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TOTAL: 60 PERIODS

TEXT BOOKS:

1. V.N. Mittle "Basic Electrical Engineering",Tata McGraw Hill Edition, New Delhi, 1990.

2. R.S. Sedha, "Applied Electronics" S. Chand & Co., 2006.

REFERENCES:

1. Muthusubramanian R, Salivahanan S and Muraleedharan K A, "Basic Electrical, Electronics and Computer Engineering",Tata McGraw Hill, Second Edition, (2006).
2. Nagsarkar T K and Sukhija M S, "Basics of Electrical Engineering", Oxford press (2005).
3. Mehta V K, "Principles of Electronics", S.Chand & Company Ltd, (1994).
4. Mahmood Nahvi and Joseph A. Edminister, "Electric Circuits", Schaum' Outline Series, McGraw Hill, (2002).
5. Premkumar N, "Basic Electrical Engineering", Anuradha Publishers, (2003).

UNIT – I ELECTRIC CIRCUITS & MEASUREMENTS

Prerequisites

Solid, Liquid and gas particles called molecules. These molecules are made up of atoms which can be further spilt into electrons, protons and neutrons. The electrons revolve around the nucleus. The electrons presents in the outer most orbits experience a very weak force of attraction for the obvious reason that according to coulomb's law, the force between two charges varies inversely with the square of the distance. These electrons are known as free electrons. The movement of electrons are known as electric current

Introduction

1.1 <u>Basic Definitions</u>

Electric current:

The continuous flow of electrons constitutes electric current. It is denoted by 'I' and is measured in amperes.

'I' is also given by I = — coulomb / sec

Electric Potential:

The electric potential at any point in an electric field is defined as the work done in brining an unit positive charge (Q) from infinity to that point against the electric field

'V' is given by V = —

Resistance:

It is the property of a conductor by which it opposes the flow of current. It is denoted by R and its unit is ohms (Ω)

Laws of resistance:

The resistance of a conductor

(i). Varies directly with its length (l)

(ii). Varies inversely with its cross sectional area (A)

(iii). Depends on the nature of the material

(iv). Depends on the temperature

$R \propto L$

And $R \propto 1/A$

$R \propto L / A$

$R = \rho L / A$

Where ρ is called specific resistance

Specific resistance:

It is defined as the resistance offered by unit cube of the material between its opposite faces. It is denoted by ρ and its unit is ohm – meter

$\rho = RA / L$

Temperature effect on resistance:

In the case of pure metals the resistance increases with increases in temperature. In case of alloys the increase in resistance with increases in temperature is relatively small and irregular. The resistance of electrolytes and insulators decreases with increases in temperature

Temperature co-efficient of resistance

It is defined as the change in resistance per ohm per degree change in temperature from 0°C. If a material has resistance of R_0, R_1, and R_2 at temperature of 0°C, t_1°C and t_2°C respectively, then

$R_1 = R_0 (1 + \alpha_0 t_1)$
$R_2 = R_0 (1+ \alpha_0 t_2)$

— = ————

R2 = ———— R1

R2 = ——— R1

$R_2 = R_1 (1+\alpha_0(t_2-t_1))$

αt = ——

1.2. DC Circuits:

Prerequisites:

A DC circuit (Direct Current circuit) is an electrical circuit that consists of any combination of constant voltage sources, constant current sources, and resistors. In this case, the circuit voltages and currents are constant, i.e., independent of time. More technically, a DC circuit has no memory. That is, a particular circuit voltage or current does not depend on the past value of any circuit voltage or current. This implies that the system of equations that represent a DC circuit do not involve integrals or derivatives.

Introduction:

In electronics, it is common to refer to a circuit that is powered by a DC voltage source such as a battery or the output of a DC power supply as a DC circuit even though what is meant is that the circuit is DC powered.

If a capacitor and/or inductor is added to a DC circuit, the resulting circuit is not, strictly speaking, a DC circuit. However, most such circuits have a DC solution. This solution gives the circuit voltages and currents when the circuit is in DC steady state. More technically, such a circuit is represented by a system of differential equations. The solution to these equations usually contains a time varying or transient part as well as constant or steady state part. It is this steady state part that is the DC solution. There are some circuits that do not have a DC solution. Two simple examples are a constant current source connected to a capacitor and a constant voltage source connected to an inductor.

Electro-magnetic force(E.M.F):

Electromotive Force is, the voltage produced by an electric battery or generator in an electrical circuit or, more precisely, the energy supplied by a source of electric power in driving a unit charge around the circuit. The unit is the volt. A difference in charge between two points in a material can be created by an external energy source such as a battery. This causes electrons to move so that there is an excess of electrons at one point and a deficiency of electrons at a second point. This difference in charge is stored as electrical potential energy known as emf. It is the emf that causes a current to flow through a circuit.

Voltage:

Voltage is electric potential energy per unit charge, measured in joules per coulomb. It is often referred to as "electric potential", which then must be distinguished from electric potential energy by noting that the "potential" is a "per-unit-charge" quantity. Like mechanical potential energy, the zero of potential can be chosen at any point, so the difference in voltage is the quantity which is physically meaningful. The difference in voltage measured when moving from point A to point B is equal to the work which would have to be done, per unit charge, against the electric field to move the charge from A to B.

Potential Difference:

A quantity related to the amount of energy needed to move an object from one place to another against various types of forces. The term is most often used as an abbreviation of "electrical potential difference", but it also occurs in many other branches of physics. Only changes in potential or potential energy (not the absolute values) can be measured.

Electrical potential difference is the voltage between two points, or the voltage drop transversely over an impedance (from one extremity to another). It is related to the energy needed to move a unit of electrical charge from one point to the other against the electrostatic field that is present. The unit of electrical potential difference is the volt (joule per coulomb). Gravitational potential difference between two points on Earth is related to the energy needed to move a unit mass from one point to the other against the Earth's gravitational field. The unit of gravitational potential differences is joules per kilogram.

Electromagnetism:

When current passes through a conductor, magnetic field will be generated around the conductor and the conductor become a magnet. This phenomenon is called electromagnetism. Since the magnet is produced electric current, it is called the electromagnet. An electromagnet is a type of magnet in which the magnetic field is produced by a flow of electric current. The magnetic field disappears when the current ceases. In short, when current flow through a conductor, magnetic field will be generated. When the current ceases, the magnetic field disappear.

Applications of Electromagnetism:

Electromagnetism has numerous applications in today's world of science and physics. The very basic application of electromagnetism is in the use of motors. The motor has a switch that continuously switches the polarity of the outside of motor. An electromagnet does the same thing. We can change the direction by simply reversing the current. The inside of the motor has an electromagnet, but the current is controlled in such a way that the outside magnet repels it.

Another very useful application of electromagnetism is the "CAT scan machine." This machine is usually used in hospitals to diagnose a disease. As we know that current is present in our body and the stronger the current, the strong is the magnetic field. This scanning technology is able to pick up the magnetic fields, and it can be easily identified where there is a great amount of electrical activity inside the body

The work of the human brain is based on electromagnetism. Electrical impulses cause the operations inside the brain and it has some magnetic field. When two magnetic fields cross each other inside the brain, interference occurs which is not healthy for the brain.

Ohm's Law:

Ohm's law states that the current through a conductor between two points is directly proportional to the potential difference or voltage across the two points, and inversely proportional to the resistance between them. The mathematical equation that describes this relationship is:

$$I = \frac{V}{R}$$

where I is the current through the resistance in units of amperes,
V is the potential difference measured across the resistance in units of volts,
and R is the resistance of the conductor in units of ohms.

More specifically, Ohm's law states that the R in this relation is constant, independent of the current.

AC Circuits:

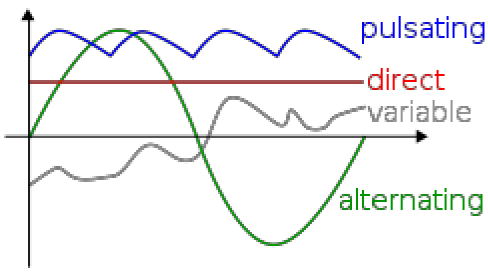
Prerequisites:

An alternating current (AC) is an electrical current, where the magnitude of the current varies in a cyclical form, as opposed to direct current, where the polarity of the current stays constant.

The usual waveform of an AC circuit is generally that of a sine wave, as this results in the most efficient transmission of energy. However in certain applications different waveforms are used, such as triangular or square waves

Introduction:

Used generically, AC refers to the form in which electricity is delivered to businesses and residences. However, audio and radio signals carried on electrical wire are also examples of alternating current. In these applications, an important goal is often the recovery of information encoded (or modulated) onto the AC signal.



Kirchhoff's law:

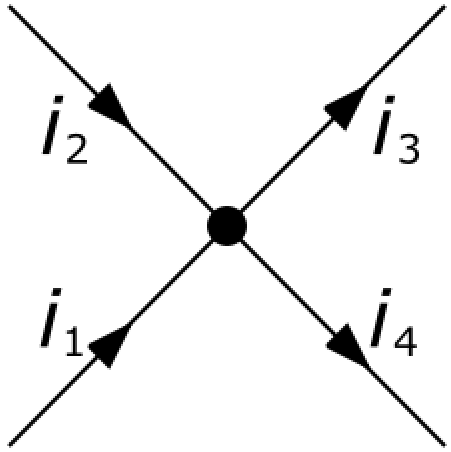
Kirchhoff's Current Law:

First law (Current law or Point law):

Statement:

The sum of the currents flowing towards any junction in an electric circuit equal to the sum of currents flowing away from the junction.

Kirchhoff's Current law can be stated in words as the sum of all currents flowing into a node is zero. Or conversely, the sum of all currents leaving a node must be zero. As the image below demonstrates, the sum of currents I_b, I_c, and I_d, must equal the total current in I_a. Current flows through wires much like water flows through pipes. If you have a definite amount of water entering a closed pipe system, the amount of water that enters the system must equal the amount of water that exists the system. The number of branching pipes does not change the net volume of water (or current in our case) in the system.



$$i_1 + i_2 = i_3 + i_4$$

Kirchhoff's Voltage Law:

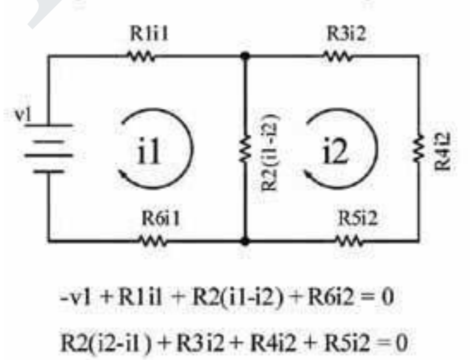
Second law (voltage law or Mesh law):

Statement:

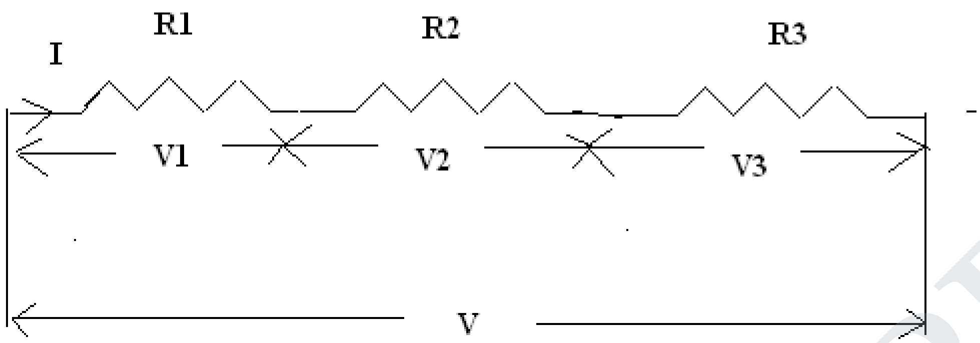
In any closed circuit or mesh, the algebraic sum of all the electromotive forces and the voltage drops is equal to zero.

Kirchhoff's voltage law can be stated in words as the sum of all voltage drops and rises in a closed loop equals zero. As the image below demonstrates, loop 1 and loop 2 are both closed loops within the circuit. The sum of all voltage drops and rises around loop 1 equals zero, and the sum of all voltage drops and rises in loop 2 must also equal zero. A closed loop can be defined as any path in which the originating point in the loop is also the ending point for the loop. No matter how the loop is defined or drawn, the sum of the voltages in the loop must be zero

Figure 2. Kirchoff's Voltage Law



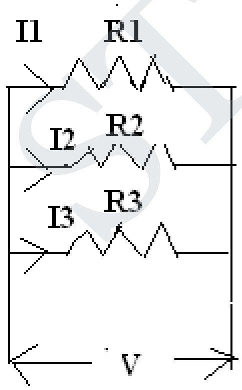
Steady State Solution of DC Circuits:
Resistance in series connection:



The resistors R_1, R_2, R_3 are connected in series across the supply voltage "V". The total current flowing through the circuit is denoted as "I". The voltage across the resistor R_1, R_2 and R_3 is V_1, V_2, and V_3 respectively.

$V_1 = I*R_1$ (as per ohms law)
$V_2= I*R_2$
$V_3 = I*R_3$
$V = V_1+V_2+V_3$
$= IR_1+IR_2+IR_3$
$= (R_1+R_2+R_3)\ I$
$IR = (R_1+R_2+R_3)\ I$
$\mathbf{R = R_1+R_2+R_3}$

Resistance in parallel connection:



The resistors R_1, R_2, R_3 are connected in parallel across the supply voltage "V". The total current flowing through the circuit is denoted as "I". The current flowing through the resistor R_1, R_2 and R_3 is I_1, I_2, and I_3 respectively.

$I = V / R$ (as per ohms law)

$I_1 = V_1 / R_1$

$I_2 = V_2 / R_2$

$I_3 = V_3 / R_3$

$V_1 = V_2 = V_3 = V$

From the above diagram

$I = I_1 + I_2 + I_3$

$= V_1 / R_1 + V_2 / R_2 + V_3 / R_3$

$= V / R_1 + V/R_2 + V/R_3$

$I = V (1/R_1 + 1/R_2 + 1/R_3)$

$V / R = V (1/R_1 + 1/R_2 + 1/R_3)$

$$\mathbf{1/R = 1/R_1 + 1/R_2 + 1/R_3}$$

Problems based on ohm's law

Problem 1:

A current of 0.5 A is flowing through the resistance of 10Ω.Find the potential difference between its ends.

Given data:

Current I= 0.5A.

Resistance R=1Ω

To find

Potential difference V = ?

Formula used:

$V = IR$

Solution:

$V = 0.5 \times 10 = 5V$.

Result :

The potential difference between its ends = 5 V

Problem :2

A supply voltage of 220V is applied to a 100 Ω resistor. Find the current flowing through it.

Given data

Voltage V = 220V

Resistance R = 100Ω

To find:

Current I = ?

~~Formula used:~~

Current I = V / R

~~Solution:~~

Current I = 220/100

= 2.2 A

Result:

The current flowing through the resistor = 2.2 A

Problem : 3

Calculate the resistance of the conductor if a current of 2A flows through it when the potential difference across its ends is 6V.

Given data

Current I = 2A

Voltage V = 6V

To find:

Resistance R = ?

Formula used:

Resistance R = V / I

Solution:

Resistance R = 6 / 2

= 3 Ω

Result:

The value of resistance R = 3Ω

Problem: 4

Calculate the current and resistance of a 100 W, 200V electric bulb.

Given data:

Power P = 100W

Voltage V = 200V

To find:

Current I =?

Resistance R =?

Formula used:

Power P = V *I

Current I = P / V

Resistance R = V / I

Solution:

Current I = P / V
= 100 / 200
= 0.5 A

Resistance R = V / I
= 200 / 0.2
= 400 Ω

Result:

The value of the current I = 0.5 A
The value of the Resistance R = 400 Ω

Problem: 5

A circuit is made of 0.4 Ω wire, a 150Ω bulb and a 120Ω rheostat connected in series. Determine the total resistance of the circuit.

Given data:

Resistance of the wire = 0.4Ω
Resistance of bulb = 1 5 0 Ω
Resistance of rheostat = 120Ω

To find:

The total resistance of the circuit R_T =?

Formula used:

The total resistance of the circuit $R_T = R_1+R_2+R_3$

Solution:

Total resistance ,R = 0.4 + 150 +120

= 270.4Ω

Result:

The total resistance of the circuit R_T = 270.4 Ω

Problem 6:

Three resistances of values 2Ω, 3Ω and 5Ω are connected in series across 20 V, D.C supply .Calculate (a) equivalent resistance of the circuit (b) the total current of the circuit (c) the voltage drop across each resistor and (d) the power dissipated in each resistor.

Given data:

$R_1 = 2\Omega$
$R_2 = 3\Omega$
$R_3 = 5\Omega$
V = 20V

To find:

R_T =?
I_T =?
V_1, V_2, V_3 =?
P_1, P_2, P_3 =?

Formula used:

$R_T = R_1+R_2+R_3$ (series connection)
$I_T = V_T / R_T$
$V_1 = R_1*I_1$
$V_2= R_2*I_2$
$V_3 = R_3*I_3$
$P_1=V_1*I_1$
$P_2=V_2*I_2$
$P_3=V_3*I_3$

Solution:

$R_T = R_1+R_2+R_3$
$= 2+3+5$
$\mathbf{R_T = 10\Omega}$

$I_T = V_T / R_T$
$= 20 / 10$
$\mathbf{I_T = 2\ A}$

In series connection $I_1 = I_2 = I_3 = I_T = 2A$

$V_1 = I_1*R_1$
$= 2*2$
$\mathbf{V_1 = 4\ V}$

$V_2 = I_2*R_2$
$= 2*3$
$\mathbf{V_2 = 6\ V}$

$V_3 = I_3*R_3$
$= 5*2$
$\mathbf{V_3 = 10V}$

$P_1 = V_1*I_1$
$= 4*2$
$\mathbf{P_1 = 8W}$

$P_2 = V_2*I_2$
$= 6*2$

P_2 = 12W
$P_3 = V_3 * I_3$
$= 10*2$
P_3 = 20W

Result:
(a). Equivalent resistance of the circuit $R_T = 10\Omega$
(b). The total current of the circuit $I_T = 2A$
(c). Voltage drop across each resistor $V_1 = 4$ V, $V_2 = 6$ V, $V_3 = 10V$
(d). The power dissipated in each resistor $P_1 = 8W$, $P_2 = 12W$, $P_3 = 20W$

AC Instantaneous and RMS:

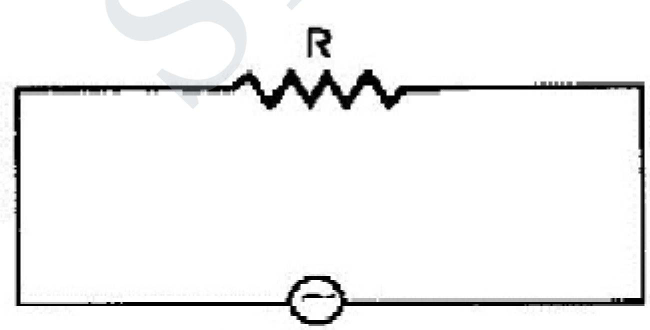
Instantaneous Value:

The Instantaneous value of an alternating voltage or current is the value of voltage or current at one particular instant. The value may be zero if the particular instant is the time in the cycle at which the polarity of the voltage is changing. It may also be the same as the peak value, if the selected instant is the time in the cycle at which the voltage or current stops increasing and starts decreasing. There are actually an infinite number of instantaneous values between zero and the peak value.

RMS Value:

The average value of an AC waveform is NOT the same value as that for a DC waveforms average value. This is because the AC waveform is constantly changing with time and the heating effect given by the formula ($P = I^2.R$), will also be changing producing a positive power consumption. The equivalent average value for an alternating current system that provides the same power to the load as a DC equivalent circuit is called the "effective value". This effective power in an alternating current system is therefore equal to: (I^2.R. Average).
As power is proportional to current squared, the effective current, I will be equal to $\sqrt{I^2 \text{ Ave}}$. Therefore, the effective current in an AC system is called the Root Mean Squared or R.M.S.

Pure Resistive circuit:

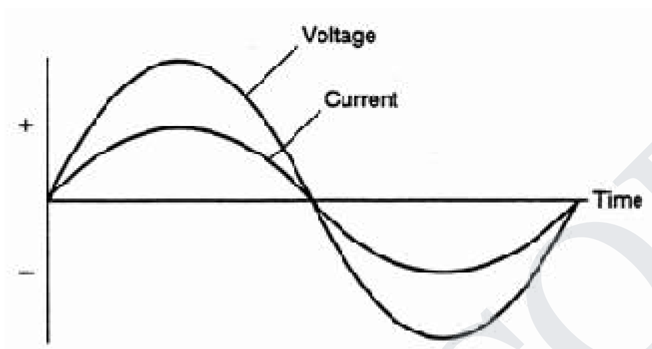


$E = E_0 \sin \omega t$

Resistors are “passive” devices that are they do not produce or consume any electrical energy, but convert electrical energy into heat. In DC circuits the linear ratio of voltage to current in a resistor is called its resistance. However, in AC circuits this ratio of voltage to current depends upon the frequency and phase difference or phase angle (φ) of the supply. So when using resistors in AC circuits the term **Impedance**, symbol **Z** is the generally used and we can say that DC resistance = AC impedance, R = Z.

It is important to note, that when used in AC circuits, a resistor will always have the same resistive value no matter what the supply frequency from DC to very high frequencies, unlike capacitor and inductors.

For resistors in AC circuits the direction of the current flowing through them has no effect on the behaviour of the resistor so will rise and fall as the voltage rises and falls. The current and voltage reach maximum, fall through zero and reach minimum at exactly the same time. i.e, they rise and fall simultaneously and are said to be “in-phase” as shown below.



We can see that at any point along the horizontal axis that the instantaneous voltage and current are in-phase because the current and the voltage reach their maximum values at the same time, that is their phase angle θ is 0^o. Then these instantaneous values of voltage and current can be compared to give the ohmic value of the resistance simply by using ohms law. Consider below the circuit consisting of an AC source and a resistor.

The instantaneous voltage across the resistor, V_R is equal to the supply voltage, V_t and is given as:

$V_R = V_{max} \sin\omega t$

The instantaneous current flowing in the resistor will therefore be:

$I_R = V_R / R$

$= V_{max} \sin\omega t / R$

$= I_{max} \sin\omega t$

In purely resistive series AC circuits, all the voltage drops across the resistors can be added together to find the total circuit voltage as all the voltages are in-phase with each other. Likewise, in a purely resistive parallel AC circuit, all the individual branch currents can be added together to find the total circuit current because all the branch currents are in-phase with each other.

Since for resistors in AC circuits the phase angle φ between the voltage and the current is zero, then the power factor of the circuit is given as cos $0^o = 1.0$. The power in the circuit at any instant in time can be found by multiplying the voltage and current at that instant.

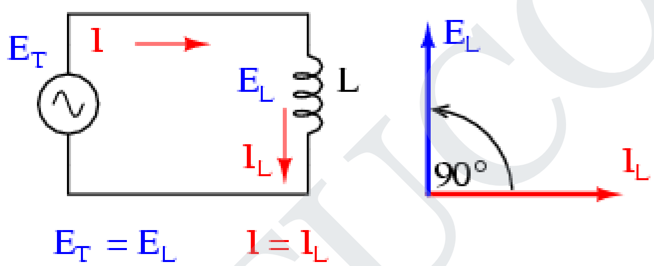
Then the power (P), consumed by the circuit is given as P = Vrms I cos Φ in watt's. But since cos Φ = 1 in a purely resistive circuit, the power consumed is simply given as, P = Vrms I the same as for Ohm's Law.

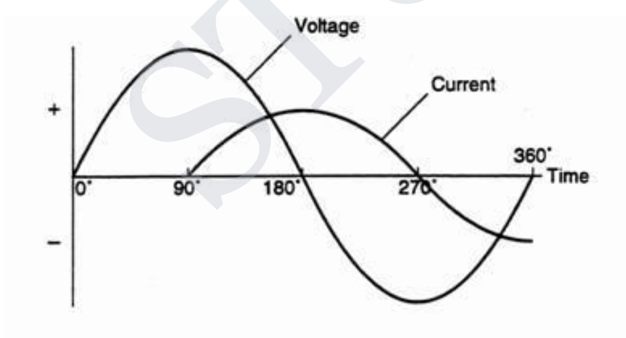
This then gives us the "Power" waveform and which is shown below as a series of positive pulses because when the voltage and current are both in their positive half of the cycle the resultant power is positive. When the voltage and current are both negative, the product of the two negative values gives a positive power pulse.

Then the power dissipated in a purely resistive load fed from an AC rms supply is the same as that for a resistor connected to a DC supply and is given as:

P = V rms * I rms
= I 2 rms * R
= V 2 rms / R

Pure Inductive circuits:





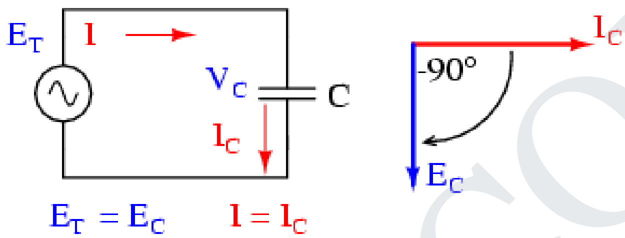
This simple circuit above consists of a pure inductance of L Henries (H), connected across a sinusoidal voltage given by the expression: V(t) = V_{max} sin ωt. When the switch is closed this sinusoidal voltage will cause a current to flow and rise from zero to its maximum value. This rise

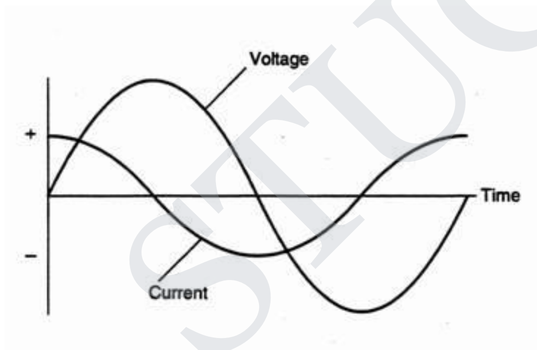
or change in the current will induce a magnetic field within the coil which in turn will oppose or restrict this change in the current.
But before the current has had time to reach its maximum value as it would in a DC circuit, the voltage changes polarity causing the current to change direction. This change in the other direction once again being delayed by the self-induced back emf in the coil, and in a circuit containing a pure inductance only, the current is delayed by 90^o.

The applied voltage reaches its maximum positive value a quarter ($1/4f$) of a cycle earlier than the current reaches its maximum positive value, in other words, a voltage applied to a purely inductive circuit “LEADS” the current by a quarter of a cycle or 90^o as shown below.

The instantaneous voltage across the resistor, V_R is equal to the supply voltage, V_t and is given as:
$V_L = V_{max} \sin(\omega t + 90)$
$I_L = V / X_L$
$X_L = 2\pi f L$

Pure Capacitive circuits:





When the switch is closed in the circuit above, a high current will start to flow into the capacitor as there is no charge on the plates at $t = 0$. The sinusoidal supply voltage, V is increasing in a positive direction at its maximum rate as it crosses the zero reference axis at an instant in time given as 0^o. Since the rate of change of the potential difference across the plates is now at its maximum value, the flow of current into the capacitor will also be at its maximum rate as the maximum amount of electrons are moving from one plate to the other.

As the sinusoidal supply voltage reaches its 90^o point on the waveform it begins to slow down and for a very brief instant in time the potential difference across the plates is neither increasing nor decreasing therefore the current decreases to zero as there is no rate of voltage change. At this 90^opoint the potential difference across the capacitor is at its maximum (V_{max}), no current flows into the capacitor as the capacitor is now fully charged and its plates saturated with electrons.

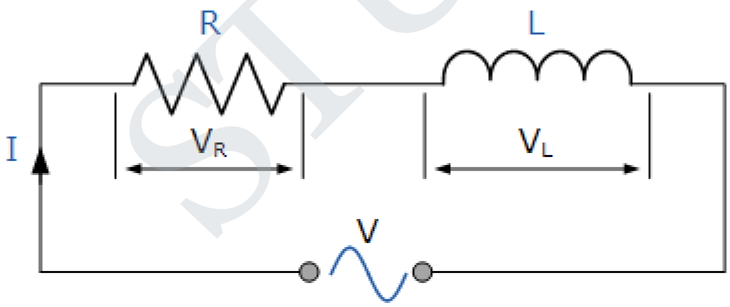
At the end of this instant in time the supply voltage begins to decrease in a negative direction down towards the zero reference line at 180^o. Although the supply voltage is still positive in nature the capacitor starts to discharge some of its excess electrons on its plates in an effort to maintain a constant voltage. These results in the capacitor current flowing in the opposite or negative direction.

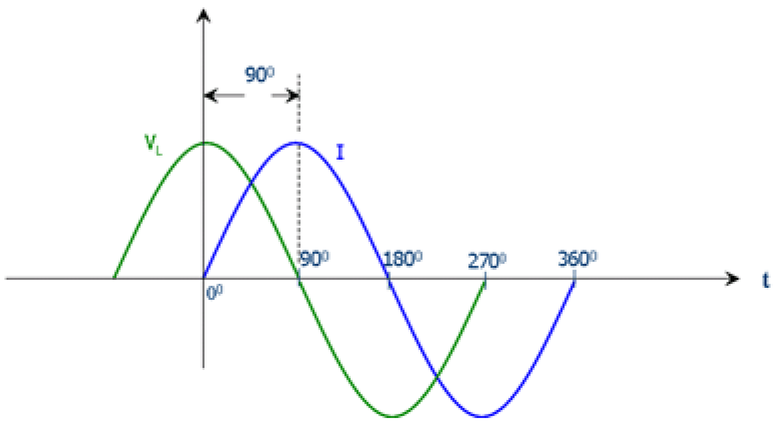
When the supply voltage waveform crosses the zero reference axis point at instant 180^o, the rate of change or slope of the sinusoidal supply voltage is at its maximum but in a negative direction, consequently the current flowing into the capacitor is also at its maximum rate at that instant. Also at this 180^o point the potential difference across the plates is zero as the amount of charge is equally distributed between the two plates.

Then during this first half cycle 0^o to 180^o, the applied voltage reaches its maximum positive value a quarter ($1/4f$) of a cycle after the current reaches its maximum positive value, in other words, a voltage applied to a purely capacitive circuit "LAGS" the current by a quarter of a cycle or 90^o as shown below.

$I_C = I_{max} \sin(\omega t + 90)$
$I_L = V / X_C$
$X_C = 1 / 2\pi fC$

RL Series circuit:





In other words, an Inductor in an electrical circuit opposes the flow of current, (i) through it. While this is perfectly correct, we made the assumption in the tutorial that it was an ideal inductor which had no resistance or capacitance associated with its coil windings.

However, in the real world "ALL" coils whether they are chokes, solenoids, relays or any wound component will always have a certain amount of resistance no matter how small associated with the coils turns of wire being used to make it as the copper wire will have a resistive value.

Then for real world purposes we can consider our simple coil as being an "Inductance", L in series with a "Resistance", R. In other words forming an **LR Series Circuit.**

A **LR Series Circuit** consists basically of an inductor of inductance L connected in series with a resistor of resistance R. The resistance R is the DC resistive value of the wire turns or loops that goes into making up the inductors coil

The above *LR series circuit* is connected across a constant voltage source, (the battery) and a switch. Assume that the switch, S is open until it is closed at a time t = 0, and then remains permanently closed producing a "step response" type voltage input. The current, i begins to flow through the circuit but does not rise rapidly to its maximum value of Imax as determined by the ratio of V / R(Ohms Law).

This limiting factor is due to the presence of the self induced emf within the inductor as a result of the growth of magnetic flux, (Lenz's Law). After a time the voltage source neutralizes the effect of the self induced emf, the current flow becomes constant and the induced current and field are reduced to zero.

We can use Kirchoffs Voltage Law, (KVL) to define the individual voltage drops that exist around the circuit and then hopefully use it to give us an expression for the flow of current.

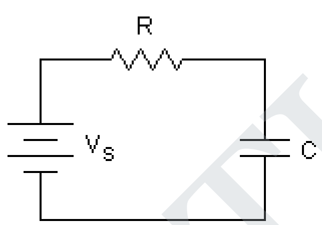
Vt = VR + VL
VR = I*R
VL = i dL / dt
V(t) = I*R + i dL / dt

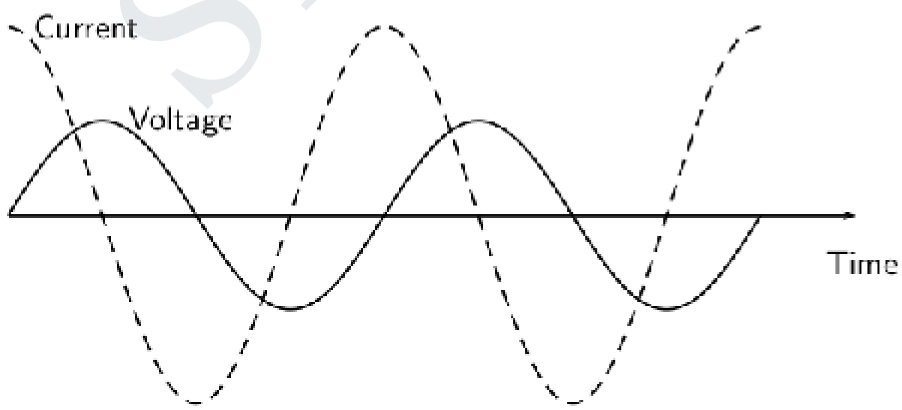
Since the voltage drop across the resistor, V_R is equal to IxR (Ohms Law), it will have the same exponential growth and shape as the current. However, the voltage drop across the inductor, V_L will have a value equal to: $Ve^{(-Rt/L)}$. Then the voltage across the inductor, V_L will have an initial value equal to the battery voltage at time t = 0 or when the switch is first closed and then decays exponentially to zero as represented in the above curves.

The time required for the current flowing in the LR series circuit to reach its maximum steady state value is equivalent to about **5 time constants** or 5τ. This time constant τ, is measured by τ = L/R, in seconds, were R is the value of the resistor in ohms and L is the value of the inductor in Henries. This then forms the basis of an RL charging circuit were 5τ can also be thought of as "5 x L/R" or the *transient time* of the circuit.
The transient time of any inductive circuit is determined by the relationship between the inductance and the resistance. For example, for a fixed value resistance the larger the inductance the slower will be the transient time and therefore a longer time constant for the LR series circuit. Likewise, for a fixed value inductance the smaller the resistance value the longer the transient time.

However, for a fixed value inductance, by increasing the resistance value the transient time and therefore the time constant of the circuit becomes shorter. This is because as the resistance increases the circuit becomes more and more resistive as the value of the inductance becomes negligible compared to the resistance. If the value of the resistance is increased sufficiently large compared to the inductance the transient time would effectively be reduced to almost zero.

RC Series circuit:





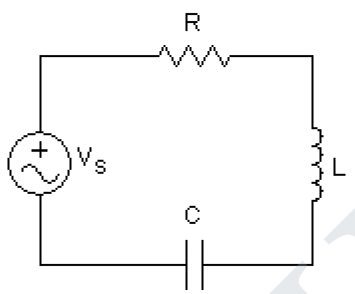
The fundamental passive linear circuit elements are the resistor (R), capacitor (C) and inductor (L). These circuit elements can be combined to form an electrical circuit in four distinct ways: the RC circuit, the RL circuit, the LC circuit and the RLC circuit with the abbreviations indicating which components are used. These circuits exhibit important types of behaviour that are fundamental to analogue electronics. In particular, they are able to act as passive filters. This article considers the RL circuit in both series and parallel as shown in the diagrams.

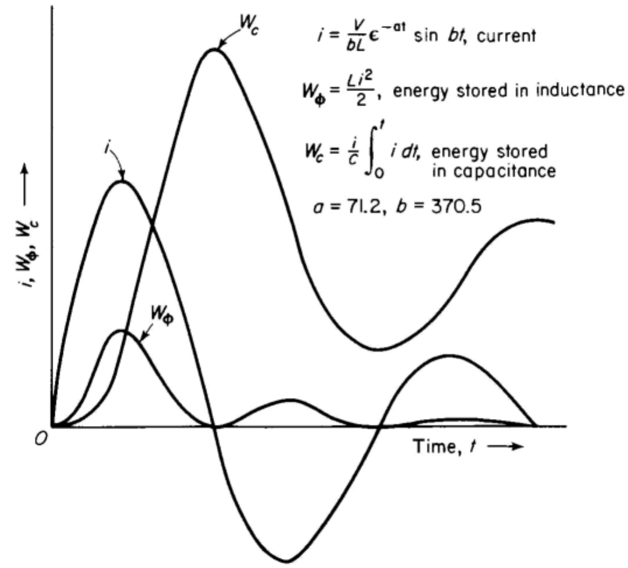
In practice, however, capacitors (and RC circuits) are usually preferred to inductors since they can be more easily manufactured and are generally physically smaller, particularly for higher values of components.

Both RC and RL circuits form a single-pole filter. Depending on whether the reactive element (C or L) is in series with the load, or parallel with the load will dictate whether the filter is low-pass or high-pass.

Frequently RL circuits are used for DC power supplies to RF amplifiers, where the inductor is used to pass DC bias current and block the RF getting back into the power supply.

RLC Series Circuit:





Difference between AC AND DC:

Current that flows continuously in one direction is called direct current. Alternating current (A.C) is the current that flows in one direction for a brief time then reverses and flows in opposite direction for a similar time. The source for alternating current is called AC generator or alternator.

Cycle:

One complete set of positive and negative values of an alternating quantity is called cycle.

Frequency:

The number of cycles made by an alternating quantity per second is called frequency. The unit of frequency is Hertz(Hz)

Amplitude or Peak value

The maximum positive or negative value of an alternating quantity is called amplitude or peak value.

Average value:

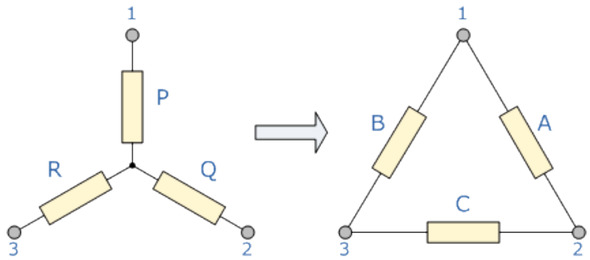
This is the average of instantaneous values of an alternating quantity over one complete cycle of the wave.

Time period:

The time taken to complete one complete cycle.

Star Delta transformation:

Star to Delta transformation:

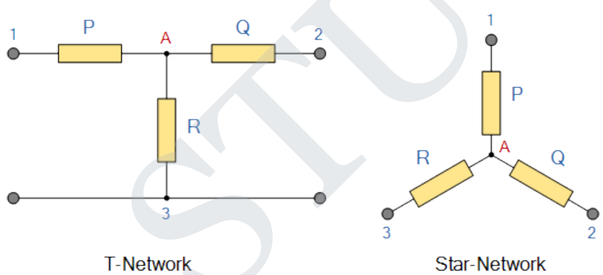


Star Delta Transformations allow us to convert impedances connected together from one type of connection to another. We can now solve simple series, parallel or bridge type resistive networks using Kirchhoff´s Circuit Laws, mesh current analysis or nodal voltage analysis techniques but in a balanced 3-phase circuit we can use different mathematical techniques to simplify the analysis of the circuit and thereby reduce the amount of math's involved which in itself is a good thing.

Standard 3-phase circuits or networks take on two major forms with names that represent the way in which the resistances are connected, a **Star** connected network which has the symbol of the letter, Y (wye) and a **Delta** connected network which has the symbol of a triangle, Δ (delta).

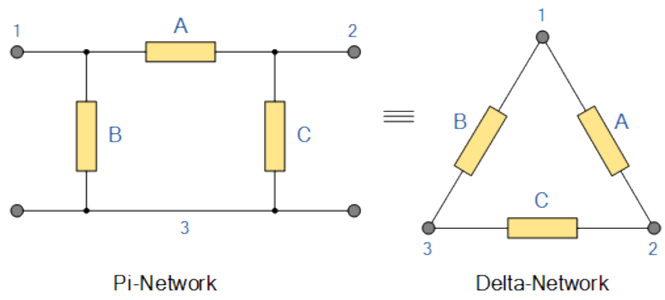
If a 3-phase, 3-wire supply or even a 3-phase load is connected in one type of configuration, it can be easily transformed or changed it into an equivalent configuration of the other type by using either the **Star Delta Transformation** or **Delta Star Transformation** process.

A resistive network consisting of three impedances can be connected together to form a T or "Tee" configuration but the network can also be redrawn to form a Star or Y type network as shown below.



As we have already seen, we can redraw the T resistor network to produce an equivalent Star or Y type network. But we can also convert a Pi or π type resistor network into an equivalent Delta or Δ type network as shown below.

Pi-connected and Equivalent Delta Network.



Having now defined exactly what is a Star and Delta connected network it is possible to transform the Y into an equivalent Δ circuit and also to convert a Δ into an equivalent Y circuit using a the transformation process. This process allows us to produce a mathematical relationship between the various resistors giving us a **Star Delta Transformation** as well as a **Delta Star Transformation**.

These Circuit Transformations allow us to change the three connected resistances (or impedances) by their equivalents measured between the terminals 1-2, 1-3 or 2-3 for either a star or delta connected circuit. However, the resulting networks are only equivalent for voltages and currents external to the star or delta networks, as internally the voltages and currents are different but each network will consume the same amount of power and have the same power factor to each other.

The value of the resistor on any one side of the delta, Δ network is the sum of all the two-product combinations of resistors in the star network divide by the star resistor located "directly opposite" the delta resistor being found.

For example, resistor A is given as:

A= (PQ + QR + RP) / R with respect to terminal 3

and resistor B is given as:

B = (PQ + QR + RP) / Q with respect to terminal 2 and

resistor C given as:

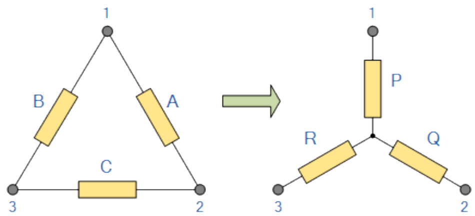
B = (PQ + QR + RP) / R with respect to terminal 1.

By dividing out each equation by the value of the denominator we end up with three separate transformation formulas that can be used to convert any Delta resistive network into an equivalent star network as given below.

Star Delta Transformation allows us to convert one type of circuit connection into another type in order for us to easily analyze the circuit and star delta transformation techniques can be used for either resistances or impedances.

One final point about converting a star resistive network to an equivalent delta network. If all the resistors in the star network are all equal in value then the resultant resistors in the equivalent delta network will be three times the value of the star resistors and equal, giving: $R_{DELTA} = 3R_{STAR}$

Delta to Star Transformation



Compare the resistances between terminals 1 and 2.
P+Q= A in parallel with (B+C)
P+Q = A(B+C) / A+B+C……………….(1)

Resistance between the terminals 2 and 3.
Q+R = C in parallel with (A+B)
Q+R=C(A+B) / A+B+C……………….(2)

Resistance between the terminals 1 and 3.
P+R = B in parallel with (A+C)
P+R = B(A+C) / A+B+C………………(3)

This now gives us three equations and taking equation 3 from equation 2 gives:
P+R-Q-R = (B(A+C)) –(C(A+B)) / A+B+C
P-Q =(BA + BC – CA – BC) / A+B+C
P-Q = BA – CA / (A+B+C)……………(4)

Then, re-writing Equation 1 will give us:
P+Q = (AB+AC) / A+B+C ……………………(5)

Equ (4) + Equ (5)
P+Q+ P-Q = (AB+AC) / A+B+C + (BA – CA) / A+B+C
2P = (AB+AC+BA-CA) / A+B+C
2P = 2AB / A+B+C
P = AB / A+B+C

Then to summarize a little about the above maths, we can now say that resistor P in a Star network can be found as Equation 1 plus (Equation 3 minus Equation 2) or Eq1 + (Eq3 – Eq2). Similarly, to find resistor Q in a star network, is equation 2 plus the result of equation 1 minus equation 3 or Eq2 + (Eq1 – Eq3) and this gives us the transformation of Q as:
Q = AC / A+B+C
and again, to find resistor R in a Star network, is equation 3 plus the result of equation 2 minus equation 1 or Eq3 + (Eq2 – Eq1) and this gives us the transformation of R as:
R = BC / A+B+C

When converting a delta network into a star network the denominators of all of the transformation formulas are the same: A + B + C, and which is the sum of ALL the delta resistances. Then to convert any delta connected network to an equivalent star network

If the three resistors in the delta network are all equal in value then the resultant resistors in the equivalent star network will be equal to one third the value of the delta resistors, giving each branch in the star network as: $R_{STAR} = 1/3R_{DELTA}$

Measuring Instruments:

Classification of instruments

(i). Depending on the quality measured
(ii). Depending on the different principles used for their working
(iii). Depending on how the quantity is measured

Depending on the quality measured

Voltmeter
Ammeter
Energy meter
Ohm meter

Depending on the different principles used for their working

Moving Iron type
Moving coil type
Dynamometer type
Induction type

Depending on how the quantity is measured

Deflecting type
Integrating type
Recording type

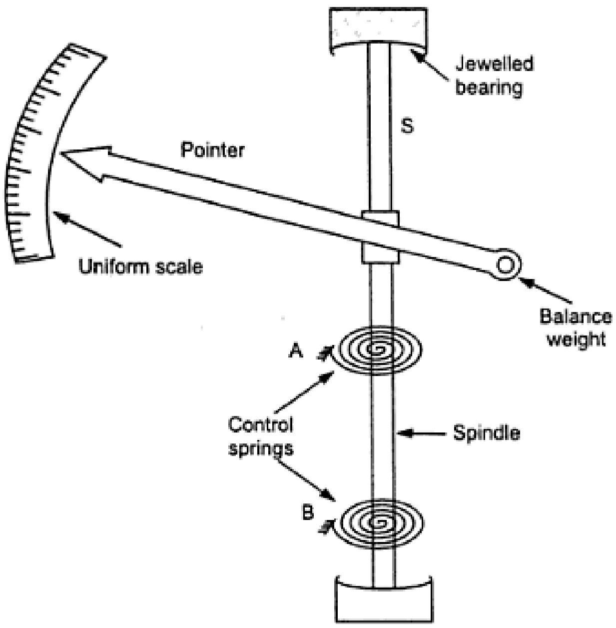
Deflecting Torque

The deflecting torque moves the moving system and the pointer from the zero position. The deflecting torque can be obtained through magnetic, thermal, electromagnetic or electro dynamic effects

Controlling torque

The controlling torque acts in a direction opposite to that of deflecting torque. When the controlling torque (TC) and the deflecting torque (TD) are numerically equal the pointer takes a definite position. In the absence of TC the pointer would deflect to maximum position irrespective of the quantity to be measured. Moreover TC also helps in bringing the moving system to zero position when the instrument is disconnected from the circuit. The controlling torque is obtained through spring control and gravity control

Spring Control:



The arrangement for spring control consists of two phosphor bronze spiral hair springs attached to a moving system. The springs are made of materials which (i). are not affected by fatigue. (ii). Have low temp-coefficient of resistance (iii). Have low specific resistance (iv). Are non-magnetic

As the pointer deflects the springs get twisted in the opposite direction. The combined twist produces the necessary controlling torque which is proportional to angle of deflection of moving system θ. If we consider a permanent magnet moving coil meter with spring control system the deflecting torque will be proportional to the current passing through it and the controlling torque will be proportional to the angle of deflection

Thus $T_D \alpha I$

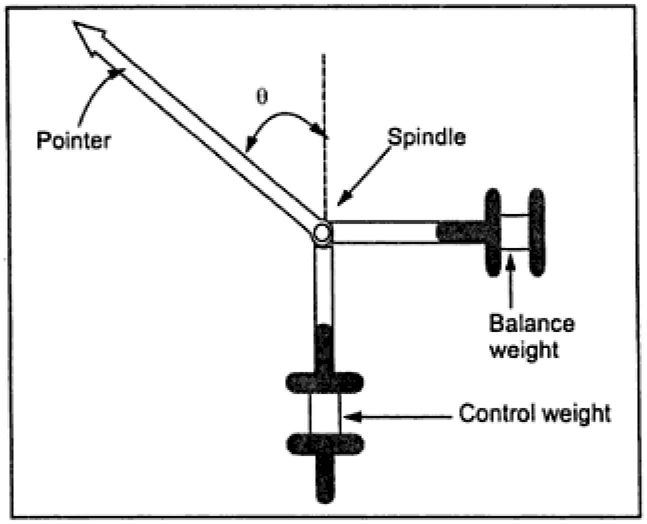
$T_C \alpha \theta$

Since $T_D = T_C$

We have $\theta \alpha I$

Thus the spring controlled instruments having uniform scale

Gravity control



In gravity controlled instruments, as shown in Fig. 12.2 (a) a small adjustable weight is attached to the spindle of the moving system such that the deflecting torque produced by the instrument has to act against the action of gravity. Thus a controlling torque is obtained. This weight is called the control weight. Another adjustable weight is also attached is the moving system for zero adjustment and balancing purpose. This weight is called Balance weight.
When the control weight is in vertical position as shown in Fig. 12.2 (a), the controlling torque is zero and hence the pointer must read zero. However, if the deflecting torque lifts the controlling weight from position A to B as shown in Fig.12.2 (b) such that the spindle rotates by an angle θ, then due to gravity a restoring (or controlling) torque is exterted on the moving system.

The controlling (or restoring) torque, Tc , is given by
$Tc = Wl \sin \theta = k\ g \sin \theta$
where W is the control weight;
l is the distance of the control weight from the axis of rotation of the moving system;
and k g is the gravity constant.
Equation shows the controlling torque can be varied quite simply by adjustment of the position of the control weight upon the arm which carries it. Again, if the deflecting torque is directly proportional to the current,
i.e., $Td = kI$
We have at the equilibrium position
$Td = Tc$
$kI = k\ g \sin \theta$
$I = g\ k\ \sin \theta / k$
This relation shows that current I is proportional to sin θ and not θ. Hence in gravity controlled instruments the scale is not uniform. It is cramped for the lower readings, instead of being uniformly divided, for the deflecting torque assumed to be directly proportional to the quantity being measured.

Advantanges of Gravity Control
1. It is cheap and not affected by temperature variations.
2. It does not deteriorate with time.

3. It is not subject to fatigue.

Disadvantages of Gravity Control

1. Since the controlling torque is proportional to the sine of the angle of deflection, the scale is not uniformly divided but cramped at its lower end.
2. It is not suitable for use in portable instruments (in which spring control is always preferred).
3. Gravity control instruments must be used in vertical position so that the control weight may operate and also must be leveled otherwise they will give zero error. In view of these reasons, gravity control is not used for indicating instruments in general and portable instruments in particular.

Damping Torque

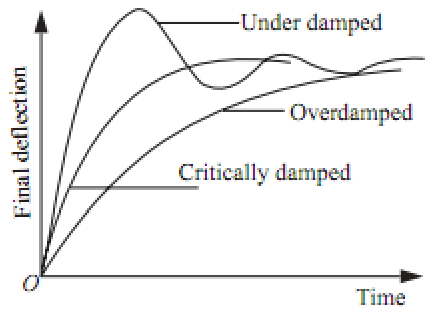


Fig. 12.3 *Dynamic response of a measuring instrument*

We have already seen that the moving system of the instrument will tend to move under the action of the deflecting torque. But on account of the control torque, it will try to occupy a position of rest when the two torques are equal and opposite. However, due to inertia of the moving system, the pointer will not come to rest immediately but oscillate about its final deflected position as shown in Fig and takes appreciable time to come to steady state. To overcome this difficulty a damping torque is to be developed by using a damping device attached to the moving system.

The damping torque is proportional to the speed of rotation of the moving system,
that is Tv = kv d dt θ
where kv = damping torque constant
d dt θ = speed of rotation of the moving system

Depending upon the degree of damping introduced in the moving system, the instrument may have any one of the following conditions as depicted in Fig.

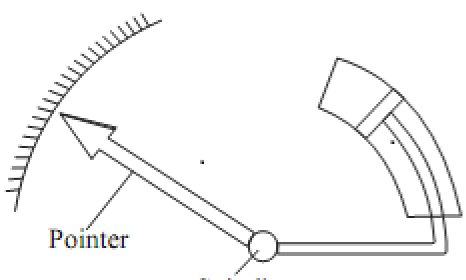
1. Under damped condition: The response is oscillatory
2. Over damped condition: The response is sluggish and it rises very slowly from its zero position to final position.
3. Critically damped condition: When the response settles quickly without any oscillation, the system is said to be critically damped.

In practice, the best response is slightly obtained when the damping is below the critical value i.e., the instrument is slightly under damped.

The damping torque is produced by the following methods: Air Friction Damping & Fluid friction damping

Air Friction Damping

In this type of damping a light vane or vanes having considerable area is attached to the moving system to develop a frictional force opposing the motion by reason of the air they displace. Two methods of damping by air friction are depicted in Fig.

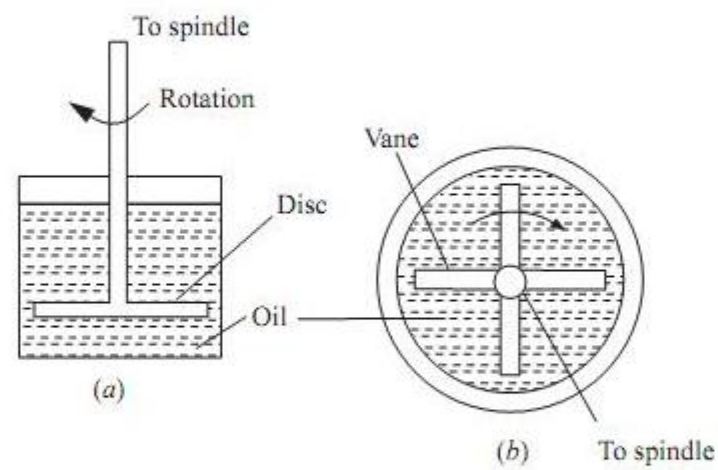


(b)

The arrangement shown in Fig consists of a light aluminum vane which moves in a quadrant (sector) shaped air chamber. The chamber also carries a cover plate at the top. The vane is mounted on the spindle of the moving system. The aluminum vane should not touch the air-chamber walls otherwise a serious error in the deflection of the instrument will be introduced. Now, with the motion, the vane displaces air and thereby a damping force is created on the vane that produces a torque (damping) on the spindle. When the movement is quicker the damping force is greater; when the spindle is at rest, the damping force is zero.

The arrangement of Fig. consists of a light aluminum piston which is attached to the moving system. This piston moves in a fixed chamber which is closed at one end. Either circular or rectangular chamber may be used. The clearance (or gap) between the piston and chamber walls should be uniform throughout and as small as possible. When the piston moves rapidly into the chamber the air in the closed space is compressed and the pressure of air thus developed opposes the motion of the piston and thereby the whole moving system. If the piston is moving out of the chamber, rapidly, the pressure in the closed space falls and the pressure on the open side of the piston is greater than that on the opposite side. Motion is thus again opposed. With this damping system care must be taken to ensure that the arm carrying the piston should not touch the sides of the chamber during its movement. The friction which otherwise would occur may introduce a serious error in the deflection.
The air friction damping is very simple and cheap. But care must be taken to ensure that the piston is not bent or twisted. This method is used in moving iron and hot wire instruments.

Fluid Friction Damping



This form is damping is similar to air friction damping. The action is the same as in the air friction damping. Mineral oil is used in place of air and as the viscosity of oil is greater, the damping force is also much greater. The vane attached to the spindle is arranged to move in the damping oil. It is rarely used in commercial type instruments. The oil used must fulfill the following requirements. It should not evaporate quickly . It should not have any corrosive effect on metals. Its viscosity should not change appreciably with temperature. It should be good insulator.

Advantages of Fluid Friction Damping

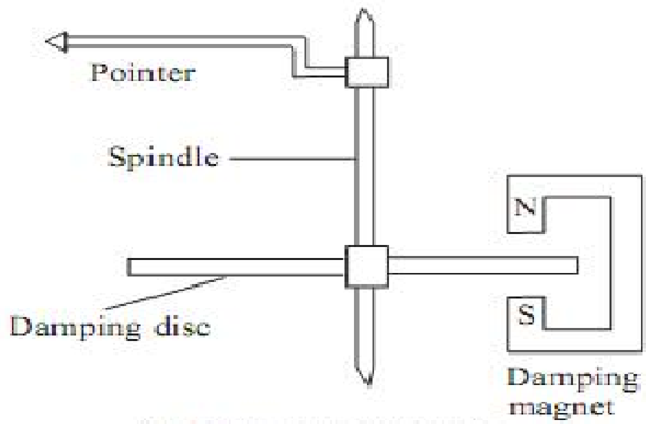
1. The oil used for damping can also be used for insulation purpose in some forms of instruments which are submerged in oil.
2. The clearance between the vanes and oil chamber is not as critical as with the air friction clamping system.
3. This method is suitable for use with instruments such as electrostatic type where the movement is suspended rather than pivoted.
4. Due to the up thrust of oil, the loads on bearings or suspension system is reduced thereby the reducing the frictional errors.

Disadvantages of Fluid Friction Damping

1. The instruments with this type of damping must be kept always in a vertical position.
2. It is difficult to keep the instrument clean due to leakage of oil.
3. It is not suitable for portable instruments. The fluid friction damping can be used for laboratory type electrostatic instruments.

<u>Eddy current damping</u>

Eddy Current Damping

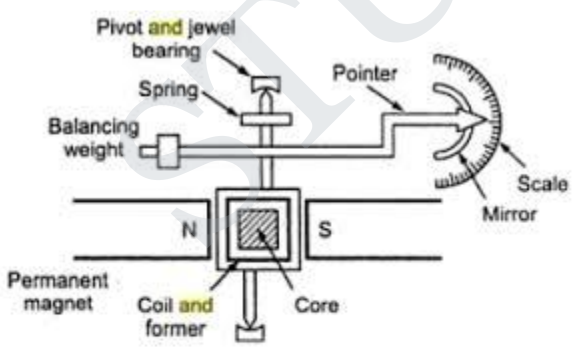


(a) Eddy current damping

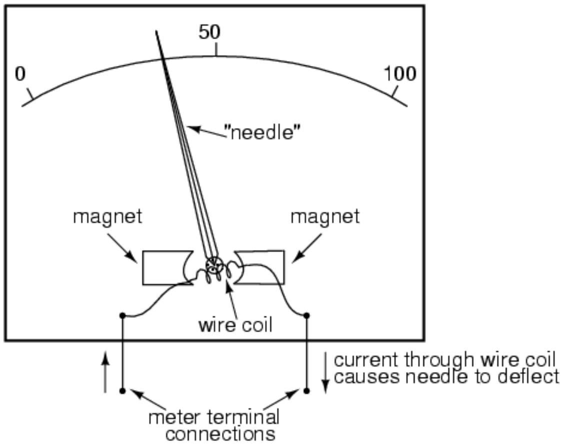
Eddy current damping is the most efficient form of damping. The essential components in this type of damping are a permanent magnet; and a light conducting disc usually of alumninum. When a sheet of conducting material moves in a magnetic field so as to cut through lines of force, eddy currents are set up in it and a force exists between these currents and the magnetic field, which is always in the direction opposing the motion. \

This force is proportional to the magnitude of the current, and to the strength of field. The former is proportional to the velocity of movement of the conductor, and thus, if the magnetic field is constant, the damping force is proportional to the velocity of the moving system and is zero when there is no movement of the system.

PMMC



Permanent magnet, moving coil (PMMC) meter movement



The permanent magnet moving coil instrument or PMMC type instrument uses two permanent magnets in order to create stationary magnetic field. These types of instruments are only used for measuring the dc quantities as if we apply ac current to these type of instruments the direction of current will be reversed during negative half cycle and hence the direction of torque will also be reversed which gives average value of torque zero. The pointer will not deflect due to high frequency from its mean position showing zero reading. However it can measure the direct current very accurately.

Construction of permanent magnet moving coil instruments.
We will see the construction of these types of instruments in four parts and they are described below:

Stationary part or magnet system: In the present time we use magnets of high field intensities, high coercive force instead of using U shaped permanent magnet having soft iron pole pieces. The magnets which we are using nowadays are made up of materials like alcomax and alnico which provide high field strength.

Moving coil: The moving coil can freely moves between the two permanent magnets as shown in the figure given below. The coil is wound with many turns of copper wire and is placed on rectangular aluminum which is pivoted on jeweled bearings.

Control system: The spring generally acts as control system for PMMC instruments. The spring also serves another important function by providing the path to lead current in and out of the coil.
Damping system: The damping force hence torque is provided by movement of aluminium former in the magnetic field created by the permanent magnets.

Meter: Meter of these instruments consists of light weight pointer to have free movement and scale which is linear or uniform and varies with angle

Deflecting torque Equation:
Let us derive a general expression for torque in permanent magnet moving coil instruments or PMMC instruments. We know that in moving coil instruments the deflecting torque is given

by the expression:

$$T_d = N\ B\ l\ dI$$

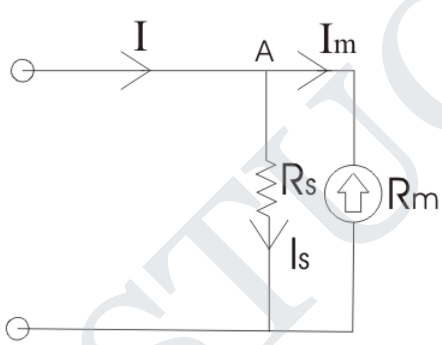
where N is number of turns,
B is magnetic flux density in air gap,
l is the length of moving coil,
d is the width of the moving coil,
And I is the electric current.

Now for a moving coil instruments deflecting torque should be proportional to current, mathematically we can write T_d = GI.
Thus on comparing we say G = NBIdl.
At steady state we have both the controlling and deflecting torques are equal.
T_c is controlling torque, on equating controlling torque with deflection torque we have GI = K.x where x is deflection thus current is given by

$$I = K / G\ x$$

Since the deflection is directly proportional to the current therefore we need a uniform scale on the meter for measurement of current.

Now we are going to discuss about the basic circuit diagram of the ammeter. Let us consider a circuit as shown below:



The current I is shown which breaks into two components at the point A. The two components are I_s and I_m. Before I comment on the magnitude values of these currents, let us know more about the construction of shunt resistance. The basic properties of shuntresistance are written below,

The electrical resistance of these shunts should not differ at higher temperature, it they should posses very low value of temperature coefficient. Also the resistance should be time independent. Last and the most important property they should posses is that they should be able to carry high value of current without much rise in temperature. Usually manganin is used for making dc resistance. Thus we can say that the value of I_s much greater than the value of I_m as resistance of shunt is low. From the we have,

Is .Rs = ImRm
Where R_s is resistance of shunt and R_m is the electrical resistance of the coil.
Is = I – Im
M= I / Im = 1+ (Rm + Rs)
Where m is the magnifying power of the shunt.

Errors in Permanent Magnet Moving Coil Instruments
There are three main types of errors
(a) Errors due to permanent magnets:
Due to temperature effects and aging of the magnets the magnet may lose their magnetism to some extent. The magnets are generally aged by the heat and vibration treatment.

(b) Error may appear in PMMC Instrument due to the aging of the spring.
However the error caused by the aging of the spring and the errors caused due to permanent magnet are opposite to each other, hence both the errors are compensated with each other.

(c) Change in the resistance of the moving coil with the temperature:
Generally the temperature coefficients of the value of coefficient of copper wire in moving coil is 0.04 per degree Celsius rise in temperature. Due to lower value of temperature coefficient the temperature rises at faster rate and hence the resistance increases. Due to this significant amount of error is caused.

Advantages of Permanent Magnet Moving Coil Instruments
(1)The scale is uniformly divided as the current is directly proportional to deflection of the pointer. Hence it is very easy to measure quantities from these instruments.
(2)Power consumption is also very low in these types of instruments.
(3)Higher value of torque is to weight ratio.
(4)These are having multiple advantages, a single instrument can be used for measuring various quantities by using different values of shunts and multipliers.

Disadvantages of Permanent Magnet Moving Coil Instruments
(1) These instruments cannot measure ac quantities.
(2) Cost of these instruments is high as compared to moving iron instruments

Moving Iron instruments

Moving-iron instruments are generally used to measure alternating voltages and currents. In moving-iron instruments the movable system consists of one or more pieces of specially-shaped soft iron, which are so pivoted as to be acted upon by the magnetic field produced by the current in coil.

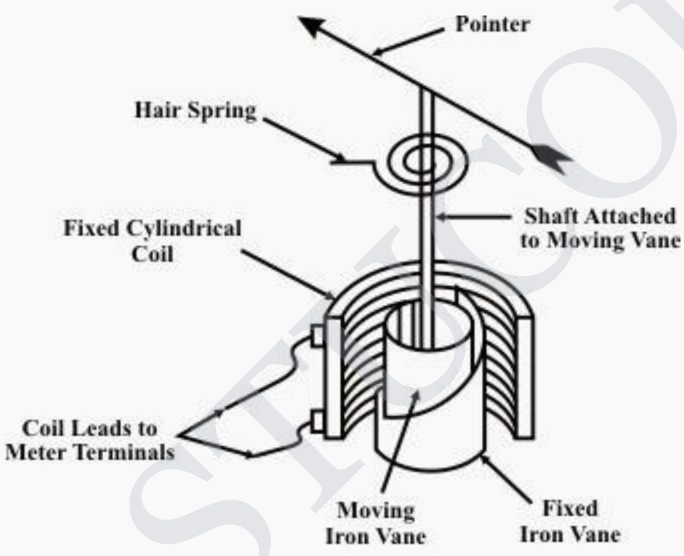
There are two general types of moving-iron instruments namely:
1. Repulsion (or double iron) type (figure 1)
2. Attraction (or single-iron) type (figure 2)

The brief description of different components of a moving-iron instrument is given below:

Moving element: A small piece of soft iron in the form of a vane or rod.

Coil: To produce the magnetic field due to current flowing through it and also to magnetize the iron pieces.

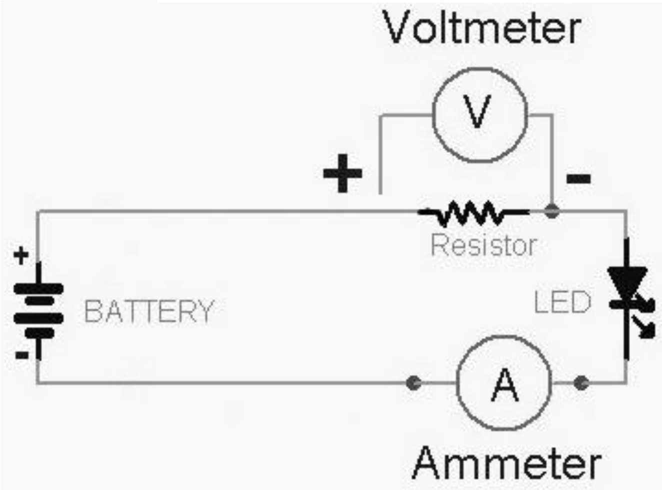
Repulsion type



Repulsion type.

In repulsion type, a **fixed** vane or rod is also used and magnetized with the same polarity.
Control torque is provided by spring or weight (gravity).
Damping torque is normally pneumatic, the damping device consisting of an air chamber and a moving vane attached to the instrument spindle.
Deflecting torque produces a movement on an aluminum pointer over a graduated scale.
The deflecting torque in any moving-iron instrument is due to forces on a small piece of

magnetically 'soft' iron that is magnetized by a coil carrying the operating current. In repulsion type moving–iron instrument consists of two cylindrical soft iron vanes mounted within a fixed current-carrying coil. One iron vane is held fixed to the coil frame and other is free to rotate, carrying with it the pointer shaft. Two irons lie in the magnetic field produced by the coil that consists of only few turns if the instrument is an ammeter or of many turns if the instrument is a voltmeter.



Current in the coil induces both vanes to become magnetized and repulsion between the similarly magnetized vanes produces a proportional rotation. The deflecting torque is proportional to the square of the current in the coil, making the instrument reading is a true 'RMS' quantity Rotation is opposed by a hairspring that produces the restoring torque. Only the fixed coil carries load current, and it is constructed so as to withstand high transient current.
Moving iron instruments having scales that are nonlinear and somewhat crowded in the lower range of calibration.

Measurement of Electric Voltage and Current
Moving iron instruments are used as Voltmeter and Ammeter only.
Both can work on AC as well as on DC.

Ammeter
Instrument used to measure current in the circuit.
Always connected in series with the circuit and carries the current to be measured.
This current flowing through the coil produces the desired deflecting torque.
It should have low resistance as it is to be connected in series.

Voltmeter
Instrument used to measure voltage between two points in a circuit.
Always connected in parallel.

Current flowing through the operating coil of the meter produces deflecting torque.
It should have high resistance. Thus a high resistance of order of kilo ohms is connected in series with the coil of the instrument.

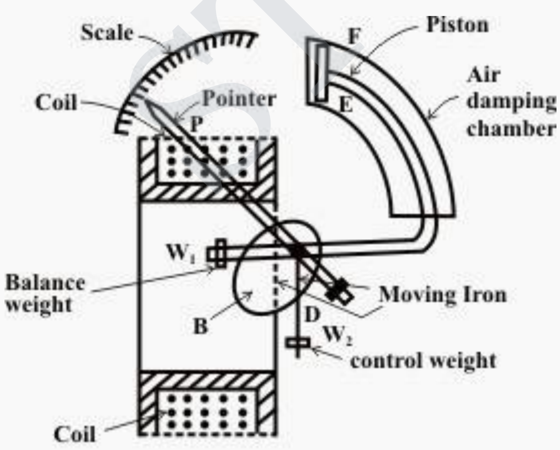
Ranges of Ammeter and Voltmeter
For a given moving-iron instrument the ampere-turns necessary to produce full-scale deflection are constant.
One can alter the range of ammeters by providing a shunt coil with the moving coil.
Voltmeter range may be altered connecting a resistance in series with the coil. Hence the same coil winding specification may be employed for a number of ranges.

Advantages

1. The instruments are suitable for use in AC and DC circuits.
2. The instruments are robust, owing to the simple construction of the moving parts.
3. The stationary parts of the instruments are also simple.
4. Instrument is low cost compared to moving coil instrument.
5. Torque/weight ratio is high, thus less frictional error.

Errors
(i). Error due to variation in temperature.
(ii). Error due to friction is quite small as torque-weight ratio is high in moving coil instruments.
(iii). Stray fields cause relatively low values of magnetizing force produced by the coil. Efficient magnetic screening is essential to reduce this effect.
(iv). Error due to variation of frequency causes change of reactance of the coil and also changes the eddy currents induced in neighbouring metal.
(v). Deflecting torque is not exactly proportional to the square of the current due to non-linear characteristics of iron material.

Attraction type



Attraction type

The basic construction of attraction type moving iron instrument is illustrated bellow
A thin disc of soft iron is eccentrically pivoted in front of a coil. This iron tends to move inward that is from weaker magnetic field to stronger magnetic field whencurrent flowing through the coil. In attraction moving instrument gravity control was used previously but now gravity control method is replaced by spring control in relatively modern instrument. By adjusting balance weight null deflection of the pointer is achieved. The required damping force is provided in this instrument by air friction. The figure shows a typical type of damping system provided in the instrument, where damping is achieved by a moving piston in an air syringe.

Theory of Attraction Type Moving Iron Instrument
Suppose when there is no current through the coil, the pointer is at zero, the angle made by the axis of the iron disc with the line perpendicular to the field is φ. Now due current I and corresponding magnetic field strength, the iron piece is deflected to an angle θ. Now component of H in the direction of defected iron disc axis is Hcos{90 - (θ + φ) or Hsin(θ + φ). Now force F acting on the disc inward to the coil is thus proportional to $H^2\sin(\theta + \varphi)$ hence the force is also proportional to $I^2\sin(\theta + \varphi)$ for constant permeability. If this force is acting on the disc at a distance l from the pivot, then deflection torque,

$Td = Fl \cos(\theta+\Phi)$
Thus $Td = I2 \sin(\theta+\Phi)\cos(\theta+\Phi)$
$Td = kI2 \sin 2(\theta+\Phi)$
Where k is constant.

Now, as the instrument is gravity controlled, controlling torque will be
$Tc = k' \sin\theta$
Where k ‘is constant

<u>Dynamo meter type watt meter</u>

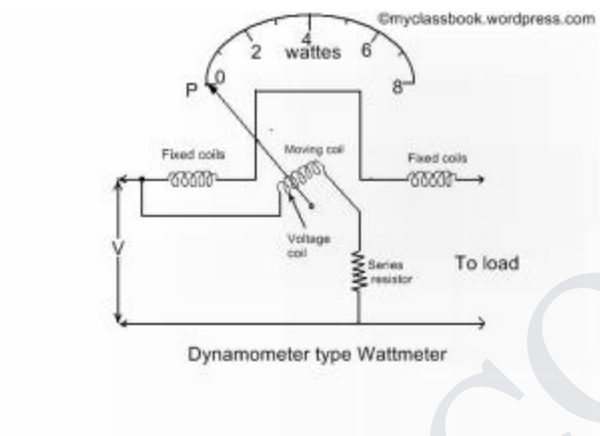
In general, a watt meter is used to measure the electric power of a circuit, or sometime it also measures the rate of energy transferred from one circuit to another circuit. When a moving coil (that is free to rotate) is kept under the influence of a current carrying conductor, then automatically a mechanical force will be applied to the moving coil, and this force will make a little deflection of the moving coil. If a pointer is connected with the moving coil, which will move of a scale, then the deflection can be easily measured by connecting the moving coil with that pointer. This is the principle of operation of all dynamo meter type instruments, and this principle is equally applicable for dynamo meter type watt meter also.

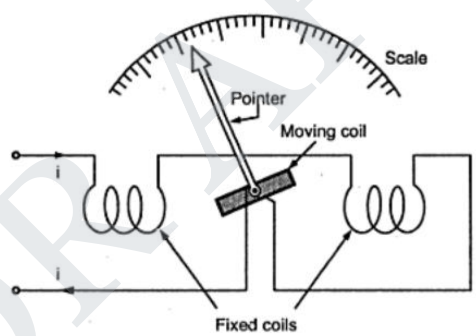
This type of watt meter consists of two types of coil, more specifically current coil and voltage coil. There are two current coils which are kept at constant position and the measurable current will flow through those current coils. A voltage coil is placed inside those two current coils, and this voltage coil is totally free to rotate. The current coils are arranged such a way, that they are connected with the circuit in series. And the voltage coil is connected in parallel with the circuit.

As simple as other voltmeter and ammeter connection. In fact, a watt meter is a package of an ammeter and a voltmeter, because the product of voltage and current is the power, which is the measurable quantity of a watt meter

When current flows through the current coils, then automatically a magnetic field is developed around those coils. Under the influence of the electromagnetic field, voltage coil also carries some amount of current as it is connected with the circuit in parallel. In this way, the deflection of the pointer will proportional to both current and voltage of the circuit. In this way, Watt = Current × Voltage equation is satisfied and the deflection shows the value of power inside the circuit. A dynamo meter type watt meter is used in various applications where the power or energy transfer has to be measured.

Construction and Working Principle of Electrodynamometer Type Wattmeter





Now let us look at constructional details of **electrodynamometer**. It consists of following parts There are two types of coils present in the electrodynamometer.
They are :

(a) Moving coil : Moving coil moves the pointer with the help of spring control instrument. A limited amount of current flows through the moving coil so as to avoid heating. So in order to limit the current we have connect the high value resistor in series with the moving coil. The moving is air cored and is mounted on a pivoted spindle and can moves freely. In **electrodynamometer type wattmeter**, moving coil works as pressure coil. Hence moving coil is connected across the voltage and thus the current flowing through this coil is always proportional to the voltage.

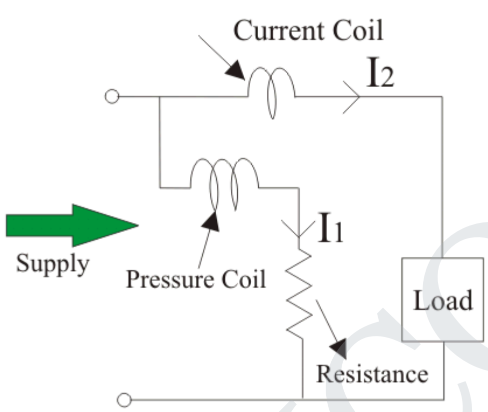
(b) Fixed coil: The fixed coil is divided into two equal parts and these are connected in series with the load, therefore the load current will flow through these coils. Now the reason is very obvious of using two fixed coils instead of one, so that it can be constructed to carry considerable amount of electric current. These coils are called the current coils of electrodynamometer type wattmeter. Earlier these fixed coils are designed to carry the current of about 100 amperes but

now the modern wattmeter are designed to carry current of about 20 amperes in order to save power.
(c) Control system: Out of two controlling systems i.e.
(1). Gravity control
(2) Spring control, only spring controlled systems are used in these types of wattmeter. Gravity controlled system cannot be employed because they will appreciable amount of errors.

(d) Damping system: Air friction damping is used, as eddy current damping will distort the weak operating magnetic field and thus it may leads to error.

(e) Scale: There is uniform scale is used in these types of instrument as moving coil moves linearly over a range of 40 degrees to 50 degrees on either sides.

Now let us derive the expressions for the controlling torque and deflecting torques. In order to derive these expressions let us consider the circuit diagram given below:



We know that instantaneous torque in electro dynamic type instruments is directly proportional to product of instantaneous values of currents flowing through both the coils and the rate of change of flux linked with the circuit.

Let I_1 and I_2 be the instantaneous values of currents in pressure and current coils respectively. So the expression for the torque can be written as:
T = I1*I2*(dM / dx)
Where x is the angle

Now let the applied value of voltage across the pressure coil be V= $\bar{V} \sin \omega t$

Assuming the electrical resistance of the pressure coil be very high hence we can neglect reactance with respect to its resistance. In this the impedance is equal to its electrical resistance therefore it is purely resistive
The expression for instantaneous current can be written as $I_2 = v / R_p$ where R_p is the resistance of pressure coil.
I2 = $\bar{V} \sin \omega t / Rp$

If there is phase difference between voltage and electric current, then expression for instantaneous current through current coil can be written as

$I1 = I(t) = \bar{I} \sin(\omega t - \Phi)$

As current through the pressure coil in very very small compare to current through currentcoil hence current through the current coil can be considered as equal to total load current.

Hence the instantaneous value of torque can be written as $\bar{V} \sin \omega t / Rp * \bar{I} \sin(\omega t - \Phi) * (dM / dx)$

Average value of deflecting torque can be obtained by integrating the instantaneous torque from limit 0 to T where T is the time period of the cycle Td = deflecting torque = VI cosΦ /Rp *(dM / dx)

Controlling torque is given by $T_c = K_x$ where K is spring constant and x is final steady state value of deflection.

Advantages of Electrodynamometer Type Wattmeter

Following are the advantages of electrodynamometer type wattmeters and they are written as follows:

(a). Scale is uniform up to certain limit

(b). They can be used for both to measure AC as well as DC quantities as scale is calibrated for both

Errors in Electrodynamometer Type Wattmeter

Following are the errors in the electrodynamometer type watt meters:

(a) Errors in the pressure coil inductance.

(b) Errors may be due to pressure coil capacitance.

(c) Errors may be due to mutual inductance effects.

(d) Errors may be due connections.(i.e. pressure coil is connected after current coil)

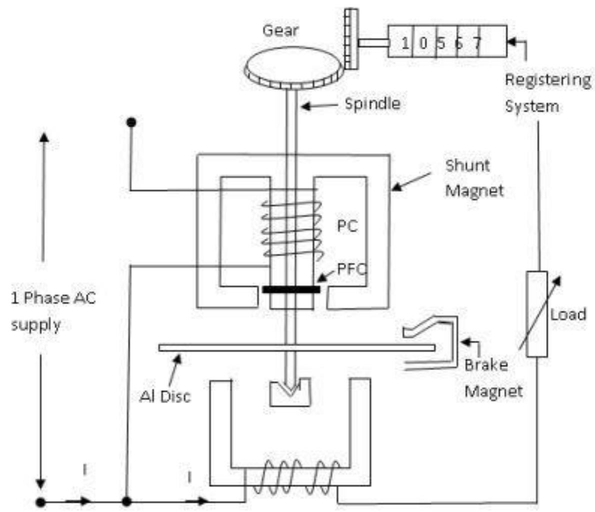
(e) Error due to Eddy currents.

(f) Errors caused by vibration of moving system.

(g) Temperature error.

(h) Errors due to stray magnetic field.

Single phase Energy meter



Single phase induction type energy meter is also popularly known as **watt-hour meter**. This name is given to it. This article is only focused about its constructional features and its working. Induction type energy meter essentially consists of following components:

1. Driving system
2. Moving system
3. Braking system and
4. Registering system

Driving system

It consists of two electromagnets, called **"shunt" magnet** and **"series" magnet**, of laminated construction. A coil having large number of turns of fine wire is wound on the middle limb of the shunt magnet.

This coil is known as "**pressure or voltage**" coil and is connected across the supply mains. This voltage coil has many turns and is arranged to be as highly inductive as possible. In other words, the voltage coil produces a high ratio of inductance to resistance. This causes the current and therefore the flux, to lag the supply voltage by nearly 90 degree

Adjustable copper shading rings are provided on the central limb of the shunt magnet to make the phase angle displacement between magnetic field set up by shunt magnet and supply voltage is approximately 90 degree.

The copper shading bands are also called the power factor compensator or compensating loop. The series electromagnet is energized by a coil, known as **"current"** ***coil*** which is connected in series with the load so that it carry the load current. The flux produced by this magnet is proportional to, and in phase with the load current.

Moving system

The moving system essentially consists of a light rotating aluminium disk mounted on a vertical spindle or shaft. The shaft that supports the aluminium disk is connected by a gear arrangement to the clock mechanism on the front of the meter to provide information that consumed energy by the load.

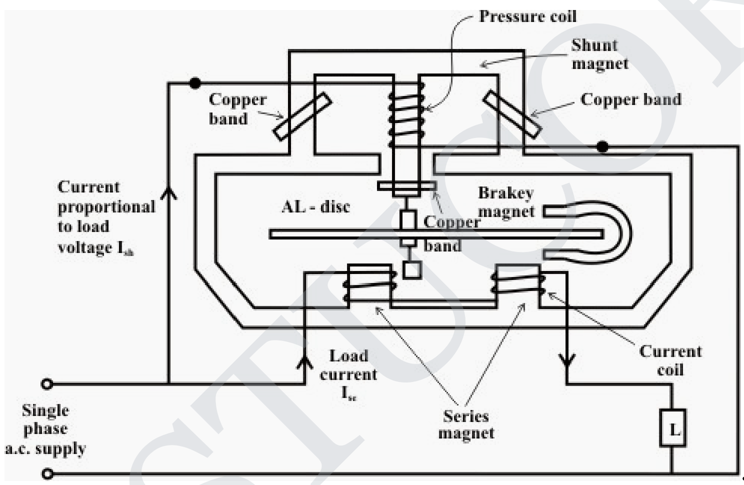
The time varying (sinusoidal) fluxes produced by shunt and series magnet induce eddy currents in the aluminium disc The interaction between these two magnetic fields and eddy currents set up a driving torque in the disc. The number of rotations of the disk is therefore proportional to the energy consumed by the load in a certain time interval and is commonly measured in **kilowatt-hours (Kwh)**.

Braking system

Damping of the disk is provided by a **small permanent magnet**, located diametrically opposite to the a.c magnets. The disk passes between the magnet gaps. The movement of rotating disc through the magnetic field crossing the air gap sets up eddy currents in the disc that reacts with the magnetic field and exerts a braking torque.

By changing the position of the brake magnet or diverting some of the flux there form, the speed of the rotating disc can be controlled.

Registering or counting system



The registering or counting system essentially consists of gear train, driven either by worm or pinion gear on the disc shaft, which turns pointers that indicate on dials the number of times the disc has turned.

The energy meter thus determines and adds together or integrates all the **instantaneous power values** so that total energy used over a period is thus known. Therefore, this type of meter is also called an **"integrating" meter**.

Working of Single phase induction type Energy Meter

The basic working of Single phase induction type Energy Meter is only focused on two mechanisms:

1. Mechanism of rotation of an aluminum disc which is made to rotate at a speed proportional to the power.
2. Mechanism of counting and displaying the amount of energy transferred.

Mechanism of rotation of an aluminum disc

The metallic disc is acted upon by two coils. One coil is connected 0r arranged in such a way that it produces a magnetic flux in proportion to the voltage and the other produces a magnetic flux in proportion to the current. The field of the voltage coil is delayed by 90 degrees using a lag coil.

This produces eddy currents in the disc and the effect is such that a force is exerted on the disc in proportion to the product of the instantaneous current and voltage.

A permanent magnet exerts an opposing force proportional to the speed of rotation of the disc – this acts as a brake which causes the disc to stop spinning when power stops being drawn rather than allowing it to spin faster and faster. This causes the disc to rotate at a speed proportional to the power being used.

Mechanism of displaying the amount of energy transferred

The aluminum disc is supported by a spindle which has a worm gear which drives the register. The register is a series of dials which record the amount of energy used.

The dials may be of the cyclometer type, an odometer-like display that is easy to read where for each dial a single digit is shown through a window in the face of the meter, or of the pointer type where a pointer indicates each digit.

It should be noted that with the dial pointer type, adjacent pointers generally rotate in opposite directions due to the gearing mechanism.

UNIT II – ELECTRICAL MECHANICS

2.1 DC GENERATOR - INTRODUCTION

An electrical generator is a device that **converts mechanical energy to electrical energy**, generally using electromagnetic induction. The source of mechanical energy may be a reciprocating or turbine steam engine, water falling through a turbine or waterwheel, an internal combustion engine, a wind turbine, a hand crank, or any other source of mechanical energy.

The Dynamo was the first electrical generator capable of delivering power for industry. The dynamo uses electromagnetic principles to convert mechanical rotation into an alternating electric current. A dynamo machine consists of a stationary structure which generates a strong magnetic field, and a set of rotating windings which turn within that field. On small machines the magnetic field may be provided by a permanent magnet; larger machines have the magnetic field created by electromagnets. The energy conversion in generator is based on the principle of the production of dynamically induced e.m.f. whenever a conductor cuts magneticic flux, dynamically induced e.m.f is produced in it according to Faraday's Laws of Electromagnetic induction. This e.m.f causes a current to flow if the conductor circuit is closed.

2.1.1 CONSTRUCTION OF D.C. MACHINES

A D.C. machine consists mainly of two part the stationary part called stator and the rotating part called rotor.The stator consists of main poles used to produce magnetic flux ,commutating poles or interpoles in between the main poles to avoid sparking at the commutator but in the case of small machines sometimes the interpoles are avoided and finally the frame or yoke which forms the supporting structure of the machine. The rotor consist of an armature a cylindrical metallic body or core with slots in it to place armature windings or bars,a commutator and brush gears The magnetic flux path in a motor or generator is show below and it is called the magnetic structure of generator or motor.

The major parts can be identified as,

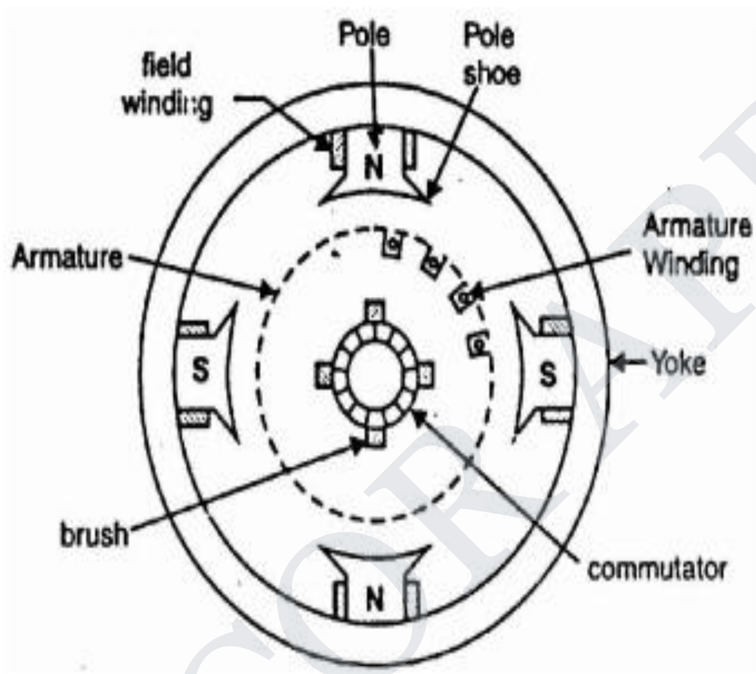
1. Frame
2. Poles
3. Armature
4. Field winding
5. Commutator
6. Brush
7. Other mechanical parts

Frame

Frame is the stationary part of a machine on which the main poles and commutator poles are bolted and it forms the supporting structure by connecting the frame to the bed plate. The ring shaped body portion of the frame which makes the magnetic path for the magnetic fluxes from the main poles and interpoles is called Yoke**.**

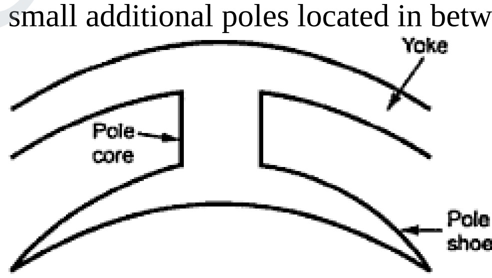
Why we use cast steel instead of cast iron for the construction of Yoke?

In early days Yoke was made up of cast iron but now it is replaced by cast steel.This is because cast iron is saturated by a flux density of 0.8 Wb/sq.m where as saturation with cast iron steel is about 1.5 Wb/sq.m.So for the same magnetic flux density the cross section area needed for cast steel is less than cast iron hence the weight of the machine too.If we use cast iron there may be chances of blow holes in it while casting.so now rolled steels are developed and these have consistent magnetic and mechanical properties.



poles:

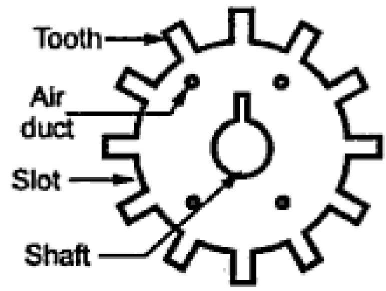
Solid poles of fabricated steel with separate/integral pole shoes are fastened to the frame by means of bolts. Pole shoes are generally laminated. Sometimes pole body and pole shoe are formed from the same laminations. The pole shoes are shaped so as to have a slightly increased air gap at the tips. Inter-poles are small additional poles located in between the main poles.



These can be solid, or laminated just as the main poles. These are also fastened to the yoke by bolts. Sometimes the yoke may be slotted to receive these poles. The inter poles could be of tapered section or of uniform cross section. These are also called as commutating poles or com poles. The width of the tip of the com pole can be about a rotor slot pitch.

Armature

The armature is where the moving conductors are located. The armature is constructed by stacking laminated sheets of silicon steel. Thickness of these lamination is kept low to reduce eddy current losses. As the laminations carry alternating flux the choice of suitable material, insulation coating on the laminations, stacking it etc are to be done more carefully. The core is divided into packets to facilitate ventilation. The winding cannot be placed on the surface of the rotor due to the mechanical forces coming on the same. Open parallel sided equally spaced slots are normally punched in the rotor laminations.



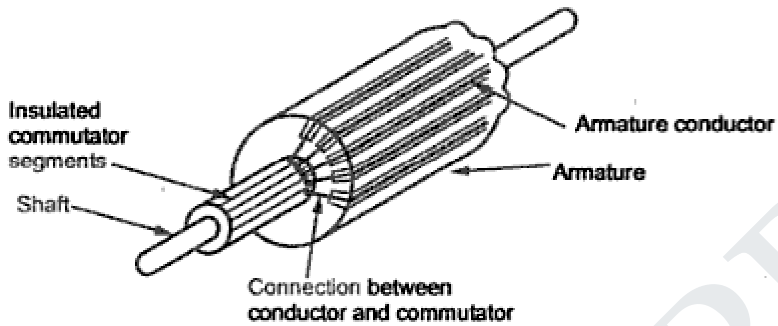
These slots house the armature winding. Large sized machines employ a spider on which the laminations are stacked in segments. End plates are suitably shaped so as to serve as 'Winding supporters'. Armature construction process must ensure provision of sufficient axial and radial ducts to facilitate easy removal of heat from the armature winding.

Field windings:

In the case of wound field machines (as against permanent magnet excited machines) the field winding takes the form of a concentric coil wound around the main poles. These carry the excitation current and produce the main field in the machine. Thus the poles are created electromagnetically. Two types of windings are generally employed. In shunt winding large number of turns of small section copper conductor is used. The resistance of such winding would be an order of magnitude larger than the armature winding resistance. In the case of series winding a few turns of heavy cross section conductor is used. The resistance of such windings is low and is comparable to armature resistance. Some machines may have both the windings on the poles. The total ampere turns required to establish the necessary flux under the poles is calculated from the magnetic circuit calculations. The total mmf required is divided equally between north and south poles as the poles are produced in pairs. The mmf required to be shared between shunt and series windings are apportioned as per the design requirements. As these work on the same magnetic system they are in the form of concentric coils. Mmf 'per pole' is normally used in these calculations. Armature winding As mentioned earlier, if the armature coils are wound on the surface of the armature, such construction becomes mechanically weak. The conductors may fly away when the armature starts rotating. Hence the armature windings are in general pre-formed, taped and lowered into the open slots on the armature. In the case of small machines, they can be hand wound. The coils are prevented from flying out due to the centrifugal forces by means of bands of steel wire on the surface of the rotor in small groves cut into it. In the case of large machines slot wedges are additionally used to restrain the coils from flying away. The end portion of the windings are taped at the free end and bound to the winding carrier ring of the armature at the commutator end. The armature must be dynamically balanced to reduce the centrifugal forces at the operating speeds. Compensating winding One may find a bar winding housed in the slots on the pole shoes. This is mostly found in d.c. machines of very large rating. Such winding is called compensating winding. In smaller machines, they may be absent.

Commutator:

Commutator is the key element which made the d.c. machine of the present day possible. It consists of copper segments tightly fastened together with mica/micanite insulating separators



on an insulated base. The whole commutator forms a rigid and solid assembly of insulated copper strips and can rotate at high speeds. Each commutator segment is provided with a 'riser' where the ends of the armature coils get connected. The surface of the commutator is machined and surface is made concentric with the shaft and the current collecting brushes rest on the same. Under-cutting the mica insulators that are between these commutator segments has to be done periodically to avoid fouling of the surface of the commutator by mica when the commutator gets worn out. Some details of the construction of the commutator are seen in Fig

Brush and brush holders:

Brushes rest on the surface of the commutator. Normally electro-graphite is used as brush material. The actual composition of the brush depends on the peripheral speed of the commutator and the working voltage. The hardness of the graphite brush is selected to be lower than that of the commutator. When the brush wears out the graphite works as a solid lubricant reducing frictional coefficient. More number of relatively smaller width brushes are preferred in place of large broad brushes. The brush holders provide slots for the brushes to be placed. The connection Brush holder with a Brush and Positioning of the brush on the commutator from the brush is taken out by means of flexible pigtail. The brushes are kept pressed on the commutator with the help of springs. This is to ensure proper contact between the brushes and the commutator even under high speeds of operation. Jumping of brushes must be avoided to ensure arc free current collection and to keep the brushcontact drop low. Other mechanical parts End covers, fan and shaft bearings form other important mechanical parts. End covers are completely solid or have opening for ventilation. They support the bearings which are on the shaft. Proper machining is to be ensured for easy assembly. Fans can be external or internal. In most machines the fan is on the non-commutator end sucking the air from the commutator end and throwing the same out. Adequate quantity of hot air removal has to be ensured. Bearings Small machines employ ball bearings at both ends. For larger machines roller bearings are used especially at the driving end. The bearings are mounted press-fit on the shaft. They are housed inside the end shield in such a manner that it is not necessary to remove the bearings from the shaft for dismantling.

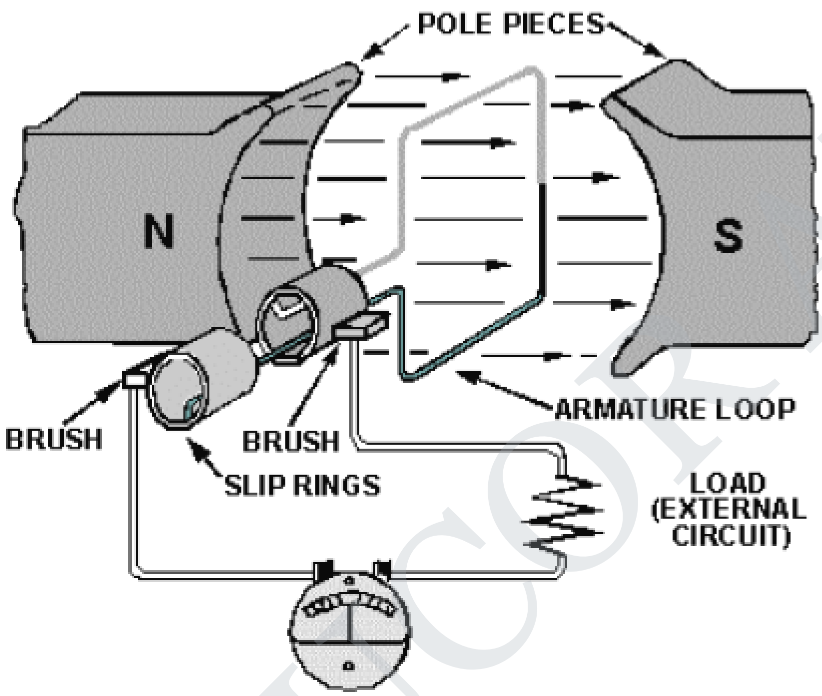
End Shields or Bearings

If the armature diameter does not exceed 35 to 45 cm then in addition to poles end shields or frame head with bearing are attached to the frame.If the armature diameter is greater than 1m

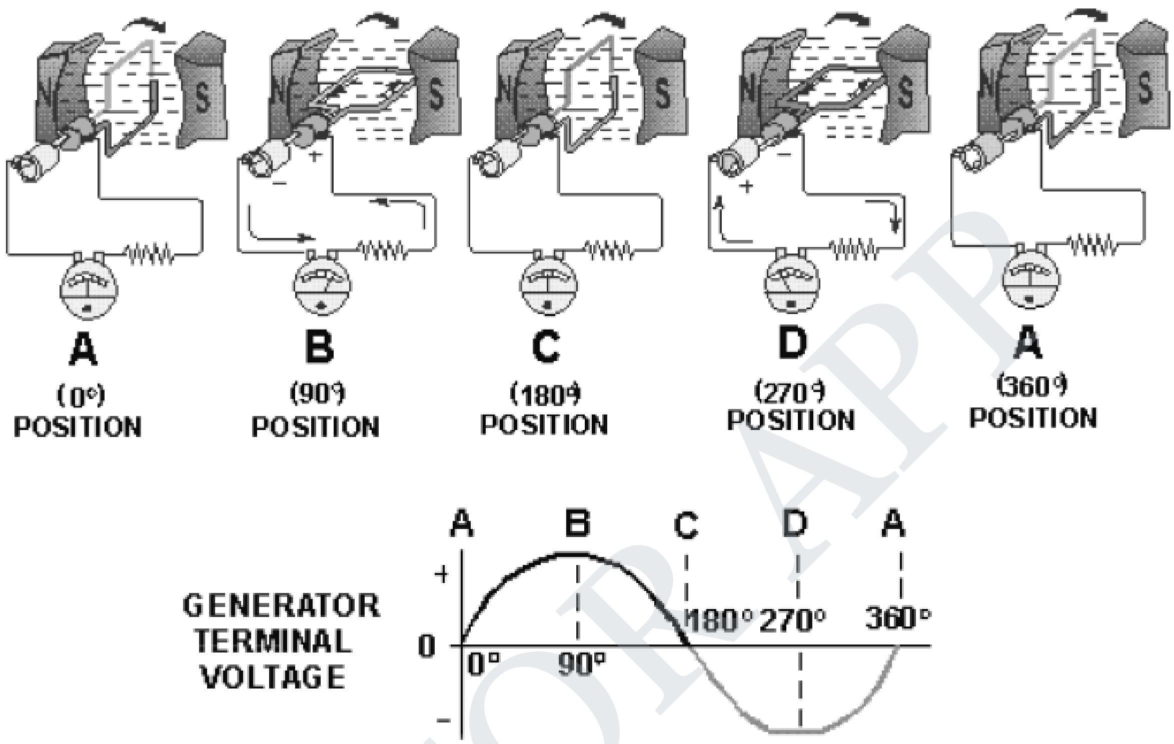
pedestral type bearings are mounted on the machine bed plate outside the frame.These bearings could be ball or roller type but generally plain pedestral bearings are employed.If the diameter of the armature is large a **brush holder yoke** is generally fixed to the frame.

2.1.2 PRINCIPLE OF OPERATION

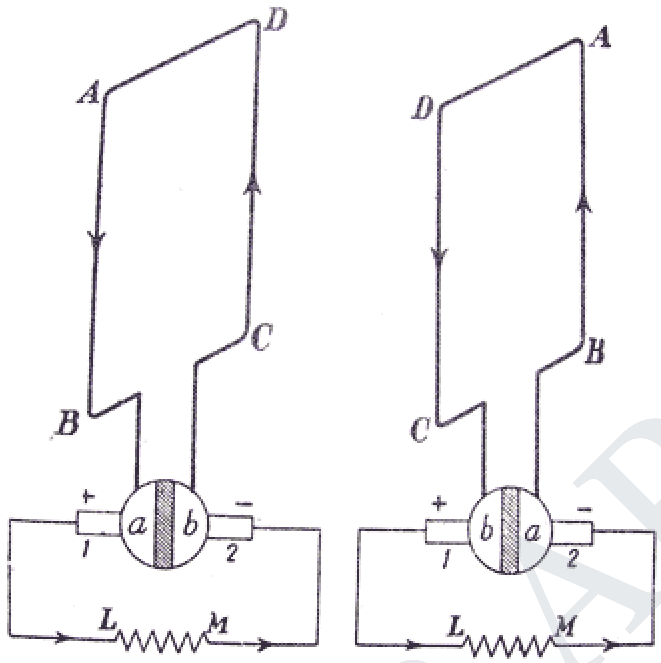
DC generator converts mechanical energy into electrical energy. when a conductor move in a magnetic field in such a way conductors cuts across a magnetic flux of lines and emf produces in a generator and it is defined by faradays law of electromagnetic induction emf causes current to flow if the conductor circuit is closed.



The pole pieces (marked N and S) provide the magnetic field. The pole pieces are shaped and positioned as shown to concentrate the magnetic field as close as possible to the wire loop. The loop of wire that rotates through the field is called the ARMATURE. The ends of the armature loop are connected to rings called SLIP RINGS. They rotate with the armature. The brushes, usually made of carbon, with wires attached to them, ride against the rings. The generated voltage appears across these brushes. The elementary generator produces a voltage in the following manner (fig. 1-3). The armature loop is rotated in a clockwise direction. The initial or starting point is shown at position A. (This will be considered the zero-degree position.) At 0º_ the armature loop is perpendicular to the magnetic field. The black and white conductors of the loop are moving parallel to the field. The instant the conductors are moving parallel to the magnetic field, they do not cut any lines of flux. Therefore, no emf is induced in the conductors, and the meter at position A indicates zero. This position is called the NEUTRAL PLANE. As the armature loop rotates from position A (0º) to position B (90º), the conductors cut through more and more lines of flux, at a continually increasing angle. At 90º_ they are cutting through a maximum number of lines of flux and at maximum angle. The result is that between 0º_ and 90º_, the induced emf in the conductors builds up from zero to a maximum value. Observe that from 0º_ to 90º_, the black conductor cuts DOWN through the field. At the same time the white conductor cuts UP through the field.



The induced emfs in the conductors are series-adding. This means the resultant voltage across the brushes (the terminal voltage) is the sum of the two induced voltages. The meter at position B reads maximum value. As the armature loop continues rotating from 90º_ (position B) to 180º_ (position C), the conductors which were cutting through a maximum number of lines of flux at position B now cut through fewer lines. They are again moving parallel to the magnetic field at position C. They no longer cut through any lines of flux. As the armature rotates from 90º_ to 180º_, the induced voltage will decrease to zero in the same manner that it increased during the rotation from 0º_ to 90º_. The meter again reads zero. From 0º_ to 180º_ the conductors of the armature loop have been moving in the same direction through the magnetic field. Therefore, the polarity of the induced voltage has remained the same. This is shown by points A through C on the graph. As the loop rotates beyond 180º_ (position C), through 270º_ (position D), and back to the initial or starting point (position A), the direction of the cutting action of the conductors through the magnetic field reverses. Now the black conductor cuts UP through the field while the white conductor cuts DOWN through the field. As a result, the polarity of the induced voltage reverses. Following the sequence shown by graph points C, D, and back to A, the voltage will be in the direction opposite to that shown from points A, B, and C. The terminal voltage will be the same as it was from A to C except that the polarity is reversed (as shown by the meter deflection at position D). The voltage output waveform for the complete revolution of the loop is shown on the graph in figure



2.1.3 GENERATOR E.M.F EQUATION

Let

Φ = flux/pole in weber

Z = total number of armture conductors

= No.of slots x No.of conductors/slot

P = No.of generator poles

A = No.of parallel paths in armature

N = armature rotation in revolutions per minute (r.p.m)

E = e.m.f induced in any parallel path in armature

Generated e.m.f Eg = e.m.f generated in any one of the parallel paths i.e E.

Average e.m.f geneated /conductor = **$d\Phi/dt$** volt (n=1)

Now, flux cut/conductor in one revolution **$d\Phi = \Phi P$** Wb

No.of revolutions/second = N/60

Time for one revolution, **dt = 60/N** second

Hence, according to Faraday's Laws of Electroagnetic Induction,

E.M.F generated/conductor is

$$\frac{d\varnothing}{dt} = \frac{\varnothing PN}{60}$$

For a simplex wave-wound generator

No.of parallel paths = 2

No.of conductors (in series) in one path = Z/2

E.M.F. generated/path is

$$\frac{\varnothing\, PN}{60} \times \frac{Z}{2} = \frac{\varnothing ZPN}{120} \text{ volt}$$

For a simplex lap-wound generator

No.of parallel paths = P

No.of conductors (in series) in one path = Z/P

E.M.F.generated/path

$$\frac{\varnothing\, PN}{60} \times \frac{Z}{P} = \frac{\varnothing ZN}{60} \text{ volt}$$

In general generated e.m.f

$$E_g = \frac{\varnothing ZN}{60} \times \left(\frac{P}{A}\right) \text{ volt}$$

where A = 2 for simplex wave-winding

A = P for simplex lap-winding

2.1.4 TYPES OF D.C. GENERATORS

The magnetic field in a d.c. generator is normally produced by electromagnets rather than permanent magnets. Generators are generally classified according to their methods of field excitation. On this basis, d.c. generators are divided into the following two classes:

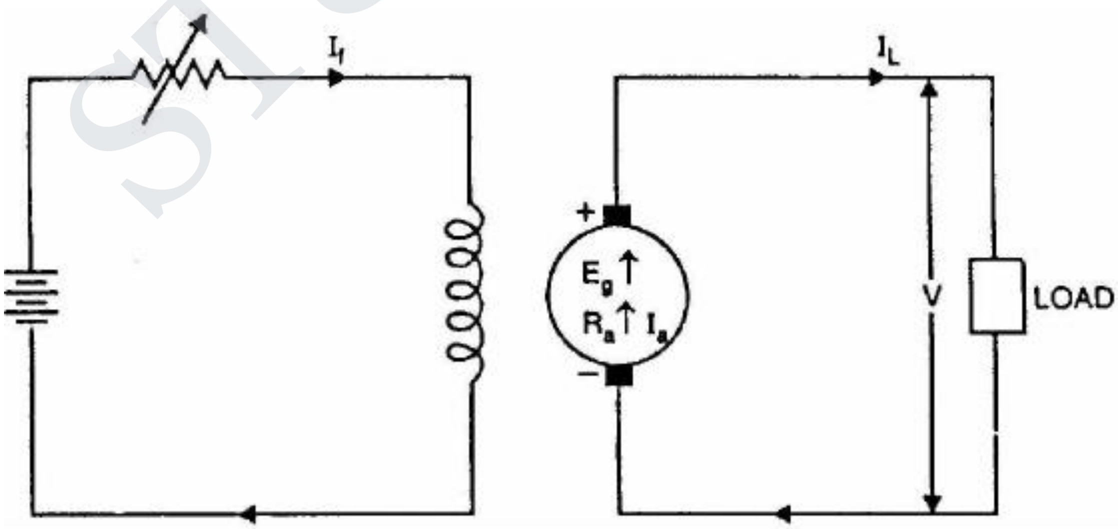
(i) Separately excited d.c. generators

(ii) Self-excited d.c. generators

The behaviour of a d.c. generator on load depends upon the method of field excitation adopted.

(i)Separately Excited D.C. Generators

A d.c. generator whose field magnet winding is supplied from an independent external d.c. source (e.g., a battery etc.) is called a separately excited generator. Fig shows the connections of a separately excited generator. The voltage output depends upon the speed of rotation of armature and the field current (Eg =PfØ ZN/60 A). The greater the speed and field current, greater is the generated e.m.f. It may be noted that separately excited d.c. generators are rarely used in practice. The d.c. generators are normally of self-excited type.



Armature current, Ia = IL
Terminal voltage, V = Eg - IaRa
Electric power developed = EgIa
Power delivered to load = EgIa - Ia^{2}Ra

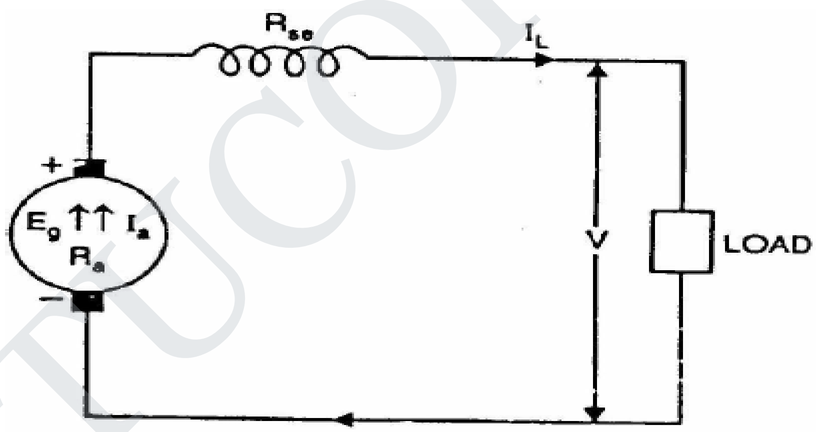
(ii)Self-Excited D.C. Generators

A d.c. generator whose field magnet winding is supplied current from the output of the generator itself is called a self-excited generator. There are three types of self-excited generators depending upon the manner in which the field winding isconnected to the armature, namely;

(a) Series generator;
(b) Shunt generator;
(c) Compound generator

(a) Series generator

In a series wound generator, the field winding is connected in series with armature winding so that whole armature current flows through the field winding as well as the load. Fig. shows the connections of a series wound generator. Since the field winding carries the whole of load current, it has a few turns of thick wire having low resistance. Series generators are rarely used except for special purposes e.g., as boosters.

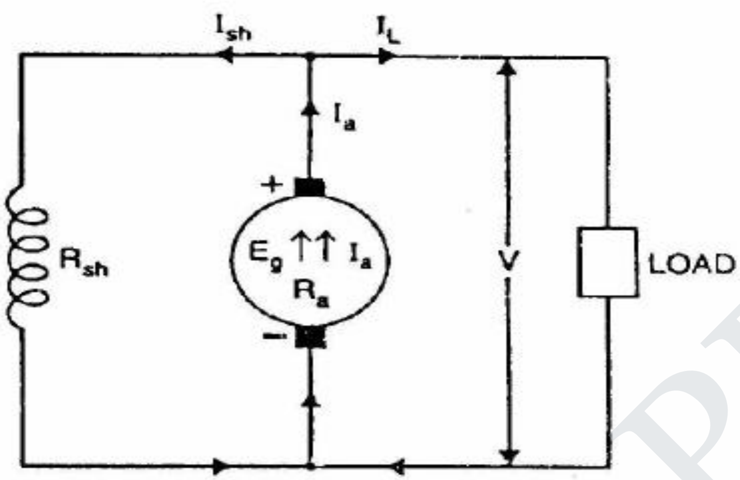


Armature current, Ia = Ise = IL = I(say)
Terminal voltage, V = EG - I(Ra + Rse)
Power developed in armature = EgIa
Power delivered to load

$$= E_g I_a - I_a^2(R_a + R_{se}) = I_a[E_g - I_a(R_a - R_{se})] = VI_a \text{ or } VI_L$$

(b) Shunt generator

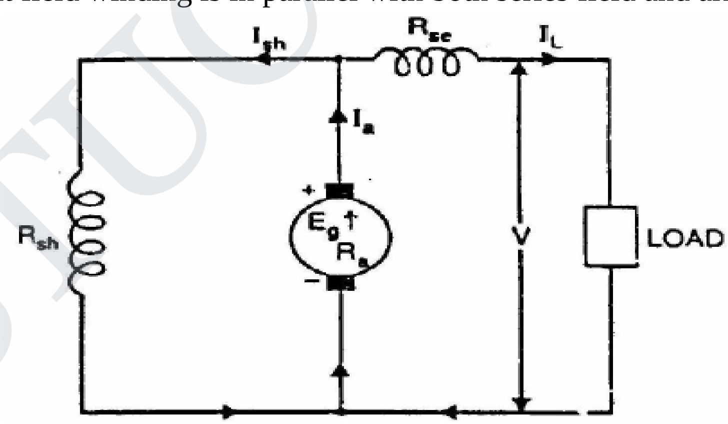
In a shunt generator, the field winding is connected in parallel with the armature winding so that terminal voltage of the generator is applied across it. The shunt field winding has many turns of fine wire having high resistance. Therefore, only a part of armature current flows through shunt field winding and the rest flows through the load. Fig. shows the connections of a shunt-wound generator.



Shunt field current, Ish = V/Rsh
Armature current, Ia = IL + Ish
Terminal voltage, V = Eg - IaRa
Power developed in armature = EgIa
Power delivered to load = VI_L

(c) Compound generator

In a compound-wound generator, there are two sets of field windings on each pole—one is in series and the other in parallel with the armature. A compound wound generator may be: Short Shunt in which only shunt field winding is in parallel with the armature winding.Long Shunt in which shunt field winding is in parallel with both series field and armature winding



Short shunt

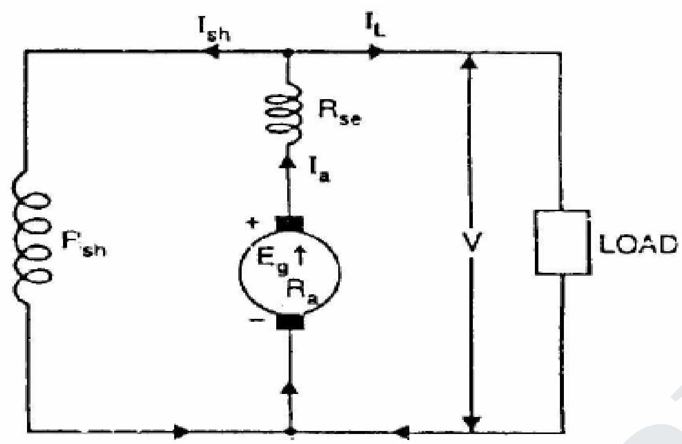
Series field current, $I_{se} = I_L$

Shunt field current, $I_{sh} = \dfrac{V + I_{se}R_{se}}{R_{sh}}$

Terminal voltage, $V = E_g - I_aR_a - I_{se}R_{se}$

Power developed in armature $= E_gI_a$

Power delivered to load $= VI_L$



Long shunt

Series field current, $I_{se} = I_a = I_L + I_{sh}$

Shunt field current, $I_{sh} = V/R_{sh}$

Terminal voltage, $V = E_g - I_a(R_a + R_{se})$

Power developed in armature $= E_g I_a$

Power delivered to load $= VI_L$

2.1.5 GENERATOR CHARACTERISTICS:

The three most important characteristics or curves of a d.c generator are

1. OpenCircuitCharacteristic (O.C.C.)

This curve shows the relation between the generated e.m.f. at no-load (E0) and the field current (If) at constant speed. It is also known as magnetic characteristic or no-load saturation curve. Its shape is practically the same for all generators whether separately or self-excited. The data for O.C.C. curve are obtained experimentally by operating the generator at no load and constant speed and recording the change in terminal voltage as the field current is varied.

2. Internal or Total characteristic (E/Ia)

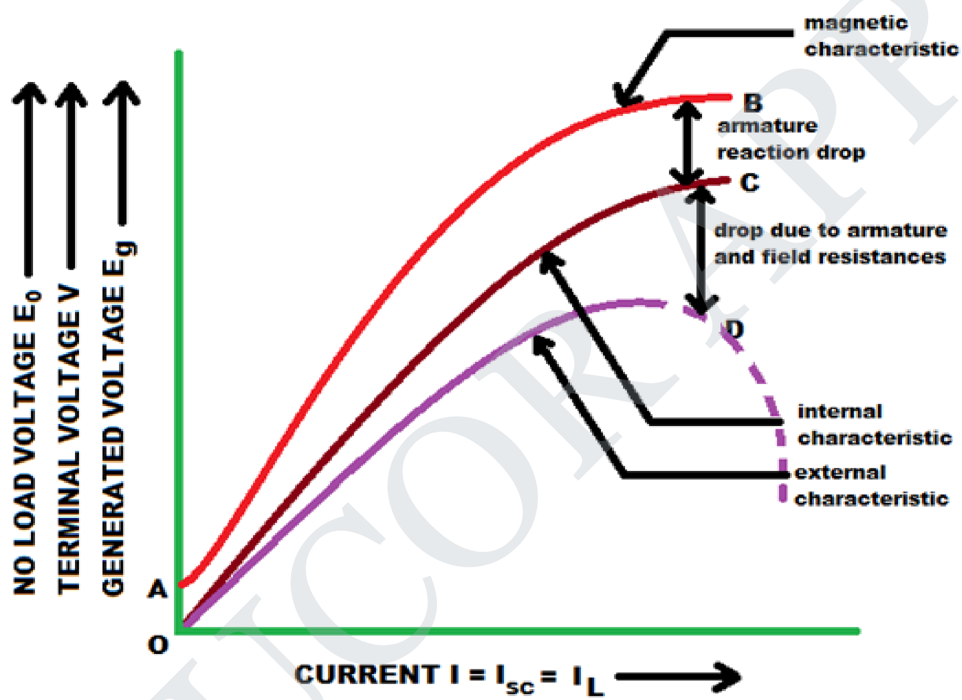
This curve shows the relation between the generated e.m.f. on load (E) and the armature current (Ia). The e.m.f. E is less than E0 due to the demagnetizing effect of armature reaction. Therefore, this curve will lie below the open circuit characteristic (O.C.C.). The internal characteristic is of interest chiefly to the designer. It cannot be obtained directly by experiment. It is because a voltmeter cannot read the e.m.f. generated on load due to the voltage drop in armature resistance. The internal characteristic can be obtained from external characteristic if winding resistances are known because armature reaction effect is included in both characteristics

3. External characteristic (V/IL)

This curve shows the relation between the terminal voltage (V) and load current (IL). The terminal voltage V will be less than E due to voltage drop in the armature circuit. Therefore, this curve will lie below the internal characteristic. This characteristic is very important in determining the suitability of a generator for a given purpose. It can be obtained by making simultaneous

2.1.5.1 characteristics Series of DC generator:

Fig. shows the connections of a series wound generator. Since there is only one current (that which flows through the whole machine), the load currentis the same as the exciting current.



(i)O.C.C.

Curve 1 shows the open circuit characteristic (O.C.C.) of a series generator. It can be obtainedexperimentally by disconnecting the field winding from the machine and exciting it from aseparate d.c. source

(ii) Internal characteristic

Curve 2 shows the total or internal characteristic of a series generator. It gives the relation between the generated e.m.f. E. on load and armature current. Due to armature reaction, the flux in the machine will be less than the flux at no load. Hence, e.m.f. E generated under load conditions will be less than the e.m.f. EO generated under no load conditions. Consequently, internal characteristic curve generated under no load conditions. Consequently, internal characteristic curve lies below the O.C.C. curve; the difference between them representing the effect of armature reaction

(iii)Externalcharacteristic

Curve 3 shows the external characteristic of a series generator. It gives the relation between terminal voltage and load current IL.

V= E-Ia(Ra+Rse)

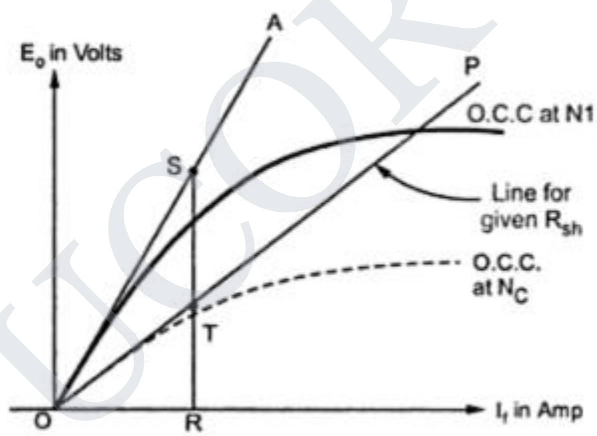
Therefore, external characteristic curve will lie below internal characteristic curve by an amount equal to ohmic drop[i.e., Ia(Ra+Rse)] in the machine. The internal and external characteristics of a d.c. series generator can be plotted from one another as shown in Fig. Suppose we are given the internal characteristic of the generator. Let the line OC represent the resistance of the whole machine i.e. Ra+Rse.If the load current is OB, drop in the machine is AB i.e.

AB = Ohmic drop in the machine = OB(Ra+Rse)

Now raise a perpendicular from point B and mark a point b on this line such that ab = AB. Then point b will lie on the external characteristic of the generator. Following similar procedure, other points of external characteristic can be located. It is easy to see that we can also plot internal characteristic from the external characteristic.

Characteristics Shunt DC generator:

Fig shows the connections of a shunt wound generator. The armature current Ia splits up into two parts; a small fraction Ish flowing through shunt field winding while the major part IL goes to the external load.



(i) O.C.C.

The O.C.C. of a shunt generator is similar in shape to that of a series generator as shown in Fig. The line OA represents the shunt field circuit resistance. When the generator is run at normal speed, it will build up a voltage OM. At no-load, the terminal voltage of the generator will be constant (= OM) represented by the horizontal dotted line MC.

(ii)Internal characteristic

When the generator is loaded, flux per pole is reduced due to armature reaction. Therefore, e.m.f. E generated on load is less than the e.m.f. generated at no load.As a result, the internal characteristic (E/Ia) drops down slightly as shown in Fig.

(iii)External characteristic

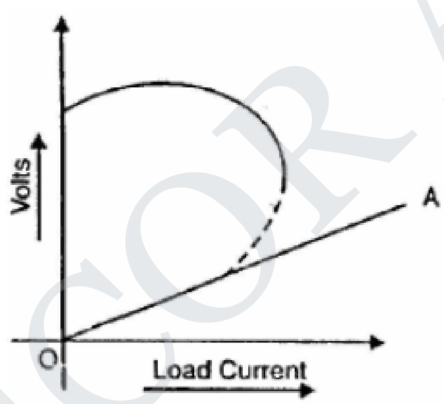
Curve 2 shows the external characteristic of a shunt generator. It gives the relation between terminal voltage V and load current IL.

$V = E – I_aR_a = E -(I_L +I_{sh})R_a$

Therefore, external characteristic curve will lie below the internal characteristic curve by an amount equal to drop in the armature circuit [i.e., $(I_L +I_{sh})R_a$] as shown in Fig

Critical External Resistance for Shunt Generator

If the load resistance across the terminals of a shunt generator is decreased, then load current increase? However, there is a limit to the increase in load current with the decrease of load resistance. Any decrease of load resistance beyond this point, instead of increasing the current, ultimately results in reduced current. Consequently, the external characteristic turns back (dottedcurve) as shown in Fig. The tangent OA to the curve represents the minimum external resistance required to excite the shunt generator on load and is called critical external resistance. If the resistance of the external circuit is less than the critical external resistance (represented by tangent OA in Fig, the machine will refuse to excite or will de-excite if already running This means that external resistance is so low as virtually to short circuit the machine and so doing away with its excitation.



There are two critical resistances for a shunt generator viz.,

(i) critical field resistance

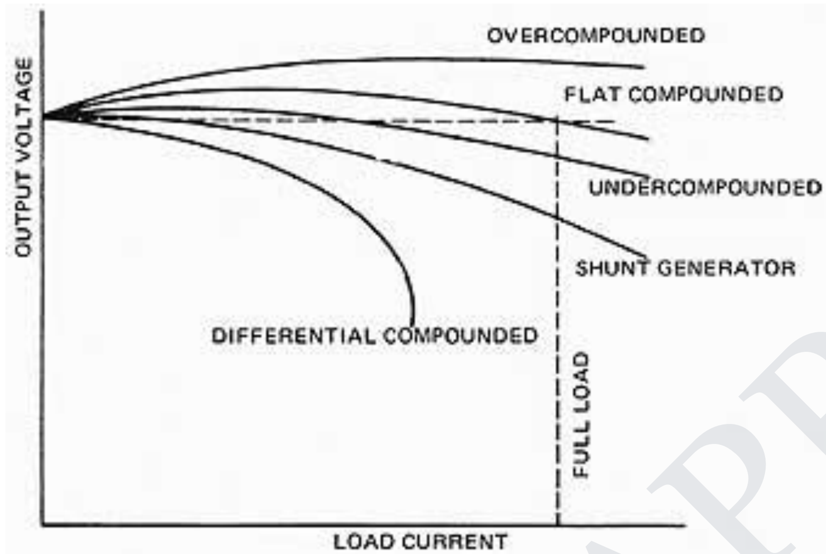
(ii) critical external resistance. For the shunt generator to build up voltage, the former should not be exceeded and the latter must not be gone below

Characteristics compound generator:

In a compound generator, both series and shunt excitation are combined as shown in Fig. The shunt winding can be connected either across the armature only (short-shunt connection S) or across armature plus series field (long-shunt connection G). The compound generator can be cumulatively compounded or differentially compounded generator. The latter is rarely used in practice. Therefore, we shall discuss the characteristics of cumulatively compounded generator. It may be noted that external characteristics of long and short shunt compound generators are almost identical.

External characteristic

Fig. shows the external characteristics of a cumulatively compounded generator. The series excitation aids the shunt excitation. The degree of compounding depends upon the increase in series excitation with the increase in load current.



(i) If series winding turns are so adjusted that with the increase in load current the terminal voltage increases, it is called over-compounded generator. In such a case, as the load current increases, the series field m.m.f. increases and tends to increase the flux and hence the generated voltage. The increase in generated voltage is greater than the IaRa drop so that instead of decreasing, the terminal voltage increases as shown by curve A in Fig.
(ii) If series winding turns are so adjusted that with the increase in load current, the terminal voltage substantially remains constant, it is called flat-compounded generator. The series winding of such a machine has lesser number of turns than the one in over-compounded machine and, therefore, does not increase the flux as much for a given load current. Consequently, the full-load voltage is nearly equal to the no-load voltage as indicated by curve B in Fig
(iii) If series field winding has lesser number of turns than for a flat compounded machine, the terminal voltage falls with increase in load current as indicated by curve C m Fig. Such a machine is called under-compounded generator.

2.1.6 APPLICATIONS OF DC GENERATOR

DC Separately Exited Generator:

As a supply source to DC Motors, whose speed is to be controlled for certain applications. Where a wide range of voltage is required for the testing purposes.

DC Shunt Generator

The terminal voltage of DC shunt generator is more or less constant from no load to full load .Therefore these generators are used where constant voltage is required.

- For electro plating
- Battery charging
- For excitation of Alternators.

DC Series Generator

The terminal voltage of series generator increases with load current from no load to full load .Therefore these generators are,

- Used as Boosters
- Used for supply to arc Lamps

DC Compound Generator:

Differential Compound generators are used to supply dc welding machines. Level compound generators are used to supply power for offices, hostels and Lodges etc. Over compound generators are used to compensate the voltage drop in Feeders.

2.2 DC MOTOR - INTRODUCTION

A machine that converts dc power into mechanical energy is known as dc motor. Its operation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force. The direction of the force is given by Fleming's left hand rule.

How DC motors work?

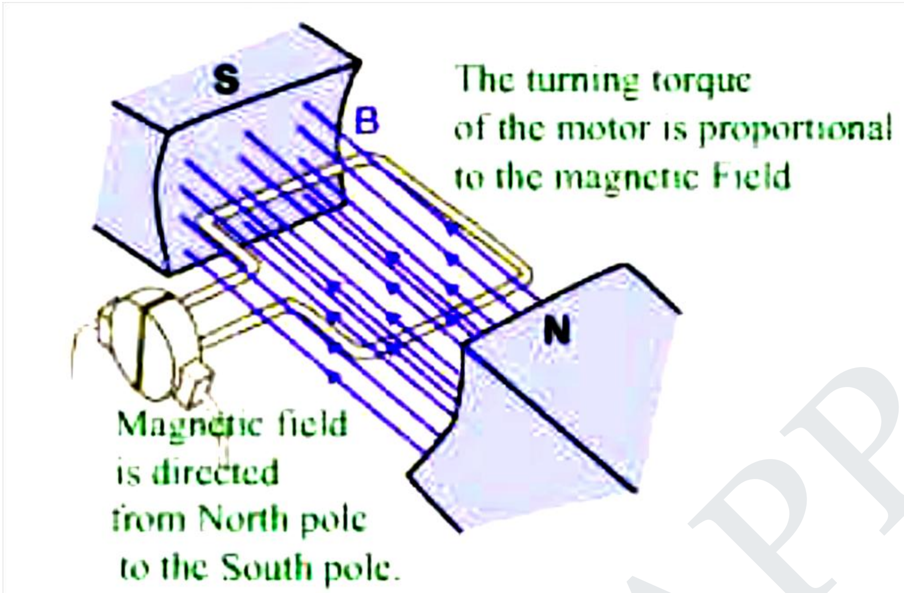
There are different kinds of D.C. motors, but they all work on the same principles.When a permanent magnet is positioned around a loop of wire that is hooked up to a D.C. power source, we have the basics of a D.C. motor. In order to make the loop of wire spin, we have to connect a battery or DC power supply between its ends, and support it so it can spin about its axis. To allow the rotor to turn without twisting the wires, the ends of the wire loop are connected to a set of contacts called the commutator, which rubs against a set of conductors called the brushes. The brushes make electrical contact with the commutator as it spins, and are connected to the positive and negative leads of the power source, allowing electricity to flow through the loop. The electricity flowing through the loop creates a magnetic field that interacts with the magnetic field of the permanent magnet to make the loop spin.

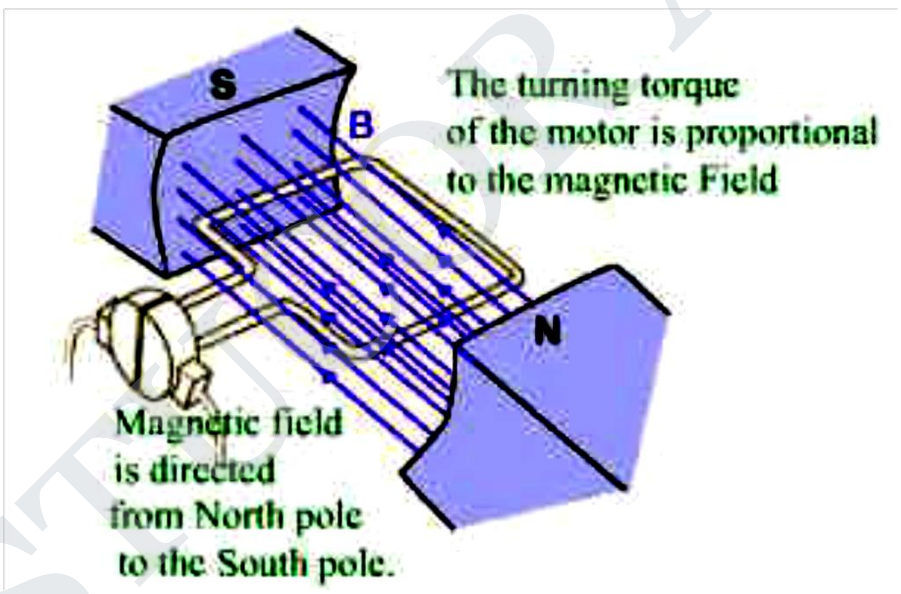
2.2.1 PRINCIPLES OF OPERATION

It is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming's Left-hand rule and whose magnitude is given by

Force, $F = B\,I\,l$ newton

Where B is the magnetic field in weber/m^2.
I is the current in amperes and
l is the length of the coil in meter.
The force, current and the magnetic field are all in different directions.
If an Electric current flows through two copper wires that are between the poles of a magnet, an upward force will move one wire up and a downward force will move the other wire down.





2.2.2 BACK OR COUNTER EMF

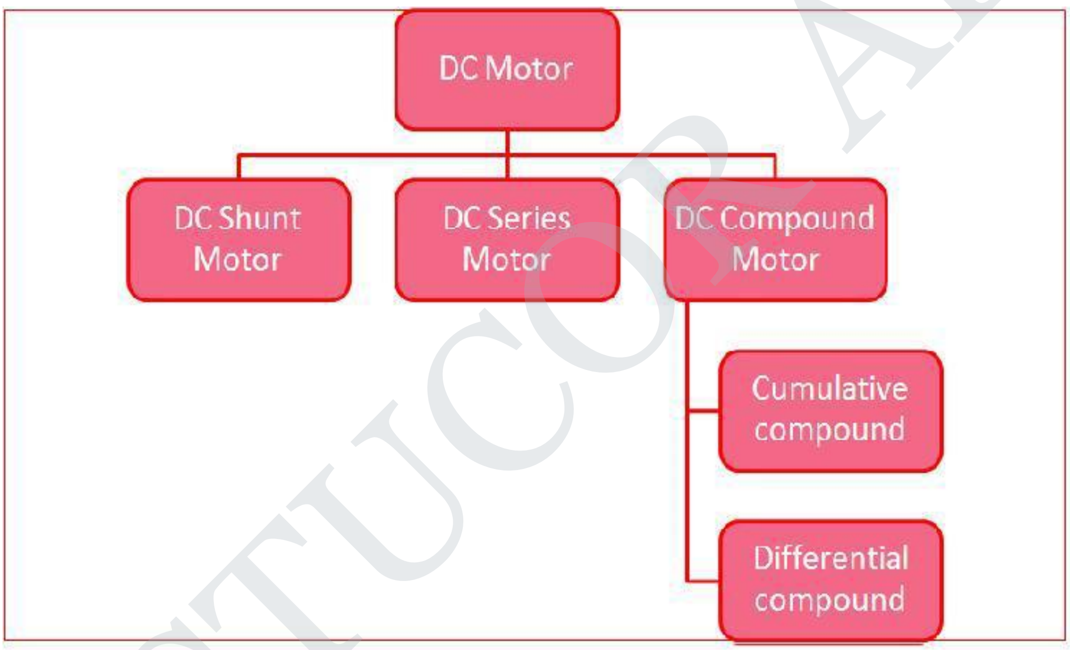
When the armature of a d.c. motor rotates under the influence of the driving torque, the armature conductors move through the magnetic field and hence an e.m.f. is induced in them. The induced e.m.f. acts in opposite direction to the applied voltage V(Lenz's law) and is known as back orcounter e.m.f. Eb.

2.2.3 SIGNIFICANCE OF BACK E.M.F

The presence of back e.m.f. makes the d.c. motor a self-regulating machine i.e., it makes the motor to draw as much armature current as is just sufficient to develop the torque required by the load. Back e.m.f. in a d.c. motor regulates the flow of armature current i.e., it automatically changes the armature current to meet the load requirement.

2.2.4 CLASSIFICATION OF MOTOR

DC motors are more common than we may think. A car may have as many as 20 DC motors to drive fans, seats, and windows. They come in three different types, classified according to the electrical circuit used. In the shunt motor, the armature and field windings are connected in parallel, and so the currents through each are relatively independent. The current through the field winding can be controlled with a field rheostat (variable resistor), thus allowing a wide variation in the motor speed over a large range of load conditions. This type of motor is used for driving machine tools or fans, which require a wide range of speeds.



In the series motor, the field winding is connected in series with the armature winding, resulting in a very high starting torque since both the armature current and field strength run at their maximum. However, once the armature starts to rotate, the counter EMF reduces the current in the circuit, thus reducing the field strength. The series motor is used where a large starting torque is required, such as in automobile starter motors, cranes, and hoists.

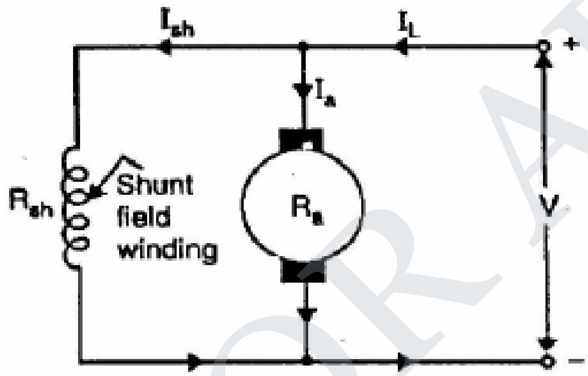
The compound motor is a combination of the series and shunt motors, having parallel and series field windings. This type of motor has a high starting torque and the ability to vary the speed and is used in situations requiring both these properties such as punch presses, conveyors and elevators.

2.2.5 DC MOTOR TYPES

1. Shunt Wound
2. Series Wound
3. Compound wound

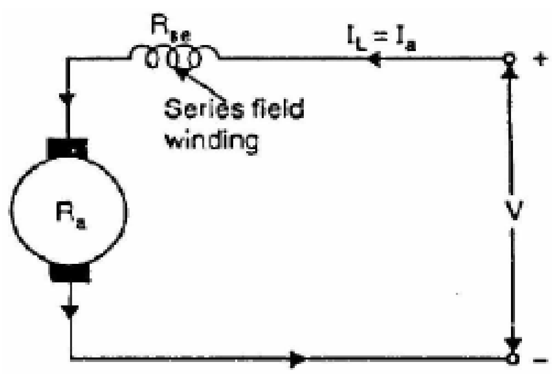
1. Shunt Motor

In shunt wound motor the field winding is connected in parallel with armature. The current through the shunt field winding is not the same as the armature current. Shunt field windings are designed to produce the necessary m.m.f. by means of a relatively large number of turns of wire having high resistance. Therefore, shunt field current is relatively small compared with the armature current



2. Series Motor

In series wound motor the field winding is connected in series with the armature. Therefore, series field winding carries the armature current. Since the current passing through a series field winding is the same as the armature current, series field windings must be designed with much fewer turns than shunt field windings for the same mmf.Therefore, a series field winding has a relatively small number of turns of thick wire and, therefore, will possess a low resistance.



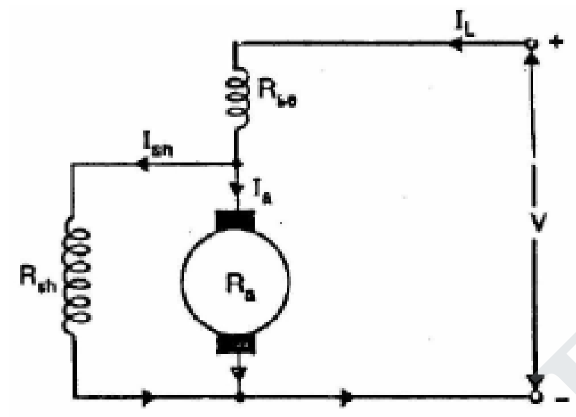
3. **Compound Wound Motor**

Compound wound motor has two field windings; one connected in parallel with the armature and the other in series with it. There are two types of compound motor connections

1) Short-shunt connection

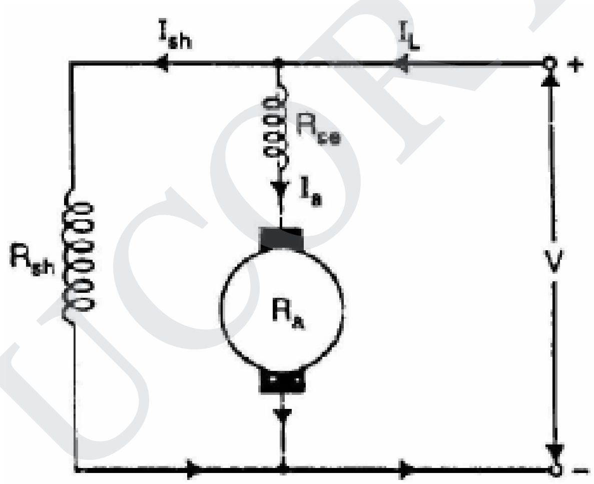
2) Long shunt connection

When the shunt field winding is directly connected across the armature terminals it is called short-shunt connection.



Short-shunt connection

When the shunt winding is so connected that it shunts the series combination of armature and series field it is called long-shunt connection.



Long-shunt connection

2.2.6 VOLTAGE EQUATION OF MOTORS

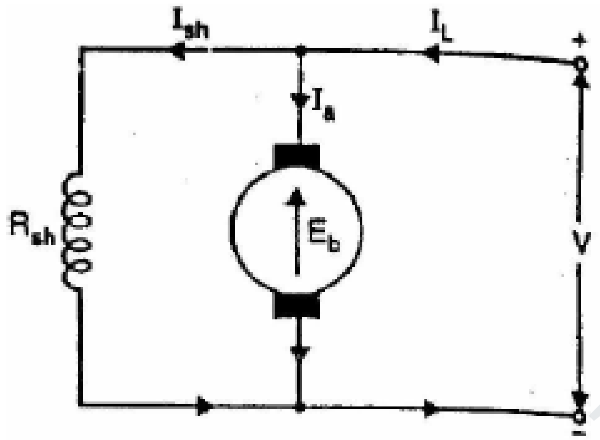
Let in a d.c. motor

V = applied voltage

E_b = back e.m.f.

R_a = armature resistance

I_a = armature current



Since back e.m.f. Eb acts in opposition to the applied voltage V, the net voltage across the armature circuit is V-Eb.
The armature current Ia is given by

$$I_a = \frac{V - E_b}{R_a}$$

$$V = E_b + I_a R_a$$

2.2.7 APPLICATIONS OF DC MOTORS:

1. D.C Shunt Motors:

It is a constant speed motor.Where the speed is required to remain almost constant from noload to full load.Where the load has to be driven at a number of speeds and any one of which is nearly constant.
Industrial use:

- Lathes
- Drills
- Boring mills
- Shapers
- Spinning and Weaving machines.

2. D.CSeries motor:

It is a variable speed motor.The speed is low at high torque.At light or no load ,the motor speed attains dangerously high speed.The motor has a high starting torque.(elevators,electric traction)
Industrial Uses:

- Electric traction
- Cranes
- Elevators
- Air compressor

3. D.C Compound motor:

Differential compound motors are rarely used because of its poor torque characteristics. Industrial uses:

- PressesShears
- Reciprocating machine.

2.3 TRANSFORMER – INTRODUCTION

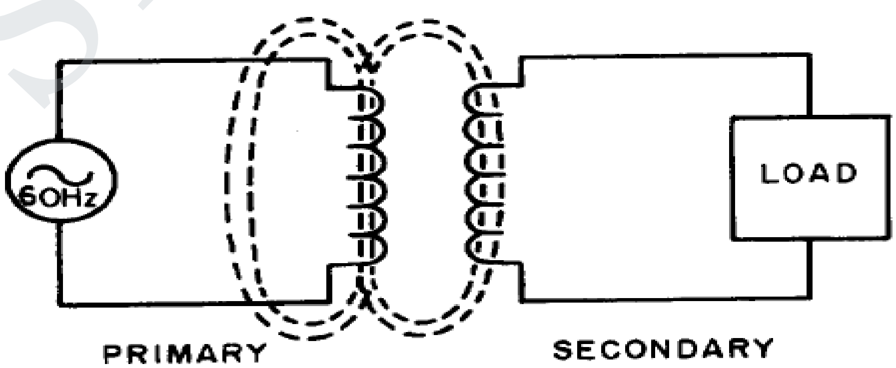
A TRANSFORMER is a device that transfers electrical energy from one circuit to another by electromagnetic induction (transformer action). The electrical energy is always transferred without a change in frequency, but may involve changes in magnitudes of voltage and current. Because a transformer works on the principle of electromagnetic induction, it must be used with an input source voltage that varies in amplitude. There are many types of power that fit this description; for ease of explanation and understanding, transformer action will be explained using an ac voltage as the input source.

2.3.1 BASIC OPERATION OF A TRANSFORMER

In its most basic form a transformer consists of:

- A primary coil or winding.
- A secondary coil or winding.
- A core that supports the coils or windings.

Refer to the transformer circuit in figure as you read the following explanation: The primary winding is connected to a 60 hertz ac voltage source. The magnetic field (flux) builds up (expands) and collapses (contracts) about the primary winding. The expanding and contracting magnetic field around the primary winding cuts the secondary winding and induces an alternating voltage into the winding. This voltage causes alternating current to flow through the load. The voltage may be stepped up or down depending on the design of the primary and secondary windings.



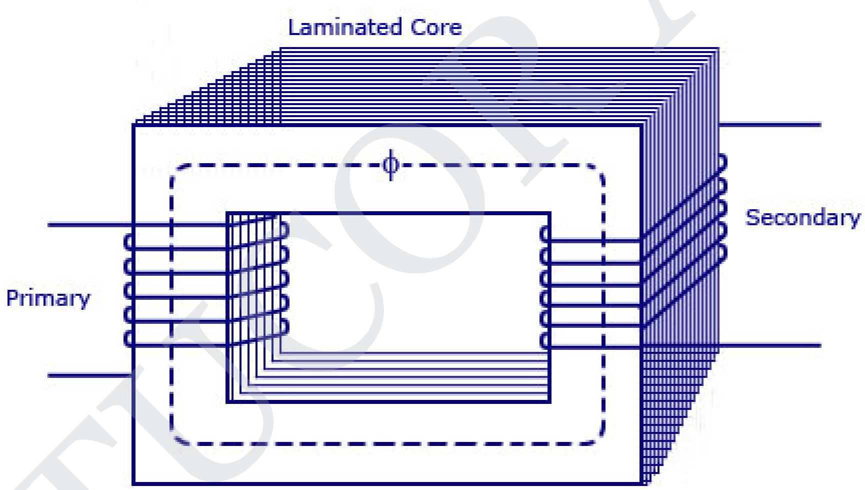
2.3.2 AN IDEAL TRANSFORMER

An ideal transformer is shown in the adjacent figure. Current passing through the primary coil creates a magnetic field. The primary and secondary coils are wrapped around a core of very high magnetic permeability, such as iron, so that most of the magnetic flux passes through both the primary and secondary coils.

2.3.3 BASIC WORKING PRINCIPLE OF TRANSFORMER

A transformer can be defined as a static device which helps in the transformation of electric power in one circuit to electric power of the same frequency in another circuit. The voltage can be raised or lowered in a circuit, but with a proportional increase or decrease in the current ratings.

The main principle of operation of a transformer is mutual inductance between two circuits which is linked by a common magnetic flux. A basic transformer consists of two coils that are electrically separate and inductive, but are magnetically linked through a path of reluctance. The working principle of the transformer can be understood from the figure below.



As shown above the transformer has primary and secondary windings. The core laminations are joined in the form of strips in between the strips you can see that there are some narrow gaps right through the cross-section of the core. These staggered joints are said to be 'imbricated'. Both the coils have high mutual inductance. A mutual electro-motive force is induced in the transformer from the alternating flux that is set up in the laminated core, due to the coil that is connected to a source of alternating voltage. Most of the alternating flux developed by this coil is linked with the other coil and thus produces the mutual induced electro-motive force. The so produced electro-motive force can be explained with the help of Faraday's laws of Electromagnetic Induction as

$$e=M*dI/dt$$

If the second coil circuit is closed, a current flows in it and thus electrical energy is transferred magnetically from the first to the second coil.

The alternating current supply is given to the first coil and hence it can be called as the primary winding. The energy is drawn out from the second coil and thus can be called as the secondary winding.
In short, a transformer carries the operations shown below:

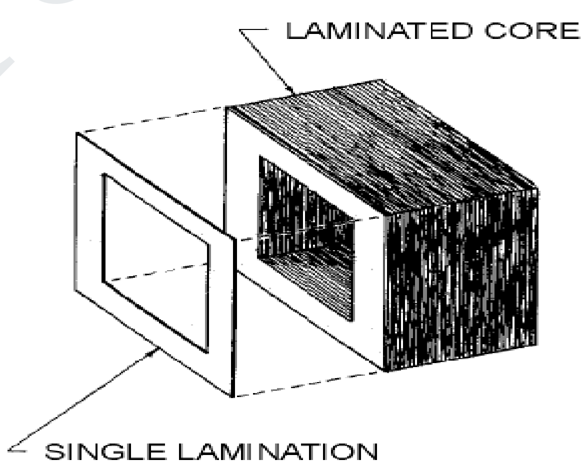
- Transfer of electric power from one circuit to another.
- Transfer of electric power without any change in frequency.
- Transfer with the principle of electromagnetic induction.
- The two electrical circuits are linked by mutual induction

2.3.4 TRANSFORMER CONSTRUCTION

Two coils of wire (called windings) are wound on some type of core material. In some cases the coils of wire are wound on a cylindrical or rectangular cardboard form. In effect, the core material is air and the transformer is called an AIR-CORE TRANSFORMER. Transformers used at low frequencies, such as 60 hertz and 400 hertz, require a core of low-reluctance magnetic material, usually iron. This type of transformer is called an IRON-CORE TRANSFORMER. Most power transformers are of the iron-core type.
The principle parts of a transformer and their functions are:

- The CORE, which provides a path for the magnetic lines of flux.
- The PRIMARY WINDING, which receives energy from the ac source.
- The SECONDARY WINDING, which receives energy from the primary winding and delivers it to the load.
- The ENCLOSURE, which protects the above components from dirt, moisture, and mechanical damage.

(i) CORE



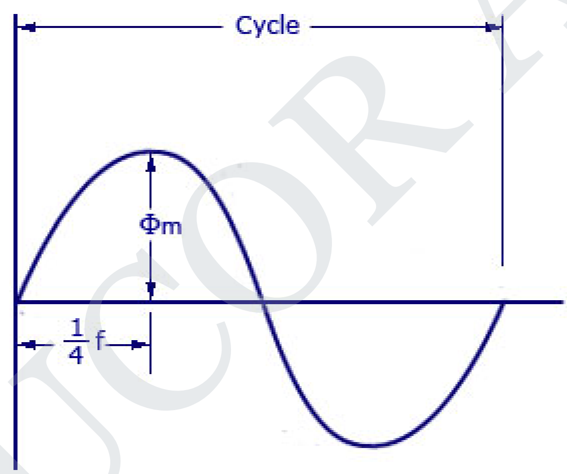
There are two main shapes of cores used in laminated-steel-core transformers. One is the HOLLOWCORE, so named because the core is shaped with a hollow square through the center. This shape of core. Notice that the core is made up of many laminations of steel it shows how the transformer windings are wrapped around both sides of the core.

(ii) WINDINGS

As stated above, the transformer consists of two coils called WINDINGS which are wrapped around a core. The transformer operates when a source of ac voltage is connected to one of the windings and a load device is connected to the other. The winding that is connected to the source is called the PRIMARY WINDING. The winding that is connected to the load is called the SECONDARY WINDING. The primary is wound in layers directly on a rectangular cardboard form.

2.3.5 EMF Equation of Transformer:

Let the applied voltage V1 applied to the primary of a transformer, with secondary open-circuited, be sinusoidal (or sine wave). Then the current I1, due to applied voltage V1, will also be a sine wave. The mmf N1 I1 and core flux Ø will follow the variations of I1 closely. That is the flux is in time phase with the current I1 and varies sinusoidally.



Let,

N_A = Number of turns in primary

N_B = Number of turns in secondary

$Ø_{max}$ = Maximum flux in the core in webers = B_{max} X A

f = Frequency of alternating current input in hertz (H_Z)

As shown in figure above, the core flux increases from its zero value to maximum value $Ø_{max}$ in one quarter of the cycle , that is in ¼ frequency second.

Therefore, average rate of change of flux = $Ø_{max}$/ ¼ f = 4f $Ø_{max}$Wb/s

Now, rate of change of flux per turn means induced electro motive force in volts.

Therefore,

average electro-motive force induced/turn = 4f $Ø_{max}$volt

If flux Ø varies sinusoidally, then r.m.s value of induced e.m.f is obtained by multiplying the average value with form factor.

Form Factor = r.m.s. value/average value = 1.11

Therefore, r.m.s value of e.m.f/turn = 1.11 X 4f $Ø_{max}$ = 4.44f $Ø_{max}$

Now, r.m.s value of induced e.m.f in the whole of primary winding

= (induced e.m.f./turn) X Number of primary turns

Therefore,

$E_A = 4.44f\, N_A Ø_{max} = 4.44fN_A B_m A$

Similarly, r.m.s value of induced e.m.f in secondary is

$E_B = 4.44f\, N_B Ø_{max} = 4.44fN_B B_m A$

In an ideal transformer on no load, $V_A = E_A$ and $V_B = E_B$, where V_B is the terminal voltage

Voltage Transformation Ratio.

The ratio of secondary voltage to primary voltage is known as the voltage transformation ratio and is designated by letter K. i.e.

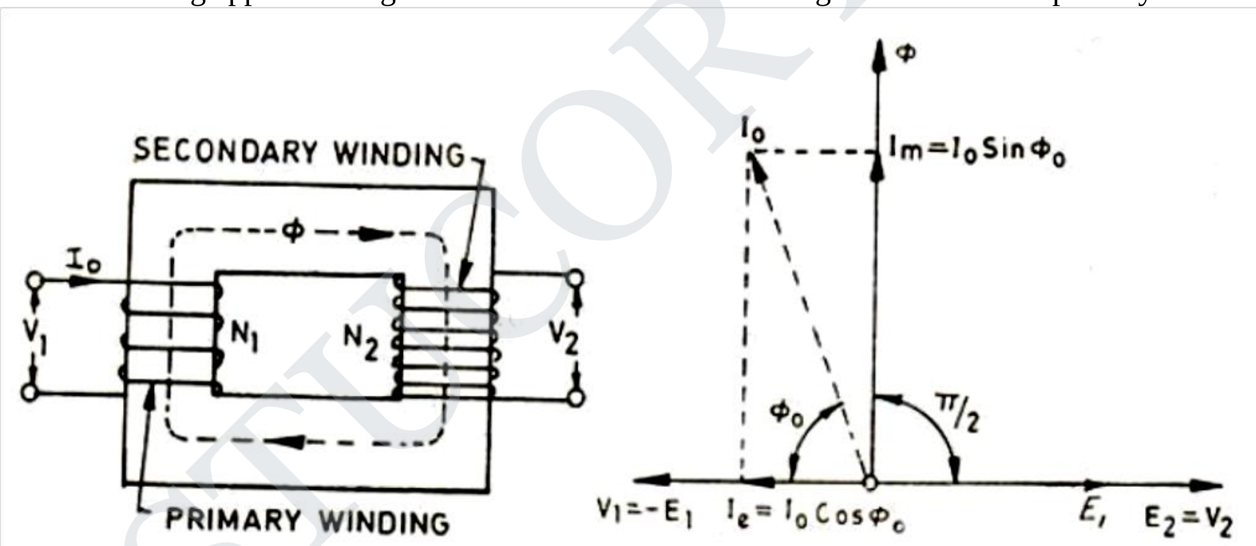
Voltage transformation ratio, K = V2/V1 = E2/E1 = N2/N1

Current Ratio.

The ratio of secondary current to primary current is known as current ratio and is reciprocal of voltage transformation ratio in an ideal transformer.

2.3.6 Transformer on No Load.

When the primary of a transformer is connected to the source of an ac supply and the secondary is open circuited, the transformer is said to be on no load. The Transformer on No Load alternating applied voltage will cause flow of an alternating current I0 in the primary



winding, which will create alternating flux Ø. No-load current I0, also known as excitation or exciting current, has two components the magnetizing component Im and the energy component Ie. Im is used to create the flux in the core and Ie is used to overcome the hysteresis and eddy current losses occurring in the core in addition to small amount of copper losses occurring in the primary only (no copper loss occurs in the secondary, because it carries no current, being open circuited.)

From vector diagram shown in above it is obvious that

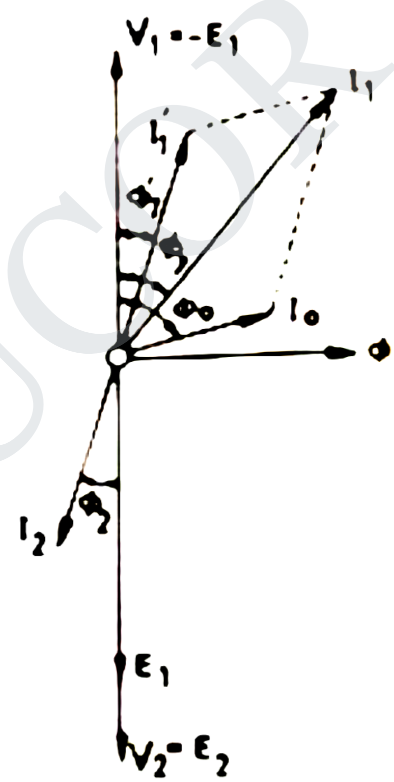
1. Induced emfs in primary and secondary windings, E1 and E2 lag the main flux Ø by and are in phase with each other.

2. Applied voltage to primary V1 and leads the main flux Ø by and is in phase opposition to E1.

3. Secondary voltage V2 is in phase and equal to E2 since there is no voltage drop in secondary.
4. Im is in phase with Ø and so lags V1 by
5. Ie is in phase with the applied voltage V1.
6. Input power on no load = V1Ie = V1I0 cos Ø0 where Ø0 = $\tan^{-1}$

2.3.7 Transformer on Load:

The transformer is said to be loaded, when its secondary circuit is completed through an impedance or load. The magnitude and phase of secondary current (i.e. current flowing through secondary) I2 with respect to secondary terminals depends upon the characteristic of the load i.e. current I2 will be in phase, lag behind and lead the terminal voltage V+2+ respectively when the load is non-inductive, inductive and capacitive. The net flux passing through the core remains almost constant from no-load to full load irrespective of load conditions and so core losses remain almost constant from no-load to full load. Vector diagram for an ideal transformer supplying inductive load is shown



Resistance and Leakage Reactance In actual practice, both of the primary and secondary windings have got some ohmic resistance causing voltage drops and copper losses in the windings. In actual practice, the total flux created does not link both of the primary and secondary windings but is divided into three components namely the main or mutual flux Ø linking both of the primary and secondary windings, primary leakage flux $ØL_1$ linking with primary winding only and secondary leakage flux $ØL_2$ linking with secondary winding only. The primary leakage flux $ØL_1$ is produced by primary ampere-turns and is proportional to primary current, number of primary turns being fixed. The primary leakage flux $ØL_1$ is in phase with I_1 and produces self induced emf $ØL_1$ is in phase with I_1 and produces self induced emf EL_1 given as 2f L_1 I_1 in the primary winding.

The self induced emf divided by the primary current gives the reactance of primary and is denoted by X1.

i.e. $X1 = EL1/I1 = 2\pi fL1I1/I1 = 2FL1$,

Similarly leakage reactance of secondary $X2 = EL2/E2 = 2f\pi L2I2/I2 = 2\pi fL2$

Equivalent Resistance and Reactance. The equivalent resistances and reactance's of transformer windings referred to primary and secondary sides are given as below Referred to primary side Equivalent resistance,

Equivalent resistance, = X'1 = Referred to secondary side

Equivalent resistance,

Equivalent resistance, = $X2 + K^2X1$

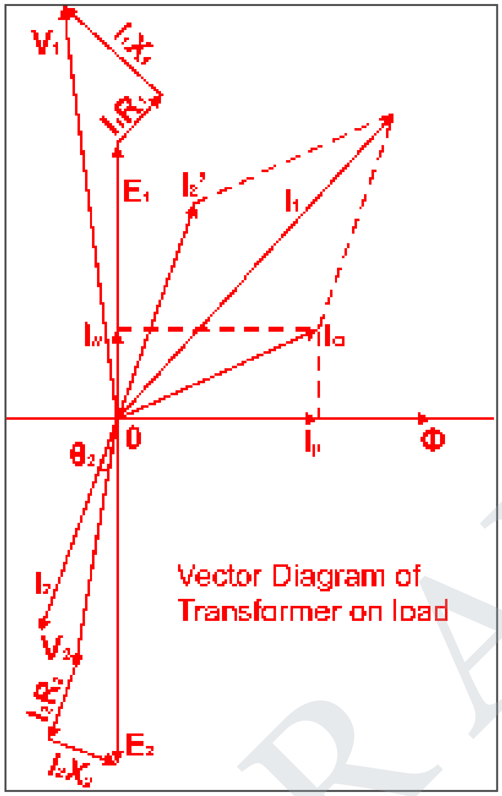
Where K is the transformation ratio.

2.3.8 EQUIVALENT CIRCUIT OF TRANSFORMER

Equivalent impedance of transformer is essential to be calculated because the electrical power transformer is an electrical power system equipment for estimating different parameters of electrical power system which may be required to calculate total internal impedance of an electrical power transformer, viewing from primary side or secondary side as per requirement. This calculation requires **equivalent circuit of transformer referred to primary** or **equivalent circuit of transformer referred to secondary** sides respectively. Percentage impedance is also very essential parameter of transformer. Special attention is to be given to this parameter during installing a transformer in an existing electrical power system. Percentage impedance of different power transformers should be properly matched during parallel operation of power transformers. The percentage impedance can be derived from equivalent **impedance of transformer** so, it can be said that **equivalent circuit of transformer** is also required during calculation of % impedance.

Equivalent Circuit of Transformer Referred to Primary

For drawing **equivalent circuit of transformer referred to primary**, first we have to establish general **equivalent circuit of transformer** then, we will modify it for referring from primary side. For doing this, first we need to recall the complete vector diagram of a transformer which is shown in the figure below.



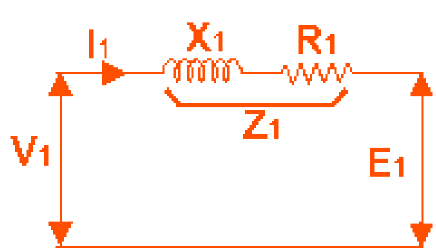
Let us consider the transformation ratio be,

$$K = \frac{N_1}{N_2} = \frac{E_1}{E_1}$$

In the figure right, the applied voltage to the primary is V_1 and voltage across the primary winding is E_1. Total current supplied to primary is I_1. So the voltage V_1 applied to the primary is partly dropped by I_1Z_1 or $I_1R_1 +$ $j.I_1X_1$ before it appears across primary winding. The voltage appeared across winding is countered by primary induced emf E_1.

$$V_1 - (I_1R_1 + jI_1X_1) = E_1$$

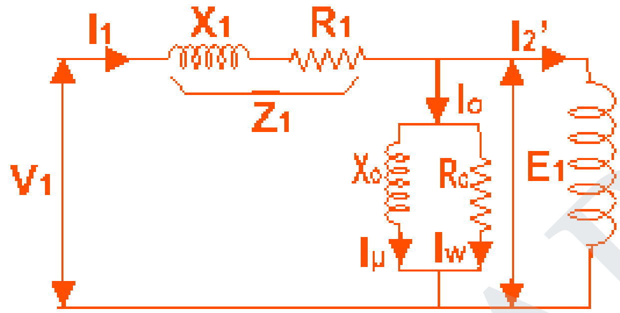
The equivalent circuit for that equation can be drawn as below,



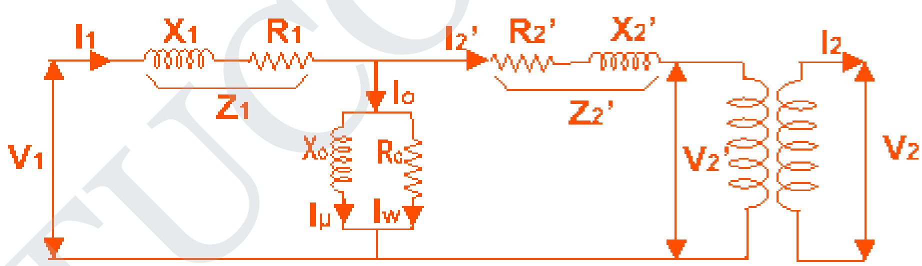
From the vector diagram above, it is found that the total primary current I_1 has two components, one is no - load component I_o and the other is load component I_2'. As this primary current has two a component or branches, so there must be a parallel path with primary winding of transformer. This parallel path of current is known as excitation branch of equivalent circuit of transformer. The resistive and reactive branches of the excitation circuit can be represented as

$$R_0 = \frac{E_1}{I_w} \ and \ X_0 = \frac{E_1}{I_\mu}$$

Equivalent Circuit of Primary Side of Transformer



The load component I_2' flows through the primary winding of transformer and induced voltage across the winding is E_1 as shown in the figure right. This induced voltage E_1transforms to secondary and it is E_2 and load component of primary current I_2' is transformed to secondary as secondary current I_2. Current of secondary is I_2. So the voltageE_2 across secondary winding is partly dropped by I_2Z_2 or I_2R_2 + j.I_2X_2 before it appears across load. The load voltage is V_2.



Equivalent Circuit of Transformer referred to Primary

Again $I_2'.N_1 = I_2.N_2$

$$\Rightarrow I_2 = I_2' \frac{N_1}{N_2}$$

$$\Rightarrow I_2 = KI_2'$$

Therefore,

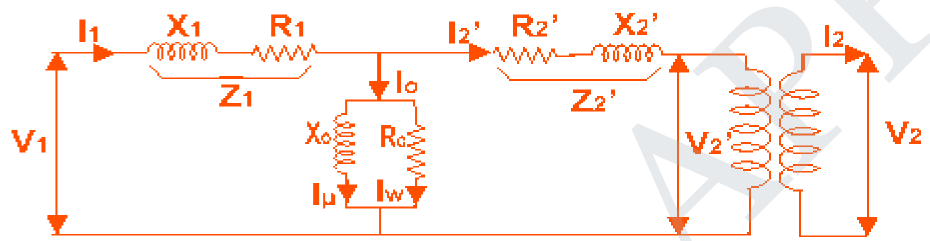
$$KZ_2I_2 = KZ_2KI_2' = K^2Z_2I_2'$$

From above equation, secondary impedance of transformer referred to primary is,

$$Z_2' = K^2Z_2$$

$$Hence,\ R_2' = K^2R_2 \quad and\ X_2 = K^2X_2$$

So, the complete equivalent circuit of transformer referred to primary is shown in the figure below,

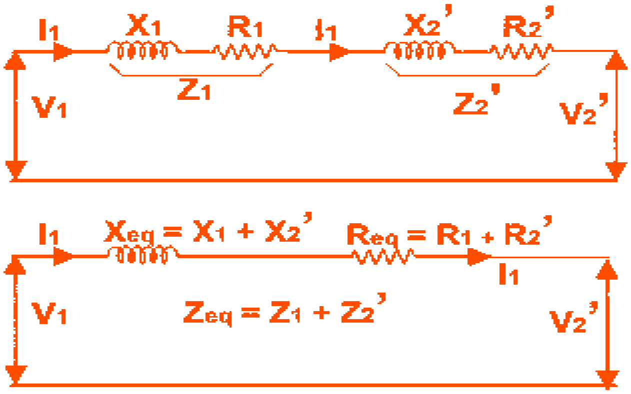


Equivalent Circuit of Transformer referred to Primary

Approximate Equivalent Circuit of Transformer

Since I_o is very small compared to I_1, it is less than 5% of full load primary current, $I_o$changes the voltage drop insignificantly. Hence, it is good approximation to ignore the excitation circuit in approximate equivalent circuit of transformer. The winding resistanceand reactance being in series can now be combined into equivalent resistance and reactance of transformer, referred to any particular side. In this case it is side 1 or primary side.

$$Here\ V_2' = KV_2$$



Approximate equivalent circuit of transformer referred to primary

Equivalent Circuit of Transformer Referred to Secondary

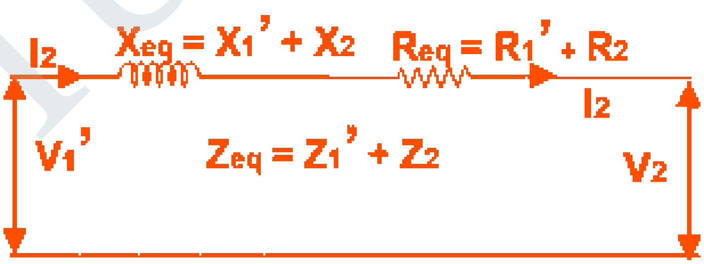
In similar way, approximate equivalent circuit of transformer referred to secondary can be drawn. Where equivalent impedance of transformer referred to secondary, can be derived as

$$Z_1 = \frac{Z_1}{K^2}$$

$$Therefore,\ R_1' = \frac{R_1}{K^2}$$

$$X_1' = \frac{X_1}{K^2}$$

$$Here,\ V_1' = \frac{V_1}{K}$$



Approximate equivalent circuit of transformer referred to secondary

2.3.9 VOLTAGE REGULATION

The voltage regulation is the percentage of voltage difference between no load and full load voltages of a transformer with respect to its full load voltage.

Explanation of Voltage Regulation of Transformer

Say an electrical power transformer is open circuited, means load is not connected with secondary terminals. In this situation, the secondary terminalvoltage of the transformer will be its secondary induced emf E_2. Whenever full load is connected to the secondary terminals of the transformer, ratedcurrent I_2 flows through the secondary circuit and voltage drop comes into picture. At this situation, primary winding will also draw equivalent full load current from source. The voltagedrop in the secondary is I_2Z_2 where Z_2 is the secondary impedance of transformer. Now if at this loading condition, any one measures the voltage between secondary terminals, he or she will getvoltage V_2 across load terminals which is obviously less than no load secondary voltage $E_2$and this is because of I_2Z_2 voltage drop in the transformer.

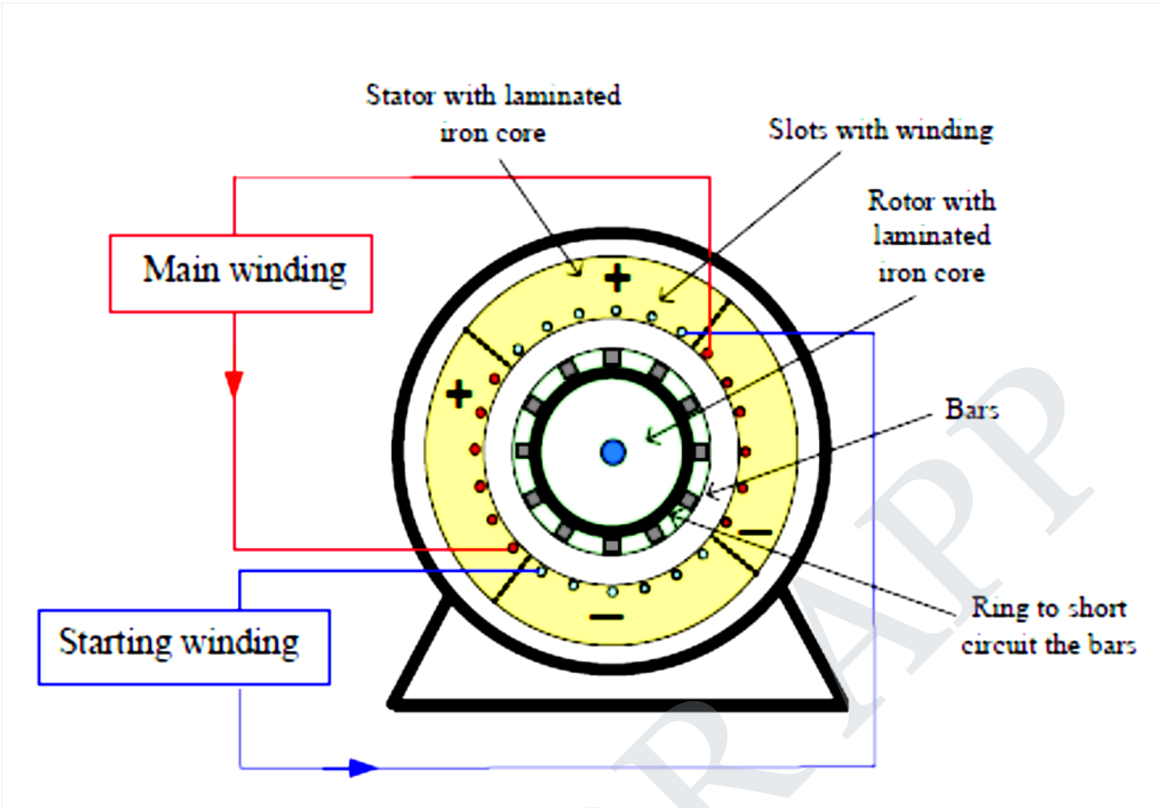
Expression of **Voltage Regulation of Transformer**, represented in percentage, is

$$\text{Voltage regulation } (\%) = \frac{E_2 - V_2}{V_2} \times 100\%$$

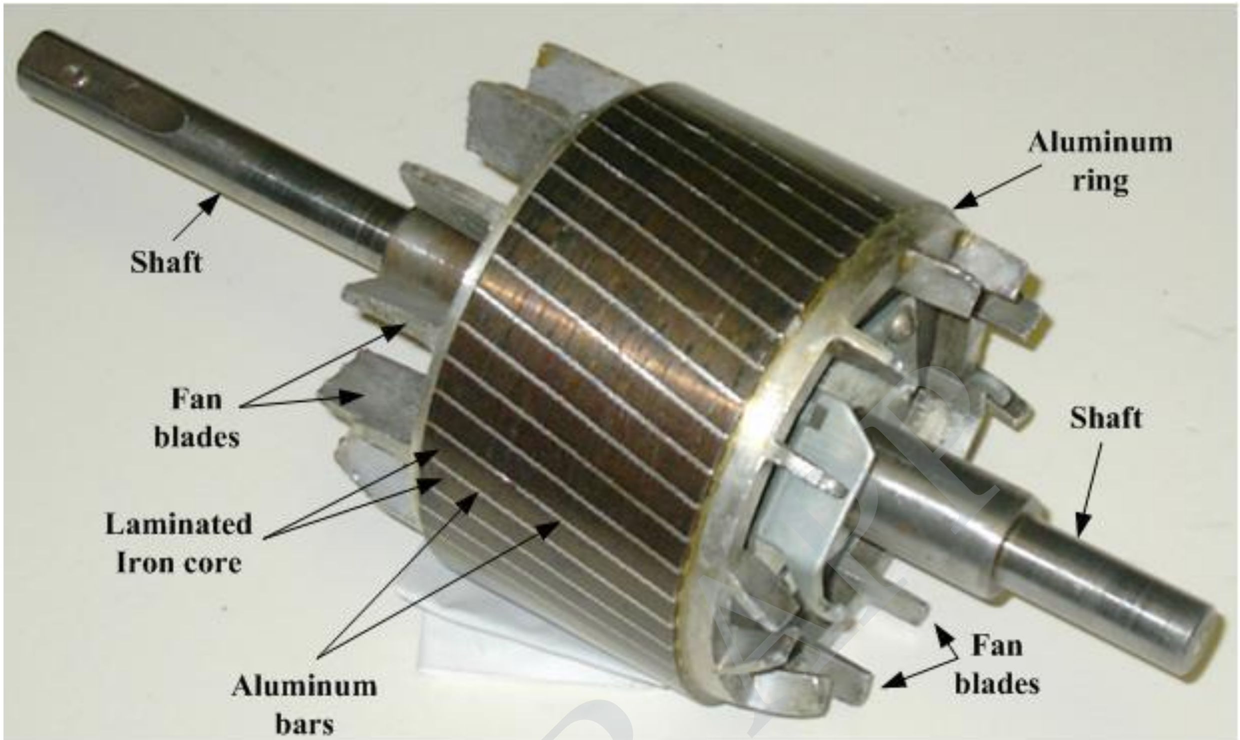
2.4 SINGLE PHASE INDUCTION MOTOR – INTRODUCTION

The single-phase induction machine is the most frequently used motor for refrigerators, washing machines, clocks, drills, compressors, pumps, and so forth.

- The single-phase motor stator has a laminated iron core with two windings arranged perpendicularly.
- One is the main and
- The other is the auxiliary winding or starting winding



- This "single-phase" motors are truly two phase machines.
- The motor uses a squirrel cage rotor, which has a laminated iron core with slots.
- Aluminum bars are molded on the slots and short-circuited at both ends with a ring.



The single-phase induction motor operation can be described by two methods:

- Double revolving field theory; and
- Cross-field theory.

Double revolving theory is perhaps the easier of the two explanations to understand

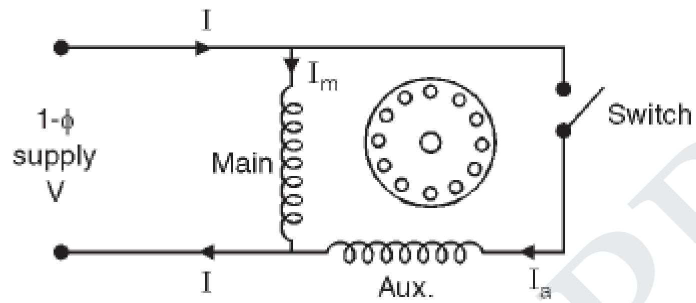
Double revolving field theory

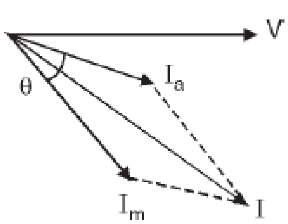
- A single-phase ac current supplies the main winding that produces a pulsating magnetic field.
- Mathematically, the pulsating field could be divided into two fields, which are rotating in opposite directions.
- The interaction between the fields and the current induced in the rotor bars generates opposing torque

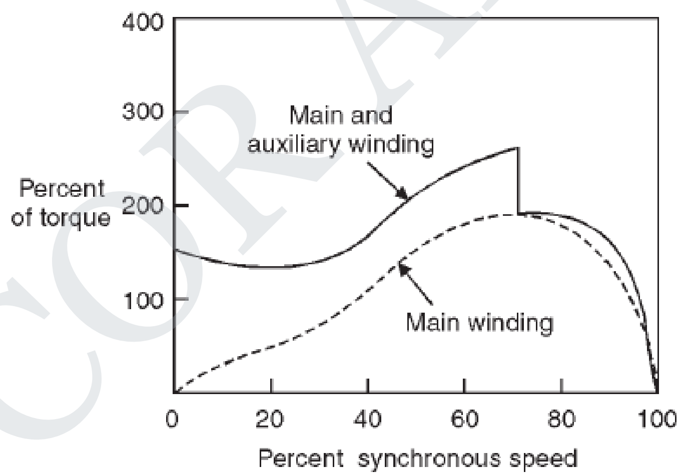
2.4.1 STARTING METHODS

The single-phase IM has no starting torque, but has resultant torque, when it rotates at any other speed, except synchronous speed. It is also known that, in a balanced two-phase IM having two windings, each having equal number of turns and placed at a space angle of 90^0(electrical), and are fed from a balanced two-phase supply, with two voltages equal in magnitude, at an angle of 90^0, the rotating magnetic fields are produced, as in a three-phase IM. The torque-speed characteristic is same as that of a three-phase one, having both starting and also running torque as shown earlier. So, in a single-phase IM, if an auxiliary winding is introduced in the stator, in addition to the main winding, but placed at a space angle of 90^0 (electrical), starting torque is produced. The currents in the two (main and auxiliary) stator windings also must be at an angle of 90^0 , to produce maximum starting torque, as shown in a balanced two-phase stator. Thus, rotating magnetic field is produced in such motor, giving rise to starting torque. The various starting methods used in a single-phase IM are described here.

1. RESISTANCE SPLIT-PHASE MOTOR



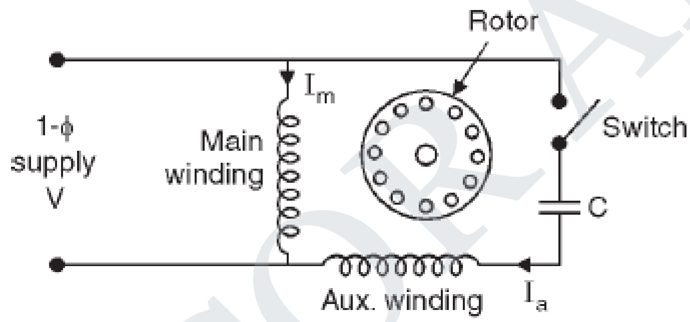


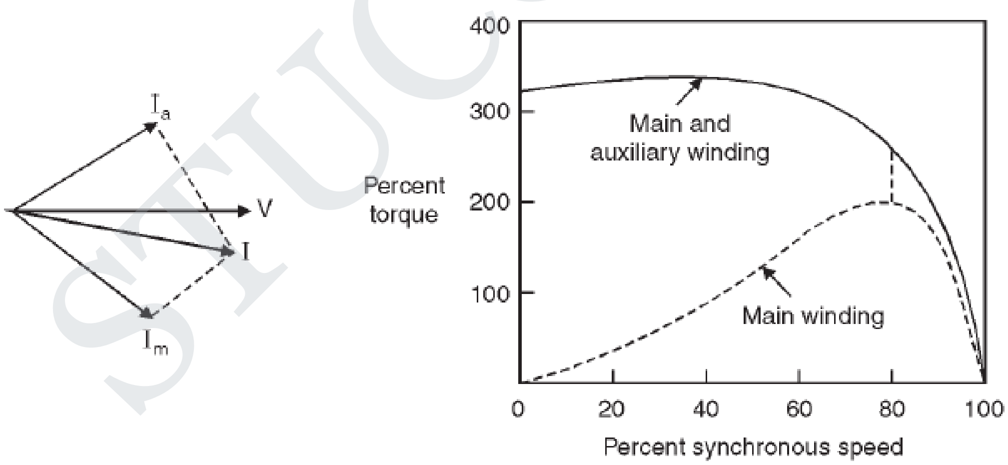


The schematic (circuit) diagram of this motor is given in Fig. As detailed earlier, another (auxiliary) winding with a high resistance in series is to be added along with the main winding in the stator. This winding has higher resistance to reactance () ratio as compared to that in the main winding, and is placed at a space angle of from the main winding as given earlier. The phasor diagram of the currents in two windings and the input voltage is shown in Fig.The current () in the auxiliary winding lags the voltage (*V*) by an angle, *aaXR*/°90*aIa*φ, which is small, whereas the current () in the main winding lags the voltage (*V*) by an angle, *mIm*φ, which is nearly . The phase angle between the two currents is (°90*a*φ−°90), which should be at least . This results in a small amount of starting torque. The switch, S (centrifugal switch) is in series with the auxiliary winding. It automatically cuts out the auxiliary or starting winding, when the motor attains a speed close to full load speed. The motor has a starting torque of 100−200% of full load torque, with the starting current as 5-7 times the full load current. The torque-speed characteristics of the motor with/without auxiliary winding are shown in Fig.The change over occurs, when the auxiliary winding is switched off as given earlier. The direction of rotation is reversed by reversing the terminals of any one of two windings, but not both, before connecting the motor to the supply terminals. This motor is used in applications, such as fan, saw, small lathe, centrifugal pump, blower, office equipment, washing machine, etc.

2. CAPACITOR-START MOTOR

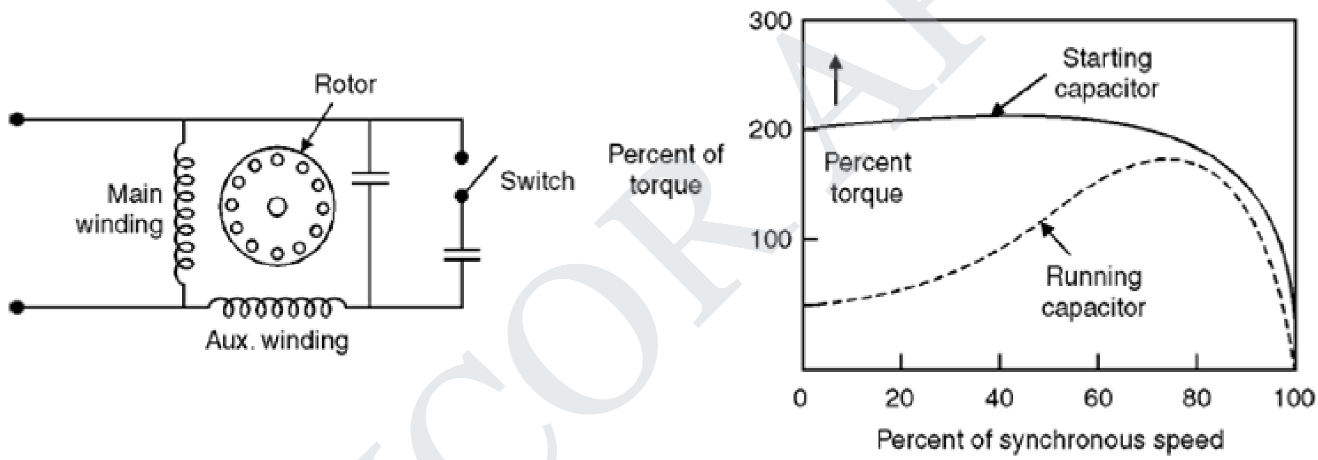
The schematic (circuit) diagram of this motor is given in Fig. It may be observed that a capacitor along with a centrifugal switch is connected in series with the auxiliary winding, which is being used here as a starting winding. The capacitor may be rated only for intermittent duty, the cost of which decreases, as it is used only at the time of starting. The function of the centrifugal switch has been described earlier. The phasor diagram of two currents as described earlier, and the torque-speed characteristics of the motor with/without auxiliary winding, are shown in Fig. This motor is used in applications, such as compressor, conveyor, machine tool drive, refrigeration and air-conditioning equipment, etc.





3. Capacitor-start and Capacitor-run Motor

In this motor two capacitors − $C_s$for starting, and C_r for running, are used. The first capacitor is rated for intermittent duty, as described earlier, being used only for starting. A centrifugal switch is also needed here. The second one is to be rated for continuous duty, as it is used for running. The phasor diagram of two currents in both cases, and the torque-speed characteristics with two windings having different values of capacitors, are shown in respectively. The phase difference between the two currents is ($\varphi_m+\varphi_a>90^0$) in the first case (starting), while it is90^0 for second case (running). In the second case, the motor is a balanced two phase one, the two windings having same number of turns and other conditions as given earlier, are also satisfied. So, only the forward rotating field is present, and the no backward rotating field exists. The efficiency of the motor under this condition is higher. Hence, using two capacitors, the performance of the motor improves both at the time of starting and then running. This motor is used in applications, such as compressor, refrigerator, etc.



Beside the above two types of motors, a Permanent Capacitor Motor with the same capacitor being utilised for both starting and running, is also used. The power factor of this motor, when it is operating (running), is high. The operation is also quiet and smooth. This motor is used in applications, such as ceiling fans, air circulator, blower, etc.

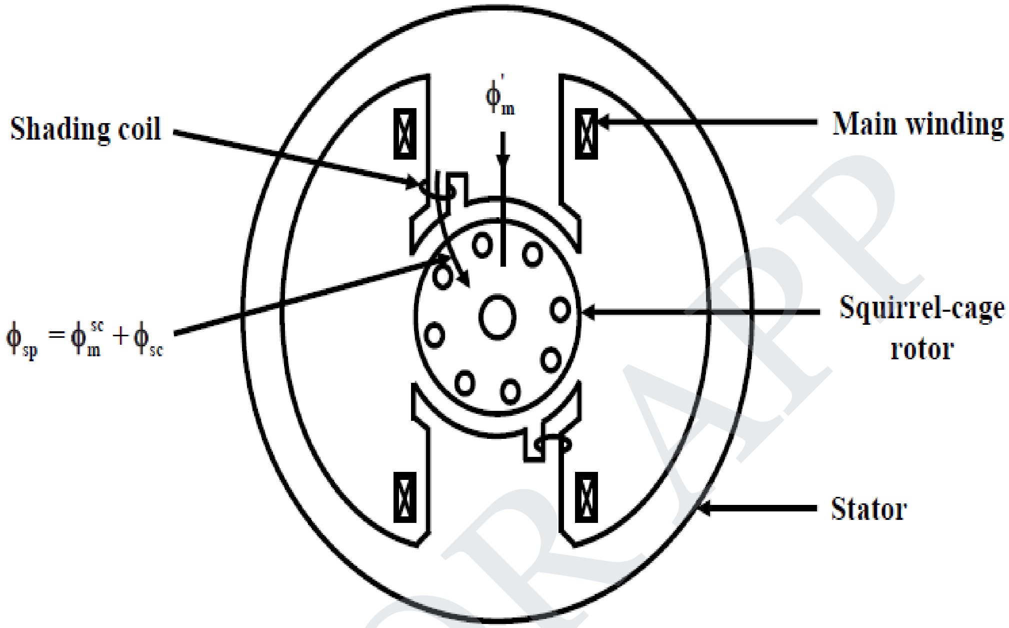
4. Shaded-pole Motor

A typical shaded-pole motor with a cage rotor is shown in Fig. 34.8a. This is a single-phase induction motor, with main winding in the stator. A small portion of each pole is covered with a short-circuited, single-turn copper coil called the shading coil. The sinusoidally varying flux created by ac (single-phase) excitation of the main winding induces emf in the shading coil. As a result, induced currents flow in the shading coil producing their own flux in the shaded portion of the pole.

Let the main winding flux be $\varphi_m=\varphi_{max}\sin_{wt}$

The reversal of the direction of rotation, where desired, can be achieved by providing two shading coils, one on each end of every pole, and by open-circuiting one set of shading coils and by short-circuiting the other set.

The fact that the shaded-pole motor is single-winding (no auxiliary winding) self-starting one, makes it less costly and results in rugged construction. The motor has low efficiency and is usually available in a range of 1/300 to 1/20 kW. It is used for domestic fans, record players and tape recorders, humidifiers, slide projectors, small business machines, etc. The shaded-pole principle is used in starting electric clocks and other single-phase synchronous timing motors.



no starting torque is produced in the single-phase induction motor with only one (main) stator winding, as the flux produced is a pulsating one, with the winding being fed from single phase supply. Using double revolving field theory, the torque-speed characteristics of this type of motor are described, and it is also shown that, if the motor is initially given some torque in either direction, the motor accelerates in that direction, and also the torque is produced in that direction. Then, the various types of single phase induction motors, along with the starting methods used in each one are presented. Two stator windings − main and auxiliary, are needed to produce the starting torque. The merits and demerits of each type, along with their application area, are presented. The process of production of starting torque in shade-pole motor is also described in brief. In the next module consisting of seven lessons, the construction and also operation of dc machines, both as generator and motor, will be discussed.

UNIT III SEMICONDUCTOR DEVICES AND APPLICATIONS

Prerequisites

The semiconductor device i.e., solid state device is capable of amplifying the weak signal. The devices are solid rather than hollow like the vaccum tube. These semiconductor devices are smaller in size, more rugged and less power consumption than vaccum tubes. The various semiconductor devices include semiconductor diode, Zener diode, transistor, JFET, MOSFET, UJT, SCR, DIAC and TRIAC etc. The semiconductor devices have very wide range of applications in various fields such as communication systems, medical electronics, microprocessor based systems, instrumentation, process control, aerospace, consumer electronics, etc.

1.INTRODUCTION

1.1 Basic Definitions

Valence electrons

The electrons present in the outer most orbit that are loosely bound to the nucleus are called valence electrons.

Conduction electrons

When an electric field is applied, the valence electrons get detached themselves from the nucleus, constituting the flow of current. These electrons are called conduction electrons.

Energy band

The (range of) energy possessed by the electrons in an atom is called energy band.

Conduction band

The (range of) energy possessed by the conduction electrons is called conduction band.

Valence electrons

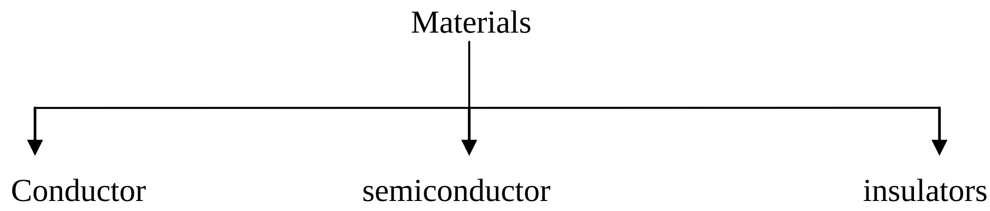
The (range of) energy possessed by the valence electrons is called valence band.

Forbidden energy gap

The gap between the valence band and the conduction band is called forbidden energy gap.

2. CLASSIFICATION OF MATERIALS

The materials are classified based on their conducting property. Energy band theory can be used to explain the classification of materials.



2.1 Conductors

Conductor is materials that easily conducts or pass the current. There are plenty of free electrons available for electric conduction. In terms of energy band theory, the conductors have overlapping of valence band and conductive band.

Example: Copper, Aluminum, iron, etc

Properties: 1. It is rigid, non directional and crystalline in nature.

2. Conductivity is good.

3. Low melting and boiling temperatures.

2.2 Semiconductors

Semiconductor is a material with partially filled conduction band and valence band. The current in the semiconductor is due to the movement of electrons and holes. As the temperature increases the conduction increases.

Example: Silicon, Germanium, etc.

Properties: 1. It is rigid, directional and crystalline in nature.

2. Conductivity can be increased if proper doping material is added.

3. Low melting and boiling temperatures.

2.3 Insulators

In the case of insulators, the valence electrons are very tightly bound to their parent atom. The valence band and conduction band are separated by a large forbidden energy gap. The insulators have full valence band and an empty conduction band.

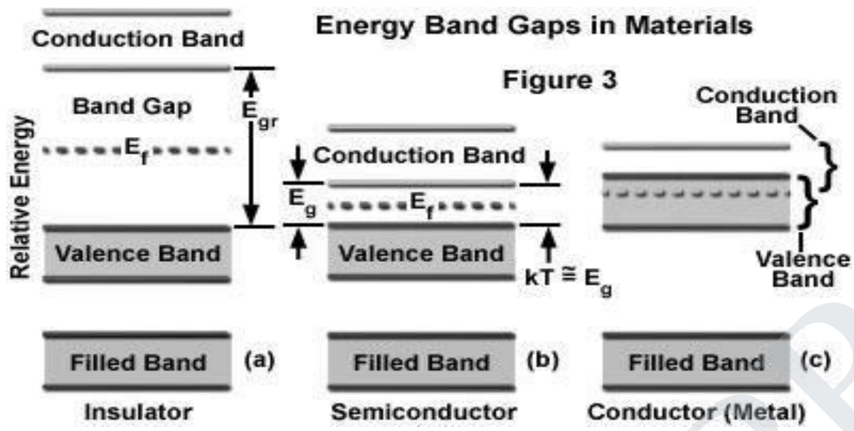
Example: Paper, Mica. Sodium chloride, etc.

Properties: 1. It is rigid, Unidirectional and crystalline in nature.

2. Conductivity is poor in the solid form.

3. High melting and boiling temperatures.

Energy band structure



2.4 Comparison of Conductors,Semiconductors and Insulators

S.No	Conductors	Semiconductors	Insulators
1	Easily conducts the electrical current.	Conducts the electric current less than conductor and greater than insulator.	Does not conduct any current.
2	Has only one valence electron in its outermost orbit.	Has four valence electron in its outermost orbit.	Has eight valence electron in its outermost orbit.
3	Conductor formed using metallic bonding.	Semiconductors are formed due to covalent bonding.	Insulators are formed due to ionic bonding.
4	Valence and conduction bands are overlapped.	Valence and conduction bands are separated by forbidden energy gap of 1.1eV.	Valence and conduction bands are separated by forbidden energy gap of 6 to 10eV.
5	Resistance is very small	Resistance is high	Resistance is very high
6	It has positive temperature coefficient	It has negative temperature coefficient	It has negative temperature coefficient
7	Ex: copper,aluminium,etc	Ex: silicon, germanium, etc	Ex: Mica, Paper, etc

2.5 Classification of Semiconductor

Semiconductor

Intrinsic Semiconductor

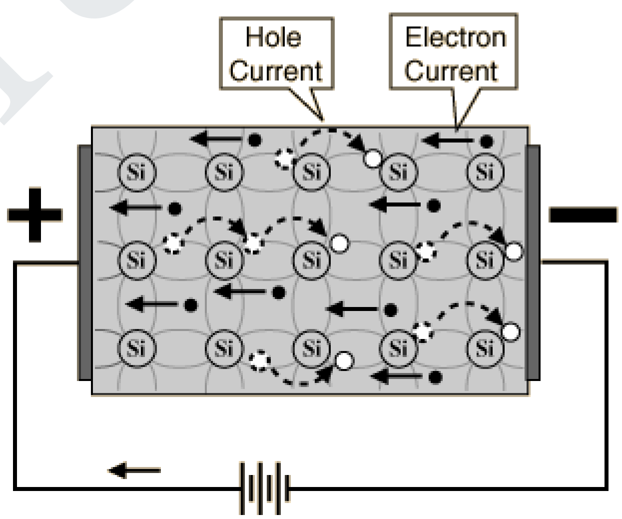
Extrinsic Semiconductor

2.6 Intrinsic Semiconductor

- *An intrinsic semiconductor also called an undoped semiconductor or i- type semiconductor.*
- *It is a pure semiconductor without any significant dopant species present.*
- The number of charge carriers determined by the properties of the m aterial itself instead of the amount of impurities.
- In intrinsic semiconductors the number of excited electrons and the number of holes are equal: n = p.

Conductivity of Intrinsic semiconductor

- ➢ *The electrical conductivity of intrinsic semiconductors can be due to crystal defects or to thermal excitation.*
- ➢ Both electrons and holes contribute to current flow in an intrinsic semiconductor.



- *The current which will flow in an intrinsic semiconductor consists of both electron and hole current.*
- That is, the electrons which have been freed from their lattice positions into the conduction band can move through the material.
- In addition, other electrons can hop between lattice positions to fill the vacancies left by the freed electrons.
- This additional mechanism is called hole conduction because it is as if the holes are migrating across the material in the direction opposite to the free electron movement.
- The current flow in an intrinsic semiconductor is influenced by the density of energy states which in turn influences the electron density in the conduction band.
- This current is highly temperature dependent.

Thermal excitation:

- In an intrinsic semiconductor like silicon at temperatures above absolute zero, there will be some electrons which are excited across the band gap into the conduction band and which can produce current.
- When the electron in pure silicon crosses the gap, it leaves behind an electron vacancy or "hole" in the regular silicon lattice.
- Under the influence of an external voltage, both the electron and the hole can move across the material.
- In n-type semiconductor:

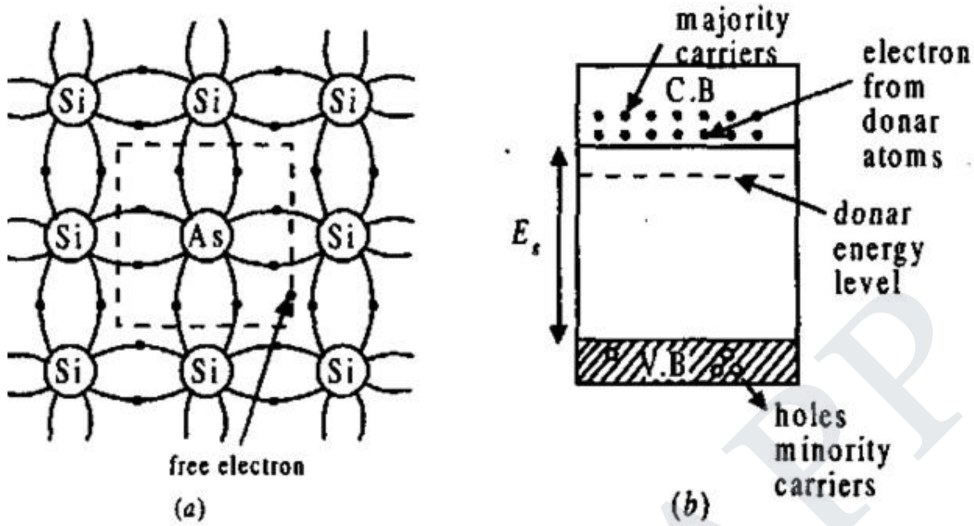
  The dopant contributes extra electrons, dramatically increasing the conductivity
- *In p-type semiconductor:*

  The dopant produces extra vacancies or holes, which likewise increase the conductivity.

2.7 Extrinsic Semiconductor

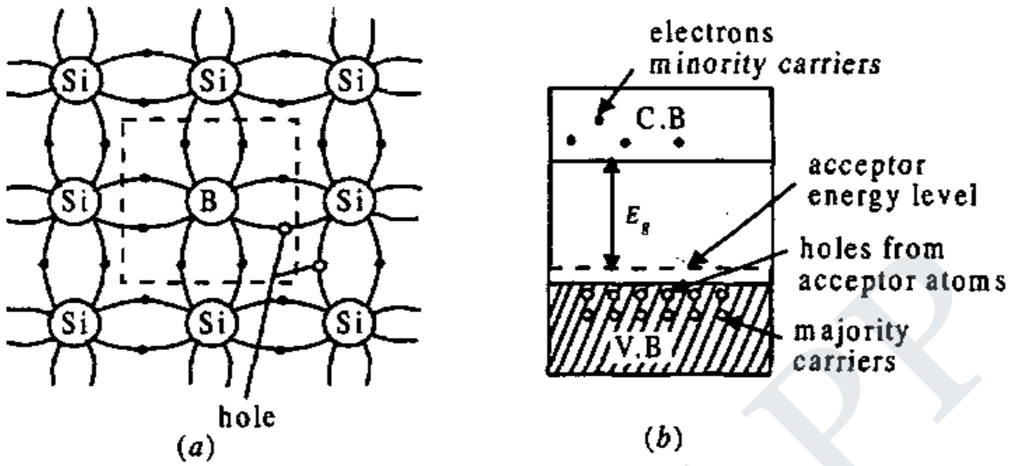
- The electrical conductivity of a pure semiconductor is very small.
- To increase the conductivity, impurities are added.
- The impurity added semiconductor is called extrinsic semiconductor.
- The process of adding impurity is called doping.
- The added impurity is called dopant.
- Usually one or two atoms of impurity is added per 10^6 atoms of a semiconductor.
- There are two types (i) p-type and (ii) n-type semiconductors.

(i) n-type semiconductor:



- *When an impurity, from V group elements like arsenic (As), antimony having 5 valence electrons is added to Ge (or Si), the impurity atom donates one electron to Ge (or Si).*
- The 4 electrons of the impurity atom is engaged in covalent bonding with Si atom.
- The fifth electron is free. This increases the conductivity.
- The impurities are called donors.
- The impurity added semiconductor is called n-type semiconductor, because their increased conductivity is due to the presence of the negatively charged electrons, which are called the majority carriers.
- The energy band of the electrons donated by the impurity atoms is just below the conduction band.
- The electrons absorb thermal energy and occupy the conduction band.
- Due to the breaking of covalent bond, there will be a few holes in the valence band at this temperature.
- These holes in n-type are called minority carriers.

(ii) p-type semiconductor:

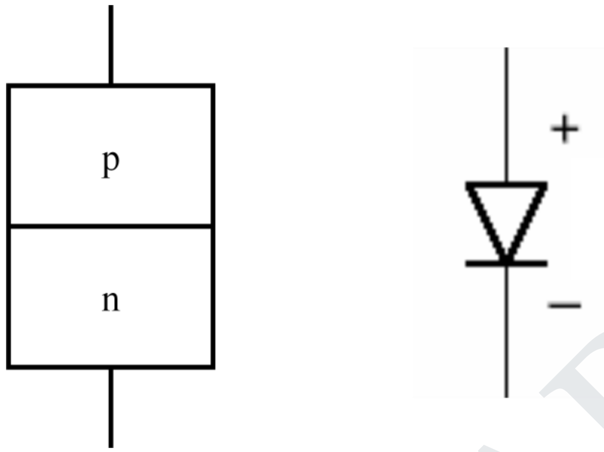


- *If a III group element, like indium (In), boron (B), aluminium (AI) etc., having three valence electrons, is added to a semiconductor say Si, the three electrons form covalent bond.*
- There is a deficiency of one electron to complete the 4th covalent bond and is called a hole.The presence of the hole increases the conductivity because these holes move to the nearby atom, at the same time the electrons move in the opposite direction.
- The impurities added semiconductor is called p-type semiconductor.
- The impurities are called acceptors as they accept electrons from the semiconductor
- Holes are the majority carriers and the electrons produced by the breaking of bonds are the minority carriers.

3. PN JUNCTION DIODE

- A p–n junction is formed by joining P-type and N-type semiconductors together in very close contact.
- The term junction refers to the boundary interface where the two regions of the semiconductor meet.
- Diode is a two-terminal electronic component that conducts electric current in only one direction.
- The crystal conducts conventional current in a direction from the p-type side (called the anode) to the n-type side (called the cathode), but not in the opposite direction.

Symbol of PN junction diode

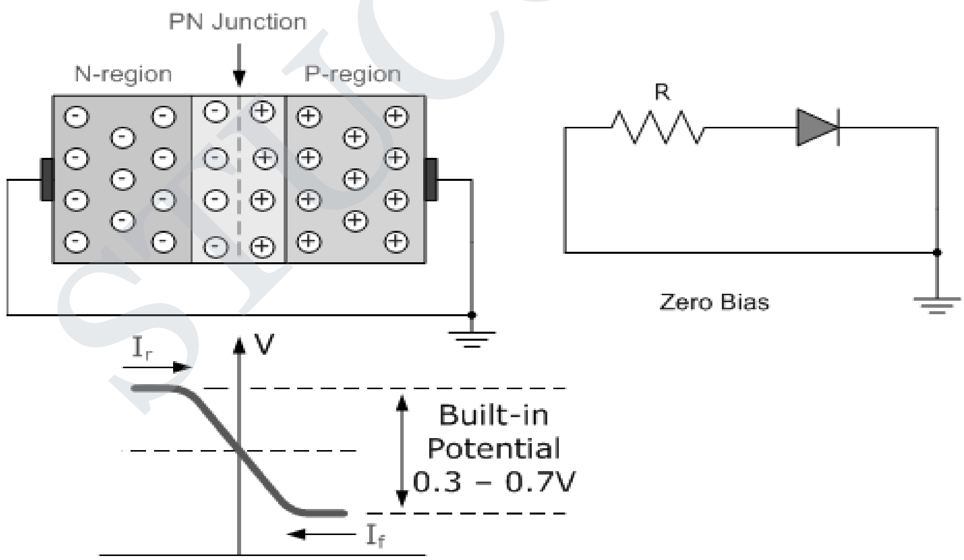


3.1Biasing

"Biasing" is providing minimum external voltage and current to activate the device to study its characteristics.

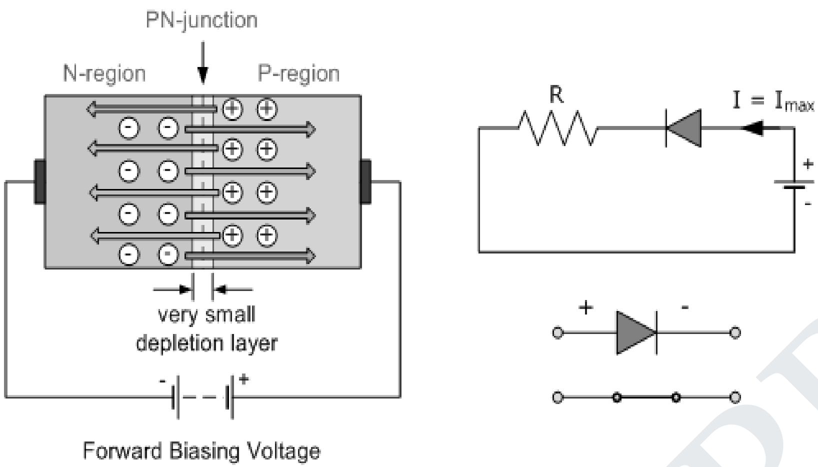
There are two operating regions and two "biasing" conditions for the standard Junction Diode and they are:

- **Zero Bias:**



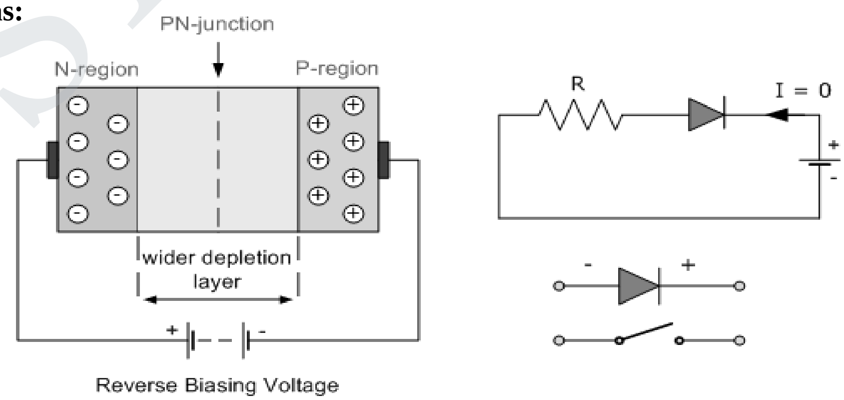
When a diode is **Zero Biased** no external energy source is applied and a natural **Potential Barrier** is developed across a depletion layer.

(i) Forward Bias:



- When the positive terminal of a battery is connected to P-type semiconductor and negative terminal to N-type is known as **forward bias** of PN junction.
- The applied forward potential establishes an electric field opposite to the potential barrier. Therefore the potential barrier is reduced at the junction. As the potential barrier is very small (0.3V for Ge and 0.7V for Si),a small forward voltage is sufficient to completely eliminate the barrier potential, thus the junction resistance becomes zero.
- In otherwords, the applied positive potential repels the holes in the 'P' region so that the holes moves towards the junction and applied negative potential repels the electrons in the 'N' region towards the junction results in depletion region starts decreasing. When the applied potential is more than the internal barrier potential then the depletion region completely disappear, thus the junction resistance becomes zero.
- Once the potential barrier is eliminated by a forward voltage, j unction establishes the low resistance path for the entire circuit, thus a current flows in the circuit, it is called as **forward current**.

(ii)Reverse Bias:



- For reverse bias, the negative terminal is connected to P-type semiconductor and positive terminal to N type semiconductor.
- When reverse bias voltage is applied to the junction, all the majority carriers of ‘P’ region are attracted towards the negative terminal of the battery and the majority carriers of the N region attracted towards the positive terminal of the battery, hence the depletion region increases.
- The applied reverse voltage establishes an electric field which acts in the same direction of the potential barrier. Therefore, the resultant field at the junction is strengthened and the barrier width is increased. This increased potential barrier prevents the flow of charge carriers across the junction, results in a high resistance path.
- This process cannot continue indefinitely because after certain extent the junction break down occurs. As a result a small amount of current flows through it due to minority carriers. This current is known as “**reverse saturation current**”.

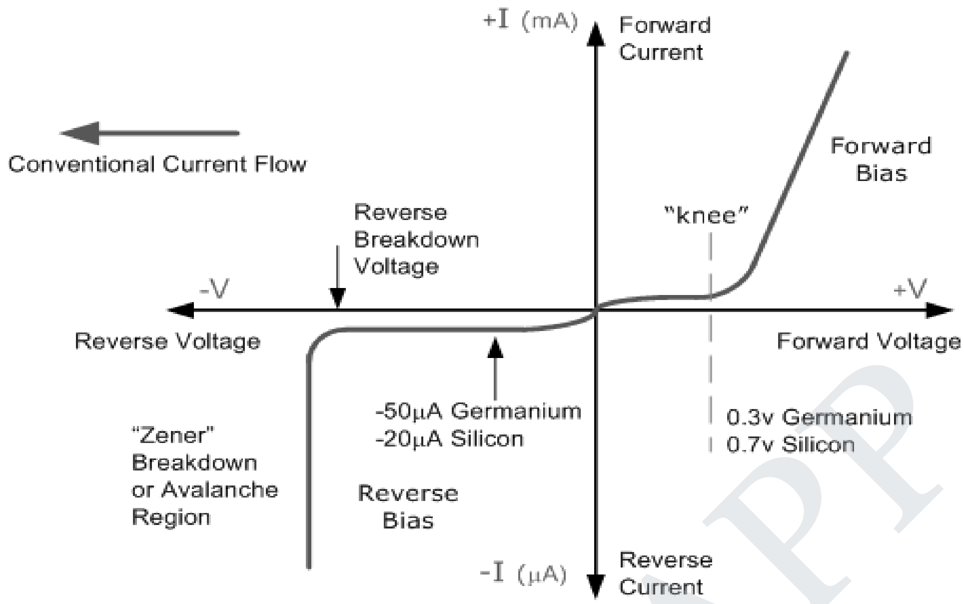
3.2 V-I characteristics of PN junction diode

Forward Bias:

- *The application of a forward biasing voltage on the junction diode results in the depletion layer becoming very thin and narrow which represents a low impedance path through the junction thereby allowing high currents to flow.*
- The point at which this sudden increase in current takes place is represented on the static I-V characteristics curve above as the "**knee**" point.

Reverse Bias:

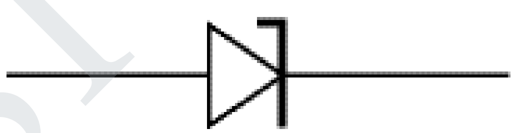
- *In Reverse biasing voltage a high resistance value to the PN junction and practically zero current flows through the junction diode with an increase in bias voltage.*
- However, a very small leakage current does flow through the junction which can be measured in microamperes, (μA).
- One final point, if the reverse bias voltage Vr applied to the diode is increased to a sufficiently high enough value, it will cause the PN junction to overheat and fail due to the avalanche effect around the junction.
- This may cause the diode to become shorted and will result in the flow of maximum circuit current, and this shown as a step downward slope in the reverse static characteristics curve below.



4. ZENER EFFECT

- In a general purpose PN diode the doping is light; as a result of this the breakdown voltage is high. If a P and N region are heavily doped then the breakdown voltage can be reduced.
- When the doping is heavy, even the reverse voltage is low, the electric field at barrier will be so strong thus the electrons in the covalent bonds can break away from the bonds. This effect is known as **Zener effect.**

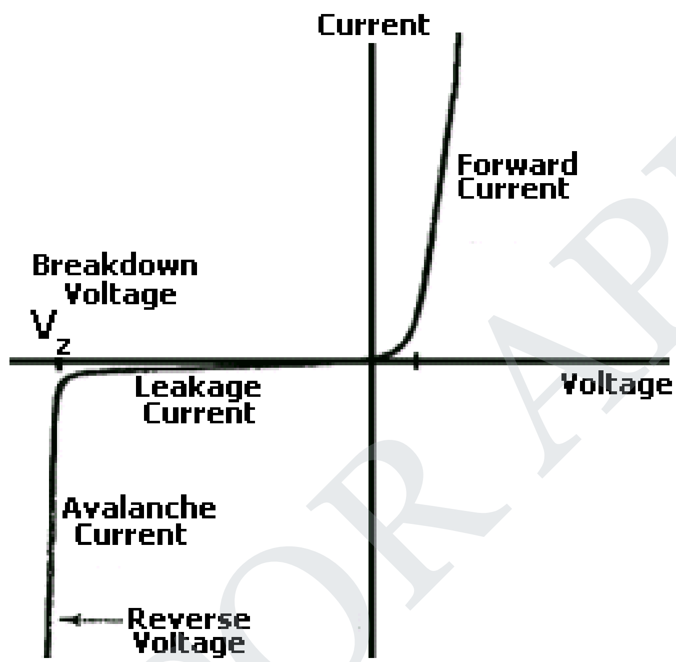
5. ZENER DIODE



- A diode which exhibits the zener effect is called a **Zener Diode**. Hence it is defined as a reverse biased heavily doped PN junction diode which operates in breakdown region. The zener diodes have been designed to operate at voltages ranging from a few volts to several hundred volts.
- **Zener Breakdown** occurs in junctions which is heavily doped and have narrow depletion layers. The breakdown voltage sets up a very strong electric field. This field is so strong enough to break or rupture the covalent bonds thereby generating electron hole pairs.

- Even a small reverse voltage is capable of producing large number of current carrier. When a zener diode is operated in the breakdown region care must be taken to see that the power dissipation across the junction is within the power rating of the diode otherwise heavy current flowing through the diode may destroy it.

5.1 V-I characteristics of Zener diode



- *The illustration above shows this phenomenon in a current vs voltage graph with a zener diode connected in the forward direction .It behaves exactly as a standard diode.*

- In the reverse direction however there is a very small leakage current between 0v and the zener voltage –i.e. just a tiny amount of current is able to flow.

- Then, when the voltage reaches the breakdown voltage (v_Z),suddenly current can flow freely through it.

5.2 Application of Zener diode

a) as voltage regulator

b) as peak clippers

c) for reshaping waveforms

6. RECTIFIERS

The “rectifier” is a circuit that converts AC voltages and currents into pulsating DC voltages and currents. It consists of DC components and the unwanted ac ripple or harmonic components which can be removed by using filter circuit. Thus the output obtained will be steady DC voltage and magnitude of DC voltage can be varied by varying the magnitude of AC voltage.

Filters: A circuit that removes ripples (unwanted ac components) present in the pulsating dc voltage.

Regulator: A circuit that maintains the terminal voltage as constant even if the input voltage or load current varying.

6.1 Types of rectifiers:

Rectifiers are grouped into two categories depending on the period of conduction.

(a)Half wave rectifier (b) Full wave rectifier

Half wave Rectifier:

Principle

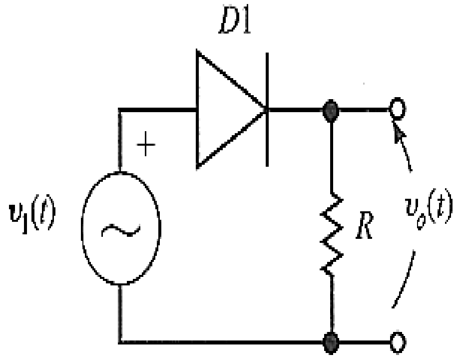
It is a circuit that converts alternating voltage or current into pulsating voltage or current for half the period of input cycle hence it is named as “**half wave rectifier**”.

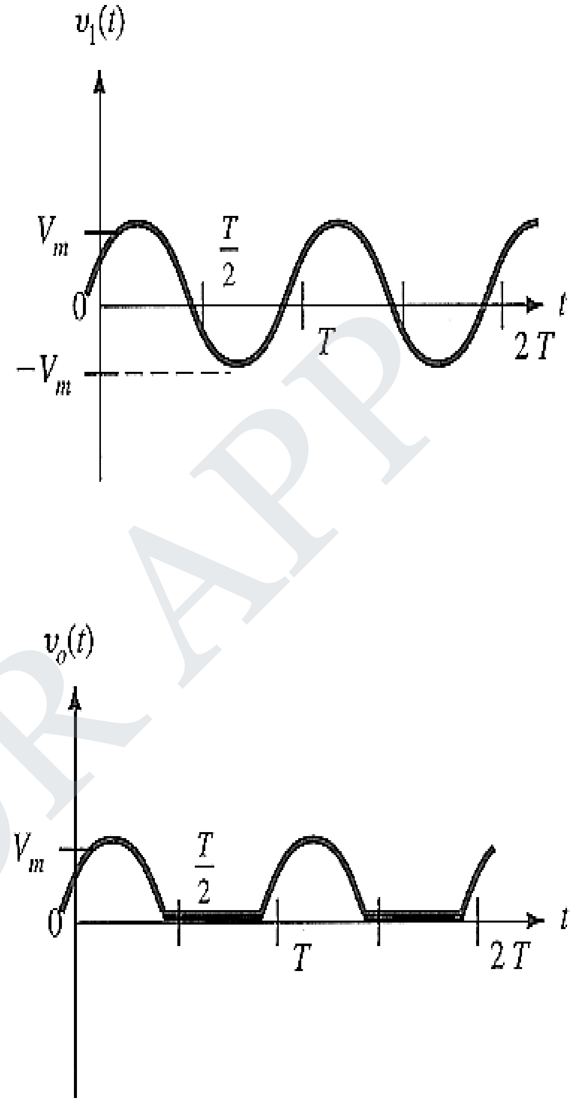
Construction

- It consists of step-down transformer, semiconductor diode and the load resistance.
- The step-down transformer – reduce the available ac voltage into required level of smaller ac voltage.
- The diode can be used to convert the ac into pulsating dc.

Operation

- During the positive half cycle of input, the diode D is forward biased, it offers very small resistance and it acts as closed switch and hence conducts the current through the load resistor.
- During the negative half cycle of the input diode D is heavily reverse biased, it offers very high resistance and it acts as open switch hence it does not conduct any current. The rectified output voltage will be in phase with AC input voltage for completely resistive load.


D1
$v_1(t)$
+
R
$v_o(t)$


$v_1(t)$
V_m
$\frac{T}{2}$
0
t
T
2 T
$-V_m$
$v_o(t)$
V_m
$\frac{T}{2}$
0
t
T
2 T

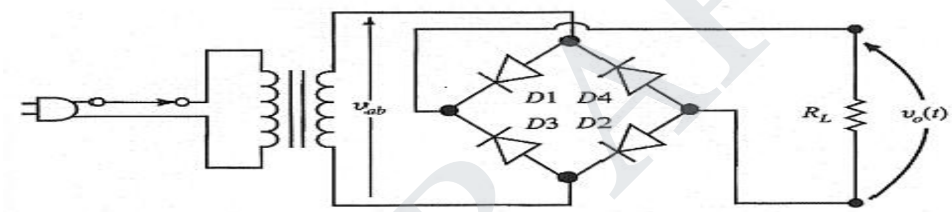
Full wave Rectifier:

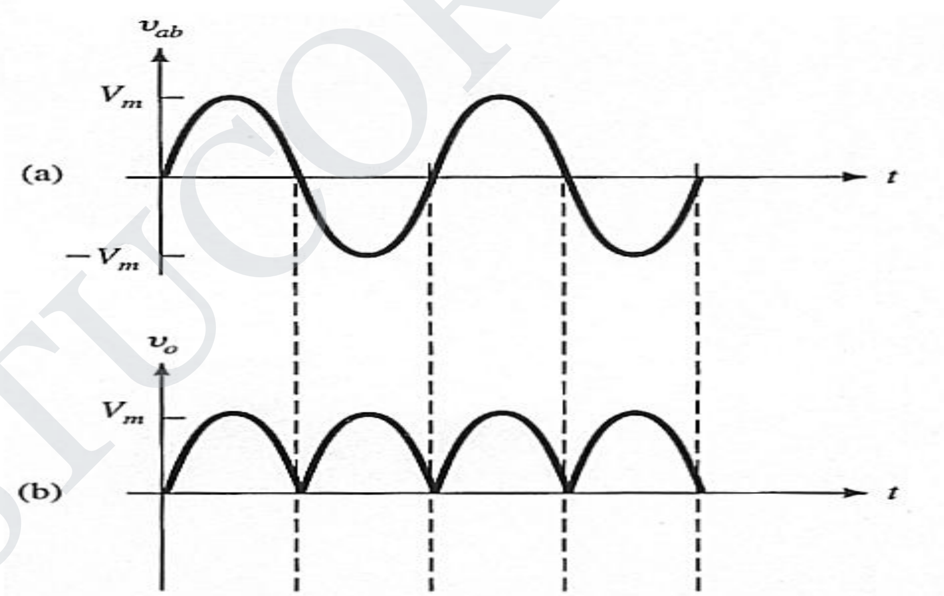
Principle

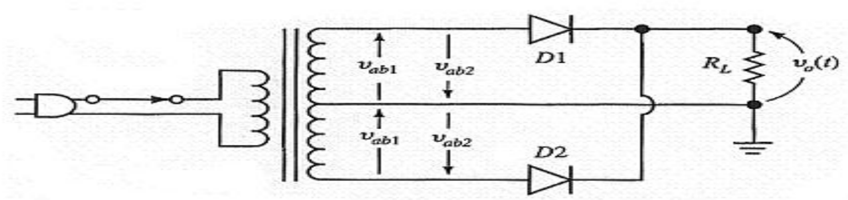
A circuit that converts the ac voltage or current into pulsating voltage or current during both half cycle of input is known as "full wave rectifier".

Operation

- During positive half cycle of ac input, diode D_1 becomes forward biased, provides very small resistance and acts as closed switch, resulting in the flow of current.
- During negative half cycle, diode D_1 reverse biased, offers high resistance and it acts as open circuit.







Voltage Regulation:

Ratio of Difference of secondary voltage to Primary voltage to secondary voltage.

7. BIPOLAR JUNCTION TRANSISTOR

- A bipolar junction transistor is a three terminal semiconductor device in which the operation depends on the interaction of majority and minority carriers.
- Transistor refers to Transfer Resistor i.e., signals are transferred from low resistance circuit into high resistance circuit.
- BJT consists of silicon crystal in which a layer of 'N' type silicon is sandwiched between two layers of 'P' type silicon. The semiconductor sandwiched is extremely smaller in size.
- In other words, it consists of two back to back PN junction joined together to form single piece of semiconductor crystal. These two junctions gives three region called Emitter, Base and Collector.
- There are two types of transistors such as PNP and NPN. The arrow on the emitter specifies whether the transistor is PNP or NPN type and also determines the direction of flow of current, when the emitter base junction is forward biased.

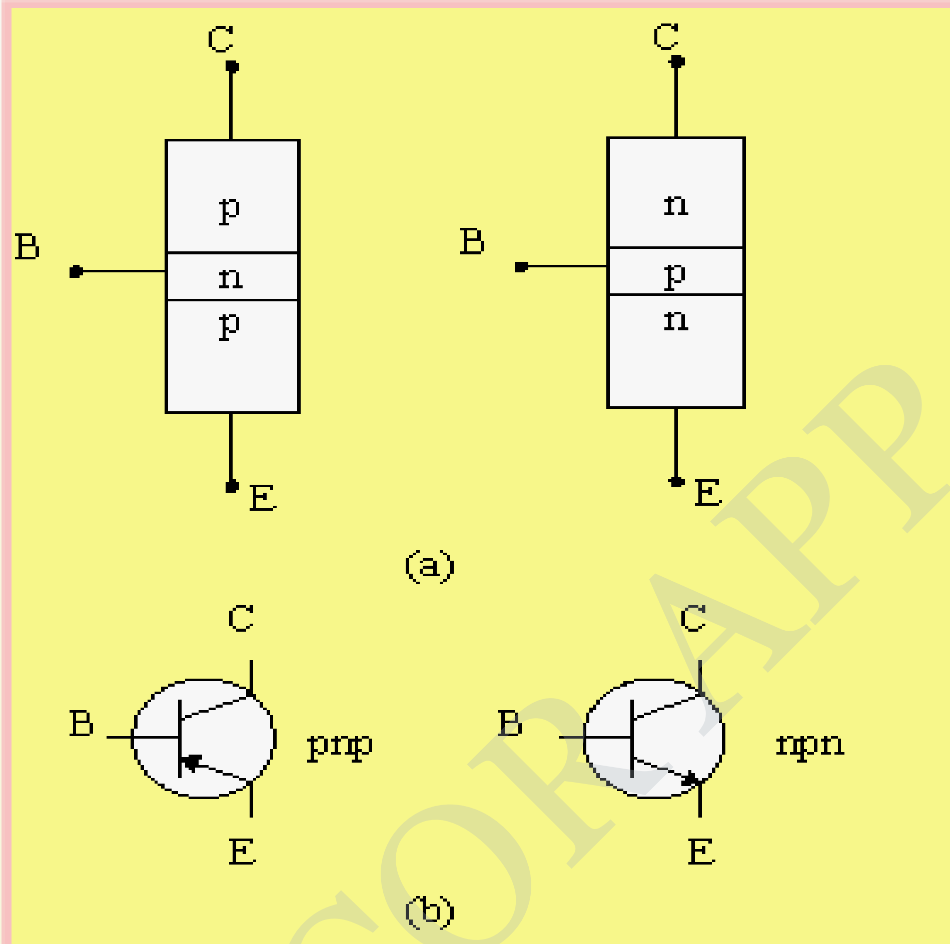


Fig. 4.1: (a) Position of terminals (b) Type of BJT

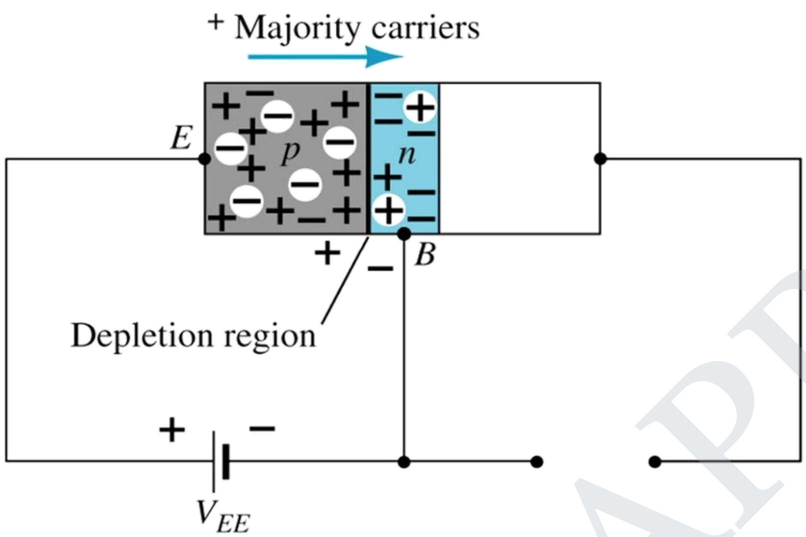
Emitter: It is more heavily doped than any of the other region because its main function is to supply majority charge carriers to the base.

Base: It forms the middle section of the transistor. It is very thin as compared to either the emitter or collector and is very lightly doped.

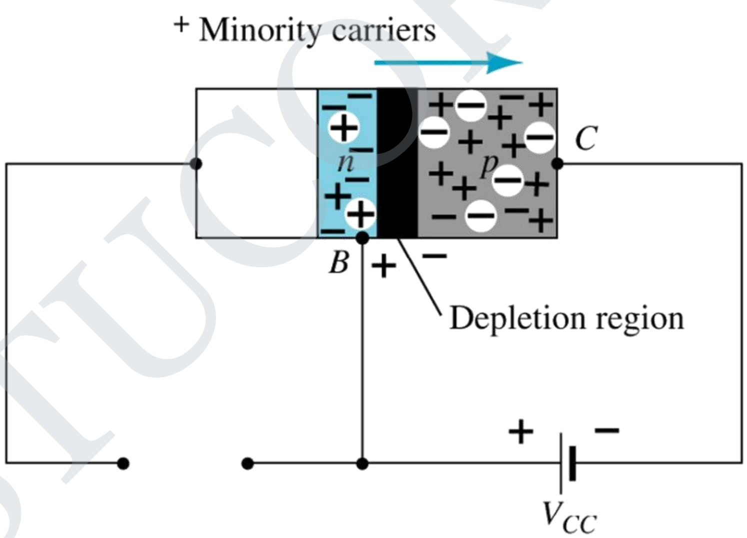
Collector: Its main function is to collect the majority charge carriers coming from the emitter and passing through the base. In most transistors, collector region is made physically larger than the emitter because it has to dissipate much greater power.

7.1 Operation of Transistor

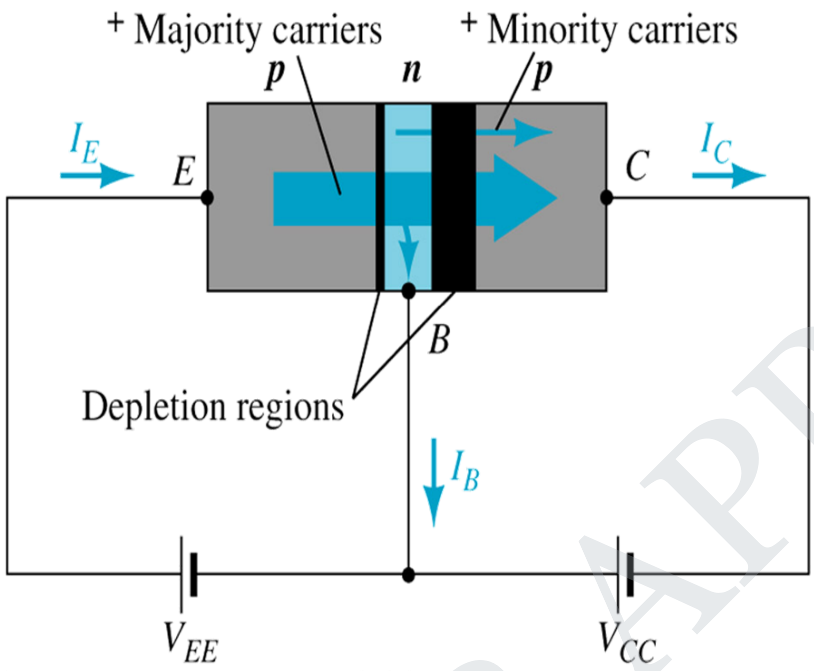
- The basic operation will be described using the pnp transistor. The operation of the pnp transistor is exactly the same if the roles played by the electron and hole are interchanged.
- One p-n junction of a transistor is reverse-biased, whereas the other is forward-biased.
- Both biasing potentials have been applied to a pnp transistor and resulting majority and minority carrier flows indicated.



Forward biased junction of a pnp transistor



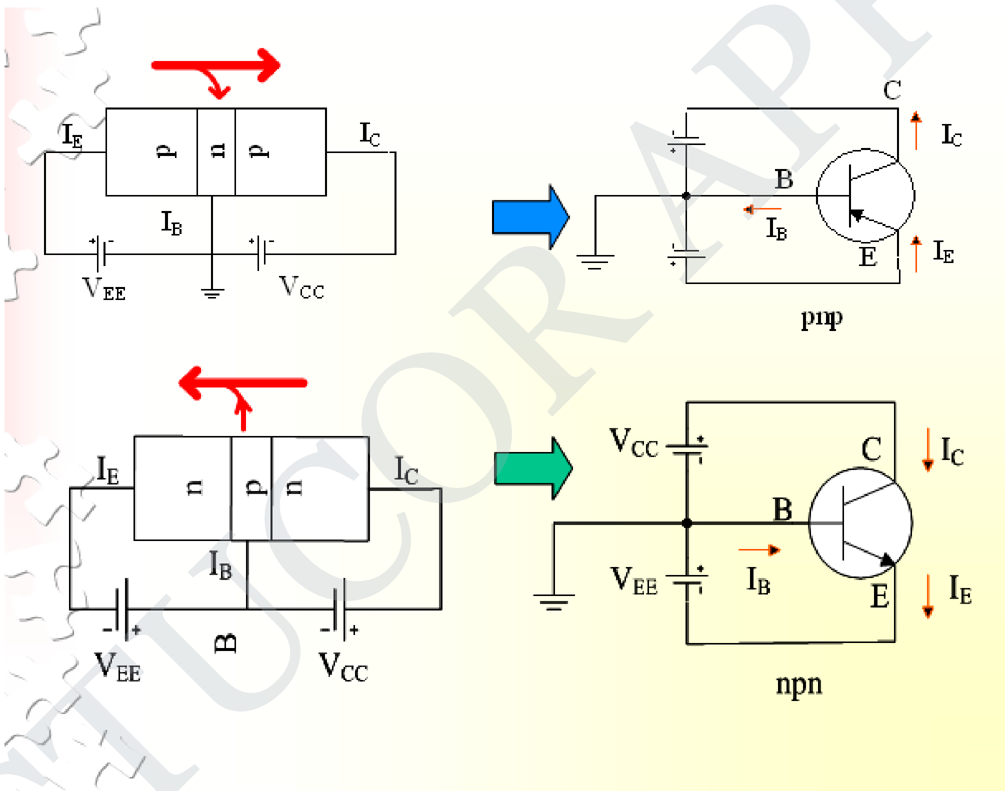
Reverse biased junction of pnp transistor



- Majority carriers (+) will diffuse across the forward-biased p-n junction into the n-type material.
- A very small number of carriers (+) will through n-type material to the base terminal. Resulting IB is typically in order of microamperes.
- The large number of majority carriers will diffuse across the reverse-biased junction into the p-type material connected to the collector terminal.
- Majority carriers can cross the reverse-biased junction because the injected majority carriers will appear as minority carriers in the n-type material.
- Applying KCL to the transistor :
  - $I_E = I_C + I_B$
- The comprises of two components – the majority and minority carriers
  - $I_C = I_{Cmajority} + I_{COminority}$
- I_{CO} – I_C current with emitter terminal open and is called leakage current.

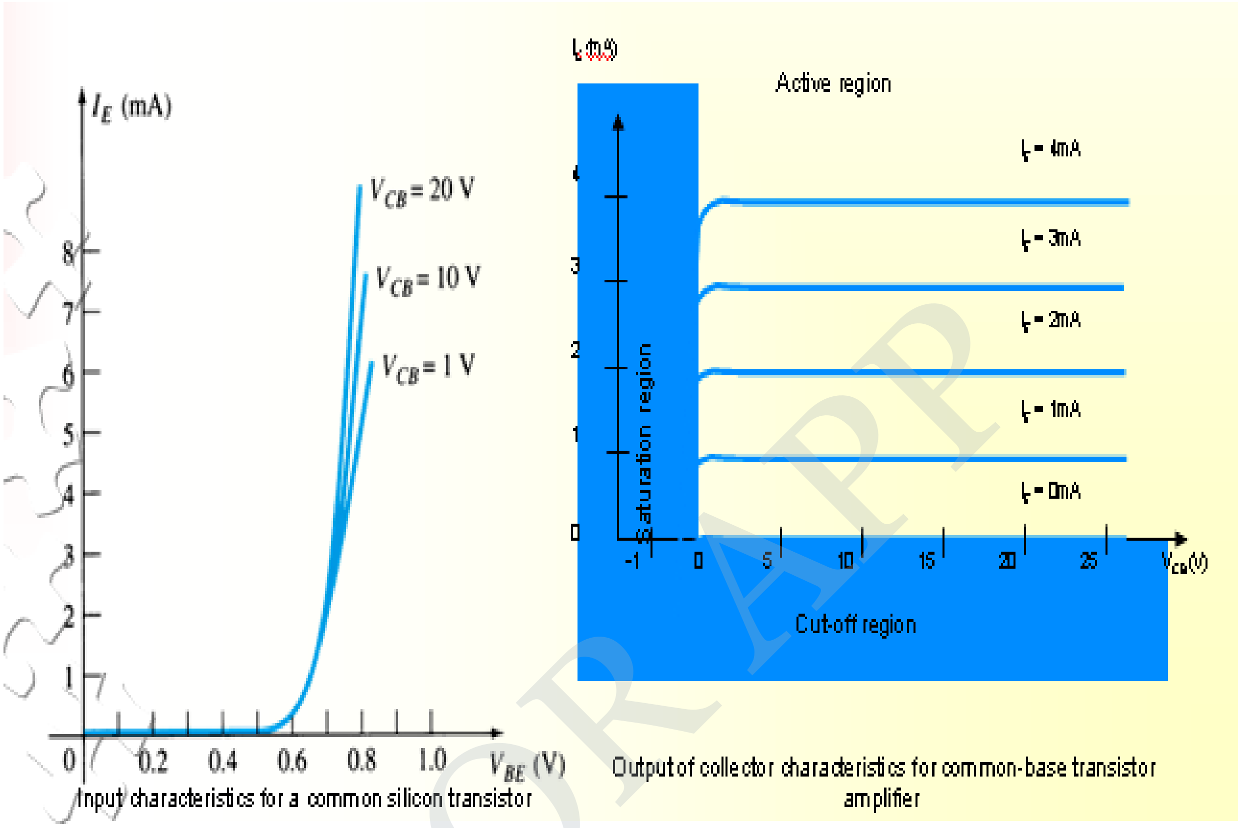
7.2 Common Base configuration

- Common-base terminology is derived from the fact that the :
  - base is common to both input and output of the configuration.
  - base is usually the terminal closest to or at ground potential.
- All current directions will refer to conventional (hole) flow and the arrows in all electronic symbols have a direction defined by this convention.
- Note that the applied biasing (voltage sources) are such as to establish current in the direction indicated for each branch.



- To describe the behavior of common-base amplifiers requires two set of characteristics:
  - Input or driving point characteristics.
  - Output or collector characteristics
- The output characteristics has 3 basic regions:
  - Active region –defined by the biasing arrangements
  - Cutoff region – region where the collector current is 0A

- Saturation region- region of the characteristics to the left of V_{CB} = 0V



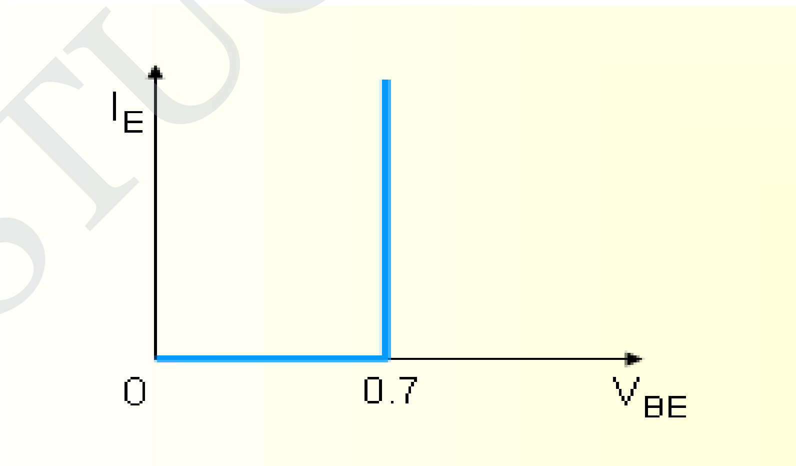
Input characteristics for a common silicon transistor

Output of collector characteristics for common-base transistor amplifier

Active region	Saturation region	Cut-off region
• I_E increased, I_C increased • BE junction forward bias and CB junction reverse bias • Refer to the graf, $I_C \approx I_E$ • I_C not depends on V_{CB} • Suitable region for the transistor working as amplifier	• BE and CB junction is forward bias • Small changes in V_{CB} will cause big different to I_C • The allocation for this region is to the left of V_{CB} = 0 V.	• Region below the line of I_E=0 A • BE and CB is reverse bias • no current flow at collector, only leakage current

- The curves (output characteristics) clearly indicate that a first approximation to the relationship between IE and IC in the active region is given by
    - $I_C \approx IE$
- Once a transistor is in the 'on' state, the base-emitter voltage will be assumed to be

V_{BE} = 0.7V



- In the dc mode the level of I_C and I_E due to the majority carriers are related by a quantity called alpha

$$\alpha = I_C / I_E$$

$$I_C = \alpha I_E + I_{CBO}$$

- It can then be summarize to $I_C = \alpha I_E$ (ignore I_{CBO} due to small value)
- For ac situations where the point of operation moves on the characteristics curve, an ac alpha defined by
- Alpha a common base current gain factor that shows the efficiency by calculating the current percent from current flow from emitter to collector. The value of α is typical from 0.9 ~ 0.998.

7.3 Common Emitter configuration

- It is called common-emitter configuration since :
  - emitter is common or reference to both input and output terminals.
  - emitter is usually the terminal closest to or at ground potential.
- Almost amplifier design is using connection of CE due to the high gain for current and voltage.
- Two set of characteristics are necessary to describe the behavior for CE; input (base terminal) and output (collector terminal) parameters.

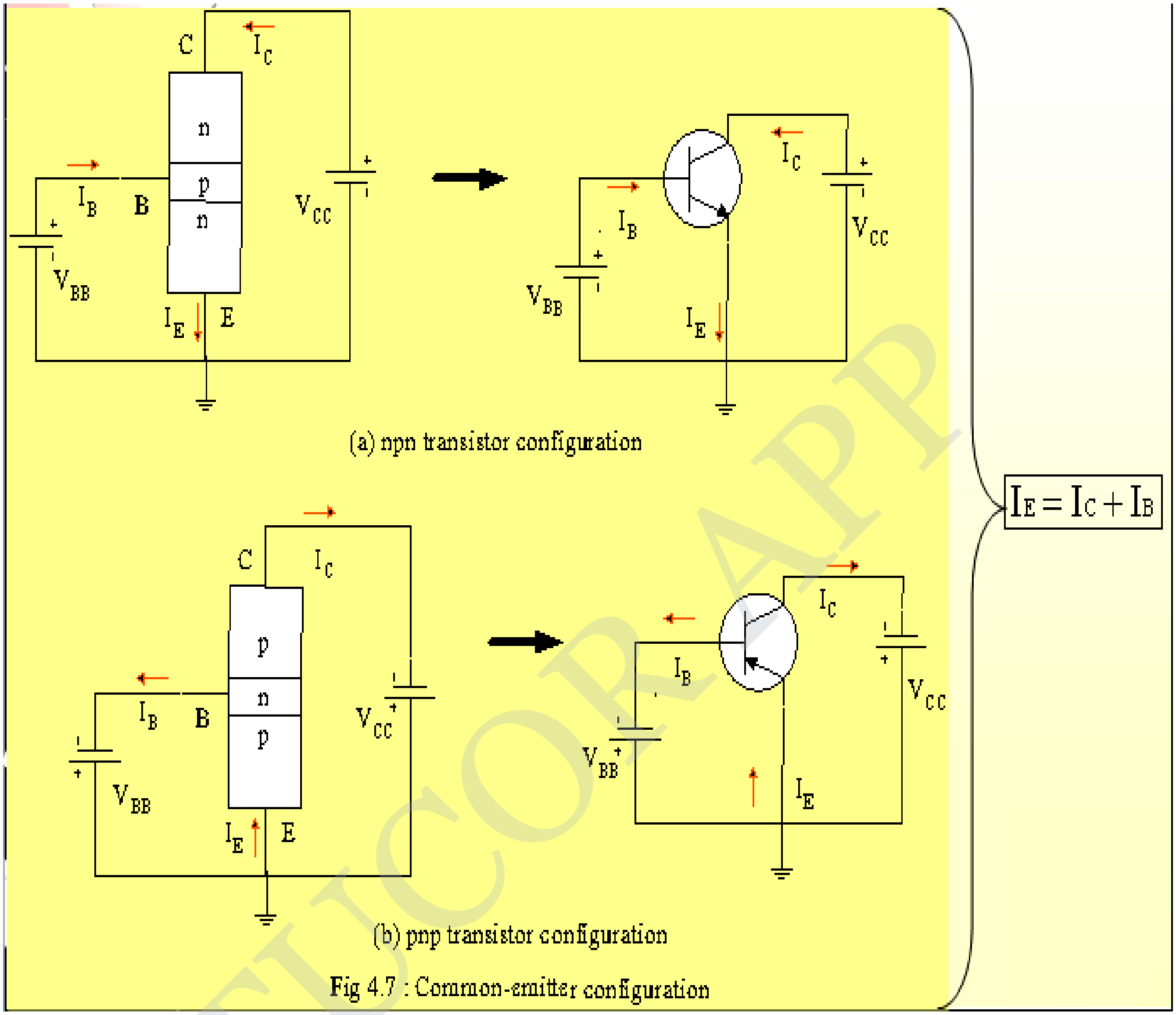
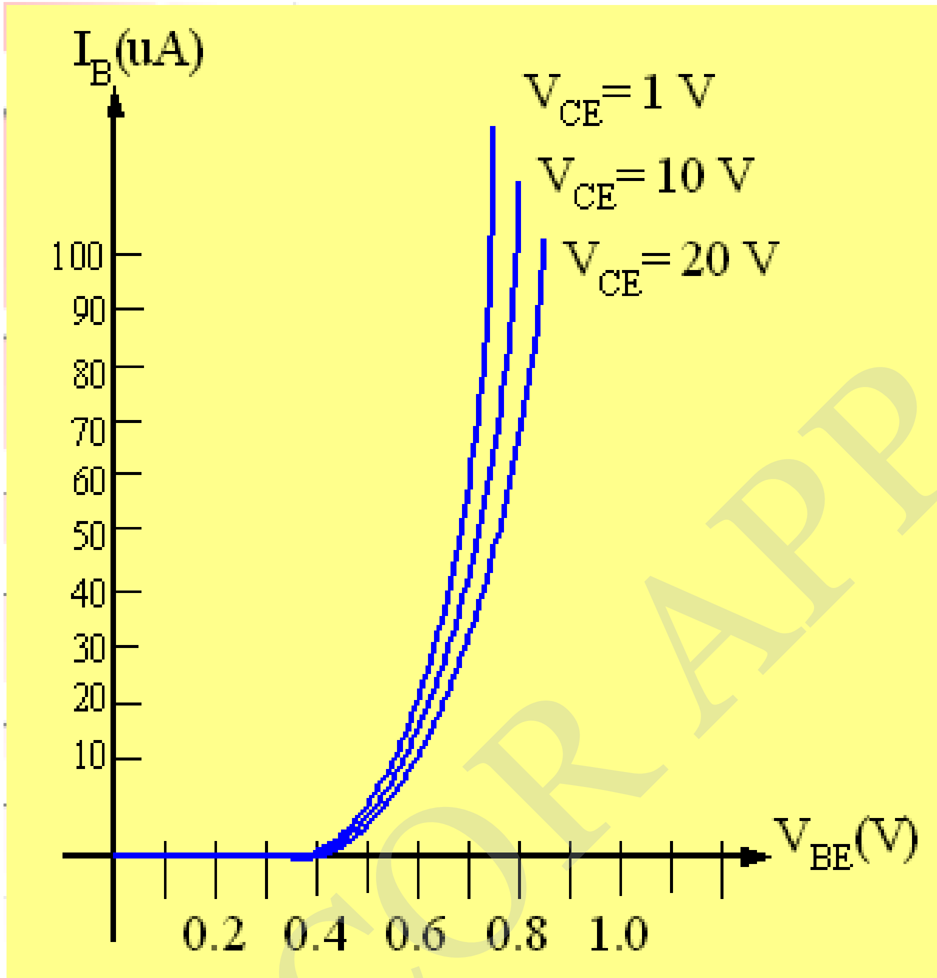
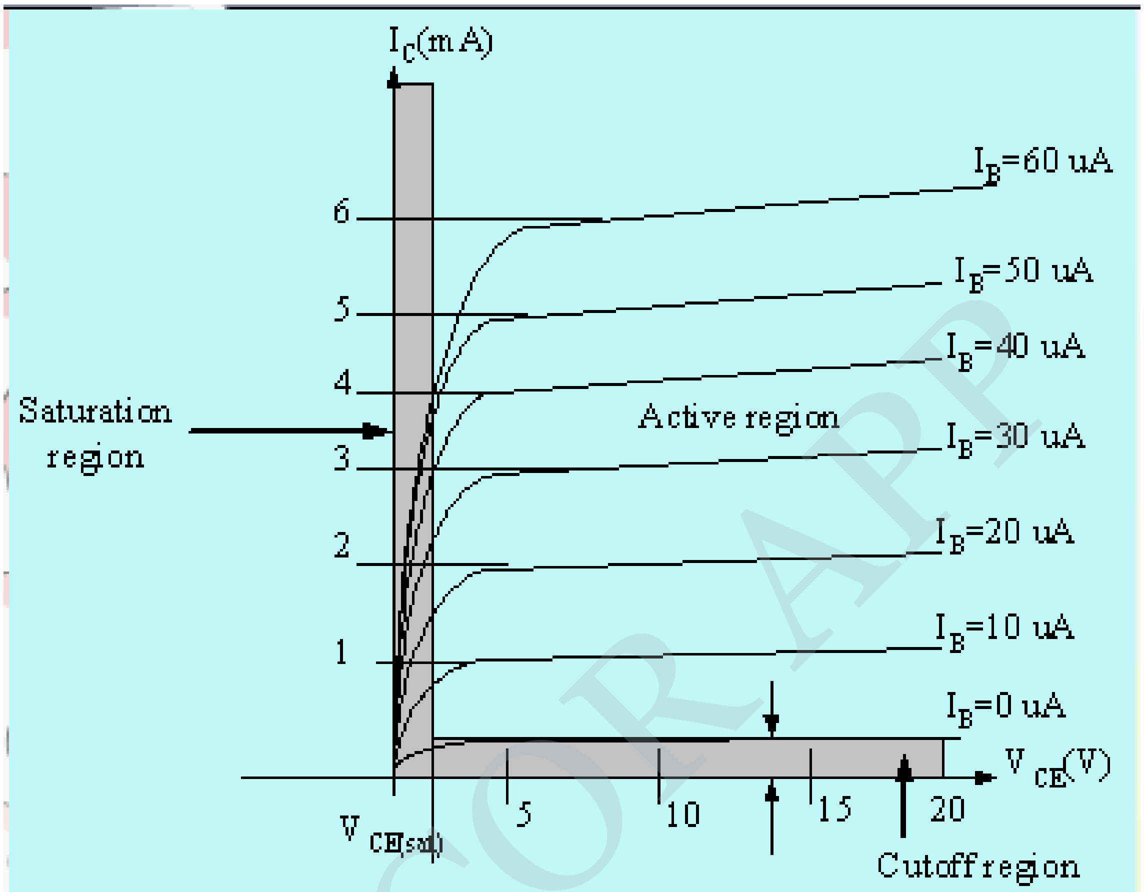


Fig 4.7 : Common-emitter configuration



Input characteristics for CE configuration

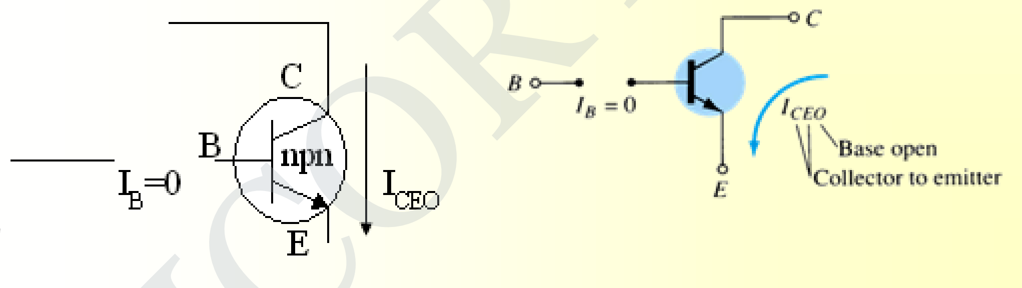
- I_B in microamperes compared to milliamperes of I_C.
- I_B will flow when V_{BE} > 0.7V for silicon and 0.3V for germanium
- Before this value I_B is very small and no I_B.
- Base-emitter junction is forward bias
- Increasing V_{CE} will reduce I_B for different values.



Output characteristics for CE configuration

- For small V_{CE} ($V_{CE} < V_{CESAT}$, I_C increase linearly with increasing of V_{CE}
- $V_{CE} > V_{CESAT}$ I_C not totally depends on V_{CE} → constant I_C
- I_B(uA) is very small compare to I_C (mA). Small increase in I_B cause big increase in I_C
- I_B=0 A → I_{CEO} occur.
- Noticing the value when I_C=0A. There is still some value of current flows.

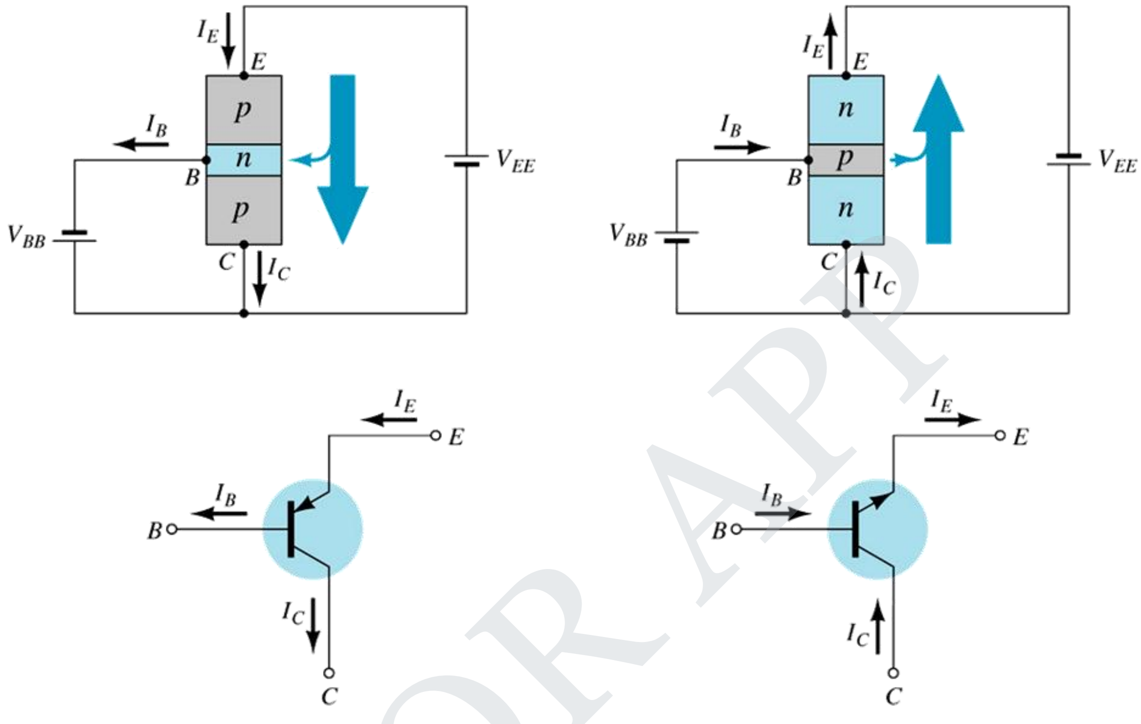
Active region	Saturation region	Cut-off region
• B-E junction is forward bias • C-B junction is reverse bias • can be employed for voltage, current and power amplification	• B-E and C-B junction is forward bias, thus the values of I_B and I_C is too big. • The value of V_{CE} is so small. • Suitable region when the transistor as a logic switch. • NOT and avoid this region when the transistor as an amplifier.	• region below I_B=0µA is to be avoided if an undistorted o/p signal is required • B-E junction and C-B junction is reverse bias • I_B=0, I_C not zero, during this condition I_C=I_{CEO} where is this current flow when B-E is reverse bias.



7.4 Common Collector configuration

- Also called emitter-follower (EF).
- It is called common-emitter configuration since both the
  - signal source and the load share the collector terminal as a common connection point.
- The output voltage is obtained at emitter terminal.
- The input characteristic of common-collector configuration is similar with common-emitter. configuration.
- Common-collector circuit configuration is provided with the load resistor connected from emitter to ground.

- It is used primarily for impedance-matching purpose since it has high input impedance and low output impedance.



(a) (b)

- For the common-collector configuration, the output characteristics are a plot of I_E vs V_{CE} for a range of values of I_B.

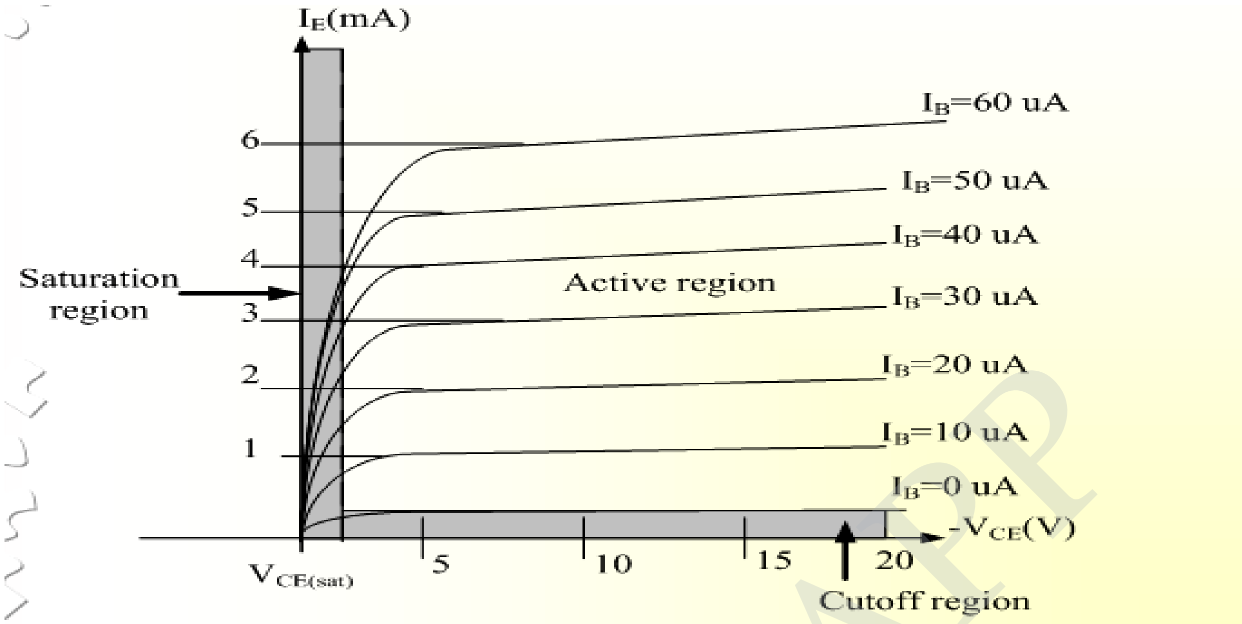
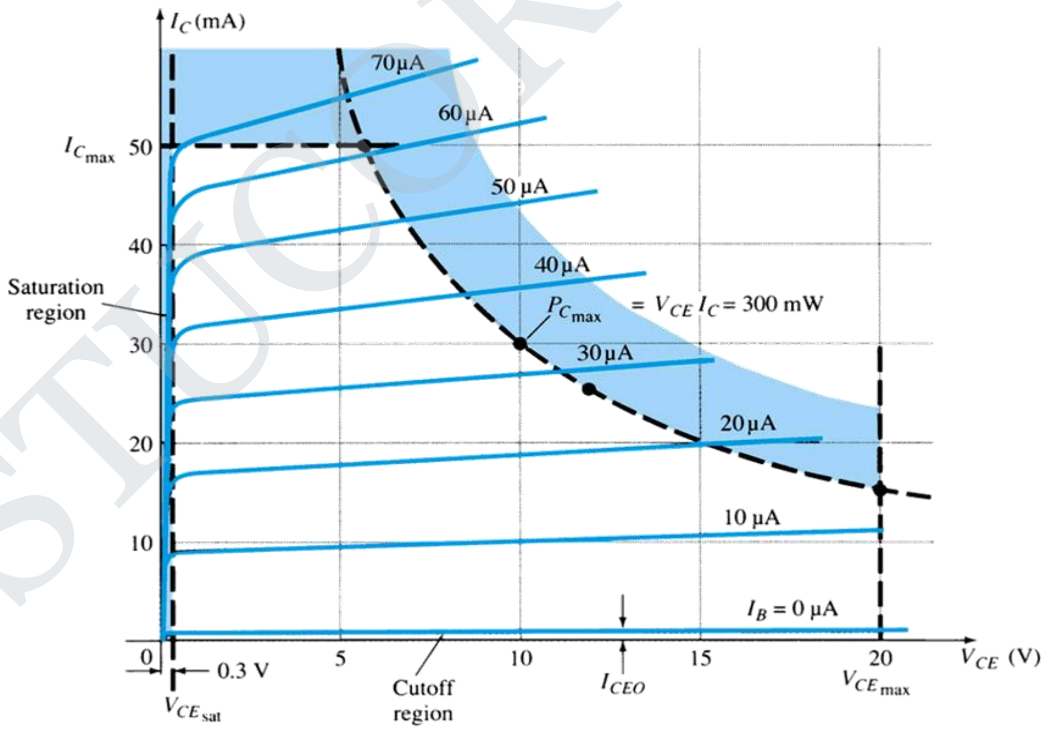


Fig 4.9 : Output characteristic in CC configuration for npn transistor



Input characteristics of CC configuration

7.5 Small Signal Amplifier

When the input signal is so weak as to produce small fluctuations in the collector current compared to its quiescent value, the amplifier is known as Small Signal Amplifier.

In other words, as the name indicates, the input applied to the circuit is $V_{in} << V_{th}$. It has only one amplifying device.

$$\alpha = I_C / I_E$$

$$I_C = \alpha I_E + I_{CBO}$$

Voltage and current equation for hybrid parameters:

$$V_1 = h_{11}i_1 + h_{12}V_2$$

$$I_2 = h_{21}i_1 + h_{22}V_2$$

The values of h-parameters:

$$h_{11} = V_1 / i_1$$

$$h_{12} = V_1 / V_2$$

$$h_{21} = i_2 / i_1$$

$$\mathbf{h_{22} = i_2 / V_2}$$

UNIT-IV DIGITAL ELECTRONICS

4.1 BINARY NUMBER SYSTEM

4.1.1.1 Introduction

The number system that you are familiar with, that you use every day, is the decimal number system, also commonly referred to as the base-10 system. When you perform computations such as 3 + 2 = 5, or 21 – 7 = 14, you are using the decimal number system. This system, which you likely learned in first or second grade, is ingrained into your subconscious; it's the natural way that you think about numbers. Evidence exists that Egyptians were using a decimal number system five thousand years ago. The Roman numeral system, predominant for hundreds of years, was also a decimal number system (though organized differently from the Arabic base-10 number system that we are most familiar with). Indeed, base-10 systems, in one form or another, have been the most widely used number systems ever since civilization started counting.

In dealing with the inner workings of a computer, though, you are going to have to learn to think in a different number system, the binary number system, also referred to as the base-2 system.

Consider a child counting a pile of pennies. He would begin: "One, two, three, …, eight, nine." Upon reaching nine, the next penny counted makes the total one single group of ten pennies. He then keeps counting: "One group of ten pennies… two groups of ten pennies… three groups of ten pennies … eight groups of ten pennies … nine groups of ten pennies…" Upon reaching nine groups of ten pennies plus nine additional pennies, the next penny counted makes the total thus far: one single group of one hundred pennies. Upon completing the task, the child might find that he has three groups of one hundred pennies, five groups of ten pennies, and two pennies left over: 352 pennies.

More formally, the base-10 system is a positional system, where the rightmost digit is the ones position (the number of ones), the next digit to the left is the tens position (the number of groups of 10), the next digit to the left is the hundreds position (the number of groups of 100), and so forth. The base-10 number system has 10 distinct symbols, or digits (0, 1, 2, 3,…8, 9). In decimal notation, we write a number as a string of symbols, where each symbol is one of these ten digits, and to interpret a decimal number, we multiply each digit by the power of 10 associated with that digit's position.

For example, consider the decimal number: 6349. This number is:

$$6\,3\,4\,9 = 6 \cdot 10^3 + 3 \cdot 10^2 + 4 \cdot 10^1 + 9 \cdot 10^0$$

10^3 position (i.e., thousands position)	10^2 position (i.e., hundreds position)	10^1 position (i.e., tens position)	10^0 position (i.e., ones position)

Consider: Computers are built from transistors, and an individual transistor can only be ON or OFF (two options). Similarly, data storage devices can be optical or magnetic. Optical storage devices store data in a specific location by controlling whether light is reflected off that location or is not reflected off that location (two options). Likewise, magnetic storage devices store data in a specific location by magnetizing the particles in that location with a specific orientation. We can have the north magnetic pole pointing in one direction, or the opposite direction (two options).

Computers can most readily use two symbols, and therefore a base-2 system, or binary number system, is most appropriate. The base-10 number system has 10 distinct symbols: 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. The base-2 system has exactly two symbols: 0 and 1. The base-10 symbols are termed digits. The base-2 symbols are termed binary digits, or bits for short. All base-10 numbers are built as strings of digits (such as 6349). All binary numbers are built as strings of bits (such as 1101). Just as we would say that the decimal number 12890 has five digits, we would say that the binary number 11001 is a five-bit number.

1.2 The Binary Number System

Consider again the example of a child counting a pile of pennies, but this time in binary. He would begin with the first penny: "1." The next penny counted makes the total one single group of two pennies. What number is this?

When the base-10 child reached nine (the highest symbol in his scheme), the next penny gave him "one group of ten", denoted as 10, where the "1" indicated one collection of ten. Similarly, when the base-2 child reaches one (the highest symbol in his scheme), the next penny gives him "one group of two", denoted as 10, where the "1" indicates one collection of two.

Back to the base-2 child: The next penny makes one group of two pennies and one additional penny: "11." The next penny added makes two groups of two, which is one group of 4: "100." The "1" here indicates a collection of two groups of two, just as the "1" in the base-10 number 100 indicates ten groups of ten.

Upon completing the counting task, base -2 child might find that he has one group of four pennies, no groups of two pennies, and one penny left over: 101 pennies. The child counting the same pile of pennies in base-10 would conclude that there were 5 pennies. So, 5 in base-10 is equivalent to 101 in base-2. To avoid confusion when the base in use if not clear from the context, or when using multiple bases in a single expression, we append a subscript to the number to indicate the base, and write:

$$5_{10} = 101_2$$

Just as with decimal notation, we write a binary number as a string of symbols, but now each symbol is a 0 or a 1. To interpret a binary number, we multiply each digit by the power of 2 associated with that digit's position.

For example, consider the binary number 1101. This number is:

$$\underline{1\,1\,0\,1} = 1 \cdot 2^3 + 1 \cdot 2^2 + 0 \cdot 2^1 + 1 \cdot 2^0 = 13_{10}$$

2^3 position	2^2 position	2^1 position	2^0 position
(i.e., eights position)	(i.e., fours position)	(i.e., twos position)	(i.e., ones position)

Since binary numbers can only contain the two symbols 0 and 1, numbers such as 25 and 1114000 cannot be binary numbers.

We say that all data in a computer is stored in binary—that is, as 1's and 0's. It is important to keep in mind that values of 0 and 1 are logical values, not the values of a physical quantity, such as a voltage. The actual physical binary values used to store data internally within a computer might be, for instance, 5 volts and 0 volts, or perhaps 3.3 volts and 0.3 volts or perhaps reflection and no reflection. The two values that are used to physically store data can differ within different portions of the same computer. All that really matters is that there are two different symbols, so we will always refer to them as 0 and 1.

A string of eight bits (such as 11000110) is termed a byte. A collection of four bits (such as 1011) is smaller than a byte, and is hence termed a nibble. (This is the sort of nerd-humor for which engineers are famous.)

The idea of describing numbers using a positional system, as we have illustrated for base-10 and base-2, can be extended to any base. For example, the base-4 number 231 is:

$$2\,3\,1 = 2 \cdot 4^2 + 3 \cdot 4^1 + 1 \cdot 4^0 = 45_{10}$$

4^2 position	4^1 position	4^0 position
(i.e., sixteens position)	(i.e., fours position)	(i.e., ones position)

1.3 Converting Between Binary Numbers and Decimal Numbers

We humans about numbers using the decimal number system, whereas computers use the binary number system. We need to be able to readily shift between the binary and decimal number representations.

Converting a Binary Number to a Decimal Number

To convert a binary number to a decimal number, we simply write the binary number as a sum of powers of 2. For example, to convert the binary number 1011 to a decimal number, we note that the rightmost position is the ones position and the bit value in this position is a 1. So, this rightmost bit has the decimal value of $1 \cdot 2^0$. The next position to the left is the twos position, and the bit value in this position is also a 1. So, this next bit has the decimal value of $1 \cdot 2^1$. The next position to the left is the fours position, and the bit value in this position is a 0. The leftmost position is the eights position, and the bit value in this position is a 1. So, this leftmost bit has the decimal value of $1 \cdot 2^3$. Thus:

$$1011_2 = 1 \cdot 2^3 + 0 \cdot 2^2 + 1 \cdot 2^1 + 1 \cdot 2^0 = 8 + 2 + 1 = 11_{10}$$

1. The binary number 110110 as a decimal number.

Solution:

For example, to convert the binary number 10101 to decimal, we annotate the position values below the bit values:

1	0	1	0	1
16	8	4	2	1

Then we add the position values for those positions that have a bit value of 1: 16 + 4 + 1 = 21. Thus

$$10101_2 = 21_{10}$$

You should “memorize” the binary representations of the decimal digits 0 through 15 shown below.

Decimal Number	Binary Number
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111

Decimal Number	Binary Number
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

You may be wondering about the leading zeros in the table above. For example, the decimal number 5 is represented in the table as the binary number 0101. We could have represented the binary equivalent of 5 as 101, 00101, 0000000101, or with any other number of leading zeros. All answers are correct.

Sometimes, though, you will be given the size of a storage location. When you are given the size of the storage location, include the leading zeros to show all bits in the storage location. For example, if told to represent decimal 5 as an 8-bit binary number, your answer should be 00000101.

Converting a Decimal Number to a Binary Number: Method 2

The second method of converting a decimal number to a binary number entails repeatedly dividing the decimal number by 2, keeping track of the remainder at each step. To convert the decimal number *x* to binary:

Step 1. Divide *x* by 2 to obtain a quotient and remainder. The remainder will be 0 or 1.

Step 2. If the quotient is zero, you are finished: Proceed to Step 3. Otherwise, go back to Step 1, assigning *x* to be the value of the most-recent quotient from Step 1.

Step 3. The sequence of remainders forms the binary representation of the number.

1.4 Hexadecimal Numbers

In addition to binary, another number base that is commonly used in digital systems is base 16. This number system is called hexadecimal, and each digit position represents a power of 16. For any number base greater than ten, a problem occurs because there are more than ten symbols needed to represent the numerals for that number base. It is customary in these cases to use the ten decimal numerals followed by the letters of the alphabet beginning with A to provide the needed numerals. Since the hexadecimal system is base 16, there are sixteen numerals required. The following are the hexadecimal numerals:

0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

The following are some examples of hexadecimal numbers:

10_{16} 47_{16} $3FA_{16}$ $A03F_{16}$

The reason for the common use of hexadecimal numbers is the relationship between the numbers 2 and 16. Sixteen is a power of 2 ($16 = 2^4$). Because of this relationship, four digits in a binary number can be represented with a single hexadecimal digit. This makes conversion between binary and hexadecimal numbers very easy, and hexadecimal can be used to write large binary numbers with much fewer digits. When working with large digital systems, such as computers, it is common to find binary numbers with 8, 16 and even 32 digits. Writing a 16 or 32 bit binary number would be quite tedious and error prone. By using hexadecimal, the numbers can be written with fewer digits and much less likelihood of error.

To convert a binary number to hexadecimal, divide it into groups of four digits starting with the rightmost digit. If the number of digits isn't a multiple of 4, prefix the number with 0's so that each group contains 4 digits. For each four digit group, convert the 4 bit binary number into an equivalent hexadecimal digit. (See the Binary, BCD, and Hexadecimal Number Tables at the end of this document for the correspondence between 4 bit binary patterns and hexadecimal digits)

2. Convert the binary number 10110101 to a hexadecimal number

Divide into groups for 4 digits	1011 0101
Convert each group to hex digit	B 5
	$B5_{16}$

3. Convert the binary number 0110101110001100 to hexadecimal

Divide into groups of 4 digits	0110 1011 1000 1100
Convert each group to hex digit	6 B 8 C
	$6B8C_{16}$

To convert a hexadecimal number to a binary number, convert each hexadecimal digit into a group of 4 binary digits.

4. Convert the hex number 374F into binary

	3 7 4 F
Convert the hex digits to binary	0011 0111 0100 1111
	0011011101001111_2

There are several ways in common use to specify that a given number is in hexadecimal representation rather than some other radix. In cases where the context makes it absolutely clear that numbers are represented in hexadecimal, no indicator is used. In much written material where the context doesn't make it clear what the radix is, the numeric subscript 16 following the hexadecimal number is used. In most programming languages, this method isn't really feasible, so there are several conventions used depending on the language. In the C and C++ languages, hexadecimal constants are represented with a '0x' preceding the number, as in: 0x317F, or 0x1234, or 0xAF. In assembler programming languages that follow the Intel style, a hexadecimal constant begins with a numeric character (so that the assembler can distinguish it from a variable name), a leading '0' being used if necessary. The letter 'h' is then suffixed onto the number to inform the assembler that it is a hexadecimal constant. In Intel style assembler format: 371Fh and 0FABCh are valid hexadecimal constants. Note that: A37h isn't a valid hexadecimal constant. It doesn't begin with a numeric character, and so will be taken by the assembler as a variable name. In assembler programming languages that follow the Motorola style, hexadecimal constants begin with a '$' character. So in this case: $371F or $FABC or $01 are valid hexadecimal constants.

1.5 Binary Coded Decimal Numbers

Another number system that is encountered occasionally is Binary Coded Decimal. In this system, numbers are represented in a decimal form, however each decimal digit is encoded using a four bit binary number.

5. The decimal number 136 would be represented in BCD as follows:

136 = 0001 0011 0110

1 3 6

Conversion of numbers between decimal and BCD is quite simple. To convert from decimal to BCD, simply write down the four bit binary pattern for each decimal digit. To convert from BCD to decimal, divide the number into groups of 4 bits and write down the corresponding decimal digit for each 4 bit group.

There are a couple of variations on the BCD representation, namely packed and unpacked. An unpacked BCD number has only a single decimal digit stored in each data byte. In this case, the decimal digit will be in the low four bits and the upper 4 bits of the byte will be 0. In the packed BCD representation, two decimal digits are placed in each byte. Generally, the high order bits of the data byte contain the more significant decimal digit.

6. The following is a 16 bit number encoded in packed BCD format:

   01010110 10010011

   This is converted to a decimal number as follows:

   0101 0110 1001 0011

   5 6 9 3

   The value is 5693 decimal

7. The same number in unpacked BCD (requires 32 bits)

   00000101 00000110 00001001 00000011

   5 6 9 3

The use of BCD to represent numbers isn't as common as binary in most computer systems, as it is not as space efficient. In packed BCD, only 10 of the 16 possible bit patterns in each 4 bit unit are used. In unpacked BCD, only 10 of the 256 possible bit patterns in each byte are used. A 16 bit quantity can represent the range 0-65535 in binary, 0-9999 in packed BCD and only 0-99 in unpacked BCD.

Fixed Precision and Overflow

we haven't considered the maximum size of the number. We have assumed that as many bits are available as needed to represent the number. In most computer systems, this isn't the case. Numbers in computers are typically represented using a fixed number of bits. These sizes are typically 8 bits, 16 bits, 32 bits, 64 bits and 80 bits. These sizes are generally a multiple of 8, as most computer memories are organized on an 8 bit byte basis. Numbers in which a specific number of bits are used to represent the value are called fixed precision numbers. When a specific number of bits are used to represent a number, that determines the range of possible values that can be represented. For example, there are 256 possible combinations of 8 bits, therefore an 8 bit number can represent 256 distinct numeric values and the range is typically considered to be 0-255. Any number larger than 255 can't be represented using 8 bits. Similarly, 16 bits allows a range of 0-65535.

When fixed precision numbers are used, (as they are in virtually all computer calculations) the concept of overflow must be considered. An overflow occurs when the result of a calculation can't be represented with the number of bits available. For example when adding the two eight bit quantities: 150 + 170, the result is 320. This is outside the range 0-255, and so the result can't be represented using 8 bits. The result has overflowed the available range. When overflow occurs, the low order bits of the result will remain valid, but the high order bits will be lost. This results in a value that is significantly smaller than the correct result.

When doing fixed precision arithmetic (which all computer arithmetic involves) it is necessary to be conscious of the possibility of overflow in the calculations.

Signed and Unsigned Numbers.

we have only considered positive values for binary numbers. When a fixed precision binary number is used to hold only positive values, it is said to be unsigned. In this case, the range of positive values that can be represented is 0 -- 2^n-1, where n is the number of bits used. It is also possible to represent signed (negative as well as positive) numbers in binary. In this case, part of the total range of values is used to represent positive values, and the rest of the range is used to represent negative values.

There are several ways that signed numbers can be represented in binary, but the most common representation used today is called two's complement. The term two's complement is somewhat ambiguous, in that it is used in two different ways. First, as a representation, two's complement is a way of interpreting and assigning meaning to a bit pattern contained in a fixed precision binary quantity. Second, the term two's complement is also used to refer to an operation that can be performed on the bits of a binary quantity. As an operation, the two's complement of a number is formed by inverting all of the bits and adding 1. In a binary number being interpreted using the two's complement representation, the high order bit of the number indicates the sign. If the sign bit is 0, the number is positive, and if the sign bit is 1, the number is negative. For positive numbers, the rest of the bits hold the true magnitude of the number. For negative numbers, the lower order bits hold the complement (or bitwise inverse) of the magnitude of the number. It is important to note that two's complement representation can only be applied to fixed precision quantities, that is, quantities where there are a set number of bits.

Two's complement representation is used because it reduces the complexity of the hardware in the arithmetic-logic unit of a computer's CPU. Using a two's complement representation, all of the arithmetic operations can be performed by the same hardware whether the numbers are considered to be unsigned or signed. The bit operations performed are identical, the difference comes from the interpretation of the bits. The interpretation of the value will be different depending on whether the value is considered to be unsigned or signed.

8. Find the 2's complement of the following 8 bit number
   00101001

11010110	First, invert the bits
+ 00000001	Then, add 1
= 11010111	

The 2's complement of 00101001 is 11010111

9. Find the 2's complement of the following 8 bit number 10110101

01001010	Invert the bits
+ 00000001	then add 1
= 01001011	

The 2's complement of 10110101 is 01001011

The counting sequence for an eight bit binary value using 2's complement representation appears as follows:

01111111	7Fh	127	largest magnitude positive number
01111110	7Eh	126	
01111101	7Dh	125	
…			
00000011	03h		
00000010	02h		
00000001	01h		
00000000	00h		
11111111	0FFh	-1	
11111110	0FEh	-2	
11111101	0FDh	-3	
…			
10000010	82h	-126	
10000001	81h	-127	
10000000	80h	-128	largest magnitude negative number

Counting up from 0, when 127 is reached, the next binary pattern in the sequence corresponds to -128. The values jump from the greatest positive number to the greatest negative number, but that the sequence is as expected after that. (i.e. adding 1 to –128 yields –127, and so on.). When the count has progressed to 0FFh (or the largest unsigned magnitude possible) the count wraps around to 0. (i.e. adding 1 to –1 yields 0).

ASCII Character Encoding

The name ASCII is an acronym for: American Standard Code for Information Interchange. It is a character encoding standard developed several decades ago to provide a standard way for digital machines to encode characters. The ASCII code provides a mechanism for encoding alphabetic characters, numeric digits, and punctuation marks for use in representing text and numbers written using the Roman alphabet. As originally designed, it was a seven bit code. The seven bits allow the representation of 128 unique characters. All of the alphabet, numeric digits and standard English punctuation marks are encoded. The ASCII standard was later extended to an eight bit code (which allows 256 unique code patterns) and various additional symbols were added, including characters with diacritical marks (such as accents) used in European languages, which don't appear in English. There are also numerous non-standard extensions to ASCII giving different encoding for the upper 128 character codes than the standard. For example, The character set encoded into the display card for the original IBM PC had a non-standard encoding for the upper character set. This is a non-standard extension that is in very wide spread use, and could be considered a standard in itself.

Some important things to points about ASCII code:

- The numeric digits, 0-9, are encoded in sequence starting at 30h
- The upper case alphabetic characters are sequential beginning at 41h
- The lower case alphabetic characters are sequential beginning at 61h
- The first 32 characters (codes 0-1Fh) and 7Fh are control characters. They do not have a standard symbol (glyph) associated with them. They are used for carriage control, and protocol purposes. They include 0Dh (CR or carriage return), 0Ah (LF or line feed), 0Ch (FF or form feed), 08h (BS or backspace).
- Most keyboards generate the control characters by holding down a control key (CTRL) and simultaneously pressing an alphabetic character key. The control code will have the same value as the lower five bits of the alphabetic key pressed. So, for example, the control character 0Dh is carriage return. It can be generated by pressing CTRL-M. To get the full 32 control characters a few at the upper end of the range are generated by pressing CTRL and a punctuation key in combination. For example, the ESC (escape) character is generated by pressing CTRL-[(left square bracket).

Conversions Between Upper and Lower Case ASCII Letters.

ASCII code chart that the uppercase letters start at 41h and that the lower case letters begin at 61h. In each case, the rest of the letters are consecutive and in alphabetic order. The difference between 41h and 61h is 20h. Therefore the conversion between upper and lower case involves either adding or subtracting 20h to the character code. To convert a lower case letter to upper case, subtract 20h, and conversely to convert upper case to lower case, add 20h. It is important to note that you need to first ensure that you do in fact have an alphabetic character before performing the addition or subtraction. Ordinarily, a check should be made that the character is in the range 41h–5Ah for upper case or 61h-7Ah for lower case.

Conversion Between ASCII and BCD

ASCII code chart that the numeric characters are in the range 30h-39h. Conversion between an ASCII encoded digit and an unpacked BCD digit can be accomplished by adding or subtracting 30h. Subtract 30h from an ASCII digit to get BCD, or add 30h to a BCD digit to get ASCII. Again, as with upper and lower case conversion for alphabetic characters, it is necessary to ensure that the character is in fact a numeric digit before performing the subtraction. The digit characters are in the range 30h-39h.

Table 4.1 Equivalent Numbers in Decimal, Binary and Hexadecimal Notation:

Decimal	Binary	Hexadecimal
0	00000000	00
1	00000001	01
2	00000010	02
3	00000011	03
4	00000100	04
5	00000101	05
6	00000110	06
7	00000111	07
8	00001000	08
9	00001001	09
10	00001010	0A
11	00001011	0B
12	00001100	0C
13	00001101	0D
14	00001110	0E
15	00001111	0F
16	00010000	10
17	00010001	11
31	00011111	1F
32	00100000	20
63	00111111	3F
64	01000000	40
65	01000001	41
127	01111111	7F
128	10000000	80
129	10000001	81
255	11111111	FF
256	0000000100000000	0100
32767	0111111111111111	7FFF
32768	1000000000000000	8000
65535	1111111111111111	FFFF

ASCII Character Set

Low Order Bits		High Order Bits							
		0000	0001	0010	0011	0100	0101	0110	0111
		0	1	2	3	4	5	6	7
0000	0	NUL	DLE	Space	0	@	P	`	p
0001	1	SOH	DC1	!	1	A	Q	a	q
0010	2	STX	DC2	"	2	B	R	b	r
0011	3	ETX	DC3	#	3	C	S	c	s
0100	4	EOT	DC4	$	4	D	T	d	t
0101	5	ENQ	NAK	%	5	E	U	e	u
0110	6	ACK	SYN	&	6	F	V	f	v
0111	7	BEL	ETB	'	7	G	W	g	w
1000	8	BS	CAN	(	8	H	X	h	x
1001	9	HT	EM	)	9	I	Y	i	y
1010	A	LF	SUB	*	:	J	Z	j	z
1011	B	VT	ESC	+	;	K	[	k	{
1100	C	FF	FS	,	<	L	\	l	|
1101	D	CR	GS	-	=	M	]	m	}
1110	E	SO	RS	.	>	N	^	n	~
1111	F	SI	US	/	?	O	_	o	DEL

4.2 LOGIC GATES

All digital systems are made from a few basic digital circuits that we call logic gates. These circuits perform the basic logic functions that we will describe in this chapter. The physical realization of these logic gates has changed over the years from mechanical relays to electronic vacuum tubes to transistors to integrated circuits containing thousands of transistors.

In this appendix you will learn:

- Definitions of the basic gates in terms of truth tables and logic equations
- DeMorgan's Theorem
- How gates defined in terms of positive and negative logic are related
- To use multiple-input gates
- How to perform a sum of products and a product of sums design from a truth table specification

4.2.1 The Three Basic Logic Gates

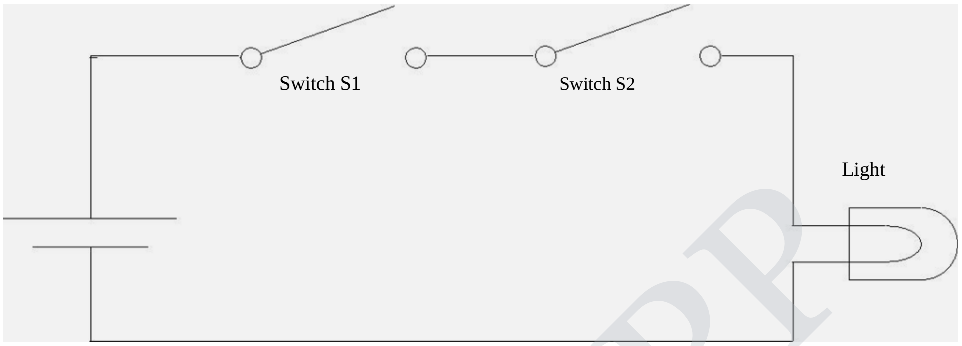
Much of a computer's hardware is comprised of digital logic circuits. Digital logic circuits are built from just a handful of primitive elements, called logic gates, combined in various ways.

In a digital logic circuit, only two values may be present. The values may be −5 and + 5 volts. Or the values may be 0.5 and 3.5 volts. Or the values may be… you get the picture. To allow consideration of all of these possibilities, we will say that digital logic circuits allow the presence of two logical values: 0 and 1.

So, signals in a digital logic circuit take on the values of 0 or 1. Logic gates are devices which compute functions of these binary signals.

The AND Gate

Consider the circuit below which consists of a battery, a light, and two switches in series:



When will the light turn on? It should be clear that the light will turn on only if both switch S1 and switch S2 are shut.

It is quite likely that you encounter the and operation in some shape or form hundreds of times each day. Consider the simple action of withdrawing funds from your checking account at an ATM. You will only be able to complete the transaction if you have a checking account and you have money in it. The ATM will only permit the transaction if you have your ATM card and you enter your correct 4-digit PIN. To enter the correct PIN, you have to enter the first digit correctly and enter the second digit correctly and enter the third digit correctly and enter the fourth digit correctly.

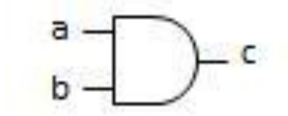
Returning to the circuit above, we can represent the light's operation using a table:

S1	S2	Light
open	open	off
open	closed	off
closed	open	off
closed	closed	on

The switch is a binary device: it can be open or closed. Let’s represent these two states as 0 and 1. Likewise, the light is a binary device with two states: off and on, which we will represent as 0 and 1. Rewriting the table above with this notation, we have:

S1	S2	Light
0	0	0
0	1	0
1	0	0
1	1	1

This table, which displays the output for all possible combinations of the input, is termed the truth table for the AND operation. In a computer, this and functionality is implemented with a circuit called an AND gate. The simplest AND gate has two inputs and one output and is represented pictorially by the symbol:



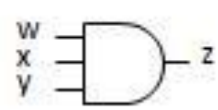
where the inputs have been labeled *a* and *b*, and the output has been labeled *c*. If both inputs are 1 then the output is 1. Otherwise, the output is 0.

We represent the and operation by using either the multiplication symbol (i.e., " · ") or by writing the inputs together. Thus, for the AND gate shown above, we would write the output *c* as c = a b or as c = ab. This would be pronounced: "*c* = *a* and *b*."

The truth table for the AND gate is shown below. The output *c* = ab is equal to 1 if and only if (iff) a is 1 and b is 1. Otherwise, the output is 0.

a	*b*	*c*
0	0	0
0	1	0
1	0	0
1	1	1

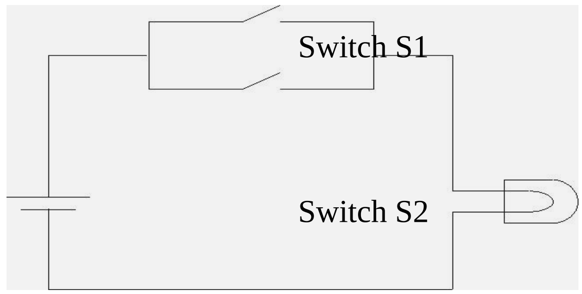
AND gates can have more than one input (however, an AND gate always has just a single output). Let's consider a three-input AND gate:



w	*x*	*y*	*z*
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

The OR Gate

Now consider the circuit shown below, that has 2 switches in parallel.



Light

It is evident that the light will turn on when either switch S_1 is shut or switch S_2 is shut or both are shut.

It is quite likely that you encounter the ***or*** operation in some shape or form hundreds of times each day. Consider the simple action of sitting on your couch at home at two in the morning studying for your Digital Logic class. Your phone will ring if you get a call from Alice or from Bob. Your home's security alarm will go off if the front door opens or the back door opens. You will drink a cup of coffee if you are drowsy ***or*** you are thirsty.

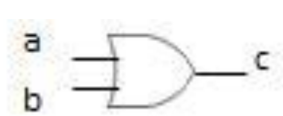
We can represent the light's operation using a table

S1	S2	Light
open	open	off
open	closed	on
closed	open	on
closed	closed	on

Changing the words *open* and *off* to 0 and the words *shut* and *on* to 1 and the table becomes:

S1	S2	Light
0	0	0
0	1	1
1	0	1
1	1	1

This is the truth table for the OR operation. This ***or*** functionality is implemented with a circuit called an OR gate. The simplest OR gate has two inputs and one output and is represented pictorially by the symbol:



If either or both inputs are 1, the output is 1. Otherwise, the output is 0.

We represent the or operation by using the addition symbol. Thus, for the OR gate above, we would write the output c as c = a + b. This would be pronounced: "*c* = *a* or *b*."

The truth table for the OR gate is shown below. The output is 1 if *a* is 1 ***or*** *b* is 1; otherwise, the output is 0.

a	*b*	*c*
0	0	0
0	1	1
1	0	1
1	1	1

The NOT Gate

The last of our basic logic gates is the NOT gate. The NOT gate always has one input and one output. If the input is 1, the output is 0. If the input is 0, the output is 1. This operation—chaging the value of the binary input—is called complementation, negation or inversion. The mathematical symbol for negation is an apostrophe. If the input to a NOT gate is P, the output, termed the complement, is denoted as P′.

The pictorial symbol for a NOT gate is intended to depict an amplifier followed by a bubble, shown below. Sometimes the NOT operation is represented by just the bubble, without the amplifier.

The truth table for the NOT gate is shown below:

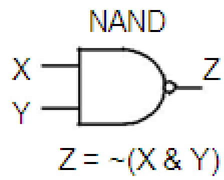
P	*P'*
0	1
1	0

Three New Gates

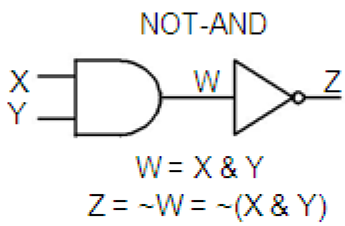
Three new gates, NAND, NOR, and Exclusive-OR, can be formed from our three basic gates: NOT, AND, and OR.

NAND Gate

The logic symbol for a NAND gate is like an AND gate with a small circle (or bubble) on the output.we see that the output of a NAND gate is 0 (low) only if both inputs are 1 (high) . The NAND gate is equivalent to an AND gate followed by an inverter (NOT-AND).



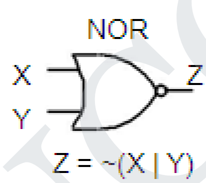
X	Y	Z
0	0	1
0	1	1
1	0	1
1	1	0



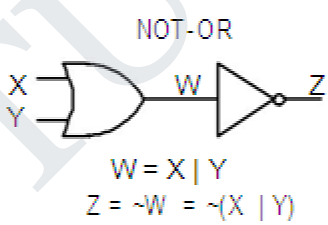
X	Y	W	Z
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

NOR Gate

The logic symbol for a NOR gate is like an OR gate with a small circle (or bubble) on the output. From the truth table .we see that the output of a NOR gate is 1 (high) only if both inputs are 0 (low). The NOR gate is equivalent to an OR gate followed by an inverter (NOT-OR), as shown by the two truth tables.



X	Y	Z
0	0	1
0	1	0
1	0	0
1	1	0



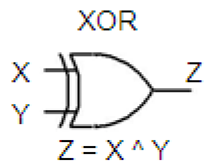
X	Y	W	Z
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

Exclusive-OR Gate.

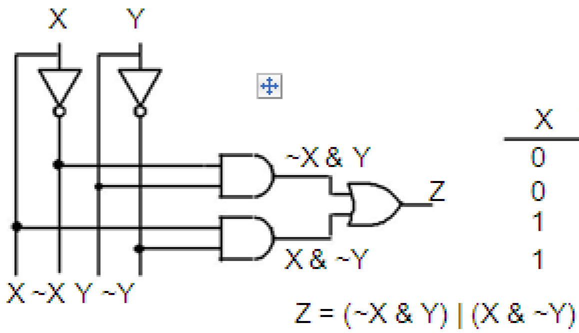
The XOR gate logic symbol is like an OR gate symbol with an extra curved vertical line on the input. From the truth table .we see that the output Z of an XOR gate is 1 (true or high) if either input, X or Y, is 1 (true or high), but not both. The output Z will be zero if both X and Y are the same (either both 1 or both 0).

The equation for the XOR gate is given as Z = X ^ Y. In this book we will use the symbol ^ as the XOR operator. Sometimes the symbol or the dollar sign $ is used to denote

Exclusive-OR. We will use the symbol ^ because that is the symbol recognized by the Verilog software used to program a CPLD.



X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	0



X	Y	~X	~Y	~X & Y	X & ~Y	Z
0	0	1	1	0	0	0
0	1	1	0	1	0	1
1	0	0	1	0	1	1
1	1	0	0	0	0	0

4.3 BOOLEAN ALGEBRA

Boolean algebra is an algebraic structure defined by a set of elements, B, together with two binary operators, + and., provider that the following postulates are satisfied.

T1: Commutative Law
(a) A+B = B+A
(b) A B = BA

T2: Associative Law
(a)(A+B) +C = A+ (B+C)
(b)(A B) C = A (B C)

T3: Distributive Law
(a) A (B +C) = A B + AC
(b) A + (B C) = (A +B) (A+C)

T4: Identity Law
(a) A+A =A
(b) A A =A

T5: Negative Law
(a) (A') =A'
(b) (A'') = A

T6: Redundant Law
(a) A+AB=A
(b) A (A +B) =A

T7: Null Law
(a) 0 + A = A
(b) 1 A = A

(c) $1 + A = 1$
(d) $0\ A = 0$

T8: Double Negation Law
(a) $A' + A = 1$
(b) $A'\ A = 0$

T9: Absorption Law
(a) $A + A'B = A + B$
(b) $A\ (A' + B) = AB$

T10: De Morgan's Theorem
(a) $(A+B)' = A'\ B'$
(b) $(AB)' = A' + B'$

Example 1:

Using theorems,

$$A + A'B = A\,1 + A'B$$
$$= A\,(1 + B) + A'B$$
$$= A + AB + A'B$$
$$= A + B\,(A + A')$$
$$= A + B$$

Using Truth Table

A	B	A+B	A’B	A+A’B
0	0	0	0	0
0	1	1	1	1
1	0	1	0	1
1	1	1	0	1

4.3.1 Verification Of De Morgan's Theorems:

- De Morgan's First Theorem states:

The complement of a product of variables is equal to the sum of the complements of the individual variables

- De Morgan's Second Theorem states:

The complement of sum of variables is equal to the product of the complements of the dividable variables

- **FIRST LAW**

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

Figure: De Morgan’s First Law

- **SECOND LAW**

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

Figure: De Morgan’s Second Law

4.4 ADDER

4.4.1 Half Adder

Half adder is a circuit that will add two bits & produce a sum & a carry bit. It needs two input bits & two output bits.Fig.4.1 shows the block diagram of a half adder.

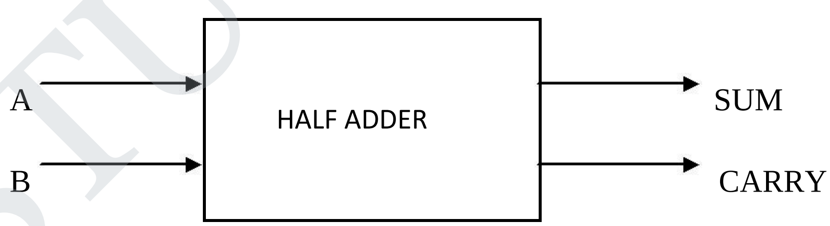
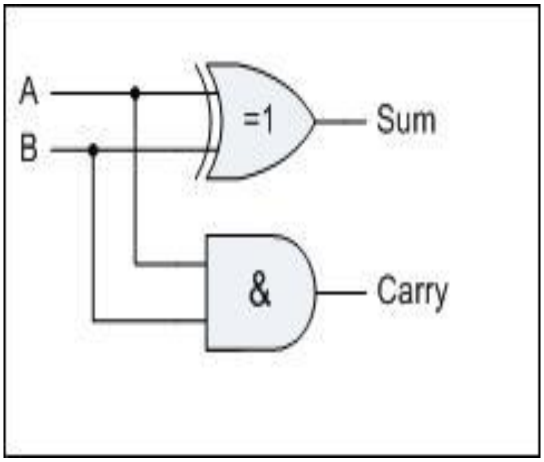


Figure: Block diagram of a Half Adder

Ex-OR gate will only produce an output "1" when "EITHER" input is at logic "1", so we need an additional output to produce a carry output, "1" when "BOTH" inputs "A" and "B" are at logic "1" and a standard AND Gate fits the bill nicely. By combining the Ex-OR gate with the AND gate results in a simple digital binary adder circuit known commonly as the "Half Adder" circuit.



INPUTS		OUTPUTS	
A	B	SUM	CARRY
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Figure: Logic diagram & Truth table for half adder

4.4.2 Full Adder

A half adder has only two inputs &there is no provision to add a carry coming from the lower order bits when multi addition is performed. For this purpose, a full adder is designed.

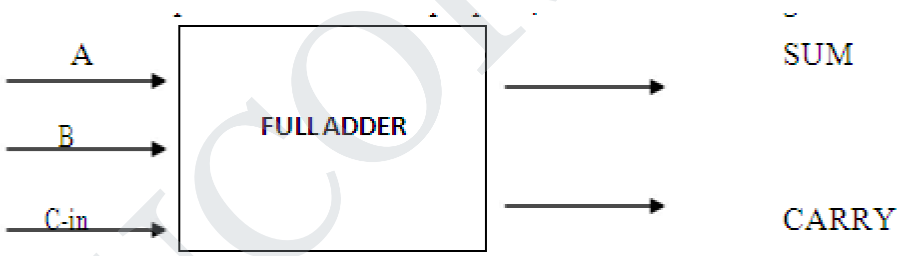


Figure: Block diagram of a Half Adder

The 1-bit Full Adder circuit is basically two half adders connected together and consists of three Ex-OR gates, two AND gates and an OR gate, six logic gates in total. The truth table for the full adder includes an additional column to take into account the Carry-in input as well as the summed output and carry-output.

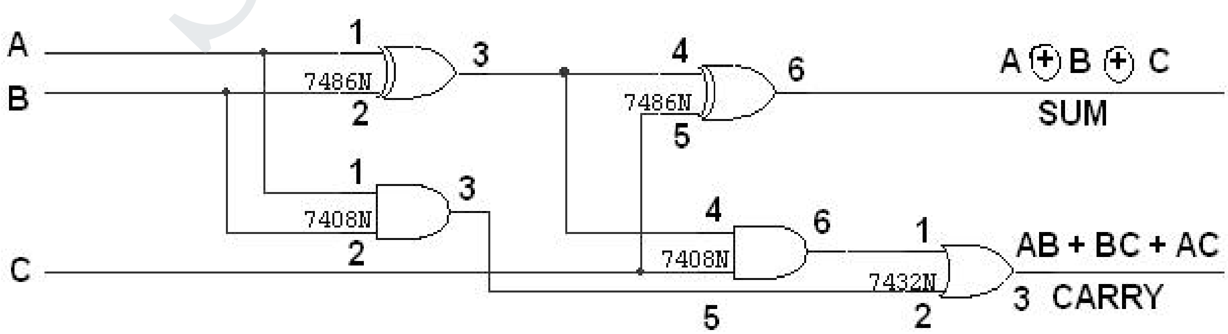


Figure: Logic diagram of a Full adder using two Half Adders

Table: Truth Table for Full Adder

INPUTS			OUTPUTS	
A	B	C	CARRY	SUM
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

4.5 FLIP FLOP

4.5.1 RS Flip Flop

RS Flip Flop have two inputs, S and R. S is called set and R is called reset. The S input is used to produce HIGH on Q (i.e. store binary 1 in flip-flop). The R input is used to produce LOW on Q (i.e. store binary 0 in flip-flop). Q' is Q complementary output, so it always holds the opposite value of Q. The output of the S-R Flip Flop depends on current as well as previous inputs or state, and its state (value stored) can change as soon as its inputs change. The circuit and the truth table of RS Flip Flop is shown below.

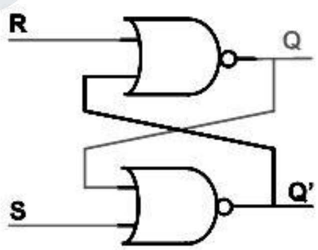


Figure : RS Flip Flop

Table: Truth table for RS Flip Flop

S	R	Q	Q+
0	0	0	0
0	0	1	1
0	1	X	0
1	0	X	1
1	1	X	0

The operation has to be analyzed with the 4 inputs combinations together with the 2 possible previous states.

- When S = 0 and R = 0: If we assume Q = 1 and Q' = 0 as initial condition, then output Q after input is applied would be Q = (R + Q')' = 1 and Q' = (S + Q)' = 0. Assuming Q = 0 and Q' = 1 as initial condition, then output Q after the input applied would be Q = (R + Q')' = 0 and Q' = (S + Q)' = 1. So it is clear that when both S and R inputs are LOW, the output is retained as before the application of inputs. (i.e. there is no state change).

- When S = 1 and R = 0: If we assume Q = 1 and Q' = 0 as initial condition, then output Q after input is applied would be Q = (R + Q')' = 1 and Q' = (S + Q)' = 0. Assuming Q = 0 and Q' = 1 as initial condition, then output Q after the input applied would be Q = (R + Q')' = 1 and Q' = (S + Q)' = 0. So in simple words when S is HIGH and R is LOW, output Q is HIGH.

- When S = 0 and R = 1: If we assume Q = 1 and Q' = 0 as initial condition, then output Q after input is applied would be Q = (R + Q')' = 0 and Q' = (S + Q)' = 1. Assuming Q = 0 and Q' = 1 as initial condition, then output Q after the input applied would be Q = (R + Q')' = 0 and Q' = (S + Q)' = 1. So in simple words when S is LOW and R is HIGH, output Q is LOW.
- When S = 1 and R =1 : No matter what state Q and Q' are in, application of 1 at input of NOR gate always results in 0 at output of NOR gate, which results in both Q and Q' set to LOW (i.e. Q = Q'). LOW in both the outputs basically is wrong, so this case is invalid.

It is possible to construct the RS Flip Flop using NAND gates (of course as seen in Logic gates section). The only difference is that NAND is NOR gate dual form (Did I say that in Logic gates section?). So in this case the R = 0 and S = 0 case becomes the invalid case. The circuit and Truth table of RS Flip Flop using NAND is shown below.

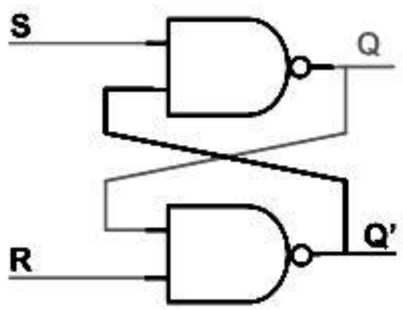


Figure : S-R using NAND Gates

Table Truth table for SR Flip Flop

S	**R**	**Q**	**Q+**
1	1	0	0
1	1	1	1
0	1	X	0
1	0	X	1
0	0	X	1

If you look closely, there is no control signal, so this kind of Flip Flopes or flip-flops are called asynchronous logic elements. Since all the sequential circuits are built around the RS Flip Flop, we will concentrate on synchronous circuits and not on asynchronous circuits.

4.5.2 RS Flip Flop with Clock

We have seen this circuit earlier with two possible input configurations: one with level sensitive input and one with edge sensitive input. The circuit below shows the level sensitive RS Flip Flop. Control signal "Enable" E is used to gate the input S and R to the RS Flip Flop. When Enable E is HIGH, both the AND gates act as buffers and thus R and S appears at the RS Flip Flop input and it functions like a normal RS Flip Flop. When Enable E is LOW, it drives LOW to both inputs of RS Flip Flop. As we saw in previous page, when both inputs of a NOR Flip Flop are low, values are retained (i.e. the output does not change).

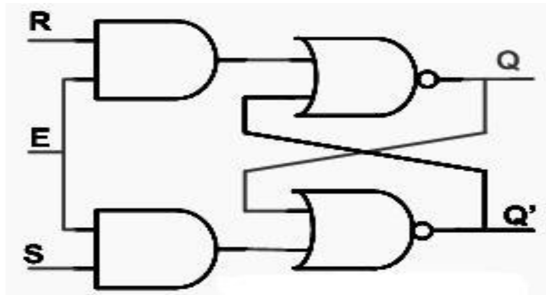


Figure : S-R with Edge Sensitive and Level sensitive

Set up and Hold time

For synchronous flip-flops, we have special requirements for the inputs with respect to clock signal input. They are

- **Setup Time:** Minimum time period during which data must be stable before the clock makes a valid transition. For example, for a posedge triggered flip-flop, with a setup time of 2 ns, Input Data (i.e. R and S in the case of RS flip-flop) should be stable for at least 2 ns before clock makes transition from 0 to 1.
- **Hold Time:** Minimum time period during which data must be stable after the clock has made a valid transition. For example, for a posed triggered flip-flop, with a hold time of 1 ns. Input Data (i.e. R and S in the case of RS flip-flop) should be stable for at least 1 ns after clock has made transition from 0 to 1.

If data makes transition within this setup window and before the hold window, then the flip-flop output is not predictable, and flip-flop enters what is known as meta stable state. In this state flip-flop output oscillates between 0 and 1. It takes some time for the flip-flop to settle down. The whole process is called Meta stability. You could refer to tidbits section to know more information on this topic. The waveform below shows input S (R is not shown), and CLK and output Q (Q' is not shown) for a SR posed flip-flop.

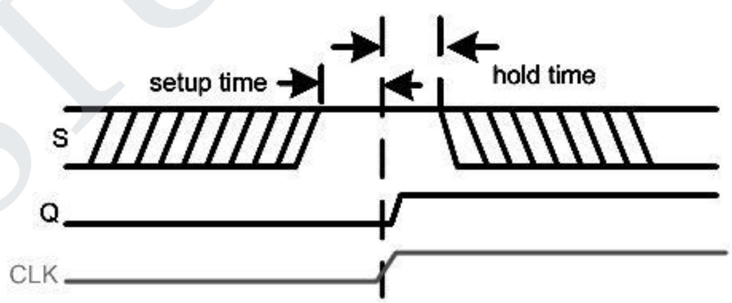


Figure: Waveform for S-R and CLK

4.5.3 D Flip Flop

The RS Flip Flop seen earlier contains ambiguous state; to eliminate this condition we can ensure that S and R are never equal. This is done by connecting S and R together with an inverter. Thus we have D Flip Flop: the same as the RS Flip Flop, with the only difference that there is only one input, instead of two (R and S). This input is called D or Data input. D Flip Flop is called D transparent Flip Flop for the reasons explained earlier. Delay flip-flop or delay latch is another name used. Below is the truth table and circuit of D Flip Flop.

In real world designs (ASIC/FPGA Designs) only D latches/Flip-Flops are used.

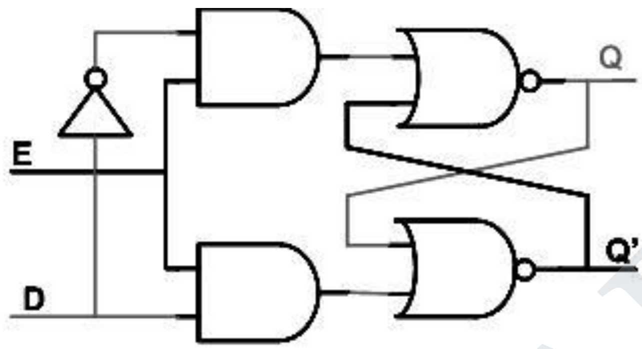


Figure 2.12: D Flip Flop with Edge Sensitive and Level sensitive

Table: Truth table for D Flip Flop

D	Q	Q+
1	X	1
0	X	0

Below is the D Flip Flop waveform, which is similar to the RS Flip Flop one, but with R removed.

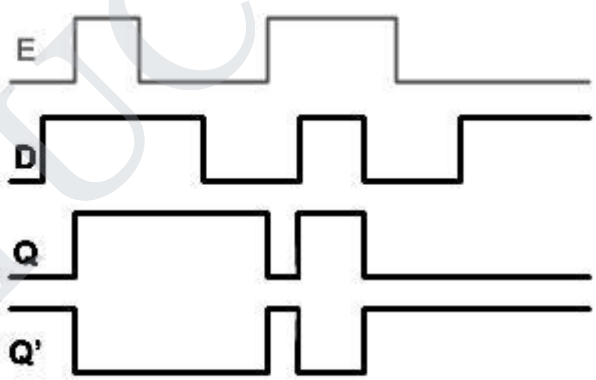


Figure: D Flip Flop waveform

4.5.5 JK Flip Flop

The ambiguous state output in the RS Flip Flop was eliminated in the D Flip Flop by joining the inputs with an inverter. But the D Flip Flop has a single input. JK Flip Flop is similar to RS Flip Flop in that it has 2 inputs J and K as shown Figurer below. The ambiguous state has been eliminated here: when both inputs are high, output toggles. The only difference we see here is output feedback to inputs, which is not there in the RS Flip Flop.

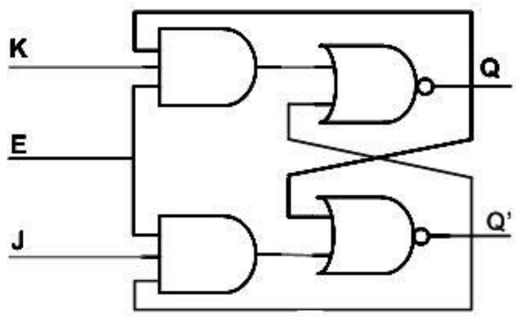


Figure: JK Flip Flop

Table: Truth table for JK Flip Flop

J	K	Q
1	1	0
1	1	1
1	0	1
0	1	0

4.4.4 T Flip Flop

When the two inputs of JK Flip Flop are shorted, a T Flip Flop is formed. It is called T Flip Flop as, when input is held HIGH, output toggles.

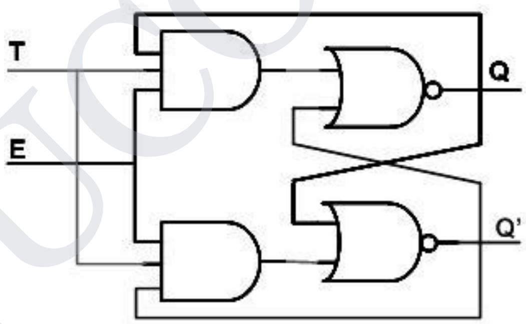


Figure : T Flip Flop

Table: T Flip Flop

T	Q	Q+
1	0	1
1	1	0
0	1	1
0	0	0

4.5.6 JK Master Slave Flip-Flop

All sequential circuits that we have seen in the last few pages have a problem (All level sensitive sequential circuits have this problem). Before the enable input changes state from HIGH to LOW (assuming HIGH is ON and LOW is OFF state), if inputs changes, then another state transition occurs for the same enable pulse. This sort of multiple transition problem is called racing.

If we make the sequential element sensitive to edges, instead of levels, we can overcome this problem, as input is evaluated only during enable/clock edges.

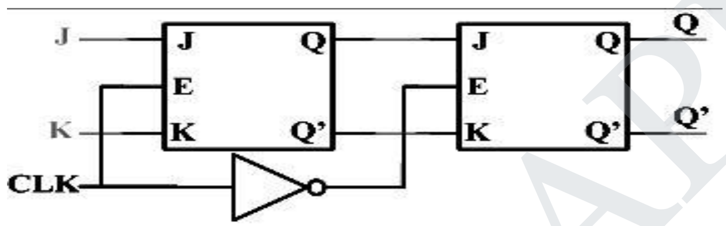


Figure: JK Master Slave Flip Flop

In the Figure above there are two Flip Flop, the first Flip Flop on the left is called master Flip Flop and the one on the right is called slave Flip Flop. Master Flip Flop is positively clocked and slave Flip Flop is negatively clocked.

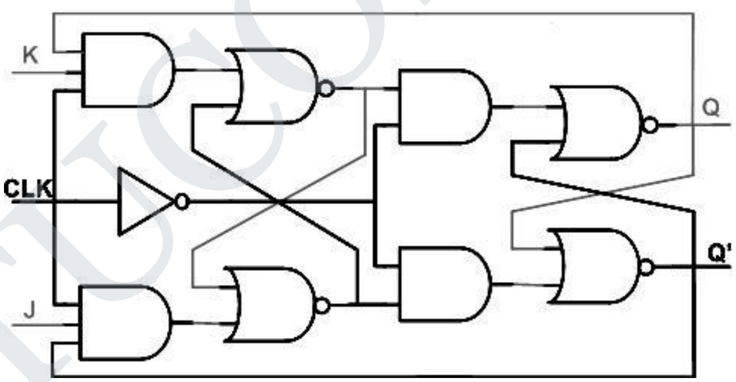


Figure : JK Master Slave Flip Flop

4.7 COUNTERS

- Counters are a specific type of sequential circuit.
- Like registers, the state, or the flip-flop values themselves, serves as the “output.”
- The output value increases by one on each clock cycle.
- After the largest value, the output “wraps around” back to 0.

Benefits of counters

- Counters can act as simple clocks to keep track of “time.”

- You may need to record how many times something has happened.
  - How many bits have been sent or received?
  - How many steps have been performed in some computation?
- All processors contain a program counter, or PC.
  - Programs consist of a list of instructions that are to be executed one after another (for the most part).
  - The PC keeps track of the instruction currently being executed.
  - The PC increments once on each clock cycle, and the next program instruction is then executed.

Counter Types

Asynchronous Counter (Ripple or Serial Counter)

Each FF is triggered one at a time with output of one FF serving as clock input of next FF in the chain.

Synchronous Counter (a.k.a. Parallel Counter)

All the FF" s in the counter are clocked at the same time.

Up Counter

Counter counts from zero to a maximum count.

Down Counter

Counter counts from a maximum count down to zero.

BCD Counter

Counter counts from 0000 to 1001 before it recycles.

Pre-settable Counter

Counter that can be preset to any starting count either synchronously or asynchronously

Ring Counter

Shift register in which the output of the last FF is connected back to the input of the first FF.

Johnson Counter

Shift register in which the inverted output of the last FF is connected to the input of the first

FF.

4.7.1 Synchronous Counter

There is a problem with the ripple counter just discussed. The output stages of the flip-flops further down the line (from the first clocked flip-flop) take time to respond to changes that occur due to the initial clock signal. This is a result of the internal propagation delay that occurs within a given flip-flop.

A standard TTL flip-flop may have an internal propagation delay of 30 ns. If you join four flip-flops to create a MOD-16 counter, the accumulative propagation delay at the highest-order output will be 120 ns. When used in high-precision synchronous systems, such large delays can lead to timing problems.

To avoid large delays, you can create what is called a synchronous counter. Synchronous counters, unlike ripple (asynchronous) counters, contain flip-flops whose clock inputs are driven at the same time by a common clock line. This means that output transitions for each flip-flop will occur at the same time. Now, unlike the ripple counter, you must use some additional logic circuitry placed between various flip-flop inputs and outputs to give the desired count waveform.

For example, to create a 4-bit MOD-16 synchronous counter requires adding two additional AND gates, as shown below. The AND gates act to keep a flip-flop in hold mode (if both input of the gate are low) or toggle mode (if both inputs of the gate are high). So, during the 0–1 count, the first flip-flop is in toggle mode (and always is); all the rest are held in hold mode. When it is time for the 2–4 count, the first and second flip-flops are placed in toggle mode; the last two are held in hold mode.

When it is time for the 4–8 count, the first AND gate is enabled, allowing the third flip-flop to toggle. When it is time for the 8–15 count, the second AND gate is enabled, allowing the last flip-flop to toggle

MOD-16 synchronous counter

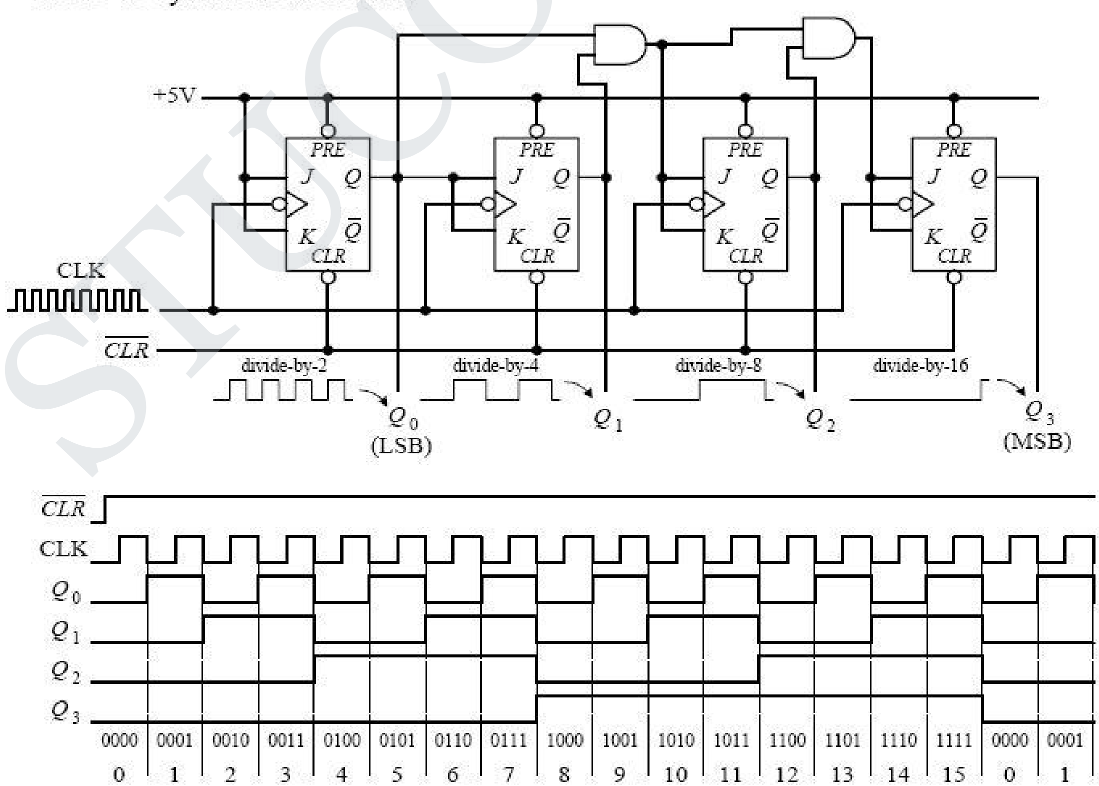


Figure: Mod 16 Synchronous Counters and Cycle Diagram

The ripple (asynchronous) and synchronous counters discussed so far are simple but hardly ever used. In practice, if you need a counter, be it ripple or synchronous, you go out and purchase a counter IC. These ICs are often MOD-16 or MOD-10 counters and usually come with many additional features. For example, many ICs allow you to preset the count to a desired number via parallel input lines.

Synchronous Up /Down Counter

The down counter counts in reverse from 1111 to 0000 and then goes to 1111. If we inspect the count cycle, we find that each flip-flop will complement when the previous flip- flops are all 0 (this is the opposite of the up counter). The down counter can be implemented similar to the up counter, except that the AND gate input is taken from Q' instead of Q. This is shown in the following Figure of a 4-bit up-down counter using T flip-flops.

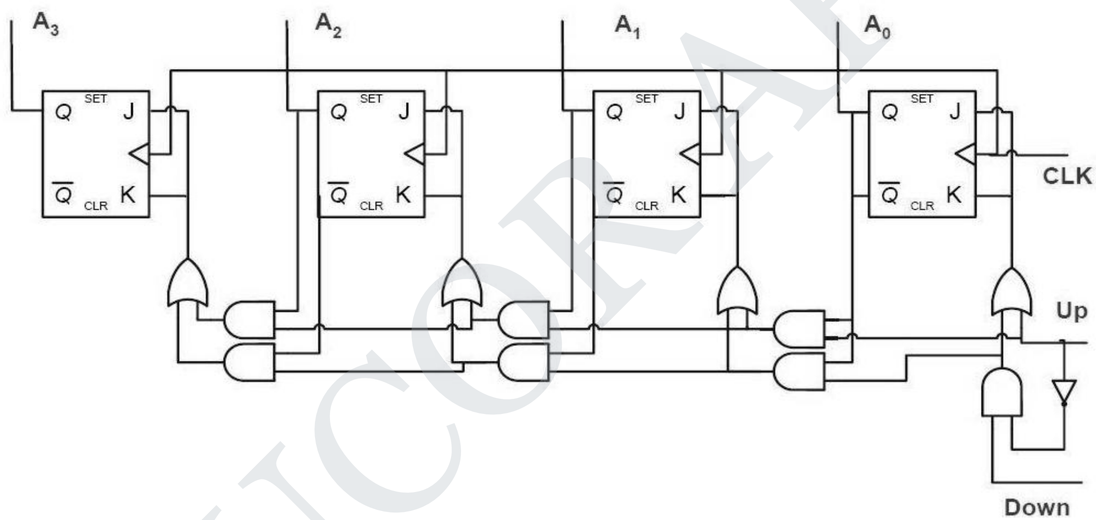


Figure: Synchronous Up /Down Counter

4.7.2 Asynchronous Up /Down Counter:

In certain applications, a counter must be able to count both up and down. The circuit below is a 3-bit up-down counter. It counts up or down depending on the status of the control signals UP and DOWN. When the UP input is at 1 and the DOWN input is at 0, the NAND network between FF0 and FF1 will gate the non-inverted output (Q) of FF0 into the clock input of FF1. Similarly, Q of FF1 will be gated through the other NAND network into the clock input of FF2. Thus the counter will count up.

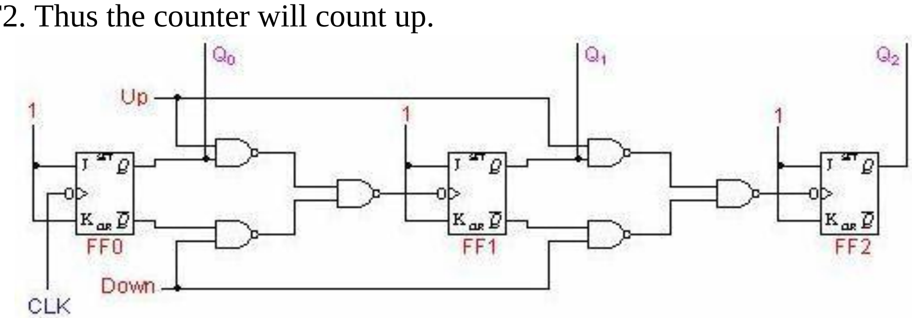


Figure: Asynchronous Up /Down Counter

When the control input UP is at 0 and DOWN is at 1, the inverted outputs of FF_0 and FF_1 are gated into the clock inputs of FF_1 and FF_2 respectively. If the flip-flops are initially y reset to 0's, then the counter will go through the following sequence as input pulses are applied

Notice that an asynchronous up-down counter is slower than an up counter or a down counter because of the additional propagation delay introduced by the NAND networks.

Design of Synchronous Counters

This section begins our study of designing an important class of clocked sequential logic circuits-synchronous fi ni t e -state machines. Like all sequential circuits, a finite-state machine determines its outputs and its next state from its current inputs and current state. A synchronous finite state machine changes state only on the clocking event.

4.8 ANALOG TO DIGITAL CONVERSION

A comparator compares the unknown voltage with a known value of voltage and then produces proportional output (i.e. it will produce either a 1 or a 0). This principle is basically used in the above circuit. Here three comparators are used. Each has two inputs. One input of each comparator is connected to analog input voltage. The other input terminals are connected to fixed reference voltage like +3/4V, +V/2 and +V/4. Now the circuit can convert analog voltage into equivalent digital signal. Since the analog output voltage is connected in parallel to all the comparators, the circuit is also called as parallel A/D converter.

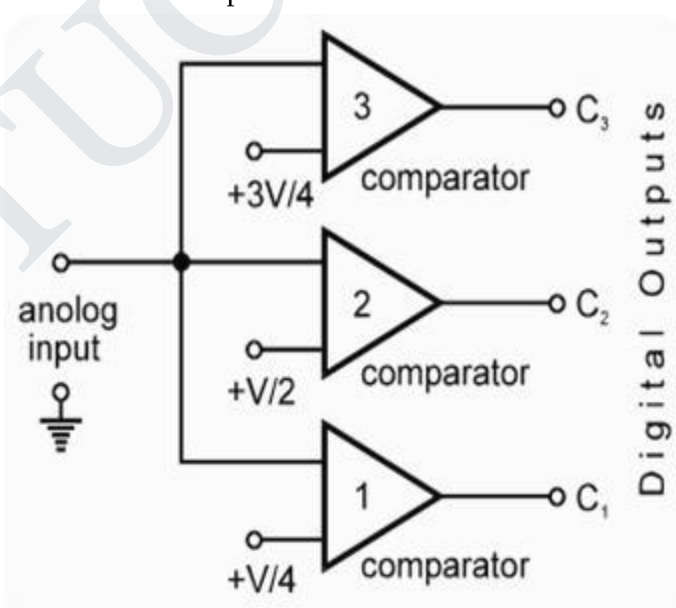


Figure: ADC Conversion

Working – Here each comparator is connected to a reference voltage of +3/4V, +V/2 and +V/4 with their outputs as $C_3C_2C_1$ respectively. Now suppose the analog input voltage change from 0 – 4V, then the actual values of reference voltages will be +3/4V = 3V, +V/2 =2V and +V/4 =1V. Now there will be following conditions of outputs of the circuit

1) When input voltage is between 0 and 1V, the output will be $C_3C_2C_1$ = 000.

2) When input voltage > 1V £ 2V, the output will be $C_3C_2C_1$ = 001.

3) When input voltage > 2V £ 3V, the output will be $C_3C_2C_1$ = 011.

4) When input voltage > 3V £ 4V, the output will be $C_3C_2C_1$ = 111.

In this way, the circuit can convert the analog input voltage into its equivalent or proportional binary number in digital style.

4.8.1 Successive Approximation Technique

The basic drawback of counter method (given above) is that it has longer conversion time. Because it always starts from 0000 at every measurement, until the analog voltage is matched. This drawback is removed in successive approximation method. In the adjacent figure, the method of successive approximation technique is shown. When unknown voltage (V_a) is applied, the circuit starts up from 0000, as shown above. The output of SAR advances with each MSB. The output of SAR does not increase step–by–step in BCD bus pattern, but individual bit becomes high–starting from MSB. Then by comparison, the bit is fixed or removed. Thus, it sets first MSB (1000), then the second MSB (0100) and so on. Every time, the output of SAR is converted to equivalent analog voltage by binary ladder. It is then compared with applied unknown voltage (V_a). The comparison process goes on, in binary search style, until the binary equivalent of analog voltage is obtained. In this way following steps are carried out during conversion.

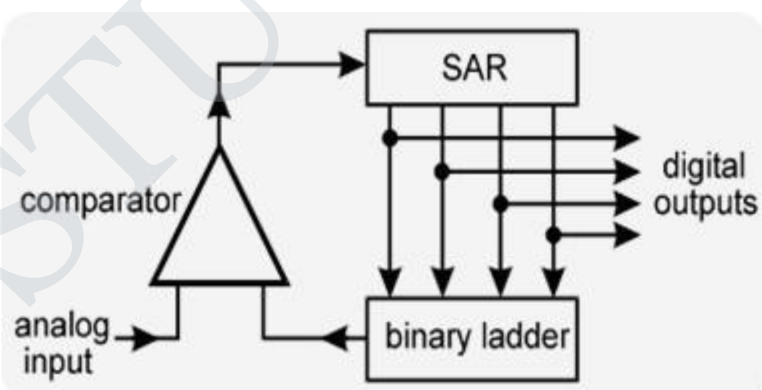


Figure: Successive Approximation Technique

Now refer the following figure and the given steps -

1) The unknown analog voltage (V_a) is applied.

2) Starts up from 0000 and sets up first MSB 1000.

3) If V_a >= 1000, the first MSB is fixed.

4) If V_a < 1000, the first MSB is removed and second MSB is set
5) The fixing and removing the MSBs continues up to last bit (LSB), until equivalent binary output is obtained.

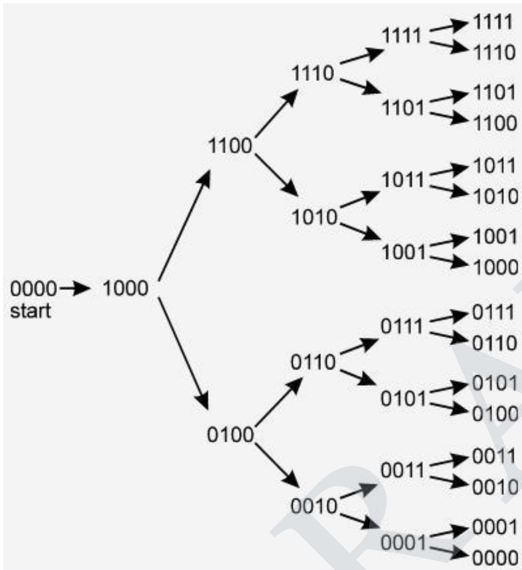


Figure 3.38 Equivalent Binary Output

4.8.2 Flash ADC

Also called the parallel A/D converter, this circuit is the simplest to understand. It is formed of a series of comparators, each one comparing the input signal to a unique reference voltage. The comparator outputs connect to the inputs of a priority encoder circuit, which then produces a binary output.

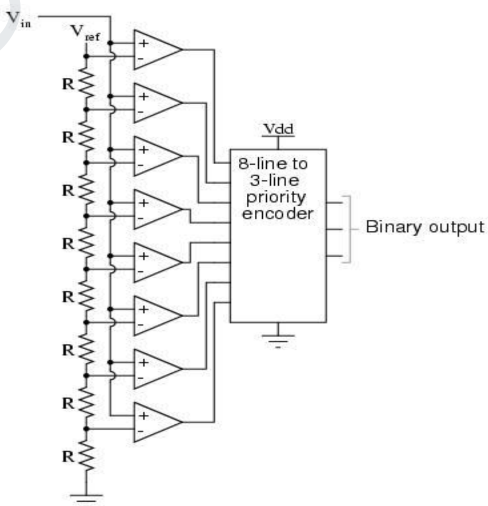
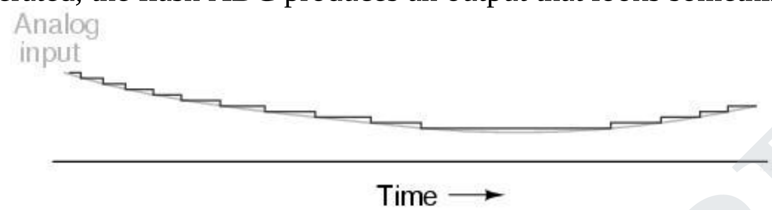


Figure: Flash ADC

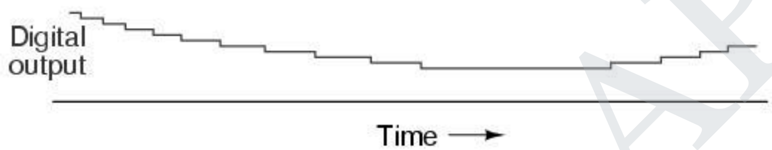
The following illustration shows a 3-bit flash ADC circuit:

V_{ref} is a stable reference voltage provided by a precision voltage regulator as part of the converter circuit, not shown in the schematic. As the analog input voltage exceeds the reference voltage at each comparator, the comparator outputs will sequentially saturate to a high state. The priority encoder generates a binary number based on the highest-order active input, ignoring all other active inputs.

When operated, the flash ADC produces an output that looks something like this



igure: Outputs



4.8 DIGITAL TO ANALOG CONVERTER (DAC):

The process of converting digital signal into equivalent analog signal is called D/A conversion. The electronics circuit, which does this process, is called D/A converter. The circuit has „n' number of digital data inputs with only one output. Basically, there are two types of D/A converter circuits: Weighted resistors D/A converter circuit and Binary ladder or R–2R ladder D/A converter circuit.

4.8.1 Weighted resistors D/A converter

Here an OPAMP is used as summing amplifier. There are four resistors R, 2R, 4R and 8R at the input terminals of the OPAMP with R as feedback resistor. The network of resistors at the input terminal of OPAMP is called as variable resistor network. The four inputs of the circuit are D, C, B & A. Input D is at MSB and A is at LSB. Here we shall connect 8V DC voltage as logic–1 level. So we shall assume that 0 = 0V and 1 = 8V.

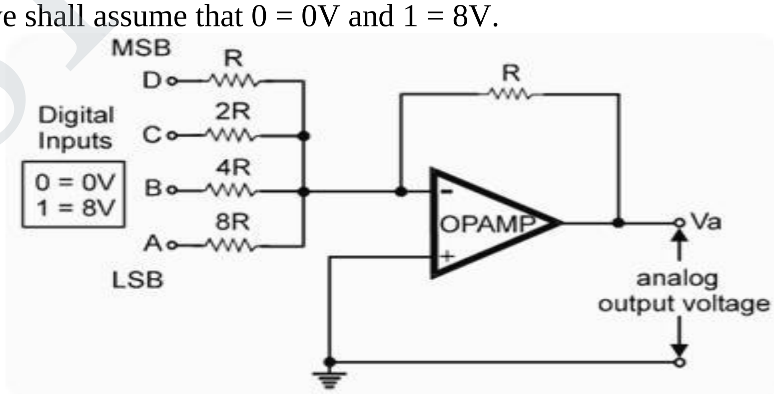


Figure: Weighted resistors D/A converter

Now the working of the circuit is as follows. Since the circuit is summing amplifier, its output is given by the following equation –

$$v_0 = R\left(\frac{D}{R} + \frac{C}{2R} + \frac{B}{4R} + \frac{A}{8R}\right)$$

Working of the circuit

When input DCBA = 0000, then putting these value in above equation (1) we get –

$$v_0 = R\left(\frac{0}{R} + \frac{0}{2R} + \frac{0}{4R} + \frac{0}{8R}\right) = 0V$$

When digital input of the circuit DCBA = 0001, then putting these value in above equation (1) we get

$$v_0 = R\left(\frac{0}{R} + \frac{0}{2R} + \frac{0}{4R} + \frac{8V}{8R}\right) = -R\frac{8V}{8R} = -1V$$

When digital input of the circuit DCBA = 0010, then putting these value in above equation (1) we get

–

$$v_0 = R\left(\frac{0}{R} + \frac{0}{2R} + \frac{8V}{4R} + \frac{0}{8R}\right) = -R\frac{8V}{4R} = -2V$$

…………… so on.

In this way, when digital input changes from 0000 to 1111 (in BCD style), output voltage (Vo) changes proportionally. This is given in the conversion chart. There are some main disadvantages of the circuit.

They are

1) Each resistor in the circuit has different value.
2) So error in value of each resistor adds up.
3) The value of resistor at MSB is the lowest. Hence, it draws more current.
4) Also, its heat & power dissipation is very high.
5) There is the problem of impedance matching due to different values of resistors.

4.8.2 R–2R Ladder D/A Converter

It is modern type of resistor network. It has only two values of resistors the R and 2R. These values repeat throughout in the circuit. The OPAMP is used at output for scaling the output voltage. The working of the circuit can be understood as follows. For simplicity, we ignore the OPAMP in the above circuit (this is because its gain is unity). Now consider the circuit, without OPAMP. Suppose the digital input is DCBA = 1000. Then the circuit is reduced to a small circuit.

$$output = \left(\frac{2R}{2R+2R}\right) \times (+V) = \frac{V}{2}$$

Its output is given by –

Reduced circuit of R-2R ladder, when we consider that all inputs=0

Now suppose digital input of the same circuit is changed to DCBA = 0100. Then the output voltage will be V/4, when DCBA = 0010, output voltage will be V/8, for DCBA = 0001, output voltage will be V/16 and so on. The general formula for the above circuit of R–2R ladder, including the OPAMP also, will be –

$$v_0 = -R\left(\frac{D}{2R} + \frac{C}{4R} + \frac{B}{8R} + \frac{A}{16R}\right)$$

You can take (R) common from the above formula and simplify it. With the help of this formula, we can calculate any combination of digital input into its equivalent analog voltage at the output terminals.

UNIT – V FOUNDAMENTALS OF COMMUNICATION ENGINNERING

5.1. Types of signal

Analog signal and digital signal

Definitions of Analog vs Digital signals

An **Analog signal** is any continuous signal for which the time varying feature (variable) of the signal is a representation of some other time varying quantity, i.e., analogous to another time varying signal. It differs from a digital signal in terms of small fluctuations in the signal which are meaningful.

A **digital signal** uses discrete (discontinuous) values. By contrast, non-digital (or analog) systems use a continuous range of values to represent information. Although digital representations are discrete, the information represented can be either discrete, such as numbers or letters, or continuous, such as sounds, images, and other measurements of continuous systems.

Properties of Digital vs Analog signals

Digital information has certain properties that distinguish it from analog communication methods. These include

Synchronization – digital communication uses specific synchronization sequences for determining synchronization.

Language – digital communications requires a language which should be possessed by both sender and receiver and should specify meaning of symbol sequences.

Errors – disturbances in analog communication causes errors in actual intended communication but disturbances in digital communication does not cause errors enabling error free communication. Errors should be able to substitute, insert or delete symbols to be expressed.

Copying – analog communication copies are quality wise not as good as their originals while due to error free digital communication, copies can be made indefinitely.

Granularity – for a continuously variable analog value to be represented in digital form there occur quantization error which is difference in actual analog value and digital representation and this property of digital communication is known as granularity.

Differences in Usage in Equipment

Many devices come with built in translation facilities from analog to digital. Microphones and speaker are perfect examples of analog devices. **Analog technology** is cheaper but there is a limitation of size of data that can be transmitted at a given time.

Digital technology has revolutionized the way most of the equipments work. Data is converted into binary code and then reassembled back into original form at reception point. Since these can be easily manipulated, it offers a wider range of options. Digital equipment is more expensive than analog equipment.

Comparison of Analog vs Digital Quality

Digital devices translate and reassemble data and in the process are more prone to loss of quality as compared to analog devices. Computer advancement has enabled use of error detection and error correction techniques to remove disturbances artificially from digital signals and improve quality.

Differences in Applications

Digital technology has been most efficient in cellular phone industry. Analog phones have become redundant even though sound clarity and quality was good.

Analog technology comprises of natural signals like human speech. With digital technology this human speech can be saved and stored in a computer. Thus digital technology opens up the horizon for endless possible uses.

Comparison chart

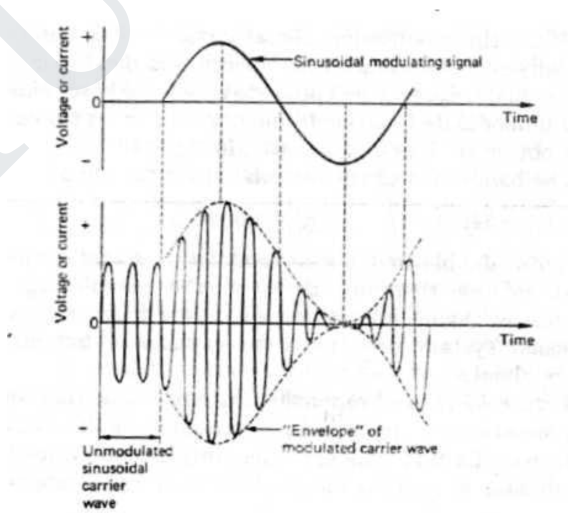
	Analog	**Digital**
Signal	Analog signal is a continuous signal which represents physical measurements.	Digital signals are discrete time signals generated by digital modulation.
Waves	Denoted by sine waves	Denoted by square waves
Representation	Uses continuous range of values to represent information	Uses discrete or discontinuous values to represent information
Example	Human voice in air, analog electronic devices.	Computers, CDs, DVDs, and other digital electronic devices.
Technology	Analog technology records waveforms as they are.	Samples analog waveforms into a limited set of numbers and records them.
Data transmissions	Subjected to deterioration by noise during transmission and write/read cycle.	Can be noise-immune without deterioration during transmission and write/read cycle.
Response to Noise	More likely to get affected reducing accuracy	Less affected since noise response are analog in nature
Flexibility	Analog hardware is not flexible.	Digital hardware is flexible in implementation.
Uses	Can be used in analog devices only. Best suited for audio and video transmission.	Best suited for Computing and digital electronics.
Applications	Thermometer	PCs, PDAs

	Analog	Digital
Bandwidth	Analog signal processing can be done in real time and consumes less bandwidth.	There is no guarantee that digital signal processing can be done in real time and consumes more bandwidth to carry out the same information.
Memory	Stored in the form of wave signal	Stored in the form of binary bit
Power	Analog instrument draws large power	Digital instrument drawS only negligible power
Cost	Low cost and portable	Cost is high and not easily portable
Impedance	Low	High order of 100 megaohm
Errors	Analog instruments usually have a scale which is cramped at lower end and give considerable observational errors.	Digital instruments are free from observational errors like parallax and approximation errors.

5.2. Principles of Amplitude modulation

Amplitude Modulation (AM) plus frequency division multiplexing (FDM) is one way of solving above problem. Each conversation is shifted to a different part of the frequency spectrum by using a high-frequency waveform to "carry" each individual speech signal. These high frequencies are called carrier frequencies .

Amplitude modulation is the process of varying the amplitude of the sinusoidal carrier wave by the amplitude of the modulating signal, and is illustrated in Fig.

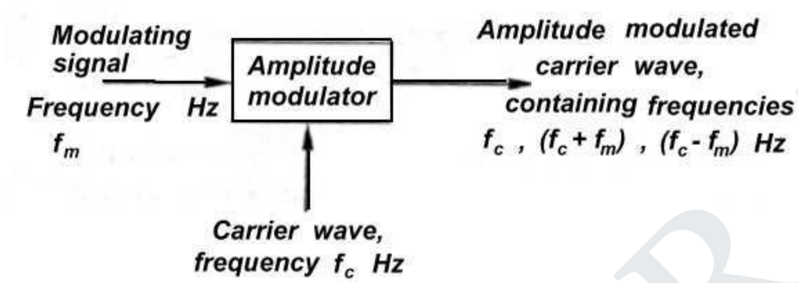


The unmodulated carrier wave has a constant peak value and a higher frequency than the modulating signal , but, when the modulating signal is applied, the peak value of the carrier varies in accordance with the instantaneous value of the modulating signal, and the outline wave shape or "envelope" of the modulated wave's peak values is the same as the original modulating signal wave shape. The modulating signal waveform has been superimposed on the carrier wave.

When a sinusoidal carrier wave of frequency fc Hz is amplitude - modulated by a sinusoidal modulating signal of frequency fm Hz , then the modulated carrier wave contains three frequencies .

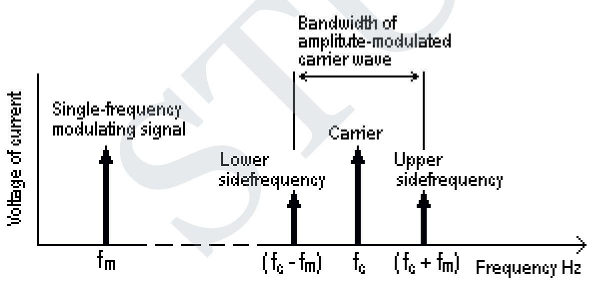
1) fc Hz : Original carrier frequency
2) (fc + fm) Hz : The sum of carrier and modulating signal frequencies
3) (fc - fm) Hz : The difference between carrier and modulating signal

This is illustrated in Fig



It should be noted that two of these frequencies are new, being produced by the amplitude-modulation process, and are called side-frequencies.

The sum of carrier and modulating signal frequencies is called the upper side-frequency. The difference between carrier and modulating signal frequency is called the lower side-frequency. This is illustrated in the frequency spectrum diagram of Fig.

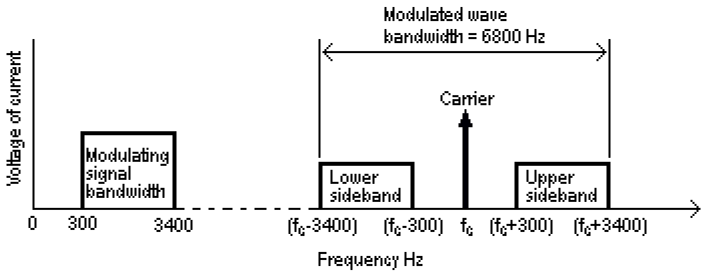


The bandwidth of the modulated carrier wave is

(fc + fm) - (fc - fm) = 2 fm

i.e. double the modulating signal frequency

The complete amplitude-modulated wave band of lower sideband plus carrier plus upper sideband shown in Fig. 8 takes up more frequency bandwidth than is really necessary to transmit the information signal since all the information is carried by either one of the sidebands alone . The carrier component is of constant amplitude and frequency so does not carry any of the information signal at all . It is possible by using special equipment to suppress both the carrier and one sideband and to transmit just the other sideband with no loss of information. This method of working is called single sideband working (SSB) . This method is not used for domestic radio broadcasting , but it is used for some long-distance radio telephony systems and for multi-channel carrier systems used in national telephone networks.



5.3 Principle of frequency modulation

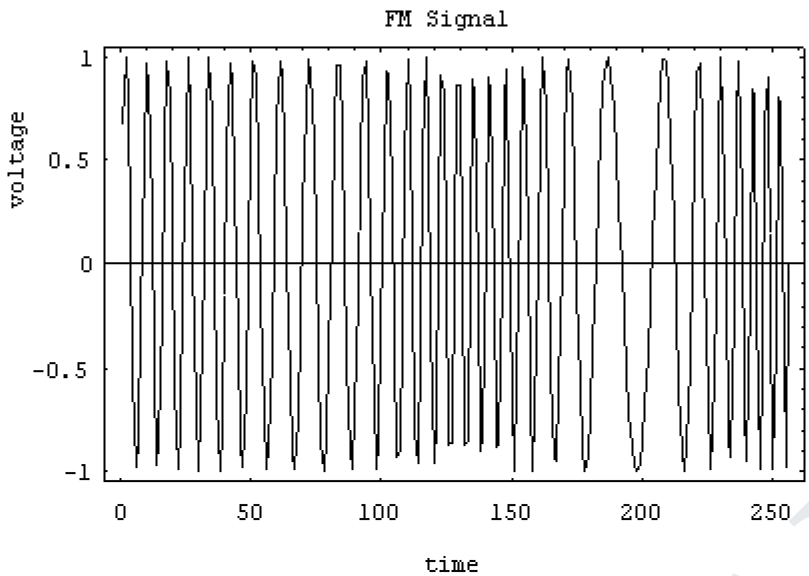
Frequency modulation uses the information signal, $V_m(t)$ to vary the carrier frequency within some small range about its original value. Here are the three signals in mathematical form:

Information: $V_m(t)$
Carrier: $V_c(t) = V_{co} \sin (2 p f_c t + f)$
FM: $V_{FM} (t) = V_{co} \sin (2 p [f_c + (Df/V_{mo}) V_m (t)] t + f)$

We have replaced the carrier frequency term, with a time-varying frequency. We have also introduced a new term: Df, the peak frequency deviation. In this form, you should be able to see that the carrier frequency term: $f_c + (Df/V_{mo}) V_m (t)$ now varies between the extremes of f_c - Df and f_c + Df. The interpretation of Df becomes clear: it is the farthest away from the original frequency that the FM signal can be. Sometimes it is referred to as the "swing" in the frequency.

We can also define a modulation index for FM, analogous to AM:
b = Df/f_m , where f_m is the maximum modulating frequency used.
The simplest interpretation of the modulation index, b, is as a measure of the peak frequency deviation, Df. In other words, b represents a way to express the peak deviation frequency as a multiple of the maximum modulating frequency, f_m, i.e. Df = b f_m.

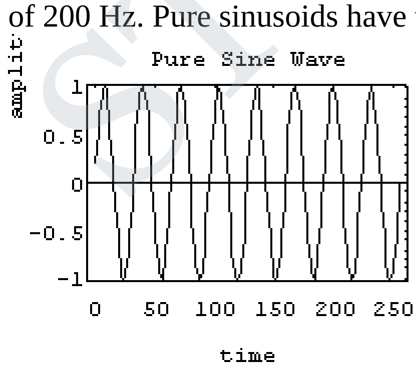
Example: suppose in FM radio that the audio signal to be transmitted ranges from 20 to 15,000 Hz (it does). If the FM system used a maximum modulating index, b, of 5.0, then the frequency would "swing" by a maximum of 5 x 15 kHz = 75 kHz above and below the carrier frequency.
Here is a simple FM signal:

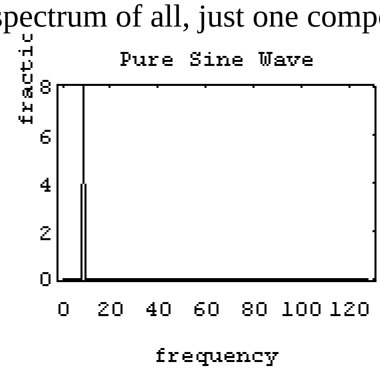


Here, the carrier is at 30 Hz, and the modulating frequency is 5 Hz. The modulation index is about 3, making the peak frequency deviation about 15 Hz. That means the frequency will vary somewhere between 15 and 45 Hz. How fast the cycle is completed is a function of the modulating frequency.

FM Spectrum

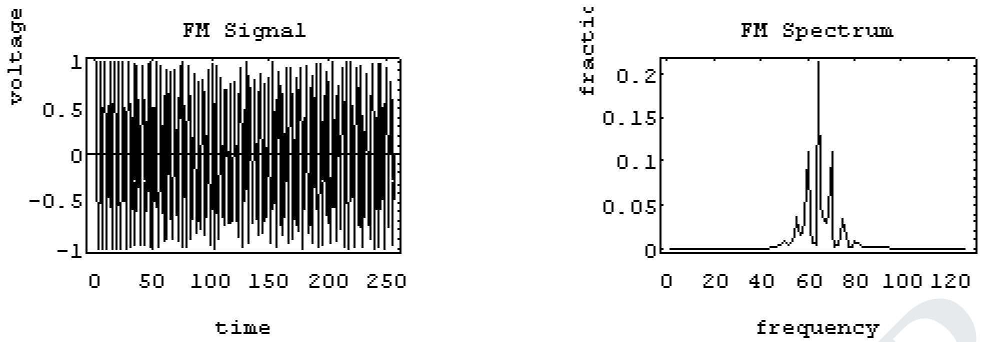
A spectrum represents the relative amounts of different frequency components in any signal. Its like the display on the graphic-equalizer in your stereo which has leds showing the relative amounts of bass, midrange and treble. These correspond directly to increasing frequencies (treble being the high frequency components). It is a well-know fact of mathematics, that any function (signal) can be decomposed into purely sinusoidal components (with a few pathological exceptions) . In technical terms, the sines and cosines form a complete set of functions, also known as a basis in the infinite-dimensional vector space of real-valued functions (gag reflex). Given that any signal can be thought to be made up of sinusoidal signals, the spectrum then represents the "recipe card" of how to make the signal from sinusoids. Like: 1 part of 50 Hz and 2 parts of 200 Hz. Pure sinusoids have the simplest spectrum of all, just one component:





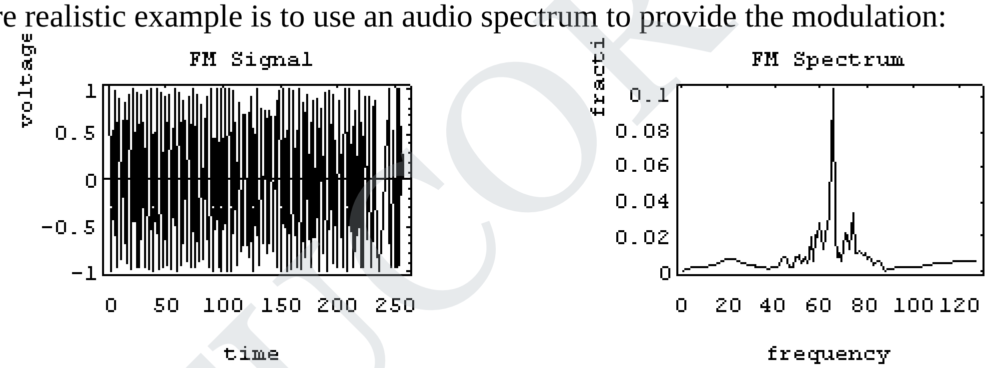
In this example, the carrier has 8 Hz and so the spectrum has a single component with value 1.0 at 8 Hz

The FM spectrum is considerably more complicated. The spectrum of a simple FM signal looks like:



The carrier is now 65 Hz, the modulating signal is a pure 5 Hz tone, and the modulation index is 2. What we see are multiple side-bands (spikes at other than the carrier frequency) separated by the modulating frequency, 5 Hz. There are roughly 3 side-bands on either side of the carrier. The shape of the spectrum may be explained using a simple heterodyne argument: when you mix the three frequencies (f_c, f_m and Df) together you get the sum and difference frequencies. The largest combination is $f_c + f_m$ + Df, and the smallest is $f_c - f_m$ - Df. Since Df = b f_m, the frequency varies (b + 1) f_m above and below the carrier.

A more realistic example is to use an audio spectrum to provide the modulation:



In this example, the information signal varies between 1 and 11 Hz. The carrier is at 65 Hz and the modulation index is 2. The individual side-band spikes are replaced by a more-or-less continuous spectrum. However, the extent of the side-bands is limited (approximately) to (b + 1) f_m above and below. Here, that would be 33 Hz above and below, making the bandwidth about 66 Hz. We see the side-bands extend from 35 to 90 Hz, so out observed bandwidth is 65 Hz.

You may have wondered why we ignored the smooth humps at the extreme ends of the spectrum. The truth is that they are in fact a by-product of frequency modulation (there is no random noise in this example). However, they may be safely ignored because they are have only a minute fraction of the total power. In practice, the random noise would obscure them anyway.

Example: FM Radio

FM radio uses frequency modulation, of course. The frequency band for FM radio is about 88 to 108 MHz. The information signal is music and voice which falls in the audio spectrum. The full audio spectrum ranges form 20 to 20,000 Hz, but FM radio limits the upper modulating frequency to 15 kHz (cf. AM radio which limits the upper frequency to 5 kHz). Although, some of the signal may be lost above 15 kHz, most people can't hear it anyway, so there is little loss of fidelity. FM radio maybe appropriately referred to as "high-fidelity."

If FM transmitters use a maximum modulation index of about 5.0, so the resulting bandwidth is 180 kHz (roughly 0.2 MHz). The FCC assigns stations) 0.2 MHz apart to prevent overlapping signals (coincidence? I think not!). If you were to fill up the FM band with stations, you could get 108 - 88 / .2 = 100 stations, about the same number as AM radio (107). This sounds convincing, but is actually more complicated (agh!).

FM radio is broadcast in stereo, meaning two channels of information. In practice, they generate three signals prior to applying the modulation:
the L + R (left + right) signal in the range of 50 to 15,000 Hz.
a 19 kHz pilot carrier.
the L-R signal centered on a 38 kHz pilot carrier (which is suppressed) that ranges from 23 to 53 kHz .

So, the information signal actually has a maximum modulating frequency of 53 kHz, requiring a reduction in the modulation index to about 1.0 to keep the total signal bandwidth about 200 kHz.

FM Performance

Bandwidth
As we have already shown, the bandwidth of a FM signal may be predicted using:
$BW = 2 (b + 1) f_m$
where b is the modulation index and
f_m is the maximum modulating frequency used.

FM radio has a significantly larger bandwidth than AM radio, but the FM radio band is also larger. The combination keeps the number of available channels about the same.
The bandwidth of an FM signal has a more complicated dependency than in the AM case (recall, the bandwidth of AM signals depend only on the maximum modulation frequency). In FM, both the modulation index and the modulating frequency affect the bandwidth. As the information is made stronger, the bandwidth also grows.

Efficiency
The efficiency of a signal is the power in the side-bands as a fraction of the total. In FM signals, because of the considerable side-bands produced, the efficiency is generally high. Recall that conventional AM is limited to about 33 % efficiency to prevent distortion in the receiver when the modulation index was greater than 1. FM has no analogous problem.

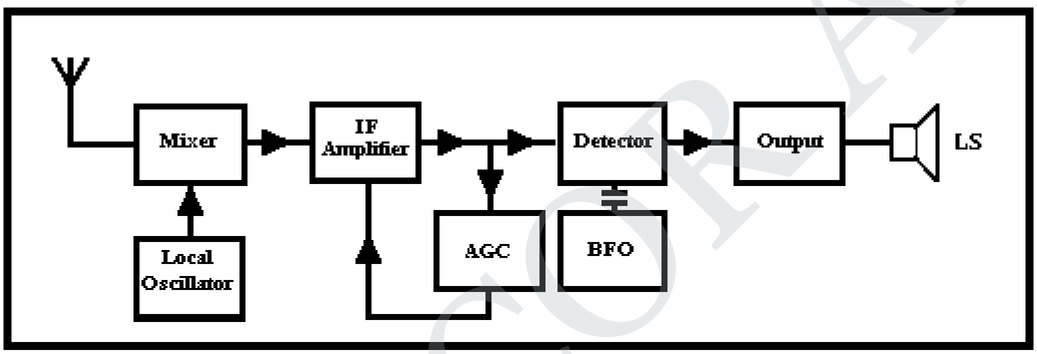
The side-band structure is fairly complicated, but it is safe to say that the efficiency is generally improved by making the modulation index larger (as it should be). But if you make the modulation index larger, so make the bandwidth larger (unlike AM) which has its disadvantages. As is typical in engineering, a compromise between efficiency and performance is struck. The modulation index is normally limited to a value between 1 and 5, depending on the application.

Noise

FM systems are far better at rejecting noise than AM systems. Noise generally is spread uniformly across the spectrum (the so-called white noise, meaning wide spectrum). The amplitude of the noise varies randomly at these frequencies. The change in amplitude can actually modulate the signal and be picked up in the AM system. As a result, AM systems are very sensitive to random noise. An example might be ignition system noise in your car. Special filters need to be installed to keep the interference out of your car radio.

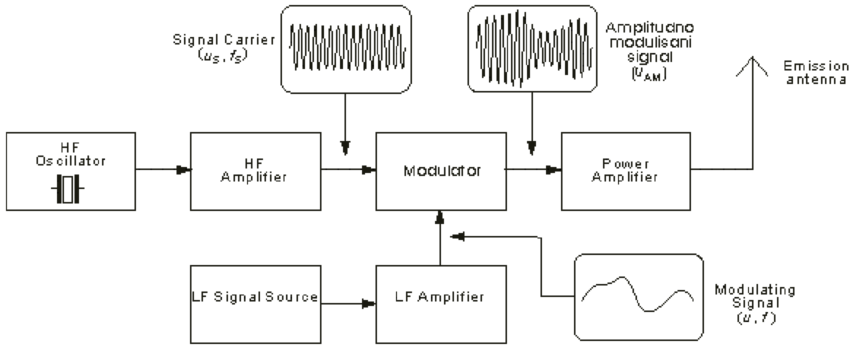
FM systems are inherently immune to random noise. In order for the noise to interfere, it would have to modulate the frequency somehow. But the noise is distributed uniformly in frequency and varies mostly in amplitude. As a result, there is virtually no interference picked up in the FM receiver. FM is sometimes called "static free, " referring to its superior immunity to random noise.

5.4.Block diagram of radio



AM Transmitter

In order to better understand the way the radio transmitter works, block - diagram of a simple AM (amplitude modulated) signal transmitter is shown on Pic. The amplitude modulation is being performed in a stage called the modulator. Two signals are entering it: high frequency signal called the carrier (or the signal carrier), being created into the HF oscillator and amplified in the HF amplifier to the required signal level, and the low frequency (modulating) signal coming from the microphone or some other LF signal source (cassette player, record player, CD player etc.), being amplified in the LF amplifier. On modulator's output the amplitude modulated signal UAM is acquired. This signal is then amplified in the power amplifier, and then led to the emission antenna.

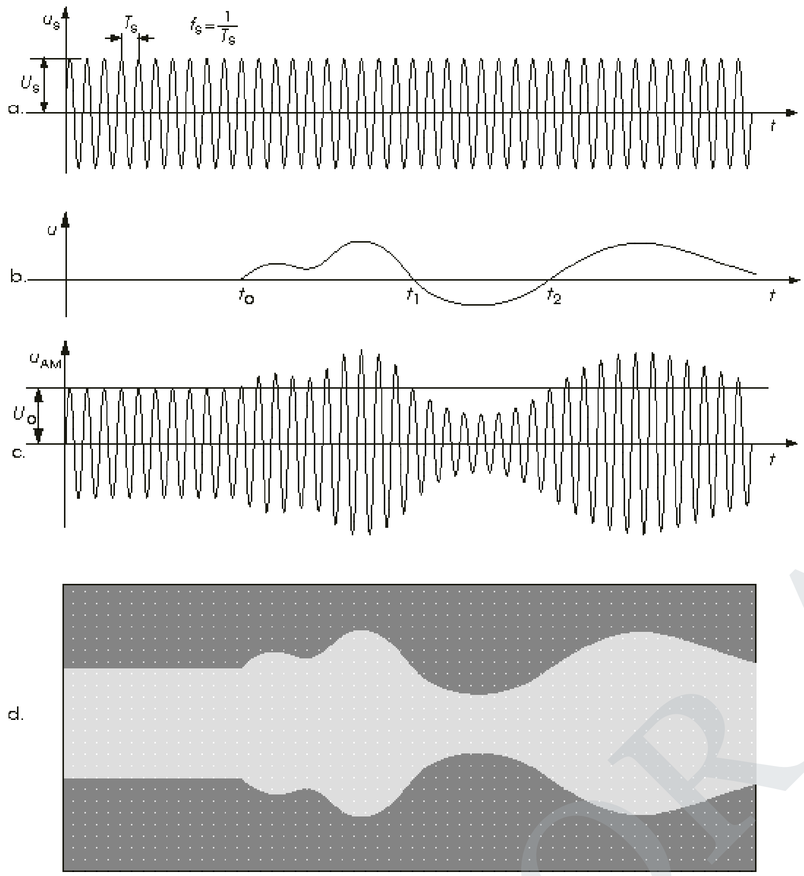


Pic. 2.2. AM Transmitter Block Diagram

The shape and characteristics of the AM carrier, being taken from the HF amplifier into the modulator, are shown on Pic. As you can see, it is a HF voltage of constant amplitude US and frequency fS. On Pic. the LF signal that appears at the input of the modulator at the moment t0 is shown. With this signal the modulation of the carrier's amplitude is being performed, therefore it is being called the modulating signal. The shape of the AM signal exiting the modulator is shown on Pic. From the point t0 this voltage has the same shape as that on Pic. From the moment t0 the amplitude of AM signal is being changed in accordance with the current value of the modulating signal, in such a way that the signal envelope (fictive line connecting the voltage peaks) has the same shape as the modulating signal.

Let's take a look at a practical example. Let the LF signal on Pic. be, say, an electrical image of the tone being created by some musical instrument, and that the time gap between the points t0 and t2 is 1 ms. Suppose that carrier frequency is fS=1 MHz (approximately the frequency of radio Kladovo, exact value is 999 kHz). In that case, in period from t0 till t2 signals us on Pic. and AM on should make a thousand oscillations and not just eighteen, as shown in the picture. Then It is clear that it isn't possible to draw a realistic picture, since all the lines would connect into a dark spot. The true picture of AM signal from this example is given on Pic. That is the picture that appears on screen of the oscilloscope, connected on the output of the modulator: light coloured lines representing the AM signal have interconnected, since they are thicker than the gap between them.

Block - diagram on Pic is a simplified schematic of an AM transmitter. In reality there are some additional stages in professional transmitters that provide the necessary work stability, transmitter power supply, cooling for certain stages etc. For simple use, however, even simpler block diagrams exist, making the completion of an ordinary AM transmitter possible with just a few electronic components.



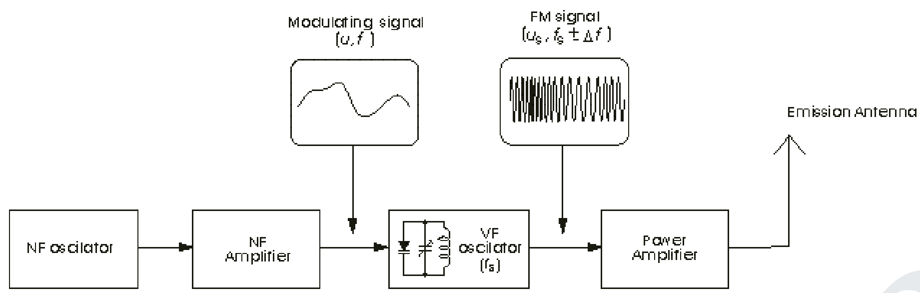
Pic.2.3. Voltage wave envelopes of an AM signal: a- The (signal) Carrier, b- The Modulating Signal (LF signal being transferred), c- AM (amplitude - modulated) signal, d- true look of the AM signal.

FM Transmitter

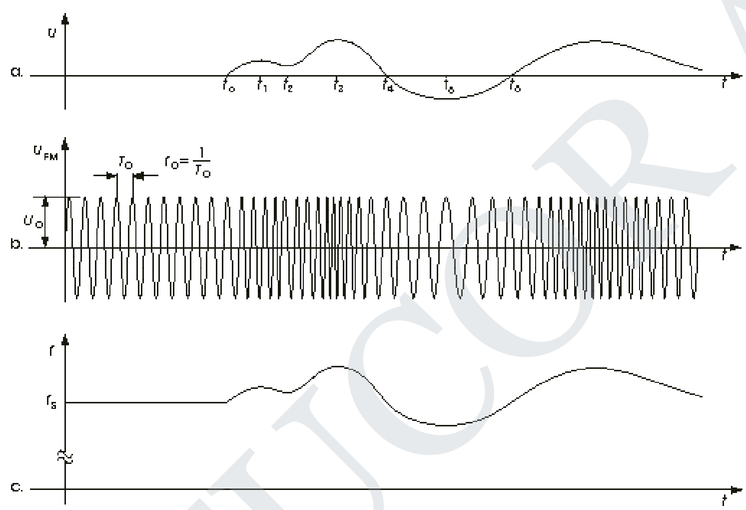
Block diagram of an FM (frequency modulated) transmitter is given on Pic.2.4. Information being transferred, i.e. the modulating signal, is a signal from some LF source. it is being amplified in LF amplifier and then led into the HF oscillator, where the carrier signal is being created. The carrier is a HF voltage of constant amplitude, whose frequency is, in the absence of modulating signal, equal to the transmitter's carrier frequency fS. In the oscillatory circuit of the HF oscillator a varicap (capacitive) diode is located. It is a diode whose capacitance depends upon the voltage between its ends, so when being exposed to LF voltage, its capacitance is changing in accordance with this voltage. Due to that frequency of the oscillator is also changing, i.e. the frequency modulation is being obtained. The FM signal from the HF oscillator is being proceeded to the power amplifier that provides the necessary output power of the transmission signal.

Voltage shapes in FM transmitter are given on Pic.2.5. Pic.2.5-a shows the LF modulating signal. The frequency modulation begins at moment t0 and the transmission frequency begins to change, as shown on Pic.2.5-b: Whilst current value of the LF signal is raising so is the trasmitter frequency, and when it is falling the frequency is also falling. As seen on Pic.2.5-c, the information (LF signal) is being implied in frequency change of the carrier.

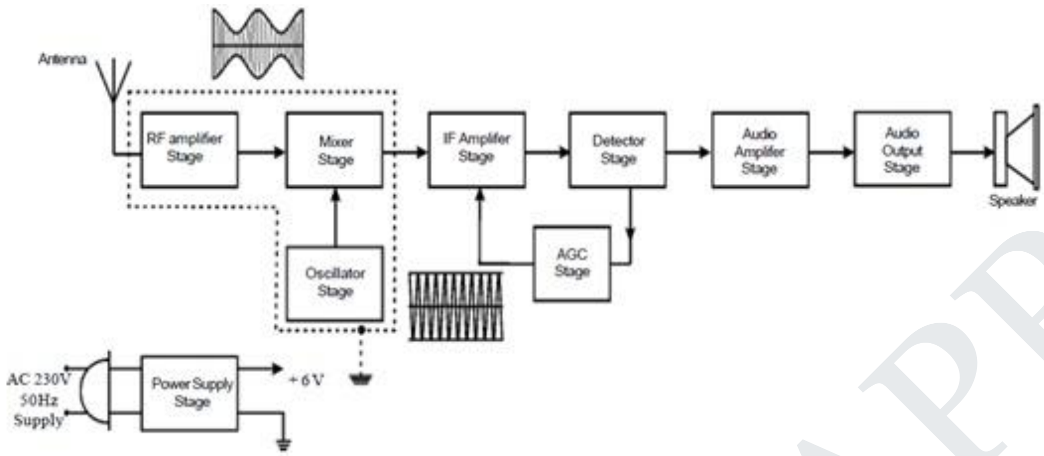
The carrier frequencies of the radio difusion FM transmitters (that emmit the program for "broad audience") are placed in the waveband from 88 MHz til 108 MHz, the maximum frequency shift of the transmitter (during the modulation) being ±75 kHz. Because of that the FM signal should be drawn much "thicker", but it would result in a black-square-shaped picture.



Picture 2.4. FM transmmiter Block diagram



AM radio broad cast transmitter



AM broadcasting is the process of radio broadcasting using amplitude modulation (AM). AM was the first method of impressing sound on a radio signal and is still widely used today. Commercial and public AM broadcasting is authorized in the medium wave band worldwide, and also in parts of the long wave and short wave bands. Radio broadcasting was made possible by the invention of the amplifying vacuum tube, the Audion(triode), by Lee de Forest in 1906, which led to the development of inexpensive vacuum tube AM radio receivers and transmitters during World War I. Commercial AM broadcasting developed from amateur broadcasts around 1920, and was the only commercially important form of radio broadcasting until FM broadcasting began after World War II. This period is known as the "Golden Age of Radio". Today, AM competes with FM, as well as with various digital radio broadcasting services distributed from terrestrial and satellite transmitters. In many countries the higher levels of interference experienced with AM transmission have caused AM broadcasters to specialize in news, sports and talk radio, leaving transmission of music mainly to FM and digital broadcasters.

AM radio technology is simpler than frequency modulated (FM) radio, Digital Audio Broadcasting (DAB), satellite radio or HD (digital) radio. An AM receiver detects amplitude variations in the radio waves at a particular frequency. It then amplifies changes in the signal voltage to drive aloudspeaker or earphones. The earliest crystal radio receivers used a crystal diode detector with no amplification, and required no power source other than the radio signal itself.

In North American broadcasting practice, transmitter power input to the antenna for commercial AM stations ranges from about 250 to 50,000watts. Experimental licenses were issued for up to 500,000 watts radiated power, for stations intended for wide-area communication during disasters. One such superstation was Cincinnati station WLW, which used such power on occasion before World War II. WLW's superpower transmitter still exists at the station's suburban transmitter site, but it was decommissioned in the early 1940s and no current commercial broadcaster in the U.S. or Canada is authorized for such power levels. Some other countries do authorize higher power operation (for example the Mexican station XERF formerly operated at 250,000 watts). Antenna design must consider the coverage desired and stations may be required, based on the terms of their license, to directionalize their transmitted signal to avoid interfering with other stations operating on the same frequency.

Radio receiver

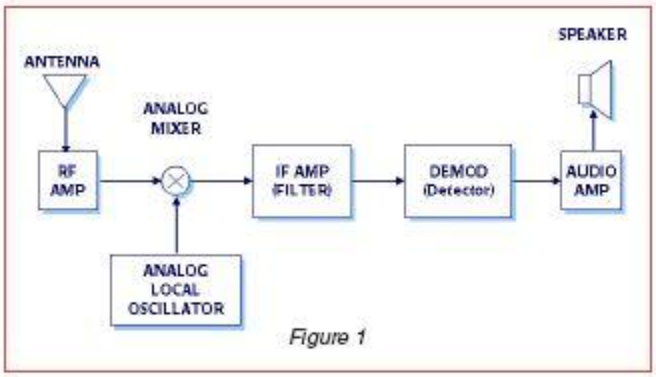
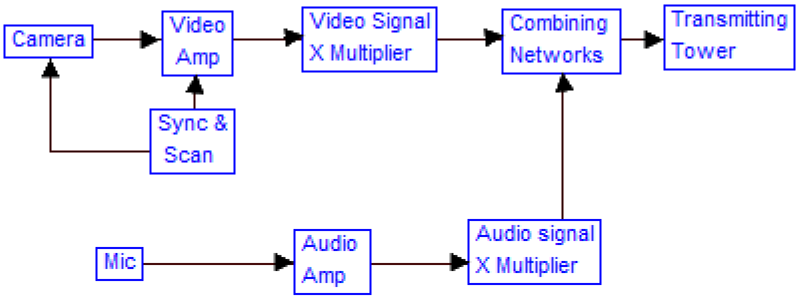


Figure 1

In the early days of what is now known as early radio transmissions, say about 100 years ago, signals were generated by various means but only up to the L.F. region.
Communication was by way of morse code much in the form that a short transmission denoted a dot (dit) and a longer transmission was a dash (dah). This was the only form of radio transmission until the 1920's and only of use to the military, commercial telegraph companies and amateur experimenters.
Then it was discovered that if the amplitude (voltage levels - plus and minus about zero) could be controlled or varied by a much lower frequency such as A.F. then real intelligence could be conveyed e.g. speech and music. This process could be easily reversed by simple means at the receiving end by using diode detectors. This is called modulation and obviously in this case amplitude modulation or A.M.
This discovery spawned whole new industries and revolutionized the world of communications. Industries grew up manufacturing radio parts, receiver manufacturers, radio stations, news agencies, recording industries etc.

Disadvantages to A.M. radio
Firstly because of the modulation process we generate at least two copies of the intelligence plus the carrier. For example consider a local radio station transmitting on say 900 Khz. This frequency will be very stable and held to a tight tolerance. To suit our discussion and keep it as simple as possible we will have the transmission modulated by a 1000 Hz or 1Khz tone.
At the receiving end 3 frequencies will be available. 900 Khz, 901 Khz and 899 Khz i.e. the original 900 Khz (the carrier) plus and minus the modulating frequency which are called side bands. For very simple receivers such as a cheap transistor radio we only require the original plus either one of the side bands. The other one is a total waste. For sophisticated receivers one side band can be eliminated.
The net effect is A.M. radio stations are spaced 10 Khz apart (9 kHz in Australia) e.g. 530 Khz...540 Khz...550 Khz. This spacing could be reduced and nearly twice as many stations accommodated by deleting one side band. Unfortunately the increased cost of receiver complexity forbids this but it certainly is feasible

Block diagram of television transmitter



Basic Television Transmitter

The basic television Broadcast transmitter block diagram is shown in figure (a).
The block diagram can be broadly divided into two separate section, viz., one that - Generates an electronic signal (called video signal) corresponding to the actual picture and then uses this video signal to modulate an R-F carrier so as to be applied to the transmitting antenna for transmission, other that generates an electronic signal (called audio signal) containing sound information and then uses this signal to modulate another RF carrier and then applied to the transmitting antenna for transmission.

However only one antenna is used for transmission of the video as well as audio signals. Thus these modulated signals have to be combined together in some appropriate network. In addition there are other accessories also. For instance, video as well as audio signals have to be amplified to the desired degree before they modulate their respective RF carriers.
This function is performed by video and audio amplifiers. The block picture signal transmitter and audio signal transmitter shown in figure (a) may consist of modulators as the essential component; Video signal transmitter employs an AM transmitter as amplitude-modulation is used for video signals whereas audio signal transmitter employs FM modulator as frequency modulation is used for sound information. Scanning circuits are used to mike the electron beam scan the actual picture to produce the corresponding video signal. The scanning by electron beam is in the receiver too. The beam scans the picture tube to reproduce the original picture from the video signal and this scanning at the receiver must be matched properly to the scanning at the transmitter. It is for this reason that synchronizing Circuits are used at the transmitter as well as receiver.

Complete TV transmitter Block Diagram

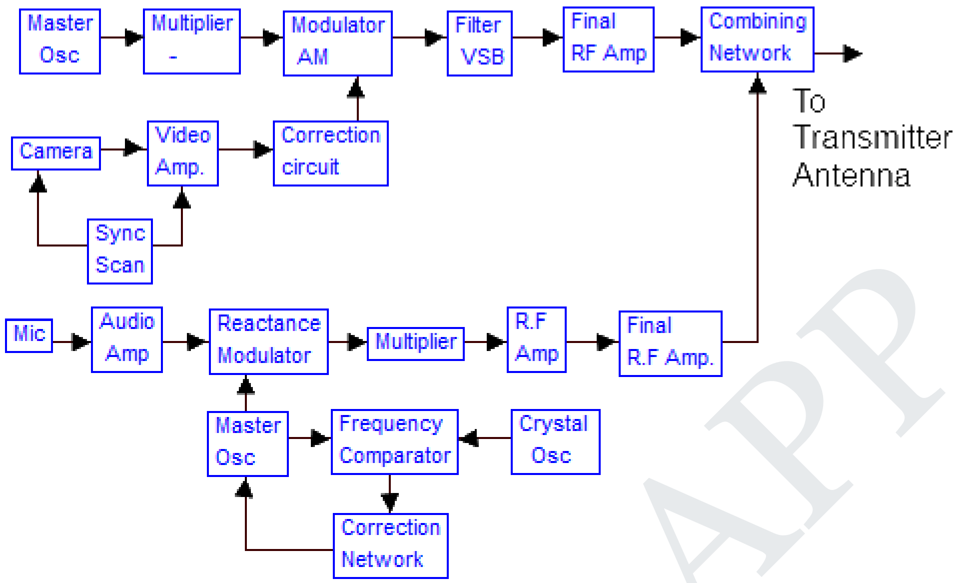
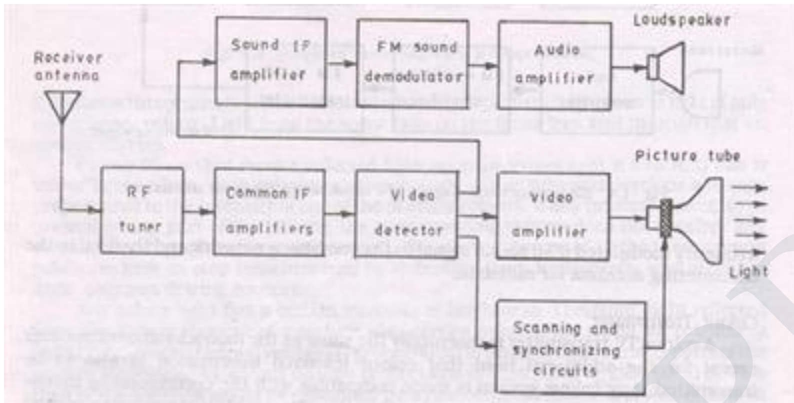


Fig (b) Complete T.V transmitter

Figure (b) depicts the complete block diagram of a Television Broadcast Transmitter. The important block have already been discussed individually in the preceding sections. that makes understanding of the diagram shown here much more simple. A brief explanation is given ahead.
The block diagram can be broadly divided into two -sections, viz., an amplitude modulated transmitter and a frequency modulated transmitter. Former is used for video modulation whereas latter is used for audio modulation.
Master oscillator in both generates an RF carrier frequency. Generally, a master oscillator generates a sub multiple of carrier and then drives harmonic generators (frequency multipliers) to achieve correct value carrier. Harmonic generators are nothing but class C tuned amplifiers whose output tuned circuit is to tuned to some harmonic of the input signal. In actual practice, master oscillator and harmonic generator are s crated or isolated by a buffer stage to av214Joactrrig of the harmonic generator on the oscillator output. The carrier is then fed to an amplitude modulator in video transmitter and a frequency modulator in audio transmitter. Into-the modulator, the modulation signal is also fed with proper amplitude. Since low-level modulation is employed, the modulating signal is amplified by linear amplifiers up-to the desired degree required for transmission. Video and audio signals on separate carriers are then combined together so as to be fed to the transmitting antenna as on signal.

Block diagram of television receiver



Television Receiver

A radio receiver designed to amplify and convert the video and audio radio-frequency signals of a televisionbroadcast that have been picked up by a television antenna; the receiver reproduces the visual imagebroadcast and the accompanying sound. Television receivers are designed for color or black-and-whiteoperation; both nonportable and portable models are produced. Those manufactured in the USSR arecapable of receiving signals from television stations transmitting in specifically assigned portions of thevery-high-frequency (VHF) band (48.5–100 megahertz and 174–230 megahertz; 12 channels) andultrahigh-frequency (UHF) band (470–638 megahertz; several tens of channels).

Television receivers must simultaneously amplify and convert video and audio radio-frequency signals.They are usually designed with a superheterodyne circuit, and versions differ in the methods used toextract and amplify the audio signal. The principal components of a television receiver are shown in Figure1.

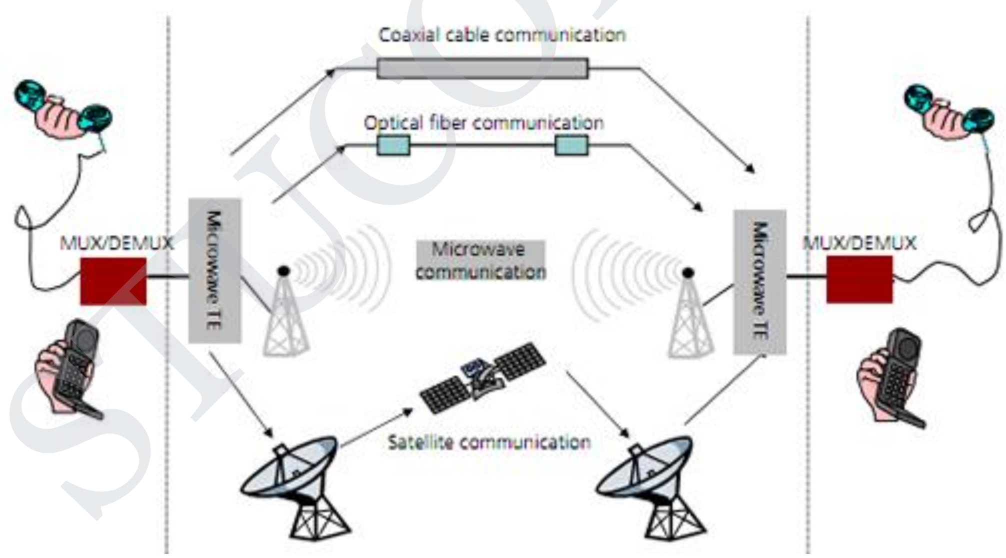
The tuner selects the signals of the desired channel and converts them to a lower frequency within theintermediate-frequency passband. The signal-processing circuits include an intermediate-frequencyamplifier for the video signal, an amplitude detector, a video amplifier for the brightness signal, and, incolor receivers, a color-processing circuit for the chrominance signal. The processing circuit produces abrightness signal and a color-difference signal, which are fed to the control electrodes of a kinescope; anaudio signal, which is fed to the audio channel; and horizontal and vertical synchronizing pulses (or acomposite television signal), which are fed to a scanning generator. In the color television system used inthe USSR, the color-processing circuit for the chrominance signal consists of a band-pass amplifier, inwhich the chrominance signal is extracted, channels for the direct and delayed signals, an electronicswitching device, two frequency detectors for the color-difference signals, a matrix circuit, and amplifiersfor the three color-difference signals. The color processing circuit has provisions for the extraction anddecoding of the chrominance signal and fo r line selection, as well as chrominance disconnect circuits thatoperate when black-and-white transmissions are received.

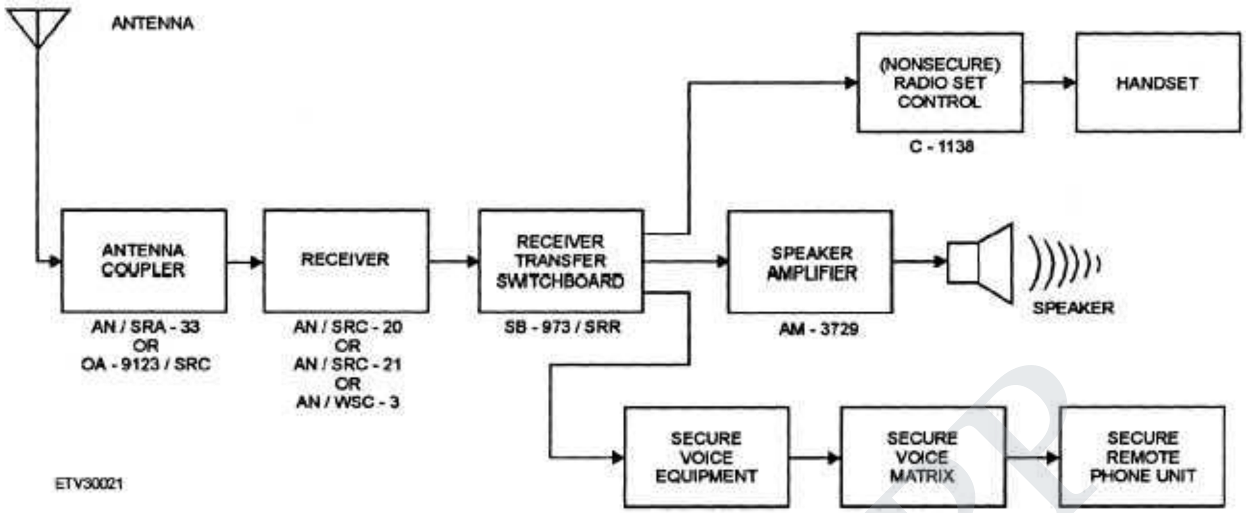
The scanning generators include horizontal and vertical scanning circuits that produce sawtooth currentsin the horizontal and vertical scanning coils of the deflection system.

The high voltage for feeding thesecond anode of the kinescope is derived from a special highvoltage winding of the line transformer or by rectifying pulses from the transformer; the voltage for the focusing electrode is similarly derived.

The kinescope's interface includes static and dynamic white balance controls, switches for extinguishingthe electron guns, and regulators for focusing the beams. The demagnetizing circuit for a color kinescopecreates a damped alternating current in a demagnetizing loop that circles the kinescope screen. Thecurrent demagnetizes the shadow mask and tube rim, which are made of steel. The audio section consists of an amplifier for the difference frequency, which in the USSR is 6.5 megahertz, a frequency detector for the audio signal, and a low-frequency amplifier from which the audiosignal is fed to a high-quality acoustical system, usually composed of several loudspeakers. The power-supply section converts mains voltage into the supply voltages for all components of the television set,including the kinescope and vacuum tube heaters.

Microwave communication





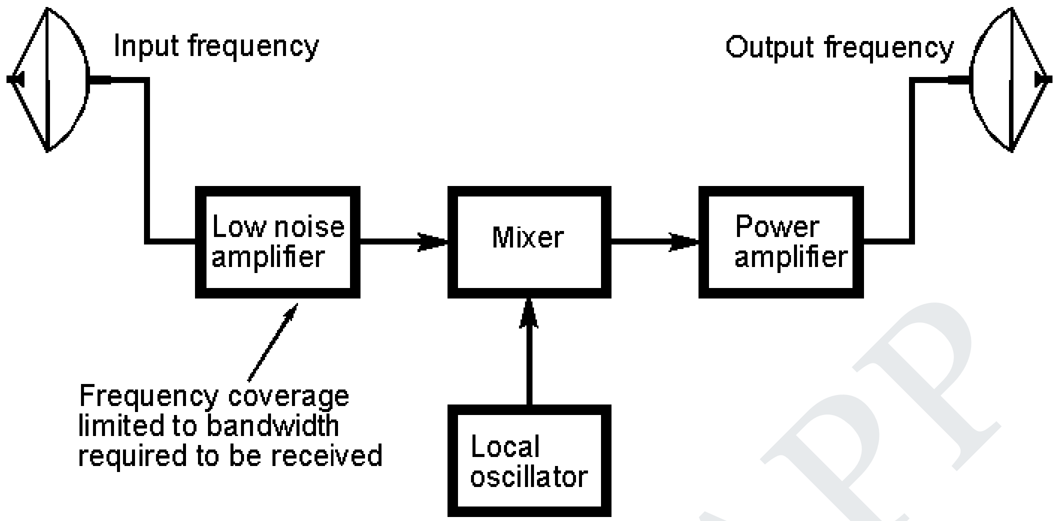
Microwave transmission refers to the technology of transmitting information or energy by the use ofelectromagnetic waves whose wavelengths are conveniently measured in small numbers of centimetre; these are called microwaves. This part of the radio spectrum ranges across frequencies of roughly 1.0 gigahertz (GHz) to 30 GHz. These correspond to wavelengths from 30 centimeters down to 1.0 cm.

Microwaves are widely used for point-to-point communications because their small wavelength allows conveniently-sized antennas to direct them in narrow beams, which can be pointed directly at the receiving antenna. This allows nearby microwave equipment to use the same frequencies without interfering with each other, as lower frequency radio waves do. Another advantage is that the high frequency of microwaves gives the microwave band a very large information-carrying capacity; the microwave band has a bandwidth 30 times that of all the rest of the radio spectrum below it. A disadvantage is that microwaves are limited to line of sight propagation; they cannot pass around hills or mountains as lower frequency radio waves can.

Microwave radio transmission is commonly used in point-to-point communication systems on the surface of the Earth, in satellite communications, and in deep space radio communications. Other parts of the microwave radio band are used for radars, radio navigation systems, sensor systems, and radio astronomy.

The next higher part of the radio electromagnetic spectrum, where the frequencies are above 30 GHz and below 100 GHz, are called "millimeter waves" because their wavelengths are conveniently measured in millimeters, and their wavelengths range from 10 mm down to 3.0 mm. Radio waves in this band are usually strongly attenuated by the Earthly atmosphere and particles contained in it, especially during wet weather. Also, in wide band of frequencies around 60 GHz, the radio waves are strongly attenuated by molecular oxygen in the atmosphere. The electronic technologies needed in the millimeter wave band are also much more difficult to utilize than those of the microwave band.

Satellite communication



A **communications satellite** or **comsat** is an artificial satellite sent to space for the purpose oftelecommunications. Modern communications satellites use a variety of orbits including geostationary orbits, Molniya orbits, elliptical orbits and low (polar and non-polar) Earth orbits.

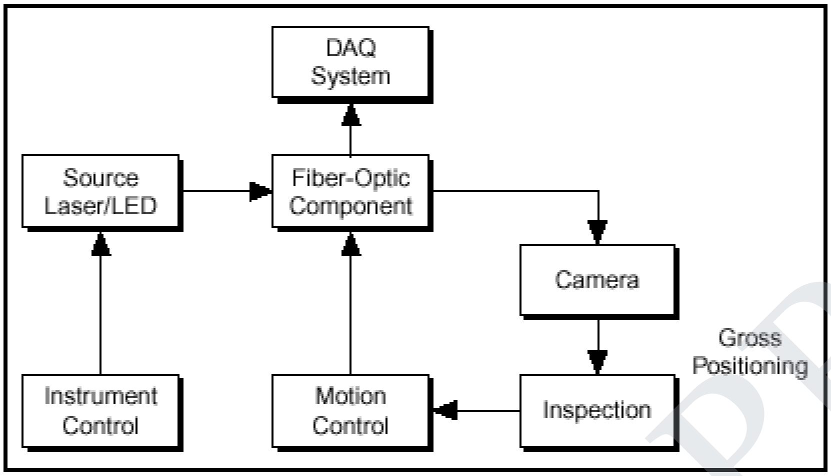
For fixed (point-to-point) services, communications satellites provide a microwave radio relay technology complementary to that of communication cables. They are also used for mobile applications such as communications to ships, vehicles, planes and hand-held terminals, and for TV and radio broadcasting.

Communications Satellites are usually composed of the following subsystems:

- Communication Payload, normally composed of transponders, antenna, and switching systems
- Engines used to bring the satellite to its desired orbit
- Station Keeping Tracking and stabilization subsystem used to keep the satellite in the right orbit, with its antennas pointed in the right direction, and its power system pointed towards the sun
- Power subsystem, used to power the Satellite systems, normally composed of solar cells, and batteries that maintain power during solar eclipse
- Command and Control subsystem, which maintains communications with ground control stations. The ground control earth stations monitor the satellite performance and control its functionality during various phases of its life-cycle.

The bandwidth available from a satellite depends upon the number of transponders provided by the satellite. Each service (TV, Voice, Internet, radio) requires a different amount of bandwidth for transmission. This is typically known as link budgeting and a network simulator can be used to arrive at the exact value.

Optical fiber communication



Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. The light forms an electromagnetic carrier wave that ismodulated to carry information. First developed in the 1970s, fiber-optic communication systems have revolutionized the telecommunications industry and have played a major role in the advent of theInformation Age. Because of its advantages over electrical transmission, optical fibers have largely replaced copper wire communications in core networks in the developed world. Optical fiber is used by many telecommunications companies to transmit telephone signals, Internet communication, and cable television signals. Researchers at Bell Labs have reached internet speeds of over 100 petabits per second using fiber-optic communication.

The process of communicating using fiber-optics involves the following basic steps: Creating the optical signal involving the use of a transmitter, relaying the signal along the fiber, ensuring that the signal does not become too distorted or weak, receiving the optical signal, and converting it into an electrical signal.Optical fiber is used by many telecommunications companies to transmit telephone signals, Internet communication, and cable television signals.

Due to much lower attenuation and interference, optical fiber has large advantages over existing copper wire in long-distance and high-demand applications. However, infrastructure development within cities was relatively difficult and time-consuming, and fiber-optic systems were complex and expensive to install and operate. Due to these difficulties, fiber-optic communication systems have primarily been installed in long-distance applications, where they can be used to their full transmission capacity, offsetting the increased cost. Since 2000, the prices for fiber-optic communications have dropped considerably. The price for rolling out fiber to the home has currently become more cost-effective than that of rolling out a copper based network. Prices have dropped to $850 per subscriber in the US and lower in countries like The Netherlands, where digging costs are low and housing density is high.

GLOSSARY

A: symbol for ampere, the SI unit of current.

AC: literally, alternating current. Often used loosely to refer to other things which involve alternating current; for example AC voltage probably means either alternating emf or alternating potential difference.

Active device: a device which does something. It is nearly always a source of emf, but its important property could be that it is sending a signal of some kind. (See also passive device.)

Active terminal: of a power point is the "live" or high potential (high voltage) terminal. The neutral terminal is supposed to remain close to earth potential, but it may vary from that. See also earth.

Alternating current: (AC) a current which is continually changing its value and direction in a regular fashion. Usually it means a current which can be described by the equation: $i = i_o \sin(2p\ f\ t)$ (a "sinusoidal" current) in which i is current, i_o is a constant called the amplitude of the current, t is time and f is the frequency of the current. In Australia the frequency of commercially generated AC power is 50 Hz, which means that the current changes direction 100 times per second (twice for each cycle).

Ammeter: current meter; a contraction of ampere-meter.

Amp: colloquial name for ampere.

Amp hour: colloquial for ampere hour.

Ampere: the SI unit of electric current. Its symbol is A, so a current of 5 amperes is written as 5 A. A typical domestic appliance such as a toaster will carry a current of several amperes

Ampère, André-Marie: (1775-1836) French physicist who gave his name to the unit of current. Ampere hour: a unit for describing the life of a battery which depends on how much current it can produce for how long. Symbol A.h. A battery with a life of 1 A.h is nominally capable of producing a current of 1 A for 1 h, or 0.5 A for 2 h, etc, before it goes flat. Since the product of current and time has the dimensions of charge, it follows that if you run a battery with 1.00 A.h capacity until it is flat, then 1 A.h or 3.6 ¥ 103 C of mobile charge will have passed through the battery. You can estimate the energy that can be delivered from a battery by taking the product of its life and its emf. For example a 2 V battery with a life of 5 A.h should be able to deliver about (2 V) x (5 A.h) which equals 2 x 5 x 60 x 60 J or 7 kJ.

Analogue meter: a meter which is read by noting the position of a pointer against a scale. Angular frequency: frequency multiplied by the number 2π. The "angular" bit is essentially a red herring, but is related to the fact that an angle of 2π radians is one revolution. Usual symbol: w (Greek lower-case omega). The SI unit is the reciprocal second, symbol s^{-1}, but some folks, confused by the "angular" part of the name, use radian per second ($rad.s^{-1}$).

Battery: strictly a collection of electrochemical cells, but commonly refers also to a single electrochemical cell. The key property of a battery or cell is its emf. For a battery consisting of several cells, the total emf is equal to the sum of the cells' individual emfs.

C: the symbol for coulomb, the SI unit of charge. Not to be confused with the italic symbol C for capacitance.

capacitance: property of a conductor or a pair of conductors which tells how good it is at holding separated charge for a given potential (in the case of one conductor) or potential difference for a pair of conductors. Defined as the quotient: charge divided by potential (difference). The usual symbol is C (printed in italics in books - don't confuse it with the symbol C for coulomb). The SI unit of capacitance is the farad.

Capacitor: a two-terminal device designed to have the property of capacitance. It usually consists of two conducting objects separated by insulating material. It can also be thought of as a device for storing energy.

Cell: see electrochemical cell, photovoltaic cell, charging.

Charge: the basic electrical property of matter. Usual symbol q, occasionally Q. There are two kinds of charge which we call positive and negative. Of the particles which constitute atoms, every proton has a positive charge of +e, every electron has a charge of -e, while neutrons have no charge. (The value e is often called the electron charge rather than the proton charge because the electron was discovered before the proton.) Normally the total charge of an atom is zero; the number of protons in the nucleus is equal to the number of electrons in the atom; the atom is electrically neutral. Charge does not exist independently of matter.

Charging: "charging" a battery is a misnomer for "energising" it. It means putting energy into the battery by forcing a current through the battery, against the battery's emf. The termcharging is misleading because the total charge in the battery is always the same; although mobile charge passes through the battery during "charging" and "discharging" what matters is the state of the chemicals in the battery and the energy that you can get from it.

Circuit: strictly, a circuit is just one conducting loop containing a string of electrical components joined end to end. In common parlance the meaning is often extended to include any arrangement of components, which may contain many different loops.

Circuit diagram: see schematic diagram.

Conductance: the opposite of resistance; a good conductor has a low resistance; defined as the reciprocal of resistance or as the quotient, current through the object divided by the potential difference across it. Usual symbol: G. The SI unit is the siemens, symbol S.

Conduction: the process by which charged particles move in an organised way through a material thus forming a current.

Conductor: an electrical conductor is any thing or any material which can carry an electric current. (In other contexts a conductor might be something that carries heat from one place to another or a person who minds a travelling tram.) See also insulator, semiconductor.

Constant: steady, unchanging, having the same value during some interval of time. A constant current (DC) does not change with time. See also uniform.

Conventional current: part of a model which supposes that current consists of moving positive charge. Conventional current goes from the positive terminal of a battery, through a circuit and back into the battery's negative terminal. Even though we know that for a metallic wire a better model describes negatively charged electrons as carrying the current, the concept of conventional current is well established and causes no problems in circuit theory. Unless a context tells you otherwise, assume that all references to current mean conventional current.

Coulomb: the SI unit of charge, symbol C, named after Charles Augustin Coulomb (1736 - 1806) who formulated the law of interaction between charged particles. A coulomb of separated charge is a huge quantity.

Current: an electric current is something that exists in a closed electrical circuit and is measured using an ammeter. It is not the same as energy or voltage. The name is analogous with water current in a river or an air current which is moving air. What moves in an electric current is electrically charged particles, inside a conductor, whose total charge is zero or neutral. The usual symbol is I; some books use i for changing current. The SI unit of current is the ampere (symbol A). See also conventional current.

DC: literally, direct current, which usually means a steady unchanging current. DC is often used as an adjective to refer to other things associated with direct current; for example DC voltage usually means steady emf or steady potential difference.

Digital meter: a meter which displays its readings as numbers (digits).

Direct current: usually a constant current but the term could refer to a current with a constant direction and a slowly changing value. A battery produces direct current.

Direction. Referring to circuits, direction does not mean direction in space but one of two possible ways that you might trace out a circuit or part of a circuit. Such "directions" might be described by terms such as "clockwise" or "from the positive terminal to the negative terminal". To completely specify a current, you need to know its direction as well as its value.

Dynamic resistance: a property of a circuit component defined in terms of potential difference (V) across the device and the current (i) through it as dV/di. It is not the same as resistance. For devices which obey Ohm's law dynamic resistance is equal to resistance. The SI unit is the ohm, symbol Ω.

Earth: literally just that, or a connection from a circuit to the earth - also called ground. It is useful because the earth can be regarded as a good conductor, which provides a convenient path for the completion of many circuits. Connection is usually made through a wire from the circuit or apparatus to the earth; such a connection is always available through the earth pin of a standard power point. (See also earth potential.)

Earth potential: for all practical purposes the earth always stays at the same potential, so it is a convenient reference for specifying potentials, and it is conventionally assigned a potential of zero volts. For example if you see a reference to a potential (rather than a potential difference) of 100 V, that means 100 V above earth potential.

Electricity: apart from being the name of the subject, electricity does not have a well-defined technical meaning. How, then, should we translate common usages of the term? To 'generate electricity' usually means to create emf, but when you 'buy electricity' you pay for energy. Some people say that electricity means charge, but if you mean charge, it's probably better to say charge.

Electromagnetic field: an electric field and a magnetic field together. Since electric and magnetic fields are intimately linked to one another it makes sense to have a name which indicates both together. Electromagnetic waves, including light, consist of electromagnetic fields. electromagnetic induction: a process in which an emf is created either by moving a conductor through a region containing a magnetic field, or by having a magnetic field which changes with time. It is the process used to produce "electricity" (electrical energy) in power generators.

Electric field: a physical quantity which has a definite value at each point in space and which determines amongst other things, the electrical force that would be experienced by a charged particle at each point. We think of the field as existing in space even though there may be no particle there to experience the force. Electric field is produced in two ways. (1) An electric field exists in the space surrounding any charged particle. (2) An electric field is created by a magnetic field which varies with time. The SI unit of electric field is the volt per metre, symbol V.m-1.

Electron: type of fundamental particle which carries the smallest possible magnitude of a free charge. The electron's charge is written symbolised as -e. The symbol e represents the value of the fundamental charge: e = 1.60 ¥ 10-19 C. Electrons are constituents of all atoms and are the charged particles which carry the current in a metallic wire.

emf: (pronounced "ee em eff") a physical quantity which describes the ability of an electrical source to deliver energy. You can also think of it as the property of the source which creates current in a circuit. Derived from the nineteenth century term "electromotive force" which is ok (pronounced "okay") as far as the electromotive bit goes, but it is not a force as we define force now. The emf of a battery is responsible for producing a potential difference between the battery's terminals. If the battery is not connected to anything else, that potential difference is equal to the emf. The SI unit is the volt, symbol V. [Not to be confused with electromagnetic field which the popular press sometimes refers to as EMF.]

Energy: can't be easily defined. It is a physical quantity which, if you do the calculations correctly, always gives the same total energy for the whole universe. Its meaning is best learned through many examples, the same way that we learn normal language. It can be misleading to think of energy as a kind of substance - it is more subtle than that. Energy is what you are asked to pay for when you get your electricity bill. The SI unit of energy is the joule, symbol J.

Farad: the SI unit of capacitance, named after Michael Faraday, symbol F. One farad is a very large capacitance; values of capacitors used in typical circuits are in the microfarad range (micro = one millionth).

Faraday: an outmoded unit of charge, which we would now define as the charge of a mole of protons, 96 406 coulombs

Faraday, Michael: (1791 - 1867) pioneer researcher in electricity and regarded as one of the all-time greats of physics.

Frequency: the repetition rate for any process or phenomenon that repeats itself exactly; it is the number of cycles divided by the total time interval taken. It is also equal to the reciprocal of the period, the time taken for one complete cycle. Usual symbol: f. The SI unit of frequency is the hertz, symbol Hz.

Ground: see earth.

Hertz: the SI unit of frequency, equivalent to one cycle per second; symbol Hz.

Impedance: a property of a circuit component, instrument or some other device which encapsulates the relationship between the potential difference (PD) across the device and the current through it.

Input: Literally something that is put in to something else or the cause of some effect which you could call the output.

Insulator: any thing or type of material which is a very poor conductor of electricity. Electrical wires (conductors) are covered on the outside with insulating material in order to guard against accidental short circuits.

Internal resistance: is just resistance. The redundant "internal" is often added when one is referring to something like a battery or an instrument.

J: symbol for joule, the SI unit of energy.

Joule: the SI unit of energy, symbol J. Named after English physicist James Prescott Joule (1818 - 1889) who helped to establish the concept of energy.

Kilowatt hour: non-SI unit of energy, used by electricity authorities for billing, equal to 3.**6** megajoules. The symbol is kW.h, which is sometimes sloppily written as kWh.

kV: symbol for kilovolt, 10^3 V.

Load: something which takes electrical energy from a circuit. It is sometimes called an energy **s**ink. A household light globe becomes a load when it is connected to the mains and switched on.

mA: symbol for milliampere, 10^{-3} A.

Magnetic field: a physical quantity which has a definite value at each point in space. We think of the field as existing in space even though there may be no particle there to experience the force. Magnetic fields can be produced by magnets made of magnetic materials (iron in particular), by electric currents and by electric fields which change with time. The SI unit of magnetic field is the tesla, symbol T.

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milliamp: colloquial for milliampere; one thousandth of an ampere. Symbol: mA.

multimeter: an instrument which can be used for measuring any one of several different electrical quantities, usually potential difference (voltage), current and resistance. The user has to select the quantity to be measured, by selecting some switch settings.

mV: symbol for millivolt, 10^{-3} V.

Negative: see positive and negative.

Neutral: (1) having zero net charge. The wires in a circuit remain neutral even though charged electrons move inside them. (2) A different meaning occurs with the neutral wire or terminal in a household wiring; in that case neutral means having near-zero potential - see under active terminal.

Nominal value: literally "named value", usually a rough estimate of the intended value of something. Nobody is too fussed when the real value turns out to be somewhat different.

ohm: SI unit of resistance; symbol Ω (the Greek letter, capital omega).

Ohm, Georg Simon: (1787 - 1854) German scientist who gave his name to the unit of resistance.

Ohm's law: the statement that the resistance of some objects (notably metallic objects), held at constant temperature, is independent of the potential difference across the object or the current through it. There are many interesting objects which don't obey Ohm's law. Some people confuse Ohm's law with the definition of resistance but an object can have a (variable) resistance, even though it does not obey Ohm's law.

Open circuit: (1) a break in what was meant to be a circuit or (2) the broken circuit itself. Turning a switch off creates an open circuit

Output: explained under input.

Parallel. Two components are in parallel if, when tracing a path between two points in a circuit, you find that you have the alternative of branching off and tracing through either one component or the other, before those alternative paths rejoin. Whether two things are in parallel or series depends critically on the two points that you are tracing the path between; it makes no sense to say that things are in parallel without reference to those points.

Passive device: a passive circuit component has no emf. The term comes from the idea that it responds to something done to it by an active device, such as a battery. Light globes and capacitors are passive devices.

Period: the time interval required for exactly one cycle of a repetitive process or phenomenon of any kind. It is equal to the reciprocal of the process's frequency. Usual symbol, T. The SI unit is the second, symbol s.

PD: lazy person's way of writing potential difference.

polarity: the property of a device which means that it has a positive terminal and a negative terminal.

potential difference: difference in potential between two points in space.

power: rate of transfer of energy. For a steady rate (constant power) it can be expressed as $E/\Delta t$ where E is the energy transferred in the time interval Δt. Usual symbol: P. The SI unit is the watt (symbol W).

resistance: a property of an object associated with energy dissipation which occurs when a current exists in the object.

resistor: a two-terminal device designed to have the property of resistance. It is usually desirable that a resistor should obey Ohm's law and have a resistance that is fairly stable against temperature changes. Most resistors are painted with a code consisting of coloured bands which tell you the resistance.

semiconductor: a kind of material intermediate between a conductor and an insulator. Semiconductors are used to make transistors, diodes and photovoltaic cells.

series. Circuit components are said to be connected in series with each other if they form a chain without branches.

short circuit: a conducting path, or part of a circuit, with negligible or relatively low resistance. The term is most commonly used to indicate an accidental path, which causes a much bigger current than the one you wanted.

static resistance: exactly the same as resistance. The "static" qualifier is added in order to emphasise that one does not mean dynamic resistance.

source: usually means a source or giver of electrical energy in a circuit, so it is a general term for something that has an emf. It could also mean the source of a signal, but signal sources also have emf. When current rather, than emf, is important one may refer to a current source, but a source is still a source.

terminal: part of a component or a circuit to which something else gets connected. For example a battery has two terminals both of which have to be joined into a circuit before you get anything from the battery.

volt: the SI unit of potential, potential difference and emf, symbol V, named after Alessandro Volta.

Volta, Alessandro: (1745 - 1827) Italian physicist who gave his name to lots of things electrical.

voltage: a colloquial term which could mean either emf or potential difference. It usually means potential difference. If you know which one you mean it is better to use the more exact term.

voltmeter: an instrument for measuring potential difference. (It does not measure emf directly; values of emf have to be inferred from other measurements.)

W: symbol for watt, the SI unit of power.

watt: the SI unit of power, symbol W, equivalent to 1 joule per second. Named after Scottish engineer, James Watt (1736-1819).

work: energy which is transferred by any mechanism other than heat flow. Work is done on a charged particle when it moves between two places with different potentials. A source ofemf can increase the energy of a charged particle that passes through it. The SI unit is the joule, symbol J

Amplification: a method for increasing the amplitude (or loudness) of electrical signals

Amplifier: An electronic device which generates a high power signal based on the information supplied by a lower powered signal. A perfect amplifier would add or subtract nothing from the original except additional power - these have not been invented yet

CMOS: (Complementary Metal Oxide Semiconductor) - one family of digital logic devices. Some CMOS devices can operate with power supplies from 3 Volts to 15 Volts - others are limited to the traditional logic 5 Volt power supply.

Power Amp: An amplifier that is designed to drive loudspeakers or other relatively low impedance loads. Usually combines voltage and current amplification. May be integrated with the preamp (see below).

Semiconductor: Silicon (or various other materials) that are specially treated so as to form diodes, transistors, MOSFETs, light emitting diodes (LEDs) etc. The basis of all modern electronics.

Analogue to Digital Converter (ADC): A device that converts the infinite range of an analogue signal into discrete "steps". Normally, a good audio ADC will use sufficient "steps" to resolve the smallest musical detail. For CD, this is a 16 bit converter, having 65,536 discrete levels covering the most negative signal level to the most positive

Binary: the basic counting system used in computer logic. Two values are available - 0 and 1. A zero is normally represented by a 0 Volt signal, and a one by a voltage of approximately 5 Volts - these levels are dependent upon the type of logic used

Binary Code: a coding scheme that communicates information by using a series of "1s" and "Os" that are represented, respectively, by the digital "ON" and "OFF" states

Bit Stream: the bit rate, or flow of information, between a sender and receiver in digital communication. Also called Digital Bit Stream.

Bit: a unit of the binary code that consists of either a single "1" or "O." (Commonly 5V or 0V respectively.)

Byte: a unit of the binary code that consists of eight bits. One byte is required to code an alphabetic or numeric character, using an eight-bit character set code.

CODEC: COder / DECoder - the component of any digital ssubsystem which performs analogue to digital and digital to analogue conversions.

Digital/Analogue Conversion: a method used to recreate an analogue signal that has been coded into binary data and transmitted as a digital signal.

Digital/Analogue Converter (DAC): a device used to generate a replica of the original analogue signal that has been coded into binary data and transmitted as a digital signal.

Amplitude: the loudness of sound waves and electrical signals. Amplitude is measured in decibels (dB) or volts

Attenuation: the decrease of a signal's amplitude level over any distance during transmission or through purpose designed attenuators. Attenuation measures signal loss in decibels (dB)

Bandwidth: the measure of a range of frequencies containing an upper and lower limit

Cable: a type of linear transmission medium. Some of the common types of cables include: hook up wire, coaxial (shielded) cables, lamp amd mains cable, figure-8 (zip) cable and fibre optics

Coaxial Cable: a metallic cable constructed in such a way that the inner conductor is shielded from EMR (electromagnetic radiation) interference by the outer conductor. Coaxial cable is less susceptible to more transmission impairments than twisted pair cable, and it has a much greater bandwidth; thus coaxial cable is used by most analogue and digital systems for the transmission of low level signals.

Crossover: A filter network which separates frequencies into "bands" which match the capabilities of the loudspeaker drivers within an enclosure.

Crosstalk: a noise impairment when a signal from one pair of wires affects adjacent wires or one channel affects the adjacent channel.

Cutoff Frequency: Normally defined as the frequency where the output from a filter has fallen by 3dB from the maximum level obtainable through the filter.

Frequency: The rate at which an alternating current changes in a cyclic manner from positive to negative and back again (one cycle). The basic unit of measurement is the Hertz (Hz), which equates to one cycle per second.

Frequency Modulation (FM): a modulation technique that records changes in an information signal by modifying the frequency of the carrier signal according to changes in the amplitude of the information signal.

QUESTION BANK

UNIT I ELECTRICAL CIRCUITS & MEASUREMENTS

1. **What is meant by charge?**
   Charge is an electrical property of the atomic particles which matter consists. The charge of an electron is so small. Charge in motion represents current. The unit of charge is coulomb.

2. **What is meant by Current?**
   The flow of free electrons in a conductor is called current. Unit is ampere (A). I = Q/t

3. **What is meant by Voltage?**
   The poterntial difference between two points is called as voltage. Unit is Volts (V). V=W/Q , W=work done in joules & Q = charge in coulombs

4. **State Ohm's Law.**
   The potential difference across any two ends of a conductor is directly proportional to the current flowing between the two ends provided the temperature of the conductor remains constant.

5. **State Krichoff's Voltage Law**
   KVL states that the algebraic sum of voltages in a closed path is zero.

6. **State Krichoff's current Law.**
   KCL states that the algebraic sum of currents in a node is zero.

7. **Give short notes on resistor.**
   It is a property of a substance3 which opposes the flow of electrons. It is denoted by R and its unit is Ohm

8. **Distinguish between a Branch and a node of a circuit.**
   A pair of network which connects the various points of the network is called branch
   A point at which two or more elements are joined together is called node.

9. **Distinguish between a mesh and a loop of a circuit.**
   A mesh is a loop that does not contain other loops. All meshes are loop, but all loops are not meshes. A loop is any closed path of branches

10. **Write down the formula for a star connected network is converted into a delta network?**
    RA=(R1 R2)/(R1 +R2+ R3)
    RB=(R1 R3)/(R1 +R2+ R3)
    RC=(R2 R3)/(R1 +R2+ R3)

11. Write down the formula for a delta connected network is converted into a star network?

R1=(RARB+RBRC+RCRA)/RC
R2=(RARB+RBRC+RCRA)/RB
R3=(RARB+RBRC+RCRA)/RA

12. Define line currents and phase currents?

The currents flowing in the lines are called as line currents
The currents flowing through phase are called phase currents

13. Define line voltage and phase voltage?

The voltage across one phase and neutral is called line voltage & the voltage between two lines is called phase voltage

14. Give the phase value & Line value of a star connected system.

VL= 3Vph

15. Give the phase value and line valued of a delta connected system.

IL= 3Iph

16. What is the power equation for a star connected system?

P= 3I V cosΦ L L W

17. What is the power equation for a delta connected system?

P= 3I V cosΦ L L W

18. What is meant by Real power?

Real power means the useful power transfer from source to load. Unit is watts.

19. What is meant by apparent power?

Apparent power is the product of voltage and current and it is not true power. Unit is VA

20. What is reactive power?

If we consider the circuit as purely inductive the output power is reactive power. Its unit is VAR

21. Define Instrument.

Instrument is defined as a device for determining the value or magnitude of a quantity or variable.

22. Mention the two main differences between an ammeter and a voltmeter.

Ammeter Voltmeter
It is a current measuring device it is a voltage measuring device
Always connected in series with circuit Always connected in parallel with circuit

The resistance is very small The resistance is very high

23. What is control system?

A system consists of a number of components connected together to perform a specific function . In a system when the output quantity is controlled by varying the input quantity then the system is called control system.

24. What are the two major types of control system?

The two major types of control system are open loop and closed loop

25. Define open loop control system.

The control system in which the output quantity has no effect upon the input quantity are called open loop control system. This means that the output is not feedback to the input for correction.

26. .Define closed loop control system.

The control system in which the output has an effect upon the input quantity so as to maintain the desired output value are called closed loop control system

27. Mention the errors in Moving iron instruments.

Hysteresis error
Temperature error
Stray magnetic field error
Frequency error
Eddy current error

28. Mention any two precautions to be taken while using an Ammeter.

It should never be connected across any source.
The polarity must be observed correctly.
First use the highest range and then decrease the voltage range until the sufficient deflection is obtained.

29. Define Form factor and Crest factor.

Form factor= RMS value / Average Value
Crest(peak) factor=Maximum Value / RMS value

30. Which type of instrument is called as universal instrument?

The moving iron instrument are known as universal instruments, because these instruments can be used for AC and DC.

31. What are the applications of MI instruments?

i) Used as multirange ammeters and voltmeters.
ii) Used as in expensive indicators such as charging and discharging current indicators in automobiles.

iii)Extensively used in industries for measurement of AC voltage and current where errors of the order of 5% to 10% are accepetable.

32. What is meant by eddy current damping?

When the conductor moves in a magnetic field an emf is induced in it and if a closed path is provided ,a current flows known as eddy current. This current intersect with the magnetic field to produce an electromagnetic torque , which opposes the deflecting torque.

33. How is electrical power measured?

i) Using Voltmeter-ammeter method for DC circuits.
ii)Using Watt meters for AC circuits.

34. What do you mean by compensation coil in a wattmeter?

By connecting a compensating coil in series with a pressure coil, The error caused by the pressure coil flowing in the current coil can be neutralized.

35. What are the three types of power used in a a.c circuit?

i) Real power or active power P=EI cos□
ii) Reactive power Q=EI sin□
iii) Apparent power,S=EI

36. Define average value.

The average value of an alternating current is that value of steady direct current which transfers the same charge as the alternating current flowing for the same time.

37. Define RMS value.

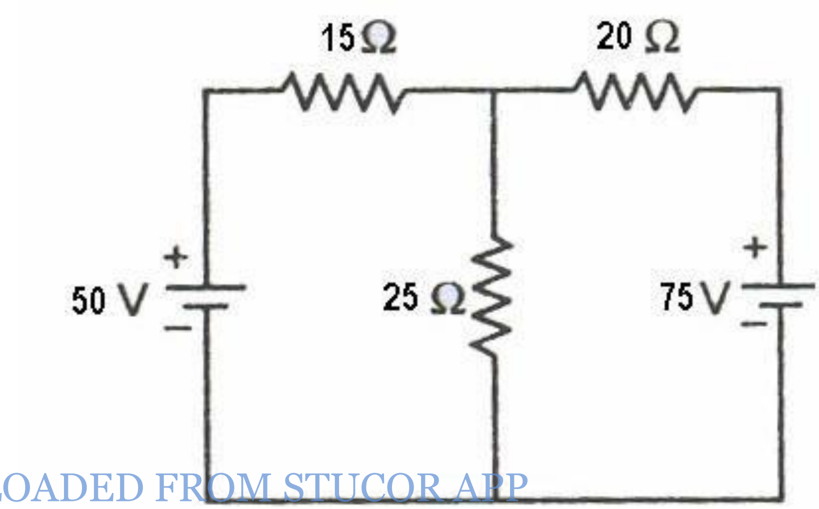
The effective value of an alternating current is that value of steady ,direct current which produces the same heat as that produced by the alternating current when passed which produces the same heat as that produced by the alternating current when passed through the same resistance for the same interval of time.

38. Define reactive power.

The power consumed by a pure reactance (XL or Xc) in a a.c circuit is called reactive power. The unit is VAR. Q=EIsin□.

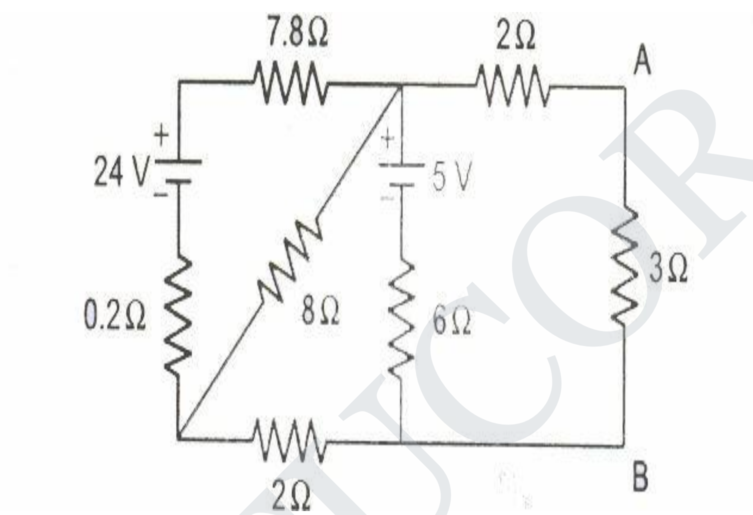
PART B

1. Apply KCL and KVL to the circuit shown in fig.

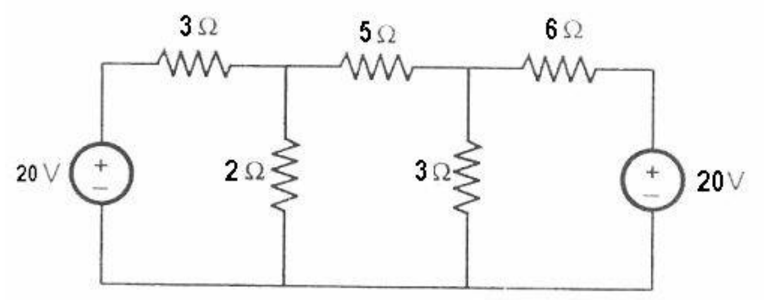


DEPARTMENT OF

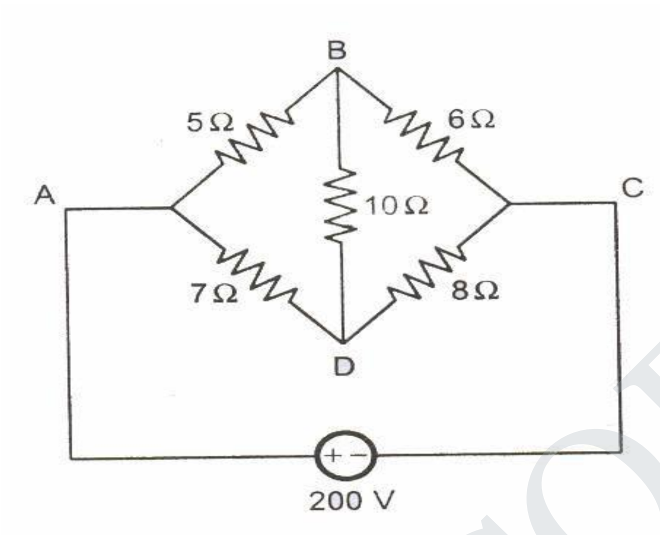
2. Find the current through branch AB by using mesh current analysis



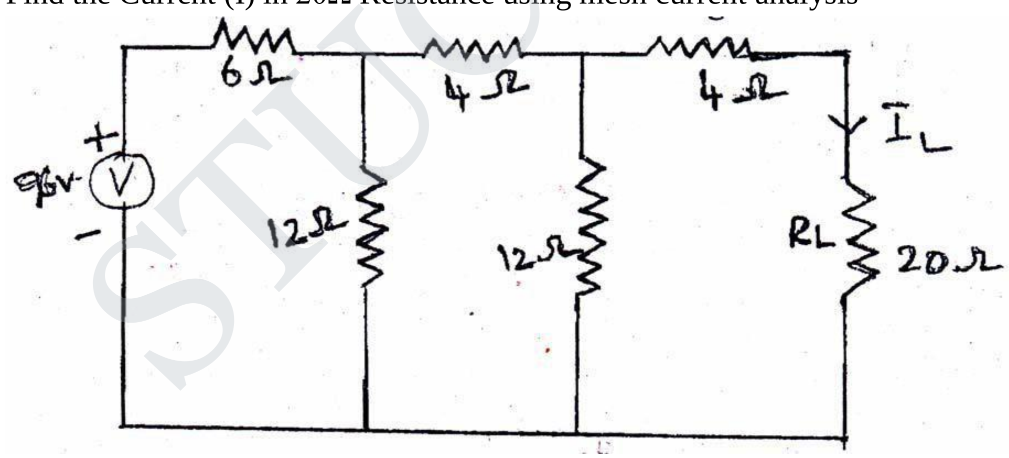
3. Find the current through 5 ohm resistance using mesh current analysis.



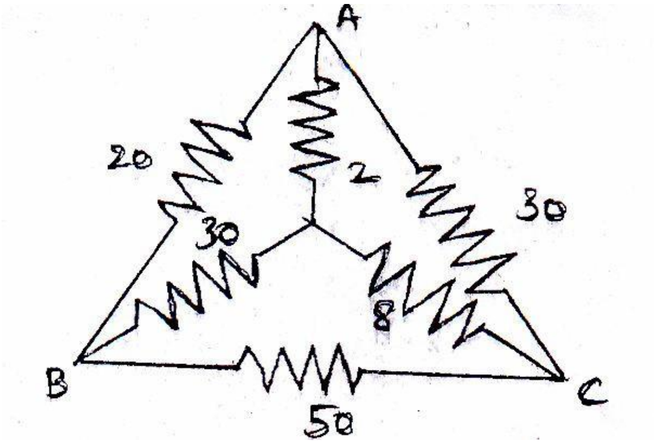
4. Find the current through 10 ohm resistance using mesh current analysis.



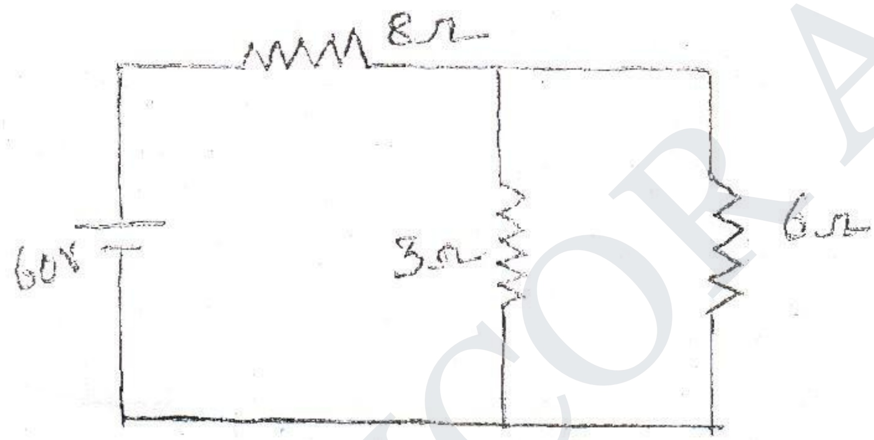
5. Find the Current (I) in 20Ω Resistance using mesh current analysis



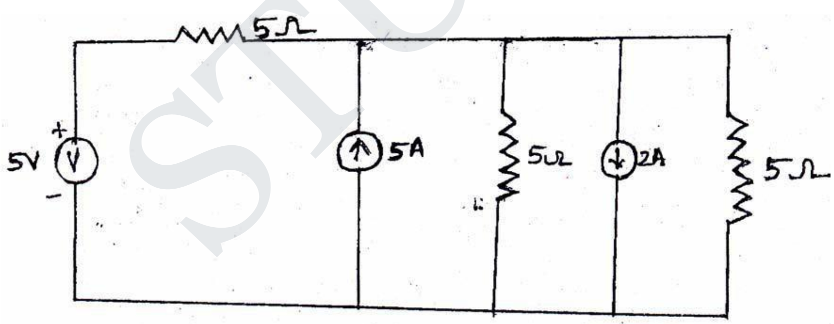
6. Find the resistance between A & B , A & C



7. Consider the following network as shown in figure. Determine the power observed by the 6Ω .



8. Find the total Current and total Resistance in the circuit given



9. Derive the equation for given star network transformation in to delta network
10. Explain the construction and operation of moving coil instruments
11. Explain the construction and operation of moving iron repulsion type instruments
12. Explain the construction and operation of moving iron attraction type instruments
13. Explain the construction and operation of dynamo meter type watt meter
14. Explain the construction and operation of induction type single phase energy meter

UNIT II ELECTRICAL MECHANICS

1. What is an electric generator?

An electrical machine, which converts mechanical energy into electrical Energy, is called as electric generator.

2. What is an electric motor?

An electrical machine, which converts electrical energy into mechanical Energy, is called as electric motor.

3. What is meant by magnetic flux?

The magnetic lines of force existing around a magnet is called magnetic flux. It's unit is Weber.

4. State faraday's law of electromagnetic induction.

Whenever a conductor cuts the magnetic lines of force an emf is induced in it.

5. State Fleming's Right hand rule.

If three fingers of right hand, namely thumb, index finger and middle finger are outstretched so that everyone of them is at right angles with the remaining two, and the index finger is made to point in the direction of lines of flux, thumb in the direction of the relative motion of the conductor and the middle finger gives the direction of the induced emf in the conductor.

6.What is the use of commutator?

A device is used in a dc generator to convert the alternating emf into unidirectional emf is called commutator.

7.What is the function yoke?

- It serves the purpose of outermost cover of the dc machine. So that the insulating material get protected from harmful atmospheric elements like moisture, dust and various gases like SO_2, acidic fumes etc.
- It provides mechanical support to the poles.

8.What is the choice of material for the following?

1.Yoke 2.pole 3.Field winding 4.Armature winding

1.Yoke:

It is prepared by using cast iron because it is cheapest.

2.Pole:

It is made up of cast iron or cast steel.

3.Field winding:

It is made up of aluminium or copper.

4.Armatuer winding:

It is made up of cast iron or cast steel.

9.What is the function of brush?

To collect current from commutator and make it available to the stationary external circuit.

10.Write down the emf equation for d.c generator.

$$\boxed{E = (\phi NZ / 60)(P/A)} \quad V$$

Where
P = number of poles
Z = Total number of conductors
A = number of parallel paths
Φ = flux per pole
N = speed in rpm

11.What are all the two types of excitation?

i. Separate excitation

When the field winding is supplied from external, separate dc supply i.e. Excitation of field winding is separate then the generator is called separately excited generator.

ii. Self excitation

When the field winding is supplied from the armature of the generator itself then it is called as self-excitation.

12.What is meant by residual magnetism?

Practically though the generator is not working, without any current through field winding, the field poles posses some magnetic flux. This is called as residual magnetism.

13.Give the types of DC generator.

1.Self excited generator

- Series Generator
- Shunt Generator
- Compound Generator
  - Long shunt compound generator
  - Short shunt compound generator
  - Cumulative and differential compound Generator

2. Separately excited generator

14.List out the applications of various types of generators.

- **Separately excited generator**

As a separate supply is required to excite the field, the use is restricted to some special applications like electroplating, electro refining of materials etc

- **Shunt generator**

Commonly used in battery charging and ordinary lighting purposes.

- **Series Generators**

Commonly used as boosters on dc feeders, as a constant current generators for welding generator and arc lamps.

- **Cumulatively compound generators**

These are used for domestic lighting purposes and to transmit energy over long distance.

- **Differential compound generator**

The use of this type of generators is very rare and it is used for special application like electric arc welding.

15.what is the principle of DC motor?

Whenever a current carrying conductor placed in a magnetic field, it experiences a mechanical force.

16.State that the Fleming's left hand rule.

The rules states that outstretch the three fingers of the left hand namely the first finger, middle finger and thumb such that they are mutually perpendicular to each other. Now point the first finger in the direction of magnetic field and the middle finger in the direction of the current then the thumb gives the direction of the force experienced by the conductor.

17.What is Lenz's law?

Lenz's law states the direction of induced emf is always so as to oppose the cause producing it.

18.Give the torque equation of a DC motor.

Ta=0.159fIa.PZ/A N-m

Ia - Armature current
P - Number of poles
Z - Total number of conductors
A -Number of parallel paths

19.List the different types of DC motor.

- DC series motor
- DC Shunt motor
- DC Compound motor
  - Long shunt compound motor
  - Short shunt compound motor

20.List out the characteristics of DC motor.

i. Torque-Armature current characteristics (T VS Ia)
ii. Speed-Armature current characteristics (N VS Ia)

21.What are all the applications of DC motor?

- **DC Shunt motor:**
  Blowers and fans
  Centrifugal and reciprocating pumps
  Lathe machines
  Machine tools
  Milling machines
  Drilling machines

- **DC Series motor:**
  Cranes
  Hoists, Elevators
  Trolleys,Conveyors,Electric locomotives

- **DC Cumulative compound motor**:
  Rolling mills
  Punches
  Shears
  Heavy planers
  Elevators

22. How is voltage generated in rotating machines?

In rotating machines voltage is generated in windings or group of coils by rotating them through a magnetic field or by mechanically rotating a magnetic field past the winding or by designing the magnetic circuit so that the reluctance varies with rotation of the rotor.

23.What is the basic principle of dc motor?

A machine that converts dc power into mechanical power is known as a dc motor its operation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force. The direction of force is given by Fleming's left hand rule and magnitude is given by

F= BIL netwons.

Basically there is no constructional difference between a dc motor and dc generator.
The same dc machine can be run as a generator (or) motor.

24. What is back emf in d.c motors?

As the motor armature rotates, the system of conductor come across alternate North and South pole magnetic fields causing an emf induced in the conductors. The direction of the emf induced in the conductors. The direction of the emf induced is in the direction opposite to the current .As this emf always opposes the flow of current in motor operation it is called back emf.

25. Mention the different parts of a d.c generator.

The different parts of dc generator are

(i) Magnetic frame (or) yoke.
(ii) pole core and pole shoes

(iii) pole coil or field coils
(iv) armature windings or conductors
(v) armature coils
(vi) commutator
(vii) Brushes and bearing.

26.What are the characteristics of DC generator?

The characteristics of DC generator are

i) no load or saturation characteristics(Ea/ If)
ii) internal characteristics(E/If)
iii) external characteristics(V/If)

27.Write the various losses occurring in DC generator

- Copper loss
- Iron loss
- Mechanical loss

28. Mention the difference between core and shell type transformers.

In core type, the windings surround the core considerably and in shell type the core surround the winding.

29. What is the purpose of laminating the core in a transformer?

The purpose of laminating the core in a transformer is to reduce eddy current loss.

30. Give the emf equation of a transformer and define each term

Emf induced in primary coil E1 = 4.44 fΦ mN1 volt

Emf induced in secondary coil E2 = 4.44fΦ mN2 volt

Where f is the frequency of AC input Φ m is the maximum value of flux in the core N1, N2 are the number of primary and secondary turns.

31.Define voltage regulation of a transformer

When a transformer is loaded with a constant primary voltage, the secondary voltage decreases for lagging Power factor load, and increases for leading pf load because of its internal resistance and leakage reactance. The change in secondary terminal voltage from no load to full load expressed as a percentage of no loads or full load voltage is termed as regulation.

% regulation down = (0V2 -V2) x 100/0V2

% regulation up = (0V2 -V2) x 100/V2

32. Why transformers are rated in kVA?

Copper loss of a transformer depends on current and iron loss on voltage. Hence total losses depend on Volt- Ampere and not on the power factor. That is why the rating of transformers is in kVA and not in kW.

33. What are the typical uses of auto transformer?

(i) To give small boost to a distribution cable to correct for the voltage drop.
(ii) As induction motor starters.
(iii) As furnace transformers
(iv) As interconnecting transformers
(v) In control equipment for single phase and 3 phase elective locomotives.

34. When will a Bucholz relay operate in a transformer?

- Bucholz rely is a protective device in a transformer.
- If the temperature of the coil exceeds its limit, Bucholz relay operates and gives an alarm.

35. Why are breathers used in transformers?

Breathers are used to entrap the atmospheric moisture and thereby not allowing it to pass on to the transformer oil.

Also to permit the oil inside the tank to expand and contract as its temperature increases and decreases.

36. What is the function of transformer oil in a transformer?

Nowadays instead of natural mineral oil, synthetic oils known as ASKRELS (trade name) are used. They are Noninflammable; under an electric arc do not decompose to produce inflammable gases. PYROCOLOR oil possesses high dielectric strength.
Hence it can be said that transformer oil provides,

(i) good insulation and
(ii) cooling.

37. An 1100/400 V, 50 Hz single phase transformer has 100 turns on the secondary winding. Calculate the number of turns on its primary.

We know V1 / V2 = k = N2 / N1
Substituting 400/1100 = 100/N1
N1 = 100/400 x 1100 = 275 turns.

38. What are the functions of no-load current in a transformer?

No-load current produces flux and supplies iron loss and copper loss on no-load.

39. What is meant by a transformer?

The transformer is a static piece of apparatus by means of which electrical power is transformed from one alternating current circuit to another with desired change in voltage and current. Without any change in the frequency. It works on the principle of mutual induction

40. What are the advantages of a transformer?

i) Less I2R loss in the transmission line
ii) Less voltage drop in the line
iii) Efficiency of the transmission line is increased
iv) Volume of the conductor required is less.

41. What are the properties of ideal transformer?

i) It has no loss
ii) Its winding have zero resistance.
iii) Leakage flux is zero i.e 100% flux produced by primary links with the secondary
iv) Permeability of core is so high that negligible current is required to establish the flues is it.

42. What are the important parts of a transformer?

Transformer consists of winding and magnetic core. The core is square or rectangle shape. It consists of limb and yoke core is made up of lamination which is used to reduce eddy current losses.

43. Define voltage transformation ratio?

The ratio of secondary induced emf to primary induced emf is called as voltage regulation ratio devoted by K.

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

44. Write the expression for equivalent resistance and reactance of transformer referred to primary.

Equivalent resistance Ro1 = R1 + R21 = R1 + R2/K2
Equivalent reactance Xo1 = X1 + X11 = X1 + X2/K2

45. Define voltage regulations of a transformer.

The decrease in secondary terminal voltage expressed as a fraction of the no load secondary terminal voltage is called voltage regulation of a transformer.

46. What are the losses occurring in a transformer?

i) Core losses
ii) Copper losses

47. What is meant by core or iron losses?

Core or iron losses are caused as the core gets subjected to an alternating flux.

48. What is meant by hysteresis losses?

Due to alternating flux set up in the magnetic core of the transformer, it undergoes a cycle of magnetization and demagnetization.

Due to hysteresis effect there is loss of energy in this process which is called hysteresis loss.

49. What is meant by copper loss?

The copper losses are due to the power wasted in the form of I2R due to the resistances of the primary and secondary windings.

50. What is meant by eddy current loss?

The induced emf in the core tries to set up eddy currents in the core and hence responsible for the eddy current losses.

51.Define all day efficiency?

All day efficiency is the ratio energy (in kwh) delivered in a 24 hours period to the energy (in kwh) input for the same length of time.

$$\text{All day Efficiency} = \frac{\text{Output in kwh}}{\text{Input in kwh}} \quad \text{(for 24 hrs)}$$

52. Define efficiency of a transformer?

The efficiency of a transformer is defined as the ratio of the output power to the input power.

$$\eta = \frac{\text{power output}}{\text{power input}}$$

53. What is the function of capacitor in a single phase induction motor?

Capacitor is used to improve the power factor of the motor. Due to the capacitor connected in series with the auxiliary winding, the capacitive circuit draws a leading current which increases the split phase angle α between two phase currents Im and Ist.

54. What is the use of shading coil in the shaded pole motor?

In shaded pole motors, the necessary phase-splitting is produced by induction. These motors have salient poles on stator and a squirrel cage type rotor. The poles are shaded i.e.; each pole carries a copper band one of its unequally divided part called shading band.
When single phase A.C. supply is given to the stator winding, due to shading provided to the poles, a rotating magnetic field is generated.

55. Why capacitor-start induction motors advantageous?

In capacitor-start induction motors, capacitor is connected in series with the auxiliary winding. When speed of the motor approaches to 75 to 80% of the synchronous speed, the starting winding gets disconnected due to the operation of the centrifugal switch. The capacitor remains in the circuit only at start. The starting torque is proportional to phase angle α and hence such motors produce very high starting torque.

56. List out four applications of shaded pole induction motor?

Shaded pole motors have very low starting torque, low power factor and low efficiency. These motors are commonly used for small fans, toy motors, advertising displays, film projectors, record players, gramophones, hair dryers, photo copying machines etc.

57. What are the types of single phase induction motors?

The types of single phase induction motors are:

1. Split phase induction motor.
2. Capacitor start induction motor.
3. Capacitor start and capacitor run motor.
4. Shaded pole induction motor.

PART B

1. Draw a neat sketch of a DC generator and label the component parts. Name the material used for each component part.
2. Draw a constructional diagram for a generator and explain the parts dividually.
3. Explain different methods of excitation
4. Explain the different characteristics are available in DC series and DC shunt Generator.
5. Explain and derive the emf and torque equation .
6. Write the applications for different types of motors and generators

UNIT III SEMICONDUCTOR DEVICES AND APPLICATIONS

1) Define Transistor

Transistor consists of two junctions formed by sand witching either P-type or N-type semiconductor between a pair of opposite types.

2). Write the current amplification factor for a CB transistor.

α = Change in Collector Current / at constant VCB
Change in emitter current

3) Write the formula for input resistance in a CB transistor

Input resistance = Change in base - emitter voltage /
Change in emitter current/at constant VCB

4). Write the current amplification factor for a CE transistor.

b = Change in Collector Current /
Change in base current at constant VCE

5). Define transistor action.

A transistor consists of 2 coupled PN junctions. The base is a common region to both junctions and makes a coupling between them. Since the base regions are smaller, a significant interaction between junctions will be available. This is called transistor actions.

6).Define delay time

It is defined as the time required for the current to rise from 0 to 10% of its maximum value.

7). Define rise time

It is the time required for the current to rise from 0 to 90 percentage of the maximum value.

8). Define turn-on time

It is the time required for the current to rise from 0 to 90 percentage of the maximum value ton = td + tr

9).Define fall time

It is the time required for the Collector current to fall from 90 to 10 percentage of Ics.

10).Define Storage time

It is the time required to fall from 100 to 90 percent of Ics.

11).Define turn-off time

It is the time required to fall from 100 to 90 percent of Ics.

Toff=ts+tr

12).Define hybrid parameters.

Any linear circuit having input and output terminals can be analysed by four parameters(one measured on ohm, one in mho and two dimensionless) called hybrid or hparameters.

13). What are the use of h - Parameters?

It perfectly isolates the input and output circuits.

Its source and load currents are taken into account.

14).Define power transistors

Power transistors are those which handles a large amount of current and also dissipates large amount of power across collector base junction.

15).Define current amplification factor in CC transistor.

g =Change in emitter current

Change in base current / at constant VCE

16)Which is the most commonly used transistor configuration? Why?

The CE Configuration is most commonly used. The reasons are

- High Current gain
- High voltage gain
- High power gain
- Moderate input to output ratio.

17) What are the values of input resistance in CB, CE & CC Configuration

CB - Low about 75
CE - Medium About 750
CC - Very high about 750

18) Write the voltage and current equation for hybrid parameters.

$$V_1 = h_{11}i_1 + h_{12}V_2$$
$$I_2 = h_{21}i_1 + h_{22}V_2$$

19) What are the values of h-parameters?

$$h_{11} = V_1/ i_1$$
$$h_{12} = V_1 / V_2$$
$$h_{21} = i_2 / i_1$$
$$h_{22} = i_2 / V_2$$

20) h – parameter is applied to linear circuit True or False.

True

21) What are the advantages of transistors?

1.Low operating voltage.
2.Higher efficiency.
3.Small size and ruggedness

22) What are the types of transistors?

- Unipolar junction transistor
- Bipolar junction transistor.

23) What are the basic techniques used to construct a transistor?

- Grown type.
- Alloy type.
- Electro chemically etched type
- Diffusion type.
- Epitaxial type.
-

24)What is mean by characteristics of transistor?

The interrelation of the various currents and voltages can be plotted graphically which are commonly known as the characteristics of transistor.

25)What are the types of BJT?

- n-p-n type.
- p-n-p type.

PART B

- 1. Explain the working of NPN transistor
- 2. Explain the working of PNP transistor
- 3. Explain the current components of the transistor
- 4. What are the basic techniques used for the construction of a transistor?
- 5. Explain the common base configuration.
- 6. Draw the hybrid model for CE configuration

UNIT IV DIGITAL ELECTRONICS

1) Given the two binary numbers X = 1010100 and Y = 1000011, perform the subtraction (a) X -Y and (b) Y - X using 2's complements.

a) X = 1010100

2's complement of Y = + 0111101

Sum = 10010001

Discard end carry

Answer: X - Y = 0010001

b) Y = 1000011

2's complement of X = + 0101100

Sum = 1101111

There is no end carry,

Therefore the answer is Y-X = -(2's complement of 1101111) = -0010001

2). Given the two binary numbers X = 1010100 and Y = 1000011, perform the subtraction (a) X -Y and (b) Y - X using 1's complements.

a). X - Y = 1010100 - 1000011

X = 1010100

1's complement of Y = + 0111100

Sum = 10010000

End -around carry = + 1

Answer: X - Y = 0010001

b). Y - X = 1000011 - 1010100

Y = 1000011

1's complement of X = + 0101011

Sum = + 1101110

There is no end carry.

Therefore the answer is Y - X = -(1's complement of 1101110) = -0010001

3). What is meant by parity bit?

A parity bit is an extra bit included with a message to make the total number of 1's either even or odd. Consider the following two characters and their even and odd parity:

	With even parity	With odd parity
ASCII A = 1000001	01000001	11000001
ASCII T = 1010100	11010100	01010100

In each case we add an extra bit in the left most position of the code to produce an even number of 1's in the character for even parity or an odd number of 1's in the character for odd parity. The parity bit is helpful in detecting errors during the transmission of information from one location to another.

4).Define binary logic?

Binary logic consists of binary variables and logical operations. The variables are designated by the alphabets such as A, B, C, x, y, z, etc., with each variable having only two distinct values: 1 and 0. There are three basic logic operations: AND, OR, and NOT.

5).Define logic gates?

Logic gates are electronic circuits that operate on one or more input signals to produce an output signal. Electrical signals such as voltages or currents exist throughout a digital system in either of two recognizable values. Voltage- operated circuits respond to two separate voltage levels that represent a binary variable equal to logic 1 or logic 0.

6).Define duality property.

Duality property states that every algebraic expression deducible from the postulates of Boolean algebra remains valid if the operators and identity elements are interchanged. If the dual of an algebraic expression is desired, we simply interchange OR and AND operators and replace 1's by 0's and 0's by 1's.

7).Find the complement of the functions $F_1 = x'yz' + x'y'z$ and $F_2 = x(y'z' + yz)$. By applying De Morgan's theorem as many times as necessary.

F1' = (x'yz' + x'y'z)' = (x'yz')'(x'y'z)' = (x + y' + z)(x + y +z')

F2' = [x(y'z' + yz)]' = x' + (y'z' + yz)'

= x' + (y'z')'(yz)'

= x' + (y + z)(y' + z')

8).Find the complements of the functions F1 = x'yz' + x'y'z and F2 = x(y'z' + yz). by taking their duals and complementing each literal.

F_1 = x'yz' + x'y'z

The dual of F1 is (x' + y + z')(x' + y' + z)

Complementing each literal: (x + y' + z)(x + y + z')

F_2 = x(y'z' + yz).

The dual of F2 is x + (y' + z')(y + z).

Complement of each literal: x' + (y + z)(y' + z')

9).State De Morgan's theorem.

De Morgan suggested two theorems that form important part of Boolean algebra. They are,

1) The complement of a product is equal to the sum of the complements.

(AB)' = A' + B'

2) The complement of a sum term is equal to the product of the complements.

(A + B)' = A'B'

10).Reduce A.A'C

A.A'C = 0.c [A.A' = 1]

= 0

11). Reduce A(A + B)

A(A + B) = AA + AB

= A(1 + B) [1 + B = 1]

= A.

12. Reduce A'B'C' + A'BC' + A'BC

A'B'C' + A'BC' + A'BC = A'C'(B' + B) + A'B'C

= A'C' + A'BC [A + A' = 1]

= A'(C' + BC)

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

13.) Reduce AB + (AC)' + AB'C(AB + C)

AB + (AC)' + AB'C(AB + C) = AB + (AC)' + AAB'BC + AB'CC

= AB + (AC)' + AB'CC [A.A' = 0]

= AB + (AC)' + AB'C [A.A = 1]

= AB + A' + C' =AB'C [(AB)' = A' + B']

= A' + B + C' + AB'C [A + AB' = A + B]

= A' + B'C + B + C' [A + A'B = A + B]

= A' + B + C' + B'C

=A' + B + C' + B'

=A' + C' + 1

= 1 [A + 1 =1]

14. Simplify the following expression Y = (A + B)(A + C')(B' + C')

Y = (A + B)(A + C')(B' + C')

= (AA' + AC +A'B +BC)(B' + C') [A.A' = 0]

= (AC + A'B + BC)(B' + C')

= AB'C + ACC' + A'BB' + A'BC' + BB'C + BCC'

= AB'C + A'BC'

15).Simplify the following using De Morgan's theorem [((AB)'C)'' D]'

[((AB)'C)'' D]' = ((AB)'C)'' + D' [(AB)' = A' + B']

= (AB)' C + D'

= (A' + B')C + D'

16.Show that (X + Y' + XY)(X + Y')(X'Y) = 0

(X + Y' + XY)(X + Y')(X'Y) = (X + Y' + X)(X + Y')(X' + Y) [A + A'B = A + B]

= (X + Y')(X + Y')(X'Y) [A + A = 1]

= (X + Y')(X'Y) [A.A = 1]

= X.X' + Y'.X'.Y

= 0 [A.A' = 0]

17).Prove that ABC + ABC' + AB'C + A'BC = AB + AC + BC

ABC + ABC' + AB'C + A'BC =AB(C + C') + AB'C + A'BC

=AB + AB'C + A'BC

=A(B + B'C) + A'BC

=A(B + C) + A'BC

=AB + AC + A'BC

=B(A + C) + AC

=AB + BC + AC

=AB + AC +BC ...Proved

18).Convert the given expression in canonical SOP form Y = AC + AB + BC

Y = AC + AB + BC

=AC(B + B') + AB(C + C') + (A + A')BC

=ABC + ABC' + AB'C + AB'C' + ABC + ABC' + ABC

=ABC + ABC' +AB'C + AB'C' [A + A =1]

19).Convert the given expression in canonical POS form Y = (A + B)(B + C)(A + C)

Y = (A + B)(B + C)(A + C)

= (A + B + C.C')(B + C + A.A')(A + B.B' + C)

= (A + B + C)(A + B + C')(A + B +C)(A' + B +C)(A + B + C)(A + B' + C)

[A + BC = (A + B)(A + C) (Distributive law]

= (A + B + C)(A + B + C')(A' + B + C)(A' + B + C)(A + B' + C)

20) Write down the steps in implementing a Boolean function with levels of NAND Gates?

Simplify the function and express it in sum of products.

Draw a NAND gate for each product term of the expression that has at least two literals. The inputs to each NAND gate are the literals of the term. This constitutes a group of first level gates. Draw a single gate using the AND-invert or the invert-OR graphic symbol in the second level, with inputs coming from outputs of first level gates.

A term with a single literal requires an inverter in the first level. How ever if the single literal is complemented, it can be connected directly to an input of the second level NAND gate.

21) Give the general procedure for converting a Boolean expression in to multilevel NAND diagram?

- Draw the AND-OR diagram of the Boolean expression.
- Convert all AND gates to NAND gates with AND-invert graphic symbols.
- Convert all OR gates to NAND gates with invert-OR graphic symbols.
- Check all the bubbles in the same diagram. For every bubble that is not compensated by another circle along the same line, insert an inverter or complement the input literal.

22) What are combinational circuits?

A combinational circuit consists of logic gates whose outputs at any time are determined from the present combination of inputs. A combinational circuit performs an operation that can be specified logically by a set of Boolean functions. It consists of input variables, logic gates, and output variables.

23) Give the design procedures for the designing of a combinational circuit.

The procedure involves the following steps,

- From the specification of the circuit, determine the required number of inputs and outputs and assign a symbol to each.
- Derive the truth table that defines the required relationships between inputs and outputs.
- Obtain the simplified Boolean functions for each output as a function of the input variables.
- Draw the logic diagram and verify the correctness of the design.

24) Define half adder.

A combinational circuit that performs the addition of two bits is called a half adder. A half adder needs two binary inputs and two binary outputs. The input variables designate the augend and addend bits; the output variables produce the sum and carry

25) Define full adder?

A combinational circuit that performs the adtion of three bits is a full adder.It consists of three inputs and two outputs.

The carry into sign bit position and the carry out of the sign bit position. If these two carries are not equal, an overflow has occurred.

26. **Represent binary number 1101 - 101 in power of 2 and find its decimal equivalent**

$N = 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 + 1 \times 2^{-1} + 0 \times 2^{-2} + 1 \times 2^{-3}$

$= 13.625_{10}$

27. **What are the different classification of binary codes?**

1. Weighted codes

2. Non - weighted codes

3. Reflective codes

. Sequential codes

5. Alphanumeric codes

6. Error Detecting and correcting codes.

28. **Write the names of basic logical operators.**

1. NOT / INVERT

2. AND

3. OR

29. **Simplify the following expression**

y = (A + B) (A = C) (B + C)

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

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

= A B C + A C C + A B B + A B C + B B C + B C C

= A B C = A B C

30. **Show that the NAND connection is not associative**

The NAND connection is not associative says that

A . B . C A . B. C

A . B + C A + B C

AB + C A + BC

31. **What is a Logic gate?**

Logic gates are the basic elements that make up a digital system. The electronic gate is a circuit that is able to operate on a number of binary inputs in order to perform a particular logical function.

32. **Write the names of Universal gates.**

1. NAND gate

2. NOR gate

33. **Why are NAND and NOR gates known as universal gates?**

The NAND and NOR gates are known as universal gates, since any logic function can be implemented using NAND or NOR gates.

34. **Define combinational logic**

When logic gates are connected together to produce a specified output for certain specified combinations of input variables, with no storage involved, the resulting circuit is called combinational logic.

35. **Explain the design procedure for combinational circuits**

¢ The problem definition

¢ The determination of number of available input variables & required O/P variables.

¢ Assigning letter symbols to I/O variables

¢ Obtain simplified boolean expression for each O/P.

¢ Obtain the logic diagram.

36. **Define half adder and full adder**

The logic circuit which performs the addition of two bits is a half adder.

The circuit which performs the addition of three bits is a full adder.

PART – B

1. a. Write the verilog code generate for parallel load up / down Counter b. Write a verilog code for D Flip Flop and R-S Flip Flop
2. Explain R-S Flip Flop and Clocked R-S Flip Flop
3 .a. Explain S-R Flip Flop
b. Explain D Flip Flop
4. a. Explain JK Flip Flop
b. Explain T Flip Flop
5.a. Explain Master Slave Flip Flop
b. Explain the Edge Triggered Flip Flop
6. a. Convert it JK Flip Flop in to T Flip Flop
b. Convert it JK Flip Flop in to D Flip Flop

7. a. Convert it D Flip Flop in to T Flip Flop
   b. Convert it T Flip Flop in to D Flip Flop
8. a. Explain Serial in Serial out Shift Register
   b. Explain Serial in parallel out Shift Register
9. a. Explain parallel in parallel out Shift Register
   b. Explain parallel in Serial out Shift Register
10. Design sequential circuit for a state diagram?

UNIT V FUNDAMENTALS OF COMMUNICATION ENGINEERING

1. What do you mean by radio communication?

Ans. The process sending audio signal from a source to distant destination using carrier wave is called radio communication.

2. Explain communication system with the help of block diagram?

Source destination

3.Wite name of sub units of radio communication system?

i. Transmitters
ii. Transmission Channel
iii. Receiver

4 What do you understand by modulation?

Ans. The process of varying one of the characteristics of a high frequency wave ai accordance with the instantaneous value of a low frequency signal is called modulation.

5 What is modulating wave?

Ans. Low frequency signal is called modulating wave.

6 What is carrier wave?

Ans. High frequency wave is called carrier wave.

7 What are different types of modulation?

Ans. i. Amplitude modulation (AM)
ii. Frequency Modulation (FM)
iii. Phase modulation (PM)

8 Give the definition of Amplitude modulation (AM)?

Ans . Amplitude modulation (AM) is a technique used in electronic communication, most commonly for transmitting information via a radio carrier wave. AM works by varying the strength of the transmitted signal in relation to the information being sent.

9 Give the definition of Frequency Modulation (FM).

Ans. Frequency modulation (FM) conveys information over a carrier wave by varying its instantaneous frequency in accordance with the frequency of the carrier wave.

10 What is modulation index?
Ans. Modulation index of amplitude modulation is defined as the ratio of the amplitude of the modulating wave to the amplitude of the carrier wave

11 what are the disadvantages of AM?
i. Smaller operating range
ii. Poor audio Quality
iii. Low Efficiency
iv. Reception noisy

12 What are the advantages of FM?
Ans.
i. Noiseless Reception
ii. Better Quality
iii. High operating range
iv. Efficiency is very high

13. What are the disadvantages of FM?
Ans. i. Costly equipments
ii. Smaller area of reception
iii.Much wider channel is required

14. What is demodulation?
Ans. The process of recovering the audio signal from modulated wave is known as demodulation. Or detection. Thus demodulation is reverse process of modulation .

15 Give the definition of phase modulation (PM)?
Ans. In this he phase of the carrier wave is varied in accordance with the instantaneous value of modulating signal.

16 What GSM and CDMA stands for?
Ans. GSM stands for Global system for mobile communication.
CDMA stands for Code division multiple access.

17 What do you understand by the term television.
Ans. Television (TV) is the most widely used telecommunication medium for transmitting and receiving moving images that are either monochromatic ("black and white") or color, usually accompanied by sound. "Television" may also refer specifically to a television set, television programming or television transmission.

18 Determine the size of antenna working at frequency of 20 kHz and wave length of wave 1.5*106 m given that velocity of light to be3*108 m/s .
Ans. λ = c/f
= 3*108 m/s/20*103 = 15*103 m
Size of antenna = λ/4 = 3750 m. ans.

19 What is super heterodyne radio receiver ?
Ans. It is an improved radio receiver which employs the principle of heterodyning (means frequency translation

20. What is the basic principle of communication satellites?
Ans. communication satellites has uplink and down link frequency and used for various research works and weather forecasting.

PART-B

1. What do you understand by the term communication systems?

2.What is Modulation and why it is needed?

3.What are the types of modulation?

4.Deduce the expression for modulation index for AM.

5.Explain the advantages of FM over AM.

6.Derive the expression for modulation index or index of modulation for FM?

7. Determine the size of antenna working at frequency of 20 kHz and wave length of wave 2.5*106 m given that velocity of light to be 3*108 m/s .Comment on the result obtained.

8. Explain the principle of mobile communication .

9. How communication satellites work?

10. Briefly explain the working of super heterodyne radio receiver with the help of block diagram

11. Briefly discuss the principle of mobile communication?

12. What do you understand by Multiple-Access Techniques?

Reg. No. :

Question Paper Code: E3109

B.E./B.Tech. DEGREE EXAMINATION, JUNE 2010

Second Semester

Mechanical Engineering

GE2151 — BASIC ELECTRICAL AND ELECTRONICS ENGINEERING

(Regulation 2008)

(Common to Aeronautical Engineering, Automobile Engineering, Civil Engineering, Marine Engineering, Production Engineering, Biotechnology, Chemical Engineering, Petroleum Engineering, Plastic Technology, Polymer Technology, Textile Technology and Textile Technology (Fashion Technology))

Time : Three hours Maximum : 100 Marks

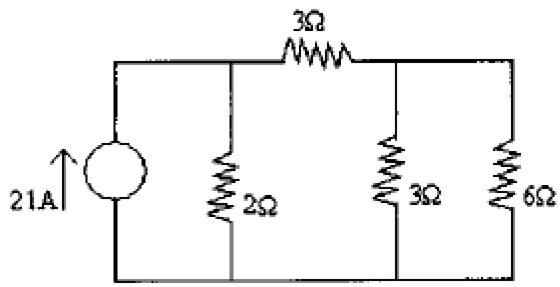
Answer ALL Questions

PART A — (10 × 2 = 20 Marks)

1. Find the effective value of the cosine wave $V_m \cos(\omega t + \Phi)$.
2. It is required to convert a 5mA meter with 20Ω internal resistor into 5A ammeter. Calculate the value of shunt resistance required and multiply factor of the shunt.
3. What is the greatest advantage of DC MOTORS?
4. What is leakage flux?
5. What is junction capacitance?
6. For a certain transistor $I_C = 5.505\text{mA}$, $I_B = 50\mu A$, $I_{CO} = 5\mu A$, determine the value of β & I_E.
7. Prove that $A + \overline{A}B = A + B$.
8. Why divide-by-n counter called so?
9. Mention the need of modulating the information signals.
10. Define Total internal reflection.

PART B — (5 × 16 = 80 Marks)

11. (a) Describe Kirchoffs laws. For the circuit shown in the figure below. Determine the current through 6 Ω resistor and the power supplied by the current source. (16)



Or

(b) Explain the principle and operation of PMMC instruments. How ammeter and voltmeter can be constructed using PMMC instruments? (16)

12. (a) (i) A 220-V d.c. series motor runs at 700rev/min when operating at its full-load current of 20A. The motor resistance is 0.5 Ω and the magnetic circuit may be assumed unsaturated. What will be the speed if :

(1) the load torque is increased by 44%?

(2) the motor current is 10 A? (8)

(ii) Explain the operation and principle of a DC motor. (8)

Or

(b) (i) Determine the actual output power of an induction motor using the following data.

No. of poles = 2

Frequency = 50 Hz

Rated voltage = 415 V

Name plate full speed = 2980 rpm

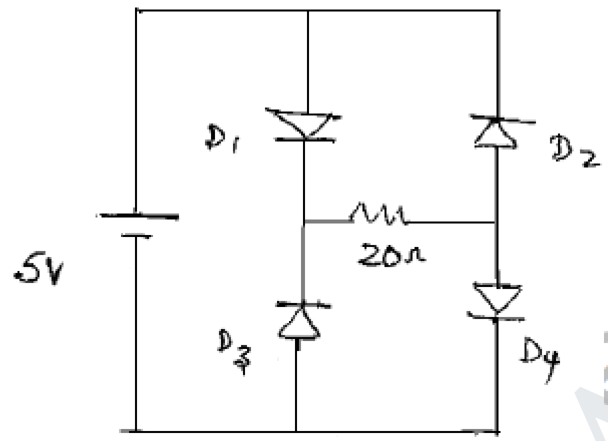
Measured speed at 423 V = 2990 rpm

Name plate rated power = 22 kW. (8)

(ii) Explain the construction and operation of single phase alternators. (8)

13. (a) (i) Explain the V – I characteristics of a diode. (12)

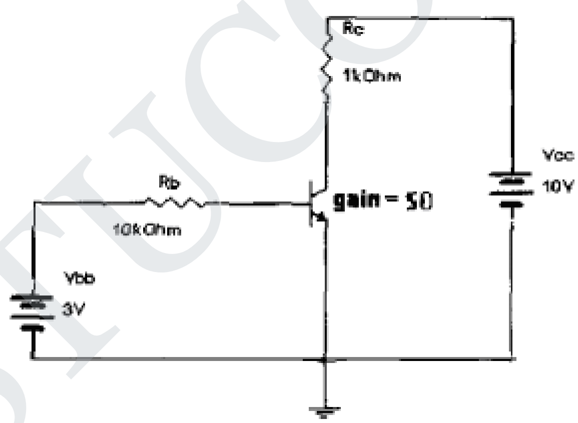
(ii) Find the current through the 20 Ω resistor shown below. Each silicon diode has a barrier potential of 0.7 V and a dynamic resistance of 2 Ω. (4)



Or

(b) (i) Explain the input and output characteristics of transistors in CB configuration. (10)

(ii) Determine whether or not the transistor in circuit below is in saturation. Assume $V_{CE(sat)} = 0.2$ V. (6)



14. (a) (i) Represent the given function with THREE AND gates and ONE OR gate.

$\overline{A}BC + A\overline{B}C + AB\overline{C} + ABC$. (10)

(ii) Explain the operation of half adder with a neat diagram. (6)

Or

(b) (i) Explain the operation of 4 bit synchronous UP counter with a neat diagram. (12)

(ii) Express the function XOR gate using NAND gates. (4)

15. (a) (i) A 10MHz sinusoidal carrier wave of amplitude 10mV is modulated by a 5KHz sinusoidal audio signal wave of amplitude 6mV. Find the frequency components of the resultant modulated wave and their amplitudes. (4)

(ii) Explain with suitable diagram Diode detector for AM signals. (12)

Or

(b) Discuss the usage of satellite for long distance communication with a neat block diagram of basic satellite transponder. (16)

Reg. No. :

J 3907

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2009.

Second Semester

Civil Engineering

GE 2151 — BASIC ELECTRICAL AND ELECTRONICS ENGINEERING

(Common to Aeronautical Engineering, Automobile Engineering, Mechanical Engineering, Production Engineering, Marine Engineering, Petroleum Engineering, Biotechnology, Chemical Engineering, Fashion Technology, Polymer Technology, Rubber and Plastics Technology and Textile Technology)

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Distinguish between a mesh and a loop of a circuit.
2. What is RMS value of a periodic current?
3. Write voltage equation of the motor.
4. What is emf equation of a transformer?
5. What are the applications of a diode?
6. What are the bias conditions of the base-emitter and base-collector junction for a transistor to operate as an amplifier?
7. Convert the binary fraction 0.101 into decimal equivalent.
8. Draw the symbol for OR gate and write its truth table.
9. Define modulation. What are the different types of modulation?
10. Define the term modulation index for frequency modulation.

PART B — ($5 \times 16 = 80$ marks)

11. (a) (i) Using nodal method find current through $8\,\Omega$ resistor of fig. 1. (8)

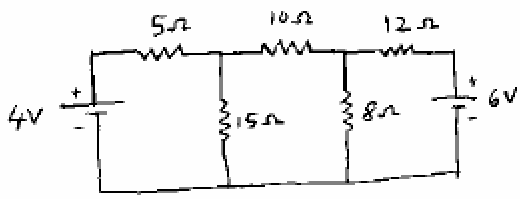


Fig. 1

(ii) A series circuit of $R = 10\Omega$ and $X_c = 15\Omega$ has an applied phasor voltage $V = 50\underline{\vert -90^\circ}\,V\,rms$. Find the real power, reactive power, complete power and power factor. (8)

Or

(b) (i) Three impedances of $42\underline{\vert -35^\circ}\,\Omega$ are connected in delta to a three phase, three wire, 350 volts ABC system. Find the line currents. (8)

(ii) With a neat sketch explain the working of dynamometer type watt meter. (8)

12. (a) (i) A dc shunt generator supplies a load of 7.5 kW at 200V. Calculate the induced emf if armature resistance is $0.6\,\Omega$ and field resistance is $80\,\Omega$. (8)

(ii) Derive emf equation of a dc generator. (8)

Or

(b) (i) Explain the principle of operation of a single phase transformer. (8)

(ii) With a neat sketch explain the working of split-phase induction motor. (8)

13. (a) (i) Explain the working of PN diode in forward and reverse bias conditions. (8)

(ii) Draw the circuit diagram for full-wave rectifier and explain its working. (8)

Or

(b) (i) What are the different terminals in a transistor? Draw the symbol of npn transistor and explain its working. (8)

(ii) Draw the circuit diagram of a transistor amplifier and explain how it amplifies the input signal? (8)

14. (a) (i) Draw the logic diagram of a clocked master slave JK flip flop and explain its working. (8)

(ii) Describe the operation performed by the following arithmetic circuits. $(2 \times 4 = 8)$

(1) Full adder

(2) Half-adder.

Or

(b) (i) Draw the logic diagram of a 4 bit buffer register and explain its working. (8)

(ii) Explain with a neat sketch the working of a successive approximation ADC. (8)

15. (a) (i) Explain the need for modulation. (4)

(ii) Draw the block diagram of radio broadcasting and reception system and explain the function of each block. (12)

Or

(b) (i) Draw the circuit diagram of balanced modulator and explain its operation.

(ii) With a neat block diagram explain the principle of operation of FAX.