Basics of Electrical, Electronics and Communication Engineering

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Preface

This is an introductory level text book in electrical, electronics and communication Engineering. It is prepared as per the syllabus for first year B Tech in Calicut University. The resources used were many internationally reputed text books, suggestions from experienced faculty members and students from electrical science branches of engineering in various engineering institutions. This book intended also for the students in non-electrical science branches.

We seek for suggestions from the readers for improving the book in future editions.

Acknowledgements

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We place it on record our sincere thanks to the students of ECE Dept of GECT for their strenuous efforts on proof reading.

We appreciate the support given by our family members during this work.

Authors

Contents

Chapter 1

Basic Concepts in Electrical Engineering

Basic concepts of electrical engineering are discussed in this chapter.

1.1 Introductory concepts and basic elements

Electric current

Electric current is the rate of flow of electric charges. Electrons are negatively charged particles and their flow in conductors results in electric current.

By definition, current i,

$$i = \frac{dq}{dt} \tag{1.1}$$

If Q is the amount of charge flowing through a conductor in T seconds, then, current I is given by the expression,

$$I = \frac{Q}{T} \tag{1.2}$$

The unit of charge is Coulomb. 1 Coulomb = 6.24 $\times 10^{18}$ electrons.

The unit of current is Ampere, A. 1 Ampere = 1 Coulomb/sec.

Electromotive force

Energy is required for the movement of charge from one point to another. In order to move electrons along a conductor, some amount of work is required. The work required must be supplied by an electromotive force (emf) provided by a battery or a similar device.

Potential difference

Potential difference is the difference between the voltages at two ends of a conductor.

A current carrying element is shown in figure 1.1. The voltage across the element v_{ab} is given by

$$V_{ab} = \frac{W}{Q} \tag{1.3}$$

where work done (W) is measured in Joules and the charge (Q) in Coulombs.

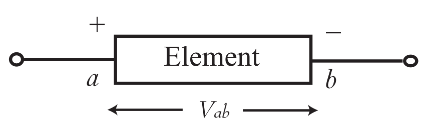


Figure 1.1: Potential drop across a current carrying element

The positive (+) and negative (-) signs shown on figure 1.1 define the polarity of the voltage V_{ab}. With this definition, V_{ab} represents the voltage at point a relative to point b. Equivalently we may also say that the voltage at point a is V_{ab} volts higher than the voltage at point b.

Electric circuit

An electric circuit is a closed connection formed by various electric elements (Resistor, inductor, capacitor, voltage source, current source etc.). The fundamental circuit model is shown in figure 1.2. The circuit is made up of a source V_S which provides a voltage across its terminals and a resistor R_L as load.

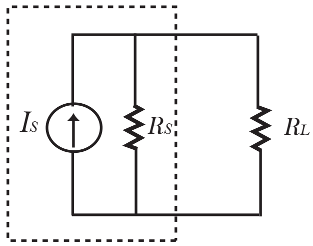
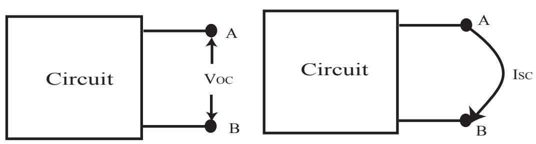


Figure 1.9: Real current source

1.7 Open circuit voltage and short circuit current

Consider any circuit with two output terminals A and B (Figure 1.10(a)). The open-circuit voltage V_{oc} across terminals A and B is the voltage which appears with nothing connected between them. i.e., $R_{AB} = \infty$



(a) Open circuit (b) Short circuit

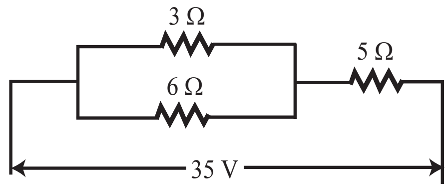
Figure 1.10: Open circuit and short circuit

In the circuit shown in Figure 1.10(b) terminals A and B are connected together with a piece of wire i.e., zero resistance, then the short-circuit current is the current that flows through the wire. Short circuit current I_{SC} is that current which flows between two terminals when they are shorted. i.e., R_{AB} = 0.

Example 1
A resistor of 5 Ω is connected in series with a parallel combination of 6 Ω and 3 Ω. Find the supply current taken from a 35 V dc source.

Solution

Let R_P be the equivalent resistance of the parallel combination of 3 Ω and 6 Ω.



Then $\frac{1}{R_P} = \frac{1}{3} + \frac{1}{6} = \frac{3}{6}$

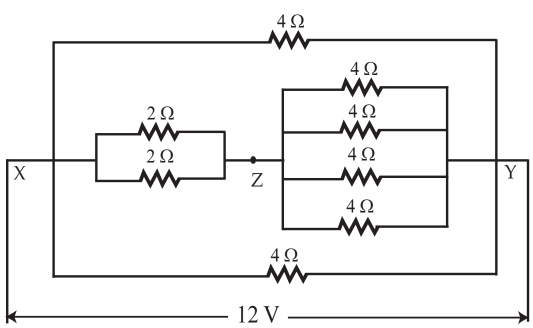
Therefore, $R_P = 2\ \Omega$

Total resistance in the circuit, $R = R_P + 5 = 2 + 5 = 7\ \Omega$

Supply current, $I = \frac{V}{R} = \frac{35}{7} = 5$ A

Example 2

Find the total resistance of the circuit across the terminals X and Y. Also find the power consumed by the circuit if a 12 V battery is connected across XY.



Solution

$$R_{XZ} = \frac{2 \times 2}{2 + 2} = 1\ \Omega$$
$$\frac{1}{R_{ZY}} = \frac{1}{4} + \frac{1}{4} + \frac{1}{4} + \frac{1}{4} = \frac{4}{4} = 1\Omega$$

which starting and end points for tracing the path are, in effect, the same node and touches no other node more than once.

Mesh A mesh is a special case of loop that does not have any other loops within it or in its interior. All meshes are loops but all loops are not meshes.

2.1.1 Kirchoff's Current Law (KCL)

KCL states that at any instant of time, the algebraic sum of currents at a node is zero.

Mathematically,

$$\sum_{n=1}^{N} i_n = 0$$

where N is the number of branches that are connected to the node. The term 'algebraic sum' indicates that we have to take account of the current direction, as well as magnitude, when applying Kirchoff's Current Law. Consider the node shown in figure 2.1. By adopting the sign convention that current flowing into a node is taken as positive (+) while current flowing out of the node is negative (-), application of KCL gives

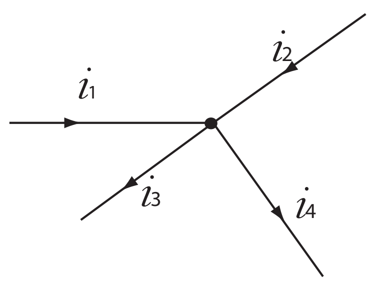


Figure 2.1: KCL

$$+i_1 + i_2 - i_3 - i_4 = 0$$

i.e.,

$$i_1 + i_2 = i_3 + i_4$$

or sum of incoming currents = sum of outgoing currents.

Thus, Kirchoff's Current Law (KCL) can be stated in other words: At any instant of time, the sum of all currents flowing into a node is equal to the sum of all currents leaving the same node.

2.1.2 Kirchoff's Voltage Law (KVL)

KVL states that the algebraic sum of voltages around a closed path at any instant of time is zero.

Mathematically,

$$\sum_{n=1}^{N} V_n = 0$$

where N is the number of voltages in the loop. Voltages include emf and voltage drop across resistors.

$$\sum IR + \sum E.M.F = 0 \quad \text{in a closed circuit}$$

When applying Kirchoff's law attention should be made to the algebraic signs of voltage drops and emfs. The following sign convention may be followed.

Sign convention

While applying Kirchoff's laws, attention should be paid while assigning the signs of emfs and voltage drops.

Sign of battery emf

A rise in voltage should be given a positive sign and a fall in voltage should be given as negative sign. As we go from negative terminal of a battery to its positive terminal, as shown in figure 2.2(a), there is a rise in potential, hence the voltage should be given positive sign. If we go from positive terminal to negative terminal as shown in figure 2.2(b), then there is a fall in potential, hence this voltage is given negative sign.

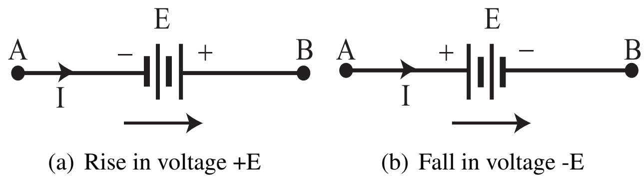


Figure 2.2: Sign of battery emf

Sign of IR drops
If we go through a resistor in the same direction of the current, as shown in figure 2.3(a), there is a fall in potential because current flows from higher potential to lower potential. Therefore this voltage drop is assigned negative sign. If we go in the direction opposite to that of current, as shown in figure 2.3(b), then there is a rise in voltage. Hence this voltage is given positive sign.

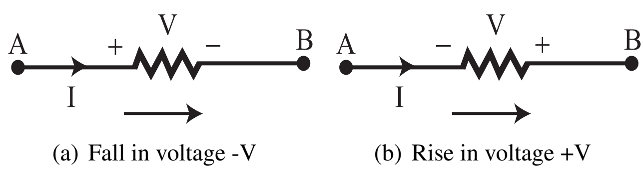


Figure 2.3: Sign of battery emf

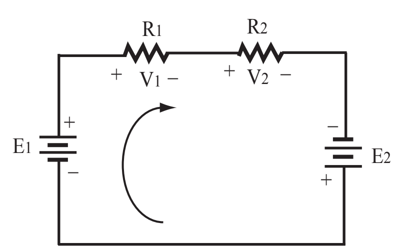


Figure 2.4: KVL

Illustration of KVL
Consider the figure 2.4 which shows a single loop circuit in which KVL

Example 5

Find the loop currents in the electric circuit shown in Figure 2.13.

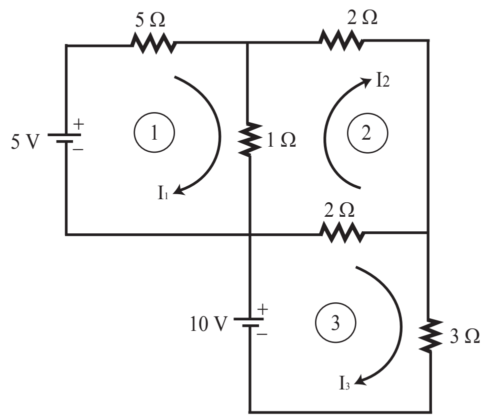


Figure 2.13:

Solution

From the loop 1 : $5I_1 + (I_1 - I_2) = 5$

$$5I_1 + (I_1 - I_2) = 5 \tag{2.8}$$

From loop 2 : $2I_2 + (I_2 - I_1) + 2(I_2 - I_3) = 0$

$$5I_2 - I_1 - 2I_3) = 0 \tag{2.9}$$

From loop 3: $(I_3 - I_2)2 + 3I_3 = 10$

$$5I_3 - 2I_2 = 10 \tag{2.10}$$

Solving 2.8, 2.9 and 2.10, we get,

$$I_1 = 1.03 \text{ A}$$
$$I_2 = 1.198 \text{ A}$$
$$I_3 = 2.48 \text{ A}$$

Example 6

Find V_3 and its polarity if the current I in the circuit shown in figure 2.14 is 0.4 A.

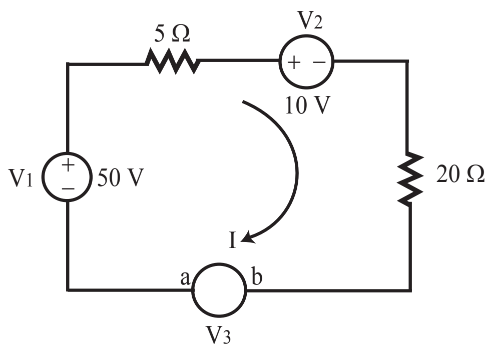


Figure 2.14:

Solution

Assume V_3 has the polarity with terminal 'a' is positive
Applying KVL and starting from left corner of the circuit,

$$\begin{aligned} V_1 - 5I - V_2 - 20I + V_3 &= 0 \\ 50 - 2 - 10 - 8 + V_3 &= 0 \\ V_3 &= -30V \end{aligned}$$

Negative value of V_3 implies that the terminal 'b' is positive with respect to terminal 'a' (opposite to the assumed polarity).

Example 7

Two coils connected in series have a total resistance of 9 Ω and when connected in parallel have a resistance of 2 Ω. Find the resistance of each coil.

Solution

Let the resistance of two coils be R_1 and R_2.

3.6 Magneto motive force

Magneto motive force (mmf) is the force which establishes the magnetic flux in a magnetic circuit. When a current is passed through a coil, a magnetic flux is set up around it. The product of current (I) and number of turns (N) of the coil gives MMF.

MMF F is given by the expression,

$$F = NI$$

Its unit is Ampere-turns (AT).

3.7 Magnetic field intensity

Magnetic field intensity is the magnetic motive force per unit length of the magnetic circuit. It is denoted by H and its unit is Ampere-turns/meter. Magnetic field intensity is also called magnetic field strength or magnetizing force.

$$H = \frac{\text{mmf}}{l} = \frac{F}{l}$$

$$H = \frac{NI}{l}$$

Or

$$F = NI = Hl \tag{3.1}$$

3.8 Permeability

The ability of a material to conduct magnetic flux through it is called permeability of that material. It is represented by the letter μ and the unit Henry/meter. The flux and hence the flux density B are directly proportional to the magnetizing force H.

i.e.,

$$B \propto H$$

Thus coefficient of coupling may be defined as the ratio of actual mutual inductance present between the two coils to the maximum possible value of mutual inductance.

Example 1

Find the induced emf in a conductor when rotated in a uniform field of magnetic flux 2 mWb in 0.02 s. Given number of turns of the conductor is 100.

Solution

Given $N = 100$ turns

$$\text{Induced emf, } e = -N\frac{d\Phi}{dt}$$
$$= -100 \times \frac{2 \times 10^{-3}}{0.02}$$
$$= -100 \times \frac{0.002}{0.02} = -10 \text{ V}$$

Example 2

A current of 5 A when flowing through a coil of 1000 turns, produces a flux of 0.3 mWb. Determine the inductance of the coil.

Solution

Given,

$I = 5$ A

$N = 1000$ turns

$\Phi = 0.3$ mWb $= 0.3 \times 10^{-3}$ Wb

We have, inductance of the coil, L = $\frac{N\Phi}{I}$

$$= \frac{1000 \times 0.3 \times 10^{-3}}{5} = 0.06 \text{ H}$$

Example 3

A coil consists of 750 turns and a current of 10 A in coil produces a magnetic flux of 1.2 mWb. Calculate the inductance of the coil. If the

Chapter 4

Single Phase AC Circuits

4.1 AC Fundamentals

An alternating voltage is any voltage that varies both in magnitude and polarity with respect to time. Similarly an alternating current is any current that varies both in magnitude and direction with respect to time. An ac circuit is a circuit in which alternating current flows that reverses its direction at regular intervals of time. Alternating current systems have many advantages compared to direct current systems. Alternating currents can be easily generated, transmitted and utilized as compared to direct current systems.

4.2 Generation of sinusoidal emf

A sinusoidal voltage can be generated either by rotating a coil in a stationary magnetic field or by rotating a magnetic field within a stationary coil.

Consider a rectangular single turn coil rotating in a uniform magnetic field with a constant angular velocity ω rad/sec in the anticlockwise direction as shown in Figure 4.1.

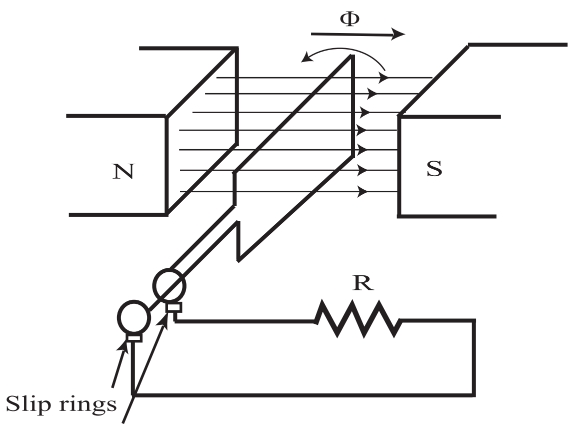
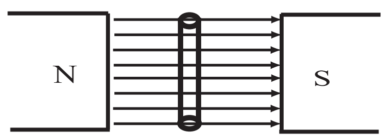
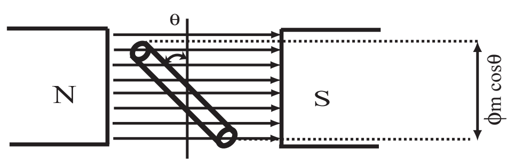


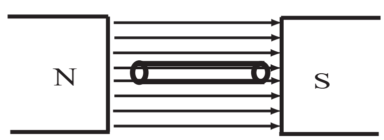
Figure 4.1: Generation of sinusoidal emf



(a) Maximum flux linkage (Φ_m) when $\theta = 0^\circ$



(b) Flux linkage = Φ_m cos θ



(c) Minimum flux linkage (zero) when $\theta = 90^\circ$

Figure 4.2: Flux linkage when coil rotates in a magnetic field

where E_m and I_m are peak values of induced emf and current respectively and ω is the angular velocity of the coil given by

$$\omega = 2\pi f$$

where f is the frequency in Hz.

From the expressions of emf and current, it is clear that instantaneous values of emf and current vary as the sine functions of angle θ. So they are known as sinusoidal voltage and current. When the emf or current is plotted against time, a sine wave as shown in Figure 4.3 is obtained.

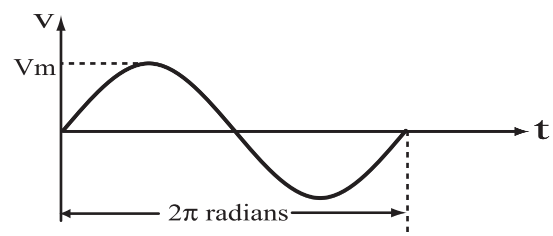


Figure 4.3: Sine wave

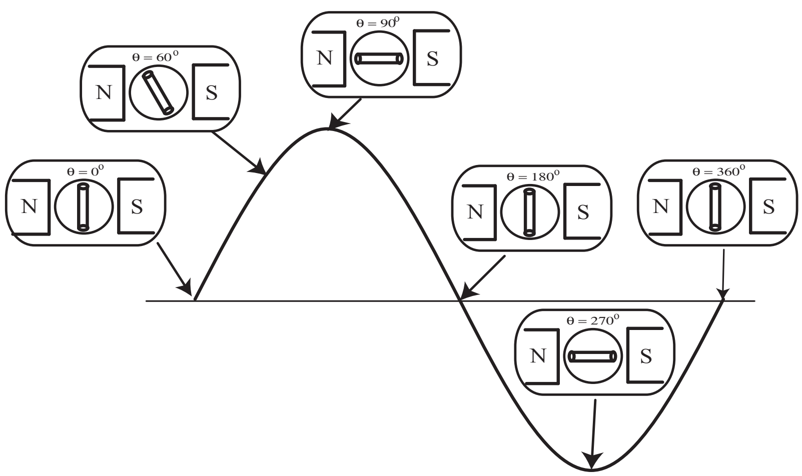


Figure 4.4: Position of coil and induced emf

where V and I are rms values of voltage and current.

The term cos ϕ is called power factor of the circuit and cos $\phi = \frac{R}{Z}$ (From impedance triangle shown in Figure 4.20(b))

4.12 AC through series R-C circuit

Consider an ac circuit in which a resistor of R ohms and a capacitor of capacitance C Farads are connected in series as shown in figure 4.22.

Let V = rms value of applied voltage

I = rms value of resultant current

$V_R = IR$ = voltage drop across R (in phase with I)

$V_C = IX_C$ = Voltage drop across capacitor C (lagging I by $90°$
)

where $X_C = \frac{1}{\omega C}$, reactance offered by capacitor

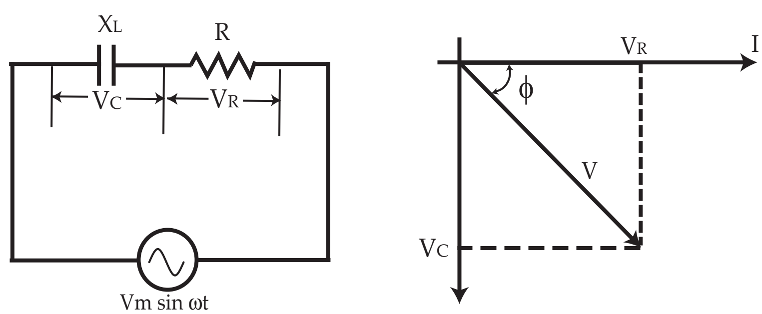


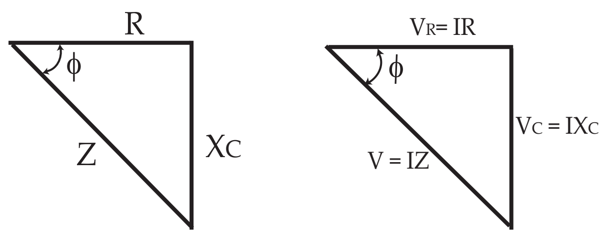
Figure 4.22: Series RC circuit and phasor diagram

From the phasor diagram shown in Figure 4.22, the applied voltage V is the vector sum of V_R and V_C and current I is leading the voltage V by an angle ϕ.

i.e., $V = \sqrt{V_R^2 + V_C^2} = \sqrt{(IR)^2 + (IX_C)^2} = I \times \sqrt{R^2 + X_C^2}$

Hence, $I = \dfrac{V}{\sqrt{R^2 + X_C^2}} = \dfrac{V}{Z}$

The term $\sqrt{R^2 + X_C^2}$ is called the *impedance* Z of the RC circuit.



(a) Impedance triangle (b) Voltage triangle

Figure 4.23: Impedance triangle and voltage triangle for an RC circuit.

From the impedance triangle,

$$\tan\phi = \frac{X_C}{R}$$

$$\phi = \tan^{-1}\frac{X_C}{R}$$

Hence the instantaneous value of applied voltage is given by

$$v = V_m \sin \omega t$$

and instantaneous value of current $i = I_m \sin(\omega t + \phi)$

$$\text{where } I_m = \frac{V_m}{Z} = \frac{V_m}{\sqrt{R^2 + X_C^2}}$$

Voltage, current and power waveforms for R-C circuit are shown in Figure 4.24.

Power in series R-C circuit

In a series R-C circuit, power consumed by capacitor is zero. Power is consumed by resistance only. It is interesting to note that in the circuits discussed the sections 4.8 through 4.12, frequency of power waveform is double of that of voltage and current waveforms.

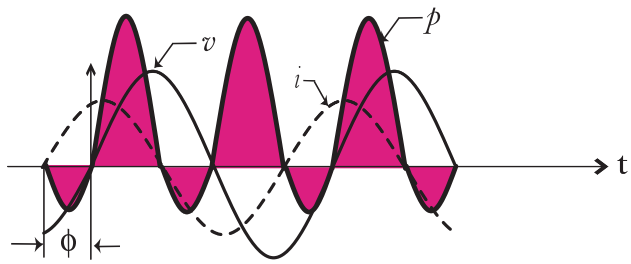


Figure 4.24: Voltage, current and power waveforms in RC circuit

i.e., Average power, $P = V_R I$ where $V_R = V\cos\phi$ from voltage triangle shown in 4.23(b).

Therefore, $P = V\cos\phi \times I = VI\cos\phi$

where V and I are rms values of voltage and current.

The term cos ϕ is called power factor of the circuit and $\cos\phi = \dfrac{R}{Z}$ (From impedance triangle shown in Figure 4.20(b))

4.13 AC through series R-L-C circuit

Consider an ac circuit in which a resistor of resistance $R\ \Omega$, an inductor of inductance L Henry and a capacitor of capacitance C Farads connected in series across an ac supply of V volts as shown in Figure 4.25.

Let V = rms value of applied voltage

I = rms value of resultant current

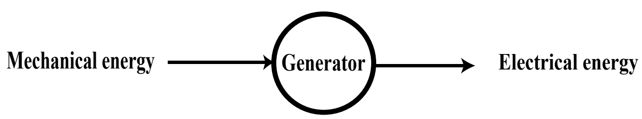
Chapter 7

DC machines

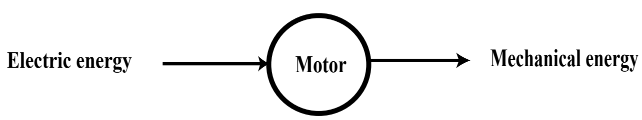
7.1 Introduction

Direct current (dc) machines were the first electrical machines that came to industrial use. The use of dc machines is now very much limited since the power supply is usually available in AC only. However, they are still used in certain applications like traction, cranes etc.

There are two types of dc machines, the dc generator and the dc motor. The dc machine which converts mechanical energy into electrical energy is called a dc generator. The dc machine which converts electrical energy into mechanical energy is called a dc motor.



(a) Generator



(b) Motor

Figure 7.1: Schematic representation of generator and motor

7.2 Principle of dc Generator

A dc generator is a rotating machine which converts mechanical energy into electrical energy. DC generators work on the principle of *electromagnetic induction*. According to Faraday's law of electromagnetic induction, whenever a conductor cuts magnetic lines of flux a dynamic emf is induced in the conductor. This emf causes a current flow if the circuit is closed. The essential requirements of a dc generator are

1. A magnetic field
2. Conductors or coils
3. Relative motion between the magnetic field and the conductors

7.3 Simple loop generator

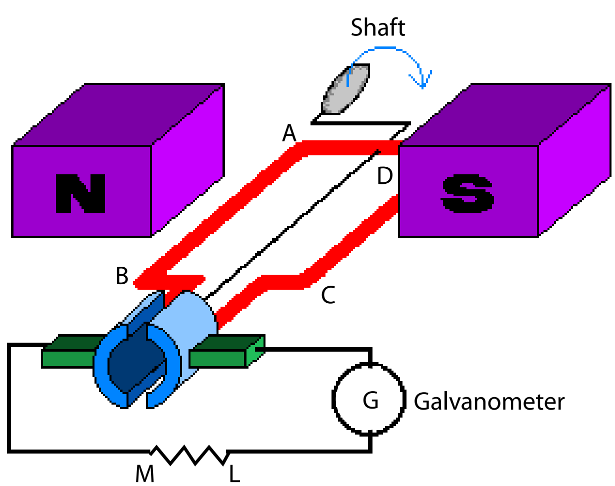


Figure 7.2: A simple loop generator

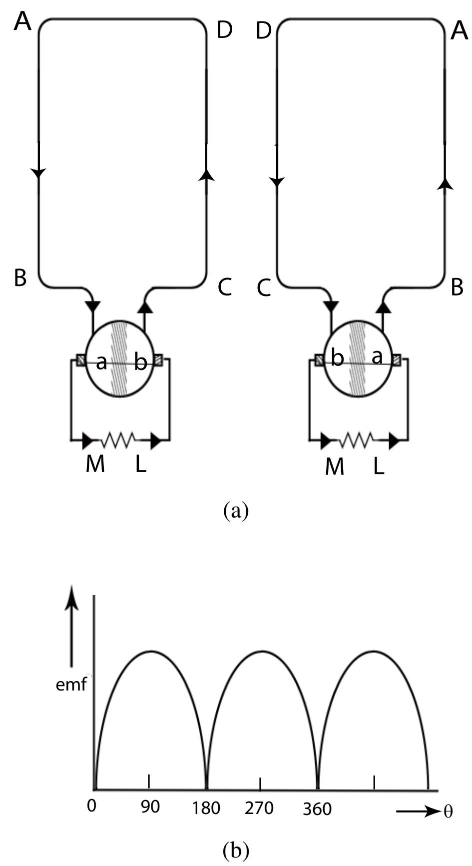


Figure 7.3: emf generated by loop generator

Figure 7.2 shows the arrangement of a single turn coil ABCD rotating at a constant speed in a uniform magnetic field produced by two poles. The two ends of the coil are connected to a split ring[1]. An emf is induced in the coil which is proportional to the rate of flux linkage. Figure 7.3(a) shows the schematic diagram of coil connections with split ring. The direction of induced current in the coil is from A to B and from C to D during the first half revolution. Therefore the current

[1] A slip ring splitted into two

will flow through the load resistor from M to L. In the next half revolution, the direction of induced current will be from D to C and from B to A as shown in the figure. The current will again flow from M to L through the load resistor.

In a dc generator the emf induced in the coil is alternating. In order to get a unidirectional current an arrangement known as *commutator* is used. The function of commutator in a dc generator is to convert the alternating current produced in the armature (coil) into direct current in the external circuit. In the figure the ends of the armature are connected to a split ring which acts as commutator.

7.4 Constructional details of dc Machine

A direct current machine can be used as a generator or as a motor. When the dc machine is driven by a prime mover, it converts mechanical energy into electrical energy and so it acts as a generator. If electrical energy is supplied to the machine, it works as a motor and it converts electrical energy into mechanical energy.

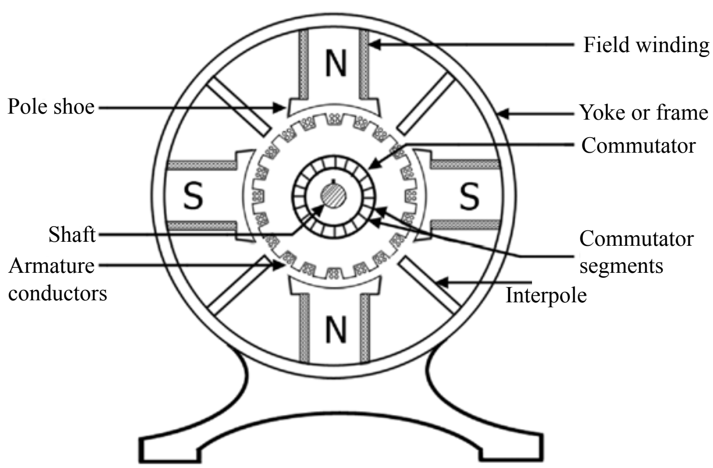


Figure 7.4: Construction of a dc generator

The constructional features of a dc machine are given below.

7.6 Types of dc generators

DC generators are classified according to the method of excitation of their field windings. The production of the magnetic flux in the generator by circulating current in the field winding is called excitation. DC generators are classified as given in the chart 7.8.

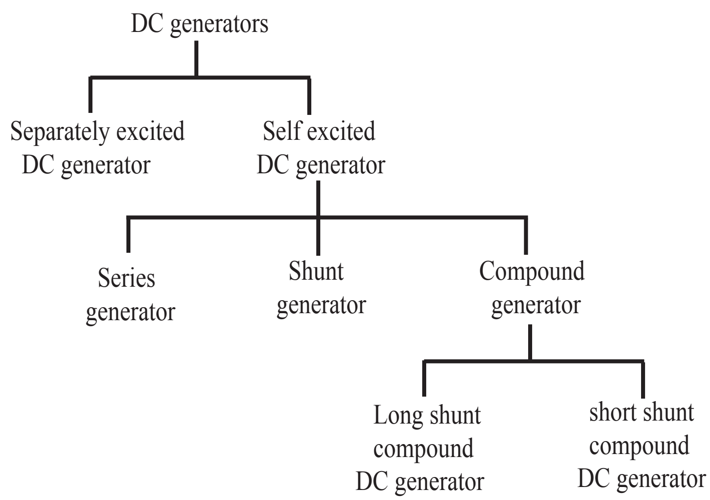


Figure 7.8: Different types of dc generators

7.7 Separately excited dc generator

In this type of machine, the field winding is excited by a separate dc source. The schematic diagram of separately excited dc machines is shown in figure 7.9.

Let I_a = Armature current

R_a = Armature resistance

E = Generated emf

I_L = Current through the load

Chapter 8

Three phase induction motor

8.1 Introduction

Three phase induction motor is extensively used for various kinds of industrial drives. The three phase induction motor has a three phase wound stator to which the three phase supply is connected. The power transfer to the rotor is by 'induction' and that is why these motors are called induction motors. Three phase induction motors possess many advantages such as simple design, low cost, rugged construction and reliable operation. They have good speed regulation and high starting torque.

8.2 Construction

The main parts of a three phase induction motor are (i) Stator and (ii) Rotor. The stator is the stationary part and the rotor is the rotating part. The rotor is separated from the stator by a small air gap whose thickness(length) depends on the power rating of the motor. There are two types of three phase induction motors based on the construction of rotor

1. Squirrel cage induction motor

2. Slip ring induction motor

Therefore, rotor current frequency,

$$f_r = sf \tag{8.6}$$

where f is the supply frequency in Hertz and s is the slip

Rotor current frequency = Slip × Supply frequency to stator

8.3.3 Applications of three phase induction motors

Squirrel cage induction motors are used in centrifugal pumps, fans, conveyors, compressors, reciprocating pumps, line shafting, lathe works, line shafting, etc.
Slip ring induction motors are used in lifts, hoists, cranes, conveyors, pumps, flour mills, etc.

Advantages of induction motors

1. Simple design.
2. Low cost compared to other motors of the same capacity.
3. High overload capacity.
4. Very rugged construction.
5. Requires little maintenance.
6. Have reasonable good efficiency and provides reliable operation.
7. Has good speed regulation and high starting torque.
8. Uses readily available power supply (three phase AC).

Disadvantages of induction motors

1. Wide variation in speed is not possible.
2. Its speed decreases with increase in load.

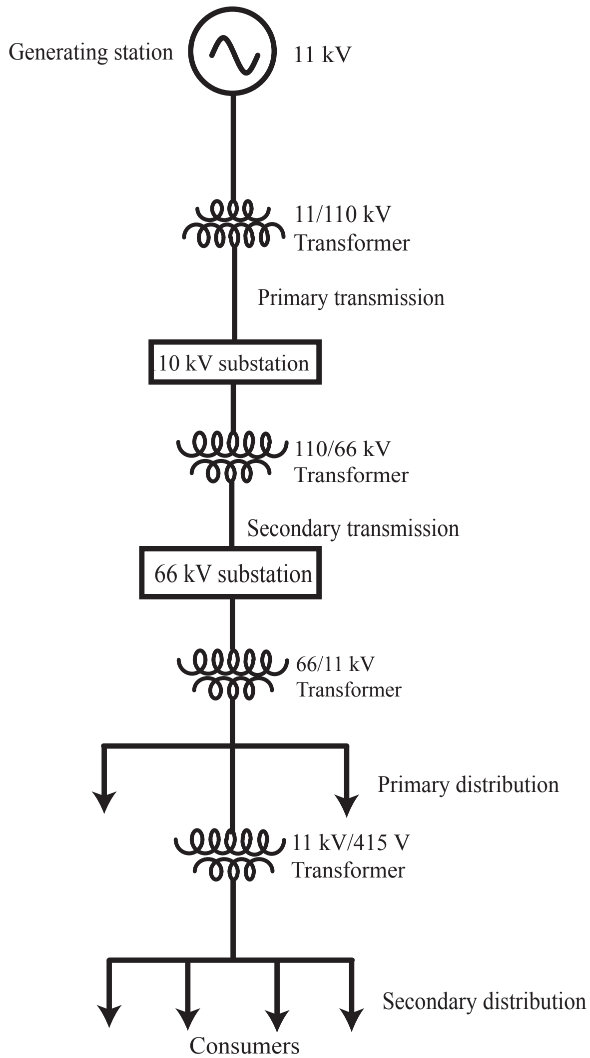


Figure 10.1: Typical power transmission system

Secondary distribution system
The three phase four wire network, that supply power to low tension consumer points from secondary distribution network. The specified

Chapter 11

Electrical estimation

Electrical estimation for a small residential building is discussed in this section.

11.1 Electrical installations-estimating and costing of material

Electrical installation means electric wiring and fittings installed in a particular place. i.e., a residential building, a factory, a commercial complex etc. All installations should be in accordance with Indian Electricity Rules 1956.

11.1.1 Steps for estimation

- **Installation plan**

  Drawing installation plan on suitable scale and mark locations of electrical points. Switch boards, main switch, energy meter etc. are marked using specified symbols in discussion with the client and architect.

- **Load calculation and selection of switch gears**

  Calculation of total connected load. Choosing proper rating of energy meter, main switch and fuse/MCB (Main circuit Breaker).

Basics of Electronics
and
Communication Engineering

Chapter 12

Amplifiers and Oscillators

12.1 Principle of electronic amplifiers

Amplification means making things bigger. In the context of electronics, it is the process of increasing the amplitude of signals. The functional block that accomplishes the task of signal amplification is called amplifier. Here, the term amplifier usually describes an electronic amplifier, in which the input signal is usually a voltage or a current.

There are both passive and active amplifiers. Example for passive amplifier is a step-up transformer. If an alternating voltage signal is applied at the input, a larger voltage signal will be available at the output. The power delivered to a load will be always less than the power absorbed at the input. Thus a transformer may provide voltage amplification but it cannot provide power amplification. Even though several passive amplifiers exist there, the most important and useful electronic amplifiers are active amplifiers.

A widely used symbol for an amplifier is shown in figure 12.1. Here V_i is the input voltage, V_o is the output voltage and A_v represents voltage gain which is the ratio of the output voltage to input voltage.

The active amplifiers take power from an external energy source and use it to boost the input signal. Thus it delivers an output signal whose waveform corresponds to the input signal but its power level is higher.

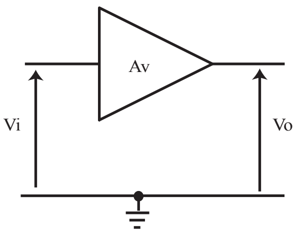


Figure 12.1: Symbol of amplifier

The additional power content in the output signal is supplied by the DC (Direct Current) power source used to bias the active device. A block schematic for an active amplifier is given in figure 12.2.

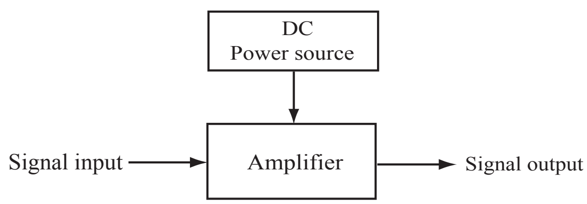


Figure 12.2: A schematic of active amplifier.

The output waveform of an amplifier must be an exact replica of the input waveform. It preserves the details of the signal waveform and any deviation of the output waveform from the shape of the input waveform is considered as distortion.

12.2 Characteristics of an amplifier

Following are the important desirable characteristics of an amplifier.

1. Gain $A = \dfrac{V_\circ}{V_i}$ should be large.

2. Input resistance R_i should be large.

3. Output resistance $R_\circ$ should be small.

12.11 Feedback systems

A feedback system is one in which a part or fraction of the output is combined with the input. Feedback systems use the output information to modify the input signal to achieve the desired result.

Feedback systems are of two types (a). Negative feedback systems (b). Positive feedback systems.

In the *negative feedback systems*, feedback tends to reduce the input. This kind of feedback is called degenerative feedback. Negative feedback reduces the amplifier gain but it has many advantages such as gain stability, reduction in distortion and noise, increase in bandwidth, increase in input impedance and decrease in output impedance etc.

In the *positive feedback systems*, the feedback tends to increase the input. This form of feedback is called regenerative feedback. Since positive feedback causes excessive distortion and instability, it is seldom used in amplifiers. However, it increases the strength of the original signal and hence it is employed in oscillator circuits.

A feedback amplifier essentially consists of two parts, an amplifier and a feedback network as shown in Figure 12.21. The function of feedback network is to return a fraction of the output energy (voltage or current) to the input of the amplifier.

12.12 Feedback in amplifiers

For an amplifier without feedback, the gain equals the ratio of output to input of the amplifier. i.e., Gain $A = V_o/V_i$

A is called the open-loop gain. i.e., the gain of the amplifier without feedback.

A block diagram illustrating the principle of feedback in an amplifier is shown in Figure 12.21. Here x_s represents the signal which may be voltage or current applied to the whole system. The output of the amplifier $x_\circ$ is applied to a feedback network which has a gain β. Thus the feedback network produces a signal $x_f = \beta x_\circ$ which is subtracted from the input source signal, x_s. The resulting signal, x_i, also called the error signal, is the input to the amplifier which in turn produces the output signal $V_\circ = A \times x_i$.

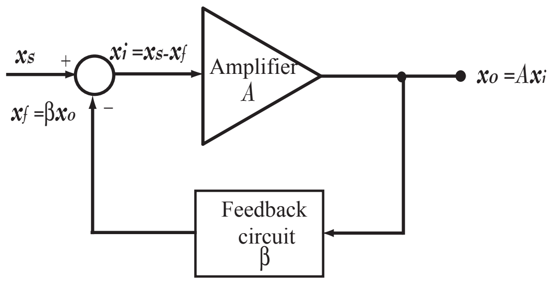


Figure 12.21: Block diagram illustrating the principle of feedback

Thus the actual input to the amplifier becomes

$x_i = x_s - x_f = x_s - \beta x_\circ$ in case of negative feedback and

$x_i = x_s + x_f = x_s + \beta x_\circ$ in case of positive feedback.

Consider a negative feedback case. The actual input to the amplifier,

$$x_i = x_s - \beta x_\circ \tag{12.12}$$

We have amplifier gain,

$$A = \frac{x_\circ}{x_i} \tag{12.13}$$

$$Ax_i = x_o \tag{12.14}$$

Substituting equation 12.12 in equation 12.14, we get,

$$A(x_s - \beta x_o) = x_o \tag{12.15}$$

Rearranging,

$$(1 + A\beta)x_o = Ax_s \tag{12.16}$$

Or

$$\frac{x_\circ}{x_s} = \frac{A}{1 + A\beta} \tag{12.17}$$

$x_\circ/x_s$ is the gain of the amplifier with feedback which is usually given the symbol G. Therefore the gain with negative feedback is expressed as,

12.13 Oscillators

An oscillator can be described as a source of alternating voltage. An amplifier delivers an amplified version of input signal while oscillator generates an output waveform without an input signal. The additional power content in the output signal is supplied by an external DC power source.

The oscillator requires no external signal to initiate or maintain the energy conversion process. Instead, an output signal is produced as long as a DC power source is connected. Figure 12.23, depicts the comparison between amplifier and oscillator.

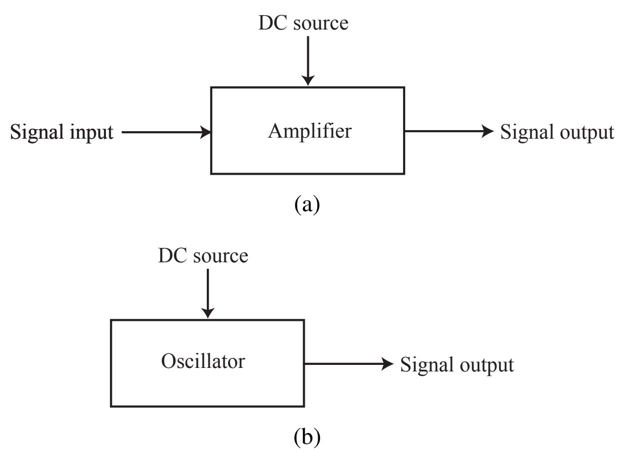


Figure 12.23: Comparison between amplifier and oscillator

12.14 Principle of oscillators

Oscillators are amplifiers with positive feedback. Consider a feedback amplifier with an input signal V_{in} and output $V_\circ$ as shown in Figure 12.24.

A is the open loop gain of the amplifier. Without feedback, output voltage of amplifier is $V_\circ = A \times V_{in}$. Since positive feedback is used, feedback voltage V_f is added with input signal V_{in}. Thus the input to the amplifier $V_e = V_{in} + V_f$.

Inputs		Output
A	B	$Q = \overline{A \oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1

Table 13.9: Truth table for EX-NOR gate

13.1.4 Universal gates

It is possible to implement any Boolean expression using only NAND gates. In a similar manner, it can be shown that NOR gates alone can be used to implement any Boolean operation. Therefore NAND and NOR gates are called universal gates.

Figure 13.12 illustrates that NOT, AND and OR gates can be implemented using NAND gates.

Figure 13.12 illustrates that NOT, OR and AND gates can also be implemented using NOR gates.

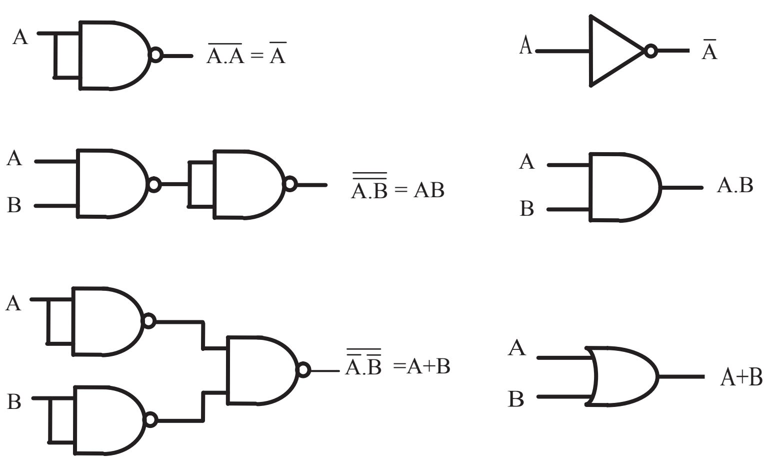


Figure 13.12: NAND as universal gate

13.7 Generating Boolean expression from logic circuit

If a logic circuit is given, we can generate Boolean expression directly from it. Consider the Figure 13.18. The Boolean expression for the logic circuit is

$$Q = AB + \overline{(A + B)}$$

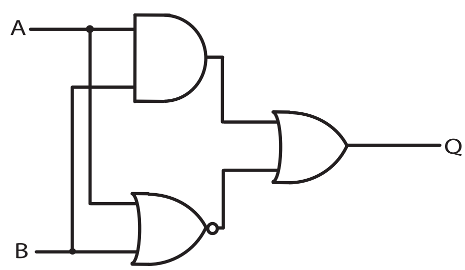


Figure 13.18:

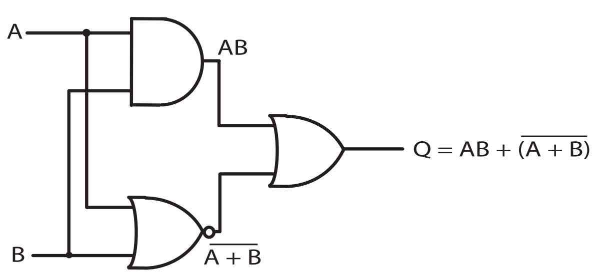


Figure 13.19: Obtaining Boolean expression

Example

Write the Boolean expression for the logic diagram given in Figure 13.20 and simplify it and draw the logic diagram to implement the simplified expression.

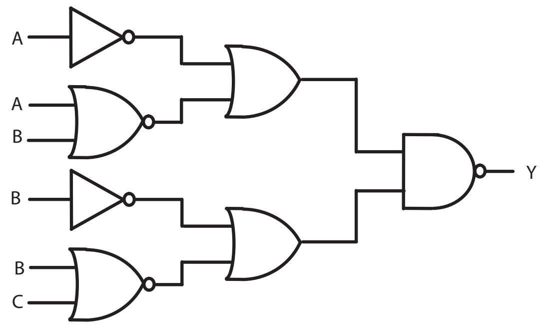


Figure 13.20:

Solution

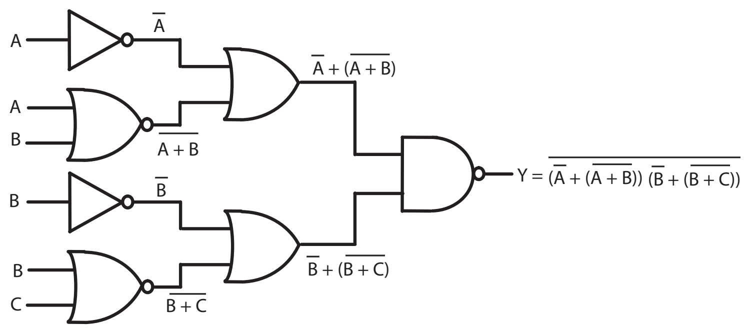


Figure 13.21:

From the circuit shown in Figure 13.21 we get the output expression

$Y = \overline{(\overline{A} + \overline{A + B})(\overline{B} + \overline{B + C})}$

Using De Morgan's law,

$$= \overline{(\overline{A} + \overline{A + B})} + \overline{(\overline{B} + \overline{B + C})}$$
$$= \overline{\overline{(A)}}.\overline{\overline{(A + B)}} + \overline{\overline{(B)}}.\overline{\overline{(B + C)}}$$
$$= A.(A + B) + B.(B + C)$$
$$= A.A + A.\ B + B.B + B.C$$

$$= A + AB + B + BC$$
$$= A(1 + B) + B(1 + C)$$
$$= A + B$$

The logic diagram to implement the simplified expression is shown in Figure 13.22.

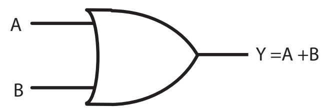


Figure 13.22: Simplified logic diagram for $\overline{(\overline{A} + \overline{A + B})(\overline{B} + \overline{B + C})}$

Exercise
Write the Boolean expression for the logic diagram given in Figure 13.23 and simplify it and draw the logic diagram to implement the simplified expression.

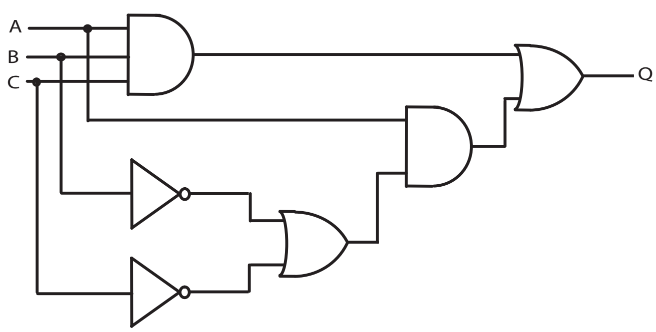


Figure 13.23: Circuit for exercise

13.8 Implementation of logic circuits using universal gates

As discussed in section 13.1.4 in page 244 NAND and NOR gates are called universal gates, because any logic circuits can be fabricated us-

3. The horizontal deflection system, including the time-base generator and synchronization circuitry.

4. Power supplies.

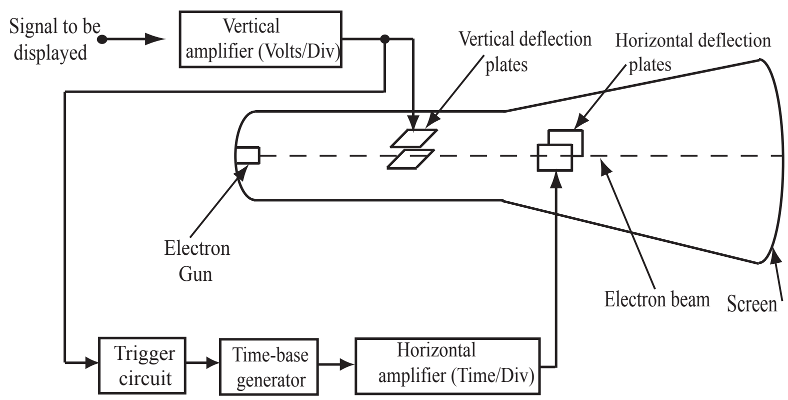
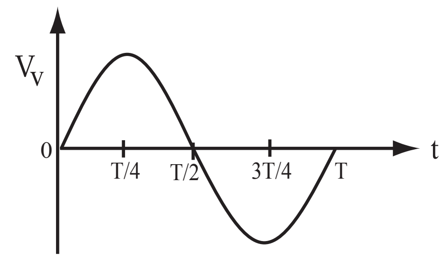


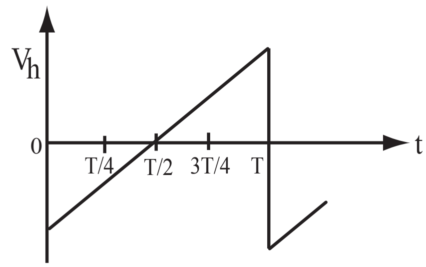
Figure 14.1: Block diagram for a CRO

The waveform to be displayed is fed to the vertical deflection system (Y-input) of the CRT. The horizontal deflection system provides the voltage for moving the beam horizontally. It has a sawtooth generator or a time-base generator and a synchronization circuit. The time base generator produces a sawtooth waveform (see figure 14.3(b)) for horizontal deflection of the electron beam. The purpose of the synchronization circuit is to start the horizontal sweep at a specific instant, with respect to the waveform under observation. It synchronizes two types of deflections so that horizontal deflection starts at the same point of the input vertical signal each time it sweeps. In addition to the internal sweep, there is a provision for external horizontal input (X-input). The operation of vertical section and horizontal section are independent of each other.

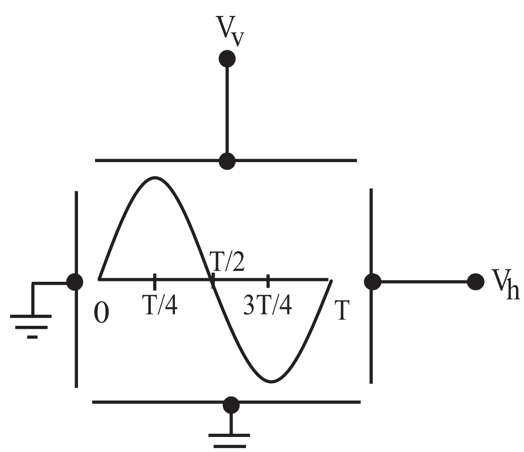
Cathode ray tube and its various components are discussed in the following section.



(a) Voltage signal applied to vertical deflection plate



(b) Voltage signal applied to horizontal deflection plate



(c) Waveform displayed on CRO

Figure 14.3: Voltages applied to deflection plates and displayed waveform

Quantity being Measured	Input Device (Sensor)	Output Device (Actuator)
Temperature	Resistive thermometers Thermocouple Thermistor p-n junction	Heater Fan
Light Level	LDR Photodiode Phototransistor Solar Cell (Photo voltaic)	Lights & Lamps LED's & Displays Fibre Optics
Force/Pressure	Strain Gauge Pressure Switch Piezoelectric Load Cells	Lifts & Jacks Electromagnetic Vibration
Position	Potentiometer Encoders Opto-switch LVDT Motor	Motor Solenoid Panel meters
Speed	Tacho-generator Opto-coupler Doppler Effect Sensors	AC and DC Motors Stepper Motor Brake
Sound	Microphone Piezo-electric Crystal	Loudspeaker Ultrasonic transducers Buzzer

Table 14.1: Common Transducers

14.3.1.1 Temperature sensors

The most commonly used temperature sensors are resistance thermometers, thermocouples, thermistors, and p-n junction. They can be used for the measurement of temperature.

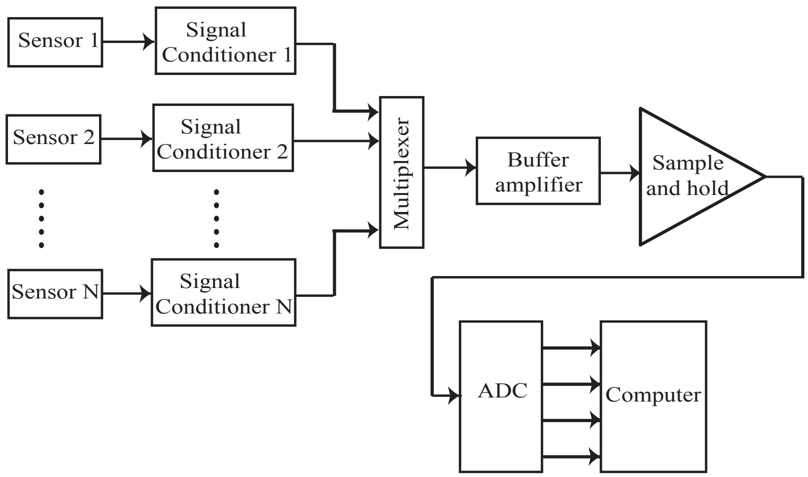


Figure 14.5: Block diagram for a data acquisition system

Data acquisition is the process of taking analog information from a number of sources and converting into digital form for further processing. It consists of several stages including sampling of the signal, analog to digital conversion, multiplexing, etc. The block diagram for data acquisition system is shown in Figure 14.5. The elements of a data acquisition system include sensors, signal conditioning units, multiplexer, buffer amplifier, sample and hold circuit, Analog to Digital Converter (ADC) and a computer.

Sensors convert the input signal into electrical signals. The sensors are connected via some signal conditioning units to a data acquisition system. Signal conditioners are used to increase the quality of the sensor output to a desired level before analog-to-digital conversion. Multiplexer is used to connect a number of analog signals, one at a time, to a common channel. The function of buffer amplifier is to provide a signal in a range close to but not exceeding the full input voltage range of the ADC. The sample and hold maintains a fixed input value during the short conversion time of the ADC. ADC produces digital output corresponding to the input.

Chapter 15

Radio communication

15.1 Introduction

The purpose of a communication system is to transmit information-bearing signals through a communication channel. Three basic blocks in any communication system are: 1) Transmitter 2) Channel and 3) Receiver.

The transmitter puts the information from the source onto the channel. The channel is the medium connecting the transmitter and the receiver and the transmitted information travels through this channel until it reaches the destination. The original message signals usually contain frequencies in the low frequency or audio frequency range. Therefore, some form of frequency-band shifting (converting to high frequency range) is necessary in order to make the signals suitable for transmission. This shifting in the range of frequencies is achieved by the process known as modulation.

The figure 15.1 depicts the elements of a communication system viz., transmitter, transmission channel and receiver. Each part plays a particular role in signal transmission, as explained below.

The transmitter processes the input signal to produce a suitable transmitted signal suited to the characteristics of the transmission channel.

Chapter 16

Radar and Navigation

16.1 Introduction

Radar is an acronym for Radio Detection and Ranging. It is an electronic system used to detect, locate or measure the velocity of targets. It collects information about distant objects or targets by sending electromagnetic waves to them and thereafter analyzing reflected waves or the echo signals from the objects. Radar can detect static or mobile objects in various conditions such as darkness, rain, fog and snow. The frequencies used by radar lies in the upper UHF and microwave range.

The basic principle of radar can be explained with the help of the block diagram as shown in figure 16.1. It consists of a transmitter and a receiver, each connected to a directional antenna. The transmitter generates high power modulated signal and transmits through the antenna. The duplexer allows the use of a single antenna for transmission and reception and also separates transmitter and receiver from each other. During transmission, the duplexer disconnects the receiver and connects the transmitter to the antenna.

The antenna radiates electromagnetic waves and these waves strike on a distant target which can reflect (echo) some of energy back to the same antenna. After transmission, the duplexer connects the antenna with the receiver and disconnects the transmitter. Then echo signals from the target are received by the receiver and processed to extract the required information. By noting the time taken for the signal to reach the target and echo signal to return back, the distance of the target can be calculated. The direction of the received echo signal gives an idea about the angular position of the target. It is also possible to detect the height, speed and direction of a moving target.

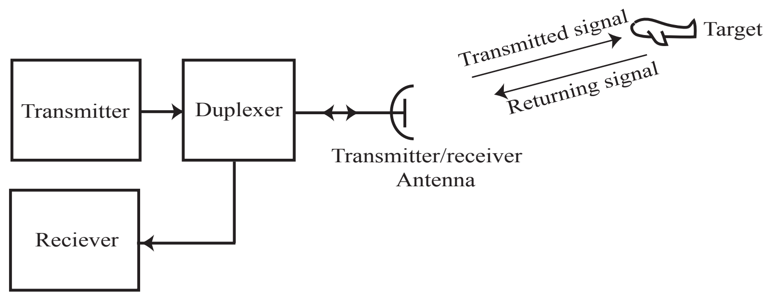


Figure 16.1: Basic block diagram for radar

The display systems of radar provide the range information such as azimuth, altitude and distance of the target. Commonly used displays are Plan position Indicator (PPI)and Amplitude Scope (A Scope).

16.2 Radar equation

Basic radar range equations is given below.

$$R = \frac{CT}{2} \tag{16.1}$$

where

R = Range.

C = Velocity of electromagnetic waves.

T = Time elapsed between transmission and reception of signal.

Consider the Figure 16.2

16.5 Navigational aids and systems

Navigation is the process of finding and controlling the movement of a vehicle from one place to another. The position of an aircraft or ship can be found by using radio navigational aids. This is achieved by the installation of radio transmitters and receivers at known locations on the earth's surface as well as at aircraft or ship which will work in conjunction with those on earth. Navigational aids include bouys, beacons, lightships, radio beacons, fog signals etc.

Navigational aids

- **Bouys** are floating objects anchored at bottom. Their shape and colour convey the message how to navigate around them.
- **Beacons** are structures permanently fixed to sea bed or land

Electronic navigation systems

- **Instrument Landing System (ILS)**
  Some applications related to remote sensing and military, aircrafts are controlled without pilots in it. ILS enables take off, flying and landing with the electronic systems on ground and air borne.
- **Ground Controlled Approach (GCA)**
  GCA is a system which assists the pilot to take off, fly and land the aircraft. This helps the pilot to land the aircraft even in hazardous atmospheric conditions such as fog, haze, snow, rain etc.
- **Radio Direction Finder (RDF)**
  RDF is used to find the direction of radio signal source. Direction of the electromagnetic signal is detected by the directional antenna. This over the horizon system helps the navigating ships.
- **Long Range Navigation (LORAN)**
  It is a terrestrial navigational system using low frequency radio transmitters that use the time interval between the radio signals

Chapter 17

Advanced communication Systems

17.1 Introduction

In the chapters 15 and 16, we had a brief review on radio communication and radar systems. In this chapter, advanced communication systems such as Microwave communication, Satellite Communication, Optical communication and Cellular communication systems are discussed.

17.2 Microwave communication

Microwaves are electromagnetic waves of very short wavelength (in the order of a few cm). Their frequencies lie in the range 1 GHz to 1000 GHz (1 GHz = 10^9 Hz). Their short wavelengths make microwaves ideal for use in radio and television broadcasting. Communication using microwaves whose wavelengths are very short is called microwave communication. Microwave communication is a category of radio communication which deals with radiation of electromagnetic waves from one point to another through free space. Useful frequency range for microwave communication lies between 300 MHz and 150

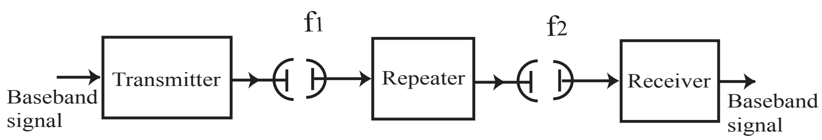


Figure 17.1: Basic block diagram for microwave communication system

GHz. Microwave communication system is line of sight (LOS) in nature limited by horizon due to earth's curvature.

Microwave communication system is classified into two broad categories namely analog and digital. Analog microwave communication systems are widely used. The analog system employs analog transmission techniques such as FM modulation and analog multiplexing technique.

17.2.1 Microwave frequency bands

Designation	Frequency range
UHF	300 MHz - 1 GHz
L Band	1-2 GHz
S Band	2-4 GHz
C Band	4-8 GHz
X Band	8-12 GHz
Ku Band	12-18 GHz
K Band	18-27 GHz
Ka Band	27-40 GHz

Table 17.1: Microwave frequency bands

17.2.2 Microwave communication system

A microwave system consists of a terminal transmitter, a number of repeater stations and a terminal receiver station (see Figure 17.1). The functions of each blocks are explained below.

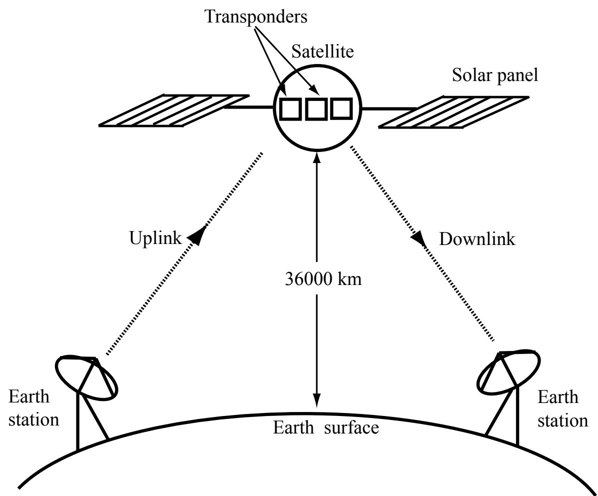


Figure 17.5: Satellite communication system

A transponder is a combination of receiver, amplifier and transmitter. Receiver in the transponder amplifies the uplink signal and converts it into another frequency downlink frequency. The block diagram for the transponder is shown in Figure 17.6.

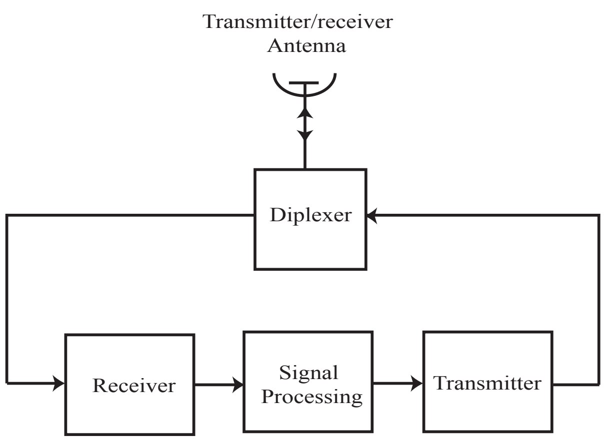


Figure 17.6: Block diagram for transponder

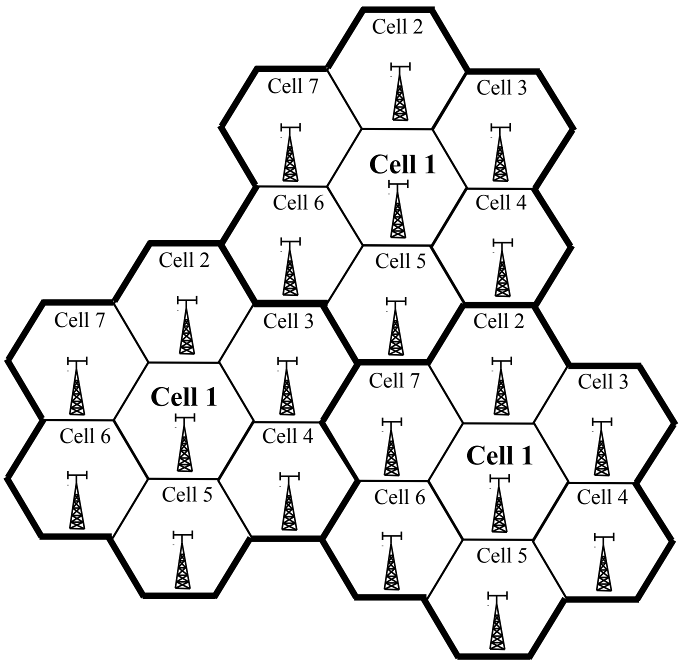


Figure 17.13: Illustration of frequency reuse concept. Cells with the same name use the same set of frequencies. A small cluster is outlined in bold and replicated over the coverage area. In this example, cluster size N = 7 and frequency reuse factor is 1/7 since each cell contains one-seventh of the total number of available channels.

Consider a cellular system which has a total of S duplex channels[1] available for use. If each cell is allocated a group of K channels ($K < S$) and if S channels are divided among N cells into unique and disjoint channel groups with each have the same number of channels, the total number of available radio channels can be expressed as $S = KN$. The N cells which collectively use the complete set of available frequencies is called a *cluster*.

The cells can be grouped in clusters of 7, 12 and 19 etc. to form a repetitive pattern. If a cluster is replicated M times within the system, the total number of duplex channels C, can be used as measure of

[1] Two way communication by using the same channel

A two channel CDMA system is shown in Figure 17.18. $m(t)$ and $c(t)$ represent message and PN sequence respectively.

Advantages of CDMA

1. Increased cellular communications security.
2. Simultaneous conversations possible.
3. Increased efficiency, meaning that the carrier can serve more subscribers.
4. Smaller phones.
5. Low power requirements and little cell-to-cell coordination needed by operators.
6. Extended reach-beneficial to rural users situated far from cells.

17.6.4 Comparison of GSM and CDMA

A comparison between CDMA and GSM is given in table 17.2.

CDMA	GSM
1. Based on spread spectrum technique.	1. Based on TDMA technique
2. Improved privacy and security.	2. Less secure.
3. Less probability of error and hence high voice quality.	3. High probability of error and hence less voice quality.
4. 1.25 MHz bandwidth per carrier	4. 200kHz bandwidth per carrier.
5. Available operating frequency 450, 800, 1900 MHz.	5. Available operating frequency 900, 1800, 1900 MHz
6. Using RUIM Card (Removable User Identity Module).	6. Using SIM Card (Subscriber Identity Module).
7. Soft/Softer hand-off (make before break)	7. Hard hand-off (break before make)

Table 17.2: Comparison between CDMA and GSM

17.7 General packet Radio Service (GPRS)

GPRS is a *packet based* communication services for wireless communication. GPRS is a step towards 3G and is often referred to 2.5G. In packet based communication data is split into packets, that are transmitted and then reassembled at the receiving end. This technique makes much more efficient use of the available channel capacity compared to circuit switching. In circuit switching, a circuit is switched permanently to a particular user. The idle time, during which there is no data transmission, in circuit switching systems is effectively utilized in packet switching.

17.7.1 Features of GPRS

Important features of GPRS are discussed below.

1. **Speed** One of the benefits of GPRS technology is that it offers a much higher data rate than with GSM.

2. **Packet switched operation** Unlike GSM which uses circuit switched techniques, GPRS technology uses packet switching in line with the Internet. This makes far more efficient use of the available capacity.

3. **Always on connectivity** It offers an 'Always On' capability. When using circuit switched techniques, charges are based on the time a circuit is used, i.e., how long the call is. For packet switched technology charges are for the amount of data carried.

4. **More applications** The packet switched technology combined with the higher data rates opens up many more possibilities for new applications.

17.7.2 GPRS services

GPRS services are defined to fall in one of two categories: Point to Point (PTP) and Point to Multipoint (PTM) services. In PTP services, packets are sent from a single source to a single destination. The PTM

COMBINED FIRST AND SECOND SEMESTER B.TECH (ENGINEERING) DEGREE EXAMINATION, MAY 2010

(2009 admissions)

EN 09.107 - BASICS OF ELECTRICAL, ELECTRONICS AND COMMUNICATION ENGINEERING

Time : Three hours Maximum:70 marks

Answer **all** questions in Part A, any **two** from Part B and **all** from part C

Section I (Basics of Electrical Engineering)

Part A

Answer **all** questions

1. A coil of 500 turns is linked by a flux of 0.4 mWb. If the flux is reversed in 0.01 second, find the e.m.f induced in the coil.

(2 marks)

2. What are the advantages and disadvantages of induction motors?

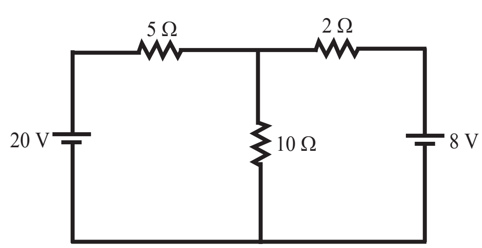
(2 marks)

3. A resistance of 12 Ω, an inductance f 0.15 H and a capacitor of 100 μF are connected in series across a 100 V, 50 Hz supply. Calculate the impedance. (1 mark)

Part B

Answer any **two** questions

4. Using kirchoff's law, find the current through 10 Ω resistor.



5. Derive EMF equation of dc generator.
6. Explain the principle of operation of synchronous generator.

(2 × 5 = 10 marks)

Part C

7. (a) i. State and explain Faraday's laws of electromagnetic induction. (5 marks)
   ii. Compare electric and magnetic circuits. (5 marks)

   or

   (b) i. Derive form factor and peak factor of a sine wave. (5 marks)
   ii. Three coils each of resistance 6 Ω and inductive reactance 8 Ω are joined in delta across 400 V, 3-phase lines. Calculate the line current and power absorbed. (2 marks)

8. (a) Explain the construction and principle of operation of single phase transformer.

   or

   (b) i. Explain the construction details of d.c generator.
   ii. Explain the principle of operation of induction motor.

(10 marks)

Section II
(Basics of Electronics and Communication Engineering)

Part A

Answer **all** questions

1. What are the advantages and disadvantages of negative feedback? (2 marks)

2. Write RADAR equation. (1 mark)
3. What is meant by frequency reuse technique ? (2 marks)

Part B

Answer any **two** questions

4. Explain briefly about various noises in amplifier.
5. Simplify the following Boolean Expression an implement using only NAND gates. (2 marks)

$$\mathrm{Y} = \overline{\mathrm{A}}\,\overline{\mathrm{B}}.\overline{\mathrm{C}} + \overline{\mathrm{A}}\,\mathrm{B}\,\overline{\mathrm{C}} + \mathrm{A}\,\mathrm{B}\,\overline{\mathrm{C}} + \mathrm{ABC}$$

6. Explain the principle of GSM. $(2 \times 5 = 10$ marks)

Part C

7. (a) i. Explain the concept of differential amplifier. (5 marks)
   ii. Compare TTL and CMOS logic (3 marks)
   iii. List the characteristics of Op-Amp. (2 marks)

or

   (b) Explain the working of CRO with neat block diagram. (10 marks)

8. (a) Draw the block diagram of superheterodyne receiver and explain. (10 marks)

or

   (b) i. Explain the basic principle of cellular communication. (5 marks)
   ii. Write short note on GPRS technology. (2 marks)

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