GOVERNMENT OF TAMIL NADU

HIGHER SECONDARY SECOND YEAR

VOCATIONAL EDUCATION

BASIC ELECTRONICS ENGINEERING

Theory & Practical

A Publication Under Free Textbook Programme of Government of Tamil Nadu

Department of School Education

Untouchability is Inhuman and a Crime

Government of Tamil Nadu

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PREFACE

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 respectivetopic 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 andpersonnel. We are especially grateful to the members of the TamilnaduState 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

HOW TO USE THE BOOK

Learning Objectives	Learning objectives briefly describe the contents of the unit. It also outlines the knowledge gained by the students.
DO YOU KNOW?	Interesting facts to motivate students to gain more information regarding the unit.
Infographics	Visual representations of the unit for better understanding.
Concept Figures	Conceptual diagrams that potrays the technique of drafting and sewing.
QR code	To facilitate reading at anytime, anywhere.
Activity	Skill oriented activities based on the units for better understanding.
Evaluation	Access students under the category of understanding, reproducing and application oriented.
Glossary	Explanation of significant terms.
Model Question Paper	A model question paper to help students to face examinations.
References	List of related books for further reading.
Case Study	Brief note on successful students who have pioneers in the field.
Career Guidance	List of job opportunities on successful completion of course

CAREER GUIDANCE AFTER COMPLETION OF 12TH STANDARD

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.

Vertical Mobility	Job / Self Employment
1. Lateral Entry for DIPLOMA in Engineering (ECE, EEE, E&I)	1. Job opportunities offered by few industries like TVS, Leyland, Lucas, TI-cycles, TITAN watches.
2. Separate allocation given for Vocational (Engg &Tech) students in Engineering (B.E.,) Courses (ECE, EEE, E&I). Even first 2 days counseling is allotted for Engineering Vocational students.	2. Audio/Video Equipment Service Centre. Computer Hardware service
3. B.Sc., (Eletronics), B.Voc (NSQF)	3. They can register their names in the "Board of Apprenticeship Training", 4th Cross street, CIT Campus, Tharamani, Chennai – 600013 for employment opportunities.
4. Lateral entry opportunities (for B.E./B.Tech.,) after completing Diploma.	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 www.ncs.gov.in for further details.

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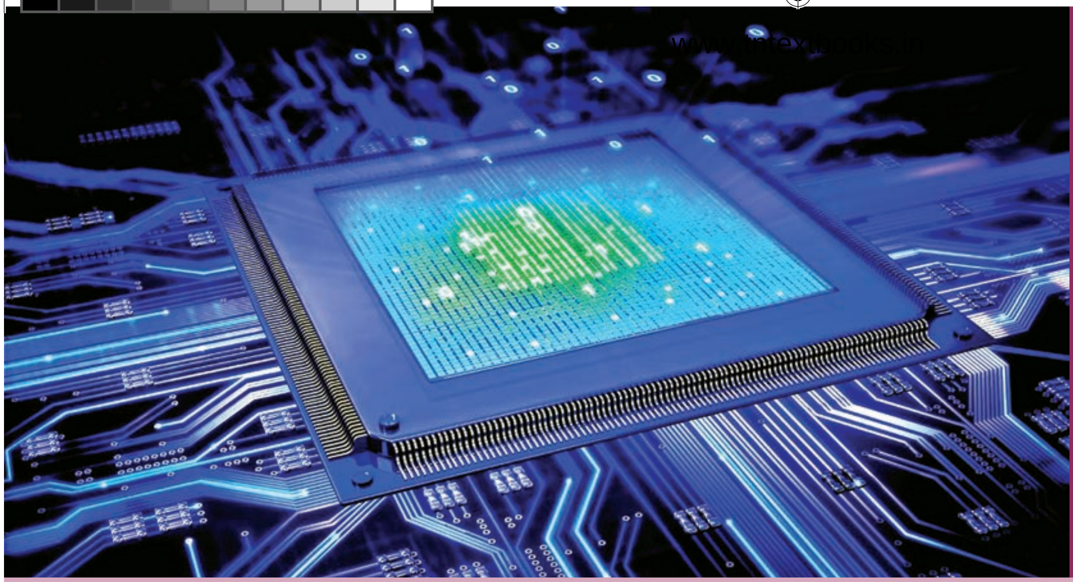


CHAPTER 1

Digital Circuit Applications

LHKW5

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

CONTENT

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.

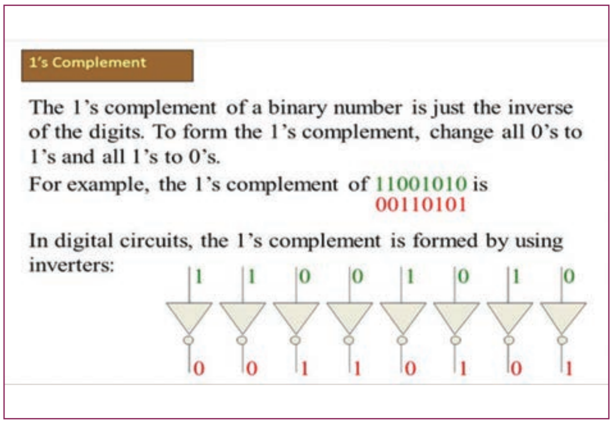


FIGURE 1.1 Example of 1's Complement circuit using inverters

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.

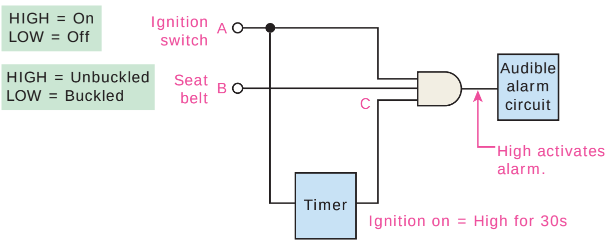


FIGURE 1.2 A simple Car-seat belt alarm circuit using AND Gate

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.

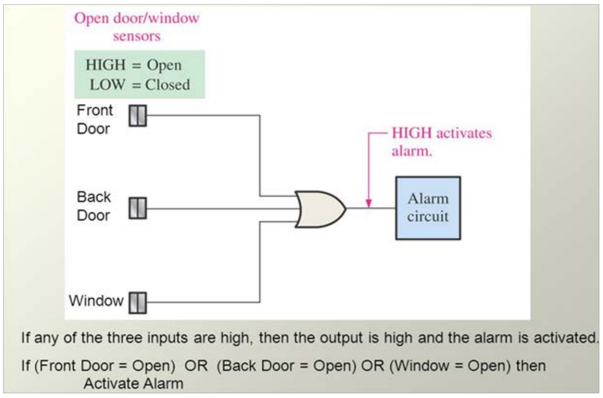


FIGURE 1.3 Simple intrusion detection alarm system using OR-gate

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

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.

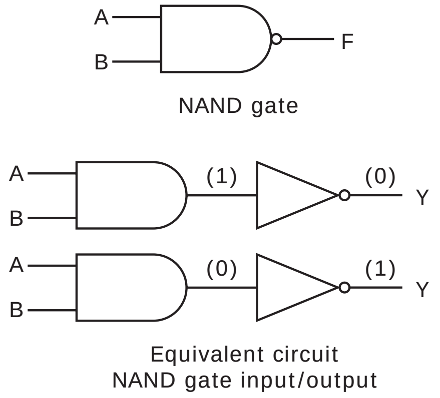


FIGURE 1.4 Symbol and Equivalent circuit of 2-input NAND gate

Operation of a NAND – gate

A NAND gate produces low output when all the inputs are high. When any of the input is low, the output will be HIGH. Figure 1.4 shows a 2-input NAND gate with the inputs labelled as A and B and the output is labelled as Y. The operation can be stated as follows.

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.

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 $Y = \overline{A \cdot B}$.

TABLE 1.1 Truth table of NAND gate

A	B	$Y = \overline{A \cdot B}$
0	0	1
0	1	1
1	0	1
1	1	0

The operation of NAND gate can also be explained with waveform. Let us look at the pulse waveform operation of a NAND gate. With reference to the truth table the output of NAND gate is low, when all of the inputs are HIGH.

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.

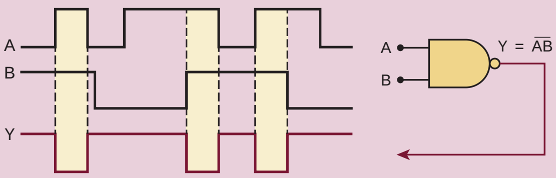


FIGURE 1.5 Waveforms of 2-input NAND-gate

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.

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 (0V).

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.

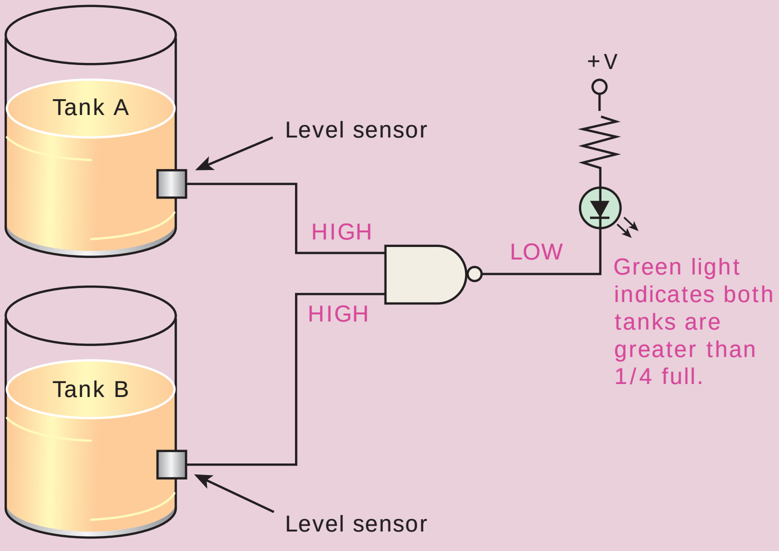
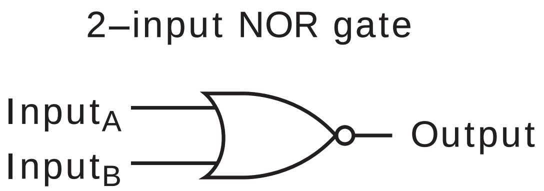


FIGURE 1.6: NAND gate with its two inputs connected to the tank level sensor

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.



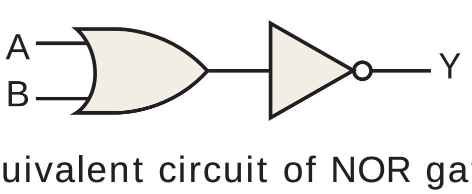


FIGURE 1.7 Symbol and Equivalent Circuit of NOR gate

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 $Y = \overline{A + B}$.

TABLE 1.2 Truth Table of NOR gate

A	B	$Y = \overline{A + B}$
0	0	1
0	1	0
1	0	0
1	1	0

The operation of NOR- gate can also be explained with waveforms. Let we look at the pulse waveform operation of a NOR gate (Figure 1.8) with reference to the truth table the output of NOR-gate is HIGH, only when both the inputs are LOW.

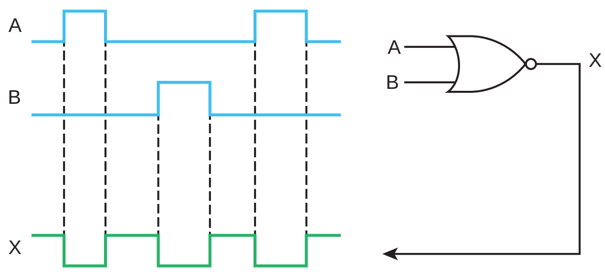


FIGURE 1.8 Waveforms of NOR gate

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.

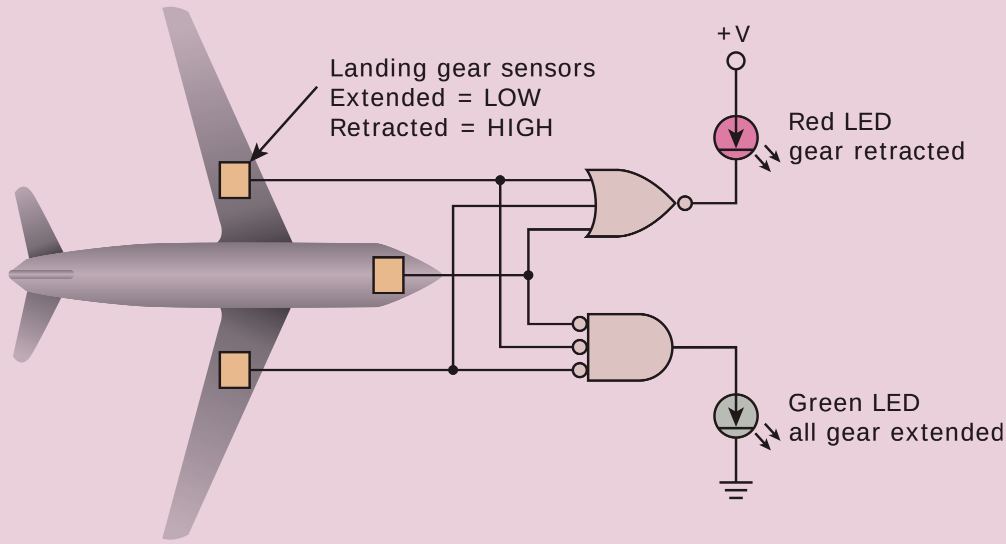


FIGURE 1.9 Aircraft functional monitoring system

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.

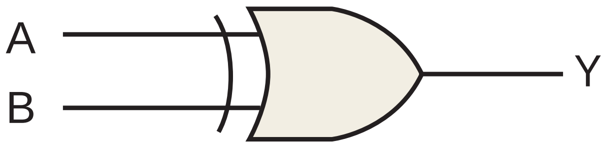


FIGURE 1.10 Symbol of Ex-OR gate

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

A	B	$Y = (\overline{A} \cdot B) + (A \cdot \overline{B})$
0	0	0
0	1	1
1	0	1
1	1	0

The logical expression for XOR-gate $Y = (\overline{A} \cdot B) + (A \cdot \overline{B})$. 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.

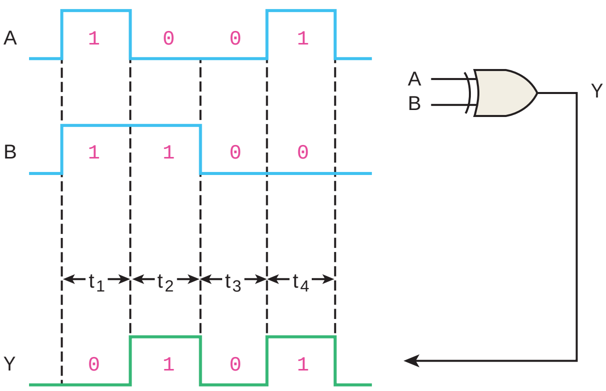


FIGURE 1.11(a) Exclusive-OR gate Operation with pulse waveform inputs

> ### 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,

which cause the XOR inputs to be at opposite levels. This condition produces a HIGH on the output of the XOR gate, indicating a failure in one of the circuits.

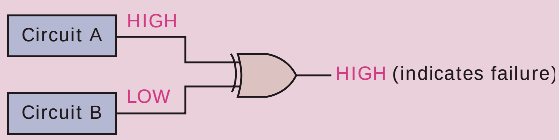


FIGURE 1.11(b) Application of XOR gate

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.

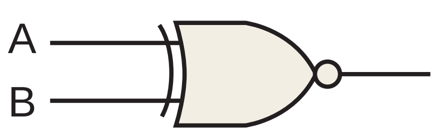


FIGURE 1.12 Symbol of X-NOR

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

TABLE 1.4 Truth table of Ex-NOR gate

A	B	$Y \; \overline{A \quad B}$
0	0	1
0	1	0
1	0	0
1	1	1

Application-Sample

EX-NOR gate

Observe the output waveforms for the XOR and XNOR gate. Determine the output waveforms for the XOR gate and for the X-NOR gate, given the input waveforms, A and B, as shown in Figure 1.13.

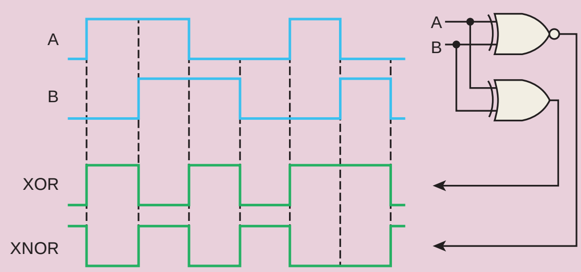


FIGURE 1.13 Output waveforms of Ex-OR and EX-NOR Gates

Solution

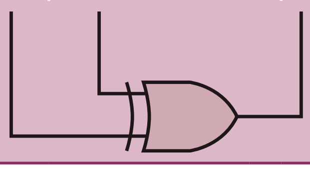
The output waveforms are shown is the Figure 1.13. We can observe that the XOR output is HIGH only when both inputs are at opposite levels. Note that the XNOR output is HIGH only when both inputs are the same. Therefore it is termed as equality comparator. Yet another simple example of XOR gate is adder, which is used to add two bits.

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.

TABLE1.5 Application of XOR as Adder

An XOR gate used to add two bits		
A	B	∑
0	0	1
0	1	0
1	0	0
1	1	1



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.

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

DO YOU KNOW? **Boolean algebra was derived by George Boole in 1854**

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.

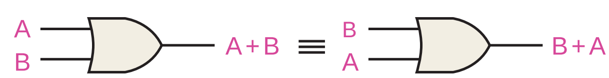


FIGURE 1.14 Commutative law using OR gate

FIGURE 1.15 Commutative law using AND gate

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.

Associative law of addition of three variables

$$A + (B + C) = (A + B) + C$$

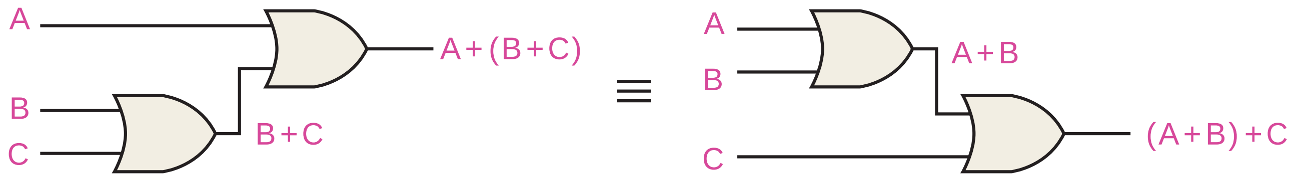


FIGURE 1.16 Associate law of three variables using OR gates

Associative law of multiplication of three variables A · (B · C) = (A · B) · C

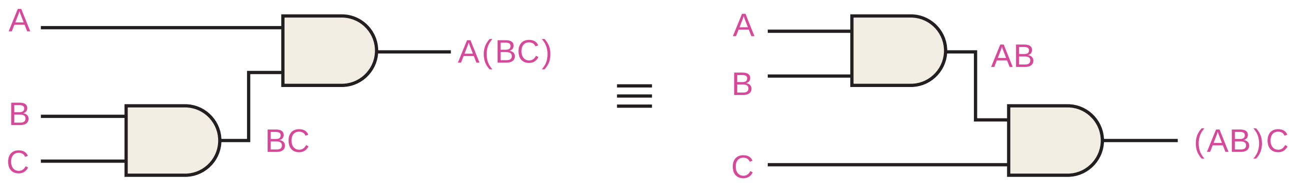


FIGURE 1.17 Associate law of three variables using AND gates

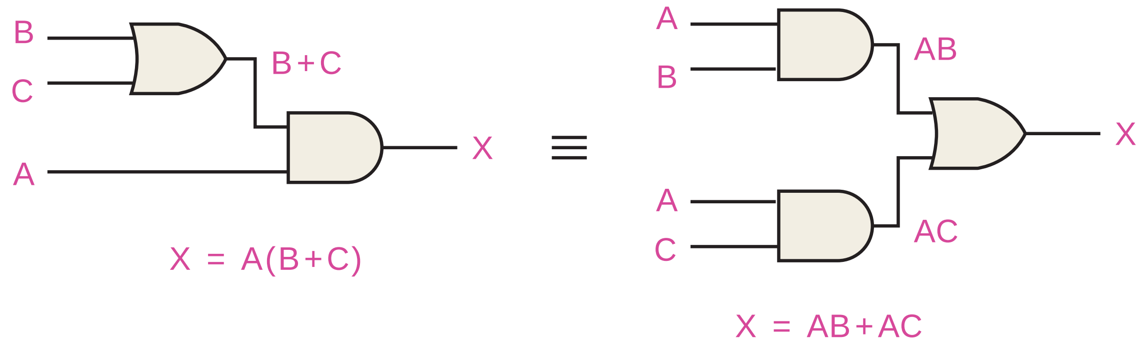


FIGURE 1.18 Distributive law using AND and OR gates

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 · (B + C) = A · B + A · C

Figure 1.18 shows gate implementation of distributed law.

TABLE 1.6 Boolean Algebra Rules

1. $A + 0 = A$	7. $A \cdot A = A$
2. $A + 1 = 1$	8. $A \cdot \bar{A} = 0$
3. $A \cdot 0 = 0$	9. $\bar{\bar{A}} = A$
4. $A \cdot 1 = A$	10. $A + AB = A$
5. $A + A = A$	11. $A + \bar{A}B = A + B$
6. $A + \bar{A} = 1$	12. $(A+B)(A + C) = A + BC$

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.

1.4 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.

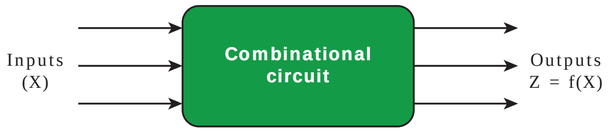


FIGURE 1.19 Combinational Logic Circuit

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.

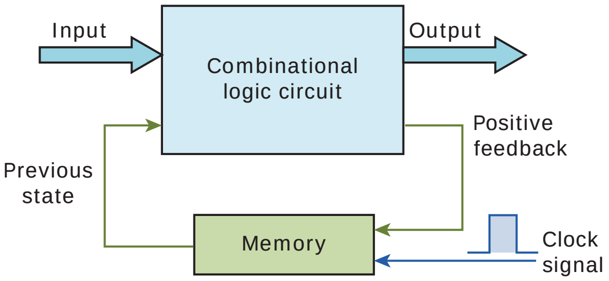


FIGURE 1.20 Block Diagram of Sequential Logic Circuit

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 for 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 **Σ**.

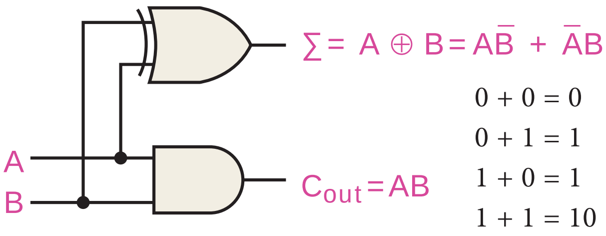


FIGURE 1.21(a) Half-Adder

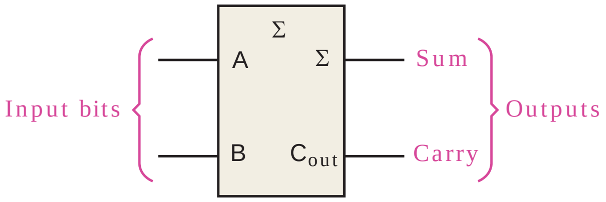


FIGURE 1.21(b) Logic symbol for a half-adder

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 as CARRY. As the AND gate generates a high output only, when both inputs are high i.e., the carry as 1.

When both inputs of EX-OR gate is high or low the output i.e., the sum is low (0). When either of the input is high the output is high. Thus its the bianary addition. The logic symbol of Half-adder is shown in Figure 1.21(b). Truth table for a half adder is given in the Table 1.7.

TABLE 1.7 Truth-Table of Half-Adder

A	B	Σ	C_{out}
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

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

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

$$\text{CARRY} \quad C = A \cdot B$$

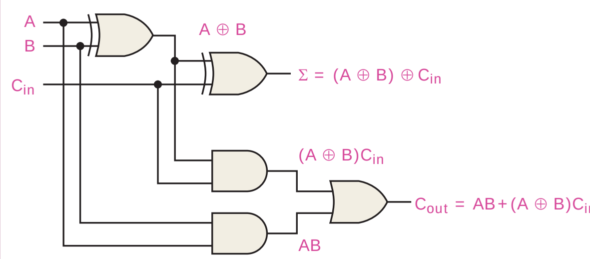
$$\text{SUM} \quad S = \overline{A} \cdot B + A \cdot \overline{B} = A \oplus B$$

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.

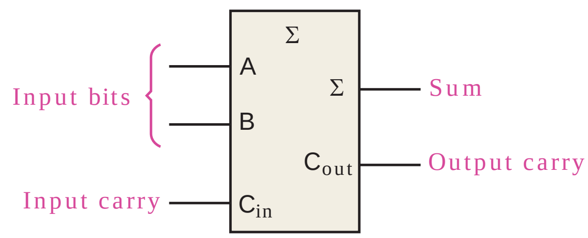
Full Adder

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.

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_{IN}), called the CARRY IN and two outputs SUM and CARRY OUT(C_{OUT}).



(a) Complete logic circuit for a full-adder



(b) Logic symbol of full-adder

(each half-adder is enclosed by a shaded area)

FIGURE 1.22 A simple circuit of full adder

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.

TABLE 1.8 Truth Table of Full-Adder

A	B	C_{in}	Σ	C_{out}
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

C_{in} = input carry, sometimes designated as *CI*
C_{out} = output carruy, 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.

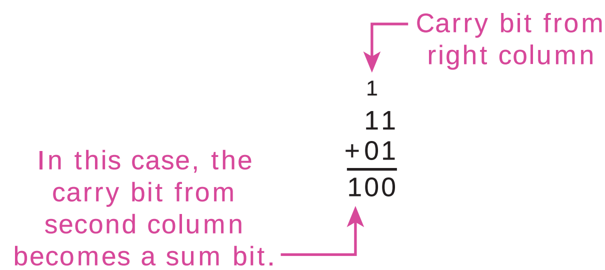


FIGURE 1.23(a) Addition of 2 parallel bits

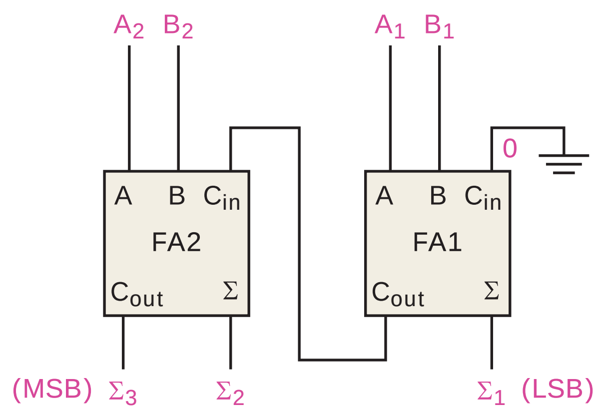


FIGURE 1.23(b) Block Diagram of 2-bit Parallel Adder

Figure 1.23(a) shows the method of 2-bit parallel addition and Figure 1.23(b) shows the schematic block diagram of the same. As we know, from the difference between the half-adder and full-adder, that the half-adder is a logic circuit which adds two 1-bit circuits but, does not add carry from previous addition. Therefore, full-adders came into action. A full-adder can add two 1-bit numbers along with the carry from previous addition.

Coming back to the parallel binary adder, it also has two full-adders. When we start add two numbers, the first step we follow is the addition of LSB (Least Significant Bit) of two numbers. After this, if we have any carry, we forward it to higher order columns. Now, the adder performs the similar task. It adds the LSBs of both the numbers and if any carry bit is there, it passes it to the carry-in terminal of another.

We may use half-adder for the addition of LSBs of both numbers as for the addition of LSBs there is no previous carry from previous addition. But, for the

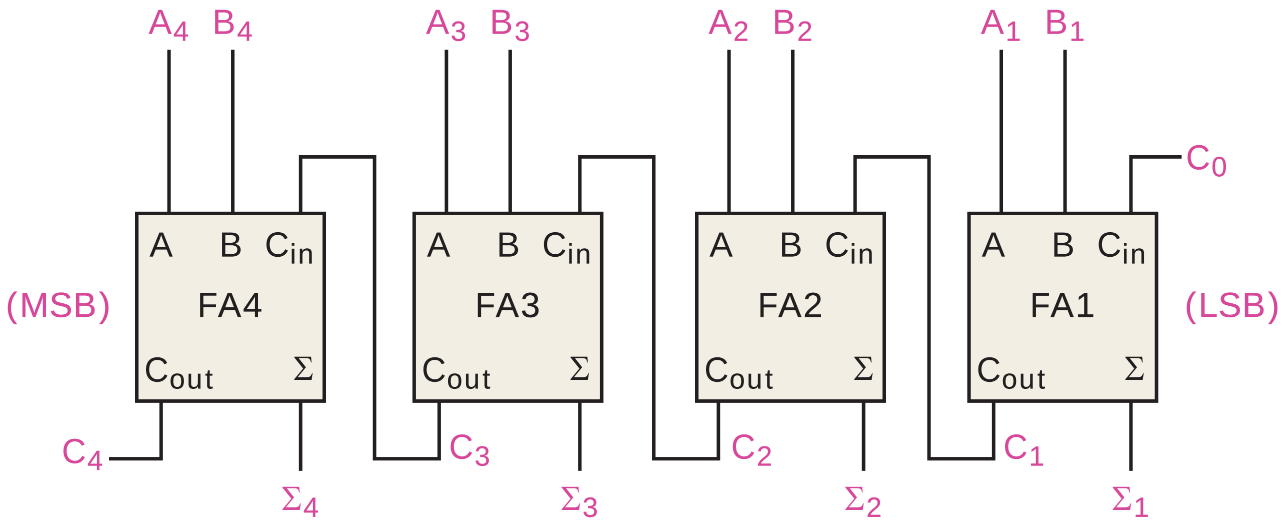


FIGURE 1.24(a) Four-Bit Parallel Binary Adder Block Diagram

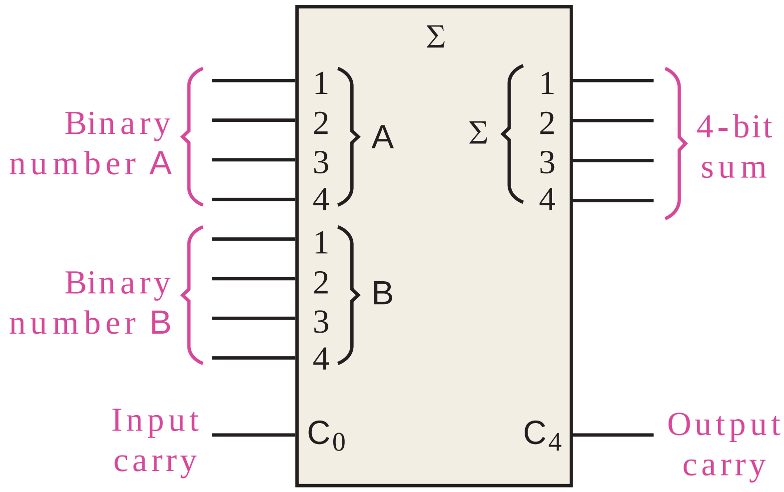


FIGURE 1.24(b) Logic Symbol

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

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. It 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

	1			
0	0		1	1
-0	-1	Borrow 1	-0	-1
0	1		1	0

FIGURE 1.25 Binary Subtraction Rules

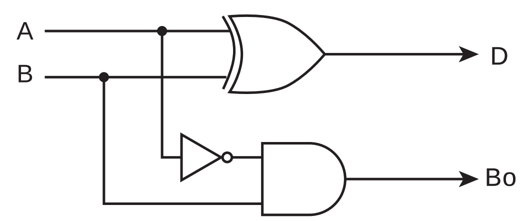


FIGURE 1.26 (a) Half Subtractor Circuit

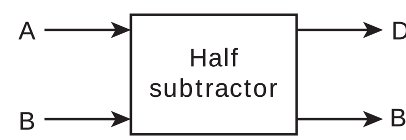


FIGURE 1.26 (b) Symbol of Half Subtractor

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

Input		Output	
A	B	Difference	Borrow
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

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)

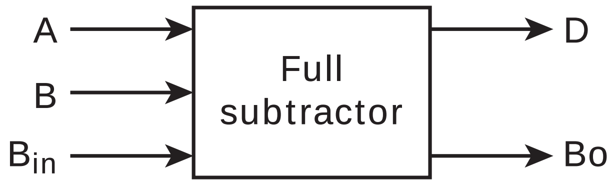


FIGURE 1.27 (a) Symbol of Full-Subtractor

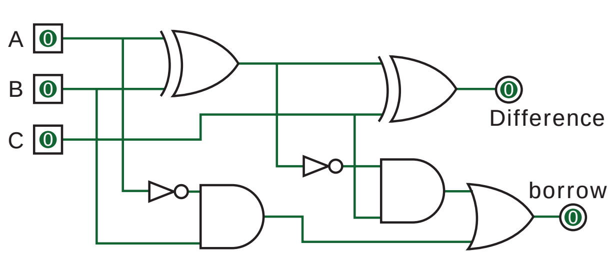


FIGURE 1.27 (b) Circuit diagram of Full Subtractor

Full-Subtractor is formed by using two half-subtractors and one OR gate. 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 1.10 Truth Table of Full-Subtractor

A	B	C	Difference	Borrow
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

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.

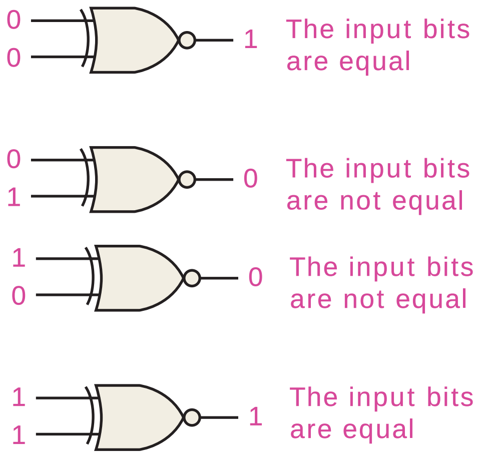


FIGURE 1.28 Basic Comparator Operation

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.

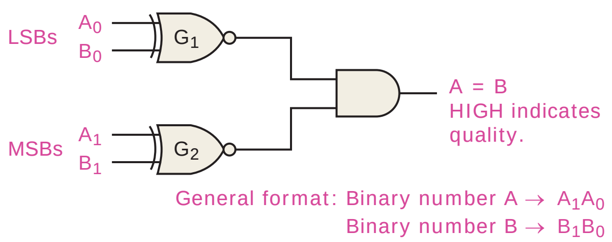
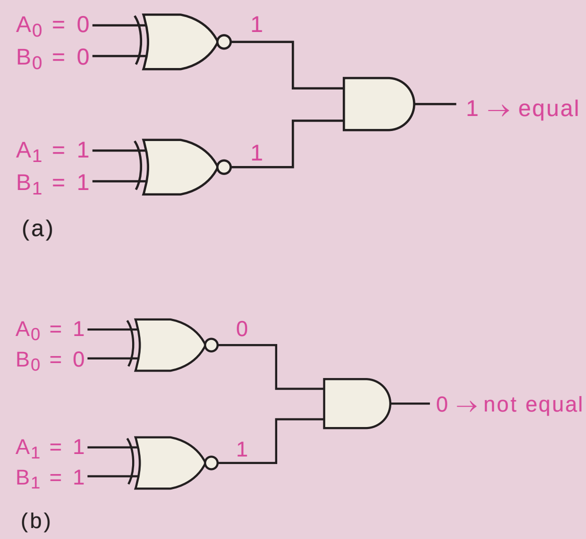


FIGURE 1.29 Logic diagram for equality comparison of two 2-bit numbers

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 Figures1.30(a) & (b) and determine the output by the following the logic levels through the circuit.



FIGURES 1.30 (a)&(b) Application of Comparators

Solution

(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.

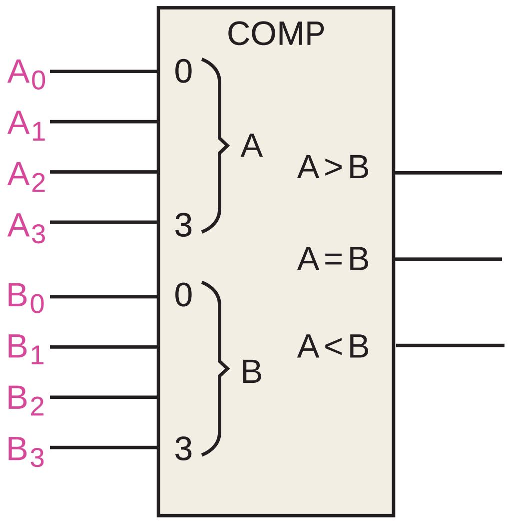


FIGURE 1.31 Logic symbol for a 4-bit comparator with inequality operation

To determine the inequality of binary numbers A and B, we first examine the highest order bit in each number. The following conditions are possible:

1. If A_3 = 1 and B_3 = 0, number A is greater than number B.
2. If A_3 = 0 and B_3 = 1, number A is less than number B.
3. IF A_3 = B_3, then you must examine the next lower bit position for an inequality.

These three operations are valid for each-bit position in the numbers. The general procedure used in a comparator is to check for an inequality in a bit position, starting with highest order bits (MSBs). When such an inequality is found, the relationship of the two numbers is established and any other inequalities in lower-order bit positions must be ignored because it is possible for an opposite indication to occur, the highest-order indication must take precedence. This can be explained through an example.

EXAMPLE 1.3

Determine the input numbers for the outputs A = B, A > B, and A < B shown in Figure 1.32.

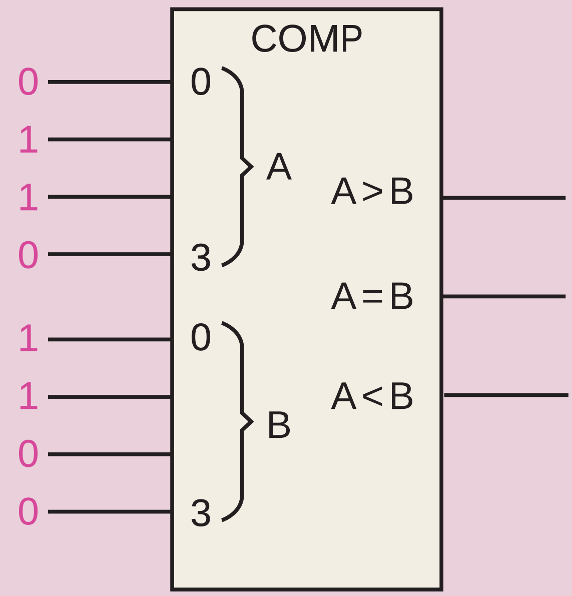


FIGURE 1.32 Application of Comparator

Solution

The number on the A inputs is 0110, the number on the B inputs is 0011. Then, the A > B output is HIGH and the other outputs are LOW.

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.

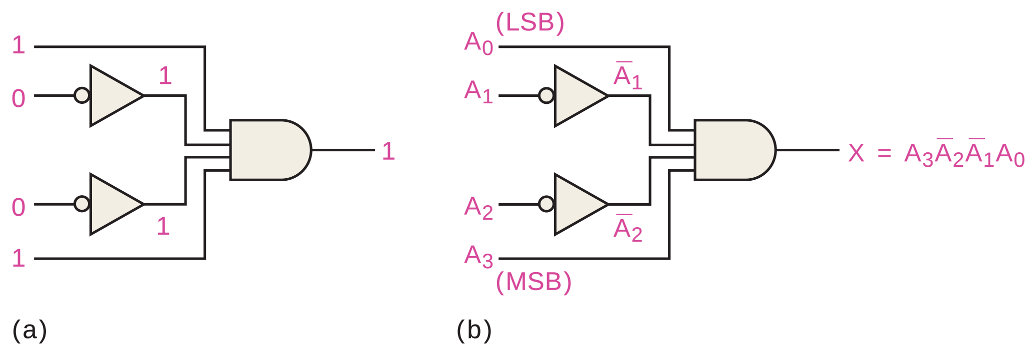


FIGURE 1.33 Decoding logic for the binary code 1001 with an active-HIGH output

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:

$$X = A_3\,A_2\,A_1\,A_0 \quad (1011)$$

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.

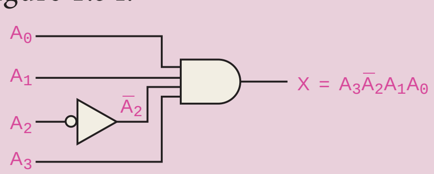


FIGURE 1.34 Decoding logic for producing a HIGH output when 1011 is on the inputs.

1.7 Encoders

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 Figure1.35. This is a basic 10-line-to-4-line encoder.

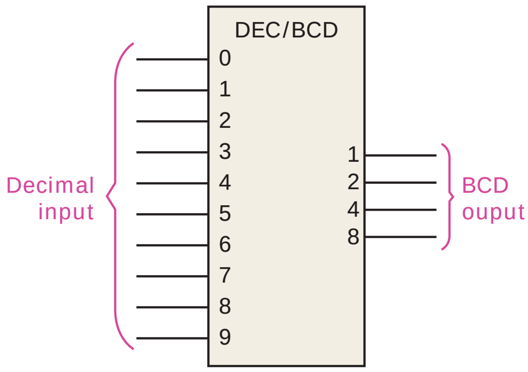


FIGURE1.35 Logic symbol for a Decimal-to-BCD encoder

The BCD (8421) code is listed in Table1.11. 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 $A_3 = 8 + 9$.

TABLE 1.11 Decimal to BCD Encoder

	BCD Code			
DECIMAL DIGIT	A_3	A_2	A_1	A_0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

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

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

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.

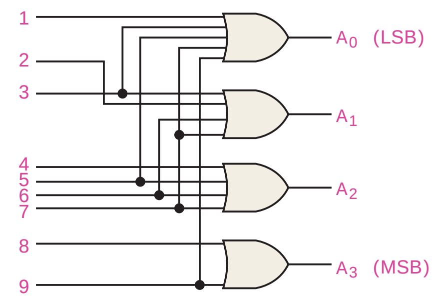


FIGURE 1.36 Basic logic diagram of Decimal-to-BCD encoder.

Note
A 0-digit input is not needed because the BCD outputs are all low, when there are no HIGH inputs.

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.

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.

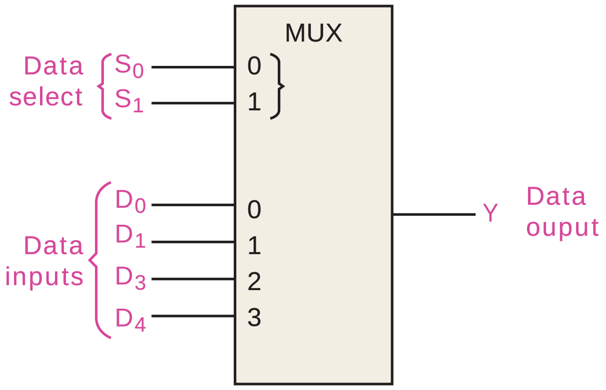


FIGURE 1.37 Logic symbol for a 1-of-4 data selector/multiplexer

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.

1.9 Flip-Flops

The output of the digital circuits studied in previous chapters are dependent entirely on the input, i.e., if the input changes, the output also changes. However, there are requirements for a digital device or circuit whose output will remain unchanged, once set, even if there is a change in input. Such a device can be used to store a binary number. A flip-flop is one such circuit.

Definition

A flip-flop is a bi-stable circuit made up of logic gates. A bi-stable circuit can exist in either of the two stable states indefinitely 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.

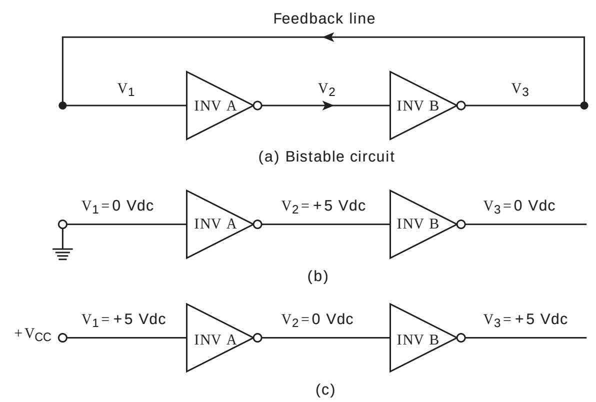


FIGURE 1.39 Flip-Flop using inverters

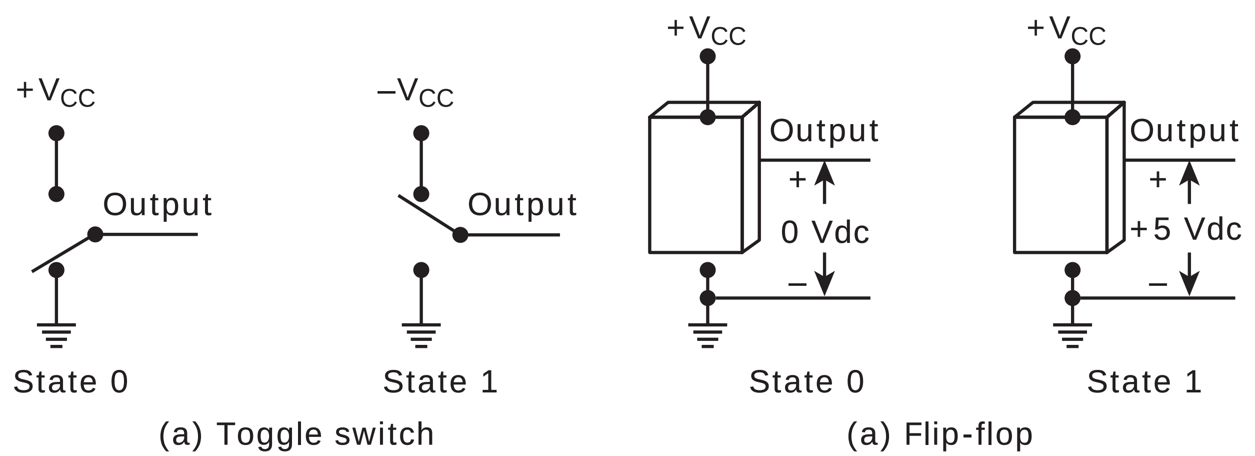


FIGURE 1.38 Flip-Flop Operations

For the moment, remove the feedback line and consider V_1 as the input and V_3 as the output as shown in Figure 1.39(b). There are only two possible signals in a digital system, and in this case, we will define L = 0 = 0 V DC and H = 1 = + 5 V DC. If V_1 is set to 0 V DC, then V_3 will also be 0 V DC. Now, if the feedback line shown in Figure 1.39(a) is reconnected, the ground can be removed from V_1 and V_3 will remain at 0 V DC. This is true since, once the input of INV A is grounded, the output of INV B will go low and can then be used to hold the input of INV A low by using the feedback line. This is one stable state V_3 = 0 V DC. Conversely, if V_1 is +5 V DC, V_3 will also be +5 V DC as seen in Figure 1.39(c). The feedback line can again be used to hold V_1 at + 5 V DC since V_3 is also at + 5 V DC. This is the second stable state V_3 = + 5 V DC.

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.

TABLE 1.12 Truth Table of RS flip-flop

R	S	Q	Action
0	0	Last State	No Change
0	1	1	SET
1	0	0	RESET
1	1	?	Forbidden

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.

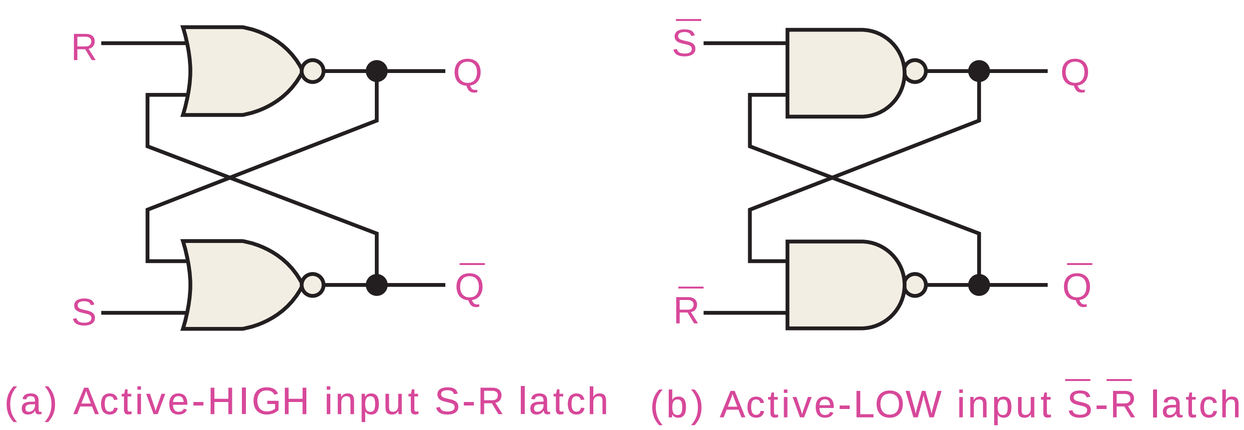


FIGURE 1.40 Latch using NOR or NAND gates

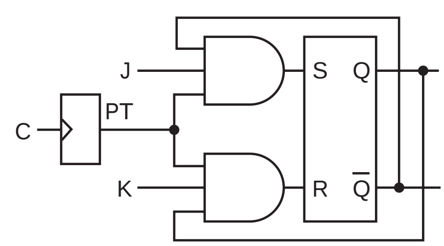
2. The second input condition R = 0 and S = 1 forces the output of NOR gate B low. Both inputs to NOR-gate A are now low, and the NOR-gate output must be high. Thus, a 1 at the S input is said to SET the flip-flop and it switches to the stable state where Q = 1.
3. The third input condition is R = 1 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 $\overline{Q}$ 0 at the same time. But, this violates the basic definition of a flip-flop that requires Q to be the complement of $\overline{Q}$, 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 $\overline{Q}$ 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:



(a) One way to implement a JK flip-flop

FIGURE 1.41 JK-flip-flops with Positive-Edge

TABLE 1.13 Truth Table of JK Flip-flop

C	J	K	$Q_n + 1$	Action
↑	0	0	Q_n Last State	No Change
↑	0	1	0	RESET
↑	1	0	1	SET
↑	1	1	$\overline{Q}_n$(toggle)	Toggle

1. Q output is connected back to the input of the lower AND gate.
2. $\overline{Q}$ 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.

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 triggered D flip-flop and negative edge triggered D flip-flop. Thus, the output has two stable states based on the inputs as summarized in Table 1.14.

TABLE 1.14 Truth Table of D Flip-Flop

Clock	INPUT	OUTPUT	
	D	Q	Q'
LOW	X	0	1
HIGH	0	0	1
HIGH	1	1	0

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 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.

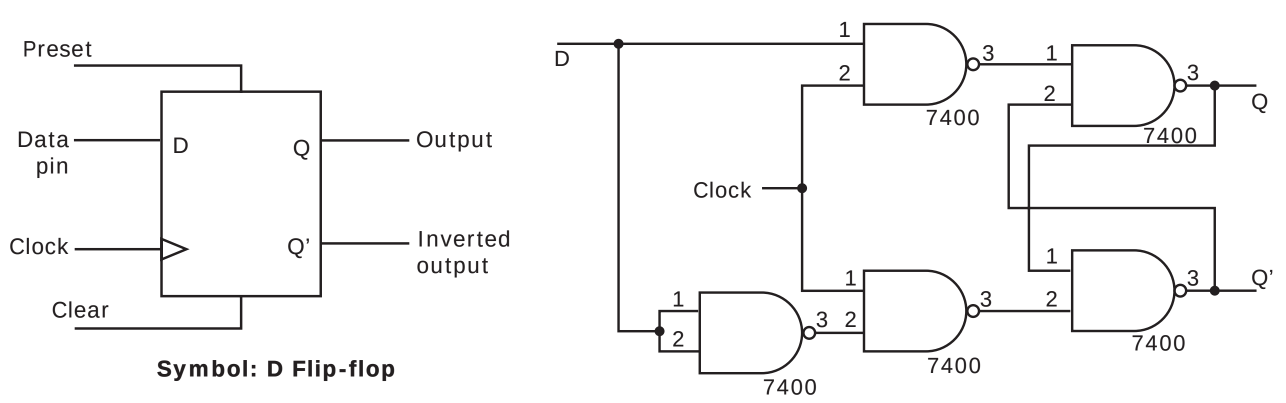


FIGURE 1.42(a) D Flip-Flop Symbol (b) D Flip-Flop using NAND gates

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 $\overline{Q}_0$ 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 $\overline{Q}_0$ 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 $\overline{Q}_0$ output of FF0 can never occur at exactly the same time. Therefore, the 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 Q0 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_0 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

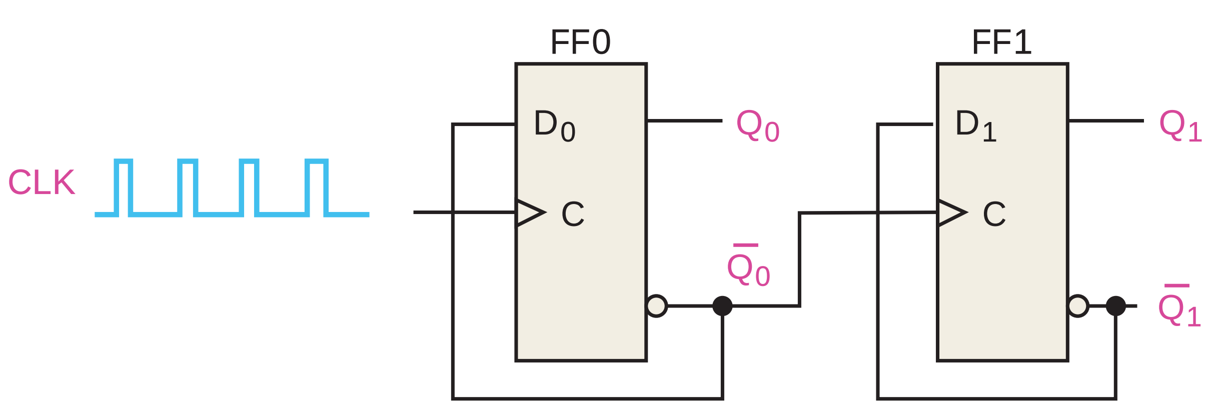


FIGURE 1.43 A 2-bit asynchronous binary counter

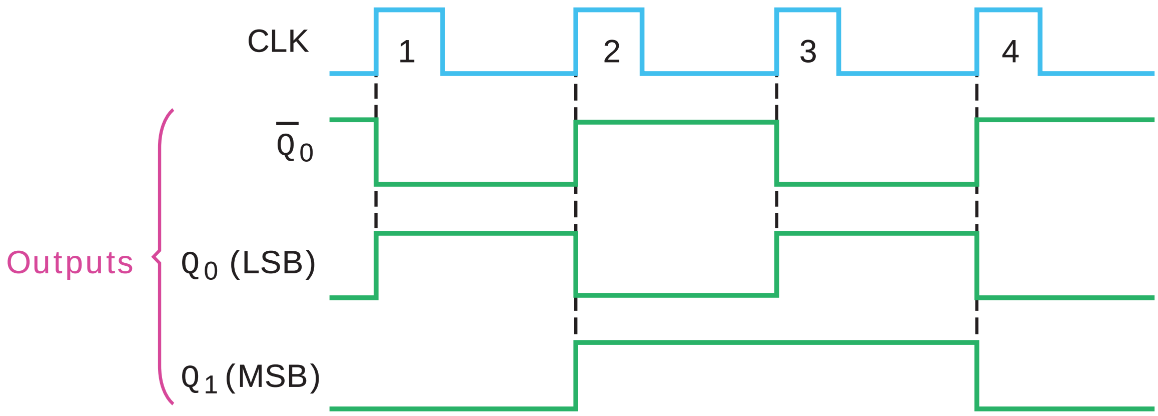


FIGURE 1.44 Timing diagram for the counter given in Figure 1.43

(MSB), the sequence of counter states represents a sequence of binary numbers as listed in Table 1.15.

TABLE 1.15 Binary state sequence for the counter shown in Fig 1.43

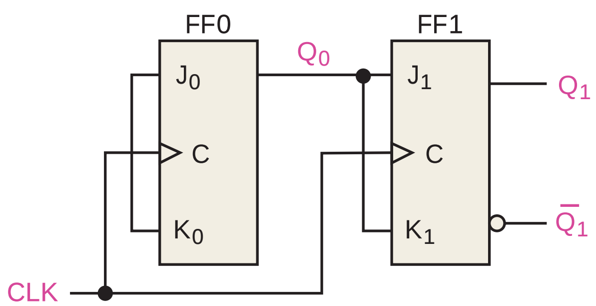
Clock Pulse	Q_1	Q_0
Initially	0	0
1	0	1
2	1	0
3	1	1
4 (recycle)	0	0

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.

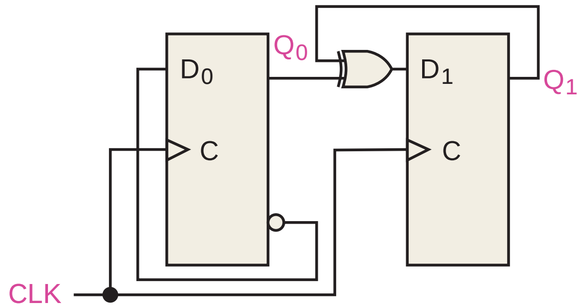
Synchronous Counters

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 1.45(a). Notice that an arrangement different from that for the asynchronous counter must be used for the J_1 and K_1 inputs of FF1 in order to achieve a binary sequence. A D flip-flop implementation is shown in Figure 1.45(b).



(a) J-K flip-flop



(b) D flip-flop

FIGURE 1.45 2-bit synchronous binary counters

1.11 Registers (shift)

Shift registers are a type of sequential logic circuit used primarily for the storage of digital data and typically do not possess a characteristic internal sequence of states.

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.
>
> A register is a digital circuit with two basic functions: data storage and data movement.

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 1.46.

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 1.47 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.

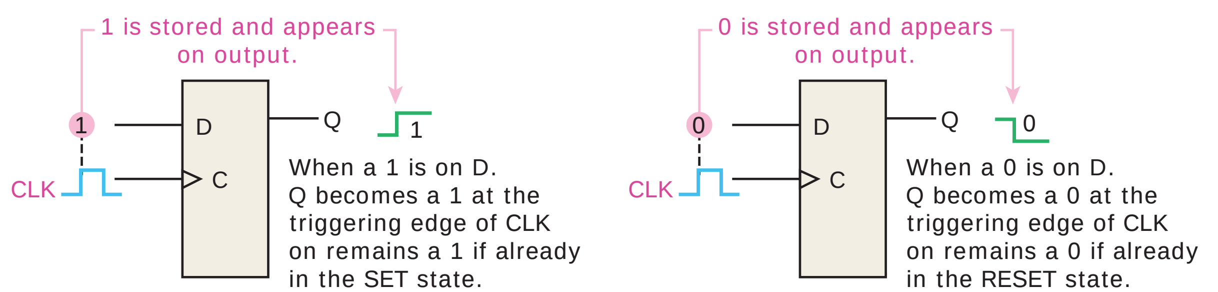


FIGURE 1.46 The flip-flop as a storage element.

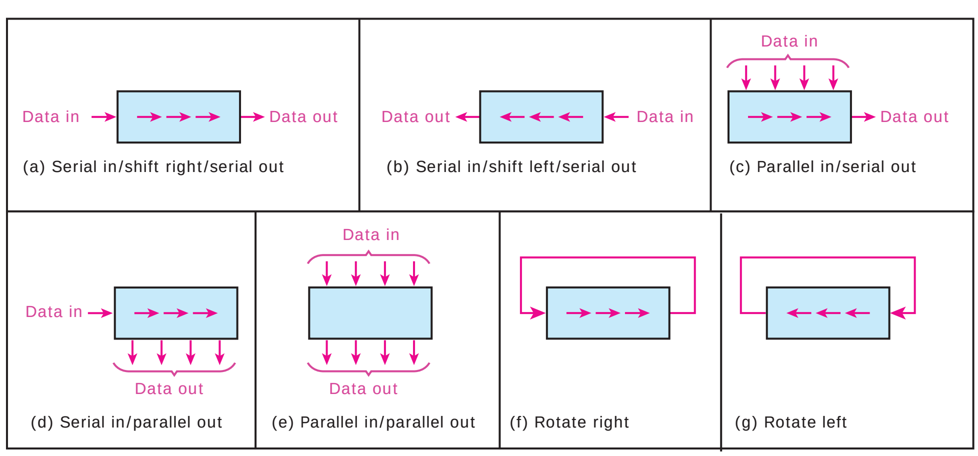


FIGURE 1.47 Basic data movement in shift registers. (Four bits are used for illustration. The bits move in the direction of the arrows.)

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

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

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. The Complement of the variable is

   (a) 0
   (b) 1
   (c) equal to the variable
   (d) the inverse of the variable

3. 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

4. According to Distributive law

   (a) A(B + C) = AB + AC
   (b) A(BC) = ABC
   (c) A(A + 1) = A
   (d) A + AB = A

5. 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

6. An Exclusive OR function is expressed as

   (a) A · B + A · B
   (b) $\left(\overline{A}\cdot B+A\cdot\overline{B}\right)$
   (c) $\left(\overline{A}+B\right)\left(A+\overline{B}\right)$
   (d) (A + B) (A + B)

7. The AND operation can be produced with

   (a) two NAND gates
   (b) three NAND gates
   (c) one NOR gate
   (d) three NOR gates

8. 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

9. 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

10. In general, a multiplexer has

    (a) one data input, several data outputs and selection inputs
    (b) one data input, one data outputs and one selection input
    (c) several data inputs, several data outputs and selection inputs
    (d) several data inputs, one data output and selection inputs

11. The flip-flop belongs to a category of logic circuits known as

    (a) monostable multivibrator
    (b) bistable multivibrators
    (c) astable multivibrators
    (d) one-shots

12. Asynchronous counters are known as

    (a) ripple counters
    (b) multiple clock counters
    (c) decade counter
    (d) modulus counters

13. 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

14. 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)
6. Draw the circuit of Half-adder.
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. Explain in detail the construction of Ex-OR and Ex-NOR gate with truth table.
2. Why NAND & NOR gates are called as Universal gates? Explain with an example.
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. Explain the working of JK-flip-flop.
4. Write about shift register.

Answers

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

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.

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 to a short distance without any signal loss. The Carrier Wave (CW) or Radio Frequency (RF) can travel 3 x 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.

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. 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 broad cast at different frequencies. This is achieved by process of modulation.

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 λ= c/f = 3x10^8 / 15k

   = 300000000/15000 = 20 km

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

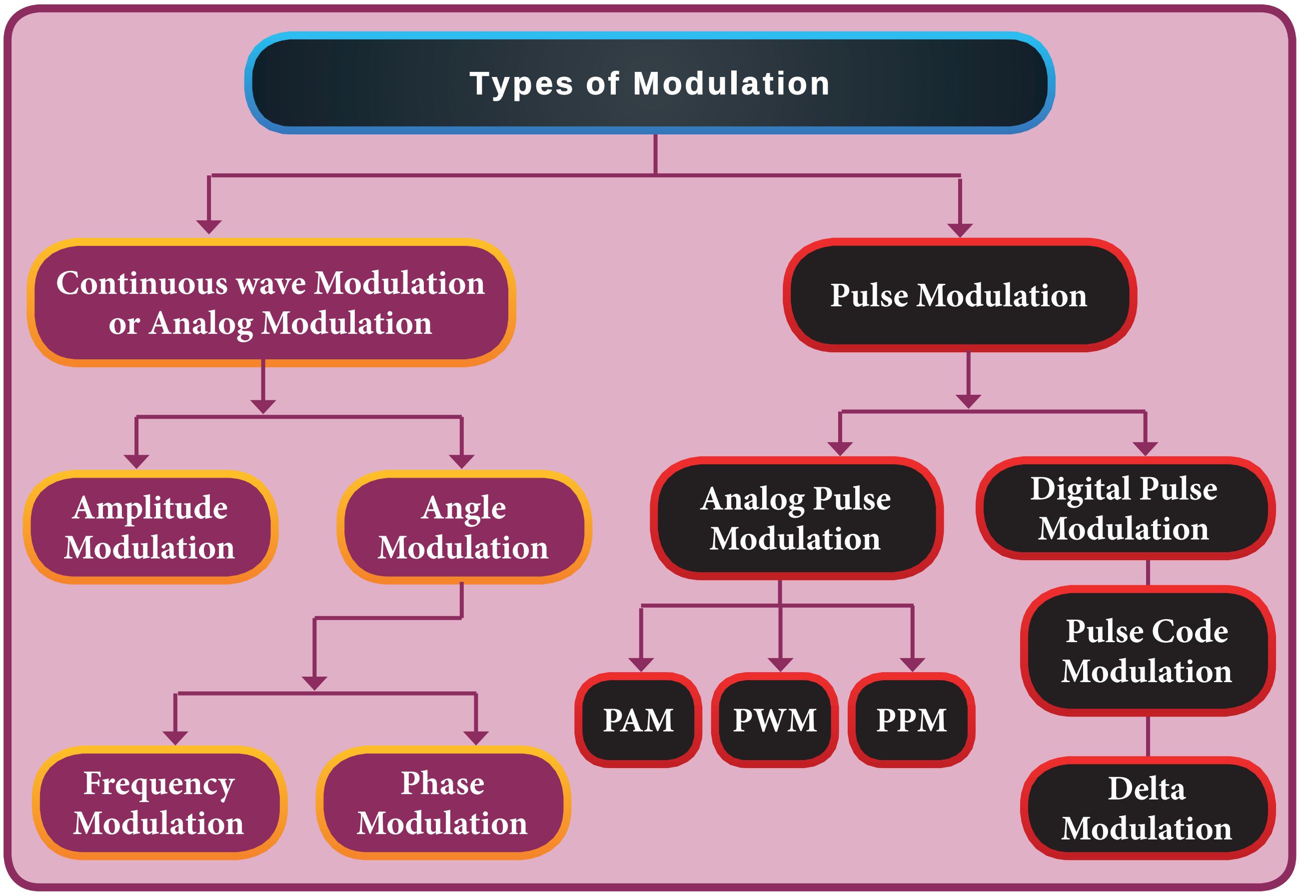
3. It reduce antenna height
4. It reduce bandwidth
5. It transmit information to a long distance without interference.
6. Attenuation of audio signals are high.

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.

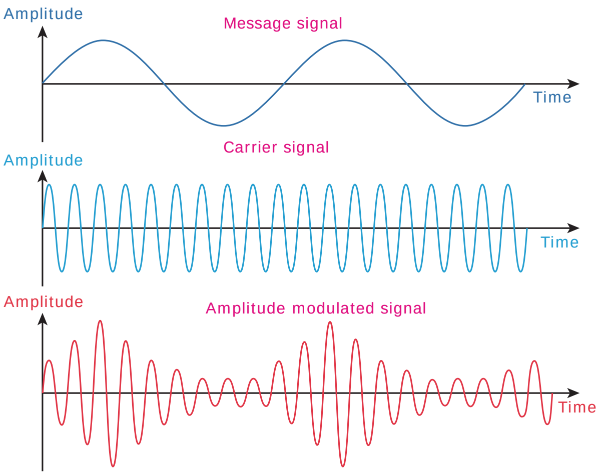


FIGURE 2.1 Amplitude modulation

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 types 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 broad casting.
- 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.

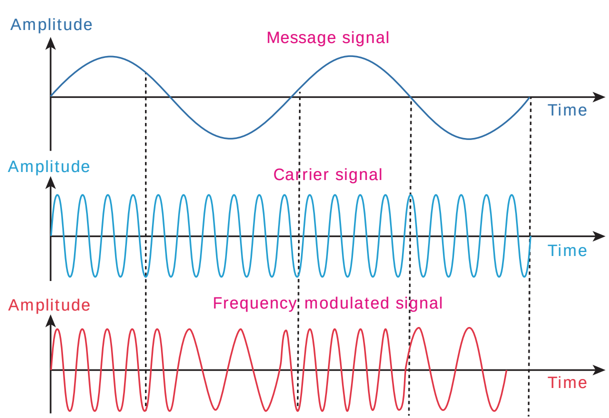


FIGURE 2.2 Frequency modulation

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 contain 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 remain 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 than 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 carrier signal, keeping the amplitude and frequency of the carrier signal constant level.

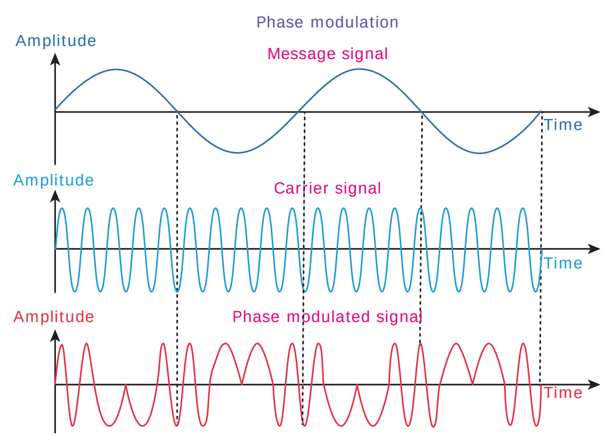


FIGURE 2.3 Phase modulation

The figure 2.3 shows the phase modulation. The first waveform of figure 2.3(a) shows the modulating signal which contains information. The second waveform figure 2.3(b) shows the high frequency carrier signal which contains no information. The waveform figure 2.3(c) shows the resultant phase modulated signal.

From above the three figures it can be observed that the phase of the carrier signal is varied in accordance with the instant amplitude of the message signal. In this type of modulation, when the phase is changed, it also affects the frequency, so this modulation also comes under frequency modulation.

The frequency and phase modulation comes under angle modulation. When the frequency or phase of the carrier signal is varied in accordance with the amplitude of the modulating or message signal, then it is called angle modulation.

2.5.3.1 Advantages of Phase Modulation

1. Modulation does not catch any channal noise.
2. Low power consumption

2.5.3.2 Disadvantages of Phase Modulation

Circuit used for Phase Modulation and demodulation is complicated than AM and FM.

2.5.3.3 Applications

This type of modulation is used in

- SatelliteCommunication
- TV remote
- Wi-Fi.

DO YOU KNOW?

Frequency modulation and phase modulation are also called angle modulation.

2.6 Pulse Modulation

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

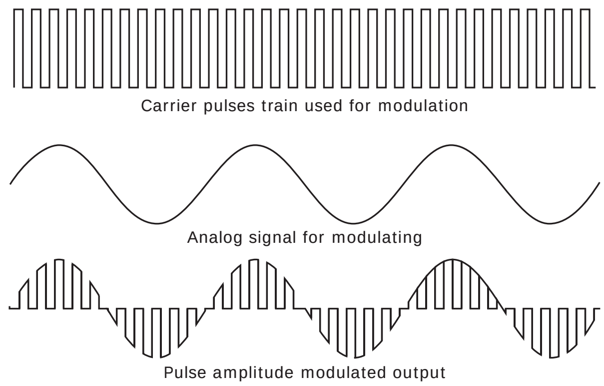


FIGURE 2.4 Pulse amplitude modulation

2.6.2.1 Advantage

Generation and detection is easy.

2.6.2.2 Disadvantages

1. Noise interference is high.
2. Transmission bandwidth is too large.

2.6.2.3 Application of Pulse Amplitude Modulation (PAM)

It is used in many micro controllers for generating the control signals and used in Photobiology.

2.6.3 Pulse Width Modulation (PWM)

Pulse width modulation or pulse duration modulation is a modulation process used in mask communication systems for encoding the amplitude of a signal into a pulse width or duration of another signal, usually a carrier signal, for transmission. Figure 2.5 shows pulse width modulation signal.

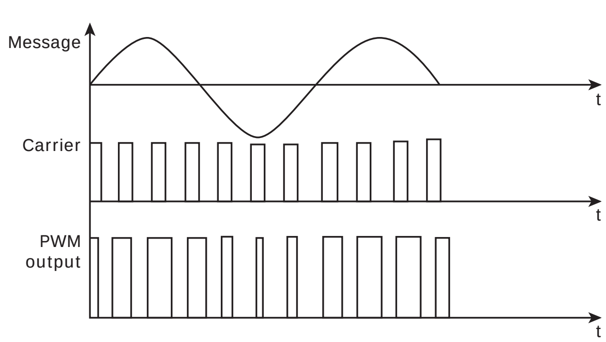


FIGURE 2.5 Pulse Width Modulation

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.

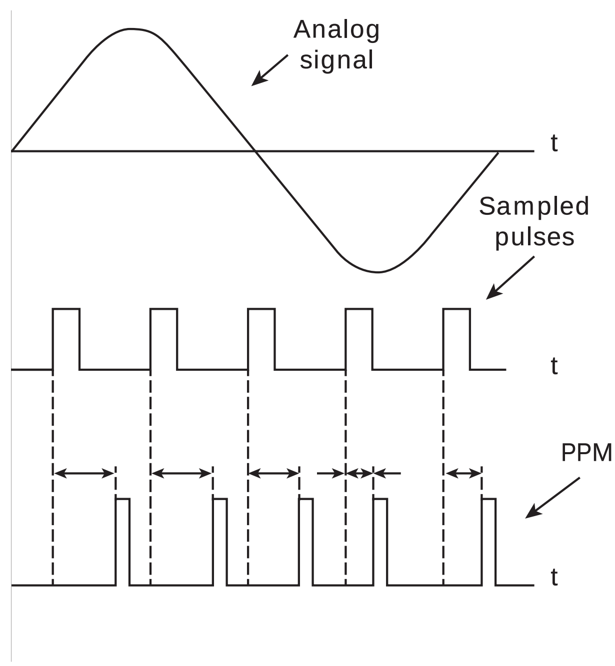


FIGURE 2.6 Pulse Position Modulation

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.

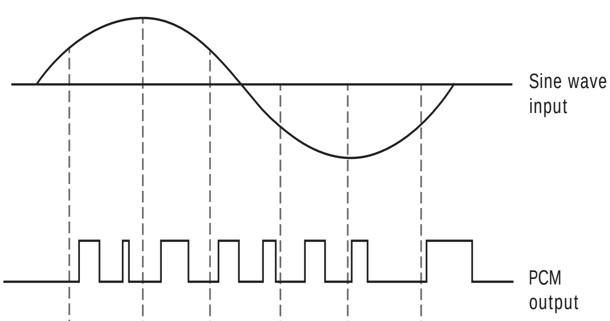


FIGURE 2.7 Pulse Code Modulation

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.

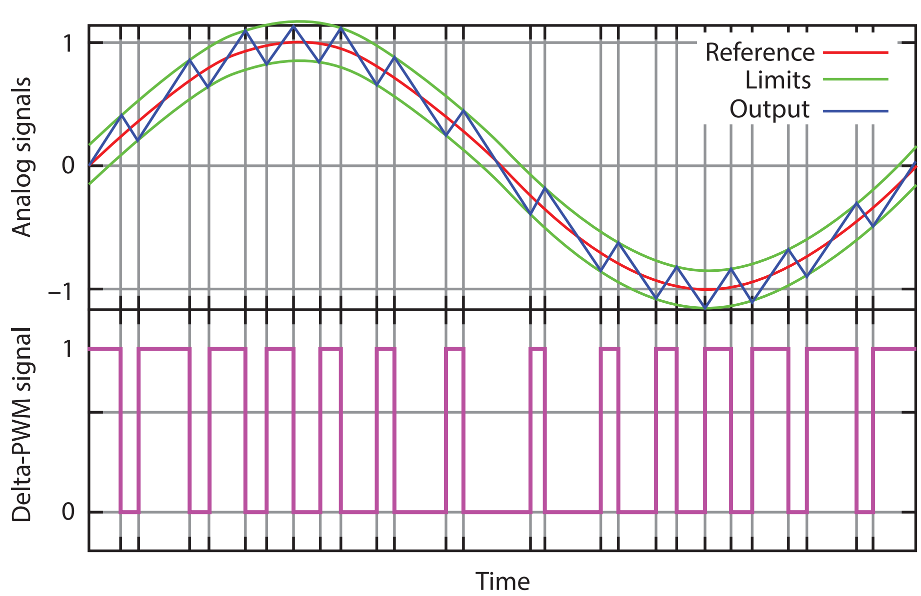


FIGURE 2.8 Delta Modulation

Difference between Continuous Wave Modulation and Pulse Modulation	
Continuous wave modulation or Analog modulation	**Pulse modulation**
The modulated signal is in the form of continuous signals.	The modulated signal is in the form of pulses.
It is not used for sampling technique.	It is used for sampling technique.
It require less bandwidth.	It require large bandwidth.
It has only analog modulation.	Pulse modulation has both analog and digital nature.
High frequency sine wave is used as carrier.	In pulse modulation, the train of pulses is used as a carrier.
Input signal is analog signal only.	The input signal is either analog or digital.
The example of continuous wave modulation is AM (Amplitude Modulation), FM (Frequency Modulation) and PM (Phase Modulation).	The example of pulse modulation is PAM, PPM, PWM, PCM and DM.
It is used in radio and TV broadcasting.	It is used in satellite communication.

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

FIGURE 2.9 Types of Modem

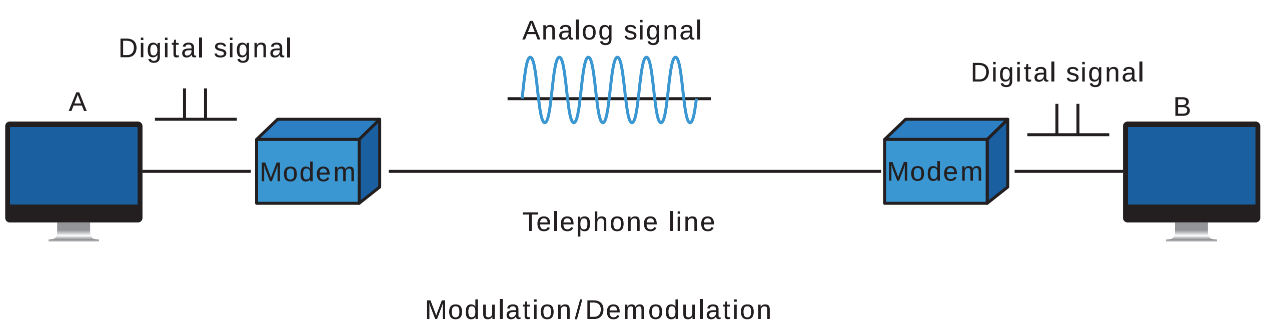


FIGURE 2.10 Modem

digital data. Wireless modem converts digital data into radio signals and back.

2.8.2 Types of Modem

1. On the basis of directional capacity, modems are divded 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 diveded 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.

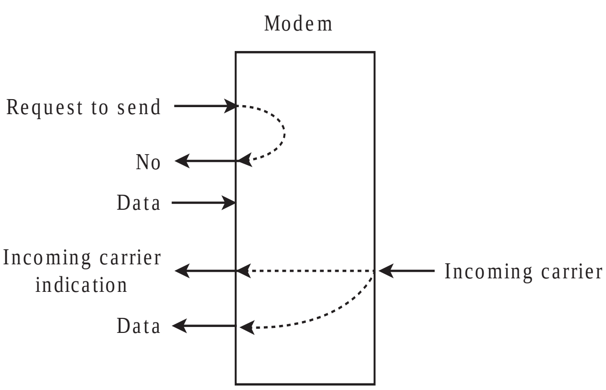


FIG 2.11 Half-duplex modem

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.

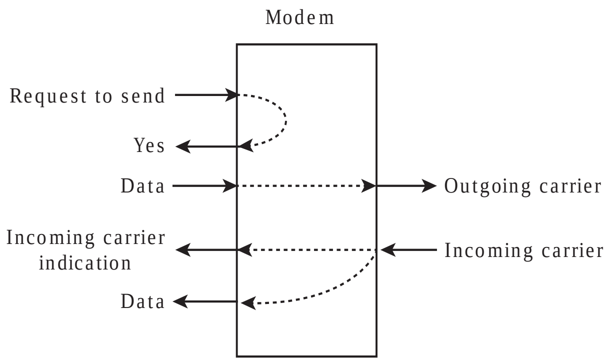


FIGURE 2.12 Full-duplex modem

2.8.2.3 2-Wire Modem

Figure 2.13 shows the 2-wire modem. These modems make use of the same pair of wires for outgoing and incoming carriers. Due to the use of only one pair of wires which is extended into the subscribers location, this type of leased 2-wire connection is less expensive than the 4-wire connection.

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.

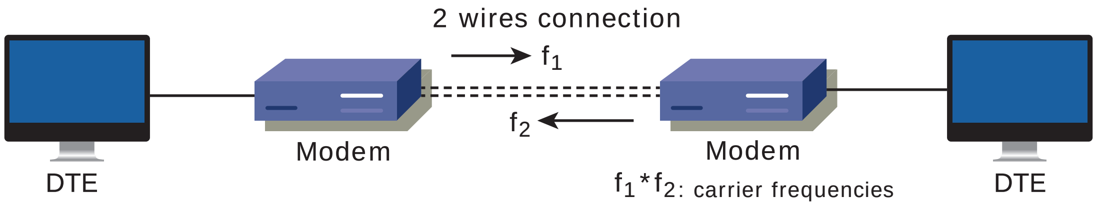


FIGURE 2.13 2-Wire Modem

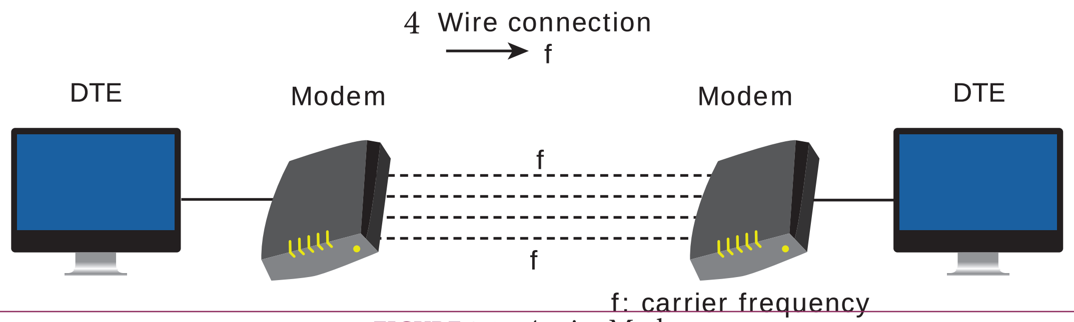


FIGURE 2.14 4-wire Modem

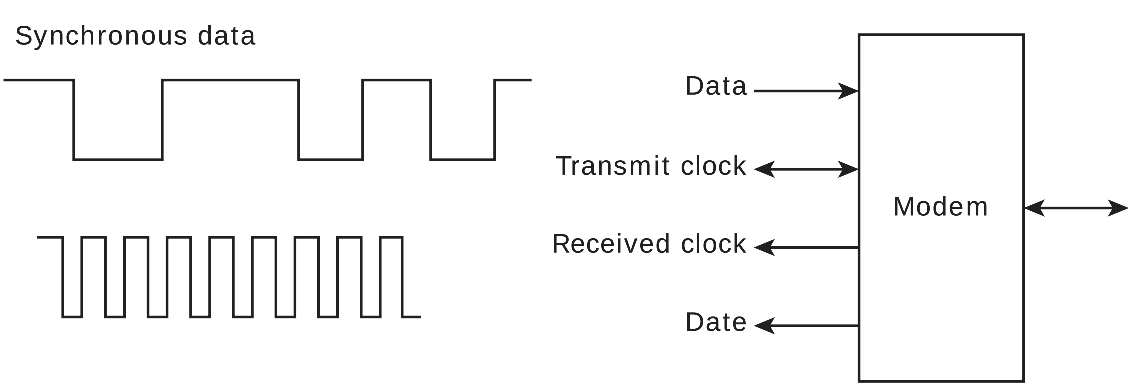


FIGURE 2.15 Synchronous Modem

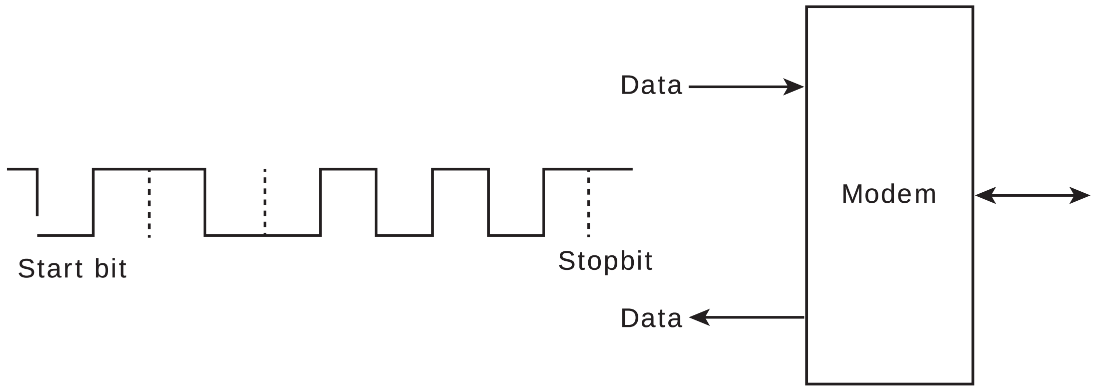


FIGURE 2.16 Asynchronous Modem

2.8.2.6 Asynchronous Modem

Figure 2.16 shows the Asynchronous modem. Asynchronous modem can handle data bytes with start and stop bits. There is no separate timing signal or clock between the modem and the DTE. The internal timing pulses are synchronized to the leading edge of the start pulse.

2.8.2.7 Applications of Modem

Modems were originally used for connecting users to the internet or for sending faxes, but a majority of modems in use today are used by businesses in a variety of different applications. Some of these applications include data transfers, remote management, broadband backup, point of scale, machine to machine among many others.

2.9 Antenna

An antenna is a transducer that converts Radio Frequency (RF) signal into electrical signal or electrical signal into radio Frequency signal. Antennas are used for both the purpose of transmitting and receiving. Antennas play an important role in the communication system. They are designed for different applications, with different materials, structures for better communication.

Antennas are essential components of all radio equipment, and are used in Radio broadcasting, Television broadcasting, Two way radio, Communication receiver, Radar, Satellite communications and other devices.

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 Antena Gain

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

Gain (G) = power radiated by an antenna/ 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 polorarized 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.

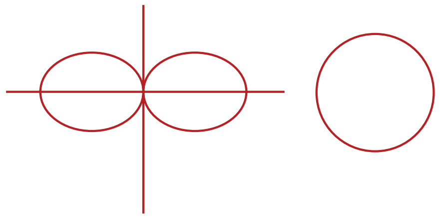


FIGURE 2.17 Polar antenna

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".

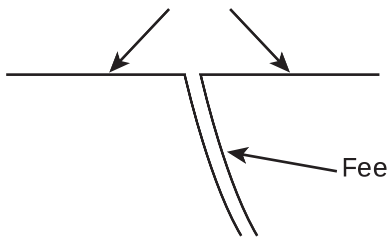


FIGURE 2.18 Dipole antenna

   The different types of dipole antennas are such as half wave dipole antenna, multiple half wave dipole antenna, folded dipole antenna, short dipole antenna, non resonant dipole and so on.

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.

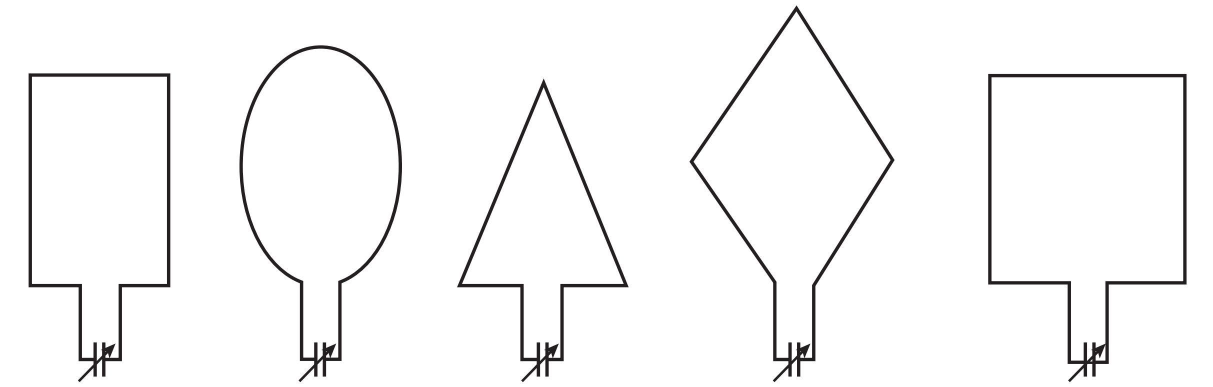


FIGURE 2.19 Loop antenna

3. Folded dipole antenna

A folded dipole is a dipole antenna with the ends folded back around and connected to each other, forming a loop as shown in figure 2.20.

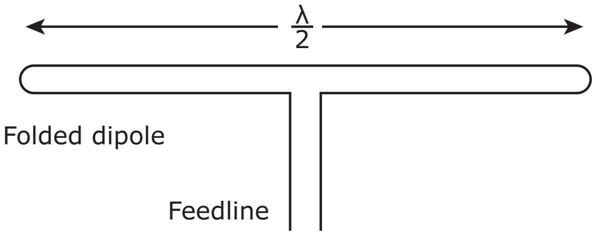


FIGURE 2.20 Folded Dipole

Typically the width of the folded dipole antenna is much smaller than the length 'l'. One of the main reasons for using a folded dipole antenna is the increase in feed impedance that it provides.

4. Yagi Uda antenna

A Yagi Antenna is the most commonly used type of antenna for TV reception. It is the most popular and easy to use type of antenna with better performance which is famous for its high gain and directivity.

The frequency range in which yagis antennas operate in around 30 GHz which belong to the VHF and UHF bands.

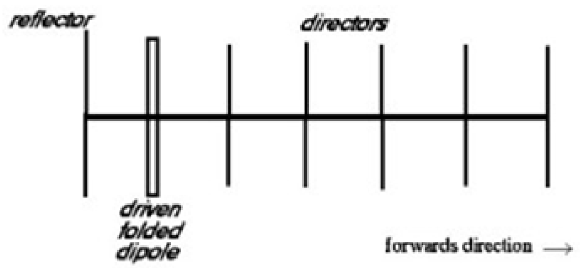


FIGURE 2.21 Yagi Uda antenna

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

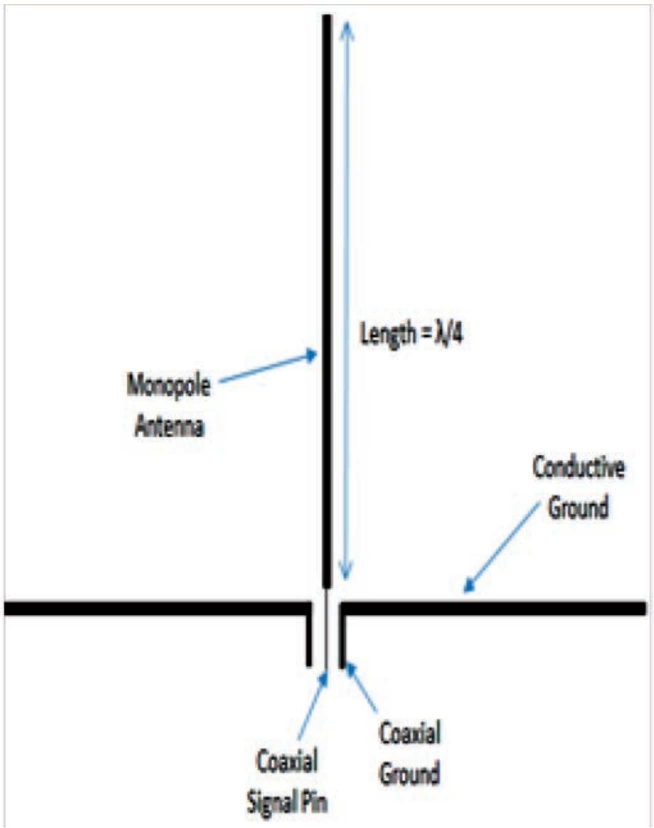


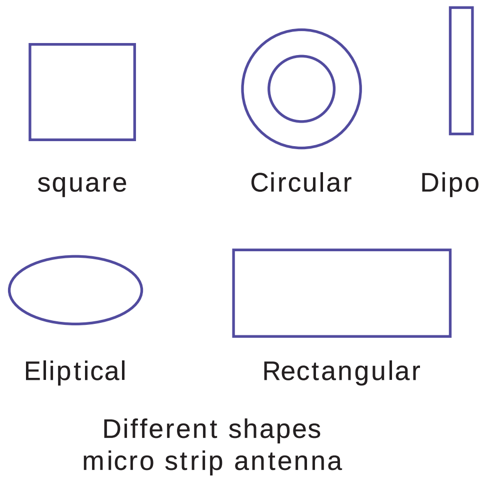
FIGURE 2.22 Monopole antenna

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 micro wave frequencies. It is a narrow



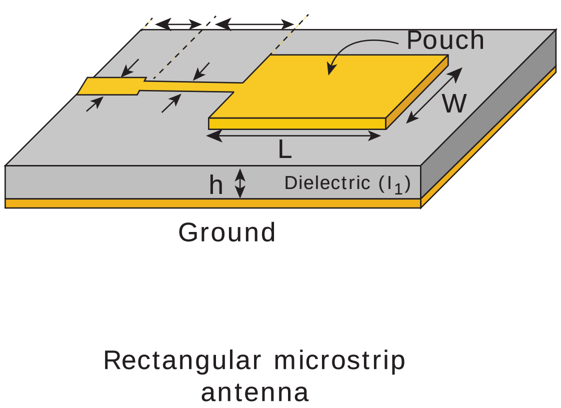


FIGURE 2.23 Microstrip antenna

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 broad cast 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

FIGURE 2.24 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.

FIGURE 2.25 Discone antenna

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 uses as antennas at UHF and microwave frequencies above 300MHz. Figure 2.26 shows different horn antenna.

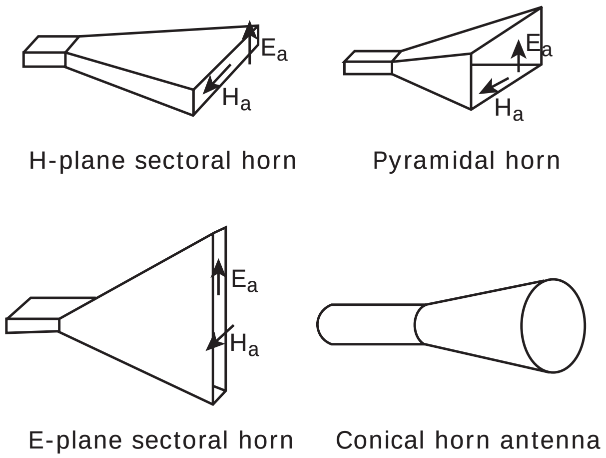


FIGURE 2.26 Horn antenna

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

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

QUESTIONS

Part – A (1 Mark)

I Choose the correct answer

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. 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 the necessity for detection?
3. Differentiate Analog and Pulse Modulation?
4. Explain Yagi Uda antenna.

Part – D (10 Marks)

IV Answer in One Page (Essay type Question)

1. Explain about Amplitude and Frequency Modulation?
2. Explain
   i. Pulse Amplitude Modulation
   ii. Pulse Width Modulation
3. Briefly explain any two types of Modem.

Answers

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

CHAPTER 3

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

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CONTENT

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.

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.


James Clerk Maxwell


Heinrich Rudolf Hertz

DO YOU KNOW?

Initially, radio waves were called as hertzian waves.

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.

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.

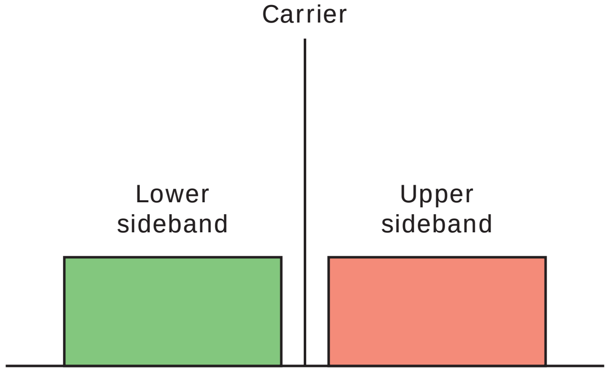


FIGURE 3.1 Modulated carrier showing sidebands in either side of the carrier

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).

3.2.1 Single sideband transmission (LSB)

It is a type of transmission which uses carrier signal with any one of the sidebands (usually USB) is called as single side band transmission. The other sideband is filtered. It uses lesser bandwidth. As a result, the power requirement for transmission is less.

3.2.2 Double sideband transmission (DSB)

It is a type of transmission which uses carrier signal with both of the sidebands (LSB & USB) is called as double side band transmission. It uses high bandwidth and hence needs more power to transmit. It is used in AM and FM transmission.

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.

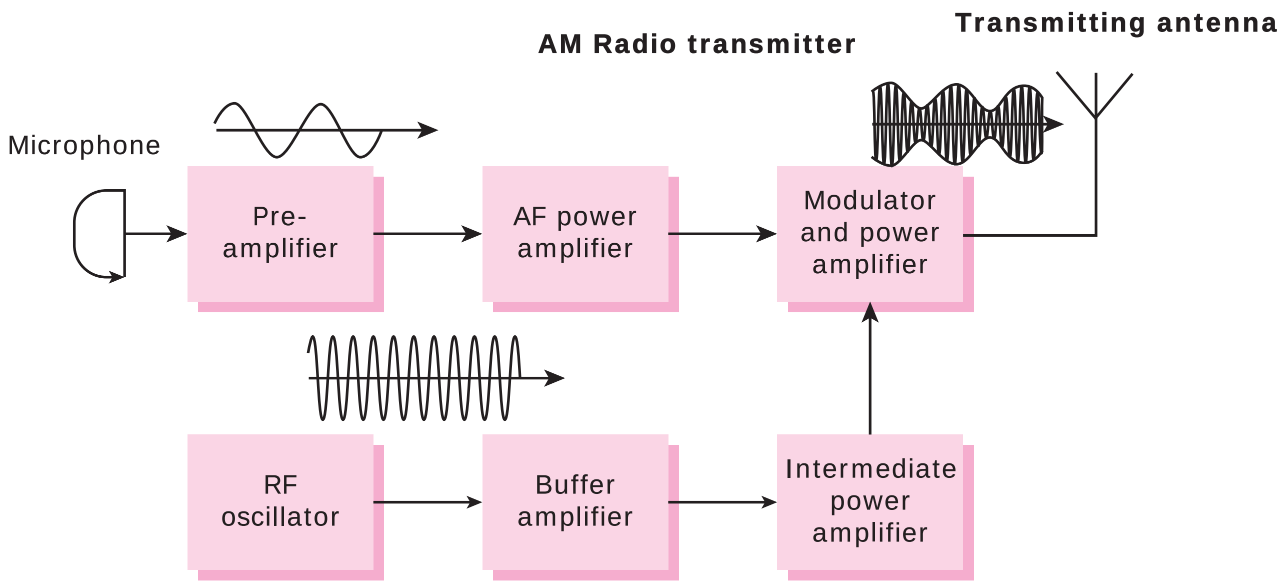


FIG 3.2 Block diagram of AM Radio transmitter

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.

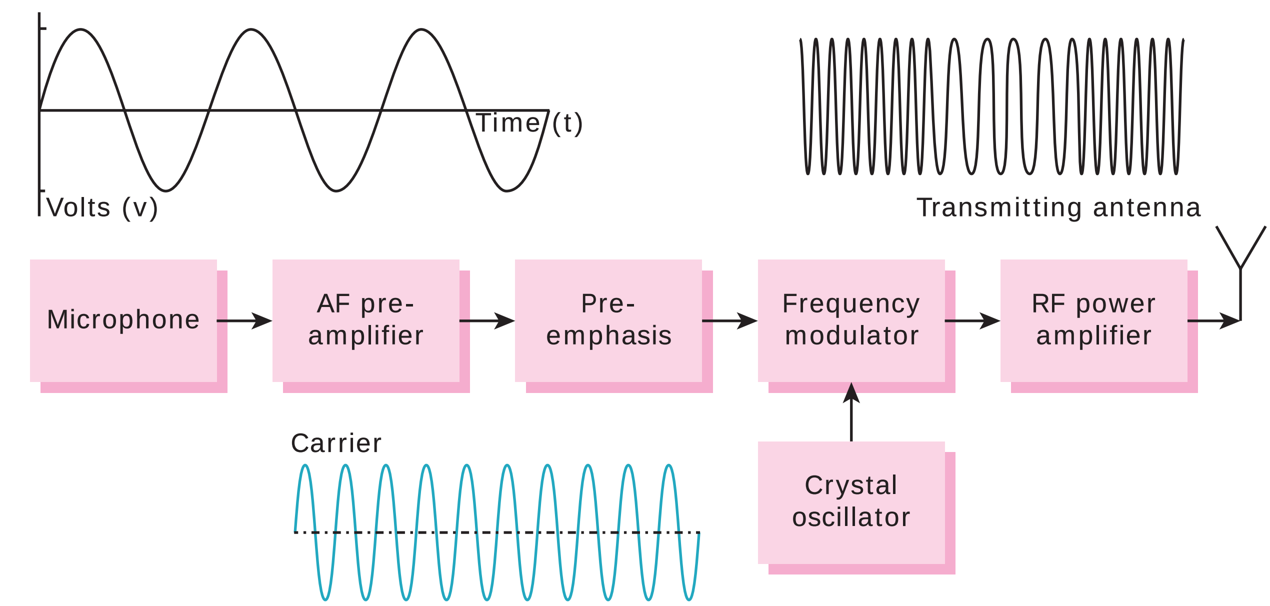


FIGURE 3.3 Block diagram of FM Radio transmitter

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

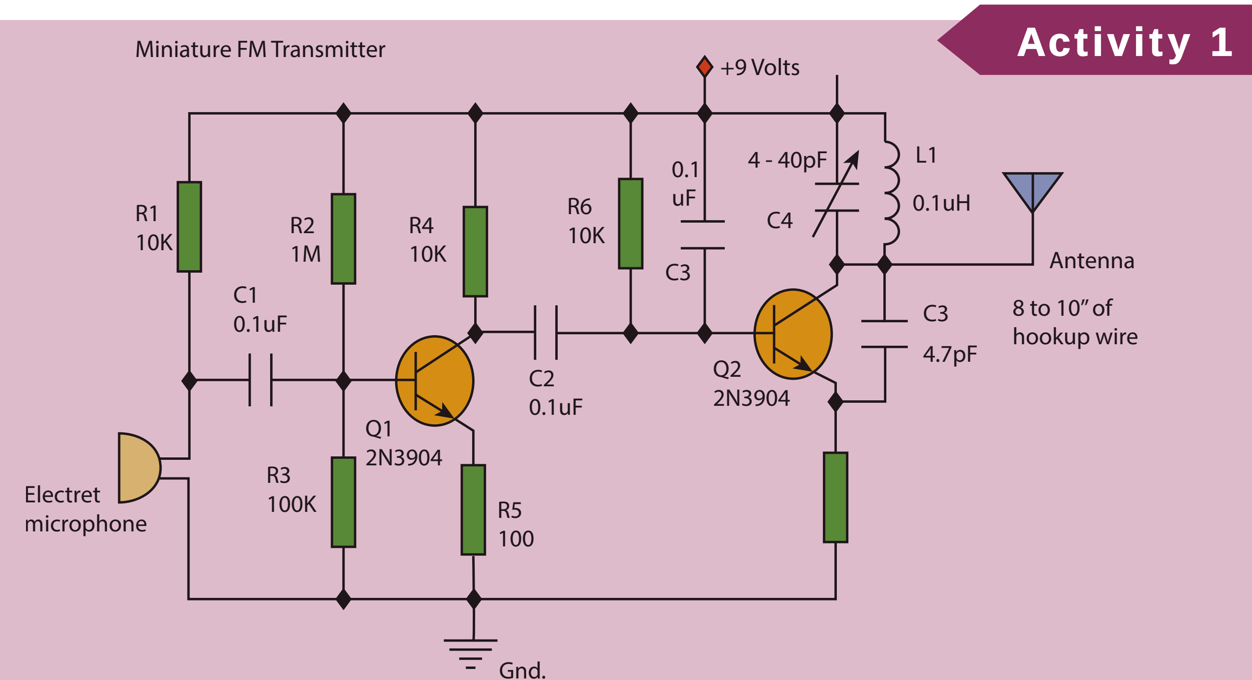


FIG 3.4 Low power FM transmitter

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

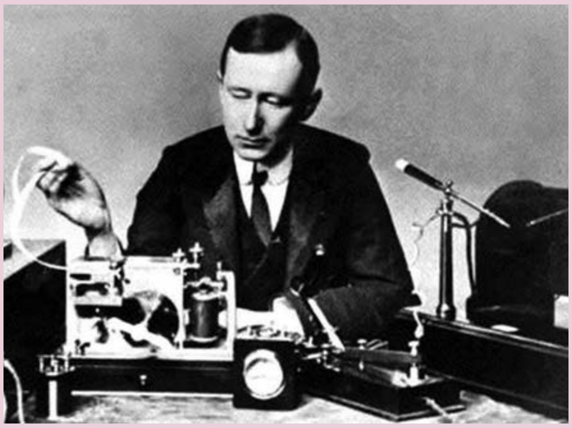
3.5 Radio Receiver

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

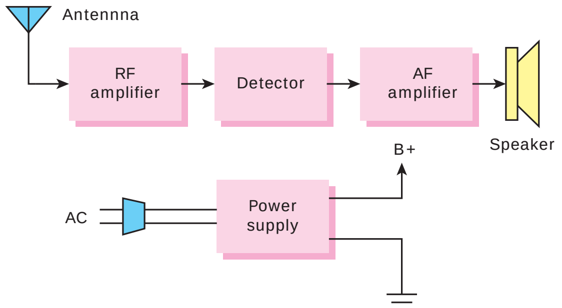


FIG 3.5 TRF radio receiver

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

> DO YOU KNOW? **TRF receiver is also called as straight radio receiver.**

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.

> DO YOU KNOW? **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.
>
> 
>
> Major Edwin Howard Armstrong

Ganged Capacitors

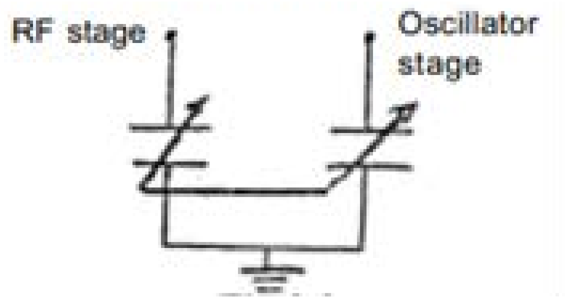


FIG 3.6 Ganged capacitors

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 Superhetrodyne Receiver

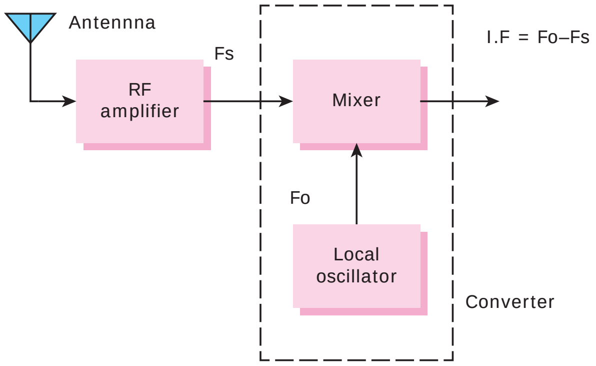


FIGURE 3.7 Block diagram explaining super heterodyning principle

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.

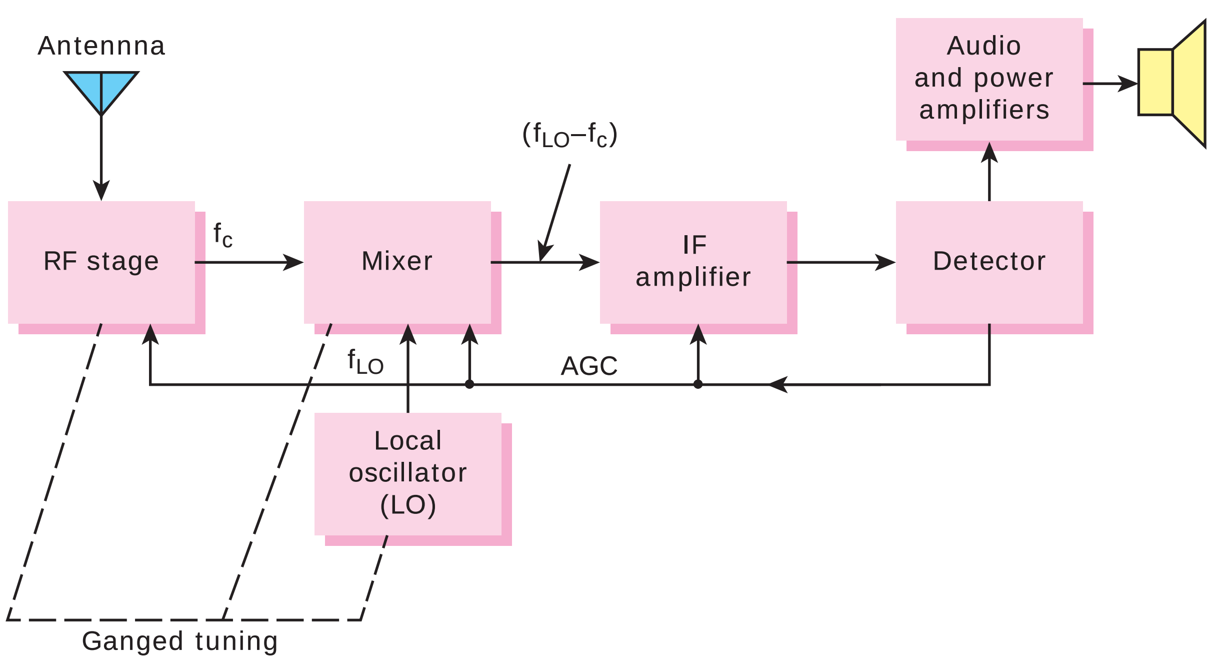


FIG. 3.8 Block diagram of AM radio receiver

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.

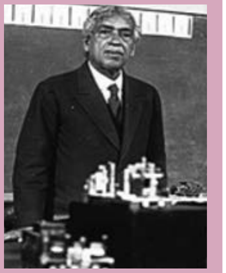
Detector

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.

DO YOU KNOW?

Sir Jagadish Chandra Bose

Crystals were first used as a detector of radio waves in 1894 by Sir Jagadish Chandra Bose.He was born in Munsiganj, Bengal Presidency (now Bangladesh), during British governance of India. Bose graduated from St. Xavier's College, Kolkata. **Sir Jagadish Chandra Bose** invented the Mercury Coherer (together with the telephone receiver) used by Guglielmo Marconi to receive the radio signal in his first transatlantic radio communication.



Sir Jagadish Chandra Bose

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.

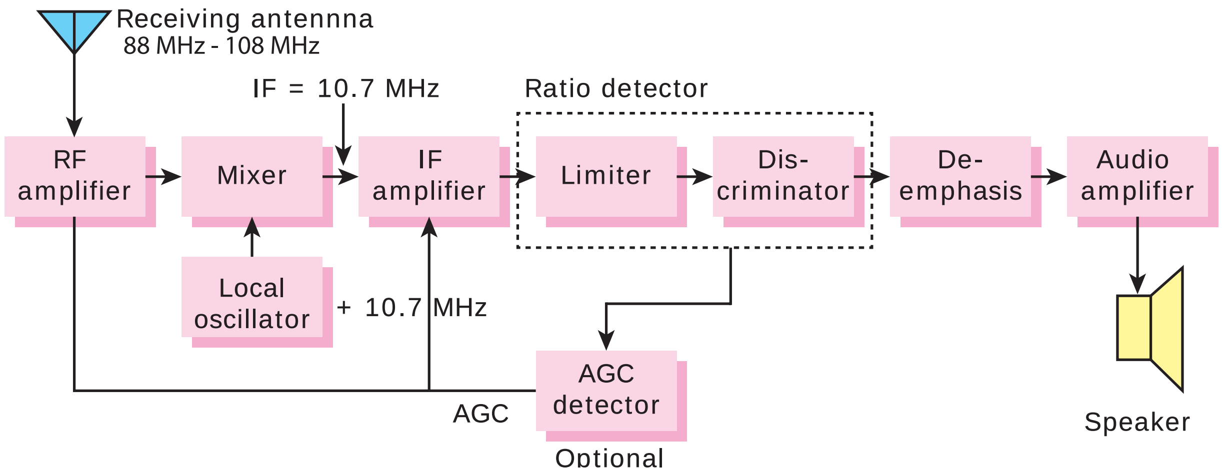


FIG 3.9 FM receiver Block diagram

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

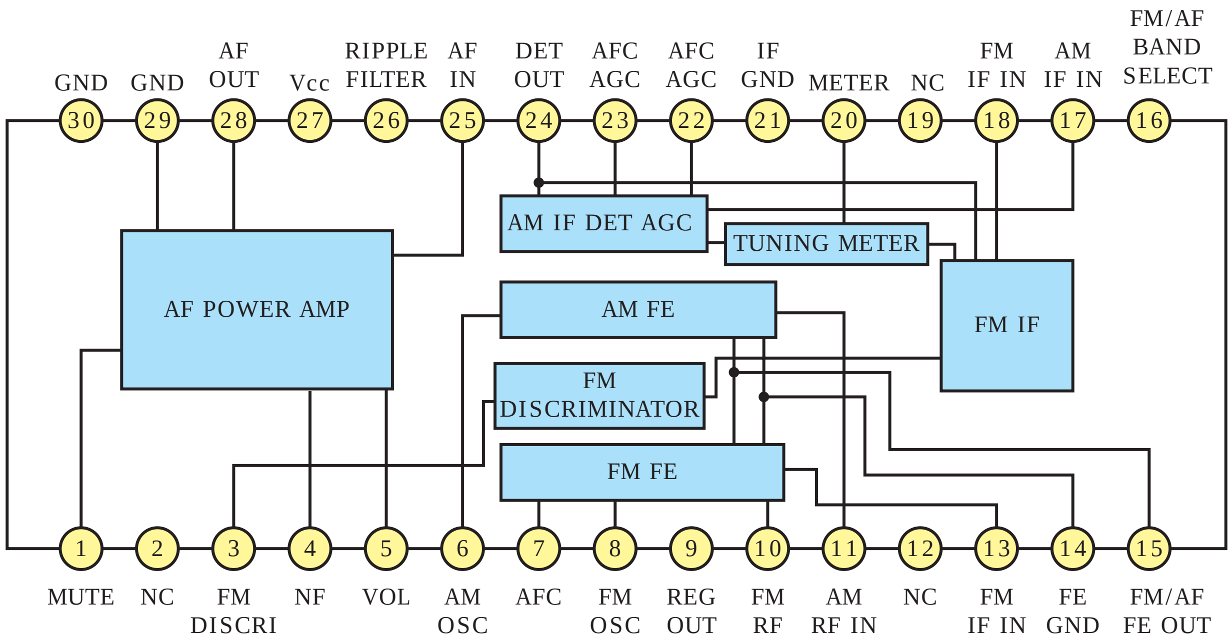


FIG 3.10 Internal construction of CXA 1619 with AF amplifier

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.

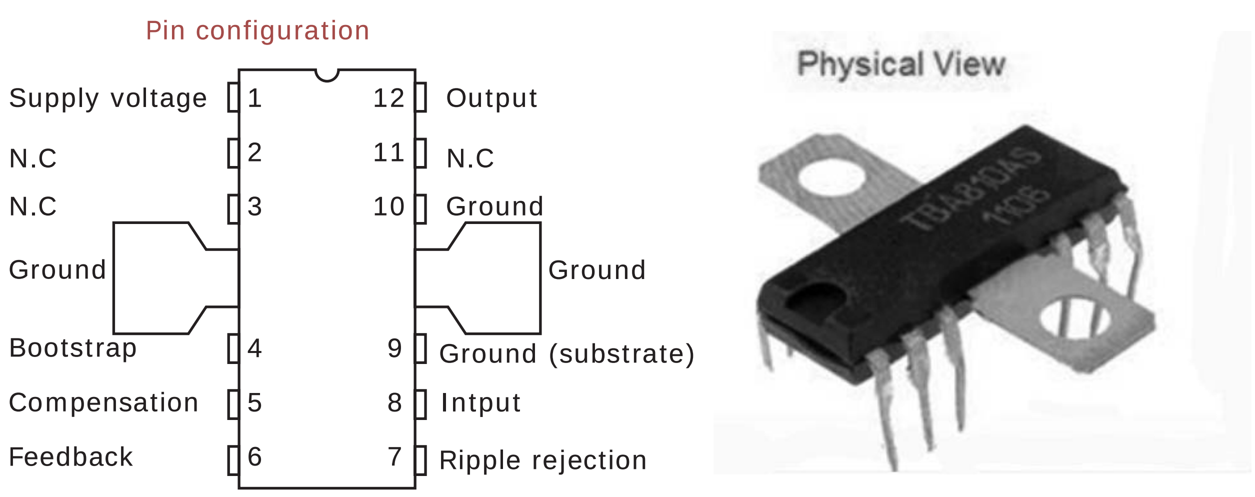


FIGURE 3.11 Internal construction of audio IC TBA 810 / CA 810

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 form 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 3.1 Comparison between AM and FM Receiver

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

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

Double Conversion

If two different IFs are used in a receiver, it is said to be Double conversion. It is used in communication receivers.

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.

Uses of Communication receivers

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

3.6.7 Digital audio broadcasting (DAB)

FIG 3.12 DAB radio receiver

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.

3.6.8 Satellite radio receiver

FIGURE 3.13 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.
4. Defective 2nd B+ 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.

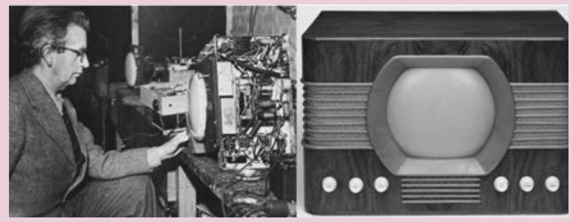
DO YOU KNOW? Initially, television was called as televisor.

Television comprises of the following three activities:

1. Capturing Pictures—Camera
2. Recording and Transmission
3. Reception or Reproduction

We discuss about these concepts in the following Sections.

HISTORY OF TELEVISION



J.L.Baird

CF Jenkins

V.K.Zworykin

T.Farnsworth

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 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.

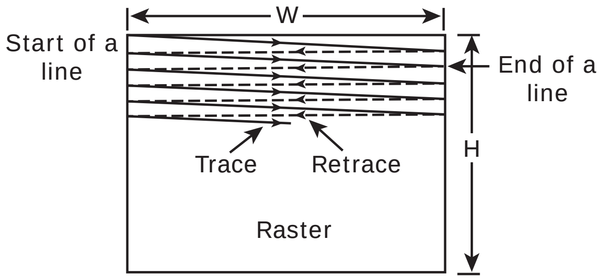


FIGURE 3.14 Scanning

Just like the same, in television, 15625 scanning lines are divided into 25 picture frames. Therefore, one frame consists of 625 (15625/25) scanning lines. Hence, as we seen earlier for a complete action picture, we need $(25 \times 625) = 15625$ scanning line. The electron ray moving from left to right and right to left is called as horizontal scanning and the ray moving from top to bottom and bottom to top is called vertical scanning.

During scanning there are two important points are worth noting.

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

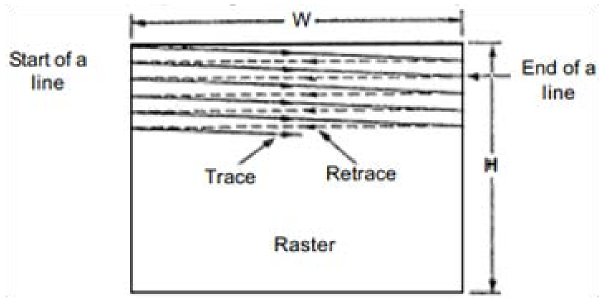


FIGURE 3.15 Sequential Scanning Or Progressive Scanning

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 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 bean 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.

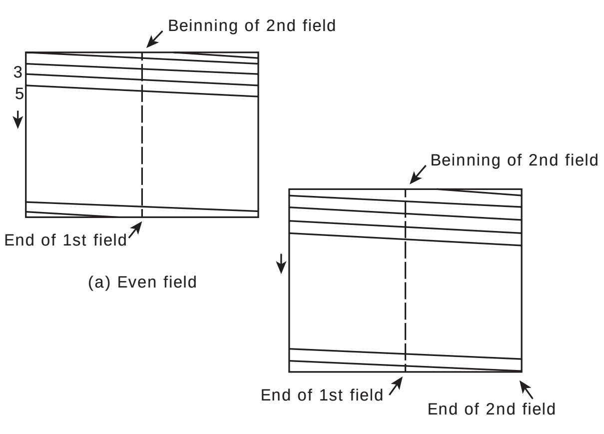


FIG 3.16 Odd and Even fields of interlaced scanning

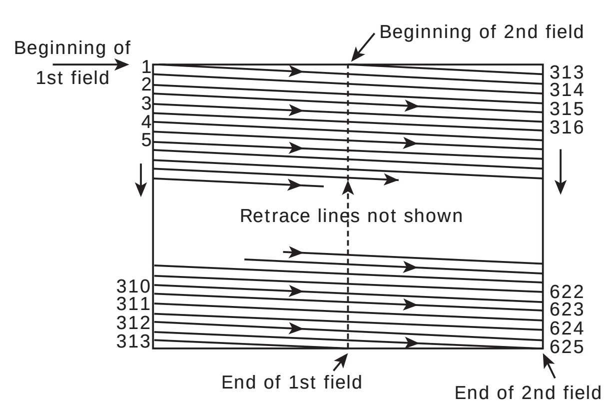


FIG 3.17 Interlaced Raster (Full frame)

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 phospor stripes and makes primary and secondary colours as shown in Figure 3.18.

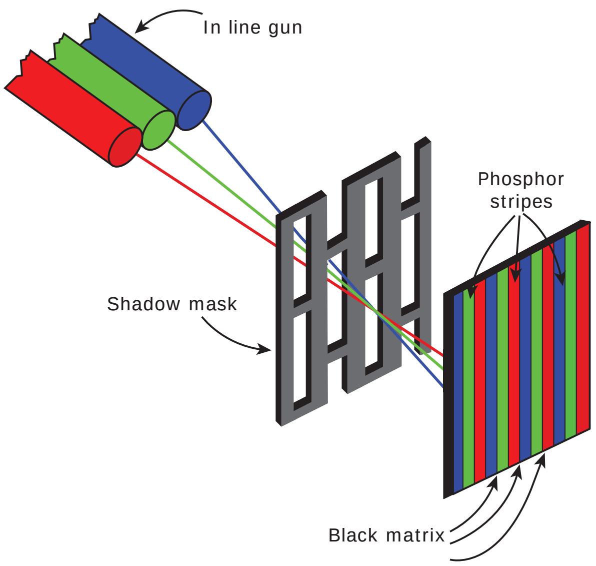


FIGURE 3.18 Colour Picture Tube Technology

DO YOU KNOW? 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 3.19.

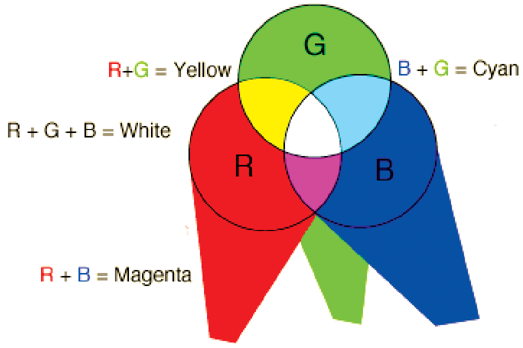


FIGURE 3.19 Additive mixing

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 3.20.

White – Blue – Green = Red

White – Green = Magenta

White – Green – Red = Blue

White – Blue = Yellow

White – Blue – Red = Green

White – Red = Cyan

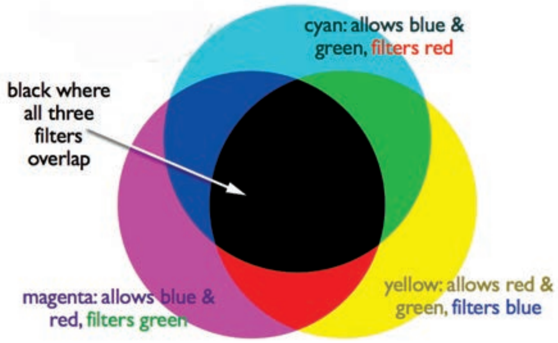


FIGURE 3.20 Subtractive mixing

Color matrix and color burst circuits are used for the mixing of colors.

Hue

It is defined as the shade of color, i.e., red or green or blue.

Saturation

It is defined as the intensity of color, i.e., high saturation of red is nothing but dark based (thick) red and low saturation of red is dull red.

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).

DO YOU KNOW? Gray scale means black, white and gray signals.

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 3.21 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 3.22 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

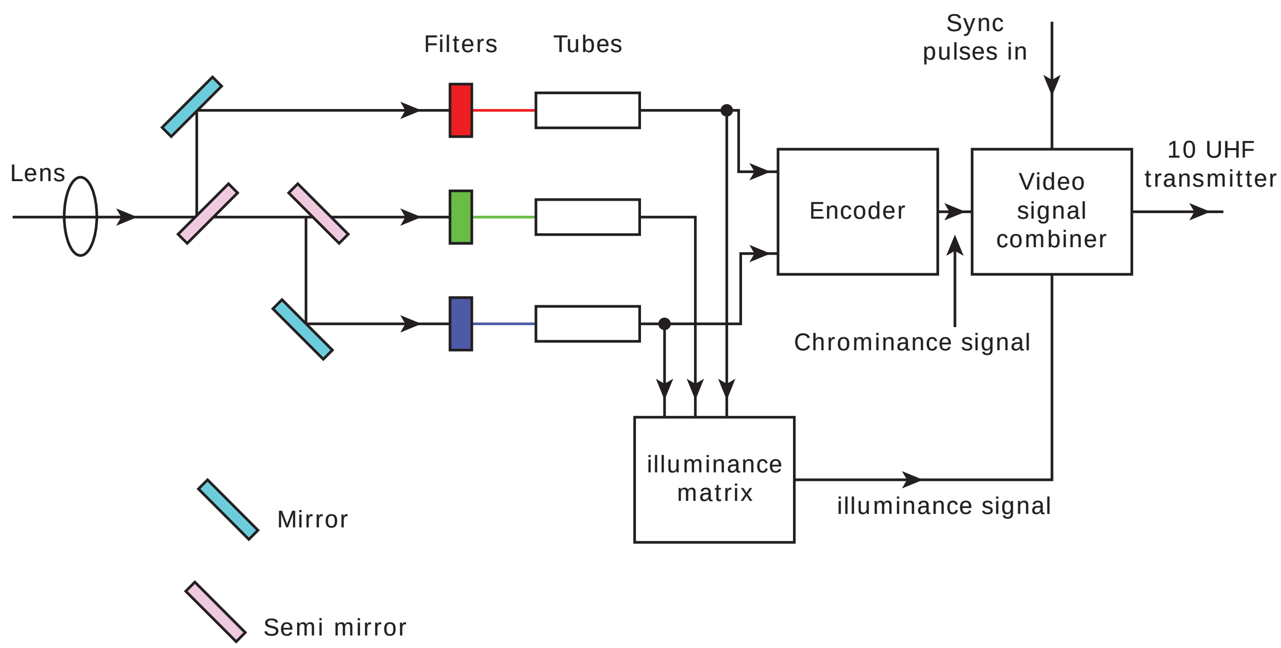


FIG 3.21 Working Principle of Colour Camera Tube

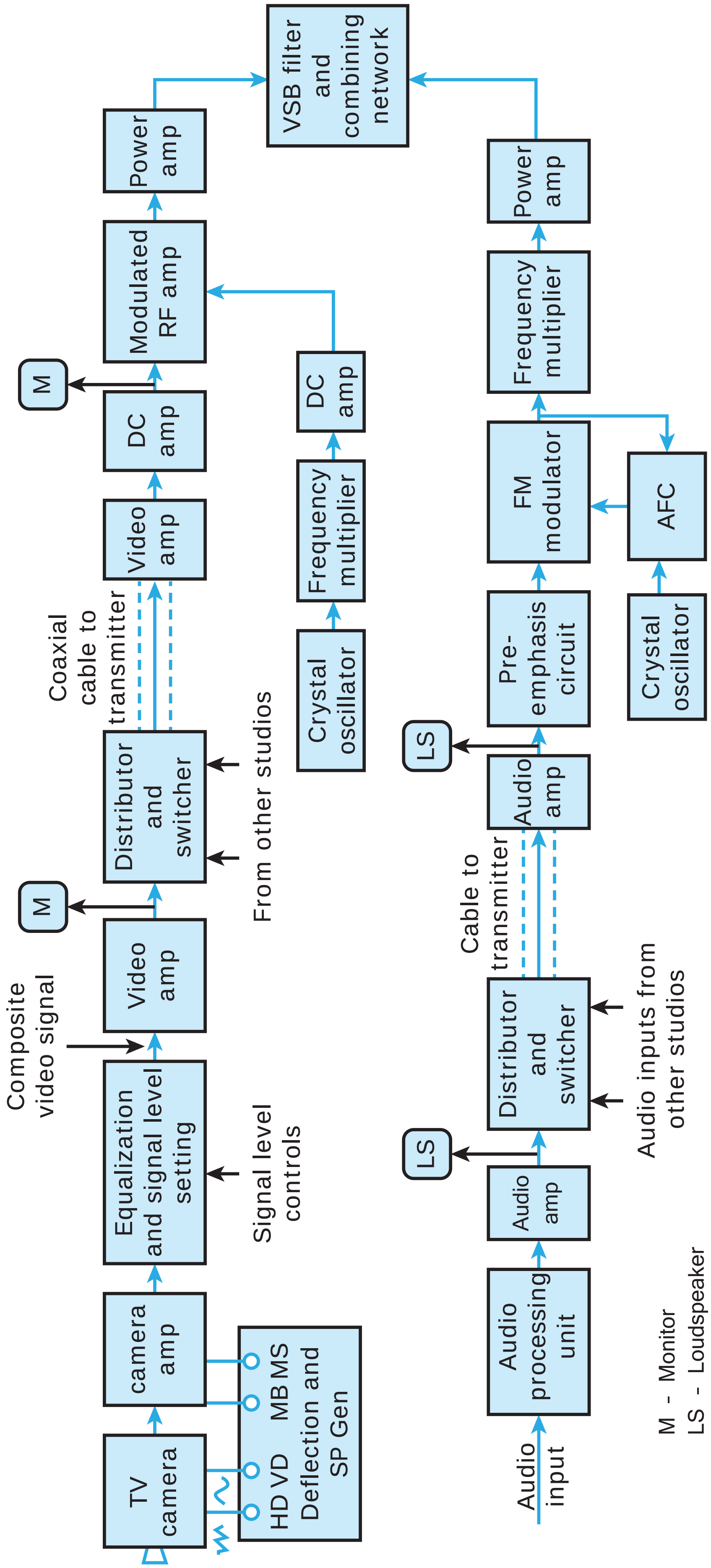


FIGURE 3.22 TV Transmitter block diagram

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)

PAL encoder

Figure 3.23 shows 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.

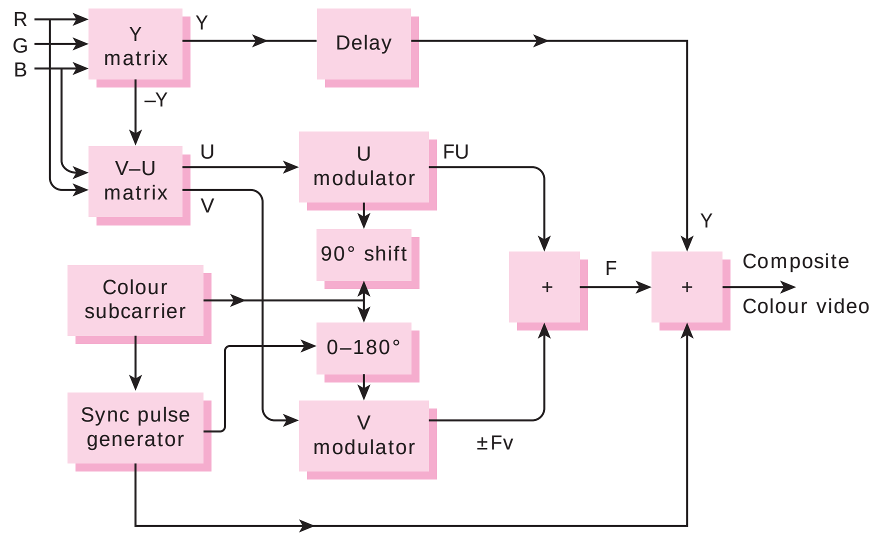


FIG 3.23 Phase Alternation by Line encoder (PAL encoder)

PAL Receiver

Figure 3.24 shows the block diagram of the PAL receiver. The functions of each component is briefly elucidated here.

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.

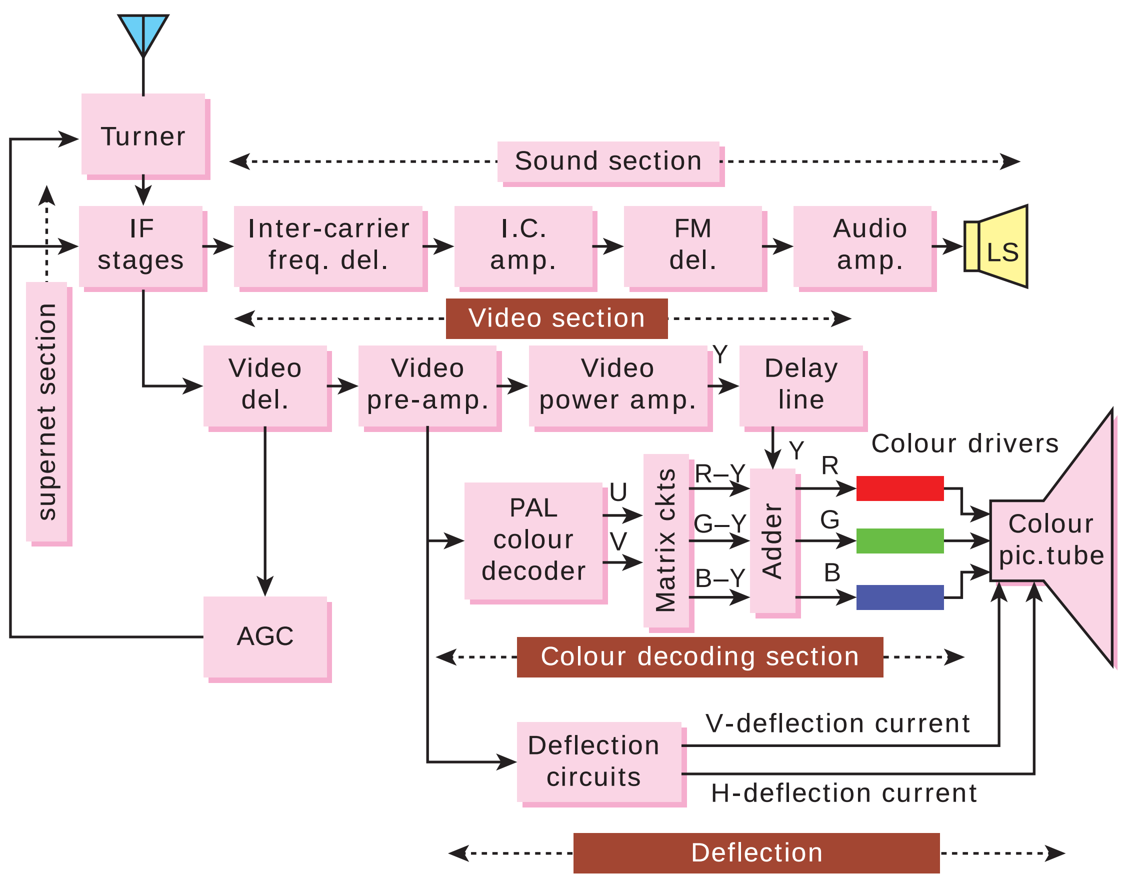


FIG 3.24 Block diagram of PAL receiver

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.

PAL decoder

Figure 3.25 shows the PAL decoder section. Here, Y signal is separated from CCVS, amplified, delayed and fed to the RGB matrix circuit. U and V (colour difference signals) are detected using sub-carrier signals and 64 μs delay and phase reverse switch and fed to the matrix circuit. R-Y, G-Y and B-Y signals are fed from the matrix circuit are given to the RGB matrix. After processing with Y signal, R, G and B signals are obtained.

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.

3.12 LCD (Liquid Crystal Display) Receivers

Figure 3.26 shows Modern colour TV receivers use LCD screens instead of Cathode ray tube 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.

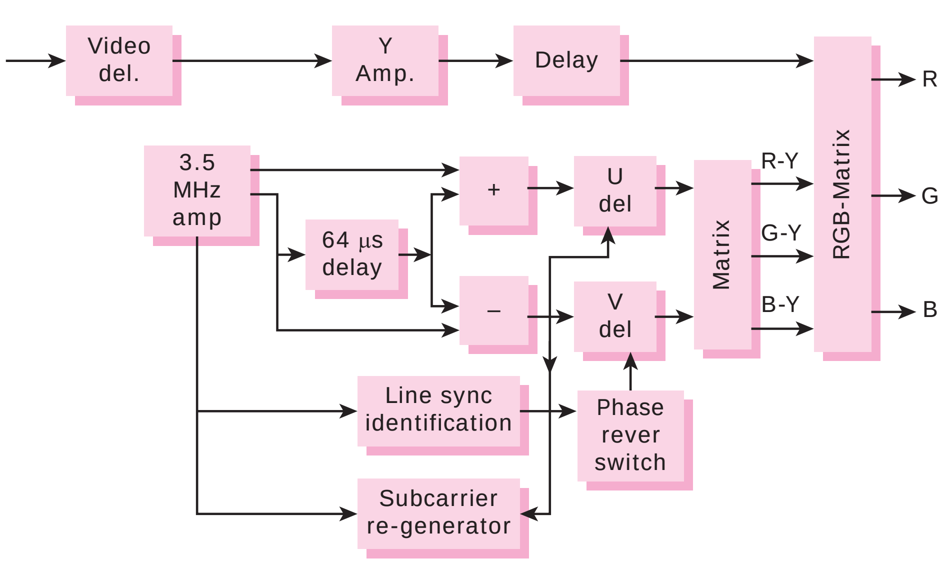


FIGURE 3.25 PAL decoder

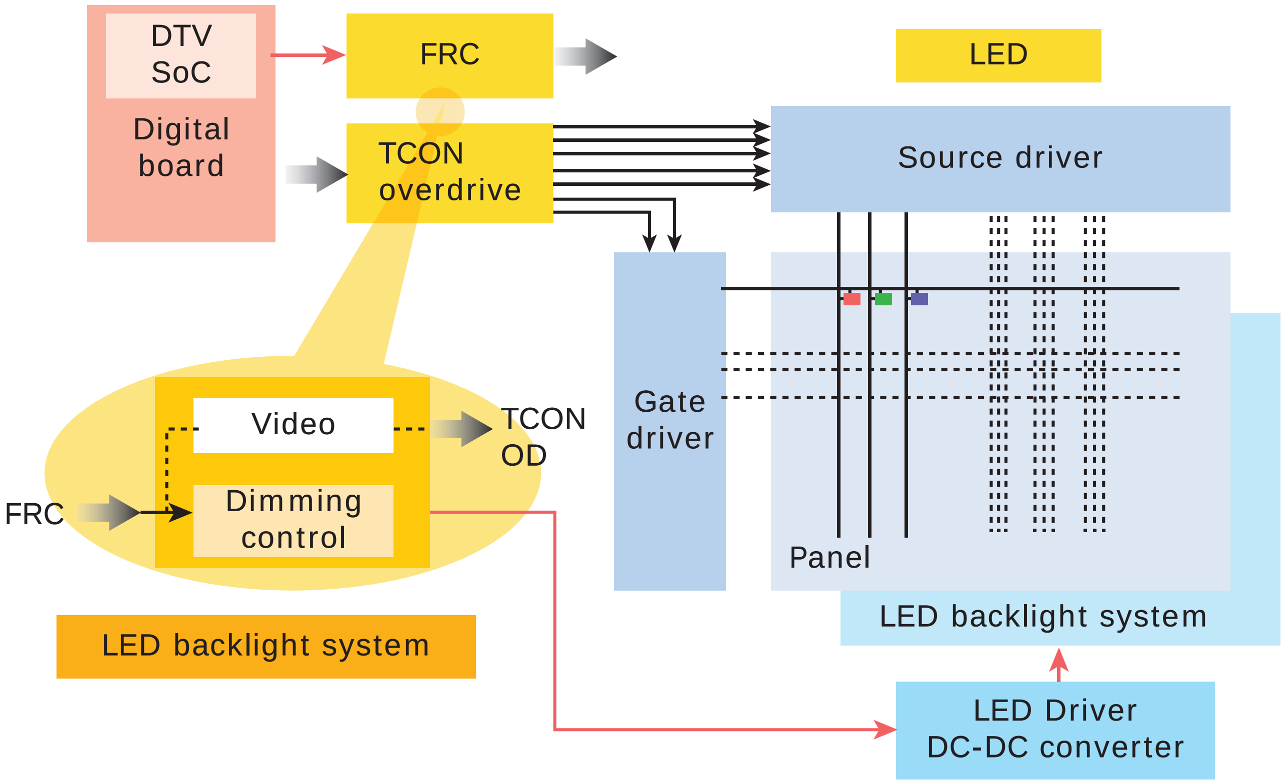


FIG 3.26 Block diagram of LCD display

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.

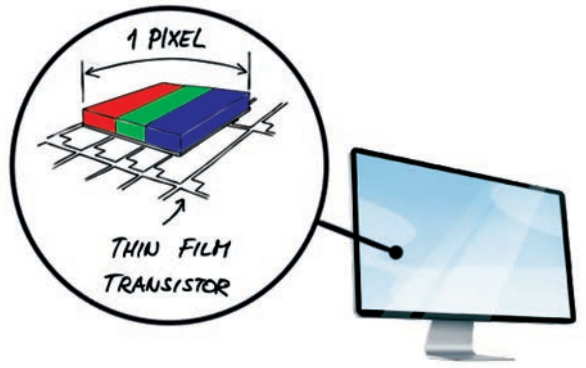


FIGURE 3.27 A single thin film MOSFET to illuminate a single pixel (dot)

TCON is Timing control circuit. TCON controls the Gate of MOSFET. Dimming control controls the LED driver to enable the brightness variation in scenes. TCON drives the gate of MOSFET in time, to get the sub pixel R or G or B or to be illuminated. Figure 3.28 shows the block diagram of an LCD screen.

Backlight

There are two main types of backlights used in LCD screens: CCFL and LEDs.

LCD panel with CCFL backlight (LCD TV)

If a CCFL (cold-cathode fluorescent lamp) backlit the LCD screen then, the type of TV receiver is called as LCD TV. In this type, backlight is given using a series of fluorescent tubes placed behind the screen as shown in Figure 3.28. These tubes are very similar to the fluorescent lamps (tube lights) used almost everywhere, but smaller in size. An inverter circuit is used to illuminate the CCFL.

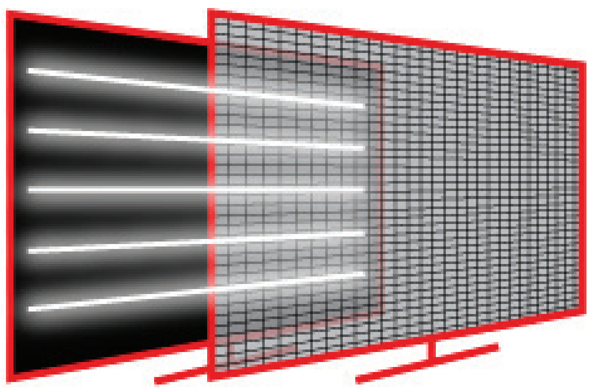


FIG 3.28 LCD panel with CCFL backlight

3.13 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 3.29. 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

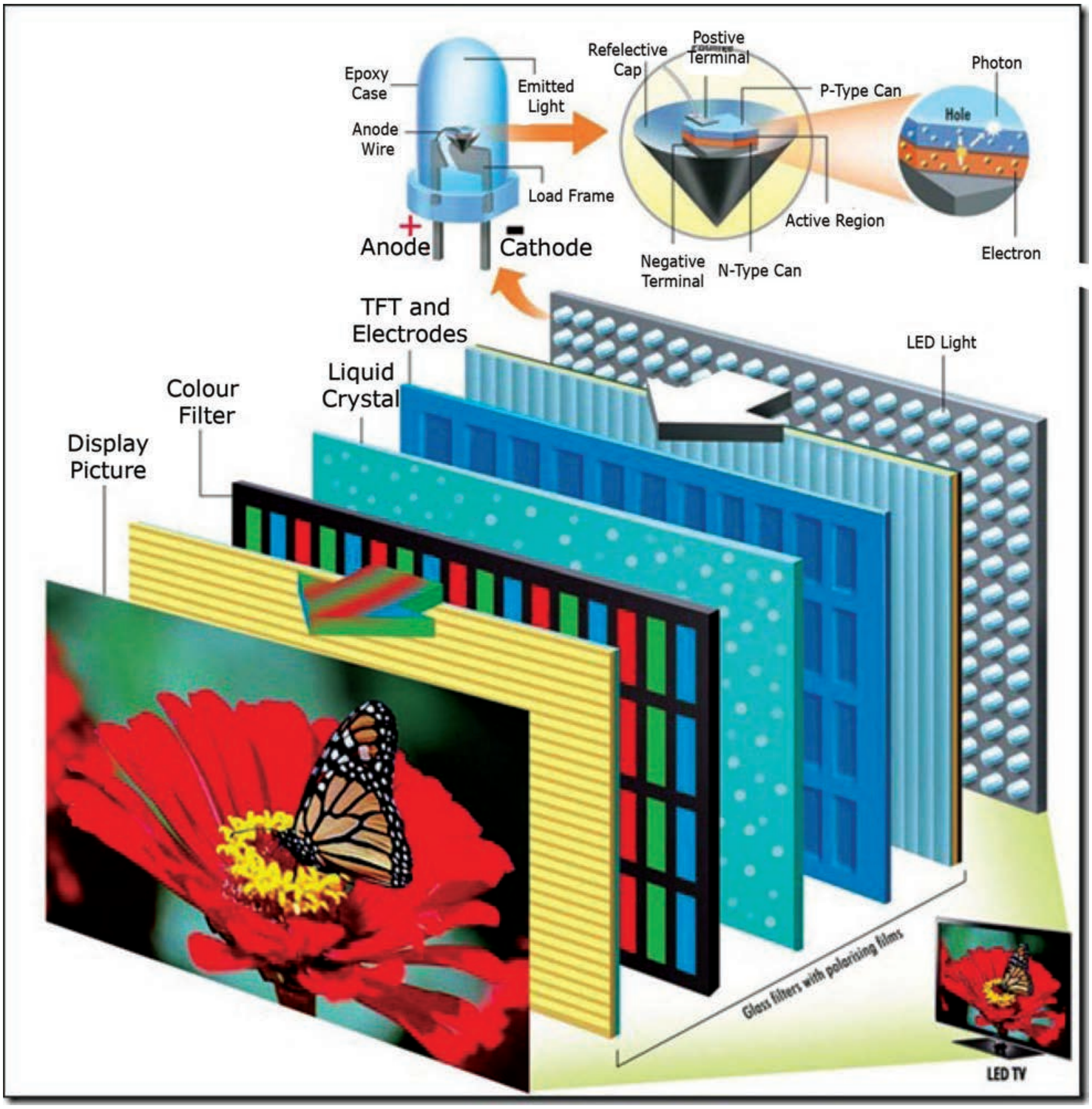


FIG 3.29 LCD Panel with Led Backlight

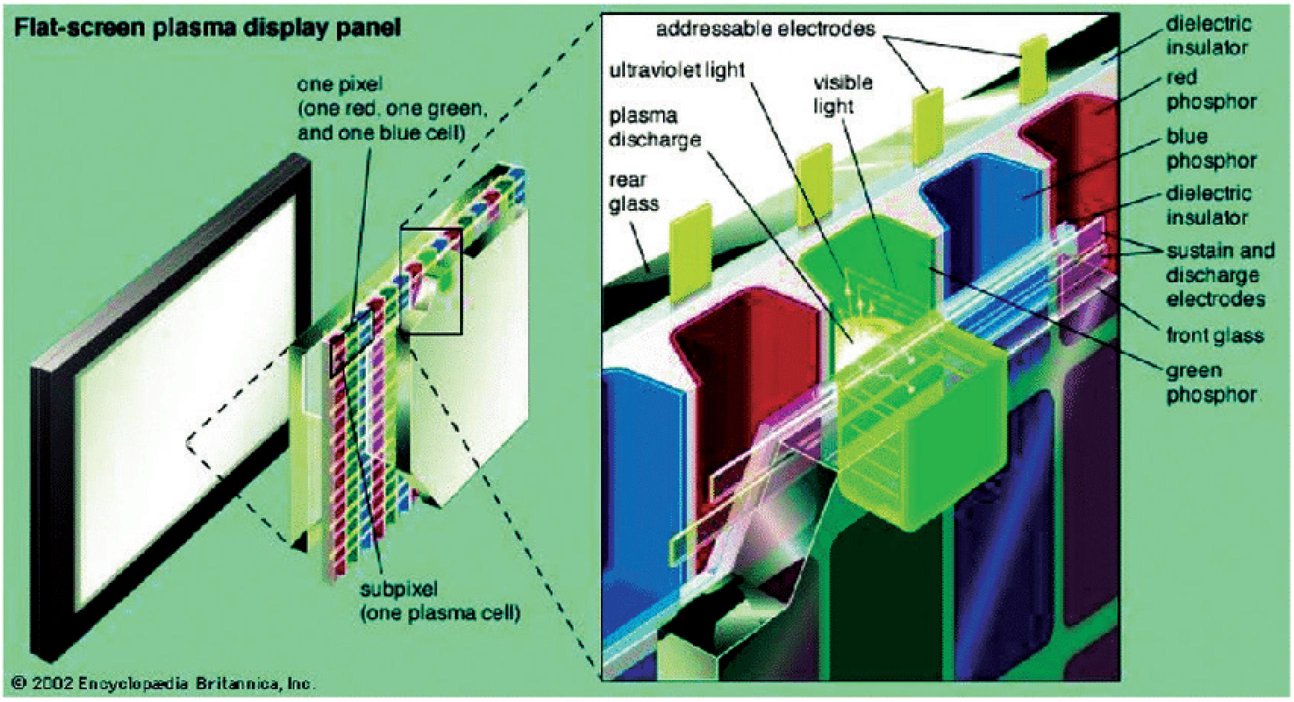


FIG 3.30 Plasma display

common to large TV displays of 30 inches (76 cm) or larger as shown in Figure 3.30. 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.

3.13.1 Quantum LED screen (Q LED)

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 colours are spread on a piece of film that acts almost as a filter within an LED TV panel as shown in Fig 3.31. 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.

3.13.2 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.

Resolution of modern LED TV receivers

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

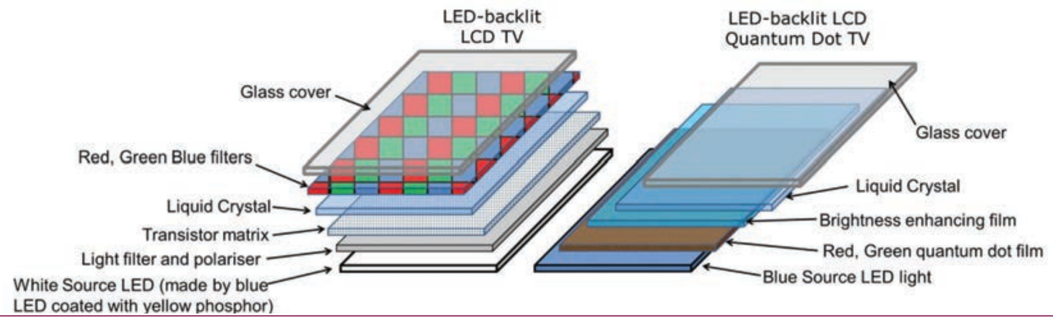


FIGURE 3.31 QLED TV Display

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.

Standard definition: A picture is divided into rows and columns. A picture with 640 rows × 480 columns is called as Standard definition.

This method contains 640 × 480 = 307200 pixels.

FIG 3.32 OLED display

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

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

QUESTIONS

Part – A (1 Mark)

I. 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
   (c) 100 kHz – 1000 kHz
   (d) 200 kHz – 200 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. Each pixel consists of ______ sub pixels

(a) One (b) Two
(c) Three (d) Four

13. How many MOSFETs are used in an LED TV screen approximately?

a) 1000 b) 10
c)100 d) 10,00,000

14. In a 8 bit LED TV, Red colour signal is converted into _____ digital signals.

a) R_0 to R_7
b) R_0 to R_1
c) R_0 to R_2
d) R_O to R_3

15. CCFL means

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

16 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. Define: VSB transmission.
3. What are the basic principles of radio receiver?
4. What is double conversion?
5. What are the advantage and disadvantage of digital audio broadcasting?
6. Give two reasons for hum in receiver
7. What is meant by scanning?

8. Write any three types of camera tube
9. What is resolving power?
10. What are the three types of resolution of High definition LED TV systems?

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 Superhetrodyne receiver.
4. Write the difference between AM and FM receiver.
5. Explain the construction of Q LED screen.

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. write note on
   i. Resolution of Modern LED TV
   ii. Servicing of LED TV receivers

ANSWERS

1. (a)	2. (a)	3. (c)	4. (c)	5. (d)	6. (a)
7. (c)	8. (b)	9. (b)	10. (d)	11. (a)	12. (c)
13. (d)	14. (a)	15. (c)	16. (b)		

CHAPTER 4

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

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.

DO YOU KNOW?

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

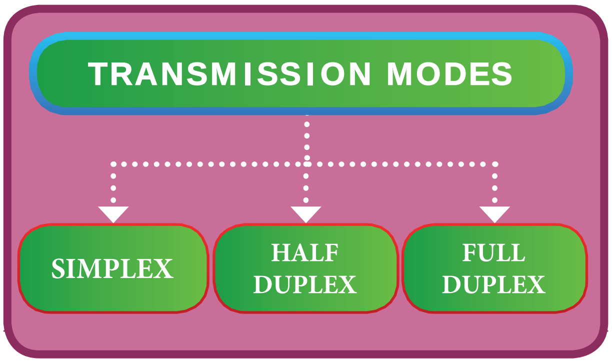


FIGURE 4.1 Different Mode of Transmission

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.

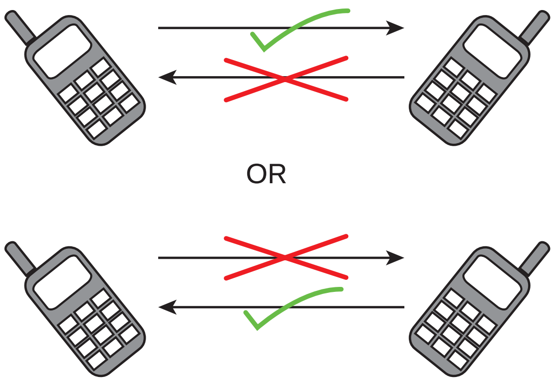


FIGURE 4.3 Half Duplex Transmission mode

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

DO YOU KNOW?

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

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-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

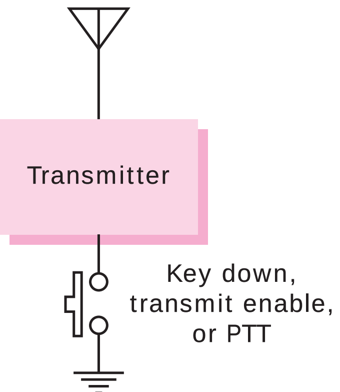


FIGURE 4.4 Typical control of Transmitter

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.

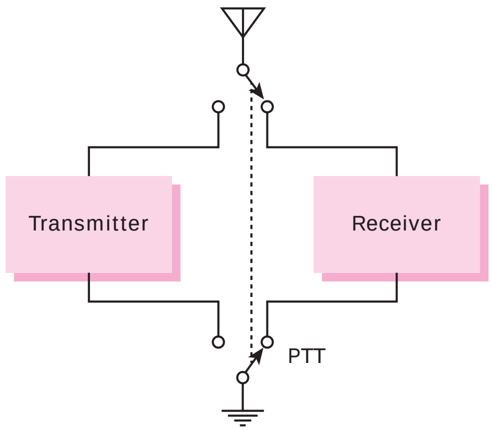


FIGURE 4.5 Typical control of Transceiver.

PTT refers to "Press-To-Talk" or "Push-To-Talk". When the PTT button is pressed, the receiver is disabled and the transmitter is keyed-on, and audio is presented to the transmitter as FM modulated signal. PTT is the three ways toggle switch and with the advent of miniaturization, it is modified by combining the PTT line with audio thus eliminating a wire.

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 driver 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.

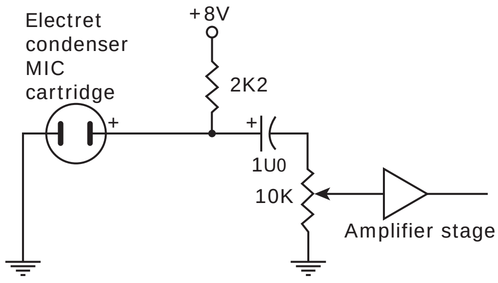


FIGURE 4.6 Electret Condenser using circuit.

The bias voltage applied to the microphone input jack is fed back to the voice coil, which actually offset or "move" the diaphragm slightly but may not have 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.

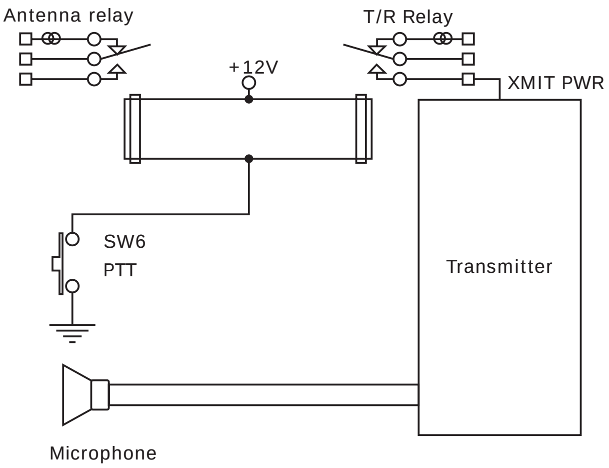


FIGURE 4.7 Hand-held PTT circuit

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.

The circuit shown in Figure 4.8 is an FM type transceiver. When the PTT button is pressed, the circuit is closed and the audio/control line voltage between R1 and R2 drops from the power supply level to a voltage of approximately 2 to 5 volts. The transistor Q1 senses this drop, thereby switches on and activates the relay K1, which in turn activates the transmitter. Audio is varied on the same line and is amplified and fed to the modulation circuit of the transmitter. Capacitor C_1 blocks the DC voltage to the next stage.

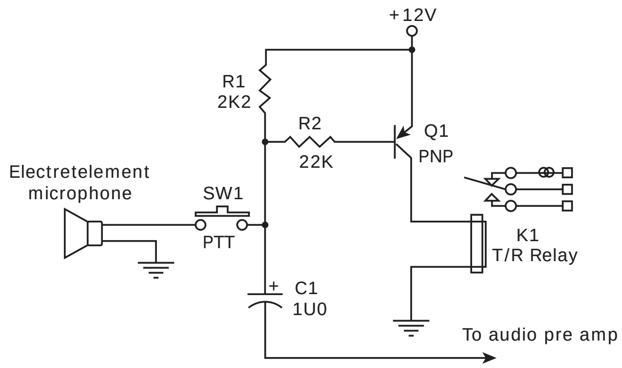


FIGURE 4.8 FM type Transceiver

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.

DO YOU KNOW? Walkie-talkies are Half-Duplex device not like mobile phone. 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".

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

FIGURE 4.9 Parts of Walkie-Talkie

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

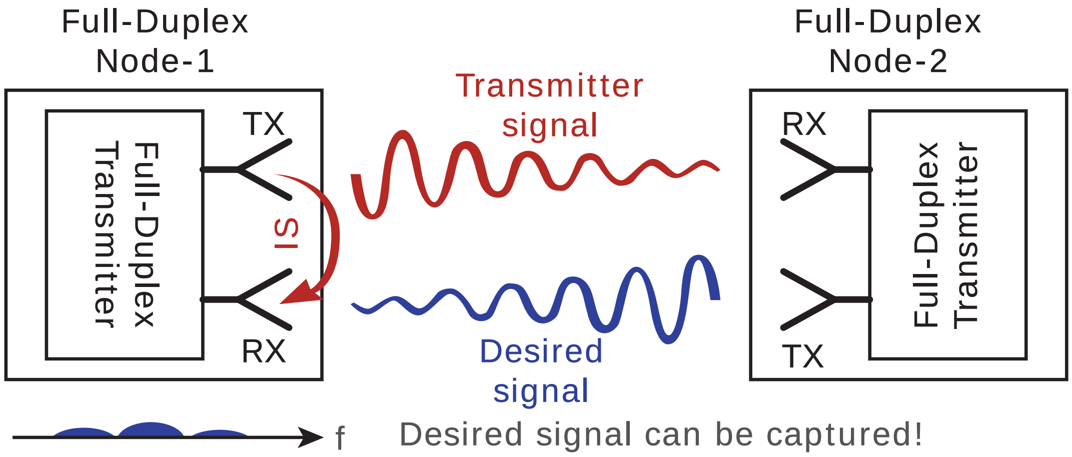


FIGURE 4.10 Full Duplex Transmission Mode

TABLE 4.1 Comparison Among Simplex, Half Duplex and Full Duplex Modes

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

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.

DO YOU KNOW?

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).

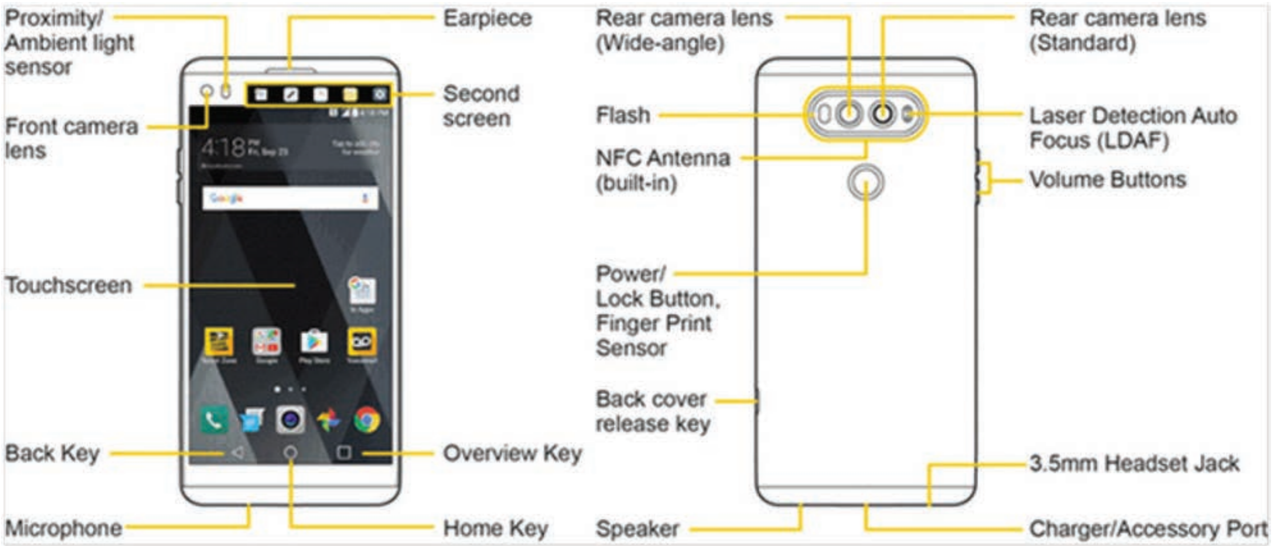


FIGURE 4.11 Parts of a Cell phone

4.4.2 Radio Waves

FIGURE 4.12 Radio waves (EMF)

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

> DO YOU KNOW?
>
> **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 smart phones 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.

DO YOU KNOW?

How To Limit The SAR?

The SAR limit is based upon a cell phone call that averages 30 minutes when the cell phone is held at the ear. Holding a phone away from the body or using a wired earpiece lowers the amount of radiation absorbed. Text messaging rather than talking, further reduces the radiation dosage.

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).

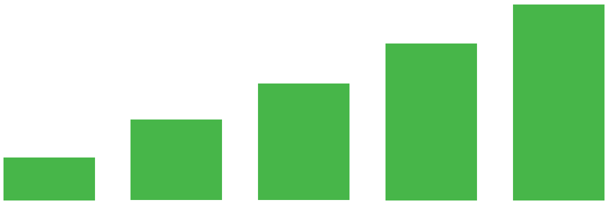


FIGURE 4.14 Cell phone Signal Strength Image

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

Activity

Dial the USSD code *#07# and check the radiation level or SAR value of your Smartphone.

Dial the USSD code *#06# and check the IMEI number of your Cell Phone

DO YOU KNOW?

In order to conserve battery life, a cell phone will vary the strength of its transmitted signal and use only the minimum necessary energy to communicate with the nearest cell tower. When user cell phone has poor connectivity, it transmits a stronger signal in order to connect to the tower, and as a result user's battery drains faster. That's why good connectivity not only reduces dropped calls, but also saves battery life.

DO YOU KNOW?

GSM means Global System for Mobile communication. When it was first developed, it was called by a French name have the meaning "Group Special Mobile". GSM was later renamed to its current name by the European Telecommunication Standard Institute (ETS) when it gained worldwide acceptance and became the European standard.

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 bya 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.

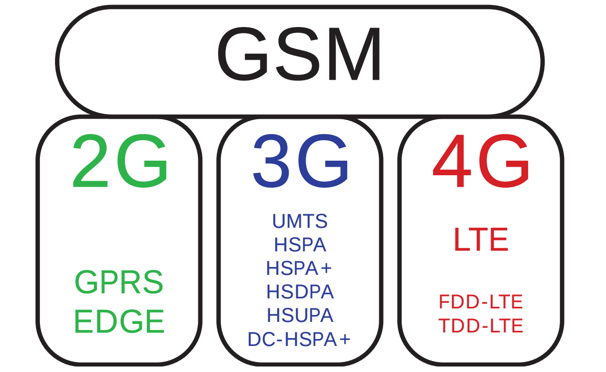


FIGURE 4.15 GSM protocol

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 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

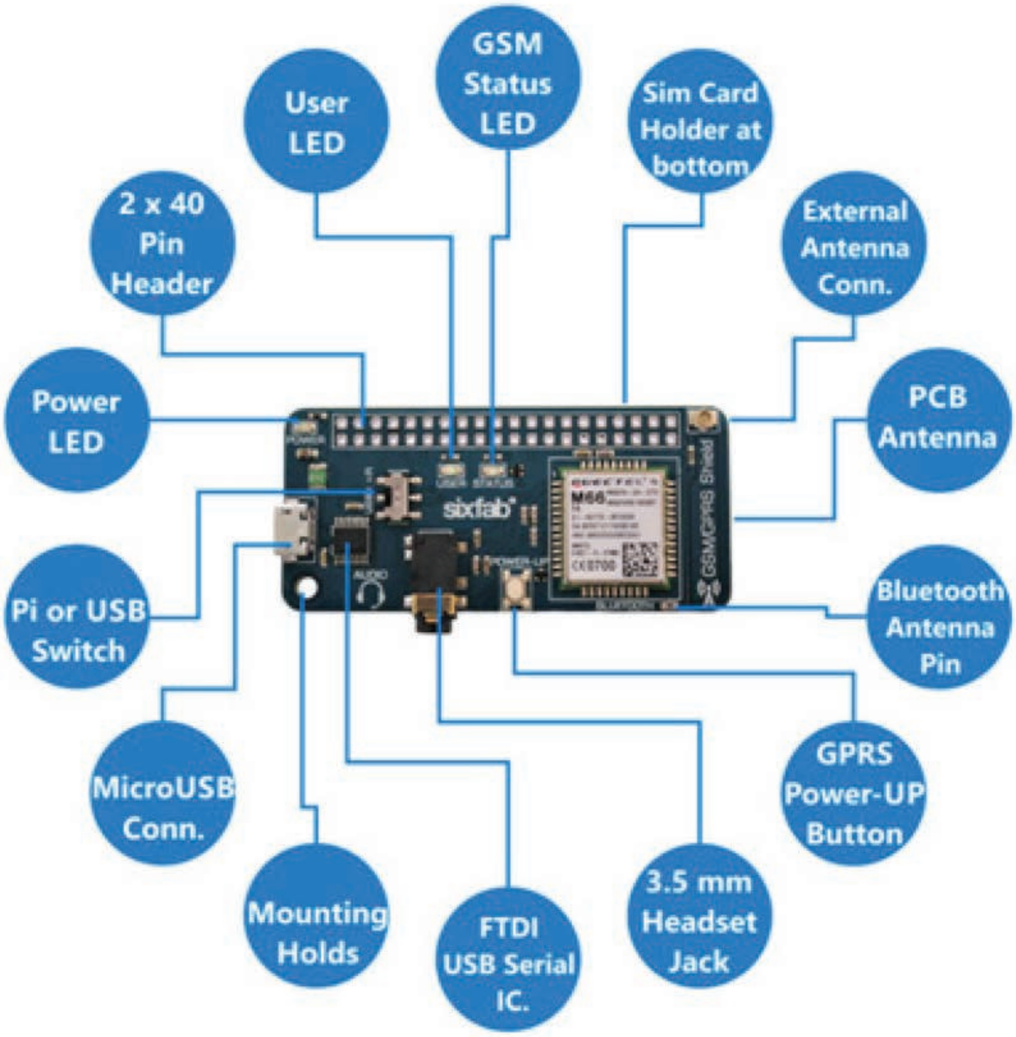


FIGURE 4.16 GPRS service provider

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.

FIGURE 4.17 Space based satellite Navigation System

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).

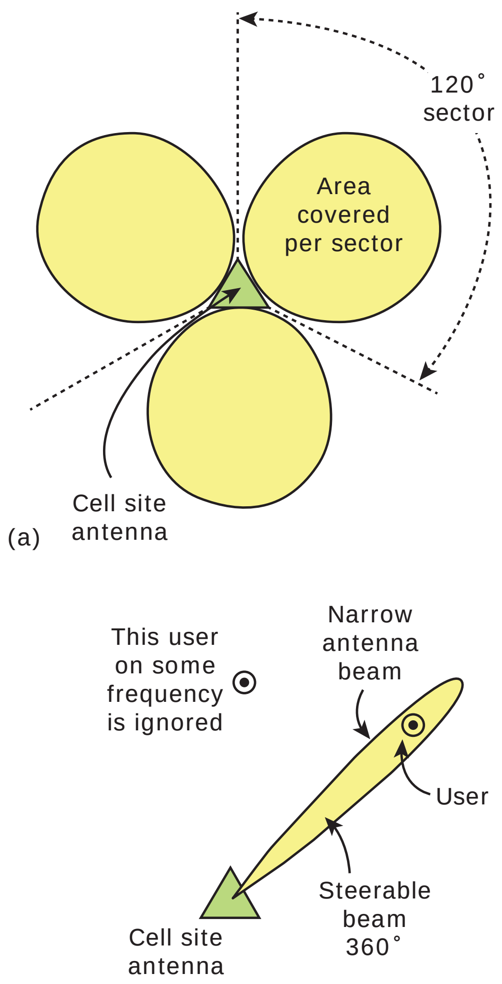


FIGURE 4.18 Physical separation methods

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

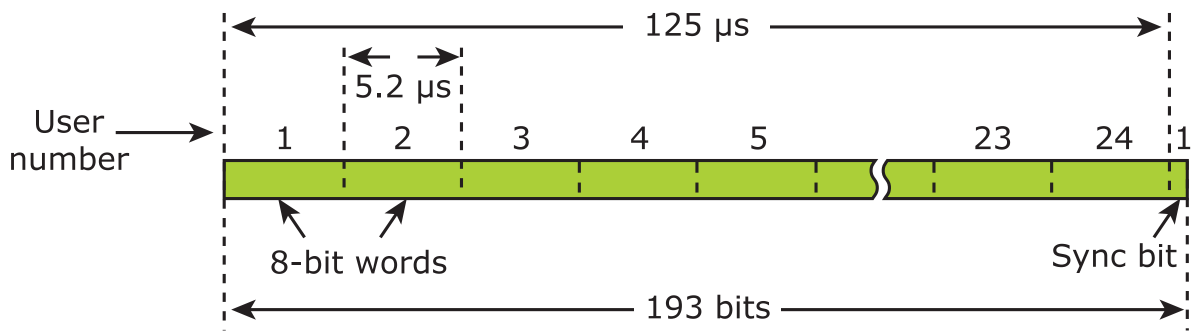


FIGURE 4.19(a) TDMA time slots allocation

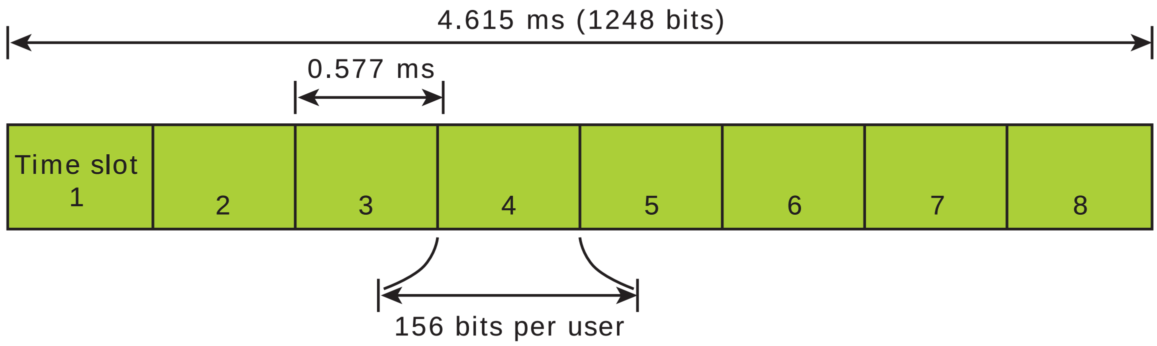


FIGURE 4.19(b) Time slot allocation to individual channel of TDMA

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 other, 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.
- 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,

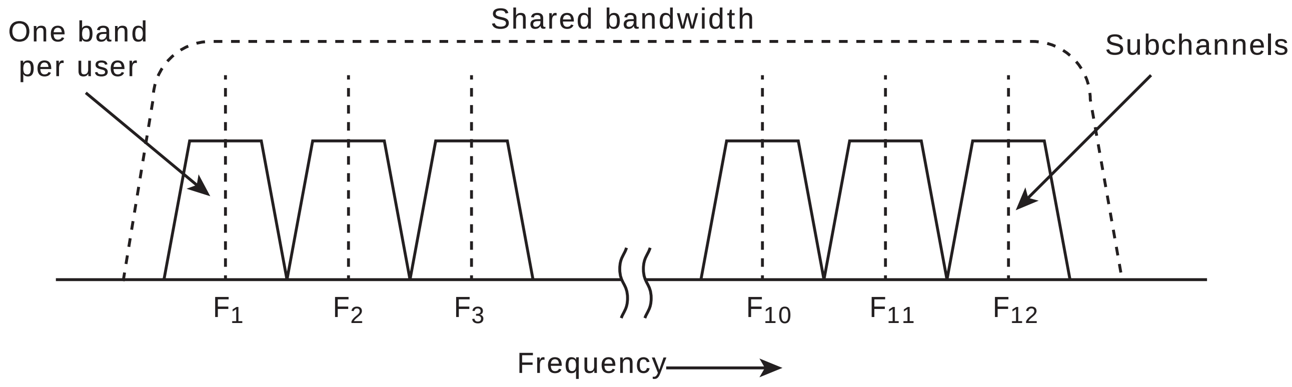


FIGURE 4.20 Channel or bandwidth.

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.
- Another advantage is its capacity; it has a very high spectral capacity that it can accommodate more users per MHz of bandwidth.

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.

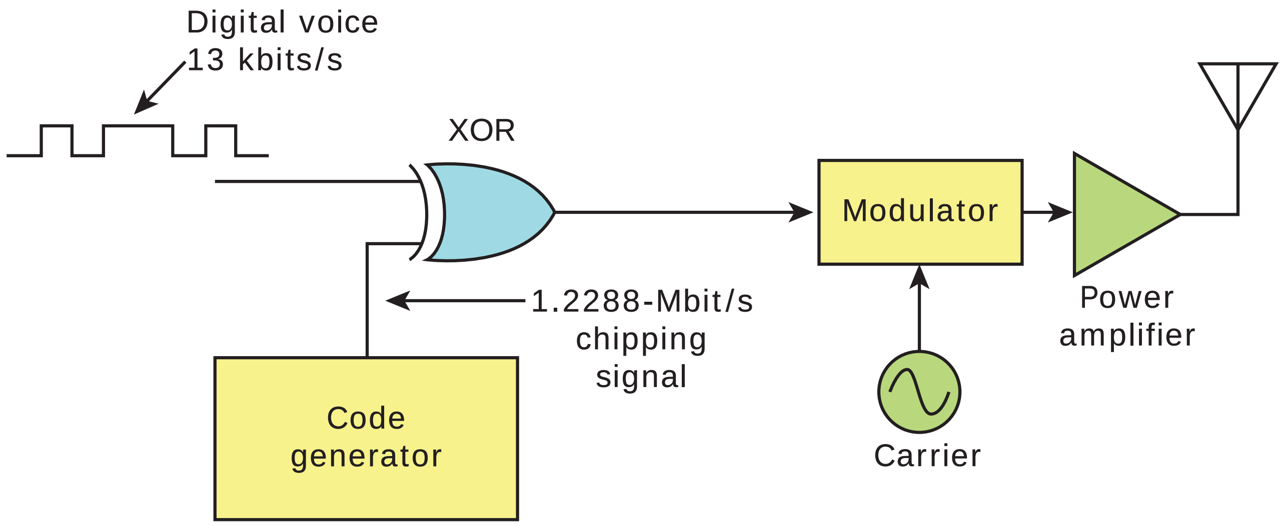


FIGURE 4.21 CDMA Block diagram

4.5.9 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.

4.5.10 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.

TABLE 4.2 Features of various mobile phone technologies

Approach	SDMA	TDMA	FDMA	CDMA
Idea	Segment space into cells/sectors	Segment sending time into disjoint time-slots, demand driven or fixed patterns	Segment the frequency band into disjoint sub-bands	Spread the spectrum using orthogonal codes
Terminals	Only one terminal can be active in one cell/ one sector	All terminals are active for short periods of time on the same frequency	Every terminal has its own frequency. Uninterrupted	All terminals can be active at the same place at the same moment. Uninterrupted
Signal separation	Cell structure, directed antennas	Synchronization in the time domain	Filtering in the frequency domain	Code plus special receivers
Advantages	Very simple, increase capacity per km2	Established, fully digital, flexible	Simple, established, robust	Flexible, less frequency planning needed, soft handover
Disadvantages	Inflexible, antennas typically fixed	Guard space needed (multipath propagation), synchronization difficult	Inflexible, frequencies are a scarce resource	Complex receivers, needs more complicated power control for senders
Comment	Only in combination with TDMA, FDMA or CDMA useful	Standard in fixed networks, together with FDMA/SDMA used in many mobile networks	Typically combined with TDMA (Frequency hopping patterns) and SDMA (frequency reuse)	Still faces some problems higher complexity. Lowered expectations; will be integrated with TDMA/FDMA

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 technologies include radio telephones mostly used in cars. Mobile radio telephone systems came before modern cellular mobile telephony technology.

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 UMTS is a completely different technology from GSM and EDGE. Also, WCDMA (Wideband Code Division Multiple Access) is used in 3G.

> **DO YOU KNOW?**
> **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.

> **DO YOU KNOW?**
> **Why 4G is called 'MAGIC'?**
>
> M – Mobile Multimedia,
>
> A – Anytime, Anywhere,
>
> G – Global Mobile Support,
>
> I – Integrated wireless solutions
>
> C – Customized Personal Service.

LTE (Long Term Evalution)

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 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.

4.6.6 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.

4.6.7 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.

4.6.8 7G

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

4.7 Other Special Technologies

In recent years, other technologies have emerged and enriched the mobile functionalities.

4.7.1 Wi-Fi

Wi-Fi is the technology for radio wireless local area networking of devices such as personal computers, gaming console, televisions, printers and mobile phones, etc. Wi-Fi compatible devices can connect to the internet via a WLAN and wireless access point. Such an access point (or Hot spot) has a range of about 20 meters (66 feet) indoors and a greater range outdoors. Hot spot coverage can be as small as a single room with walls that block radio waves.

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 4.22.

TABLE 4.3 Comparison among various generations of Mobile Phone Technology

Parameter	1G	2G	3G	4G	5G
Period	1980 -1990	1990 – 2000	2000 – 2010	2010 -2020	2020 - 2030
Bandwidth	150/900 MHz	900 MHz (25 MHz)	100 MHz	100 MHz	100 x BW/ unit area
Frequency	Analog signal (30 kHz)	Digital 1.8 GHz	1.6 – 2.0 GHz	2 -8 GHz	3 – 300 GHz
Data Rate	2 Kbps	64Kbps	144Kbps – 2 Mbps	100 Mbps – 1 Gbps	1 Gbps and above
Property	Bad voice quality,first wireless technology, poor Battery life	Digital,allows text message.	Digital Broad band with increasing speed.	High speed, supports all IPs, high Security, Better Usage	High Speed, Faster Data Transmission, More Efficient
Technology	Analog Cellular	Digital Cellular (GSM)	CDMA, MTS, EDGE.	LTE,VoLTE, WIFI	WORLD WIDE WEB
Size	Big	Medium	Medium	Small	Very Small

FIGURE 4.22 Symbol of Wi-Fi

4.7.2 Blue Tooth

Blue Tooth is a wireless technology used to transfer data between different electronic devices. The distance of data transmission is small in comparison to other modes of wireless communication. This technology eradicates the use of cords cables, adaptors and permits the electronic devices to communicate wirelessly among each other. Figure 4.23 shows the symbol of Blue Tooth.

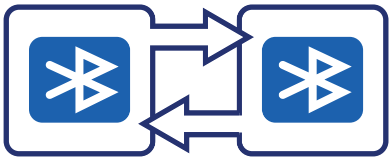


FIGURE 4.23 Symbol of Blue Tooth

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.

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.

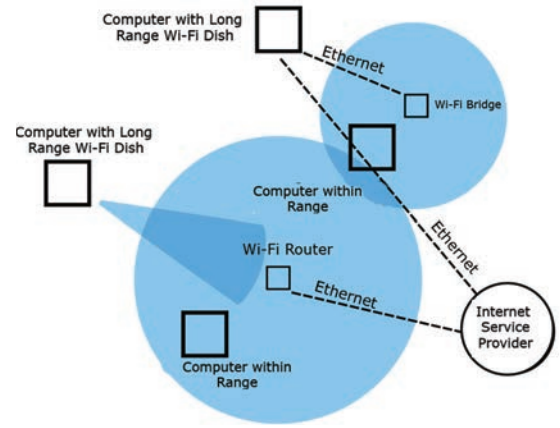


FIGURE 4.24 Hotspot Process

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 either106, 212 or 424 Kbps. NFC has three distinct modes of operation.

1. **Peer-toper 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.

4.7.5 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.

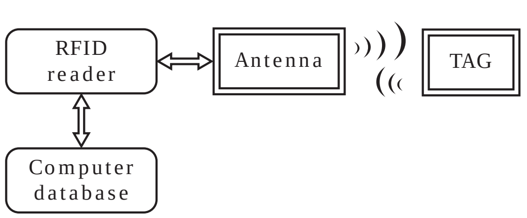


FIGURE 4.25 Parts of RFID System

A RFID system is made up of two parts as shown in Figure 4.25.

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.

DO YOU KNOW?

The first Mobile Phone was the Motorola Dyna TAC 8000X invented in 1983 by Martin Copper, 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.

DO YOU KNOW? More than 90% of adults have their mobile phone within arm's reach all the time

4.9 Benifits of Hexagons Used in Call Coverage of Cellular Network

While designing a network, two things are kept in mind.

1. A tower in cell should provide equal signal in that cell.
2. No block spots. Black spots are those areas where you won't get any signals.

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

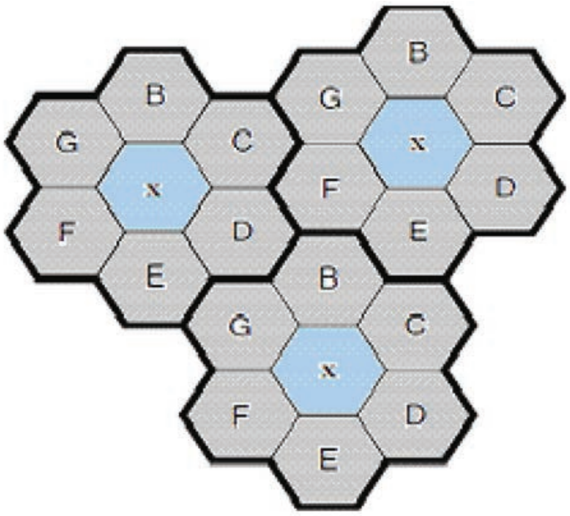


FIGURE 4.26 Hexagon

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.

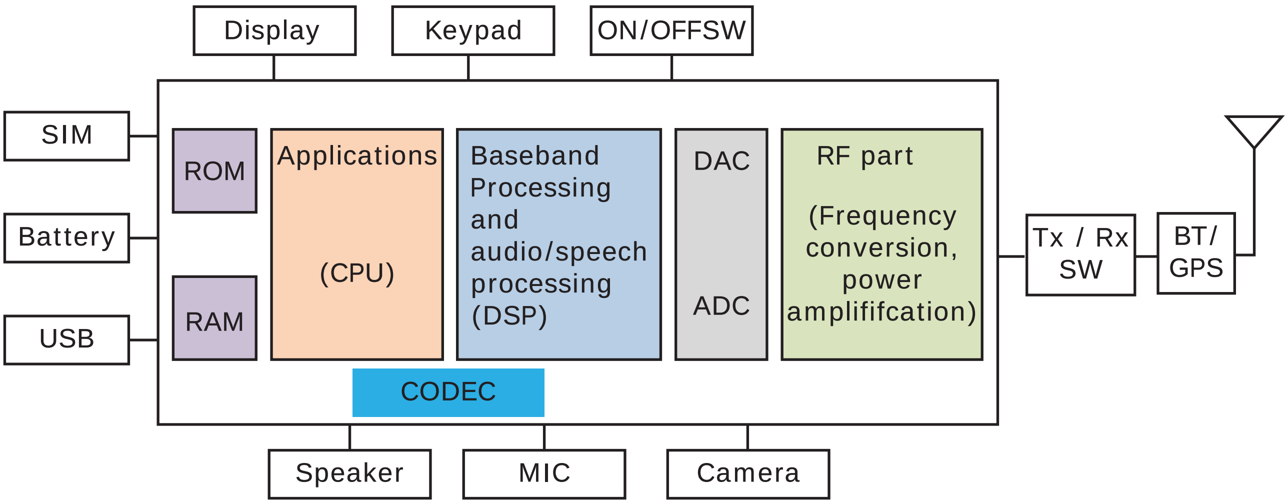


FIGURE 4.27 Components of a Cell Phone

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.

DO YOU KNOW? 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.

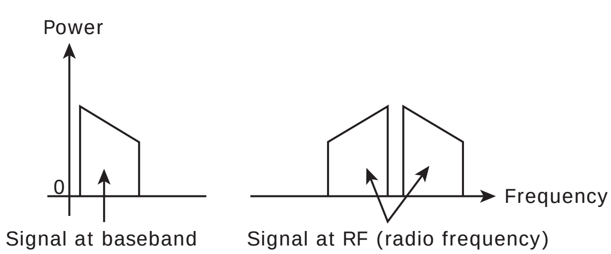


FIGURE 4.28 Base Band Spectrum

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

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 receiver 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.

DO YOU KNOW?

"i-Phone is the king of Smartphones." But despite being the biggest seller, Apples' operation system doesn't actually dominate the smartphone market. Android is owned by 82.8% of users in the world.

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.

DO YOU KNOW?

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 feds 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 givingto 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.

DO YOU KNOW? 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.

DO YOU KNOW?

- 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 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 wall papers. 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 one self.
3. **Video recorder**
   Phones are becoming video cameras and can record video more than an hour.

> **DO YOU KNOW?** 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**

> **DO YOU KNOW?**
> **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 website, 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.

> **DO YOU KNOW?** There are more mobile phones than PC, the ratio is 5 times. More than 4 billion people own mobile phones.

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**

> **DO YOU KNOW?**
> **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.

> **DO YOU KNOW?** 74% of Smartphone users use their mobile phone to help with shopping, of which 79% ultimately making a purchase. Mobile Phone users mostly spend their time on games and social networking (49% and 30%, respectively)

1. **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.
2. **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.
3. **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?

Do you know the full form of various extensions?

apk – Android Application Package file

exe – Executable files

ipA – iOS App Store Package

prc – Palm Resume Compiler

jad – Java Application Describer

adb – Android Debug Bridge

Aapt – Android Asset Packing tool

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.

Cell Phone Dictionary

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

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

GLOSSORY

Push-To-Talk	Push-To-Talk, also known as Press-To-Transmit, to switch from voice reception mode to transmit mode.
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
Transceiver	Transmit and Receive functions, the device is a Transmitter-Receiver. Similar devices include transponders, Transvertors and Repeaters.
Transponders	A device that receives a signal, and emits as a different signal in response with Telecommunications.
OFDMA	Orthogonal Frequency – Division Multiple Access
UMTS	Universal Mobile Telecommunication System
MM Tel IMS	Multimedia Telephony over Internet Protocol (IP) Multimedia Subsystem
CSMA-CD	Carrier Sense Multiple Access with collision Detection
LAN	Local Area Networks
CSMA-CA	Carrier Sense Multiple Access with Avoidance
Wi-Fi	Is a local area wireless technology
Bluetooth	Bluetooth is a wireless technology used to transfer data between different electronic devices.

NFC	Near Field Communication (NFC) enables short range communication between compatible devices.
RFID	Radio-Frequency Identification is the use of radio waves to read and capture information stored

QUESTIONS

Part – A (1 Mark)

I Multiple choice Questions

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
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 MHz
   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 128 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 PTT?
3. Write Application of walkie-talkie
4. What is the major Difference between GPS and GPRS?

5. Write the expansion of LTE, XLTE, VOLTE
6. What is FDD, TDD? Define.
7. What are the common functions of mobile phone?
8. What are the disadvantages of CDMA
9. Write Three applications of cell phone
10. What are the benefits of hexagons used in cellular network

Part – C (5 Marks)

III Answer in a paragraph

1. Tabulate the comparison of Transmission modes
2. Draw the front & back panel of a cell phone and mention it parts.
3. Explain Hotspot and Wifi
4. Draw a diagram of RFID system and explain its parts.
5. Write the advantages and disadvantages of cell phone

Part – D (10 Marks)

IV Answer in One Page (Essay type Question)

1. Discuss about the Generation of cell phone technologies.
2. Explain the Bluetooth technology with its classification, advantages and disadvantages?
3. Draw a block diagram of a simple cell phone and explain its functions.
4. Explain about cell phone applications.

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)

CHAPTER 5

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.

1WNHM

CONTENT

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 fluoroziconate 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.

DO YOU KNOW?

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.

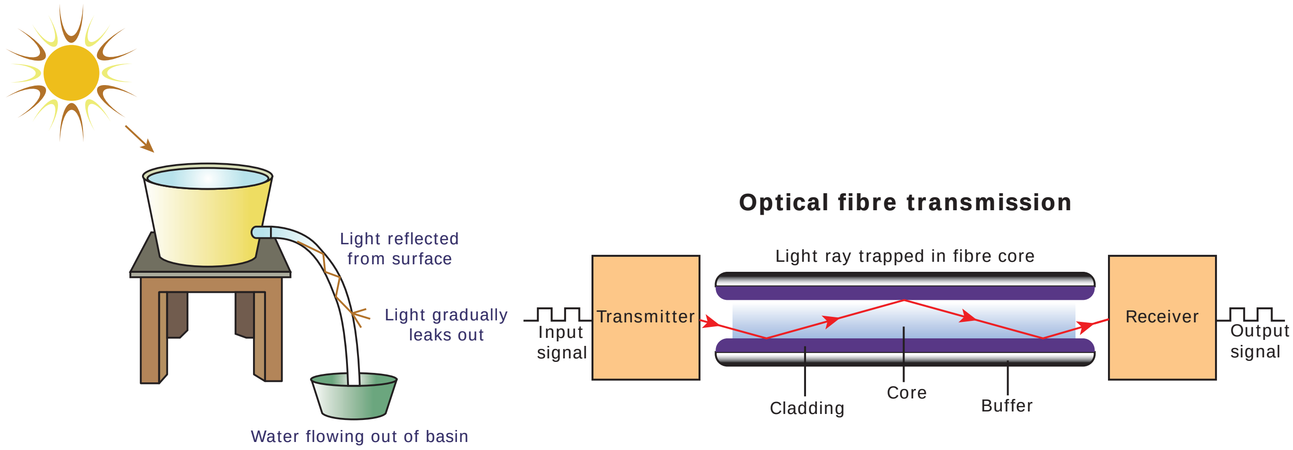


FIG 5.1 (a), (b) Internal reflection of OFC

5.2.1 Fiber Optic Communication

Fiber optic communication is based on the principle that light in a glass medium can carry more information over longer distance than electrical signals can carry in a copper or coaxial medium or radio frequencies through a wireless medium. The purity of today's glass fiber, combination with improved system enables fiber to transmit digitized light signals hundreds of kilometers without amplifications.

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.

5.3 Construction of an Optical Fiber

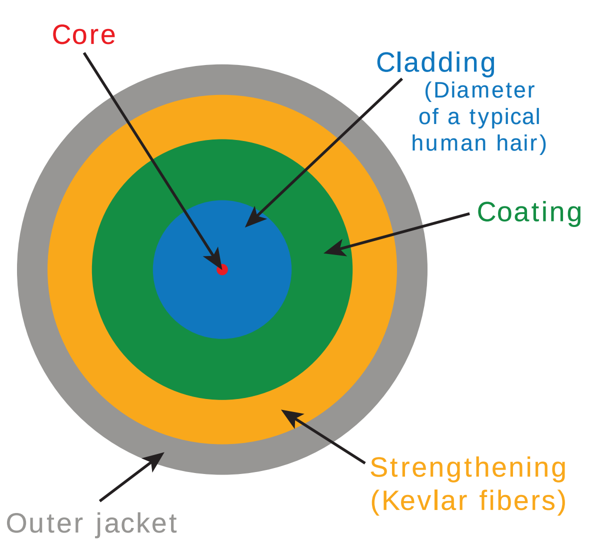


FIGURE 5.2 Construction of optical fiber.

5.3.1 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 cylinderical rod shape, made up of dielectric material. Dielectric material conducts no electrical signal. Light propogates 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

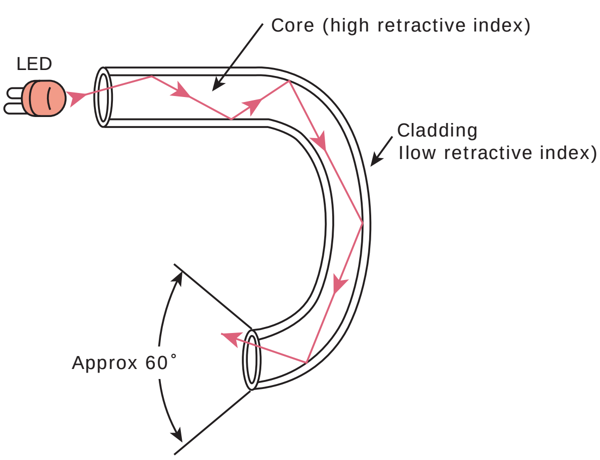


FIGURE 5.3 Working principle of OFC

Figur 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.

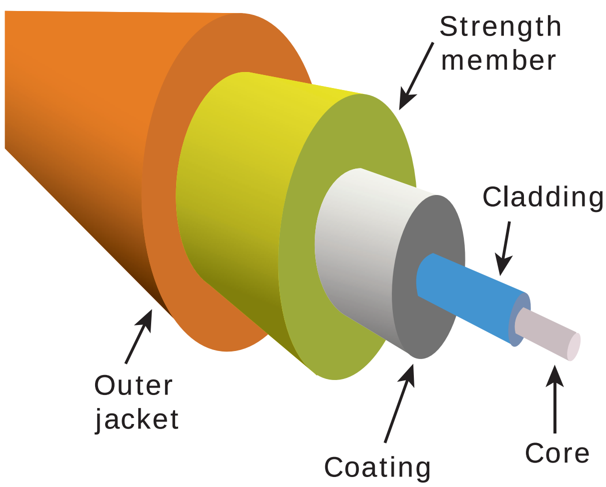


FIGURE 5.4 Structure of Optical Fiber.

> **DO YOU KNOW?**
>
> Whether the audio and video signal can be transmitted through OFC as in original form?
>
> No.., Any signal audio or video or any other should be converted into light signal and be transmitted through OFC.

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

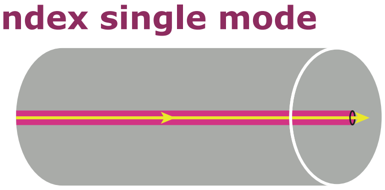


FIGURE 5.5 Step index single mode

Figure 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 Telcommunication areas

Step index multimode

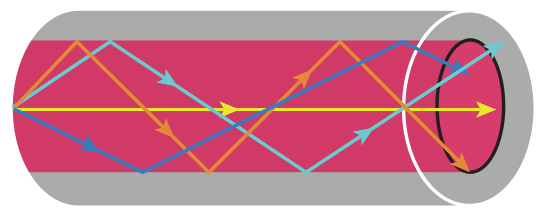


FIGURE 5.6 Step index multimode

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 code or code 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

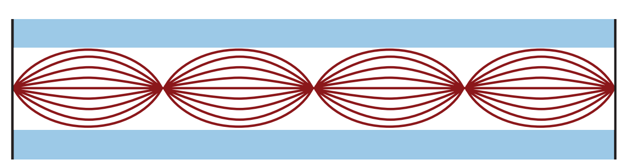


FIGURE 5.7 Graded index fiber (Multimode)

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	
Step index fiber	**Graded index fiber**
The refractive index of the core is uniform	The refractive index of the core is non-uniform
The light rays propagate in zig-zag manner inside the core of step index fiber	The light rays will not cross the graded index fiber
It is too slow for most uses	It is too fast for most uses
Lower bandwidth	Higher bandwidth

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)

	Optical fiber	Co-axial cable
Basis of comparison	Transmission of the signal is in optical form(light form)	Transmission of the signal is in electrical form
Comparison of cable	Glass and plastic	Plastic or usually copper wire
Efficiency	High	Low
Cost	Expensive	Less expensive
Bending effect	Can affect the signal transmission	Bending of wire does not affect the signal transmission
Data transmission rate	2 Gbps	44.736 Mbps
Installation of cable	Difficult	Easy
Bandwidth	Very high	Moderately high
External magnetic field	Does not affect the cable	Affects the cable
Noise immunity	High	Intermediate
Diameter of the cable	Small	Large
Weight	Lighter weight	Heavier weight

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

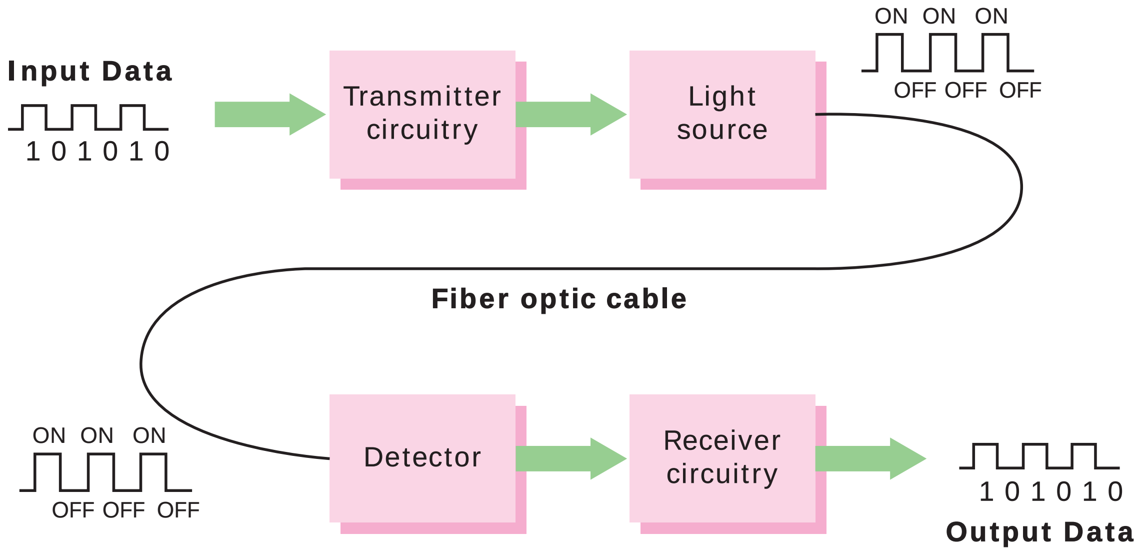


FIGURE 5.8 Working of Fiber Optic Communication

used as light sources. LEDs are used for short distances and low data rate communication. Laser diodes are used for long distances and high data rate communication.

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.

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.

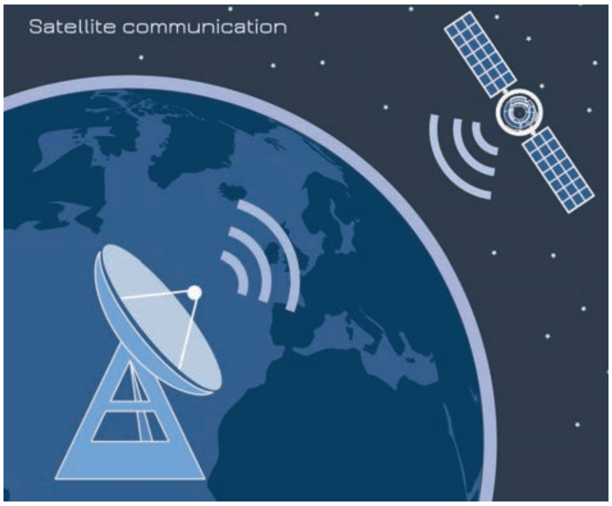
Light guides

- 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.

5.7 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.

DO YOU KNOW?

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.

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.

DO YOU KNOW?

Which is the natural satellite to the earth… its nothing but "Moon"..

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.


Aryabhata (1975)


PSLV-C42

DO YOU KNOW?

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.

XII EE_English version CHAPTER 05.indd 121 1/22/2022 12:50:50 PM

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 satelliets system.

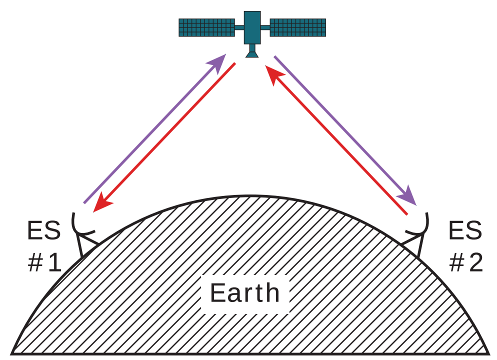


FIGURE 5.9 Active Satellite

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.

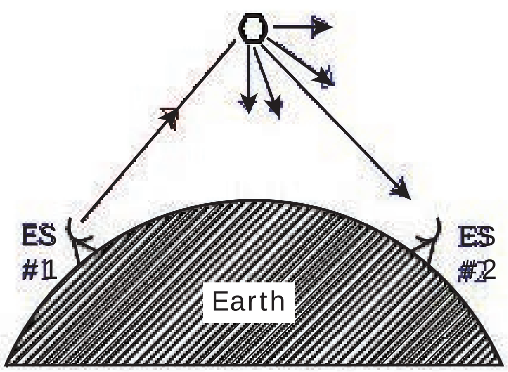


FIGURE 5.10 Passive satellites system.

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 over comes 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 Up-link 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.

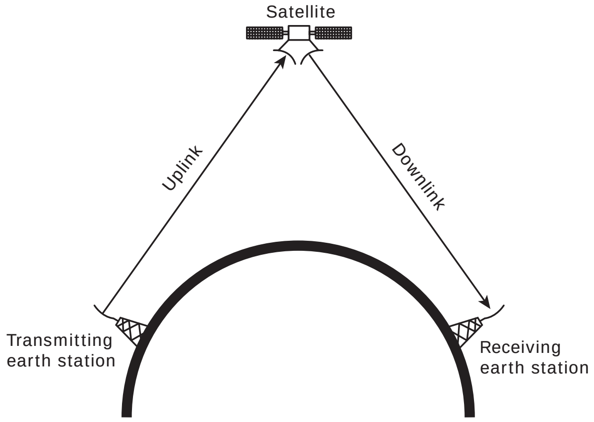


FIGURE 5.11 Working of communication Satellite

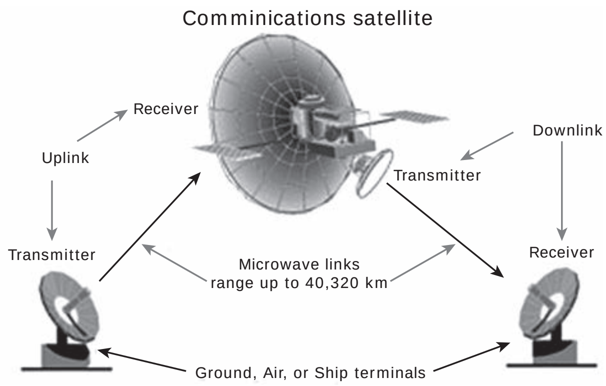


FIGURE 5.12

The transmission of signal from first earth station to satellite through a channel is called as Up-link. Similarly the transmission of signal from satellite to second earth station through a channel is called Down-link. This action can be done in vice-versa.

Earth stations send the information to satellites in the form of high powered, high frequency (GHz) range signals. The satellite receives and re-transmits the signals back to earth where they are received by other earth stations in the coverage area of the satellite.

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 satellites 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.

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.

> **DO YOU KNOW?**
> **What is the meaning of microwave?**
> Microwave means "very Short Wave"

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)

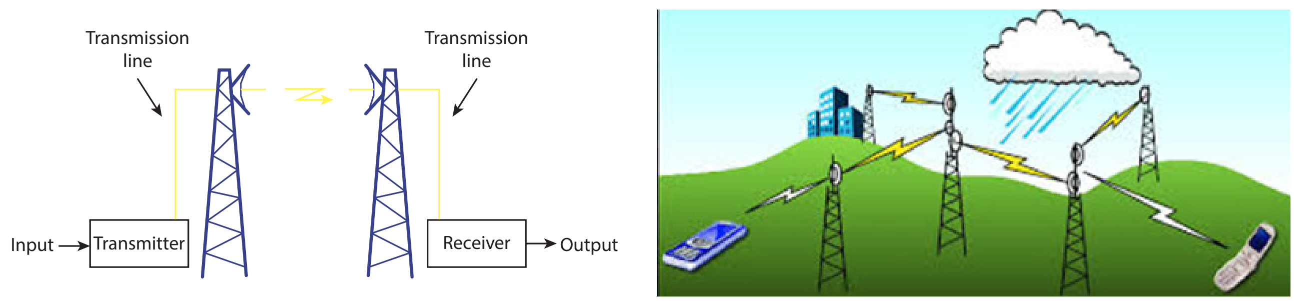


FIGURE 5.13 Microwave Communication

5.9 Radar systems

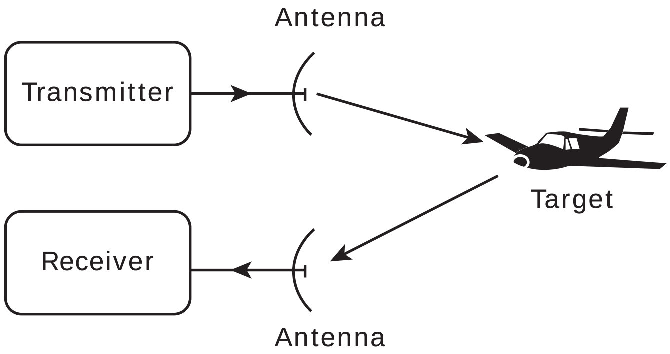
Radar stands for Radio Detection And Ranging. It is a type of radio system where radio frequency signals are used to determine the position of speed of an object. Often the objective is passive, so the reflection of RF signal from the object is used to find the speed or velocity of the object. Radar 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.



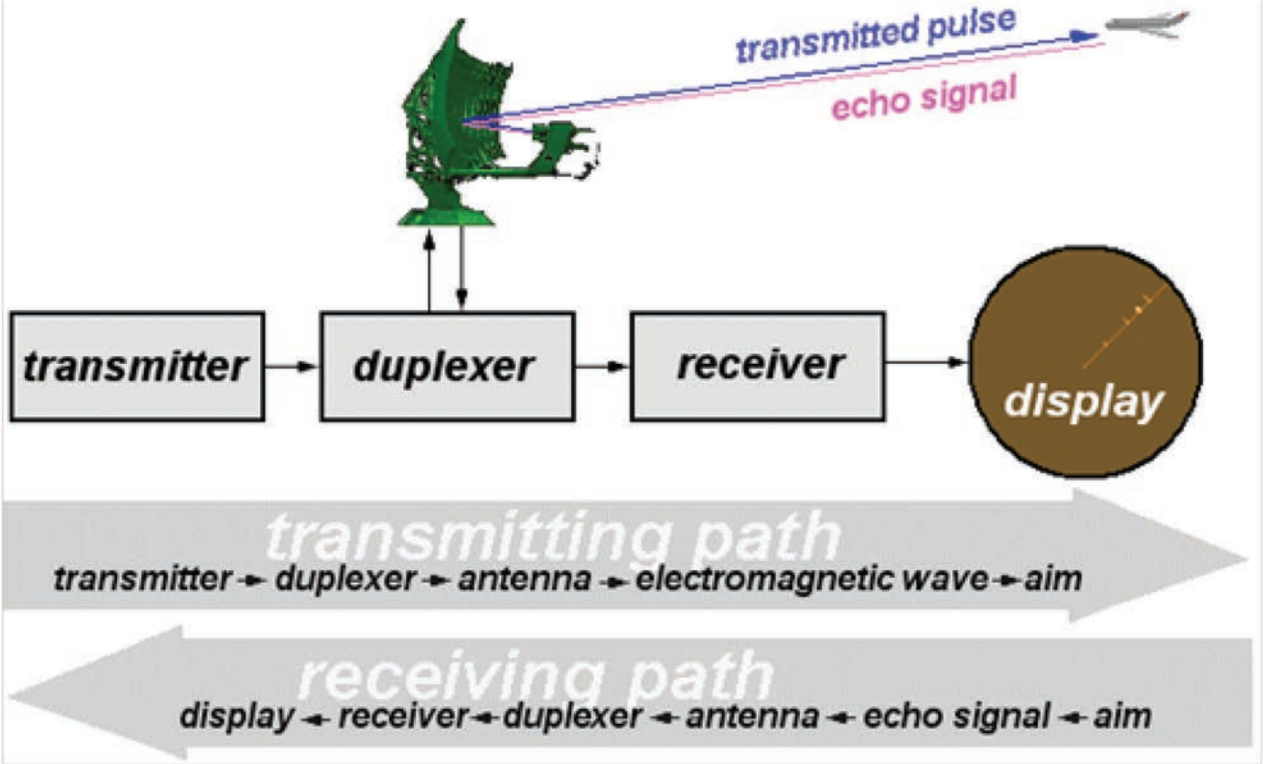


FIGURE 5.14 Tthe block diagram of RADAR

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)**

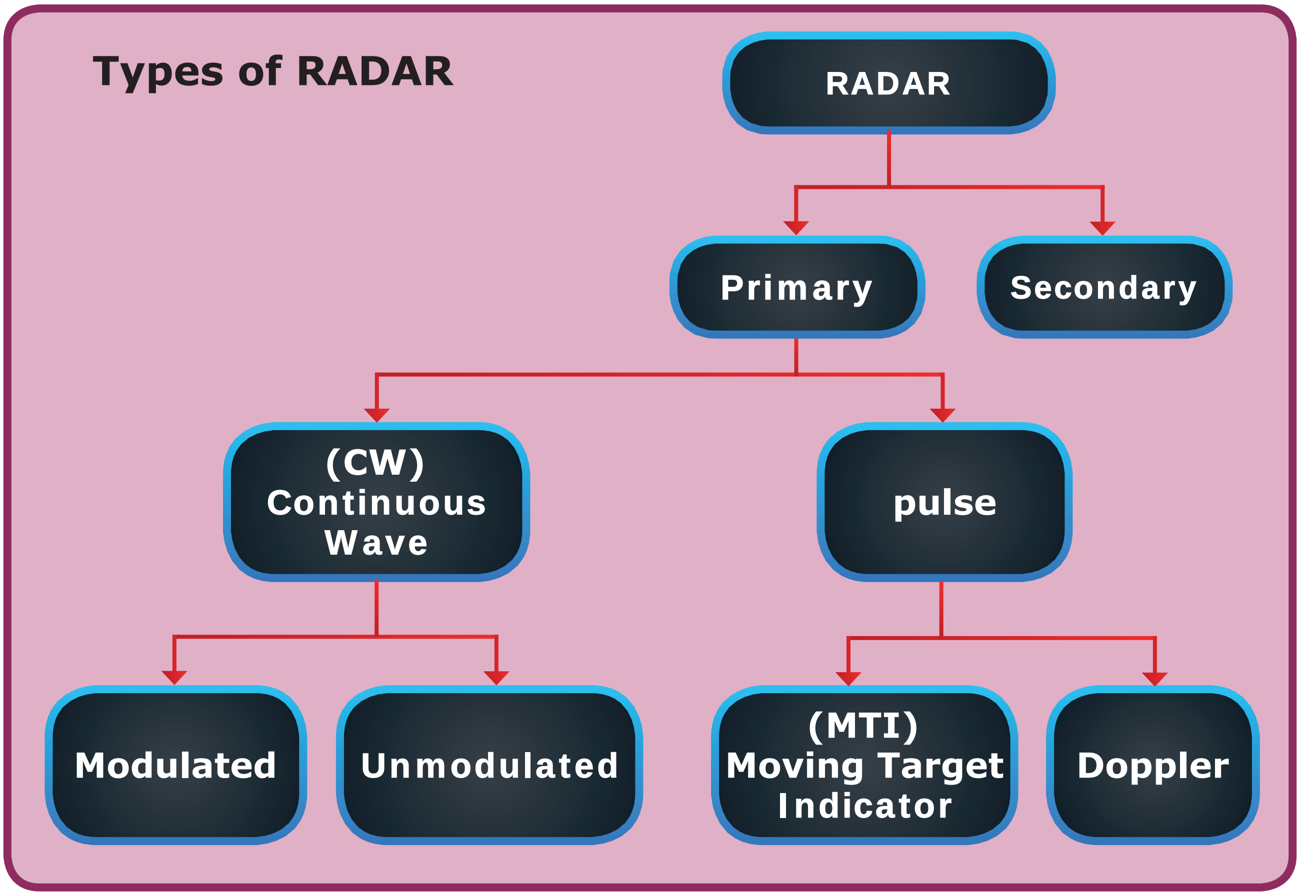
  Radar are used for safety controlling of the air traffic
- **Air Craft Navigation**

  The weather avoidance radars and ground mapping radars are employed in aircrafts to avigate 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



- Law Enforcement

  High way police force widely uses radars to measure the vehicle speed for safety regulation.

- Military area

  They are used in Air, Naval and Ground for defense purposes.

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 fitting any nearby objects, and some of them reflect back to the object that made the noise. SONAR works using, this echo principles.

A method or device detecting or locality objects especially underwater 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

They 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 under water 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.

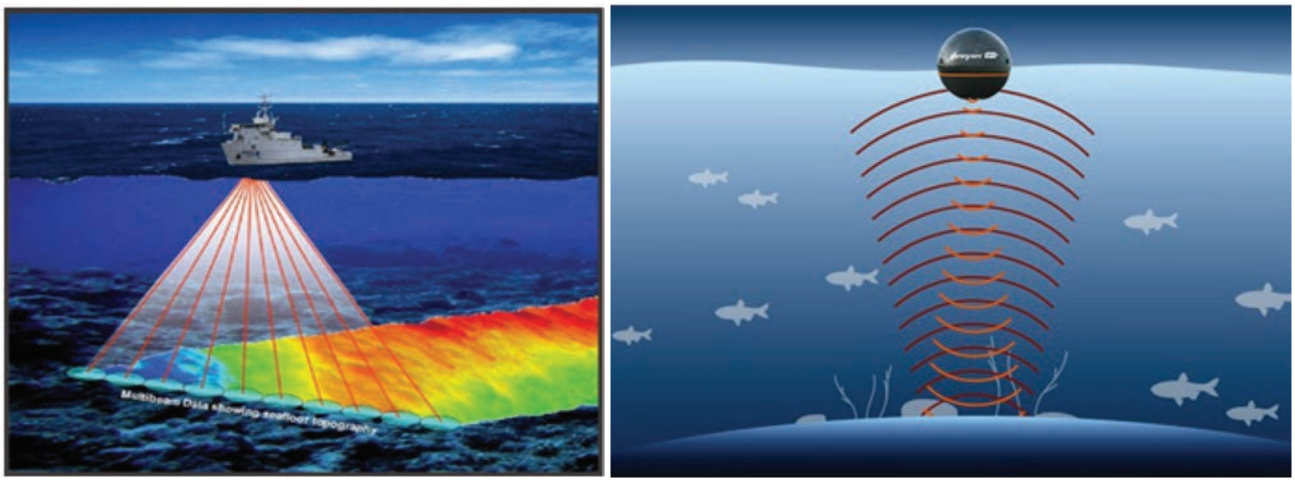


FIGURE 5.15 SONAR Technology

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.

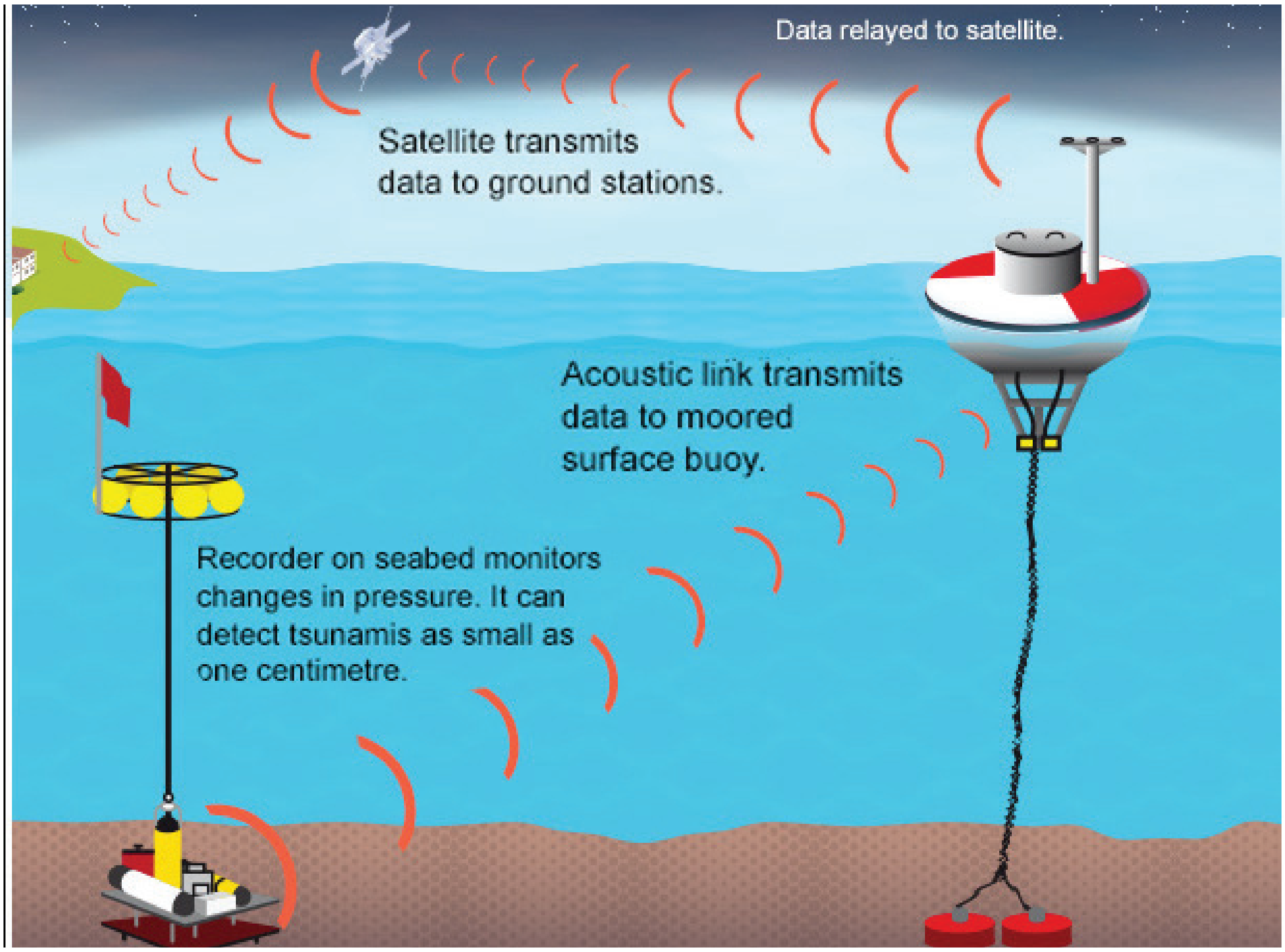


FIGURE 5.16 (a) Tsunami warning system

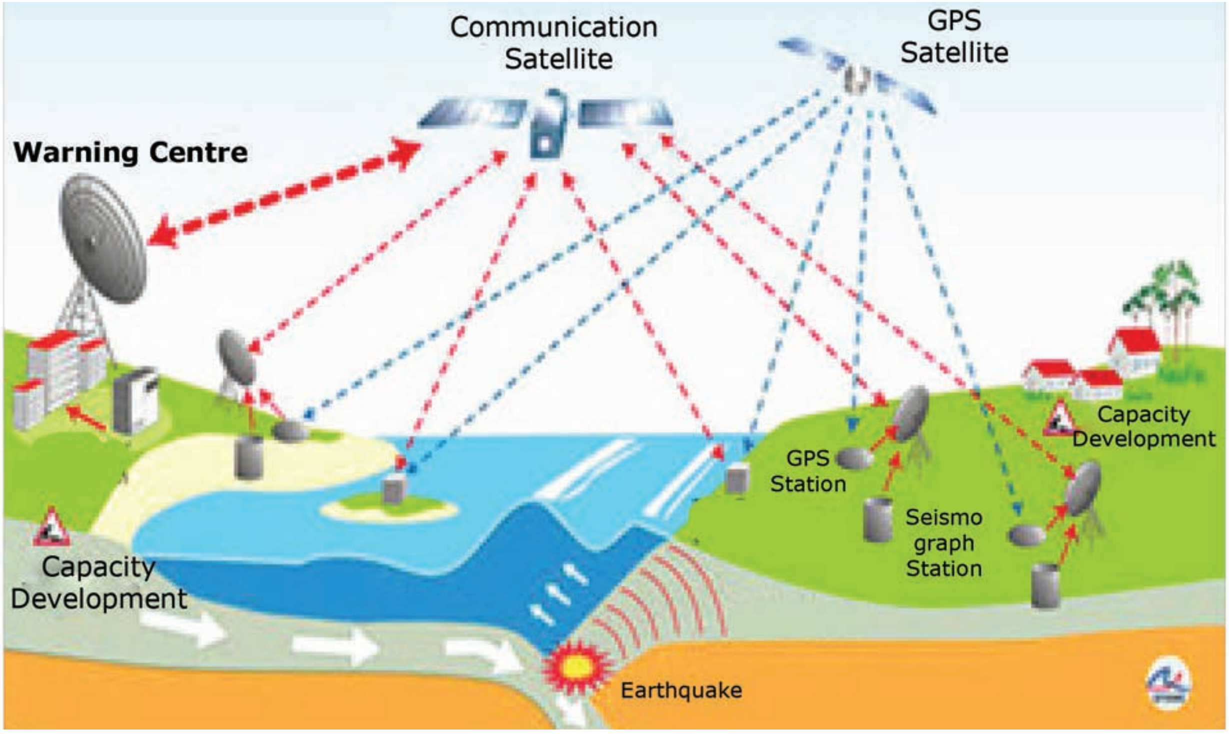


FIGURE 5.16(b) Tsunami warning system

There are two types of tsunami warning systems

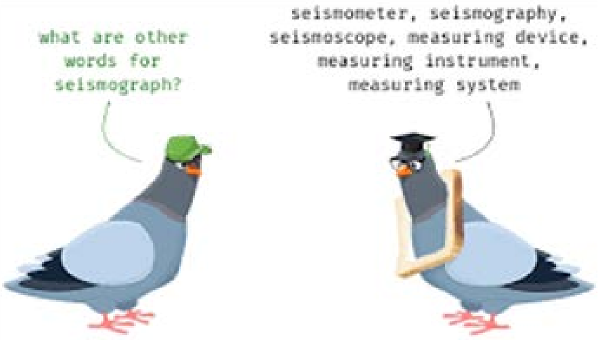
1. International tsunami warning systems
2. Regional warning systems

Figure 5.16 shows the Tsunami warning system.

> **DO YOU KNOW?** 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.

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 magnetude 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

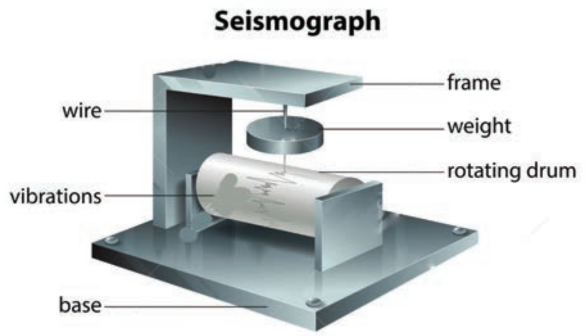


FIGURE 5.17 Seismograph

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.

DO YOU KNOW?

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.

5.12.4 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.

5.12.5 Navigation

Air navigation is the determination of position and direction on or above the surface of the Earth. Avionics can use

FIGURE 5.18 The cockpit of flight Airbus A380

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.

5.12.6 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.

5.12.7 Aircraft Flight-Control System

DO YOU KNOW?

Who invented autopilot System

Autopilot was first invented by Lawrence Sperry during World War I

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.

5.12.8 Collision-Avoidance Systems

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).

5.12.9 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.

5.12.10 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.

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

Optical fiber	A glass or plastic fiber that has the ability to guide light along its axis
Cable	One or more optical fibers enclosed, with strength members in a protective
Multi mode fiber	An optical fiber that has a core large enough to propogate more than one mode of light
Orbit	The path a satellite takes while travelling around the earth.
Down link	The signal that comes down a satellite to an earth station.
Earth station	An installation located on the earth's surface and intented for communication with one or more satellites.
Repeater	A device that amplifies incoming electrical signals and retransmits them towards the earth station(s) at a different frequency.
Transponder	A transmitter – receiver device that transmits signals automatically when it receives pre – determined signal.
Duplex	A term meaning two way communication
Uplink	The signal that transmits an earth station to a satellite.

Part – A (1 Mark)

I Multiple choice Questions

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 μm & 10 μm
   b. 1 μm & 20 μm
   c. 30 μm & 40 μm
   d. 2 μm & 5 μm

3. The diameter of step index multimode is ________
   a. 62.5μm/125 μm
   b. 72.5μm/125 μm
   c. 32.5μm/125 μm
   d. 42.5μm/125 μm

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

6. Solar cells in satellites mostly made up of ________
   a. Silicon
   b. Germanium
   c. Copper
   d. Aluminium

7. The first Indian 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. How is optical fiber classified?
4. What is RADAR?
5. Write about the types of RADAR.
6. Write the uses of Earth observation satellite.
7. Define the uses of Tsunami Warning System.
8. Define: Seismograph.
9. Write short notes on an Avionics.
10. Write about weather satellite?

Part – C (5 Marks)

III Answer in a paragraph

1. How does OFC work?
2. What are the advantages and disadvantages of OFC?
3. What are the uses of RADAR?
4. Explain about Microwave communication.
5. List out the applications of SONAR.

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.

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)

CHAPTER 6

Digital Image Processing

LEARNING OBJECTIVE

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

'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.

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.

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.

DO YOU KNOW?

Do you know the first photograph?

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.

DO YOU KNOW?

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.

FIGURE 6.1 First Digital Image

6.2 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 6.2 shows the pixel representation of an image. Pixel is also known as PEL. From the Figure 6.2, 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 6.2.

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.

Total number of pixels

=

Number of rows x 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

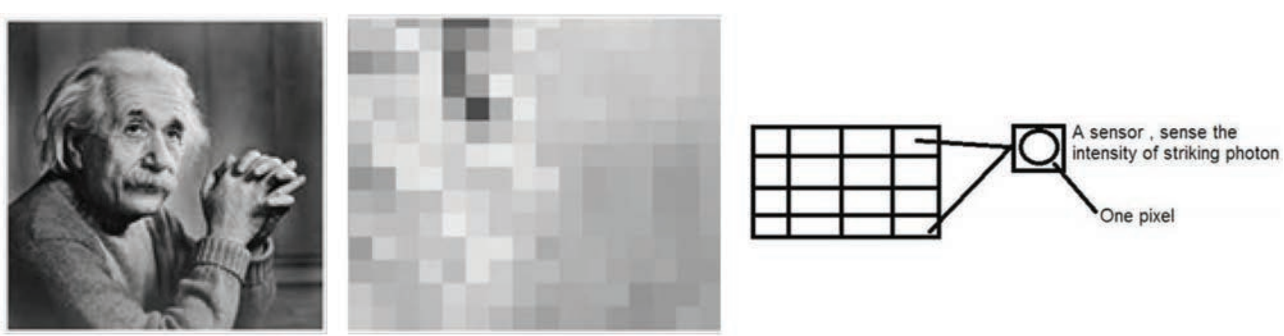


FIGURE 6.2 Pixel representation of an image

means absence of light and also denotes darkness. Further, it means that whenever a pixel has a value of 0, it means at that point, black color is formed. For example, the following matrix is filled with 0s.

$$\begin{matrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{matrix}$$

Total no. of pixels
=
total no. of rows x total no. of columns
= 3 x 3 = 9

It means that an image is formed with 9 pixels, and that image is having a dimension of 3 rows and 3 columns and most important that all the pixels in the image are black.

6.3 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-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 6.1 Illuminance and light conditions

Illuminance	Light condition
1,00,000 lux	Strong Sunlight
10,000 lux	Full day light
500 lux	Office light
100 lux	Poorly lit room

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

6.4 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.

DO YOU KNOW?

The first color photograph

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.

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.

6.4.1 Electromagnetic energy spectrum

Figure 6.3 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.

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.

6.4.2 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

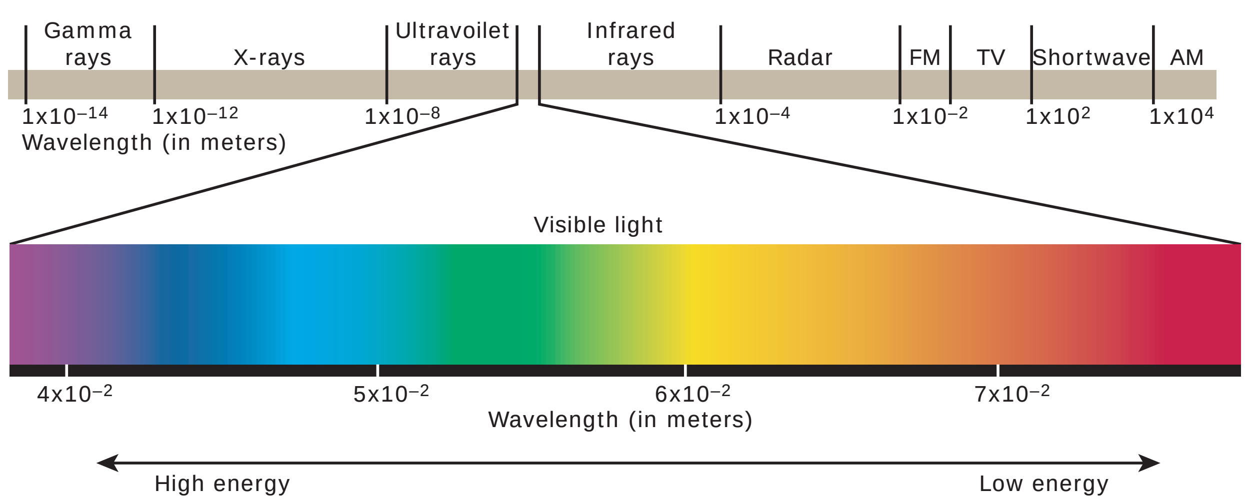


FIGURE 6.3 Electromagnetic Spectrum

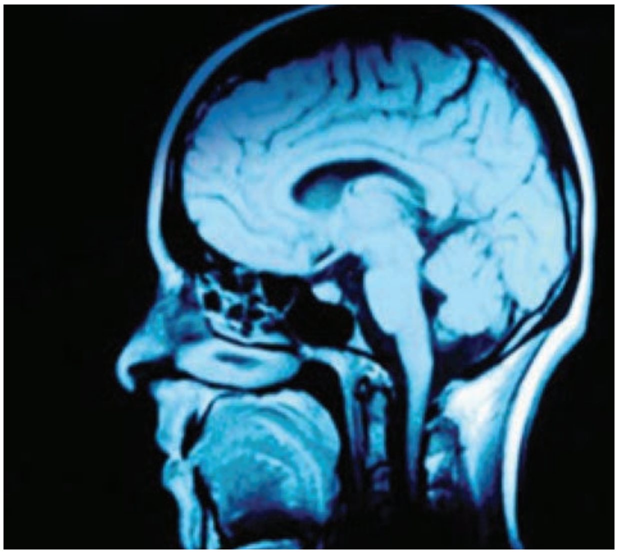



FIGURE 6.4 Gamma ray and X-ray images

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.

6.4.3 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.

6.4.4 Fundamental steps of digital image processing

Figure 6.5 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.

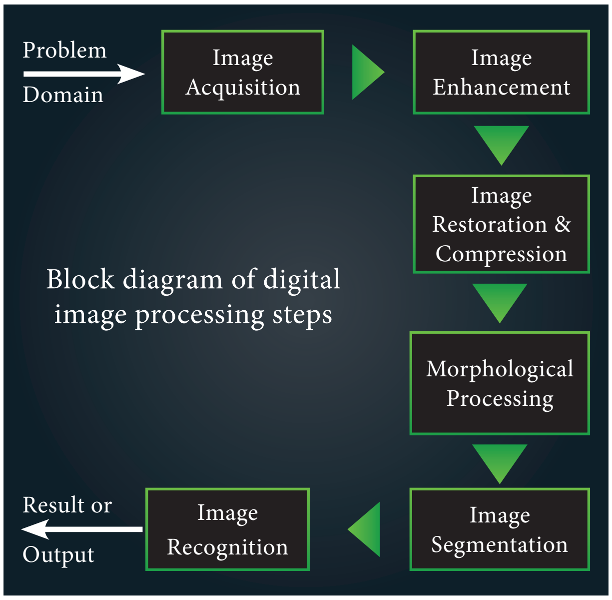


FIGURE 6.5 Block diagram of digital image processing steps

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 6.6 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 6.7shows image restoration in a still image.

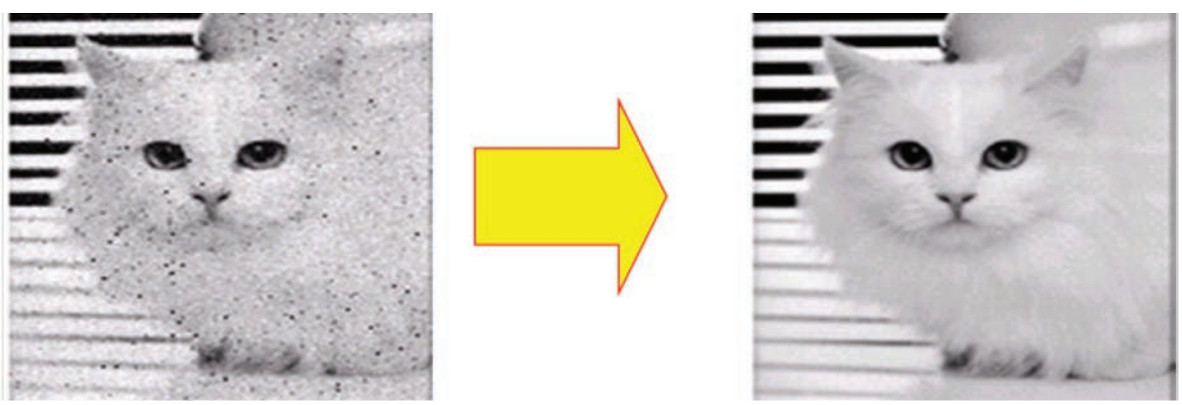


FIGURE 6.6 Image enhancement and noise removal applied on still image

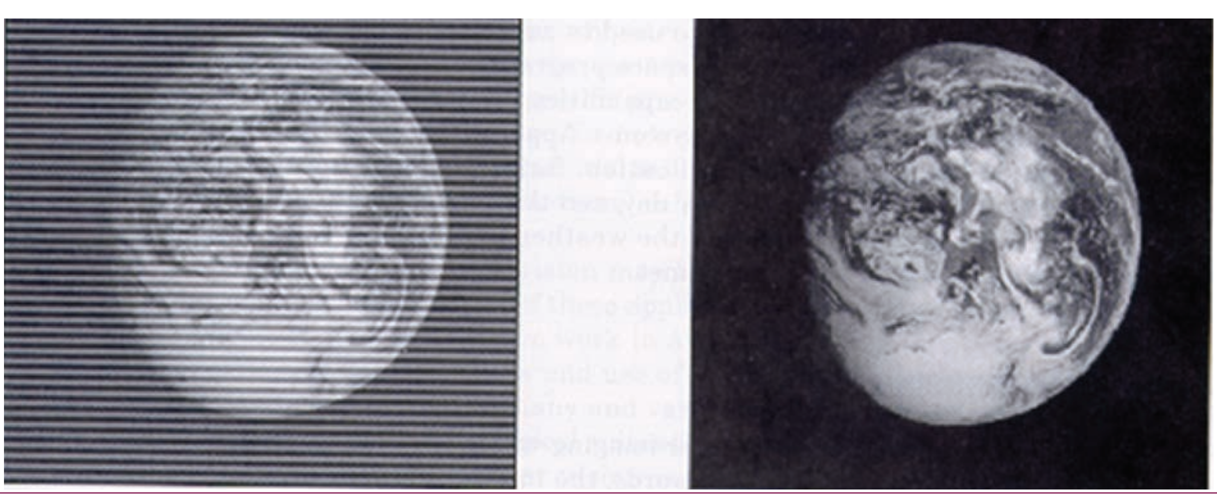


FIGURE 6.7 Image restoration correcting an out-off focus image

FIGURE 6.8 Compression of brain image, Original image (left), Compressed image (middle) and Reconstructed image from compressed image (right)

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 6.8 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 6.9 shows some of the morphological operations like binarization and thinning applied in a biometric fingerprint image.

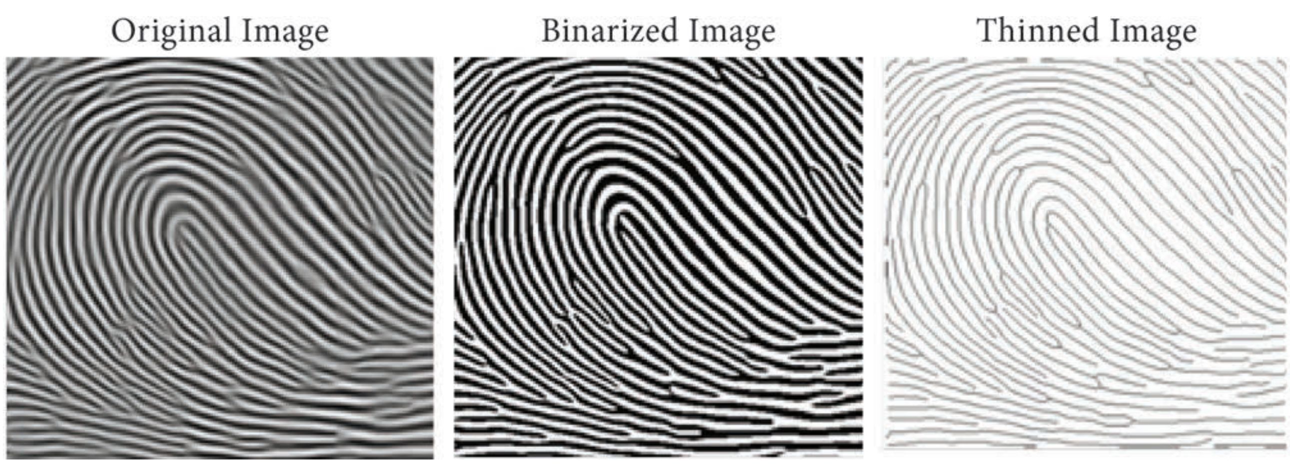


FIGURE 6.9 Morphological Operations in Fingerprint biometric image

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 6.10 shows the segmentation of a Palm image.

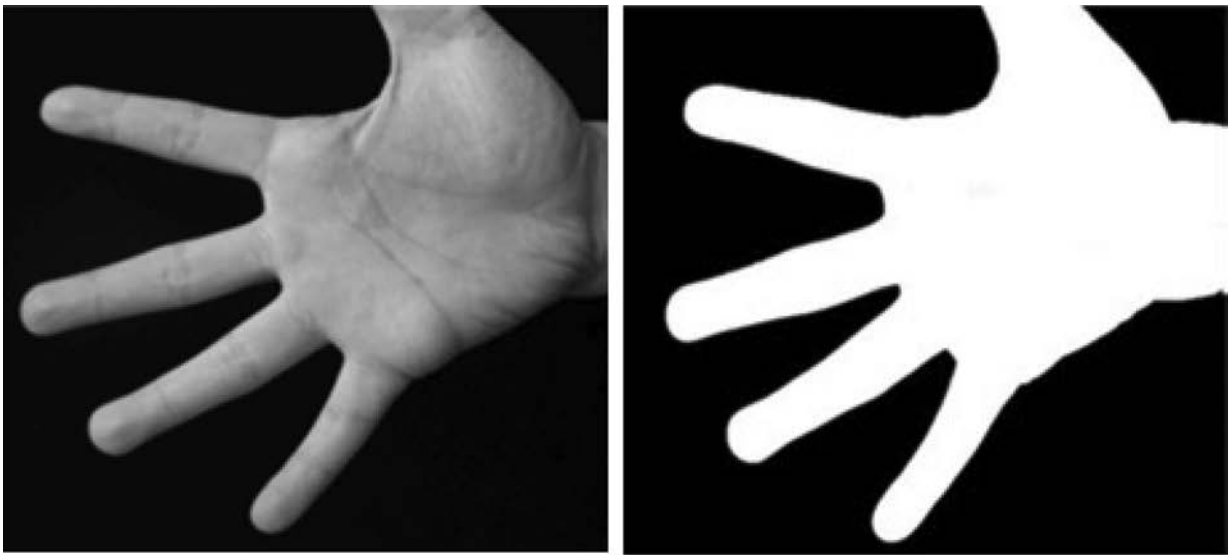


FIGURE 6.10 Segmentation of Palm Image

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 6.11 shows face recognition of a person for different expressions.

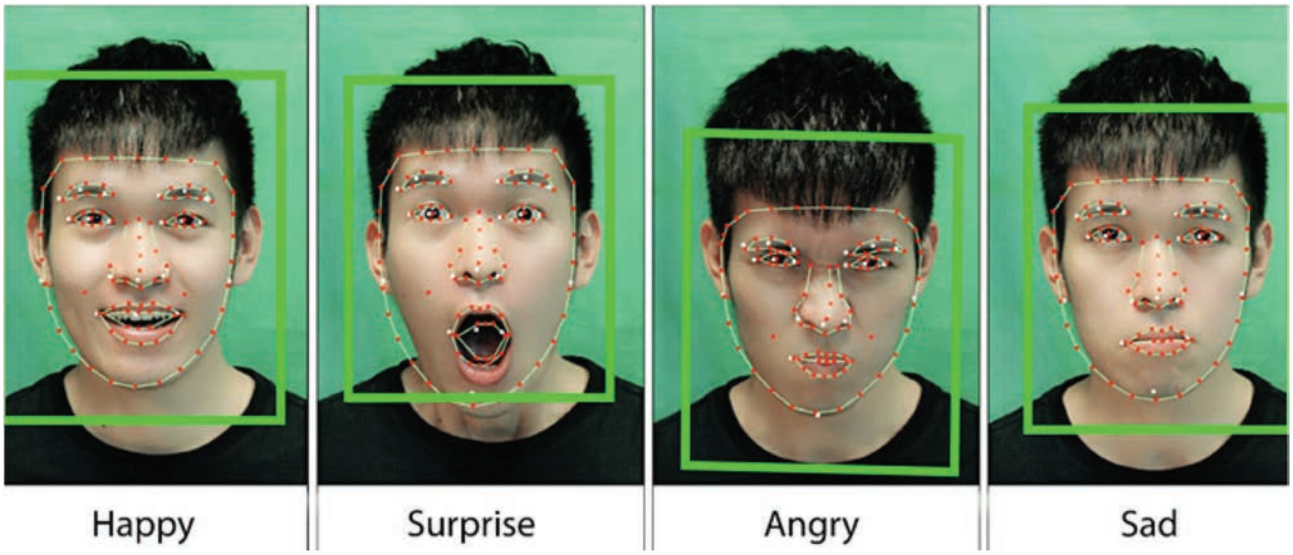


FIGURE 6.11 Face recognition of an individual based on the expression of a person

6.4.5 Applications of Digital Image Processing

The field of Digital Image Processing has experienced continuous and significant development in recent years. The usefulness of this technology is apparent in many different disciplines covering medicine through remote sensing. The availability of image processing hardware has further enhanced the usefulness of image processing.

The broad areas of digital image processing applications include.

- Medical field
- Remote sensing
- Intelligent transportation systems
- Automatic visual inspection system
- Moving object tracking
- Video processing
- Pattern recognition
- Transmission and encoding

1 **Medical field**

For medical diagnosis, different types of imaging modalities such as X-ray, Ultrasound, Computed aided tomography (CT), etc., are used.

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 infra-red 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 Newyork 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.

6.5 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 converts 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.

DO YOU KNOW? 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.

6.5.1 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 6.12 shows the mechanism of flow of charge carrier in CCD sensor.

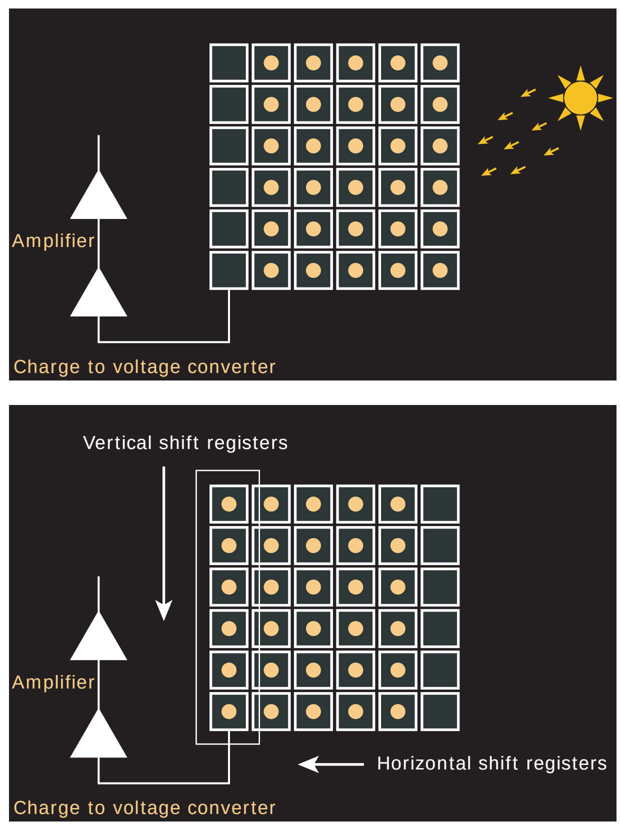


FIGURE 6.12 Mechanism of charge production in CCD sensors

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.

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

6.5.2 CMOS Sensor

DO YOU KNOW?

Eric R. Fossum is one of the inventors of CMOS image sensors in the year 1995, which is used in nearly all smart phones 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 6.13 shows the working principle of CMOS sensor. Initially, the 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.

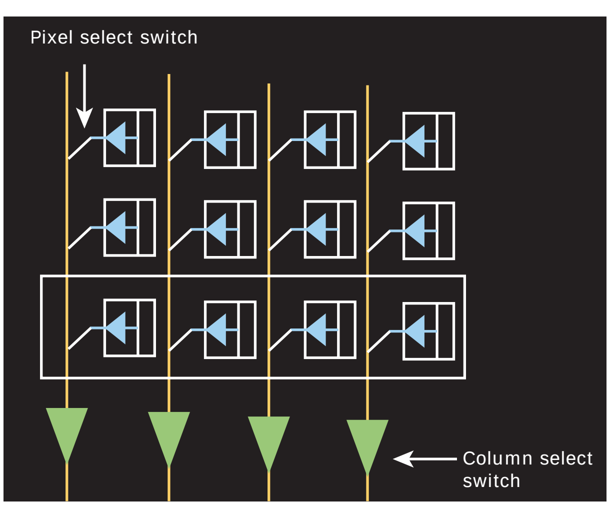


FIGURE 6.13 Working Principle of CMOS sensor

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.

6.6 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.

Basically, 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

TABLE 6.2 **Comparison of CCD and CMOS sensors**

S. No.	Specification	CCD	CMOS
1	System Integration	Being old technology, it is not possible to integrate the timers and ADC to the main sensors.	It is like IC fabrication technology, quite possible to integrate with peripheral devices.
2	Power Consumption	Requires different power supplies for different timing clocks. Typically, 7 V to 10 V (Requires more power).	Requires single power supply. Typical voltage rating is from 3.3 V to 5 V (Requires Less power)
3	Processing Speed	Speed is comparatively less. It is further increased by using multiple shift registers.	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.
4	Noise and Sensitivity	It has more sensitivity, because the dynamic range is quite high. Less noise.	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.
5	Image Distortion	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.	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.

TABLE: 6.3 Comparison of analog and digital camera features

Analog camera (photo film)	Digital camera
Light from the subject of the photograph enters the camera and falls on a film.	Light from the subject of the photograph enters the camera and falls on a digital sensor.
Images are captured on photographic film, which cannot be reused again.	Images are captured as digital files and stored on removable media cards, which are reusable.
Needs few days to processing the photography.	Provides real instant photography within a second or two of the exposure. Real-time visualization of the captured image while taking pictures using built-in LCD screen.
The film negative requires post processing using chemicals such as developing tank, dark room for printing negatives, etc.	The digital image file requires only a photo shop with a computer screen in light room.
No power or batteries needed.	It needs DC power.

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.

6.6.1 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 6.14 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 micro-chip 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.

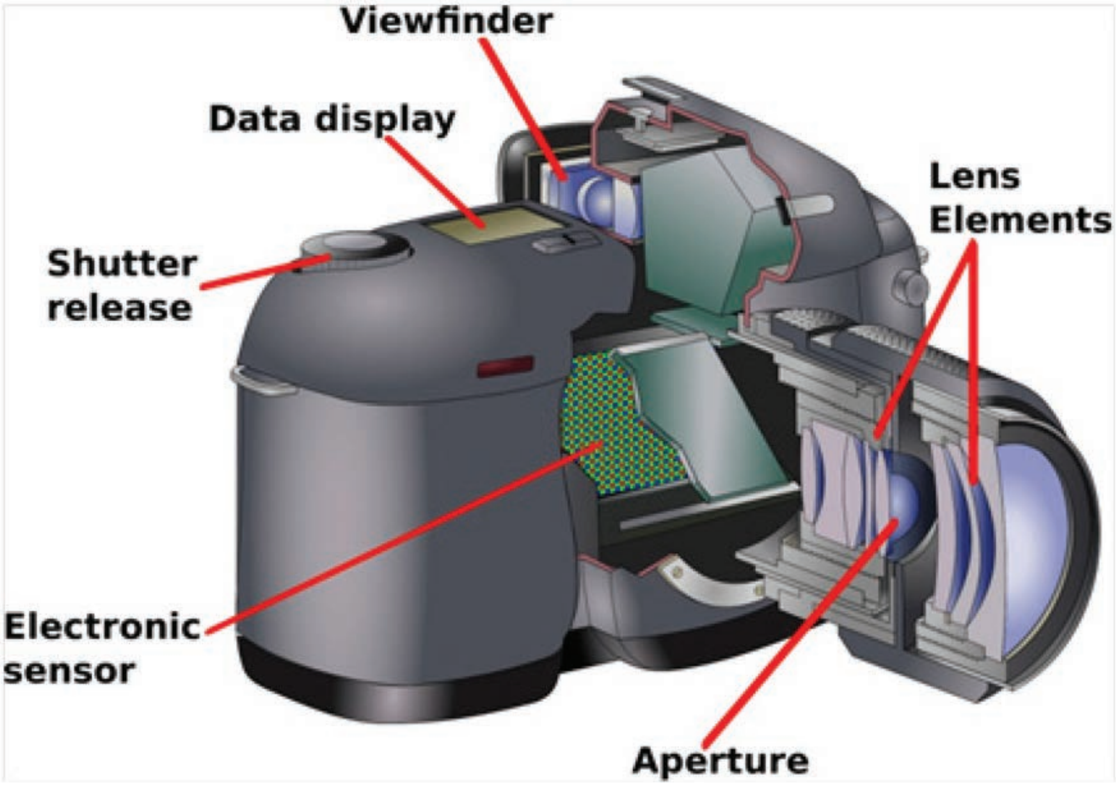


FIGURE 6.14 Basic components of a digital camera

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.

6.7 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.

6.7.1 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

6.7.2 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.

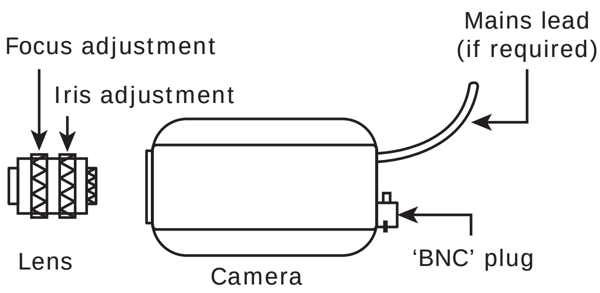


FIGURE 6.15 Parts of CCTV Camera

6.7.3 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.

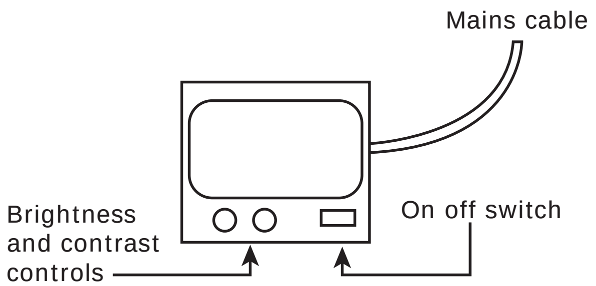


FIGURE 6.16 Parts of CCTV Monitor

6.7.4 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 co axial connectors. However, only one source can be observed at a time.

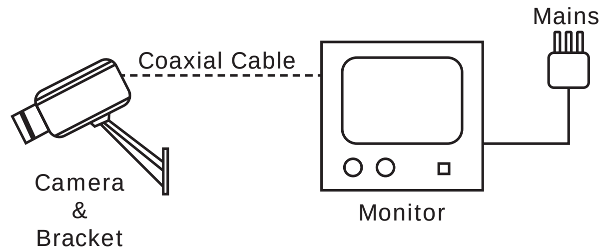


FIGURE 6.17 Simple CCTV system

6.7.5 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 upto three hundred meters only. Figure 6.18 shows the mains powered CCTV system.

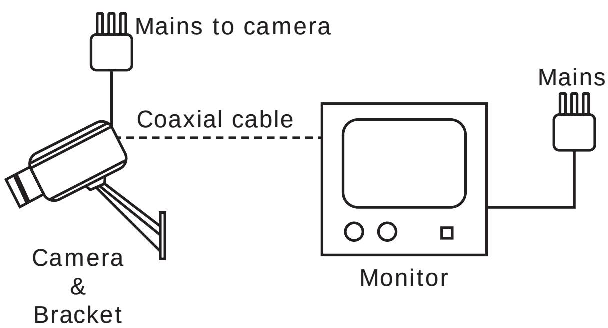


FIGURE 6.18 Mains Powered CCTV system

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.

6.7.6 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.

6.7.7 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.

6.7.8 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).

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

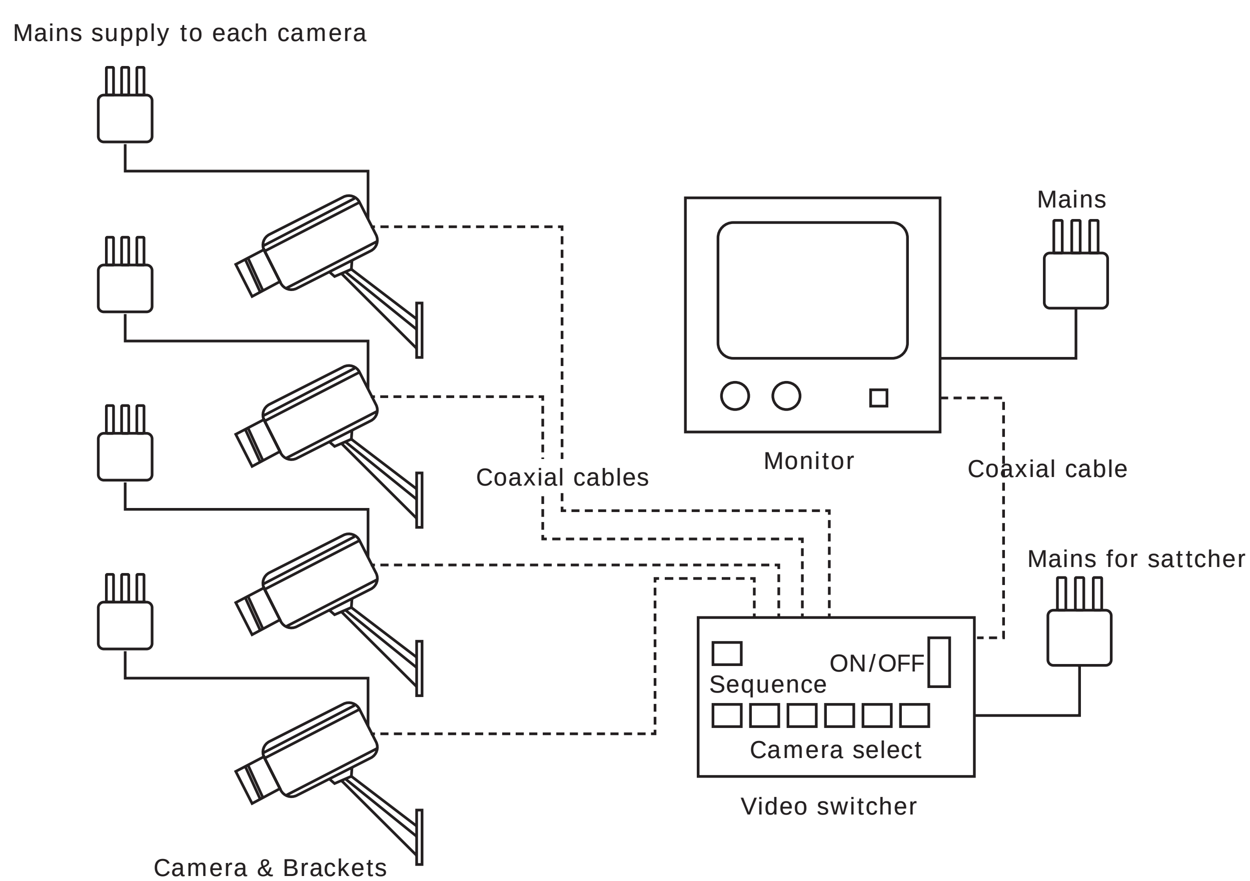


FIGURE 6.19 Multiple Camera Display System

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.

LEARNING OUTCOME

At the end of this chapter, the student could understand

- Fundamental steps of Digital image processing
- Various application of Digital image processing
- Working principles of image sensors (CCD, CMOS)
- Basic functions of Digital camera
- Fundamental elements of CCTV System

GLOSSARY

Electromagnetic spectrum	The complete range of electromagnetic radiation from short wavelength (gamma radiation) to long wavelength (radio waves).
Image	An image records visual snapshots of the world around us.
Imaging Device	A piece of equipment that captures an image. Example includes digital camera, side-scan sonar system and scanning electron microscope.
Sharpening	An area process that emphasizes the details in an image.
Pixel	A square unit of visual information that represents a tiny part of a digital image.
Dynamic range	The ratio between the brightest and dimmest gray level acceptable to an imaging system.
Mapping	The mathematical conversion of one set of numbers into a different set based upon some transformation.
Focal length	The distance between the center of a lens, or its secondary principal point and the imaging sensor. It determines the size of the image.
Infrared (IR)	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.

Mega pixel	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.
Memory card	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.
Shutter	A mechanism in the camera that controls the duration of light transmitted to the film or sensor.

QUESTIONS

Part – A (1 Mark)

I 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

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.
4. What is meant by pixel?
5. Write any four application of Digital image processing
6. What is image enhancement?
7. Which sensor is mostly used in smart phones? Why?

8. Write the applications of CCD sensor.
9. What is meant by viewfinder?
10. What are the uses of CCTV System?

Part – C (5 Marks)

III Explain the following questions

1. Explain the different types of image processing.
2. Compare CCD and CMOS sensors.
3. Explain simple CCTV system.
4. 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. Describe CMOS sensors with neat diagram.
4. Explain main powered CCTV system with neat diagram.

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)

CHAPTER 7

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

GUW6X

CONTENT

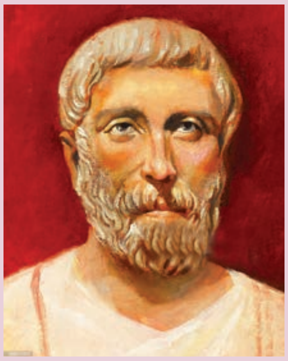
HISTORY OF SOUND

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.

Galilio Galili



Phythagoras

Robert Boyle

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.

DO YOU KNOW?

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.

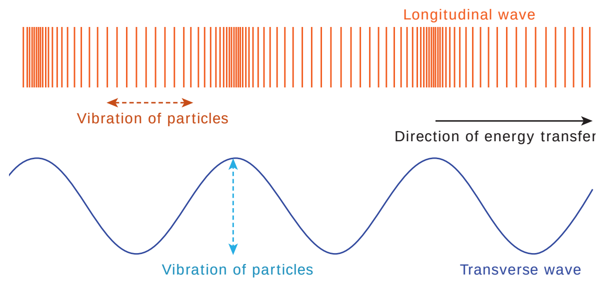


FIGURE 7.1 Longitudinal and Transverse Wave

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

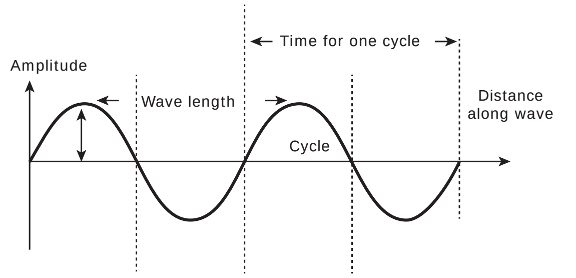


FIGURE 7.2 Characteristics of Sound waves

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 λ (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 sinusodal 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

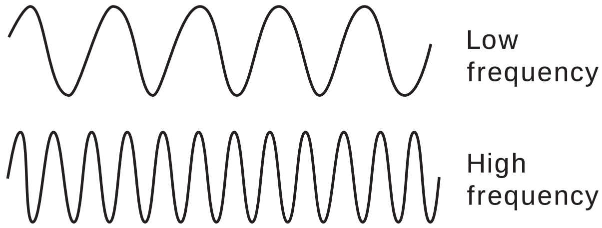


FIGURE 7.3 High and low frequency

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.

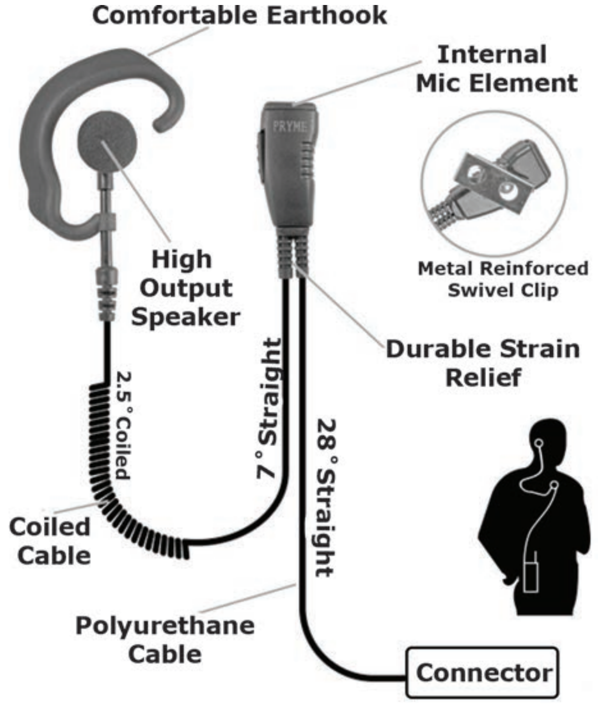


FIGURE 7.4 Lavalier Microphone

7.3.2 Crystal microphone

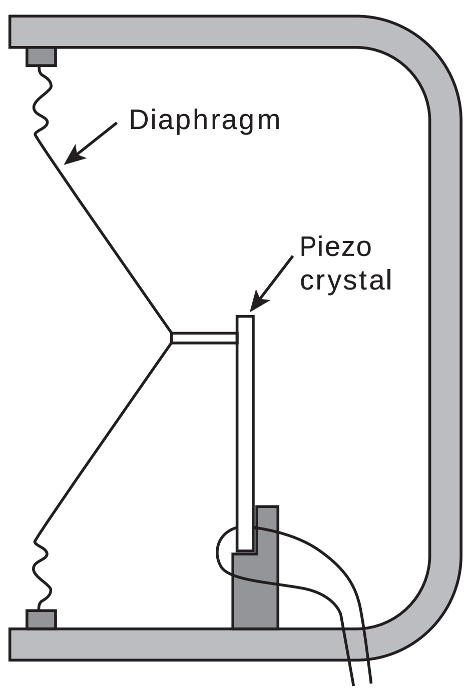


FIGURE 7.5 Crystal Microphone

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 Michrophones (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 chips. 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 Head phones

Headphones are a pair of small speakers, which are used for listening to sound from a music player, computer, Laptop, Smart phone 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

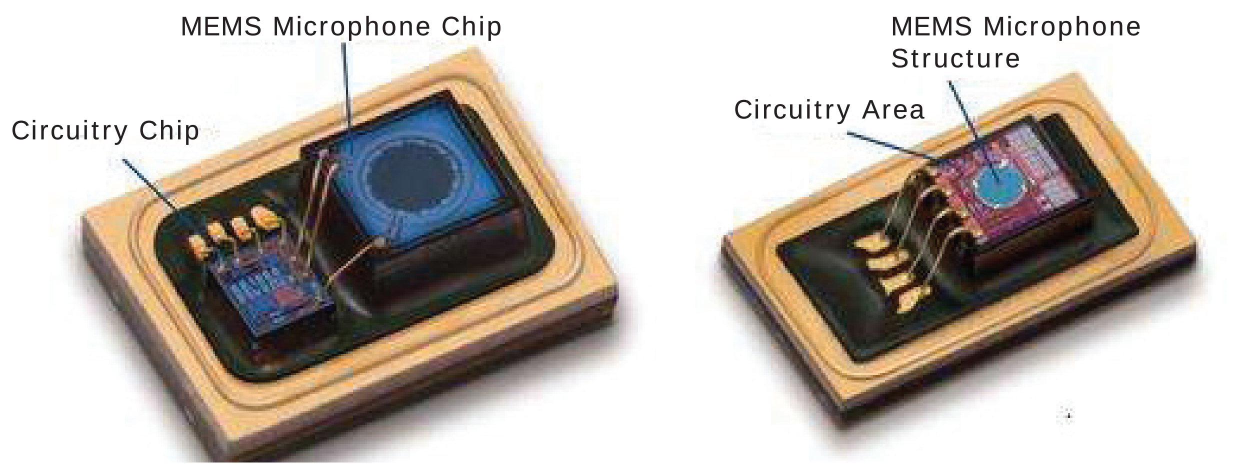


FIGURE 7.6 MicroElectroMechanical Michrophones (MEMS)

the ear and are commonly called ear buds. Nowadays, headphones can be either wireless or wired.

DO YOU KNOW?

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

FIGURE 7.7 Headphones

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 electro dynamic 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.

FIGURE 7.8 Flat panel speakers

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 charecteristics and durability.

FIGURE 7.9 Piezoelectric Speakers

Piezoelectric are solid state technology which makes them durable and good for use as a microphone under water. These speakers are used as michrophones 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 sub divided 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 Figure7.11 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

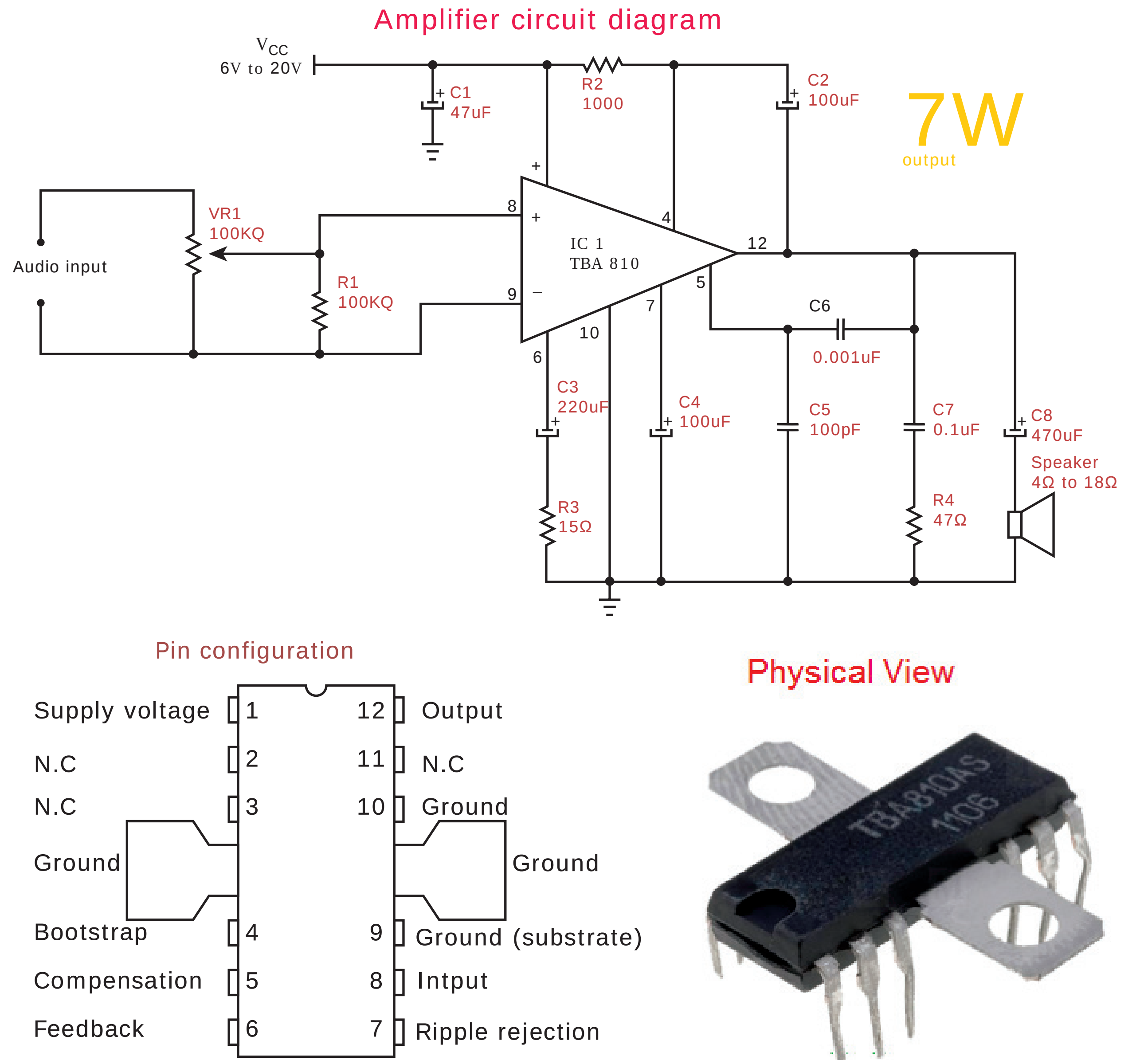


FIGURE 7.11 Audio Amplifier using TBA 810 IC

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,

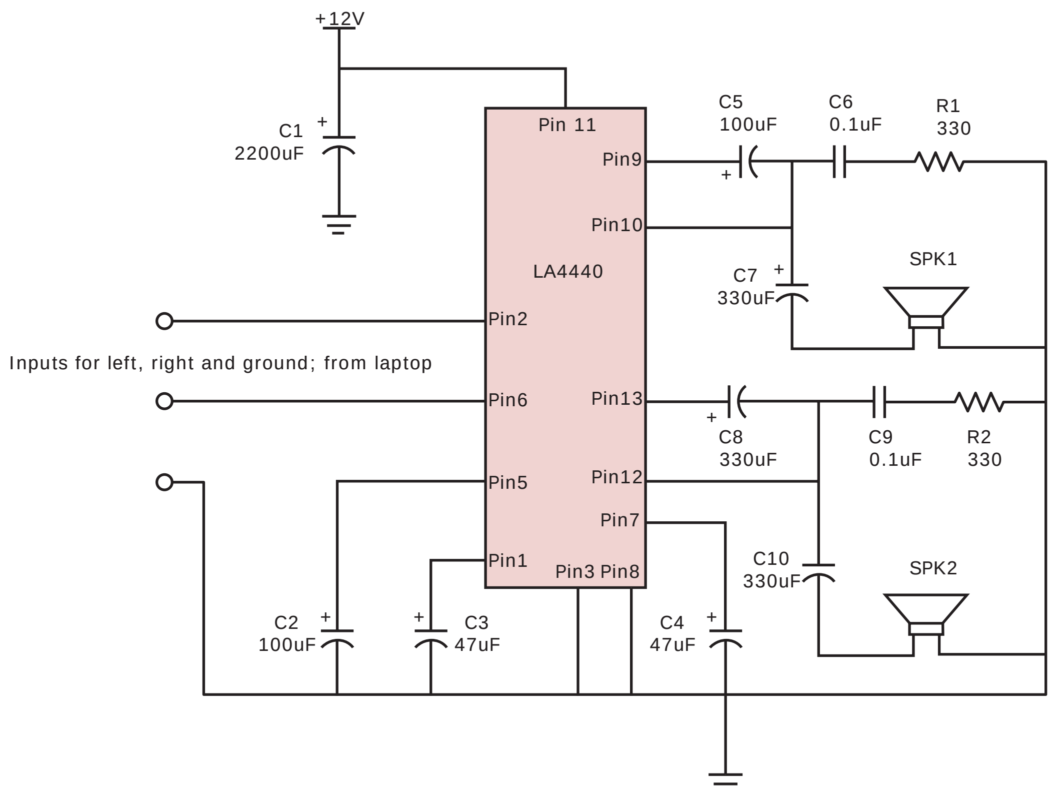


FIGURE 7.12 The Audio amplifier circuit diagram

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° 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 C_4 and voltage divider resistors R_2, R_3, 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 C_1 and C_2 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.

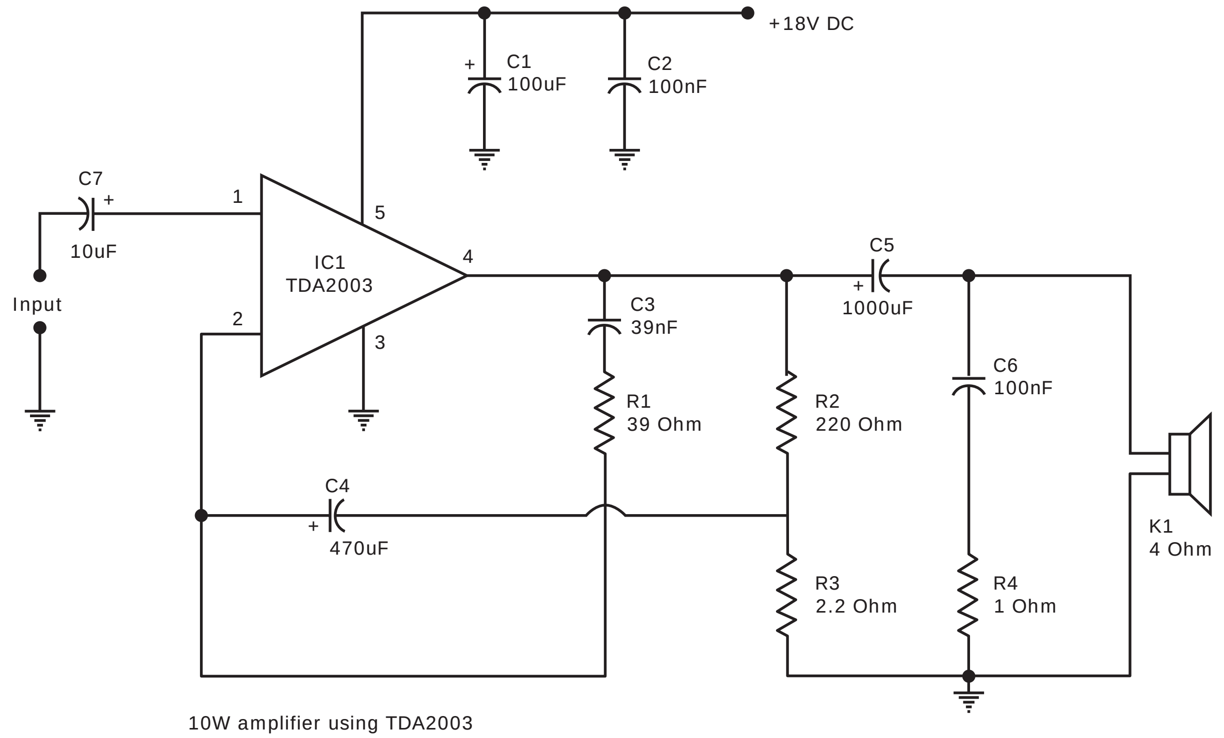


FIGURE 7.13 Audio Amplifier using TDA 2003

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

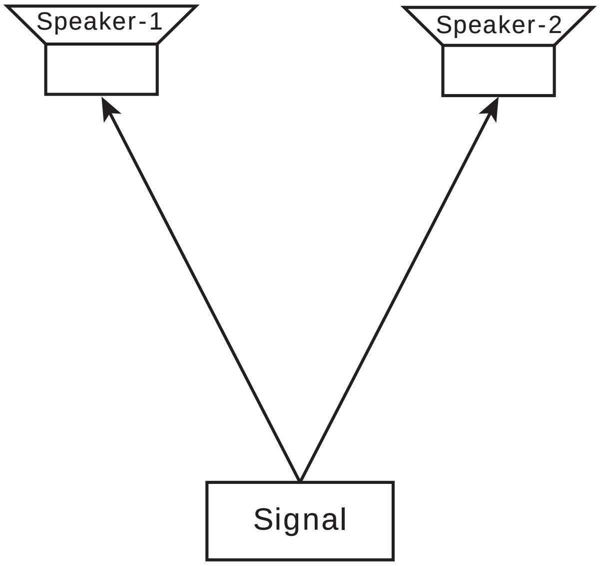


FIGURE 7.14 Monaural sounds

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.

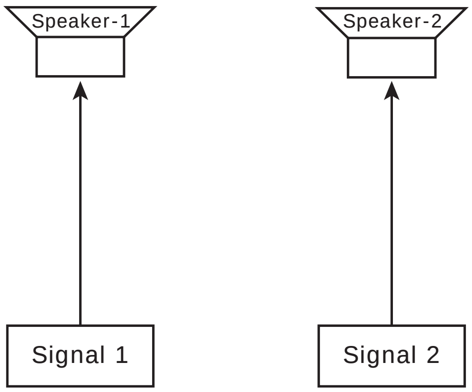


FIGURE 7.15 stereo phonic sounds

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 microphone 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 loud speakers. 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 feed Back
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

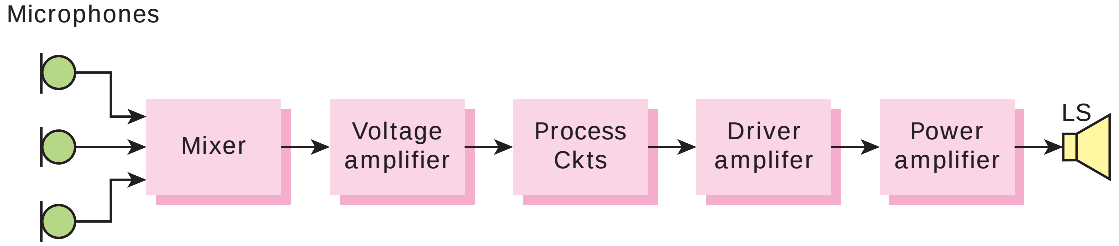


FIGURE 7.16 PA system

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

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.

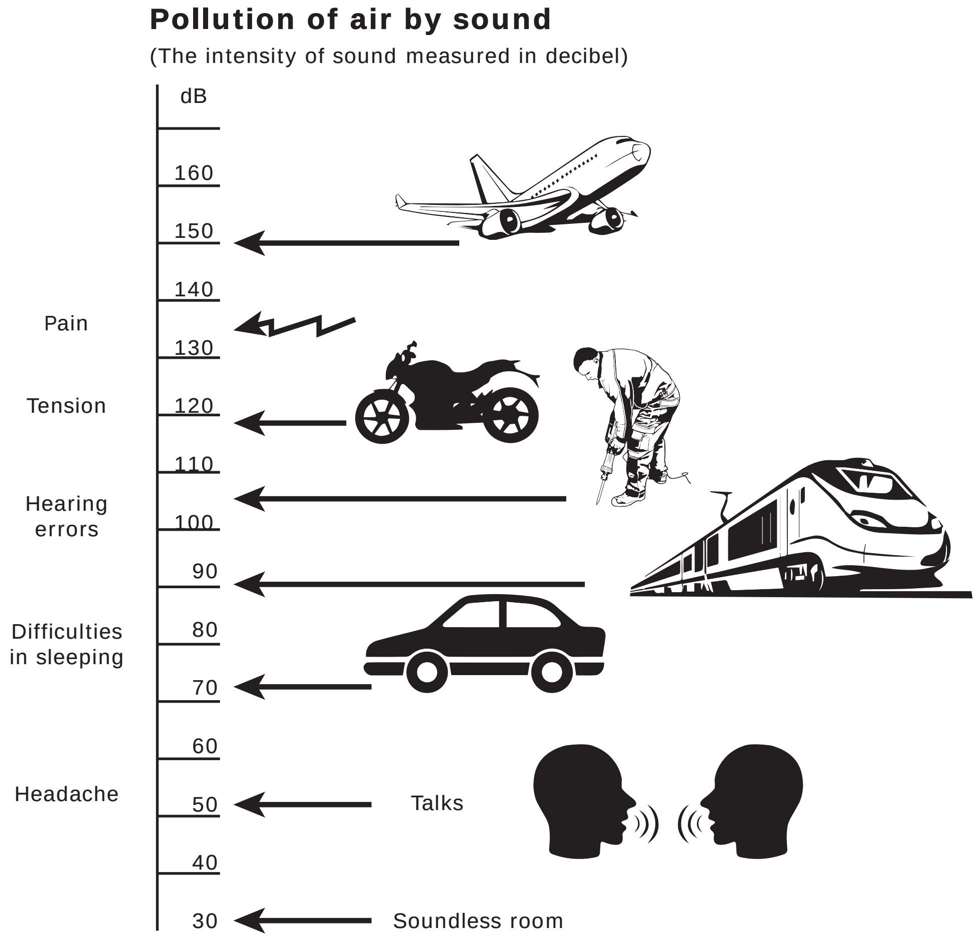


FIGURE 7.17 Various sources of sound pollution and their effects

TABLE 7.1. Intensity of sound noise sources and human perception

Noise source	Intensity of sound (dB)	Human perception
Threshold of hearing	0	Threshold of hearing
Breathing	10	Just audible
Sound of leaves in trees	20	Very quiet
Whispering	30	Very quiet
Normal conversation	30-40	Quiet
Homes and Restaurant	45-50	Quiet
Loud conversation	65	Moderately loud
Lawn mower	60-80	Moderately loud
Vacuum cleaner	80	Moderately loud
Traffic noise	60-90	Loud
Heavy trucks	90-100	Very loud
Thunderstorm	110	Very loud
Rock music	120	Uncomfortably loud
Jet take off (100 m distance)	120	Uncomfortably loud
Jet engine (at 15 m distance)	140	Painfully loud
Rocket engine	170-180	Painfully loud

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 : 75 dBA (Day time)
   70 dBA (Night time)
2. commercial area : 65 dBA (Day time)
   55 dBA (Night time)
3. residential area : 55 dBA (Day time)
   45 dBA (Night time)
4 silence zone : 50 dBA (Day time)
   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

- **Characterices 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

Acoustic	The science and scientific study of sound. The properties of a room or environment that affect the qualities of sound.
Ambient noise level	'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.,
Attenuate	To make weaker. An attenuator uses resistance to reduce output voltage, as with a volume control.
Bass	The lower end of the frequency range, from about 20 Hz to 300 Hz.
dB (Decibel)	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.
Equaliser	A device that permits the precise control of specific frequency ranges. Examples are: Graphic, parametric, notch filter, cut only.
Filter	A device that removes unwanted frequencies or noise from a signal
Frequency	The number of times that a periodic function or vibration occurs or repeats itself in one second
Frequency response	The range of frequencies that are reproducible by a speaker or electronic component
Hz (Hertz)	A unit of measure that equals one cycles per second
Impedance	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)

Mixer	An electronic device that permits the combining of a number of inputs into one or more outputs. Mixers commonly provider of variety of controls-tone, volume, balance and effects – for each 'channel'.
Pitch tone	A function of frequency
Reflection	A term that describes the amount of sound 'bouncing' off of hard surfaces.
Reverberation	Sound waves that confirm to bounce around a space after the sound source has ended
Room	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
SPL (Sound Pressure Level)	The measurement of the loudness or amplitude of sound expressed in decibels (dB)
Transducer	A device which converts sound into electrical energy (a microphone), or electrical energy into sound (a spectrum)

QUESTIONS

Part – A (1 Mark)

ZYD13

I Multiple choice Questions

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 throguh __________

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. Infra-audio d. Infrasound

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 52^0C?

a. Dynamic b. Crystal

c. Rubber d. condenser

9. The part of the ear that responds to sound waves like a microphones diaphragm is the _____________

a. Lobe

b. Ear drum

c. Bones of the middle ear

d. Fluid in the ear

10. _____ is early reflection of sound

a. Echo

b. Reverberation

c. Pure sound

d. Intelligible sound

11. Sound which has jarring and unpleasant effect on our ears is called?

a. Frequency b. Amplitude

c. Noise d. Musical sounds

12. Multiple reflections are called _____________

a. Reverberations

b. Refraction

c. Echo

d. Compressions

13. A higher pitch means?

a. Zero frequency

b. Lower frequency

c. Higher frequency

d. Lower loudness

14. Bass response is

a. Maximum high frequency response

b. Emphasizing the high audio frequency

c. By passing high audio frequency

d. By passing low audio frequency

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. Explain the working functions of crystal microphone
4. Draw and explain audio amplifier using TDA 2003.

Part – D (10 Marks)

IV Answer in One Page (Essay type Question)

1. Explain the various applications of Acoustic Engineering
2. How acoustic engineering is essential in auditorium and theater design? Explain in detail.
3. Draw the block diagram of PA system and explain each block
4. Explain DTS & Dolby techniques in theater sound system.

Answers

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

CHAPTER 8

Power Electronics

LEARNING OBJECTIVE

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

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)

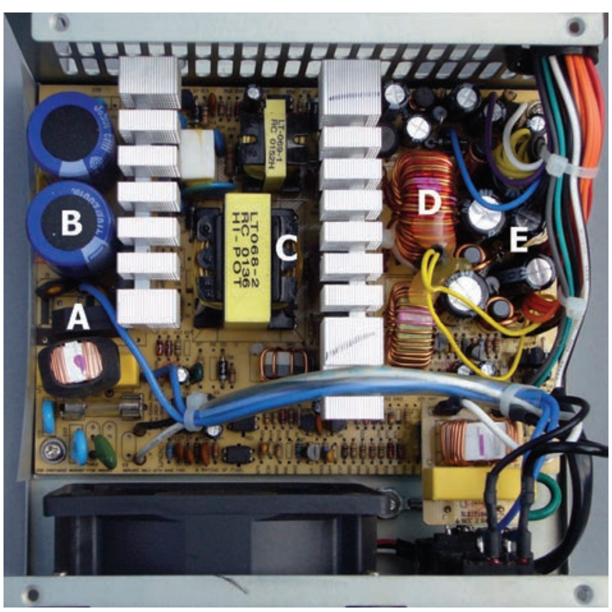
Applications of power electronics range in size from a switched mode power supply in an AC adapter, battery chargers, audio amplifiers, fluorescent lamp ballasts, through variable frequency drives and DC motor drives used to operate pumps, fans, and manufacturing machinery, up to gigawatt-scale high 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

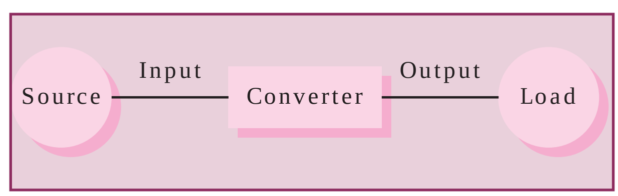


FIGURE 8.1 Power Electronics

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

> **DO YOU KNOW?**
>
> **The Difference between Electrical and Electronics Circuits**
>
> *Both involve moving electricity around a circuit to* ***power*** useful products and machines, but that is where the similarity ends!
>
> *The main* ***difference between*** *electrical and* ***electronic*** circuits is that electrical circuits have no decision making (processing) capability, whilst ***electronic*** circuits do.

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.

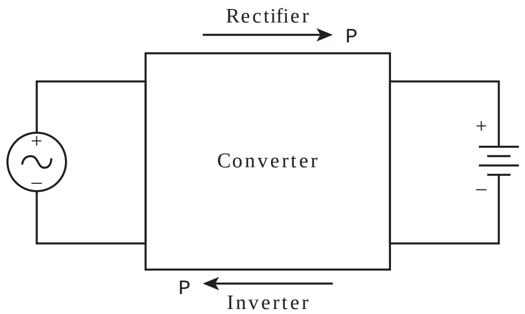


FIGURE 8.2 A converter can operate as a rectifier or an inverter, depending on the direction of average power P.

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.

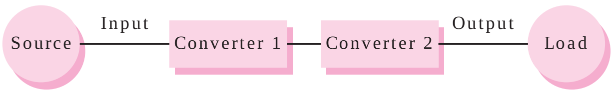


FIGURE 8.3 Two converters are used in a multistep process.

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.

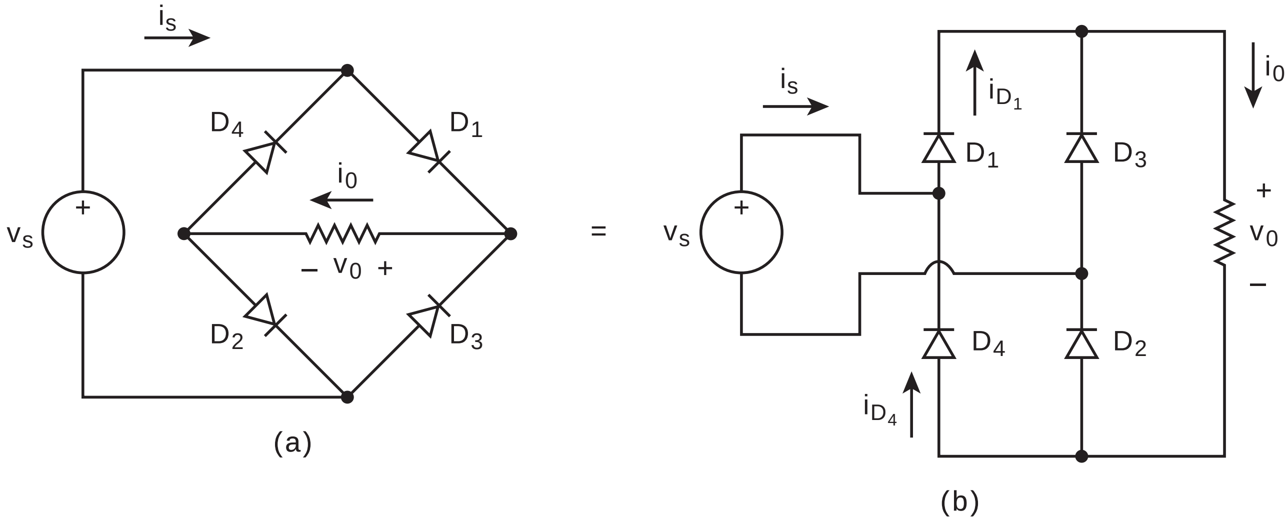


FIGURE 8-4 Full-wave bridge rectifier. (a) Circuit diagram. (b) Alternative representation.

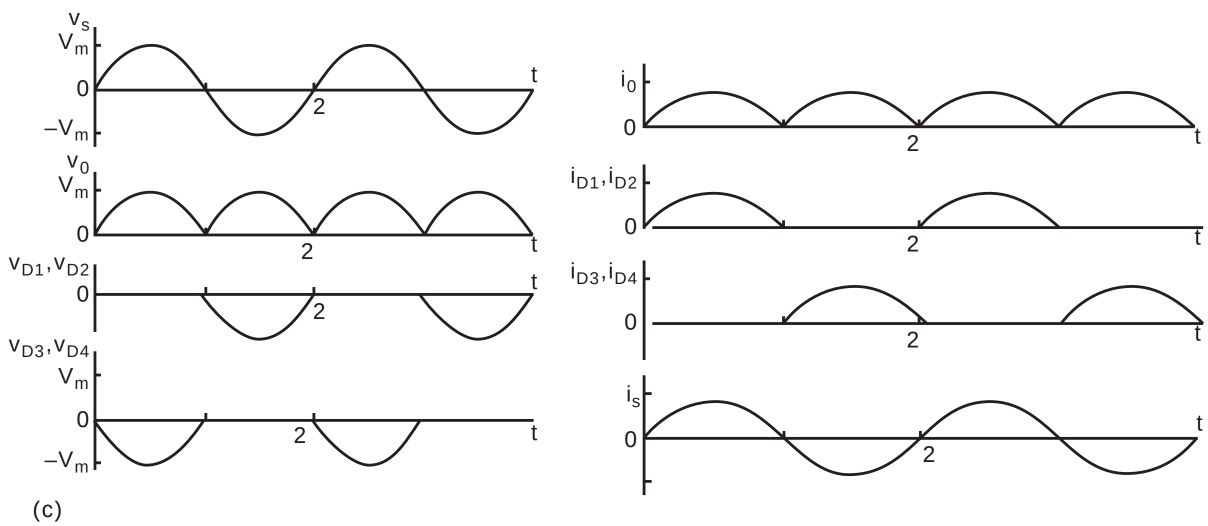


FIGURE 8.4(c) Full–Wave Bridge Rectifier Voltage & Current Wave forms

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 iD1 - iD4, 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 2ω, where ω is the frequency of the AC input since two periods of the output occur for every period of the input.

8.3 DC TO AC - Inverter

Inverter is an electronic circuit, which converts direct current (DC) into alternating current (AC). The input voltage, output voltage and frequency, and all power handling depend upon the DC source. 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 tuneable 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

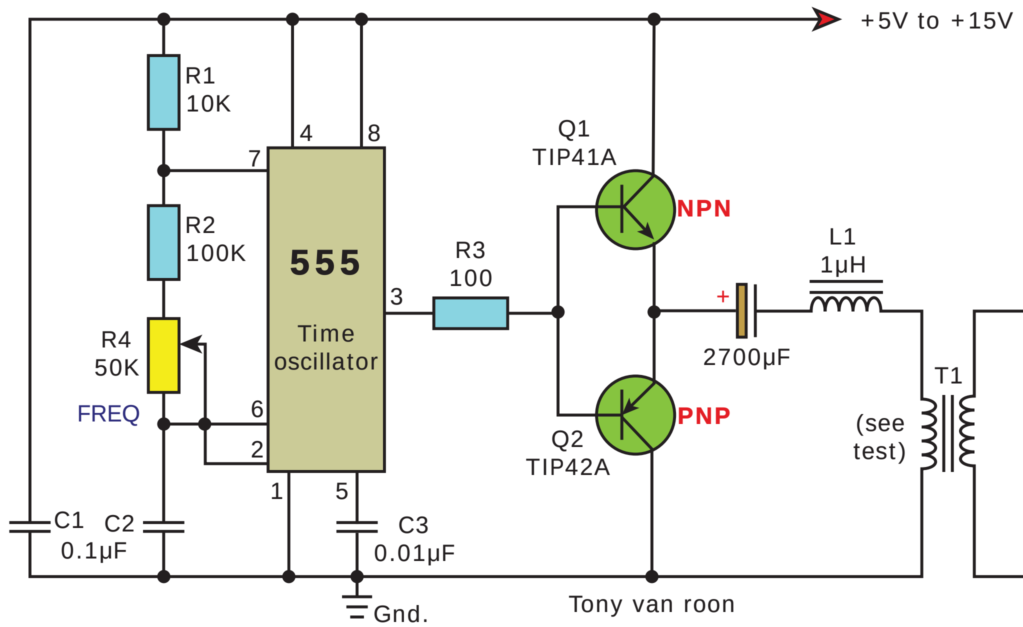


FIGURE 8.5 12 V DC to 220 V AC inverter using 555

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

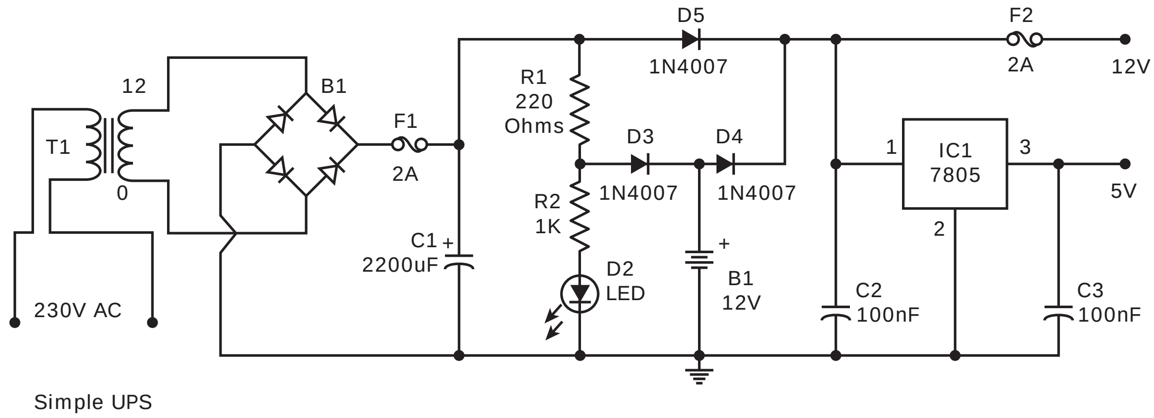


FIGURE 8.6 Simple UPS circuit

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

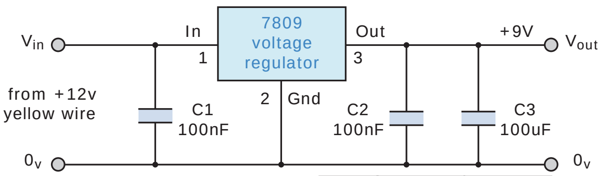
A voltage regulator is a circuit used to regulate the output voltage level for a given application. When a steady, reliable and fixed output voltage is required, the regulator circuit provides a constant output voltage irrespective of the changes in the input voltage or load conditions. Also, it acts as a buffer for protecting components from damages.

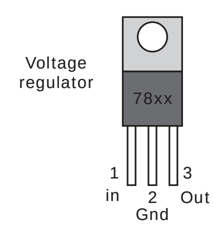
Basically, there are two types of voltage regulators available

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.





Type	Min. input voltage	Output voltage
7805	7V	+5V
7806	8V	+6V
7808	10V	+8V
7809	11V	+9V
7812	15V	+12V
7815	18V	+15V
7818	22V	+18V
7824	30V	+24V

FIGURE 8.7 7809 V DC to DC voltage regulator

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

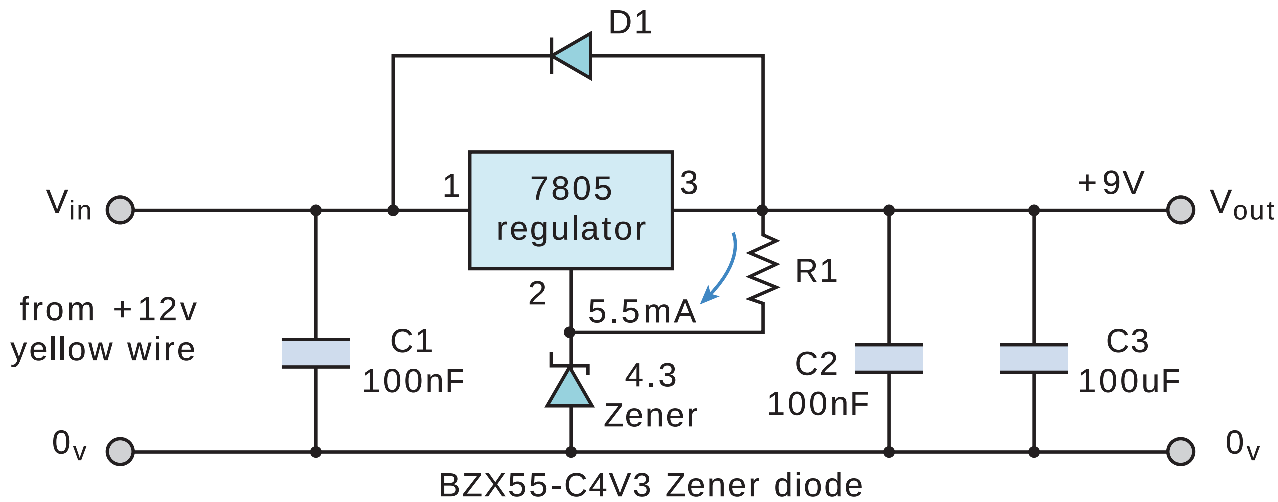


FIGURE 8.8 7805 dc to dc voltage regulator circuit

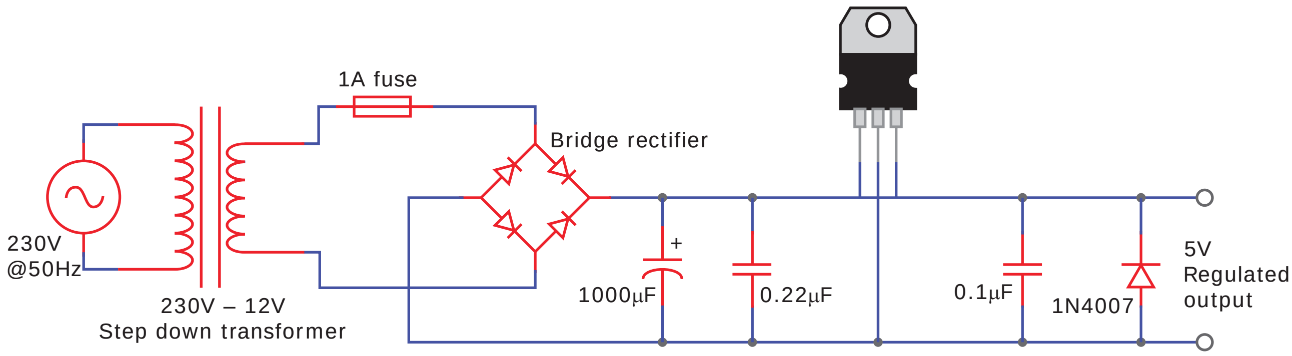


FIGURE 8.9 5 V regulator circuit using 7805

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 over-voltage protection.

TABLE 8.1 Pin Description of 7805

Pin No	Pin	Description
1	INPUT	Pin 1 is the INPUT Pin. A positive unregulated voltage is given as input to this pin. Voltage range 7-25 V.
2	GROUND	Pin 2 is the GROUND Pin. It is common to both Input and Output.
3	OUTPUT	Pin 3 is the OUTPUT Pin. The output is regulated at 5 V and the maximum current supplied is 1.5 A.

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.

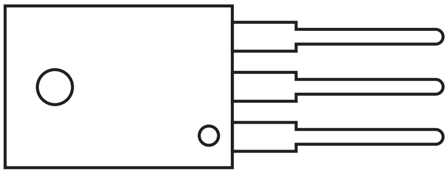


FIGURE 8.10 Pin diagram of Negative Voltage Regulators

TABLE 8.2 Negative Voltage Regulators and their output voltage

IC Number	Output Voltage
7905	-05 Volts
7912	-12 Volts
7915	-15 Volts
7918	-18 Volts

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

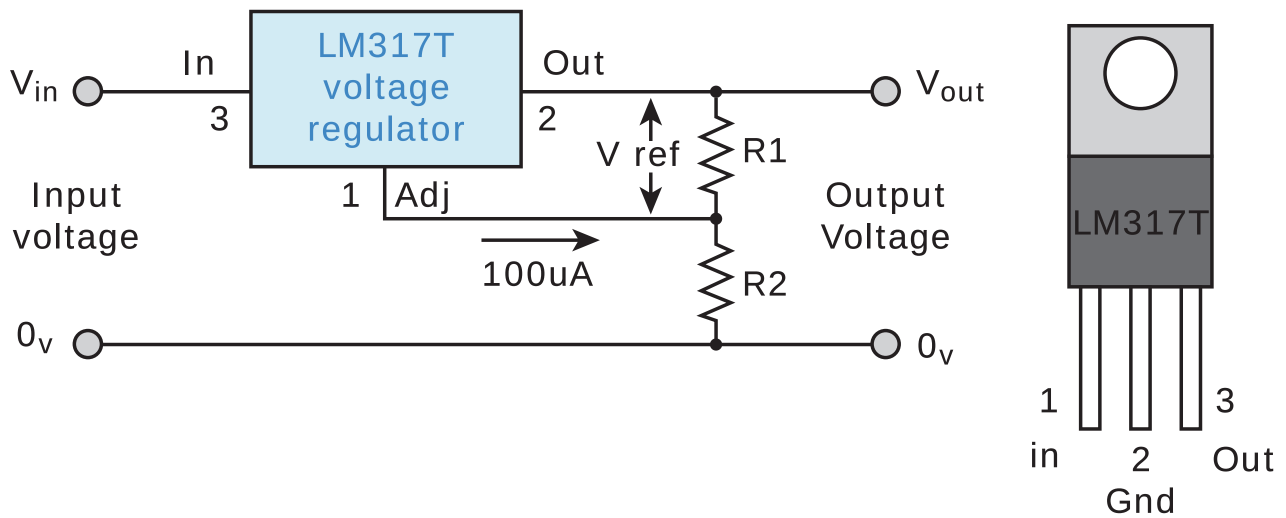


FIGURE 8.11 Variable Voltage Regulator using LM317

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.

8.6.1 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

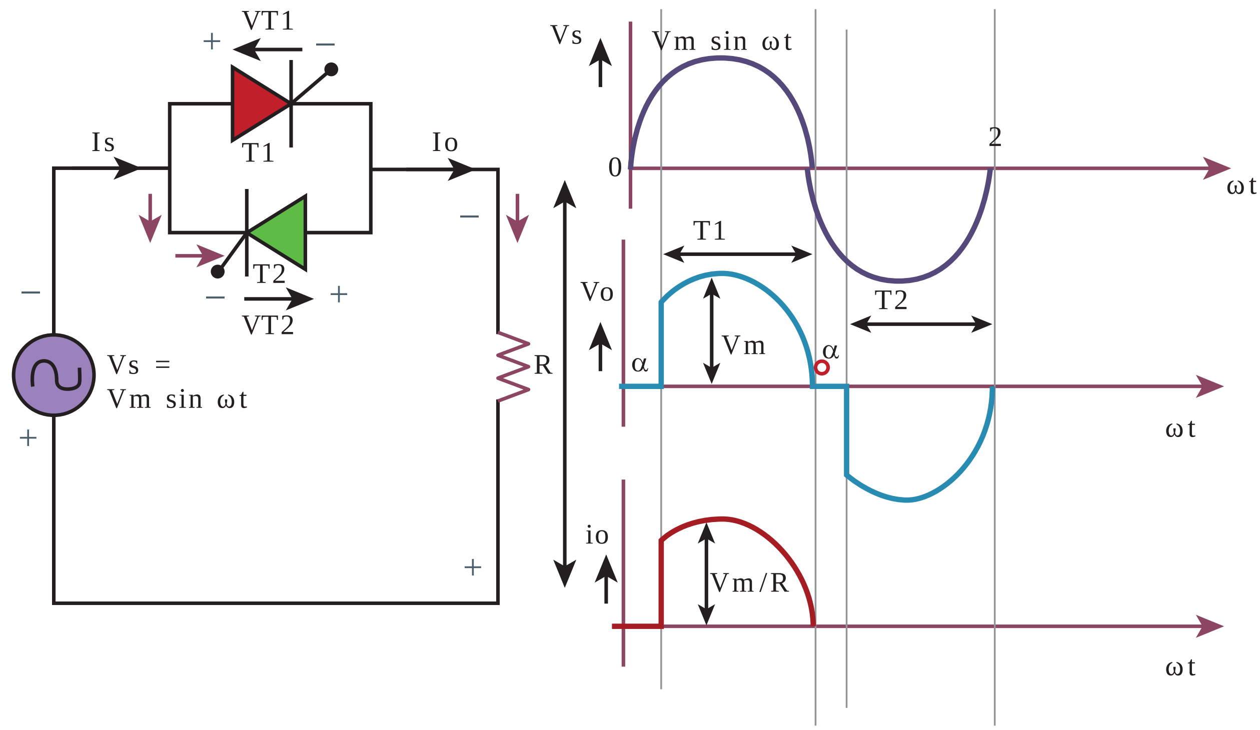


FIGURE 8.12 Single-phase AC voltage controller with a resistive load; (b) Waveforms.

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 Vsw 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 $1/\sqrt{2}$ times the rms load current if the SCRs are on for equal time intervals.

For the circuit of Fig. 8.12, S1 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, S1 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 S2 during the negative half-cycle of the source, providing a path for negative load current. If the gate signal for S2 is a half period later than that of S1, 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 supress 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

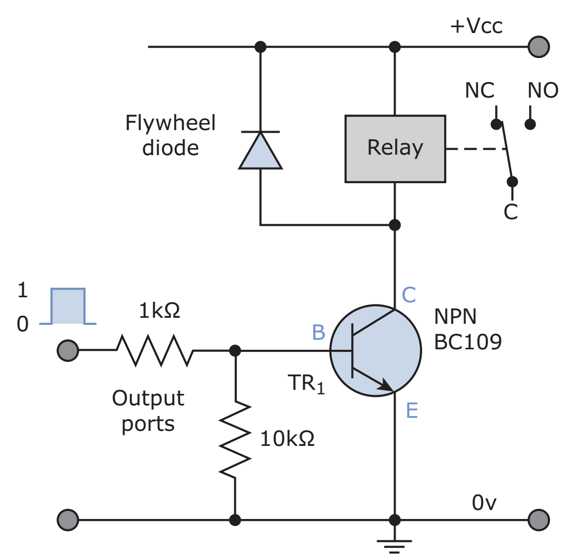


FIGURE 8.13 NPN Relay Switching Circuit

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 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 8.14. 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

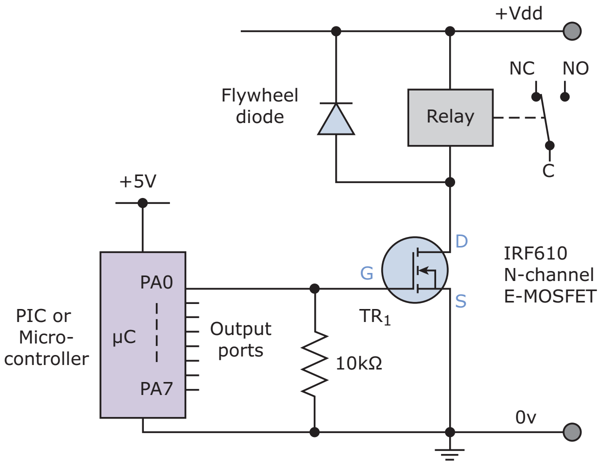


FIGURE 8.14 Microcontroller Relay Switching Circuit

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.

8.7.3 Switching Circuit Using UIN2003a IC

ULN2003A is a relay driver IC consisting of a Darlington array. It is made up of seven open collector Darlington pairs with common emitter. ULN2003A 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 8.15 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 ULN2003A 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.

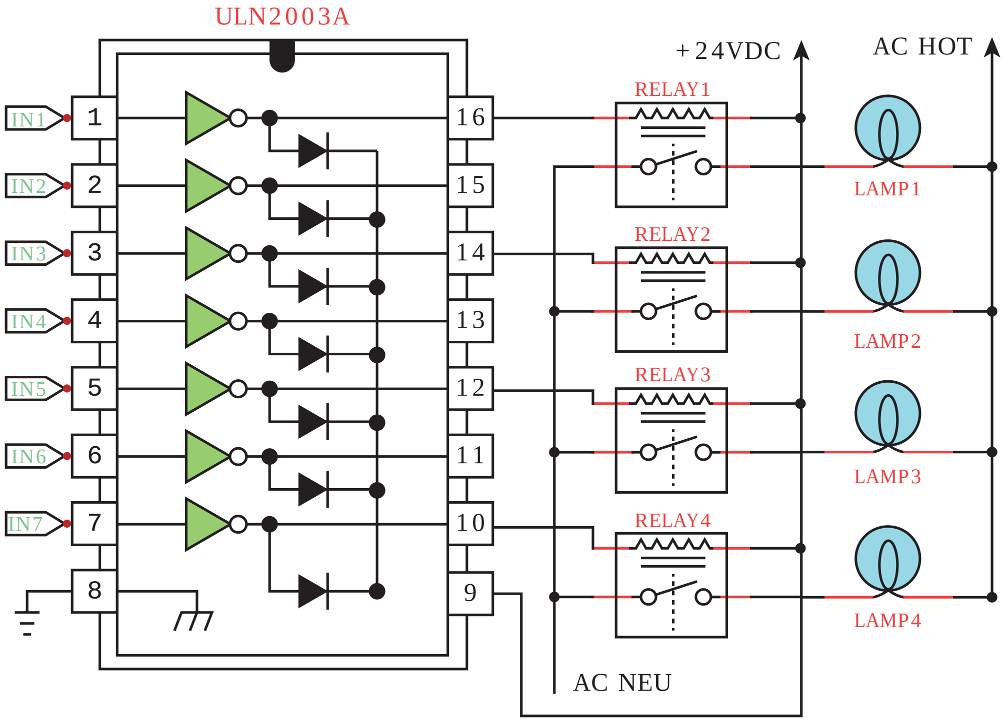


FIGURE 8.15 ULN2003A Relay Switching Circuit

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 8.16 shows the externel structure of SMPS and Figure 8.17 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.

FIGURE 8.16 Externel structure of SMPS

FIGURE 8.17 Internal structure of SMPS

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 8.18 shows the block diagram of SMPS

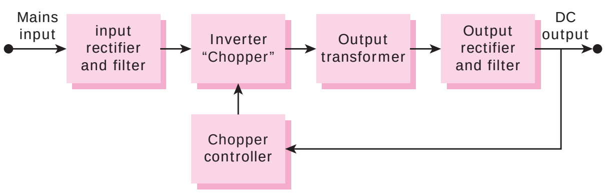


FIGURE 8.18 Block diagram of SMPS

Input Rectifier stage

If the SMPS has an AC input, then the first stage is to convert the input to DC. This is called rectification. An SMPS with a DC input does not require this stage. In some power supplies (mostly computer ATX power supplies), the rectifier circuit can be configured as a voltage doubler by the addition of a switch operated either manually or automatically. This feature permits operation from power sources that are normally at 115 V or at 230 V.

The rectifier produces an unregulated DC voltage which is then sent to a large filter capacitor. The current drawn from the mains supply by this rectifier circuit occurs in short pulses around the AC voltage peaks.

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

Rectifier	Conversion of AC to DC
Inverters	Conversion of DC to AC
UPS	Uninterrupted power supply
DC to DC	to maintain different DC Voltages
AC to AC	to maintain different AC Voltages
SMPS	Switch Mode Power Supply

QUESTIONS

Part – A (1 Mark)

I Multiple choice Questions

GSO1H

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

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

Part – B (3 Marks)

II Answer in one or two sentences

1. Define the term power electronics
2. Write the applications of Power Electronics
3. What is the objective of power electronics?
4. Write down the three primary types of inverters
5. What is the purpose of UPS?
6. Write about DC to DC converters
7. Write down the advantages of SMPS
8. Write the advantages of UPS.
9. Draw the Pin details of 7805 IC
10. What is switching circuits?

Part – C (5 Marks)

III Answer in a paragraph

1. Write down the converter relationship between DC input/DC output and its application.
2. Draw the single phase full-wave rectifier
3. Write short notes on DC to AC-Inverter
4. Write down the important points on 7805 voltage regulator IC

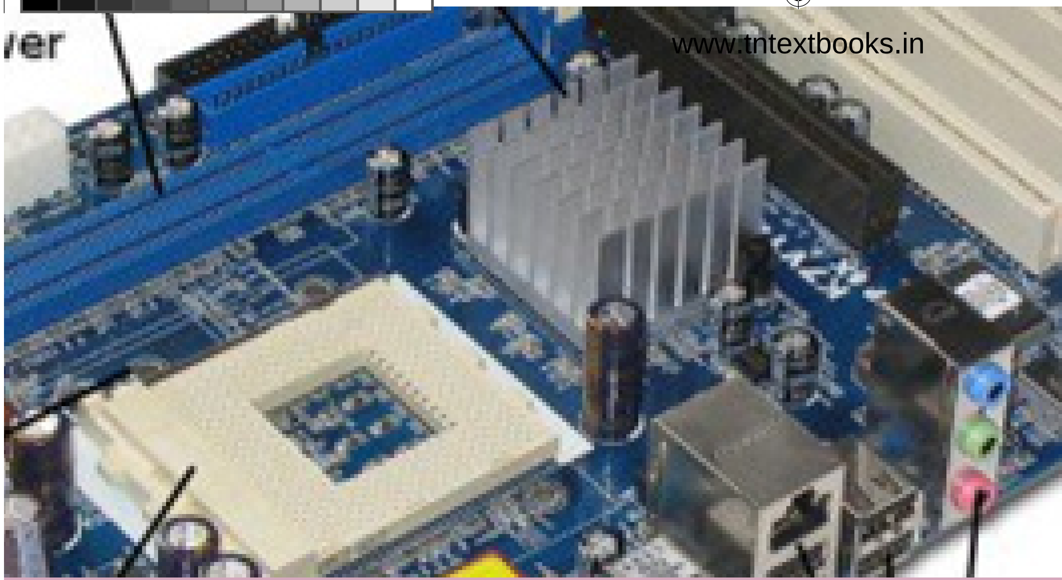
Part – D (10 Marks)

IV Answer in One Page (Essay type Question)

1. Draw the circuit diagram of UPS and define its working
2. Explain the working of voltage regulator using IC 7805
3. Draw the circuit diagram of switching circuit using ULN 2003 A –IC
4. Draw the block diagram of SMPS and explain each block briefly.

ANSWERS

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



CHAPTER 9

Computer Hardware Techniques

LEARNING OBJECTIVE

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

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 indispensible 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.

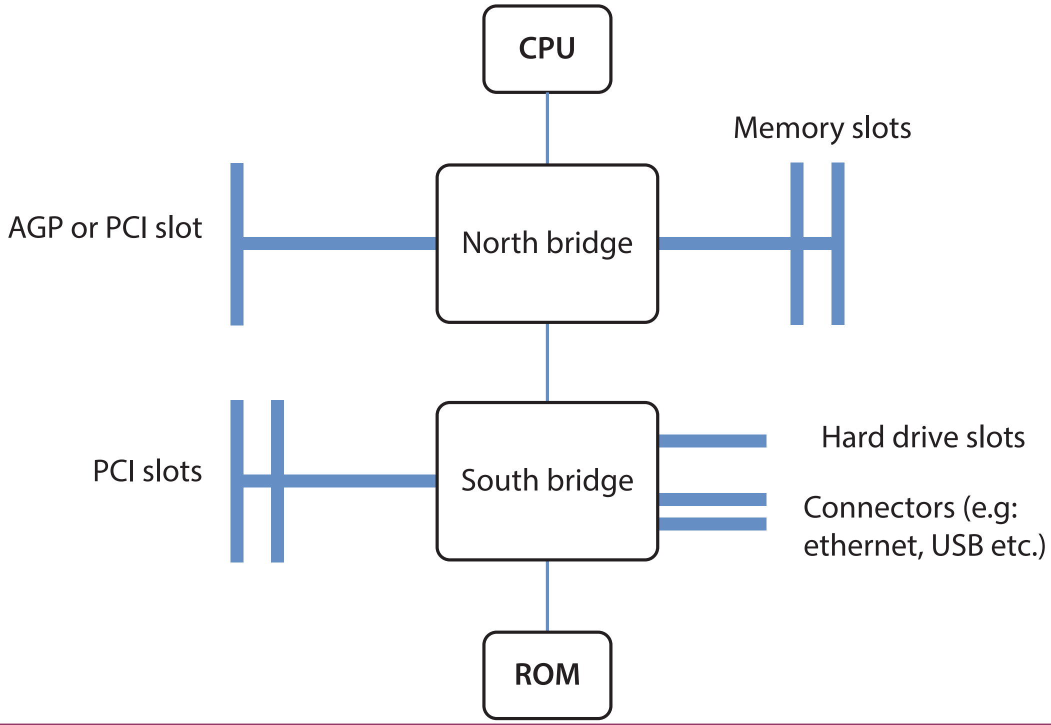


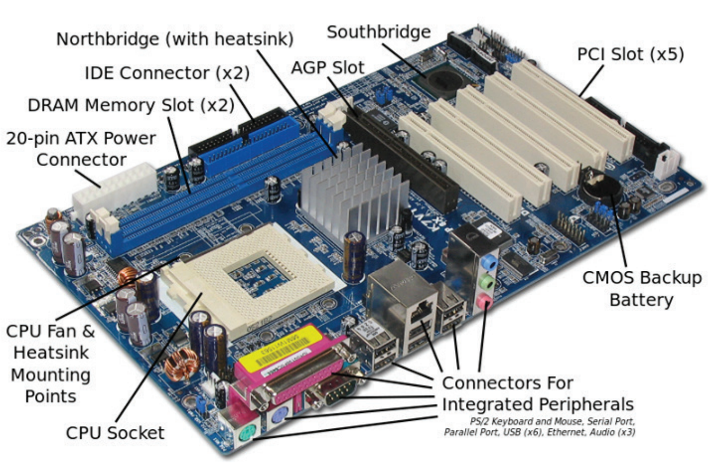
FIGURE 9.1 Schematic Diagram of Mother Board

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 mother board.

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.
- 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).



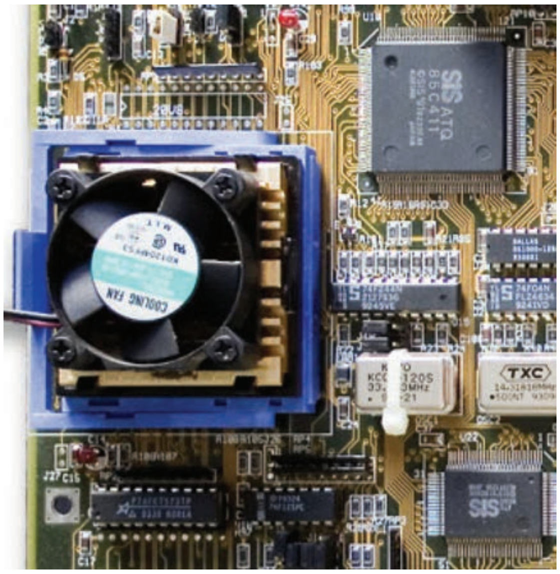


FIGURE 9.2 View of Mother Board with magnified view of the CPU

- A slot for a Video or Graphics Card (VGA) is used to connect the graphics card for communicating the information from CPU or any other device with the display. There are a number of different types of slots available, which includes the Accelerated Graphics Port (AGP) and Peripheral Component Interconnect Express (PCIE).
- Additional slots to connect hardware in the form of Peripheral Component Interconnect (PCI) devices.

9.1.1 Processor

A processor is an integrated electronic circuit that performs arithmetical, logical, input/output (I/O) and other basic instructions that are passed from an operating system (OS). The four primary functions of a processor are fetching, decoding, execution and write-back. Most other processes are dependent on the operations of a processor. Since this processor performs many more micro functions without committing any error, this single integrated chip is called as Microprocessor (µp). But, the µp is about two inches by two inches in size. This little chip is called Brain of the computer.

CPU (Central Processing Unit)

Central Processing Unit (CPU) is the heart and brain of the computer. It runs the Operating System and Application Software installed on the computer to do whatever the user wants to do. The µp handles most operations on a computer, but some operations are handled by specialized tools such as Graphics Processing Units (GPUs). µp is located on the motherboard. The µp gets very hot and therefore needs its own cooling system in the form of a heat sink and fan.

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-

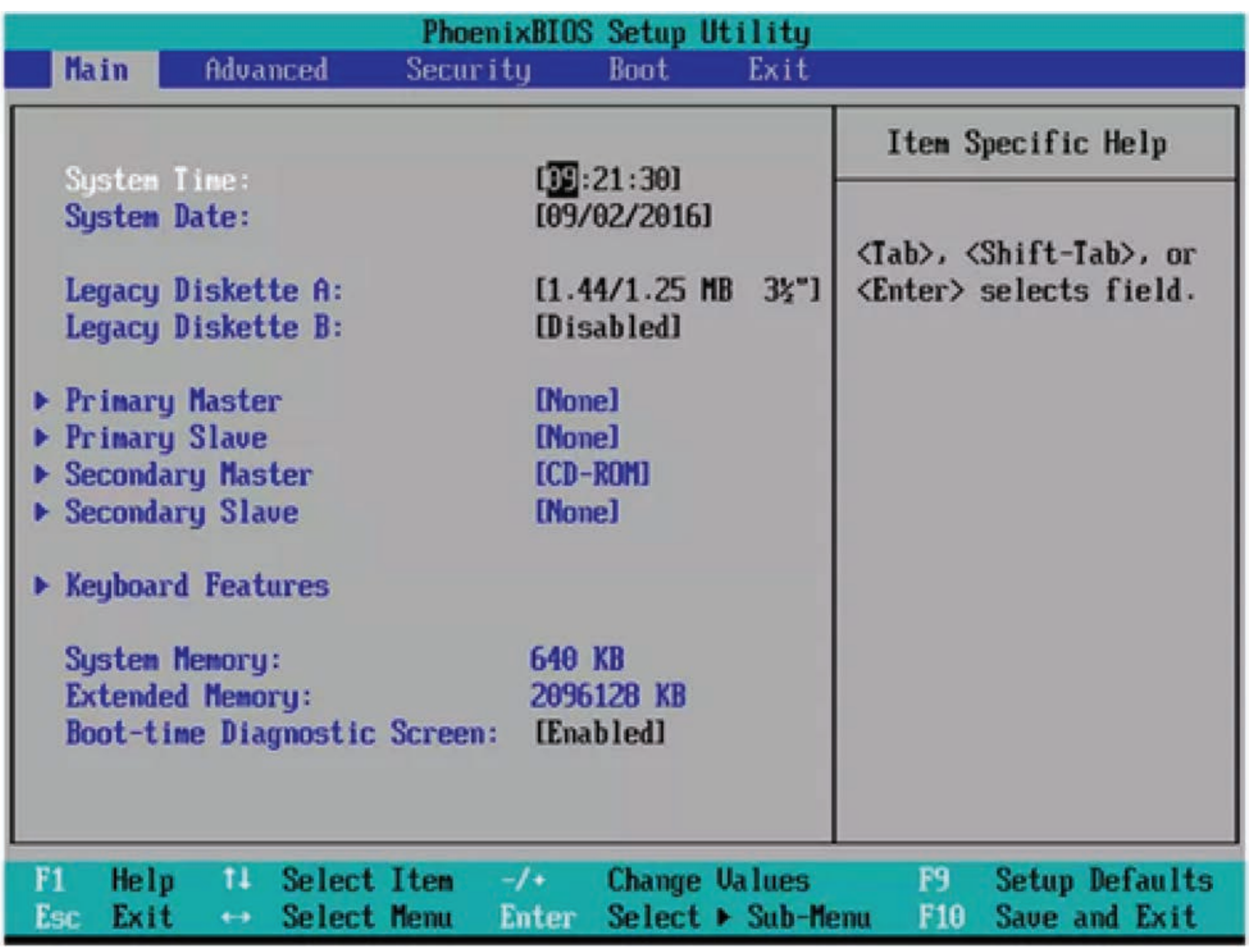


FIGURE 9.3 View of a BIOS set-up

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.

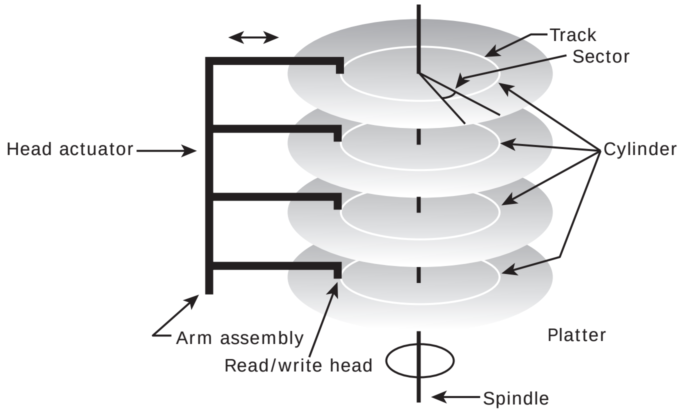



FIGURE 9.4 Outer-view and the parts of a Hard-disk

9.5 CMOS Battery

The CMOS battery is a Lithium-ion battery about the size of a coin. It can hold a charge for up to ten years before needing to be replaced. If the CMOS battery dies, the BIOS settings will reset to their defaults when the computer is turned off.

Motherboards also include a small separate block of memory made from CMOS RAM chips. It kept alive by a battery (known as a CMOS battery) even when the PC's power is off. This prevents reconfiguration when the PC is powered on.

Tip: If the user turn on the computer and notice that the hardware settings have changed, or that user system clock has reset to a date in the past (like January 1st, 1970), i.e., the CMOS battery is dead and needs to be replaced.

Some motherboards, including most modern ATX motherboards will continue to provide power to the CMOS, if the battery is replaced while the computer is powered on.

Warning: If the user wants to replace the CMOS battery, make sure to consult the motherboard documentation for the details and safety information. Visit the motherboard manufacturer's support website, if the user needs to download a new copy of the manual.

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 Zilogs (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.

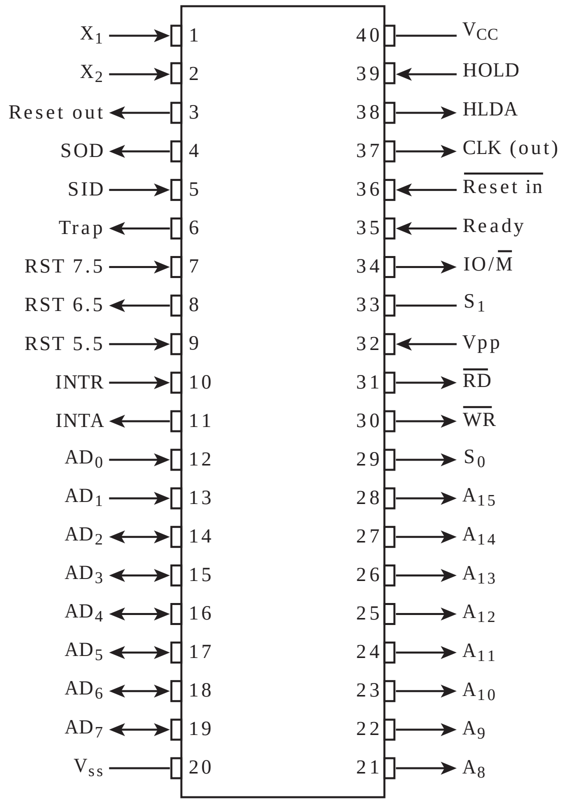


FIGURE 9.5 Pin diagram of 8085 microprocessor

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.

The three control signals are RD, WR & ALE.

- **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.

Power supply

There are 2 power supply signals – VCC & VSS. VCC indicates +5 V power supply and VSS indicates ground signal.

Clock signals

There are 3 clock signals, i.e. X1, X2, CLK OUT.

- X1, X2 – A crystal is connected at these two pins and is used to set frequency of the internal clock generator. This frequency is internally divided by 2.
- CLK OUT – This signal is used as the system clock for devices connected with the microprocessor.

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.

9.8.2 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.

9.9 Computer Ports

9.9.1 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 9.6 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.

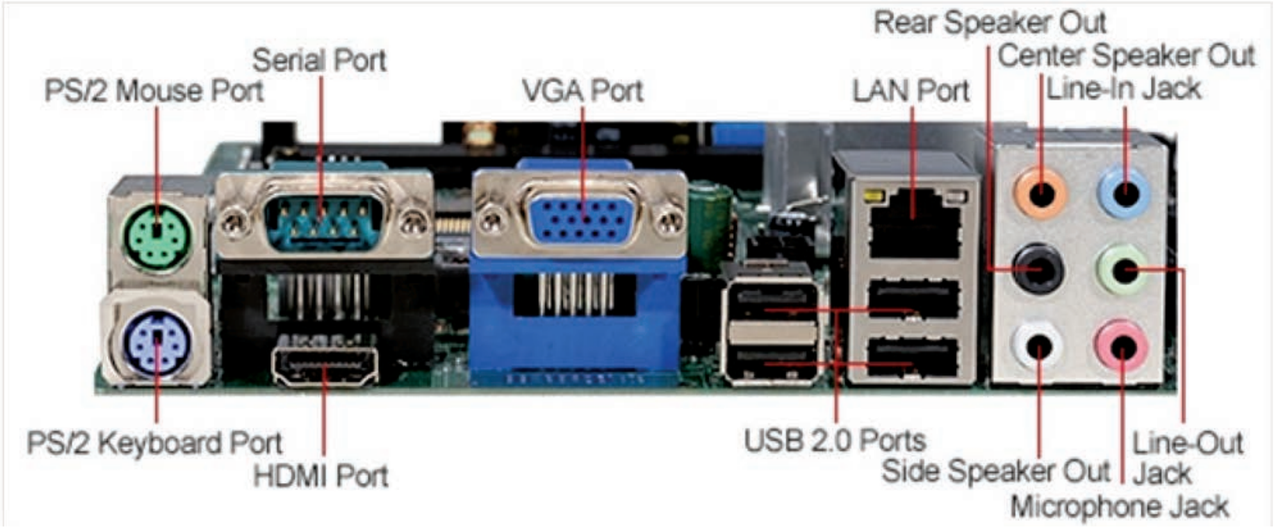


FIG 9.6 View of a port at the backside of the Computer

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 that 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.

9.9.2 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.

9.9.3 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.

9.9.4 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.

9.9.5 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.

9.9.6 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.

9.9.7 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 9.7 shows the USB and Ethernet connectors.

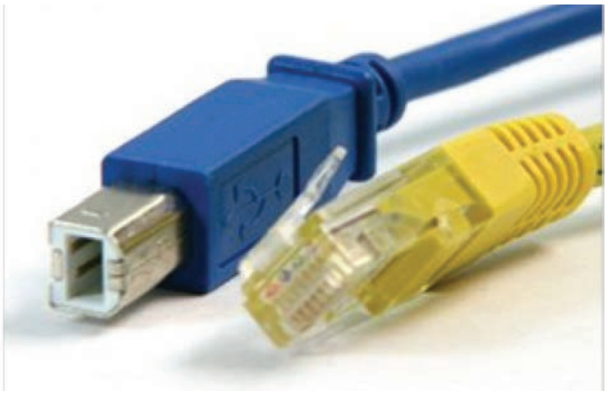


FIGURE 9.7 USB and Ethernet Connectors

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

TABLE 9.1 Comparison of Ports available in computers

	USB 3.1 Gen 2	USB 3.1 Gen 1 (USB 3.0)	USB 2.0	USB 1.1	Serial	Parallel
Industry Standard	Yes	Yes	Yes	Yes	Yes	No
Bandwidth	10 Gbps	5 Gbps	480 Mbps	12 Mbps	115 Kbps	115 KBps EPP/ECP - 3 MBps
Number of Devices	127 devices on a single USB bus	127 devices on a single USB bus	127 devices on a single USB bus	127 devices on a single USB bus	Limited to the number of ports available on the computer.	Limited to the number of ports available on the computer.
Bus Power	Yes, can provide up to 900 mA at 5V (Also USB Power Delivery)	Yes, can provide up to 900 mA at 5V (Also USB Power Delivery)	Yes, can provide up to 500 mA at 5V	Yes, can provide up to 500 mA at 5V	No	No
Cable Length Limit	Cable can be of any length as long as electrical spec is met. Practical max length is 1m.	Cable can be of any length as long as electrical spec is met. Practical max length is 3m.	5 m / 16 ft	5 m / 16 ft	3 m / 10 ft	1.8 m / 6 ft
Plug'n'Play	Yes	Yes	Yes	Yes	No	No
Hot Swapable	Yes	Yes	Yes	Yes	No	No

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.

9.9.8 USB Vs Serial and Parallel

Table 9.1 lists the comparison between the various ports available in computers.

9.9.9 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 9.8 shows some of these connectors with an example of the HDMI connector.

FIGURE 9.8 HDMI interface cable and 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.
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 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.

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).

Embedded-system Constraints

An embedded system is designed by keeping the following three constrains in mind.

1. Available system memory
2. Available processor speed
3. The system needs to limit power because of continuous running. The program runs by managing power dissipation to minimum.

Besides, any embedded system design has few other constraints like performance, power, size and the design and manufacturing costs.

Processor Embedded into a System

The processor is the heart of the embedded system. The instructions, defined in the instruction set of a processor, arrange in a sequence in a program. The program executes in the sequence of their fetch from the memory. The processor has two essential units. Program Flow Control Unit (CU) and Execution Unit (EU). The processor runs the cycles of fetch-and-execution of a set of instructions.

A processor is present in one of the following forms:

1. Single VLSI (Very Large Scale Integrated) Chip.
2. A core in an ASIP (Application Specific Instruction-set Processor)
3. A core in an ASIC (Application Specific Integrated Circuit) or
4. A core in SoC (System-on-Chip)

(Core means a part of the functional circuit on to VLSI or VVLSI chip. System-on-Chip means a VLSI or VVLSI chip with all cores, software, digital and analog circuits of the system on one chip).

9.12.1 Microprocessor

A microprocessor is used as general-purpose processor when software is located in the external memory chip or secondary memory.

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.

9.12.2 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, ATMEL 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 9.9 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

TABLE 9.2 Pin Description of Arduino UNO

Pin Category	Pin Name	Details
Power	Vin, 3.3V, 5V, GND	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.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
Input/Output Pins	Digital Pins 0 - 13	Can be used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide reference voltage for input voltage.

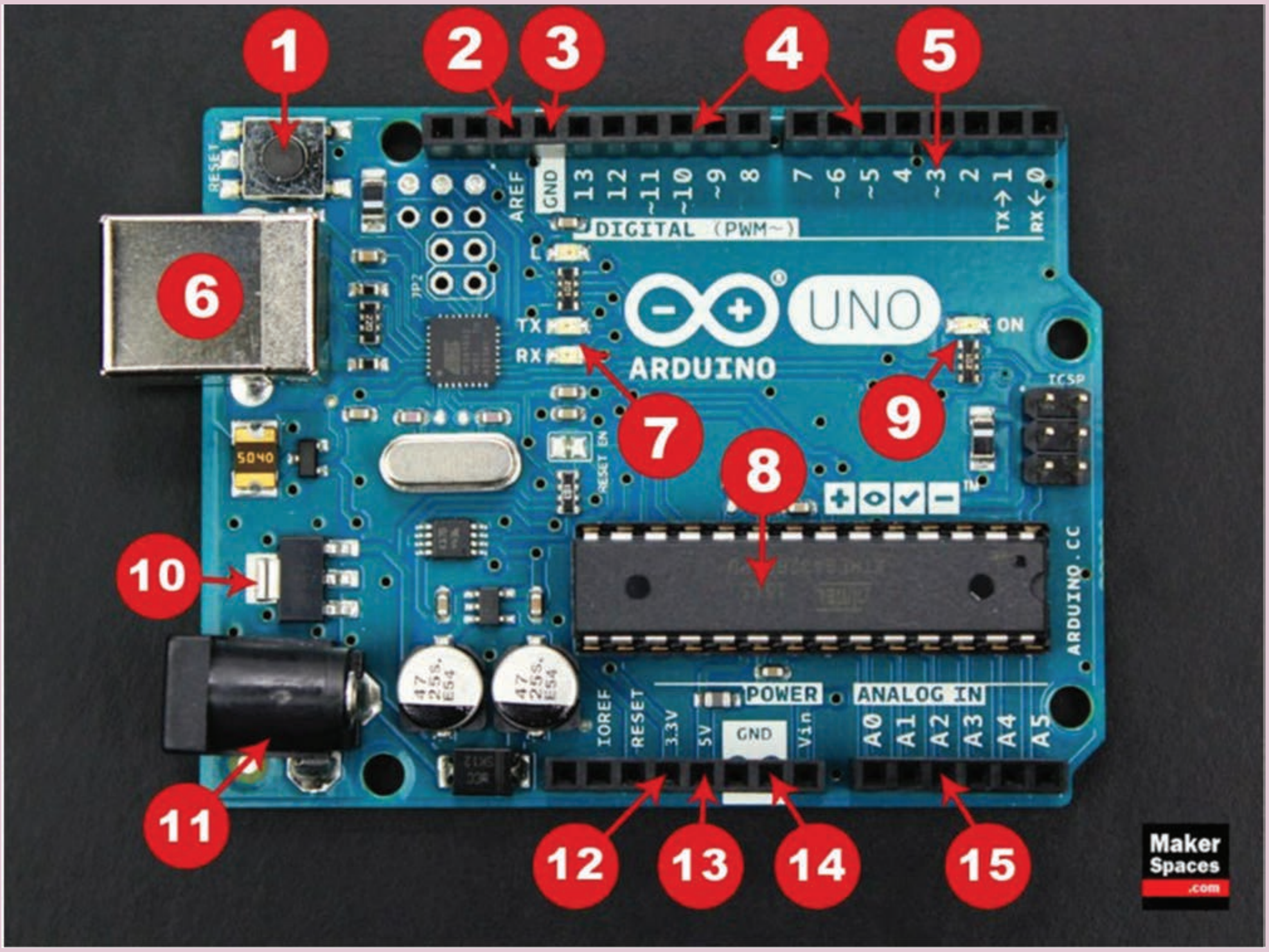


FIG 9.9 Pin diagram of Arduino UNO Board

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

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 Uno are summarized in Table 9.2. The pin configuration of Arduino Uno is shown in Fig 9.19.

Arduino IDE

For programming the Arduino, an integrated development environment called Arduino IDE is available, which can be downloaded from the company's website. The website provides numerous simple coding and designs.

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.

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 9.10.

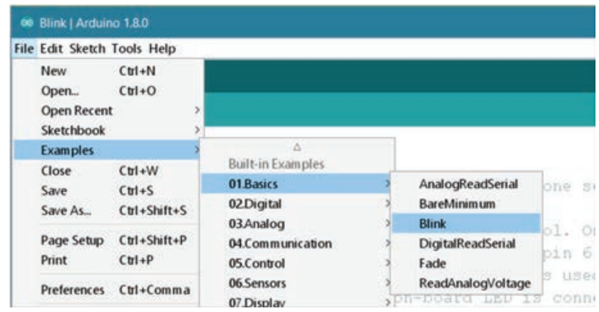


FIG 9.10 Screen showing LED blink application in Arduino Uno IDE

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 9.11.

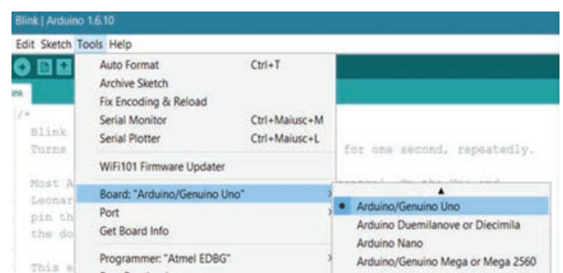


FIG 9.11 Selection of port available in Arduino Uno board

Then, the selection of the serial device of the board from the Tools menu as shown in Fig 9.12. This is likely to be COM3 or higher (COM1 and COM2 are usually reserved for hardware serial ports). To find out the ports available in the board, the user can disconnect the board and re-open the menu. Reconnect the board and select that serial port.

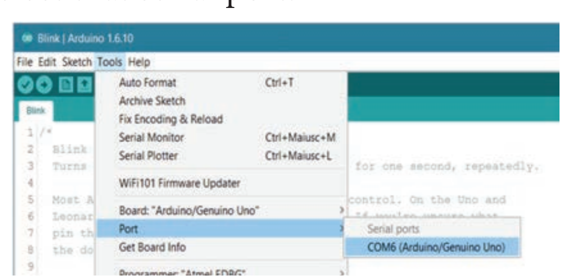


FIG 9.12 Serial port selection in Arduino Uno Board

Now, simply click the "Upload" button in the environment. Wait for a few seconds, the user can realize that the RX and TX LEDs are flashing as shown in Fig 9.13. If the upload is successful, the message "Done uploading." will appear in the status bar.

FIG 9.13 Snapshot of LED blinking

A few seconds after the upload finishes, the user can see the pin 13 (L) LED on the board start to blink (in orange).

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 9.14 & Fig 9.15 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.
- **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

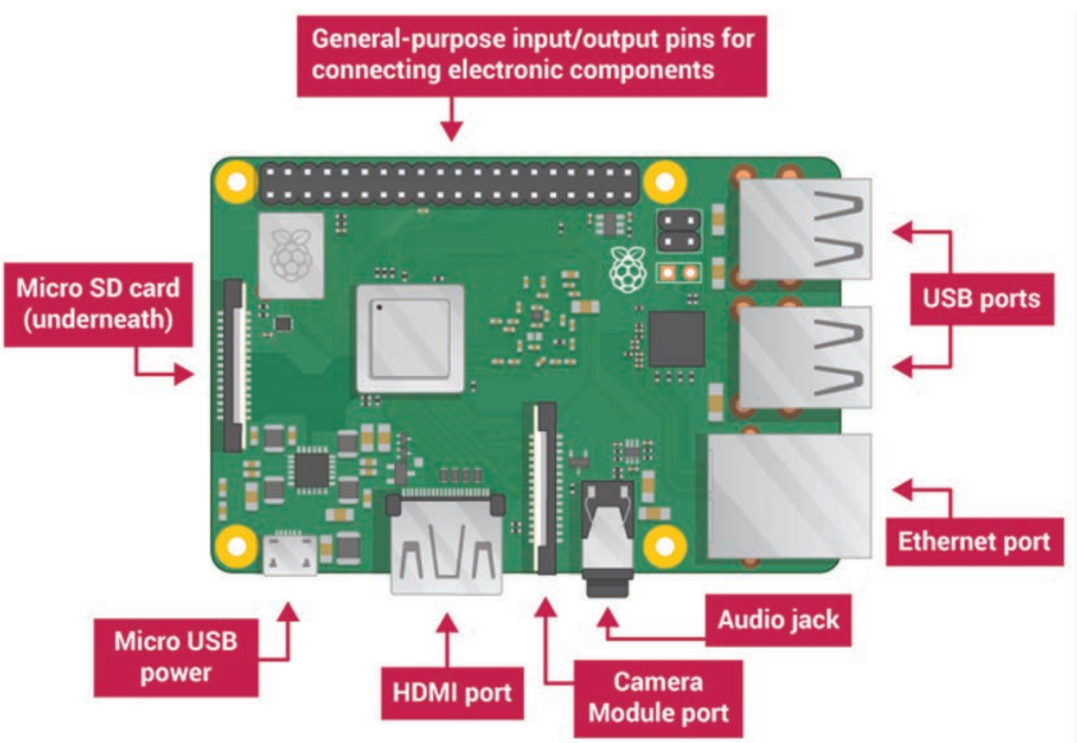


FIG 9.14 Raspberry board and its components

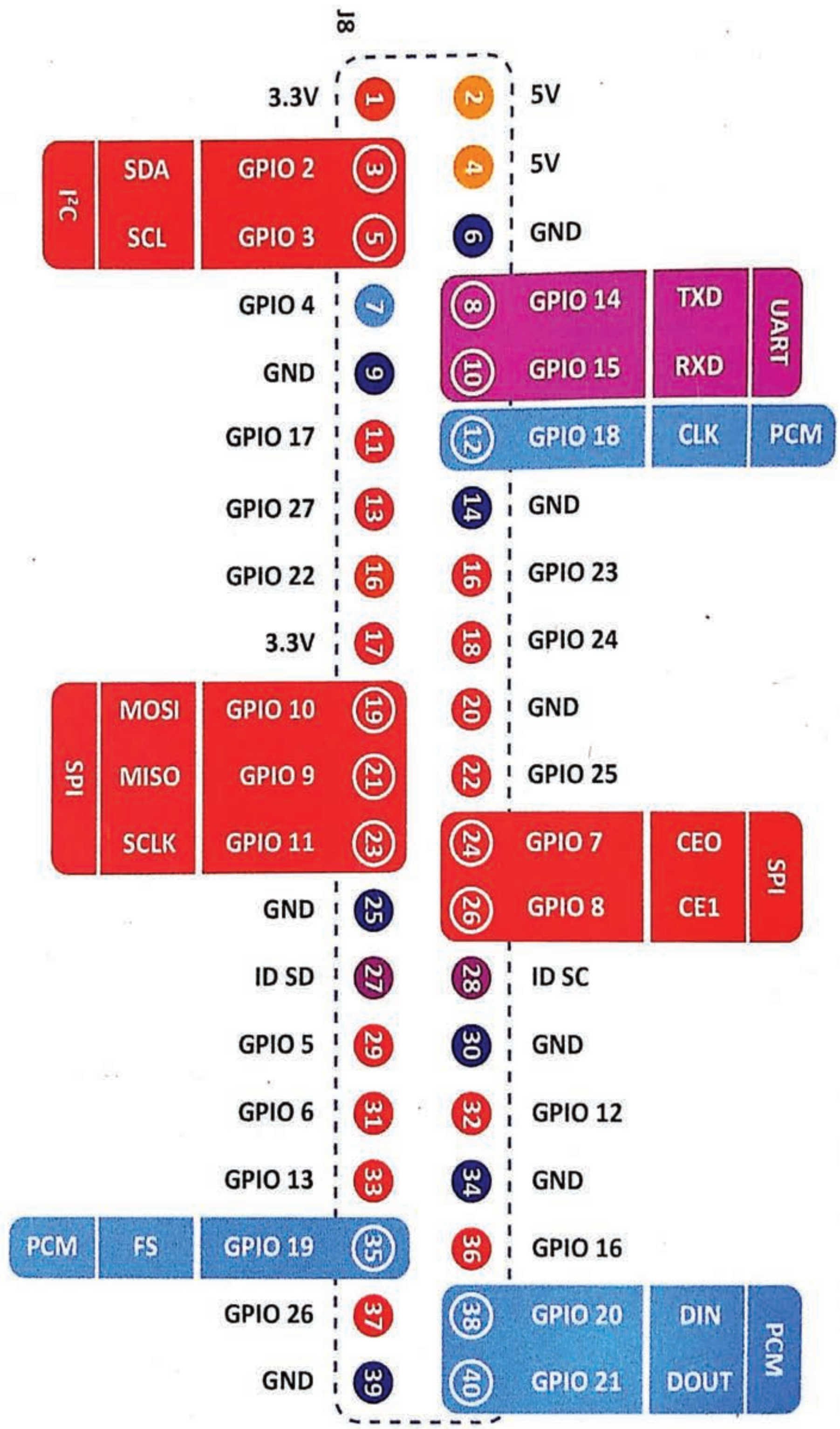


FIG 9.15 General purpose Input/Output Pins for connecting electronic compenents

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) 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 9.16.

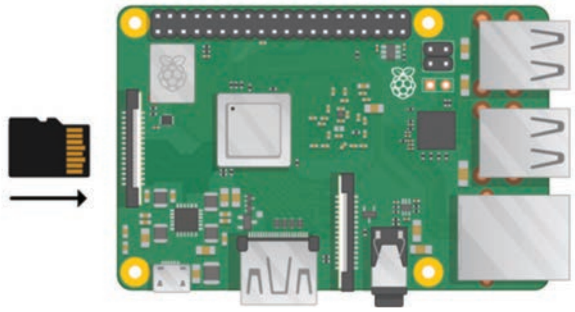


FIG 9.16 Check for SD card in Raspberry board

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 9.17.

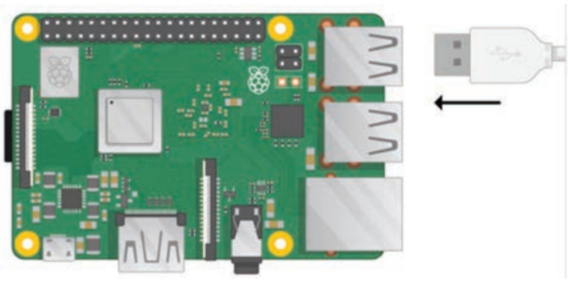


FIG 9.17 Connecting a mouse to the Raspberry board

Then, connect the keyboard in the same way as mouse as shown in Fig 9.18.

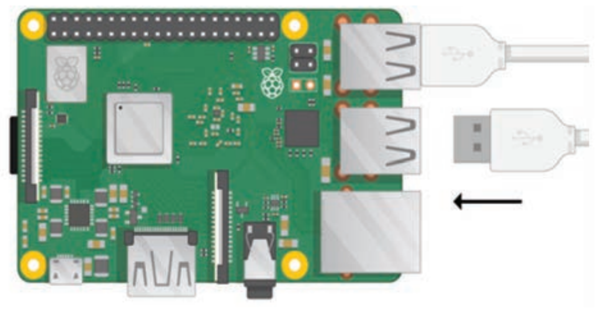


FIG 9.18 Interfacing of keyboard with Raspberry board

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 9.19. 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.

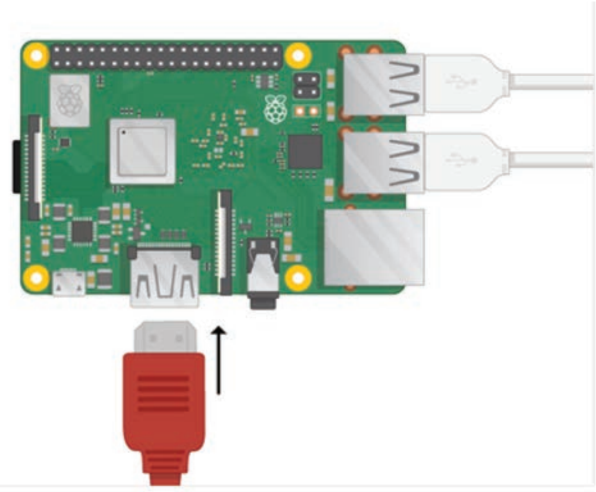


FIG 9.19 Monitor Interface with Raspberry Pi

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 9.20.

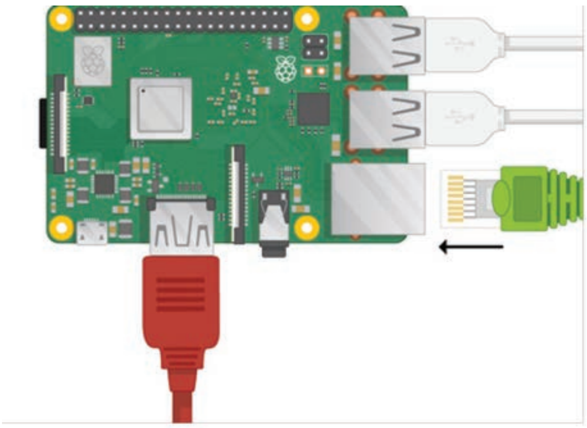


FIG 9.20 Interface the speakers with Raspberry Pi

Notice that the micro USB power port has a longer flat side on top. Plug the power supply into a socket and connect it to the micro USB power port as shown in Fig 9.21.

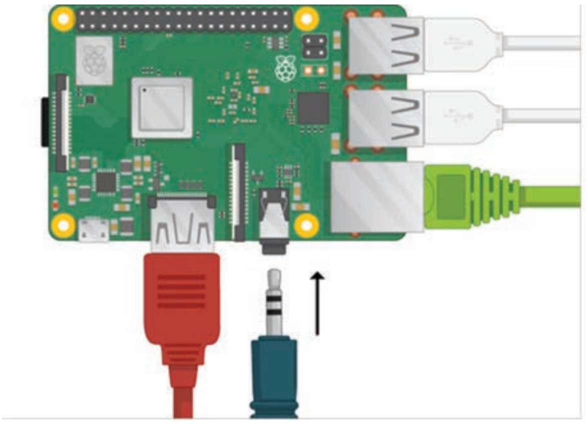


FIG 9.21 Interface with the Power supply

Finally, the user can see a red light on the Raspberry Pi and raspberries on the monitor.

The Pi will boot up into a graphical desktop.

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

µP	Microprocessor
Memory	Used to store data and instructions
BIOS	Basic Input and Output System
CMOS Battery	Complementary Metal Oxide Semiconductor Battery
Chipsets	Group of Small circuits
Northbridge	Internal Memory Controller
Southbridge	External Memory Controller
HDMI	High Definition Media Interface
USB	Universal Serial Bus
Arduino	Physical programmable circuit board called as microcontroller
Raspberry Pi	Mini Computer Board - having Mini Microprocessor and Microcontroller – best example for embedded system
Python	Computer language used to interface with Raspberry board

QUESTIONS

Part – A (1 Mark)

N28E5

I 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. The mother board is sometimes shortened to _____________
   a. CMOS B. MOBO
   c. BIOS D. None of the above
3. Brain of computer is _____________
   a. Microprocessor
   b. Microcontroller
   c. Micro Connectors
   d. None of the above
4. L1 and L2 are _____________
   a. Cache memory
   b. Secondary Memory
   c. UART
   d. None of the above
5. 2 GHz CPU gets _____________ billion pulses per second
   a. Two b. One
   c. Three d. None of the above
6. There are _____________ interrupt signals in 8085 microprocessors
   a. 9
   b. 5
   c. 3
   d. None of the above.
7. The analog signal voltage of arduino terminal is
   a. 3.3
   b. 5
   c. 9
   d. None of the above.
8. The digital signal voltage of arduino terminal is
   a. 3.3
   b. 5
   c. 9

d. None of the above.

9. The voltage received from the output source of arduino is

a. 3.3

b. 5

c. 9

d. None of the above.

10. ---------------------- 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. What is BIOS?
2. What is Micro Processor?
3. List out the characteristics of main Memory?
4. Explain- CMOS Battery?
5. Expand UART, USB, HDMI
6. What is Microcontroller?
7. Define embedded system
8. What is meant Arduino?
9. What is Raspberry Pi? ?
10. Explain Python?

Part – C (5 Marks)

III Explain the following questions

1. List out the advantages and disadvantages of Cache Memory?
2. Explain about switches and jumpers
3. Describe about input / output port
4. What is printer? Explain the types of printers

Part – D (10 Marks)

IV Answer the following questions in detail

1. Explain Mother Board components and their functions?
2. Explain the Memory Unit? List out it Advantages and Disadvantages?
3. Explain the Pin Diagram of Arduino UNO Board?

ANSWERS

1. (a) 2. (b) 3. (a) 4. (a) 5. (a) 6. (b) 7. (a) 8. (b) 9. (b) 10. (a)

CHAPTER 10

Introduction to Biomedical Instruments

LEARNING OBJECTIVE

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)

2QM5Y

CONTENT

Introduction

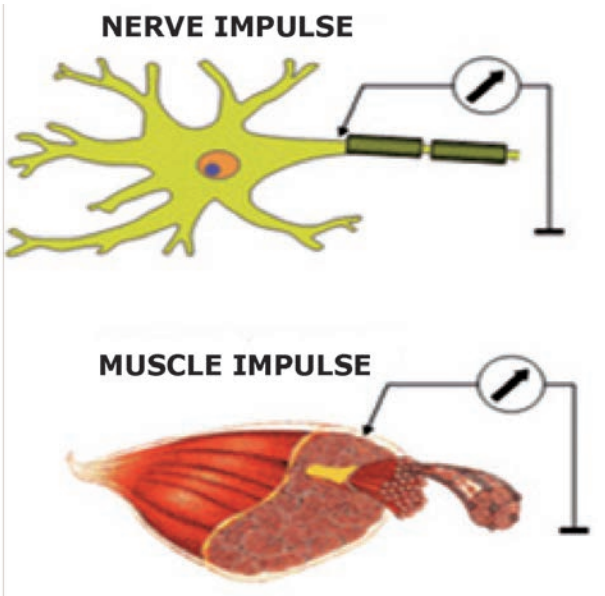


FIGURE 10.1 Biopotential from nerve and muscle

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.

DO YOU KNOW?

The difference between the electric current and bioelectric current?

Electric current is due to the movement of electrons in a circuit, whereas bioelectric current is due to movement of ions across the cell membrane.

Characteristics of Biopotential signals

The important characteristics of a biopotential signals recorded from our body are summarized in Table 10.1

TABLE 10.1 Types of Biopotential Signals and their characteristics

Parameter	Signal Characteristics
Electro cardiogram (ECG)	Frequency range: 0.05 to 500 Hz 0.05 to 120 Hz is adequate Typical signal voltage: 1 mV Voltage range: 10μV to 5 mV
Electro encephalogram (EEG)	Frequency: 0.1 to 100 Hz 0.5 to 70 Hz is adequate Voltage: 2 to 200 μV Typical voltage: 50 μV
Electromyogram (EMG)	Frequency: 5 to 2000 Hz Voltage: 25 to 5000 μV
Electro retinogram (ERG)	Frequency: DC to 20 Hz Voltage: 0.5μV to 1mV Amplitude: 0.5 mV
Electro culogram (EOG)	Frequency: DC to 100 Hz Voltage: 10 to 3500 μV Amplitude: 0.5 mV

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 10.2 Basic Medical Instruments

Components of Biomedical Instrument

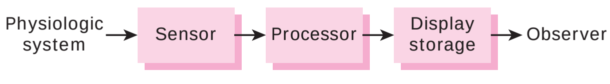


FIGURE 10.3 Basic Component of a Biomedical instrument

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.

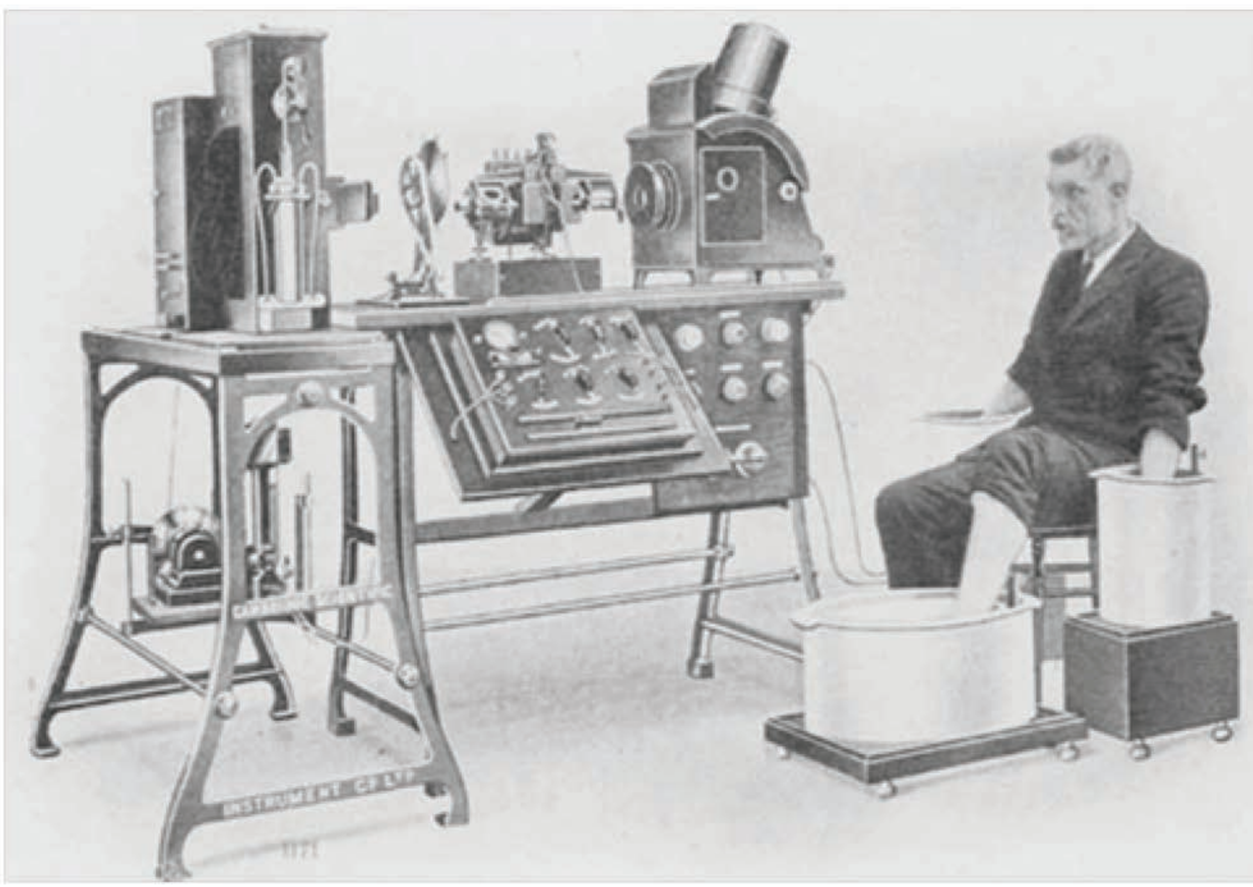


FIGURE 10.4 First ECG machine

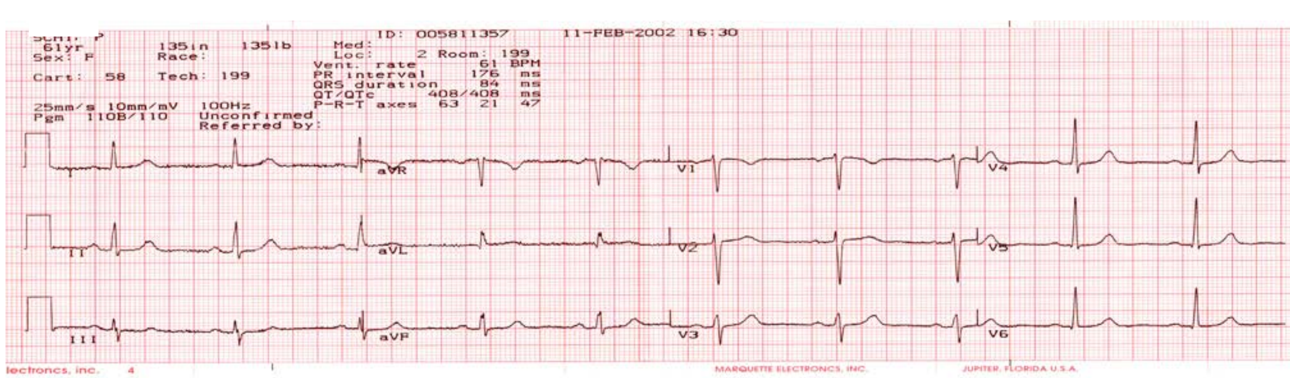
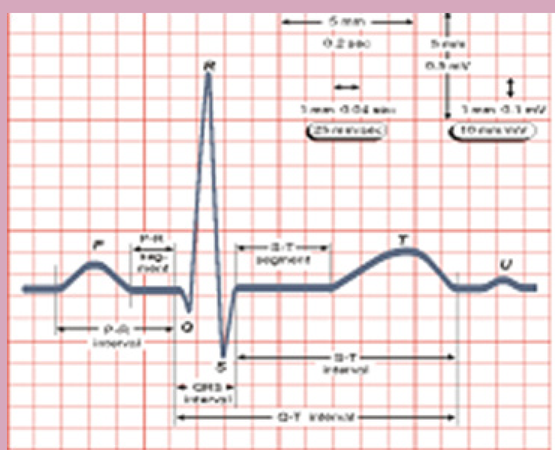


FIGURE 10.5 Standard 12 leads ECG recordings

DO YOU KNOW? **The components of ECG and their relationship with cardiac activity?**

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.

Typical applications

Diagnosis of

1. Ischemia
2. Arrhythmia
3. Conduction defects

(a) 12 Lead ECG Machine

(b) Different types of ECG electrodes

FIGURE 10.6

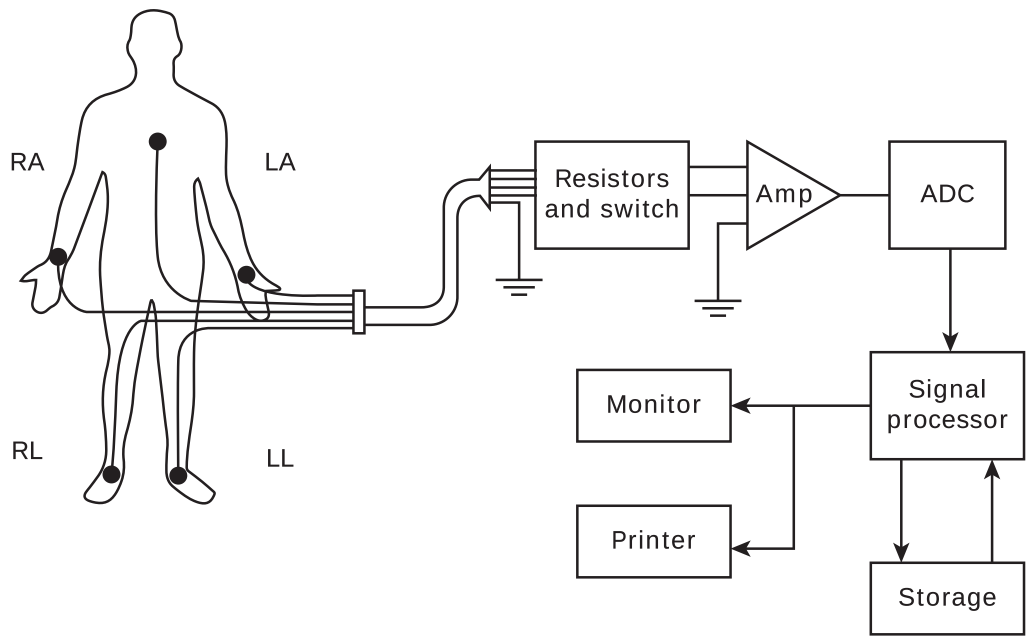


FIGURE 10.6 (c) Block Diagram of Electro cardiograph

10.2 Electro Encephalo Graph (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 10.7 shows EEG machine and its electrodes arrangement on the head of a man. Figure 10.8 illustrates the various EEG waveforms.

The characteristics of these waves are given in Table 10.2.

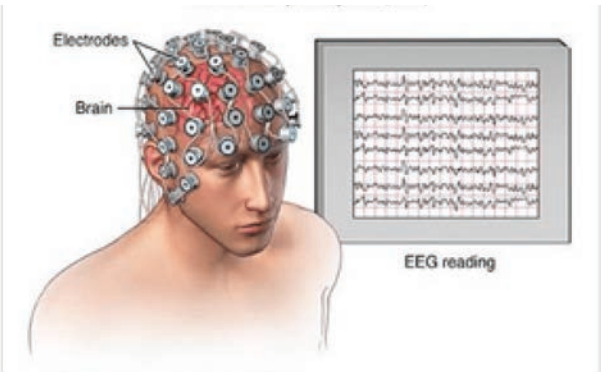


FIGURE10.7 EEG machine and the electrodes arrangements on the head

Application of EEG

The EEG is used to diagnose the following diseases

1. Level of consciousness

TABLE 10.2 EEG signal Characteristics		
Name of the waveform	Frequency range	Occurrence
Alpha	8 to 13 Hz	Normal persons awake in a resting state and disappear during sleep.
Beta	14 to 30 Hz	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.
Theta	4 to 7 Hz	During emotional stress
Delta waves	Below 3.5 Hz	Deep sleep or in serious organic brain disease

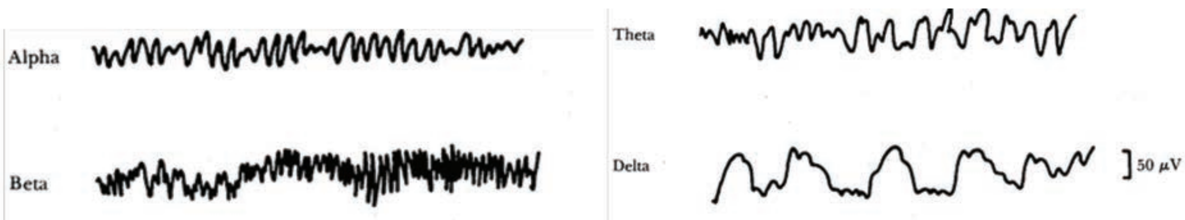


FIGURE 10.8 Components of EEG waveform

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

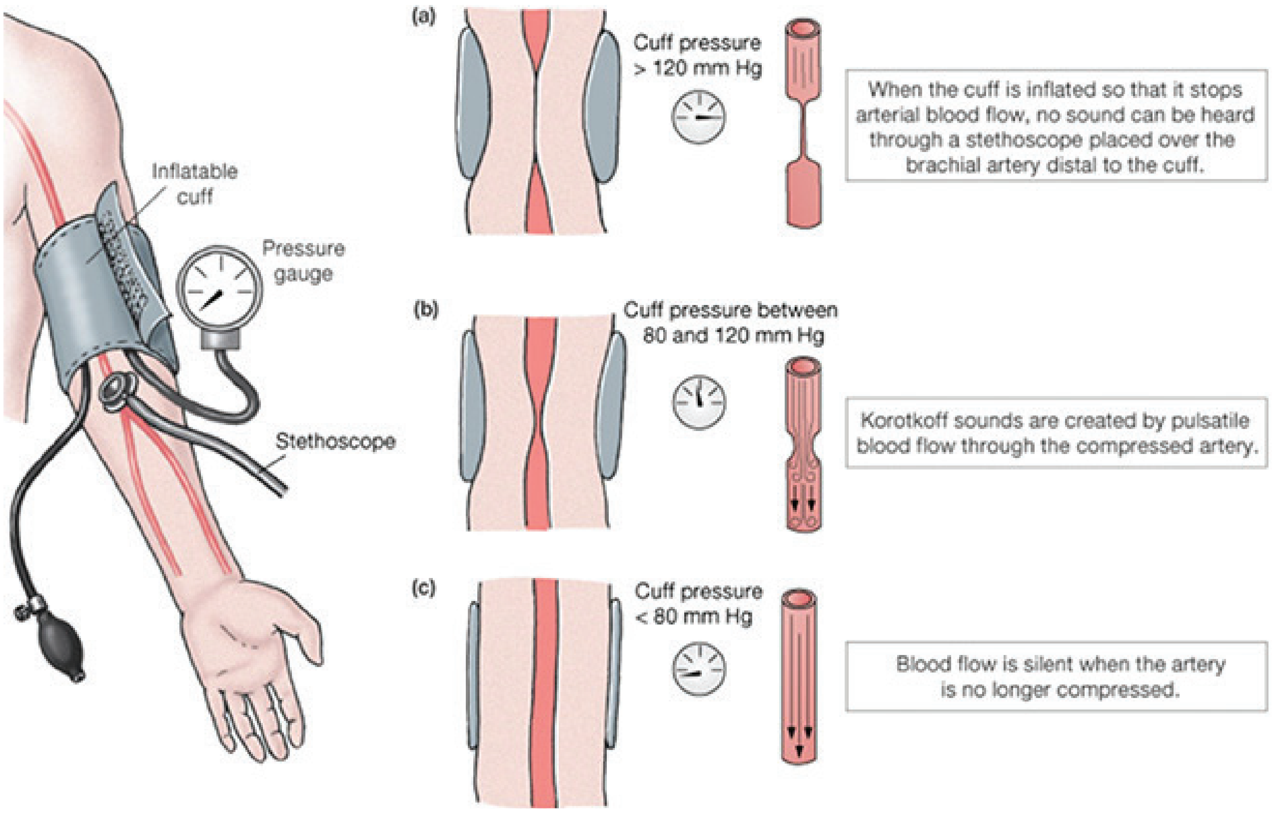


FIGURE 10.9 Working Principle of Sphygmomanometer

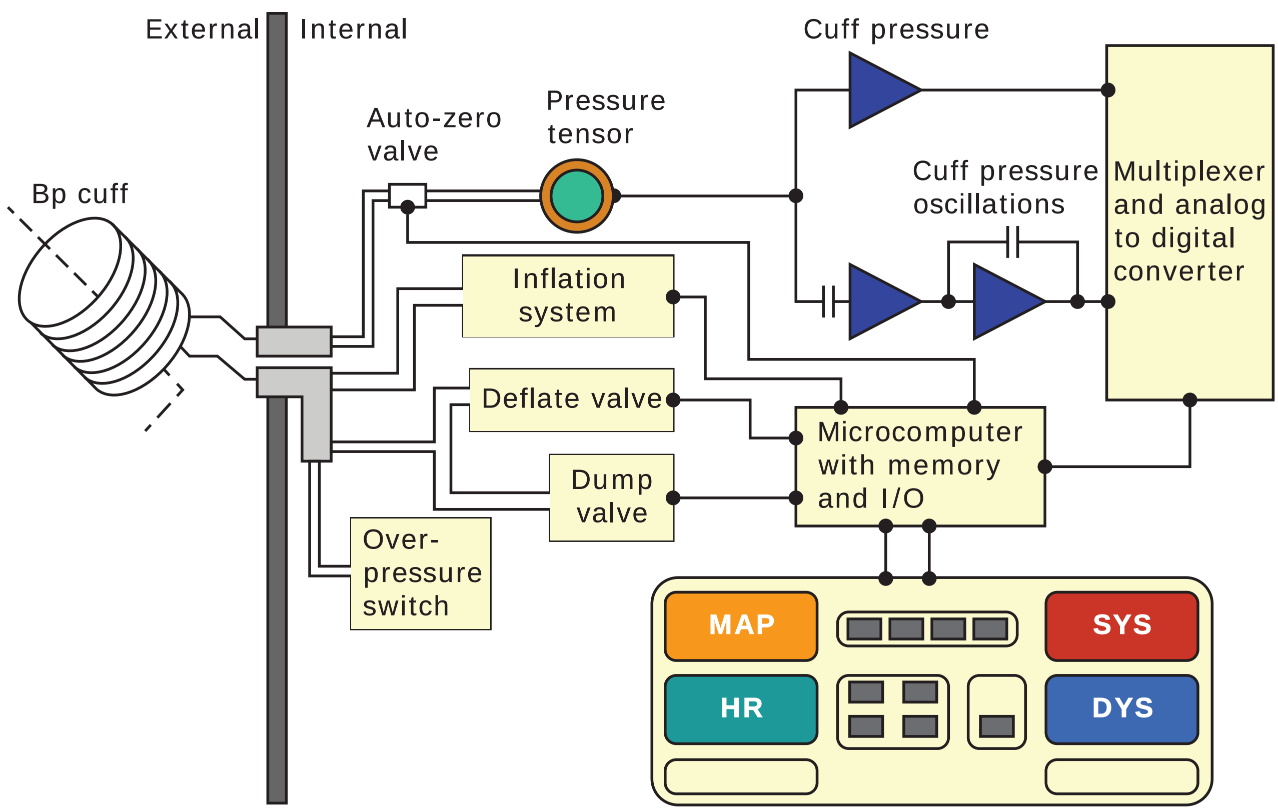


FIGURE 10.10 Components of Automatic BP Monitor: Here, MAP-Mean Average Pressure, SYS-Systolic Pressure, DYS-Diastolic Pressure and HR- Heart Rate

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 10.9 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 10.10.

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 HbO_2. 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 10.11(a) shows the image of Pulse

FIGURE 10.11 (a) Pulse Oximeter

Oximeter and figure 10.11(b) shows the absorption relationship of Hb and HbO_2.

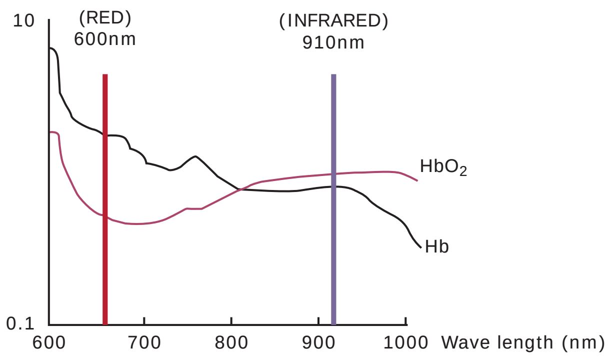


FIGURE 10.11 (b) Absorption Characteristics of HbO2 and Hb

Principle of Operation of Pulse Oximeter

Figure 10.12 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

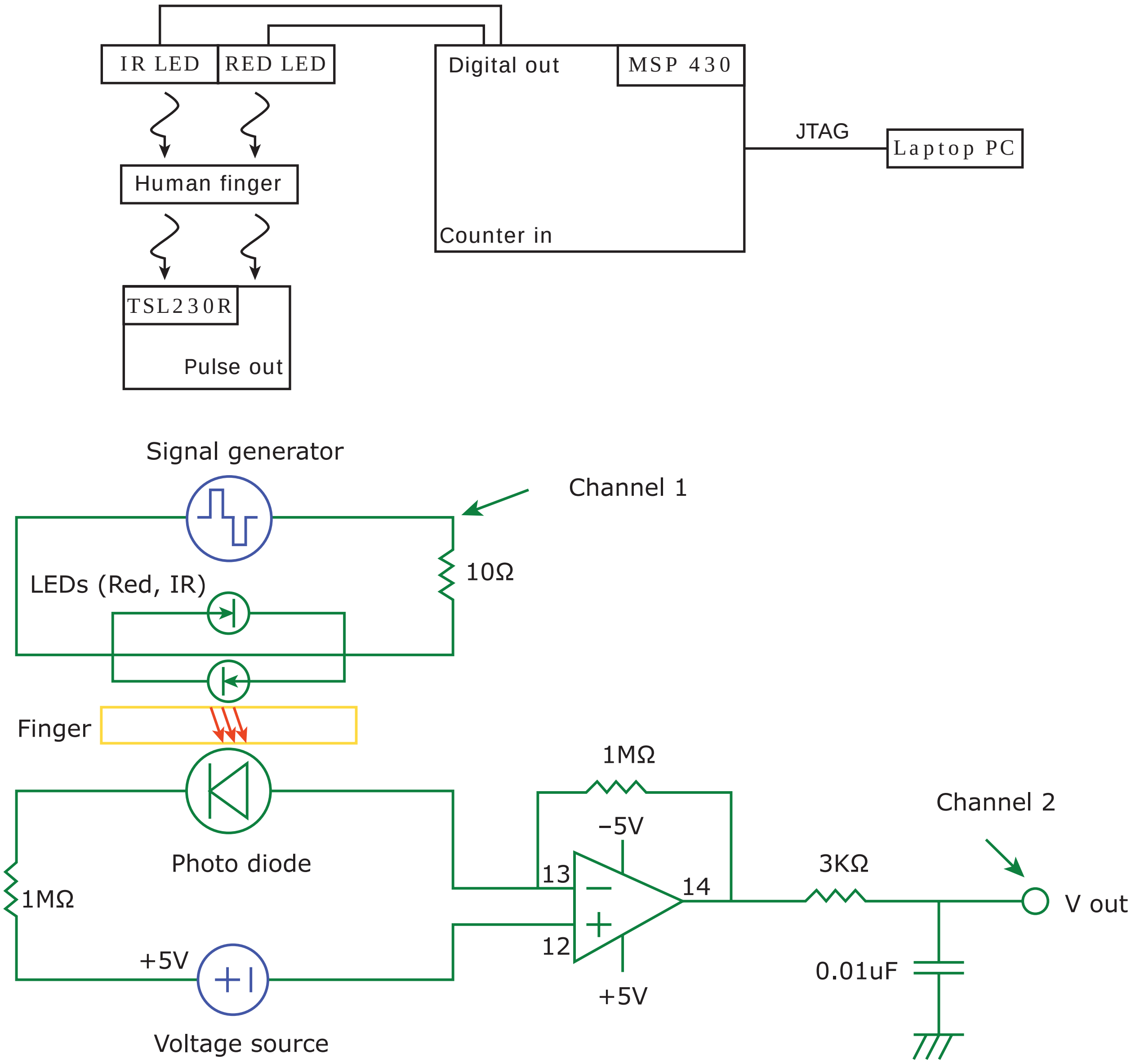


FIGURE 10.12 Block diagram and Circuit Diagram of a simple Pulse Oximeter

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 photo-detector 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 10.13 shows the waveform displayed in the pulseoximeter.

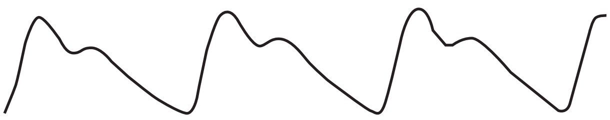


FIGURE 10.13 Pulse Oximeter displays the waveform

Applications of Puloximeter

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 10.14 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.

FIGURE 10.14 Snapshot of a Treadmill Machine

10.6 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 10.15.

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.

10.7 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.

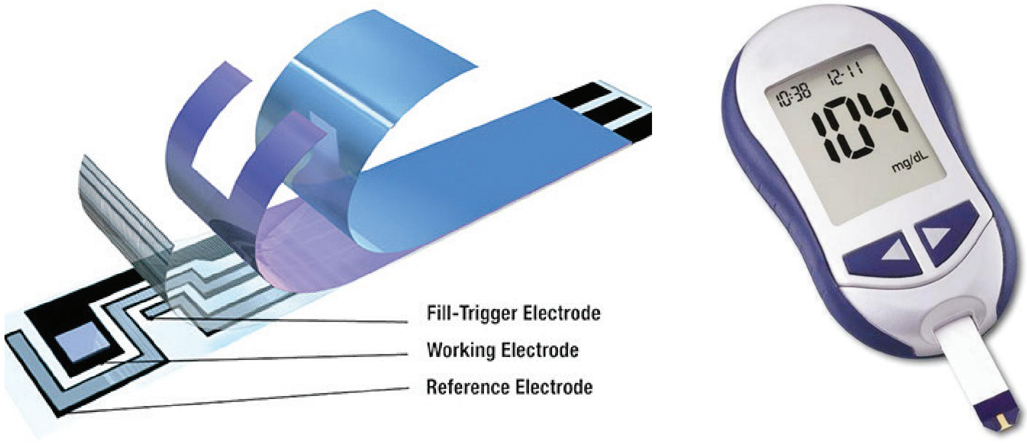


FIGURE 10.15 Components of Glucose Strip and Glucometer

DO YOU KNOW?

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.

10.7.1 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.

FIGURE 10.16 Endoscopy machine and its components

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 10.16 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

Name of the Endoscopy	Application
Gastroscopy	To see the gullet, stomach and upper small intestine.
Colonoscopy	To see the large intestine.
Laparoscopy	To see the "stomach cavity" and the organs therein.
Proctoscopy	This is used to check for piles and other conditions of the anus and rectum.
Cystoscopy	To see the urinary bladder.
Bronchoscopy	To see the air passages to the lungs.
Laryngoscopy	To see the larynx or voice box.
Nasopharyngoscopy	To see the nose and related cavities.
Arthroscopy	To see inside joints such as the knee joint.
Thoracoscopy	To see inside the chest cavity.

DO YOU KNOW?

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.

DO YOU KNOW?

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.

DO YOU KNOW?

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.

FIGURE 10.17(a) Ultrasound Scanner, (b): Ultrasound image of a growing foetus inside a mother's uterus.

10.7.2 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 10.17(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 10.17(b).

Components of Ultrasound Machine

Figure 10.18 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

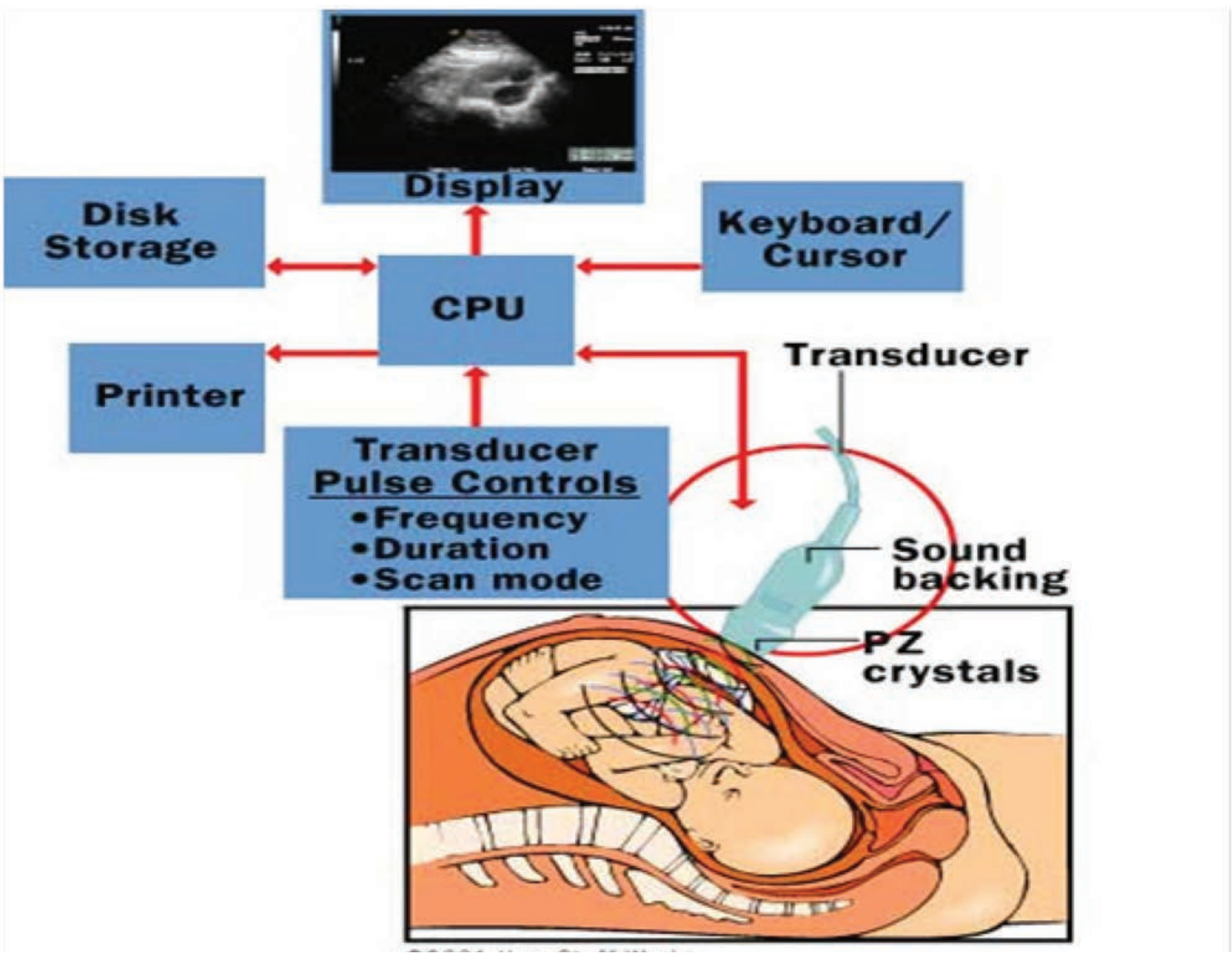


FIGURE 10.18 Components of a Basic Ultrasound Scanner

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.
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

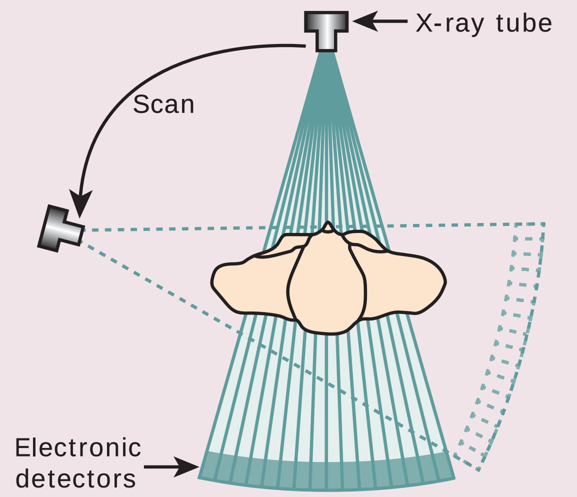
Ultrasound has been used in a variety of clinical fields including obstetrics and gynecology, cardiology and cancer detection. The main advantage of ultrasound is that certain structures can be observed without using radiation. Ultrasound can also be done much faster than X-rays or other radiographic techniques.

10.8 Computed Tomography Scanner

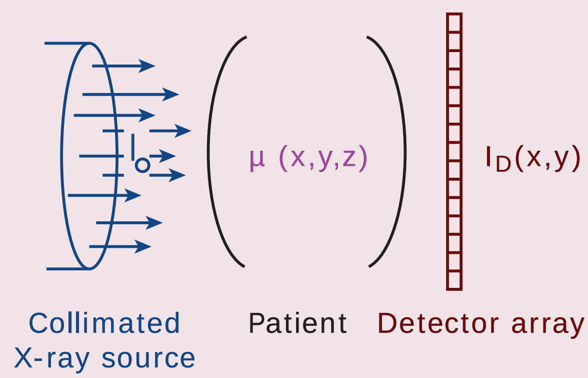
Tomography is imaging by sections or sectioning. A device used in tomography is called a tomograph, while the image produced is a tomogram. Computed Tomography (CT) or Computed Axial Tomography (CAT), utilizes X-ray technology and sophisticated computers to create images of cross-sectional "slices" of 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 10.19(a) CT-Scanner

Figure 10.19(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.



CT Principle



Operation of CT

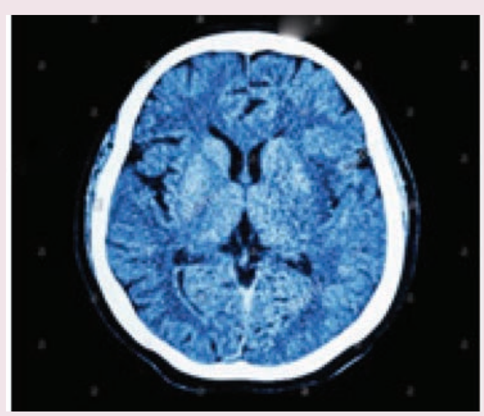

CT image of brain

FIGURE 10.19(b) Principle, Operation and Image of the CT

Advantages

- Desired image detail is obtained
- Fast image rendering
- Filters may sharpen or smooth the reconstructed images

Disadvantages

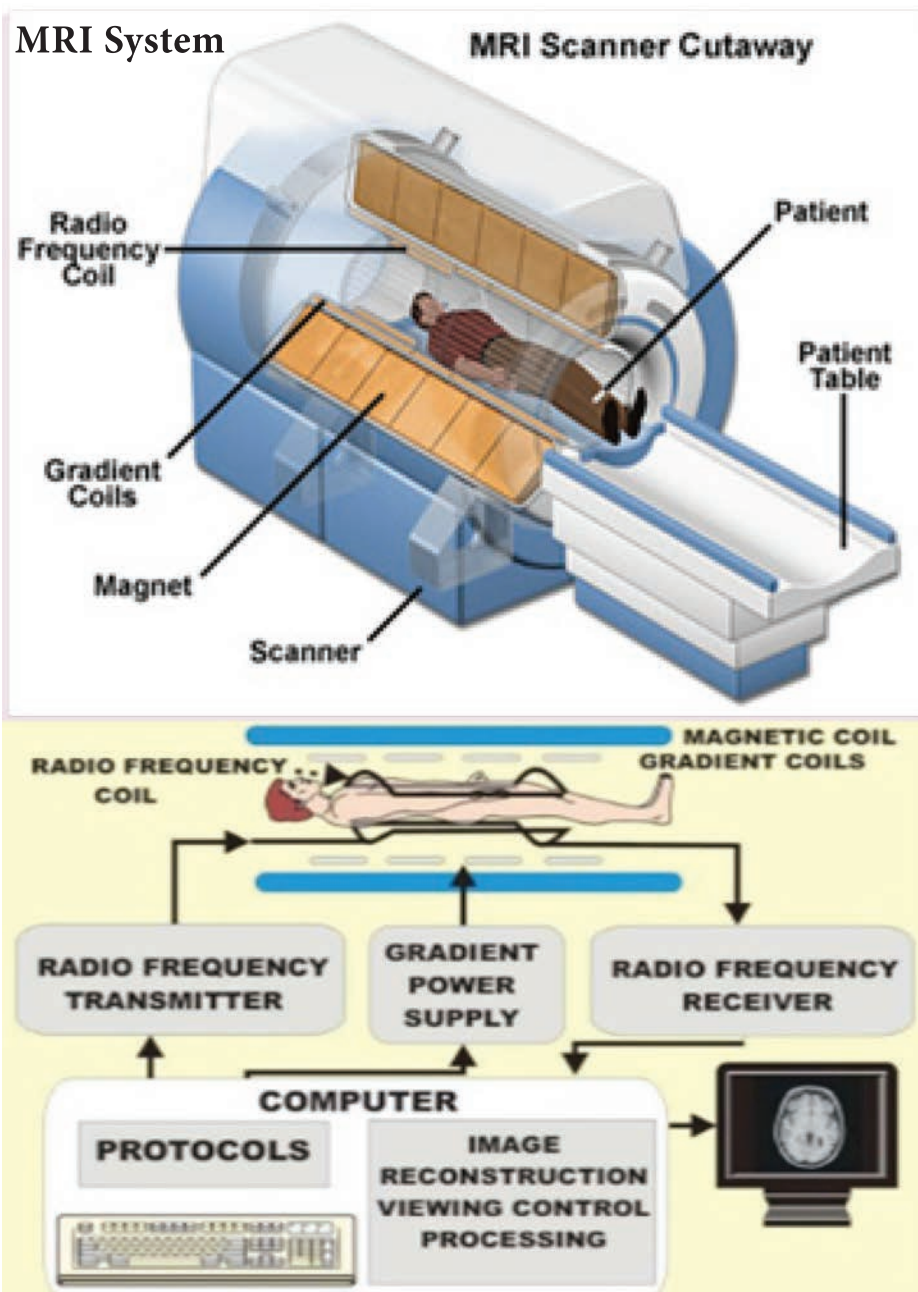
- Multiple reconstructions may be required if significant detail is required from areas of the study that contain bone and soft tissue
- Need for quality detectors and computer software
- X-ray exposure

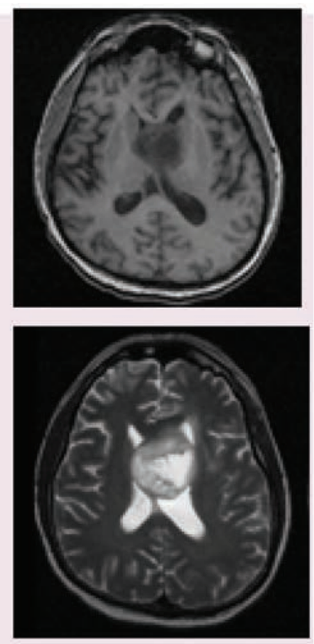
Do you know? Who invented the CT?

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.

10.9 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 10.20 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





MRI images

FIGURE 10.20 MRI system and MR images 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.

DO YOU KNOW? 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.

Applications

MRI is used to diagnose or monitor the conditions such as:

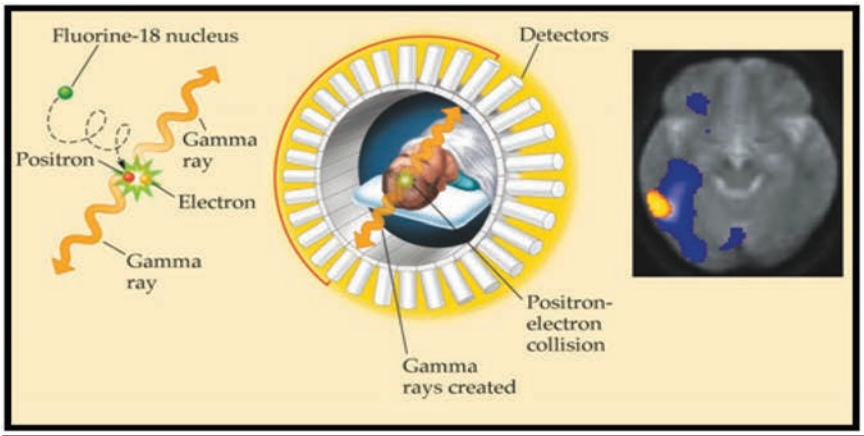
- Tumours and other cancer related abnormalities.
- Certain types of heart problems.
- Blockages or enlargements of blood vessels
- Diseases of the liver, such as cirrhosis, and that of other abdominal organs.
- Diseases of the small intestine, colon, and rectum

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.

10.10 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



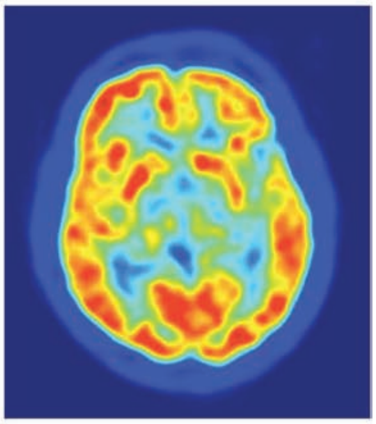


FIGURE 10.21 PRINCIPLE OF PET AND ITS IMAGE

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.

Figure 10.21 shows the principle of PET imaging. PET imaging starts with the injection of metabolically active tracer – a biologic molecule that carries with it a positron emitting isotope.

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.
- 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.

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

Biopotential	Potential generated at the cell level due to mobility of ions across cell membrane
Electrocardiograph	Instrument used to measure the electrical activity of the heart
Electroencephalogram	Instrument for measuring the electrical activity of the brain
Blood Pressure Monitor	Instrument to quantify the pressure of the Blood
Pulseoximeter	Instrument used to measure the oxygen saturation of blood
Tread Mill Test	Instrument used to test vital parameters of the human being during exercise
Glucometer	Instrument used to quantify the amount of glucose level in blood
Endoscopy	Instrument used to capture the image of the internal organs like stomach, intestine, etc.
Ultrasound Imaging	Instrument used to capture the image of the internal organs and tissues using ultrasound
Computed Tomography	Instrument used to image soft tissues and bones using X-ray
Magnetic Resonance Imaging	Instrument used to image soft tissues and bones using magnetic and radio frequency waves
Positron Emission Tomography	Instrument used to image the brain and its functions using gamma rays

QUESTIONS

Part – A (1 Mark)

I Multiple choice Questions

1. Bioelectric waveforms and Instruments ends with the suffixes ----------- and ----------- respectively
   (a) Graph, gram
   (b) Gram, graph
   (c) Graphy, gramy
   (d) Gramy, graphy
2. Lead I, II and III in ECG are
   (a) Bipolar Leads
   (b) Unipolar Leads
   (c) Monopolar Leads
   (d) Tripolar Leads
3. Brain waves comprise of
   (a) Alpha, Beta, Theta and Delta waveform patterns
   (b) Alpha, Theta, Zeta and Delta waveform patterns
   (c) Beta, Theta, gamma and Delta waveform patterns
   (d) Alpha, Beta, gamma and Delta waveform patterns
4. Ultrasound transducers are made from (a)
   (a) Piezoelectric material
   (b) Photovoltaic material
   (c) Thermoelectric material
   (d) None of the above
5. Magnetic resonance imaging (MRI) is a ……………. Technique
   (a) Ionizing
   (b) non-ionizing
   (c) nuclear
   (d) radiation
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 (3 Marks)

II Answer in one or two sentences

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 (5 Marks)

III Answer in a paragraph

1. Briefly explain the principle of operation of an Electrocardiograph with a neat sketch.
2. Explain the functions of Treadmill Test Machine.
3. Write a short note on the operations of a Blood Pressure Monitor.

Part – D (10 Marks)

IV Answer in One Page (Essay type Question)

1. Discuss in detail the working principle and testing procedure of a Glucometer with neat sketch.
2. Explain about Electro Encephalo Graph and its uses.
3. Describe the operating principle of CT scan using functional block diagram.

ANSWERS

1 (a)	2 (a)	3 (a)	4 (a)	5 (b)
6 (a)	7 (a)	8 (a)	9 (d)	10 (c)

CASE STUDY 1

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;

1. Dr.R.Manikandan, and Dr.S.Rajendran, "*Basic Electrical and Electronics Engineering*", Second semester B.E/B.Tech students as per Anna University Regulation-2017, Isn't Publiching (opc) Pvt.Ltd, 1st Edition 2018. ISBN:978-81-934080-0-1
2. Dr.R.Manikandan, Er.S.Sugumar, and Dr.S.Rajendran, "*Electrical Circuits Simulation Practical Lab Manual*", ***M-Scheme***, Polytechnic Colleges, Star Publications, First Edition 2017, Coimbatore-641 012.
3. R.Manikandan, R.Venkateswaran, and S.Sugumar, "*Electrical Circuits Simulation Practical Lab Manual*", ***L-Scheme***, Polytechnic Colleges, Star Publications, First Edition 2013, Coimbatore-641 012.
4. R.Manikandan, and M.G.Anand, "*Electrical Circuits Laboratory Manual*", Second semester B.E/B.Tech students as per Anna University Regulation-2013, Sri Maruthi Publishers, Chennai-600 049.

CASE STUDY 2

M.KARTHIKEYAN, D.C.Tech, B.sc.CS.,
Old STUDENT (1992), Radio & Tv Vocational Group,
Ttn-Swami Dayananda Hr. Sec. School, Manjakkudi,
Thiruvarur District.
Managing Director of "Chip Systems" & "IdeaMart", Chennai & Kodavasal.
Chairman of "Vanigam Business Forum",
Secretary of "Anandham Youth Foundation."

"Today a reader, tomorrow a leader – Margaret Fuller"

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 (Dt) on 1992.

Today, I am a Managing & Technical Director of "Chip Systems" in Chennai & Trichy and the Chairman of "Vanigam Buisness 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 System are providing Cell phone, Laptop, Computer, LED/LCD, Photocopier, UPS/Inverter Services, CCTV & solar power installation, PCB Designing, LED lights Assembling & Etcs. 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.

Theory

Model Question Paper

BASIC ELECTRONIC ENGINEERING

Time – 2.30 Hours Max.Marks: 90

PART –A

Choose the correct answer: **15 x 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?
21. "Transceiver and Transponder" – Compare the devices.
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 ELECTRONICS ENGINEERING

Practical

CONTENTS

Practical

SAFETY PRECAUTIONS

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 a 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 FOLLOWS 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 two 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.

EXERCISE 1

Encoder and Decoder

Aim: To study Encoder and Decoder using in the Digital Electronics

APPARATUS/COMPONENTS REQUIRED

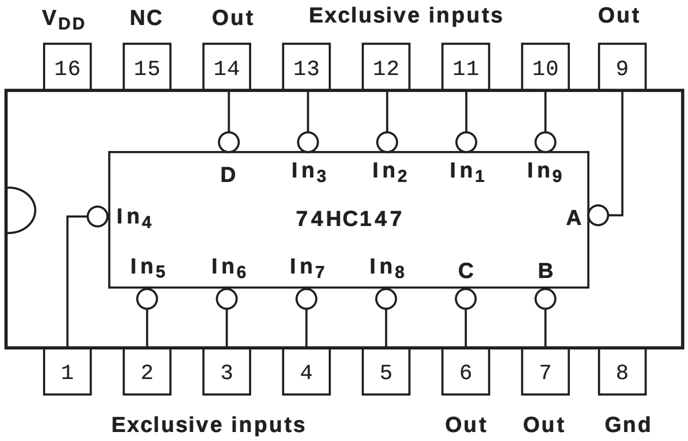
S. NO	Apparatus/ Components	Range/Value	Quantity
1	Encoder 74147 IC		1
2	PROBES	Red & Black	Multiple
3	Bread Board	5”	1
4	Seven Segment LED	1cm	4
5	Decoder 7447 IC	---	1

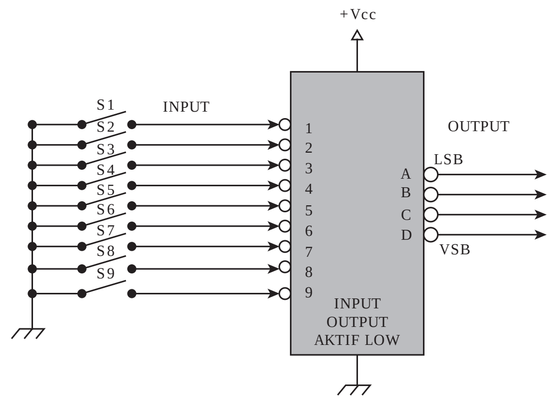
THEORY

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





Active – Low Decimal Input									Active Low BCD Output			
D1	D2	D3	D4	D5	D6	D7	D8	D9	Q1	Q2	Q3	Q4
1	1	1	1	1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	1	1	1	1	0
X	0	1	1	1	1	1	1	1	1	1	0	1
X	X	0	1	1	1	1	1	1	1	1	0	0
X	X	X	0	1	1	1	1	1	1	0	1	1
X	X	X	X	0	1	1	1	1	1	0	1	0
X	X	X	X	X	0	1	1	1	1	0	0	1
X	X	X	X	X	X	0	1	1	1	0	0	0
X	X	X	X	X	X	X	0	1	0	1	1	1
X	X	X	X	X	X	X	X	0	0	1	1	

2. Decoder

BCD To 7- Segment Decoder

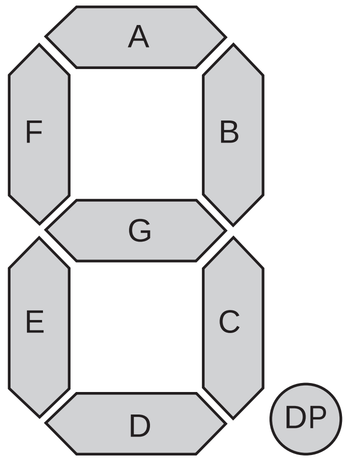
Seven Segment Display is most popular device used in digital systems. For displaying data using this device, the data have to be converted from BCD to 7 Segment code. The decoder circuit has 4 input lines for BCD data which are D0, D1, D2, & D3, and seven output lines to drive a 7-segment display. If 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 resisters connected are simply for limiting the current.

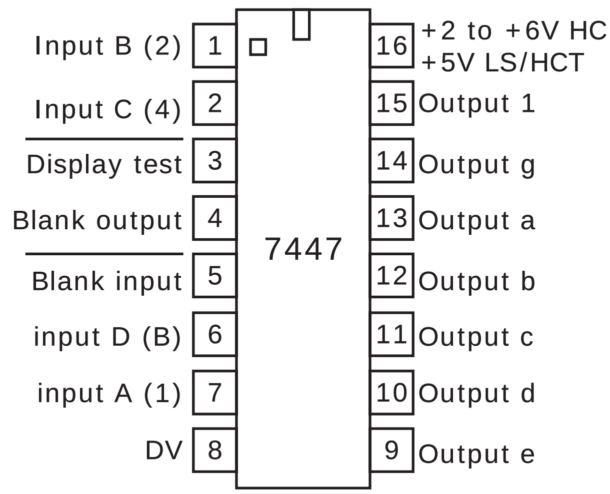
LT: (Lamp Test)

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

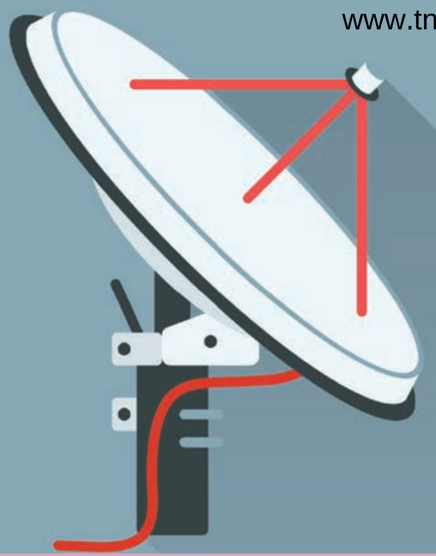
PIN NO	DESCRIPTION
1	BCD B Input
2	BCD C Input
3	Lamp Test
4	RB Output
5	RB Input
6	BCD D Input
7	BCD A Input
8	Ground
9	7 – Segment e Output
10	7 – Segment d Output
11	7 – Segment c Output
12	7 – Segment b Output
13	7 – Segment a Output
14	7 – Segment g Output
15	7 – Segment f Output
16	Vcc – Positive Supply

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.



EXERCISE 2

Install, Point and Testing of Dish Antenna

Aim: To study the installation and testing of dish antenna

APPARATUS / COMPONENT REQUIRED

S.No.	Name of Components / Apparatus	Quantity
1	DTH Antenna(Direct-To-Home)	1
2	LNB (Low Noise Block down converter)	1
3	Satellite Receiver	1
4	RG6 Co-axial cable 25 meter	1
5	TV Set	1
6	Wrench	1
7	Drill	1
8	Hammer	1
9	Small chisel	1
10	Compass	1
11	Satellite dish	1
12	"L" shaped wall mounts	1
13	4 stainless steel fixings	4
14	4 hexagonal screws4 stainless steel fixings	4
15	'F' connector X 2	2
16	Coaxial cable	25 meters
17	Digital TV receiver	1
18	Marker	1

THEORY

Dish Antenna is a receiver antenna which receives the signals propogated 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 feets 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 be 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

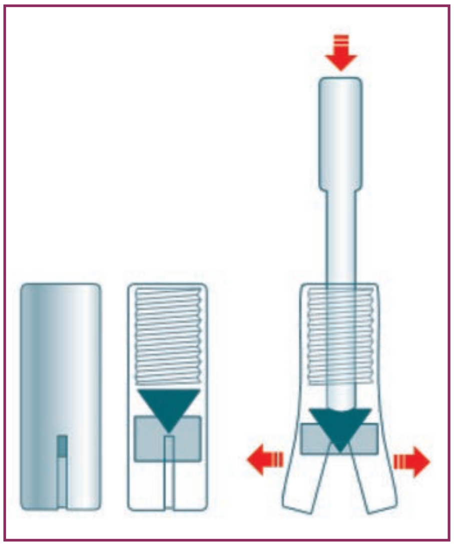
1. The antenna must be fixed very strong, even should not disturbed by any natural calamities such as storm, rain etc.
2. We can use the RG6 cable wires to connect the TV and the antenna.
3. The cable must be 25m length.
4. We can take the transmission line via walls or ground.

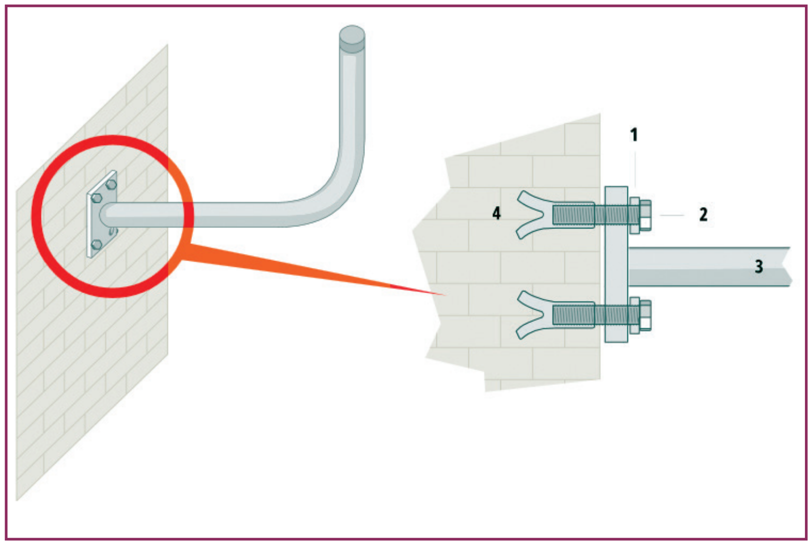
PROCEDURE FOR THE INSTALLATION OF ANTENNA

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 appropiate diameter (see the number engraved on the fixing). The ideal depth for the holes is about 0.5 cm + wall plug length.

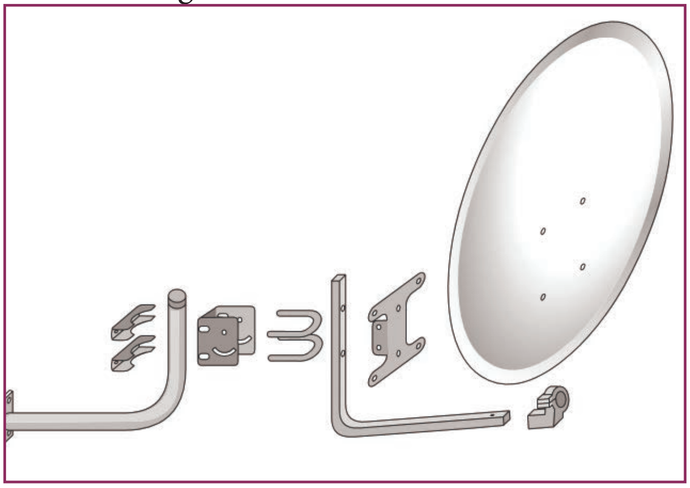
How the stainless steel fixings work

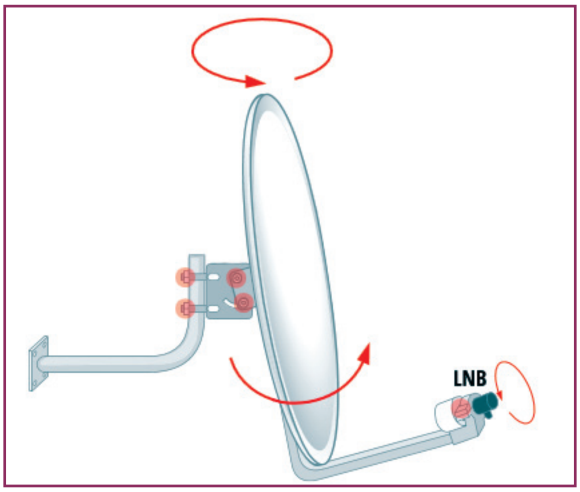




- Put the four fixings in their holes, and use the hammer and the chisel to fix them.
- Now take the "L" wall mount, and screw it to the fixings. Don't forget the washers.
- (1) Washer / (2) Screw / (3) L mount / (4) Fixing

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 orientiate 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 azimut, elevation and LNB polarization/skew values.

Azimut

This is the dish position with respect to north. It is mesaured 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.

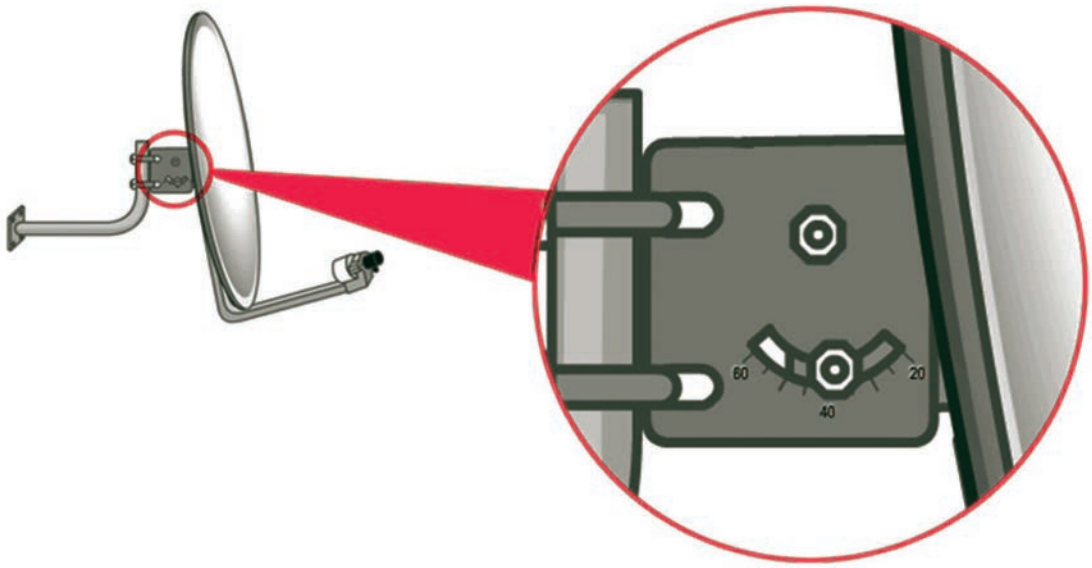
Imagine you are in Madrid and you want to get the Astra satellite signal. Using Dishpointer we get this: 147º azimut, 38º elevation, 25º polarisation.

Azimut, 147º

- Firstly, let's move the dish using the right azimut.
- Use the marker for the azimut (147º)
- 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, 38º

Skew the dish until the right position is reached, looking at the numbers engraved on the mount behind the dish.

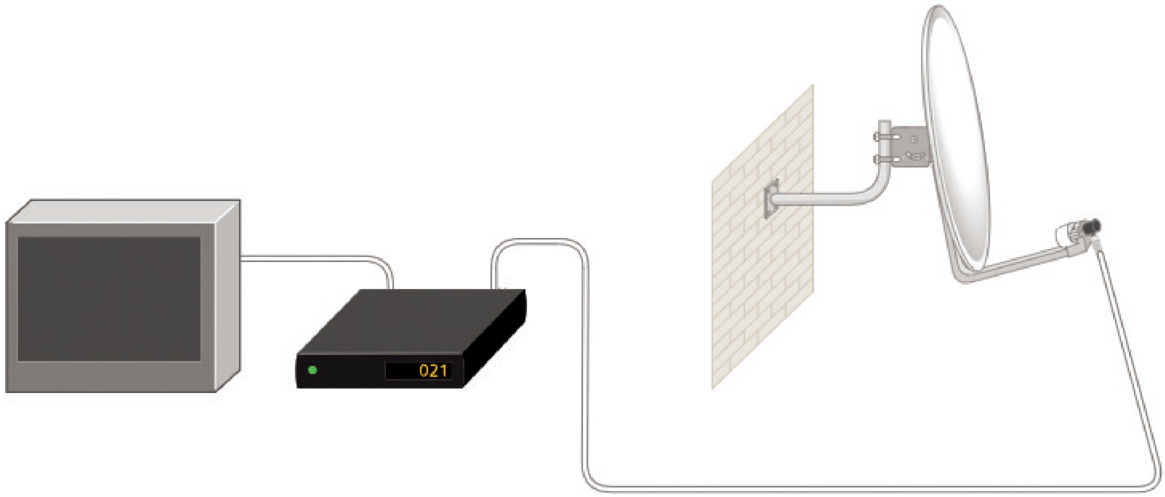


Polarisation, 25 º

- 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 satelllite 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

Place Latitude Longitude AZ EL

Mumbai 18.93N 72.85E 128.56 56.37

Delhi 28.67N 77.23E 146.26 51.24

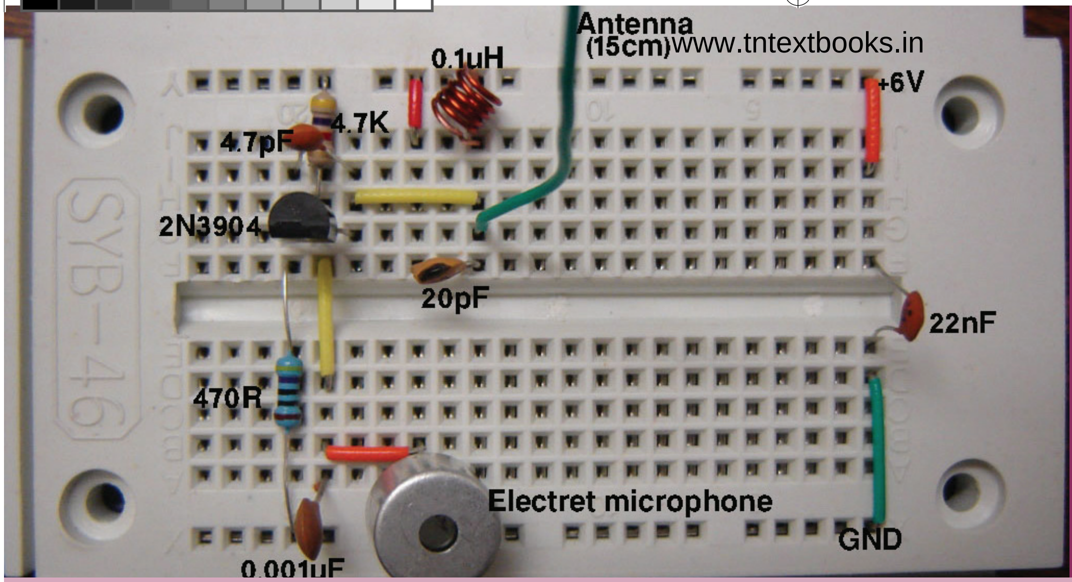
Chennai 13.08N 80.30E 130.79 67.03

Salem 11.63N 78.13E 123.63 66.09

Separate parts of Dish antenna

Result

Thus, a dish antenna is **INSTALLED, POINTED, TESTED** and tuned. The picture obtained in the screen is clear.



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EXERCISE 3

Constructions of FM receiver

Aim: To Construct FM receiver using CXA 1619 and TBA810 IC

APPARATUS / COMPONENT REQUIRED

S.No.	Name of Components / Apparatus	Quantity
1	Components as per the circuit	1
2	Multi meter	1
3	RF/AF Signal Generator	1
4	Soldering Iron	1
5	Wires	1
6	Lead	1
		1

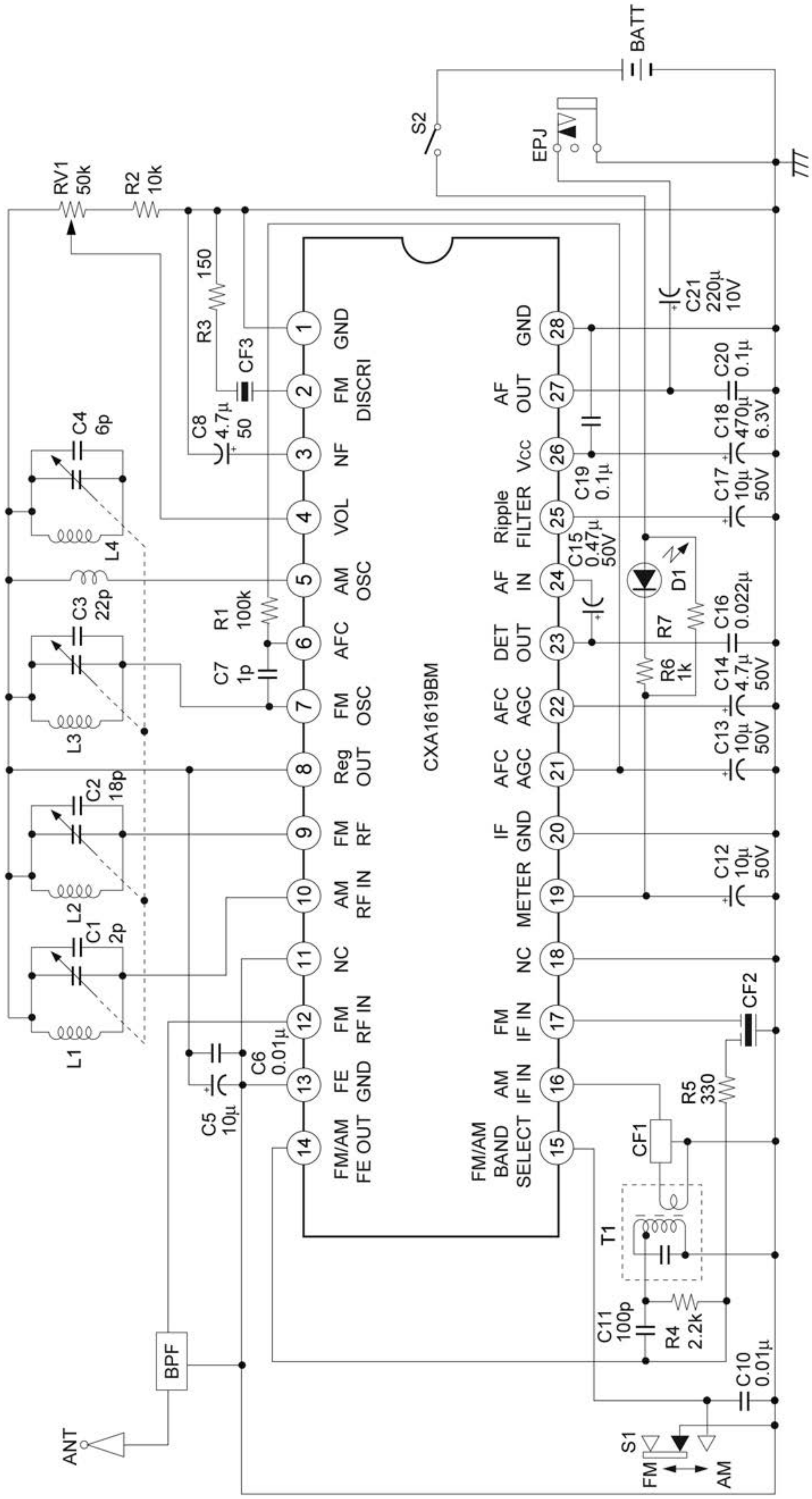
Parts of FM receiver

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.



CXA1619BM
RV1 50k
R2 10k
R3 150
CF3
C8 4.7µ 50
R1 100k
C7 1p
C4 6p
C3 22p
C2 18p
C1 2p
L1
L2
L3
L4
C5 10µ
C6 0.01µ
BPF
ANT
S2
BATT
EPJ
C21 220µ 10V
C20 0.1µ
C18 470µ 6.3V
C17 10µ 50V
C19 0.1µ
C15 0.47µ 50V
D1
R7
C16 0.022µ
R6 1k
C14 4.7µ 50V
C13 10µ 50V
C12 10µ 50V
CF2
R5 330
CF1
T1
C11 100p
R4 2.2k
C10 0.01µ
S1
FM
AM
1 GND
2 FM DISCRI
3 NF
4 VOL
5 AM OSC
6 AFC
7 FM OSC
8 Reg OUT
9 FM RF
10 AM RF IN
11 NC
12 FM RF IN
13 FE GND
14 FM/AM FE OUT
15 FM/AM BAND SELECT
16 AM IF IN
17 FM IF IN
18 NC
19 METER
20 IF GND
21 AFC AGC
22 AFC AGC
23 DET OUT
24 AF IN
25 Ripple FILTER
26 Vcc
27 AF OUT
28 GND

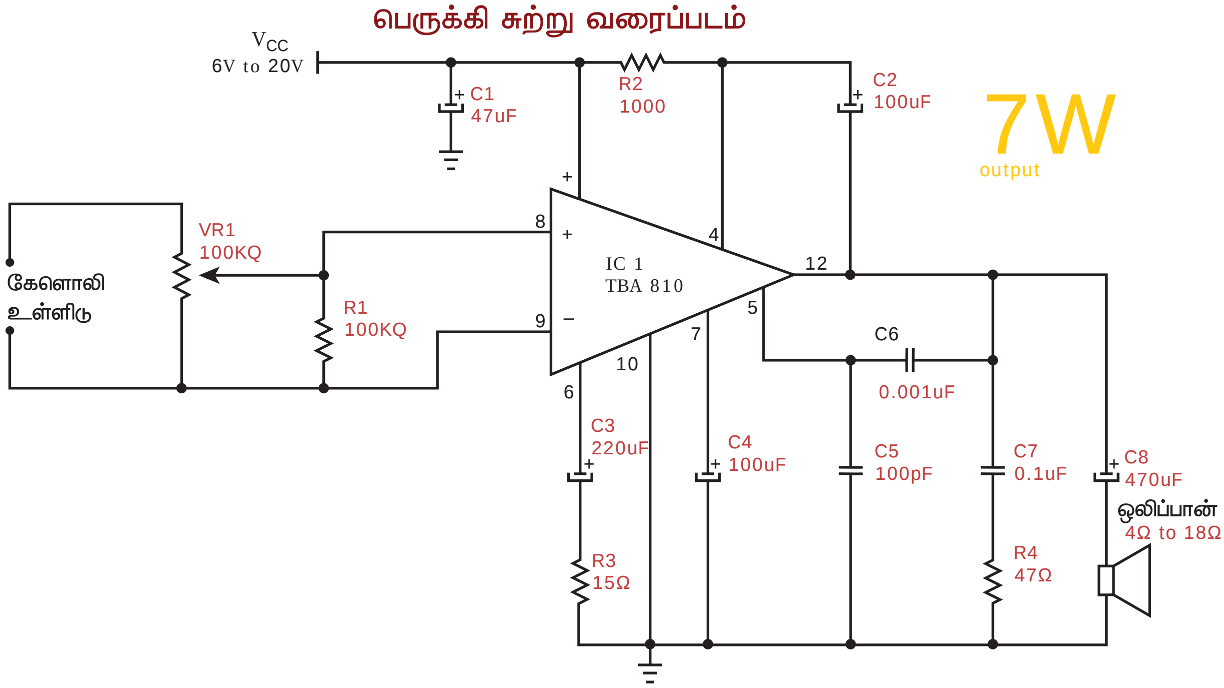
CXA 1619- Voltage Reading

Pin No	Voltage
4	
12	
26 (B⁺)	
27	

TBA 810 – Voltage Reading

Pin No	Voltage
1 (B+)	
8	
12	

பெருக்கி சுற்று வரைப்படம்



Procedure

- Connect as per the circuit diagram
- Connect 6 V DC supply to the FM circuit
- Measure pin voltages of CXA 1619 and TBA810 IC using multimeter and tabulate

Result

- Thus I understand the construction of FM receiver using CXA 1619 and TBA810 IC

EXERCISE 4

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

S.No	Name of the Component/Apparatus	Range	Quantity
1	IC with Heat sink	TDA 2003	1
2	4", 8 watts, 4 ohms	1	1
3	Volume control	10 k ohms	1
4	Resistor	220 ohms	1
		33 ohms	1
		2.2 ohms	1
		1 ohms	1
5	Capacitor	1000 mF	1
		470 mF	1
		100 mF	1
		10 mF	1
		100 nF	2
		47 nF	1
6	DC power supply	12 V/ 500 mA	1
7	PCB/General purpose board	1	1
8	25 W	1	
9	Lead & wires	As per requirements	
10	Multimeter	1	
11	FM Radio Receiver	1	

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.

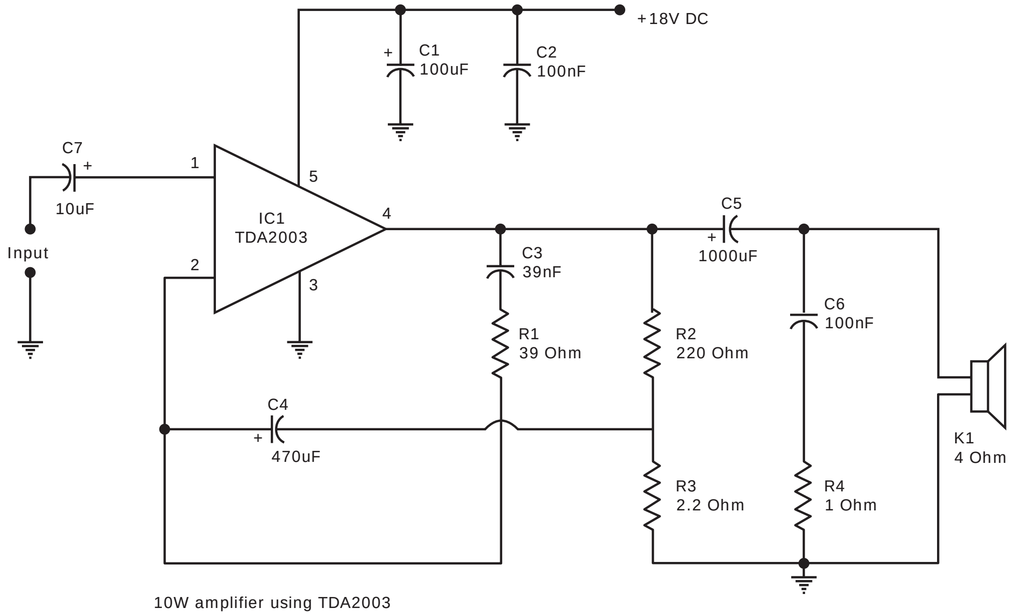
TDA2003 Amplifier circuit diagram built for 8Ω speaker and this circuit can provide upto 10 watts output, you can apply 6 to 12V power supply to this circuit.

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 Resistors 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.

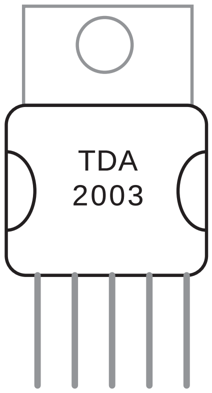
Circuit Diagram



10W amplifier using TDA2003

TDA2003 Pinout

TDA2003 Pinout



1 Non inverting input
2 Inverting input
3 Ground
4 Output
5 Supply voltage

This TDA2003 IC can take supply voltage Vs between 8 to 18 Volts, and gives output power depends on load resistor RL, maximum 10 Watts if RL = 2Ω. 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

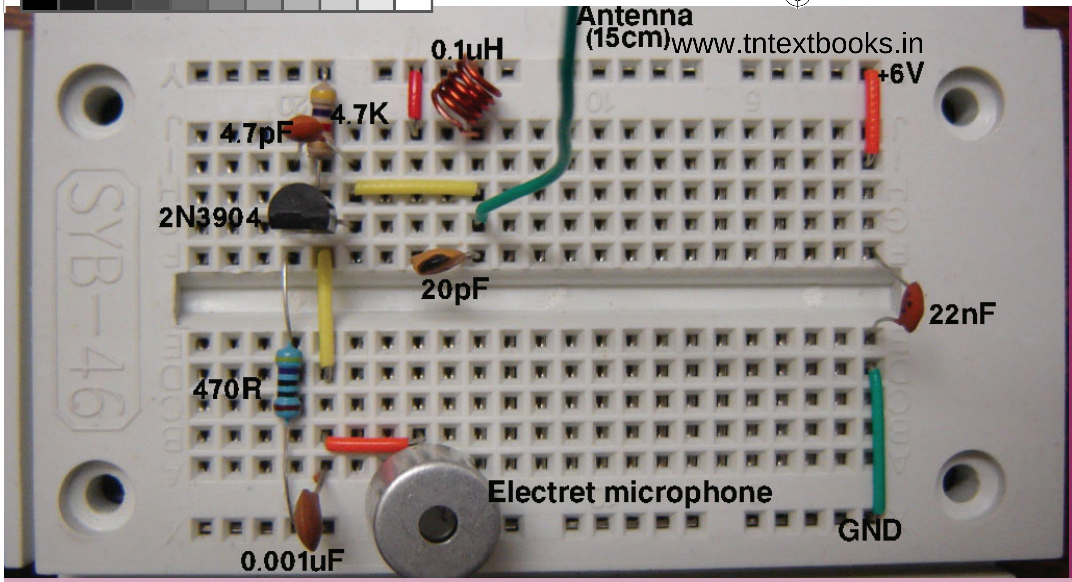
Pin No.	Volts
1	
2	
3	
4	
5	

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.



EXERCISE 5

Rectification of Faults in FM Receiver

Aim: To identify the reasons for dead fault and rectification of an FM receiver.

APPARATUS / COMPONENT REQUIRED

S.No.	Name of Components / Apparatus	Quantity
1	A dead FM receiver	1
2	Multi meter	1
3	RF/AF Signal Generator	1
4	Soldering Iron	1
5	Wires	1
6	Lead	1
		1

Dead fault

If there is no sound when a FM Radio receiver is switched ON, then it is termed to be dead fault.

Common reasons for dead fault:

1.There may be a fault in the speaker.

2. check the power cord.

3. check the ON/OFF switch.

4. Power transformer may become fault.

5. There may be fault in the bridge rectifier.

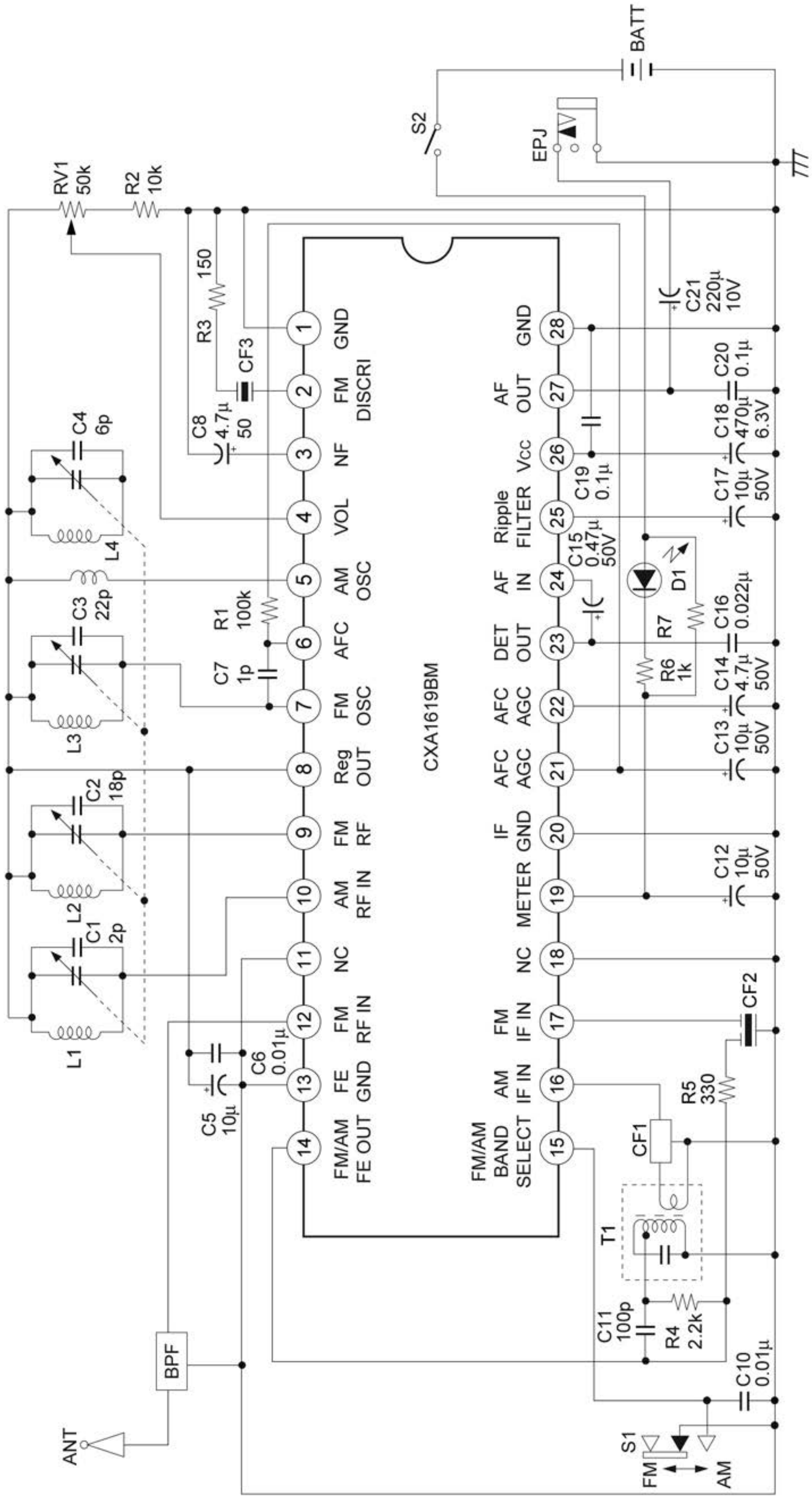
6. The filter capacitor of B+ would be damaged.

7. The main filter capacitor may be damaged.

8. Check for dry soldering and removal of copper in the PCB

9. Check the TBA 810 IC in the audio stage (ie B+ voltage). Change the IC if there is a fault.

10. Check the voltage (B+) of CXA 1619 IC and replace if its faulty.

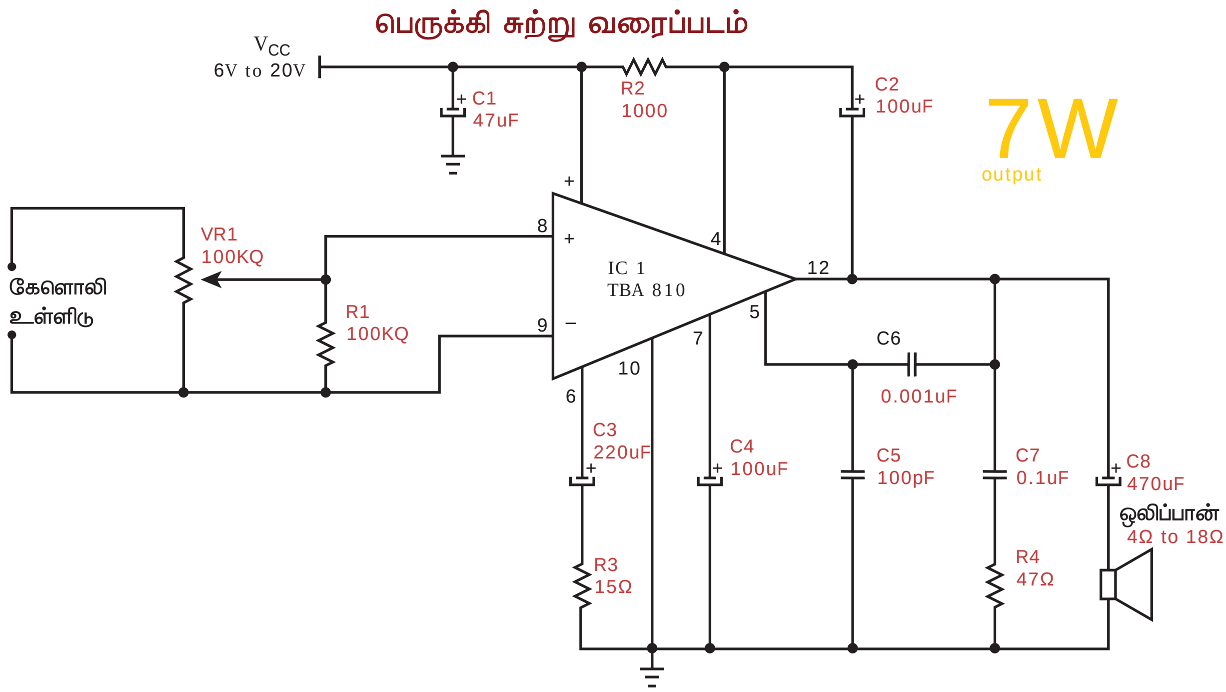

CXA1619BM
BATT
S2
EPJ
RV1 50k
R2 10k
R3 150
CF3
C8 4.7µ 50
R1 100k
C7 1p
C21 220µ 10V
C20 0.1µ
C18 470µ 6.3V
C19 0.1µ
C17 10µ 50V
C15 0.47µ 50V
D1
R7
C16 0.022µ
R6 1k
C14 4.7µ 50V
C13 10µ 50V
C12 10µ 50V
CF2
R5 330
CF1
T1
C11 100p
R4 2.2k
C10 0.01µ
S1
FM
AM
ANT
BPF
C5 10µ
C6 0.01µ
L1
L2
L3
L4
C1 2p
C2 18p
C3 22p
C4 6p
GND
FM DISCRI
NF
VOL
AM OSC
AFC
FM OSC
Reg OUT
FM RF
AM RF IN
NC
FM RF IN
FE GND
FM/AM FE OUT
FM/AM BAND SELECT
AM IF IN
FM IF IN
NC
METER
IF GND
AFC AGC
AFC AGC
DET OUT
AF IN
Ripple FILTER
Vcc
AF OUT
GND

CXA 1619- Voltage Reading

Pin No	Voltage
4	
12	
26 (B^+)	
27	

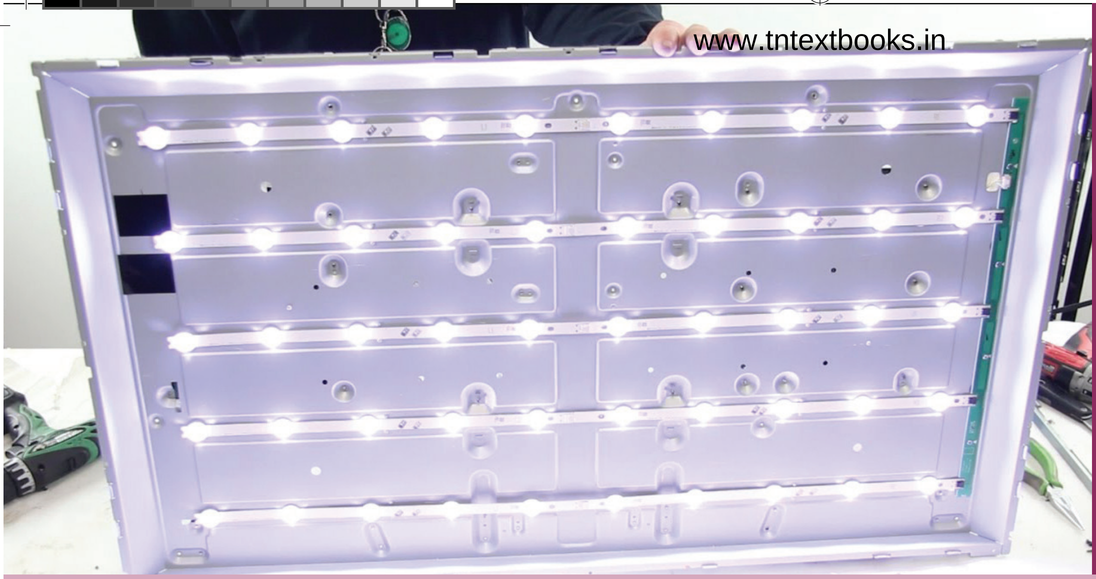
TBA 810 – Voltage Reading

Pin No	Voltage
1 (B+)	
8	
12	



Result

- Understand the reasons of dead fault and the way of rectification happened in a Radio receiver.



EXERCISE 6

LED TV Fault

Aim: To understand and rectifying the (No light, sound good) in a LED TV

APPARATUS / COMPONENT REQUIRED

S.No.	Name of Components / Apparatus	Quantity
1	A faulty LED TV receiver	1
2	Soldering Iron	1
3	LED's	Required Nos
4	LED tester	1

Note:

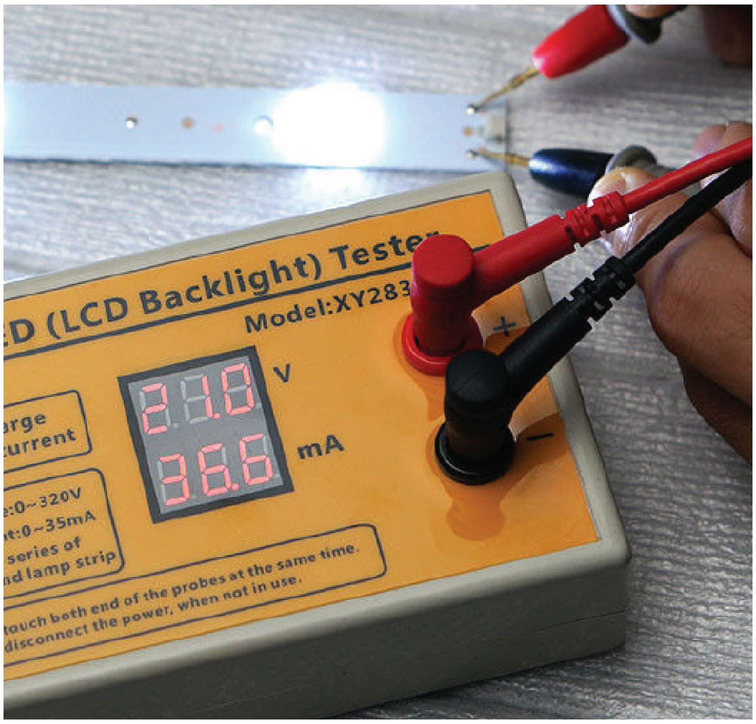
- Though there may be a chance for many faults, but "No light and good sounds" is the frequently appearing faults.
- Reasons for the fault and method of rectification.

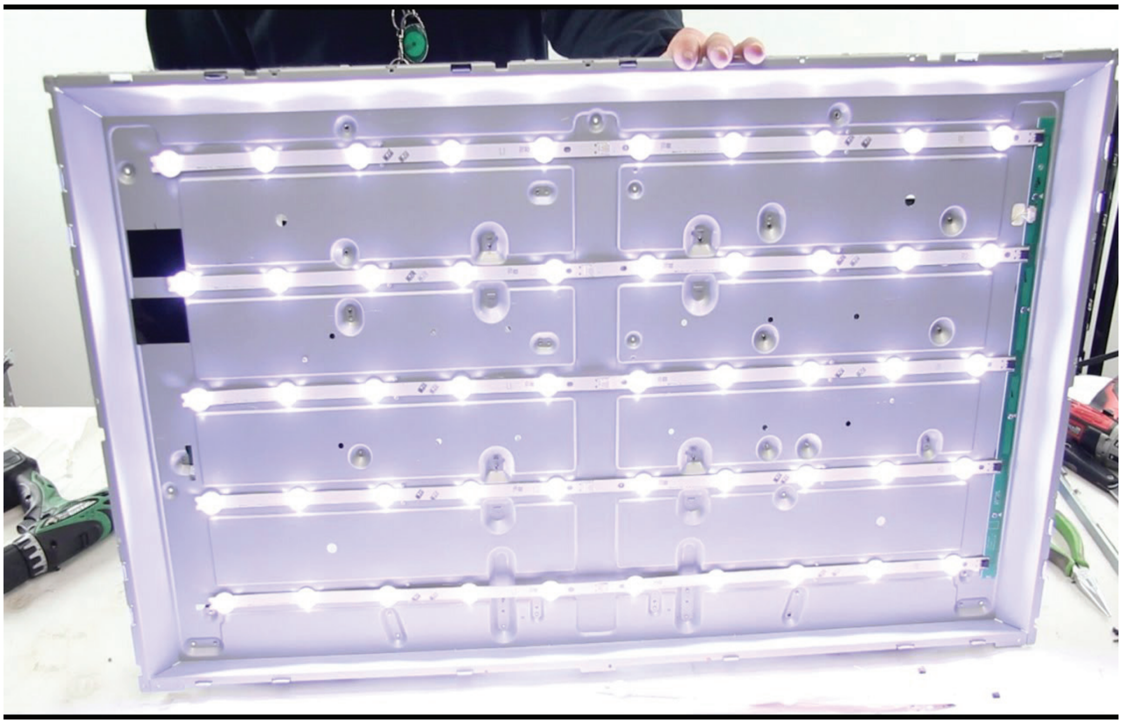
Fault

- Floor the light of a hand torch on the surface of the faulty LED TV
- If picture appears on the spot of light fall, it denotes there is a fault in the back light.

Rectification

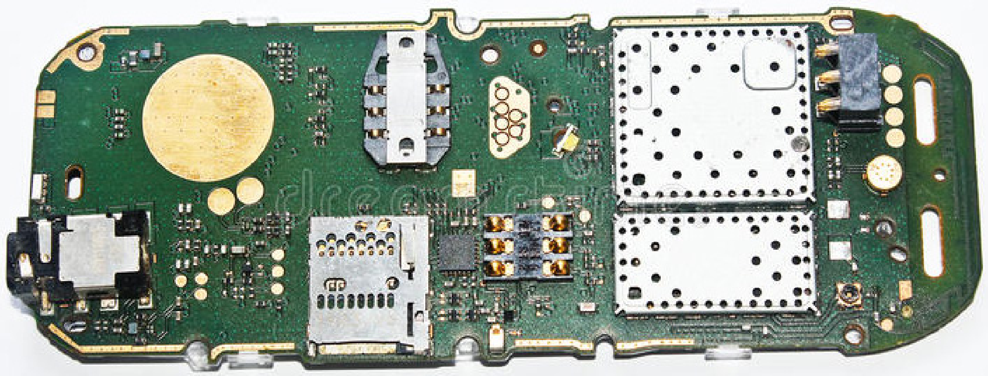
1. First open the back door of the LED TV. Switch 'ON' the LED TV, if the white LED's are not glowing, check the voltage coming to them.
2. Check the LED's separately by using LED tester
3. Replace the faulty LED with Good LED's of same voltage rating
4. Switch 'ON' the LED TV and check its performance





Result:

- Thus I understand the sound good no light fault and the method of rectification.



EXERCISE 7

Study of Mobile Phone - Big Parts

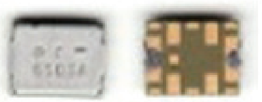
Aim: To understand Mobile Phone - Big Parts

APPARATUS / COMPONENT REQUIRED

S.No.	Name of Components / Apparatus	Quantity
1	Mobile Phone	1
2	Multimeter	1

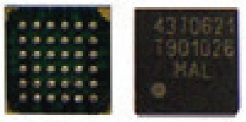
Identification of Big Parts

1. Antenna switch



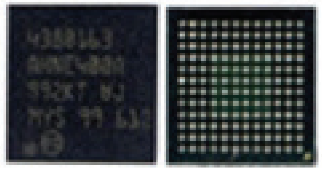
It is found in the Network section of a Mobile phone and made up of metal and non-metal. In GSM sets, it is found in white colour and in CDMA sets as golden metal. Its working function is to search the network and passes forward after tuning. If the antenna switch is faulty then there will be no network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

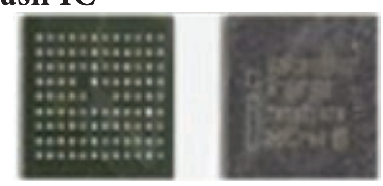
8. ROM

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

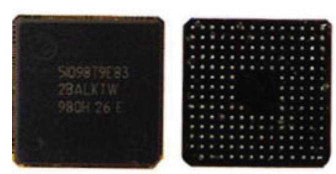
It is found in the Power section of a mobile phone. It sends and receives commands of the Operating Program in a mobile Phone. If RAM is faulty, then there will be software problem in the mobile phone and get hanged and dead.

10. Flash IC



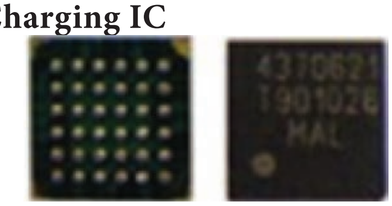
It is found in the power section of a Mobile Phone. It is also called EEPROM IC, Memory IC, RAM IC and ROM IC. Software of the mobile phone is installed in the Flash IC. If Flash IC is faulty, then the mobile phone will not work properly and it goes to the dead condition.

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.

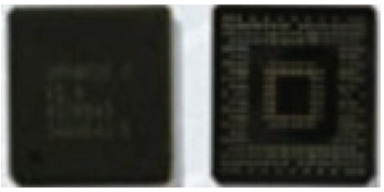
12. Charging IC



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**

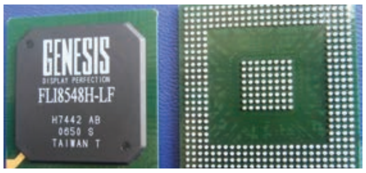


It is found in the Power section. It is also called MAD IC, RAP IC and UPP. It is the largest IC on the PCB of a mobile phone and it looks different from all other ICs. It controls all section of a mobile phone. If CPU is faulty, then the mobile phone will get dead.

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.

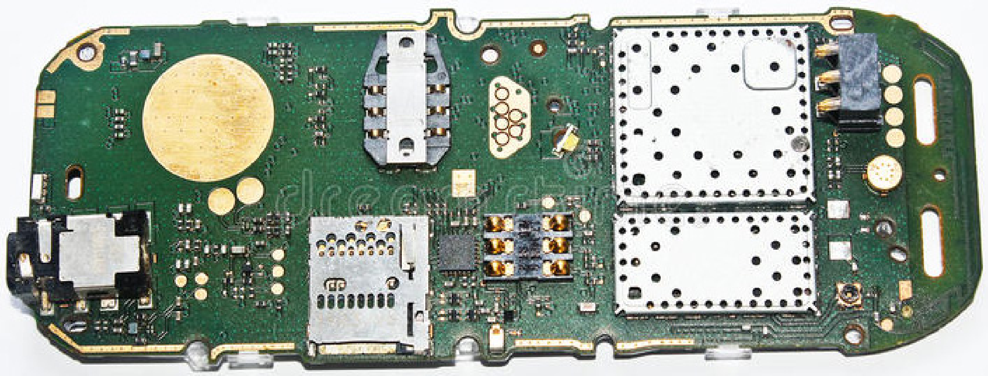
16. **Audio IC**



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.

Result:

- Thus I understand the various big parts of mobile phone



EXERCISE 8

Study of Mobile Phone - Small Parts

Aim: To understand Mobile Phone - Small Parts

APPARATUS / COMPONENT REQUIRED

S.No.	Name of Components / Apparatus	Quantity
1	Mobile Phone	1
2	Multimeter	1

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.

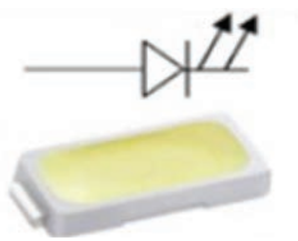
3. Diodes

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

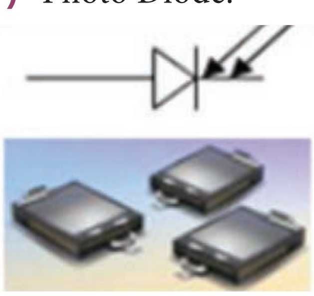


It is found in white or light-yellow colour and emits lights.

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.

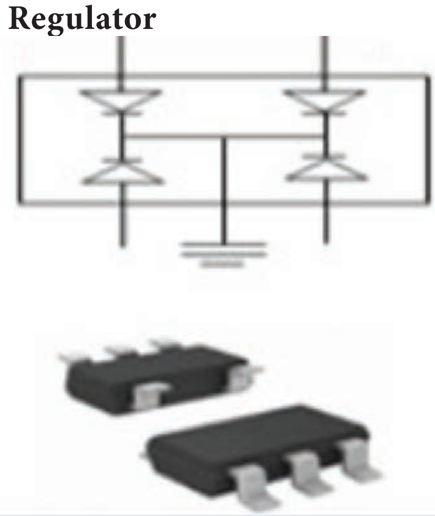


It is used for Infrared. It captures Infrared Rays.

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. It is the smallest electronic components on the PCB of a mobile phone. It decreases current and passes forward.

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.

iii) Network Capacitors

It is found in any section of a mobile phone. It is made from two or more non-electrolytic capacitors.

8. 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.

9. 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.

Result:

- Thus I understand the various small parts of mobile phone

EXERCISE 9

Cell Phone Service

AIM: To test and rectifying the faults of a cell phone.

APPARATUS/COMPONENTS REQUIRED

S.No.	Name of the Apparatus/Components	Range/Value	Quantity
1	Faulty cell phone		1
2	Multimeter		1
3	Magnifying glass		1
4	Berger wire		1
5	Soldering station		1
6	Electrician Knife		1

Theory

Two types of testing methods are followed while testing a cell phone

They are:
1. Cold Testing
2. Hot Testing

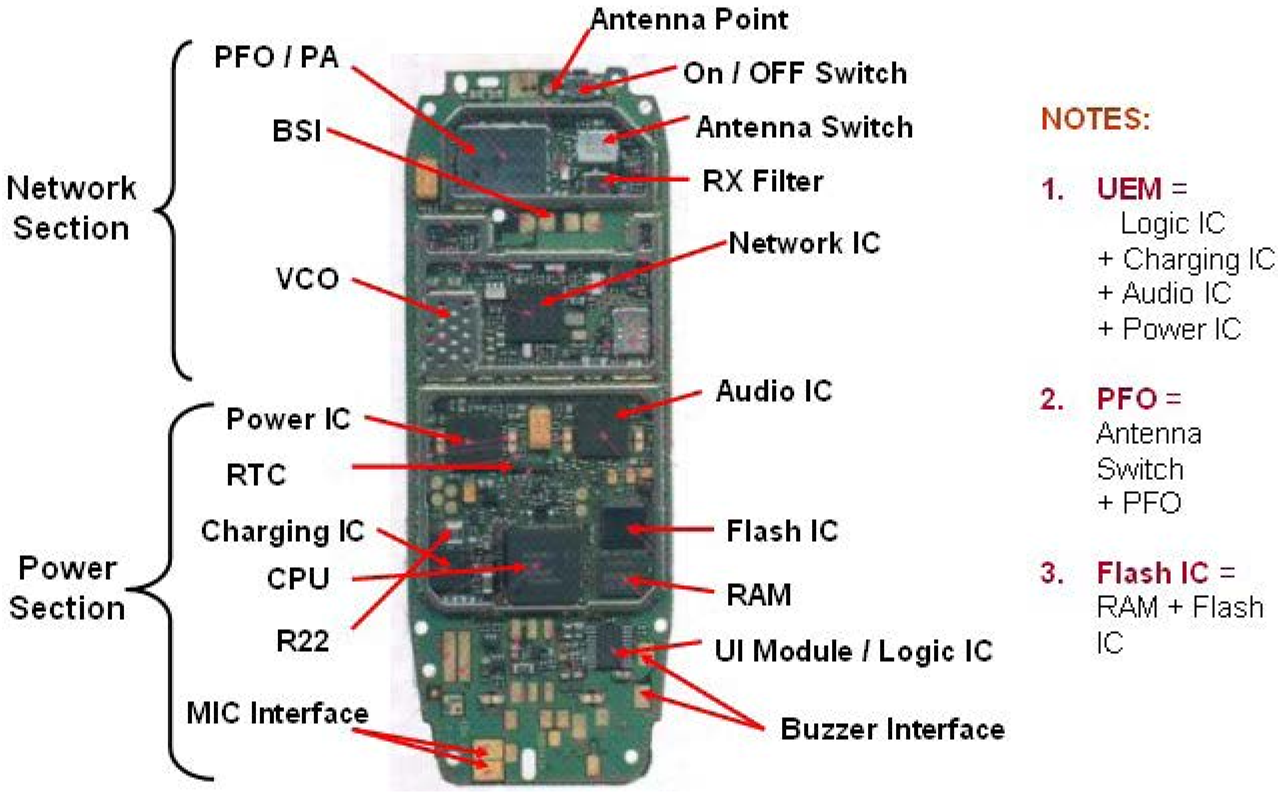
Cold Testing

Measuring the resistance value of the cell phone by keeping the cell phone in switched off state that is without giving any supply is called cold test method.

Hot Testing

Finding the faults giving proper supply to the cell phone its called hot test method

MOBILE PHONE PARTS



Procedure

1. The cold testing method, circuit continuity can be checked with the help of multimeter. By getting a beep sound continuity is confirmed.

2. Against to the normal way, keep the red probe (+ve) in the earth point of the PCB and keep the black probe at the point of testing device.

3. In hot testing method, keep the selector switch multimeter in DC voltage range and the voltages against to the prescribed voltages as shown in the table below

4. Keep the block probe if the multimeter in the earth point of PCB and red probe in the points to be measured and read the voltages.

Testing Chart

S. No	Parts / testing point	Prescribed Resistance	Read Resistance	Stage	Pres. Voltage	Read Voltage
1	Battery Connector	500 to 700			3.7v	
2	Battery charger sensor	Adove 800			---	---
3	Power supply connect	600 to 700			5v – 6v	
4	Battery charger output	300 to 400			3.7v -4.3v	
5	ON / OFF Switch	600 to 900			3v – 3.5v	
6	Head phone connector	500 to 700			0 – 2.5v	
7	Speaker connector	300 to 600			0 -2.5v	
8	Screen power connecting pin	250 to 400			1.8v -2.8v	
9	Screen signal connecting pin	500 to 800			0 -1.8v	
10	Sim card pin 1 connector	500 to 700			1.8v -3.2v	
11	Sim card pin 4 connector	Beep Sound			---	---
12	Sim card pin 2,3,6 connector	400 to 800			0 -2.8v	
13	Micro card pin 4	500 to 600			2.8v	
14	Micro card connector pin 1,2,3,5,7,8	600 to 800			0v – 2.8v	

15	Micro card connector pin 6	Beep Sound			---	---
16	Analog MIC connector	700 to 900			1.8v – 3v	
17	Camera power connector	250 to 400			1.8v – 2.9v	
18	Camera signal connector	600 to 900			0v -1.8v	
19	Switch point	400 to 800			1.8 v– 2.8v	
20	Vibration mode connector	400 to 500			1.9v -2.8v	
21	RTC	400 to 500			---	---
22	Data Rx & Tx	600 to 700			1.8v – 2.8v	

Result

I understand the testing procedure of a cell phone by comparing the prescribed resistances and voltages of various pins with the reading of cold and hot testing methods

EXERCISE 10

Smart phone faults and Rectification technique

AIM: To understand general faults in a smart phone and the rectification techniques.

APPARATUS/COMPONENTS REQUIRE

S.No.	Name of the Apparatus/Components	Range/Value	Quantity
1	Faulty Smart Phone		1
2	Multimeter		1
3	Thinner		Required
4	Soldering Iron		1
5	Berge Wires		Required
6	New Sim Card		1
7	Lithium Iron Battery		1

Some of the parts that cause faults

1. Speaker
2. Microphone
3. Caller
4. Network
5. Charger
6. Screen
7. Insert Sim

1.Procedure:

Speaker fault

When making a call, caller can not hear sound but receiver can hear sound is called speaker faults. To rectify this fault

1. Remove and check the speaker
2. When speaker O.K, check dry soldering in the mother board and rectify it.
3. Check the SMD component like capacitor, transistor and resistor near audio IC.
4. Update smart phone software.
5. Make berge connection
6. Finally change audio IC.

Microphone fault

When making a call, caller can hear sound but receiver can not hear sound is called microphone fault. To rectify this fault

1. Remove and check the microphone
2. When microphone O.K, check dry soldering in the mother board and rectify it.
3. Check the SMD component lick capacitors, transistors and resistor near audio IC.
4. Update smart phone software.
5. Make berger connection.
6. Finally changer audio IC

Caller fault

In this fault, caller bell and microphone not functioning. To rectify it,

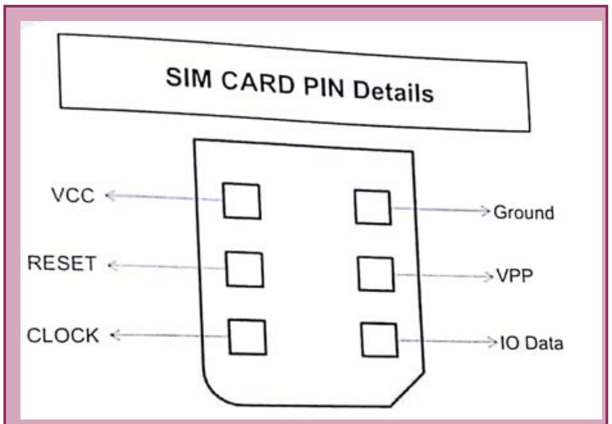
1. Remove and check the caller bell.
2. Check the mother board for any dry soldering.
3. Check the SMD component like capacitors, transistors and resistor near audio IC.
4. Make berge connection tom receive caller signal and check the voltage.
5. Update smart phone software.
6. Finally change audio IC.

Network fault

No signal received and send even the sim inserted and this is called network fault. To rectify it

1. Go to setting
   go to menu settings > Network selection> Manual >Setting > Select network.

2. Change the sim card.
3. Check any fault in the Sim plate.
4. Clean the mother board using thinner.
5. Check antenna parts, antenna key, power amplifier IC, network IC, VCO.
6. Update smart phone software.
7. Finally change network IC.



1. VCC – positive working voltage pin (2.8v)
2. Reset – mobile purpose while Restarting
3. Clock – Purpose of Delivery Acknowledgement Reports and Clock
4. GROUND – Negative Voltage
5. VPP – Dummy
6. I/O Data – Input & Output data (Memory purpose)

Charging fault

When connecting a charger with smart phone, no charging then it is called charging fault.

1. Check the power supply and ensure it have 5 V to 9 V.
2. Check the ampere unit of power supply.
3. Replace the power supply.
4. Replace the battery.
5. Clean the power supply connector with thinner.
6. Finally change the charger control IC.

Screen fault

When screen having no light and only a white image, then it is called screen faults.

1. Check whether screen connector is loosely connected.
2. Check any dust in the male and female connector and clean with thinner.
3. If no light in the screen, switch ON the screen.
4. Ensure any light in the screen.
5. Check any dry soldering in the screen drive control IC.
6. Check the flashing part.
7. Make berge connection.
8. Replace screen and screen driver control IC.

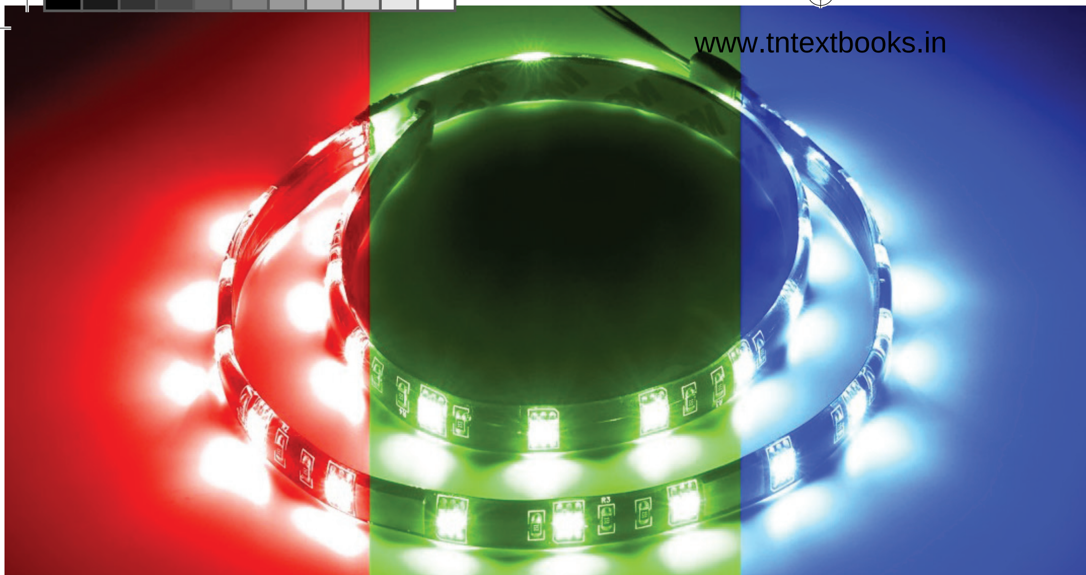
SIM inserting fault

1. Screen shows insert sim, then switch off the phoneand reinsert the sim.
2. Replace new sim card.
3. Check the sim plate.
4. If the sim plate is loosely connected make adjustments.
5. Clean the mother board by thinner.
6. Check 2.8 volts in the sim.

S. No	Name of Hardware Components	Continuity Test	State	Reference Voltage	Measured Voltage
1	Battery	---	---	3.7v	
2	Power Supply	---	---	5v to 9v	
3	On/off switch Off 1 2 3 4 On 1 4 3 2	Beep Sound Beep Sound		----	---
4	Power Supply Connector	---	---	5v to 9v	
5	Speaker	30 Ω (Beep)		---	---
6	Caller	20 Ω (Beep)		---	---
7	Microphone	600 Ω (one side) 1 Ω (Other side)		---	---
8	Vibrator	(Beep)		3v	Rotate
9	Battery Connector	---	---	1v to 3.7v	

RESULT

Thus I understand the fault and rectification techniques of smart phone.



EXERCISE 11

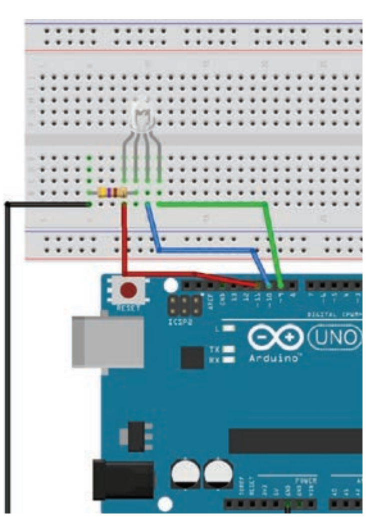
RGB LED

Aim: To control a RGB (Red, Green, Blue) LED with the help of Arduino.

APPARATUS / COMPONENTS REQUIRED

S.No.	Name of Components / Apparatus	Quantity
1	Arduino	1
2	Bread board	1
3	Jumper Wires	1
4	RGB LED	1
5	Three 270 Ω resistors	1

Circuit diagram



Circuit Diagram Illustrating the Connections With Arduino 20

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:

```
/* RGB LED Add name of coder and date of writing the program, for better documentation. */
intredPin = 11;
intgreenPin = 10;
intbluePin = 9;
void setup()
{
pinMode(redPin, OUTPUT);
pinMode(greenPin, OUTPUT); 21          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);
}
voidsetColor(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.

EXERCISE 12

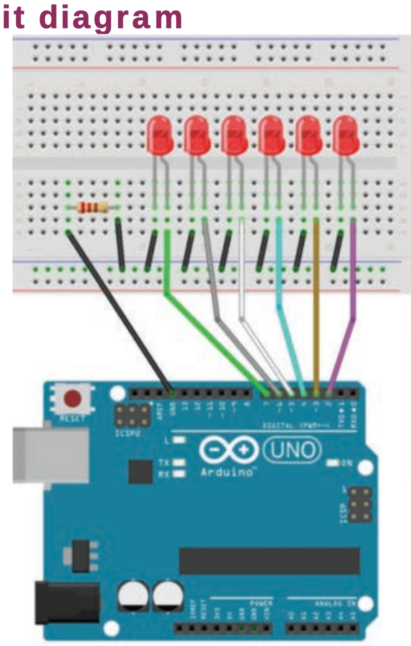
Glowing of Multiple LEDs

Aim: To turn on/off the LEDs in a sequential manner using Arduino board.

APPARATUS / COMPONENTS REQUIRED

S.No	Apparatus / Components Required	Range	Quantity
1	Arduino Board		1
2	Bread Board		1
3	LED's		1
4	Jumper Wires		1

Circuit diagram



Representation of Arduino With Multiple Leds 23

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.
intledPins[] = {
2, 7, 4, 6, 5, 3 }; // an array of pin numbers to which LEDs are attached
intpinCount = 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 (intthisPin = 0; thisPin<pinCount; thisPin++) {
pinMode(ledPins[thisPin], OUTPUT);
}
}
void loop() {
// loop from the lowest pin to the highest:
for (intthisPin = 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 (intthisPin = 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

Class XII - Basic Electronics Engineering

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