This book is written in accordance with the new guidelines formulated by Tamilnadu Government Curriculum Framework (TNCF-2017) Committee to strengthen the higher secondary education on par with the Global Standards by providing different kinds of learning opportunities to promote holistic approach to education. The objectives of this book on Electronics Equipment is not only for knowledge upgradation but also for providing basic skills viz., hands-on-experience with electronic circuits, trouble shooting of minor problem in electronic equipment, handling of test and measuring equipment and installation and maintenance of equipment.

This book covers the up-to-date curriculum in the area of Electronics and related fields to discourage rote learning and to encourage the multidisciplinary approach of Electronics with different subject areas. Each Chapter has been designed and written in such a way to inculcate the basic knowledge of the Electronics in the students and also to give opportunity to the stakeholders to provide a platform for exhibiting their creativity. The success of this endeavor depends on the participation of the students, subject teachers and school headmasters to encourage the students to giving the opportunities for own learning to pursue imaginative activities and inquisitiveness.

Each Chapter starts with the introduction of the respective topic and covers the contribution from different domains such as brief history of scientists and their related inventions, proverbs or Tamil literature quotes related to the particular scientific concept, learning objectives, learning outcomes and detailed description of the concepts with the related figures, equations for the easy and in-depth understanding of the subject matter. Further, several solved problems and self-evaluation exercises are given in each Chapter to motivate the students for self-learning and to develop self-confidence in the subject matter and for practical application.

We appreciate the initiatives, encouragement and guidance extended by the Tamilnadu Curriculum Development committee headed by Prof. M. Anandakrishnan, who is responsible for shaping this book to this formidable level. We are grateful to the contributions of several teachers, headmaster, technical staff and office staff for the development of this textbook to this level. We are indebted to the institutions and organisations, which have generously
permitted us to draw upon their resources, material and personnel. We are especially grateful to the members of the Tamilnadu State Council for Education Research and Training (SCERT) for their valuable support. For the systemic reform and continuous improvement in the standard of this book, we welcome critical comments and valuable suggestions, which will enable us to undertake further revision and refinement of the subject matters covered in this book.

We hope this book will bring an appreciable change in the teaching-learning process. We wish all the stakeholders to make use of this book effectively, to get the intended outcomes and benefits.

With best wishes,

Prof. Dr. Damodaran Nedumaran
Chairperson
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</table>
After completion of Higher Secondary (+2) Vocational Engineering (EE) course, students can pursue the following courses / Jobs / Self-employment as detailed below:

**Vocational Stream**

The Vocational Engineering students are blessed with two major opportunities after completing their +2.

<table>
<thead>
<tr>
<th>Vertical Mobility</th>
<th>Job / Self Employment</th>
</tr>
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<tbody>
<tr>
<td>2. Separate allocation given for Vocational (Engg &amp;Tech) students in Engineering (B.E.,) Courses (ECE, EEE, E&amp;I). Even first 2 days counseling is allotted for Engineering Vocational students.</td>
<td>2. Audio/Video Equipment Service Centre. Computer Hardware service</td>
</tr>
<tr>
<td>3. B.Sc., (Eletronics), B.Voc (NSQF)</td>
<td>3. They can register their names in the “Board of Apprenticeship Training”, 4th Cross street, CIT Campus, Tharamani, Chennai - 600013 for employment opportunities.</td>
</tr>
<tr>
<td>4. Lateral entry opportunities (for B.E./B.Tech.,) after completing Diploma.</td>
<td>4. The students who need for employment opportunities and career guidance, including counselling both in Government, Private and Public sector can see the website of <a href="http://www.ncs.gov.in">www.ncs.gov.in</a> for further details.</td>
</tr>
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<td>85</td>
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<td>125</td>
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## Case Study

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BASIC ELECTRONICS
ENGINEERING
Theory
# Digital Circuit Applications

## LEARNING OBJECTIVE

Through this chapter the students can learn about the following:

- Construction of Combinational Gates and its applications
- Classification of Logic gates – Arithmetic circuits like, Adder and Subtractor
- How the Digital signals are Decoded and Encoded
- The way of Multiplexing and De-Multiplexing
- Construction and working Flip-flops (Memory)
- Construction of Binary Counters and Registers and its Applications

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</tbody>
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## Introduction

Though you are little familiar with digital circuits, i.e., particularly the basic gates (AND, OR, NOT), the utility of these circuits in constructing many discrete circuits for instrumentation application are discussed in detail in this Chapter. Further, we are going to discuss about the combinational gates.
1.1 Application of Basic Gates

NOT – Gate Application

By using the inverter (NOT) gate, we can get the 1's complement value of any given number because the output of NOT- gate is complement of the input. Figure 1.1 illustrates an example of 1's Complement digital circuit.

**FIGURE 1.1 Example of 1's Complement circuit using inverters**

AND – Gate Application

By using AND gate very simple but important application can be executed. An AND gate is used in a simple automobile seat alarm system to detect, when ignition switch is ON and the seat belt is unbuckled. If the ignition switch is ON, a HIGH is produced on input A of the AND gate. If the seat belt is not properly locked, HIGH is produced in input B of the AND gate. Also, when the ignition switch is turned on, a timer is started that produces a HIGH on input C for 30 seconds. If all three conditions exist- that is, if the ignition is ON and that seat belt is unbuckled and the timer is running - the output of the AND gate is HIGH and an audible alarm is energised to remind the driver. Figure 1.2 shows a simple car-seat belt alarm circuit using AND gate.

**FIGURE 1.2 A simple Car-seat belt alarm circuit using AND Gate**

OR- Application

A simplified portion of an intrusion detection and alarm system is shown in Figure 1.3. This system can be used for one room in a house which has two windows and one door (3 input OR gate is used). The sensors are magnetic switches that produce a HIGH output, when open and a Low output when closed. As along as the windows and doors are secured, the switches are closed and all three of the OR gate inputs are low. When one of the windows or door is opened a HIGH is produced on that input to the OR gate and the gate output goes HIGH. It then activates and latches an alarm circuit to warn about the intrusion.

**FIGURE 1.3 Simple intrusion detection alarm system using OR-gate**

This shows a simple basic gate can be employed in few of the very common and important applications in day today life.
CHAPTER 1 Digital Circuit Applications

1.2 Combinational Gates

Now, let us see some of the other gates constructed by using these basic gates, which are called as combinational gates. The following are some of the important gates.

1. NAND
2. NOR
3. EX-OR
4. EX-NOR

NAND gate

The term NAND is derived from NOT-AND gates. It is nothing but complemented output of AND gate. The standard logic symbol for 2-input NAND gate is shown Figure 1.4.

![NAND gate symbol and equivalent circuit](image)

**TABLE 1.1 Truth table of NAND gate**

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>( Y = A \cdot \overline{B} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

The operation of a NAND gate is opposite to that of a AND gate. In a NAND gate, low-level (0) is the active output level, as indicated by the bubble on the output. Table 1.1 shows the logical operation of the 2 input NAND gate. The logic expression for two input NAND gate is \( Y = A \cdot \overline{B} \).

EXAMPLE 1.1

If the two waveforms A and B shown in Figure 1.5 are applied to the NAND gate inputs, determine the resulting output waveform. Bubble indicates an active-LOW output.

![Waveforms of 2-input NAND-gate](image)

**Solution:** Output waveform Y is LOW only during the four time intervals, when both input waveforms A and B are HIGH as shown in the timing diagram (Figure 1.5).

**Activity**

Determine the output waveform and show the timing diagram if input waveform B is inverted.

For a 2-input NAND gates, the output Y is low only when, inputs A and B are HIGH. Output \( Y' \) is HIGH when either A or B is low, or when both inputs A and B are low.
**Application Sample (NAND gate)**

In a house there are two water tanks. Each tank has a sensor that detects when the water level drops to 25% of full level. The sensor produces a HIGH level of 5 V when the tanks are more than one quarter-full. When the volume of water in a tank drops to one quarter-full, the sensor senses and gives an output Low Level (0 V).

**Solution:** Figure 1.6 shows a NAND gate with its two inputs connected to the tank level sensor and its output connected to the indicator panel. The operation can be stated as follows: if the tank A and B are above the one-quarter full, the LED is ON.

As long as both the sensors output are HIGH (5 V), indicating that both tanks are more than one-quarter full, the NAND gate output is low (0 V), the green LED circuit is arranged so that low voltage turns it on. The resistor limits the LED current.

**NOR - gate**

The NOR–gate is derived from the combination of NOT-OR gate. It is nothing but complemented output of OR gate. The standard logic symbols for 2-input NAND gate is shown in Figure 1.7.

**Operation of a NOR-gate**

A NOR-gate produces a LOW output when any of its input is HIGH. The output will be HIGH when only all of the inputs are LOW. Figure 1.7 shows the NOR gate labelled A and B are inputs and Y as the output. The operations can be stated as follows.

For a 2-input NOR gate, output Y is LOW, when either input A or input B is HIGH or the output Y is HIGH only when both inputs are LOW.

The operation of NOR gate is opposite to that of OR gate. In a NOR gate, the low output is the active output level as indicated by the bubble on the output. Table 1.2 shows the logical operation of the 2-input NOR gate. The logic expression for two input NOR gate is \( Y = A + B \).
If the two waveforms shown in Figure 1.8 are applied to a NOR gate, what is the resulting output waveform?

Solution
Whenever any input of the NOR gate is HIGH, the output is LOW as shown by the output waveform Y in the timing diagram.

**Activity**

Invert input B and determine the output waveform in relation to the inputs.

**Universal gate**

NAND and NOR gates are termed as universal gates. Because by using these gates (either NAND or NOR), we can derive the operations of any other gates function.

**Application Sample (NOR- gate)**

Figure 1.9 shows how different functions of an aircraft are combined together to get information monitoring an aircraft.
**Exclusive-OR and Exclusive NOR-gate**

Exclusive-OR and Exclusive-NOR gate are formed by a combination of the earlier gates that we discussed so far. These gates are used in many fundamental applications and treated as basic logic elements. Standard symbol for Exclusive OR (XOR as short) gate is shown in Figure 1.10.

**FIGURE 1.10 Symbol of Ex-OR gate**

The XOR gate has only two inputs. The output of XOR gate is HIGH, only when the inputs of the gates are in opposite logic levels. The output of the gate is low when the inputs are identical i.e., both are LOW or HIGH.

For an XOR gate the output Y is HIGH only when inputs A is low and B is HIGH and vice versa. It will be LOW on other conditions. The unique characteristic of XOR gate is that it produces HIGH output only when an odd number of HIGH inputs are present.

Table 1.3 shows the logical operation of two-input XOR-gate.

**TABLE 1.3 Truth table of XOR gate**

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>( Y = \overline{A} \cdot B + A + \overline{B} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

The logical expression for XOR-gate \( Y = \overline{A} \cdot B + A + \overline{B} \). This can be often shortened and given as \( Y = A \oplus B \). It is also called as “Inequality Comparator”.

**Operation with Waveform Inputs**

As we have done with the other gates, let us examine the operation of XOR and XNOR gates with pulse waveform inputs. As before, we apply the truth table operation during each distinct time interval of the pulse waveform inputs as illustrated in Figure 1.11(a) for an XOR gate. We can see that the input waveforms A and B are at opposite levels during time intervals \( t_2 \) and \( t_4 \). Therefore, the output Y is HIGH during these two times. Since both inputs are at the same level, either both HIGH and both LOW, during time intervals \( t_1 \) and \( t_3 \), the output is LOW as shown in the timing diagram.

**Application Sample**

**EX-OR gate**

A certain system contains two identical circuits operating in parallel. As long as both are operating properly, the outputs of the circuits are always the same. If one of the circuits fails, the outputs will be at opposite level at some time. Derive a way to detect that a failure occurred in one of the circuits.

**Solution**

The outputs of the circuits are connected to the inputs of an XOR gate as shown in Figure 1.11(b). A failure in either one of the circuits produces differing outputs,
CHAPTER 1
Digital Circuit Applications

EXCLUSIVE–NOR GATE

The standard symbol for Exclusive–NOR (X-NOR) gate is shown in Figure 1.12. The bubble on the output of the X-NOR symbol indicates that its output is opposite to that of the XOR gate, i.e., the output is complemented XOR gate.

For an exclusive-NOR gate (X-NOR), output Y is low when input A is LOW and input B is HIGH, or when A is HIGH and B is LOW. Y is HIGH only when both A and B are HIGH or both LOW.

Table 1.4 shows the logical operation of a two-input X-NOR gate. The logical expression for X-NOR gate is \( Y = (\overline{A} \cdot B) + (A \cdot \overline{B}) \). This can be often standard and given as \( Y = \overline{A \oplus B} \).

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>( Y = \overline{A \oplus B} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

An Application

An Exclusive-OR gate can be used as a two-bit modulo-2 adder. We know the basic rules for binary addition are as follows: \( 0 + 0 = 0, 0 + 1 = 1, 1 + 0 = 1, \) and \( 1 + 1 = 10 \). An examination of the truth table for an XOR gate shows that its output is the binary sum of the two input bits. In the case where the inputs are both 1s, the output is the sum 0, but you lose the carry of 1. We will see how XOR gates are combined to make complete adding circuits. Table 1.5 illustrates an XOR gate used as a modulo-2 adder.
1. Commutative law

The law by addition and multiplication say that the order in which variable are OR-ed (or) AND-ed makes no different as the sum assured is arrived at either way. These laws of addition and multiplication for two variables are written algebraically as follows.

Commutative law of addition of two variables

\[ A + B = B + A \]

Commutative law of multiplication for two variables

\[ A \cdot B = B \cdot A \]

Figure 1.14 and Figure 1.15 illustrate the commutative law applied to the OR gate and the AND gate.

1.3 Boolean algebra

Though you have studied three important basic Boolean operations Addition (OR), multiplication (AND), complementation or inversion (NOT). Other than these, there are three important basic laws as like in mathematical algebra. They are,

1. Commutative law
2. Associative law
3. Distributive law

The Boolean is used to simplify the gate (digital) circuits

Though NAND and NOR gates are called as universal gates, among NAND gate is more versatile. So far, we have learned seven types of gate circuits consisting AND, OR, NOT, NAND, ENOR, XOR and EX-NOR. We can buy IC's that perform any of these seven basic functions. But, in the market NAND gate is the more widely available IC.

Activity

Write the Boolean expression for a three input NAND gate.

### TABLE1.5 Application of XOR as Adder

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>( \sum )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Though NAND and NOR gates are called as universal gates, among NAND gate is more versatile. So far, we have learned seven types of gate circuits consisting AND, OR, NOT, NAND, ENOR, XOR and EX-NOR. We can buy IC’s that perform any of these seven basic functions. But, in the market NAND gate is the more widely available IC.

2. Associative law

These law of addition and multiplication say that in the ORing or ANDing of several variables (more than two), grouping of the variables is immaterial and the addition results obtained are the same. These laws of addition and multiplication for three variables are written algebraically as follows. Figure 1.16 and Figure 1.17 illustrate the associative law as applied to OR and AND gates.

\[ A + (B + C) = (A + B) + C \]

\[ A \cdot (B \cdot C) = (A \cdot B) \cdot C \]

1. **Commutative law**

The law by addition and multiplication say that the order in which variable are OR-ed (or) AND-ed makes no different as the sum assured is arrived at either way. These laws of addition and multiplication for two variables are written algebraically as follows.

Commutative law of addition of two variables

\[ A + B = B + A \]

Commutative law of multiplication for two variables

\[ A \cdot B = B \cdot A \]

Figure 1.14 and Figure 1.15 illustrate the commutative law applied to the OR gate and the AND gate.

\[ \begin{align*}
  A & \quad B \\
  \Rightarrow & \quad A + B = B + A \\
\end{align*} \]

**FIGURE 1.14** Commutative law using OR gate

\[ \begin{align*}
  A & \quad B \\
  \Rightarrow & \quad A \cdot B = B \cdot A \\
\end{align*} \]

**FIGURE 1.15** Commutative law using AND gate

1. **Associative law**

These law of addition and multiplication say that in the ORing or ANDing of several variables (more than two), grouping of the variables is immaterial and the addition results obtained are the same. These laws of addition and multiplication for three variables are written algebraically as follows. Figure 1.16 and Figure 1.17 illustrate the associative law as applied to OR and AND gates.

\[ A + (B + C) = (A + B) + C \]

\[ A \cdot (B \cdot C) = (A \cdot B) \cdot C \]
3. Distributive law

This law states that ORing several variables and ANDing the result with the single variable is equivalent to ANDing the single variable with each of several variables and the ORing the products. The law is algebraically written as follows.

\[ A \cdot (B + C) = A \cdot B + A \cdot C \]

Figure 1.18 shows gate implementation of distributed law.

### Boolean Algebra Rules

Though we discussed this in 11th Standard, it is better to recapture the basic rules that are useful in manipulation and simplification of Boolean algebra expressions and are calculated using Table 1.6.

#### Table 1.6 Boolean Algebra Rules

<table>
<thead>
<tr>
<th>Rule</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>( A + 0 = A )</td>
</tr>
<tr>
<td>2.</td>
<td>( A + 1 = 1 )</td>
</tr>
<tr>
<td>3.</td>
<td>( A \cdot 0 = 0 )</td>
</tr>
<tr>
<td>4.</td>
<td>( A \cdot 1 = A )</td>
</tr>
<tr>
<td>5.</td>
<td>( A + A = A )</td>
</tr>
<tr>
<td>6.</td>
<td>( A + \overline{A} = 0 )</td>
</tr>
<tr>
<td>7.</td>
<td>( A \cdot A = A )</td>
</tr>
<tr>
<td>8.</td>
<td>( A \cdot \overline{A} = 0 )</td>
</tr>
<tr>
<td>9.</td>
<td>( \overline{A} = A )</td>
</tr>
<tr>
<td>10.</td>
<td>( A + AB = A )</td>
</tr>
<tr>
<td>11.</td>
<td>( A + \overline{A} B = A + B )</td>
</tr>
<tr>
<td>12.</td>
<td>( A + B ) (A + C ) = A + AC )</td>
</tr>
</tbody>
</table>

### Classification of Logic circuit

Logic circuit may be classified into two broad categories:

1. Combinational logic circuits
2. Sequential logic circuits.
A combinational logic circuit contains logic gates only but does not contain storage elements. Sequential logic circuit contains storage elements in addition to logic gates. When logic gates are connected together to provide a specified output for certain specified combination of input variables without any storage, the resulting network is known as combinational logic circuit. The block diagram of logic combinational circuit is shown in Figure 1.19.

Sequential Logic Circuit

It accepts input binary variables and generates output variables depending on the logical combination of logic gates. The combinational logic circuits with memory element is called as sequential logic circuit, which is shown in Figure 1.20.

A combinational circuit connected with feedback path termed as memory elements. The memory elements are device, capable of storing binary information within them.

Arithmetic Circuits

One of the essential functions of most computers and calculators is the performance of manipulating the arithmetic operations. The logic gates discussed so far can be used to perform arithmetic operations such as addition, subtraction, multiplication and division, which is used in electronic calculators and digital instruments. Since these circuits are electronic, they are very fast. Performing an addition takes less than 1 µs.

Now we will discuss some of the arithmetic operating circuits such as Half-adder, full-adder, parallel binary adder, half-subtractor and full-subtractor. The logic functions that are commonly used are OR, AND, and EX-OR gates.

Half-Adder

A logic circuits used for the addition of two single bit numbers is referred as a Half-Adder. When we add two binary numbers, we start with the least significant column. This means that we have to add two bits with the possibility of a carry. The circuit of a half-adder is shown Figure 1.21(a). Note in the Figure that the output sum is denoted by the mathematical symbol $\Sigma$.

$$\Sigma = A \oplus B = AB + \overline{A}B$$

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 + 0</td>
<td>0</td>
</tr>
<tr>
<td>0 + 1</td>
<td>1</td>
</tr>
<tr>
<td>1 + 0</td>
<td>1</td>
</tr>
<tr>
<td>1 + 1</td>
<td>10</td>
</tr>
</tbody>
</table>

FIGURE 1.21(a) Half-Adder

It consists of an EX-OR gate and an AND gate. The output of an EX-OR gate is called SUM, while the output of the AND gate is called CARRY. As the AND gate generates a high output only, when both inputs are high i.e., the carry as 1.

FIGURE 1.21(b) Logic symbol for a half-adder
The third-bit is the CARRY from a lower column. This shows that we used a logic circuit with 3-inputs and 2-outputs. Such a circuit is called full-adder. Hence, full adder may be defined as logic circuits that add 3-bits, i.e., two bits to be added and CARRY-bit from lower-bit order, which results in SUM and CARRY. Figures 1.22(a) and (b) show the logic circuit and logic symbol of full-adder circuit, respectively. It has two inputs called A and B plus a third input (C\text{IN}), called the CARRY IN and two outputs SUM and CARRY OUT (C\text{OUT}).

From the truth table a half-adder, the logical equations for CARRY and SUM can be written as,

\begin{equation}
C \text{ARRY} = A \cdot B \\
\text{SUM} = \overline{A} \cdot B + A \cdot \overline{B} = A \oplus B
\end{equation}

This Circuit is called as half-adder, because it cannot accept a CARRY-IN from previous additions. This is the reason that half-adder circuits can be used for binary additions of lower cost bit only. For higher order columns, we use 3-input adder called full-adder.

**Full Adder**

Full adder circuit is nothing but two half-adder circuits connected to an OR gate. As we seen in half-adder circuit, it has only two inputs and there is no provision to add CARRY coming from the lower-bit order when multi-bit addition is performed. For this purpose, we use a logic circuit, which can add three bits.

Table 1.7

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>Σ</th>
<th>C\text{out}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Σ = sum  
C\text{out} = output carry  
A and B = input variables (operands)

Truth table of full-adder for all possible inputs/outputs is given in Table 1.8 and can be easily checked for its validity. From the Figure 1.22(a), we can observe that the output CARRY is high when two or more number of inputs are high. Yet another output SUM will get high output, when an odd number of inputs are high. This can be verified from Table 1.8. The full adder can do more than a million additions per second.
Carry bit from right column
In this case, the carry bit from second column becomes a sum bit.

FIGURE 1.23(a) Addition of 2 parallel bits

FIGURE 1.23(b) Block Diagram of 2-bit Parallel Adder

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C_in</th>
<th>Σ</th>
<th>C_out</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

TABLE 1.8 Truth Table of Full-Adder

C_in = input carry, sometimes designated as CI
C_out = output carry, sometimes designated as Co
Σ = sum
A and B = input variables (operands)

Parallel Binary Adder

The parallel binary adder is a combinational circuit of various full-adders in parallel structure. When more than one 1-bit numbers are to be added, there can be full-adder circuit for every column to perform the addition. The number of full-adder in a parallel binary adder depends on the number of bits present in the number for the addition. If 4-bit numbers are to be added, then there will be 4-full adder in the parallel binary adder. The parallel binary adder can be designed with the help of basic logic gates. The sub-module in the logic circuit will resemble the logic gate of half-adder and full-adder to understand it clearly. Let us put light on designing and working of the 2-bit parallel binary adder.

Logic Circuit of 2-Bit parallel Binary Adder

The 2-Bit parallel binary adder can be designed with the help of Ex-OR gate and AND gate. If you carefully observe the logic circuit of 2-bit parallel binary adder, you can notice that 2-full adder circuits are connected in a parallel manner. Now, we easily guess and understand the working of this.
addition of bits present in higher order column, we must use full-adder because there may be or may not be a carry from previous addition.

With this, we complete the discussion of about 2-Bit parallel binary adder. As like, it is also better to know how two numbers with 4-bits are to be added. To perform this task, we definitely need 4-bit parallel binary adder.

Let us focus on the block diagram given in Figure 1.24(a), which represents a 4-bit parallel binary adder. It consists of 4-full adders, each of the 4-full adders have 3-input terminals and 2-output terminals. The input terminals are available for entering two numbers to be added and one input terminal is used for entering the previous carry.

The carry generated from the addition will be generated from $C_{\text{out}}$ terminal. The sum of the addition will be generated from the sum bit of the adder. It must be noted here that $C_{\text{out}}$ stands for carry-out and $C_{\text{in}}$ stands for carry-in. The connection will be such that the $C_{\text{out}}$ terminal to the $C_{\text{in}}$ terminal of next full-adder used for high order column.

**FIGURE 1.24(a) Four-Bit Parallel Binary Adder Block Diagram**

**FIGURE 1.24(b) Logic Symbol**
For addition of LSBs, we have a choice of either to use half-adder or to use full-adder. This is because we don’t have previous carry, so half adder can also be used. If we want to use full adder, then $C_{in}$ terminal of the full adder can be grounded.

For other full adders connected to higher order column, this will not be a major issue, because the $C_{out}$ terminal of the previous adder can be connected to the carry-in of adders connected to higher order columns.

### Significance of Parallel Binary Adder

With the help of full-adder, we cannot add numbers of more than 1-Bit. As the number of bits increases in a number, the column of addition also increases. A full-adder can add only one column, thus for each column we used a full-adder. This combined design of all full adder results in a combinational circuit, which is called parallel binary adder.

### Half-Subtractor

Half Subtractor is a digital circuit which process the subtraction of two 1-bit (0, 1) numbers. In this, the two numbers involved are called as Minuend and Subtrahend nothing but the inputs, named as X and Y. X is the Minuend and Y is the Subtrahend. There are two outputs named as D (differences) and B (Borrow). The word ‘HALF’ before the subtractor signifies that it deals with only two 1-bit numbers, it has nothing to do with the borrow from the previous stage. Figure 1.25 clearly elaborates the subtraction rule of binary numbers. The logic circuit of the Half-Adder is shown in Figure 1.26(a) and the symbol is shown in Figure 1.26(b). The operation of this logic circuit is based on the rules of binary subtraction given in truth table (Table 1.9) reproduce on the basis of subtraction process.

### Procedure for Subtraction

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>Difference</th>
<th>Borrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**FIGURE 1.25 Binary Subtraction Rules**

![Half Subtractor Circuit](image)

**FIGURE 1.26 (a) Half Subtractor Circuit**

![Symbol of Half Subtractor](image)

**FIGURE 1.26 (b) Symbol of Half Subtractor**

### Circuit of Half-Subtractor

The logic circuit of Half-Subtractor involves usage of logic circuits. In order to design logic circuit, we should understand two concepts. First, the difference operation of half-subtractor resembles operation of EX-OR gate. Thus, we can easily utilise the EX-OR gate for generating difference bit. Similarly, the borrow generated by half-subtractor can be easily obtained by using the combination of NOT gate and AND gate.

**TABLE 1.9 Truth Table of Half-Subtractor**

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
**Truth Table of Half-Subtractor**

In case of half subtractor there are two inputs. Thus the number of possible combinations will be 4. The resultant of all the 4 inputs will be described as outputs. The output of half-subtractor is described in two columns. One will signify the difference bit and another will signify the borrow bit. To derive the truth table, just use the EX-OR operation of two inputs for generating difference and NOT followed by AND operation for generating the borrow bit.

**Full-Subtractor**

The binary subtraction half-subtractor can handle only 2-bits at a time and can be used for the least significant column of a subtraction problem. Just like a full-adder, a full-subtractor circuit is required to perform a multi-bit subtraction, where a borrow from the previous bit position may also be there.

It has 3-inputs viz., X (minuend), Y (subtrahend) and $B_{in}$ (borrow from the previous stage). It has two outputs such as $D$ (difference) and $B_{out}$ (borrow) as shown in the symbol given in Figure 1.27(a)

![Figure 1.27(a) Symbol of Full-Subtractor](image)

**Figure 1.27(b) shows the circuit diagram of Full-Subtractor. For subtraction of n-bit numbers directly, we have to cascade n-full-subtractors. Truth table for full-subtractor is given in Table 1.10.**

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Difference</th>
<th>Borrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**1.5 Comparators**

The basic function of comparator is to compare the magnitudes of two binary quantities to determine the relationship of those quantities.

**Equality**

The Exclusive NOR gate can be used as a basic comparator, because its output is 0, if the two input bits are not equal and 1, if the input bits are equal. Figure 1.28 shows the Exclusive-NOR gate as 2-bit comparator.

![Figure 1.28 Basic Comparator Operation](image)
To compare two binary-bits containing two bits each, an additional Exclusive-NOR gate is necessary. The two least significant bits (LSBs) of the two numbers are compared by gate G1, and the two most significant bits (MSBs) are compared by gate G2, as shown in Figure 1.29. If the two numbers are equal, their corresponding bits are the same and the output of each Exclusive-NOR gate is 1. If the corresponding sets of bits are not equal, a 0 occurs on that Exclusive-NOR gate output.

In order to produce a single output indicating an equality or inequality of two numbers, an AND gate can be combined with XNOR gates as shown in Figure 1.29. The output of each Exclusive-NOR gate is applied to the AND gate input. When the two input bits for each Exclusive-NOR gates are equal, the corresponding bits of the numbers are equal and a 0 appears on at least one input of the AND gate to produce a 1 on its output. Thus, the output of the AND gate indicates equality (1) or inequality (0) of the two numbers. The following example clearly explains this operation for two specific cases.

**EXAMPLE 1.2**

Apply each of the following sets of binary numbers to the comparator inputs in Figures 1.30(a) & (b) and determine the output by the following the logic levels through the circuit.

<table>
<thead>
<tr>
<th>A₀</th>
<th>B₀</th>
<th>A₁</th>
<th>B₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

(a) The output is 1 for inputs 10 and 10 as shown in Figure 1.30(a).
(b) The output is 0 for inputs 11 and 10, as shown in Figure 1.30(b).

**Activity**

Repeat the process for binary inputs of 01 and 10.

**Note**

The basic comparator can be expanded to any number of bits. The AND gate sets the condition that all corresponding bits of the two numbers must be equal if the two numbers themselves are equal.

**Inequality**

In addition to the equality output, many IC comparators provide additional outputs that indicate which of the two binary numbers being compared is larger. That is, there is an output that indicates when number A is greater than number B (A > B) and an output that indicates when number A is less than number B (A < B), as shown in Figure 1.31.
CHAPTER 1  Digital Circuit Applications

Activity

What are the outputs when $A_3A_2A_1A_0 = 1001$ and $B_3B_2B_1B_0 = 1010$?

1.6 Decoders

An electronic device that converts signals from one form to another i.e., code into set of signals. Decoding is the process of converting code into plain text or any format that is useful for subsequent processes. It does the reverse of encoding. It converts encoded data communicated during transmission (like TV signals from satellite and Computer e-mails) and files to their original states.

In digital electronics, a binary decoder is a combinational logic circuit that converts binary information from the 'n' coded inputs to a maximum of $2^n$
unique outputs. They are used in wide variety of applications, including data demultiplexing, seven segment displays and memory address decoding.

**Basic Binary Decoder**

We need to determine when a binary 1001 occurs on the inputs of a digital circuit. An AND can be used as the basic decoding element because it produces a HIGH output only when all of its inputs are HIGH. Therefore, we must make sure that all of the inputs to the AND gate are HIGH when the binary number 1001 occurs. This can be done by inverting the two middle inputs (the 0s), as shown in Figure 1.33.

![Decoding logic for the binary code 1001 with an active-HIGH output](image)

**FIGURE 1.33 Decoding logic for the binary code 1001 with an active-HIGH output**

### EXAMPLE 1.4

Determine the logic required to decode the binary number 1011 by producing a HIGH level on the output.

**Solution**

The decoding function can be formed by complementing only the variables that appear as 0 in the desired binary number as follows:

$$X = A_3 \bar{A}_2 A_1 A_0$$ (1011)

This function can be implemented by connecting the true (un-complemented) variables $A_0$, $A_1$ and $A_3$ directly to the inputs of an AND gate and inverting the variables $A_2$ before applying it to the AND gate input. The decoding logic is shown in Figure 1.34.

![Decoding logic for producing a HIGH output when 1011 is on the inputs.](image)

**FIGURE 1.34 Decoding logic for producing a HIGH output when 1011 is on the inputs.**

### 1.7 Encoder

Encoder is a device, circuit, transducer, software program, algorithm or person that converts information from one format or code to another for the purpose of standardisation or compression. An encoder is a combinational logic circuit that essentially performs a “reverse” decoder function. An encoder accepts an active level on one of its inputs representing a digit, such as a decimal or octal digit and converts it to a coded output, such as BCD or binary. Encoders can also be devised to encode various symbols and alphabetic characters. The process of converting from familiar symbols or numbers to a coded format is called encoding.

**Decimal-to-BCD Encoder**

This type of encoder has ten inputs. One for each decimal digit and four outputs corresponding to the BCD code as shown in the Figure 1.35. This is a basic 10-line-to-4-line encoder.
Finally, $A_0$ is always for decimal digit 1, 3, 5, 7 or 9

$$A_0 = 1 + 3 + 5 + 7 + 9$$

Now, let us implement the logic circuitry required for encoding each decimal digit to a BCD code by using the logic expressions just developed. It is simply a matter of ORing the appropriate decimal input lines to form each BCD output. The basic encoder logic resulting from these expressions is shown in Figure 1.36.

The BCD (8421) code is listed in Table 1.11. From this table, you can determine the relationship between each BCD bit and the decimal digits in order to analyse the logic. For instance, the most significant bit of the BCD code, $A_3$, is always 1 for decimal digit 8 or 9. An OR expression for bit $A_3$ in terms of the decimal digits can therefore be written as $A_3 = 8 + 9$.

The basic operation of the circuit shown in Figure 1.36 is briefly described as follows: When a HIGH appears on one of the decimal input lines, the appropriate levels occur on the four BCD output lines. For instance, if input line 9 is HIGH (assuming all other input lines are LOW), this condition will produce a HIGH on outputs $A_0$ and $A_3$ and LOWs on outputs $A_1$ and $A_2$, which is the BCD code (1001) for decimal 9.

### Table 1.11 Decimal to BCD Encoder

<table>
<thead>
<tr>
<th>DECIMAL DIGIT</th>
<th>$A_3$</th>
<th>$A_2$</th>
<th>$A_1$</th>
<th>$A_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Bit $A_2$ is always 1 for decimal digit 4, 5, 6 or 7 and can be expressed as an OR function as follows:

$$A_2 = 4 + 5 + 6 + 7$$

Bit $A_1$ is always 1 for decimal digit 2, 3, 6 or 7 and can be expressed as

$$A_1 = 2 + 3 + 6 + 7$$

### 1.8 Multiplexer

A multiplexer (MUX) is a device allowing one or more low speed analog or digital signal to be selected, combined and transmitted at a higher speed on a single shared medium or within a single shared device. A MUX function is a multiple-input, single-output switch.
Multiple signals share one device or transmission conductor such as copper or fibre optic cable. In telecommunication, the analog or digital signals transmitted on several communication channels by a multiplex method. These signals are single-output higher-speed signals. A 4-to-1 multiplexer contains four input signals and 2-to-1 multiplexer has two input signals and one output signal.

A logic symbol for a 4-input multiplexer (MUX) is shown in Figure 1.37. Notice that there are two data-select lines because with two select bits, any one of the four data-input lines can be selected.

**Multiplexing**

The technique of transmitting multiple signals over a single medium is defined as Multiplexing. This technique is widely used in the Open System Interconnection (OSI) model. The different types of multiplexing technologies are:

- Wavelength Division Multiplexing (WDM)
- Frequency Division Multiplexing (FDM)
- Dense Wavelength Division Multiplexing (DWDM)
- Conventional Wavelength Division Multiplexing (CWDM)
- Reconfigurable Optical Add-Drop Multiplexer (ROADM)

- Orthogonal Frequency Division Multiplexing (OFDM)
- Add/Drop Multiplexing (ADM)
- Inverse Multiplexing (IMUX)

**Multivibrators**

Though we studied about Multivibrators in eleventh standard, it is essential to recollect the working of Bi-stable Multivibrators before entering into the Flip-flop.

**Bi-stable or flip-flop multivibrator**

The bistable multivibrator has both the states (HIGH, LOW) at stable condition. It requires an external triggering pulse to change the operation from either one state to the other. Thus, one pulse is used to generate half-cycle of square wave and another pulse to generate the next half-cycle of square wave. It is also known as a flip-flop multivibrator because of its assured two possible states. So that, it can store one bit of information and is widely used in digital logic and computer memory. Hence, a flip-flop is nothing but storage (memory) device, which can store one-bit at a time.
and can be made to change its state by means of some external signal. The most important use of this property is that a flip-flop can “store” binary information. We have seen that a logic gate can make a logical decision based on the immediate conditions at the input terminals. However, the gates normally do not have a memory characteristic to retain the input data. On the other hand, flip-flops have the valuable feature of remembering. The reason is that a flip-flop circuit is bi-stable.

Because the flip-flop’s output remains at 0 or 1 depending on the last input signal, the flip-flop can be said to be in “remember” condition. Another name for the flip-flop is bi-stable multivibrator. We shall discuss three important types of flip-flops viz. (i) R–S flip-flop and (ii) J–K flip-flop (iii) D-flip-flop.

**Flip-Flop or Latch**

Any device or circuit that has two stable states is said to be bi-stable. For instance, a toggle switch has two stable states. It is either up or down, depending on the position of the switch as shown in Figure 1.38(a). The switch is also said to have memory since it will remain as set until someone changes its position. A flip-flop is a bi-stable electronic circuit that has two stable states—that, i.e., its output is either 0 or +5 V DC as shown in Figure 1.38(b).

The flip-flop also has memory, since its output will remain as set until something is done to change it. As such, the flip-flop (or the switch) can be regarded as a memory device. In fact, any bistable device can be used to store one binary digit (bit). For instance, when the flip-flop has its output set at 0 V DC, it can be regarded as storing a logic 0 and when its output is set at +5 V DC, as storing a logic 1. The flip-flop is often called a latch, since it will hold, or latch, in either stable state.

**Basic Idea**

One of the easiest ways to construct a flip-flop is to connect two inverters in series as shown in Figure 1.39(a). The line connecting the output of inverter B (INV B) back to the input of inverter A (INV A) is referred to as the feedback line.

---

**FIGURE 1.39** Flip-Flop using inverters

---

**FIGURE 1.38** Flip-Flop Operations

---

**FIGURE 1.39** Flip-Flop using inverters

---
NOR-Gate latch

The basic flip-flop shown in Figure 1.39(a) can be improved by replacing the inverters with either NOR or NAND gates. The additional inputs on these gates provide a convenient means for application of input signals to switch the flip-flop from one stable state to the other. Two 2-input NOR gates are connected as shown in Figure 1.40(a) to form a flip-flop. Notice that, if the two inputs labelled R and S are ignored, this circuit will function exactly as the one shown in Figure 1.39(a).

This circuit is redrawn in a more conventional form as shown in Figure 1.40. From this, we will study the function of NOR-latch. The flip-flop actually has two outputs, defined in more general terms as \( Q \) and \( \overline{Q} \). It should be clear that regardless of the value of \( Q \), its complement is \( \overline{Q} \). There are two inputs to the flip-flop defined as R and S. The input/output possibilities for this RS flip-flop are summarized in the truth table in Table 1.12.

![Figure 1.40 Latch using NOR or NAND gates](image)

Table 1.12

<table>
<thead>
<tr>
<th>R</th>
<th>S</th>
<th>Q</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Last State</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>SET</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>?</td>
<td>RESET</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td>Forbidden</td>
</tr>
</tbody>
</table>

1. The first input condition in the truth table is \( R = 0 \) and \( S = 0 \). Since 0 at the input of a NOR gate has no effect on its output, the flip-flop simply remains in its present state; that is, \( Q \) remains unchanged.
CHAPTER 01
Digital Circuit Applications

2. The second input condition \( R = 0 \) and \( S = 1 \) forces the output of NOR gate B low. Both inputs to NOR-gate A are now low, and the NOR-gate output must be high. Thus, a 1 at the \( S \) input is said to SET the flip-flop and it switches to the stable state where \( Q = 1 \).

3. The third input condition is \( R = 1 \) and \( S = 0 \) forces the output of NOR gate A low, and hence both the inputs to NOR gate B are now low, the output must be high. Thus, a 1 at the \( R \) input is said to RESET the flip-flop and it switches to the stable state where \( Q = 0 \) (or \( Q = 1 \)).

4. The last input condition \( R = 1 \) and \( S = 1 \) is forbidden, as this forces the outputs of both NOR gates to the low state. In other words, both \( Q = 0 \) and \( \bar{Q} = 0 \) at the same time. But, this violates the basic definition of a flip-flop that requires \( Q \) to be the complement of \( \bar{Q} \), and so it is generally agreed never to impose this input condition. Incidentally, if this condition is for some reason imposed and the next input is \( R = 0 \), \( S = 0 \), then the resulting state \( Q \) depends on propagation delays of two NOR gates. If delay of gate A is less, i.e., it acts faster, then \( Q = 1 \), else it is 0. Such dependence makes the job of a design engineer difficult, as any replacement of a NOR gate will make \( Q \) unpredictable. That’s why \( R = 1 \), \( S = 1 \) is forbidden and truth table entry is a question mark (?). It is also important to remember that TTL gate inputs are quite noise-sensitive and therefore should never be left unconnected (floating). Each input must be connected either to the output of a prior circuit, or if unused, to GND or \(+ V_{cc}\).

### Edge-Triggered Jk Flip-Flop

Setting \( R = S = 1 \) with an edge-triggered RS flip-flop forces both \( Q \) and \( \bar{Q} \) to the same logic level. This is an illegal condition, and it is not possible to predict the final state of \( Q \). The JK flip-flop accounts for this illegal input and is therefore a more versatile circuit. Among other things, flip-flops can be used to build counters. Counters can be used to count the number of PTs or NTs of a clock. For the purpose of counting, the JK flip-flop is an ideal element to use. There are many commercially available edge-triggered JK flip-flops. Let’s see how they function.

### Positive-Edge-Triggered J K Flip-Flops

In Figure 1.41, the pulse-forming box changes the clock into a series of positive pulses, and thus this circuit will be sensitive to PTs of the clock. The basic circuit is identical to the previous positive-edge-triggered RS flip-flop with two important conditions:

![FIGURE 1.41 JK-flip-flops with Positive-Edge](image)

#### TABLE 1.13 Truth Table of JK Flip-flop

<table>
<thead>
<tr>
<th>C</th>
<th>J</th>
<th>K</th>
<th>( Q_n ) + 1</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \uparrow )</td>
<td>0</td>
<td>0</td>
<td>( Q_n ) Last State</td>
<td>No Change</td>
</tr>
<tr>
<td>( \uparrow )</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>RESET</td>
</tr>
<tr>
<td>( \uparrow )</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>SET</td>
</tr>
<tr>
<td>( \uparrow )</td>
<td>1</td>
<td>1</td>
<td>( \bar{Q}_n ) (toggle)</td>
<td>Toggle</td>
</tr>
</tbody>
</table>

1. \( Q \) output is connected back to the input of the lower AND gate.
2. \( \bar{Q} \) output is connected back to the input of the upper AND gate.
This cross-coupling from outputs to inputs changes the RS flip-flop into a JK flip-flop. Now, the S input is labelled as J, and R input is labelled as K. Here’s how it works:

1. When J and K are both low, both AND gates are disabled. Therefore, clock pulses have no effect. This first possibility is the initial entry in the truth table (Table 1.13). As shown, when J and K are both 0s, Q retains its last value.

2. When J is low and K is high, the upper gate is disabled, so there’s no way to set the flip-flop. The only possibility is reset. When Q is high, the lower gate passes a RESET pulse as soon as the next positive clock edge arrives. This forces Q to become low (the second entry in the truth table). Therefore, J = 0 and K = 1 means that the next PT of the clock resets the flip-flop (unless Q is already reset).

3. When J is high and K is low, the lower gate is disabled, so it is impossible to reset the flip-flop. But, you can set the flip flop as follows. When Q is low, Q is high; therefore, the upper gate passes a SET pulse on the next positive clock edge. This drives Q into the high state (the third entry in the truth table). As you can see, J = 1 and K = 0 means that the next PT of the clock sets the flip-flop (unless Q is already high).

4. When J and K are both high (notice that this is the forbidden state with an RS flip-flop), it is possible to set or reset the flip-flop. If Q is high, the lower gate passes a RESET pulse on the next PT. On the other hand, when Q is low, the upper gate passes a SET pulse on the next PT. Either way Q changes to the complement of the last state (see the truth table). Therefore, J = 1 and K = 1 mean the flip-flop will toggle (switch to the opposite state) on the next positive clock edge.

D Flip-Flop or D Latch

D Flip-flops are used as a part of memory storage elements and data processors as well. D flip-flop can be built using NAND gate or with NOR gate. Due to its versatility they are available as IC packages. The major applications of D flip-flop are to introduce delay in timing circuit, as a buffer, sampling data at specific intervals. D flip-flop is simpler in terms of wiring connection compared to JK flip-flop. Figures 1.42(a) & (b) show the D flip-flop symbol and D flip-flop using NAND gates, respectively. Whenever the clock signal is LOW, the input is never going to affect the output state. The clock has to be high for the inputs to get active. Thus, D flip-flop is a controlled Bi-stable latch where the clock signal is the control signal. Again, this gets divided into positive edge
they are clocked simultaneously. Within each of these two categories, counters are classified primarily by the type of sequence, the number of states, or the number of flip-flops in the counter.

**Asynchronous Counters**

The term asynchronous refers to events that do not have a fixed time relationship with each other and generally, do not occur at the same time. An asynchronous counter is one in which the flip-flops (FF) within the counter do not change states at exactly the same time because they do not have a common clock pulse.

**A 2-Bit Asynchronous Binary Counter**

Figure 1.43 shows a 2-bit counter connected for asynchronous operation. Notice that the clock (CLK) is applied only to the clock input (C) of the first flip-flop FF0, which is always the least significant bit (LSB). The second flip-flop FF1 is triggered by the $Q_0$ output of FF0. FF0 changes state at the positive-going edge of each clock pulse, but FF1 changes only when triggered by a positive-going transition of the $Q_0$ output of FF0. Because of the inherent propagation delay time through a flip-flop, a transition of the input clock pulse (CLK) and a transition of the $Q_0$ output of FF0 can never occur at exactly the same time. Therefore, the

<table>
<thead>
<tr>
<th>Clock</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>X</td>
<td>0 1</td>
</tr>
<tr>
<td>HIGH</td>
<td>0</td>
<td>0 1</td>
</tr>
<tr>
<td>HIGH</td>
<td>1</td>
<td>1 0</td>
</tr>
</tbody>
</table>

**Table 1.14 Truth Table of D Flip-Flop**

- **D**: Input
- **Q**: Output
- **Q’**: Output of the previous flip-flop

**1.10 Counters**

As you learned in previous Section, flip-flops can be connected together to perform counting operations. Such a group of flip-flops is a counter, which is a type of finite state machine. The number of flip-flops used and the way in which they are connected determine the number of states (called the modulus) and also the specific sequence of states that the counter goes through during each complete cycle. Counters are classified into two broad categories according to the way they are clocked: asynchronous and synchronous. In asynchronous counters, (commonly called ripple counters), the first flip-flop is clocked by the external clock pulse and then each successive flip-flop is clocked by the output of the preceding flip-flop. In synchronous counters, the clock input is connected to all of the flip-flops so that

![Figure 1.43 A 2-bit asynchronous binary counter](image)
two flip-flops are never simultaneously triggered, so the counter operation is asynchronous.

From the Timing Diagram shown in Figure 1.44, let us examine the basic operation of the asynchronous counter by applying four clock pulses to FF0 and observing the $\overline{Q}_0$ output of each flip-flop. Figure 1.44 illustrates the changes in the state of the flip-flop outputs in response to the clock pulses. Both flip-flops are connected for toggle operation ($D = Q$) and are assumed to be initially RESET ($Q$ LOW). The positive-going edge of CLK1 (clock pulse 1) causes the $\overline{Q}_0$ output of FF0 to go HIGH as shown in Figure 1.44. At the same time the $\overline{Q}_0$ output goes LOW, but it has no effect on FF1 because a positive-going transition must occur to trigger the flip-flop.

After the leading edge of CLK1, $Q_0 = 1$ and $Q_1 = 0$. The positive-going edge of CLK2 causes $Q_0$ to go LOW. Output $\overline{Q}_0$ goes HIGH and triggers FF1, causing $Q_1$ to go HIGH. After the leading edge of CLK2, $Q_0 = 0$ and $Q_1 = 1$. The positive-going edge of CLK3 causes $Q_0$ to go HIGH again. Output $Q_0$ goes LOW and has no effect on FF1. Thus, after the leading edge of CLK3, $Q_0 = 1$ and $Q_1 = 1$. The positive-going edge of CLK4 causes $Q_1$ to go LOW, while $Q_0$ goes HIGH and triggers FF1, causing $Q_1$ to go LOW.

After the leading edge of CLK4, $Q_0 = 0$ and $Q_1 = 0$. The counter has now recycled to its original state (both flip-flops are RESET). In the timing diagram, the waveforms of the $Q_0$ and $Q_1$ outputs are shown relative to the clock pulses as illustrated in Figure 1.44.

For simplicity, the transitions of $Q_0$, $Q_1$ and the clock pulses are shown as simultaneous even though this is an asynchronous counter. There is, of course, some small delay between the CLK and the $Q_0$ transition and between the $Q_0$ transition and the $Q_1$ transition. Note in Figure 1.44 that the 2-bit counter exhibits four different states, as you would expect with two flip-flops ($2^2 = 4$). Also, notice that if $Q_0$ represents the least significant bit (LSB) and $Q_1$ represents the most significant bit (MSB), the sequence of counter states represents a sequence of binary numbers as listed in Table 1.15.

<table>
<thead>
<tr>
<th>Clock Pulse</th>
<th>$Q_1$</th>
<th>$Q_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initially</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4 (recycle)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

FIGURE 1.44 Timing diagram for the counter given in Figure 1.43

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Since it goes through a binary sequence, the counter in Figure 1.43 is a binary counter. It actually counts the number of clock pulses up to three, and on the fourth pulse it recycles to its original state ($Q_0 = 0$, $Q_1 = 0$). The term recycle is commonly applied to counter operation, since it refers to the transition of the counter from its final state back to its original state.

**A 3-Bit Asynchronous Binary Counter**

The state sequence for a 3-bit binary counter is listed in Table 1.16, and a 3-bit asynchronous binary counter is shown in Figure 1.45(a). The basic operation is the same as that of the 2-bit counter except that the 3-bit counter has eight states, due to its three flip-flops.

<table>
<thead>
<tr>
<th>Clock Pulse</th>
<th>$Q_2$</th>
<th>$Q_1$</th>
<th>$Q_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initially</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8 (recycle)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

A timing diagram is shown in Figure 1.45(b) for eight clock pulses. Notice that the counter progresses through a binary count of zero through seven and then recycles to the zero state. This counter can be easily expanded for higher count, by connecting additional toggle flip-flops.
Synchronous Counters

The term synchronous refers to events that have a fixed time relationship with each other. A synchronous counter is one in which all the flip-flops in the counter are clocked at the same time by a common clock pulse. J-K flip-flops are used to illustrate most synchronous counters. D flip-flops can also be used but generally require more logic because of having no direct toggle or no-change states.

A 2-Bit Synchronous Binary Counter is shown in Figure 1.46(a). Notice that an arrangement different from that for the asynchronous counter must be used for the J₁ and K₁ inputs of FF1 in order to achieve a binary sequence. A D flip-flop implementation is shown in Figure 1.46(b).

The operation of a J-K flip-flop synchronous counter is as follows: First, assume that the counter is initially in the binary 0 state; that is, both flip-flops are RESET. When the positive edge of the first clock pulse is applied, FF0 will toggle and Q₀ will therefore go HIGH. What happens to FF1 at the positive-going edge of CLK1? To find out, let us look at the input conditions of FF1. Inputs J₁ and K₁ are both LOW because Q₀, to which they are connected, has not yet gone HIGH. Remember, there is a propagation delay from the triggering edge of the clock pulse until the Q output actually makes a transition. So, J = 0 and K = 0 when the leading edge of the first clock pulse is applied. This is a no-change condition, and therefore FF1 does not change state. A timing detail of this portion of the counter operation is shown in Figure 1.47(a).

After CLK1, Q₀ = 1 and Q₁ = 0 (which is the binary 1 state). When the leading edge of CLK2 occurs, FF0 will toggle and Q₀ will go LOW. Since FF1 has a HIGH (Q₀ = 1) on its J₁ and K₁ inputs at the triggering edge of this clock pulse, the flip-flop toggles and Q₁ goes HIGH. Thus, after CLK2, Q₀ = 0 and Q₁ = 1 (which is a binary 2 state).

The timing detail for this condition is shown in Figure 1.47(b). When the leading edge of CLK3 occurs, FF0 again toggles to the SET state (Q₀ = 1), and FF1 remains SET (Q₁ = 1) because its J₁ and K₁ inputs are both LOW (Q₀ = 0). After this triggering edge, Q₀ = 1 and Q₁ = 1 (which is a binary 3 state). The timing detail is shown in Figure 1.47(c).

Finally, at the leading edge of CLK4, Q₀ and Q₁ go LOW because both have a toggle condition on their J and K inputs. The timing detail is shown in Figure 1.47(d). The counter has now recycled to its original state, binary 0. Examination of the D flip-flop counter in Figure 1.46(b) will show the timing diagram is the same as for the J-K flip-flop counter.
Shift Register Operations

Shift registers consist of arrangements of flip-flops and are important in applications involving the storage and transfer of data in a digital system. A register has no specified sequence of states, except in certain very specialized applications.

A register in general, is used solely for storing and shifting data (1s and 0s) entered into it from an external source and typically possesses no characteristic internal sequence of states.

The storage capability of a register makes it an important type of memory device. Figure 1.49 illustrates the concept of storing a 1 or a 0 in a D flip-flop. A 1 is applied to the data input as shown, and a clock pulse is applied that stores the 1 by setting the flip-flop. When the 1 on the input is removed, the flip-flop remains in the SET state, thereby storing the 1. A similar procedure applies to the storage of a 0 by resetting the flip-flop, as illustrated in Figure 1.49.
The storage capacity of a register is the total number of bits (1s and 0s) of digital data it can retain. Each stage (flip-flop) in a shift register represents one bit of storage capacity; therefore, the number of stages in a register determines its storage capacity. The shift capability of a register permits the movement of data from stage to stage within the register or into or out of the register upon the application of clock pulses. Figure 1.50 illustrates the types of data movement in shift registers. The block represents any arbitrary 4-bit register, and the arrows indicate the direction of data movement.

**FIGURE 1.49** The flip-flop as a storage element.

1 is stored and appears on output.

When a 1 is on \( D \).

\( Q \) becomes a 1 at the triggering edge of CLK on remains a 1 if already in the SET state.

0 is stored and appears on output.

When a 0 is on \( D \).

\( Q \) becomes a 0 at the triggering edge of CLK on remains a 0 if already in the RESET state.

**FIGURE 1.50** Basic data movement in shift registers. (Four bits are used for illustration. The bits move in the direction of the arrows.)

**LEARNING OUTCOME**

At the end of this chapter the students would have learned about the following:

- Construction of Combinational Gates and its applications
- Working of Arithmetic circuits like, Half, Full-adder and Half & Full Subtractor
- The way of Decoding and Encoding of Signals
- Multiplexing and De-Multiplexing
- Basic working of Flip-flops (Memory)
- Construction of Binary Counters and Registers and its Applications
GLOSSARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAND gate</td>
<td>A logic gate that produces a LOW output only when all the inputs are HIGH.</td>
</tr>
<tr>
<td>NOR gate</td>
<td>A logic gate in which the output is LOW when one or more of the inputs are HIGH.</td>
</tr>
<tr>
<td>OR gate</td>
<td>A logic gate that produces a HIGH output when one or more inputs are HIGH.</td>
</tr>
<tr>
<td>Sequential circuit</td>
<td>A digital circuit whose logic states follow a specified time sequence.</td>
</tr>
<tr>
<td>Propagation delay time</td>
<td>The time interval between the occurrence of an input transition and the occurrence of the corresponding output transition in a logic circuit.</td>
</tr>
<tr>
<td>Truth table</td>
<td>A table showing the inputs and corresponding output(s) of a logic circuit.</td>
</tr>
<tr>
<td>Adder</td>
<td>Digital circuit used to add binary digits.</td>
</tr>
<tr>
<td>Subtractor</td>
<td>Digital circuit used to subtract binary digits.</td>
</tr>
<tr>
<td>Encoder</td>
<td>Encoder is a device that converts information from one format or code to another.</td>
</tr>
<tr>
<td>Decoder</td>
<td>The process of converting code into plain text or any format. It’s a reverse process of Encoding.</td>
</tr>
<tr>
<td>Multiplexer</td>
<td>A Multiple input and Single output switch.</td>
</tr>
<tr>
<td>Flip-flop</td>
<td>A Bi-stable digital circuit which can store a binary digit at a time.</td>
</tr>
<tr>
<td>Counter</td>
<td>Flip-flops connected together to perform counting operations.</td>
</tr>
<tr>
<td>Registers</td>
<td>A type of sequential logic circuit used primarily for the storage of digital data.</td>
</tr>
</tbody>
</table>

QUESTIONS

I Multiple choice Questions

1. When both input of the NAND gate goes HIGH, what will be the output?
   (a) 1 (b) 0 (c) 10 (d) 01

2. When a pulse is applied to each input of a 2-input NOR-gate. One pulse goes HIGH at t=0.8 ms and goes back LOW at t = 3 ms. The output pulse can be described as follows
   (a) It goes LOW at t = 0 and back HIGH at t = 3 ms
   (b) It goes LOW at t = 0.8 ms and back HIGH at t = 3 ms
   (c) It goes LOW at t = 0.8 ms and back HIGH at t = 1 ms
   (d) It goes HIGH at t = 0.8 ms and back LOW at t = 1 ms
3. The Complement of the variable is
   (a) 0
   (b) 1
   (c) equal to the variable
   (d) the inverse of the variable

4. According to Commutative law of addition
   (a) AB = BA
   (b) A = A + A
   (c) A + (B+C) = (A+B) + C
   (d) A + B = B + A

5. According to Distributive law
   (a) A(B + C) = AB + AC
   (b) A(BC) = ABC
   (c) A(A + 1) = A
   (d) A + AB = A

6. Which one of the rule is not a valid rule of Boolean algebra?
   (a) A + 1 = 1
   (b) A = A
   (c) AA = A
   (d) A + 0 = A

7. An Exclusive OR function is expressed as
   (a) A \cdot B + A \cdot B
   (b) (A \cdot B + A \cdot \overline{B})
   (c) \overline{A +B}(A + \overline{B})
   (d) (A + B) (A + B)

8. The AND operation can be produced with
   (a) two NAND gates
   (b) three NAND gates
   (c) one NOR gate
   (d) three NOR gates

9. A Half-adder is characterised by
   (a) two inputs and two outputs
   (b) three inputs and two outputs
   (c) two inputs and three outputs
   (d) two inputs and one output

10. A 4-Bit parallel adder can add
    (a) two 4-bit Binary numbers
    (b) two 2-bit Binary numbers
    (c) four bits at a time
    (d) four bits in sequence

11. In general, a multiplexer has
    (a) one data input, several data outputs and selection inputs
    (b) one data input, one data output and one selection input
    (c) several data inputs, several data outputs and selection inputs
    (d) several data inputs, one data output and selection inputs

12. The flip-flop belongs to a category of logic circuits known as
    (a) monostable multivibrator
    (b) bistable multivibrators
    (c) astable multivibrators
    (d) one-shots

13. Asynchronous counters are known as
    (a) ripple counters
    (b) multiple clock counters
    (c) decade counter
    (d) modulus counters

14. An Asynchronous counter differs from a synchronous counter in
    (a) the number of states in its sequence
    (b) the method of clocking
    (c) the type of flip-flops used
    (d) the value of the modulus
15. To serially shift a byte of data into a shift register, there must be
(a) one clock pulse
(b) one load pulse
(c) eight clock pulses
(d) one clock pulse for each 1 in the data

II Answer in one or two sentences
1. Write the any three names of combinational gates.
2. Draw the construction of NAND gate with truth table.
3. Construct OR gate using NAND gate (diagram).
4. Define encoder
5. Write shortly about Multiplexer (MUX)
7. Write the truth table of Full-Adder.
8. If a bit is to be stored, how it can be?
9. Write briefly about asynchronous counter.
10. Write about decoder

III Answer in a paragraph
1. Why NAND & NOR gates are called as Universal gates? Explain with an example.

2. Explain in detail the construction of Ex-OR and Ex-NOR gate with truth table.
3. If any 2 bits are to be added, how it can be done through a logic gate circuit? Justify with necessary diagrams?
4. Is it possible to perform subtraction in logic gates? Prove with circuit and table.
5. Define Multiplexer.

Part – D (10 Marks)

IV Answer in One Page (Essay type Question)
1. What are the three basic Boolean laws. Define each with example.
2. Construct full adder and half subtractor circuits. Prove with truth table.
3. Two parallel bits are to be added—Construct the necessary circuit and prove.
4. Explain the working of JK-flip-flop.
5. Write about shift register.

Answers
1. (b)  2. (b)  3. (d)  4. (d)  5. (a)
6. (b)  7. (b)  8. (a)  9. (a) 10. (b)
11. (d) 12. (b) 13 (a) 14(b) 15. (a)
CHAPTER 2

Transmission and Reception

LEARNING OBJECTIVE

In this chapter, the students can easily.....
- Understand the modulation and demodulation
- Learn the difference between analog modulation and pulse modulation.
- Learn the function of modem
- Study about the different types of modem
- Understand the different types of antenna and its uses

CONTENT

2.1 Introduction
2.2 Principles of Transmission and Reception
2.3 Modulation
2.4 Types of Modulation
2.5 Analog Modulation
2.6 Pulse Modulation
2.7 Demodulation
2.8 Modem
2.9 Antenna
2.10 Types of Antenna.

2.1 Introduction

Any message or data want to be sent from one place to another through any media is known as transmission. Earlier the transmission was successful to a short distance, later it was possible to a very long distances, because of modulation. The ultimate aim of transmission is to reach a receiver.

A device which can receive the transmitted signal is known as receiver. The transmitted signals have to demodulate in order to get the actual message or data. So in this chapter we learn about modulation, demodulation and devices that are used to transmit and receive the signal (i.e.,) antenna.
CHAPTER 2  Transmission and Reception

2.2 Principles of Transmission and Reception

Transmission and reception are the most important technique for the communication system. A microphone converts the audio frequencies (20Hz to 20 kHz) into audio electrical signal. The signal is weak so it needs to be strengthened using amplifier.

Audio signals can travel only a short distance without any signal loss. The Carrier Wave (CW) or Radio Frequency (RF) can travel $3 \times 10^8$ meter per second. The process of superimposing audio signal over the carrier wave is known as Modulation. The modulated wave is radiated and travels through space, finally it reaches the receiving antenna.

After receiving the signal by the receiving antenna, it enters the receiver. In order to get back the original audio signal, the RF should be removed by using simple detector circuit which is called as detection or Demodulation. The demodulated signal is amplified and fed to the loudspeaker. It converts audio electrical signal into audio sound signal.

Without modulation, all signals at same frequencies from different transmitters would be mixed up. There by giving impossible situation to tune to any one station particular transmitters. In order to separate the various signals, radio stations must broadcast at different frequencies. This is achieved by process of modulation.

2.3 Modulation

Modulation is the process of changing the characteristic (amplitude, frequency or phase) of the carrier signal, in accordance with the amplitude of the message signal. A device that performs modulation is called modulator.

2.3.1 Need for modulation

1. Separation of signal from different transmitters.

Audio frequencies are within the range of 20 Hz to 20 kHz.

2. Size of antenna

Antennas should have length at least equal to a half of the wavelength of the signal to be transmitted.

For an electromagnetic wave of frequency 15 kHz,

The wavelength $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{15000} = 20$ km

It is impossible to build ($\lambda/2=20/2$) 10 km antenna. In modulation, signal which of low frequency are translated to the high frequency of the electromagnetic spectrum using radio waves.

3. It reduce antenna height

4. It reduce bandwidth

5. It transmit information to a long distance without interference.

6. Attenuation of audio signals are high.

2.4 Types of Modulation

The modulation may be classified according to the nature of carrier wave into

1. Continuous wave modulation or Analog modulation

2. Pulse modulation

Classification of modulation is given below in the flow chart.
2.5 Analog Modulation

In analog modulation, analog signal (Sinusoidal signal) is used as a carrier signal that modulated the message signal or data signal. Three parameters of sinusoidal waves are amplitude, frequency and phase. So the types of analog modulation are

1. Amplitude Modulation (AM)
2. Frequency Modulation (FM)
3. Phase Modulation (PM)

2.5.1 Amplitude Modulation (AM)

Amplitude modulation is a type of modulation where the amplitude of the carrier signal is varied (changed) in accordance with the amplitude of the message signal while the frequency and phase of carrier signal remain constant.

The first waveform of figure 2.1 shows the modulating signal (or) message signal which contains information. The second waveform of figure 2.1 shows the high frequency carrier signal which contains no information. The third waveform of figure 2.1 shows the resultant amplitude modulated signal.
From the above three figures, it can be observed that the amplitude of the carrier signal is varied in accordance with the amplitude of the message signal while the frequency and phase of carrier signal remain constant.

2.5.1.1 AM advantages
- AM is the simplest type of modulation.
- Hardware design of both transmitter and receiver is very simple and less cost effective.

2.5.1.2 Disadvantages
1. Low efficiency
2. Limited operating range
3. Noise in reception
4. Poor audio quality

2.5.1.3 Applications
- This type of modulation is used in AM radio broadcasting.
- It is also used in computer modem.

2.5.2 Frequency Modulation
Frequency modulation is a type of modulation where the frequency of the carrier signal is varied in accordance with the amplitude of the message signal while amplitude and phase of carrier signal remain constant.

The figure 2.2 shows the frequency modulation. The first waveform of figure 2.2 shows the modulating signal which contains information. The second waveform of figure 2.2 shows the high frequency carrier signal containing no information. The third waveform of figure 2.2 shows the resultant frequency modulated signal. From the above three figures, it can be observed that the frequency of the carrier signal is varied in accordance with the amplitude of message signal. While the amplitude of the carrier signal remains constant.

2.5.2.1 FM advantages
- Much more bandwidth
- Less Radiated Power

2.5.2.2 Disadvantages
Circuit needed for FM modulation and demodulation is slightly complicated compared to AM.

2.5.2.3 Application
This type of modulation is used in FM Radio broadcasting.

2.5.3 Phase modulation
Phase modulation is a type of modulation where the phase of the carrier signal is varied (changed) in accordance with the phase of the message signal, keeping the amplitude and frequency of the carrier signal constant.

The figure 2.3 shows the phase modulation. The first waveform of
In pulse modulation a message signal is converted from analog to digital message and then modulated by using carrier waves. Pulse modulation is a process in which the signal is transmitted in the form of pulses.

2.6.1 Types of Pulse Modulation
This is divided into
1. Analog Pulse Modulation
2. Digital Pulse Modulation

Analog Pulse Modulation is further classified as
- Pulse Amplitude Modulation (PAM)
- Pulse Width Modulation (PWM)
- Pulse Position Modulation (PPM)

Though Digital Pulse Modulation has more number of classifications, here we are going to study only two kinds of it.
- Pulse Code Modulation (PCM)
- Delta Modulation (DM)

2.6.2 Analog Pulse Modulation
2.6.2.1 Pulse Amplitude Modulation (PAM)

Pulse Amplitude Modulation is a technique in which the amplitude of each pulse is controlled by the instantaneous amplitude of the modulation signal. It is a modulation system in which the signal is sampled at regular intervals and each sample is made proportional to the amplitude of the signal at the instant of sampling. It transmits the data by encoding in the amplitude as a series of pulses. It is similar to amplitude modulation. Figure 2.4 shows pulse amplitude modulation.
2.6.3.1 Advantage of PWM
Noise interference is less.

2.6.3.2 Disadvantage of PWM
High switching loss occur in this type.

2.6.3.3 Application
It is used to control the direction of a servometer.

2.6.4 Pulse Position Modulation (PPM)
PPM is a modulation in which the amplitude and width are kept constant but the position of each pulse is varied in accordance with the amplitude of the modulating signal. Figure 2.6 shows pulse position modulation signal.

2.6.4.1 Advantage
Noise interference is very low.

2.6.4.2 Disadvantage
The synchronisation between transmitter and receiver is required. It is not possible for every time.

2.6.4.3 Application
It is mostly used in RF communication.
2.6.5 Digital Pulse Modulation (DPM)

The digital modulation is employed for efficient communication. The main advantages of the digital modulation over analog modulation include high noise immunity, bandwidth and permissible power. In digital modulation the modulating signal is converted from analog to digital.

2.6.5.1 Pulse Code modulation (PCM)

The pulse code modulation is the method of converting analog signal into a digital signal (i.e.,) 1s and 0s. As the resultant signal is a coded pulse train, this is called as pulse code modulation.

The following figure 2.7 shows example of PCM output with respect to instantaneous values of a given sine wave.

![FIGURE 2.7 Pulse Code Modulation](image)

2.6.5.2 Advantage of Pulse Code Modulation

It is more convenient for long distance communication.

2.6.5.3 Disadvantage of Pulse Code Modulation

It requires larger bandwidth.

2.6.5.4 Application

It is used in the satellite communication and space communication.

2.6.6 Delta Modulation (DM)

A Delta Modulation is an analog to digital and digital to analog signal conversion technique used for transmission of voice information where quality is not of primary importance. DM is the simplest form of pulse code modulation. In delta modulation, the transmitted data are reduced to 1bit data stream. Figure 2.8 shows Delta Modulation signal.

2.6.6.1 Advantage

It has lower bandwidth

2.6.6.2 Disadvantage

Overload distortion occur in this type of modulation.

![FIGURE 2.8 Delta Modulation](image)
CHAPTER 2 Transmission and Reception

2.6.6.3 Application

It is mainly used in voice transmission applications such as telephone and radio communication.

2.7 Demodulation or Detection

Demodulation or detection is a process of recovering the original modulating signal from the modulated carrier wave. (ie) the demodulation is the reverse process of modulation. The devices used for demodulation are called demodulators or detectors.

2.7.1 Necessity of Demodulation

The wireless signals transmitted from a transmitter consist of RF carrier waves and audio frequency signal waves. If the modulated wave is directly fed to the loudspeaker, no sound will be heard from the loudspeaker. This is because of the simple reason that the frequency of the carrier wave is very high and the loudspeaker diaphragm cannot respond to such high frequencies due to large inertia of their vibrating discs etc. Such RF wave does not produces any effect on human ear as their frequencies are much beyond the audible frequency range (20Hz to 20KHz approximately). Hence it becomes essential to separate the audio signal from the modulated carrier wave.

2.8 Modem

Modem stands for Modulator / Demodulator. A modem converts digital signals generated by the computer into analog signals which can be transmitted over a telephone or cable lines and transforms incoming analog signals into their digital equivalents. It is a hardware device that allows a computer or other devices such as a router or a switch to access. Figure 2.9 shows the different types of Modem.

2.8.1 Working of modem

Figure 2.10 shows the working principle of Modem. A Modem is typically used to send digital data over a phone line. The sending modem modulates the data (Digital) into a signal (Analog) that is compatible with the phone line and the receiving modem demodulates the signal back (Analog) into

---

<table>
<thead>
<tr>
<th>Difference between Continuous Wave Modulation and Pulse Modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous wave modulation or Analog modulation</td>
</tr>
<tr>
<td>The modulated signal is in the form of continuous signals.</td>
</tr>
<tr>
<td>It is not used for sampling technique.</td>
</tr>
<tr>
<td>It require less bandwidth.</td>
</tr>
<tr>
<td>It has only analog modulation.</td>
</tr>
<tr>
<td>High frequency sine wave is used as carrier.</td>
</tr>
<tr>
<td>Input signal is analog signal only.</td>
</tr>
<tr>
<td>The example of continuous wave modulation is AM (Amplitude Modulation), FM (Frequency Modulation) and PM (Phase Modulation).</td>
</tr>
<tr>
<td>It is used in radio and TV broadcasting.</td>
</tr>
</tbody>
</table>
4.2 **CHAPTER 2** Transmission and Reception

2.8.2 Types of Modem

1. On the basis of directional capacity, modems are divided into half-duplex modem and full-duplex modem.

2. On the basis of connection to the line, they are classified into 2-wire modem and 4-wire modem.

3. On the basis of transmission mode they are divided into asynchronous modem and synchronous modem.

2.8.2.1 Half-duplex Modem

Figure 2.11 shows the half-duplex modem. The term half-duplex means that the signal can travel in either direction, but the transmission will take place in only one direction at a time. These modems have only one carrier frequency. This type of arrangement uses more channel bandwidth and the data communication takes place at a very slow rate.

2.8.2.2 Full-duplex Modem

Figure 2.12 shows the full-duplex modem. These modems can transmit in both directions simultaneously. They also make use of two carrier frequencies (one for each direction). Each carrier makes use of half of the bandwidth which is available to it. The process of transmission and receiving of data by this modem can take place at full speed.

Digital data. Wireless modem converts digital data into radio signals and back.
2.8.2.4 4-Wire Modem

Figure 2.14 shows the 4-wire modem. In this type of connection, separate wires are used for incoming and outgoing carrier. Data can be transmitted on half and full-duplex mode through these settings. The same carrier frequency can be used for transmissions in both directions as the physical path is separate for each in this case.

2.8.2.5 Synchronous Modem

Figure 2.15 shows the synchronous modem. Synchronous modem can handle a continuous stream of data bits but requires a clock signal. The data bits are always synchronized to the clock signal. There are separate bits for the data bits being transmitted and received.
CHAPTER 2  Transmission and Reception

2.9.1 History of Antenna
The first antenna was built in 1888 by German physicist Heinrich Hertz. He developed wireless communication system in which he forced an electrical spark to occur in the gap of dipole antenna. He used a loop antenna as a receiver and observed a similar disturbance. By 1901, Marconi was sending information across the Atlantic. For a transmit antenna he used several wires attached to the ground across the antenna ocean the receiver antenna was a 200 m wire help up by a kite.

2.9.2 Properties of Antenna
- Antenna Gain
- Aperture
- Directivity and bandwidth
- Polarization
- Effective length
- Polar diagram

2.9.2.1 Antenna Gain
Antenna gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source.

\[
\text{Gain (G)} = \frac{\text{power radiated by an antenna}}{\text{power radiated by reference antenna}}
\]
2.9.2.2 Aperture
It is also known as the effective aperture of the antenna that actively participate in transmission and reception of electromagnetic waves. The power received by the antenna gets associated with collective area. This collective area is known as effective aperture.

2.9.2.3 Directivity and bandwidth
It is defined as the measure of concentrated power radiation in a particular direction. Bandwidth can be defined as the range of frequencies over which an antenna can properly radiates energy and receives energy.

2.9.2.4 Polarization
An electromagnetic wave launched from an antenna may be polarized vertically and horizontally. If the wave gets polarized in the vertical direction, it requires vertical antenna. If the wave gets polarized in horizontal way, it needs a horizontal antenna to launch it. Sometimes circular polarization is used, it is a combination of both horizontal and vertical ways.

2.9.2.5 Effective length
It can be defined for both transmitting and receiving antennas. It is the ratio of area under non-uniform current distribution area under uniform current distribution.

2.9.2.6 Polar diagram
In case of a transmitting antenna, this is a plot that discusses about the strength of the power field radiated by the antenna in various angular directions. Figure 2.17 shows the polar pattern of polar antenna.

2.10 Types of Antenna
Some important types of antenna are given below:

1. Dipole antenna
A dipole antenna is the simplest type of radio antenna. Consisting of a conductive wire rod that is half the length of the maximum wavelength the antenna is to generate. This wire rod is split in the middle, and the two sections are separated by an insulator. Each rod is connected to a coaxial cable at the end closest to the middle of the antenna as shown in Figure 2.18. Radio frequency voltages are applied to dipole antennas at the centre, between the two conductors. Dipole means “two poles”.

![Dipole antenna](image)

2. Loop antenna
A loop antenna is a radio antenna consisting of a loop or coil of wire, tubing or other electrical conductor usually fed by a balanced source or feeding a balanced load. An example is the ferrite (loopstick) antenna used in most AM broadcast radios. Loop antennas are simple and easy to construct. They are available in different shapes like circular, elliptical, rectangular etc., as shown in figure 2.19. The fundamental characteristics of the loop antenna are independent of its shape.
CHAPTER 2  Transmission and Reception

FIGURE 2.21  Yagi Uda antenna

Figure 2.21 shows a Yagi antenna. It consists of three elements normally director, folded dipole and reflector. The number of director may be added to increase the directivity of the antenna.

Advantages of Yagi antenna

- High gain
- High Directivity

Disadvantages of Yagi Antenna

- Prone of noise
- Prone to atmospheric effects.

Applications

- Mostly used for Television reception. It is very widely used as a high gain HF, VHF, and UHF bands.

5. Monopole antenna

A monopole antenna is a class of radio antenna consisting of a straight rod shaped conductor, often mounted perpendicularly over some type of
conductive surface, called a grounded plane. Therefore, the length of the antenna is determined by the wavelength of the radio waves it is used with. The monopole antenna was invented in 1895 by Erugliems Marconi, so it is sometimes called the Marconi antenna. Common types of monopole antenna are the whip, rubber, ducky, helical, random wire, inverted L and T antenna, inverted F and mast radiator. It is also known as ground plane antenna. Figure 2.22 shows the monopole antenna.

6. Microstrip antenna

Microstrip antennas are also known as patch antennas or printed antennas. These are mostly used at microwave frequencies. It is a narrow
band wide beam antenna. It is an antenna fabricated using micro strip techniques on a printed circuit board. It is a kind of internal antenna. They are mostly used in microwave frequencies. It consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. Micro strip antennas patches are in variety of shapes such as rectangular, square, triangular and circular, etc., as shown in Figure 2.23.

It is used in mobile satellite communication system, Direct broadcast television (DBS), wireless LANs, GPS system, missiles and telemetry, UHF patch antennas for space.

7. **Dish antenna or Parabolic antenna**

Dish antenna is an antenna that uses a parabolic reflector, a curved surface with the cross sectional shape of a parabola to direct the radio waves. The main advantage of a parabolic antenna is that it has high directivity. It was intervened by German Physicist Heinrich Hertz. A dish antenna is known simply as a dish, is a common in microwave systems. This type of antenna can be used for satellite communication and broadcast reception, radio astronomy and radar. They are also used in radio telescope. Figure 2.24 shows a Dish antenna.

8. **Discone antenna**

A discone antenna is a version of biconical antenna in which one of the cones is replaced by a disc. It is usually mounted vertically, with the disc at the top and cone beneath as shown in figure 2.25. It has three major components: the disc, the cone and the insulator.

![Discone antenna](image)

The discone wideband coverage makes it attractive in commercial military amateur radio and radio scanner applications.

9. **Horn antenna or microwave horn**

It is an antenna that consists of a flaring metal waveguide (a metal pipe used to carry radio waves), shaped like a horn to direct radio waves in a beam. Horns are widely used as antennas at UHF and microwave frequencies above 300MHz. Figure 2.26 shows different horn antenna.

![Horn antenna](image)

An advantage of horn antennas is that since they have no resonant elements, they can operate over a wide range of frequencies, a wide bandwidth.
# LEARNING OUTCOME

After learning this unit, the student can able to deliver,
- The process of modulation
- The types of analog and pulse modulation
- The necessity of demodulation
- The working principles of Modem
- The uses of different antenna

# GLOSSARY

<table>
<thead>
<tr>
<th>Terms</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude</td>
<td>The magnitude of a voltage or current waveform indicating, the strength of a signal.</td>
</tr>
<tr>
<td>Data</td>
<td>All information, facts, numbers, letters, symbols etc., which can be produced by the computer.</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>The available space between two given points on the electromagnetic spectrum.</td>
</tr>
<tr>
<td>Gain</td>
<td>An increase in the power amplitude of the signal</td>
</tr>
<tr>
<td>Modem</td>
<td>A combined device for modulation and demodulation</td>
</tr>
<tr>
<td>Half duplex</td>
<td>Allowing the transmission of signals in both direction but not simultaneously.</td>
</tr>
<tr>
<td>Full duplex</td>
<td>Can communicate with one another in both direction.</td>
</tr>
<tr>
<td>Modulator</td>
<td>It is a device that performs modulation.</td>
</tr>
<tr>
<td>Demodulator</td>
<td>It is a device that performs demodulation.</td>
</tr>
<tr>
<td>Antenna</td>
<td>A metallic device for sending or receiving radio waves.</td>
</tr>
</tbody>
</table>

# QUESTIONS

Part – A  (1 Mark)

1. The device which converts audio signal into electrical signal is called___________
   (a) Microphone
   (b) Modem
   (c) Antenna
   (d) Loud speaker

2. The device which converts electrical signal into audio signal is called___________
   (a) Microphone
   (b) Modem
   (c) Antenna
   (d) Loud speaker
3. Audio frequency are within the range of _______________
   (a) 20 Hz to 20 kHz
   (b) 30 Hz to 30 MHz
   (c) 100 Hz to 30 kHz
   (d) 88 MHz to 108 MHz
4. In Amplitude Modulation, __________ of carrier signal is varied in accordance with the amplitude of the message signal.
   (a) Phase
   (b) Frequency
   (c) Amplitude
   (d) None of the above
5. The type of modulation is used in satellite is _______________
   (a) Amplitude Modulation
   (b) Frequency Modulation
   (c) Phase Modulation
   (d) Angle Modulation
6. Which modulation is the odd one?
   (a) PAM
   (b) PWM
   (c) PPM
   (d) FM
7. A transducer which converts RF signal into electrical signal or electrical signal into RF signal is called ____________.
   (a) Antenna
   (b) Loud speaker
   (c) Microphone
   (d) Modem
8. The type of antenna used in VHF and UHF bands is ____________.
   (a) Dipole antenna
   (b) Folded dipole antenna
   (c) Yagi Uda antenna
   (d) Loop antenna
9. Antenna used in mobile is ______.
   (a) Dipole antenna
   (b) Folded dipole antenna
   (c) Yagi Uda antenna
   (d) Microstrip antenna
10. _____ is used in Radar.
    (a) Microstrip antenna
    (b) Dish antenna
    (c) Loop antenna
    (d) Horn antenna

Part – B (3 Marks)

II Answer in one or two sentences
1. What is modulation?
2. Define: Amplitude modulation.
3. What is meant by Phase Modulation?
4. What are the advantage and disadvantages of frequency modulation?
5. What is demodulation?
6. Define: Pulse Modulation
7. What are the different types of analog modulation?
8. What is Modem?
9. What is an Antenna?
10. Write short notes on Pulse Amplitude Modulation

CHAPTER 2 Transmission and Reception
11. What are the different types of Pulse Modulation?


Part – C  
(5 Marks)

III  Answer in a paragraph

1. What is the need for modulation?
2. Explain about Frequency Modulation.
3. What is Pulse Width Modulation?
4. Explain about the necessity for detection?
5. Differentiate Analog and Pulse Modulation?

Part – D  
(10 Marks)

IV  Answer in One Page (Essay type Question)

1. Explain briefly any two types of analog modulation.
2. Explain about any two types of Pulse Modulation.
3. What are the properties of an antenna?
4. Briefly explain about the types of Modem.

Answers
1. (a) 2. (d) 3. (a) 4. (c) 5. (c)
6. (d) 7. (a) 8. (c) 9. (d) 10. (b)
Transmitters and Receivers

LEARNING OBJECTIVE
In this chapter, the students can easily study and understand the
- Basic concepts of communication
- Working principle of transmitter
- Sideband Transmission techniques
- Functions of AM radio transmitter
- Functions of FM radio transmitter
- Working principle of AM radio receiver
- Working principle of FM radio receiver
- Servicing of FM radio receiver
- Scanning Concepts
- Working principle of camera tube
- Description of TV transmitter
- Description of TV receiver
- Functions of LCD TV
- Functions of LED TV

CONTENT
3.1 Transmitter
3.2 Sidebands Transmission
3.3 AM radio transmitter
3.4 FM radio transmitter
3.5 AM radio receiver
3.6 FM radio receiver
3.7 Servicing of FM radio receiver
3.8 TV Transmission And Reception
3.9 Camera tube
3.10 TV transmitter
3.11 TV Receiver
3.12 LCD TV
3.13 LED TV
Introduction

In this 21st century, the world is ruled by communication gadgets. Though there are so many latest communication devices like Cell Phone, Computer (Internet) etc., still people are much enjoying the utility of Radio and Television receivers. It is so powerful and strong to the extent, which make the people to sit in front of those devices even hours together. Hence, it is inevitable to study and learn about the principle, working and applications of Radio and TV transmitters and receivers.

As a user, we are always familiar with receivers (either Radio or TV). Rightly to say, without transmitter (transmission) the receiver cannot exist. So, naturally before the arrival of the receiver the transmitter would have born. Hence, let us discuss about the functions of the transmitter first.

3.1 Transmitter

An equipment which is used to transmit RF waves by producing carrier waves and then modulated with AF waves is called as transmitter.

3.2 Sideband

A sideband is a band of frequencies higher than or lower than the value of carrier frequency, as a result of the modulation process.

If the modulating signal (audio or video signal) is modulated with the carrier signal, the resultant signal has carrier with sidebands in both sides (lower and upper values) of the carrier signal. Fig. 3.1 shows the carrier and its sidebands.

3.1.1 Radio transmitters

However, various types of radio transmitters are in use, we shall discuss here only about AM and FM transmitters. Generally, transmission is of three types.

1. Single Sideband Transmission (SSB)
2. Double Sideband Transmission (DSB)
3. Vestigial Sideband Transmission (VSB)

First let us discuss about Sideband.

HISTORY OF TRANSMISSION

Radio waves were first mathematically predicted in 1864 by Scottish mathematical physicist James Clerk Maxwell. Using this concept, in November 1888 German scientist Heinrich Rudolf Hertz became the first person to transmit electromagnetic waves in free space.

Initially, radio waves were called as hertzian waves.

FIGURE 3.1  Modulated carrier showing sidebands in either side of the carrier

For example, if a carrier signal of 1000 kHz is modulated with 5 kHz audio signal, the resultant signal has 1000 kHz ± 5 kHz, that is 995 kHz to 1005 kHz. The difference between this range (995 to 1005 KHz) is 10 kHz, which is called as bandwidth. The range 995 to 1000 kHz
is called as lower sideband (LSB) and the range 1000 to 1005 kHz is termed as upper sideband (USB). Figure 3.1 shows LSB and USB with carrier. Both sidebands (one is the mirror image of the other) have same information. Any one sideband is enough to send information (audio or video).

### 3.2.3 Vestigial sideband transmission (VSB)

It is a type of transmission which uses carrier signal with any one of the sidebands (LSB or USB) and part of the other sideband is called as vestigial side band transmission. It is used in TV transmission. The other sideband cannot be filtered fully because of very high frequency. So, part of the sideband is used with one full sideband. It uses lesser bandwidth and power than DSB, but uses more bandwidth and power than SSB.

### 3.3 AM Radio Transmitter

It is an equipment which transmits the amplitude modulated waves.

AM Radio transmitter uses double sideband transmission. Its bandwidth is 10 kHz. AM transmission broadcast range lies from 540 kHz to 30 MHz. It is classified as various bands such as medium wave band and shortwave bands.

Figure 3.2 shows the block diagram of AM Radio transmitter. It consists of the following stages.
**Microphone**

It converts AF signal into electrical signal.

**Audio pre amplifier**

This is the first stage voltage amplifier. Here, noise is filtered and AF signal voltage is amplified.

**AF power amplifier**

It amplifies the power of the AF signal and fed to the modulator and power amplifier.

**RF Oscillator**

It produces high frequency noiseless carrier waves using crystal. It is designed in such a way that its frequency is not affected by the voltage fluctuations and heat. Therefore, a crystal is used to generate the oscillations and hence it is called as crystal oscillator.

**Buffer Amplifier**

It is an impedance matching Class-A type amplifier. It prevents crystal oscillator and power amplifier from overload and signal loss. Hence, the frequency of the carrier waves is maintained constant. It also amplifies the power of the carrier waves.

**Intermediate power amplifier**

It amplifies the high frequency carrier signal and sends to the modulator.

**Modulator and Power amplifier**

Here, AF signal and carrier signal are amplitude modulated. Power amplifier amplifies the modulated waves and sends to the transmitting antenna.

**Transmitting antenna**

It converts the modulated waves into electromagnetic waves and transmits into space.

---

### 3.4 FM Radio Transmitter

It is an equipment which transmits the frequency modulated waves.

FM transmission broadcast range lies between 88 MHz and 108 MHz. FM Radio transmitter uses double sideband transmission. The bandwidth of an FM signal is not as straight forward to calculate as that of an AM signal. Taking the example of a typical broadcast FM signal that has a deviation of ±75 kHz and a maximum modulation frequency of 15 kHz, the bandwidth of 98% of the power approximates to $2(75+15) = 180$ kHz. Figure 3.3 shows the block diagram of FM Radio transmitter. It consists of the following stages.

**Microphone**

It converts AF signal into electrical signal, which is sent to an audio pre-amplifier.

**Audio pre-amplifier**

It amplifies the incoming AF signal and feeds to pre-emphasis stage.

**Pre emphasis**

Here AF signal’s amplitude is artificially boosted to improve S/N ratio and sent to the frequency modulator stage.

**Crystal Oscillator**

It produces noiseless high frequency waves and sends to the frequency modulator stage. It uses crystal.

**Frequency modulator**

In this stage, AF signal and RF signal are frequency modulated and sent to RF power amplifier.
CHAPTER 3 Transmitters and Receivers

RF power amplifier
Here, RF waves are amplified and sent to the transmitting antenna.

Transmitting antenna
It converts the modulated waves into electromagnetic waves and transmits into space.

Activity 1
Construct a low power FM transmitter circuit as in the Fig 3.4 and check it with an FM receiver.

FIG 3.4 Low power FM transmitter

FIGURE 3.3 Block diagram of FM Radio transmitter
3.5 Radio Receiver

It is an instrument, which receives the radio signals from the broadcasting stations and reproduce sound.

HISTORY OF RADIO RECEIVER

In 1895, Italian scientist Guglielmo Marconi succeeded in telecommunication, which is called as Radio communication. He proved the wireless telecommunication through Morse code in December 12, 1901 over a distance about 3500 km.

The simplest radio receiver is the crystal radio receiver. It was made by Henrich Hertz German scientist in the year 1907. It was designed to work up to 50 Kilometers. Then, in the year 1909, the Tuned Radio Frequency receiver was made.

Basic Principle

The principle of operation of the radio receivers is more or less similar in all type of radio receivers and is summarized below.

Reception

An aerial is necessary for the reception of radio waves. It receives the radio waves into the receiver.

Selection

It is the ability to select a desired radio station from various radio station. This work is performed by a LC resonant network.

Detection

In this process, radio frequency signals are converted into audio frequency signals. It is performed by a crystal diode.

Reproduction

The conversion of audio signal into sound is called reproduction. It is performed by a speaker.

Abilities of Receivers

The quality and specialty of a radio receiver is determined on the basis of the following abilities.

Sensitivity

It is the ability to produce sufficient audio output even for weak input radio frequency signal. It depends on the R.F. and I.F amplification capabilities.

Selectivity

It is the ability to select only the desired signal or radio station from the signals, which are received by the aerial. It depends on accurate alignment of the tuned circuits. Hence, converter and R.F amplifier are designed in such a way to improve the selectivity. If selectivity increases, frequency and adjacent channels interference of a receiver decreases.

Fidelity

It is the ability to amplify the complete range of audio frequency without loss. It depends upon the design of AF amplifiers.

Stability

It is the ability to produce stable output without variation. AVC circuit is used to produce stability in the sound.
**Signal to Noise ratio**

It is the ratio between the signal and noise. A noise limiter stage is used to improve this quality.

**Types of Radio Receivers**

Generally, the radio receivers are classified into the following two types.

1. TRF radio receiver
2. Superhetrodyne radio receiver

### 3.5.1 TRF Radio receiver

![Fig 3.5 TRF radio receiver](image)

Fig. 3.5 shows the block diagram of a tuned radio frequency receiver. The functions of each block are discussed below:

**RF amplifier**

It is a tuned radio frequency amplifier. It amplifies the radio frequency signal which is selected by antenna.

**Detector**

It is employed between the RF and IF amplifiers. It works as amplitude modulated detector. It converts RF signal into AF signal. In this section, crystal and signal diodes are used.

**AF amplifier**

It amplifies the strength of audio signals. It contains pre-amplifier, driver and output amplifiers. The pre and driver amplifiers are voltage amplifiers. The output amplifier is power amplifier. The speaker converts audio signal into sound.

**Power supply**

It supplies the required voltage to all stages of the receiver. Battery or battery eliminator is used as power supply.

**Merits**

1. It is a simple receiver.
2. Simple circuits are used.
3. Alignment is not necessary.

**Demerits**

1. Sensitivity and selectivity are low.
2. Poor fidelity.
3. Low stability.

### 3.5.2 Superhetrodyne Radio Receiver

This receiver works under the principle of heterodyning. Modern radio receivers are mostly of super heterodyne types. It has converter stage which changes the incoming single into intermediate frequency (IF) signals.

Major Edwin Howard Armstrong was an American inventor, developed FM radio and the super heterodyne receiver system.

Major Armstrong designed a different type of radio of radio receiver in the year 1917. This receiver is known as Super heterodyne (shortly superhet) receiver. It’s sensitivity and selectivity are high. All the modern radio receivers work under the principle of Super heterodyne. In USA, the first regular broadcast began in 1920. In India, first Radio station was established in 23rd July 1927 at Bombay.
Ganged Capacitors

If two variable capacitors are fitted in a common shaft, it is called as Ganged capacitor. One variable capacitor is used to select the desired radio station at the RF stage and the other one is used in oscillator stage to produce the suitable oscillator frequency to the desired radio station. Fig 3.6 shows the connection of two variable capacitors as Gang.

Ganged Tuning

Selecting required radio station using Ganged capacitors is called as Ganged tuning.

Electronic Tuning

Presently, varicap diode is used to select a required radio station in electronic tuning. For that, digital tuning circuits are used.

Principle of Superheterodyne Receiver

The process of beating (mixing) two different signals to produce a new signal is called as Heterodyning. Fig 3.7 shows the block diagram of super heterodyning principle.

3.5.3 Super heterodyning principle

If two different signals are mixed through a transistor, four types of signals are obtained in the output of the transistor. They are

1. First signal \( F_o \)
2. Second signal \( F_s \)
3. Addition of the two signals is represented as \( (F_o + F_s) \)
4. Difference between the two signals is represented as \( (F_o - F_s) \)

Apart from these, an unwanted signal called harmonics is produced due to the mixing of the two signals. Out of them, the difference between the two is taken as intermediate frequency (IF) and the remaining signals are filtered. This is the principle of superheterodyning. The receivers which follow this principle are named as superhet receivers. This principle is used in AM, FM, Communication, Radar and Television receivers.

Merits

1. Good sensitivity and selectivity
2. Good fidelity
3. Good stability

Demerits

1. It needs alignment and tracking
2. Complicated circuits are used
3.5.4 Interferences in Superhet Radio receiver

Generally, Superhet receivers have better selectivity and sensitivity. But, the following two interferences are occurred.

1. Image frequency
2. Adjacent channels interference.

Image frequency and method of rejecting it

If two nearby radio stations being received at a time, this defect is said to be image frequency. Rejecting image frequency depends upon the selectivity of RF stage. It should be rejected before IF stage. Once it enters IF stage, it cannot be eliminated.

Adjacent channel interference

In superhet receiver, when the bandwidth is reduced from required level, this type of interference is developed. When two different radio stations are selected very closely, interference occurs. To eliminate this, low IF signal should be selected. So, in superhet receivers, low intermediate frequency (low IF signal) is selected to avoid both the interferences. In double conversion receivers, these two interferences are eliminated completely, because they use two different IF signals, one is high and the other is low. So a double conversion receiver should have two converters and two IF amplifiers.

3.5.5 AM Radio Receiver

A receiver which receives amplitude modulated radio signals is called amplitude modulated (AM) radio receiver. Figure 3.8 shows the block diagram of AM radio receiver.

RF Amplifier

It consists of an aerial. The aerial receives the electromagnetic waves and convert them into RF electrical signals. This stage amplifies the RF signals obtained from the aerial. Its output signal is coupled with converter stage.

![Block diagram of AM radio receiver](image-url)
**Converter**

It is also known as first detector or frequency changer. It has mixer and local oscillator stages. The local oscillator produces unmodulated radio frequency signals. The mixer stage mixes the oscillator signal and RF signal. In the output of this stage, intermediate frequency (IF) is selected. The value of IF signal is equal to the difference of oscillator and signal frequencies \( IF = F_o - F_s \). The value of IF in AM radio receiver is 455 KHz.

**IF Amplifier**

It amplifies the strength of IF signals to improve the sensitivity. It is a transformer coupled amplifier. Its input has tuned circuit. IF transformers (IFT) are used in it. It employs one or two tuned intermediate frequency amplifiers.

**Detector**

It is also known as demodulator or detector. The signal diodes are used in this stage. It filters the carrier signal and separates the audio signal from the IF signal and AF signal is sent to the audio stage. Diode detectors are used in this type.

**Automatic Volume Control (AVC)**

**Fading**

In radio reception, variations in the signal strength are called fading. The signal received by the antenna varies continuously. Because, the signals reaches the receiving aerial from the transmitting antenna through ionosphere. Since, the density of ionosphere changes continuously, the signal voltage also varies continuously. So, an instable output sound would be produced in the receiver. An automatic volume control (AVC) is employed to eliminate the fading. It controls the volume of the receiver automatically.

**Audio amplifiers**

This stage consists of voltage and power amplifiers. The voltage amplifier is working as pre-amplifier, whereas the power amplifier is working as output amplifier. This stage amplifies the voltage and power of the audio signals. Hence, the fidelity is improved by this stage. Push-pull amplifier is used as output amplifier. The loudspeaker converts the audio signals into sound.

**Power supply**

Power source is supplied through either battery or battery eliminator.

**Uses of AM radio receivers**

It was widely used for communication in the recent past years. After FM receivers are used widely, presently the usage of AM receivers became obsolete.

**3.6 FM Radio Receiver**

A receiver which receives frequency modulated radio signals is called frequency modulation (FM) radio receiver. It is also called as superhet receiver. Fig 3.9 shows the block diagram of FM receiver.
RF Amplifier

It selects the desired RF signals through the aerial. It amplifies the RF signals, by which it improves the selectivity.

Local oscillator

It is a Hartley oscillator. It produces un-modulated radio frequency signals and fed into the mixer.

Mixer

It receives two signals as inputs viz. RF signal and oscillator signal. It mixes them and gives IF signal as output. The value of IF is 10.7 MHz.

IF Amplifier

This is employed between the discriminator and the mixer. It amplifies the IF signal and also improves the sensitivity.

Limiter

It controls the noise pulses which are mixed with signals. It works as a clipper.

AVC

It is an automatic volume control. It controls the volume of the receiver automatically.

Discriminator

It is a demodulator. It separates audio signal from frequency modulated IF signal. Crystal diodes are used as detector diodes. Quadrature detectors are used in IC used circuits.

De-emphasis

Pre-emphasised audio signals are de-emphasised into its original state by using RC network.

Audio amplifier

This stage amplifies the audio frequency signal. It is divided into pre-amplifier, driver, and output amplifier. Pre and driver amplifiers are voltage amplifiers. Output amplifier is a power amplifier. It improves the fidelity.

Power supply

Power source is supplied through either battery or eliminator.

3.6.1 Construction of modern FM receiver

Modern FM receivers use CXA 1619. It has all stages except power supply. It has both AM and FM receiving circuits. Using
a band selector switch, we can select either AM or FM reception. Also it has an audio power amplifier. This IC operates on a 6 volts DC power source. The internal construction of IC CXA 1619 is shown in Figure 3.10.

**3.6.2 Audio amplifier IC**

If the main IC has no audio amplifier, a separate audio section IC is used in modern FM receivers. Most of the radio receivers have IC TBA810/CA810 as audio section.

**Internal construction of IC TBA810/CA810**

Fig 3.11 shows internal construction of audio IC TBA810/CA810. It has both voltage amplifiers and a power amplifier. Its operating voltage is about 6 to 12 volt DC.

**FIG 3.10 Internal construction of CXA 1619 with AF amplifier**

**FIGURE 3.11 Internal construction of audio IC TBA 810 / CA 810**
Important pin details are summarized below:

**Supply voltage**: Pin number 1 should be given positive supply voltage and pin number 9 and 10 should be connected to ground (earth).

**Audio input**: Pin number 8 should be given AF input from volume control center pin.

**Audio output**: Pin number 12 and an earth connection should be connected to speaker.

It has two heat sinks on either side of the IC to reduce heat.

**Advantage of FM receivers**
Clear reception than AM.

**Disadvantage of FM receivers**
It can only be transmitted and received to a shorter distance than AM.

**Uses of FM receivers**
It is widely used for communication and entertainment purpose.

### 3.6.3 Comparison between AM and FM Receivers

The comparison between AM and FM receivers are listed in Table 3.1.

#### 3.6.4 De-emphasis & Limiter

**De-Emphasis**
At the FM receiver, an operation opposite to pre-emphasis is used, known as De-emphasis. The amplitude of high frequency signal is decreased relatively. RC low-pass filter network is used. This network is having a time constant of 75 µs. It also helps to reduce the noise frequency of the signal.

**Limiter**
The amplitude of FM signal should be constant. But, while traveling from transmitter to receiver, fading, absorption and reflection of radio waves produce unwanted variation in the amplitude of signals. Hence, the variations should be removed for clear reception. So, limiter is used for this purpose. It is used prior to discriminator.

It is also known as ‘clipper’. It is similar to IF amplifier which works as a saturated amplifier. In this stage, the input FM Signal is operated between the cut-off point and saturation point of amplifier. Any amplitude variations beyond these points does not reach the output.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>AM Receiver</th>
<th>FM Receiver</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Receives and Processes the AM Signals</td>
<td>Receives and Processes the FM Signals</td>
</tr>
<tr>
<td>2.</td>
<td>Operating frequency range is from 500 kHz to 30 MHz</td>
<td>Operating frequency range is from 88 MHz to 108 MHz</td>
</tr>
<tr>
<td>3.</td>
<td>Intermediate Frequency (IF) value is 455 kHz</td>
<td>Intermediate Frequency (IF) value is 10.7 MHz</td>
</tr>
<tr>
<td>4.</td>
<td>Bandwidth is 10 kHz</td>
<td>Bandwidth is 200 kHz</td>
</tr>
<tr>
<td>5.</td>
<td>Employs detector</td>
<td>Employs discriminator</td>
</tr>
<tr>
<td>6.</td>
<td>Does not employ limiter</td>
<td>Employs limiter</td>
</tr>
<tr>
<td>7.</td>
<td>Interference and distortion are more</td>
<td>Interference and distortion are less.</td>
</tr>
</tbody>
</table>
### 3.6.5 FM Detectors

Generally, three types of detector or discriminator circuits were used in FM receivers. They are,

1. Travis discriminator
2. Foster-Seeley discriminator
3. Ratio detector

But, presently Quadrature detector is used in IC based radio receiver circuits.

#### Quadrature detector

This type of FM detector only requires one coil and some external components, making it ideally suited for use within integrated circuits. In this circuit, using RC phase shift network, 90 degree phase shift of IF signal is produced and mixed with the original signal (signal before phase shift) in a mixer to get the carrier waves removed.

#### Activity 2

Construct an FM receiver on your own using CXA 1619 IC

### 3.6.6 Communication Receivers

It is a special type of superhet receiver which receives code words. For that purpose, it contains Beat Frequency Oscillator. It is also based on the principle of super heterodyning. Two different IF stages are used in it. It is capable of receiving signals in the 2 to 16 MHz range.

### 3.6.7 Digital audio broadcasting (DAB)

Digital Audio broadcasting (DAB) is an advanced radio technology. It provides higher quality sound than FM and has greater SNR. In many countries, DAB stations are broadcast in either Band III (174–240 MHz) or L band (1.452–1.492 GHz). The snapshot of the DAB radio receiver is shown in Figure 3.12.

#### Advantages

1. Crystal clear reception than FM
2. A single DAB station transmits a wide 1500 kHz bandwidth signal that carries from 9 to 12 Channels, from which the listener can choose his/her choice.

#### Disadvantages

1. Incompatible with other types of radio receivers, so that a new DAB receiver must be purchased.
2. High cost radio receiver.

#### Uses of Communication receivers

1. Used in sending telegraph messages, but now became obsolete.
2. Amateur radio communication.
3.6.8 Satellite radio receiver

Radio receivers receiving programs using satellites are called satellite radio receivers.

The basic formatting of satellite radio is identical to terrestrial radio broadcasts, but most of the stations are presented without commercial interruptions. This is due to the fact that satellite radio is subscription-based, just like cable and satellite television. Satellite radio also requires specialized radio receiver just like satellite television. Satellite radio uses the 2.3 GHz S-band in North America. Satellite radio reception can also be received through DTH TV Satellite set-top box.

Advantages

1. Crystal clear reception than FM.
2. No commercial advertisements.

Disadvantages

1. Incompatible with other types of radio receivers, so that a new satellite receiver must be purchased.
2. High cost radio receiver.
3. Subscription should be paid for receiving satellite radio reception.

Alignment of Radio receivers

Alignment is a process which makes a receiver works with accuracy.

Since most of the modern digital tuning receivers use crystal, which do not need alignment for receivers. But in some receivers, variable capacitors and button trimmers are used. It needs small adjustment, whenever necessary.

3.6.9 Testing of Radio receivers

Static Test

It is also known as primary test. It is the test which is done before giving the supply to the receiver.

Dynamic test

It is also known as secondary test. It is the test which is done after giving supply to the receiver. This test is nothing but measurement of voltage and current.

Soak Test

After servicing a receiver we should test it by putting in ‘ON’ condition for long hours to confirm whether it operates well or not. This type of testing is called as Soak test.

Vibration Test

After servicing an intermittently working receiver, we should vibrate it slightly to confirm whether it is working properly.
or not. This method of testing is called as Vibration test. Mostly, this test is performed after resoldering of dry soldered components in the receiver.

Signal Test
It is also called as signal injection. It is the test which is used to check the stages by giving external signals. Signal injectors or signal generators are used for this purpose. Faulty stages can be identified by this test.

3.7 Servicing of FM Radio receivers

Trouble shooting techniques
It includes both the fault finding and its rectification. It is a sensitive job. It requires circuit diagram, proper tools, test equipment and identical components.

Precautions to be taken before servicing receivers
1. First, note the name, model, number of bands and stages in the receiver. Then, list the number of transistors and integrated circuits used in the circuit.
2. To prevent shock, the receiver should not be opened until the mains-cord is unplugged.
3. After opening the receiver, the missed and burnt components (parts) should be observed.
4. After giving the supply to the receiver, observe for any spark, smoke or burning smell.

Types of faults
The defects in a receiver can commonly be classified into two types.
1. Live fault
2. Dead fault

Live fault
If some sound is heard from a faulty radio in ‘ON’ condition, but receiver not working properly, it is termed as ‘Live fault’.

Dead fault
If no sound is heard even after a radio receiver is in ‘ON’ condition, it is said to be ‘Dead Fault’.

3.7.1 Rectification

Dead fault
1. Check power cord.
2. Check on-off switch & AC fuse.
3. Check for defective Power transformer.
4. Check for Defective Bridge diodes.
5. Check the main filter capacitor.
6. Check the second B+ filter capacitor.
7. Check for dry soldering and copper track cut.
8. Check B+ to Audio IC like TBA 810/ CA 810 for testing the condition of the IC.
9. Check B+ to CXA 1619 IC for ensuring its reliability.

Live faults
Distorted audio
1. Check speaker.
2. Check the volume control.
3. Check for defective filter capacitor.
4. Check for faulty series capacitor connected with speaker.
5. Check for faulty Audio IC TBA 810 or defective CXA 1619 IC.

Low volume
1. Check speaker.
2. Check the volume control.
3. Check for low B+.
4. Check for faulty series capacitor connected with speaker.
5. Check for dry soldering or copper track cut.
6. Check for faulty Audio IC TBA 810.
7. Check for defective CXA 1619.

**Noise only: No signal (Radio stations not received)**
1. Ganged capacitor may be faulty
2. Faulty trimmer.
3. Faulty CXA 1619 IC

**Hum with distorted audio**
This fault occurs due to pulsating DC supplied to the receiver.
1. Defective power transformer.
2. Defective diodes.
3. Defective main filter capacitor.

### 3.8 TV Transmission And Reception

**Introduction - TV transmission principle**
Television means “To see from a distance”. Video and audio signals are transmitted from TV transmitter and is viewed in various places using TV receivers.

-History of Television

The first demonstration of actual television was given by J.L.Baird in UK and C.F.Jenkins in USA around 1927. However a complete shape of television was developed by V.K.Zworykin and T.Farnsworth. We could understand that prior to the development of Television, the camera tube would have been developed, since any image shown in the TV should be captured through the camera first. Of course the camera tube was also developed by Zworykin. Initially TV was developed through vacuum tubes then by semiconductor devices like transistors and ICs. In this fast developing world, the Television is playing important role in Communication.

**3.8.1 Scanning**
Scanning can be compared to our eyes. While reading a book, the eye starts to read from left end and move towards right end. On finishing the right end, automatically the eye will come to the next line i.e., left end of the next line and starts to read towards right end and this will continue. As like this, the same activity should be happened in camera tube and television picture tube. When this is happened in the camera tube the image falls on the camera tube is divided into many parts and these
CHAPTER 3  Transmitters and Receivers

separated parts are once again framed as a picture in the television picture tube. This is achieved through the process called scanning.

The electron ray from the electron gun moved from left to right and right to left and top to bottom and bottom to top of the television screen and camera tube is known as Scanning as shown in Fig. 3.14.

To form a picture on the television screen we need 15625 scanning lines per second. Since the scanning speed is very high, it is not visible to our eyes. Because the eye's persistent of vision is 1/16th of a second. Thus, if the scanning rate per second is made greater than sixteen, the eye is not able to integrate the changing levels of brightness in the scene. The motion picture on the television is easily compared with the screening of cinema. In cinema projection, 24 picture frames should be crossed in front of the camera in one second. If there is any change in this, the action may not be real.

1. The electron ray which moves from left to right alone is visible to our eyes, since it alone carries the signal. This line is termed as Trace line.

2. When the ray is moved from right to left, it don’t have any signal in it and it is blanked by applying blanking pulses. This line is termed as Retrace line.

Sequential Scanning or Progressive Scanning

The electron ray starts to scan from line one and follow continuously (trace line and retrace line) making full scanning of 15625 lines in 25 frames in one second is called as progressive scanning as shown in Fig. 3.15. In this method, there was an unavoidable problem occurred.

Flicker Effect

Although the rate of 24 frames per second in motion pictures and that of scanning 25 frames per second in television pictures is enough to cause an illusion of continuity, they are not rapid enough to allow the brightness of one picture or frame to blend smoothly into the next through the time, when the screen is blanked between successive frames. This results in a definite flicker of light that is very annoying to the observer, when the screen is made alternately bright and dark. This problem can be solved in motion pictures by showing each picture twice, so that 48 views of the scene are shown per second.

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although there are still the same 24 frames per second. As a result of the increased blanking rate, flicker is eliminated.

### 3.8.2 Interlaced Scanning

In television pictures, effective rate of 50 vertical scenes per second is utilized to reduce flicker. This is accomplished by increasing the downward rate of travel of the scanning electron beam, so that every alternate line gets scanned instead of every successive line. Then, when the beam reaches the bottom of the picture frame, it quickly returns to the top to scan those lines that were missed in the previous scanning. Thus, the total number of lines are divided into two groups called ‘Fields’. Each field is scanned alternatively. This method of scanning is known as interlaced scanning and is illustrated in the Figs 3.16 and 3.17. It reduces flicker to an acceptable level, since the area of the screen is covered at twice the start of a rate. This is like reading alternate lines of a page from top to bottom once and then going back to read the remaining lines down to the bottom.

In the 625 line TV system, for successful interlaced scanning, the 625 lines of each frame or picture are divided into sets of 312.5 lines and each set is scanned alternately to cover the entire picture area. To achieve this the horizontal sweep oscillator is made to work at a frequency of 15625 Hz (15625/25 = 625 lines), but the vertical sweep circuit is run at a frequency of 50 instead of 25 Hz. Note that the beam is deflected from top to bottom in half of the time and the horizontal oscillator is still operating at 15625Hz, only half the total lines, i.e. 312.5 (625/2=312.5) get scanned during each vertical sweep. Since the first field ends in a half line and the second field commences at middle of the line on the top of the target plate or screen (see Fig 8.17), the beam is able to scan the remaining 312.5 alternate lines during its downward journey. Thus, the beam scans 625 lines (312.5 X 2=625) per frame at the scan rate of 15625 lines (312.5 × 50 =15625) per second. Therefore, with interlaced scanning the flicker effect is eliminated without increasing the speed of scanning, which in turn does not need any increase in the channel bandwidth.

**Horizontal Sync & Blanking Pulse Detail**

The line period for one complete horizontal line is 64 μs. In that, trace line period is 52 μs and retrace time period is 12 μs.
Vertical Sync and blanking pulse detail

The time period of one field is 20 ms. In this, vertical the time taken for trace is 18.72 ms and 1.28 ms is for retrace.

### 3.8.3 Colour Picture tube

**Picture tube converts electrical signal into picture.**

Colour picture tube has three cathodes viz., Red, Green and Blue. Further, it has three filaments, three control grids and three accelerating grids and three focussing grids and one final anode. A particular colour electron beam strikes on the phosphor stripes and makes primary and secondary colours as shown in Figure 3.18.

![Figure 3.18](image-url)  
**Figure 3.18 Colour Picture Tube Technology**

#### Deflection Yoke

The physical placement of the two pairs of coils around the neck of the picture tube and the orientation of the magnetic fields produced by them are shown in Fig 3.9. In combination, the vertical and horizontal deflection coils are called the ‘Yoke’. This yoke is fixed outside and close to the neck of the tube just before it begins to flare out.

![Figure 3.19](image-url)  
**Figure 3.19 Deflection yoke**

- Deflection yoke works using the principle of electromagnetic deflection whereas in a CRO electrostatic deflection is used.

### 3.9 Camera Tube

A Television camera tube may be called the eye of a Television system. It converts an optical image into a sequence of electrical signal.
Photo emission
Converting optical images into electrical signal is called as photo emission.

Photo conductivity
The resistance value of target material varies when exposed to light. When resistance value varies, the conductivity also varies. This is known as photo conductivity.

There are four types of camera tubes.
1. Iconoscope
2. Image Orthicon
3. Vidicon
4. Plumbicon

The first developed storage type of camera tube was 'Iconoscope'. Now, it has been replaced by Image-Orthicon (IO) of its high light sensitivity, stability and high quality picture capabilities. The light sensitivity is the ratio of the signal output to the incident illumination. IO uses photo emissive principle.

Next developed camera tube was the Vidicon and is much simpler in operation. Similar to the Vidicon is another tube known as Plumbicon developed by Philips of Holland. Both tubes follow the principle of photo conductivity.

3.9.1 Characteristics of Camera tubes

Light transfer characteristics
It is nothing but, the output current of the camera tube, which depends upon the light falls on the glass face plate.

Spectral Response
The camera tube could able to sense the light variation that our eyes could able sense.

Sensitivity
It is the capacity of converting video signal of very small image. The camera tube should have a required level of sensitivity.

Dark current
The output signal received, when no light falls on the glass face plate, is called Dark current.

Lag characteristics
When the camera tube could not able to sense the high speed light variation, it is known as Lag characteristics.

Resolving Power
Sensing the White and Black portions of the picture and giving the output accordingly is known as Resolving power.

Mixing of colours
Red, Green and Blue are primary colours. Mixing these primary colours results in all the other colors viz., Magenta, Cyan and yellow, called as complementary colors.

Mixing of colors is done in two methods. a) Additive mixing b) Subtractive mixing

Additive mixing
This process is performed by adding (mixing) primary colours and as a result complementary colours are produced as shown in Figure 3.20.

FIGURE 3.20 Additive mixing
**Percentage of mixing**
30% Red + 59% Green = Yellow (89%)
30% Red + 11% Blue = Magenta (41%)
11% Blue + 59% Green = Cyan (70%)
30% R + 59% G + 11% B = White (100%)

**Subtractive mixing**

It is performed by subtracting (filtering) colours from white as shown in Fig 3.21.
White – Blue – Green = Red
White – Green = Magenta
White – Green – Red = Blue
White – Blue = Yellow
White – Blue – Red = Green
White – Red = Cyan

If we combine hue and saturation together, we get Chroma or chrominance signal, which we can define as the overall value of the color. If we remove all chrominance information, we have only gray scale signal.

**Gray scale**

It is a range of gray (or grey) shades from white to black. The gray scale is luminance signal (Monochrome signal).

Color video signal has 2 basic components such as the luminance information (brightness) and the chroma information (color).

**3.9.2 Colour camera tube principle**

**Basic colour camera tube principle**

Figure 3.22 illustrates the working principle of a Colour Camera Tube. Dichroic mirrors are used to split the white light from the lens into the 3 separate colors and sent to the color tubes in the camera. Zinc sulphide and cryolite are coated in the glass plate to form dichroic mirrors. Dichroic mirrors reflects or allow particular colour light. Thus, Red, Green and Blue colour light are fed to relevant camera tube. RGB Camera tubes convert light into electrical video signal.

The individual color signals from the tubes are encoded (modulated) and added to the luminance signals generated by a matrix circuit. Finally, sync pulses are also added. The combination of chrominance signal, luminance signal and sync pulses are called as Composite Colour Video Signal (CCVS).
3.10 TV Transmitter

Figure 3.23 depicts the complete block diagram of a TV transmitter. The individual functions of the major sections are briefly explained here:

**TV Camera & Composite Video Signal**

Any program that is produced in the studio must be captured by the camera and converted into a signal. In this stage, deflection and synchronizing pulses are also produced. The deflection pulses are sent to the camera and the synchronizing pulses are sent to the camera amplifier. In camera amplifier, the signals from camera tube and sync pulses are attached. It is amplified and fixed to certain level. This is composite video signal.

**Video amplifier and monitor**

The composite video signal produced is amplified to the required level. The quality of the signal is monitored through the monitor placed.

**Distributor & Switcher**

The signal from other transmission studios are received here and amplified. The quality of the signal is monitored by a monitoring room.

**Modulation and Transmission Section**

In TV transmission, video waves are amplitude modulated and sound waves are frequency modulated. Hence, the respective carrier waves are generated through crystal oscillators are fed to the modulators. Vestigial sideband transmission is used in TV broadcasting. The modulations are carried over and sent to the transmitter for transmission.

**Types of TV transmission**

There are three types of color TV transmission

1. Phase Alternation by Line (PAL, Germany)
2. National Television Systems Committee (NTSC, America)
3. Sequential Colour And Memory (SECAM, France)
FIGURE 3.23 TV Transmitter block diagram
**PAL encoder**

In PAL encoder, the RGB signals are mixed and formed as Y signal (30% R + 59% G + 11% B = White (100%)). B-Y (U signal) is derived by mixing B and Y and R-Y (V signal) is derived by mixing R and Y. These U and V signals are called as colour difference signals. G-Y signal is not used to transmit, because it takes a lot of bandwidth, it will be retrieved from mixing of R-Y and B-Y signals in the receiver.

U signal is modulated by colour subcarrier frequency of 4.43 MHz with 90° shift. It is referred as FU. V signal is modulated by the colour subcarrier frequency of 4.43 MHz with 0 or 180° shift. It is referred as ± Fv. Both are added in a matrix circuit and given to final matrix. In final matrix circuit, delayed Y, colour signals, sync and blanking signals are given to form as Composite colour video signal.

**Antenna**

It receives RF signals and converts into electrical signal and then fed to the tuner.

**Tuner**

TV receiver also uses super heterodyning principle. It has RF amplifier, mixer and local oscillator, which generate the IF output.

**Common IF Amplifier**

This stage filters noise and amplifies the two IF signals. Video IF is 38.9 MHz and sound IF is 33.4 MHz.

**Video Detector**

It filters the carrier signal and separates the composite colour video signal.

**Video section**

PAL decoder detects the chrominance signals U and V. It is further mixed to get R-Y, B-Y and G-Y signals. Adder circuit combines these signals with delayed Y signal to get RGB signal. RGB signals are amplified to a large extent by three separate video
amplifiers and are fed to the corresponding cathodes of the picture tube.

**Colour Picture Tube**

Here, RGB signals are converted into electron beam by the RGB cathodes and then scanned line by line of the picture using deflection stage. The corresponding RGB stripes are illuminated by the electrons. Thus, colour scenes can be seen in the screen.

**Automatic Gain Control (AGC)**

AGC circuit controls gain of RF and IF stages to deliver almost constant signal gain to the receiver, despite changes in the signal gain from TV station.

**Deflection Section**

This section has two sub divisions such as 1) Horizontal deflection 2) Vertical deflection

Horizontal section deflects the electron beam from the RGB cathodes horizontally to get line by line picture. Vertical section creates frame by frame (Fields) of picture by deflecting the beam vertically.

**Sound section**

Inter-carrier sound IF of 5.5 MHz is amplified and detected to get audio signal. Audio signal is amplified and fed to the Speaker.

**Speaker**

It converts audio signal into sound.

**Power supply**

It gives regulated voltage to the TV receiver. Mostly, Switched Mode Power Supply circuit (SMPS) is used.
screens. Usually, the colour video signal is in analogous state, which is converted into 8 or 10 bits digital data signal using Analog to digital converter circuit. That is, Red signal is converted into $R_0$, $R_1$, $R_2$, $R_3$, $R_4$, $R_5$, $R_6$, and $R_7$. Green is converted into $G_0$ to $G_7$ and Blue is converted into $B_0$ to $B_7$.

Over 10 lakh of MOSFETs (Thin film transistors TFT) are used in the LCD panel. Figure 3.27 shows a single thin film MOSFET illuminating a single pixel in LCD screen. The MOSFET’s gate is controlled by Timing control circuit (TCON). Source is given the digital data signal. The drain is earthed. The corresponding MOSFET works when RGB data is given and makes the sub pixel (dot) RGB to be illuminated. This is called as addressing of sub pixels.

**FIGURE 3.26 PAL decoder**

**FIGURE 3.27** A single thin film MOSFET to illuminate a single pixel (dot)

### 3.11 TV Receivers

This 21st Century witnessed major change in television technology. The prime and important device which is essential to convert the video signal into visual picture is the CRT tube that has tremendous developments such as LCD, LED, QLED, etc. These devices have so many advantages like handy, easy to handle, consuming less power, giving better picture quality, which ultimately replaced the traditional CRT TV screens. Let us study about LCD and LED TV screens in this Section.

#### 3.11.1 LCD (Liquid Crystal Display) Receivers

Modern colour TV receivers use LCD screens instead of Cathode ray tube
3.11.2 LED (Light Emitting Diode) TV

If Light emitting diodes are used to backlit an LCD screen, then this type of TV receiver is called as LED TV. This type of backlight is a series of LEDs placed behind the screen as shown in Fig 3.30. LEDs are more energy efficient and a lot smaller than a CCFL, enabling a thinner television screen.
Plasma Display
Plasma means semi solid form. A plasma display panel is a type of flat panel display common to large TV displays of 30 inches (76 cm) or larger as shown in Figure 3.31. They are called “plasma” displays because they use small cells containing electrically charged ionized gases, which are plasmas. Plasma screens work by exciting tiny pockets of gas (Xenon and Neon), changing them to a plasma state. In that state, the electrons of that gas emit ultraviolet light, which is not visible to the human eye. The ultraviolet light is then absorbed and re-emitted into the visible spectrum of light by the phosphor inside each cell. Each pixel consists of three sub pixels: one red, one blue, and one green. The more excited the gas, the brighter the color produced.
3.11.3 Quantum LED screen (QLED)

QLED refers to an LED TV using quantum dots to enhance its performance and that TV is called as QLED TV.

Quantum dots don’t directly emit the colors we see and the colors are spread on a piece of film that acts almost as a filter within an LED TV panel as shown in Fig 3.32. LED backlights beam pass through this film and the light is refined to an ideal color temperature. This enhances the brightness and color of the pixel.

3.11.4 OLED TV

OLED stands for Organic Light-Emitting Diode. OLEDs are made with organic compounds that light up when fed electricity, hence the term emissive display. A single OLED is the size of one pixel, so it takes millions of them lighting up and shutting off independently to fill the TV screen. It requires no backlight. Because of this flexibility, when an OLED TV’s pixels are shut off, they are completely off and appear completely black. While QLED TVs can be made very thin, OLED TVs can be made even thinner, and even flexible. Figure 3.33 shows a typical OLED TV.

FIGURE 3.32 QLED TV Display

FIG 3.31 Plasma display
Resolution refers to the number of pixels that forms the picture on the TV. It is termed in rows and columns. A single pixel or discrete picture element consists of a tiny dot on the screen. In today’s TVs, there are one million to eight million such dots approximately. To look very closely or using a magnifying glass, these pixel can be perceived. Higher the number of pixels, resolution, i.e., clarity of the picture increases.

Three types of high definition LED TV systems are available.

1. High Definition 1024 × 1080 (rows × columns) = 11,05,920 pixels.
2. Full High Definition 1920 × 1080 = 20,73,600 pixels.
3. Ultra High definition or 4 K resolution 3840 × 2160 = 82,94,400 pixels.

3.11.5 Servicing of LED TV Receivers

Symptom: No light on the screen; sound ok.
Show a torch light on the display. If video is seen in that particular area.

If fault is in LCD TV
1. Fault is with inverter circuit.
2. CCFL may be defective.

If fault is in LED TV
1. Open the back cover of LED TV and switch ON the TV. If white LED array does not glow, check the supply voltage given to LED array.
2. Check each LED separately.
3. Replace the defective LEDs.
LEARNING OUTCOME

At the end of this chapter, the student could understand working principles of
- AM and FM Radio transmission
- Working principles of AM and FM Radio receiver
- Various Radio & TV fault finding techniques
- Working principles of TV transmission and reception
- The principles of LCD and LED TV panels

GLOSSARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower side band</td>
<td>The sideband lower in frequency than the transmitter’s carrier</td>
</tr>
<tr>
<td>Upper side band</td>
<td>The sideband higher in frequency than the transmitter carrier</td>
</tr>
<tr>
<td>Fading</td>
<td>Gradually grow faint and disappear</td>
</tr>
<tr>
<td>Alignment</td>
<td>Adjusting all of the tuned circuits to the correct frequency</td>
</tr>
<tr>
<td>Scanning</td>
<td>It is the process by which an electron beam spot is made to move across perfect angular area</td>
</tr>
<tr>
<td>Flicker</td>
<td>It is a visible change in brightness between cycles displayed on video displays</td>
</tr>
<tr>
<td>High definition</td>
<td>Providing images that show a lot of detail very clearly</td>
</tr>
<tr>
<td>Remote control</td>
<td>Equipment that we use for controlling television system from a short distance</td>
</tr>
<tr>
<td>Tuner</td>
<td>The part of a radio or television that receives broadcast signals</td>
</tr>
</tbody>
</table>

QUESTIONS

Part – A (1 Mark)

1. Choose the correct answer

   1. The bandwidth of AM transmission is ______
      (a) 5 kHz      (b) 10 kHz      (c) 20 kHz    (d) 100 kHz
   2. AM broadcast range is from ______
      (a) 88 MHz – 108 MHz      (b) 540 kHz – 30 MHz

   3. The bandwidth of FM transmission is ________
      (a) 10 kHz      (b) 20 kHz      (c) 100 kHz    (d) 200 kHz
4. FM broadcast range is from ______
   (a) 88 MHz – 108 MHz
   (b) 100 kHz – 30 MHz
   (c) 500 kHz to 5000 KHz
   (d) 200 kHz – 200 MHz

5. First radio station was established in __________
   (a) Chennai    (b) Mumbai
   (c) Delhi      (d) Calcutta

6. The intermediate frequency of AM radio receiver is ______
   (a) 10 kHz    (b) 100 kHz
   (c) 455 kHz   (d) 445 kHz

7. The intermediate frequency of FM radio receiver is ______
   (a) 10.7 MHz  (b) 10.2 MHz
   (c) 15.5 MHz  (d) 13.5 MHz

8. Which radio receiver is used double conversion ________.
   (a) Tune Radio frequency receiver
   (b) Amplitude modulated radio receiver
   (c) Frequency modulated radio receiver
   (d) Communication radio receiver

9. If no sound is heard even after a radio receiver is connection, it is said to be______
   (a) Live fault
   (b) Dead fault
   (c) Hum fault
   (d) Intermediate fault

10. Frame frequency of Television receiver is _____.
    (a) 25 Hz        (b) 50 Hz
    (c) 625 Hz      (d) 15625 Hz

11. Horizontal frequency of television receiver is ____________.
    (a) 25 Hz        (b) 50 Hz
    (c) 625 Hz      (d) 15625 Hz

12. The line period for one complete horizontal line is __________.
    (a) 64 µs        (b) 12 µs
    (c) 54 µs      (d) 32 µs

13. Each pixel consists of ______ sub pixels
    (a) One         (b) Two
    (c) Three       (d) Four

14. How many MOSFETs are used in an LED TV screen approximately?
    a) 1000       b) 10
    c) 100        d) 10,000

15. In an 8 bit LED TV, Red colour signal is converted into _____ digital signals.
    a) R₀ to R₇
    b) R₀ to R₁
    c) R₀ to R₂
    d) R₀ to R₃

16. CCFL means
    a) Colour coded Fluorescent lamp
    b) Cold cathode filament light
    c) Cold-cathode fluorescent lamp
    d) Colour controlled filament lamp

17. What gases are used in Plasma display?
    a) Oxygen and carbon mono oxide
    b) Xenon and Neon
    c) Hydrogen and helium
    d) Nitrogen and helium
Part – B  (3 Marks)

II  Answer in one or two sentences
1. What are the types of transmission?
2. What is sideband?
4. What is buffer amplifier?
5. What are the basic principles of radio receiver?
6. What is double conversion?
7. What are the advantages and disadvantages of digital audio broadcasting?
8. What are the precautions that should be taken before servicing receivers?
9. Give two reasons for hum in receiver
10. What is meant by scanning?
11. Write any three types of camera tube
12. What is resolving power?
13. What are the three types of resolution of High definition LED TV systems?
14. What is addressing of a sub pixel?

Part – C  (5 Marks)

III  Answer in a paragraph
1. Describe the various abilities of radio receiver.
2. Draw and explain the block diagram of TRF receiver.
3. Explain about the principle of Superheterodyne receiver.
4. Write the difference between AM and FM receiver.
5. Write notes about colour picture tube.
6. What are the characteristics of Camera tube?
7. Explain how each sub pixel RGB is addressed in an LED TV?
8. Explain briefly LCD TV in terms of backlight.
9. Explain LED TV in terms of backlight.
10. Explain the construction of Q LED screen.
11. In a defective LCD/LED TV, when we show a torchlight on the display, if video is seen in that particular area, what are the probable defects in the TV receiver?

Part – D  (10 Marks)

1. Draw and explain the block diagram of AM radio transmitter.
2. Draw and explain the block diagram of FM receiver.
3. What are the reasons for dead fault in radio receiver?
4. Explain colour camera tube principle with diagram.
5. Explain about Television transmitter.
6. Explain how an LED panel works using TCON and gate driver circuits?
7. Explain about plasma display.

ANSWERS
1. (a)  2. (d)  3. (a)  4. (c)  5. (c)  6. (d)  7. (a)  8. (c)  9. (b)  10. (b)  11. (d)  12. (a)  13. (c)  14. (d)  15. (a)  16. (c)  17. (b)
Communication Devices and their Technologies

Learning Objective

In this chapter, a student can understand the working principle of the following communication devices:

- Pagers
- Walkie Talkies
- Cell Phones

Content

4.1 Transmission Modes
4.2 Half Duplex
4.3 Full Duplex
4.4 Cell phones
4.5 Working principle of a Cell phone
4.6 Generation of Cell phone Technologies
4.7 Other Special Technologies
4.8 Types of Cell phone Applications
4.9 Benefits of Hexagons used in call coverage of a cellular network
4.10 Parts of Cell phone
4.11 Cell phone functions
4.12 Uses of Cell phones
4.13 Advantages and Disadvantages of cell phones
4.14 Cell Phone Parts
4.15 Cell Phone Dictionary

Introduction

Any device used to transfer information is called a communication device. Human beings have been enjoying the benefit of communication devices for the past 100 years. The first communication tool developed by human is the telegraph at the end of 19th century.

Scientist Samuel F.B. Morse was the first person, who developed the first communication machine called Telegraph.

The technology used in Telegraph to transfer information from one end to other is called Morse-Code. Then, Alexander Graham Bell developed the first phone to transfer the sound. Subsequently, the world witnessed the arrival of Radio invented by Marconi. First Television broadcast happened in the year 1928 in New York, America. The later part of the 20th Century (1970 – 80) witnessed the arrival of Cell phone. During the 21st century, the cell phone is taking over the World.
Cell phones are powerful, portable and modern personal communication devices with numerous useful features. The characteristics of the modern device are smaller, lighter and having more functionality. Smart phone is one type of cell phone with extra computing functionality and connectivity capabilities. It enhances communication and allows the user to download and install application.

**THINK ABOUT THIS**
Do you know your mobile phone is a smart phone or a Non-smart phone?

### 4.1 Transmission Modes

Transmission is the backbone of all communication devices. There are three modes of transmission and is categorized in the block diagram shown in Figure 4.1

<table>
<thead>
<tr>
<th>TRANSMISSION MODES</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIMPLEX</td>
</tr>
<tr>
<td>HALF DUPLEX</td>
</tr>
<tr>
<td>FULL DUPLEX</td>
</tr>
</tbody>
</table>

**FIGURE 4.1** Different Mode of Transmission

Transmission modes describe the direction of flow of signal between two connected devices. The main differences among the three modes are given here. In a Simplex mode of transmission the communication is unidirectional, whereas in Half Duplex mode of transmission, the communication is two directional and the channel is alternatively used by the connected devices. On the other hand, in the Full Duplex mode of transmission, the communication is bi-directional and the channel is used by both the connected devices simultaneously.

#### 4.1.1 Simplex

In a Simplex transmission mode, the communication between the sender and receiver occurs only in one direction. That means, the sender can only transmit the data and receive the data. The receiver cannot reply in reverse to the sender. Simplex is like a one-way road in which the traffic moves only in one direction, no vehicle from opposite direction is allowed to enter. The entire channel capacity is utilized by the sender. The best example for Simplex transmission is Pager.

**FIGURE 4.2** Front view of a Pager.

The Simplex transmission mode can be better understand with an example of electronic device, called Pager as shown in Figure 4.2. A pager is a small telecommunication device that receives alert signals and/or short messages. A miniature, short range wireless receiver captures a message, usually accompanied by a beep. So, the device is known as “beeper”. A pager consists a miniature keyboard and a Liquid Crystal Display (LCD) screen that can display several lines of text and/or simple graphics having the size of a pocket calculator. This instrument is not in use today.

#### 4.2 Half Duplex

In a Half-Duplex transmission mode, the communication between sender and receiver occurs and both can transmit and receive the information. But, only one is allowed to transmit at a time. Half-Duplex is still a one-way road, in which a vehicle travelling in opposite direction of the traffic has to wait till the road is empty.
The entire channel capacity is utilized by the transmitter, transmitting at the particular time.

Half-Duplex can be understood with an example of Walkie-Talkies. As the speaker at both the end of Walkie-talkies can speak, but they have to speak one by one. Both cannot speak simultaneously.

Walkie-Talkie was invented in 1937, by Canadian Donald Hings (1907-2004) and around the same time by American inventor Alfred Gross (1918-2000). Both men saw their invention developed for military use during World War-II.

**WALKIE-TALKIE USING FREQUENCY MODULATION**

A walkie-talkie is a radio communication device that transmits and receives voices through radio channels. The physical body looks similar to that of a cordless phone and contains

4.2.1 Walkie-Talkie

Walkie-talkie is a hand-held two-way radio transceiver based on the principle of Half-Duplex communication. Multiple Walkie-talkies use a single radio channel, i.e., only one radio on the channel can transmit at a time, although any number can listen. The transceiver is normally in the receiver mode. When the user wants to talk, he/she presses a “Push-To-Talk” (PTT) button that turn-off the receiver and turn-on the transmitter. Typical Walkie-talkies resemble a telephone handset, possibly slightly larger but, still a single unit with an antenna mounted on the top of the unit. In the case of the cell phone, the earpiece is only loud enough to be heard by the user, whereas a Walkie-talkie has a built-in speaker that can be used to hear the user’s immediate nearby region. Hand-held transceivers may be used to communicate between each other, or to vehicle mounted base stations.

Walkie-Talkies work up to 27.2 Kilometres range. Obviously, this distance is dramatically reduced by obstacles such as buildings and mountains.

**FIGURE 4.4** Typical control of Transmitter

Microphone, speaker, antenna and the Push-To-Talk button. It works on batteries and is one of the easiest modes of communication between people of set distance from each other. A transmitter is a unit is shown in Figure 4.4 that generates an RF signal, when power and control are applied along with audio. A transceiver is a system that contains transmitter, receiver, antenna control, power supply, and switching component as shown in Figure 4.5.
any adverse effect on the audio, since the DC resistance of the dynamic element is usually less than 150 ohms and the voltage across the element is less than a volt.

**PTT Control**

The circuit shown in Figure 4.7 describes the operating principle of hand held PTT circuit.

![Figure 4.7 Hand-held PTT circuit](image)

When the PTT button is activated, one or two relays close. One relay mutes the receiver and enables the transmitter. Another relay switches the antenna from the receiver to the transmitter mode. The reason for using the two relays is that one relay switches power and the other relay switches the antenna from the receiver to the transmitter. Microphone audio is applied to the transmitter as modulated signal.

**Microphone**

In Walkie-Talkie, Electrets condenser is used as a microphone, which is shown in Figure 4.6. This is a small condenser microphone with a miniature amplifier inside the element. The amplifier is used to enhance the power of the signal to drive the transmitter. The audio signal outputted on the diaphragm is converted into a small electrical signal, which appears at the junction of the resister and capacitor.

![Figure 4.6 Electret Condenser using circuit](image)
Walkie-talkies are Half-Duplex devices not like mobile phones. Which means only one can talk other can listen at a same time. Now what happened if both the person tried to talk simultaneously? Channel got jammed and no one can able to listen. So, Walkie-talkie users often follow this as a protocol whenever a person completes his talking he said “over” and “over & out”.

This circuit is the example of interfacing external equipment to single line control transceivers.

Wi-Fi and Bluetooth technology allows duplex mode which means that transmission and reception can occur simultaneously. The transmission is always on and the power of such devices is in milli-watts (MW). Very high power will cause the device to heat up quickly and would drain out the battery. Less power means that the transmission range is also very short (around 10 meters). Walkie-talkies work on a Half-Duplex channel, the power range depends on the model opted and it can range from 2–7 Watts and accordingly the transmission range lies anywhere between 2–8 kilo-meters. All Walkie-talkies need a frequency bandwidth to work; these devices are work on the free range allowed by the government (27MHz). This band interferes with the noise generated by the electronic gadgets like computer monitors, generators and two wheeler engines.

**Transmitter and Receiver**

An electronic gate is used to transmit the signal to the antenna. The receiver is always closed, when the transmitter is on. The transmitter end user always says “Roger” or “Over” to mark the end of the sent signal and releases the “push-To-Talk” button before the receiver starts communicating.

Figure 4.9 shows the parts of the Walkie-Talkie hand-set and their functions are summarized below:

**4.2.2 Parts of a Walkie-Talkie**

1. **ANTENNA**
   Sends and receives radio waves
2. **LCD DISPLAY**
   Shows channel number, battery life etc.,
3. **MONITOR**
   Switches the Walkie-talkie to monitoring mode so it can be used as a listening device or baby monitor.
4. **MENU SELECT BUTTONS**
   Marked with plus (+) and minus (-) symbols
5. **MENU BUTTON**
   Used for changing functions and settings. There is a provision to lock...
the keypad to prevent the channel or other settings from changing accidentally while the radio is in the user's pocket.

6. LOUD SPEAKER
   For making the audible sound.

7. PUSH-TO-TALK BUTTON (PTT)

8. ON/OFF switch and volume control

9. LED indicator light shows when channels are busy

10. MICROPHONE
    Unlike some models, Walkie-talkie has separate Loudspeaker and Microphone.

11. TRANSMIT CALL TONE
    This sends a tone signal to other radios on the same channel alerting them that the user wants to talk.

Applications

1. Military and Police organizations use the handheld radios for variety of purposes.
2. These are widely used among amateur radio operators

Advantages

1. These are robust, easy-to-use, and simple.
2. Lots of people need to listen and only needs to talk at once.

Disadvantages

1. The Analog units are most inexpensive
2. They are not designed for communication over longer ranges.
3. Users are hearing additional noises on the two-way radios or other conversations (interference with radios)
4. The device will stop working when the battery runs down.
5. Discrete communication is the problem of the device. Normally when someone transmits a message everyone can hear it.

4.3 Full Duplex

In a Full-duplex transmission mode shown in figure 4.10, the communication between the sender and the receiver occurs, simultaneously. The duplex transmission mode is like a two-way road in which traffic can flow in both the direction at the same time. Here, the entire capacity of the channel is shared by both the transmitted signal, travelling in opposite directions by sharing the channel capacity in two different ways. In this mode of communication, the user physically separates the link in two parts, viz. one for sending and other
TABLE 4.1 Comparison Among Simplex, Half Duplex and Full Duplex Modes

<table>
<thead>
<tr>
<th>Comparison Parameter</th>
<th>Simplex</th>
<th>Half Duplex</th>
<th>Full Duplex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direction of</td>
<td>Unidirectional</td>
<td>Bidirectional</td>
<td>Bidirectional</td>
</tr>
<tr>
<td>communication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Send/receive Options</td>
<td>A sender can send data but</td>
<td>A sender can send as well as receive</td>
<td>A sender can send as well as receive</td>
</tr>
<tr>
<td></td>
<td>cannot receive</td>
<td>the data but one at a time</td>
<td>the data simultaneously</td>
</tr>
<tr>
<td>Performance</td>
<td>Poor performance than</td>
<td>Better performance than simplex mode</td>
<td>Superior performance among the three</td>
</tr>
<tr>
<td></td>
<td>the Half Duplex and</td>
<td>but inferior to full-duplex mode</td>
<td>modes</td>
</tr>
<tr>
<td></td>
<td>Full Duplex modes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example</td>
<td>Keyboard and Monitor</td>
<td>Walkie-Talkie</td>
<td>Telephone</td>
</tr>
</tbody>
</table>

receiving. Then, the user lets the capacity of a channel to be shared by the two signals travelling in opposite directions. Full Duplex can be understood with an example of a Cell phone. When two people communicate over a cell phone, both are free to speak and listen at the same time. Table 4.1 lists the comparison among the three types of communication modes.

From the Table 4.1, it is clear that the Full Duplex transmission modes offer better performance and also increases the throughput of the bandwidth.

4.4 Cell Phone

A cell phone is a portable device that access to cellular radio system. It has many names like, mobile phone, smart phone or telephone. This device is classified into two categories.

1. Simple device
2. Smart device

In simple devices, the user can access to make and receive the calls and send/receive the messages. While smart devices have the facility to access the internet with the above said two facilities.

4.4.1 Basic Principle of Cell Phones

A cell phone is a two-way radio, consisting of a radio transmitter and a receiver as shown in Figure 4.11. The cell phone converts the received voice into an electrical signal, which is then transmitted as radio waves to the nearest cell tower. Then, the network of cell towers relays the radio wave to the dialed cell phone, which converts back the radio wave to an electrical signal and then to sound waves. In the basic form, a cell phone works just like a Walkie-talkie.

In additional to the basic function of the voice calls, most modern cell phones come with additional features such as web surfing, camera, games, messaging and music. Smart phones can perform similar functions of a portable computer.

What is Cellular Network?

A cellular Network, also known as a mobile network is a network of mobile base stations that provide coverage for the user to establish phone calls, text messages and data services (Mobile internets).
4.4.2 Radio Waves

Cell phones use radio waves for communication purposes as shown in Figure 4.12. Radio waves transmit digitized voice or data in the form of oscillating electric and magnetic fields, called the electromagnetic field (EMF). The rate of oscillation is called frequency of radio waves, which carry the information and travel in air at the speed of light. Cell phones transmit radio waves in all directions. The waves can be absorbed and reflected by surrounding objects before they reach the nearest cell tower. For example, when the mobile phone is placed near to user’s head during a call, a portion of the emitted energy is observed into user’s head and body. In this event, much of the cell phone’s EMF energy is wasted and no longer available for communication. In the following sections, the various components of the cell phone communication are presented.

4.4.3 Antenna

Cell phone contain at least one radio antenna in order to transmit or receive radio signals. An antenna converts an electric signal to the transmitting radio wave and receiver. Some cell phones use one antenna as the transmitter and the receiver, while others have multiple transmitting or receiving antennas. Figure 4.13 shows a Cell phone antenna.

FIGURE 4.13 Cell Phone Antenna

An antenna is a metallic element (such as copper) having particular size and shape for transmitting and receiving specific frequencies of the radio waves. Older generation cell phones have external or extractable antennas, while modern

What is SAR?

Specific Absorption Rate (SAR) is the guidelines created for measuring the rate at which the body tissue absorbs radiation during cell phone operation. It is set at a maximum of 1.6 watts/kilogram of radiation energy absorbed by the body. Over exposure of cell phone radiation might cause cancer.
cellphones contain more compact antennas built inside the device. It is important to understand that any metallic components in the device (such as the circuit board and the metal frame) can interact with the transmission antenna(s) and contribute to the pattern of the transmitted signal. Many modern smartphones also contain more than one type of antenna. In addition to the cellular antenna, they may also have Wi-Fi, Bluetooth and/or GPS antennas.

4.4.4 Connectivity

The magnitude of the received signal from the cell tower is called the “signal strength” which is commonly indicated by “bars” on the cell phone as shown in Figure 4.14. The connectivity between a cell phone and its cellular network depends on both signals and is affected by many factors, such as the distance between the phone and the nearest cell tower, the number of obstacles/hindrance between them and the type of wireless technology (e.g. GSM or CDMA).

A poor reception (fewer bars) normally indicates a long distance and/or much signal interruption between the cell phone and the cell tower.

4.5 Working Principle of a Cell Phone

To communicate with a mobile phone, it is necessary to be within the range of the base station of the operator and receive a radio signal of sufficient quality. This is indicated by the bars on the display screen of the phone. Today, they are often accompanied by a sign (for example, “4G”, “3G” or “E” for EDGE) specifying the type of technology available in the area.

When making a call on a mobile, the first thing the phone does is search for the nearest signal from the base station.
antenna of its operator and establishes a radio link with it. To receive a call, the principle is the same, except that it is the base station antenna that needs to establish the connection. And in this case, to route the call, the operator needs to know the network cell of the recipient. This is why, when they are switched on, even some times when not being used for calls, mobiles ‘report’ to the network and update their applications (for smart phones) at regular intervals.

### 4.5.1 Mobile Phone Technologies

Cellular technology is one of the mobile technologies that gave mobile phones the name “cell phone”. Cellular technology basically refers to having many small interconnected transmitters. The other main concept of cellular technology was that it has “multiple access”, meaning it places multiple voice or data connection into a single radio channel.

#### Types of Cellphone Technologies

Many people use mobile phones, but do not know about the technology variances. In India, many mobile phones runs based on GSM and CDMA networks only. Now-a-days 4G is extremely growing in India, which operates mainly based on LTE Network technology. An overview of the important and widely used mobile network technologies in India and across the world is presented in the following sections.

### 4.5.2 GSM (Global System For Mobile Communication)

GSM is the original 2G standard launched in 1991. It was the first major mobile technology. The Figure 4.15 GSM protocol was initially based on time division, meaning calls take turns using the radio signal.

GSM is the global technology authenticates SIM cards and performs simultaneously voice and data transmission.

3G GSM is better for world travellers, which covered most of the countries but, weak in rural locations. GSM traditionally work on 900, 1800 and 1900MHz and was initially designed, only for circuit switched voice service, which is a combination of FDD (Frequency Division Duplex) and TDD (Time Division Duplex).

### 4.5.3 GPRS (General Packet Radio Service)

GPRS is the service provided by the GSM network as shown in Figure 4.16. This is a packet data transport-based service, which provides mobile internet over a mobile device. This uses same radio interface of the mobile used to make calls. GPRS is the slowest one and sent data in packets, just like the computer network. GPRS mainly devised for data communication between wireless devices. Data communication may include email, internet, MMS, SMS etc. GPRS technology is slowly replaced by current CDMA (Code Division Multiple Access) and LTE (Long Term Evaluation) based solutions. There are nodes and protocols used for GPRS services.

GPRS support Nodes are devised in to two

1. **SGSN**: Serving GPRS Support Node in VPLMN (Visited Public Land Mobile Network) for GPRS functionality in GSM network.
2. **GGSN**: Gateway GPRS Support Node between Mobile and Internet.
4.5.4 Global Positioning System (GPS)

GPS is a space-based satellite Navigation system that provides location and time information in all weather conditions, anywhere on or near the earth where there is an unobstructed Line-of-Sight to four or more GPS Satellites. The system provides critical capabilities to military, civil and commercial users around the world. It is maintained by the United States Government and is freely accessible to anyone with a GPS receiver. Figure 4.17 shows the representation of GPS.

The GPS is made up of a network of 24 satellites placed into orbit by US Department of Defences. GPS was originally intended for military applications but, in the 1980s, the US Government made the system available for civilian use. GPS works in any weather conditional, anywhere in the world and 24 hours a day. There are no subscription fees or setup charges to use GPS.
**Major Differences between GPS and GPRS**

1. GPS (Global Positioning System) will give you location in terms Latitude and Longitude.
2. GPRS will allow user to transfer data over cellular networks.

### 4.5.5 SDMA (Space Division Multiple Access)

SDMA uses physical separation methods that permit the sharing of wireless channels. User’s cell sites are spaced from one another to avoid interference. The method is widely used in cellular radio systems. In addition to spacing, directional antennas are used to avoid interference. Most cell sites use three antennas to create 120° sectors that allow frequency sharing (Fig. 4.18 (a)). New technologies like smart antennas or adaptive arrays use dynamic beamforming to shrink signals into narrow beams that can be focused on specific users, excluding all others (Fig. 4.18 (b)).

SDMA separates users on shared frequencies by isolating them with directional antennas. Most cell sites have three antenna arrays to separate their coverage into isolated 120° sectors as shown in Figure 4.18(a). Adaptive arrays use beamforming to pinpoint desired users while ignoring any others on the same frequency as shown in Figure 4.18(b).

One unique variation of SDMA, Polarization Division Multiple Access (PDMA), separates signals by using different polarizations of the antennas. Two different signals then can use the same frequency, one transmitting a vertically polarized signal and the other transmitting a horizontally polarized signal. The signals would not interfere with one another even if they are on the same frequency because they are orthogonal and the antennas would not respond to the oppositely polarized signal. Separate vertical and horizontal receiver antennas are used to recover the two orthogonal signals. This technique is widely used in satellite systems.

Polarization is also used for multiplexing in fibre optic systems. The new 100-Gbit/s systems use Dual Polarization Quadrature Phase Shift Keying (DP-QPSK) to achieve high speeds on a single fibre. The high-speed data is divided into two slower data streams, one using vertical light polarization and the other horizontal light polarization. Polarization filters separate the two signals at the transmitter and the receiver and merge them back into the high-speed stream.
4.5.6 TDMA (Time Division Multiple Access)

TDMA is a technology used in digital wireless cellular telephony communication. TDMA allocates each user a different time slot on a given frequency as shown in Figure 4.19(a). TDMA divides each cellular channel into three time slots as shown in Figure 4.19(b) in order to increase the amount of data that can be carried. TDMA used by Digital-American Mobile Phone Service (D-AMPS), Global System for Mobile Communications (GSM) and Personal Digital Cellular (PDC). Each of these systems implement TDMA in somewhat different and potentially incompatible ways. TDMA is also used for Digital Enhanced Cordless Telecommunication (DECT). TDMA technology was more popular in Europe, Japan and Asian countries, whereas CDMA is widely used in North and South America. But now a day both technologies are very popular through out of the world.

Advantages of TDMA

- TDMA can easily adapt to transmission of data as well as voice communication.
- TDMA has an ability to carry 64 kbps to 120 Mbps of data rates.
- TDMA allows the operator to provide services like fax, voice-band data, SMS and bandwidth-intensive applications such as multimedia and video conferencing.
- Since TDMA technology separates users according to time, it ensures that there will be no interference from simultaneous transmissions.
- TDMA provides users with an extended battery life, since it transmits only portion of the time during conversations.
- TDMA is the most cost-effective technology to convert an analog system to digital.
Disadvantages of TDMA

- Disadvantage using TDMA technology is that the users have a predefined time slot. When moving from one cell site to another, if all the time slots in this cell are full the user might be disconnected.

- Another problem in TDMA is that it is subjected to multipath distortion. To overcome this distortion, a time limit can be used on the system. Once the time limit is expired the signal is ignored.

4.5.7 FDMA (Frequency Division Multiple Access)

FDMA is the process of dividing one channel or bandwidth into multiple individual bands, each for use by a single user as shown in Figure 4.20. Each individual band or channel is wide enough to accommodate the signal spectra of the transmissions to be propagated. The data to be transmitted is modulated on to each subcarrier and all of them are linearly mixed together.

- FDMA divides the shared medium bandwidth into individual channels. Subcarriers modulated by the information to be transmitted occupy each sub-channel.

- The best example of this is the cable television system. The medium is a single co-axial cable that is used to broadcast hundreds of channels of video/audio programming to homes. The co-axial cable has a useful bandwidth from about 4 MHz to 1 GHz. This bandwidth is divided into 6 MHz wide channels. Initially, one TV station or channel used a single 6 MHz band. But with digital techniques, multiple TV channels may share a single band today using compression and multiplexing techniques in each channel.

- This technique is also used in fibre optic communications systems. A single fibre optic cable has enormous bandwidth that can be subdivided to provide FDMA. Different data or information sources are each assigned a different light frequency for transmission. Light generally is not referred by frequency but by its wavelength (λ). As a result, fibre optic FDMA is called Wavelength Division Multiple Access (WDMA) or just Wavelength Division Multiplexing (WDM).

- One of the older FDMA systems is the original analog telephone system, which used a hierarchy of frequency multiplex techniques to put multiple telephone calls on single line. The analog 300 Hz to 3400 Hz voice signals were used to modulate subcarriers in 12 channels from 60...
kHz to 108 kHz. Modulator/mixers created single sideband (SSB) signals, both upper and lower sidebands. These subcarriers were then further frequency multiplexed on subcarriers in the 312 kHz to 552 kHz range using the same modulation methods. At the receiving end of the system, the signals were sorted out and recovered with filters and demodulators.

Original aerospace telemetry systems used an FDMA system to accommodate multiple sensor data on a single radio channel. Early satellite systems shared individual 36 MHz bandwidth transponders in the 4GHz to 6GHz range with multiple voice, video, or data signals via FDMA. Today, all of these applications use TDMA digital techniques.

4.5.8 CDMA (Code Division Multiple Access)

Code Division Multiple Access (CDMA) is a digital wireless technology that uses spread-spectrum techniques. CDMA does not assign a specific frequency to each user. Instead, every channel uses the full available spectrum. Individual conversations are encoded with a pseudo-random digital sequence. CDMA consistently provides better capacity for voice and data communications than other commercial mobile technologies, allowing more subscribers to connect at any given time and it is the common platform on which 3G technologies are built. Simply, FDMA (Frequency Division Multiple Access) with TDMA is CDMA. CDMA is based on encoding multiple connections with different keys and then decoding them on the receiving end. Figure 4.21 shows block diagram of the CDMA technology.

The following are two main CDMA–based carriers,

1. Verizon
2. Sprint

CDMA is better for large, rural areas and has traditionally not able to do voice data at the same time. CDMA authenticates the device itself.

Advantages of CDMA

One of the main advantages of CDMA is that dropouts occur only when the phone is at least twice as far from the base station. Thus, it is used in the rural areas where GSM cannot cover.

![CDMA Block diagram](image-url)
Although WCDMA is designed to operate on evolved GSM core networks, it uses code division multiple access (CDMA) for its air interface. In fact, the majority of the 3G systems in operation employ CDMA, while the rest use time division multiple access (TDMA). The TDD mode of WCDMA actually employs a combination of TDMA and CDMA. CDMA allows multiple users to share a channel at the same time, while TDMA allows users to share the same channel by chopping it into different time slots. CDMA offers the benefits of multipath diversity and soft hands off. As an air interface technology, WCDMA is able to artificially increase a signal’s bandwidth. It does so by modulating each baseband symbol with a binary or quaternary signature with a much higher rate than that of the original data symbol. Table 4.2 summarizes the various features of the mobile phone technologies.

Disadvantages of CDMA

- Channel pollution, where signals from too many cell sites are present in the subscriber’s phone but none of them is dominant. When this situation arises, the quality of the audio degrades.
- When compared to GSM, it has lack of international roaming capabilities.
- The ability to upgrade or change to another handset is not easy with this technology because the network service information for the phone is put in the actual phone unlike GSM, which uses SIM card.
- Limited variety of the handset, because at present the major mobile companies use GSM technology.

4.5.9 WCDMA (Wideband Code Division Multiple Access)

The WCDMA system is part of the UMTS (Universal Mobile Telecommunications System). It is developed by the 3G Partnership Program (3GPP), which composed of evolved core cellular networks that belong to the Global System for Mobile (GSM) communications network worldwide.

WCDMA features: It supports two modes of operations viz.

- **Frequency Division Duplex (FDD):** Separates users by employing both codes as well as frequencies. One frequency is used for the uplink, while another is used for the downlink.
- **Time Division Duplex (TDD):** Separates users by employing codes, frequencies and time, wherein the same frequency is used for both uplink and downlink.

4.5.10 OFDMA (Orthogonal Frequency-Division Multiple Access)

OFDMA is the access technique used in Long-Term Evolution (LTE) cellular systems to accommodate multiple users in a given bandwidth. Orthogonal frequency division multiplexing (OFDM) is a modulation method that divides a channel into multiple narrow orthogonal bands that are spaced, so they don’t interfere with one another. Each band is divided into hundreds or even thousands of 15 kHz wide sub-carriers. The data to be transmitted is divided into many lower-speed bit streams and modulated onto the subcarriers. Time slots within each sub-channel data stream are used to package the data to be transmitted as shown in Figure 4.23. This technique is spectrally efficient, so it provides very high data rates and also less affected by multipath propagation effects.
OFDMA assigns a group of subcarriers to each user. The subcarriers are part of the large number of subcarriers used to implement OFDM for LTE. The data may be voice, video, or something else, and it is assembled into time segments that are transmitted over some of the assigned sub-carriers. To implement OFDMA, each user is assigned a group of sub-channels and related time slots. The smallest group of sub-channels assigned is 12 and called a resource block (RB). The system assigns the number of RBs to each user as needed.

### 4.5.11 UMTS (Universal Mobile Telecommunication System)

UMTS (Universal Mobile Telecommunication System) is a so-called “third-generation (3G),” broad band, packet-based transmission of text, digitized voice, video, and multimedia at data rates up to and possibly higher than 2 megabits per second (Mbps), offering a consistent...
set of services to mobile computer and phone users irrespective of their location in the world. Based on the Global System for Mobile (GSM) communication standard, UMTS is the planned standard for mobile users around the world by 2002. Once UMTS is fully implemented, computer and phone users can be constantly attached to the Internet as they travel and have the same set of capabilities irrespective of the location. Users will have access through a combination of terrestrial wireless and satellite transmissions. Until UMTS is fully implemented, users can have multi-mode devices that switch to the currently available technology (such as GSM 900 and 1800) where UMTS is not yet available.

4.5.12 MMTel IMS (Multimedia Telephony over Internet protocol Multimedia Subsystem)

MMTel is a new technology to provide voice, video and other telephony services over LTE network (VoLTE). MMTel uses IMS (Internet protocol (IP) Multimedia Subsystem) to deliver voice, video and chat services to user. Additionally, it specifies the way to share images, videos and files in real time.

MMTel standard is a joint project by 3GPP (3rd Generation Partnership Project) and ETSI/TISPAN (European Telecommunications Standards Institute/Telecoms and Internet Converged Services and Protocols for Advanced Networks). It is considered as the evolution of stereo typed fixed and mobile telephony service, which is mostly dependent on circuit-switched technologies. MMTel is designed for All-IP (Internet Protocol) networks with support for legacy system.

4.5.13 Other Methods

A unique and widely used method of multiple access is Carrier Sense Multiple Access with Collision Detection (CSMA-CD). This is the classical access method used in Ethernet Local-Area Networks (LANs). It allows multiple users of the network to access the single cable for transmission. All network nodes listen continuously. When they want to send data, they listen first and then transmit if no other signals are on the line. For instance, the transmission will be one packet or frame. Then, the process repeats. If two or more transmissions occur simultaneously, a collision occurs. The network interface circuitry can detect a collision, and then the nodes will wait a random time before retransmitting.

A variation of this method is called Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA). This method is similar to CSMA-CD. However, a special scheduling algorithm is used to determine the appropriate time to transmit over the shared channel. While the CSMA-CD technique is most used in wired networks, CSMA-CA is the preferred method in wireless networks.

4.6 Generation of Cellphone Technologies

Evaluation of Cell phone Technologies, Mobile wireless technologies is a system used by cellular telephone manufacturers and service providers to classify wireless communication into several generations; each generation is characterized by new frequency bands, higher data rates and non–backward compatible transmission technology. In the recent past, mobile wireless technologies have undergone technology evolution from 0G TO 7G.

4.6.1 0G

This is the generation which came before cell phones mobile telephony technology. They were introduced before the first generation of cellular telephones, therefore labelled zero generation systems. Such
UMTS is a completely different technology from GSM and EDGE. Also, WCDMA (Wideband Code Division Multiple Access) is used in 3G.

4.6.2 1G (14.4 Kbps)

It is an old, analog mobile telephony type. Outdated some 10-15 years’ ago. It transmits and receives voice only. The cell phones used was big in size and had poor battery life.

4.6.3 2G (9.6/14.4 Kbps)

2G was digital rather than analog. 2G capabilities are achieved by allowing multiple users on a single channel via multiplexing. 2G cellular phones are used for data along with voice. 2G introduced Encryption technology for data transfer. There were GSM and CDMA version of 2G.

2.5G

2G cellular technology with GPRS is called 2.5G. It provides the usages of E-mails, web browsing and camera facilities.

E (or) EDGE (or) 2.75 G

‘E’ stands for EDGE (Enhanced Data Rule for GSM Evolution) also called the Enhanced GPRS. The network design is almost unchanged, but the data speed is increased noticeably. Transmission of data rate above 100Kbps is called 2.75 G.

4.6.4 3G (500 – 700 Kbps)

The 3G rollout of GSM and used CDMA. 3G introduced higher transfer rates, up to 200Kbps and later versions could achieve multiple Megabits per second. 3G has multimedia services support along with live video streaming, which makes it more popular. In 3G, universal access and portability across different device types are made possible (Telephone, PDC etc.). In the 3G Network, the UMTS (Universal Mobile Telecommunications System) is used. The

Why Mobile Phone has 10 Digit numbers?

The number of digits in a mobile phone number decides the maximum mobile phones the user can have without dealing the country code.

H (or) H+

This is mainly a transport layer protocol used for increasing the speed in 3G technology that use W-CDMA called HSPA (High Speed Packet Access). HSPA is evolved by combination of two technologies. HSPA + is an upgrade of the HSPA.

1. HSDPA (High Speed Downlink Packet Access)
2. HSUPA (High Speed Uplink Packet Access)

4.6.5 4G

The major advantage of 4G is mobile broadband internet services provided to internal systems such as laptops, wireless modem, etc., Speeds for 4G are further increased to keep up with data access a demand used by various services. High definition streaming is now supported in 4G. Increases bandwidth available for voice and data communications by using radio interface combined with a number of network improvements. It is the upgrade path for GSM and CDMA based networks.

Why 4G is called ‘MAGIC’?

M – Mobile Multimedia,
A – Anytime, Anywhere,
G – Global Mobile Support,
I – Integrated wireless solutions
C – Customized Personal Service.
4th Generation Network called LTE, often called 4G LTE, is the currently used network standard and is quite different from 2G and 3G. LTE is designed only as a data network. LTE brought very high bandwidth to mobile devices, hotspots and peripherals. So that, its data transfer becomes fast.

**AWS (Advanced wireless Services)**

AWS is also referred to as UMTS band IV. It used microwave frequencies in two segments. Frequency range of 1710 to 1755MHz is used for uplink and 2110 to 2155 MHz is used for downlink.

**XLTE**

XLTE provides a minimum of double the bandwidth of LTE. XLTE ready devices automatically identifies both the 700 MHz and the AWS spectrum in XLTE cities. It leads by Verizon in 2014. XLTE is faster than LTE.

**VoLTE**

VoLTE (Voice Over LTE) service in 4G connection will handle the user's internet traffic, while making/receiving a voice call. VoLTE is a voice technology that works over the LTE data connection rather than 3G voice bands. It has extremely high voice quality, which requires that both the participants are using VoLTE and are in VoLTE enabled areas. It also includes the ability to make video calls.

**5G**

Currently there is no 5G technology deployed but under testing. When this become available it will provide very high speeds to the consumers. It would also provide efficient use of available bandwidth. The 5th Generation network called NR (New Radio) of simple 5G. It adds support for microwave frequencies with LTE, previously unused in mobile telephony (currently 28 and 36 GHZ planned) much wider channel bandwidths (up to 400MHz carriers) and adaptive antenna technology, allowing for very narrow radio beams focusing RF rays in the direction of mobile phone locations. Initially, 5G will work simultaneously with 4G, so a mobile phone will maintain a parallel connection with both 4G and 5G radio access networks in what we called as EN-DC (EUTRAN / New Radio Dual Connectivity). The 5G radio would allow for speeds of 1Gbps and above.

**6G**

Future 6G integrates 5G with satellite network for global coverage. It will give ultra-fast internet access used to create more smart homes / cities.

**7G**

7G works on space roaming and it will convert the world completely wireless.

**Other Special Technologies**

In recent years, other technologies have emerged and enriched the mobile functionalities.
Wi-Fi most commonly uses the 2.4 GHz (12cm) (UHF) and 5.8 GHz (5cm) SHF radio bands. These wavelengths work best for line-of-sight Wi-Fi calling when the user calls to a phone number over the internet. It is different from VoLTE. The calls are going over the network. Also, promises the ability to swap seamlessly between Wi-Fi and wireless phone network. The symbol for Wi-Fi in mobile phones is shown in Figure 4.24.

### Key features of Blue Tooth technology

1. Less complication
2. Less power consumption
3. Available at cheaper rate
4. Robustness

Blue tooth technology permits hands free headset for incoming voice calls, ability of printing, fax and automatic synchronization of PDA.

### TABLE 4.3 Comparison among various generations of Mobile Phone Technology

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
<th>5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>150/900 MHz</td>
<td>900 MHz (25 MHz)</td>
<td>100 MHz</td>
<td>100 MHz</td>
<td>100 x BW/ unit area</td>
</tr>
<tr>
<td>Frequency</td>
<td>Analog signal (30 kHz)</td>
<td>Digital 1.8 GHz</td>
<td>1.6 – 2.0 GHz</td>
<td>2 -8 GHz</td>
<td>3 – 300 GHz</td>
</tr>
<tr>
<td>Data Rate</td>
<td>2 Kbps</td>
<td>64Kbps</td>
<td>144Kbps – 2 Mbps</td>
<td>100 Mbps – 1 Gbps</td>
<td>1 Gbps and above</td>
</tr>
<tr>
<td>Property</td>
<td>Bad voice quality, first wireless technology, poor Battery life</td>
<td>Digital,allows text message.</td>
<td>Digital Broad band with increasing speed.</td>
<td>High speed, supports all IPs, high Security, Better Usage</td>
<td>High Speed, Faster Data Transmission, More Efficient</td>
</tr>
<tr>
<td>Technology</td>
<td>Analog Cellular</td>
<td>Digital Cellular (GSM)</td>
<td>CDMA, MTS, EDGE.</td>
<td>LTE,VoLTE, WIFI</td>
<td>WORLD WIDE WEB</td>
</tr>
<tr>
<td>Size</td>
<td>Big</td>
<td>Medium</td>
<td>Medium</td>
<td>Small</td>
<td>Very Small</td>
</tr>
</tbody>
</table>
Classification
Various types of Blue tooth technology are available in the market, which helps the consumers to communicate wirelessly. The different types of Blue tooth devices are PC cards, radios, dongles and head sets, Laptops and other internet enabled equipment use Blue tooth technology such as wireless mouse and keyboard to communicate wirelessly. Music players like iPods, Music phones, or other MP3 players make use of stereo headphones.

Advantages of the Bluetooth
- Wireless – Bluetooth works without cable.
- Low energy consumption – Bluetooth uses low power signals and thus requires little energy.
- Bluetooth Technology is inexpensive– Bluetooth is cheap to manufacture.
- Sharing voice and data – Bluetooth allows devices to share voice and data communications.

Disadvantages of the Bluetooth
- Bluetooth devices cannot be connected with more than one device at the same time, because it finds problem in discovering another devices.
- Bluetooth has a range of 15 to 30 feet. The small range is a disadvantage for some who may want to use a Bluetooth device outside of the 30-foot radius.
- Bluetooth uses the battery power of a particular device in order to operate.
- Many cell phone makers send phones with Bluetooth powered off in order to maximize the battery life of the phone.

4.7.3 Hotspot
A Hotspot is a physical location where people may obtain internet access, using Wi-Fi technology, through a Wireless Local Area Network (WLAN) using a router connected to an internet service provider.

Hotspot is classified into two,
1. Public Hotspot
2. Private Hotspot

Public Hotspot
Public Hotspot may be created by business for use by customers such as Railway stations, Airport, etc., It is typically created from wireless access points (AP) configured to provide internet access, controlled to some degree by the venue. It connects the user’s Laptop or Tablets to the Internet.

Private Hotspot
Private Hotspot may be configured on a smartphone or tablet with a Mobile network data plan to allow internet access to other devices. If both the Hotspot device and the devices accessing it are connected to the same Wi-Fi Network.

![Hotspot Process](image)

With a mobile Hotspot, user can create an Internet connection for up to five cell phone devices on a 3G phone and up to 10 on a 4G LTE smartphones. After a few quick steps, the phone creates its own secure Wi-Fi network, which user devices can join. There is no need for a USB cable, and multiple user can share user phone’s mobile data plan.
4.7.4 Near Field Communication (NFC)

NFC enables short range communication between compatible devices. This requires at least one transmitting device and another to receive the signal. NFC device will be considered either passive or active.

Passive NFC devices include tags and other small transmitters that can send information to other NFC devices without the need for a power source of their own.

Active devices are able to send and receive data and can communicate with each other as well as passive devices. Smart phones are by far the most common form of active NFC device.

Just like Bluetooth and Wi-Fi, and all manner of another wireless signals, NFC works on the principle of sending information over radio waves. NFC is another standard for wireless transitions. The transmission frequency for data across NFC is 13.56 MHz. User can send data at either 106, 212 or 424 Kbps. NFC has three distinct modes of operation.

1. **Peer-to-peer mode**
   This is most common use in smart phones. In this mode, exchange of information switches between active (when sending) and passive modes (when receiving).

2. **Read and write mode**
   This mode is a one-way data transmission. The active device, possibly user smartphone, links up with another device in order to read information from it.

3. **Card Emulation**
   The NFC device can function as a smart or contactless credit card and make payments or tap into public transport systems.

4.7.4 Radio Frequency Identification (RFID)

Radio-Frequency Identification (RFID) is the use of radio waves to read and capture information stored on a tag attached to an object. A tag can be read from several feet away and does not need to be within direct Line-of-sight of the reader to be tracked.

A RFID system is made up of two parts as shown in Figure 4.27.

1. **Tag or Label**
2. **A Reader.**

**Tag or Labels**

There are embedded with a transmitter and a receiver. The tags have two parts. A microchip is used to store and process information, and an antenna is used to receive and transmit the signal. The tag contains the specific serial number for one specific object. To read the information encoded on a tag, a two-way radio transmitter-receiver called an interrogator or reader emits a signal to the tag using an antenna. The tag responds with the information written in its memory bank. The interrogator will then transmit the results to an RFID computer program.

**Reader**

The stored information on the RFID tags are scanned by the RFID reader. It cannot find a specific pair, but they can tell how many of each pair are on the shelf and which pairs need to be replenished. The reader can learn all of this information without having to scan each individual item.
The first Mobile Phone was the Motorola Dyna TAC 8000X invented in 1983 by Martin Cooper, a senior employee at Motorola. It could only store 30 contacts with a weight of around 1.1Kg and offered talk time of 30 minutes. Its retail price was roughly $3999. The first mobile phone call was placed to Dr. Joel S. Engel of Bell Labs by Martin Cooper.

4.8 Types of Mobile Applications

Mobile Applications are three types and are summarized below:

Native application: Native App installed from application store like Android's Google play and Apple's App store. This type of application which can be installed into your devices is known as native application. Example, WhatsApp, Angry birds, etc.,

Web application: Web applications run from mobile web browsers like Chrome, Fire box, Opera, Safari etc., using Mobile networks or Wi-Fi. Web browser applications are m.facebook.com, m.gmail.com, m.yahoo.com, m.rediffmail.com, etc.

Hybrid Application: Hybrid apps are combination of native app and web app. They can run on devices or offline and are written using web technologies like HTMLS and CSS, (e.g.) eBay, Flipkart, etc.

Square

Won't create black spots. But distance from its centre to corner is higher than distance in any side. This will create issues in providing equal level of signals at every point.

Circle

Since distance from centre to any point in the circle would be same, so there won't be any issue in providing equal level of signals at every point. But, when we arrange circles together, many areas would be created which won't be covered by any circle. These areas are called BLOCKSPOTS, where signals from nearby could be received.

Hexagon

Hexagon or the beehive structure overcomes all the above said issues. Its distance from centre to any point is the same and it can be arranged in such a way that no block spots are created.

4.10 Parts of Cell Phone

Figure 4.28 shows the block diagram of a cell phone, which helps us to understand the functions of a Cell phone's circuit.

A cell phone handset comprises of two sections viz., RF and Baseband and is described as follows.
4.10.1 RF

RF refers to Radio Frequency, the mode of communication for wireless technologies of all kinds, including cordless phones, Radars, Ham radios, GPS, radio and television broadcasts. RF technology is part of our lives; we scarcely notice it for its ubiquity. From baby monitors to cell phones, Blue tooth to remote control tags, RF waves are all around us.

RF waves are electromagnetic waves which propagate at the speed of light or 186000 miles per second (300000 km/s).

4.10.2 Base Band

In signal processing, baseband describe signals and systems whose range of frequencies is measured from zero to a maximum bandwidth or highest signal frequency as shown in Figure 4.29. It is sometimes used as a noun for a band of frequencies starting at zero. In telecommunication, it is the frequency range occupied by a message signal prior to modulation. It can be considered as a synonym to low pass.

![Base Band Spectrum](Image)

Base band is also sometimes used as a general term for part of the physical components of a wireless communications product. Usually, it includes the control circuiting (microprocessors), the power supply and amplifiers. A baseband processor is an IC that is mainly used in a mobile phone to process function of communication.

Basically, Baseband is also composed of two sections, the Analog and Digital processing sections.

Cell phones have three sections since baseband is divided into two functions as above, while the RF section remains as a whole circuit section.

1. Radio Frequency section
2. Analog baseband processor
3. Digital Baseband processor

An interesting thing is that nearly 90% of the mobile phones in Japan are water proof, as the people of Japan are very fond of mobile phones that they use it even in the shower.
Radio Frequency Processing Section

The RF section is the part of the cell phone circuit known as RF Transceiver. It is the section that transmits and receives certain frequencies to a network and synchronizes the same to another phone. A simple mobile phone uses these two circuits to communicate with another mobile phone.

The RF

A radio section is based on two main circuits.

1. Transmitter
   A Transmitter is a circuit or device, which is used to transmit radio signals in the air.

2. Receiver
   A Receiver is simply like radios which are used to receive transmissions(Radiation), which is spread in the air by any transmitter on a specific frequency.

The two-way communication is made possible by setting two transmitters and two receivers synchronized in such a way that transmitter in a cell phone is synchronized with the frequency of another cell phone’s receiving frequency or vice versa. So, the first cell phone transmits the radiation in the air, while the other phone receives it. And the same process is present in the opposite side as well. So, these two Hand-held cell phones correspond to one another, more or less simultaneously.

4.10.3 Analog Baseband Processor

The analog baseband processing section is composed of different types of circuits. This section converts and processes the analog into digital (A/D) signal and digital into analog (D/A) signal.

Control Section

This is the section which acts as the controller of the input and output of any analog and digital signal.

The present Mobile Phones have more computing power than the computer used for the APOLLO II to land on the moon.

Power Management

A power management section in mobile phones is designed to handle energy consumed in mobile phones. There are two main sub sections in a single power section.

Power Distribution and Switching section

A power distribution section is designed to distribute desired voltages and currents to the other sections of a phone. These sections take power from a battery (3.6 Volts) and in some places the power is converted or stepped-down to various volts like 2.8V, 1.8V, 1.6V, etc., while in other places it is stepped-up to higher voltages like 4.8V. This section is commonly designed around a power IC, which is used to distribute and regulate the voltage used in other components.

Charging Section

The charging section is based on a charging IC which takes power from an external source and feeds to the battery to power-up again, when it is exhausted. This section uses convertibility of 6.4V from an external battery charger and regulates it to 5.8V, while giving to the battery. The battery is charged by this process and it is ready to use. A battery session is a time...
which is provided by the manufacturer of a cell phone for standby or talk time.

**Audio codecs section**

This section is where analog and digital audio properties are processed like the microphone, earpiece, speaker, headset, ring-tones and also the vibrator circuits.

### 4.10.4 Digital Baseband Processor

Digital Baseband processor section is used in mobile phones to handle data and output signal like switching, driving application commands, memory accessing and executing.

**How to test CPU usage on mobile devices?**

There are various tools available in the market like Google play or app store from where you can install apps like CPU monitor use on, CPU stats, CPU-2 etc. This is an advanced tool which records historical information about processes running on your device.

Digital Base Band parts and sections are described below:

1. **CPU (Central Processing Unit)**

   The Central Processing Unit is responsible for interpreting and executing most of the commands from the user interface. It is often called the “brain” of the microprocessor, or the Central Processor. It includes Flash and Memory circuits, RAM(Random Access Memory), ROM(Read Only Memory), Bluetooth, Wi-Fi, Camera, Screen Display, Keypads, USB (Universal Serial Bus), SIM (Subscriber Identity Module) card, etc.

   Every mobile phone has a different concept and design in various aspects, but the methods and operational flow are all exactly the same. It differs on how and what certain IC chips and parts are being used and installed in a certain mobile phone circuitry.

**4.11 Mobile Phones Functions**

There are varieties of designs and functions are available in Mobile Phones. But, the most common functions of mobile phones include voice, communications, data and some other common applications.

### 4.11.1 Voice and Traditional Phone Functions

The primary function of a mobile phone is voice communication. Like traditional landline phones, mobile phones allow one user to call another and talk from afar. Functions related to voice communications include automatic redial, last number recall, caller ID logging of incoming and outgoing calls, speaker phone or hands free capabilities and speed dialling. Also, some phones are equipped with voice activated dialling and features like silent mode, which disables ringing or indicates incoming calls and alerts by vibration. Many mobile phones also feature the ability to block calls from unwanted numbers or customize ringtones to send an audible indication of the source of the incoming call.

### 4.11.2 Data Functions

Modern Mobile Phones offer some degree of text or data transfer as well with voice functions. User can send brief, typed message to other mobile phones and share files such as pictures and video or access the internet through the use of integrated web browsers and other internet applications optimized to function with a small screen.

- 70% of mobile phones are manufactured in China.
- Around 80% of the world’s population has a mobile phone.
4.12 Uses of Mobile Phones

The mobile phone is the user device, already started functioning as more than just a communications device. Mobile serve as watches and alarm clocks. Mobile phones also have free games, calculators, address book, contact list, calendar functions, radio, notepad, reminder services, etc. Owners also have tended to customise phones with their own ringtones, themes and wallpapers. All the above functions are just for starters. Some of the more advanced functions in mobile phone are also presented here:

1. **Digital Camera**
   Phones capture pictures and let user save them to others and to computers.

2. **Audio Recorder**
   Mobile Phones can be used to record conversations or even brief notes to oneself.

3. **Video Recorder**
   Phones are becoming video cameras and can record video more than an hour.

   ~In Mobile Phones, within 3 Minutes of delivery, 90% text messages are read.

4. **Multimedia Messaging**
   Everything recorded can be shared with others by using MMS.

5. **E-mail Client**
   The phone can be used to connect to any POP or IMAP server and to allow receiving and sending email.

6. **Web Client**
   ~What is Web Service?
   It is a component used in software to perform the task of interfacing between one program to another.

   Phones can also browse websites, via a WAP and/or HTML browser. Most websites may not look great on the small screen. But, it is still possible to connect to any website.

7. **Document Viewer**
   It is increasingly possible to view documents on the cell phone in the popular MS office file format.

8. **Computer adjunct**
   For many, the cell phone has replaced the PDA as the complement to the computer with a remote desktop application; it also becomes possible to make the mobile phone a window to one's computer.

9. **Music player**
   ~What are the MT and MO in SMS?
   Sending Message is known as MO (Message originate) and receiving the message is known as MT (Message Terminate)

   The big things in 2005 are reckoned to be the combining of music capabilities on the mobile phone. While phones can play MP3, it can be used to play music streamed from the internet.

10. **Television**
    In India, all operators have been promoting many TV channels on the cell phone over next generation network like EDGE.

11. **Wallet**
    The phone can also be used to pay for purchases like a credit or debit card. There is already a billing relationship that exists between the subscriber and the operator and that can be used to make payments to merchants.
12. **Bar code and QR code readers**

Phone also have the facility to read bar and QR (Quick Response) codes and that can have very interesting applications in all field, especially commerce.

### 4.13 Advantages and Disadvantages of Cell Phones

#### 4.13.1 Advantages

It helps in communicating with people around, while in working. Mobile Technology has made this possible and brought people together. User can easily go online with his mobile devices and reach across different countries of the world. It is made to make user work easy and helps to become more productively and efficient. Since the mobile technology is growing rapidly, the technicians have ample sources of earning through mobile repairing.

- **Instant Communication**
  It has paved the way to SMS, text messaging call, video chat and apps that allow people to instantly communicate to everyone across the globe.

- **Web Surfing**
  These devices are integrated with mobile browsers that enable them to research and access websites anytime and anywhere. It is convenient for people to surf the web and have easy access to information.

- **Camera**
  Camera plays an important role in taking selfie, posting photos in social media, etc. That’s why the smartphone manufacturers releases the phones equipped with best camera configurations.

4. **Entertainment**

Smartphones are also viewed as a source of entertainment. Watching movies and reading e-books, games, music are also convenient through cell phones.

5. **Education**

Smart phone also aid education, especially in children with easy access to information and helpful content. Children can have a more interactive learning through watching education applications. They can also easily surf the internet, if they want to search something about a topic.

6. **Productivity Apps**

Smart phones can do almost everything with the help of APPs. The functionality of apps varies from each other such as photo and video editor, ticket booking, online store, payment system, data analysis, personal assistant, etc.

7. **GPS**

Smartphones are equipped with Global Positioning system (GPS). This technology allows people to locate certain addresses and area all around the world.

8. **Privacy**

With smartphones user can do whatever they want without anyone knowing it. User secure all with a password. Online transaction can also be done through smartphones.

9. **Alarm Notes & reminder**

User can also add notes and reminders in user mobile phone in the favour of user help.

10. **Data Transfer**

User can easily transfer data from one device to another device. User photos, documents, videos and
other important documents are easily transferred from one device to another device within seconds. User can also store data in it.

11. More Utilities
All the features are now available in one device viz., Calendar, Calculator, built-in-Torch, etc.

!! Do you know the full form of various extensions? !!

<table>
<thead>
<tr>
<th>Extension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>apk</td>
<td>Android Application Package file</td>
</tr>
<tr>
<td>exe</td>
<td>Executable files</td>
</tr>
<tr>
<td>ipA</td>
<td>iOS App Store Package</td>
</tr>
<tr>
<td>prc</td>
<td>Palm Resume Compiler</td>
</tr>
<tr>
<td>jad</td>
<td>Java Application Describer</td>
</tr>
<tr>
<td>adb</td>
<td>Android Debug Bridge</td>
</tr>
<tr>
<td>Aapt</td>
<td>Android Asset Packing tool</td>
</tr>
</tbody>
</table>

4.13.2 Disadvantages
Use of internet makes it dangerous for user to secure users’ phones from viruses. Using a mobile phone, always make user connected and available to people, which sometimes becomes a headache because user is answerable every time. Accidents are caused daily due to the distractions caused because of mobile devices.

1. Costly
It can be expensive, since the user wants data connectivity and therefore the user needs to maintain the data plan.

2. Addiction
When user wakes up in the morning, the user has the habit of checking his/her phone. This problem may lead to a serious addition, which may include addiction to games, social media, etc.

3. Privacy threads
Even if smartphones are made private. Still there are security risks and threads everywhere. Hacker are always present and virtual viruses are potent. Smartphones are vulnerable to these threats when user accesses the internet. Thus, user needs to be extra cautions of opening sites and link.

4. Extra work
Smartphones are widely used in business. Users are working an extra workload which does not even exist before.

5. Uncensored content
Children can see, intentionally or not the uncensored content including violence pornographic content, etc. If user have children, make sure the user regulate their use of smartphones.

6. Poor social interaction
People no longer interact with people outside as they tend to spend more time with their smartphones.

7. Distraction
Despite the productivity, smartphones can really be distracting. When users attend to the notifications, users shall find themselves attached to the phone.

8. Brain Damage
Medical field claims that the radiation from Mobile Phone causes brain damage. Smartphones are also found to have a negative impact on users' health. Smartphones emit radio frequency energy which can be absorbed by the tissues in the body. Sleep deprivation is also one of the common bad effects of using smartphones. Moreover, phones produce HEV light, which can damage user eyes' retina.

9. Study Loss
Students are subjected to very high loss due to very bad attention in their studies. This is the biggest disadvantages for students.
10. Stolen of Data
If users have personal images, videos or files, etc., in their devices, other peoples can easily steal their images and videos. An android mobile phone is easy to copy data from one device to another but; IOS operating system has little safety.

4.14 Mobile Phones Parts
Mobile phone parts are classified into two categories.
- Big parts
- Small Parts

4.14.1 Identification of Big Parts

1. Antenna switch

It is found in the Network section of a Mobile phone and made up of metal and non-metal. In GSM sets, it is found in white colour and in CDMA sets as golden metal. Its working function is to search the network and passes forward after tuning. If the antenna switch is faulty then there will be no network in the mobile phone.

2. PFO (Power Frequency Oscillator)

It is found near the antenna switch in the Network section of the Mobile Phone. It is also called PA (Power Amplifier) and Band Pass filter. Its working function is to filter and amplify network frequency and to select the home network. If the PFO is faulty, then there will be no network in the mobile phone. If it gets short, then the mobile phone will be in dead condition.

3. RF IC/ HAGER/ Network IC

It is found near the PFO in the network section of the mobile phone. It is also called RF signal processor. It works as transmitter and receiver of audio and radio waves according to the instruction from the CPU. If the RF IC is faulty, then there will be a problem with network in the mobile phone, sometimes mobile phones can even in dead condition.

4. 26 MHz Crystal Oscillator

It is also near the PFO and also called Network Crystal. It is made up of metal. It creates frequency during outgoing call. If this crystal is faulty, then there will be no outgoing call and no network in the mobile phone.

5. VCO (Voltage-Controlled Oscillator)

It is found near the Network IC in the Network Section of a mobile phone. It sends time, date and voltage to the RF IC/Hager and the CPU. It also creates frequency after taking command from the CPU. If it is faulty, then there will be no network in the mobile phone and it will display “call end” or “call failed”.

6. Rx Filter

It is found in the Network Section of a mobile phone. It filters frequency during incoming call. If it is faulty, then there will be Network problem during incoming calls.

7. Tx Filter

It is found in the Network section of a mobile phone. It filters frequency during outgoing calls. If it is faulty, then there will be Network problem during outgoing calls.
8. ROM
It is found in the Operating Program in a Mobile Phone. It loads current Operating Program in a mobile phone. If ROM is faulty, then there will be a software problem in the mobile phone and the set will be in dead condition.

9. RAM
It is found in the Power section of a mobile phone. It sends and receives commands of the Operating Program in a mobile Phone. If RAM is faulty, then there will be software problem in the mobile phone and get hanged and dead.

10. Flash IC
It is found in the power section of a Mobile Phone. It is also called EEPROM IC, Memory IC, RAM IC and ROM IC. Software of the mobile phone is installed in the Flash IC. If Flash IC is faulty, then the mobile phone will not work properly and it goes to the dead condition.

11. Power IC
It is found in the power section of a Mobile Phone. There are many small components mainly capacitor around this IC. RTC is near the Power IC. It takes power from battery and supplies to all other parts of a mobile. If power IC is faulty, then the set will get dead.

12. Charging IC
It is found near the power section's resistor. It takes current from the charger and charges the battery. If charging IC is faulty, then the set will not get charged. If the charging IC is short, then the set will get dead.

13. RTC (Simple Silicon Crystal)
It is found in the power section near power IC. It is made up of either metal or non-metal. It is of long shape. It helps to run the date and the time in a mobile phone. If RTC is faulty, then there will be no date and time in the mobile phone and the set can even get dead.

14. CPU
It is found in the Power section. It is also called MAD IC, RAP IC and UPP. It is the largest IC on the PCB of a mobile phone and it looks different from all other ICs. It controls all section of a mobile phone. If CPU is faulty, then the mobile phone will get dead.

15. Logic IC/UI IC
It is found any section of a mobile phone. It has 20 pins or legs. It is also called UI IC and Interface IC. It controls Ringer, vibrator and LED of a mobile phone. If Logic IC is faulty, then ringer, vibrator and LED of mobile phone will not work properly.

16. Audio IC
It is found in power section of a mobile phone. It is also called COBBA IC and Melody IC. It controls speaker and microphone of a mobile phone. If audio IC is faulty, then speaker and microphone of a mobile phone will not work and the set can even get dead.

### 4.14.2 Identification of Small Parts

1. **Crystal**
   Two types of crystals are used in a mobile phone.
   
   i) **Network Crystal**
   This crystal is found in the network section of a mobile phone. It is made up of metal. It filters the network. If the network crystal is faulty, then there will be no network in the mobile phone.

   ii) **Simple Silicon Crystal**
   This crystal is found in the power section of a mobile phone. It is made up of either metal or non-metal and is of long shape. It runs the clock of a mobile phone. If the crystal is faulty, then the clock of the mobile phone will not work and the set can get dead.

2. **Coupler**
   This electronic component is found in the network section of a mobile phone. It is for neither black nor white colour and has six pins bend inside. It filters the network. If the coupler is faulty, then there will be no network in the mobile phone.

3. **Diodes**
   Four types of diodes are used in mobile phones.

   i) **Rectifier Diode.**
   It is found in black colour and convert AC into DC. It passes current in one direction. It does not pass current in reverse direction.

   ii) **LED**
   It is found in white or light-yellow colour and emits lights.

   iii) **Zener Diode**
   It is found in charging section. It filters and minimizes current and passes forward. It acts as voltage regulator. Zener diode has fixed capacity like 4 V, 6 V, 8 V, etc.

   iv) **Photo Diode.**
   It is used for Infrared. It captures Infrared Rays.
4. Transistors

This electronic component is found in any section of the mobile phone. It is black in colour and has three legs. It does the work of switching.

5. Regulator

This electronic component is found in any section of a mobile phone. It is of black colour and five or six legs. It filters voltage fluctuations and regulates the voltage.

6. Resistance

There are two types of resistance on a PCB of a mobile phone.

i) Chip Resistance.
   It can be found in any section of a mobile phone. It is of black colour. In some sets it is also found in blue and green colour.
   
   ii) Network Resistance
   It can be found in any section of a mobile phone. It is made from two or more chip resistance.

7. Capacitors

Three types of capacitors are found in a mobile phone.

i) Non-electrolytic Capacitor.
   It is found in any section of a mobile phone. It can be light black, yellow or brown in colours. It has no positive (+) or negative (-) side (Non-Polar device). It filters DC.

ii) Electrolytic Capacitor
   It is found in any section of a mobile phone. Its size is larger than non-electrolytic capacitor. It is found in two colours.
   a) Orange with Brown strip
   b) Black with White strip
   The side with the strip is positive (+) and the other side is negative (-). It filters and stores charge.
Network Capacitors
It is found in any section of a mobile phone. It is made from two or more non-electrolytic capacitors.

Coils
It is found in any section of a mobile phone. It is found in many shapes and sizes. Coils are found in two colours.

i) Black and White
ii) Blue and White

It has winding of copper coil inside. It filters and decreases current and voltage.

Boost coil
Its size is little bigger than coil. It is found in black colour and look like butter. It increases current. If this coil gets damaged, then it has to be changed.

LEARNING OUTCOME
A student will understand the working principle of the following communication devices, in this chapter.

1. PAGERS
2. WALKIE TALKIES
3. CELL PHONES

4.15 Cell Phone Dictionary

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1G</td>
<td>First Generation in Mobile Telephony</td>
</tr>
<tr>
<td>2G</td>
<td>Second Generation in Mobile Telephony</td>
</tr>
<tr>
<td>3G</td>
<td>Third Generation in Mobile Telephony</td>
</tr>
<tr>
<td>4G</td>
<td>Fourth Generation in Mobile Telephony</td>
</tr>
<tr>
<td>BGA</td>
<td>Ball Grid Array</td>
</tr>
<tr>
<td>BSI</td>
<td>Battery Status Indicator</td>
</tr>
<tr>
<td>CDMA</td>
<td>Code Division Multiple Access</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>DCT</td>
<td>Digital Core Technology</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile Communication</td>
</tr>
<tr>
<td>IMEI</td>
<td>International Mobile Equipment Identity</td>
</tr>
<tr>
<td>PDA</td>
<td>Personal Digital Assistant</td>
</tr>
<tr>
<td>PFO</td>
<td>Power Frequency Oscillator</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>ROM</td>
<td>Read Only Memory</td>
</tr>
<tr>
<td>RTC</td>
<td>Read Time Clock</td>
</tr>
<tr>
<td>Rx</td>
<td>Receive/Receiver (Receiving Station)</td>
</tr>
<tr>
<td>SMD</td>
<td>Surface Mount Device</td>
</tr>
<tr>
<td>Tx</td>
<td>Transmit/Transmitter (Transmitting Station)</td>
</tr>
<tr>
<td>UEM</td>
<td>Universal Energy Manager</td>
</tr>
<tr>
<td>VCO</td>
<td>Voltage – Controlled Oscillator</td>
</tr>
</tbody>
</table>
## GLOSSARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push-To-Talk</td>
<td>Push-To-Talk, also known as Press-To-Transmit, to switch from voice reception mode to transmit mode.</td>
</tr>
</tbody>
</table>
| Electret Microphone | Type of Electrostatic capacitor based Microphone  
|                | Electret = Electricity + Magnet.                                           |
| G             | Short for General Packet Radio Service (GPRS) or Generation                |
| EDGE          | Enhanced Data rated for GSM                                               |
| H+            | Refers to Evolved High Speed Packet Access (HSPA+)                         |
| LTE           | Long Term Evaluation Having higher data speed.                            |
| VoLTE         | Stands for Voice over LTE.                                                |
| GPRS          | General Packet Radio Service.                                             |
|               | Packet oriented mobile data standard on the 2G and 3G cellular communication network. |
| GPS           | Global Positioning System                                                |
| SDMA          | Space Division Multiple Access                                            |
| TDMA          | Time Division Multiple Access                                             |
| PDMA          | Polarization Division Multiple Access                                     |
| DP-QPSK       | Dual Polarization Quadrature Phase Shift keying                           |
| D-AMPS        | Digital-American Mobile Phone Service                                     |
| GSM           | Global System for Mobile Service                                          |
| PDC           | Personal Digital Cellular                                                |
| DECT          | Digital Enhanced Cordless Telecommunication                              |
| CDMA          | Code Division Multiple Access                                             |
| WCDMA         | Wideband Code Division Multiple Access                                    |
| FDMA          | Frequency Division Multiple Access                                        |
| WDMA          | Wavelength Division Multiple Access                                       |
| WDM           | Wavelength Division Multiplexing                                          |
**Chapter 4: Communication Devices and their Technologies**

**Questions (1 Mark)**

1. Who developed the first communication machine
   a. Samuel F.B Morse
   b. Canadian Donald Hings
   c. Alfred Gross
   d. None of the Above

2. Walkie talkies work up to
   a. 27.2 Kilometers
   b. 58 Kilometers
   c. 18 Kilometers
   d. None of the Above

3. Who invented the walkie talkie
   a. Canadian Donald Hings
   b. Martin copper
   c. Samuel F.B Morse
   d. None of the Above

4. The magnitude of the received signal from the cell tower is called
   a. Signal strength
   b. Bars
   c. Wave length
   d. None of the above

---

**Table: Communication Devices and Technologies**

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transceiver</td>
<td>Transmit and Receive functions, the device is a Transmitter-Receiver. Similar devices include transponders, Transvertors and Repeaters.</td>
</tr>
<tr>
<td>Transponders</td>
<td>A device that receives a signal, and emits as a different signal in response with telecommunications.</td>
</tr>
<tr>
<td>OFDMA</td>
<td>Orthogonal Frequency – Division Multiple Access</td>
</tr>
<tr>
<td>UMTS</td>
<td>Universal Mobile Telecommunication System</td>
</tr>
<tr>
<td>MM Tel IMS</td>
<td>Multimedia Telephony over Internet Protocol (IP) Multimedia Subsystem</td>
</tr>
<tr>
<td>CSMA-CD</td>
<td>Carrier Sense Multiple Access with collision Detection</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Networks</td>
</tr>
<tr>
<td>CSMA-CA</td>
<td>Carrier Sense Multiple Access with Avoidance</td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>Is a local area wireless technology</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>Bluetooth is a wireless technology used to transfer data between different electronic devices.</td>
</tr>
<tr>
<td>NFC</td>
<td>Near Field Communication (NFC) enables short range communication between compatible devices.</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio-Frequency Identification is the use of radio waves to read and capture information stored</td>
</tr>
</tbody>
</table>
5. Who invented the first mobile phone?
   a. Martin copper  
   b. Alfred Gross  
   c. Samuel F.B Morse  
   d. None of the above

6. Beeper is the example of ____________ Transmission mode
   a. Hulf duplex  
   b. Simplex  
   c. Full duplex  
   d. None of the above

7. Which device invented during world war II
   a. Cell phone  
   b. Pagerb.  
   c. Walkie talkie  
   d. None of the above

8. Which condenser is used as a microphone in communication devices
   a. Electrolyte condenser  
   b. Gang condenser  
   c. Electret condenser  
   d. None of the above

9. Walkie talkies are work on the ___
   a. 7 KHz  
   b. 10-18 KHz  
   c. 27 KHz  
   d. None of the above

10. Baby Monitor is used in _____
    a. UPS  
    b. Computer  
    c. Walkie Talkie  
    d. None of the above

11. TDMA has an ability to carry _____ of data rates
    a. 64 kbps to 12 kbps  
    b. 240 kbps  
    c. 30 kbps to 48 kbps  
    d. None of the above

12. FDMA is the best example of ________ system
    a. Cable Television  
    b. CCTV  
    c. LED TV  
    d. None of the above

13. OFDMA (Orthogonal Frequency Division Multiple Access) is the access used in
    a. VOLTE  
    b. LTE  
    c. E  
    d. None of the above

14. Internet protocol (IP) Multimedia sub system is
    a. UMTS  
    b. RFID  
    c. MMTelIMS  
    d. None of the above

15. Enhanced GPRS is called ________
    a. EDGE  
    b. 2.5 G  
    c. OG  
    d. None of the above

16. Hot spot has a range of about
    a. 150 feet  
    b. 66 feet  
    c. 17 feet  
    d. None of the above
17. Wi-fi most commonly uses bands
   a. UHF band
   b. VHF band
   c. SHF & UHF band
   d. None of the above

18. NFC has ______ distinct mode of operation
   a. 3
   b. 10
   c. 7
   d. None of the above

19. 26 MHz Crystal Oscillator is also called _______
   a. Simple silicon
   b. Piezo electric crystl
   c. Network crystal
   d. None of the above

20. If _______ is faulty, there will be a software problem in mobile phone
   a. RAM
   b. ROM
   c. CPU
   d. None of the above

Part – B  (3 Marks)

II Answer in one or two sentences

1. What are the types of transmission mode?
2. What is PPT? Define
3. What is a cell phone? Classify this
4. What is cellular network?
5. Define SAR. How to limit this?
6. What is the major Difference between GPS and GPRS?
7. How are the GPRS support nodes devised?

8. Write the expansion of PDMA, DP-QPSK, DECT
10. What is H (or) H+
11. Why the 4G is called “MAGIC”? 
12. Write the functions of WI – FI?
13. What are the parts of WI – FI?

14. Why “CPU” called ‘brain’ of the micro processor?
15. What are the common functions of mobile phone?
16. How mobile phone parts classified?
17. What are the two types of resistance used in a mobile phone?
18. Write down the four types of diodes using a mobile phone?
19. What type of crystals is used in a mobile phone?
20. If the interface IC is Faculty – Identify the fault?

21. What is the function of VCO?
22. Brief about PFO
23. Write the expansion of any 3 file extension names?
24. Name some special technologies used in a mobile phones.
25. What is Simplex? Give an example?
26. What is resource block?
27. What are the modes of operation in NFC?
28. What are the MT and MO in SMS?

Part – C  (5 Marks)

III Answer in a paragraph

1. How is Electret condenser is used as a microphone?
2. Explain the operating principle of hand held PTT?
3. How FM type transceiver works?
4. Tabulate the comparison of Transmission modes
5. Draw the front & back panel of a cell phone and mention it parts.
6. Explain the GPRS.
7. What are the advantages and disadvantages of TDMA?
8. Tabulate the features of various mobile phone technologies.
10. Draw a Comparison table among various generations of mobile phone technologies.
11. Explain about the Near Field Communication (NFC)?
12. Draw a diagram of RFID system and explain its parts.
13. What are the types of mobile applications? Explain.
14. Why Hexagons used to represent call coverage in a cellular Network?
15. Describe the baseband signals and systems?
16. Write the types of Capacitors found in a mobile phone? Explain.
17. Explain the GPS.
18. Explain the GPRS.

**ANSWERS**
1. (b)  2. (a)  3. (a)  4. (a)  5. (a)
6. (b)  7. (c)  8. (c)  9. (c)  10. (c)
11. (a) 12. (a) 13. (b) 14. (c) 15. (a)
16. (b) 17. (c) 18. (a) 19. (c) 20. (b)
Communication Techniques

LEARNING OBJECTIVE

In this chapter, the students can easily.....

- Understand the working principle and application of OFC.
- Study the difference between OFC and wire communication.
- Understand the types of satellite communication and uses.
- Describe the function of RADAR and SONAR.
- Learn about microwave communication.
- Describe the function of Tsunami warning system, Seismograph and Avionics.

CONTENT

5.1 Introduction
5.2 OFC Technology
5.3 Construction of an Optical Fiber Cable
5.4 Difference between Copper Cable and OFC
5.5 Advantages and Disadvantages of OFC
5.6 Applications of OFC
5.7 Satellite Communication
5.8 Microwave Communication
5.9 RADAR
5.10 SONAR
5.11 Tsunami System
5.12 Seismography and Avionics
5.1 **Introduction**

In this present scenario, we use to say “the world becomes so fast”, comparatively before 50 to 100 years. It means whether the rotation of earth becomes faster. The same 24 hours is observed on those days and today. Then which makes us to feel like that?

On those days if a message has to be conveyed or intimated to a person who is at a distance, say near town, or nearby country or near to a continent, it took few hours, few days and few months, respectively. So that the reaction times, is also long. This makes us to realize that the world gives much time to us.

But now, in this 21st century, any incident happening in any tiny part of this world, can be seen or heard by the other people all over the world in no time or even to say on live.

How it becomes realized? This all because of the communication system. Hence let us study and understand the basic concepts of few communication systems in this chapter.

5.2 **OFC Technology**

Fiber optics (optical fibers) are long thin, strands of very pure glass about the diameter of a human hair. They are arranged in bundles called optical cables and used to transmit light signal over long distances.

Optical fibre is mostly made from Silicon Dioxide (Sio2) but some little amount of other materials such as fluorozirconate glasses, fluoroaluminate glasser and Chalcogenide glasses as well as crystoline materials like sapphire glasses are used for longer wavelength infrared or other specialized applications.

---

**HISTORY OF OPTICAL FIBER**

In 1870, John Tyndall, using a jet of water that flowed from one container to another and a beam of light, demonstrated that light used internal reflection to follow a specific path. As water poured out through the spout of the first container. Tyandall directed a beam of sunlight at the path of the water. The light as seen by the audience, followed a zigzag path inside the curved path of the water. This Simple experiments illustrated in Figure 5.1(a) marked the first research into the guided transmission of light.

**Who invented fiber optic technology?**

Indian Dr. Narinder Singh Kapany invented the fiber optical cable based on John.Tyndall experiments. He is also called father of fiber optics.
5.3 Elements of OFC

Three basic elements of an optical fiber are the core, the cladding and the outer coating. Figure 5.2 shows the construction of an optical fiber.

- The core is usually made of glass or plastic depending on the transmission spectrum desired. The core is the light transmitting portion of the fiber. The core is cylindrical rod shape, made up of dielectric material. Dielectric material conducts no electrical signal. Light propagates mainly along the core of the fibre. It is described as having a radius of an index of refraction.
- The cladding is usually made of the same material as the core but with a slightly lower refracting index.
- The coating usually comprises of one or more coats of a plastic material to protect the fiber from the physical environment.

5.3.2 Working principle of OFC

The propagation of light through the fiber is based on the principle of total internal reflection. The fig 5.1 shows the internal reflection of OFC.
Fig 5.3 shows the working principle of an OFC. An Optical Fiber is a cylindrical di-electric wave guide (non-conducting waveguide) that transmits light along its axis, by the process of total internal reflection. To confine the Optical Signal in the core, the refractive index of the core must be greater than that of the cladding. Because the cladding does not absorb any light from the core, and the light wave can travel longer distances. Fig 5.4 shows the structure of optical fibers.

Fig 5.5 shows the step index single mode OFC. This type of fiber allows only one path or mode for travelling the light with in the fiber. The core diameter of this type is 5µm and 10µm with a 125µm cladding.

**Application**
- Long distance communication
- All Telecommunication areas

**Step index multimode**

Fig 5.6 shows the type of step index multimode. This type of fiber has an index refraction profile that steps from low to high or high to low as measured from cladding to core or core to cladding. The diameter of this type is 62.5µm/125µm. The term multimode refers to the fact that multiple modes or paths are possible for the light to travel through the fiber.

**Graded Index Fiber Multimode**

Fig (5.7) shows the Multimode graded index fiber. Graded index fiber is a type of fiber where the refractive index of the core is lower towards outside of the fiber. The core in a graded index fiber has an index of refraction that radially decreases continuously from the center to the cladding interface. As a result, the light travels faster at the edge of the core than in the center as shown in Figure 5.7.

5.3.3 **Types of Optical Fiber**

There are three types of optical fiber commonly used.

1. Step index single mode
2. Step index multi mode
3. Graded index

**Step index single mode**

Fig (5.5) shows the step index single mode OFC. This type of fiber allows only one path or mode for travelling the light with in the fiber. The core diameter of this type is 5µm and 10µm with a 125µm cladding.

**Application**
- Long distance communication
- All Telecommunication areas

**Step index multimode**

Fig 5.6 shows the type of step index multimode. This type of fiber has an index refraction profile that steps from low to high or high to low as measured from cladding to core or core to cladding. The diameter of this type is 62.5µm/125µm. The term multimode refers to the fact that multiple modes or paths are possible for the light to travel through the fiber.

**Graded Index Fiber Multimode**

Fig (5.7) shows the Multimode graded index fiber. Graded index fiber is a type of fiber where the refractive index of the core is lower towards outside of the fiber.

The core in a graded index fiber has an index of refraction that radially decreases continuously from the center to the cladding interface. As a result, the light travels faster at the edge of the core than in the center as shown in Figure 5.7.
The diameter of this type of fiber is 50 µm, 62.5 µm and 100µm. The main application of graded index is in medium range communications such as Local Area Network (LAN).

### Difference between step index and graded index fiber

<table>
<thead>
<tr>
<th></th>
<th>Step index fiber</th>
<th>Graded index fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>The refractive index</td>
<td>The core is uniform</td>
<td>The core is non-uniform</td>
</tr>
<tr>
<td>of the core</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The light rays</td>
<td>The light rays will not cross the</td>
<td></td>
</tr>
<tr>
<td>propagate in zig-zag</td>
<td>graded index fiber</td>
<td></td>
</tr>
<tr>
<td>manner inside the core</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is too slow for</td>
<td>It is too fast for the most uses</td>
<td></td>
</tr>
<tr>
<td>most uses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower bandwidth</td>
<td>Higher bandwidth</td>
<td></td>
</tr>
</tbody>
</table>

### 5.3.4 Wire or Co–axial Cable communication

In wire communication, the medium of transmission is a pair of conductors called the transmission line. This means, in wire communication the transmitter and receiver are connected through a wire or line. However the installation and maintenance of a transmission line is not only costly and complex, but also occupies more space. Apart from, its message transmission capability is also limited.

### 5.4 Difference between Optical Fiber and Co–axial cable (Copper wire)

<table>
<thead>
<tr>
<th>Basis of comparison</th>
<th>Optical fiber</th>
<th>Co–axial cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission of the signal is in optical form</td>
<td>Transmission of the signal is in electrical form</td>
<td></td>
</tr>
<tr>
<td>Comparison of cable</td>
<td>Glass and plastic</td>
<td>Plastic or usually copper wire</td>
</tr>
</tbody>
</table>

### 5.4.1 How a fiber optic communication works?

A fiber optic communication network consists of

1. transmitting and receiving circuitry
2. a light sources
3. detector devices

The figure 5.8 shows the above network. When the input data in the form of electrical signals is given to the transmitter circuitry, it converts them into light signals with the help of light source. This source is a LED, whose amplitude frequency and phases must remain stable and free from fluctuation in order to have efficient transmission. The light beam from the light source is carried by an OFC to the detector circuitry.

With the help of detector circuit the light signal is converted into electrical signal by a receiver circuitry. Laser diodes also are
Communications

Voice, data and video transmission are the most common uses of fiber optics and these include,
- Telecommunication.
- Local Area Network.
- Industrial control systems.
- Avionic systems.
- Military common control and Communication systems.
- Hydrophones are used for seismic and SONAR application.

Sensors

- Sensors are used to measure various physical qualities like strain, pressure, temperature and other physical parameters.

Light guides

- Light guides are used in medical and other applications where bright light needs to be shined on a target without a clear line of sight path.

Optical Gyroscope

- Optical gyroscope with OFC has been developed and widely used for navigation purpose in aero planes.
- Optical fiber illumination is also used for decoration purposes.

5.5 Advantages and Disadvantages of OFC

5.5.1 Advantages of OFC

- Greater bandwidth than metal cables.
- Low power loss.
- Faster speed with less attenuation.
- Smaller size and less weights.
- Greater information carrying capacity.
- Higher security.
- Electrical insulator.

5.5.2 Disadvantages of OFC

- Difficult in splice.
- Highly susceptible.
- Expensive to install

5.6 Applications of OFC

Some of the main applications of an OFC are summarized below.


5.7 

Satellite Communication

5.7.1 Satellite

Normally in the solar system the planets are termed as satellites to Sun. Because the planets are revolving around the Sun in a particular orbit. Likewise each planet is having one or more small planets called sub-planets which revolving that particular planet in a defined orbit. These sub-planets are called as Natural satellites.

5.7.2 Types of Satellites

Satellites are classified into two types

1. Natural Satellites
2. Artificial Satellites (Man-Made)

5.7.3 Natural Satellites

Any planet in the solar system which goes around a particular planet is called Natural Satellites. In the solar system there are six planetary satellite systems containing 185 known natural satellites.

5.7.4 Artificial Satellites

Artificial Satellite are man-made objects(satellites) orbiting the Earth and other planets in the Solar system. Artificial Satellites are used to study the Earth, other planets to help us to communicate and even to observe the distance universe. Example Aryabhata, Baskara, Rohini, INSAT 1A, IRS...

HISTORY OF ARTIFICIAL SATELLITE

The first artificial satellite was Sputnik – 1 launched by the Soviet Union on 4th October 1945. It may also carry message recording, playback and programming facilities. The signals received by the receiver are generally weak. They are amplified by the receiver and then televised. Sputnik-2 was launched on 3rd November 1957 and carried the first living passenger into orbit, a dog named Laika. India’s first Satellite, Aryabhata was launched in the year 1975. Now approximately 2000 artificial satellites are revolving around the earth for communication purposes.

- How do satellites get power?

The sun is the main energy source for satellites. That is why all satellites have solar panel mounted on them. Each panel contains array of thousands of small solar cells which are made of silicon.

- So far how many satellites are launched by India?

So far India launched 93 satellites.

What do artificial satellites do?

Satellites are launched into space through rockets. A satellite orbits the earth while its speed is balanced by the pull of Earth’s gravity.
Artificial satellites are further classified into two type

1. Active Satellites
2. Passive Satellites

Active Satellites

An active satellite carries an antenna system, a transmitter, a receiver and a power supply. It works as microwave repeater or transponder in the sky. Figure 5.9 shows the active satellites system.

Passive Satellites

A passive satellite is a metal coated plastic balloon or metallic sphere that works as a passive reflection. It reflects the microwave signal from one region of the earth to another region. Figure 5.10 shows the passive satellites system.

5.7.5 Space Communication

In satellite communication, electromagnetic waves are used as carrier signals. These signals carry the information such as audio, video or any other signal between ground and space and vice-versa. Since satellite communication happens through space, it is also known as Space Communication.

5.7.6 Need of Satellite Communication

Two kinds of propagation are used in earlier communication.

1. Ground wave propagation
2. Sky wave propagation

Ground wave propagation

Ground wave propagation is suitable for frequencies upto 30 MHz. This method of communication makes use of the troposphere conditions of the earth.

Sky wave propagation

Suitable bandwidth for this type is broadly between 30 MHz to 40 MHz and it makes use of the ionosphere properties of the earth.

The station distance is limited to few thousands kilometers in both Ground Wave propagation and Sky Wave propagation. Satellite communication overcomes this limitation.

5.7.7 Satellites Classification

Satellites can be classified by their function since they are launched into space to do a specific job. The satellite must be designed specifically to fulfill its role.

The most important satellites are

1. Communication Satellites
2. Astronomical Satellites
3. Navigation Satellites
4. Bio Satellites
5. Weather Satellites
6. Remote Sensing Satellites
7. Nano Satellites
8. Earth Observation Satellites
5.7.8 Communication Satellites

Communication satellites are artificial satellites that relay received signals from an earth station and then retransmit the signal to other earth stations. They commonly move in a geostationary orbit. Communication satellites are placed in three earth orbits.

1. Geostationary Earth Orbit
2. Medium Earth Orbit
3. Low Earth Orbit

Satellites in Geostationary Earth Orbit (GEO) enable to get fax, video conferencing, Internet, long distance fixed phone service, television broadcasting and broadband multimedia service are provided all over the globe.

Satellites in Medium Earth Orbit (MEO) are used for mobile cell phone communication, fixed phones and other personal communications.

Satellites in Low Earth Orbit (LEO) are used paging fax, ship tracking, fixed ordinary phones, broad band multimedia, and monitoring of remote industrial spots.

Besides, Communication Satellites are helping in long way during natural calamities. In the aftermath of the earthquake the satellites pictured and helps the search and rescue teams to keep in touch with one another and were also able to maintain international communications.

5.7.9 Working of Communication Satellite

A satellite is a body that moves around another body in a particular path(orbit). A communication satellite is nothing but a microwave repeater station in space. It is helpful in telecommunications.

A repeater is a circuit which increases the strength of received signal and then transmits it. But, this repeater works as a transponder. (it changes the frequency band of transmitted signal from the received one).

The frequency with which the signal is sent into the space is called as Uplink frequency. Similarly with which the signal is sent by the transponder to earth station is called as Down-link frequency. The fig 5.11 and fig 5.12 illustrates the concept clearly.
Astronomical Satellites
Astronomical Satellites are used for observation of distance planets, galaxies and other outer space objects. These are used to monitor and image space.

Navigation Satellites
A satellite navigation or SATNAV system is a system that uses satellites to provide autonomous geo – spatial positioning. The system can be used for providing position, navigation or for tracking the position of something fitted with a receiver (satellite tracking). A satellite navigation system with global coverage may be termed a global navigation satellite system (GNSS).

Bio Satellites
Bio satellites are satellites designed to carry living organisms generally for scientific experimentation.

Weather Satellites
Weather satellites are type of satellites that is primarily used to monitor the weather and climate of the earth. These Satellites are polar orbiting satellites, covering the entire earth asynchronously or geo stationarily, hovering over the same spot on the equator.

Remote Sensing Satellites
Remote sensors collect data by detecting the energy that is reflected from Earth. These sensors can be on satellites. Remote sensor scan be either passive or active. Passive sensors respond to external stimuli. They record natural energy that is reflected or emitted from the earth’s surface. Remote sensing satellites are usually put into space to monitor resources important for humans. It might track animal migration watch agricultural crops for weather damages or see forests fire and deforestation.

Nano Satellites
Nano Satellite are very small satellites which weigh less than 10 kg. It uses MEMS (Micro – Electro – Mechanical system) technology. It is widely used in laser communication.

Earth Observation Satellites
Earth Observation Satellite is intended for monitoring of earth surface in visible, NIR and MIR electromagnetic waves with the resolution of 8 meters for the purpose of agricultural, search of minerals and energy resources, land tenure, forestry, water resources control, monitoring of situation in emergency areas.

5.7.10 Application of Satellite Communication
- Military Communication
- Tele Communication
- Satellite phone
- VSAT (Very small aperture terminal)
- Cable TV
- DBS (Direct Broadcast satellite - DTH)
- GPS (Global Positioning System)
- Satellite Internet
- Weather forecasting
- Photography
- Navigation etc…..

5.8 Microwave Communication
Sending and receiving the signal via microwaves is called Microwave Communication. It is also known as “line of sight” Communication. It should be composed of voice, data, television, telephony or radio signals. Microwaves are also emitted by natural objects as well as from space.

CHAPTER 5 Communication Techniques
Microwave is a part of electromagnetic spectrum, comprising the bands between 300 MHz and 300 GHz. Microwave Communication is used for point to point communication. It requires a direct line of sight path between the transmitter and receiver. Microwave communications avoid the need for a physical connection between the transmitter and receiver.

Microwave communication would generally require a repeater, which is placed in every few tens of miles of distance between the transmitter and the receiver. When satellites are used for microwave communication rather than for broadcasting purposes, highly directive antennas are essential to provide the required acts as a repeater in microwave communication.

The satellites acts as a repeater in microwave communication. Figure 5.13 shows the microwave communication.

5.8.1 Advantages of Microwave Communication

- It has larger bandwidth and hence large amount of information can be transmitted using it.
- It helps to manage crowded spectrum with the use of high selective receivers.
- The channels will not overlap or do not cause interference to nearby channels.
- Wired communication is not possible in hilly remote areas where there is microwave communication is suitable choice in that place.

5.8.2 Disadvantages of Microwave Communication

- Microwave Communication is limited to line of sight mode only, other modes of communication are not possible.
- It is difficult to implement lumped components such as resistors, inductors and capacitors at microwave frequencies.

5.8.3 Application of Microwave Communication

Microwave Communications are used in the following fields.

- Wireless communications (space, cellular, phones, Bluetooth, satellites…)
- Radar and Navigation (to detect aircraft, ship, space craft, weather formation, etc…..)
- Remote sensing (land surface …)
- RF Identification (security, product tracking, animal tracking…)
- Broadcasting (mobile phones and WiFi…)
- Heating (baking, food process, ovens, drying….)
- Bio-medical applications (diagnostics)

![Microwave Communication](image-url)

**FIGURE 5.13** Microwave Communication
5.9 Radar systems

Radar stands for Radio Detection And Ranging. It is a type of radio system where radio frequency signals are used to determine the position of speed of an object. Often the objective is passive, so the reflection of RF signal from the object is used to find the speed or velocity of the object. Radar is used for a variety purposes including weather monitoring, air traffic control, speed enforcement astronomy, navigation and military application. Figure 5.14 shows the block diagram of Radar.

Transmitter

The radar transmitter produces the short duration RF pulses of energy that are sent to the space by the antenna.

Duplexer

The duplexer alternatively switches the antenna between the transmitter and receiver so that only one antenna can be used for both transmission and reception. This switching is necessary because the high power pulses of the transmitter would destroy the receiver if energy were allowed to enter into the receiver.
**Receiver**
The receivers amplify and demodulate the received RF-signals. The receiver provides usable signals on the output.

**Radar antenna**
The antenna transfers the transmitter energy to the signals in space with the required distribution and efficiency.

**Indicator**
The indicator should present a continuous, easily understandable, graphic picture of the relative position of radar target to the observer.

The radar screen displays the echo signals as bright blimps.

5.9.1 Types of RADAR
The following flow charts shows the different types of Radars

5.9.2 Applications of Radar

- **Air Traffic Control (ATC)**
  Radar are used for safety controlling of the air traffic

- **Air Craft Navigation**
  The weather avoidance radars and ground mapping radars are employed in aircrafts to navigate it properly in all the conditions.

- **Ship Navigation and safety**
  Radars are used for beaconing and used an aid of navigation and also used to find the depth of sea.

- **Space**
  Radars are used for docking and safely landing of spacecrafts.

- **Remote Sensing and Environment**
  They are employed in remote sensing for detecting weather conditions of the atmosphere and tracking of planetary conditions.
5.10 SONAR Technology

SONAR (Originally an acronym for Sound Navigation And Ranging) is a technique that uses sound propagation. Sonar uses the echo principle by sending out sound waves under water or through the human body to locate objects.

When man or animal or machine makes a noise, it sends sound waves into the environment around it. Those waves bounced back after hitting any nearby objects, and some of them reflect back to the object that made the noise. SONAR works using this echo principle.

A method or device detecting or locality objects especially under water by means of sound waves sent out to be reflected by the objects also a device for detecting the presence of a vessel (such as a submarine) by the sound, it emits in water. Figure 5.15 shows the SONAR technology.

5.10.1 Types of SONAR

There are two types of SONAR

1. Active SONAR
2. Passive SONAR

Active SONAR

Active SONAR is emitting pulses of sound and listening echoes. It sends out sound pulses. Then receives the returning sound echo.

Passive SONAR

It is essentially listening for the sound made by vessels. It receives sound echoes without transmitting their own sound signals.

5.10.2 Uses of Active SONAR

- Detecting and tracking submarines, ships, etc. (under-water combat)
- Mapping the ocean flour (navigation / Surveillance)
- Detecting underwater mines

5.10.3 Uses of Passive SONAR

Listening to the noise from enemy submarines, surface vessels etc over long range.

Many animals use echo-location for hunting and navigation purposes.
5.10.4 Applications of SONAR

- To detect, track and destroy enemy ships and submarines.
- Detecting underwater mines.
- To determine navigational location.
- Mapping the Ocean floor.
- In research it is used to find animal location and tracking.
- In medical, it is used in sonography and auditory research.

5.11 Tsunami System

5.11.1 What is Tsunami?

A Tsunami is a series of fast moving waves in the ocean caused by powerful earthquakes or volcanic eruptions. A tsunami has a very long wavelength. It can be hundreds of kilometres long.

5.11.2 Need of Tsunami Warning System

The east and west coasts of India and the island regions are likely to be affected by tsunamis generator mainly due to earthquakes in the subductions zones. Hence there was a need for developing tsunami warning system.

5.11.3 Tsunami Warning System

Tsunami warning system is used to detect tsunami in advance and issue warnings to prevent losses of life and property damage

It is made up of two equally important components

1. A network of sensors to detect tsunamis.
2. A communication infrastructure to issue timely alarms to permit evacuation of the costal areas.

FIGURE 5.16 (a) Tsunami warning system
A Seismograph is a device for measuring the movement of the earth and consists of a ground-motion detection sensor, called a seismometer, coupled with a recording system.

A Seismograph is an instrument which is used to detect and record earthquake. Generally it consists of a mass attached to a fixed base. During an earthquake, the base moves and the mass does not.

The motion of the base with respect to the mass is commonly transferred into an electrical voltage. Figure 5.17 shows the seismograph.

The electrical voltage is recorded on paper, magnetic tape or recording medium. This record is proportional to the motion of the seismometer mass relative to the earth but it can be mathematically converted to a record of the absolute motion of the ground.

The magnitude of an earthquake is determined by recording of the seismic waves resulting from the vibration generator by the seismic source. Sensitive seismograph, which greatly magnify these ground motions that can detect strong

There are two types of tsunami warning systems

1. International tsunami warning systems
2. Regional warning systems

Figure 5.16 shows the Tsunami warning system.

Where is the tsunami warning system located in India?

Answer: In Hyderabad

5.12 Seismograph and Avionics

5.12.1 Seismograph

A Seismograph is a device for measuring the movement of the earth and consists of a ground-motion detection sensor, called a seismometer, coupled with a recording system.
earthquakes from sources anywhere in the world. The time, locations and magnitude of an earthquake can be determined from the data recorded by seismograph station.

5.12.2 Avionics system
Avionics are the electronic Systems used on aircraft, artificial satellites and space craft. Avionic system included communications, navigations, the display and magnet of multiple system and the hundreds of systems that’s are fitted to aircraft to perform individual function.

How does the word Avionics come from?
The word avionics comes from aviation + electronics

5.12.3 Aircraft AVIONICS
The cockpit of an aircraft is a typical location for avionic equipment, including control, monitoring, communication, navigation, weather, and anti-collision systems. The majority of aircraft power their avionics using 14- or 28volt DC electrical systems; however, larger, more sophisticated aircraft (such as airliners or military combat aircraft) have AC systems operating at 400 Hz, 115 volts AC. A separate international organisation called Airlines Electronic Engineering Committee (AEEC) prepare the International standards for Avionics equipment. Figure 5.18 shows the Cockpit of flight Airbus A380.

5.12.3 Communications
Communications connect the flight deck to the ground and the flight deck to the passengers. Onboard communications are provided by public-address systems and aircraft intercoms.

The VHF aviation communication system works on the airband of 118.000 MHz to 136.975 MHz. Each channel is spaced from the adjacent ones by 8.33 kHz in Europe, 25 kHz elsewhere. VHF is also used for line of sight communication such as aircraft-to-aircraft and aircraft-to-ATC. Amplitude modulation (AM) is used, and the conversation is performed in simplex mode. Aircraft communication can also take place using HF (especially for trans-oceanic flights) or satellite communication.
Aircraft have means of automatically controlling flight. Initially Autopilot system was developed to fly bomber planes steady enough to hit accurate targets from even 25,000 feet. Nowadays most commercial planes are equipped with aircraft flight control systems in order to reduce pilot error and workload at landing or take off.

The first simple commercial auto-pilots were used to control heading and altitude and had limited authority on things like thrust and flight control surfaces. In helicopters, auto-stabilization was used in a similar way. The first systems were electromechanical. The advent of electronic (fly by wire) and electro-actuated flight surfaces (rather than the traditional hydraulic) has increased safety.

### 5.12.4 Navigation

Air navigation is the determination of position and direction on or above the surface of the Earth. Avionics can use satellite navigation systems (such as GPS and WAAS), ground-based radio navigation systems (such as Ominidirectional Range (VOR) or LORAN), or any combination thereof. Navigation systems calculate the position automatically and display it to the flight crew on moving map displays. Older avionics required a pilot or navigator to plot the intersection of signals on a paper map to determine an aircraft’s location; modern systems calculate the position automatically and display it to the flight crew on moving map displays.

### 5.12.5 Monitoring

The first hints of glass cockpits emerged in the 1970s when flight-worthy Cathode Ray Tube (CRT) screens began to replace electromechanical displays, gauges and instruments. A «glass» cockpit refers to the use of computer monitors instead of gauges and other analog displays. Aircraft were getting progressively more displays, dials and information dashboards that eventually competed for space and pilot attention. In the 1970s, the average aircraft had more than 100 cockpit instruments and controls.

Glass cockpits started to come into being with the Gulfstream GIV private jet in 1985. One of the key challenges in glass cockpits is to balance how much control is automated and how much the pilot should do manually. Generally they try to automate flight operations while keeping the pilot constantly informed.

### 5.12.6 Aircraft Flight-Control System

Aircraft Flight-Control System

Autopilot was first invented by Lawrence Sperry during World War I

---

Who invented autopilot System

Autopilot was first invented by Lawrence Sperry during World War I

To supplement air traffic control, most large transport aircraft and many smaller ones use a Traffic Alert and Collision Avoidance System (TCAS), which can detect the location of nearby aircraft, and provide instructions for avoiding a mid-air collision. Smaller aircraft may use simpler traffic alerting systems such as TPAS, which are passive (they do not actively interrogate the transponders of other aircraft) and do not provide advisories for conflict resolution.

To help avoid Controlled Flight into Terrain (CFIT), aircraft use systems such as Ground-Proximity Warning Systems (GPWS), which use radar altimeters as a key element. One of the major weaknesses of GPWS is the lack of «look-ahead» information, because it only provides altitude above terrain «look-down». In order to overcome this weakness, modern aircraft use a Terrain Awareness Warning System (TAWS).
5.12.8 Flight recorders
Commercial aircraft cockpit data recorders, commonly known as “black boxes”, store flight information and audio from the cockpit. They are often recovered from an aircraft after a crash to determine control settings and other parameters during the incident.

5.12.9 Weather Systems
Weather radar
Weather systems such as weather radar (typically Arinc 708 on commercial aircraft) and lightning detectors are important for aircraft flying at night or in instrument meteorological conditions, where it is not possible for pilots to see the weather ahead. Heavy precipitation (as sensed by radar) or severe turbulence (as sensed by lightning activity) are both indications of strong convective activity and severe turbulence, and weather systems allow pilots to deviate around these areas.

5.12.10 Lightning Detector
Lightning detectors like the Storm-scope or Strike-finder have become inexpensive enough that they are practical for light aircraft. In addition to radar and lightning detection, observations and extended radar pictures (such as NEXRAD) are now available through satellite data connections, allowing pilots to see weather conditions far beyond the range of their own in-flight systems. Modern displays allow weather information to be integrated with moving maps, terrain, and traffic onto a single screen, greatly simplifying navigation.

Modern weather systems also include wind shear and turbulence detection and terrain and traffic warning systems. Inplane weather avionics are especially popular in Africa, India, and other countries where air-travel is a growing market, but ground support is not as well developed.

5.12.11 Aircraft Management Systems
There has been a progression towards centralized control of the multiple complex systems fitted to aircraft, including engine monitoring and management. Health and Usage Monitoring Systems (HUMS) are integrated with aircraft management computers to give maintainers early warnings of parts that will need replacement.

The integrated modular avionics concept proposes an integrated architecture with application software portable across an assembly of common hardware modules. It has been used in fourth generation jet fighters and the latest generation of airliners.

5.12.12 Mission or Tactical avionics
Military aircraft have been designed either to deliver a weapon or to be the eyes and ears of other weapon systems. The vast array of sensors available to the military is used for whatever tactical means required. As with aircraft management, the bigger sensor platforms (like the E3D, JSTARS, ASTOR, Nimrod MRA4, Merlin HM Mk 1) have mission-management computers.

Police and EMS aircraft also carry sophisticated tactical sensors.

5.12.13 Military Communications
While aircraft communications provide the backbone for safe flight, the tactical systems are designed to withstand the rigors of the battle field. UHF, VHF Tactical (30–88 MHz) and SatCom systems combined with ECCM(Electronics Counter-Counter Measures)methods.
5.12.14 Electronic Counter-CounterMeasures (ECCM)

Electronic Counter-CounterMeasures (ECCM) is the method by which you endeavour to combat the ECM systems of the enemy by either making your equipment ECM-resistant or by using techniques to nullify his jamming and/or decoy systems. It is an extremely sensitive area in that any disclosure of ECCM measures designed into a system are likely to inform the enemy of its vulnerability to ECM.

Against jamming systems, the most commonly used method is frequency agility, whereby the transmissions are made to “hop” over a large frequency band in a random fashion. This means that either the jammer has to spread its power over the entire band with the inevitable loss of strength on any particular frequency, or it must attempt to follow the signal as it hops randomly.

The latest technique is the use of “stealth” techniques to combat the radar system. This beginning is to be employed in aircrafts and consists of a number of methods to reduce the radar cross section of the aim. The main techniques employed are

- to design the airframe itself to avoid sharp corners and flat surfaces which act as radar reflectors, and
- the use of radar absorbent material which minimises the amount of energy reflected back to the radar.

At the aircraft the most important parts of the fuselage can be covered in radar absorbent material to make it extremely difficult to detect.

A number of anti-radiation missiles have been developed. The missile is passive in operation so that it cannot be picked up by ESM systems, and normally locks on to the sidelobes of the radar transmission. The main countermeasures against this type of missile are low sidelobes, frequency agility, and the use of decoy transmitters which must be positioned close enough to the surveillance radar to “seduce” the missile but not so close as to endanger the main system.

LEARNING OUTCOME

At the end of this chapter, the students can learn about

- The principle of OFC.
- Advantages and disadvantages of OFC.
- The difference between OFC and cable communication.
- The different types of satellite and its applications.
- The basic function of RADAR and SONAR.
- The application of Avionics and Seismograph.
Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Fiber</td>
<td>A glass or plastic fiber that has the ability to guide light along its axis</td>
</tr>
<tr>
<td>Cable</td>
<td>One or more optical fibers enclosed, with strength members in a protective</td>
</tr>
<tr>
<td>Multi mode Fiber</td>
<td>An optical fiber that has a core large enough to propagate more than one</td>
</tr>
<tr>
<td></td>
<td>mode of light</td>
</tr>
<tr>
<td>Orbit</td>
<td>The path a satellite takes while travelling around the earth.</td>
</tr>
<tr>
<td>Downlink</td>
<td>The signal that comes down a satellite to an earth station.</td>
</tr>
<tr>
<td>Earth Station</td>
<td>An installation located on the Earth's surface and intended for communication with one or more satellites.</td>
</tr>
<tr>
<td>Repeater</td>
<td>A device that amplifies incoming electrical signals and retransmits them towards the earth station(s) at a different frequency.</td>
</tr>
<tr>
<td>Transponder</td>
<td>A transmitter–receiver device that transmits signals automatically when it receives pre–determined signal.</td>
</tr>
<tr>
<td>Duplex</td>
<td>A term meaning two way communication</td>
</tr>
<tr>
<td>Uplink</td>
<td>The signal that transmits an earth station to a satellite.</td>
</tr>
</tbody>
</table>

Part – A (1 Mark)

1. The principle of OFC technology was ____________
   a. Electromagnetic induction
   b. Internal reflection
   c. Electro motive force
   d. Mutual inductance

2. The core diameter of step index single mode is ____________
   a. 5 \( \mu m \) & 10 \( \mu m \)
   b. 1 \( \mu m \) & 20 \( \mu m \)
   c. 30 \( \mu m \) & 40 \( \mu m \)
   d. 2 \( \mu m \) & 5 \( \mu m \)

3. The diameter of step index multimode is ____________
   a. 62.5\( \mu m \)/125 \( \mu m \)
   b. 72.5\( \mu m \)/125 \( \mu m \)
   c. 32.5\( \mu m \)/125 \( \mu m \)
   d. 42.5\( \mu m \)/125 \( \mu m \)

4. Which of the following fiber has higher bandwidth?
   a. Step index single mode
   b. Step index multimode
   c. Graded index multimode
   d. None of the above

5. ____________ is the primary source of power for satellites
   a. Sun
   b. Light
   c. Heat
   d. None of the above

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6. Solar cells in satellites mostly made up of _________
   a. Silicon  
   b. Germanium 
   c. Copper  
   d. Aluminium

7. The first artificial satellite was _________
   a. Sputnik-1  
   b. Apple 
   c. PSLV-1  
   d. Aryabhata

8. The name of dog travelled in sputnik-2 was _________
   a. Leno  
   b. Laika 
   c. Lucy  
   d. Leha

9. _________ is widely used in laser Communication
   a. Bio Satellites  
   b. Weather Satellites 
   c. Nano Satellites  
   d. Earth observation Satellites

10. Microwave Communication is also called _________
    a. Satellites Communication 
    b. Optical fibre Communication 
    c. Line of sight Communication 
    d. Space Communication

11. Microwave frequency ranges were _________
    1. 1 GHz to 30 GHz  
    2. 100 KHz to 30 MHz 
    3. 550 KHz to 1650 KHz  
    4. 300 MHz to 300 GHz

12. _________ works as microwave repeater.
    a. Amplifier  
    b. Satellite 
    c. Antenna  
    d. SONAR

13. Radar is used to determine location or speed of an _________
    a. Ship  
    b. Object 
    c. Wave  
    d. Metal

14. SONAR uses _________ principles by sending out sound waves under water.
    a. Electromagnetic 
    b. Electromotive 
    c. Echo  
    d. Mutual inductance

15. A seismograph is an instrument to detect and record _________
    a. Weather report 
    b. Earthquake 
    c. Tsunami  
    d. Natural resouces.

Part – B (3 Marks)

II Answer in one or two sentences

1. What are fiber optics?
2. What are the basic elements of fiber optics?
3. What are fiber optics basics?
4. How is optical fiber classified?
5. Write the difference between step index and graded index fiber.
6. What are the advantage and disadvantage of OFC?
7. What is RADAR?
8. Write about the types of RADAR.
9. What is Satellite communication?
10. Write the uses of Earth observation satellite.
11. Define the uses of Tsunami Warning System.
13. Write short notes on an Avionics.
15. What do Satellites do?

Part – D (10 Marks)

IV Answer in One Page (Essay type Question)

1. Explain briefly the difference between optical fiber and co-axial cable.
2. What are the applications of OFC?
3. Draw the block diagram of RADAR and explain.
4. Explain about any five artificial satellites.
5. How does Communication satellite work?

Part – C (5 Marks)

III Answer in a paragraph

1. Explain the types of optical fiber.
2. How does OFC work?
3. What are the advantages and disadvantages of OFC?
4. What are the uses of RADAR?
5. Explain about Microwave communication.
6. List out the applications of SONAR.

ANSWERS

1. (b) 2. (a) 3. (a) 4. (c) 5. (a)
6. (a) 7. (d) 8. (b) 9. (c) 10. (c)
11. (d) 12. (b) 13. (b) 14. (c) 15. (b)
In this chapter, the students can

- Study the fundamental steps involved in Digital image processing
- Expose current applications of Digital image processing
- Study the importance of Image sensors (CCD, CMOS) in the digital camera technology
- Understand the basic functions of Digital camera
- Understand the Fundamental concepts of CCTV system

**CONTENT**

6.1 Introduction
6.2 Image Processing
6.3 Image Sensors – CCD, CMOS
6.4 Digital Cameras
6.5 CCTV system
6.6 PIXELS
6.7 Light Sensitivity

**6.1 Introduction**

‘A picture is worth more than thousand words’. It refers that a single still image or an image of a subject conveys meaning of the subject matter effectively than a description. Seventy percent of human perception is only through vision. It will give much more meaningful information to the user.

An image is a pictorial representation of an object or scene. There are two types of images. They are

1. Analog
2. Digital

Analog is a continuously varying quantity. Analog images are captured by traditional photographic sensor portrays on paper based media or transparent media.
Digital images are produced by electro-optical sensors and composed of elements of tiny equal areas, called picture elements, abbreviated as pixels or pels arranged in a rectangular array.

Digital image processing can be defined as the computer manipulation of digital values contained in an image for the purposes of image correction, image enhancement and feature extraction.

A digital image processing system consists of computer hardware (PCs) and dedicated image processing software necessary to analyse digital image data.

The application of image processing is important in several areas of science, engineering and technology. It can be realized through the following applications.

1. Improvement of pictorial information for human perception.
2. Image processing for autonomous machine application.
3. Efficient storage and transmission.

### HISTORY

In the early 1920s, one of the first applications of digital imaging was in the newspaper industry. The pictures were sent by submarine cable between London to New York. This took several hours to send a picture. Then, Barlane cable picture transmission system was introduced. This system used a specialized printing equipment to code the picture before sending and reconstructing the same after receiving. The early Barlane systems were capable of coding the images in only five different gray levels.

In 1929, Barlane systems with 15 grays levels resulted in higher quality images. The new reproduction processes based on photographic techniques was evolved during this period. In 1960s, the improvements in computing technology and the onset of the space led to a surge of work in digital image processing. For example, computers used to improve the quality of images of the moon taken by the Ranger 7 probe.

In 1970s, Digital Image Processing (DIP) was used in medical applications. Especially, it was used in Computerized Axial Tomography (CAT) scanners. Thereafter, DIP techniques have exploded and they are now used for all kinds of tasks in all fields of science, technology, engineering and medicine. Figure 6.1 shows the first digital image taken.

Digital images are produced by electro-optical sensors and composed of elements of tiny equal areas, called picture elements, abbreviated as pixels or pels arranged in a rectangular array.

The world’s first photograph made in a camera was taken in 1826 by Joseph Nicéphore Niépce. The photograph was taken from the upstairs’ windows of Niépce’s estate in the Burgundy region of France. This image was captured via a process known as heliography, which used Bitumen of Judea coated onto a piece of glass or metal; the Bitumen then hardened in proportion to the amount of light that hit it.
6.2 Image Processing

In the image processing technique, analog image is converted into digital image. Now we may raise one question, what is a Digital Image?

An image may be defined as a two-dimensional function, $f(x, y)$, when $x$ and $y$ are spatial coordinates and the amplitude of $f$ at any pair of coordinates $(x, y)$ is called the intensity of gray level of the image at that point. When $x$, $y$ and the amplitude values $f$ are all finite, discrete quantities, we call the image as a digital image. The term gray level is used often to refer to the intensity of monochrome images. Color images are formed by a combination of individual 2D images.

For example: In the RGB color system, a color image consists of three (red, green & blue) individual components. For this reason, many of the techniques developed for monochrome images can be extended to color images by processing the three components, individually.

An image may be continuous with respect to the $x$ and $y$ coordinates and also in amplitude. Converting such an image to digital form requires that coordinates as well as the amplitude of the image to be digitized.

6.2.1 Electromagnetic energy spectrum

Figure 6.2 shows the electromagnetic spectrum, in which human eye can visualize and distinguish the visible region of the spectrum. If you want to see the images taken using the other regions of the spectrum such as X-ray, gamma ray, UV, Infrared, etc., you need to generate the images using specialized instruments and those images are processed using digital image processing methods.

The first digital photograph was taken all the way back in 1957; that is almost 20 years before Kodak’s engineer invented the first digital camera. The photo is a digital scan of a shot initially taken on film. The picture depicts Russell Kirsch’s son and has a resolution of 176×176 – a square photograph worthy of any Instagram profile.

The first color photograph was taken by the mathematical physicist, James Clerk Maxwell. The piece above is considered the first durable color photograph and was envied by Maxwell at a lecture in 1861. The inventor of the SLR, Thomas Sutton, was the man who pressed the shutter button, but Maxwell is credited with the scientific process that made it possible. For those having trouble identifying the image, it is a three-color bow.
Image processing is used everywhere in the world. The areas of application of image processing are classified according to the images generated from their energy source. The principal energy source for images is the electromagnetic energy spectrum. The other energy sources may be acoustic, ultrasonic and electronic.

Images generated using gamma rays are called gamma ray imaging. Similarly, using X-rays are called X-ray imaging. These types of images are widely used in the medical field. Figure 6.3 shows some of the medical images taken using X-ray and gamma ray.

### 6.2.2 Image Sampling and Quantization

There are many ways to acquire or get images. But, the output from most of the sensors is a continuous or analog waveform. In order to generate a digital image, this continuous sensor data is converted into digital form. This comprises of two processes.

1. **Sampling:** Digitization spatial coordinates \((x, y)\) is called image sampling. To be suitable for computer processing, an image function \(f(x, y)\) must be digitized both in spatial and magnitude domains.
2. Quantization: Digitizing the amplitude values is called quantization. Quality of digital image is determined to a large degree by the number of samples and discrete gray levels used in sampling and quantization processes.

6.2.3 Types of Image processing

There are no specific boundaries in the image, i.e., image processing at one end and computer vision at the other end. Image processing is divided into three basic types.

Low – Level Image processing

This process involves basic operations such as noise reduction in the image, image enhancement in terms of contrast and image sharpening. Here, the input and output of these processes are images.

Medium – Level Image processing

This process involves operations such as image segmentation, description of the objects presented in the image and the classification of objects. The inputs of this process are images, but the outputs are features extracted from these images. i.e., edges, contours.

High-level Image processing

This process involves operations such as image analysis. The inputs of this process are features of images and the outputs are also the important features of images.

6.2.4 Fundamental steps of digital image processing

Figure 6.4 shows the steps involved in digital image processing. The important steps involved in image processing are described as follows.

Image Acquisition

It is the first step in any image processing application. Note that the acquisition could be as simple as being given an image that is already in digital form. Generally, the image acquisition stage involves preprocessing, such as sampling, scaling, coding, etc.

![Block diagram of digital image processing steps](image)

Image Enhancement

It is the process of improving the quality of a digitally stored image by manipulating the image with software. For example, removing noise, sharpening or brightening an image, this makes easier to identify key features. Figure 6.5 shows the image enhancement on a noisy input image, which exhibits improved features as well as complete removal of noise (salt and pepper noise).

Image Restoration

It is the process of recovering an image from a degraded version. The degradation may come in many forms like blurred, noisy image and camera out of focus problem. In order to restore the original
image, we have to apply the inverse process to restore the degraded pixels. Figure 6.6 shows image restoration in a still image.

**Image Compression**

It is a process used to reduce the amount of data required to faithfully represent original file. This technique should not affect or degrade the quality of the image, but it will reduce the file sizes up to 60-70% and hence many files can be combined into one compressed document, which makes the communication of image over internet at a faster transmission rate. Figure 6.7 shows the compression and decompression (reconstruction) of a brain image.
**Morphological Processing**

It is used to extract image components that are useful in the representation and description of region shape such as boundary extraction, skeletons, convex hull, morphological filtering, thinning and pruning. Figure 6.8 shows some of the morphological operations like binarization and thinning applied in a biometric fingerprint image.

![Figure 6.8 Morphological Operations in Fingerprint biometric image](image)

**Image Segmentation**

It is a technique of dividing or partitioning an image into parts called segments. The ultimate goal of segmentation is to find meaning from an image such as identification of an object, understanding the interactions, etc. Figure 6.9 shows the segmentation of a Palm image.

![Figure 6.9 Segmentation of Palm Image](image)

**Image Recognition**

It is the process of identifying and detecting an object or a feature in a digital image or video. For example, computers can use machine vision technologies in combination with a camera and artificial intelligence software to achieve image recognition. Figure 6.10 shows face recognition of a person for different expressions.
2. Remote sensing

In this application, sensors mounted on a remote sensing satellite or multi-spectral scanners mounted on an aircraft capture the pictures of the earth's surface. These pictures are processed by transmitting to the earth station. Techniques used to interpret the objects and regions are employed in flood control, city planning, resource mobilization, agricultural production monitoring, etc.

3. Intelligent transportation system

This technique is used in Automatic number plate recognition and Traffic sign recognition.

4. Automatic visual inspection system

This application improves the quality and productivity of the product in the industries. For example, any faulty components in electronic or electromechanical systems can be identified by this application. Higher amount of thermal energy is generated by these faulty components. The infra-red images are taken to detect the distribution of thermal energies in the assembly.
From this, the faulty components can be identified by analyzing the infrared images.

5. **Moving object tracking**
   This application enables to measure motion parameters and acquire visual record of the moving object. The different types of approach to track an object are
   i. Motion based tracking
   ii. Recognition based tracking

6. **Video processing**
   A video is a very fast movement of pictures. The quality of a video depends on the number of frames/seconds and the resolution of each frame being used. Video processing involves noise reduction, detail enhancement, motion detection, frame rate conversion, aspect ratio conversion, color space conversion, etc.

7. **Pattern recognition**
   In pattern recognition, image processing is used to identifying the objects from the images and then machine learning is used to train the system for the change in pattern. Pattern recognition is used in computer aided diagnosis, recognition of handwriting, recognition of image, etc.

8. **Transmission and encoding**
   The very first image that has been transmitted from London to New York via a submarine cable. The picture that was sent took three hours to reach from one place to another.
   Nowadays, we are able to see live video feed, or live CCTV footage from one continent to another with just a delay of second. It means that lot of techniques have been developed in this field for transmission and encoding. Many different file formats have been developed to meet the requirements of high or low bandwidth to encode photos and then streaming over the internet.

### 6.3 Image Sensors

Image sensor is an electronic device that converts an optical image into an electronic signal. It is widely used in digital cameras and imaging devices to produce digital image from the received light energy.

There are two types of digital camera sensors. They are,

1. **Charge Coupled Device (CCD) sensor**
2. **Complementary Metal Oxide Semiconductor (CMOS) sensor**

Both these sensors consist of millions of photosites called pixels. These photosites convert the incoming light into the charge or electron. The CCD and CMOS sensors are quite different, but common in many aspects. The similarities are as follows.

These sensors first convert the incoming light into the charge. So the photosites or the pixels are exposed to the light for certain amount of time. During this time, the charge will get collected in these pixels. Then, the charge is collected by the pixels and transferred for further processing. Finally, the charge is converted into voltage and amplified using an amplifier.

**CCDs were invented by Willard Boyle and George E. Smith from AT &T Bell Labs, in the year 1969. The first self-contained digital camera (1975) was built by engineer Steven Sasson of Kodak, which gave a black–and–white image of 0.01 megapixels.**
6.3.1 Working of CCD Sensors

The CCD sensor consists of millions of pixels. When these pixels are exposed to the incoming light, they convert the light into the charge. Then, the charge gets accumulated in these pixels. The accumulated charge is then transferred to the horizontal shift registers. Figure 6.11 shows the mechanism of flow of charge carrier in CCD sensor.

Further, the charge has been transferred into the vertical shift register. In the shift registers, the charge is converted into voltage, sequentially. After voltage conversion, voltage corresponding to each pixel is amplified by an amplifier. Then, the output voltage is converted into the digital data by an analog to digital convertor. In this way, the charge of each pixel is converted into corresponding voltage level. This procedure is repeated for all the frames.

6.3.2 CMOS Sensor

Eric R. Fossum is one of the inventors of CMOS image sensors in the year 1995, which is used in nearly all smartphones and digital cameras.

The fabrication technology of CMOS sensor is similar to that of the integrated circuit. In this sensor, many peripherals circuits are integrated inside the single chip. In the CMOS sensor, charge-voltage conversion as well as voltage amplification is carried out in the pixel itself. By using this technique, the processing speed of the CMOS sensor is much higher than the CCD sensor. In CMOS sensor, the voltage which is entering into each pixel is read in a line by line fashion. Figure 6.12 shows the working principle of CMOS sensor. Initially, the

Applications

CCD sensors widely used in many scientific, engineering and technological applications. It is mainly used in many instruments such as,

1. Photocopiers
2. Security Surveillance Camera
3. Fax machine
4. Dentistry X-rays
5. Camcorder
first row pixel is activated using the pixel select switch. Then, this switch connects the output voltage of the pixel to the column line. By activating the column select switch, one-by-one, the data of each pixel of the specific row are read. The same procedure is repeated for the remaining lines.

**Applications**

CMOS sensors can be used for various industrial and medical applications. Some of imported applications are given here:

1. Machine vision
2. Coin detection
3. Finger print pattern imaging

### Comparison of CCD and CMOS sensors

The comparison between CCD and CMOS sensors are summarized in Table 6.1.

#### 6.4 Digital Cameras

A camera is an imaging device which uses the spectrum of light to capture still images on a light sensitive medium (a photographic film or an electronic sensor). The functioning of a camera is not very different from the functioning of human eye, however the latter is more advanced and its precision is unmatched.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Specification</th>
<th>CCD</th>
<th>CMOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>System Integration</td>
<td>Being old technology, it is not possible to integrate the timers and ADC to the main sensors.</td>
<td>It is like IC fabrication technology, quite possible to integrate with peripheral devices.</td>
</tr>
<tr>
<td>2</td>
<td>Power Consumption</td>
<td>Requires different power supplies for different timing clocks. Typically, 7 V to 10 V (Requires more power).</td>
<td>Requires single power supply. Typical voltage rating is from 3.3 V to 5 V (Requires Less power)</td>
</tr>
<tr>
<td>3</td>
<td>Processing Speed</td>
<td>Speed is comparatively less. It is further increased by using multiple shift registers.</td>
<td>The speed is high, because the charge conversion is made by the same pixel. It can be further increased by using multiple column select lines.</td>
</tr>
<tr>
<td>4</td>
<td>Noise and Sensitivity</td>
<td>It has more sensitivity, because the dynamic range is quite high. Less noise.</td>
<td>It has less sensitivity because the charge to voltage convertor circuit and amplification circuit integrated in the same pixel. It has low fill factor causes more noise level.</td>
</tr>
<tr>
<td>5</td>
<td>Image Distortion</td>
<td>If the sensor is exposed for a longer time, then it will be affected by Blooming effect. This distortion can be reduced by using anti-blooming technique.</td>
<td>This sensor is affected by the distortion called Rolling shutter. This is due to capturing the fast moving object by the sensor. This distortion can be reduced by exposing all the pixels at the same time.</td>
</tr>
</tbody>
</table>
Basicall,y camera can be classified into two types. They are

1. Analog camera
2. Digital camera

In analog camera, the light from the scene travels through the lens and strikes some sort of light sensitive surface inside the camera, called photographic film. The light falls on the photographic film produces the image on the film, which is chemically processed to visualize the image. Thus, analog camera mostly depends on mechanical and chemical processes for producing a picture.

Digital camera is the alteration of the conventional analog camera. This camera depends on digital processes, i.e., the light falls on the object is converted into image using a CCD or CMOS sensor, which converts the image into digital data format (0 and 1). Therefore the images are easily processed and recognized by a computer using mathematical algorithms. The 0’s and 1’s in a digital camera are kept as strings of tiny dots called pixels.

Table 6.2 summarizes the features of analog and digital camera technologies.

### 6.4.1 Components of Digital Camera

All types of camera comprises of some basic components such as a lens/lenses, view finder, aperture, shutter and data memory. When the shutter is closed, no light travels through the lens. When the shutter is pressed the shutter opens and light travels through the lens, which in turn strikes the light sensitive material inside the camera. Figure 6.13 shows the components of a digital camera. In this section, we discuss about the function of the various components that are unique to digital photography.

1. **Image sensor**

The image sensor is basically a microchip having a width of 10 mm. It contains millions of light sensitive pixels, also called arrays, which individually measures the light striking on each pixel. A color filter
sits atop the image sensor, which only allows certain pixels to measure certain colors of light waves. There are two types of image sensors. They are CCD sensor and CMOS sensor.

2. Digital convertor
The data collected in each pixel is converted into a digital signal (0 and 1). This process is manipulated by the convertor.

3. Circuit Board
The digital camera carries a circuit board that holds all of the computer chips (IC), which is used to record the data. The circuitry on the board carries the data from the image sensor and other chips to the storage medium, i.e., memory card.

4. Display Screen/View Finder
The digital camera’s display screen is used to make changes to the camera settings as well as to compose and to review the photos, after they are shot. Some digital cameras still use a view finder for composing the scene, offering the display screen as a second composition option. Nowadays LCD screen is used as a view finder.

5. Lens
The lens is one of the most vital parts of a camera. The light enters through the lens starts the photo process. Lenses can be either fixed permanently to the body or interchangeable. They can also vary in focal length, aperture and other details. There are four types of digital camera. They are
   i. Fixed-focus lens
   ii. Fixed-zoom lens
   iii. Optical-zoom lens
   iv. Digital-zoom lens

6. Aperture
An aperture is a hole through which light passes to the camera sensor. The size of the hole can be varied using an iris-like diaphragm.
7. Shutter Release

The shutter-release button is the mechanism that releases the shutter and enables the ability to capture the image. The time duration of the shutter is left open or exposed is determined by the shutter speed.

6.4.2 Functions of Digital Camera

Figure 6.14 shows the Single Lens Reflex (SLR) camera. The functions of simple camera or an advanced Digital SLR camera are same by the process of recording the digital image and storing the data on a memory card.

In case of auto-focus cameras, this is done automatically using a microprocessor, a range finder and a miniature motor. They rotate the lens by sensing the amount of light present and the range of focus.

Once the photographer is satisfied with the preview, he/she presses the shutter button. Now, the camera retracts the mirror, and the conditioned light falls on the sensor and the image is captured. In digital SLRs, the sensor transfers the captured image to a memory device, mostly a card or chip.

6.5 CCTV System

Closed Circuit Television (CCTV) is a system in which the circuit is closed and all the elements are directly connected. This system is quite different from the commercial TV broadcast, where any TV can be tuned to receive the transmitted signal. In this system, the video pictures produced from the camera can be viewed in real-time or recorded. A CCTV system comprises a video camera, camera lens, a monitor and video recorder.

6.5.1 Applications

CCTV systems have many useful security applications. It is used in retail shops, banks, hospitals, schools, government establishments, etc. The true scope for applications is almost unlimited. Some examples are listed below.

- Traffic monitoring
- Industrial process monitoring
- Survey work
- Indoor and outdoor stadium surveillance
- Zoo security
- Hidden in buses to control vandalism
- Parking lot surveillance
- Public safety
6.5.2 The camera

The starting point for any CCTV system must be the camera. The camera creates the video pictures that will be transmitted to the monitoring position. Except few specialist systems, CCTV cameras are not fitted with a lens. The lens is provided separately and is connected to the camera. The correct selection of camera and lens is important to achieving the desired results across all lighting and environment conditions. Figure 6.15 shows the parts of a CCTV camera.

6.5.3 The Monitor

The picture created by the camera needs to be reproduced at the control position. A CCTV monitor is almost like a television receiver except that it does not have any tuning circuits. Previously, CRT monitors are used for all security applications including video surveillance and fire monitoring. Presently, LCD and LED displays are used in video security applications. Figure 6.16 shows the parts of CCTV Monitor.

6.5.4 Simple CCTV Systems

Figure 6.17 shows a simple CCTV system. In this system, a camera is directly connected to a monitor by a coaxial cable with the power to the camera being provided by the monitor. This arrangement is known as a line driven system. Multiple cameras can be connected to a single monitor, if it has sufficient powered coaxial connectors. However, only one source can be observed at a time.

6.5.5 Mains Powered Systems

Camera systems can be AC powered from a main electrical supply and a separate coaxial cable carries the video information from the camera to the monitor. This method allows cameras to be further remote from the monitor position. In case of line driven camera, the video passes along the coaxial cable to a distance of up to three hundred meters only. Figure 6.18 shows the mains powered CCTV system.

The arrangement allows for greater system flexibility. When more than one camera is required, a video switcher can
be provided. Using video switcher, any camera can be selected by the operator for viewing or a sequence can be set to rotate the camera through the screen most suitable to the application.

### 6.5.6 Multiple Camera Displays

Figure 6.19 shows the multiple camera display system. In this, all the cameras are required to be viewed by each individual monitor or a Quad screen splitter. As the name implies, this allows the presentation of four cameras on a single screen. Many quads now incorporate digital image processing. This means that image is compressed to a quarter of its size. However, each picture is only 23% of the screen resolution.

### 6.5.7 Video Motion Detection (VMD)

A single operator watching multiple displays gets tired and not able to see all activity at all the time. The primary function of a VMD is to relieve CCTV operators from the difficulty of monitoring many screens, which may not change for extended periods. A VMD can be set to react to different types of activity observed by the camera and alert the operator and even activate recording.

### 6.5.8 Video Recording

Analog CCTV systems are moving to digital technology and video recording is leading this transition. The previous methods of recording video are by video cassette recorders (VCR), which were replaced by digital video recorder (DVR).

DVRs now offer so many advantages over analog VCRs in security applications. Video footage can digitally recorded, processed and streamed over digital networks at virtually any level of image quality, including high definition (HD).

![Diagram of Multiple Camera Display System](image-url)
Users now make use of digital-only technologies such as relative analytics, scene search, motion-and-activity-detection alarms and remote access over IP networks. The cost of storage capacity on physical media such as hard disc drives (HDDs), digital versatile discs (DVDs), or network attached storage (NAS) is a small fraction of analog tape-based recording cost.

The use of DVR also offers permanent storage of video footage with no loss of image quality over time. All of these factors have driven the security industry toward adopting DVR as the standard for video recording.

There are three types of DVRs. They are
1. Embedded DVRs
2. Hybrid DVRs
3. PC based DVRs.

### 6.6 PIXELS

Pixel is the smallest element of an image. Each pixel correspond to anyone value. In an 8-bit grey scale image, the value of the pixel ranges between 0 and 255. The value of pixel at any point corresponds to the intensity of the light photons striking at that point. Each pixel stores a value proportional to the light intensity at that particular location. Figure 6.20 shows the pixel representation of an image. Pixel is also known as PEL. From the Figure 6.20, we can have more understanding of the pixel. In this picture thousands of pixels that together make up the image. If we zoom the image to the extent that we are able to see some pixels division, it looks like the one shown in the middle of Figure 6.20.

#### Calculation of total number of pixels

We have defined an image as a two dimensional signal or matrix. From this, the number of pixel is equal to number of rows multiplied with number of columns.

\[
\text{Total number of pixels} = \text{Number of rows} \times \text{number of columns}
\]

In other words, the number of (x, y) coordinate pairs make up the total number of pixels.

#### Gray Level

The value of the pixel at any point denotes the intensity of image at that location, and that is also known as gray level.

#### Pixel value (0)

A pixel can have only one value and this value denotes the intensity of light at that point of image. Now, we can see the unique value of 0 (zero). The value 0 means absence of light and also denotes darkness. Further, it means that whenever a pixel has a value of 0, it means at that
infrared light, is required. For detection in complete darkness and difficult conditions such as smoke, haze and dust, a thermal network camera provides a best solution. Different light conditions offer different illumination. Many natural scenes have fairly complex illumination, with both shadows and high lights, which give different lux readings in different parts of a scene. We must understand that one lux reading does not indicate the light condition for a scene as a whole, nor does it say anything about the direction of the light. Table 6.3 lists the illuminance versus light condition.

<table>
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<th>Illuminance</th>
<th>Light condition</th>
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<tr>
<td>1,00,000 lux</td>
<td>Strong Sunlight</td>
</tr>
<tr>
<td>10,000 lux</td>
<td>Full day light</td>
</tr>
<tr>
<td>500 lux</td>
<td>Office light</td>
</tr>
<tr>
<td>100 lux</td>
<td>Poorly lit room</td>
</tr>
</tbody>
</table>

There are number of factors that influence the light sensitivity of a camera, which include:

- Exposure time
- F – stop
- Sensor quality and size
- Lens quality
- Color temperature

**6.7 Light sensitivity**

Light sensitivity or minimum illumination refers to the smallest amount of light needed or the camera to produce an image of useable quality. Minimum illumination is presented in lux (lx), which is a measure of illuminance. The image is better and more light is available in the scene, is not to be overexposed. Otherwise, the amount of light is insufficient; the image will be noisy or dark. The amount of light that is required to produce a good–quality image depends on the camera and how sensitive to light it is. To capture good quality images in low light or dark conditions, a day and night camera that takes advantage of near-
GLOSSARY

<table>
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<th>Definition</th>
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<tr>
<td>Electromagnetic spectrum</td>
<td>The complete range of electromagnetic radiation from short wavelength (gamma radiation) to long wavelength (radio waves).</td>
</tr>
<tr>
<td>Image</td>
<td>An image records visual snapshots of the world around us.</td>
</tr>
<tr>
<td>Imaging Device</td>
<td>A piece of equipment that captures an image. Example includes digital camera, side-scan sonar system and scanning electron microscope.</td>
</tr>
<tr>
<td>Sharpening</td>
<td>An area process that emphasizes the details in an image.</td>
</tr>
<tr>
<td>Pixel</td>
<td>A square unit of visual information that represents a tiny part of a digital image.</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>The ratio between the brightest and dimmest gray level acceptable to an imaging system.</td>
</tr>
<tr>
<td>Mapping</td>
<td>The mathematical conversion of one set of numbers into a different set based upon some transformation.</td>
</tr>
<tr>
<td>Focal length</td>
<td>The distance between the center of a lens, or its secondary principal point and the imaging sensor. It determines the size of the image.</td>
</tr>
<tr>
<td>Infrared (IR)</td>
<td>Low frequency light below the visible spectrum. Infrared is used in surveillance cameras to provide a light source to record images in dark and zero light conditions.</td>
</tr>
<tr>
<td>Mega pixel</td>
<td>A mega pixel contains 1,000,000 pixels and is the unit of measure used to describe the size used to describe the size of the sensors in a digital camera.</td>
</tr>
<tr>
<td>Memory card</td>
<td>In digital photography, a memory card is a removable device used in digital cameras to store the image data captured by the camera. Example compact flash, smart media, SD/SDHS/SDXC/XD and others.</td>
</tr>
<tr>
<td>Shutter</td>
<td>A mechanism in the camera that controls the duration of light transmitted to the film or sensor.</td>
</tr>
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QUESTIONS

Part – A  (1 Mark)

1. Choose the best answer

   1. 1024 x 1024 image has resolution of
      a) 1048576
      b) 1148576
      c) 1248576
      d) 1348576

2. In M x N, M is number of
   a) Intensity levels
   b) Colors
   c) Rows
   d) Columns

CHAPTER 6  Digital Image Processing
3. Each element of matrix is called
   a) Dots
   b) coordinate
   c) pixels
   d) value

4. Imaging system produces
   a) High resolution image
   b) voltage signal
   c) Digital image
   d) Analog signal

5. Smallest elements of an image is called
   a) Pixel
   b) Dot
   c) Coordinate
   d) Digits

6. DPI stands for
   a) dots per image
   b) dots per inches
   c) dots per intensity
   d) diameter per inches

7. MRI in imaging stands for
   a) Magnetic resonance imaging
   b) Magnetic resistance imaging
   c) Magnetic resonance intensity
   d) Major resonance imaging

8. Digitizing amplitude values is called
   a) Radiance
   b) Illuminance
   c) Sampling
   d) Quantization

9. Black and white images have only
   a) 2 levels
   b) 3 levels
   c) 4 levels
   d) 5 levels

10. Gamma rays have largest
    a) Wave length
    b) Frequency
    c) Energy
    d) Power

11. In M x N, N is number of
    a) Intensity levels
    b) Colors
    c) Rows
    d) Columns

12. Luminance is measured in
    a) chromens
    b) Lumens
    c) Degree
    d) steradian

13. Image sensors produce
    a) voltage waveform
    b) Current
    c) Audio
    d) Discrete signals

14. Intensity levels in 8-bit images are
    a) 255
    b) 256
    c) 244
    d) 245

15. Digitizing image requires
    a) Reflection
    b) Sampling
    c) Quantization
    d) Sampling and Quantization

16. Lens has a fixed
    a) Focal length
    b) Width
    c) Length
    d) Focal width
17. What does CCTV stands for?
   a) Closed Circuit Technology
   b) Closed Circuit Technology and Video
   c) Closed Communication Television
   d) Closed Circuit Television

18. This means that your subject is sharp and not blurry
    a) Framing
    b) Exposure
    c) Focus
    d) Image noise

19. A camera lens that magnifies the image
    a) 200m lens
    b) LCD Display
    c) Exposure
    d) Autofocus

20. Electronic flash memory data storage device used for storing digital information
    a) Flash drive
    b) Tripod
    c) Flash card
    d) Memory card

Part – B (3 Marks)

II Answer the following

1. Define image.
2. Define sampling.
3. Define Quantization.

ANSWERS
1 (a) 2 (c) 3 (c) 4 (c) 5 (a) 6 (b) 7 (a) 8 (d) 9 (a) 10 (b) 11 (d) 12 (b) 13 (a) 14 (b) 15 (d) 16 (a) 17 (d) 18 (b) 19 (c) 20 (d)

Part – C (5 Marks)

III Explain the following questions

1. Explain the different types of image processing.
2. Compare CCD and CMOS sensors.
3. What are the components of Digital camera? Explain.
4. Explain simple CCTV system.
5. Write short notes on ‘PIXEL’.

Part – D (10 Marks)

IV Answer the following questions in detail

1. With block diagram, explain the fundamental steps in Digital image processing.
2. Explain any five applications of Digital image processing.
3. Explain working principles of CCD sensors with neat diagram.
4. Describe CMOS sensors with neat diagram.
5. Explain main powered CCTV system with neat diagram.
Sound Engineering

**LEARNING OBJECTIVE**

In this chapter, the student can
- Understand the characteristics of sound waves
- Study the PA system and Audio power amplifier circuits
- Understand the acoustic techniques in auditorium
- Study the theater sound system DTS/ DOLBY
- Study the applications of Acoustic Engineering
- Study the effects of noise pollution

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CHAPTER 7  Sound Engineering

7.1 Introduction

In this chapter, we can learn some fundamental knowledge and skills to enter into the field of sound engineering.

First, we have to understand, what do you mean by sound and audio? Sound is a frequency caused by vibration that can be heard by humans, animals or any device that can pick up those frequencies.

Audio means ‘of sound or of the reproduction of sound’. Specifically it refers to the range of frequencies detectable by the human ear, approximately 20 Hz to 20 kHz. The audio work involves the production, recording, manipulation and reproduction of sound waves.

We can also study about the PA system, power amplifier circuits, acoustic application and DTS/DOLBY systems.

HISTORY OF SOUND

One of the first discoveries regarding sound was made by mathematician Pythagoras, in sixth century BC. He noted the relationship between the length of a vibrating string and the tone it produces.

Italian physicist, Galileo Galilei, was the first scientist to record the relationship between the frequencies of the wave in terms of its pitch it produces. Since the sound waves produced by musical instruments vary in pitch, this was a very significant discovery. In the 1640s, Marin Mersenne was the first to measure the speed of sound in the air.

Robert Boyle discovered in the year 1660 that sound waves must travel in medium and this lead to the concept that sounds is a pressure change.

Sound travels in different mediums in different speed
- Speed of sound in solids: 5960 m/s
- Speed of sound in liquids: 1482 m/s
- Speed of sound in Air (gases): 334 m/s
- Sound cannot travel in Vacuum

7.2 Characteristics of Sound waves

Figure 7.1 shows the waveform of a sound wave. We know that sound travels in the form of wave. A wave is a vibratory disturbance in a medium which carries energy from one point to another without having direct contact between the two points.
1. Wavelength
The minimum distance in which a sound wave repeats itself is called its wavelength, i.e., it is the length of one complete wave. It is denoted by a Greek letter \( \lambda \) (lambda). In a sound wave, the combined length of a compression and an adjacent rarefaction is called its wavelength. Also, the distance between the centers of two consecutive compressions or two consecutive rarefactions is equal to its wavelength. The S.I unit for measuring wavelength is metre (m).

2. Amplitude
The maximum extent of a vibration or displacement of a sinusoidal oscillation, measured from the position of equilibrium. Amplitude is the maximum absolute valued of a periodically varying quantity. In fact, the amplitude is used to describe the size of the wave. The S.I unit of measurement of amplitude is meter (m). The amplitude of the vibrating body producing the sound determines the loudness of the sound. If the amplitude is higher, the sound produced is louder.

3. Time-Period
The time required to produce one complete wave or cycle is called time-period of the wave. Now, one complete wave is produced by one full vibration of the vibrating body. So, we can say that the time taken to complete one vibration is known as time-period. It is denoted by letter T. The unit of measuring the time-period is second (s).

4. Frequency/pitch

There are two types of waves:
1. Longitudinal waves
2. Transverse waves.

**Longitudinal Waves**: A wave in which the particles of the medium vibrate back and forth in the ‘same direction’ in which the wave is moving. Medium can be solid, liquid or gases. Therefore, sound waves are longitudinal waves.

**Transverse Waves**: A wave in which the particles of the medium vibrate up and down ‘at right angles’ to the direction in which the wave is moving. These waves are produced only in a solids and liquids but not in gases.

Sound is a longitudinal wave which consists of compressions and rarefactions travelling through a medium.

Sound wave can be described by five parameters as shown in Figure 7.2: They are
1. Wavelength
2. Amplitude
3. Time-Period
4. Frequency
5. Speed or Velocity

![Characteristics of Sound waves](image)
The number of complete waves or cycles produced in one second is called frequency of the wave. Since one complete wave is produced by one full vibration of the vibrating body, so we can say that the number of vibrations per second is called frequency. The S.I unit of frequency is Hertz or Hz. The pitch of a sound is the ear and brain interpreting the frequency of the sound. When there is a high frequency, the ear interprets the sound as a higher pitch, when the frequency is low, the ear hears the sound as a low pitch. It is a measure of sound in frequency and is shown in Figure 7.3.

5. Speed or Velocity

The distance travelled by a wave in one second is called velocity of the wave or speed of the wave. It is represented by the letter v. The S.I unit for measuring the velocity is meters per second (m/s or ms⁻¹).

7.3 Microphones

7.3.1 Lavalier Microphone (collar Mic)

Lavalier Microphone is also known as lav, a lapel or lap microphone is shown in Figure 7.4. It is a very small condenser mic designed to pick up speech from a single person. This mic is widely used for TV program, Public Address systems etc. Lavalier mic is usually attached to the subject's clothing with a specialized clip. Obviously the preferred position on the lapel or thereabouts. This provides consistent close range sound pickup and ideal for interview situations in which each participant have their own mic. It also means the subject do not worry about the mic techniques.

Further, the cable can be discreetly hide under the clothing. If there is nowhere to place the mic on the subject’s chest, it can be fixed on the collar. Lavalier mic can be quite susceptible to noise caused by movement of the subject position, i.e., it cannot be moved around too much, and make sure that the cable cannot be pulled by anyway. A small wind filter can be used to reduce wind noise.
Crystal microphone or ceramic microphone as shown in Figure 7.5 is generally a low cost microphone providing a high output voltage in the order of 10 to 100 mV. The main use of crystal microphone technology is within transducers used for a variety of monitoring applications and for automotive transmitters / sensors. This type of microphone is working on the principle of piezoelectric technology. The piezoelectric effect is the ability of certain materials to generate an electric charge when mechanical stress is applied.

In this type of microphone, alternating voltage is produced when sound makes the diaphragm vibrates. The impedance is very high usually in the order of 1 to 5 Mega Ohms. The charge produced by the piezoelectric action of the crystal is converted into voltage using electronic circuits. The natural crystals used in this type of microphones are Rochelle salt and quartz.

Crystals which demonstrate the piezoelectric effect produce voltages when they are deformed. The crystal microphone uses a thin strip of piezoelectric material attached to the diaphragm. The two sides of the crystal acquire opposite charges, when the crystal is deflected by the diaphragm. The charges are proportional to the amount of deformation and disappear, when the stress on the crystal disappears. Early crystal microphones used Rochelle salt, because of its high output, but it was sensitive to moisture and somewhat fragile. Later, microphones used ceramic materials such as barium Titanate and lead Zirconate Titanate.

7.3.3 MicroElectroMechanical Microphones (MEMS)

MEMS microphones are extremely small microphones designed to fit on a silicon chip. They are based on the same working principles as condenser microphones. They have an analog-to-digital converter (ADC) module integrated on the same chip. It converts the analog input into digital values, which are used by the modern electronic devices. MEMS find applications in modern-day electronic gadgets, such as cellphones, tablets, laptops, automotive industry, etc. Figure 7.6 shows MEMS microphones.

7.4 Headphones

Headphones are a pair of small speakers, which are used for listening to sound from a music player, computer, Laptop, Smartphone or such other electronic devices. It is also called as earphones or Headset. The modern headphones are available in much smaller format, which can be inserted into
the ear and are commonly called ear buds. Nowadays, headphones can be either wireless or wired.

The first headphone was developed in 1910 by the US navy. It was simple and was used as an earpiece device without complicated electronics.

**Working functions**

Headphone works like a speaker and opposite to microphone as shown in Figure 7.7. It converts the electrical signal into the sound signal through the vibration of the magnet, thereby vibrating the surrounding air particles.

Once the electrical signal makes its way through the wires into the headphones, it reaches a driver unit.

There are three types of driver units. They are

1. Dynamic driver
2. Planar magnetic driver
3. Electrostatic driver

Most of the headphones uses Dynamic driver unit. The Dynamic driver unit uses three main parts to work. They are

1. Permanent magnet
2. Electromagnetic coil
3. Diaphragm

Each ear cup has one permanent magnet, which firmly in place and the other is an electromagnet that moves. When the electrical signal hits the ear cup, it sent to the electromagnet, which rapidly switches its polarity back and forth depending on the
pattern it sent or the sound being reproduced. When the electromagnet switches, its polarity rapidly repelled and attracted towards the permanent magnet, which makes it vibrates. Those vibrating electromagnets are attached to what is called a ‘diaphragm’, which is a thin membrane. When the electromagnet vibrates the diaphragm, which causes the air around it to vibrate, this is what we called sound. Different frequencies vibrate at different rates so the electromagnet vibrates faster to produce high tones, or slower to produce slow tones. When we turn the volume up or down, the vibrations are more or less intense, which causes the air to vibrate more or less.

### 7.5 Loud Speakers

#### 7.5.1 Flat panel speakers

There are several kinds of flat panel speakers. Engineers have been working on flat speakers for many decades so as to decrease the size of speaker boxes. The standard flat panel speaker has an exciter attached to a square panel. The flat panel acts as a diaphragm. Different materials can be used as a diaphragm such as Vinyl or Styrofoam.

The standard flat panel electrodynamic loud speaker has been difficult to make because, it is difficult to vibrate the entire flat surface evenly while creating good frequency response, thus other speaker types have evolved to make a speaker in a flat form. Figure 7.8 shows a flat panel loud speaker.

Types of flat panel speakers

1. Ribbon
2. Planar magnetic
3. Electrostatic

#### 7.5.2 Piezoelectric Speaker

Figure 7.9 shows Piezoelectric Speakers. Piezoelectric Speakers use an expanding and contracting crystals to vibrate the air and produce sound. This type of speakers are limited in frequency response, therefore they are only used as tweeters or in small electrical devices like watches/clocks to make simple sounds. It may be possible in the future that the technology may improve, by the way of providing a speaker with good sound characteristics and durability.

Piezoelectric are solid state technology which makes them durable and good for use as a microphone under water. These speakers are used as microphones in submarines warefare, they can detect other microphones and hear sounds of other vessels.

#### 7.6 Acoustics Engineering

Acoustic is a branch of physics concerned with the study of sound (mechanical waves in gases, liquids and solids). Acoustics have
many application in the everyday world and this technology is called acoustical engineering.

The study of acoustics can be subdivided into three parts. They are production, transmission and reception. All these elements are necessary for sound generation and reproduction. For example, a ringing alarm clock cannot be heard, if it is placed inside a vacuum container. Without air, sound produced by the clock has no medium through which it can travel.

**Application of Acoustics**

Acoustics have wide range of applications in many fields. We discuss some of the important applications in this Section.

1. **Noise and environmental Acoustics**

   Noise Specialists are mostly concerned with making our world a (quitter) peaceful place. They study man-made noise caused by machinery, transportation using roadways, railways, aircraft and general activities. Knowledge produced by these scientists can be used to redesign noisy machinery or to recommend ways of redesign noiseless machinery or to recommend ways of shielding the noise. They also help law makers and public officials to create rules for limiting exposure of noise.

2. **Medical Acoustics**

   Medical researchers and Doctors used acoustics to study, diagnose and treat different types of ailments. The study of material acoustics includes the use of ultrasound and other acoustical techniques to learn how different types of sound interact with cells, tissues, organs and entire organisms. Biomedical acoustians may work with engineers, physician and speech therapist.

3. **Musical Acoustics**

   Musical acoustians study the science of how music is made, travel and heard. Since musical acoustics combines elements of art and science, people with training in this field can work in the entertainment industry and much more.

4. **Speech and Hearing Acoustics**

   Hearing specialist and speech scientists are interested in how our ears sense sounds and what types of sounds can damage our ears, how speech is made, travel and heard. People interesting in hearing and speech come from many different fields, including physics, speech and hearing science, experimental psychology, linguistics, electrical engineering and others.

5. **Architectural Acoustics**

   Architectural acoustians study how to design buildings and other spaces that have pleasing sound quality and safe sound levels. Architectural acoustics include the design of concert halls, classrooms and even heating systems, where they work with musical acoustians and noise specialists.

7.7 **Acoustics in Auditorium and Theater**

A most important part of the auditorium design is the acoustics. We start with a brief description of how your ear works in the context of listening.

**FIGURE 7.10 Auditorium**
How the ear works

The human ear has developed over the evolution of humans into an organ capable of receiving the short term fluctuations of air pressure around us and extracting vast amounts of information from them. These short term air pressure fluctuations are commonly called sound waves.

When listening in an auditorium, human brain tries to make sense of the cacophony of sound waves arriving at the ears. Here, it is useful to think of the concept of the flicker fusion threshold.

When the ear is presented with reflections of a sound that arrive much later than the direct sound, the brain interprets those as echoes, and is able to separate them from the original sound. Once the reflections arrive soon enough, after the direct sound to pass the threshold of 50 milliseconds, the brain is then able to fuse the reflected energy with the direct sound and use it to enhance the intelligibility of the speech being heard.

Acoustic design principles

The main driver behind acoustic design in auditoriums derived from the phenomenon described above. Usually, keep and enhance ‘early’ reflections to arrive at the listener not more than 50 milliseconds after the direct sound. Then, dampen or reduce the ‘late’ reflections that would arrive at the listener more than 50 ms after the direct sound. At a given listener location, if there is more early acoustic energy than late, speech will be intelligible. To that end, surfaces should be provided and shaped to provide such early reflections, and reflection paths that provide late acoustic energy should be made acoustically absorptive. This leads to certain rules of thumb as summarized below:

1. Shoebox-shaped rooms provide for strong early lateral reflections (even more important for music, but quite helpful for speech as well)

2. Reflections down from a ceiling can often provide early reflections, and therefore should be made acoustically hard (reflective)

3. The back walls of an auditorium have a risk of providing late reflections – both to the audience and to the stage: Providing acoustic absorption at such locations is usually helpful. This could be in the form of fabric panels, slatted wood finish, acoustic plaster or even acoustic drywall.

4. The audience seats and the audience themselves are usually the biggest acoustic absorption in the room. The use of the right amount of acoustic absorption in the seats can serve as a great way to achieve the acoustic goals of the space.

7.8 Audio Power Amplifier - Types

7.8.1 Audio Amplifier using TBA 810 IC

Figure 7.11 shows the circuit and pin details of audio amplifier using TBA 810 IC. It is a simple, cost-effective and capable of producing 7-watts output audio amplifier. The amplifier is fabricated as monolithic integrated circuit in a 12-lead quad–in–line plastic package, intended for use as a low frequency class B amplifier. The circuit is used in low-power audio amplifier designs.

Construction and Working Functions

The circuit shown in Figure 7.11 is constructed with TBA 810 IC and few RC components. The voltage requirement of the IC is 6 V – 20 V (500 mA) and drives 4Ω to 16Ω speaker at output.

The audio signal input is given to the pin no.8 of IC through volume control \( VR_1 \). The amplified audio output is taken from pin...
no. 12 and given to the speaker. The IC can be covered with heat sink and the tapper on both sides must be grounded. If the supply voltage is between 4 V – 6 V, the circuit provides a low power output (1 Watt). For 6 V - 20 V, the audio output power increases to higher level (7 Watts).

### 7.8.2 Audio amplifier using LA4440 IC

Figure 7.12 shows the audio amplifier using LA 4440 IC. This IC is most suitable for low power audio applications. The amplifier circuit has good ripple rejections (46 dB) and good channel separation. The IC is a dual channel audio amplifier with low distortion over a wide range from low frequencies to high frequencies. It is build with heat sink as a thermal protector for better performance. LA 4440 has over voltage, surge voltage protector and pin-to-pin short protector. These specific features are making the LA4440 as a unique audio amplifier.

#### Construction and Working Functions

This circuit is designed to provide stereo amplification to the input audio signal,
pin numbers 2 and 6 takes audio input signals. The amplified output audio signal is taken out from pin numbers 10 and 12. Maximum supply voltage to this amplifier is +18 V and it operates in the temperature range of -20°C to +75°C.

The common supply voltage is +12V. This amplifier gives 30 k-ohms input resistance. By adding input variable resistor, we can control output volume.

### Activity
Assemble the circuit given in figure 7.11 and 7.12 using PCB

#### 7.8.3 Audio Amplifier using TDA 2003

Figure 7.13 shows the circuit of the audio amplifier using TDA 2003. The IC is a monolithic, which contains a preamplifier, driver amplifier and output amplifier. The amplifier has very low harmonic distortion and high output current capability.

#### Construction and Working Functions

The circuit is constructed with the TDA 2003 IC, which has only 5-pins and all are function pins. The IC has built-in over temperature protection and short circuit protection features.

The audio input is given to the pin 1 (non-inverting pin) of the IC. Pin 2 (inverting pin) is connected with capacitor C4 and voltage divider resistors R2, R3, which acts as a feedback path. The loud speaker is connected between pin 4 and pin 3 (GND). The supply voltage is (6V – 12V) given to pin 5 and pin 3 is grounded. Capacitors C1 and C2 are used to filter out the power supply fluctuations. This circuit provides a 10 watts output.

#### 7.9 Audio effects

Mono and stereo are two classifications of reproduced sound. The main difference between mono and stereo comes with the number of audio channels used in each.
Mono is the term used to describe the sound that is only from one channel, while stereo uses 2 or more channels to provide an experience much like being in the same room where the sound is created.

### 7.9.1 Monaural sounds

Mono is a short version on monaural sound, having only one source for the audio. From the Figure 7.14, we can understand that the sound comes from only one sources even though it is transported to two different speakers, i.e., the content of the signal is always the same. When listening to music or other auditory speeches using headphones, we cannot hear any difference by removing one earphone.

Mono is still widely used in situations where stereo only takes up bandwidth and offers no advantages. A good example for this is in voice communications like in talk radio and telephone calls. The equipment needed to record mono sound is only a single microphone and the data it acquires is automatically stored in magnetic tape or converted to digital formats for storage.

### 7.9.2 Stereophonic sounds

Stereo is a short version of stereophonic sounds. In stereo, several channels are used to transport audio signals to speakers and thus to a listeners’ ears. Generally, stereo uses two channels, but it can use more. In the most common set up, one channel is...
transported to one speaker and the other channel to another speaker.

**FIGURE 7.15** stereo sounds

Figure 7.15 shows the usual setup for stereo sounds. There are two different sources that send their individual signal to one speaker each. In this system, the sounds that are transported entirely to the right speaker will appear to come from a listener's right side. The signal not only transported to one speaker in it's entirely through, but it is transported proportionally as well. That is, a small proportion of the sound can be transported to the right speaker, while the rest is sent to the left one creating more 3-dimensional hearing experiences. Sounds that are equally transported to both the speakers appear to come from the center.

This is all based on the typical set up of two sources of sound that are transported to the two speakers. Thus, stereo is used to create an inspiration of sounds coming from different directions as well as setting the sound in perspective to one another and the listener. This is especially useful in movies and audio plays to emerge the listener/viewer into the story. It is also used in music. Particularly in film songs, the guitar part is send to one speaker, while the bass is send to the other. Headphone users are easily identifying the stereophonic sounds. Removing one earphone can reveal that a particular instrument or sound is only transported to either the left or the right ear.

### 7.9.3 Equaliser

It is a control used for boosting or reducing (attenuating) the levels of different frequencies in a signal. We have the experience of hearing the treble / bass control on public address amplifier and home audio equipment, which is nothing but a basic type of equalizer. The treble control adjusts the high frequencies whereas the bass control adjusts the low frequencies. This is adequate for very basic adjustments, i.e., it only provides two controls for the entire frequency spectrum, so each control adjusts a wide range of frequencies.

Advanced equalizations system provides a fine level of frequency control. They enable to adjust a narrower range of frequencies without affecting neighboring frequencies. Equalizer is the most commonly used unnatural sound system. For example, if a sound was recorded in a room which accentuates high frequencies, an equalizer can reduce those frequencies to a more normal level. It can also be used for applications such as making sounds more by reducing the feedback.

### 7.9.4 Ambience

Ambience and ambient sound generally denotes the surrounding sounds that are present in a scene or location, such as wind, water, birds, forest murmurs, electrical hum, room tone, office clatters, traffic, and neighborhood mutterings. Ambient sound can provide a specific atmosphere of a public site in the construction of the diegetic space or the interior world of a film or sound-based media network. To the sound artist and practitioners, ambient sound injects life and substance not only to what we see on the cinematic screen but, also to the off-screen story world. The practitioners use the material layers of ambient sound to construct the experience of presence.
7.10 **PA System**

Figure 7.16 shows the block diagram of public address system. The functions of different blocks are as follows.

**Microphone**
It converts sound to an equivalent electrical signal. Generally, two or three microphones can be connected with one auxiliary input for CD is also provided.

**Mixer**
The output of microphone is fed to the mixer stage. The mixer stage is used to isolate different channels from each other before they are fed to the amplifier.

**Voltage Amplifier & Processing Circuits**
The voltage amplifier is used to amplify the mixer output further. The processing circuit block consists of the ‘master gain control’ and the ‘tone control circuits’. The tone control circuits consist of the bass and treble control circuits. The bass control circuit will amplify or cut the low frequency signals and the treble control will amplify or cut the high frequency signals.

**Driver and Power Amplifier**
The driver amplifier drives the power amplifier to give more power. It is basically a voltage amplifier. The power amplifier gives the desired power amplification to the input signal. The push-pull type of amplifier is generally used because this type eliminates the even harmonics from the output of the amplifier and avoids the core saturation of the output transformer. The power amplifier drives the loudspeakers. Matching transformers are used between them to match the low speaker impedance to the output impedance of the power amplifier.

**Requirements of PA system**
1. It must avoid the acoustic feedback
2. Distribute the sound intensity uniformly
3. Reduce reverberations
4. It must use proper speaker orientations.
5. Select proper microphones and loudspeakers.
6. It should create a sense of direction
7. Loud speaker impedance should be matched properly
8. Proper grounding should be provided
9. Use closed ring connection for loudspeakers

7.11 **Theater Sound system– DTS & DOLBY**

Just like music, surround sound format comes in many standards. The two most popular ones supported by a broad range of high-end audio systems such as DTS and Dolby Digital.

DTS is the abbreviations of digital theater system, a popular home theater audio format that was developed in 1993. Dolby Digital is the name for audio compression technology developed by the Dolby Labs. Both systems are for the
development of surround sound audio technology in movie production.

These systems provide sound codes for 5.1, 6.1 and 7.1 setups, where the first number represents the number of surround speakers, and the ‘1’ is a separate channel for subwoofer.

Both formats utilize ‘perceptual’ data reduction techniques to remove useless data in PCM signal output, thereby processing high fidelity sound. In addition to the 5.1 to 7.1 speaker playback, different formats offer cutting edge audio technology geared towards enhancing the sound quality. For instance, DTS and Dolby digital use compression to same space either on the disc, as is the case with Blue Ray and DVDs or on streaming bandwidth for services like NETFLIX.

Some versions of Dolby Digital and DTS are ‘lossy’ which means they have a degree of audio degradation from the original source, while others are lossless.

Dolby, for example, has a lossless version, Dolby True HD, and a lossy version table up very little space on Blue-Ray disc. DTS also has a lossless version, DTS –HD master Audio, that supports 7.1 channels speaker setup.

**7.12 Audio Recording**

Audio recording techniques have developed dramatically in recent years. Excellent digital equipment with vast capabilities is now quite affordable. Low cost and high technology has meant that many people are leaping directly to sophisticated recording equipment for their first recording experience.

**7.12.1 Basic Recording / Multitrack Recording**

The recording process, whether accomplished with a cassette recorder, digital multi-track recorder, hard disk recorder or any other recording medium, is essentially the same. The goal is to capture sounds onto a master recording. To do this, recording engineers employ a two-step system:

1. **Multitrack Recording** - the process of recording and overdubbing various instruments and vocals, each to its own “track.”

2. **Multitrack Mixdown** - the process of simultaneously re-recording these multiple tracks down to one set of stereo tracks (the “master recording”) which can be reproduced by a typical playback system, such as a CD player or cassette deck.

**7.12.2 Recording Studio Equipment**

In modern recording studios many traditional components are being replicated with computer technology. The essential equipment found in most recording studios is as follows:

1. **Computer**

   Computers are a central component of modern recording studios. With a computer, you can record and mix music using a digital audio work station such as Pro Tools, Cubase, Sonar, or Logic Pro, as well as use a variety of software synthesizers and effects.

2. **Audio Interface**

   Audio interfaces allow you to connect audio devices to the computer. The ones designed for recording typically have many audio inputs for microphones and line level instruments, audio outputs for studio monitors and headphones and MIDI inputs and outputs. In most cases, they can connect to the computer via a USB or IEEE 1394 (FireWire) cable.

3. **Studio Monitors and Headphones**

   Studio monitors are loudspeakers designed to reflect source audio as
accurately as possible. They are typically used by producers and sound engineers to monitor audio during recording, as well as to play back audio. Similarly, headphones are necessary for musicians to be able to hear background audio such as click tracks and other instruments while recording.

4. **Microphones**

Microphones convert sound waves to electrical impulses. When plugged into a computer via an audio interface, these impulses become digitized and can be recorded. Recording studios often have many different microphones for recording various types of sounds. For example, some microphones are designed specifically to capture vocals, while others are designed to capture instruments.

5. **Rack Effects**

Rack effects apply one or more filters to audio signals to change the way they sound. Although computers can produce nearly every type of audio effect today, rack effects, particularly vintage ones, are still commonly used in professional recording studios.

6. **Controllers**

Controllers are external devices used to control computer software. The most common type of controller is a MIDI controller, which has a keyboard much like a standard electronic keyboard, although it does not actually produce audio like an electronic keyboard.

7. **DI Boxes**

Direct input (DI) boxes convert line level signals to balanced signals. They are often used to plug electric guitars and bass guitars into an XLR (the type of connection used by most microphones) input. They are only necessary if the audio interface does not have line level inputs.

8. **Cables**

Cables are an important part of any recording studio. XLR cables are commonly used to connect microphones to audio interfaces, while 1/4-inch cables are commonly used to patch other devices together.

9. **Miscellaneous Items**

A number of miscellaneous items are often found in recording studios, including microphone stands and shockmounts, power conditioners, furniture, soundproofing materials, vintage gear such as tube microphone preamps and a collection of musical instruments.

7.13 **Home Theater System**

Home theater system is a combination of electronic components designed to recreate the experience of watching a movie in a theater. When we watch a movie on a home theater system, it gives a sense of good experience than watching on an ordinary television.

To build a home theater, we need to create the following elements.

- A large screen television (32 inches) with a clear picture.
- Atleast four speakers.
- Equipment for splitting up the surround sound signal and sending it to the speakers.
- The main thing that sets a home theater, which differs from an ordinary television setup, is the surround sound. For a proper surround sound system, two or three speakers in front of the viewer. The audio signal is split into multiple channels so that different sound information comes out of the various speakers. The most prominent sound comes out of the front speakers. When someone or something is making noise on the left side of the screen, we hear it more from a speaker to the left side. Similarly in the right side, we hear
CHAPTER 7  Sound Engineering

from the right side speaker. The third speaker sits in the center, just under or above the screen. This center speaker is very important because it anchors the sound coming from the left and right speakers. It plays all the dialogue and front sound effects so that they seem to be coming from the center of the television screen rather than from the sides.

The speakers behind the viewer fill in various sorts of background noise in the movie such as dog’s barking, rushing water and the sound of a plane overhead. They also work with the speakers in front of the viewer to give the sensation of the movement. A sound starts from the front and then moves behind the viewer.

7.14 Noise pollution

Noise pollution is a type of energy pollution in which distracting, irritating or damaging sounds are freely audible. It is a dangerous pollutant, even destroys bridges and produces cracks in buildings. The noise can cause skin and mental diseases. The various sources of noise pollution are shown in Figure 7.18.

Pollution of Air by Sound

The intensity of sound is measured in decibels. The various ranges and sources of sound pollution are given in Table 7.1. All are responsible for the noise pollution because most of our day-to-day activities generate some noise. Often neglected, this pollution adversely affects the human beings leading to irritation, loss of concentration, loss of hearing and many more.

From early morning, we hear the horns of vehicles like trucks, buses, scooters and motor cycles. The drivers always use the horns more out of habit than necessity. On a special day like festivals, marriage functions, birthday parties and from religious places, we can hear loud speakers sound drilling the common man with severe noise pollution.

Adverse Effects of Noise Pollution

Noise effect is harmful to human beings, environment and animals in many ways. Some of them are as follows.

1. Hearing Problems

Exposure to noise can damage one of the most vital organs of the body, the ear. Hearing impairment due to noise pollution can either be temporary or permanent. When the sound level crosses the 70 decibel (dB) mark, it becomes noise, for the ear. Above 80 dB produces damaging effects to the ear.

When ear is exposed to extreme loud noise, above 100 dB for a considerable period of time, it can cause irreparable damage and may lead to permanent hearing loss.

2. Cardiovascular issue

A noisy environment can be a source of heart related problems. High intensity sound causes a dramatic rise in blood pressure as noise levels constrict the arteries, disrupting the blood flow. The heart rate also increases and become one of the reasons to the cardiovascular diseases.
### TABLE 7.1. Intensity of sound noise sources and human perception

<table>
<thead>
<tr>
<th>Noise source</th>
<th>Intensity of sound (dB)</th>
<th>Human perception</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold of hearing</td>
<td>0</td>
<td>Threshold of hearing</td>
</tr>
<tr>
<td>Breathing</td>
<td>10</td>
<td>Just audible</td>
</tr>
<tr>
<td>Sound of leaves in trees</td>
<td>20</td>
<td>Very quiet</td>
</tr>
<tr>
<td>Whispering</td>
<td>30</td>
<td>Very quiet</td>
</tr>
<tr>
<td>Normal conversation</td>
<td>30-40</td>
<td>Quiet</td>
</tr>
<tr>
<td>Homes and Restaurant</td>
<td>45-50</td>
<td>Quiet</td>
</tr>
<tr>
<td>Loud conversation</td>
<td>65</td>
<td>Moderately loud</td>
</tr>
<tr>
<td>Lawn mower</td>
<td>60-80</td>
<td>Moderately loud</td>
</tr>
<tr>
<td>Vacuum cleaner</td>
<td>80</td>
<td>Moderately loud</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>60-90</td>
<td>Loud</td>
</tr>
<tr>
<td>Heavy trucks</td>
<td>90-100</td>
<td>Very loud</td>
</tr>
<tr>
<td>Thunderstorm</td>
<td>110</td>
<td>Very loud</td>
</tr>
<tr>
<td>Rock music</td>
<td>120</td>
<td>Uncomfortably loud</td>
</tr>
<tr>
<td>Jet take off (100 m distance)</td>
<td>120</td>
<td>Uncomfortably loud</td>
</tr>
<tr>
<td>Jet engine (at 15 m distance)</td>
<td>140</td>
<td>Painfully loud</td>
</tr>
<tr>
<td>Rocket engine</td>
<td>170-180</td>
<td>Painfully loud</td>
</tr>
</tbody>
</table>
3. Sleep disturbance

This is one of the noise pollution effects that can deter humans overall well-being. Noise can interrupt good night sleep, when this occurs the person feels extremely annoyed and uncomfortable. The disturbed person's energy level fall down considerably and decreases the ability to work efficiently.

Control of Noise Pollution

Due to the various impacts of noise on human beings and environment, it should be controlled. There are four fundamental ways in which noise can be controlled. They are

1. Reduce noise at the source.
2. Block the path of the noise.
3. Increase the path length of noise.
4. Protect the recipient.

7.15 Government Rules and Regulations Regarding Limit Sound

The central pollution control board of India published a rule book, with title the noise pollution (regulation and control) rules, 2000’ in the year of 2000.

In this rule book, they have devided all areas in four different zones and decided limits for noise level in respective zones.

1. industrial area :  
   a. 75 dBA (Day time)
   b. 70 dBA (Night time)
2. commercial area :  
   a. 65 dBA (Day time)
   b. 55 dBA (Night time)
3. residential area :  
   a. 55 dBA (Day time)
   b. 45 dBA (Night time)
4. silence zone :  
   a. 50 dBA (Day time)
   b. 40 dBA (Night time)

Note

1. Day time shall mean from 6.00AM to 10.00PM
2. Night time shall mean from 10.00PM to 6.00AM
3. Silence zone is an area comprissing not less than 100 meters around hospitals, educational institutions, courts, religious places or any other area which is declared as such by the competent authority.
4. dBA (A – weighted decibel) is unit of noise

Some of the noise limits for vehicles depending upon the capacity of their engines.

- 77 dBA for two wheelers between 80cc to 175cc engines
- 75 dBA for two wheelers more than 175cc engines
- 75 dBA for cars (less than 9 seater)
- 80 dBA for heavy vehicles

These are the standard noise limit which have been accepted by government of India.

Loudspeakers may be used with the permission of relevant authority.

The Public Address System(PAS) cannot be used in the night time except in closed areas.
LEARNING OUTCOME

After completing this chapter, the students can understand the following

- Characteristics of sound waves
- Basics of acoustic engineering in auditorium
- Applications of Acoustic Engineering
- PA system and Audio power amplifier circuits
- DTS/DOLBY sound systems in theater
- How to control noise pollution

GLOSSARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic</td>
<td>The science and scientific study of sound. The properties of a room or environment that affect the qualities of sound.</td>
</tr>
<tr>
<td>Ambient noise level</td>
<td>'Background' noise—from any source that affects the listeners ability to hear what is produced by a sound systems. Machinery, hum from florescent lights, traffic etc.,</td>
</tr>
<tr>
<td>Attenuate</td>
<td>To make weaker. An attenuator uses resistance to reduce output voltage, as with a volume control.</td>
</tr>
<tr>
<td>Bass</td>
<td>The lower end of the frequency range, from about 20 Hz to 300 Hz.</td>
</tr>
<tr>
<td>dB (Decibel)</td>
<td>A relative unit of measure between two sounds or a radio signals. A difference 1 dB is considered to be the smallest that can be detected by the human ear. An increase of 6 dB equals twice the sound pressure. As a measure of sound pressure levels, used to indicate loudness.</td>
</tr>
<tr>
<td>Equaliser</td>
<td>A device that permits the precise control of specific frequency ranges. Examples are: Graphic, parametric, notch filter, cut only.</td>
</tr>
<tr>
<td>Filter</td>
<td>A device that removes unwanted frequencies or noise from a signal</td>
</tr>
<tr>
<td>Frequency</td>
<td>The number of times that a periodic function or vibration occurs or repeats itself in one second</td>
</tr>
<tr>
<td>Frequency response</td>
<td>The range of frequencies that are reproducible by a speaker or electronic component</td>
</tr>
<tr>
<td>Hz (Hertz)</td>
<td>A unit of measure that equals one cycles per second</td>
</tr>
<tr>
<td>Impedance</td>
<td>The measure of total resistance to the current flow in an alternating current circuit; expressed in ohms, as a characteristics of electrical devices (Speakers and microphone)</td>
</tr>
<tr>
<td><strong>Mixer</strong></td>
<td>An electronic device that permits the combining of a number of inputs into one or more outputs. Mixers commonly provide a variety of controls—tone, volume, balance and effects—for each 'channel'.</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Pitch tone</strong></td>
<td>A function of frequency</td>
</tr>
<tr>
<td><strong>Reflection</strong></td>
<td>A term that describes the amount of sound 'bouncing' off of hard surfaces.</td>
</tr>
<tr>
<td><strong>Reverberation</strong></td>
<td>Sound waves that confirm to bounce around a space after the sound source has ended</td>
</tr>
<tr>
<td><strong>Room</strong></td>
<td>Any a closed space in which a performance is stayed. It can be as small as a closed or as large as the super dome</td>
</tr>
<tr>
<td><strong>SPL (Sound Pressure Level)</strong></td>
<td>The measurement of the loudness or amplitude of sound expressed in decibels (dB)</td>
</tr>
<tr>
<td><strong>Transducer</strong></td>
<td>A device which converts sound into electrical energy (a microphone), or electrical energy into sound (a spectrum)</td>
</tr>
</tbody>
</table>

### QUESTIONS

**Part – A   (1 Mark)**

1. Sound is produced due to ______
   - a. Friction
   - b. Circulation
   - c. Vibration
   - d. Refraction

2. Sound waves travel at ______
   - a. Same speed in different mediums
   - b. Different speed in same mediums
   - c. Different speed in different mediums
   - d. Highest speed in vacuum

3. Sound wave do not travel through _______
   - a. Vacuum
   - b. Solid
   - c. Liquid
   - d. Gases

4. The wavelength of a wave is measured in ______
   - a. Meters
   - b. Hertz
   - c. Seconds
   - d. Decibels

5. Range of frequencies which human ear hear is called ______
   - a. Pitch of sound
   - b. Loudness of sound
   - c. Audible frequency of sound
   - d. Quality of sound

6. Sounds above 20000 Hz is called ______
   - a. Ultra cool
   - b. Ultra sound
   - c. Infrasonic
   - d. Infrasonic

7. The velocity of sound in air ______
   - a. 300 m/s
   - b. 334 m/s
   - c. 1130 m/s
   - d. 350 m/s

8. Which microphone will be damaged if exposed to high temperature above 52°C?
   - a. Ultra cool
   - b. Ultra sound
   - c. Infra-audio
   - d. Infrasound
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CHAPTER 7: Sound Engineering

15. The noise level of industrial area decided by the central Government is between ____________
   a. 40-50 dBA
   b. 45-55 dBA
   c. 55-65 dBA
   d. 70-95 dBA

Part – B (3 Marks)

II Answer in few sentences

1. What is sound? How it is produced?
2. Differentiate low and high pitch?
3. In which medium, the sound can travel in higher speed? What its velocity?
4. Write the advantages of Headphones
5. Name few characteristics of sound waves
6. What is the function of mixer stage in PA system
7. Why noise pollution is dangerous?
8. What are the techniques used to control noise pollution
9. What is stereo effect?
10. Name few equipments needed to build a home theater

Part – C (5 Marks)

III Answer in a paragraph

1. Explain the two types of sound waves
2. Write short notes on stereophonic effects
3. What is equalizer? Explain
4. Explain the working functions of crystal microphone
2. How acoustic engineering is essential in auditorium and theater design? Explain in detail.

3. Explain the working functions of audio power amplifier using LA 4440 with neat diagram.

4. Draw the block diagram of PA system and explain each block.


Part – D  (10 Marks)

IV  Answer in One Page (Essay type Question)

1. Explain the various applications of Acoustic Engineering.
In this chapter, the students can understand about the following topics in Power Electronics:

- Conversion of power from one way to other say AC to DC and vice versa.
- Regulator power suppliers
- Uninterrupted power supply
- Voltage controller
- Switching circuits

**CONTENT**

8.1 Converter classification  
8.2 AC to DC converters  
8.3 DC to AC – inverters  
8.4 UPS (Uninterrupted Power Supply)  
8.5 DC to DC – converters  
8.6 AC to AC converters  
8.7 Switching circuits  
8.8 SMPS
Introduction

Power Electronics is the study of switching electronic circuits in order to control the flow of electrical energy. Power Electronics is the technology behind switching power supplies, power converters, power inverters, motor drives, and motor soft starters.

Power electronics circuits convert electric power from one form to another using electronic devices. Power electronics circuits function by using semiconductor devices as switches, thereby controlling or modifying a voltage or current.

Applications of power electronics range from high-power conversion equipment such as dc power transmission to everyday appliances, such as power supplies for computers, cell phone chargers, and hybrid automobiles. Power electronics includes applications in which circuits process milliwatts or even megawatts.

Importance of Power Electronics

As the trend towards electrification and renewable energies increases, enabling technologies such as power electronics are becoming ever more important. Power electronics is an umbrella term that encompasses the systems and products involved in converting and controlling the flow of electrical energy.

Applications of power electronics include conversion of

1. AC to DC (rectifier)
2. Conversion of dc to AC (inverter)
3. Conversion of an unregulated DC voltage to a regulated dc voltage (DC to dc converter)
4. Conversion of an ac power source from one amplitude and frequency to another amplitude and frequency. (AC to ac converter)

Applications of power electronics range in size from a switched mode power supply in an AC adapter, battery chargers, audio amplifiers, fluorescent lamp ballasts, through variable frequency drives and DC motor drives used to operate pumps, fans, and manufacturing machinery, up to gigawatt-scale high voltage direct current power transmission systems used to interconnect electrical grids. Power electronic systems are found in virtually every electronic device. For example:

Motor drives are found in pumps, blowers and mill drives for textile, paper, cement and other such facilities. Drives may be used for power conversion and for motion control. For AC motors, applications include variable-frequency drives, motor soft starters and excitation systems.

In hybrid electric vehicles (HEVs), power electronics are used in two formats: series hybrid and parallel hybrid. The difference between a series hybrid and a parallel hybrid is the relationship of the electric motor to the internal combustion engine (ICE). Devices used in electric vehicles consist mostly of dc/dc converters for battery charging and dc/ac converters to power the propulsion motor. Electric trains use power electronic devices to obtain power, as well as for vector control using pulse width modulation (PWM) rectifiers. The trains obtain their power from power lines. Another new usage for power electronics is in elevator systems. These systems may use thyristors, inverters, permanent magnet motors or various hybrid systems that incorporate PWM systems and standard motors.

The design of power conversion equipment includes many disciplines from electrical engineering. Power electronics includes applications of circuit theory, control theory, electronics, electromagnetics, microprocessors (for
control) and heat transfer. Advances in semiconductor switching capability combined with the desire to improve the efficiency and performance of electrical devices have made power electronics an important and fast-growing area in electrical engineering.

A battery charger is an example of a piece of power electronics

A PCs power supply is an example of a piece of power electronics, whether inside or outside of the cabinet

**8.1 Converter Classification**

The objective of a power electronics circuit is to match the voltage and current requirements of the load to those of the source. Power electronics circuits convert one type or level of a voltage or current waveform to another and are hence called converters. Converters serve as an interface between the source and load. This is shown in fig 8.1

![Diagram showing power electronics components](image)

**FIGURE 8.1 Power Electronics**

Converters are classified by the relationship between input and output:

1. AC input/DC output: The AC-DC converter produces a dc output from an ac input. Average power is transferred from an ac source to a dc load. The AC-DC converter is specifically classified as a rectifier. For example, an AC-DC converter enables integrated circuits to operate from a 60-Hz AC line voltage by converting the ac signal to a dc signal of the appropriate voltage.

**Application**

AC/DC converters (rectifiers) are used every time an electronic device needs to interface with the ac mains or provide an ac output.
is connected to the mains (computer, television etc.). These may simply change AC to DC or can also change the voltage level as part of their operation.

2. **DC Input/AC Output:** The DC-AC converter is specifically classified as an inverter. In the inverter, average power flows from the dc side to the AC side. Examples of inverter applications include producing a 120-V rms 60-Hz voltage from a 12-V battery and interfacing an alternative energy source such as an array of solar cells to an electric utility.

### Application

DC/AC converters (inverters) are used primarily in UPS or renewable energy systems or emergency lighting systems. Mains power charges the DC battery. If the mains fails, an inverter produces AC electricity at mains voltage from the DC battery. Solar inverter, both smaller string and larger central inverters, as well as solar micro-inverter are used in photovoltaics as a component of a PV system.

3. **DC input/DC output:** The DC-DC converter is useful when a load requires a specified (often regulated) dc voltage or current but the source is at a different or unregulated DC value. For example, 5V may be obtained from a 12-V source via a DC-DC converter.

### Application

DC/DC converters are used in most mobile devices (mobile phones, PDA etc.) to maintain the voltage at a fixed value whatever the voltage level of the battery is. These converters are also used for electronic isolation and power factor correction. A power optimizer is a type of DC/DC converter developed to maximize the energy harvest from solar photovoltaic or wind turbine systems.

4. **AC input/AC output:** The AC-AC converter may be used to change the level and/or frequency of an AC signal. Examples include a common light-dimmer circuit and speed control of an induction motor.

### Application

AC/AC converters are used to change either the voltage level or the frequency (international power adapters, light dimmer). In power distribution networks AC/AC converters may be used to exchange power between utility frequency 50 Hz and 60 Hz power grids.

Some converter circuits can operate in different modes, depending on circuit and control parameters. For example, some rectifier circuits can be operated as inverters by modifying the control on the semiconductor devices. In such cases, it is the direction of average power flow that determines the converter classification. In Fig. 8-2, if the battery is charged from the ac power source, the converter is classified as a rectifier. If the operating parameters of the converter are changed and the battery acts as a source supplying power to the ac system, the converter is then classified as an inverter.

![Figure 8.2](image)

**FIGURE 8.2** A converter can operate as a rectifier or an inverter, depending on the direction of average power P.
Power conversion can be a multistep process involving more than one type of converter. For example, an AC-DC-AC conversion can be used to modify an AC supply (source) by first converting it to direct current and then converting the dc signal to an ac signal that has an amplitude and frequency different from those of the original AC source, as illustrated in Figure 8-3.

**8.2 Converting AC to DC**

**Introduction**

The objective of a full-wave rectifier is to produce a voltage or current that is purely DC or has some specified DC component. While the purpose of the full-wave rectifier is basically the same as that of the half-wave rectifier, full-wave rectifiers have some fundamental advantages. The average current in the ac source is zero in the full-wave rectifier, thus avoiding problems associated with nonzero average source currents, particularly in transformers. The output of the full-wave rectifier has inherently less ripple than the half-wave rectifier.

In this chapter, uncontrolled and controlled single-phase and three-phase full-wave converters used as rectifiers are analysed for various types of loads. Also included are examples of controlled converters operating as inverters, where power flow is from the DC side to the AC side.

**8.2.1 Single-Phase Full-Wave Rectifiers**

The bridge rectifier is the basic single-phase full-wave rectifier.

**The Bridge Rectifier**

For the bridge rectifier of Figure 8-4, these are some basic observations:

1. Diodes D1 and D2 conduct together, and D3 and D4 conduct together. Kirchhoff’s voltage law around the loop containing the source, D1, and D3 shows that D1 and D3 cannot be on at the same time. Similarly, D2 and D4 cannot conduct simultaneously. The load current can be positive or zero but can never be negative.

2. The voltage across the load is +V_s when D1 and D2 are on. The voltage across the load is -V_s when D3 and D4 are on.
3. The maximum voltage across a reverse-biased diode is the peak value of the source. This can be shown by Kirchhoff’s voltage law around the loop containing the source, D1, and D3. With D1 on, the voltage across D3 is \(-V_s\).

4. The current entering the bridge from the source is \(i_{D1} - i_{D4}\), which is symmetric about zero. Therefore, the average source current is zero.

5. The rms source current is the same as the rms load current. The source current is the same as the load current for one-half of the source period and is the negative of the load current for the other half. The squares of the load and source currents are the same, so the rms currents are equal.

6. The fundamental frequency of the output voltage is \(2\omega\), where \(\omega\) is the frequency of the AC input since two periods of the output occur for every period of the input.

A simple 12 V DC to 220 V AC inverter circuit shown in Figure 8.5 produces an AC output of 220 V AC at line frequency. In this circuit, the 555 is configured as a low-frequency oscillator, which is tunable over the frequency range of 50 to 60 Hz by the potentiometer R4. The output of the 555 (amplified by Q1 and Q2) is fed into the input of transformer T1 (a reverse-connected filament transformer with the necessary step-up turns ratio). Capacitor C4 and inductance coil L1 are used to filter the high frequency noise and dc components in order to assure a sine wave output. The power output (in watts) of this circuit depends on the selection of required power rating of different components, especially for the transistor and the transformer.

Types of Inverters

There are three different types of outputs from inverters and hence the inverters can be classified into three primary types viz.

- Square Wave inverter
- Modified Sine wave inverter or quasi sine wave inverter
- Pure sine wave inverter

Square Wave Inverter

The input power source for the inverter is a battery and the output is a square AC waveform, which can be used to drive less-sensitive AC devices. The output from the square wave inverter can result
in noise. The output voltage, frequency, and waveform of the inverter depend on the design of the inverter.

**Quasi sine wave inverter**

The first electronic inverters to be introduced were basic square wave inverters. As time and technology progressed, a second generation power inverter became popular and was called a “modified square wave” or “quasi-sine wave” inverter. It could be more accurately called a modified-square wave.

**Sine Wave Inverter**

In a sine wave inverter, the input is from a battery and output is a pure sine AC waveform. It is used to give supply to sensitive AC devices. The output is a sine-wave with very low harmonic distortion.

**8.4 UPS (Uninterrupted Power Supply)**

An Uninterruptible Power Supply (UPS) is a device that allows an electrical/electronic gadget to keep in operation for at least a short time when the primary mains power source is lost. It also provides protection from power surge.

Figure 8.6 shows the circuit diagram of a simple UPS circuit that can deliver 12 V unregulated and 5 V regulated DC outputs. The transformer T1 step-downs...
the mains voltage to 12 V AC and then the bridge B1 rectifies it. The rectified signal is smoothed by the capacitor C1. When the mains supply is present, the battery will be charged via diode D3 and the regulator IC gets supply via diode D5. Thus, the 12 V and 5 V DC are available at the output terminals. When mains supply is not available, the battery supplies current to the regulator IC and to the 12 V DC terminal through diode D4. Also, the diode D3 blocks reverse flow of current during battery mode. Capacitors C2 and C3 act as filters.

Advantages
1. It supplies un-interrupted power output
2. AC mains power is present or not, the output is at constant level.
3. Simple and very low-cost circuitry.

8.5 DC to DC Converters

DC-DC converters are power electronic circuits that convert a DC voltage to a different DC voltage level, often providing a regulated output. The circuits described in this chapter are classified as switched-mode DC-DC converters, also called switching power supplies or switchers. This chapter describes some basic DC-DC converter circuits which are nothing Voltage Regulators.

8.5.1 Voltage Regulators

A voltage regulator is a circuit used to regulate the output voltage level for a given application. When a steady, reliable and fixed output voltage is required, the regulator circuit provides a constant output voltage irrespective of the changes in the input voltage or load conditions. Also, it acts as a buffer for protecting components from damages.

Basically, there are two types of voltage regulators available
1. Linear voltage regulator and
2. Switching regulator

The linear voltage regulators are further classified into series and shunt type of regulators. In the case of switching regulators, there are three sub-classes such as step-up, step-down and inverter type of voltage regulators.

Figure 8.7 shows a 7809 based voltage regulator circuit. It is a member of 78xx series of fixed linear voltage regulator ICs. The input 12 V DC voltage source in the circuit may have fluctuations and would not give a fixed 9 V output voltage. The voltage regulator IC shown in Figure 8.7 maintains the output voltage at a constant value of 9V.

8.5.2 Voltage Regulator-7805

Figure 8.8 shows 7805-based 9 V voltage regulator circuit that regularizes the output voltage at 9 V for the input voltage range of 7-25 V. The pin description of the 7805 is given in the Table 8.1. Here, the 5 voltage regulator IC 7805 is given an reference voltage of 4.3V using a zener diode at the pin 2. This will increase the output voltage from 5V to 9V.

Figure 8.9 shows a complete circuit diagram of a 5V regulator using
7805. In this circuit the mains 230 AC is converted into 12V AC using a step-down transformer. The voltage at the secondary of the transformer is connected to a bridge rectifier circuits, which converts the 12V AC into a fluctuating DC. The capacitors 1000 µF and 0.22 µF are used to filter-out the 50 Hz and high frequency noises, respectively. Now, 12V pure DC voltage is generated, which is fed to the input terminal (pin 1) of the 7805 regulator. The reference terminal (pin 2) is connected to the ground terminal of the power supply. At pin 3, 5V regulated DC voltage is obtained, which is further filtered for high frequency noise. The diode IN 4007 in the output terminal of 7805 provides overvoltage protection.

**TABLE 8.1 Pin Description of 7805**

<table>
<thead>
<tr>
<th>Pin No</th>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INPUT</td>
<td>Pin 1 is the INPUT Pin. A positive unregulated voltage is given as input to this pin. Voltage range 7-25 V.</td>
</tr>
<tr>
<td>2</td>
<td>GROUND</td>
<td>Pin 2 is the GROUND Pin. It is common to both Input and Output.</td>
</tr>
<tr>
<td>3</td>
<td>OUTPUT</td>
<td>Pin 3 is the OUTPUT Pin. The output is regulated at 5 V and the maximum current supplied is 1.5 A.</td>
</tr>
</tbody>
</table>
Important Points on 7805 Voltage Regulator IC

- The input voltage should always be greater than the output voltage (7 to 25 V).
- The input current and output current are almost identical. This means that when a 7.5 V, 1 A supply is given at input, the output will be 5 V, 1 A.
- The remaining power is dissipated as heat and hence a heat sink should be provided to limit the working temperature of the 7805 IC.

8.5.3 Negative Voltage Regulator- IC 79Xx (7905, 7912, 7915, 7918)

The 79xx voltage regulator series is designed to obtain negative power supply voltage required in some of the op-amp circuits. The input to these negative regulators should be a negative voltage, which 2.5V greater than the required output voltage. The pin diagram of the 79xx series is shown in Figure 8.10. Pin 1 is given a reference voltage, usually the ground voltage. Pin 2 is input terminal where the input negative voltage is given. Pin 3 is the output terminal, where the output negative is drawn. The various negative voltage regulators and their output voltages are listed in Table 8.2.

<table>
<thead>
<tr>
<th>IC Number</th>
<th>Output Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>7905</td>
<td>-05 Volts</td>
</tr>
<tr>
<td>7912</td>
<td>-12 Volts</td>
</tr>
<tr>
<td>7915</td>
<td>-15 Volts</td>
</tr>
<tr>
<td>7918</td>
<td>-18 Volts</td>
</tr>
</tbody>
</table>

Variable Voltage Power Supply: LM317T Variable Voltage Regulator

LM317 is a popular adjustable positive linear voltage regulator. It was designed by Robert C Dobkin in the year 1976 at National Semiconductor. LM337 (negative voltage counterpart of LM317) is used to regulate negative voltages. LM317 is an adjustable 3–terminal positive voltage regulator capable of supplying in excess of 1.5A over an output voltage range of 1.2V to 37V. This voltage regulator is used two external resistors to set the output voltage. Figure 8.11 shows a variable voltage regulator circuit.

8.6 AC to AC Converters

Introduction

An ac voltage controller is a converter that controls the voltage, current, and average power delivered to an ac load from an ac source. Electronic switches connect and disconnect the source and the load at regular intervals. In a switching scheme called phase control, switching takes place during every cycle of the source, in effect removing some of the source waveform before it reaches the load. Another type of control is integral-cycle control, whereby the source is connected and disconnected for several cycles at a time.

The phase-controlled ac voltage controller has several practical uses.
including light-dimmer circuits and speed control of induction motors. The input voltage source is ac, and the output is ac (although not sinusoidal), so the circuit is classified as an AC-AC converter.

8.6.11 The Single-Phase AC Voltage Controller

Basic Operation

A basic single-phase voltage controller is shown in Figure 8.12. The electronic switches are shown as parallel thyristors (SCRs). This SCR arrangement makes it possible to have current in either direction in the load. This SCR connection is called antiparallel or inverse parallel because the SCRs carry current in opposite directions. A triac is equivalent to the antiparallel SCRs. Other controlled switching devices can be used instead of SCRs.

The principle of operation for a single-phase ac voltage controller using phase control is quite similar to that of...
the controlled half-wave rectifier. Here, load current contains both positive and negative half-cycles. An analysis identical to that done for the controlled half-wave rectifier can be done on a half-cycle for the voltage controller. Then, by symmetry, the result can be extrapolated to describe the operation for the entire period.

Some basic observations about the circuit of Fig 8.12 are as follows:

1. The SCRs cannot conduct simultaneously.
2. The load voltage is the same as the source voltage when either SCR is on. The load voltage is zero when both SCRs are off.
3. The switch voltage $V_{sw}$ is zero when either SCR is on and is equal to the source voltage when neither is on.
4. The average current in the source and load is zero if the SCRs are on for equal time intervals. The average current in each SCR is not zero because of unidirectional SCR current.
5. The rms current in each SCR is $\frac{1}{\sqrt{2}}$ times the rms load current if the SCRs are on for equal time intervals.

For the circuit of Fig. 8.12, $S_1$ conducts if a gate signal is applied during the positive half-cycle of the source. Just as in the case of the SCR in the controlled half-wave rectifier, $S_1$ conducts until the current in it reaches zero. Where this circuit differs from the controlled half-wave rectifier is when the source is in its negative half-cycle. A gate signal is applied to $S_2$ during the negative half-cycle of the source, providing a path for negative load current. If the gate signal for $S_2$ is a half period later than that of $S_1$, analysis for the negative half-cycle is identical to that for the positive half, except for algebraic sign for the voltage and current.

8.7 Switching Circuits

Switching is an electronic circuit used to electrically switch-on or switch-off an electronic circuit used for power conversion circuits. An electrical switch is any device used to interrupt the flow of electrons in a circuit. Switches are binary devices: either it is in “ON” (“closed”) state or “OFF” (“open”) state using timing pulses. Transistor in a simple electronic switch, which conducts current across the collector-emitter terminals, when a voltage is applied to the base, i.e. the switch is ON or suppress the flow of current across the collector-emitter terminal, when there is no base voltage, i. e., the switch is OFF.

8.7.1 NPN Relay Switch Circuit

Relays are electromechanical devices employing an electromagnet to operate a pair of movable contacts from an open position to a closed position. A relay switch circuit shown in Figure 8.13 consists of a NPN transistor (TR1) configured as a switch drive the coil of the relay when switching pulse is applied at the base of the transistor. When the base voltage of the transistor is zero (or negative), the transistor is cut-off and acts as an open switch. In this condition, no collector current flows and the relay coil

---

**FIGURE 8.13 NPN Relay Switching Circuit**
is de-energised. When a positive voltage is applied to the base, the transistor conducts and goes to the saturation state. At this condition, the transistor acts as a closed switch. Thus, the current flowing from collector to emitter controls the current flowing through the relay coil.

### 8.7.2 NPN Emitter Follower Relay Switching Circuit

A standard common-emitter configuration for a relay switch circuit is shown in Figure 8.14. In this configuration, the relay coil is connected to the emitter terminal of the transistor to form an emitter follower circuit. The input signal is fed directly to the base, while the output is taken from the emitter load. Emitter Follower configuration is very useful for impedance matching applications because of the very high input impedance.

![Figure 8.14 NPN Emitter Follower Relay Switch Circuit](image)

### 8.7.3 PNP Emitter Relay Switching Circuit

The PNP transistor circuit shown in Figure 8.15 controls the current flows from the emitter to the collector when the base is forward biased with a voltage that is more negative than that of the emitter. For the relays load current to flow through the emitter to the collector, both the base and the collector must be negative with respect to the emitter. When Vin is HIGH the PNP transistor is switched “OFF” so that the relay coil is in OFF condition. When Vin is LOW, the base voltage is less than the emitter voltage (more negative) and the PNP transistor turns “ON”. Here, the base resistor sets the base current, which in turn sets the collector current that drives the relay coil.

![Figure 8.15 PNP Emitter Relay Switching Circuit](image)

### 8.7.4 PNP Collector Relay Switching Circuit

PNP bipolar transistor as a switch for relay switching is shown in Figure 8.16. There
are two different conditions that need to be understood as the current flows in two different directions. When a LOW voltage (with respect to the emitter) is applied to the base of the PNP transistor, current flows from the emitter to the collector and the PNP transistor switches “ON” allowing the current to flow through the relay coil. Thus, the relay is in ON condition. When a HIGH voltage is applied to the base of the PNP transistor, there is no current flow and the switch is in cut-off state. Thus the relay is in OFF condition.

### 8.7.5 Microcontroller Relay Switching Circuit

In microcontroller, the input/output port pins are not able to drive high-current components such as relays, buzzer, etc. In such a situation, the output pin of the microcontroller is connected through a MOSFET switching circuit as shown in Figure 8.17. The MOSFET switch is an ideal electrical switch as it takes virtually no gate current to turn “ON”, i.e., converting a gate voltage into a load current. Therefore, a MOSFET can be operated as a voltage-controlled switch.

In many applications, bipolar transistors can be substituted with enhancement-type MOSFETs offering faster switching action, much higher input impedance, and probably less power dissipation. The combination of very high gate impedance, very low power consumption in its “OFF” state and very fast switching capability makes the MOSFET suitable for many digital switching applications. Also, with zero gate current, its switching action cannot overload the output circuit of a digital gate or microcontroller. MOSFETs always use a flywheel diode across and relay coil to safely dissipate the back emf generated by the transistors switching action.

### 8.7.6 Switching Circuit Using UIN2003a IC

UIN2003A is a relay driver IC consisting of a Darlington array. It is made up of seven open collector Darlington pairs with common emitter. UIN2003A has a capability of handling seven different relays, simultaneously. A single Darlington pair consists of two bipolar transistors and operates in the range of 500mA to 600mA current.

Figure 8.18 shows a relay driver IC switching an electro-magnetic relays to switch a light bulb ON and OFF which is connected to 220V mains supply. The IC UIN2003A comprises of 7-NPN Darlington pairs, which is typically configured to switch the inductive loads (dissipates voltage spikes if any using suppression diode) and to drive stepper motors and lights. For switching eight such relays, ULN2803 can be used. This type of relay switching ICs are used to interface the output from microcontrollers to the actuators such as relays, buzzer, LED, lamps, etc. Here, the program in the microcontroller switches ON or OFF the relays by outputting either 1 or 0 in the respective output pins.
8.8 Switch Mode Power Supply (SMPS)

A switched-mode power supply (SMPS) is an electronic circuit that converts power using switching devices that are turned on and off at high frequencies, and storage components such as inductors or capacitors to supply power when the switching device is in its non-conduction state.

They are used in many places in a computer. In a modern computer, there is a SMPS that takes rectified AC input from the wall, performs power factor correction and then converts the output into one or more lower voltage DC outputs.

The Figure 8.19 shows the external structure of SMPS and Figure 8.20 shows the internal structure of SMPS.

SMPS is a power supply that uses a switching regulator to control and stabilize the output voltage by switching the load current on and off. These power
supplies offer a greater power conversion and reduce the overall power loss.

Voltage regulation is achieved by varying the ratio of on-to-off time. In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor. Figure 8.20 shows the block diagram of SMPS.

**Inverter stage**

This section refers to the block marked chopper in the diagram.

The inverter stage converts DC, whether directly from the input or from the rectifier stage described above, to AC by running it through a power oscillator, whose output transformer is very small with few windings at a frequency of tens or hundreds of kilohertz. The frequency is usually chosen to be above 20 kHz, to make it inaudible to humans. The switching is implemented as a multistage (to achieve high gain) MOSFET amplifier. MOSFETs are a type of transistor with a low on-resistance and a high current-handling capacity.

**Regulation**

This charger for a small device such as a mobile phone is a simple off-line switching power supply with a European plug. The simple circuit has just two transistors, an opto-coupler and rectifier diodes as active components.

A feedback circuit monitors the output voltage and compares it with a reference voltage, as shown in the block diagram above. Depending on design and safety requirements, the controller may contain an isolation mechanism (such as an opto-coupler) to isolate it from the DC output. Switching supplies in computers, TVs and VCRs have these opto-couplers to tightly control the output voltage.

**Transformer design**

Any switched-mode power supply that gets its power from an AC power line...
(called an “off-line” converter) requires a transformer for galvanic isolation. Some DC-to-DC converters may also include a transformer, although isolation may not be critical in these cases. SMPS transformers run at high frequency. Most of the cost savings (and space savings) in off-line power supplies result from the smaller size of the high frequency transformer compared to the 50/60 Hz transformers formerly used. There are additional design trade offs. The skin effect is exacerbated by the harmonics present in the high speed PWM switching waveforms. The appropriate skin depth is not just the depth at the fundamental, but also the skin depths at the harmonics. In addition to the skin effect, there is also a proximity effect, which is another source of power loss.

LEARNING OUTCOME

At the end of this chapter students would come to know about
- The basic principles of power Electronics
- Conversion process of Power supply
- Voltage regulation
- Switching circuits and applications.

GLOSSARY

<table>
<thead>
<tr>
<th>Rectifier</th>
<th>Conversion of AC to DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverters</td>
<td>Conversion of DC to AC</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterrupted power supply</td>
</tr>
<tr>
<td>DC to DC</td>
<td>to maintain different DC Voltages</td>
</tr>
<tr>
<td>AC to AC</td>
<td>to maintain different AC Voltages</td>
</tr>
<tr>
<td>SMPS</td>
<td>Switch Mode Power Supply</td>
</tr>
</tbody>
</table>

QUESTIONS

Part – A (1 Mark)

1. Multiple choice Questions

1. Conversion of AC power to DC power is ______
   a. Inversion
   b. Rectification
   c. Voltage doubler
   d. Regulation

2. The objective of a power electronics circuit is ______
   a. To reduce power consumption
   b. To avoid current shock
   c. Match the voltage and current required of the load
   d. To minimize expenditure

3. The fundamental frequency of the output voltage is ______
   a. 4 V
   b. 8 V
   c. 2 V
   d. 6 V

4. A DC to DC converters ______
   a. Converts AC to DC
   b. Converts a DC voltage to different DC voltage level
   c. Converts DC to AC
   d. Reduce AC

CHAPTER 8 Power Electronics
5. A voltage regulator _____________
   a. Gives a steady, reliable and fixed output voltage
   b. Unregulated voltage
   c. Unregulated current
   d. Low power output

6. In IC voltage regulators the way of excess power is dissipated by ______
   a. Earthing circuits
   b. Employing a heat sink
   c. Connecting a load
   d. None of the above

7. In single phase AC voltage controller the SCR connection is called as ____________.
   a. Series connection
   b. Parallel connection
   c. Anti-parallel or inverse parallel connection
   d. Series and Parallel connection

8. The purpose of connecting a MOSFET at the output pin of the microcontroller is ________.
   a. To switch off the relay
   b. To drive high-current components
   c. To drive low-voltage components
   d. To drive low-current components

9. In ULN 2003A IC the number of Darlington pairs used are __________.
   a. 3   b. 4   c. 5   d. 7

10. The function of SMPS is ____________.
    a. Rectification
    b. Inversion
    c. Voltage regulation
    d. All the above

ANSWERS
1. (b)  2. (c)  3. (c)  4. (b)  5. (a)  
6. (b)  7. (c)  8. (a)  9. (d)  10. (d)
In this chapter, the students can learn about the working principle and minor trouble shooting technique of the following:

- Digital Computer
- Mother Board and Processor
- BIOS and Memory
- CMOS Battery and CPU clock
- Switches, Jumpers and Printers
- Networking and Embedded system
- Arduino Board and Raspberry Pi

**CONTENT**

9.1 Mother Board  
9.2 Memory Unit  
9.3 Basic I/O System (BIOS)  
9.4 Secondary Memory  
9.5 CMOS Battery  
9.6 CPU Clock  
9.7 Switches & Jumpers  
9.8 Microprocessor – 8085 PIN Configuration  
9.9 Microprocessor – 8085 - Architecture  
9.10 Printers  
9.11 Computer Networking  
9.12 Embedded System  
9.13 Arduino Board  
9.14 Raspberry Pi
Introduction

We know today’s world is dominated by digital devices, of which, the digital computer plays vital role in everybody’s life. The computer becomes indispensable tool to perform all our routine, official and social works with greater accuracy and speed. Hence, it is highly essential to know about the technical features and also necessary fault rectification techniques of the computer. Basically, digital Computer consists of two broad classifications, such as hardware and software. Without the contribution of one other cannot function properly. Any action in the hardware is controlled by the software. Further, the software requires the hardware as a platform to execute the intended work. That mean, both hardware and software are inter-dependent. Hence, in this chapter, we are going to learn about digital computer’s hardware, software and related fault rectifications.

9.1 MOTHER BOARD

The computer built around the main device called Central Processing Unit or simply CPU for performing all the tasks instructed by the user. The CPU is the prime part of the Mother Board, which has a sheet of plastic that holds all the circuitry to connect the various components of a computer system. Fig 9.1 shows the schematic diagram of the motherboard. It is populated with many crucial components of the computer including the central processing unit (CPU), memory and connectors for input and output devices. The base of the motherboard consists of a very firm sheet of non-conductive material, typically some-sort of rigid plastic. Thin layers of copper or aluminium foil, referred to as traces or tracks are printed onto this sheet. These tracks are very narrow and form the circuits between the various components. In addition to the circuits, a motherboard contains a number of sockets and slots to connect the other components. Other names for this central computer unit are system board, main-board, or printed wired board (PWB). The motherboard is sometimes shortened to Mobo.

![Diagram of Mother Board](image-url)
CHAPTER 9  Computer Hardware Techniques

A chip forms an interface between the CPU, the main memory and other components. On many types of motherboards, this is referred to as the Northbridge. This chip also contains a large heat sink.

A second chip controls the input and output (I/O) functions. It is not connected directly to the CPU but to the Northbridge. This I/O controller is referred to as the Southbridge. The Northbridge and Southbridge combined together are referred as the chipset.

Several connectors, which provide the physical interface between input and output devices and the motherboard, are handled by the Southbridge.

Slots for one or more hard drives to store files. The most common types of slots are Integrated Drive Electronics (IDE) and Serial Advanced Technology Attachment (SATA).

A Read-Only Memory (ROM) chip contains the firmware or start-up instructions for the computer system. This is also called as BIOS (Basic Input Output System).

Numerous major components crucial for the functioning of the computer are attached to the motherboard. These include the processor, memory, and expansion slots. The motherboard connects directly or indirectly to every part of the PC. The type of motherboard installed in a PC has a great effect on a computer’s system speed, functional and expansion capabilities. Fig 9.2 shows the view of the motherboard.

Some of the more important parts and how the motherboard connects the various parts of a computer system are described as follows.

- A CPU socket - the actual CPU is directly soldered onto the socket. Since high speed CPU generates a lot of heat and hence there are heat sinks and mounting points for fans are provided right next to the CPU socket.

- A power connector to distribute power to the CPU and other components.

- Slots for the system’s main memory, typically in the form of DRAM chips.

### Major Motherboard Components and their Functions

Numerous major components crucial for the functioning of the computer are attached to the motherboard. These include the processor, memory, and expansion slots. The motherboard connects directly or indirectly to every part of the PC. The type of motherboard installed in a PC has a great effect on a computer’s system speed, functional and expansion capabilities. Fig 9.2 shows the view of the motherboard.

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### FIGURE 9.2 View of Mother Board with magnified view of the CPU
The various components of a µp and how they function mostly depend on the speed in which the computer works. The technological advancements in the chip design technology leads to processors having very high speed in the order of GHz. Presently, advanced PC has a 64-bit quad-core Intel i7 processor with 3.5 GHz speed. The µp has the following components viz.

- Arithmetic logic unit (ALU)
- Control unit (CU)
- Cache

### Purpose of µp

The main purpose of a computer processor is to perform any sort of computations and logical functions assigned to the computer. Besides, managing the computer's memory, handling input from users, sending the output to display devices. Computer software is encoded in machine language, which is a numeric code that µp understand and process as a series of simple commands. µp do communicate with other devices installed on a computer, such as input and output devices and memory chips.

Common manufacturers of CPUs include Intel and AMD, which make processors for desktop and laptop computers. Qualcomm and ARM, which make chips designed mostly for smaller devices like smart phones and embedded tools. The processor chip is identified by the processor type and the manufacturer. This information is usually inscribed on the chip itself. For example, Intel 386, Advanced Micro Devices (AMD) 386, Cyrix 486, Apple note, etc.

### Comparing µp

In addition to the brand name and model of a µp, there are stats that the user can compare different processing chips. The
most commonly cited statistic about a CPU is its clock speed, which refers to how many program instructions it can run in a second. Speed is typically measured in Mega-Hertz (MHz) or Giga-Hertz (GHz).

Another important measurement for comparing CPUs is the number of cores in the chip. A core is an independent processor within a processor that can run commands in parallel with other cores. There is a limit to how much software can be divided into units of commands that can run simultaneously, so adding additional cores increases the speed of the computer. But in general, µp with more cores run faster than those with fewer cores.

Depending on user needs, user may want to look at the power consumption of a particular µp. Faster processors sometimes use more energy than slower ones, but computers have become more efficient over time.

### The basic elements of a processor

- The Arithmetic Logic Unit (ALU), which carries out arithmetic and logic operations on the operands or instructions.
- A processor includes a control unit (CU) and measures the
  - Ability to process instructions at a given time.
  - Maximum number of bits/instructions.
  - Relative clock speed.
- The floating point unit (FPU), also known as a math coprocessor or numeric coprocessor, a specialized coprocessor that manipulates numbers more quickly than the basic microprocessor circuitry can.
- Registers, which hold instructions and other data. Registers supply operands to the ALU and store the results of operations.
- L1 and L2 cache memory. Their inclusion in the CPU saves time compared to get data from random Access Memory (RAM).

Most processors today are multi-core, which means that the IC contains two or more processors for enhanced performance, reduced power consumption, more efficient and simultaneous processing of multiple tasks (see: parallel processing). Multi-core set-ups are similar to having multiple, separate processors installed in the same computer, but, the processors are actually plugged into the same socket and the connection between them is faster. It is responsible for fetching, decoding, and executing program instructions as well as performing mathematical and logical calculations.

### 9.2 Memory Unit

A memory is just like a human brain. It is used to store data and instructions. Computer memory is the storage space in the computer, where data is to be processed and instructions required for processing are stored. The memory is divided into large number of small parts called cells. Each location or cell has a unique address, which varies from zero to memory size minus one. For example, if the computer has 64 kilo-words, then the memory unit has 64 * 1024 = 65536 memory locations. The address of these locations varies from 0 to 65535 (65536 – 1).

**Memory is primarily of three types**

- Cache Memory
- Primary Memory/Main Memory
- Secondary Memory
9.2.1 Cache Memory

Cache memory is a very high-speed semiconductor memory which can speed up the µp. It acts as a buffer between the µp and the main memory. It is used to hold those parts of data and program which are most frequently used by the µp. The parts of data and programs are transferred from the disk to cache memory by the Operating System, from where the µp can access them.

- Cache memory is a small block of high-speed memory (RAM) that enhances performance by pre-loading information from the (relatively slow) main memory and passing it to the processor on demand.
- Most µps have an internal cache memory (built into the processor) which is referred to as Level 1 or primary cache memory. This can be supplemented by external cache memory fitted on the motherboard. This is the Level 2 or secondary cache. In modern computers, Levels 1 and 2 cache memories are built into the processor die. If a third cache is implemented outside the die, it is referred to as the Level 3 (L3) cache.

Advantages

The advantages of cache memory are

- Cache memory is faster than main memory.
- It consumes less access time as compared to main memory.
- It stores the program that can be executed within a short period of time.
- It stores data for temporary use.

Disadvantages

The disadvantages of cache memory are

- Cache memory has limited capacity.
- It is very expensive.

9.2.2 Primary Memory (Main Memory)

Basically Primary memory is classified into two broad categories.

1. ROM
2. RAM.

ROM

Normally, ROM family consists of ROM, PROM, EPROM and EEPROM. Among these many of the computer manufacturers use EPROM as the Booting IC.

EPROM memory holds only those instructions which are essential to make the computer get ready when it is switched on. The content of this memory cannot be altered or deleted. In case if it gets corrupted, the content of this particular memory can be erased by passing ultra-violet rays through the cavity provided on the top surface of the memory. Again this memory can be re-programmed by fixing this memory in the programming kit. The content of this memory is called as BIOS setup.

9.3 Basic Input/output System (BIOS)

BIOS stands for Basic Input/output System. BIOS is a set of instructions written in Assembly or HLL and the contents are “read-only” state. The memory consists of low-level software that controls the system hardware and acts as an interface between the operating system and the hardware. BIOS is also called device drivers, or just drivers. BIOS is essentially the link between the computer hardware and software in a system.

All motherboards include a small block of Read Only Memory (ROM) which is separated from the main system memory used for loading and running software.
On PCs, the BIOS contains all the code required to control the keyboard, display screen, disk drives, serial communications and a number of miscellaneous functions.

The system BIOS is a ROM chip on the motherboard used during the start-up routine (boot process) to check out the system and prepare to run the hardware. The BIOS is stored on a ROM chip because ROM retains information even when no power is being supplied to the computer.

**BIOS (Basic Input Output System)**

User might need to access BIOS to change how the device works or to assist in troubleshooting a problem. BIOS is responsible for the POST (Power On Self Test) and therefore makes it the very first software to run when a computer is started. The BIOS firmware is non-volatile, meaning that its settings are saved and recoverable even after power has been removed from the device.

BIOS instructs the computer on how to perform a number of basic functions such as booting and keyboard control. BIOS is also used to identify and configure the hardware in a computer such as the hard-drive, floppy-drive, optical-drive, CPU, memory, etc. The snapshot of the BIOS set-up is shown in Fig 9.3.

**9.3.1 How to Access BIOS**

The BIOS is accessed and configured through the BIOS Setup Utility. All available options in BIOS are configurable via the BIOS Setup Utility. BIOS is pre-
installed when the computer is purchased (loaded by the manufacturer). The BIOS Setup Utility is accessed in various ways depending on the type of computer or motherboard make and model.

**BIOS Availability**

All modern computer motherboards contain BIOS software. BIOS access and configuration on PC systems is independent of any operating system because the BIOS is part of the motherboard hardware. It doesn’t matter if a computer is running Windows 10, Windows 8, Windows 7, Windows Vista, Windows XP, Linux, Unix, or no operating system at all, i.e., the BIOS functions outside of the operating system environment and is no way dependent upon it. BIOS are manufactured by popular firmware companies such as, Phoenix Technologies, IBM, Dell, Gateway, American Megatrends (AMI), etc.

**How to use BIOS**

BIOS contains a number of hardware configuration options that can be changed through the setup utility. Saving these changes and restarting the computer applies the changes to the BIOS and alters the way BIOS instructs the hardware to function.

Before updating BIOS, it is important to know what version is currently running on the computer. There are multiple ways to do this, from checking in the Windows Registry to installing a third-party program that will display the BIOS version.

When configuring updates, it is extremely important that the computer not be shut down partway through or the update cancelled abruptly. This could brick the motherboard and render the computer unusable, making it difficult to regain functionality.

### 9.3.2 Characteristics of Main Memory

- These are semiconductor memories.
- It is known as the main memory.
- Usually volatile memory.
- Data is lost in case power is switched off.
- It is the working (live) memory of the computer.
- Faster than secondary memories.
- A computer cannot run without this primary memory.

### 9.4 Secondary Memory

This type of memory is also known as external memory or non-volatile. It is slower than the main memory. These are used for storing data/information, permanently. µp directly does not access these memories; instead they are accessed via input-output routines. Any part of the contents in the secondary memory is processed by transferring the content to the main memory. Then, only the µp can access it. For example, disk, CD-ROM, DVD, etc. Fig 9.4 shows the hard disk and its parts.

**Characteristics of Secondary Memory**

- The secondary memories are magnetic and optical disks.
- It is known as the backup memory.
- It is a non-volatile memory, i.e., data is permanently stored even if power is switched off.
- Computer may run without the secondary memory.
- Slower than primary memories.
CMOS devices require very little power to operate. The CMOS RAM is used to store basic information about the PC’s configuration, for instance:

- Floppy disk and hard disk drive types
- Information about CPU
- RAM size
- Date and time
- Serial and parallel port information
- Plug and Play information
- Power Saving settings

The Expansion Buses

An expansion bus is an input/output pathway from the CPU to peripheral devices and it is typically made up of a series of slots on the motherboard in which the expansion boards (cards) are plugged. PCI is the most common expansion bus in a PC and other hardware platforms. Buses carry signals such as data, memory addresses, power, and control signals from component to component. Other types of buses include ISA and EISA.

Expansion buses enhance the PCs capabilities by allowing users to add missing features in their computers by slotting adapter cards into the expansion slots.
**Chipsets**

A chipset is a group of small circuits that coordinate the flow of data to and from a PC’s main components. These main components include the CPU itself, the main memory, the secondary cache, and any devices interfaced on the buses. A chipset also controls data flow to and from hard disks and other devices connected to the IDE channels.

A computer has got two main chipsets:

- The Northbridge (also called the memory controller) is in charge of controlling transfers between the processor and the RAM, which is why it is located physically near the processor. It is sometimes called the GMCH, (Graphic and Memory Controller Hub).

- The Southbridge (also called the input/output controller or expansion controller) handles communications between slower peripheral devices. It is also called the ICH (I/O Controller Hub). The term “bridge” is generally used to designate a component which connects two buses.

**9.6 CPU Clock**

The CPU clock synchronizes the operation of all parts of the PC and provides the basic timing signal for the CPU. Using a quartz crystal, the CPU clock breathes life into the microprocessor by feeding it a constant flow of pulses.

For example, a 200 MHz CPU receives 200 million pulses per second from the clock. A 2 GHz CPU gets two billion pulses per second. Similarly, in any communications device, a clock may be used to synchronize the data transfer between the sender and the receiver. A “real-time clock,” also called the “system clock,” keeps track of the time of day and makes this data available to the software. A “time-sharing clock” interrupts the CPU at regular intervals and allows the operating system to divide its time between active users and/or applications.

**9.7 Switches and Jumpers**

- **DIP (Dual In-line Package) switches** are small electronic switches found on the circuit board that can be turned on or off just like a normal switch. They are very small and so are usually flipped with a pointed object, such as the tip of a screwdriver, a bent paper clip, or a pen top. Take care when cleaning near DIP switches, as some solvents may destroy them. Dip switches are obsolete and user will not find them in modern systems.

- **Jumper pins** are small protruding pins on the motherboard. A jumper cap or bridge is used to connect or short a pair of jumper pins. When the bridge is connected to any two pins, via a shorting link, it completes the circuit and a certain configuration has been achieved.

- **Jumper caps** are metal bridges that close an electrical circuit. Typically, a jumper consists of a plastic plug that fits over a pair of protruding pins. Jumpers are sometimes used to configure expansion boards. By placing a jumper plug over a different set of pins, user can change the board’s parameters.

**NOTE**: User can check the jumper pins and jumper cap at the back of an IDE hard disk and a CD/DVD ROM/Writer.

**9.8 Microprocessor**

In order to understand the basic capabilities of the CPU, let us start our discussion with the basic fundamental component called
a microprocessor. A microprocessor is a very large scale integrating circuit in which number of functions are integrated and fabricated using Von Newman technology, i.e., it has no separate program and data memory. The first microprocessor was invented by Fair child semiconductors in the year 1959 and Intel released its first 4-bit microprocessor Intel 4004 in the year 1971. Then, 8-bit microprocessors were fabricated and released by many companies like Motorola (6800), Intel (8085) and Zilog (Z80). Presently, several 16-bit, 32-bit and 64-bit microprocessors with added-functionalities were released to meet the requirements of the system viz., speed, features, compactness, adaptability towards network communication, etc. In this Section, we discuss about the features of Intel’s 8085 microprocessor.

**PIN Configuration of 8085**

Fig 9.5 shows the pin diagram of 8085 Microprocessor and can be divided into the following seven groups.

![Diagram of 8085 microprocessor](image)

**Address bus**

A15-A8, it carries the most significant 8-bits of the memory/IO addresses.

**Data bus**

AD7-AD0, it carries the least significant 8-bits of the address and data buses.

**Control and status signals**

These signals are used to identify the nature of operation. There are 3 control signals and 3 status signals.

- **RD** – This signal indicates that the selected IO or memory device is to be read and is ready for accepting data available on the data bus.
- **WR** – This signal indicates that the data on the data bus is to be written into a selected memory or IO location.
- **ALE** – It is a positive going pulse generated when a new operation is started by the microprocessor. When the pulse goes high, it indicates that the information presented in the AD0-AD7 is the address information. When the pulse goes down it indicates that the information presented in the AD0-AD7 is data.

The three status signals are IO/M, S0 & S1.

**IO/M**

This signal is used to differentiate between IO and Memory operations, i.e. when it is high the signal indicates IO operation and when it is low then it indicates memory operation.

**S1 & S0**

These signals are used to identify the type of current operation.
9.8.2 Serial I/O Signals

There are 2 serial signals, i.e. SID and SOD and these signals are used for serial communication.

- SOD (Serial Output Data line) – The output of SOD is set/reset as specified by the SIM instruction.
- SID (Serial Input Data line) – The data on this line is loaded into accumulator whenever a RIM instruction is executed.

9.8.1 Interrupts & Externally Initiated Signals

Interrupts are the signals generated by external devices to request the microprocessor to perform a task. There are 5 interrupt signals, i.e. TRAP, RST 7.5, RST 6.5, RST 5.5, and INTR and their functionalities are listed below.

- INTA – It is an interrupt acknowledgment signal.
- RESET IN – It is used to reset the microprocessor by setting the program counter to zero.
- RESET OUT – It is used to reset all the connected devices when the microprocessor is reset.
- READY – It indicates that the device is ready to send or receive data. If READY is low, then the CPU has to wait for READY to go high.
- HOLD – It indicates that another master is requesting the use of the address and data buses.
- HLDA (HOLD Acknowledge) – It indicates that the CPU has received the HOLD request and it will relinquish the bus in the next clock cycle. HLDA is set to low after the HOLD signal is removed.

9.9 Microprocessor – 8085 Architecture

8085 is pronounced as “eighty-eighty-five” microprocessor. It is an 8-bit microprocessor designed by Intel in 1977 using NMOS technology. It has the following features.

- 8-bit data bus
- 16-bit address bus, which can address up to 64 KB
- A 16-bit program counter
- A 16-bit stack pointer
- Six 8-bit registers arranged in pairs: BC, DE, HL
- Requires +5 V supply to operate at 3.2 MHZ single phase clock
- It has many applications in instruments like washing machines, microwave ovens, mobile phones, etc.

9.9.1 8085 Microprocessor – Functional Units

8085 consists of the following functional units and are summarized below.

Accumulator

It is an 8-bit register used to perform arithmetic, logical, I/O & LOAD/STORE operations. It is connected to internal data bus & ALU.
Arithmetic and logic unit
As the name suggests, it performs arithmetic and logical operations like Addition, Subtraction, AND, OR, etc. on 8-bit data.

General purpose register
There are 6 general purpose registers in 8085 processor, i.e. B, C, D, E, H & L. Each register can hold 8-bit data.

These registers can work in pair to hold 16-bit data and their pairing combination is like B-C, D-E & H-L.

Program counter
It is a 16-bit register used to store the memory address location of the next instruction to be executed. Microprocessor increments the program whenever an instruction is being executed, so that, the program counter points to the memory address of the next instruction that is going to be executed.

Stack pointer
It is also a 16-bit register works like stack, which is always incremented or decremented by 2 after the execution of push and pop instructions.

Temporary register
It is an 8-bit register, which holds the temporary data of arithmetic and logical operations.

Flag register
It is an 8-bit register having five 1-bit flip-flops, which holds either 0 or 1 depending upon the result stored in the accumulator.

The set of 5 flip-flops, viz., Sign (S), Zero (Z), Auxiliary Carry (AC), Parity (P) and Carry (C) are available in 8085 microprocessor. Its bit positions are labelled as shown in the Fig 9.6.

<table>
<thead>
<tr>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Z</td>
<td>AC</td>
<td>P</td>
<td>CY</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIG 9.6 Bit position of the Flags in 8085 microprocessor

Instruction register and decoder
It is an 8-bit register. When an instruction is fetched from memory, then it is stored in the Instruction register. Instruction decoder decodes the information present in the Instruction register.

9.9.3 Timing and Control Unit
It provides timing and control signal to the microprocessor to perform several operations. Following are the timing and control signals, which control external and internal circuits.

- Control Signals: READY, RD, WR, ALE
- Status Signals: S0, S1, IO/M
- DMA Signals: HOLD, HLDA
- RESET Signals: RESET IN, RESET OUT

Interrupt control
As the name suggests, it controls the interrupts during a process. When a microprocessor is executing a main program and whenever an interrupt occurs, the microprocessor shifts the control from the main program to process the incoming request. After the request is completed, the control goes back to the main program.

There are 5 interrupt signals in 8085 microprocessors: INTR, RST 7.5, RST 6.5, RST 5.5, and TRAP.
Serial Input/output control
It controls the serial data communication by using two instructions viz., SID (Serial input data) and SOD (Serial output data).

Address buffer and address-data buffer
The content stored in the stack pointer and program counter is loaded into the address buffer and address-data buffer to communicate with the CPU. The memory and I/O chips are connected to these buses; the CPU can exchange the desired data with the memory and I/O chips.

9.9.4 Address Bus and Data Bus
Data bus carries the data to be stored. It is bidirectional, whereas address bus carries the location to where it should be stored and it is unidirectional. It is used to transfer the data & Address I/O devices.

8085 Architecture
Fig 9.7 depicts the architecture of 8085 and having three bus configurations in order to communicate with the internal components or sections of the microprocessor.

1. Address bus
The address bus of 8085 contains 16 address lines, in which the low-order address lines A0-A7 are multiplexed with the data bus and that should be identified using the ALE signal. It can able to address $2^{16} = 65536$ memory locations.

2. Data bus
It comprises of 8 data lines multiplexed with the lower order address lines (AD0-AD7). It can able to represent data in the range of 0-255.

3. Control bus
It is used to generate timing and control signals to control all the associated
peripherals, process data, memory related operations, input/output operations, etc. Some control signals are:
- Memory read
- Memory writes
- I/O read
- I/O Write
- Opcode fetch

**Programming the 8085**

The 8085 microprocessor has 78 instructions, which can be used to write the programs in machine (Mnemonics) or assembly (MASM) or high level (C, C++) languages employing different addressing modes supported by the microprocessor.

Likewise, most of the microprocessors perform very simple to complex operations at a very high speed using the above discussed components and codes. Mainly the CPU comprises of one or more microprocessors with advanced features like parallel processing, cache memory, speed, higher number of bits, etc.

**Video Display Cards**

In the older version computer, there is a separate add-on cards for accessing the video displays. Today’s computers have built-in VGA or Graphics Cards.

### 9.9.5 Input/Output Port

The term port is used in a number of places in computer terminology; an I/O port should not be confused with a physical port (connection) on the computer or network ports. Fig 9.8 illustrates the different ports available in a computer. A computer port is an interface or a point of connection between the computer and its peripheral devices. Some of the common peripherals are mouse, keyboard, monitor or display unit, printer, speaker, flash drive, etc. The main function of a computer port is to act as a point of attachment, where the cable from the peripheral can be plugged in and allows data to flow from and to the device.

There are two types of i/o ports.
1. Serial ports
2. Parallel ports.

1. **Serial ports**: A serial port is an interface through which peripherals can be connected using a serial protocol which involves the transmission of data one bit at a time over a single communication line.

2. **Parallel ports**: A parallel port is an interface through which the peripheral communicates with a
computer in a parallel manner. DB-25 port is with parallel interface.

Let us see some other ports and Interfaces available in a computer.

1. **VGA Port**: VGA port is found in many computers, projectors, video cards and High Definition TVs. This connector is known as DE-15. VGA port is the main interface between computers and older CRT monitors. Even the modern LCD and LED monitors support VGA ports but the picture quality is reduced.

2. **Digital Video Interface (DVI)**: DVI is a high speed digital interface between a display controller like a computer and a display device like a monitor. It was developed with an aim of transmitting lossless digital video signals and replace the analogue VGA technology.

3. **HDMI (High Definition Media Interface)**: HDMI is a digital interface to connect High Definition and Ultra High Definition devices like Computer monitors, HDTVs, Blu-Ray players, gaming consoles, High Definition Cameras etc. HDMI can be used to carry uncompressed video and compressed or uncompressed audio signals. The HDMI port of type A is shown below.

4. **USB**: Universal Serial Bus (USB) replaced serial ports, parallel ports, PS/2 connectors, game ports and power chargers for portable devices.

5. **Input output system**: It is one of the important jobs of an Operating System is to manage various I/O devices including mouse, keyboards, touch pad, disk drives etc.

6. **Device Controllers**: Any device which is connected to the computer using a socket and plug to connect with each other. It communicates with CPU in binary. It contains a register and buffer which plays an important role in communication between input, output devices and CPU like a bridge.

7. **Device Driver**: It is a software which is an interface between OS and device controller. It tells the device controller how to control the I/O device. Device drivers are software modules that can be plugged into an OS to handle a particular device. Operating System takes help from device drivers to handle all I/O devices, Input Output Mechanism, Programmed I/O Interrupts, DMA (Direct memory Access). The processor executes a program that gives it direct control of the I/O operation, including sensing device status, sending a read or write command, and transferring the data. When the processor issues a command to the I/O module, it must wait until the I/O operation is complete. If the processor is faster than the I/O module, this is wasteful of processor time.

8. **Programmed I/O**: I/O Commands to execute an I/O-related instruction, the processor issues an address, specifying the particular I/O module and external device and an I/O command. There are four types of I/O commands that an I/O module may receive when it is addressed by a processor: i) Control ii) Test iii) Read iv) Write. Let us discuss about these commands.

   i) **Control**: Used to activate a peripheral and tell it what to do. For example, a magnetic-tape unit may be instructed to rewind or to move forward one record.

   ii) **Test**: Used to test various status conditions associated with an
I/O module and its peripherals. The processor will want to know that the peripheral of interest is powered on and available for use.

iii) Read: Causes the I/O module to obtain an item of data from the peripheral and place it in an internal buffer. The processor can then obtain the data item by requesting that the I/O module place it on the data bus.

iv) Write: Causes the I/O module to take an item of data (byte or word) from the data bus and later transmit that data item to the peripheral.

9. Interrupts: The problem with programmed I/O is that the processor has to wait a long time for the I/O module of concern to be ready for either reception or transmission of data. An alternative is for the processor to issue an I/O command to a module and then go on to do some other useful work. The I/O module will then interrupt the processor to request service when it is ready to exchange data with the processor. For input, the I/O module receives a READ command from the processor. The I/O module then proceeds to read data in from an associated peripheral. Once the data are in the module's data register, the module signals an interrupt to the processor over a control line. The module then waits until its data are requested by the processor. When the request is made, the module places its data on the data bus and is then ready for another I/O operation.

10. DMA (Direct Memory Access): Direct memory access (DMA) is a feature of computer systems that allows certain hardware subsystems to access main system memory (RAM), independent of the CPU. DMA involves an additional module on the system bus. The DMA uses the system bus to transfer the data to and from the memory only when the processor does not need it or it force the processor to suspend operation temporarily. When the processor wishes to read or write a block of data, it issues a command to the DMA module.

9.9.6 Difference Between Parallel Port & Serial Port

The main difference between a serial port and a parallel port is that a serial port transmits data one bit after another, while a parallel port transmits all 8 bits of a byte in parallel. Thus, a parallel port transmits data much faster than a serial port. Computers have both serial and parallel ports along with newer technology called a USB (Universal Serial Bus) port.

9.9.7 Pin Configuration of Ports

Serial ports typically are 9-pin or 25-pin male connectors. The parallel port is a 25-pin female connector where the printer cable is interfaced. The ports COM1 and COM2 on the computer are serial ports and the LPT1 port is a parallel port. Each pin has a specific function such as transmit data, receive data, data terminal ready or auto-feed. Serial ports also refer to any port that is RS-232 (Recommended Standard 232) compliant in the telecommunications world.

9.9.8 Devices that use Serial Ports

The RS-232 standard is used by many different manufacturers of devices. Some common devices that use the serial port connection are flat screen monitors, GPS receivers, bar code scanners and satellite phones or modems.
9.9.9 Devices that use Parallel Ports

The parallel port is virtually synonymous with the printer port. Other devices that communicate with a parallel port are zip drives, scanners, joysticks, external hard drives and webcams. Today, the parallel port has been replaced by the new USB port for connecting these same devices to the computer.

9.9.10 UART

A UART (Universal Asynchronous Receiver/Transmitter) is a piece of hardware found inside the computer that translates data between parallel and serial ports. The UART takes the whole byte of data from the parallel port and transmits it serially, one bit after another. A device on the receiving end takes each bit and reassembles it back into a whole byte of parallel data. This technology makes use of a serial or parallel port configuration, but cannot be ascertained, i.e., a mute point.

9.9.11 USB

Universal Serial Bus, or USB, is a technological protocol developed in the 1990s to standardize connections between computers and the growing number of computer peripheral devices including cameras, external hard drives, memory sticks and audio-visual recorders. The USB protocol governs everything from the USB ports on the sides of most computers to the USB cables that connect the computer to USB-compliant devices like iPods, joysticks or keyboards. USB refers to the technology used a series of flat pins found in the connection headers that both transfer data and transmit electrical current to charge peripheral devices.

Difference between USB & Ethernet

USB stands for Universal Serial Bus. USB is used to connect peripheral devices to a computer. Ethernet, on the other hand, is a high-speed networking protocol. It is used primarily to connect local area networks (LANs). Ethernet can also be used to connect a DSL or cable modem to a computer. Fig 9.9 shows the USB and Ethernet connectors.

Types

The USB 1.0 specification supported speeds up to 12 megabits per second (Mbps.) USB 2.0 supports speeds up to 480 Mbps. Ethernet supports three different speeds. The slowest operates at 10 Mbps. Fast Ethernet operates at 100 Mbps. The fastest type is Gigabit Ethernet, which transmits signals at 1000 Mbps.

Features

USB is compatible with plug and play devices. This means that when the user plugs-in a USB device, the device’s drivers will begin to install automatically. When the user attaches a device to the computer by Ethernet, the user may have to install the drivers manually. If a CD is supplied with the device, place it in the CD-drive to install the software and configure the device. Some modems that connect by Ethernet require no drivers. However,
the Internet Service Provider (ISP) will probably provide the software to configure the system to connect to the Internet.

**Identification**

A USB cable has metal connectors on both ends. The type “A” connector is flat and broad. This end will be connected to the computer. Many computers have USB ports available both on the front and on back. These can be identified by a trident symbol, which shows a medium-sized circle connected to three lines. One line ends in a square, one in a smaller circle and one in a triangle. The “B” connector connects to the device. This plug is keyed so that the user can’t insert the device in the wrong way. Ethernet looks like a large telephone cable. It has a plastic tab on the end that will catch inside the plug when the user inserts it in back of the computer.

### 9.9.13 USB Vs Serial and Parallel

Table 9.1 lists the comparison between the various ports available in computers.

<table>
<thead>
<tr>
<th>TABLE 9.1 Comparison of Ports available in computers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industry Standard</strong></td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Number of Devices</strong></td>
</tr>
<tr>
<td><strong>Bus Power</strong></td>
</tr>
<tr>
<td><strong>Cable Length Limit</strong></td>
</tr>
<tr>
<td><strong>Plug’n’Play</strong></td>
</tr>
<tr>
<td><strong>Hot Swapable</strong></td>
</tr>
</tbody>
</table>

### 9.9.14 HDMI

HDMI is the short form of High Definition Multimedia Interface. HDMI is a connector and cable capable of transmitting high-quality and high-bandwidth streams of audio and video between devices. The HDMI technology is used with devices such as an HDTV, Projector, DVD player or Blu-ray player. Fig 9.10 shows the example of an HDMI interface cable and connector.

**Specification of HDMI Cable**

The HDMI standard was developed by multiple companies including Hitachi, Philips, Sony, and Toshiba. A single HDMI cable replaces the three composite audio/video cables, making it easier to connect two devices together for transmitting audio and video signals. HDMI is capable of transmitting standard, enhanced, and high-definition video signals, as well as up to 8-channels of digital audio signals.
The Different Lengths of HDMI Cables

The length of HDMI cables varies significantly. They can run from one foot to 50 feet, though it is not recommended for more than a 25 foot cable, as it may result in signal degradation or loss.

HDMI Ports

The HDMI ports are found either on the video card or motherboard on the back of the computer. It is important to note that not all computers and video cards have HDMI ports, but may have a Display Port, DVI, or VGA connector. Fig 9.10 shows some of these connectors with an example of the HDMI connector.

9.10 Printers

A computer printer is a device or an instrument that must be connected to a computer which allows users to print text and graphics on the plain papers. In some case they can be directly connected to digital camera for printing pictures without connecting to any computer.

Computer printer is one of the essential hardware, whether it is for a large company or for personal use. The usage of printer is depending upon the requirement of the company or individual person. For a big company they might print lots of paper or documents where as an individual need seldom.

There are different types and models of printers. The most commonly used computer printers are

1. Inkjet Printer: - Inkjet printers one of the user-friendly computer printers. It works by propelling variably-sized droplets of liquid or molten material (ink) onto almost any medium. They are the most common type of printer for the general consumer due to their low cost, high quality of output, capability of printing in glowing colour, and easy to use and handle.

2. Laser Printer: Laser printer uses LED-technology to obtain small particles of toner from a cartridge onto paper. They produce high quality text and graphics on plain paper. They are generally more economical to use than the ink of inkjet printers.

3. Plotters Printer: - Plotters printer is very different from others printers. Unlike other printer Pen Plotters print by moving a pen across the surface of a piece of paper. Plotters printer is the best way to produce colour high-resolution vector-based artwork, or very large drawings efficiently.
advancement in the networking field and its relative industries like hardware, software manufacturing and integration. As a result, most households have access to one or more networks. There are three broad network types:

- **Local Area Network (LAN):** Used to serve a small number of people located in a small geographical space. Peer-to-peer or client server networking methods can be employed.
- **Wide Area Network (WAN):** Formed to connect a computer with its peripheral resources across a large geographical area.
- **Wireless Local Area Network (WLAN)/Wireless Wide Area Network (WWAN):** Formed without the use of wires or physical media to connect hosts with the server. The data is transferred over radio transceivers.

4. **Dot-matrix Printer:** This printer is somehow like typewriting. They create characters by striking pins against an ink ribbon. Each pin makes a dot, and combinations of dots form characters and illustrations. The printing involves mechanical pressure, so these printers can create carbon copies and carbonless copies as well.

5. **Thermal Printer:** Thermal printer is an inexpensive printer that works by pushing heated pins against heat-sensitive paper. Thermal printers are generally used in calculators and fax machines. Thermal printers print faster and more quietly than dot matrix printers. They are also more economical since their only consumable is the paper itself.

### 9.11 Computer Networking

Computer networking is an engineering discipline that aims to study and analyse the communication process among various computing devices or computer systems that are linked or networked together to exchange information and share resources.

Computer networking depends on the theoretical application and practical implementation of the fields like computer engineering, computer sciences, information technology and telecommunication.

A router, network card and protocols are the essential pillars upon which any network is built. Computer networks are the backbone of modern-day communication. Even public switched telephone networks are controlled by computer systems; most telephonic services are also working with IP.

The increasing scope of communication has led to much

### 9.12 Embedded System

The word embedded implies that it lies inside the overall system, hidden from view, forming an integral part of the whole. An embedded system is a system whose principle function is not computational, but which is controlled by a computer embedded within it. Here the computer is nothing but the Micro Processor or Micro Controller. “Normally an Embedded System consists of a micro-controller, which is programmed and controlled by a software program. It is a reliable, real-time control system. It can work automatically or can be controlled by human or operated on diverse physical variables and in diverse environments. This is a cost-effective and sold competitively in the market.

**Applications of Embedded System**

Embedded systems are commonly found in consumer appliances, industrial, automotive, medical, commercial
and military applications. Consumer electronics includes MP3 players, mobile phones, video game consoles, digital cameras, GPS receivers, and printers. Household appliances such as microwave ovens, washing machines and dishwashers include embedded systems to provide flexibility, efficiency and added-features.

**Characteristics**

The characteristic of embedded system is,

1. The embedded systems are designed to do some specific task. (Whereas the general-purpose computer is designed for multiple tasks). Embedded systems are not always standalone devices. Many embedded systems consist of small parts within a larger device that serves a more general purpose.

2. System functions in real time. The tasks execute according to priorities. The system reacts to the events, interrupts in predetermined time interval and schedules responses according to priorities.

3. The program instructions written for embedded systems are referred to as firmware, and are stored in Read Only Memory (ROM) or Flash Memory chips. They run with limited computer hardware resources: little memory, small or non-existent keyboard or screen.

4. It has dedicated set of functions.

5. Complex dedicated-purpose algorithms.

6. Complex dedicated-purpose pre-programmed time constraints, to finish the different operations. Examples are audio, video, data and network streams and events (e.g., Screen touch, switch ON, an external Input).

**9.12.1 Components of Embedded System**

An Embedded System has three main components

1. It embeds hardware similar to a computer. The processors may be embedded processor cores. The hardware includes embedded memory, peripheral and input-output devices. It embeds main application software. The application software may perform concurrently multiple tasks. Figure 9.11 shows the units in the hardware of an embedded system.

![Component of Embedded System](image)

**FIG 9.11 Component of Embedded System**

2. Software usually embeds in the ROM Read Only Memory, flash memory or media card. The system most often does not have a hard disk or secondary memory.

3. It embeds a Real Time Operating System (RTOS). The RTOS supervises the application software and controls the access to system resources. It enables finishing the execution of the tasks of a program within specified time intervals.

**Embedded-system Constraints**

An embedded system is designed by keeping the following three constrains in mind.
Examples

1. Starts from basic - Intel 8086 – a 32 bit processor, then 80386, 80486, Pentium series i.e.,586
2. Apple, Android and Backberry mobiles use 1.5 GHz dual core processors.
3. Many mobile handheld devices use ARM 9, ARM 10, ARM 11 processors.
4. Many Servers use SPARC family processors.

9.12.3 Microcontroller

A microcontroller is an integrated chip or core in VLSI or SoC. A Microcontroller has the processor memory and several other hardware units interfaced together and integrated in a single chip using Harvard architecture.

A microcontroller is used when a small or part of the embedded software has to be located in internal memory to perform task related to the on-chip functional units like interrupt-handler, port, timer, ADC, PWM, CAN controller, ZigBee or USB interfaces.

Some of the microcontroller chips widely used in embedded system are Intel 8051, 80251 versions, ATMELE mega series and Microchip PIC16F84 or 16C76 etc.

Presently, most of the embedded system components are available are dedicated cards with interfaces for connected the input and output devices. In the following section we discuss about some of the famous embedded cards available in the market for designing purposes.

9.13 Arduino Board

Arduino Board consists of both a physical programmable circuit board called as a microcontroller and a piece of...
software or IDE (Integrated Development Environment) which can run on a computer. It is used to write and upload computer code (programme) to the physical board.

**9.13.1 Arduino-UNO Board**

The UNO is the best board to get started with electronics and coding (programme). This board gives good experience with the platform. The UNO is the most robust board to start the designs of interest. The UNO is the most used and documented board of the whole Arduino family. Fig 9.12 shows the completer Arduino Uno board.

**Specifications**

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller. It can be simply connected to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

**9.13.2 Software used in Arduino**

“Uno” means “one” in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform, for an extensive list of current, past or outdated boards. The pin descriptions of the Arduino

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**TABLE 9.2 Pin Description of Arduino UNO**

<table>
<thead>
<tr>
<th>Pin Category</th>
<th>Pin Name</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>Vin, 3.3V, 5V, GND</td>
<td>Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.</td>
</tr>
<tr>
<td>Reset</td>
<td>Reset</td>
<td>Resets the microcontroller.</td>
</tr>
<tr>
<td>Analog Pins</td>
<td>A0 – A5</td>
<td>Used to provide analog input in the range of 0-5V</td>
</tr>
<tr>
<td>Input/Output Pins</td>
<td>Digital Pins 0 - 13</td>
<td>Can be used as input or output pins.</td>
</tr>
<tr>
<td>Serial</td>
<td>0(Rx), 1(Tx)</td>
<td>Used to receive and transmit TTL serial data.</td>
</tr>
<tr>
<td>External Interrupts</td>
<td>2, 3</td>
<td>To trigger an interrupt.</td>
</tr>
<tr>
<td>PWM</td>
<td>3, 5, 6, 9, 11</td>
<td>Provides 8-bit PWM output.</td>
</tr>
<tr>
<td>SPI</td>
<td>10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)</td>
<td>Used for SPI communication.</td>
</tr>
<tr>
<td>Inbuilt LED</td>
<td>13</td>
<td>To turn on the inbuilt LED.</td>
</tr>
<tr>
<td>TWI</td>
<td>A4 (SDA), A5 (SCA)</td>
<td>Used for TWI communication.</td>
</tr>
<tr>
<td>AREF</td>
<td>AREF</td>
<td>To provide reference voltage for input voltage.</td>
</tr>
</tbody>
</table>
### Board Breakdown

Here are the components that make up an Arduino board and what each of their functions are.

1. **Reset Button** – This will restart any code that is loaded to the Arduino board
2. **AREF** – Stands for “Analog Reference” and is used to set an external reference voltage
3. **Ground Pin** – There are a few ground pins on the Arduino and they all work the same
4. **Digital Input/Output** – Pins 0-13 can be used for digital input or output
5. **PWM** – The pins marked with the (−) symbol can simulate analog output
6. **USB Connection** – Used for powering up your Arduino and uploading sketches
7. **TX/RX** – Transmit and receive data indication LEDs
8. **ATmega Microcontroller** – This is the brains and is where the programs are stored
9. **Power LED Indicator** – This LED lights up anytime the board is plugged in a power source
10. **Voltage Regulator** – This controls the amount of voltage going into the Arduino board
11. **DC Power Barrel Jack** – This is used for powering your Arduino with a power supply
12. **3.3V Pin** – This pin supplies 3.3 volts of power to your projects
13. **5V Pin** – This pin supplies 5 volts of power to your projects
14. **Ground Pins** – There are a few ground pins on the Arduino and they all work the same
15. **Analog Pins** – These pins can read the signal
CHAPTER 9  Computer Hardware Techniques

Genuino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs to work with either 5 V or 3.3 V.

Application of LED blink using Arduino Uno

To perform this application, open the LED blink example sketch: File > Examples > 01.Basics > Blink as shown in Fig 9.13.

Then select the port by using the entry in the Tools > Board menu that corresponds to the Arduino or Genuino board as shown in Fig 9.14.

WARNINGS

The Arduino Uno has a resettable polyfuse that protects computer’s USB ports from shorts and over-current. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Power

The Arduino Uno board can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board’s power jack. Leads from a battery can be inserted in the GND and Vin pin headers of the POWER connector.

The board can operate on an external supply from 6 to 20 volt. If the board is supplied with less than 7 V, the 5 V pin may supply less than five volts and the board may become unstable. If more than 12 V supply is used, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts. Further, the IOREF pin on the Arduino/
9.14 Raspberry Pi

As like Arduino Board, yet another application board was developed in the United Kingdom by the company called Raspberry Pi Foundation. It consists of series of small single-board computers to promote teaching of basic computer science in schools and in developing countries. The original model became far more popular than anticipated, selling outside its target market for uses such as robotics. It does not include peripherals (such as keyboards and mice) and cases. However, some accessories have been included in several official and unofficial bundles.

9.14.1 Raspberry Board

Fig 9.17 & Fig 9.18 shows the Raspberry board. The features of this board are summarized below:

- **USB ports** — these are used to connect a mouse and keyboard. You can also connect other components, such as a USB drive.

![Raspberry Pi Board and Components](image-url)
**SD card slot** — you can slot the SD card in here. This is where the operating system software and your files are stored.

**Ethernet port** — this is used to connect the Raspberry Pi to a network with a cable. The Raspberry Pi can also connect to a network via wireless LAN.

**Audio jack** — you can connect headphones or speakers here.

**HDMI port** — this is where you connect the monitor (or projector) here.
that you are using to display the output from the Raspberry Pi. If your monitor has speakers, you can also use them to hear sound.

- **Micro USB power connector** — this is where you connect a power supply. You should always do this last, after you have connected all your other components.
- **GPIO ports** — these allow you to connect electronic components such as LEDs and buttons to the Raspberry Pi.

### 9.14.2 Interfacing the Raspberry Pi

Let us connect the Raspberry Pi and get it operational by following the steps given below:

Check whether the Raspberry Pi already has an SD card in the slot at the underside, and if not, insert an SD card with Raspbian installed (via NOOBS) as shown in Fig 9.19.

![FIG 9.19 Check for SD card in Raspberry board](image)

Then, find the USB connector for interfacing the mouse and connect the mouse to one of the USB port on the Raspberry Pi (it doesn’t matter which one) as shown in Fig 9.20.

![FIG 9.20 Connecting a mouse to the Raspberry board](image)

Then, connect the keyboard in the same way as mouse as shown in Fig 9.21.

![FIG 9.21 Interfacing of keyboard with Raspberry board](image)

Then, look at the HDMI port on the Raspberry Pi (notice that it has a large flat side on top). Make sure the monitor is plugged into a power wall socket and turned on. Connect the monitor cable to the Pi’s HDMI port — use an adapter if necessary as shown in Fig 9.22. Nothing will display yet. If the user wants to connect the Pi to the internet via Ethernet, use an Ethernet cable to connect the Ethernet port on the Raspberry Pi to an Ethernet socket on the wall or on the internet router. If WiFi is available, then there is no need to connect to the internet.

![FIG 9.22 Monitor Interface with Raspberry Pi](image)

Sound will come from the monitor if it has speakers or the user can connect headphones or speakers to the audio jack as shown in Fig 9.23.
Finish the setup

When you start your Raspberry Pi for the first time, the Welcome to Raspberry Pi application will pop up and guide you through the initial setup. The Raspberry Pi is a fantastic single-board computer, and its power and capabilities are very useful.

Installing Raspbian OS

The users must follow the instructions in the website to install the most common OS used on the Pi called Raspbian, which is a must-have for 99 out of 100 Pi projects. When the Pi boots, it will look for a specific boot file on the SD card and once that file has been found, it will begin to execute the code inside.

Python

The Raspberry Pi can be coded in a range of different languages, including Java and C++, but, arguably, the most flexible and easy language to use is Python. Programs written in Python can take half the time to write and half the amount of code to do the same task (when compared to languages such as C and C++). Of course, learning different languages is the best thing that any designer can do, but as a first language, Python is a good language to start with.

LEARNING OUTCOME

At the End of this chapter, the students would come to know the working principle and minor trouble shooting technique of the following

- Digital Computer
- Mother Board and Processor
- BIOS and Memory
- CMOS Battery and CPU clock
- Switches, Jumpers and Printers
- Networking and Embedded system
- Arduino Board and Raspberry Pi
Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>µP</td>
<td>Microprocessor</td>
</tr>
<tr>
<td>Memory</td>
<td>Used to store data and instructions</td>
</tr>
<tr>
<td>BIOS</td>
<td>Basic Input and Output System</td>
</tr>
<tr>
<td>CMOS Battery</td>
<td>Complementary Metal Oxide Semiconductor Battery</td>
</tr>
<tr>
<td>Chipsets</td>
<td>Group of Small circuits</td>
</tr>
<tr>
<td>Northbridge</td>
<td>Internal Memory Controller</td>
</tr>
<tr>
<td>Southbridge</td>
<td>External Memory Controller</td>
</tr>
<tr>
<td>HDMI</td>
<td>High Definition Media Interface</td>
</tr>
<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
</tr>
<tr>
<td>Arduino</td>
<td>Physical programmable circuit board called as microcontroller</td>
</tr>
<tr>
<td>Raspberry Pi</td>
<td>Mini Computer Board - having Mini Microprocessor and Microcontroller – best example for embedded system</td>
</tr>
<tr>
<td>Python</td>
<td>Computer language used to interface with Raspberry board</td>
</tr>
</tbody>
</table>

Questions

Part – A (1 Mark)

1. Choose the best answer

1. The__________ is the prime part of the motherboard
   a. CPU       b. ALU
   c. FPU       d. None of the above

2. ___________ contains a number of sockets and slots to connect the other components.
   a. Micro Processor
   b. Motherboard
   c. Microcontroller
   d. None of the above

3. The motherboard is sometimes shortened to ____________
   a. CMOS       b. MOBO
   c. BIOS       d. None of the above

4. The __________ connects directly or indirectly to every part of the PC
   a. Microprocessor
   b. Microcontroller
   c. Motherboard
   d. None of the above

5. Single integrated chip is called as___________
   a. Microprocessor
   b. Printed Circuit Board
   c. Floating Point Unit (FPU)
   d. None of the above

6. Brain of computer is ____________
   a. Microprocessor
   b. Microcontroller
   c. Micro Connectors
   d. None of the above
7. CPU has its own cooling system in the form of a ____________
   a. Heat sink and fan
   b. Floating point Unit (FPU)
   c. Parallel/Serial Ports
   d. None of the above

8. Microprocessor speed is measured in ____________
   a. MHz or GHz
   b. Hz or KHz
   c. Meters/second
   d. None of the above

9. ____________ also known as a Math Co-processor or Numeric Co-processor
   a. Serial Port
   b. Parallel Port
   c. Floating point unit (FPU)
   d. None of the above

10. L1 and L2 are ____________
    a. Cache memory
    b. Secondary Memory
    c. UART
    d. None of the above

11. The memory is divided into large number small parts called ____________
    a. Cells
    b. MOBO
    c. CPU
    d. None of the above

12. ____________ is a very high-speed semiconductor memory which can speed up the microprocessor
    a. Cache memory
    b. Secondary Memory
    c. Serial/Parallel Ports
    d. None of the above

13. ____________ is a set of instructions written in assembly and the contents are read only state
    a. CMOS
    b. BIOS
    c. MOBO
    d. None of the above

14. ____________ retains information even when no power is being supplied to the computer
    a. RAM
    b. ROM
    c. CPU
    d. None of the above

15. ____________ is responsible for the post
    a. CMOS
    b. BIOS
    c. IDE
    d. None of the above

16. ____________ is also known as non-volatile memory
    a. Secondary memory
    b. Cache Memory
    c. BIOS
    d. None of the above

17. ____________ is used to store basic information about the PC’s configuration.
    a. CMOS
    b. CPU
    c. CMOS RAM
    d. None of the above

18. 2 GHz CPU gets ____________ billion pulses per second
    a. Two
    b. One
    c. Three
    d. None of the above

19. Interrupts are the signals generated by ____________ devices to request the microprocessor to perform a task.
    a. Internal
    b. External
    c. External and Internal
    d. None of the above
20. There are ___________ interrupt signals in 8085 microprocessors
   a. 9
   b. 5
   c. 3
   d. None of the above

21. ___________ are Male connectors.
   a. Serial ports and parallel ports
   b. Parallel Ports
   c. Serial Ports
   d. None of the above

22. ___________ are female connectors.
   a. Serial ports and parallel ports
   b. Parallel Ports
   c. Serial Ports
   d. None of the above

23. ___________ is virtually synonymous with the printer port.
   a. Serial and Parallel Ports
   b. Parallel port
   c. Serial Ports
   d. None of the above

24. The processor is the ___________ of the embedded system
   a. Heart
   b. Cells
   c. Memory
   d. None of the above

25. A ___________ is an integrated chip or core in VLSI or SoC
   a. Microcontroller
   b. Microprocessor
   c. Mother Board
   d. None of the above

26. ___________ is a microcontroller board based on ATmega 328P
   a. CPU
   b. Arduino Uno
   c. Raspberry
   d. None of the above

27. ___________ is a good language to start with Raspberry Pi
   a. Python
   b. Java
   c. C++
   d. None of the above

Part – B (3 Marks)

II Answer the following

1. Explain Motherboard?
2. What is BIIOS?
3. What is the usage of VGA and PCI Slots?
4. What is Processor?
5. Explain uP (Microprocessor) components?
6. What is the Purpose of uP?
7. Explain Memory Unit and their Types?
8. What is ROM?
9. Explain BIOS availability?
10. List out the characteristics of main Memory?
11. Explain- CMOS Battery?
12. What are expansion Buses?
13. What is chipset and its parts?
14. Explain CPU Clock?
15. Explain 3 clock signals?
16. Explain Serial I/O signals?
17. Explain Address Bus and Data Bus?
18. Explain Video Display Cards?
19. Difference between Parallel Port and Serial Port?
20. Explain Configuration of Ports?
21. Explain UART?

THE END
CHAPTER 9  Computer Hardware Techniques

8. Explain the Pin Description of Arduino UNO?
10. Draw the diagram of Raspberry Pi Port with its Parts?

Part – D  (10 Marks)

IV Answer the following questions in detail

1. Explain Mother Board components and their functions?
2. Explain the Basis Elements of a Processor?
3. Explain the Memory Unit? List out it Advantages and Disadvantages?
4. Explain Microprocessor and Intel 8085 Micro Processor?
5. Explain Ports and Interfaces available in a computer?
6. Comparison of Ports available in computers?
7. Explain Printers?
8. Explain Arduino Board?
9. What is Raspberry Pi?
10. Explain Raspberry Pi Board?

Part – C  (5 Marks)

III Explain the following questions

1. Draw and explain the schematic diagram of Motherboard?
2. List out the advantages and disadvantages of Cache Memory?
3. Explain secondary Memory and their characteristics?
4. Explain Buses in 8085 Architecture?
5. Explain the devices that uses Serial Ports and Parallel Ports?
6. Explain the types of USB and its features?
7. Explain Characteristics of Embedded Systems?
8. Explain the Pin Description of Arduino UNO?
22. List out difference between USB and Internet?
23. Explain HTMI?
24. How to identify the USB Ends?
25. List our examples for Micro Processor?
26. What is Microcontroller?
27. Explain Arduino Board?
28. What is Raspberry Pi?
29. How to install the Raspbian OS?
30. Explain Python?

ANSWERS

1. (a) 2. (b) 3. (b) 4. (c) 5. (a) 6. (a) 7. (a) 8. (a) 9. (c) 10. (a)
11. (a) 12. (a) 13. (b) 14. (b) 15. (b) 16. (a) 17. (c) 18. (a) 19. (b) 20. (b)
21. (c) 22. (b) 23. (b) 24. (a) 25. (a) 26. (b) 27. (a)
In this Chapter, a student can learn and understand the working principle, usage, limitations and applications of the following biomedical instruments:

- Electrocardiograph (ECG)
- Electroencephalograph (EEG)
- Blood Pressure (BP) Monitor
- Pulse oxi-meter
- Tread Mill Test (TMT)
- Glucometer
- Endoscopy
- Ultrasound Scanner
- Computed Tomography (CT) Scanner
- Magnetic Resonance Imaging (MRI)
- Positron Emission Tomography (PET)
Introduction

Human body consists of biological, chemical, physical, electrical, thermal, hydraulic, pneumatic, acoustical, magnetic and mechanical systems, all interacting with each other. It also contains a powerful computer (brain), several types of communicating systems (nerves), and a great variety of control systems (muscles).

Human body is a source of various biopotential signals, which are most useful for estimating the physiological, clinical, therapeutic and biological activities of living body. These signals can be picked up from the surface of the body or from within the body. Figure 10.1 shows the biopotential recorded from nerve and muscle, respectively. The biopotential was first recorded in 1786, by an Italian Physician Dr. Luigi Galvani. Later on, several advancements in electronics, material science and computing technology shaped the biomedical instruments in various forms like dedicated, portable, wearable, PC-based, MEMS/NEMS-based and wireless based devices.

Definition of Biopotential

1. An electric potential that is measured between points in living cells, tissues, and organs, which accompanies all biochemical processes.

2. Ionic voltages produced as a result of the electrochemical activity of excitable cells.

Characteristics of Biopotential signals

The important characteristics of a biopotential signals recorded from our body are summarized in Table 10.1

<table>
<thead>
<tr>
<th>Signal</th>
<th>Parameter</th>
<th>Signal Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrocardiogram (ECG)</td>
<td>Frequency range: 0.05 to 500 Hz 0.05 to 120 Hz is adequate</td>
<td>Typical signal voltage: 1 mV Voltage range: 10 µV to 5 mV</td>
</tr>
<tr>
<td>Electroencephalogram (EEG)</td>
<td>Frequency: 0.1 to 100 Hz 0.5 to 70 Hz is adequate Voltage: 2 to 200 µV</td>
<td>Typical voltage: 50 µV</td>
</tr>
<tr>
<td>Electromyogram (EMG)</td>
<td>Frequency: 5 to 2000 Hz Voltage: 25 to 5000 µV</td>
<td></td>
</tr>
<tr>
<td>Electoretinogram (ERG)</td>
<td>Frequency: DC to 20 Hz Voltage: 0.5 µV to 1 mV Amplitude: 0.5 mV</td>
<td></td>
</tr>
<tr>
<td>Electroculegram (EOG)</td>
<td>Frequency: DC to 100 Hz Voltage: 10 to 3500 µV Amplitude: 0.5 mV</td>
<td></td>
</tr>
</tbody>
</table>
Measurement of Biopotential

Using transducers, the ionic potential generated by our body is converted into electrical potential. Bioelectric potential waveforms generally end with the suffix gram. For example, Electrocardiogram, Electroencephalogram. Instruments used to measure biopotential generally ends with the suffix graph, e.g., Electrocardiograph, Echocardiograph. Biomedical instruments are devices that can be used to make measurements of biologic or medical quantities and give quantitative (or sometimes qualitative) results. Have you ever seen a biomedical instrument? Some of the simple biomedical instruments everybody knows are thermometer, stethoscope, etc. as shown in Figure 10.2.

Figure 10.3 shows the basic components of a biomedical instrument. Any biomedical instrument comprises of sensor that senses the physiological parameter of interest such as temperature, blood pressure, pulse rate, etc. The sensor's output signal is of low-amplitude and comprises of unwanted signals called noise, artifacts, etc. Therefore, the sensor output signal is processed in the processor unit, which may be an electronic circuit, or a computer with related software. The processed output signal can be either stored in the memory for future usage or it can be shown in a display for monitoring/diagnosis. In this Chapter, some of the basic biopotential as well as biomedical imaging instruments and their working principles are discussed.

10.1 Electrocardiograph

Have you ever seen an Electrocardiogram (ECG) record? Whenever you have suspected any problem about the normal functioning of the heart, the Physician advised to take an electrocardiogram for diagnosing the functionality of your heart. Then, the questions arises naturally are, How Electrocardiogram is recorded? What is the working principle of electrocardiograph machine? How it is used by the physician for diagnosis? What is the difference between Electrocardiograph and Electrocardiogram? In this chapter, we will try to answer these questions and to understand the concepts related with the working and usage of ECG.

Electrocardiograph is an instrument to record the electrical activity associated with the heart. Electrocardiogram is the graphical or waveform representation of the voltage versus time that is recorded using Electrocardiograph instrument. They are used to assist the Physician in diagnosing or treating some types of heart disease, determining a patient's response...
to drug therapy, and reveal trends or changes in heart function.

Electrocardiograph records small voltages of about one millivolt (mV) that appear on the skin as a result of cardiac activity. The voltage differences between electrodes are measured; these differences directly correspond to the heart’s electrical activity. The first ECG machine developed by Augustus Waller in the year 1887 using capillary electrometer is shown in Figure 10.4. Later, the physician standardized the ECG machine, which comprises of 12 standard leads for knowing the different perspective of the heart’s electrical activity. The ECG waveforms consist of P waves, QRS complex, and T waves, which are vary in amplitude and polarity. Typical 12-lead ECG waveforms are shown in Figure 10.5.
ECG comprises of P, QRS, T and U waves. P wave represents the contraction of the atria or the depolarization of atria, QRS complex corresponds to relaxation of the atria and initiation of ventricular contraction or the depolarization of ventricle, T wave corresponds to ventricular relaxation and the U wave origin is unknown.

**Working Principle of Electrocardiograph Machine**

Figures 10.6(a) shows a 12 lead ECG machine, Figure 10.6(b) depicts the various electrodes and Figure 10.6(c) illustrates the block diagram of the ECG machine, respectively. For acquiring the ECG signal from human body, four electrodes are placed on the four arms of the body viz., Right Arm (RA), Left Arm (LA), Right Leg (RL) and Left Leg (LL).

The signals picked up by the four electrodes are fed into a resistor/switching network to select one of the 12 leads viz., Lead I, Lead II, Lead III, aVR, aVL, aVF, V1, V2, V3, V4, V5, and V6. The selected/acquired signals from the switching network has very low-amplitude and is amplified by an instrumentation amplifier. In analog type of ECG machines, further processing like noise removal, base line correction and final amplification are performed using complicated circuits. But, in the digital ECG machine the signal from the instrumentation amplified is digitised using Analog-to-Digital Converter (ADC) and stored in digital form. The digitized ECG data is further processed for noise removal, base line correction and final amplification using signal processing hardware or software. The processed ECG data is stored for future use or displayed on the monitor or printed as hardcopy.

**Problem Finding in ECG**

- Frequency distortion leads to
  - High-frequency loss rounds the sharp edges of the QRS complex.
  - Low-frequency loss can distort the baseline (no longer horizontal).
- Saturation/cutoff distortion
  - Combination of input amplitude & offset voltage drives amplifier into saturation
  - Positive case: clips off the top of the R wave
Negative case: clips off the Q, S, P and T waves

Ground loops
- Patients are connected to multiple pieces of equipment; each has a separate ground (power line or common room ground wire)
- If more than one instrument has a ground electrode connected to the patient, a ground loop exists. Power line ground can be different for each item of equipment, which sends current through the patient and introduces common-mode noise.

Open lead wires
- Can be detected by impedance monitoring.

Unwanted voltage transients (Figure 10.7) are due to
- Patient movement
- Electrical stimulation signals, like defibrillation

50 Hz power line noise (Figure 10.8)
- Electric-field coupling between power grid, instrument, patient, and wiring.

Electromyogram (EMG) noise (Figure 10.9)
- Example of tensing chest muscles while ECG is being recorded.

Typical applications

Diagnosis of
1. Ischemia
2. Arrhythmia
3. Conduction defects

FIGURE 10.6 (c) Block Diagram of Electrocardiograph

FIGURE 10.7 Unwanted voltage transients in the ECG

FIGURE 10.8 50 Hz Power Line Noise in ECG

FIGURE 10.9 EMG noise in ECG
10.2 Electroencephalograph (EEG)

This instrument is used to study the activity of the human brain. Electroencephalograph (EEG) is a standard non-invasive method of recording the electrical activity of the brain. Electroencephalogram consists of curves that relate to the spontaneous electrical activity of millions of neural cells of the brain. The recording lasts for 20-40 min and is printed on paper or displayed on monitor. The voltage range of EEG signal on the surface of the brain is 1-10 mV, whereas on the surface of the skull it is 1-100 µV in the frequency range of 0.5 to 3000 Hz. EEG signal consists of alpha, beta, theta and delta waves and are shown in Figure 10.10 shows EEG machine and its electrodes arrangement on the head of a man. Figure 10.11 illustrates the various EEG waveforms.

The characteristics of these waves are given in Table 10.2.

<table>
<thead>
<tr>
<th>Name of the waveform</th>
<th>Frequency range</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>8 to 13 Hz</td>
<td>Normal persons awake in a resting state and disappear during sleep.</td>
</tr>
<tr>
<td>Beta</td>
<td>14 to 30 Hz</td>
<td>May go up to 50Hz in intense mental activity. Beta I waves: frequency about twice that of the alpha waves and are influenced in a similar way as the alpha waves. Beta II waves appear during intense activation of the central nervous system and during tension.</td>
</tr>
<tr>
<td>Theta</td>
<td>4 to 7 Hz</td>
<td>During emotional stress</td>
</tr>
<tr>
<td>Delta waves</td>
<td>Below 3.5 Hz</td>
<td>Deep sleep or in serious organic brain disease</td>
</tr>
</tbody>
</table>

FIGURE 10.10 EEG machine and the electrodes arrangements on the head

FIGURE 10.11 Components of EEG waveform
**Application of EEG**

The EEG is used to diagnose the following diseases:

1. Level of consciousness
2. Sleep Disorders
3. Brain death
4. Epilepsy
5. Multiple Sclerosis

**10.3 Blood Pressure Monitor**

The abbreviated term ‘BP’ become very familiar in our life. In every one's mind a question may arise. Why the blood needs pressure. Dear students to understand this, just you think about the water supply system in your town or a city. Houses are located in various places and in various elevations and in different ground levels. But, the water has to reach all the houses. Without giving necessary pressure, is it possible to send the water to all the houses? No. Certainly we need some pressure to send the water to all the houses. To do this, we are pumping the water by using a powerful motor. Just like this, the blood in our body has to reach each and every part and corner of our body. To perform this, it needs some pressure. This is called Blood Pressure (BP). Here the task of giving enough pressure is done by our vital and important organ “The Heart”.

Blood transports $O_2$ and nutrients to the cells and carries the metabolic waste and $CO_2$ gas from the cells through a pressurized vessel system comprising of arteries, vein, arterioles, venuoles and capillaries (covering approximately 1,00,000 km distance). The pressure is provided by the mechanical pump called, heart. Measuring this pressure at various locations of our body reveals significant clinical information. The Blood Pressure (BP) is measured as Systolic (Pressure exerted by the heart during pumping) and Diastolic pressure (Pressure exerted when...
the heart relaxes between beats). The optimal values of Systolic and Diastolic pressure for an adult should be 120 mm Hg and 80 mm Hg, respectively. BP can be measured using direct (invasive) or indirect (non-invasive) methods.

1. **Invasive** – Catheter with external or internal sensor
2. **Non-invasive** – Sphygmomanometer and Ultrasound Doppler method

In this Section, the BP measurement using Sphygmomanometer is presented. Figure 10.12 shows the Sphygmomanometer comprises of an inflatable cuff, needle valve, pressure gauge, mechanical pump and Stethoscope. During measurement of BP, the cuff is inflated using the mechanical pump and the heart sound called Korotkoff sound is heard, which is listened using a stethoscope placed on the hand below the cuff. In the inflation phase, if the korotkoff sound is not heard, the physician stops pressurizing the cuff. Then, the needle value is opened for deflation and pressure across cuff decreases and once again the korotkoff sound is heard in the stethoscope. This point is noted and the reading in the pressure gauge is noted, which corresponds to the Systolic pressure. This will continue a while and once again the korotkoff sound is not heard, that point in the pressure gauge is noted as a diastolic pressure. In the case of automatic Sphygmomanometer, inflation, deflation, pressure sensing, etc., are controlled by a microcomputer with respective sensors and electronic circuitry as shown in Figure 10.13.

### 10.4 Pulse Oximeter

This is the most important instrument to identify and diagnose the real situation of the patient. Oxygen is carried in the blood by hemoglobin which has two forms: Hb and HbO₂. These two
forms have different absorptions at different wavelengths in the red to infra-red frequency band. By measuring the absorption of the two different wavelengths and taking appropriate ratios it is possible, in theory, to evaluate the percentage of hemoglobin carrying oxygen. The principle of pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin. Oxygenated hemoglobin absorbs more infrared light and allows more red-light to pass through, whereas deoxygenated hemoglobin absorbs more red-light and allows more infrared light to pass through. Red-light is in the 600-750 nm wavelength light band, whereas infrared light is in the 850-1000 nm wavelength light band. The figure 10.14(a) shows the image of Pulse Oximeter and figure 10.14(b) shows the absorption relationship of Hb and HbO₂.

**Principle of Operation of Pulse Oximeter**

Figure 10.15 shows the functional block diagram and circuit Diagram of simple Pulse Oximeter. Its operations are summarized as follows

1. Shine light through the finger or ear lobe. Red (~660 nm) and Near Infra–Red (NIR, ~940 nm) LEDs are used to generate the respective wavelengths, since LEDs are small and emit light at appropriate wavelengths. However, standard LEDs are not sufficiently powerful, therefore, special purpose LEDs have been designed with internal lensing to give a high intensity output. In order to increase the peak power of these LEDs and to use single photodetector for both the LEDs, the LEDs are operated in a pulsed manner using timing and pulsing circuits.
2. The transmitted light through the tissue is received by a photo-diode, since photodiodes are the simplest solid–state optical detectors. When light falls on the p–n junction region, an electron–hole pair is generated. The hole and the electron are swept in opposite directions. The resulting light current is seen as a large increase in the reverse current. This light current can be converted into a voltage using a single op–amp.

3. Here, a single photo-detector (TSL230R) is being used to provide two pieces of information. Therefore, it is important to know when it is giving information about absorption of the red and the NIR wavelengths, respectively. Some form of sample–and–hold circuitry is used to perform this task.

4. Further, the amplitude of the transmitted light is controlled using Automatic Gain Control (AGC) circuitry, because it allows the frequency response of the photodiode to be 'corrected', keeps the ac signal (which varies between 0.1% and 2%
of the total signal) within a pre-defined range and allows the dc level of both the NIR and the red signals to be kept at the same level (say 2 V).

5. Filters are used to perform the necessary noise reduction (possibly using averaging).

6. Finally, the microprocessor (MSP 430) analyses the light absorption of the tissues at each wavelength and determines the respective concentrations of the oxyhemoglobin and deoxyhemoglobin by calculating the value of an index $R$ and estimating the saturation of $O_2$ ($SPO_2$) using a lookup table stored in the microprocessor.

Figure 10.16 shows the waveform displayed in the pulse oximeter.

![Figure 10.16 Pulse Oximeter displays the waveform](image)

**Applications of Pulse Oximeter**

The SpO$_2$ values are used to diagnose the conditions such as Apnea, Bronchopulmonary dysphasia and cardiac diseases. For normal patients, the SpO2 will be in the range of 95-100 %, for Mild Hypoxemia, it will be in the range of 91-94%, for Moderate Hypoxemia, it will be in the range of 86-90% and for severe Hypoxemia, it will be in the range of <85%.

**10.5 Treadmill Stress Test (TMT)**

Treadmill is an exercise machine that allows the user to walk or run in order to monitor some of the vital physiological functions of the person. Figure 10.17 shows the snapshot of a Treadmill machine. A Treadmill Stress Test measures one's heart rhythm when the heart is stressed by exercise, such as walking or running on a treadmill. TMT is used to detect the changes in rhythm of heart, while the patient is walking or exercising on a treadmill. Any change in the rhythm indicates the problem associated with the blood supply of the heart. The total TMT duration should be 10 to 15 minutes. In the beginning of the test, the patient will walk at a slow speed and every 2 to 3 minutes the patient will have to walk faster with more uphill posture of the walking treadmill belt. The TMT will stop when the heartbeat reaches a certain speed or when the patient becomes very short of breath or having pain in the chest. The components of the Treadmill are listed below:

**Alternating Current (AC) Motor**

An AC motor of capacity 2.5 to 3 HP is used to move the treadmill belt at the required speed. Continuous Duty Horsepower, often referred to as simply CHP, motor is common in today’s treadmills. It is much quieter and the actual number signifies the amount of power a motor can generate under normal usage. The industry standard CHP recommended for TMT application is 3.0 CHP. It drives the belt in the specified speed.

**Belt (Treadmill Belt)**

Belts can differ in size and strength but a 2” ply with a black polyurethane top layer is common.

**Deck**

The treadmill manufacture will list the running surface as the “deck size”. The size of the deck can differ substantially but a 20" x 55" is a common size.
Drive Train

The mechanical system that transmits power or torque from one place to another. Specifically, the drive train on a treadmill is composed of the running belt, drive belt, rollers and motor.

Heart Rate Monitor

A built-in heart-rate monitor with associated program acquires the pulse signal from the user body, calculates the heart-rate and displays on the console.

Incline

It is displayed as a percentage (or in other cases “levels”) that a treadmill will point vertically in order to create the experience of running up a hill.

LCD

It is used to display all the details of the test with waveform and results for reference.

Pulse Grips

It allows users to wrap their hands around the grip and in turn get a read-out of their BPM.

Tracking

It is a little adjustment that allows the users to keep the belt centered on the treadmill. Several other adjustment screws or bolts are available, which are used to further adjust the belt.

Quick Controls

Quick controls usually consist of one-touch buttons that will increase/decrease speed, incline and/or resistance. They are considered ideal for workouts on the fly when there is a need to make several speeds and/or incline adjustments.

Glucometer

A glucose meter or glucometer is a medical device used for measuring the approximate level of glucose in the blood, which comprises of a test strip and a read-out device. The glucose meter, determines the concentration of glucose in the solution. Most glucose meters are based on electrochemical technology, they use electrochemical test strips to perform the measurement. Glucose strips are used for glucose monitoring from blood, which is shown in Figure 10.18.

Testing Procedure

A small drop of the solution (blood) to be tested is placed on a disposable test strip and inserted into glucose meter. In each test strip, there is an enzyme called glucose oxidase. This enzyme reacts with the glucose in the blood sample and creates an acid called gluconic acid. The gluconic acid then reacts with another chemical in the testing strip called ferricyanide. The ferricyanide and the gluconic acid then combine to create ferrocyanide. Once ferrocyanide has been created, the device
sends an electronic current through the blood sample on the strip. This current is then able to read the ferrocyanide and determine how much glucose is in the sample of blood on the testing strip. Finally, the estimated glucose value is displayed on the screen of the glucose testing meter.

Factors affecting Glucose Measurement

The glucose measurement made using Glucometer may be vulnerable to the parameters such as temperature, humidity, altitude, etc., due to the changes in rate of the enzyme reaction.

Biomedical Imaging Instruments

The earliest medical images used light to create photographs, either of the anatomic structures, or of the histological specimens using microscopes. Light is still an important source for the creation of images. However, visible light does not allow us to see inside the body. X-rays were first discovered in 1895 by Wilhelm Conrad Roentgen, who was awarded the 1901 Nobel Prize in physics for this achievement. This discovery caused worldwide excitement, especially in the field of medicine, since then, diagnostic X-ray technology has evolved from film-based to completely digital where images are manipulated and viewed in a digital data format. Advanced imaging modalities such as computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET) were developed late in the 20th century and in the 21st century.

What is the first X-ray taken by Rontgen?

The first X-ray image of Rontgen's wife was taken in the year 1985 and is shown here.
In this Section, some of the important imaging modalities like Endoscopy, Ultrasound scanner, Magnetic Resonance Imaging (MRI), Computed Tomography (CT) and Positron Emission Tomography are discussed.

## 10.7 Endoscopy

Endoscopy is the insertion of a long, thin tube directly into the body to observe an internal organ or tissue in detail. The first real endoscope was developed by Phillip Bozzini in the year 1805 to examine the urethra, the bladder and vagina. It can also be used to carry out other tasks including imaging and minor surgery. Endoscopes are minimally invasive and can be inserted into the openings of the body such as the mouth or anus.

Alternatively, they can be inserted into small incisions, for instance, in the knee or abdomen. Surgery can be completed through a small incision and assisted with special instruments, such as the endoscope, is called keyhole surgery. Since modern endoscopy has relatively few risks, which delivers detailed images in a reasonably quicker time and hence it has proven incredibly useful in many areas of medicine.

### Components of an Endoscopy

The endoscope consists of a slender, flexible or rigid tube equipped with lenses and a light source. CCDs are used as detector to acquire the video from the respective organs and display in a monitor. Through the accessory channels of the endoscope,
water and air is supplied to wash and dry the surgical site. Also, it has a channel through which surgeons can manipulate tiny instruments, such as forceps, surgical scissors and suction devices. A variety of instruments can be fitted to the endoscope for different purposes. Figure 10.19 shows the various components of an Endoscope.

**Types**

Endoscopy is the most useful for investigating many systems within the human body and is named based on the applications. They are summarized in Table 10.3.

**TABLE 10.3 Types of Endoscopy**

<table>
<thead>
<tr>
<th>Name of the Endoscopy</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastroscopy</td>
<td>To see the gullet, stomach and upper small intestine.</td>
</tr>
<tr>
<td>Colonoscopy</td>
<td>To see the large intestine.</td>
</tr>
<tr>
<td>Laparoscopy</td>
<td>To see the “stomach cavity” and the organs therein.</td>
</tr>
<tr>
<td>Proctoscopy</td>
<td>This is used to check for piles and other conditions of the anus and rectum.</td>
</tr>
<tr>
<td>Cystoscopy</td>
<td>To see the urinary bladder.</td>
</tr>
<tr>
<td>Bronchoscopy</td>
<td>To see the air passages to the lungs.</td>
</tr>
<tr>
<td>Laryngoscopy</td>
<td>To see the larynx or voice box.</td>
</tr>
<tr>
<td>Nasopharyngoscopy</td>
<td>To see the nose and related cavities.</td>
</tr>
<tr>
<td>Arthroscopy</td>
<td>To see inside joints such as the knee joint.</td>
</tr>
<tr>
<td>Thoracoscopy</td>
<td>To see inside the chest cavity.</td>
</tr>
</tbody>
</table>

The meaning of the word “Endoscopy”?

The word endoscopy is derived from the Greek words “Endo” meaning “inside” and “skopeein” meaning “to see”. It is a word used in medicine to describe the procedure used to see inside of the various parts of the body.

The role of fibre-optics in Endoscopy?

Medical endoscopy really came into force in diagnostic and surgery applications after the invention of fibre-optic technology. Fibre-optic endoscopes use bundles of thin glass fibres to transmit light to and from the organ being viewed. These fibres use the principle of total internal reflection to transmit almost 100% of the light entering one end to the other end.

What is Capsule Endoscopy?

Recently a disposable flash camera slightly larger than a vitamin pill was devised to perform imaging of the small intestine. This procedure is called capsule endoscopy in which the patient swallows the minicam, which then takes pictures inside the small intestine. On its journey through the digestive tract, the tiny tumbling camera transmits images that are stored in a recorder that the person wears around the waist. After 8 hours, the camera’s battery runs out, and the capsule is eliminated in the faeces.
10.8 Ultrasonography

Ultrasonography is a medical imaging technique that uses high frequency sound waves and their echoes. These frequencies are between 1 MHz and 10 MHz and such frequencies cannot be heard by humans. The technique is similar to the echolocation used by bats, whales and dolphins, as well as SONAR used by submarines.

Principle of Ultrasonography

The typical image of Ultra sound scanner is shown in the Figure 10.20(a). The ultrasound machine transmits high-frequency (1 to 10 MHz) sound pulses into the body using a probe. The sound waves travel into the body and hit a boundary between tissues (e.g. between fluid and soft tissue, soft tissue and bone). Some of the sound waves get reflected back to the probe, while some travel on further until they reach another boundary and get reflected. The reflected waves are picked up by the probe and relayed to the machine. The machine calculates the distance from the probe to the tissue or organ (boundaries) using the speed of sound in tissue (1,540 m/s) and the time of the each echo’s return (usually on the order of millionths of a second). The machine displays the distances and intensities of the echoes on the screen, forming a two dimensional image like the one shown in Figure 10.20(b).

Components of Ultrasound Machine

Figure 10.21 shows the components of a basic ultrasound Machine and the functions of each component are described below:

1. Transducer probe - The transducer probe generates and receives sound waves using a principle called the piezoelectric (pressure electricity) effect, which was discovered by Pierre and Jacques Curie in 1880. The probe also has a sound absorbing substance to eliminate back reflections from the probe itself, and an acoustic lens to help focus the emitted sound waves. When an electric current is applied to these crystals, they change shape rapidly and the vibrations of the crystals produce sound waves that travel outward. Conversely, when sound or pressure waves hit the crystals, they emit electrical currents. Therefore, the same crystal can be used as transmitter and receiver of the sound waves.
2. **Central processing unit (CPU)** - The CPU is basically a computer that contains the microprocessor, memory, amplifiers and power supplies for the microprocessor and transducer probe. The CPU sends electrical currents to the transducer probe to emit sound waves, and also receives the electrical pulses from the probes that are created from the returning echoes. The CPU does all of the calculations involved in processing the data. Once the raw data are processed, the CPU forms the image on the monitor. The CPU can also store the processed data and/or image on disk.

3. **Transducer pulse controls** - The transducer pulse controls allow the operator, called the ultrasonographer, to set and change the frequency and duration of the ultrasound pulses, as well as the scan mode of the machine. The commands from the operator are translated into changing electric currents that are applied to the piezoelectric crystals in the transducer probe.

4. **Display** - The display is a computer monitor that shows the processed data from the CPU. Displays can be black-and-white or color, depending upon the model of the ultrasound machine.

5. **Keyboard and Cursor** - Ultrasound machines have a keyboard and a cursor, such as a trackball, built in. These devices allow the operator to add notes and to take measurements from the data.

![Components of a Basic Ultrasound Scanner](image-url)
6. **Disk storage device** - The processed data and/or images can be stored on the disk. The disks can be hard disks, floppy disks, compact discs (CDs) or digital video discs (DVDs).

7. **Printer** - Many ultrasound machines have thermal printers that can be used to capture a hard copy of the image from the display.

### Uses of Ultrasonography

Ultrasound has been used in a variety of clinical fields including obstetrics and gynecology, cardiology and cancer detection. The main advantage of ultrasound is that certain structures can be observed without using radiation. Ultrasound can also be done much faster than X-rays or other radiographic techniques.

### 10.9 Computed Tomography Imaging

Tomography is imaging by sections or sectioning. A device used in tomography is called a tomograph, while the image produced is a tomogram. Computed Tomography (CT) or Computed Axial Tomography (CAT), utilizes X-ray technology and sophisticated computers to create images of cross-sectional “slices” of the human body. CT produces cross-sectional images and also has the ability to differentiate tissue densities, which creates an improvement in contrast resolution.

Figure 10.22(a) shows the image acquired from a CT-Scanner. Figure 10.22(b) shows the principle of operation and the image of CT. In CT, the X-ray source is tightly collimated to interrogate a thin slice through the patient. The source and detectors rotate together around the patient, producing a series of one-dimensional projections at a number of different angles. The basic processes of CT consist of for steps viz., Data acquisition, Image reconstruction, Image display and Image archiving (recording). After placing the patient in the proper position of the scanner, the operator selects the correct protocols and technical parameters and starts running the machine. At the initialization of the scan, X-rays passing through the patient are attenuated depending on the tissue type. A detector system located opposite to the X-ray tube measures the attenuation values as an analogue signal. This signal is transmitted to the Analogue to digital converter (ADC), which converts the signal of attenuated values from analog to digital form and sending to computer for further processing. The computer reads this digital data and employs a mathematical formula, called a reconstruction algorithm, to generate the cross-sectional image. The mathematical basis for reconstruction of an image from a series of projections is the Radon transform. The image reconstruction, involving millions of data points, which is usually performed in less than a second by a group of array processors. The reconstructed image is displayed on a LCD monitor as an image suitable for manipulation by the operator. In the image archiving, three processes such as image manipulation, Archiving on a Picture Archiving and Communication System (PACS) and storage are performed. For this, a wide range of software is available to enhance the image on the monitor before storage. These include altering the density...
and brightness, changing the plane of the image from axial to sagittal or coronal, producing three dimensional images and demonstrating detailed angiography. Recent developments in spiral and multi-slice CT have enabled the acquisition of full three-dimensional images in a single patient breath-hold.

Advantages
- Desired image detail is obtained
- Fast image rendering
- Filters may sharpen or smooth the reconstructed images

Disadvantages
- Multiple reconstructions may be required if significant detail is required from areas of the study that contain bone and soft tissue
- Need for quality detectors and computer software
- X-ray exposure

Do you know? Who invented the CT?

In 1950, Allan M. Cormack developed the theoretical and mathematical methods used to reconstruct CT images. In 1972, Godfrey N. Hounsfield and colleagues of EMI Central Research Laboratories built the first CAT scan machine, taking Cormack’s theoretical calculation into a real application. For their independent efforts, Cormack and Hounsfield shared the Nobel Prize in medicine and physiology in 1979.

10.10 Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) is a non-ionizing technique with full three-dimensional capabilities, excellent soft-tissue contrast, and high spatial resolution (about 1mm). Figure 10.23 shows the MR instrumentation setup and the MR images. MRI machines look like a large block with a tube running through the middle of the machine, called the bore of the magnet. The bore is where the patient is located for the duration of the scan. A radio frequency electromagnetic field is briefly turned on, causing the protons to absorb some of its energy. When this field is turned off the...
protons release this energy at a resonance radio frequency, which can be detected by the scanner. The frequency of the emitted signal depends on the strength of the magnetic field. The position of protons in the body can be determined by applying additional magnetic fields during the scan which allows an image of the body to be built up. These are created by turning gradients coils on and off which creates the knocking sounds heard during an MR scan. The MR signal from a human is predominantly due to water (hydrogen) protons. Since these protons exist in identical magnetic environments, they all resonate at the same frequency. Hence, the NMR signal is simply proportional to the volume of the water. The MRI machine picks points in the patient’s body, decides what type of tissue the points define, and then compiles the points into 2-dimensional and 3-dimensional images. Once the 3-dimensional image is created, the MRI machine creates a model of the tissue. This allows the clinician to diagnose without the use of invasive surgery. The scan can last anywhere from 20-30 minutes.
Positron Emission Tomography

PET is a non-invasive, nuclear diagnostic imaging technique for measuring the metabolic activity of cells in the human body. It was developed in the mid-1970s and it was the first scanning method to give functional information about the brain. PET produces images of the body by detecting the radiation emitted from radioactive substances. These substances are injected into the body, and are usually tagged with a radioactive atom (C-11, Fl-18, O-15 or N-13) that has short decay time. These radioactive atoms are formed by bombarding normal chemicals with neutrons to create short-lived radioactive isotopes. PET detects the gamma rays given off at the site where a positron emitted from the radioactive substance collides with an electron in the tissue. The results are evaluated by a trained expert.

Applications

MRI is used to diagnose or monitor the conditions such as:

- Tumours and other cancer related abnormalities.
- Certain types of heart problems.
- Blockages or enlargements of blood vessels.
- Diseases of the liver, such as cirrhosis, and that of other abdominal organs.
- Diseases of the small intestine, colon, and rectum.

Advantages of MRI

- MRI uses no ionizing radiation; there is little risk of tissue damage from repeated scans.
- MRI acquires images directly in any orientation.
- MRI better differentiates contrast between different kinds of soft tissue.
- MRI generates images with different tissue contrast properties, with or without the use of contrast agent injection.

The magnet strength of the MRI machine and our earth?

The largest and most important components of the MRI machine are the magnets. The magnet strength is measured in units of Tesla or Gauss (1 Tesla = 10,000 Gauss). Today’s MRI machines have magnets with strengths from 5000 to 20,000 Gauss. To give perspective on the strength of these magnets, the earth’s magnetic field is about .5 Gauss, making the MRI machine 10,000 to 30,000 times stronger.
Determine the effects of a heart attack, or myocardial infarction, on areas of the heart.

Evaluate brain abnormalities, such as tumors, memory disorders and seizures and other central nervous system disorders.

Map normal human brain and heart function.

**Limitations**

- Time-consuming.
- The resolution of structures of the body with nuclear medicine may not be as clear as with other imaging techniques, such as CT or MRI.
- PET scanning can give false results if chemical balances within the body are not normal.
- Because the radioactive substance decays quickly and is effective for only a short period of time, it is important for the patient to be on time for the appointment and to receive the radioactive material at the scheduled time.
- A person who is very obese may not fit into the opening of a conventional PET/CT unit.

**Applications**

- Detect cancer.
- Determine whether a cancer has spread in the body.
- Assess the effectiveness of a treatment plan, such as cancer therapy.
- Determine if a cancer has returned after treatment.
- Determine blood flow to the heart muscle.
LEARNING OUTCOME

A student will understand the working principle of the following instruments after reading this Chapter.

1. Electrocardiograph (ECG)
2. Electroencephalograph (EEG)
3. Blood Pressure (BP) Monitor
4. Pulseoximeter
5. Tread Mill Test (TMT)
6. Glucometer
7. Endoscopy
8. Ultrasound Scanner
9. Computed Tomography (CT) Scanner
10. Magnetic Resonance Imaging (MRI)
11. Positron Emission Tomography (PET)

GLOSSARY

<table>
<thead>
<tr>
<th>Biopotential</th>
<th>Potential generated at the cell level due to mobility of ions across cell membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrocardiograph</td>
<td>Instrument used to measure the electrical activity of the heart</td>
</tr>
<tr>
<td>Electroencephalogram</td>
<td>Instrument for measuring the electrical activity of the brain</td>
</tr>
<tr>
<td>Blood Pressure Monitor</td>
<td>Instrument to quantify the pressure of the Blood</td>
</tr>
<tr>
<td>Pulseoximeter</td>
<td>Instrument used to measure the oxygen saturation of blood</td>
</tr>
<tr>
<td>Tread Mill Test</td>
<td>Instrument used to test vital parameters of the human being during exercise</td>
</tr>
<tr>
<td>Glucometer</td>
<td>Instrument used to quantify the amount of glucose level in blood</td>
</tr>
<tr>
<td>Endoscopy</td>
<td>Instrument used to capture the image of the internal organs like stomach, intestine, etc.</td>
</tr>
<tr>
<td>Ultrasound Imaging</td>
<td>Instrument used to capture the image of the internal organs and tissues using ultrasound</td>
</tr>
<tr>
<td>Computed Tomography</td>
<td>Instrument used to image soft tissues and bones using X-ray</td>
</tr>
<tr>
<td>Magnetic Resonance Imaging</td>
<td>Instrument used to image soft tissues and bones using magnetic and radio frequency waves</td>
</tr>
<tr>
<td>Positron Emission Tomography</td>
<td>Instrument used to image the brain and its functions using gamma rays</td>
</tr>
</tbody>
</table>
6. In PET imaging, a biologic molecule that carries a positron emitting isotope is called as ……………
   (a) Tracer
   (b) Tracker
   (c) dyer
   (d) verifier

7. In CT machines, which source is used?
   (a) Gamma Ray
   (b) X-ray
   (c) ultrasound
   (d) infrared

8. PET is a non-invasive, nuclear diagnostic imaging technique for measuring the …….. activity of cells in the human body.
   (a) metabolic
   (b) electric
   (c) magnetic
   (d) transport

9. A glucose meter or glucometer is a medical device used for measuring the approximate level of ………. in the blood.
   (a) RBC
   (b) cholesterol
   (c) potassium
   (d) Glucose

10. Sphygmomanometer is used to estimate blood ……….
    (a) Sugar
    (b) Sodium
    (c) pressure
    (d) flow
Part – B

II Answer in one or two sentences (3 Marks)

1. Define bioelectric current.
2. State the value of blood pressure for a normal adult.
3. What are the applications of ECG?
4. Name any four types of Endoscopy.
5. What are the types of electrodes used in EEG?
6. Enumerate the purpose of a Pulseoximeter.
7. List the applications of PET.
8. Mention the advantages of MRI.
9. State the uses of ultrasonography.
10. State the principle of operation of TMT.

Part – C

III Answer in a paragraph (5 Marks)

1. Briefly explain the principle of operation of an Electrocardiograph with a neat sketch.
2. Explain the functions of Treadmill Test Machine.
3. Give the instrumentation details of a Pulse Oximeter.
5. Explain the operations of an Endoscope.

Part – D

IV Answer in One Page (Essay type Question) (10 Marks)

1. Discuss in detail the working principle and testing procedure of a Glucometer with neat sketch.
2. Write a note on the basic function of an Ultrasound Scanner.
3. Explain the principle of operation of an MRI machine.
4. Describe the operating principle of CT scan using functional block diagram.
5. Discuss in detail the operation of Positron Emission Tomography.

ANSWERS

1 (a) 2 (a) 3 (a) 4 (a) 5 (b) 6 (a) 7 (a) 8 (a) 9 (d) 10 (c)
My name is Manikandan.R, I was raised in a small rural place, Mecheri near Mettur, Salem District at Tamil Nadu. I would like to take the opportunity to share some thoughts and learning experience about vocational studies in the field of Electrical and Electronics Engineering.

I grabbed “Vocational Course” as my area of interest in the year 2001 and successfully completed my Higher Secondary Course in 2003 at Govt Hr.Sec. School, Mettur Dam. Thereafter I completed Diploma in Electrical and Electronics Engineering in 2005 Muthayammal Polytechnic College, Rasipuram. Also, I pursued my Bachelor of Engineering (EEE) at Mahendra Engineering College, Namakkal District in the year of 2008. I also decided to go for high studies and successfully completed my Master of Engineering at Sona College of Technology at Salem, followed with Ph. D Electrical Engineering in 2017.

After my studies, I decided to take teaching as my profession, having 8 plus years of experience with various reputed institutions in Tamil Nadu. I also done some researches in the area of Electrical and Electronics submitted various thesis and some of them are listed below;

- Special electrical machines and sensor less controls
- AI Techniques for solid state drives
- dSPACE & FPGA Implementation
- Renewable Energy Resources & Applications

I also developed few application on “Digital Optic Warp, Weft Stop Motion and Counter” for textile automation, Application Number: 6337/CHE/2015, it has been disclosed as “Registered Patents with Government.

I also happy to share that I have published various books and publications and few are listed below;


270 CHAPTER 10 Introduction to Biomedical Instruments
I am Karthikeyan M, I had studied Radio & TV Group related to Electronics Vocational course in Higher Secondary Education from TTN-Swamy Dayananda Higher Secondary School, Manjakkudi, Thiruvarur District on 1992. Today, I am a Managing & Technical Director of “Chip Systems” in Chennai & Trichy and the Chairman of “Vanigam Business Forum”. Also I am a Secretary of Anandham Foundation (NGO) which supports higher education of rural students. Currently there are 272 students benefiting through this foundation.

This is all because of my School & my both Teachers who used to teach me new things every day. It was amazing practical education more than my educational book. Though it has detailed explanation & information, Practical education was taught & change my life style.

At this time, I have learned radio assembling, TV servicing and so on. The basic which I have learned helps me to think an innovative way. Now My Chip Systems are providing Cell phone, Laptop, Computer, LED/LCD, Photocopier, UPS/Inverter Services, CCTV & solar power installation, PCB Designing, LED lights Assembling & Etc. We also contribute the major role in Electronics product service training business courses in Chennai. Moreover, we offer Online course for students beneficial and we got tremendous responses from all over the world. We are creating More than 25000 Service Engineers in my beloved Electronic field all over World. I have been interviewed by various television channels for our innovative idea.

We are the trend setters on Technical Training field.

Finally, Education is not the learning of facts, but the training of the mind to think.

“Today a reader, tomorrow a leader – Margaret Fuller”
PART – A

Choose the correct answer:  \[ 15 \times 1 = 15 \]

1. Mark the odd one out.
   (a) Adder  (b) Subtractor  (c) BJT  (d) Flip-Flop

2. What type of Modulation used in Satellite Communication?
   (a) Phase modulation  (b) Pulse Modulation
   (c) Amplitude Modulation  (d) Frequency Modulation

3. Which type of Antenna mostly used for Television reception?
   (a) Yagi Antenna  (b) Loop Antenna
   (c) Monopole Antenna  (d) Micro strip Antenna

4. Which type of test is using to measure voltage and current in electronic devices?
   (a) Soak test  (b) Vibration Test
   (c) Signal Test  (d) Secondary test

5. What gases are used in Plasma Display?
   (a) Oxygen and Carbon Mono oxide  (b) Xenon and Neon
   (c) Hydrogen and Helium  (d) Nitrogen and Helium

6. Hotspot is functioning in -------- Technology.
   (a) Wi-Fi  (b) Bluetooth  (c) NFC  (d) RFID

7. Optical fibre Cable's Data Transmission rate is
   (a) 2Gbps  (b) 3Gbps  (c) 1024Mbps  (d) None of the above

8. Microwave Frequency ranges are
   (a) 1 GHz to 30 GHz  (b) 100KHz to 30 MHz
   (c) 550 KHz to 1650 KHz  (d) 300 MHz to 300 GHz

9. Image sensors produce
   (a) Voltage waveform  (b) Current  (c) Audio  (d) Discrete Signal

10. Intensity of Sound is measuring in -------- units
    (a) Decibel  (b) Coulomb  (c) Kelvin  (d) Ampere

11. LM317 IC acts as a
    (a) Voltage Regulator  (b) Invertor  (c) Convertor  (d) Rectifier

12. -------- is a good language to start with Raspberry pi
    (a) Python  (b) Java  (c) C++  (d) None of the above

13. µP is called
    (a) Ports  (b) Serial Bus  (c) Microprocessor  (d) MOBO
14. Which type of Endoscopy used for diagnosis of the nose inside?
   (a) Nasopharyngoscopy   (b) Bronchoscopy
   (c) Arthroscopy        (d) Gastroscopy

15. Source is used for Computed Tomography-CT.
   (a) Gamma ray (b) X-Ray   (c) Ultrasonic   (d) Infrared

PART - B
II. Answer to any 10 Questions. Question number 22 is compulsory. 10 x 3 = 30

16. Write briefly about Asynchronous counter.
17. List out the properties of Antenna.
18. “Both coils are perpendicular displacement in yoke coil” – why?
19. “Hotspot is classified into two” – How?
20. What is the major difference between GPS and GPRS?
22. Tabulate and lists the Illuminance versus Light conditions.
23. Write the advantages of Headphones.
24. What is the purpose of UPS?
25. Explain HTMI.
26. List out the Difference between Microcontroller and Microprocessor?
27. List out the applications of PET.
28. List out the four types of Endoscopy.

PART – C
III. Answer to any five question. Question number 35 is compulsory 5 x 5 = 25

29. Is it possible to perform subtraction in logic gates? Prove with circuit and table.
30. Explain about the Half-Duplex and Full-Duplex Modem.
31. What are the advantages and disadvantages of OFC?
32. Draw and explain the audio amplifier using TDA 2003 IC?
33. Explain the working of NPN relay switch circuit.
34. Explain the Pin Description of Arduino UNO?
35. Explain the working function of Treadmill test equipment.

PART – IV
Answer all questions. 2 x 10 = 20

36. Explain how an LED panel works using TCON and gate driver circuits? (or)
   Draw a block diagram of a simple cellphone and explain its working functions?
37. Explain the working principles of CCD sensors with neat diagram? (or)
   Draw the circuit diagram of switching circuit using ULN 2003 A – IC?
BASIC ELECTRONIC ENGINEERING

Practical
PRACTICAL

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4. Mobile Phone Repairing Tools 290
5. Probable faults and Remedies of the mobile Phones and Counting Legs or Pins of Their ICs 295
6. To Study & Rectify the Cell Phone Faults 299
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12. Glowing of Multiple LEDs 323
The following general rules and precautions are to be observed at all times in the laboratory. These rules are for the benefit of the experimenter as well as those around him/her. Additional rules and precautions may apply to a particular laboratory.

1. There must be at least two (2) people in the laboratory while working on live circuits.
2. Shoes must be worn at all times.
3. Remove all loose conductive jewellery and trinkets, including rings, which may come in contact with exposed circuits. (Do not wear long loose ties, scarves, or other loose clothing around equipments.)
4. Consider all circuits to be “hot” unless proven otherwise.
5. When making measurements, form the habit of using only one hand at a time. No part of a live circuit should be touched by the bare hand.
6. Keep the body, or any part of it, out of the circuit. Where interconnecting wires and cables are involved, they should be arranged so people will not trip over them.
7. Be as neat as possible. Keep the work area and workbench clear of items not used in the experiment.
8. Always check to see that the power switch is OFF before plugging into the outlet. Also, turn instrument or equipment OFF before unplugging from the outlet.
9. When unplugging a power cord, pull on the plug, not on the cable.
10. When disassembling a circuit, first remove the source of power.
11. “Cheater” cords and 3-to-2 prong adapters are prohibited unless an adequate separate ground lead is provided, the equipment or device is double insulated, or the laboratory ground return is known to be floating.
12. No ungrounded electrical or electronic apparatus is to be used in the laboratory unless it is double insulated or battery operated.
13. Keep fluids, chemicals, and beat away from instruments and circuits.
14. Report any damages to equipment, hazards, and potential hazards to the laboratory instructor.
15. If in doubt about electrical safety, see the laboratory instructor. Regarding specific equipment, consult the instruction manual provided by the manufacturer of the equipment. Information regarding safe use and possible hazards should be studied carefully.

ADDITIONAL RULES MUST FOLLOW WHILE SERVICE THE CELL PHONES

1. Use Right ESD-Safe Tools:
   Always Use T4, T5 and T6 screwdrivers for such repairing jobs. T4 head screwdriver is most common. 90% of your job will get done using (+) screwdriver.
2. ESD Protection:
   ESD (Electro Static Discharge) is the sudden flow of electricity between
twoclearly electrically charged objects caused by any contact between them. For ESD protection, you need to wear ESD-Safe Apron, ESD-Safe Slippers, ESD-Safe Hand Gloves and Anti-static wrist strap. It is for the safety of the electronic components on the logic board or the motherboard.

3. USE ESD-Safe Tray:
Disassemble any mobile phone handset, place all the part in separate compartments of the tray. Using a tray with different compartments for different part will your life easy.

4. Handle Delicate Parts Carefully:
Most of the parts in a mobile phone or smartphone are very delicate. Take care about them. For example make sure the LCD does not get any scratches. Make sure to handle connectors and connecting cables carefully as they are very delicate.

5. Care with Hot air and Soldering Iron:
Hot air machine and soldering iron or soldering station must be used and handled carefully. Hot air machine produces hot air with very high temperature. Make sure the direction of the nozzle is where it should be. Switch it OFF when not in use. Similarly use a hot soldering iron with care. Always place the iron in a iron stand and do not put it on the table. They need to be placed at the right place to avoid high heat.

6. Take care of customer’s data:
Many times you need to perform hard reset or factory reset or reinstall the operating system or IMEI in a mobile phone. During the process, data stored in the mobile phone memory and even external SD card might get deleted. This data can be very important for some customers. So, make sure to backup all data before performing and factory reset.
Trouble Shooting of Logic Gates

Aim: To test and identify the faults in the logic Gate-IC.

APPARATUS / COMPONENT REQUIRED

<table>
<thead>
<tr>
<th>S.No</th>
<th>Name of the Component /Apparatus</th>
<th>Range</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IC Base</td>
<td>14 PIN</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>7400</td>
<td>14 PIN</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>7404</td>
<td>14 PIN</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>7402</td>
<td>14 PIN</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>7486</td>
<td>14 PIN</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Oscilloscope</td>
<td>Dual trace</td>
<td>1</td>
</tr>
</tbody>
</table>

THEORY

Troubleshooting is the process of recognizing, isolating, and correcting a fault or failure in a circuit or system. To be an effective trouble shooter, you must understand how the circuit or system is supposed to work and be able to recognize incorrect performance. For example, to determine whether or not a certain logic gate is faulty, you must know what the output should be for a given input.

After completing this section, you should be able to

- Test for internally open inputs and outputs in IC gates
- Recognize the effects of a shorted IC input or output
- Test for external faults on a PCB board
- Troubleshoot a simple frequency counter using an oscilloscope
PROCEDURE

Internal Failures of IC Logic Gates

Opens and shorts are the most common types of internal gate failures. These can occur on the inputs or on the output of a gate inside the IC package. Before attempting any troubleshooting, check for proper dc supply voltage and ground.

Effects of an Internally Open Input

An internal open is the result of an open component on the chip or a break in the tiny wire connecting the IC chip to the package pin. An open input prevents a signal on that input from getting to the output of the gate, as illustrated in Figure 1.1(a) for the case of a 2-input NAND gate. An open TTL (bipolar)-input acts effectively as a HIGH level, so pulses applied to the good input get through to the NAND gate output as shown in Figure 1.1(a) & (b).

![Figure 1.1(a) Application of pulses to the open input will produce no pulses](image)

![Figure 1.1(b) Application of pulses to the good input will produce output pulses for bipolar NAND and AND gates because an open input typically acts as a HIGH.](image)

Conditions for Testing Gates

When testing a NAND gate or an AND gate, always make sure that the inputs that are not being pulsed are HIGH to enable the gate. When checking a NOR gate or an OR gate, always make sure that the inputs that are not being pulsed are LOW. When checking an XOR or XNOR gate, the level of the non-pulsed input does not matter because the pulses on the other input will force the inputs to alternate between the same level and opposite levels.

Troubleshooting an Open Input

Troubleshooting this type of failure is easily accomplished with an oscilloscope and function generator, as demonstrated in Figure 1.2 for the case of a quad 2-input NAND gate package. When measuring digital signals with a scope, always use DC coupling.
The first step in troubleshooting an IC, i.e., suspected of being faulty is to make sure that the dc supply voltage (VCC) and ground are at the appropriate pins of the IC. Next, apply continuous pulses to one of the inputs to the gate, making sure that the other input is HIGH (in the case of a NAND gate). In Figure 1.2(a), start by applying a pulse waveform to pin 13, which is one of the inputs to the suspected gate. If a pulse waveform is indicated on the output (pin 11 in this case), then the pin 13 input is not open. By the way, it proves that the output is not open. Next, apply the pulse waveform to the other gate input (pin 12), making sure the other input is HIGH. There is no pulse waveform on the output at pin 11 and the output is LOW, indicating that the pin 12 input is open, as shown in Figure 1.2(b). The input not being pulsed must be HIGH for the case of a NAND gate or AND gate. If this was a NOR gate, the input not being pulsed would have to be LOW.

**Effects of an Internally Open Output**

An internally open gate output prevents a signal on any of the inputs from getting to the output. Therefore, no matter what the input conditions are, the output is unaffected. The level at the output pin of the IC will depend upon what it is externally connected to. It could be HIGH, LOW, or floating (not fixed to any reference). In any case, there will be no signal on the output pin.

**Troubleshooting an Open Output**

Figure 1.2 illustrates troubleshooting an open NAND gate output. In part (a), one of the inputs of the suspected gate (pin 11 in this case) is pulsed, and the output (pin 13) has no pulse waveform. In part (b), the other input (pin 12) is pulsed and again there is no pulse waveform on the output. Under the condition that the input that is not being pulsed is at a LOW level, this test shows that the output is internally open.
Shorted Input or Output

Although not as common as an open, an internal short to the dc supply voltage, ground, other input, or an output can occur. When an input or output is shorted to the supply voltage, it will be stuck in the HIGH state. If an input or output is shorted to ground, it will be stuck in the LOW state (0 V). If two inputs or an input and an output are shorted together, they will always be at the same level.

External Opens and Shorts

Many failures involving digital ICs are due to faults that are external to the IC package. These include bad solder connections, solder splashes, wire clippings, improperly etched printed circuit boards (PCBs), and cracks or breaks in wires or printed circuit interconnections. These open or shorted conditions have the same effect on the logic gate as the internal faults, and troubleshooting is done in basically the same ways. A visual inspection of any circuit that is suspected of being faulty is the first thing a technician should do.

Result:

Through this I came to understand how to identify the faults occurring in the IC-Gates and to rectify them.
Install, Point and Testing of Dish Antenna

Aim: To study the installation and testing of dish antenna

**APPARATUS / COMPONENT REQUIRED**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of Components / Apparatus</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DTH Antenna(Direct-To-Home)</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>LNB (Low Noise Block down converter)</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Satellite Receiver</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>RG6 Co-axial cable 25 meter</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>TV Set</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Wrench</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Drill</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Hammer</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Small chisel</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Compass</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Satellite dish</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>“L” shaped wall mounts</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>4 stainless steel fixings</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
<td>4 hexagonal screws4 stainless steel fixings</td>
<td>4</td>
</tr>
<tr>
<td>15</td>
<td>‘F’ connector X 2</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>Coaxial cable</td>
<td>25 meters</td>
</tr>
<tr>
<td>17</td>
<td>Digital TV receiver</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>Marker</td>
<td>1</td>
</tr>
</tbody>
</table>
THEORY

Dish Antenna is a receiver antenna which receives the signals propagated by the satellite and given to the T.V. Receiver.

I. Choosing the correct place: First we should select the correct place for installation.

1. It must be an open place. Objects like trees, hills, buildings should be avoided because signals will be weak.
2. It should be visible and must be fixed in the direction of the satellite.
3. The place selected, must be 20 feet away from the power line.
4. It can be installed on a terrace, upstairs, outwalls or pillar.

II. Ground

A good ground connection will minimise the bad reactions.

1. The bad effects from lightning and thunder affects the receiver. It may be shocked when operation, even death will also happen. So it must be grounded properly.
2. We can make the ground with parallel to EB ground. Otherwise we can ground separately by using pipes.

III. Assembling of Antenna

1. The antenna must be fixed very strong, even should not disturbed by any natural calamities such as storm, rain etc.
2. We can use the RG6 cable wires to connect the TV and the antenna.
3. The cable must be 25m length.
4. We can take the transmission line via walls or ground.

PROCEDURE FOR THE INSTALLATION OF ANTENNA

1. Installing the wall mount
   - First of all, you have to find an appropriate location. Take into account the following two requirements:
   - The location must allow the correct orientation of the dish to the satellite.
   - Use the compass.
   - There cannot be any obstacles between the dish and the satellite. You will learn where the satellite is from the following steps.
   - Take the “L” wall mount, and attach it to the wall manually. Mark the positions of the future holes on the wall.
   - Now, drill the four holes. Be careful choosing a appropriate diameter (see the number engraved on the fixing). The ideal depth for the holes is about 0.5 cm + wall plug length.
How the stainless steel fixings work

- Put the four fixings in their holes, and use the hammer and the chisel to fix them.
- Now take the “L” wall mount, and screw it to the fixings. Don’t forget the washers.
- (1) Washer / (2) Screw / (3) L mount / (4) Fixing

2 Installing the dish

The installation process will vary depending on the brand and model of the dish. Take a look at the instructions booklet.

Mount it all, including the LNB, and screw it on tightly, except the screws that are marked in red. You will need to turn and move the dish to orientate it correctly.

3 Pointing the dish to a satellite

You should visit Lyngsat website to find out what satellite is the most interesting for you.

You will need to find out the azimuth, elevation and LNB polarization/skew values.

**Azimuth**

This is the dish position with respect to north. It is measured in degrees.
**Elevation**

This is the satellite signal beam inclination that reaches the dish. It is measured in degrees. To adjust it, you must have a look at the numbers on the rear side of the dish. Make sure that its signal covers your area.

**Polarisation / LNB Skew**

The polarisation is the LNB rotation with respect to ground. It is measured in degrees.

All this data depends on two factors:
- Your geographical location
- The position of the satellite you want to point to.

Use **Dishpointer**, to find out those values.

Imagine you are in Madrid and you want to get the Astra satellite signal. Using Dishpointer we get this: 147° azimuth, 38° elevation, 25° polarisation.

**Azimuth, 147°**

- Firstly, let’s move the dish using the right azimuth.
- Use the marker for the azimuth (147°)
- Put the compass over the piece of paper, and rotate it until the two “norths” are lined up.
- Turn the dish according to the mark with respect to the center.

**Elevation, 38°**

Skew the dish until the right position is reached, looking at the numbers engraved on the mount behind the dish.
Polarisation, 25°

- Use the piece of paper that you printed before.
- If the polarisation value is negative, turn the piece of paper over.
- The final adjustments will be made once you make all the wirings in the following step.

4. Wiring

- Cut the cable insulation as described in the following figure:
- Connect two “F” connectors, on both ends of the cable. Connect one end to the LNB of the dish and the other one to the receiver.
- Now it is time for the fine-tuning. Turn on the digital satellite receiver, choose the name of the satellite and look for the option that tells you the signal strength and quality. Then, move the dish slightly until you get the best signal quality and strength.

IV. Fixing and testing of antenna

1. First choose the direction of the satellite and then fix the stand of dish antenna. After fixing, the antenna stability and strength must be checked.
2. Angle (AZ-EL) of the dish antenna must be checked and then it must be fixed with screws and bolts. [AZ side angle left to right, EL-up and down angle].
3. Then fix LNB with V shape bolt-nut at the opposite side of the dish.
4. Cable wire must be connected between T.V and antenna.

Testing

1. Switch ON the T.V. and check the screen for clear vision and turn the antenna till clear vision is obtained.
2. Even if the picture is not clear, adjust the dish AZ(Azimuth) and EL (Elevation) correct position to get clear image.
3. If all channels are screened clear, stop the adjustment. Note the noise level in LNB which must be in high level.

4. If all the adjustments are done correctly, note the angle of the dish (EL and AZ) at the back side which is used in future purpose.

5. It is an important point, there is no iron objects while adjusting the angle. Because it make wrong deflection in the meter.

6. If all are correct, again check the strength of dish.

**Some standard angles given**

<table>
<thead>
<tr>
<th>Place</th>
<th>Latitude</th>
<th>Longitude</th>
<th>AZ</th>
<th>EL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mumbai</td>
<td>18.93N</td>
<td>72.85E</td>
<td>128.56</td>
<td>56.37</td>
</tr>
<tr>
<td>Delhi</td>
<td>28.67N</td>
<td>77.23E</td>
<td>146.26</td>
<td>51.24</td>
</tr>
<tr>
<td>Chennai</td>
<td>13.08N</td>
<td>80.30E</td>
<td>130.79</td>
<td>67.03</td>
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<tr>
<td>Salem</td>
<td>11.63N</td>
<td>78.13E</td>
<td>123.63</td>
<td>66.09</td>
</tr>
</tbody>
</table>

Separate parts of Dish antenna

**Result**

Thus, a dish antenna is **INSTALLED, POINTED, TESTED** and tuned. The picture obtained in the screen is clear.
Encoder and Decoder

Aim: To study Encoder and Decoder using in the Digital Electronics

APPARATUS/COMPONENTS REQUIRED

<table>
<thead>
<tr>
<th>S. No</th>
<th>Apparatus/ Components</th>
<th>Range/Value</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Encoder 74147 IC</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>PROBES</td>
<td>Red &amp; Black</td>
<td>Multiple</td>
</tr>
<tr>
<td>3</td>
<td>Bread Board</td>
<td>5”</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Seven Segment LED</td>
<td>1cm</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Decoder 7447 IC</td>
<td>---</td>
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</tr>
</tbody>
</table>

THEORY

1. Encoder

Encoder processes the data in binary form. System is a set of nine switches one for each numerals between 1 to 9. These switches generate 1 or 0 logic levels in response to turning them OFF or ON. When a particular number is to be fed to the digital circuit in BCD code, the switch corresponding to that number is pressed. Input is given with the help of switches also called decimal inputs. There is an IC available for performing this function (74147) which is priority encoder. The block diagram & truth table of 74147 IC is given in figure. It has active low inputs and outputs. The inputs in 74147 is given form D_1 to D_9 (decimal inputs) and outputs Q_0, Q_1, Q_2, Q_3 are BCD outputs. The meaning of the priority can be seen from truth table. For example, if inputs 2 & 5 are LOW, the output will be corresponding to 5 which has a higher priority than 2 i.e. highest numbered input has priority over lower numbered inputs.
1. Decimal to BCD Encoder

![Decimal to BCD Encoder diagram]

### Table: Active Low Decimal Input vs Active Low BCD Output

<table>
<thead>
<tr>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>D6</th>
<th>D7</th>
<th>D8</th>
<th>D9</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
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<td>X</td>
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<td>1</td>
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<td>0</td>
<td>1</td>
<td>0</td>
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<tr>
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<td>0</td>
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<td>X</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

2. Decoder

**BCD To 7-Segment Decoder**

Seven Segment Display is the most popular device used in digital systems. For displaying data using this device, the data have to be converted from BCD to 7 Segment code. The decoder circuit has 4 input lines for BCD data which are D0, D1, D2, & D3, and seven output lines to drive a 7-segment display. If the outputs are active low then the 7 segment LED must be of the common anode type, whereas if the outputs are active high then the 7-Segment LED must be of the common cathode type. Typically, a common supply voltage (+5V) drives the anodes of all the LED's. When a particular LED is forward biased, it conducts current and causes light to be emitted. Series resistors connected are simply for limiting the current.

**LT: (Lamp Test)**

This is used to check the segments of LED. If it is connected to logic 0 level, all the segments of the display connected to the decoder will be ON. For normal decoding operation, this terminal is to be connected to logic 1 level.

**RBI (Ripple blanking input)**

It is to be connected to logic 1 for normal decoding operation. If it is connected to 0 level, the segment outputs will generate data for normal 7-segment decoding for all BCD inputs except zero.
PIN DISCRIPTION OF 7447 IC

<table>
<thead>
<tr>
<th>PIN NO</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BCD B Input</td>
</tr>
<tr>
<td>2</td>
<td>BCD C Input</td>
</tr>
<tr>
<td>3</td>
<td>Lamp Test</td>
</tr>
<tr>
<td>4</td>
<td>RB Output</td>
</tr>
<tr>
<td>5</td>
<td>RB Input</td>
</tr>
<tr>
<td>6</td>
<td>BCD D Input</td>
</tr>
<tr>
<td>7</td>
<td>BCD A Input</td>
</tr>
<tr>
<td>8</td>
<td>Ground</td>
</tr>
<tr>
<td>9</td>
<td>7 – Segment e Output</td>
</tr>
<tr>
<td>10</td>
<td>7 – Segment d Output</td>
</tr>
<tr>
<td>11</td>
<td>7 – Segment c Output</td>
</tr>
<tr>
<td>12</td>
<td>7 – Segment b Output</td>
</tr>
<tr>
<td>13</td>
<td>7 – Segment a Output</td>
</tr>
<tr>
<td>14</td>
<td>7 – Segment g Output</td>
</tr>
<tr>
<td>15</td>
<td>7 – Segment f Output</td>
</tr>
<tr>
<td>16</td>
<td>Vcc – Positive Supply</td>
</tr>
</tbody>
</table>

PROCEDURE
1. Make the connection as per the given in Figure.
2. Supply inputs by toggle switches in different combinations of 1’s & 0’s.
3. Change the I/P according to the table & verify the truth table.

RESULT
The Truth Table for decimal to BCD encoder and BCD to 7- segment decoder is verified.

290 PRACTICALS
Mobile Phone Repairing Tools

AIM: To study various repairing tools used for mobile phone servicing.

APPARATUS/COMPONENTS REQUIRED:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of the Apparatus/Components</th>
<th>Range/Value</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Various Brand Mobile Phones</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Multimeter</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Regulated Power Supply</td>
<td>0-15 volts</td>
<td>1</td>
</tr>
</tbody>
</table>

THEORY

Mobile phone repairing tools are simple and easy to use. The tools are used for repairing.

Mobile cell phone repairing tools are not very expensive. Beginners must start with cheap and economical tools and gradually they gain knowledge and experience.

PROCEDURE

List of all Mobile Phone Repairing Tools and Equipment

When selecting tools and equipment for repairing mobile cell phones, it is important to select the best tools. Cheap or inexpensive tools and equipment may not be handy when repairing a mobile phone. On the other hand, best quality little expensive tools and equipment will help you to repair a mobile phone easily and comfortably.

There are hundreds of tools for mobile phone repairing available in the market. It is important to select the best brand. All the tools and equipment needed for mobile cell phone repairing:

1. Soldering Station are given below: A soldering station has 2 units – a station and an iron. It has option to control temperature depending on the heat requirement
of the soldering job being done. The soldering iron is attached with the soldering station. It is better and more convenient than traditional soldering iron. It makes soldering work much easier and faster. When buying a soldering station for mobile phone repairing one must always select an ESD-Safe (Antistatic) model. Hakko and Weller are two world renowned brands who manufacture, sell and export world class soldering irons and other soldering tools and equipment.

### Soldering Station

2. PCB Holder / PCB Stand: A PCB (Printed Circuit Board) holder or PCB stand is used to hold the PCB of a mobile phone while soldering or repairing. It holds the PCB very strongly and doesn't allow it to move thus helping in repairing. Again, it is important and wise to select a good quality PCB holder rather than a cheaper and inexpensive one.

### Precision Screwdriver

3. Precision Screwdriver: It is used to remove and tighten screws while assembling and dissembling a mobile phone. Precision screwdrivers of sizes T4, T5, T6 and forehead are good for most mobile repairing job.

### Hot Air Blower

4. Hot Air Blower: It is also called SMD (Surface Mount Device) rework system and SMD repair system. It has control to regulate or manage temperature and flow hot air. Always buy a good quality ESD-Safe hot air blower.

### Battery Booster

5. Battery Booster: It is used to boost the power of battery of a mobile phone.
6. Ultrasonic Cleaner: Used to clean PCB of a mobile phone and electronic components.

7. BGA Kit: Used to Reball and repair ball-type ICs. BGA stands for Ball Grid Array.

8. Magnifying Lamp: It is used to see the magnified view of the PCB of a mobile phone. Most magnifying lamps also have light. Magnifying lamps are available in different magnification such as 3x, 4x, 5x, 10x, 50x etc.

9. Mobile Opener: These are used to open the housing or body of a mobile phone.

10. DC Power Supply: Regulated DC (Direct Current) power supply is used to supply DC current to a mobile phone. Most repair person used DC power supply to switch ON a mobile phone without battery.

11. IRDA or Infrared Workstation: This machine is similar to hot air blower. Only difference is that it gives heat through infrared. It is very precise and give heat only where it is needed thus preventing any damage to nearby electronic components on a PCB.
12. LCD Tester: Used to check whether LCD screen of a mobile phone is faulty or not.

13. Microscope: It is used to see a magnified view of PCB or electronic components. These are available in different zoom options. Many microscopes can also be connected to a computer or a monitor.

14. Test JIG Box: This device is used to diagnose and find fault or problem in a mobile phone. It helps the mobile phone to work and function normally outside its case. This helps to test and check voltage and other test points on the PCB. In simple words it helps the mobile phone to work without battery.

**PRECAUTION**

1. Wrist Strap: It is worn in the wrist of the person who is repairing a mobile phone. It helps to discharge or ground static charge thus preventing the PCB or electronic components from any damage.

2. Antistatic Hand Gloves: It is important to wear ESD-Safe hand gloves while repairing a mobile phone to prevent PCB and electronic components from static charge.
3. Antistatic Mat: It is laid or placed on the table or workbench where mobile repairing is done. The mat is grounded using a grounding cord or normal grounding wire. This also prevents damage from static electricity.

4. Antistatic Apron: It is a dress worn by people who repair mobile phones. This also helps to discharge static electricity.

5. Smoke Absorber: This is like an exhaust fan that helps to filter smoke that comes out while soldering and Desoldering.

6. Battery Tester: This device is used to test and analyze status or condition of battery of a mobile cell phone.

RESULT

Various repairing tools used for mobile phone servicing are learnt.
Probable faults and Remedies of the mobile Phones and Counting Legs or Pins of Their ICs

AIM: To understanding how to count legs or pins of any IC.

APPARATUS/COMPONENTS REQUIRED

<table>
<thead>
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<th>S.No.</th>
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<tr>
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<td></td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Multimeter</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Regulated Power Supply</td>
<td>0-15 volts</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Battery Booster</td>
<td>3.7v</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Soldering station</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Electrician Knife</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

THEORY

When doing mobile phone repairing, user often need to check parts such as speaker, ringer, vibrator, coil, boost coil, On / Off Switch, Antenna Switch, RX Filter, PFO, BSI, Network IC, VCO, Audio IC, Power IC, RTC, Charging IC, CPU, R22, Microphone Interface, Bluetooth IC, Flash IC, RAM, Logic IC, UEM etc.

In most cases, only card level parts of a mobile cell phone include ringer, speaker, microphone, vibrator, LED, charging connector, headphone connector, data cable connector, battery, battery connector, SIM card, SIM card connector, memory card, memory card connector, camera, camera connector, keypad button, keypad connector, ON / OFF Switch, Display, Display connector, Internal antenna and PDA. Chip level small parts of a mobile phone that include small electronics with a new one. Card level parts of a mobile cell phone include ringer, speaker, microphone, vibrator, LED, charging connector, headphone connector, data cable connector, battery, battery connector, SIM card, SIM card connector, memory card, memory card connector, camera, camera connector, keypad button, keypad connector, ON / OFF Switch, Display, Display connector, Internal antenna and PDA. Chip level small parts of a mobile phone that include small electronics
components like capacitors, resistor, diode, coil, boost coil, coupler, regulator, transistors, are rarely or not tested for fault. In case there is any fault in the track of the Mobile Phone PCB then it is solved or fixed by jumper.

PROCEDURE

How to Check the faulty Parts of a Mobile Phone

1. **Ringer:** To check if the ringer of a mobile phone is faulty or damaged, keep the multimeter in buzzer mode and check the ringer. Value must be between 8 to 10 Ohms. If the value is between this range then the ringer is good and does not need replacement. If the value on multimeter is 4-5 or 12-14 then change the ringer.

2. **Vibrator or Motor:** Keep the multimeter in Buzzer Mode and check the vibrator. Value must be 8 to 16 Ohms. If the value is between 8-16 Ohms then the vibrator is good. Otherwise change it.

3. **Speaker or Earpiece:** Check the speaker / earpiece with a multimeter on Buzzer mode. Value must be in the range of 25 to 35 Ohms. If the value is in this range then the speaker / earpiece is OK and need not be changed. Otherwise, change the speaker / earpiece.

4. **Microphone or Mic:** Keep the multimeter in buzzer mode and check the microphone. Value reading on the multimeter must be in the range of 600 to 1800 Ohms. There will also be a Beep or Buzz sound from the multimeter. NOTE: Please note that only one side of the microphone will show value. If we check by reversing the Red and Black Probes / test Leads of the multimeter and check the microphone then there will be no value.

5. **Coil:** Check it with a multimeter on Buzzer Mode. If it is good then the multimeter will give a Beep or Buzz sound. If there is no sound then the coil is faulty. Replace it with a new one.

6. **Resistor:** Check it with a multimeter on Buzzer Mode. If it is good then the multimeter will give a Beep or Buzz sound. If there is no sound then the resistor is faulty. Replace it with a new one.

7. **Capacitor:** Check it with a multimeter on Buzzer Mode. If it is good then the multimeter will NOT give any Beep or Buzz sound. If there is sound then the capacitor is faulty. Replace it with a new one.

8. **Diode:** Check it with a multimeter on Buzzer Mode. If it is good then the multimeter will NOT give any Beep or Buzz sound. If there is sound then the diode is faulty. Replace it with a new one.

9. **LED:** Keep the multimeter in Buzzer mode and check the LED. If the LED is good, then they will glow otherwise not.

10. **Coil and Boosting Coil:** Check for continuity. If there is continuity, then the coil or the Boost Coil is good otherwise it is faulty.

11. **Keypad:** Keep the multimeter on Buzzer mode and check Rows and Columns or the Key Pad. If there is Beep or Buzz sound from the multimeter, then Keypad is ok, otherwise it is faulty.

12. **Battery Connector:** Keep multimeter on 20V DC and check. Value must be 1.5 to 3.5 V DC.

13. **Battery:** Check voltage with a multimeter. Keep multimeter on 20V DC and check. Value must be 3.7 V DC or above.
14. ON / OFF Switch: Check voltage with a multimeter. Keep multimeter on 20V DC and check. Value must be between 2.5 to 3.7 V DC.

15. Network IC: Use a Analog DC Power Supply to check Network IC. Switch ON DC Power Supply and call any number from your mobile phone. The Needle of the DC Ampere will start moving. This shows that the Network IC is OK and not fault.

16. Power IC and CPU: Adjust voltage of the DC Power Supply to 4.2. Place the Red Probe / Test Lead of the DC Power Power Supply to the “+” of the Battery Connector of the mobile phone and the Black Probe / Test Lead to “-“. If DC Ampere is over 6 then Power IC or CPU is damaged. Check by replacing Power IC and the CPU one by one.

17. If there is no movement of the Ampere Needle of the Power Supply then the Battery connector, On / OFF Switch Track, RTC or Network Crystal is damaged. Give heat to these components using hot air blower. If the problem is not solved then check by replacing them one by one.

18. If the Ampere Needle fluctuates below 2 ten there could be problem with software or RTC (Real Time Clock).

19. If the Ampere needle stands at some fixed point then there is problem with the Flash IC.

20. If there is beep sound from the DC Power Supply then there is problem with “+” and “-” or the mobile handset is short.

APPLICATION

Any mobile phone PCB has several IC or Integrated Circuit. These are SMD or Surface Mount Electronic Components. Before understanding how to count legs or pins of any IC, let us learn about IC. An IC is an electronic component made up of combination or integration of several other electronic components like resistor, capacitor, coil, diode, transistor etc.

There are mainly 2 types of ICs:

1. Leg-Type IC:
   This type of IC has legs or pins. These types of ICs are again divided into different categories but we will not discuss it here because it has nothing to do with mobile repairing.

2. Ball-Type IC:
   This type of IC has BGA (Ball Grid Array) underneath the IC. These types of ICs are again divided into different categories but we will not discuss it here because it has nothing to do with mobile repair.

PROCEDURE

Counting methods of Leg type IC

Counting of leg-type IC starts in Numerical Digit in Anticlockwise Direction starting from the Nose Point or Cut Point. Have a look at the photo below to understand it clearly.

Note:
- Most mobile phone repair people and technician check only above parts of any mobile phone to solve hardware problems.
- All other parts including electronic components and ICs are generally not checked for fault. There is no good sure test for these parts. The problem is either solved by jumper or by trial and error (check by replacement).
Counting methods of Balls of Ball-Type IC?

Counting of Ball-type IC is done in Both Clockwise and Anti-Clockwise Direction. Rows are counted in Digit Numbers (1, 2, 3, 4…) in Clockwise Direction. Columns are counted in Alphabet (A, B, C, D…) in Anti-Clockwise Direction.

NOTE:

When counting Columns, “I” and “O” are omitted because they look like “1” and “0”.

RESULT

The different parts and components of a Mobile Phone checking procedure of the faulty parts and the remedies of Mobile Phones and how to count and identify the LEGS/Pins of their ICs., are learnt.
To Study & Rectify the Cell Phone Faults

AIM: To study the cell phone parts like Key pad, LED, Display, Ringer, Vibrator, Earpiece, Microphone, Headphone and also their deadfaults and remedies.

APPARATUS/COMPONENTS REQUIRED

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of the Apparatus / Components</th>
<th>Range / Value</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dead Symptom Mobile Phones</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Multimeter</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Regulated Power Supply</td>
<td>0-15 volts</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Battery Booster</td>
<td>3.7 V</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Soldering station</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Electrician Knife</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

THEORY

The prime purpose of a basic mobile phone is, making calls and sending text messages. But Smart phones are similar to a Mini Computer, in which we can capture photos, videos, sharing and sending them to other cell phones, accessing the internet, creating documents and files which can also be stored. If the above parts of mobile phones become faulty, to rectify, the (User) technician should know about the functions of parts and its characteristics as follows:
Mobile Phone Repairing Tools

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parts Name</th>
<th>Definition</th>
<th>Working functions</th>
<th>Faults symptom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CPU</td>
<td>This is the most important part in the cell phone. This can also be called as Micro processor. It is the largest IC on the PCB of a Mobile Phone and it looks different from all other ICs. In some Mobile Phones have two CPUs.</td>
<td>It controls all section of a Mobile Phone.</td>
<td>If CPU is faulty then the mobile may become dead.</td>
</tr>
<tr>
<td>2</td>
<td>Power IC</td>
<td>It is found in the power section of a Mobile Phone. The IC around which there are several brown coloured capacitors. In some mobile Phones there are two Power ICs</td>
<td>It takes power from battery and supplies to all other parts of the Mobile Phone.</td>
<td>If power IC is faulty then the set will get dead.</td>
</tr>
</tbody>
</table>

PROCEDURE

1. Remove the battery and see if it gets charged or not. Check voltage using a Multimeter. The voltage must be above 3.7 Volt. Use a Battery Booster to Boost the Power of the Battery and Charge it again.
2. Check Battery Point and Battery Connector. Clean Battery Point and Battery Connector to remove any carbon deposits.
3. Resolder or change the Battery Connector.
4. Insert charger and see if the “Battery Charging” appears or not. If there is an icon of “Battery Charging” is displayed but the mobile phone does not gets switched ON then check ON / OFF Switch. Voltage of ON / OFF Switch must be 2.5 to 3.5 Volt (DC). Clean or change the ON / OFF Switch. Check track of ON / OFF Switch and Jumper if required.
5. If the charging icon is not there then check voltage of ON / OFF Switch. If the voltage is between 2.5 to 3.7 Volts DC, then RELOAD Software in the Phone (Software Flashing).
6. If the phone does not gets switched ON even after reloading software, then Heat the CPU, Power IC and Flash IC.
7. If there is no voltage on the ON / OFF Switch, then check track of the ON / OFF Switch. Jumper if required.
8. If the problem is not solved then heat, Replace or change the Power IC and CPU to fix the problem.
9. Keep the Multimeter in Buzzer Mode and Check + and – of the Battery Connector. If there is Buzzer Sound, then the Set is short. If there is short at the Battery Connector, then clean the PCB with thinner. Heat the PCB.
10. If this does not fix the set’s dead problem then remove the PFO and check for short. If there is short then replace the PFO.
11. Remove the charging connector and check for shorting. If there is short, then change the connector.
12. Remove the charging IC and check for shorting. Change if required.
13. Remove the Bluetooth IC and check for shorting. Replace if required.
Instead of displaying the particular key, some other key displayed OR when one key is pressed, some other key works simultaneously.

**Mobile Cell Phone Keypad is Not Working**

**Problem and Solution:**

- Check Facial of the Keypad.

<table>
<thead>
<tr>
<th>Mobile Phone Keypad Track Row Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row</td>
</tr>
<tr>
<td>Column</td>
</tr>
</tbody>
</table>

2. Keep Multimeter in Buzzer Mode and Check Row and Column of the Keypad. If there is Beep Sound then Pad is OK.
3. Heat or Change Keypad IC / Interface IC.
4. Heat, Reball or Change the CPU.

**Note:**

1. In a Mobile Phone, when we press a Key and it works very slow then Reload Software to Solve the Problem.
2. In all Nokia Mobile Phones, if only some key works or none of the keys are working then change the Keypad IC.
3. If Keypad problem is not solved by Hardware, then reload Software.

**Types of Faults or Problems with Keypad in any Mobile Cell Phone:**

- None of the keys working or only few keys working.
- Key pad needs hard touch. When a key is pressed single time, but it display more than one.

**FAULTS AND REMEDIES**

1. **KEYPAD**

Keypad in a cell phone is an electronic component that helps to enter data like numbers, alphabets or any other text and use to operate the function given in the mobile phone. Some mobile phones are screen touch and are operated by PDA(Personnel Digital Assistant).

**Types of Faults or Problems with Keypad in any Mobile Cell Phone:**

- None of the keys working or only few keys working.
- Key pad needs hard touch. When a key is pressed single time, but it display more than one.

14. Remove the Power IC and check for shorting. Replace with a new one, if required.
15. Remove the CPU and check for shorting. Replace, if required.
16. Remove all the Big Electrolytic Capacitors and check one by one. Replace capacitors, if required.

**Note:**

- Some mobile phones get dead if the RTC (Real Time Clock) is faulty. This happens mostly in China Mobile Phones. Change the RTC to fix the problem.
- If the mobile phone gets hang after reloading software, then change the RTC.
- If the set is still dead, then check by replacing the 26 MHz Crystal Oscillator.

**Note:**

- In a Mobile Phone, when we press a Key and it works very slow then Reload Software to Solve the Problem.
- In all Nokia Mobile Phones, if only some key works or none of the keys are working then change the Keypad IC.
- If Keypad problem is not solved by Hardware, then reload Software.

**LED**

LED in any mobile cell phone is an electronic component or part that generates light in the Mobile Phone. These are generally LED or
Light Emitting Diode. There are 2 types of connection in the Light Section of a Mobile Phone: (i) Series Connection; and (ii) Parallel Connection.

![Series connection diagram](image)

![Parallel connection diagram](image)

**Types of Faults or Problems with Light or LED in any Mobile Cell Phone:**

- No Light.
- Light in only Keypad or Display.
- Some lights not working.

**Mobile Phone Light Problem and Solution:**

Check Light Settings.

1. If settings are OK then Resolder all LED.

2. If the problem is not solved then change the display or the screen and check.

3. If the problem is not solved, then check all the LEDs. Keep the multimeter on Buzzer mode and Check LED. If LED is Good then it will Glow. If LED is Faulty then it will Not Glow.

4. Change LED or Jumper if required.

5. If the problem is not solved then Check Track of the Light Section of the PCB of the Mobile Phone and Jumper if Required.

6. If the problem is not solved the Check the Boosting Coil and Change if Required.

7. If the problem is not solved, then Heat or Change the Light IC.

8. If the problem is still not solved, then Heat, Reball or Change the Power IC.

**Note:**

**Ball-type light IC**

![Ball-type light IC diagram](image)

**Leg-Type Light IC:**

![Leg-Type Light IC diagram](image)

**Two Types of Light IC:**

1. **Ball-Type Light IC:**
   Beside the Boosting Coil, there is a Small-Sized Ball-Type IC. When this IC is desoldered, there are 8 Ball Underneath. This is the Light IC.

2. **Leg-Type Light IC:**
   Beside the Boosting Coil, there is a Small-Sized, 4+4 = 8-Leg-Type IC. This is Light IC.

3. Light IC = Back Light + Display Light
3. DISPLAY

Display in a mobile cell phone is an electronic component or part that helps to see all programs in a mobile phone. Display is available in different sizes. Display is controlled by the CPU. In some Mobile Phones there is an Interface IC called Display IC between Display and CPU.

Types of Faults or Problems with Display in any Mobile Cell Phone

- Display is blank.
- Display not working properly.
- Only Half Display Works.
- White Display.
- Display Upside Down.
- Display is Broken.
- When the Mobile Phone is Switched ON, the Logo Appears and then the Display Disappears.

Mobile Cell Phone Display Not Working Problem and Solution:

1. Clean Display Tips and Display Connector.
2. Resolder the Display Connector.
3. Change the Display.
4. Check Display Track.
5. Resolder or Change the Display IC.
6. Heat, Reball or Change the CPU.

Note:

- In some slider mobile phone sets, if there is Display problem then it is mainly because of faulty Display Track. Change the track to solve the problem.
- If the Display is upside down OR only half Display OR the Display is broken then change the Display.
- If there is white Display and the display is changed but the problem is not solved then RELOAD SOFTWARE.
- In some mobile phones like Nokia 6600, N72 etc, when the set is Switched ON, the Nokia Logo appears and then the Display disappears. This is problem of BOOT IC. Change the BOOT IC to solve the problem.

DEAD FAULT

A Dead mobile phone is a hand set that does not get switched ON.

- If the mobile phone gets dropped down on the floor or on some hard surface.
- If the mobile phone gets wet or is dropped in rain or water.
- If there is any kind or short ( in + and – )

RESULT

Through this exercise, I learned about the cell phone parts, and frequent faults and its remedies.
Construction of an Audio Power Amplifier Using TDA 2003

**Aim:** To construct audio power Amplifier using TDA 2003 & find the given fault and rectify it using FM radio receiver (Dead fault)

**APPARATUS / COMPONENTS REQUIRED**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Name of the Component/Apparatus</th>
<th>Range</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IC with Heat sink</td>
<td>TDA 2003</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>4”, 8 watts, 4 ohms</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Volume control</td>
<td>10 k ohms</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Resistor</td>
<td>220 ohms</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33 ohms</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.2 ohms</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 ohms</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Capacitor</td>
<td>1000 mF</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>470 mF</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 mF</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 mF</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 nF</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>47 nF</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>DC power supply</td>
<td>12 V/ 500 mA</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>PCB/General purpose board</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>25 W</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Lead &amp; wires</td>
<td>As per requirements</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Multimeter</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>FM Radio Receiver</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
**THEORY**

The TDA2003 has improved performance with the same pin configuration as the TDA2002. The additional features of TDA2002, very low number of external components, ease of assembly, space and cost saving, are maintained. The device provides a high output current capability (up to 3.5A) very low harmonic and cross-over distortion. Completely safe operation is guaranteed due to protection against DC and AC short circuit between all pins and ground, thermal over-range, load dump voltage surge up to 40V and fortuitous open ground.

TDA2003 is a monolithic audio power Amplifier integrated circuit. It requires very low external components to operate as a amplifier and also it can provide high current output. By implementing this TDA2003 IC in a low power audio amplifier we can built low harmonic and cross over distortion amplifier.

This IC has only 5 pins and all are function pins, this Integrated circuit has built in over temperature protection and short circuit protection features.

TDA2003 Amplifier circuit diagram built for 8Ω speaker and this circuit can provide up to 10 watts output, you can apply 6 to 12V power supply to this circuit.

**Construction & Working**

Connect Audio input signal to non inverting pin of TDA2003 IC. Here VR1 is acts as a volume control in this circuit. Inverting pin of TDA2003 is connected with C3 capacitor and R2, R3 divider Resitors to act as a feedback path. At the output loud speaker is connected through coupling capacitor.

This TDA2003 amplifier can give upto 20 Watts output when connected in Bridge configuration.
**TDA2003 Pinout**

- Non inverting input
- Inverting input
- Ground
- Output
- Supply voltage

This TDA2003 IC can take supply voltage $V_s$ between 8 to 18 Volts, and gives output power depends on load resistor $R_L$, maximum 10 Watts if $R_L = 2\Omega$. It is sensitive to minimum 14 mV input signal and provides input resistance of 50 kohms. Refer data sheet for more electrical specifications.

**Tabular column for Pin voltages of CA 810 Audio IC**

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Procedure**

1. Assemble the circuit as per the circuit diagram.
2. Audio input given to pin 1 through 10 mf capacitor (C7).
3. Pin 3 should be grounded.
4. Connect the speaker between pin 4 through 1000 mf capacitor (C5) and ground.
5. Resistors R2 & R3 are divider resistors and form the feedback path.

**Result**

Thus the power audio Amplifier is assembled using TDA 2003 IC and voltages are noted down.
Assemble a FM Radio Receiver using CXA1619 IC and Rectify the given fault

AIM: To study how to assemble a FM Radio Receiver using CXA1619 IC and find the given fault.

APPARATUS / COMPONENTS REQUIRED

<table>
<thead>
<tr>
<th>S. No</th>
<th>Name of Components/ Apparatus</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>FM radio receiver's components as mention in the circuit.</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Multimeter</td>
<td>1</td>
</tr>
<tr>
<td>3.</td>
<td>RF/AF signal generator</td>
<td>1</td>
</tr>
<tr>
<td>4.</td>
<td>Soldering Iron, etc.,</td>
<td>1</td>
</tr>
</tbody>
</table>

THEORY

CXA 1619 IC is a IC. one-chip FM/AM Radio. It has the following functions and Features.

- Small number of peripheral components.
- Low current consumption
- Large output of AF amplifier.

FUNCTIONS OF FM SECTION

- RF Amplifier, Mixer and Oscillator
- IF Amplifier
- Quadrature detection
- Tuning LED driver.
- CXA1619 structure.
TO FIND THE FAULT THAT OCCURRED IN RADIO RECEIVER

There are two types of fault in radio receiver.

1. Live fault
2. Dead fault

We have to find which one of the above faults take place in radio receiver.

AM SECTION
- RF amplifier, Mixer and OSC (With AGC)
- IF Amplifier (With IF AGC)
- Detector
- Tuning LED driver

AF SECTION
Electronic volume control

LIVE FAULT
We have to switch on the radio and to choose a program channel. In this, there is just noisy sound in the speaker without any programme, this fault in radio receiver is called live fault.

There are 5 Types of live fault in FM receiver:
1. Low volume
2. Hum noisy sound
3. Intermittent fault
4. Whistling sound
5. Motor boating sound

DEAD FAULT
If there is no sound while we switch on the radio receiver, then the fault is termed as dead fault.
PROCEDURE

Assemble a FM Radio Receiver using the given components with the support of the Circuit diagram, tools and apparatus.
Poor FM Reception

The most common problems with radio reception are weak signals or interference. Interference can be caused by anything with an electrical or magnetic current. Changing weather patterns can also cause problems with radio reception.

Interference or obstruction of a radio signal to the antenna should be kept to a minimum. The receiver and antenna should be placed away from electrical devices such as computers, refrigerators, power tools or wiring. The antenna should point in the direction of the transmitter and be positioned to minimise the effect of obstructions such as trees and buildings.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Pin No.</th>
<th>Description</th>
<th>Short form</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FM (6 V)</td>
</tr>
<tr>
<td>1</td>
<td>1,2</td>
<td>Ground</td>
<td>GND</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Phase - shift circuit connect ceramic discriminator</td>
<td>FM DICRI</td>
<td>4.88</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Negative feedback pin</td>
<td>NF</td>
<td>3.00</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>Connect variable resistor for electronic volume control</td>
<td>VOL CONT</td>
<td>1.25</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>AM local oscillation circuit</td>
<td>AM OSC</td>
<td>1.25</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>AFC variable capacitor pin</td>
<td>AFC</td>
<td>1.25</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>FM local oscillation circuit</td>
<td>FM OSC</td>
<td>1.25</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>Regulator pin 1.25 V</td>
<td>REG OUT</td>
<td>1.25</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>Connector FM RF tuning coil</td>
<td>FM RF</td>
<td>1.25</td>
</tr>
<tr>
<td>10</td>
<td>10,11</td>
<td>AM RF Input pin</td>
<td>AM RF IN</td>
<td>1.25</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>Nil</td>
<td>NC</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td>FM RF Input pin</td>
<td>FM RF IN</td>
<td>0.30</td>
</tr>
<tr>
<td>13</td>
<td>14</td>
<td>Ground(FE GND)</td>
<td>GND</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>15</td>
<td>IF output pin of FM and AM.  Connect IF filter</td>
<td>FM / AM FE OUT</td>
<td>0.36</td>
</tr>
<tr>
<td>15</td>
<td>16</td>
<td>FM and AM bands selection switch pin. During GND it becomes AM and during open it becomes FM.</td>
<td>BAND SELECT</td>
<td>1.30</td>
</tr>
<tr>
<td>16</td>
<td>17</td>
<td>Input pin of AM IF</td>
<td>AM IF IN</td>
<td>-</td>
</tr>
<tr>
<td>17</td>
<td>18</td>
<td>Input pin of FM IF</td>
<td>FM IF IN</td>
<td>0.88</td>
</tr>
<tr>
<td>18</td>
<td>19</td>
<td>Not connected</td>
<td>NC</td>
<td>-</td>
</tr>
</tbody>
</table>
Check for sources of FM interference. The FM antenna attached to the system may be picking up outside interference. To determine, if this is the case, follow these guidelines:

- Check to see if the antenna is within three feet of any other electronic or electrical devices such as: televisions, cable boxes, wireless internet routers, dimmer switches, fluorescent/energy-saving lights, blinking seasonal lights, microwaves or similar appliances
- Unplug any devices that are near the antenna to eliminate them as possible sources of interference
- In some cases, interference can be introduced through the power source connection. Moving the power cord to a different outlet that is not tied to the same circuit as any of the previously mentioned, lighting or electronics may help
- Relocate the antenna. If this solves the problem, keep it as far away from the other devices and their power cords as possible (at least three feet)
- Try another power outlet. The power outlet may be providing interference, hum, or intermittent or inconsistent voltage
- Try moving the FM antenna slightly. If reception improves, continue to move the antenna in that direction. When reception starts to degrade, move the antenna slightly in the opposite direction. Also, keep the antenna stretched out as much as possible. Signals from an FM station are “line-of-sight;” FM reception may be weaker if in a valley, or near ground level in cities with tall buildings

RESULT
Assembled a FM Radio Receiver using CXA1619IC and the learnt the fault finding.
More Common Faults in LED TV and Detail of Every Possible Fault and Solution

Aim: Rectifying the fault in an LED Receiver – No light, Sound Ok

APPARATUS/COMPONENTS REQUIRED

<table>
<thead>
<tr>
<th>S.No</th>
<th>Name of Components/Apparatus</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>defective LED TV receiver</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Soldering Iron</td>
<td>1</td>
</tr>
<tr>
<td>3.</td>
<td>LED s</td>
<td>Required amount</td>
</tr>
<tr>
<td>4.</td>
<td>LED tester</td>
<td>1</td>
</tr>
</tbody>
</table>

Checking LED array After defect is rectified, the Backlight as well as TV works properly.
Below is a list of the more common faults in LED TV and detail of every possible fault and solution

TV not turning on or taking a while to turn on

First check the set is plugged into your electricity mains! Also check to see if there is any switch that may have been turned off on the set itself! If the set is still not turning on then this is normally an electronic fault usually occurring on either the power board (PSU) or main board of the television. Sometimes components called capacitors may need to be replaced on one of these circuit boards.

TV turning itself off (sometimes on and off itself)

As per above, this is normally caused by a fault on either the power board (PSU) or the main board.

Stuck in Standby mode, Clicking sound

Similar to ‘TV not turning on’ above

No Picture or problematic picture

For LCD televisions this could possibly relate to a faulty logic/tcon or inverter board. Sometimes however the fault could be attributed to the main board. For Plasma televisions, this fault could relate to circuit boards called Y sustain, X sustain, Z sustain and Buffer/Scanning boards. Sometimes a faulty screen can also make one of these circuit boards go faulty. For LED televisions it is quite often associated with faulty LED strips which would need to be repaired or replaced. For Rear Projection televisions, most of the time it is the internal lamp that might need replacing.

Lines on the screen

There are a number of possible causes of lines appearing on a screen. These include a possibly faulty logic board, X, Y or Z Sustain boards, Scanning board or worst case scenario a faulty screen. If you suspect that the lines have appeared as a result of a knock on the screen in some way then it does increase the possibility that your screen is faulty and hence not economically worthwhile to repair.

Freezing picture

Be careful here as the television could be perfectly fine! This could be caused by a faulty aerial. If it is the television then usually it is down to a faulty main board.

Speckles on screen

Often appearing on Plasma televisions. Quite possibly down to a faulty X, Y or Z sustain board however as a worst case scenario it could be the screen itself.

Dark picture or ghosting image

Frequently this is caused by a faulty TCon board. Note that in some instances it could be a faulty screen that is causing the TCon board to go faulty.

No Sound or problematic sound

Frequently associated with a faulty main board. Sometimes, it is actually speakers but this is rare as one of the 2 speakers should still work okay if one has failed.

Volume or source/input changing automatically / randomly

This fault is often related to a main board of function PCB.
Source / Inputs not working
HDMI, Scart, USB, Aerial input may not be working. Normally, inputs at the side or back of the television are connected to the main board, hence it is usually this board that may require a repair.

No or poor signal
Be careful here as sometimes there is no actual fault with the television. Often you may have an issue with the aerial. The best way to eliminate whether the fault lies with the television or the aerial is if you may be able to plug the aerial cable into another television and see if it works. If it still does not work then the fault most likely lies with the aerial itself. If the fault does relate to the television then it could be associated with a fault main board, or depending on the type of television you have, it could be the tuner board or free sat board.

Remote not responding
This may sound obvious, but firstly try to replace the batteries on the remote! If the television still does not respond to the remote then quite possibly you may have a fault with the IR sensor in the television or the remote itself may be faulty.

Touch buttons not working
Normally this is attributable to the function panel being faulty.

Not Connecting to the Internet
If the television has wifi then the cause of this difficulty could be a faulty wifi module. If it is connected with an ethernet cable then it is possibly caused by a faulty main board.

TESTING AND CHECKING THE GIVEN FAULT
Probable causes for No light on the screen ; sound ok
Show a torch light on the display screen. If video is seen in that particular area, then defect is due to backlight in LED TV.

1. Open the back cover of LED TV and switch ON the TV. If white LED array does not glow, check the supply voltage given to LED array.
2. Check each LED separately by an LED tester which is available in market.
3. Replace the defective LEDs with the same model/voltage rating in the LED TV receiver.
4. After replacing the defective LEDs, the LED TV will function properly.

RESULT
In this Exercise, know about more common faults in LED TV and detail of every possible fault and solution, then found and rectified the defect in an LED TV receiver.
Changing of Computer BIOS Settings

AIM: To study, access and modify user Windows computer’s BIOS page and settings

THEORY

The BIOS is a set of built-in options that allows user to change system aspects like the date and time. Since the BIOS is tied to a computer's motherboard, the appearance of each computer's BIOS will vary slightly depending on the manufacturer.

The BIOS setting is as follows,

1. Booting Process.
2. Change the Boot order.
3. Create a BIOS Pass Word.
4. Change user Date & Time.
5. Change Fan Speed and System Voltage.
6. Save and Exit.

PROCEDURE

Initial Steps taken while setting the BIOS as follows,
1. Restart your computer.
   - Open Start
   - Click the power icon, and
   - Click Restart.
   - If your computer is locked, click the lock screen, then click the power icon in the bottom-right corner of the screen and click Restart.

2. If your computer is already off, press your computer’s “On” switch.
   - Wait for the computer’s first start-up screen to appear.
   - Once the start-up screen appears, user will have a very limited window in which user can press the setup key.
   - It is best to start pressing the setup key as soon as the computer begins to restart.
   - If user see “Press [key] to enter setup” or something similar flash across the bottom of the screen and then disappear, user will need to restart and try again.

3. Press and hold Del or F2 to enter setup.
   The key you’re prompted to press might also be different; if so, use that key instead.
   - User will typically use the “F” keys to access the BIOS. These are at the top of user keyboard, though user may have to locate and hold the Fn key while pressing the proper "F" key.
User can look at the computer model's manual or online support page to confirm the computer's BIOS key.

4. Wait for your BIOS to load.
   - After successfully hitting the setup key, the BIOS will load.
   - This should only take a few moments.
   - When the loading is complete, user will be taken to the BIOS settings menu.

**Adjust the BIOS Settings**

1. Familiarize yourself with the BIOS controls.
   - Since BIOS menus don't support mouse input, user will need to use the arrow keys and other computer-specific keys to navigate the BIOS.
   - User can usually find a list of controls in the bottom-right corner of the BIOS homepage.

2. Change your settings carefully.
   - When adjusting settings in the BIOS, be sure that user certain what the settings will affect.
   - Changing settings incorrectly can lead to system or hardware failure.
   - If user don't know what user want to change coming into the BIOS, user probably shouldn't change anything.
3. Change the boot order.
   - If user want to change what device to boot from, enter the Boot menu.
   - From here, user can designate which device the computer will attempt to boot from first.
   - This is useful for booting from a disc or flash drive to install or repair an operating system.
   - User will typically use the arrow keys to go over to the Boot tab to start this process.

4. Create a BIOS password.
   - User can create a password that will lock the computer from booting unless the correct password is entered.
5. Change your date and time.
   - User BIOS’s clock will dictate the Windows clock.
   - If user replace the computer’s battery, the BIOS clock will most likely be reset.

![Image of BIOS Setup Utility]

6. Change fan speeds and system voltages.
   - These options are for advanced users only.
   - In this menu, user can overclock the CPU, potentially allowing for higher performance.
   - This should be performed only if user is comfortable with the computer’s hardware.
7. Save and exit.
   - When user is finished adjusting the settings, user will need to save and exit by using the BIOS’ “Save and Exit” key in order for the changes to take effect.
   - When user save and restart, the computer will reboot with the new settings.
   - Check the BIOS key legend to see which key is the “Save and Exit” key.

RESULT
In this Practical, learnt about to access and modify user Windows computer’s BIOS page and settings.
**Aim:** To control a RGB (Red, Green, Blue) LED with the help of Arduino.

**APPARATUS / COMPONENTS REQUIRED**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of Components / Apparatus</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arduino</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Bread board</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Jumper Wires</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>RGB LED</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Three 270 Ω resistors</td>
<td>1</td>
</tr>
</tbody>
</table>

**Procedure**

1. First, fix the RGB LED in the Breadboard.
2. Connect Arduino GND pin with ground of Breadboard.
3. Provide connections from pin 11, 10 and 9 of Arduino to red, green and blue leads of RGB LED in the Breadboard.
4. Connect the common anode of RGB LED to the ground of Breadboard.
5. Resistors are connected with RGB LED to equalize the fluctuation.
6. With the help of USB cable, Arduino board could be connected with PC/Laptop.
7. In PC/Laptop open the Arduino IDE, write the program of RGB LED in new sketch file and click the verify button to compile the program.

8. Once it will be verified, then click the upload button to execute.

**Coding:**

```c
/* RGB LED Add name of coder and date of writing the program, for better documentation. */
int redPin = 11;
int greenPin = 10;
int bluePin = 9;

void setup()
{
    pinMode(redPin, OUTPUT);
    pinMode(greenPin, OUTPUT);
    pinMode(bluePin, OUTPUT);
}

void loop()
{
    setColor(255, 0, 0); // red
    delay(1000);
    setColor(0, 255, 0); // green
    delay(1000);
    setColor(0, 0, 255); // blue
    delay(1000);
    setColor(255, 255, 0); // yellow
    delay(1000);
    setColor(80, 0, 80); // purple
    delay(1000);
    setColor(0, 255, 255); // aqua
    delay(1000);
}

void setColor(int red, int green, int blue)
{
    analogWrite(redPin, red);
    analogWrite(greenPin, green);
    analogWrite(bluePin, blue);
}
```

**Results & Discussion**

1. Try to vary the delay time of RGB LED, implement it with the use of Arduino code and observe the result.

2. Write an Arduino code to display the information about the current color of glowing RGB LED in Serial Monitor.

3. Connect 6 or 8 RGB LEDs to glow in a sequential manner by making the proper changes in the program. Discuss about the connection and output you get.
Glowing of Multiple LEDs

Aim: To turn on/off the LEDs in a sequential manner using Arduino board.

APPARATUS / COMPONENTS REQUIRED

<table>
<thead>
<tr>
<th>S.No</th>
<th>Apparatus / Components Required</th>
<th>Range</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Arduino Board</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Bread Board</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>LED's</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Jumper Wires</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Circuit diagram

Procedure

1. Connect the Arduino with the LEDs using the breadboard.
2. Give the connections from Arduino board to LEDs, by joining the black wire from Arduino GND pin to all the short pin of LEDs for ground connection.
3. Join the red wire from all LED’s longer pin to Arduino’s digital pin 2, 3, 4, 5, 6, 7.
4. After giving the connection as per the schematic diagram, the USB power cable of Arduino could be connected to the PC/laptop.
5. In the PC/laptop the Arduino IDE is opened and run the proper multiple LED program.
6. After the program is uploaded to the Arduino board, the multiple LEDs turn on/off in a sequential manner.

**Coding**

/* Code for multiple LEDs*/
int timer = 100;  // The higher the number, the slower the timing.
int ledPins[] = {
  2, 7, 4, 6, 5, 3 }; // an array of pin numbers to which LEDs are attached
int pinCount = 6;  // the number of pins (i.e. the length of the array)
void setup() {
  // the array elements are numbered from 0 to (pinCount - 1).
  // use a for loop to initialize each pin as an output:
  for (int thisPin = 0; thisPin < pinCount; thisPin++) {
    pinMode(ledPins[thisPin], OUTPUT);
  }
  void loop() {
    // loop from the lowest pin to the highest:
    for (int thisPin = 0; thisPin < pinCount; thisPin++) {
      // turn the pin on:
      digitalWrite(ledPins[thisPin], HIGH);
      delay(timer);
      // turn the pin off:
      digitalWrite(ledPins[thisPin], LOW);
    }
    // loop from the highest pin to the lowest:
    for (int thisPin = pinCount - 1; thisPin >= 0; thisPin--) {
      // turn the pin on:
      digitalWrite(ledPins[thisPin], HIGH);
      delay(timer);
      // turn the pin off:
      digitalWrite(ledPins[thisPin], LOW);
    }
  }
} 24

**Result**

Try to vary the delay time of RGB LED, implement it with the use of Arduino code and observe the result.
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