction to A/D & D/A Converter

## ADC: Analog-to-Digital Converter

- ADC stands for analog-to-digital converter. It (ADC, A/D, or A-to-D Converter) is a device primarily used to convert the signal; it first takes an Analog signal and then turns it into a digital format.
- AD converters are used for different purposes, and they are used in a variety of applications, such as digital music, radio, and digital photography.
- It is also used for digital signal processing.
- Analog to digital converter is used in several technologies and electronic devices like computers, mobile phones and many others.
- Analog-to-digital converters are mainly used to convert the incoming signals that come from the physical world and are frequently converted via ADC converters into the binary format (mainly in zero and one form) of computers.
- Signals like sound and electricity may have infinite shapes and forms when they are in their Analog state. ADC may be applied to process them and modify them in an almost alternative manner.

**Working of the ADC**

- Analog to digital converter is considered a beneficial component when dealing with digital systems because it communicates with real-time signals.
- These digital systems must interpret real-world/time signals to correctly give crucial information. For instance, IoT develops fast applications and devices in daily life with the help of ADCs. We will now go into the theory and operation of ADCs.
- The simplest way to explain this is through an easy diagram. An excellent representation of both Analog and digital signals may be seen in the following image, where the red line represents the Analog input signals while the green line represents the digital output signals.

**What is the ADC sampling rate?**

- The Analog to digital converter sampling rate is also known as the sampling frequency and the rate of sampling of an ADC.
- It can be related to speed. The sampling rate is calculated using a formula in which the units are measured in SPS (sample per second) or S/s (otherwise, if you use the sampling frequency, it would be in Hz).

- One of the best things about ADC is that the more significant number of samples it takes, the higher the frequency it returns.
- The one important equation that is used for measuring the sample rate is denoted below:

$$fs = 1/T.$$

**Characteristics and considerations of TTL**

- TTL gate circuits and the IC packages that hold the gates involve important characteristics that designers consider in their digital circuit designs.
- While TTL components are no longer widely used in commercial digital circuit design, the fundamental characteristics remain important for VLSI components, such as an application-specific integrated circuit (ASIC), processor and other complex digital components used in modern electronic devices.

**These characteristics include the following:**

- **Fan-in.** This is the number of inputs connected to a gate or the number of inputs a TTL gate can handle.
- **Fan-out.** This is the number of outputs a TTL gate can drive or operate without affecting the gate's performance. This is typically 10 loads from other TTL gates.
- **Power dissipation.** This is the amount of power the gate or device will use. It's taken as the product of supply voltage, measured in volts, multiplied by the current drawn, measured in amperes, and is typically measured in milliwatts (mW).
- **Propagation delay.** This is the time needed for the gate's output to change in response to a change in the gate's inputs. This is an expression of latency, and it limits the overall digital circuit's top speed
- **Noise margin.** Digital signals aren't perfect; noise margin is the voltage range allowed for the input signal voltage that won't affect the output logic level. Standard TTL gates allow a noise margin of about 0.4 volts.
- **Temperature range.** This is the range of safe operating temperatures allowed for the gate. Standard 7400 family TTL gates have a temperature range from 0 to 70 degrees Celsius; 5400 family gates have an extended range of minus 55 to 125 degrees Celsius.
- **Special characteristics.** Some TTL gate products were fabricated for high reliability and radiation resistance for military and aerospace uses.

**Types of TTL:-**

Mr. Sonu Kumar

- TTL circuit designs evolved and diversified over decades of use to optimize certain characteristics such as speed, power consumption and output power to drive other components. The most popular types of TTL include the following:

- **Standard TTL** represents the traditional 7400 family of components with standard characteristics, including a typical power dissipation of 10 mW per gate and a propagation delay of 10 ns per gate.
- **Fast TTL** trades faster switching speeds for higher power consumption. For example, a fast TTL gate might switch in 6 ns but use 22 mW. This is sometimes called high-power TTL.
- **Low-power TTL** trades lower power consumption for slower switching speeds. For example, a low-power TTL gate might use 1 mW but have a delay of up to 33 ns.
- **Low-voltage TTL** uses a 3.3 volts direct current supply voltage instead of the usual 5 VDC supply voltage, resulting in only about 2 mW of power per gate.
- **Schottky TTL** includes Schottky diode clamps in the TTL gate, which accelerates gate switching time to about 3 ns. However, this increases power use to about 19 mW per gate.
- **Low-power Schottky TTL**, also called advanced Schottky TTL, combines low-power TTL and Schottky diodes to offer a fast 9.5 ns propagation delay and 2 mW of power use per gate.
- **Open-collector TTL** leaves the output transistor's collector lead open and effectively unpowered from the chip's supply voltage, allowing designers to incorporate high-voltage or grouped outputs to drive non-TTL loads. Examples of open-collector TTL ICs include the traditional 7401 and 7403.

**555 Timers IC**

- The word IC stands for **Integrated Circuits**. Thus, 555 timer IC is an integrated circuit chip used in various timers, pulse generators, lamp flashers, logic clocks, and oscillators.
- It is also known as the **555 timer oscillator**. The 555 timer IC comprises various components: **resistors, capacitors, RS flip-flops, comparators, BJT** (Bipolar Junction Transistor), and **buffers**.
- ➢ The 555 timer IC works as a simple timer that generates pulses or produces time delays, similar to the flip-flops and oscillator.

**Components in the 555 Timer IC**

I. **Resistors**: The purpose of resistors in the timer is to provide voltages to the two comparators.'



Sonu Kumar

II. **Transistors**: BJT transistor in the timer is used as a switch. It is also used as a component that discharges the timing capacitor, which is connected externally.

III. **Flip-flops**: It is an electronic circuit that changes its states from HIGH to LOW and vice-versa.

IV. **Buffers**: A buffer connects the input to the output, i.e., it accepts the input from the flip-flop and sends it to the output terminal. The function of the buffer is to provide adequate current to the external circuit connected to the output terminal.

V. **Comparators**: It compares the voltages connected to its two input terminals (inverting and non-inverting).

**Pin diagram of 555 Timer IC**

**Pin 1: Ground**

- The ground terminal refers to the terminal at 0 volts and is known as a short pin.

**Pin 2: Trigger**

- Trigger means activate. The trigger pin is connected to the inverting terminal in the case of the comparator (that compares two outputs).
- It also helps to convert the state of flip-flops from the set (1) to reset (0). The trigger pin works as a starter to the timer.
- It is an active low trigger that starts when the PIN 2 falls below one-third (VCC/3) of the supply voltage.

**Pin 3: Output**

- As the name implies, it is the output of the 555 Timer IC. It means that output is available at this pin. The load can be connected between the output (PIN 3) and either to PIN 1 (output) or PIN 8 (supply).
- The load connected with the PIN 3 and PIN 1 is known as **normally off load**. It is because PIN1 is the ground pin. The load connected with the PIN 3 and PIN 8 is known as **normally on load**.

**Pin 4: Reset**

- Reset means to set again. It set the reading of the timer again to zero. We can also say that it disables the timer.
- To rest the 555 Timer IC, a negative pulse is applied at the PIN 4. It is not necessary to use this pin as a reset pin only.
- We can also connect $+V_{CC}$ to the reset pin to avoid any false triggering. Here, PIN 4 will not work as reset pin.

**Pin 5: Control voltage**

- The two trigger and threshold terminals at the input of the comparators are controlled using PIN 5.
- The output waveform of the timer can be modulated by applying an external voltage to the control voltage pin.
- It is connected to the ground when not in use to avoid any noise or interference in the output.

**Pin 6: Threshold**

- It is present at the non-inverting terminal (+) of the first comparator in the 555 Timer IC circuit.
- It compares the applied voltage with the reference voltage ($2V_{CC}/3$), connected at the inverting terminal. It determines the input state of the flip-flop.

**Pin 7: Discharge**

- It is connected internally to the collector of the BJT. A capacitor is connected between the PIN 7 and the ground, which discharges through the transistor when it reaches the saturation state.
- The capacitor charges when the transistor is cut-off. The external connected resistors and capacitors determine the rate of charge.

**Pin 8: Supply terminal**

- All the voltage sources are connected to this terminal. It supplies voltage to the other terminals of the IC.

**Advantages of the 555 Timer IC**

- The three modes of 555 timer IC has various applications in different fields.
- It can produce accurate timing pulses.
- It can operate as a simple timer and can also produce time-delays.
- It is also known as a highly stable controller.
- It works in wide voltages ranges.
- It is easy and flexible to use.
- High precision.
- It can work as a voltmeter and ADC (Analog to Digital converter)..

**Disadvantages of the 555 Timer IC**

- The frequency modulation in the 555 timer IC is not very linear.
- It is not accurate with changes in the temperature. It means that there are specified limits for the timers to operate. It does not operate accurately beyond such specified temperature ranges.

- CMOS or **Complementary Metal Oxide Semiconductor** is a combination of **NMOS** and **PMOS** transistors that operates under the applied electrical field.
- The structure of CMOS was initially developed for high density and low power logic gates.
- The NMOS and PMOS are the types of Metal Oxide Semiconductor Field Effect Transistors (MOSFET).
- The CMOS transistors are used in various applications, such as **amplifiers, switching circuits, logic circuits, Integrated circuit chips, microprocessors,** etc.
- The importance of CMOS in semiconductor technology is its low power dissipation and low operating currents.
- Its manufacturing requires fewer steps as compared to the Bipolar Junction transistors.

**Connection setup of CMOS**

- The practical construction of the CMOS transistor is shown in the below image:

**Working of CMOS**

- The structure as shown consists of the NMOS transistor inverted on the top of the PMOS transistor. The substrate is of the P-type, and three N++ regions.
- The two N++ regions are small and the third N++ region is large. The two smaller regions are a part of the NMOS transistor, while the third N++ region is a part of the PMOS transistor.
- The two P++ regions are diffused into the larger N++ region to form the PMOS transistor.
- The top surface is protected and covered using the Silicon dioxide layer ($SiO_2$) with aluminum's metallization.
- CMOS has the least amount of power dissipation in the switching applications. It is because when one transistor is OFF, the other becomes ON.

**Features of CMOS Logic Gates**

- Reduced cost as it requires only a single power supply.
- Large logic swing.
- Large fan-out capability.
- Very high noise margin.
- Lower propagation delay
- High speed as compared to NMOS transistors.
- Lower power dissipation.

- Excellent temperature stability.
- Less packaging density.

**Types of CMOS logic gates**

- CMOS Inverter
- CMOS NAND
- CMOS NOR
- CMOS Operational Amplifiers

**Applications of CMOS**

1. **Integrated Circuits**
   CMOS consumes less current than other logic devices, such as TTL. Hence, the use of CMOS in the Integrated Circuit applications forms the production of ICs that has lower consumption and low dissipation.
2. **Chip designing**
   The use of CMOS in chip designing allows the high-density logic functions to be integrated on a chip.
3. **Microprocessor designing**
   CMOS requires current only during the switching state. It means that CMOS uses the power efficiently. Hence, CMOS is used in most modern processors, such as microprocessors.
4. **ASIC designing**
   It stands for Application Specific Integrated Circuits. CMOS is considered the standard transistor for the fabrication of chips. Hence, it is used in ASIC designing.
5. **CPU Memories**
   The two major advantages of CMOS are high noise immunity and low static power consumption. Due to this, it is used in the CPU (Central Processing Units) Memories.

## A/D & D/A Converters:

- **A/D Converter (Analog-to-Digital):** An A/D converter converts analog signals into digital form. It quantizes the analog input into discrete digital values. There are various types of A/D converters, including Flash, SAR (Successive Approximation), and Delta-Sigma converters.
- **D/A Converter (Digital-to-Analog):** A D/A converter does the reverse, transforming digital data into analog signals. It takes digital values and produces an equivalent continuous analog output.

- D/A converters can be based on techniques like resistor ladder, weighted sum, or current steering.

**Sample and Hold Circuit:**

- A sample-and-hold (S/H) circuit is used in A/D conversion to capture and retain the value of an analog signal at a particular point in time.
- It "samples" the analog input and "holds" that value until it's converted into digital form.

**Voltage-to-Frequency & Frequency-to-Voltage Conversion:**

- **Voltage-to-Frequency (V/F) Converter:** V/F converters transform an input voltage into a corresponding frequency signal.
- They are used in applications like frequency modulation and analog-to-digital conversion.
- **Frequency-to-Voltage (F/V) Converter:** F/V converters perform the reverse operation, converting a frequency signal back into an analog voltage.

**Multivibrators:**

- Multivibrators are electronic circuits that can generate square waveforms. They include:
- **Bistable Multivibrator:** Also known as a flip-flop, it has two stable states and is used for memory and sequential logic.
- **Monostable Multivibrator:** It has one stable state and is used for pulse generation and timing applications.
- **Astable Multivibrator:** This type has no stable state and generates a continuous square wave. It is often used in clock generators and oscillators.

**Schmitt Trigger:**

- A Schmitt trigger is a type of comparator with hysteresis. It switches its output based on the input voltage crossing certain thresholds.
- It is commonly used for debouncing switches and signal conditioning.

**IC 555 & Its Applications:**

- The IC 555 is a versatile timer IC that can operate in various modes, such as astable (oscillator), monostable (one-shot), and bistable (flip-flop).
- It is widely used in applications like pulse generation, oscillators, timers, and PWM (Pulse Width Modulation) generation.

**TTL, PMOS, CMOS, and NMOS Logic:**

Mr. Sonu Kumar

- **TTL (Transistor-Transistor Logic):** A popular digital logic family that uses bipolar transistors. It offers high speed and compatibility with many older digital systems.
- **PMOS (P-channel Metal-Oxide-Semiconductor) Logic:** A type of digital logic using P-channel MOS transistors. It's slower but consumes less power.
- **CMOS (Complementary Metal-Oxide-Semiconductor) Logic:** A low-power digital logic family using both PMOS and NMOS transistors. CMOS is prevalent in modern digital systems.
- **NMOS (N-channel Metal-Oxide-Semiconductor) Logic:** A digital logic family that uses N-channel MOS transistors. It's faster than PMOS but consumes more power.

**Interfacing Between TTL and MOS:**

- Interfacing TTL (which uses bipolar transistors) and MOS (which uses metal-oxide-semiconductor transistors) logic can be challenging due to voltage level differences.
- To interface them, level-shifting circuits or voltage translators are often used to ensure compatible signal levels.

# Module – 5 Digital Communication

## Digital Communication

- Digital communication is made from two words **digital** and **communication**. Digital refers to the discrete time-varying signal. Communication refers to the exchange of information between two or more sources.
- Digital refers to the discrete time-varying signal. Communication refers to the exchange of information between two or more sources.
- Digital communication refers to the exchange of digital information between the sender and receiver using different devices and methods.
- Digital communication is a popular technology used today in electronics. It allows us to access **video conferencing, digital meetings, online education**, etc.
- The data can travel upto long distances within a second with the help of the internet and other modes of digital communication.
- It not only saves money but also saves time and effort. It has also raised the standard of an individual's social, political, and economic life.

**What is Communication?**

- Communication refers to the exchange of information using a specific medium, such as **vacuum, space, wireless medium, wired medium**, etc.
- Good communication always transmits information with reduced attenuation and noise. The received signal is the same as the transmitted signal with clear information.
- Communication is a **two-way** process of sharing information. In digital terms, communication refers to the exchange of digital information from the transmitter to the receiver.
- The components of a communication system are the **transmitter, communication channel,** and **receiver**. The transmitter transmits the data to the communication channel, which further sends it to the receiver..

**Signals**

- A signal is an electromagnetic wave that carries information from one place to another, using a specific propagation medium, such as **air, vacuum, water**, and **solid**.
- It can travel short distances or long distances depending on the requirements. The speed of a signal wave is equal to the speed of light.

**Digital Signal**

- We can represent various physical quantities using digital signals, such as voltage and current. A signal represented in the form of **discrete values** is known as digital signal.
- It is transmitted in the form of **bits**. Only two bits (0 and 1) work in different combinations. A digital signal can take only one value at a time from the set of finite possible values.

**Types of Digital Signal**

- A signal that repeats over a period of time is termed a periodic signal. A signal that does not repeat over a period of time is termed as an aperiodic signal.
- Digital signals and analog signals are categorized as periodic and non-periodic signals. Here, we will discuss the types of the digital signal in detail.

**Periodic signals**

- A digital signal that repeats over a period of time is known as periodic signals, such as **square wave**.

**Aperiodic signals**

- A digital signal that does not repeat over a period of time is known as an aperiodic signal. It is also a discrete signal, but not of repeated pattern.

**Digital Communication System**

- A digital communication system refers to data transmission from one place to another. It is the communication between the sender and receiver.
- A sender is also known as **transmitter** that transmits the data. A communication channel between the transmitter and receiver acts as intermediate source to carry the information to the receiver.

**Source signal**

- The source signal refers to the input signal applied to the digital communication system. It is also known as the input signal. Digital communication is generally used as a conversion system from analog to digital. Thus, the input signal is generally an **analog signal.**

**Input Transducer**

- The transducer is a device used to convert one form of energy to another. In a communication system, it converts the non-electrical energy to electrical energy to make it suitable for transmission within the system.
- In the case of the analog input, the block also contains an ADC (Analog to digital converter) to convert analog to the digital signal for further processing.

**Source Encoder**

- The source encoder compresses the data to the reduced number of bits from the original bits. It helps in effective bandwidth utilization and also removes unnecessary bits.
- It means that the compressed data is in the form of binary digits. We can also say that the source encoder converts the waveforms to binary data.
- The output data is further passed to the channel encoder.

**Channel Encoder**

- The information in the signal may get altered due to the noise during the transmissions. The channel encoder works as an error correction method.
- It adds redundant bits to the binary data that helps in correcting the error bits. It enhances the transmission quality of the signal and the channel.

**Digital Modulator**

- A carrier signal modulates the received signal. It modulates the digital by varying the transmitted signal's frequency, amplitude, and phase.
- The communication channel is the medium between the transmitter and the receiver. It helps in transmitting a digital signal from the transmitter to the receiver.

**Digital Demodulator**

- The signal is demodulated and the source signal is recovered from the carrier signal.

**Channel decoder**

- The function of the channel encoder is to add the redundant bits to the binary data, as discussed above. The channel decoder works in the same but opposite way. It removes the parity bits from the binary data.
- It does not affect the signal quality and the information and transmits the data securely. The output of the channel decoder is a pure digital signal with no interference or noise.

**Source decoder**

- The source encoder works oppositely as that of the source encoder. It converts the binary data back to the waveforms.

**Output Transducer**

- The output transducer works in the opposite was as that of the input transducer. It converts the electrical energy back into its original form.
- It makes the information suitable for the user at the output to capture. The conversion is essential at both the ends of the communication system to make the system operate at a faster rate.

**Output signal**

- The output signal refers to the output from the digital communication system. It is the signal that appears at the output after passing through various communication system components. The output signal is only **a digital** signal..

**Advantages of Digital Communication**

- It is fast, more accurate, and more reliable than analog communication.
- The data with the help of digital communication can be quickly transmitted upto long distances.
- The detection and correction of errors is easy.
- It allows easy removal of noise, cross-talk, or any interference in the signal.
- It is inexpensive due to advanced technologies and compact size.
- The transmission speed of signal is high.
- It facilitates video and audio conferencing, allowing quick meetings and discussion with several people. It saves time and effort.

**Disadvantages of Digital Communication**

- **High power consumption**
  It consumes high power due to the requirement of greater number of components, higher bandwidth, and high transmission speed.
- **High transmission bandwidth**
  Digital communication requires high transmission bandwidth to transmit the signals at high speed.
- **High power loss**
  The power loss in digital communication is higher than analog communication due to the high processing speed and hardware components.

**Applications of Digital Communication**

- Image and video processing
- Data compression
- Channel coding
- Equalization
- Digital Signal Processing
- Speech processing
- Satellites
- Digital audio transmission

| Category | Digital Communication | Analog Communication |
|---|---|---|
| **Definition** | It uses digital signals with discrete values for transmitting data represented in the form of two binary digits 0 and 1. | It uses analog signals for transmitting data. |
| **Signal** | The digital signal represents one bit at a time. | The analog signal represents continuous values at a time. |
| **Noise Immunity** | Good | Poor |
| **Error Probability** | Low | High |
| **Coding** | Yes<br>The digital communication system uses an encoder and decoder to convert the information into bits and vice-versa. | No |

| | | |
|---|---|---|
| **Flexible** | More flexible | Less flexible |
| **Cost** | High cost | Low cost |
| **Power consumption** | Low | High |
| **Data transmission** | More accurate | Less accurate |
| **Signal representation** | The digital signals are represented by a square wave. | The analog signals are represented by a sine wave or cosine wave. |
| **Examples** | Clock signals | Audio signals, speech signals, sound waves, pressure waves, video signals, etc. |
| **Applications** | Digital watches, Compact Disks, computers, etc. | Radar, Telephony, etc. |

**What is BPSK?**

- Binary Phase Shift Keying (BPSK) is a modulation technique employed in communication systems to transmit information via a communication channel.
- In BPSK the carrier signal is modified by altering its phase by 180 degrees, for each symbol. A phase shift of 180 degrees denotes a binary 0 while no phase shift represents a binary 1. The BPSKs modulation process is straightforward and efficient making it suitable for scenarios where the communication channel suffers from noise and interference.

**Advantages of BPSK**

- **Simplicity:** BPSK, which stands for Binary Phase Shift Keying is a modulation scheme. It simplifies implementation, in hardware and software by utilizing two phase states; 0 degrees and 180 degrees.
- **Effective Operation with Reliability:** It has ability to operate effectively in the presence of noise or interference from signals ensuring reliable performance.
- **Less Power Consumption:** BPSK consumes power compared to alternative methods making it advantageous for battery powered devices.
- **Easy Detection:** Receivers find it easy to comprehend BPSK accurately determining the frequency and phase of the transmitted signal.
- **Compatible:** BPSK serves as a building block for complex modulation schemes like QPSK (Quadrature Phase Shift Keying) and higher order Quadrature Amplitude Modulation (QAM).

**Disadvantages of BPSK**

- **Low Data Sending Rate:** However when it comes to data transmission speed, BPSK has limitations as it can only send one piece of data at a time.
- **Less Efficient:** It inefficiently uses the signal space, same like using a whole road for just one small car.
- **Can be Tricky:** In situations such as communication, signal bouncing can pose challenges, for BPSK as it weakens the signal strength and leads to potential issues.
- **Limited Error Correction:** BPSK does not provide as much inherent error correction capability as more complex modulation schemes, therefore, error correction needs to be added separately, which can increase system complexity.
- **Not for Huge Data:** If you need to send a lot of data fast then BPSK might not be the best choice.

**Digital Communication:**

- Digital communication involves transmitting data in the form of discrete signals.
- It is the foundation of modern telecommunications, including the internet, wireless communication, and data networks.

**Nyquist Sampling Theorem:**

- The Nyquist sampling theorem, formulated by Harry Nyquist, states that in order to accurately reconstruct an analog signal from its sampled version, the sampling frequency must be at least twice the maximum frequency component in the signal.
- This is crucial for the design of digital systems like A/D converters and data transmission.

**Time Division Multiplexing (TDM):**

- TDM is a method for transmitting multiple signals over a single communication channel. Each signal is allotted a specific time slot.
- TDM is commonly used in telecommunication networks for voice and data transmission.

**Pulse Code Modulation (PCM):**

- PCM is a technique used to digitize analog signals. It involves sampling the analog signal at regular intervals, quantizing the samples into discrete values, and encoding those values as binary digits.
- PCM is widely used in telephony and audio transmission.

**Quantization Error:** Quantization error is the difference between the actual analog signal value and the quantized digital representation.



Mr. Sonu Kum.

- It's an inevitable source of error in PCM systems and can affect the quality of the reconstructed signal.

**BPSK (Binary Phase Shift Keying):**

- BPSK is a digital modulation scheme in which binary data is transmitted by changing the phase of the carrier signal.
- It uses two phases, typically 0° and 180°, to represent binary 0 and 1. BPSK is simple but is sensitive to noise.

**BFSK (Binary Frequency Shift Keying):**

- BFSK is another digital modulation scheme where binary data is transmitted by changing the frequency of the carrier signal.
- Typically, two different frequencies are used to represent binary 0 and 1. BFSK is less susceptible to noise compared to BPSK.

### Shannon's Theorem for Channel Capacity:

- Claude Shannon's theorem states that for a given communication channel with a certain signal-to-noise ratio (SNR), there exists a maximum data rate at which information can be transmitted error-free.
- This maximum rate is known as the channel capacity. The theorem provides an upper limit on data transmission rates, highlighting the importance of signal quality and coding schemes in digital communication.

## CS304 – Digital System Sem-3rd CSE RGPV

**By :- Mr. Sonu Kumar**

**Contact Number :- 6200638476**

# Thank You !!!

Mr. Sonu Kumar