DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

1 Year BEEE PART-B

PART B

BASIC ELECTRONICS ENGINEERING

Course Outcomes:

After completion of the course, students will be able to:

CO4: Apply the concept of science and mathematics to understand the working of diodes, transistors, and their applications.
CO5: Understand the characteristics of diodes and transistors.
C06: Understand the number systems, working mechanism of different combinational, sequential circuits and their role in the digital systems.

UNIT I SEMICONDUCTOR DEVICES

Introduction - Evolution of electronics – Vacuum tubes to nano electronics - Characteristics of PN Junction Diode — Zener Effect — Zener Diode and its Characteristics. Bipolar Junction Transistor — CB, CE, CC Configurations and Characteristics — Elementary Treatment of Small Signal CE Amplifier.

UNIT II BASIC ELECTRONIC CIRCUITS AND INSTRUMENTTAION

Rectifiers and power supplies: Block diagram description of a DC power supply, working of a full wave bridge rectifier, capacitor filter (no analysis), working of simple Zener voltage regulator. Amplifiers: Block diagram of Public Address system, Circuit diagram and working of common emitter (RC coupled) amplifier with its frequency response. Electronic Instrumentation: Block diagram of an electronic instrumentation system.

UNIT III DIGITAL ELECTRONICS

Overview of Number Systems, Logic gates including Universal Gates, BCD codes, Excess-3 code, Gray code, Hamming code. Boolean Algebra, Basic Theorems and properties of Boolean Algebra, Truth Tables and Functionality of Logic Gates – NOT, OR, AND, NOR, NAND, XOR and XNOR. Simple combinational circuits–Half and Full Adder, Introduction to sequential circuits, Flip flops, Registers and counters (Elementary Treatment only)

Textbooks:
1. R. L. Boylestad & Louis Nashlesky, Electronic Devices & Circuit Theory, Pearson Education, 2021.
2. R. P. Jain, Modern Digital Electronics, 4th Edition, Tata Mc Graw Hill, 2009

Reference Books:
1. R. S. Sedha, A Textbook of Electronic Devices and Circuits, S. Chand & Co, 2010.
2. Santiram Kal, Basic Electronics- Devices, Circuits and IT Fundamentals, Prentice Hall, India, 2002.
3. R. T. Paynter, Introductory Electronic Devices & Circuits – Conventional Flow Version, Pearson Education,2009.

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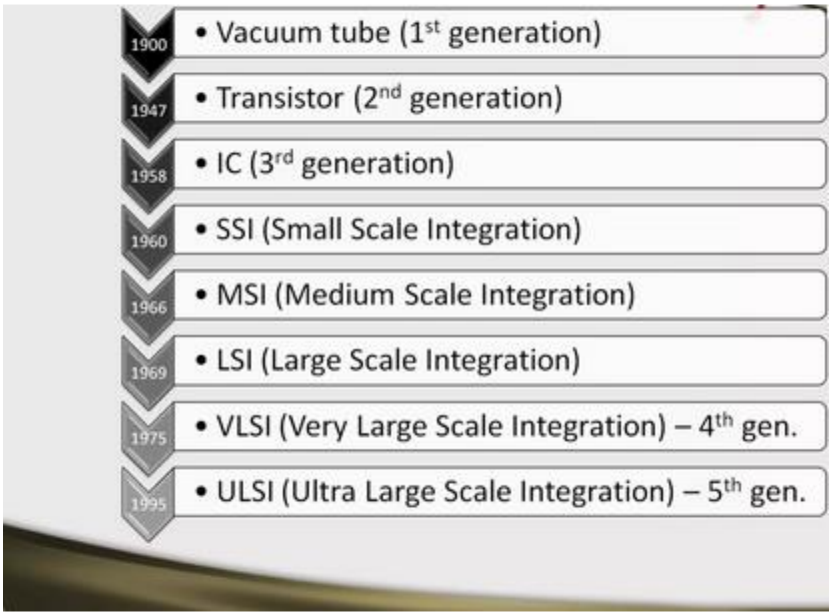
UNIT-1

ELECTRONICS

Electronics comprises the physics, engineering, technology and applications that deal with the emission, flow and control of electrons in vacuum and matter .This distinguishes it from classical electrical engineering as it uses active devices to control electron flow by amplification and rectification rather than just using passive effects such as resistance ,capacitance and inductance.

EVOLUTION OF ELECTRONICS



Classification of solids

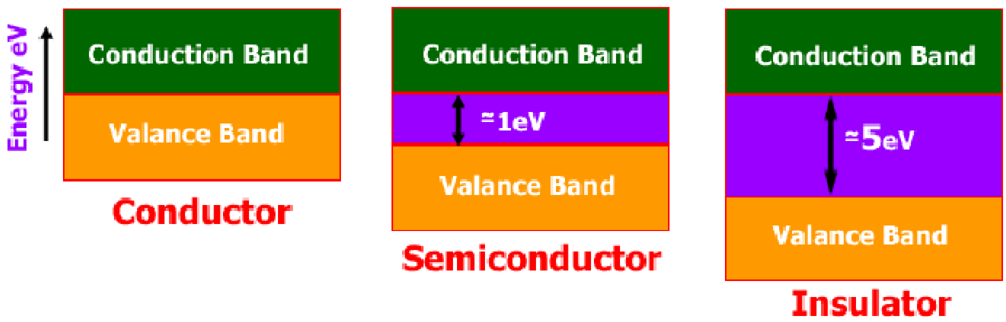


Fig: Classification of Solids on the basis of electricity Conduction

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

Classification of semiconductor

- Intrinsic Semiconductor
- Extrinsic Semiconductor

Classification of Extrinsic Semiconductor

• In n-type semiconductor: The doping contributes extra electrons, dramatically increasing

the conductivity.(Impurity: phosphorus, arsenic, antimony, bismuth or some other)

• In p-type semiconductor: The doping produces extra vacancies or holes, which likewise

increase the conductivity.(trivalent Impurity: Boron, gallium , indium aluminum)

SEMI CONDUCTOR DIODE:

Definition of Semiconductor

The materials that are neither conductor nor insulator with energy gap of about 1 eV (electron volt) are called semiconductors.

Most common materials commercially used as semiconductors are germanium (Ge) and silicon(Si) because of their property to withstand hightemperature.Thatmeanstherewillbenosignificantchangeinenergygap with changing temperature .The relation between energy gap and absolute temperature for Si and Ge are given as,

$$E_g = 1.210 - 3.60 \times 10^{-4} \times T \quad eV \quad (for\ Si)$$
$$E_g = 0.785 - 2.23 \times 10^{-4} \times T \quad eV \quad (for\ Ge)$$

Where, T = absolute temperature in

$$E_g = 1.210 - 3.60 \times 10^{-4} \times 300 \approx 1.1 \quad eV \quad (for\ Si)$$
$$E_g = 0.785 - 2.23 \times 10^{-4} \times 300 \approx 0.72 \quad eV \quad (for\ Ge)$$

^{o}K

Assumingroomtemperaturetobe300^o

K,

At room temperature resistivity of semiconductor is in between insulators and conductors . Semiconductors show negative temperature coefficient of resistivity that means its resistance decreases with increase in temperature. Both Si and Ge are elements of IV group, i.e. both elements have four valence electrons. Both form the covalent bond with the neighboring atom . At absolute zero temperature both behave like an insulator , i.e., the valence band is full while conductance band is empty but as the temperature is raised more and more covalent bonds break and electrons are set free and jump to the conduction band.

Intrinsic Semiconductors

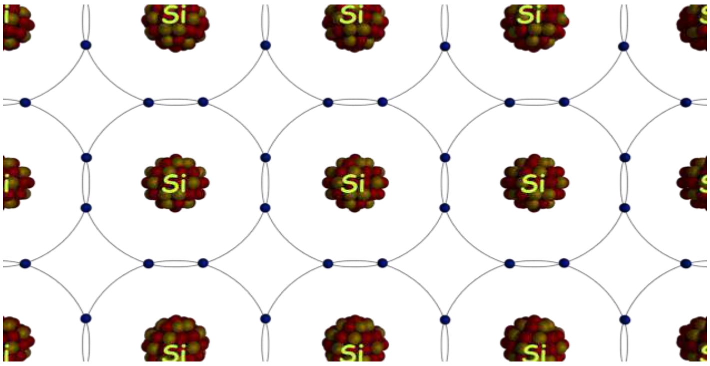
As per **theory of semiconductor** ,semiconductor in its pure form is called as intrinsic semiconductor . Impure semiconductor number of electrons (n) is equal to number of h … ductivity is very low as valence electrons are covalent bonded.

$$n_i = n_0 T^{\frac{2}{3}} e^{\frac{-V_G}{2V_T}}$$

I … n = p = n_i, where $n_i$is called the intrinsic concentration. It can be shown that n_i can be written

Where , n_0 is a constant ,T is the absolute temperature ,V_G is the semiconductor band gap voltage, and V_T is the thermal voltage.

The thermal voltage is related to the temperature by $V_T = kT/q$ Where, k is the Boltzmann constant ($k = 1.381 \times 10^{-23}$ J/K).



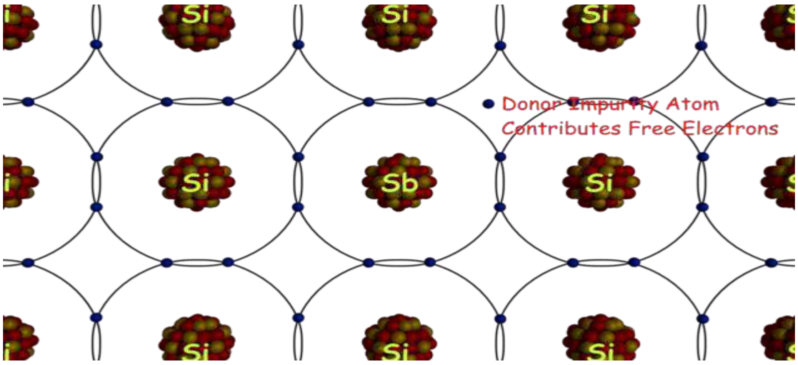
Extrinsic Semiconductors

As per **theory of semiconductor**, impure semiconductors are called extrinsic semiconductors .**Extrinsic semiconductor** is formed by adding a small amount of impurity. Depending on the type of impurity added we have two types of semiconductors :N-type and P-type semiconductors . In100 million parts of semiconductor one part of impurity is added.

N type Semiconductor

In this type of semiconductor majority carriers are electrons and minority carriers are holes. N – type semiconductor is formed by adding pentavalent (five valence electrons) impurity impure semiconductor crystal,

e.g. P . As ,Sb.

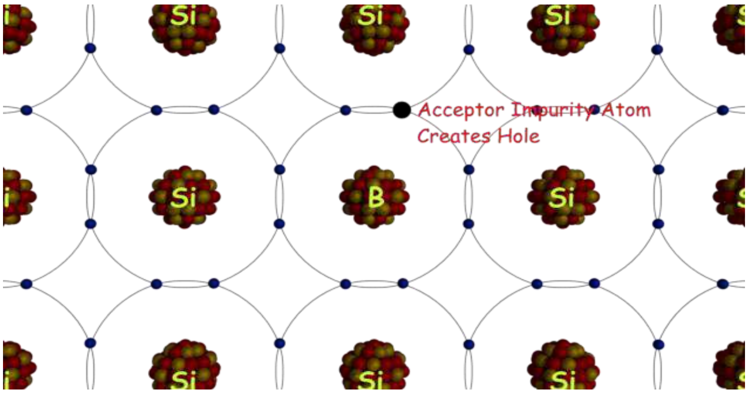


Four of the five valence electron of pentavalent impurity forms covalent bond with Si atom and the remaining electron is free to move anywhere with in the crystal. Pentavalent impurity donates electron to Si that's why N- type impurity atoms are known as donor atoms .This enhances the conductivity of pure Si. Majority carriers are electrons.

P type Semiconductors

In this type of semiconductor majority carriers are holes, and minority carriers are electrons. The p-type semiconductor is formed by adding trivalent (three valence electrons) impurity in a pure semiconductor crystal,

e .g .B ,A lBa .



Three of the four valence electron of tetra valent impurity forms covalent bonds with Si atoms .The phenomenon creates a space which we refer to a hole. When the temperature rises an electron from another covalent bond jumps to fill this space. Hence, a hole gets created behind. In this way conduction takes place. P-type impurity accepts electrons and is called acceptor atom. Majority carriers are holes.

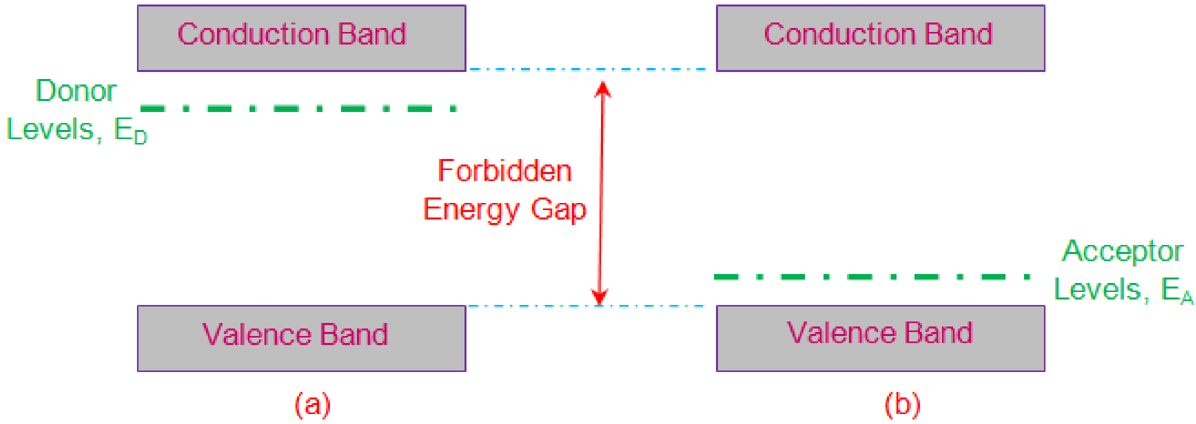


Figure 2 Energy Band Diagram of (a) *n*-type Extrinsic Semiconductor
(b) *p*-type Extrinsic Semiconductor

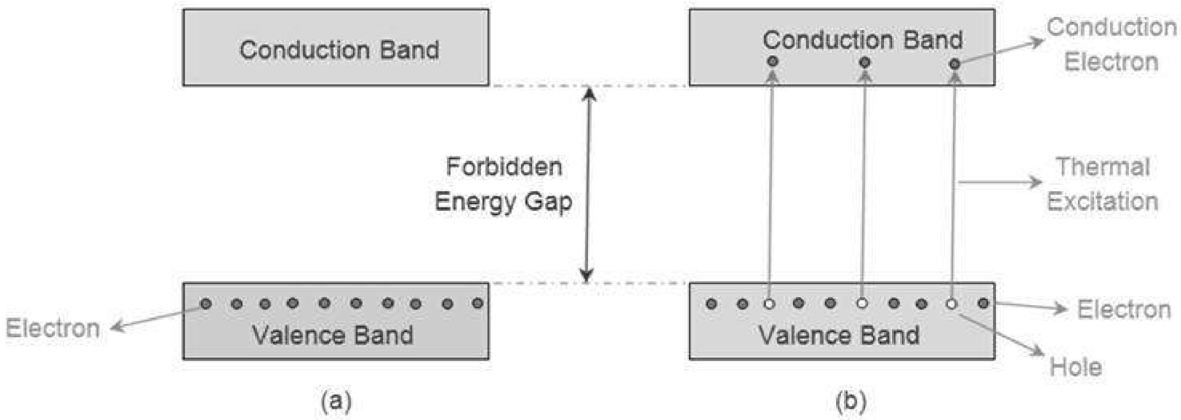


Figure 2 Energy Band Diagram of Intrinsic Semiconductor at (a) 0K (b) Temperature > 0K

<u>SEMI CONDUCTOR DIODE</u>

A **diode** is defined as a two-terminal electronic component that only conducts current in one direction(so long as it is operated within a specified voltage level). An ideal diode will have zero resistance in one direction, and infinite resistance in the reverse direction.

Although in the real world , diodes cannot achieve zero or infinite resistance . Instead ,a diode will have negligible resistance in one direction (to allow current flow), and a very high resistance in the reverse direction (to *prevent* current flow). A diode is effectively like a valve for an electrical circuit.

Semiconductor diodes are the most common type of diode. These diodes begin conducting electricity only if a certain threshold voltage is present in the forward direction (i.e., the “low resistance” direction).The diode is said to be “*forward biased*” when conducting current in this direction. When connected with in a circuit in the reverse direction (i.e. the “high resistance” direction), the diode is said to be “*reverse biased*”. A diode only blocks current in the reverse direction (i.e. when it is reverse biased) while the reverse voltage is with in a specified range . Above this range , the reverse barrier breaks .The voltage at which this break down occurs is called the “reverse break down voltage”. When the voltage of the circuit is higher than the reverse breakdown voltage, the diode is able to conduct electricity in the reverse direction(i.e. the “high resistance” direction). This is why in practice we say diodes have a high resistance in the reverse direction – not an infinite resistance.

⇒ P-N Junction:

* When a P-type Semiconductor is joined with a N-type Semiconductor, the contact that is established between them is called PN junction.
* The P-type material has high concentration of holes & the N-type material has high concentration of electrons.
* At the pn junction, free electrons from the N-type material diffuse (move) into the p-side and the free electrons combine with the holes that are near the junction.
* When an electron moves out of an atom, the atom becomes +vely charged immobile (unable to move) ion.
* The free electron moving from n-side to p-side will leave positive immobile ions on the n-side of the junction.
* The free electrons which cross the junction will occupy the holes in the p-type material making the atoms -vely charged immobile ions.

(Atoms accepting -ve charge carriers become -vely charged ions)

* On one side of the junction -ve ions are created & on the other side +ve ions are formed.

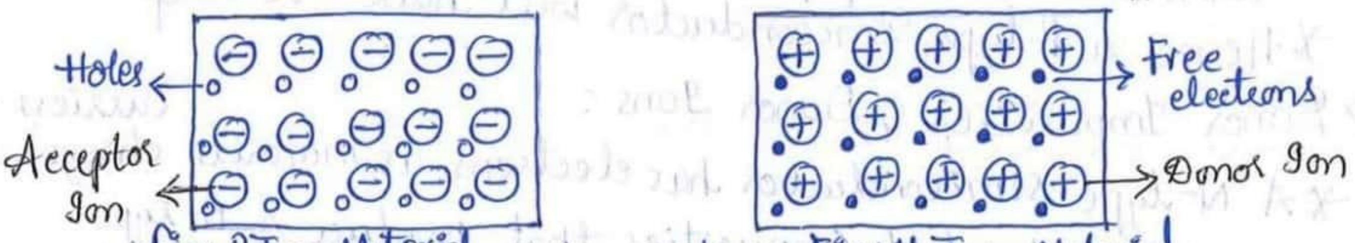


fig: P-Type Material Fig: N-Type Material

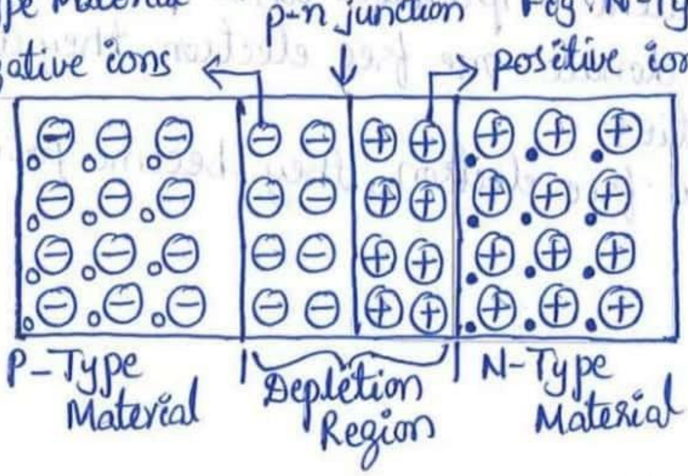


Fig: Formation of p-n junction

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* Negative ions created on the P-side will acquire negative voltage.
* This -ve voltage on p-side will stop further diffusion of electrons from the n-side.
* Positive ions created on the N-side will acquire positive voltage.
* This +ve voltage on N-side will stop further diffusion of holes from the p-side.
* Diffusion: It is defined as the movement of charge carriers from a high-concentration area to a low concentration area.
* When a pn junction is formed, initially diffusion takes place & barrier voltage is created across the junction.
* Barrier voltage stops further diffusion of charge carriers.
* Barrier Voltage depends upon amount of doping, charge carriers & junction temperature.
* Depletion Region is formed at the junction.
* Depletion region is the region which is depleted of charge carriers i.e., no mobile charge carriers are present in this region.
* If the p-type and n-type materials are equally doped, then the depletion layer is equally divided on both sides of the pn junction.

⇒ P-N Junction Diode:

Diode = Di + Electrode [It has 2 electrodes]

* A p-n junction has 2 terminals called electrodes.
* The P-region acts as Anode & N-region acts as Cathode.

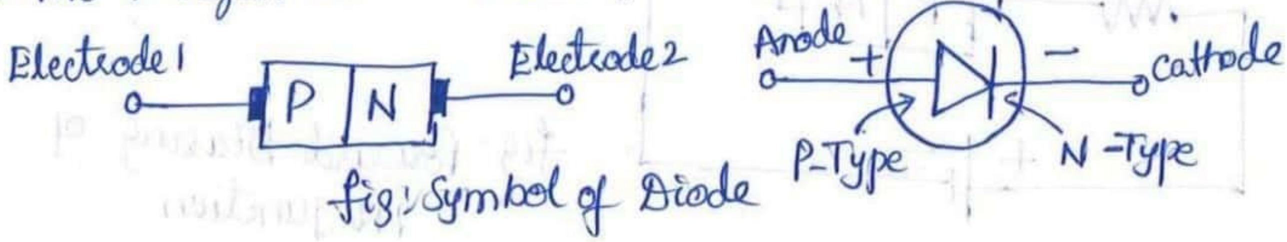

fig: Symbol of Diode

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* The arrow head in pn junction diode indicates the direction of current flow.

⇒ **Biasing of P-N Junction Diode:**

* Applying external voltage to any electronic device is called biasing.
* Definition: Applying some external voltage across two sides of the p-n junction is called biasing of p-n junction.

Types of Biasing: Depending upon the polarity of the externally applied voltage, biasing is classified as

1. Forward Biasing
2. Reverse Biasing

⇒ **Forward Biased P-n junction:**

* When the positive terminal of the battery is connected to the p-side and the negative terminal of the battery is connected to the N-side, the p-n junction is said to be a forward biased p-n junction.
* The holes on the p-side are positively charged & the electrons on the n-side are negatively charged.
* In forward biased condition, the positive terminal of the battery will repel the holes from the terminal.
* the electrons on n-side get repelled by the negative terminal of the battery.
* As a result, the width of the depletion region will be reduced. Potential barrier gets reduced.

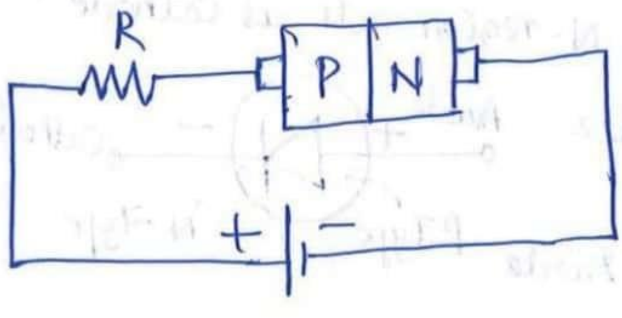

fig: Forward Biasing of PN junction

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* If the applied voltage is still increased, the depletion region & barrier potential will disappear.
* Resistor is connected to limit the flow of current.
  ↳ reduces the flow of current.
* When the voltage is gradually increased, when it reaches 0.3V, barrier voltage is overcome & depletion layer disappears for Germanium diode. For silicon potential barrier gets overcomed at 0.7V.
* Electrons on N-side get attracted by the +ve terminal of the battery & holes on P-side get attracted by the -ve terminal of the battery.
* Majority charge carriers start moving across the p-n junction causing forward current I_F to flow.
* A forward biased p-n junction offers very low resistance to current flow.

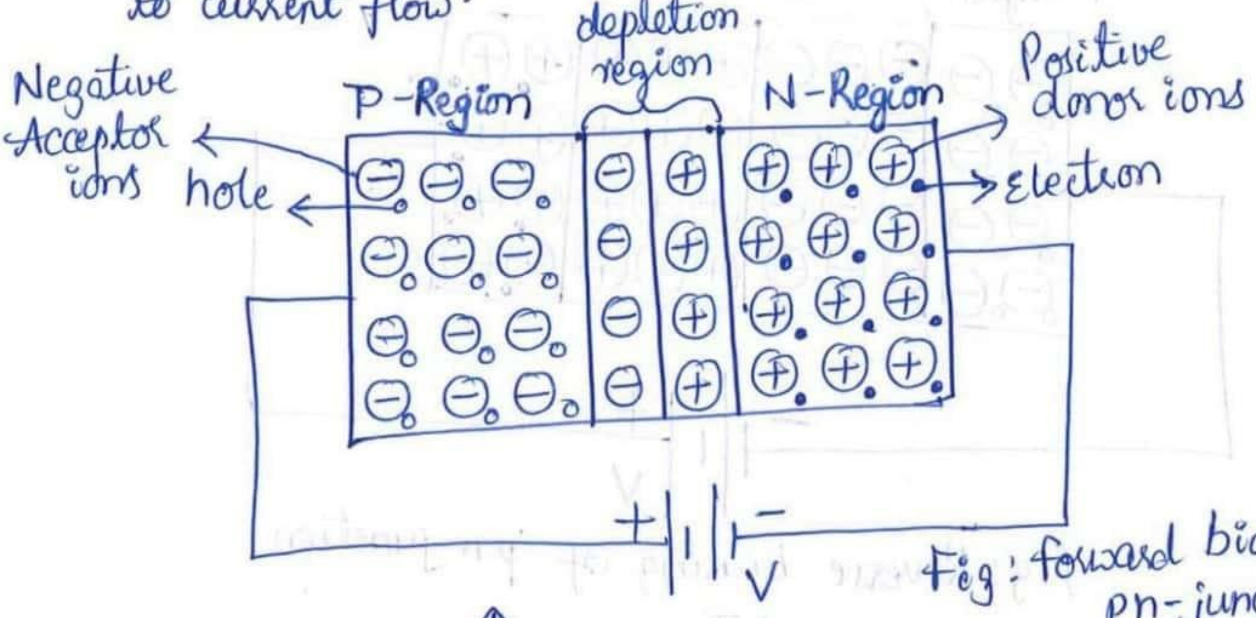

Fig: forward biasing of pn-junction

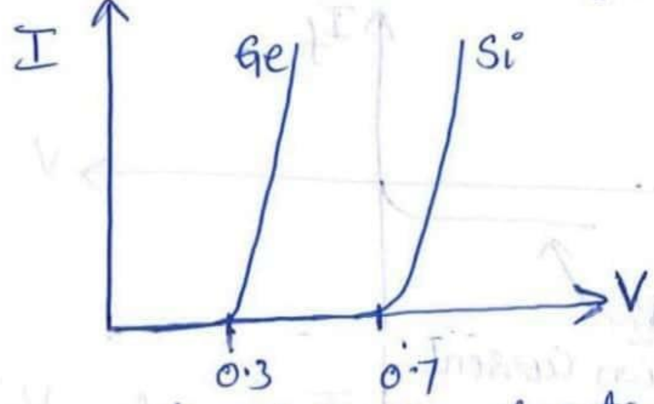

fig: V-I characteristics of forward bias

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⇒ Reverse Biased P-N Junction:

* When the negative terminal of the battery is connected to the P-side & the positive terminal of the battery is connected to the N-side, the P-N junction is called reverse biased P-N junction.
* Electrons on the n-side are attracted towards the +ve terminal of the battery & holes on the p-side gets attracted towards -ve terminal of the battery.
* As the applied voltage increases, depletion layer gets widened & the majority carriers donot cross the barrier.
* Due to minority charge carriers a small amount of current flows in the circuit which is called reverse saturation current.
* A reverse biased p-n junction offers very high resistance to current flow.

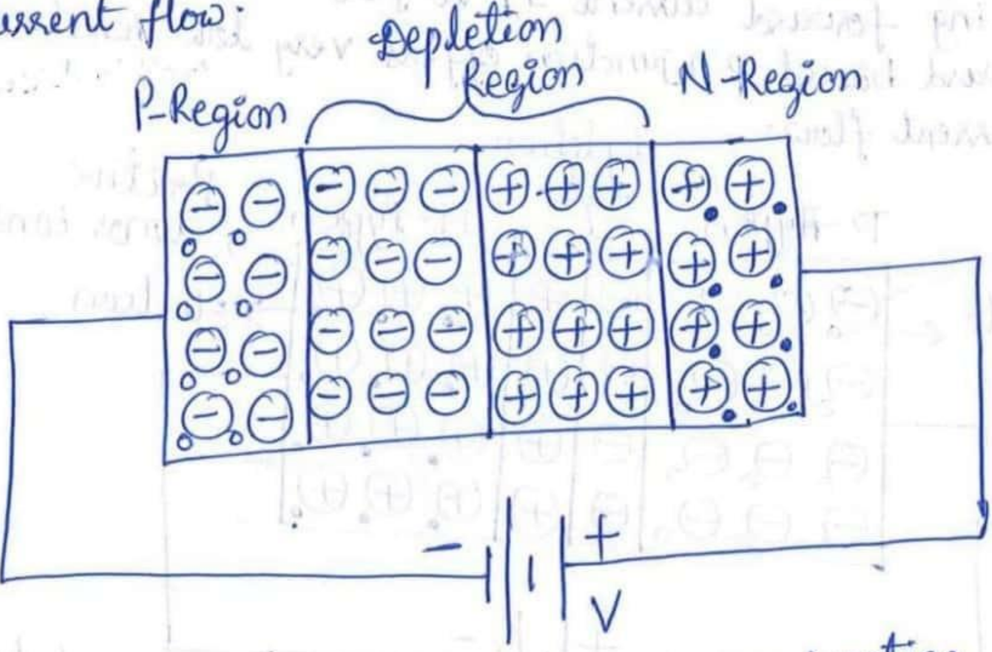

fig: Reverse biasing of p-n junction

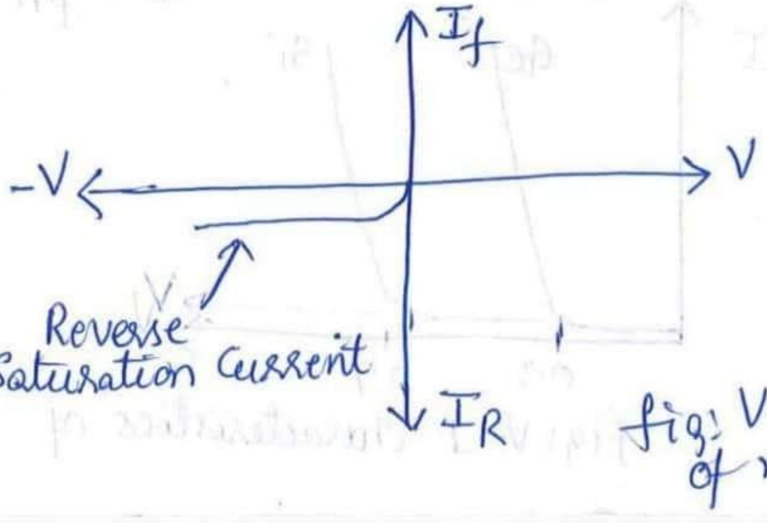

fig: V-I characteristics of reverse bias

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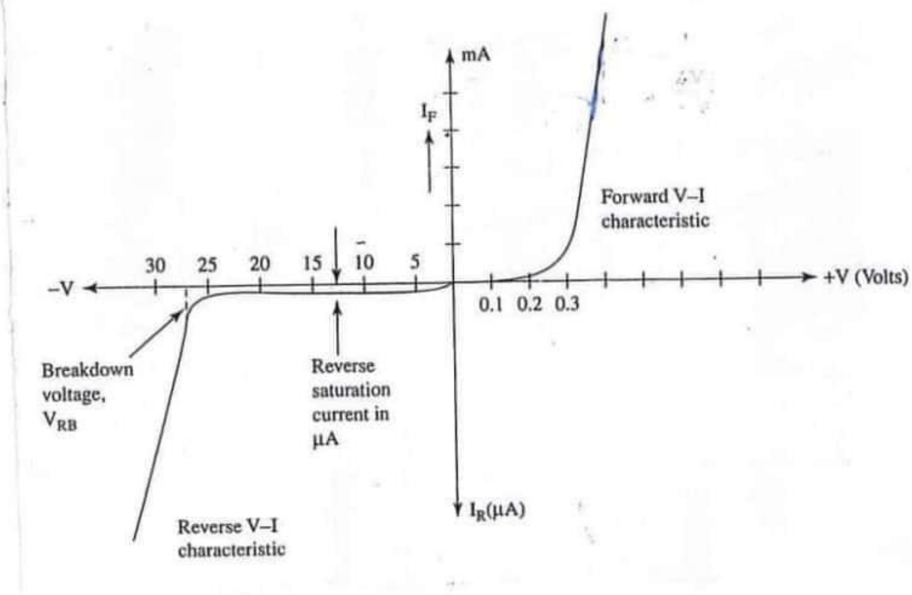
(7)

⇒ Volt-Ampere characteristics of a Diode (or) V-I characteristics of a diode

* When a p-n junction diode is connected to a source of supply such that it is forward biased, the relationship between the applied voltage 'V' and the current flowing 'I' gives us the forward V-I characteristics.
* When the applied voltage is gradually increased, for a small value of forward voltage, the forward current is very small.
* At a voltage near 0.3 V, current suddenly increases.
* Cut-in Voltage: The voltage at which forward current starts increasing is called the cut-in voltage of the diode.
  Cut in voltage for Si is 0.7V.
  Cut in voltage for Ge is 0.3V.
* When the p-n junction is reverse biased, resistance is very high & ideally no current flows.
* Due to minority charge carriers, a negligibly small current flows. This current is called leakage current of the diode.
* If the reverse voltage is increased to a large value, at one stage the p-n junction breaks down & there will be a sudden increase in the reverse current.
* Breakdown Voltage: The reverse voltage at which the diode breaks down & a large reverse current starts flowing is called the breakdown voltage.
* At the breakdown voltage, current continues to increase.



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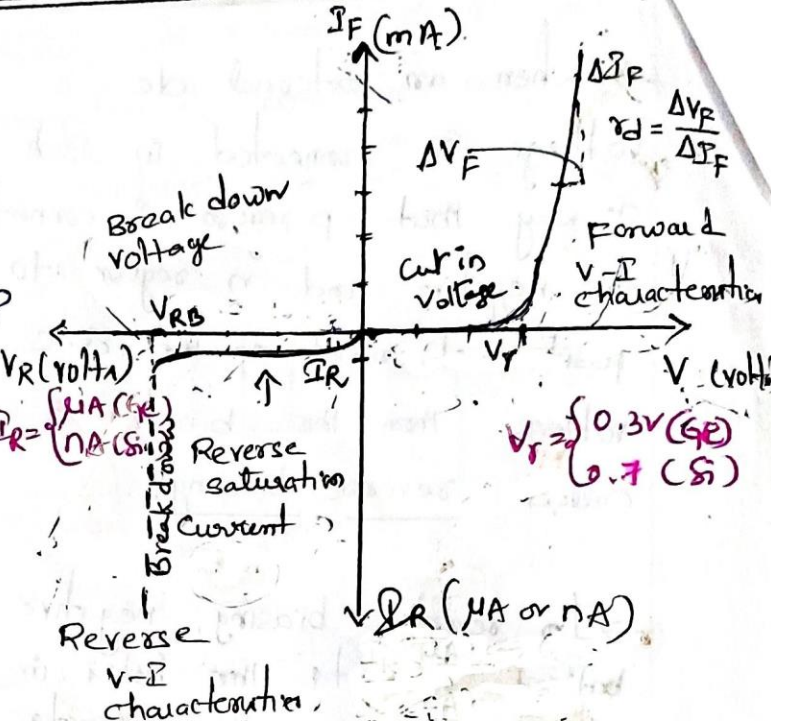
V-I Characteristics of pn junction diode



When a p-n junction diode is connected to a source of supply in such a way that it is forward biased, the relationship b/w the voltage applied and current flowing will give us a forward V-I characteristics.

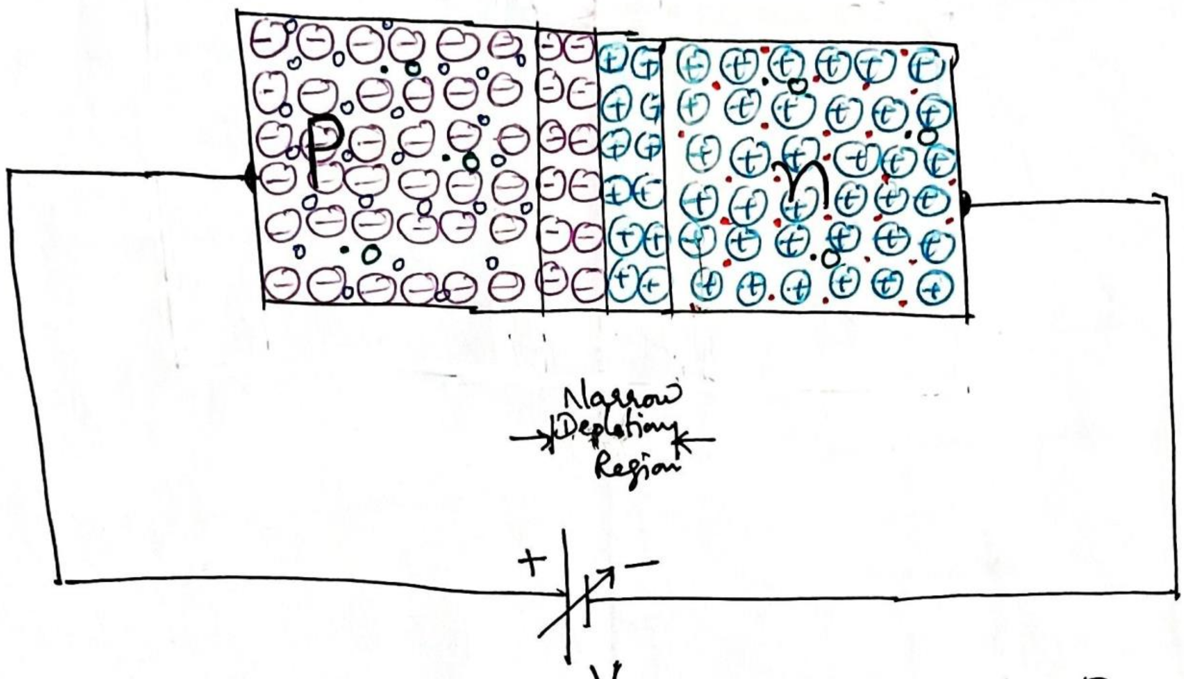
→ When the applied voltage is gradually increased, at a small value of forward voltage, the forward current is negligible small. At a voltage near 0.3V, the current suddenly increases. This voltage at which the forward current starts increasing is called the cut-in voltage of the diode. For the Ge diode forward voltage drop is 0.3V and for Si 0.7V.

For reverse characteristics, the supply connection has to be reversed. Under reverse biased conditions the junction resistance is very high and ideally no current should flow. But due to minority charge carriers, a negligibly small current of the order of micro amperes will flow. This current is also called leakage current (or) reverse saturation current of the diode. If the reverse voltage is increased to a large value, at one stage, the P-N junction will break down with a sudden rise in reverse current. (For the Ge diode reverse saturation current is of μA & for Silicon diode it is of nA)

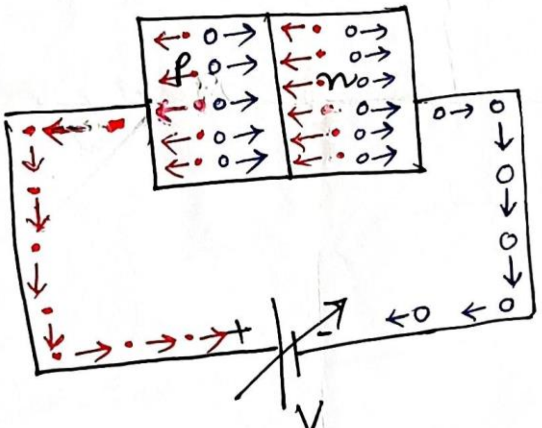
The reverse voltage at which the diode breaks down and a large reverse current starts flowing is called the breakdown voltage.

... circuited PN junction

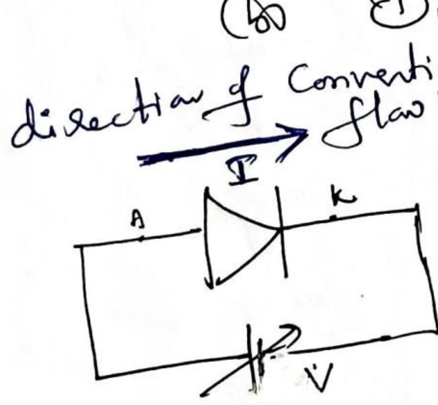
PN junction diode under forward Bias:



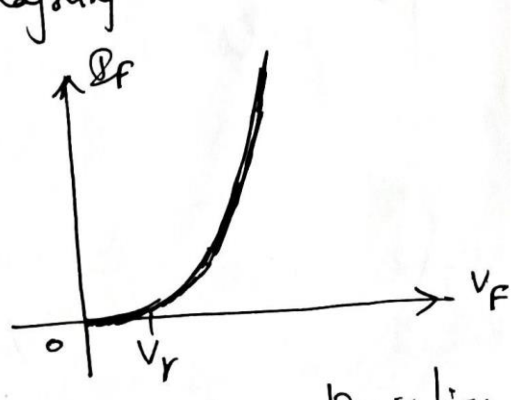
(a) PN junction diode under FB



(b) Direction of majority carriers



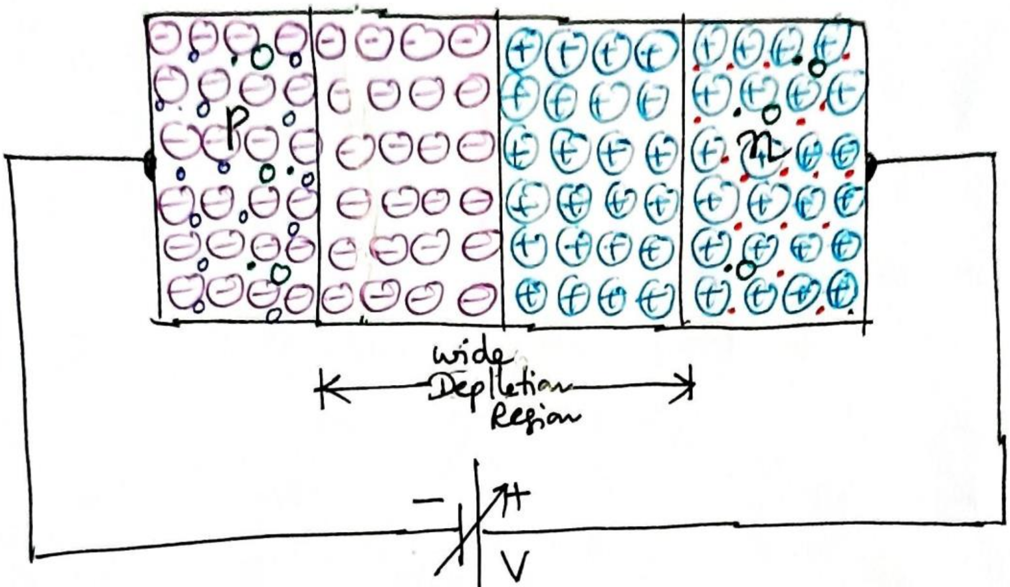
(c) Symbol of PN diode under FB



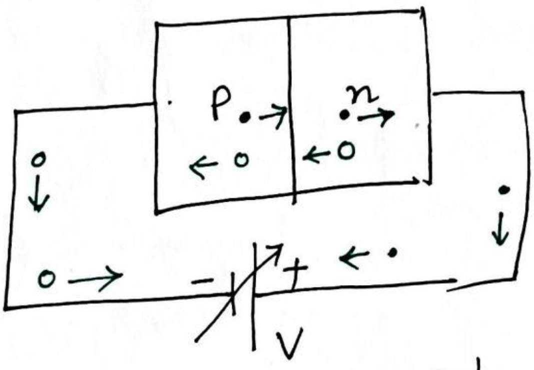
(d) VI characteristics

$$V_r = \begin{cases} 0.3V \text{ (Ge diodes)} \\ 0.7V \text{ (Si diode)} \end{cases}$$

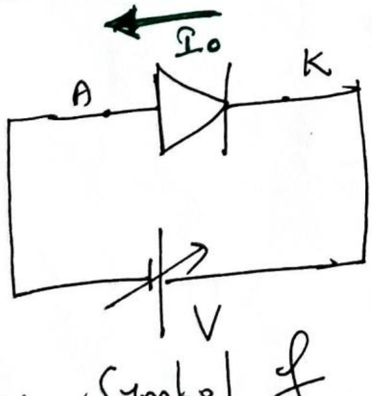
Pn junction diode under Reverse Bias:



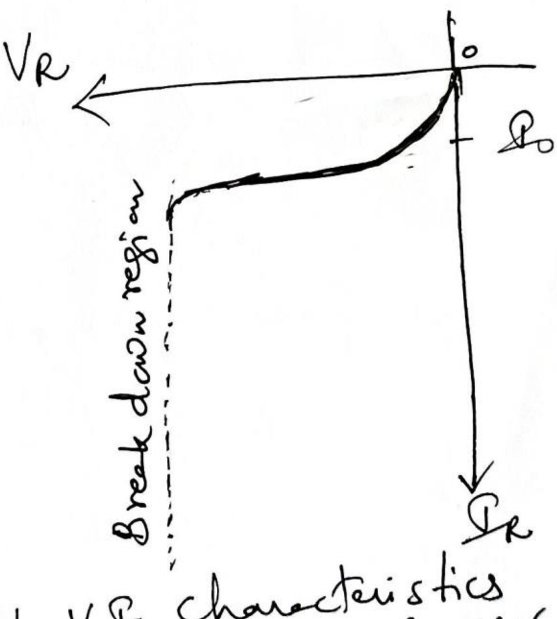
(a) Pn junction diode under RB



(b) Direction of minority Carriers



(c) Symbol of Pn diode under RB

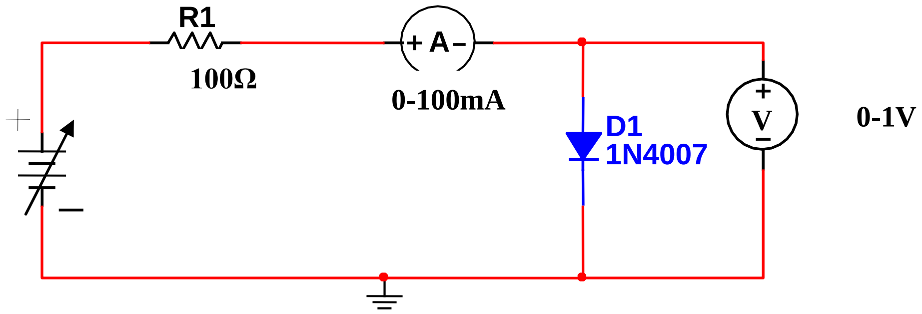


(d) VI characteristics

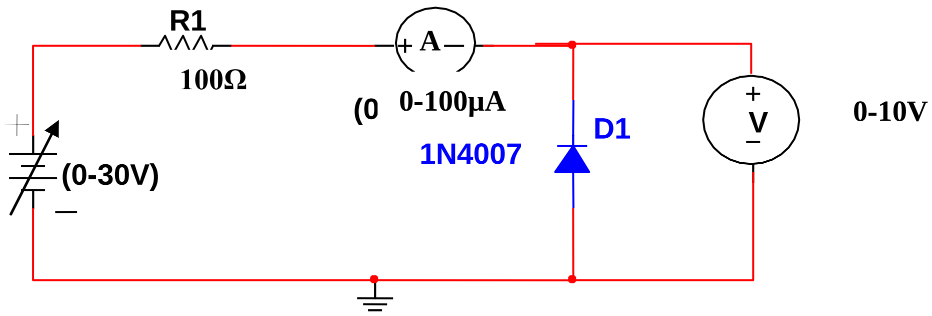
I_0 (or) I_R (or) I_S = { μA (Ge diode), nA (Si diode) }

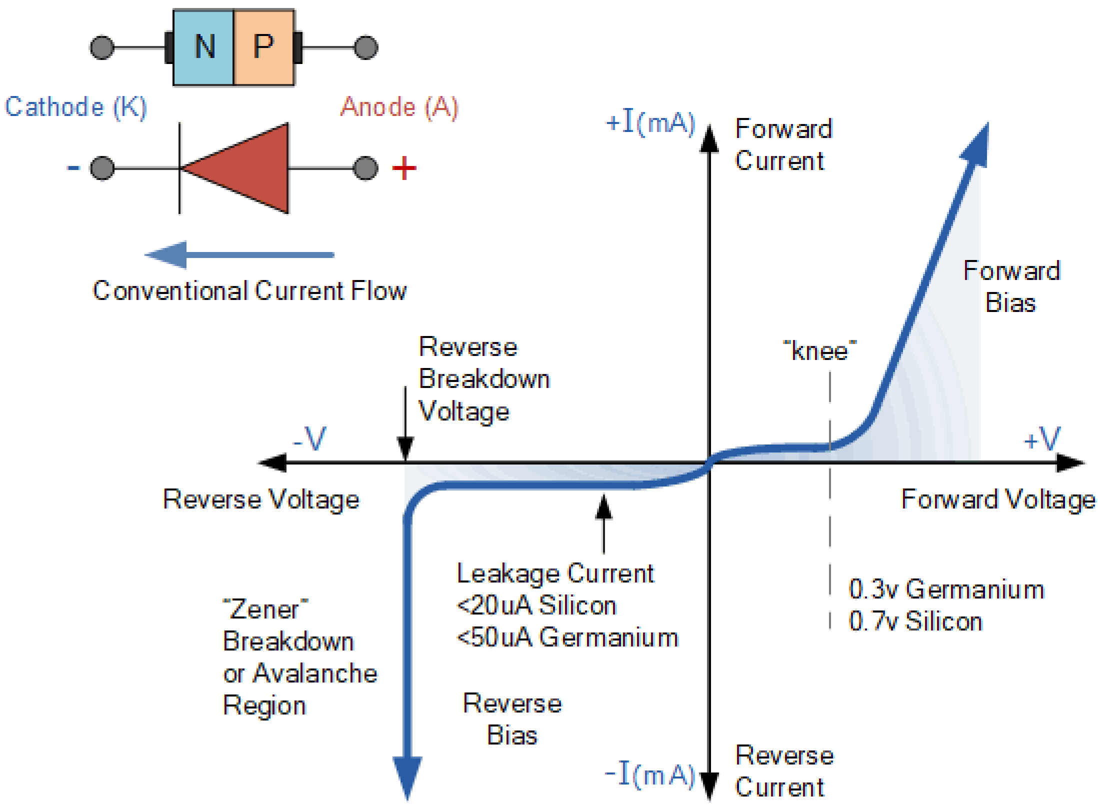
CIRCUIT DIAGRAM OF P – N JUNCTION DIODE

FORWARD BIAS:-



REVERSE BIAS:-





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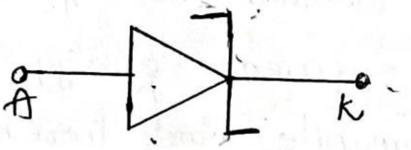
I. Special Semiconductor Diodes

Zener Diode:- When the reverse voltage reaches breakdown voltage in normal PN junction diode, the current through the junction and power dissipated at the junction will be high. Such type of operation will be destructive and the diode gets damaged. The diodes can be designed with adequate power dissipation capabilities to operate in breakdown region. Such type of diode is called Zener diode and is heavily doped than ordinary diode.

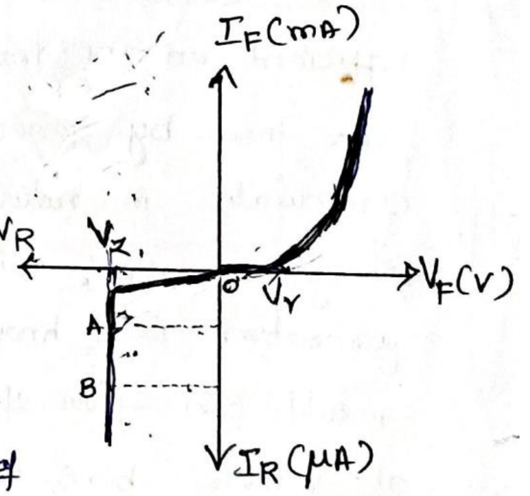
Definition:- A heavily doped PN junction diode designed to to operate in reverse breakdown region without any damage is called Zener Diode

Symbol



V-I Characteristics of Zener Diode:

From the V-I characteristics of Zener Diode shown in fig, it is found that operation at Zener Diode is same as that of ordinary PN diode under forward Bias. where as in Reverse Bias condition, breakdown of junction occurs. The breakdown voltage depends upon the amount of



doping. If the diode is heavily doped, depletion layer will be thin and consequently break down occurs at the lower reverse voltage and further the break down voltage is sharp. In lightly doped diode breakdown voltage is higher. The breakdown voltage depends on amount of doping.

Breakdown Mechanisms

The sharp increasing current under breakdown conditions are due to following two mechanisms.

(i) Avalanche breakdown
(ii) Zener breakdown

(i) Avalanche Breakdown:

As applied reverse bias increases, the field across the junction increases correspondingly. Thermally generated carriers while traversing the junction acquire lot of kinetic energy from this field. As a result velocity of these carriers increases. These electrons distrupt covalent bonds by colliding with immobile ions and create new electron-hole pairs. These new carriers again acquire sufficient energy from the field and collide with other immobile ions thereby generating further electron-hole pairs. These new carriers again acquire sufficient energy from the field and collide with other immobile ions there by generating further electron-hole pairs. This process is commulative in nature and results in generation of avalache of charge carriers, within a short time. This mechanism of carrier generation is known as avalanche Multiplication. This process results in flow of large amount of current at the same value of reverse bias. above 6V & temperature coefficient is positive.

(ii) Zener Breakdown:

When the PN regions are heavily doped, direct rupture of covalent bonds takes place because of the strong electric fields at the junction of PN diode. The new electron-hole pairs so created increases the reverse current in a reverse biased PN diode. The increase in current takes place at a constant value of reverse bias typically below 6V for heavily doped diodes. & temperature Coefficient is negative.

As a result of heavy doping of PN regions, the depletion region width becomes very small and for an applied voltage of 6V or less, the field across the depletion region becomes very high, of the order of 10^7 V/m, making condition suitable for Zener breakdown. For lightly doped diodes, Zener break down voltage becomes high and break down is then predominantly by avalanche multiplication. Through Zener break down occurs for lower breakdown voltage and avalanche breakdown occurs for higher breakdown voltage and such diodes are normally called Zener diodes

Zener Diode Applications:

From the Zener characteristics, under reverse bias condition voltage across the diode remains almost constant although the current through the diode increase as shown in region AB. Thus the voltage across the zener diode serves as a reference voltage. Hence the Zener diode can be used as a voltage regulator.

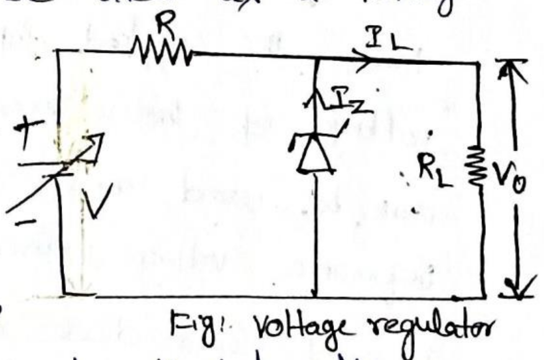


Fig: Voltage regulator

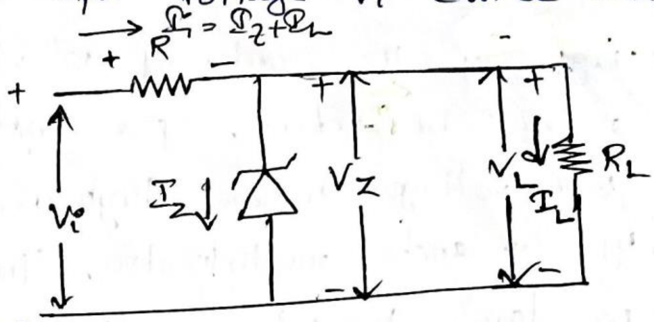
It is required to provide constant voltage across load resistance R_L, where as the input voltage may be varying over a range. As shown, Zener diode is reverse biased as long as the input voltage does not fall below V_Z, the voltage across the diode will be constant and hence the load voltage will be constant.

Zener Diode as Voltage Regulator

A zener diode under reverse bias breakdown can be used to regulate the voltage across the load, irrespective of the supply voltage or load current variations. The Zener diode is selected with V_Z equal to voltage desired across the load.

The Zener diode has a characteristics that under reverse bias condition, the voltage across it practically remains constant even if the current through it changes, by a large extent. under normal conditions, the input current $I_i = I_L + I_Z$ flows through resistor R. The input voltage V_i can be written as

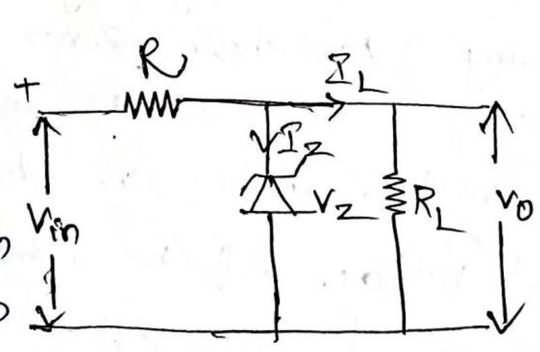
$$V_i = I_i R + V_Z$$
$$= (I_L + I_Z) R + V_Z$$



When the input voltage V_i increases as voltage across zener diode remains constant, the drop across resistor R will increase with a corresponding increase in $I_L + I_Z$. As V_Z is constant and hence the voltage across the load will also remain constant and hence I_L will be a constant. Therefore an increase in $I_L + I_Z$ will result in an increase in I_Z, which will not alter the voltage across the load.

It must be ensured that the reverse voltage applied to the zener diode never exceeds PN of the diode and at the same time, the applied input voltage must be greater than the breakdown voltage of the zener diode for its operation. The zener diode can be used as stand alone regulator circuits and also as reference voltage sources.

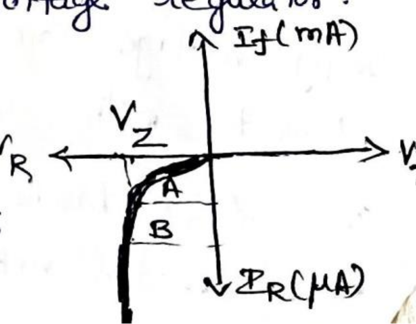
Use of zener diode as Regulator:.



Under reverse bias condition, the voltage across the diode almost constant although the current through the diode increases as shown in region AB.

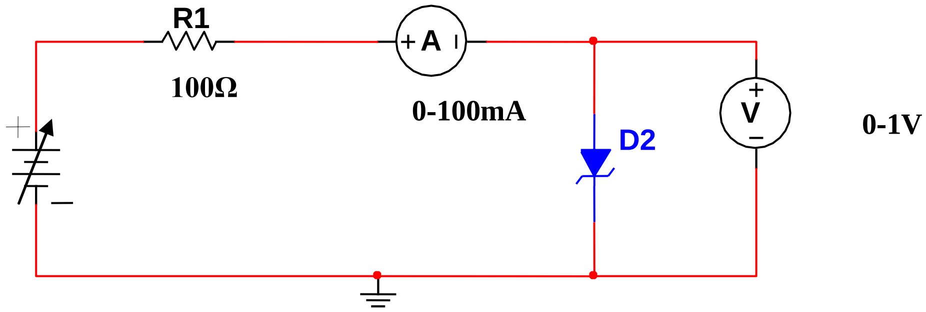
→ Thus the voltage across the zener diode serves as a reference voltage. Hence the diode can be used as a voltage regulator.

→ Fig (b) is used to provide constant voltage across load resistance R_L. where an i/p vtg may be varying over a range, the voltage across the diode will be constant.

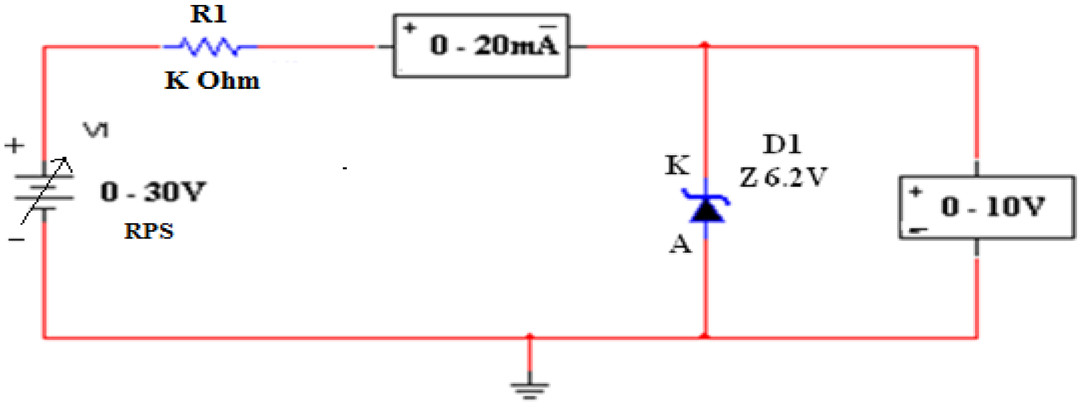


Zener diode

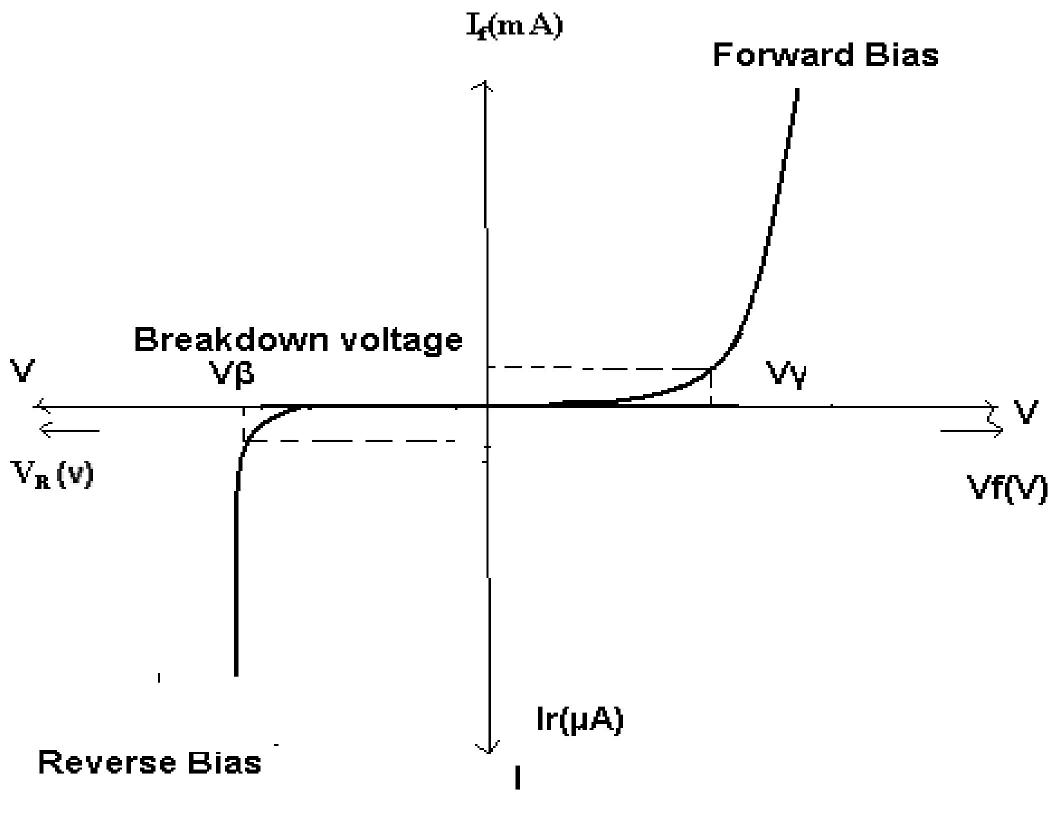
FORWARD BIAS:-



REVERSE BIAS:-



MODEL WAVEFORMS:-



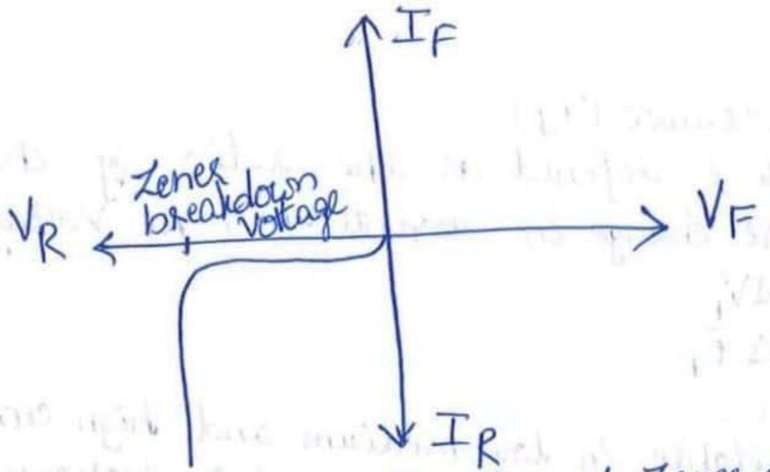


fig: V-I characteristics of Zener diode

* The reverse current can be controlled using a Resistor 'R' so that excess heat produced due to heavy current flow will not damage the diode.
* Zener diode is designed such that it can be continuously operated in the breakdown region without causing any damage.

Breakdown Mechanisms:

* There are 2 ways in which breakdown can occur in zener diode. They are: ① Avalanche Breakdown
② Zener Breakdown

⇒ Zener Breakdown:

* When the p-n junction is heavily doped, the depletion region is very narrow.
* Under reverse bias condition, the electric field across the depletion layer is very high.
* Electric field is voltage per distance.
* Due to narrow depletion region & high reverse voltage, the electric field is very high.
* Strong electric field causes electrons to break away from parent atoms.
* This kind of breakdown due to strong electric field intensity is called Zener breakdown.

* Avalanche Breakdown:
* As the applied reverse bias voltage increases, the velocity of the minority charge carriers increases.
* There will be collisions between these minority charge carriers & electrons involved in the covalent bonds of the crystal structure.

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* The collisions will make the electrons to break the covalent bonds.
* Electron-hole pairs are generated very quickly and in large numbers.
* At this stage, the junction is said to be in breakdown & current starts increasing rapidly.
  This type of breakdown is called avalanche breakdown.
* Zener breakdown occurs at voltage less than 5V.
  Avalanche breakdown occurs at voltage higher than 5V.

⇒ **Zener Resistance:**

It is the dynamic resistance of the zener diode.
Zener resistance is defined as the ratio of change in Zener Voltage to the change in Zener current.

$$R_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

⇒ **Applications of diode as Switch:** A switch has 2 states < ON / OFF

* A diode is a 2 terminal device with one terminal as positive & the other as negative.
* P-region is known as Anode & N-region is known as cathode.
* A diode allows the flow of electricity in one direction only.
* When the +ve terminal of the diode is connected to the +ve terminal of the battery & the -ve terminal of the diode to the -ve terminal of the battery, the diode acts as a closed switch.
* Hence current flows through the circuit.
* When the diode is forward biased → it is in ON state

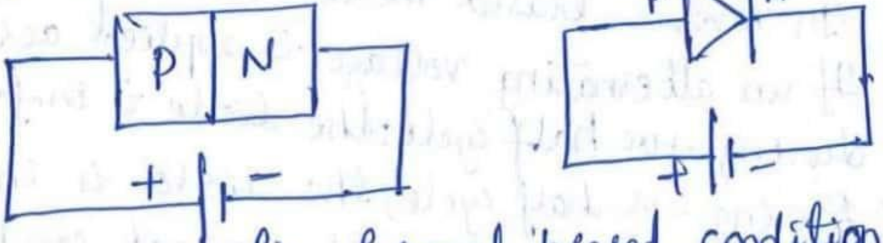

fig: forward biased condition

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* When the +ve terminal of the diode is connected to the -ve terminal of the battery and the -ve terminal of the diode is connected to the +ve terminal of the battery, the diode acts as an open switch.
* It doesnot allow current to flow through it.
* It is in reverse biased condition & the diode is in OFF state

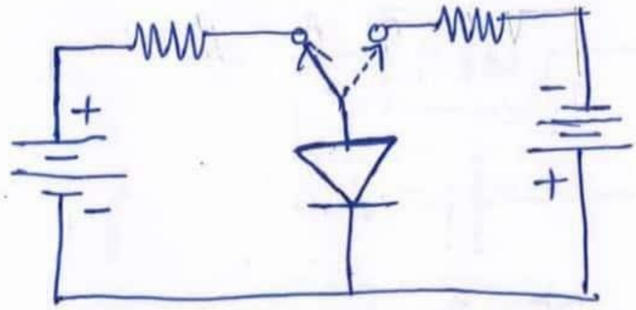

fig: Diode as a Switch

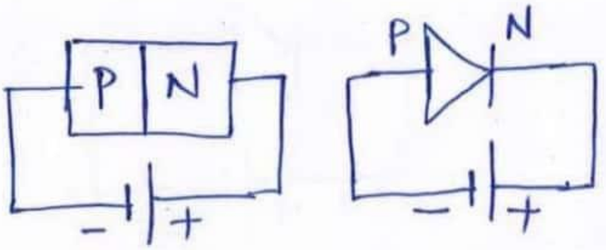

fig: Reverse biased Condition

⇒ Applications of diode as Rectifier:

* Rectifier: It is an electronic circuit consisting of diode which carries rectification process.
* Rectification: It is the process of converting alternating current to direct current.
* A rectifier is a device which converts AC signal into DC signal.
* Diode acts as rectifying element in the rectification circuit.
* A pn junction diode can be used as rectifying element as it offers low resistance when it is forward biased & offers high resistance when it is reverse biased.
* In forward biased mode: diode conducts electricity
  In reverse biased mode: diode doesnot conduct.
* If an alternating voltage is applied across the diode, during +ve half cycle, the diode is in forward bias & it conducts
* During -ve half cycle, the diode is in reverse bias & it doesnot conduct.

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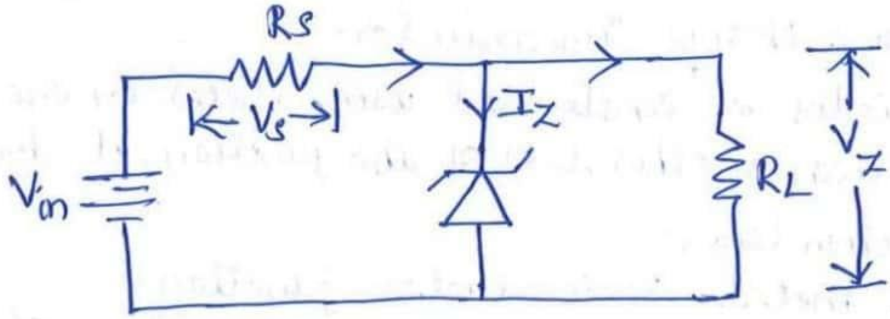
⇒ Zener diode as regulator:

* Voltage Regulator is an electronic circuit which regulates the unregulated voltage.
* The output voltage of voltage regulator is constant irrespective of the changes in the input voltage or current.



* Zener diode is connected parallel to load R_L.
* The voltage across the load has to be regulated and must not cross the value of V_Z
* A suitable zener diode with a breakdown voltage near the voltage we require across the load is taken
* Zener diode is connected in reverse bias condition.
* When the voltage across the diode exceeds the zener breakdown voltage, current starts flowing through the diode.
* As the load is parallel to the diode, the voltage drop across the load is equal to the zener breakdown voltage.
* The zener diode provides a path for the current to flow & hence the load gets protected from excessive currents.
* Hence constant output is maintained.

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The junctions are forward biased and reverse biased based on our requirement. **Forward biased** is the condition where a positive voltage is applied tothe p-type and negative voltage is applied to the n-type material. **Reverse biased** isthe condition where a positive voltage is applied to the n-type and negative voltage is applied to the p-type material.

Transistor biasing

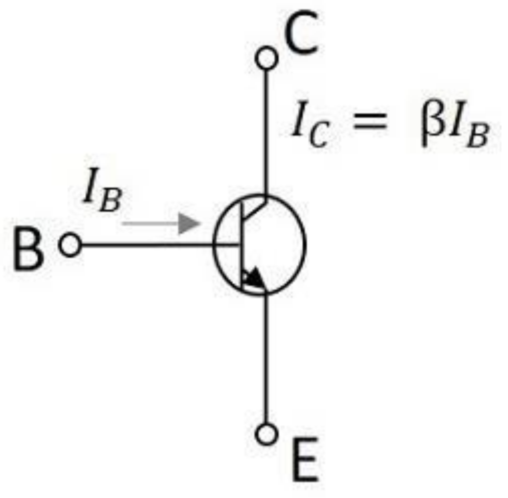
The supply of suitable external dc voltage is called as **biasing**. Either forward or reverse biasing is done to the emitter and collector junctions of the transistor. These biasing methods make the transistor circuit to work in four kinds of regions such as **Active region, Saturation region, Cutoff region** and **Inverse activeregion** seldom used This is understood by having a look at the following table.

EMITTER JUNCTION	COLLECTOR JUNCTION	REGION OF OPERATION
Forward biased	**Forward biased**	**Saturation region**
Forward biased	**Reverse biased**	**Active region**
Reverse biased	**Forward biased**	**Inverse active region**
Reverse biased	**Reverse biased**	**Cutoff region**

Among these regions, Inverse active region, which is just the inverse of active region, is not suitable for any applications and hence not used.

Active region

This is the region in which transistors have many applications. This is also called as **linear region**. A transistor while in this region, acts better as an **Amplifier**.



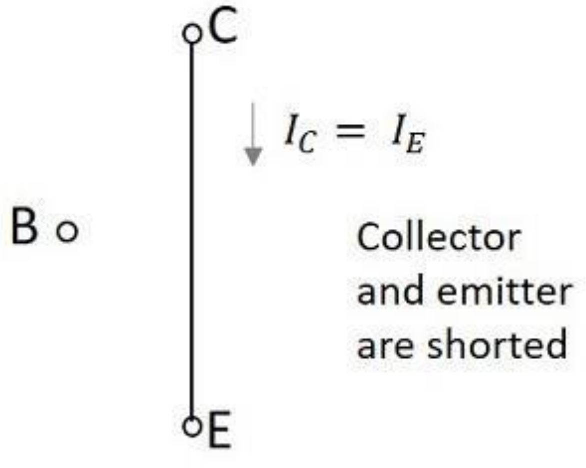
In Active region

This region lies between saturation and cutoff. The transistor operates in active region when the emitter junction is forward biased and collector junction is reverse biased. In the active state, collector current is β times the base current

Saturation region

This is the region in which transistor tends to behave as a closed switch. The transistor has the effect of its collector and Emitter being shorted. The collector and Emitter currents are maximum in this mode of operation.

The figure below shows a transistor working in saturation region.



In Saturated region

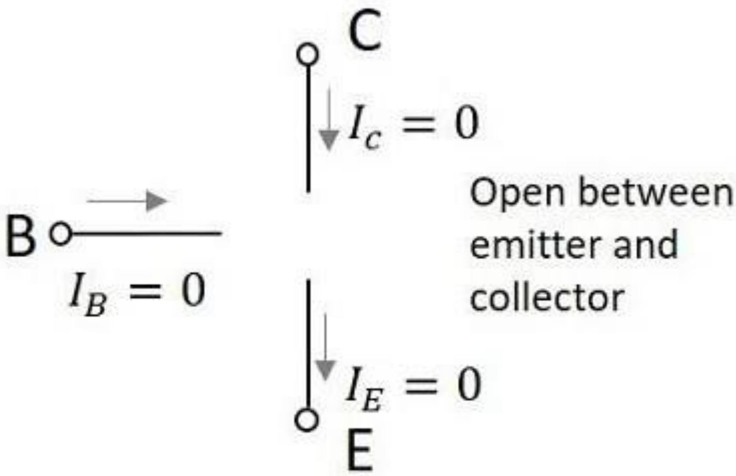
The transistor operates in saturation region when both the emitter and collector junctions are forward biased. As it is understood that, in the saturation region the transistor tends to behave as a closed switch,

.

Cutoff region

This is the region in which transistor tends to behave as an open switch. The transistor has the effect of its collector and base being opened. The collector, emitterand base currents are all zero in this mode of operation.

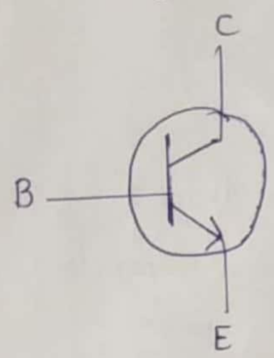
The following figure shows a transistor working in cutoff region.



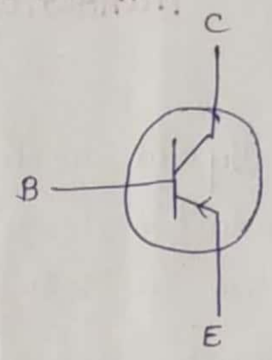
In Cutoff region

The transistor operates in cutoff region when both the emitter and collector junctionsare reverse biased. As in cutoff region, the collector current, emitter current and basecurrents are nil, we can write as

Circuit Symbols of NPN and PNP:



NPN transistor



PNP transistor

→ In a NPN transistor electrons move from N region to P region i.e from Emitter to Base. So current direction is from Base to Emitter. Arrow indicates direction of flow of current.

→ In a PNP transistor the electrons move from N region to P region i.e., from Base to Emitter. So the direction of current is from Emitter to Base. Arrow indicates the direction of flow of current.

Why the name Bipolar Junction Transistor?

Bipolar: Bipolar because in a BJT the current flow is due to both the polarities (i.e., holes whi and electrons).

Junction: Two junctions are formed at the three layers.

Transistor: Junction J_1 is Forward bias. In Forward Bias the conduction of current is high and resistivity is very low. i.e., Junction J_1 is low resistance.

Junction J_2 is Reverse Bias. Resisitivity high as the conductivity is Low.

→ When the signal is given at input the transfer of resistance signal from low resistance to high resistance. Hence called transistor.

Transistor = Transfer + Resistance.

Transistor Biasing:

→ The emitter-base junction is forward biased and collector base junction is reverse biased.

→ Due to the forward bias on the emitter base junction an emitter current flow through base into j collector.

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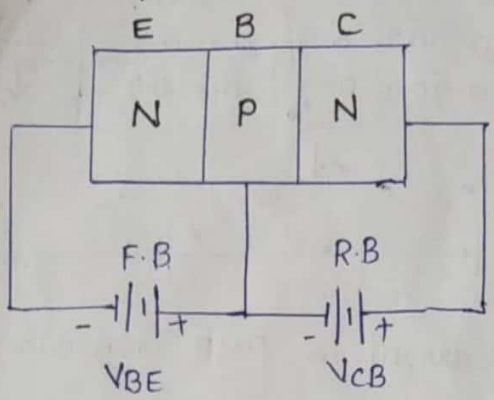
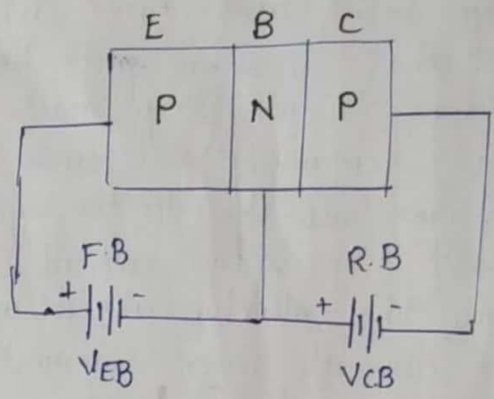
→ Though the collector-base junction is reverse biased, almost entire emitter current flows through the collector circuit.





BJT Operation and transistor Current Components.

(i) Operation and Current Components of NPN Transistor:

→ The fig shows that when F.B is applied to Emitter-Base junction of NPN transistor lot of electrons move from Emitter to base region. The base region is lightly doped with P-type impurity and the no.of holes in base region are very small.

→ So only few electrons recombine with holes in the base and remaining electrons crossover into collector region to constitute collector current I_C.

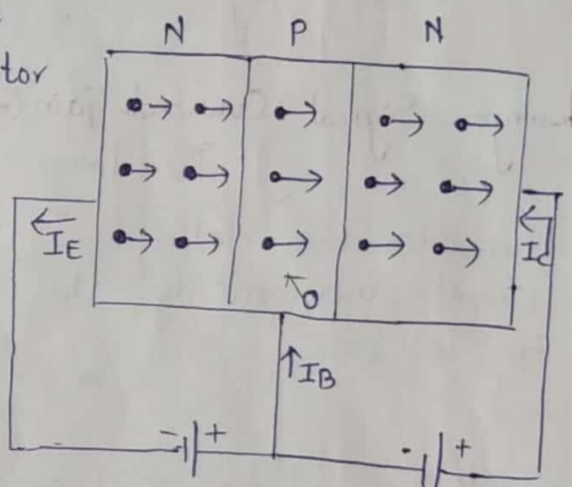


Fig: Current in NPN transistor

→ The base current and collector current summed up gives the emitter current.

i.e., $I_E = -(I_C + I_B)$

In the external circuit of the NPN BJT, the magnitudes of the emitter current I_E, Base Current I_B and Collector current I_C are related by $I_E = I_C + I_B$

→ The fig shows that when F.B is applied to Emitter Base junction of PNP transistor causes lot of ~~holls~~ holes from emitter region to crossover to the base region.

→ As the base region is lighly dopped with N-type impurity, the no. of electrons in the base region is very small and hence no of holes that recombine with holes electrons is also very small.

→ The remaining holes (more than 95%) crossover into the collector region to constitute collector current I_C. Thus the collector current and base current when summed up gives the emitter current.

i.e., $I_E = -(I_C + I_B)$

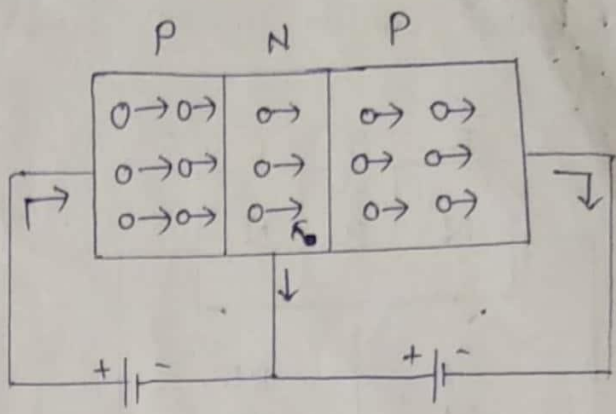


Fig: Current in PNP Transistor

In the external circuit of the PNP transistor the emitter current current I_E, the base current I_B and collector Current I_C are related by $I_E = I_C + I_B$.

Large - Signal Current Gain (α):

The large signal current gain of a common base transistor is defined as the ratio of negative of the collector-current increment to the emitter-current change from cutoff ($I_E = 0$) to I_E i.e.,

$$\alpha = \frac{-(I_C - I_{CBO})}{I_E - 0}$$

Where I_{CBO} (or I_{CO}) is the reverse saturation current gain or flowing through the reverse biased collector-base junction, i.e., the collector to base leakage current with emitter open. As the magnitude of I_{CBO} is negligible when compared to I_E, the above expression can be written as.

$$\alpha = \frac{I_C}{I_E} \rightarrow (1)$$

Since I_C and I_E are flowing in opposite directions, α is always +ve. Typical value of α ranges from 0.90 to 0.995. Also α, is not constant but varies with emitter current I_E, collector voltage V_{CB} and temperature.

General Transistor Equation:

→ When the transistor is in active region, the emitter is forward biased and collector is reverse biased. The generalized expression for collector current I_C for collector junction voltage V_C and emitter current I_E is given by

$$I_C = -\alpha I_E + I_{CBO}(1 - e^{V_C/V_T})$$

→ If V_C is negative and $|V_C|$ is very large compared with V_T, then the above equation is reduced to

$$I_C = -\alpha I_E + I_{CBO} \rightarrow (2)$$

If V_C i.e., V_{CB} is few volts, I_C is independent of V_C. Hence the collector current I_C is determined only by the fraction α of the current I_E flowing in the emitter.

Relation among I_C, I_B and I_{CBO}:

We know that $I_C = -\alpha I_E + I_{CBO}$

but $I_E = -(I_C + I_B)$

$$I_C = \alpha(I_C + I_B) + I_{CBO}$$

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

$$I_C(1-\alpha) = \alpha I_B + I_{CBO}$$

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}$$

$$I_C = \beta I_B + (1+\beta) I_{CBO} \rightarrow (3)$$

$$1+\beta = 1 + \frac{\alpha}{1-\alpha}$$

$$= \frac{1-\alpha+\alpha}{1-\alpha}$$

$$1+\beta = \frac{1}{1-\alpha}$$

Relation between I_C, I_B and I_{CEO}:

In the CE configuration I_B is input current and I_C is output current. If the base circuit is open i.e., $I_B = 0$, then a small collector current flows from collector to emitter. That is denoted by I_{CEO}, the current I_{CEO} is also called the collector to emitter leakage current.

The large signal current gain (β) is defined as

$$\beta = \frac{(I_C - I_{CEO})}{I_B}$$

~~For~~ From above eqn

$$I_C = \beta I_B + I_{CEO} \rightarrow (4)$$

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Relation between I_{CBO} and I_{CEO}:

On comparing eqⁿ ③ and ④, the relation between the leakage current between of CB & CE DRC.

$$(1+\beta) I_{CBO} + \beta I_B = \beta I_B + I_{CEO}$$

$$\boxed{I_{CEO} = (1+\beta) I_{CBO}}$$

Expression for Emitter Current: The magnitude of emitter current is

$$I_E = I_C + I_B \rightarrow (5)$$

Substitute $I_C = (1+\beta) I_{CBO} + \beta I_B$ in eqⁿ ⑤

$$I_E = (1+\beta) I_{CBO} + \beta I_B + I_B$$

$$I_E = (1+\beta) I_{CBO} + (1+\beta) I_B$$

$$I_E = \frac{1}{1-\alpha}(I_{CBO}) + \frac{1}{1-\alpha}(I_B)$$

$$\beta = \frac{\alpha}{1-\alpha}$$

$$1+\beta = 1 + \frac{\alpha}{1-\alpha}$$

$$\frac{1-\alpha+\alpha}{1-\alpha} = \frac{1}{1-\alpha}$$

DC current Gain (β_{dc} or h_{FE}):

→ The dc current gain is defined as the ratio of the collector current I_C to the base current I_B.

$$\boxed{\beta_{dc} = \frac{I_C}{I_B}}$$

→ As I_C is large compared with I_{CEO}, the large signal current gain (β) and the dc current gain (h_{FE}) are approximately equal.

Types of Transistor Configurations:

When a transistor is to be connected in a circuit, one terminal is used as an input terminal, other terminal is used as an output terminal and the third terminal is used as a common to both input and output.

Depending on input, output and common terminal transistors can be classified into three different configurations.

1. Common Base Configuration (CB)
2. Common Emitter Configuration (CE)
3. Common Collector Configuration (CC)

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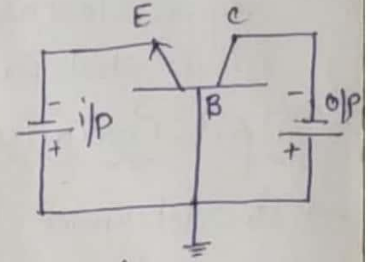
1. Common Base Configuration:

In this type of configuration the base is common to both the input (Emitter) terminal and output (collector) terminal, This is also called as grounded base configuration.



The fig below shows the circuit diagram for determining the static characteristics curve of NPN CB transistor.

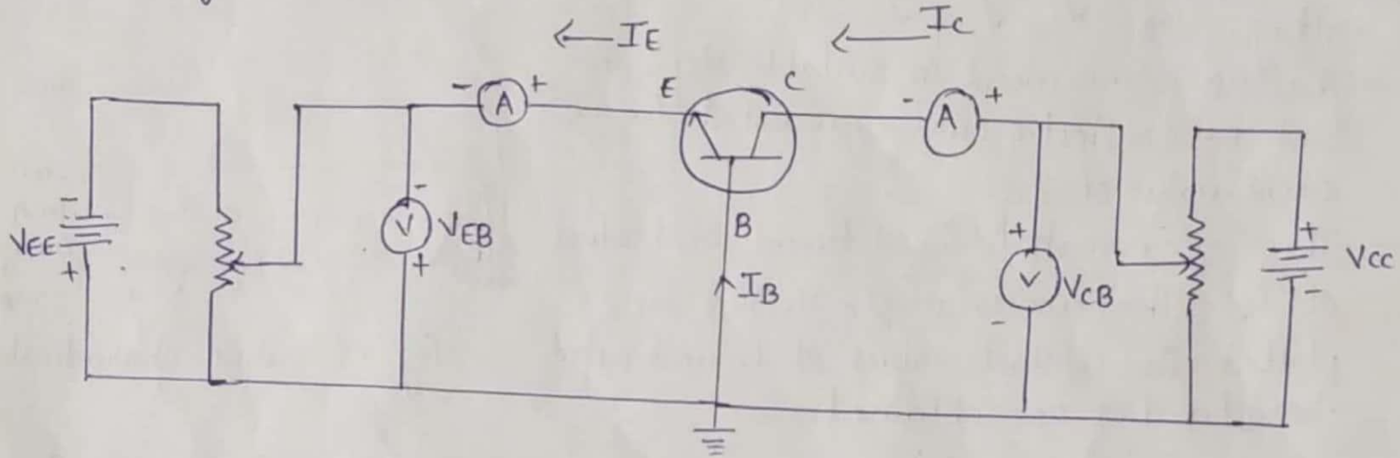


Fig: Circuit to determine CB Static Characteristics.

Input Characteristics:

→ To determine the input characteristics of CB configuration, the output voltage V_{CB} is kept constant at zero volts. The V_{EB} (i/p voltage) is increased and the corresponding input current I_E is taken.

→ This is repeated for higher values of V_{CB} and a curve is drawn for between input voltage (V_{EB}) and input current (I_E).

→ The input characteristics are as shown in the fig.

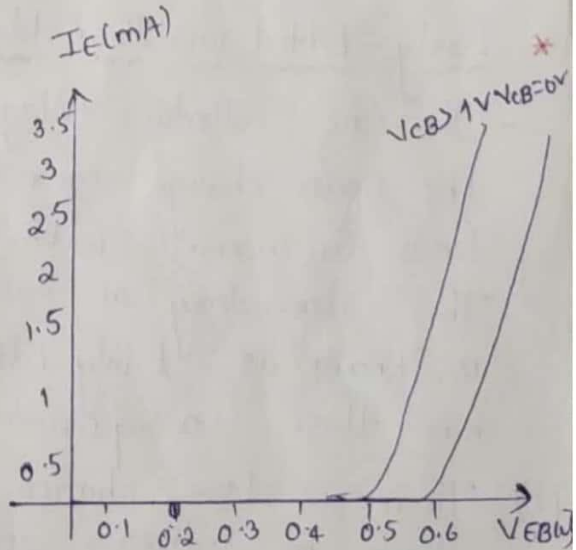


fig:- CB input characteristics

→ From the graph it is clear that at V_{CB} is zero the emitter base junction is similar to forward biased pn junction diode.

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→ As it is forward biased, the emitter current (I_E) increases rapidly with small increase in emitter-base voltage V_{EB}.
→ When V_{CB} is increase keeping V_{EB} constant, the width of base region decreases. This effect results in increase of I_E, therefore curve shift towards the left as V_{CB} is increased.

Output Characteristics:

→ To determine the output characteristics, the emitter current I_E is kept constant at suitable value by adjusting the emitter-base voltage V_{EB}.
→ The V_{CB} is increased in suitable steps and and I_C (collector current) is noted for ea each value of I_E.
→ This is repeated for different fixed values of I_E. The curves of I_C Vs V_{CB} are plotted for constant values of I_E and output characteristics are obtained.

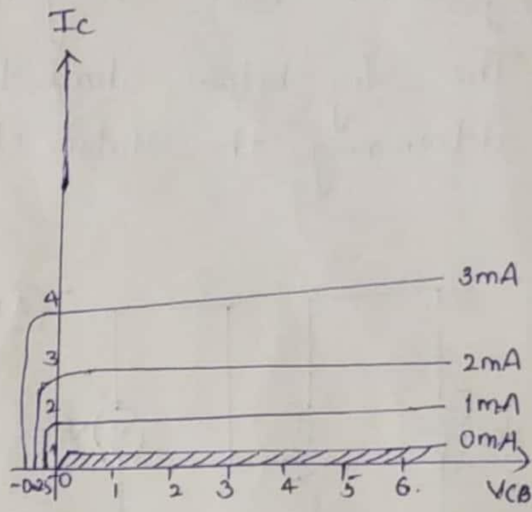


fig: CB output characteristics

→ From the characteristics curve it is el seen that I_C flows even when V_{CB} is zero. As the emitter-base junction is forward biased, the majority carriers, i.e., electrons from the emitter are injected into the base region, due to internal potential barrier at the reverse biased Collector base junction, they flow to the collector region and give rise to I_C even when V_{CB} is equal to zero.

* Early Effect (or) Base-Width Modulation:

→ If the collector voltage V_{CC} is increased, the reverse bias increases the space charge region (depletion width) between collector and base tends to increase, with the effective decrease of base width. This dependency of base width on collector-to-emitter base voltage is known as Early Effect. This decrease in effective base-width has three consequences.

(i). There is less chance for recombination within the base region. Hence α increase with increasing $|V_{CB}|$.
(ii) The minority charge carriers increases in the reverse bias as a result the reverse bias increases current increases.

iii): For extremly large voltages, the effective base-width may be reduced to zero, causing voltage breakdown in the transistor. This phenomenon is called punch through.

For higher values of V_{CB}, due to early effect the value of α increases. Ex. α changes say from 0.98 to 0.985.

* Transistor Parameters:

The slope of the CB characteristics will give the following four transisto parameters. Since these parameters have different ~~dim~~ dimensions, they are commonly known as common base hybrid parameters (or) h-parameters.

a. Input Impedance (h_{ib}):

It is defined as the ratio of change in emitter voltage to change in (input) emitter current with the output collector voltage V_{CB} kept constant.

$$h_{ib} = \frac{\Delta V_{EB}}{\Delta I_E}, \quad V_{CB} \text{ constant.}$$

Typical values of h_{ib} ranges from 20Ω to 50Ω.

b. Output ~~Imped~~ Admittance (h_{ob}):

It is defined as the ratio of change in the (output) collector current to the corresponding change in the (output) collector voltage with (input) emitter current I_E kept constant

$$h_{ob} = \frac{\Delta I_C}{\Delta V_{CB}}, \quad I_E \text{ constant.}$$

Typical values of h_{ob} ranges from 0.1 to 10 μmhos.

c. Forward Current Gain (h_{fb}):

It is defined as a ratio of the change in (output) collector current to corresponding change in the (input) emitter current keeping the (output) collector voltage V_{CB} constant

$$h_{fb} = \frac{\Delta I_C}{\Delta I_E}, \quad V_{CB} \text{ constan}$$

Typical value 0.9 to 1.0

d. Reverse Voltage Gain (h_{rb}):

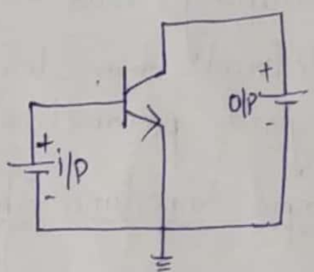
It is defined as ratio of change in (input) emitter voltage V_{EB} to corresponding change in (output) collector base voltage V_{CB}, with or input emitter current I_E constant.

$$h_{rb} = \frac{\Delta V_{EB}}{\Delta V_{CB}}, \quad I_E \text{ constant.}$$

Typical Values of order 10^{-5} to 10^{-4}

Common Emitter Configuration:

→ In this type of configuration the emitter is common to both input terminal i.e the base-emitter terminal and output terminal i.e, the emitter-collector terminal. It is also called grounded emitter configuration.



The fig below shows the circuit diagram for determining the static characteristics of CE in NPN transistor.

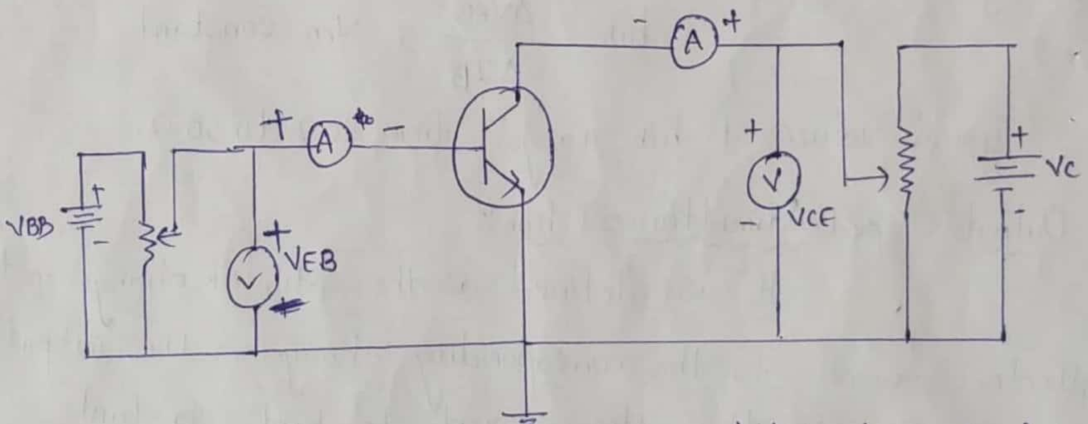


Fig: Circuit to determine CE static Characteristics.

Input charateristics:

→ To determine the input characteristics, the collector to emitter voltage is kept constant at zero volt and base current is increased from zero in equal steps by increasing VBE.

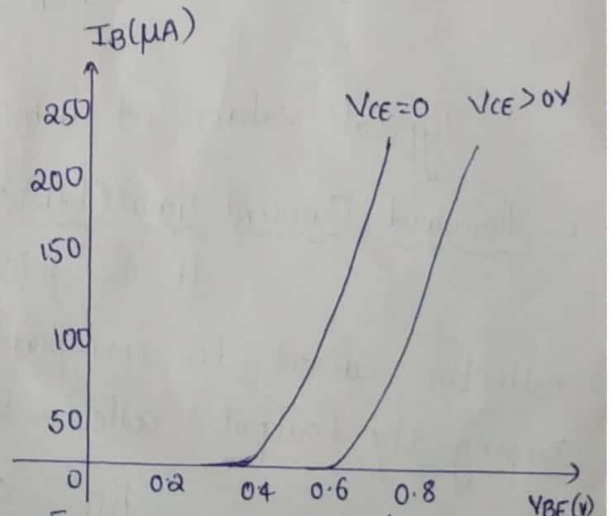


Fig CE input characteristics.

→ The value of V_{BE} is noted for each value of I_B. The procedure is repeated for higher fixed values of V_{CE} and the curves of I_B Vs V_{BE} are drawn. The input characteristics are as shown in fig.

→ When $V_{CE}=0$, the emitter-base junction is forward biased and the junction behaves as a forward biased ~~bi~~ diode. Hence the input characteristics for $V_{CE}=0$ is similar to that of forward-biased diode.

→ When V_{CE} is increased, the width of the depletion region at reverse biased collector-base junction will increase. Hence effective width of base will decrease. This causes a decrease in the base current I_B.

→ Hence to get the same value of I_B as that for $V_{CE}=0$, V_{BE} should be increased. Therefore the curve shifts to the right as V_{CE} increases.

Output Characteristics:

→ To determine the output characteristics, the base current is kept constant at a suitable value by adjusting base-emitter voltage V_{BE}.

→ The magnitude of collector-emitter voltage V_{CE} is increased in suitable steps for zero and the corresponding collector current is noted. The plot obtained is as shown in the fig.

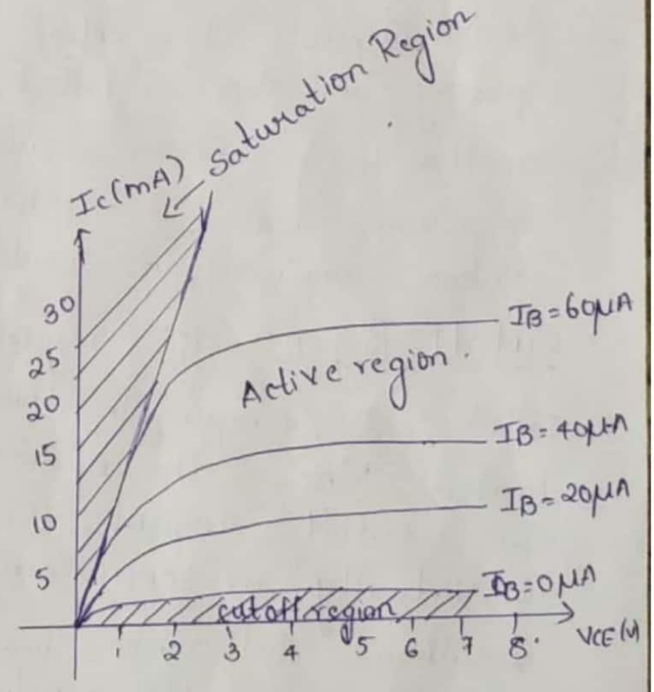


Fig: Output characteristics of CE

We know that

$\beta = \frac{\alpha}{1-\alpha}$ and $I_C = (1+\beta)I_{CBO} + \beta I_B$

For larger values of V_{CE}, due to early effect, a very small change in α is reflected in a very large change in β

For example when $\alpha = 0.98$

$\beta = \frac{0.98}{1-0.98} = 49.$

$\alpha = 0.985$

$\beta = \frac{0.985}{1-0.985} = 66$

→ Slight increase in α by 0.5% results in increase in β by about 34%.

→ Hence the output characteristics of CE configuration show a larger slope when compared with CB configuration.

→ The output characteristics have three regions namely saturation cutoff and active region.

→ ~~Th~~ Saturation Region: The region of curves to left of line OA is called Saturation Region. In this region both the junction are forward biased and an increase in the base current does not cause correspondind large change in I_C.

* When sufficient Reverse bias voltage is not given to ~~col~~ V_{CE} then the junction behaves as Forward bias. i.e., at that point both the junctions are Forward Biased and the transistor is in Saturation region and behaves as ON switch.

* The ratio of $V_{CE(sat)}$ to I_C in this region is called saturation resistance.

→ Active Region: The central region where the curves are uniform in spacing and slope is called active region. In this region the emitter-base junction is foward biased and the collector base junction is reverse biased. If the transistor has to be used ~~in~~ as a linear amplifier, it should be operated in the active region.

→ Cutoff Region: The region below the curve are uniform ~~in~~ is called cut-off region. In this region when both the diodes are reverse biased. When the operating point of the transistor ~~enet~~ enters the cutoff region, the transistor is OFF. The transistor is virtually an open circuit between collector and emitter.

* When sufficient forward bias voltage V_{BE} is not given to base-emitter junction then the ~~transistor~~ junction is similar to reverse bias. i.e., at this point when V_{BE} is less than FB voltage bothe the junctions are in R.B and transistor works as an OFF switch.

Transistor Parameters:

The slope of the CE characteristics will give the following four transistor parameters. Since these parameters have different dimensions they are commonly known as common emitter hybrid parameters or h parameter.

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a. Input Impedance (hie):

It is defined as the ratio of change in (input) base current with the (output) collector voltage VCE kept constant

$$h_{ie} = \frac{\Delta V_{BE}}{\Delta I_B}, V_{CE} \text{ constant}$$

Typical value of hie ranges from 500 to 2000Ω.

b Output admittance (hoe):

It is defined as the ratio of change in the (output) collector current to the corresponding change in the (output) collector voltage with the (input) base current I_B kept constant.

$$h_{oe} = \frac{\Delta I_C}{\Delta V_{CE}}, I_B \text{ constant}.$$

The typical values are 0.1 to 10 μmhos.

c. Forward Current Gain (hfe):

It is defined as a ratio of the change in the (output) collector current to the corresponding change in the (input) base current keeping the (output) collector voltage V_{CE} constant.

$$h_{fe} = \frac{\Delta I_C}{\Delta I_B}, V_{CE}. \text{ constant}.$$

Typical value varies from 20 to 200

d. Reverse Voltage Gain (hre):

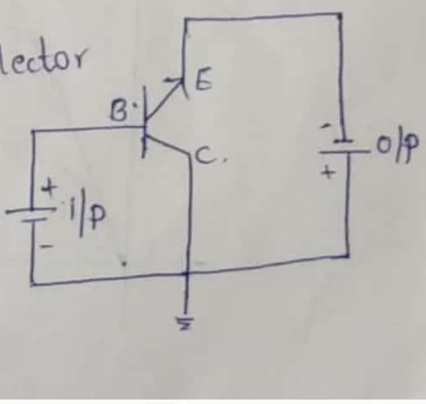
It is defined as the ratio of the change in the (input) base voltage and the corresponding change in (output) collector voltage with constant (input) base current I_B.

$$h_{re} = \frac{\Delta V_{BE}}{\Delta V_{CE}}, I_B$$

Typical values vary from in the order 10^{-5} to 10^{-4}.

Common Collector Configuration:

In this type of configuration the ~~base~~ collector is common to both input (base) terminal and output (emitter) terminal. This is also called grounded collector configuration.



The fig below shows the circuit diagram for determining the static characteristics of an NPN transistor in the common collector configuration.

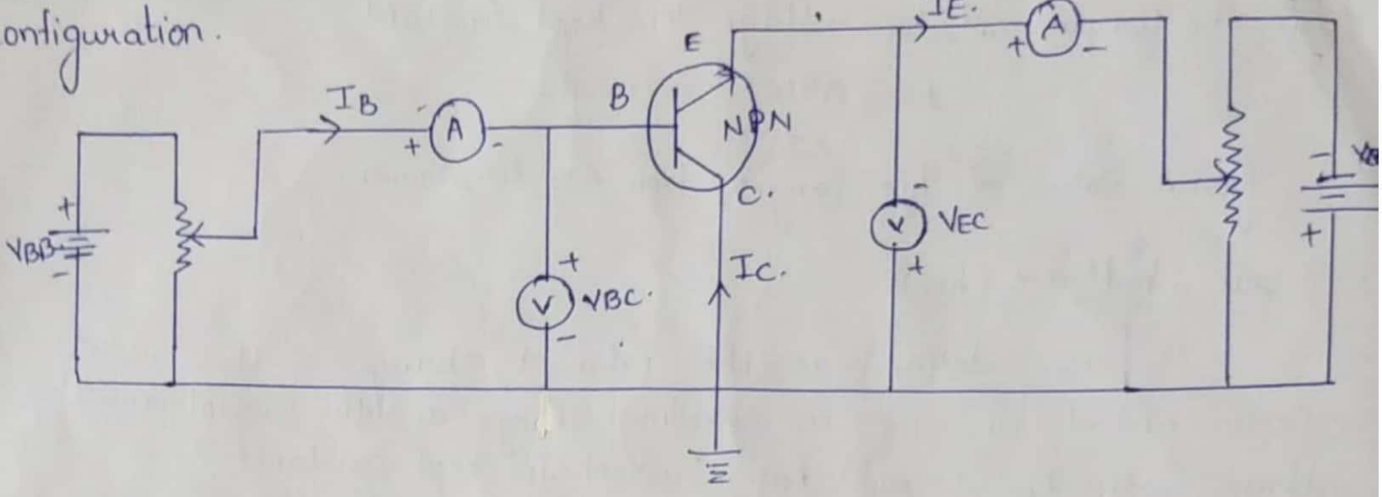


Fig: Circuit to determine CC Static characteristics

Input Characteristics:-

→ To determine the input characteristics V_{EC} is kept at a suitable fixed value. The base collector voltage V_{BC} is increased in equal steps and the corresponding increase in I_B is noted.

→ This is repeated for different fixed values of V_{EC} and curve is drawn for V_{BC} and I_B for different values of V_{CE}

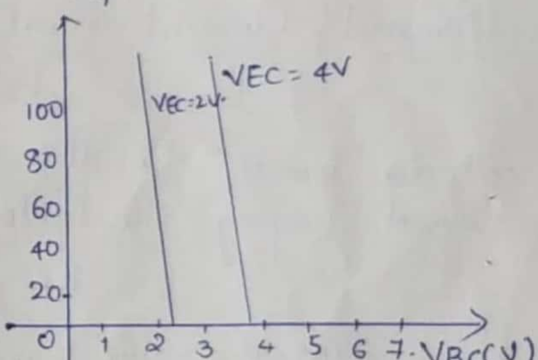
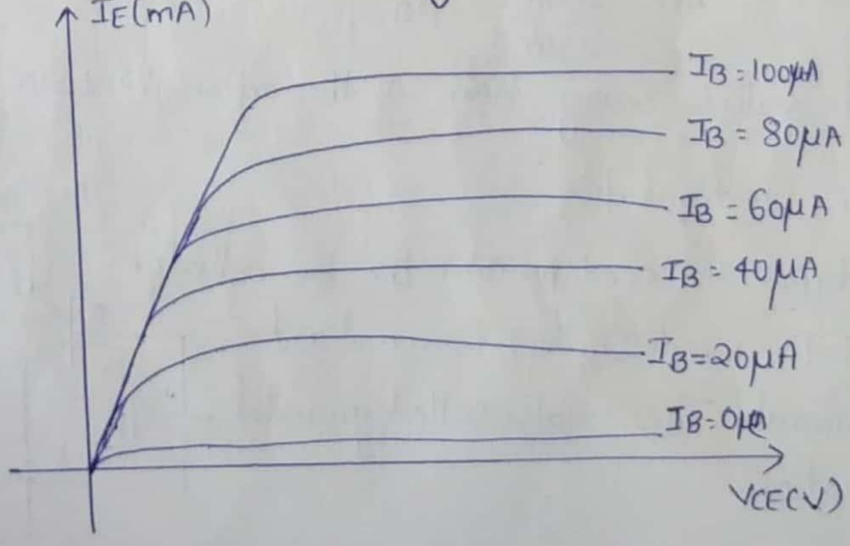


fig: input characteristics of CC.

Output characteristics: The output characteristics of CC are same as that of CE Configuration.



Comparision of Configurations.

Property.	CB	CE	CC.
Input resistance	Low (about 100 Ω)	Moderate (about 750 Ω)	High (about 750 kΩ)
Output resistance	High (about 45k Ω)	Moderate (about 45kΩ)	Low (about 25 Ω)
Current Gain	1	High	High
Voltage Gain	About 150	About 500	less than 1.
Phaseshift between input and output voltages	0 or 360°	180°	0 or 360°
Applications	For high freq circuits	For auido frequency	For impedance matching.

Current Amplification factor:

In a transistor amplifier with ac input signal, the ratio of change in output current to the change in input current is known as the current amplification factor.

In CB, current Amplification factor $\alpha = \frac{\Delta I_C}{\Delta I_E}$

In CE, current Amplification factor $\beta = \frac{\Delta I_C}{\Delta I_B}$

In CC, current Amplification factor $\gamma = \frac{\Delta I_E}{\Delta I_B}$.

Relation between α and β.

We know $\Delta I_E = \Delta I_C + \Delta I_B$.

$$\Delta I_C = \alpha \Delta I_E$$

$$\Delta I_E = \alpha \Delta I_E + \Delta I_B$$

$$\Delta I_B = (1-\alpha)\, \Delta I_E.$$

Dividing both sides by ΔI_C we get

$$\frac{\Delta I_B}{\Delta I_C} = \frac{\Delta I_C}{\Delta I_C}(1-\alpha)$$

$$\frac{1}{\beta} = \frac{1}{\alpha}(1-\alpha)$$

$$\boxed{\beta = \frac{\alpha}{1-\alpha}}$$

Now: $\Delta I_E = \Delta I_C + \Delta I_B$

dividing with ΔI_E

$$\frac{\Delta I_E}{\Delta I_C} = \frac{\Delta I_C}{\Delta I_C} + \frac{\Delta I_B}{\Delta I_C}$$

$$\frac{1}{\alpha} = 1 + \frac{1}{\beta}$$

$$\frac{1}{\alpha} = \frac{\beta+1}{\beta}$$

$$\boxed{\alpha = \frac{\beta}{\beta+1}}$$

Relation between. α, β, γ

In CC transistor amplifier circuit, I_B is the input current and I_E is output current.

$$\gamma = \frac{\Delta I_E}{\Delta I_B}.$$

$$\Delta I_B = \Delta I_E - \Delta I_C.$$

$$\gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$$

÷ by ΔI_E

$$\gamma = \frac{\frac{\Delta I_E}{\Delta I_E}}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}}$$

$$\boxed{\gamma = \frac{1}{1-\alpha}.}$$

Now $\Delta I_E = \Delta I_C + \Delta I_B$

diving with ΔI_B

$$\frac{\Delta I_E}{\Delta I_B} = \frac{\Delta I_C}{\Delta I_B} + \frac{\Delta I_B}{\Delta I_B}$$

$$\boxed{\gamma = \beta + 1}$$

Relation between α, β, γ

$$\alpha = \frac{\beta}{\beta+1}$$

$$\alpha = \frac{\beta}{\gamma}$$

$$\boxed{\beta = \alpha\gamma}$$

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Common Emitter Amplifier Circuit Working & Its Characteristics

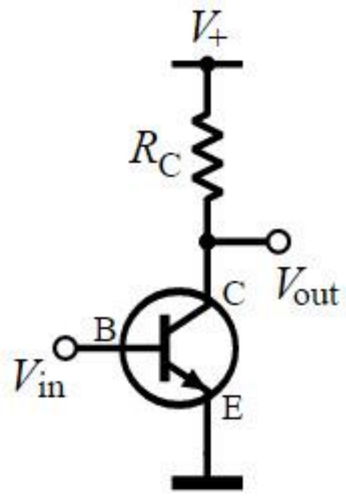
There are **different types of transistor amplifiers** operated by using an AC signal input. This is interchanged between the positive value and negative value, hence this is the one way of presenting the common emitter amplifier circuit to function between two peak values. This process is known as the biasing amplifier and it is an important amplifier design to establish the exact operating point of a transistor amplifier which is ready to receive the signals hence it can reduce any distortion to the output signal. In this article, we will discuss common emitter amplifier analysis.

What is an Amplifier?

The Amplifier is an electronic circuit that is used to increase the strength of a weak input signal in terms of voltage, current, or power. The process of increasing the strength of a weak signal is known as Amplification. One most important constraint during the amplification is that only the magnitude of the signal should increase and there should be no changes in the original signal shape. The transistor (BJT, FET) is a major component in an amplifier system. When a transistor is used as an amplifier, the first step is to choose an appropriate configuration, in which the device is to be used. Then, the transistor should be biased to get the desired Q-point. The signal is applied to the amplifier input and output gain is achieved.

What is a Common Emitter Amplifier?

The common emitter amplifier is a three basic single-stage bipolar junction transistor and is used as a voltage amplifier. The input of this amplifier is taken from the base terminal, the output is collected from the collector terminal and the emitter terminal is common for both the terminals. The basic symbol of the common emitter amplifier is shown below.



Common Emitter Amplifier

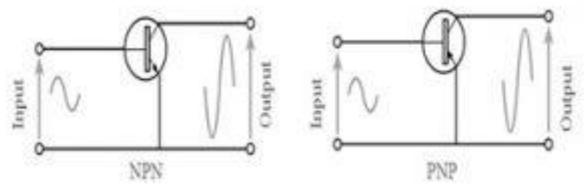
Common Emitter Amplifier Configuration

In electronic circuit design, there are three kinds of transistor configurations are used like common emitter, common base, and common collector, In that, the most frequently used one is common emitter due to its main attributes.

This kind of amplifier includes the signal which is given to the base terminal then the output is received from the collector terminal of the circuit. But, as the name suggests, the main attribute of the emitter circuit is familiar for both the input as well as output.

The configuration of a common emitter transistor is widely used in most electronic circuit designs. This configuration is evenly appropriate to both the transistors like PNP and NPN transistors but NPN transistors are most frequently used due to the widespread use of these transistors.

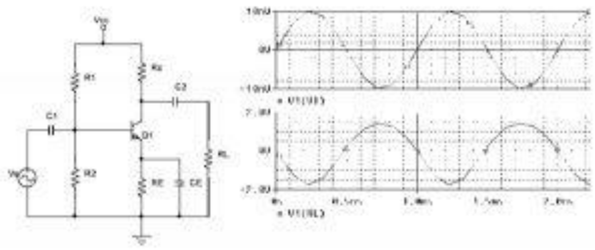
In Common Emitter Amplifier Configuration, the Emitter of a BJT is common to both the input and output signal as shown below. The arrangement is the same for a PNP transistor, but bias will be opposite w.r.t NPN transistor.



CE Amplifier Configurations

Operation of Common Emitter Amplifier

When a signal is applied across the emitter-base junction, the forward bias across this junction increases during the upper half cycle. This leads to an increase in the flow of electrons from the emitter to a collector through the base, hence increases the collector current. The increasing collector current makes more voltage drops across the collector load resistor RC.



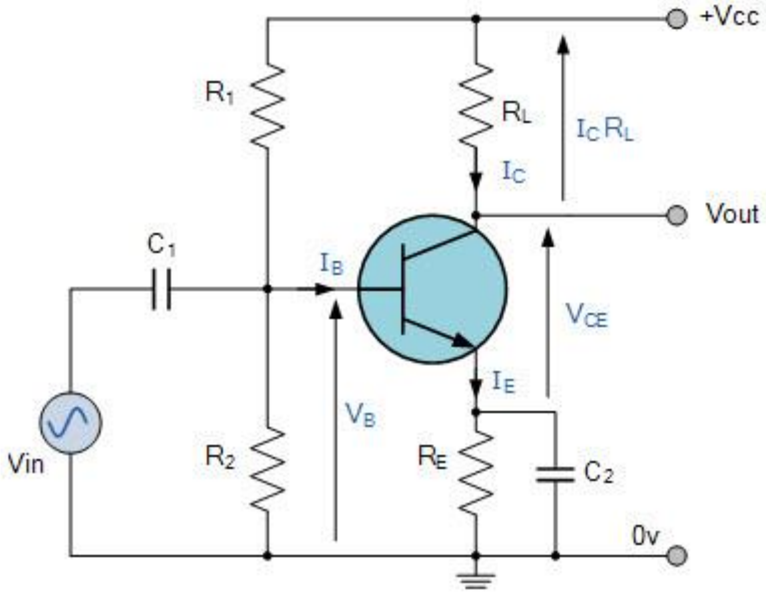
Operation of CE Amplifier

The negative half cycle decreases the forward bias voltage across the emitter-base junction. The decreasing collector-base voltage decreases the collector current in the whole collector resistor Rc. Thus, the amplified load resistor appears across the collector resistor. The common emitter amplifier circuit is shown above.

From the voltage waveforms for the CE circuit shown in Fig. (b), It is seen that there is a 180-degree phase shift between the input and output waveforms.

Working of Common Emitter Amplifier

The below circuit diagram shows the working of the common emitter amplifier circuit and it consists of voltage divider biasing, used to supply the base bias voltage as per the necessity. The voltage divider biasing has a potential divider with two resistors are connected in a way that the midpoint is used for supplying base bias voltage.



Common Emitter Amplifier Circuit

There are different types of electronic components in the common emitter amplifier which are R1 resistor is used for the forward bias, the R2 resistor is used for the development of bias, the RL resistor is used at the output it is called the load resistance. The RE resistor is used for thermal stability. The C1 capacitor is used to separate the AC signals from the DC biasing voltage and the capacitor is known as the coupling capacitor.

The figure shows that the bias vs gain common emitter amplifier transistor characteristics if the R2 resistor increases then there is an increase in the forward bias and R1 & bias are inversely proportional to each other. The alternating current is applied to the base of the transistor of the common emitter amplifier circuit then there is a flow of small base current. Hence there is a large amount of current flow through the collector with the help of the RC resistance. The voltage near the resistance RC will change because the value is very high and the values are from 4 to 10kohm. Hence there is a huge amount of current present in the collector circuit which amplified from the weak signal, therefore common emitter transistors work as an amplifier circuit.

Voltage Gain of Common Emitter Amplifier

The current gain of the common emitter amplifier is defined as the ratio of change in collector current to the change in base current. The voltage gain is defined as the product of the current gain and the ratio of the output resistance of the collector to the input resistance of the base circuits. The following equations show the mathematical expression of the voltage gain and the current gain.

$$\beta = \Delta Ic / \Delta Ib$$

$$Av = \beta \, Rc/Rb$$

Circuit Elements and their Functions

The common emitter amplifier circuit elements and their functions are discussed below.

Biasing Circuit/ Voltage Divider

The resistances R1, R2, and RE used to form the voltage biasing and stabilization circuit. The biasing circuit needs to establish a proper operating Q-point otherwise, a part of the negative half cycle of the signal may be cut-off in the output.

Input Capacitor (C1)

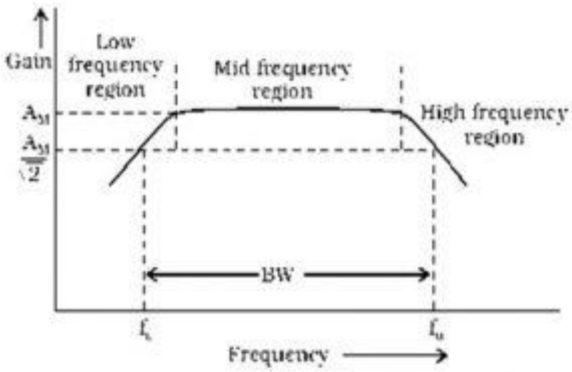
The capacitor C1 is used to couple the signal to the base terminal of the BJT. If it is not there, the signal source resistance, Rs will come across R2, and hence, it will change the bias. C1 allows only the AC signal to flow but isolates the signal source from R2

Emitter Bypass Capacitor (CE)
An Emitter bypass capacitor CE is used parallel with RE to provide a low reactance path to the amplified AC signal. If it is not used, then the amplified AC signal following through RE will cause a voltage drop across it, thereby dropping the output voltage.

Coupling Capacitor (C2)
The coupling capacitor C2 couples one stage of amplification to the next stage. This technique used to isolate the DC bias settings of the two coupled circuits.

CE Amplifier Frequency Response

The voltage gain of a CE amplifier varies with signal frequency. It is because the reactance of the capacitors in the circuit changes with signal frequency and hence affects the output voltage. The curve drawn between voltage gain and the signal frequency of an amplifier is known as frequency response. The below figure shows the frequency response of a typical CE amplifier.



Frequency Response

From the above graph, we observe that the voltage gain drops off at low (< FL) and high (> FH) frequencies, whereas it is constant over the mid-frequency range (FL to FH).

At Low Frequencies (< FL) The reactance of coupling capacitor C2 is relatively high and hence very small part of the signal will pass from the amplifier stage to the load.
Moreover, CE cannot shunt the RE effectively because of its large reactance at low frequencies. These two factors cause a drops off of voltage gain at low frequencies.

At High Frequencies (> FH) The reactance of coupling capacitor C2 is very small and it behaves as a short circuit. This increases the loading effect of the amplifier stage and serves to reduce the voltage gain.
Moreover, at high frequencies, the capacitive reactance of base-emitters junction is low which increases the base current. This frequency reduces the current amplification factor β. Due to these two reasons, the voltage gain drops off at a high frequency.

At Mid Frequencies (FL to FH) The voltage gain of the amplifier is constant. The effect of the coupling capacitor C2 in this frequency range is such as to maintain a constant voltage gain. Thus, as the frequency increases in this range, the reactance of CC decreases, which tends to increase the gain.
However, at the same time, lower reactance means higher almost cancel each other, resulting in a uniform fair at mid-frequency.

We can observe the frequency response of any amplifier circuit is the difference in its performance through changes within the input signal's frequency because it shows the frequency bands where the output remains fairly stable. The circuit bandwidth can be defined as the frequency range either small or big among ƒH & ƒL.

So from this, we can decide the voltage gain for any sinusoidal input in a given range of frequency. The frequency response of a logarithmic presentation is the Bode diagram. Most of the audio amplifiers have a flat frequency response that ranges from 20 Hz – 20 kHz. For an audio amplifier, the frequency range is known as Bandwidth.

Frequency points like ƒL & ƒH are related to the lower corner & the upper corner of the amplifier which are the gain falls of the circuits at high as well as low frequencies. These frequency points are also known as decibel points. So the BW can be defined as

BW = fH – fL

The dB (decibel) is 1/10th of a B (bel), is a familiar non-linear unit to measure gain & is defined like 20log10(A). Here 'A' is the decimal gain which is plotted over the y-axis.

The maximum output can be obtained through the zero decibels which communicate toward a magnitude function of unity otherwise it occurs once Vout = Vin when there is no reduction at this frequency level, so

VOUT/VIN = 1, so 20log(1) = 0dB

We can notice from the above graph, the output at the two cut-off frequency points will decrease from 0dB to -3dB & continues to drop at a fixed rate. This reduction within gain is known commonly as the roll-off section of the frequency response curve. In all basic filter and amplifier circuits, this roll-off rate can be defined as 20dB/decade, which is equal to a 6dB/octave rate. So, the order of the circuit is multiplied with these values.

These -3dB cut-off frequency points will describe the frequency where the o/p gain can be decreased to 70 % of its utmost value. After that, we can properly say that the frequency point is also the frequency at which the gain of

Single Stage Common Emitter Amplifier

The single-stage common emitter amplifier is shown below and different circuit elements with their functions are described below.

Biasing Circuit

The circuits like biasing as well as stabilization can be formed with resistances like R1, R2 & RE

Input Capacitance (Cin)

The input capacitance can be denoted with 'Cin' which is used to combine the signal toward the base terminal of the transistor.

If this capacitance is not used, then the resistance of the signal source will approach across the resistor 'R2' to alter the bias. This capacitor will allow simply AC signal to supply.

Emitter Bypass Capacitor (CE)

The connection of the emitter bypass capacitor can be done in parallel to RE to give a low reactance lane toward the amplified AC signal. If it is not utilized, then the amplified AC signal will flow throughout RE to cause a voltage drop across it, so the o/p voltage can be shifted.

Coupling Capacitor (C)
This coupling capacitor is mainly used to combine the amplified signal toward the o/p device so that it will allow simply AC signal to supply.

Working

Once a weak input AC signal is given toward the base terminal of the transistor, then a small amount of base current will supply, because of this transistor act, high AC. current will flow throughout collector load (RC), so high voltage can come into view across the collector load as well as the output. Thus, a feeble signal is applied toward the base terminal which appears in the amplified form within the collector circuit. The amplifier's voltage gain like Av is the relation between the amplified input and output voltages.

Frequency Response & Bandwidth

The amplifier's voltage gain like Av for several input frequencies can be concluded. Its characteristics can be drawn on both the axis like a frequency on X-axis whereas voltage gain is on Y-axis. The graph of frequency response can be attained which is shown in the characteristics. So we can observe that the gain of this amplifier can be decreased at very high and low frequencies, however, it stays stable over an extensive range of mid-frequency area.

The fL or low cut off frequency can be defined as when the frequency is below 1. The range of frequency can be decided at which the amplifier gain is double the gain of mid-frequency.

The fL(upper cut off frequency) can be defined as when the frequency is in the high range at which the amplifier's gain is 1/√2 times the gain of mid-frequency.

Bandwidth can be defined as the interval of frequency among low-cut off & upper cut-off frequencies.

BW = fU – fL

Advantages

The advantages of a common emitter amplifier include the following.

- The common emitter amplifier has a low input impedance and it is an inverting amplifier
- The output impedance of this amplifier is high
- This amplifier has the highest power gain when combined with medium voltage and current gain
- The current gain of the common emitter amplifier is high

Disadvantages

The disadvantages of a common emitter amplifier include the following.

- In the high frequencies, the common emitter amplifier does not respond
- The voltage gain of this amplifier is unstable
- The output resistance is very high in these amplifiers
- In these amplifiers, there is a high thermal instability
- High output resistance

Applications

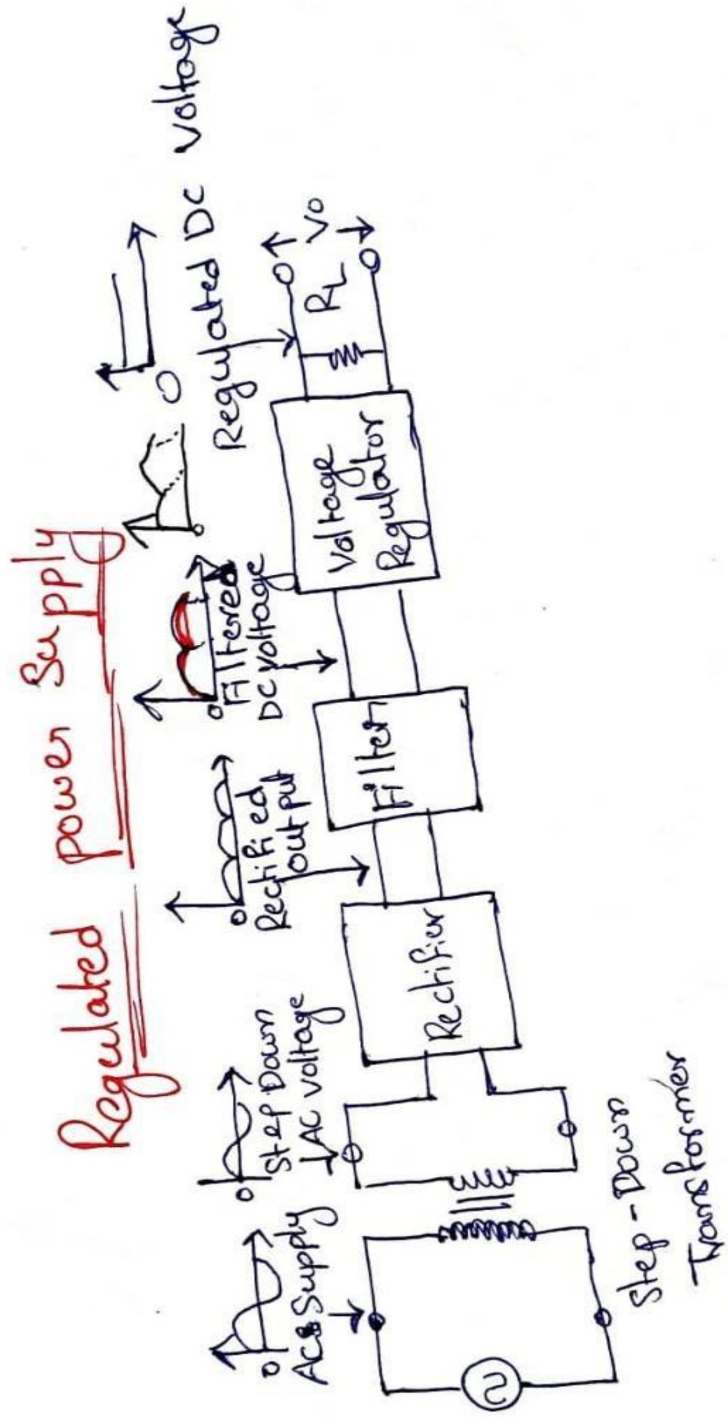
The applications of a common emitter amplifier include the following.

- The common emitter amplifiers are used in the low-frequency voltage amplifiers.
- These amplifiers are used typically in the RF circuits.
- In general, the amplifiers are used in the Low noise amplifiers
- The common emitter circuit is popular because it’s well-suited for voltage amplification, especially at low frequencies.
- Common-emitter amplifiers are also used in radio frequency transceiver circuits.
- Common emitter configuration commonly used in low-noise amplifiers.

UNIT-2

What is Regulated Power Supply?

An electronic circuit that produces a stable DC voltage of fixed value across the load terminals irrespective of changes in the load is known as **regulated power supply**. Thus, the primary function of a regulated power supply is to convert an AC power into a steady DC power. The regulated power supply is sometimes also called as a **linear power supply**.



The regulated power supply ensures that the output power at the load terminals should remain constant even if the input power varies. The regulated power supply receives an AC power as input and generates a constant DC power as output. A regulated power supply is basically an embedded circuit consisting of various blocks.

Block Diagram and Operation of Regulated Power Supply

The block diagram of a typical regulated power supply is shown in Figure-1.

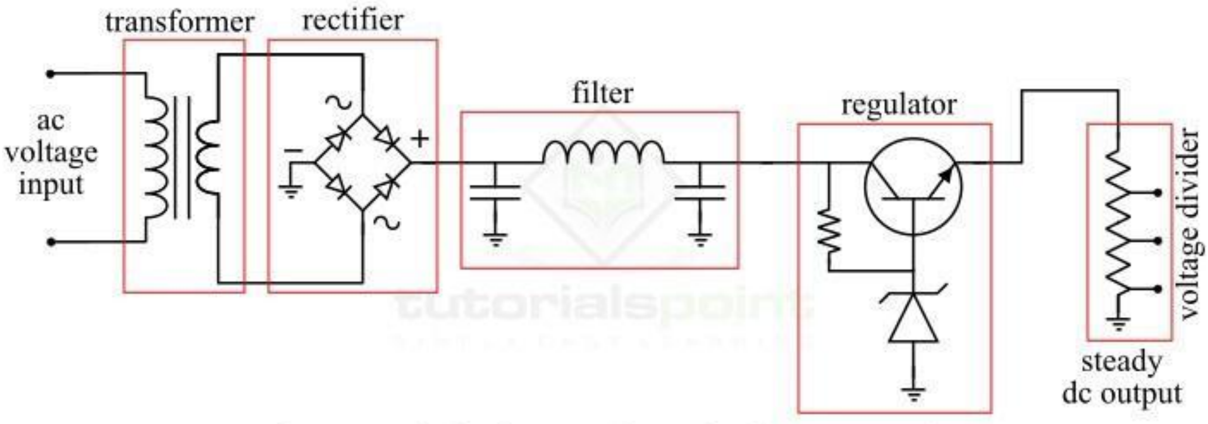


Figure 1 - Block Diagram of Regulated Power Sypply

The regulated power supply consists of the following four major parts −

- Step-down transformer
- Rectifier circuit
- DC filter circuit
- Voltage regulator

Now, let us discuss the operation of each block of the regulated power supply one by one.

Function of Step-Down Transformer

The step-down transformer used in the circuit of the regulated power supply changes the input AC voltage to the desired lower voltage value. Also, this transformer provides an electrical isolation between two circuits. The reduced output AC voltage of the step-down transformer is used as the input to the rectifier circuit.

Function of Rectifier Circuit

The rectifier circuit is used to convert the input AC voltage into a DC voltage. It consists of diodes that perform the rectification process, i.e. conversion of the AC voltage into the DC voltage. However, the output of the rectifier is a pulsating direct voltage. In practice, a full wave rectifier is used for the rectification due to its technical advantages. This full wave rectifier can be a center-tapped full-wave rectifier or a bridge rectifier. The full wave rectifier converts both positive and negative cycles of AC voltage into DC voltage.

Function of Filter Circuit

Since the output of the rectifier is a pulsating direct voltage which has very high ripple content. Hence, the raw output of the rectifier is undesirable. In order to get a pure ripple free direct voltage, a DC filter circuit is used. We have different types of filter circuits such as capacitor filter choke input filter, π-filter, and LC filter. Therefore, the filter circuit converts the pulsating direct voltage into the constant direct voltage having almost zero ripple content.

Voltage Regulator

The voltage regulator constitutes the last block of the regulated power supply. It monitors and corrects the fluctuations in the output voltage of the power supply. The output voltage may change or fluctuate due to any change in the input AC voltage or the change in the load or change in any physical parameters such as temperature of the circuit. Thus, the voltage regulator takes care of this problem. The voltage regulator maintains the DC voltage constant at the output terminals.

A zener diode operated in zener region, a transistor series regulator, fixed and variable IC regulators are commonly used in different regulated power supplies as the voltage regulator.

Features of Regulated Power Supply

Following are the main features of the regulated power supply −

- The regulated power supplies have the efficiency ranging from 20% to 25%.
- Regulated power supplies are relatively more reliable.
- Regulated power supplies have less complex circuit and less weight.
- Regulated power supplies give faster response.
- The cost and noise level of the regulated power supplies is low.

Applications of Regulated Power Supplies

As discussed earlier, the regulated power supplies are the embedded circuits that convert an unregulated AC power supply into a steady DC power supply which is the basic requirement of several electronic circuits. Hence, the regulated power supplies are extensively used in several applications such as −

- Mobile charging circuits
- Testing circuits
- Bench power supplies
- Oscillators and amplifiers
- Electronic computers
- Automatic control systems, etc.

Full wave bridge rectifier

The bridge rectifier is made up of four diodes namely D_1, D_2, D_3, D_4 and load resistor R_L. The four diodes are connected in a closed loop (Bridge) configuration to efficiently convert the Alternating Current (AC) into Direct Current (DC). The main advantage of this bridge circuit configuration is that we do not require an expensive center tapped transformer, thereby reducing its cost and size.

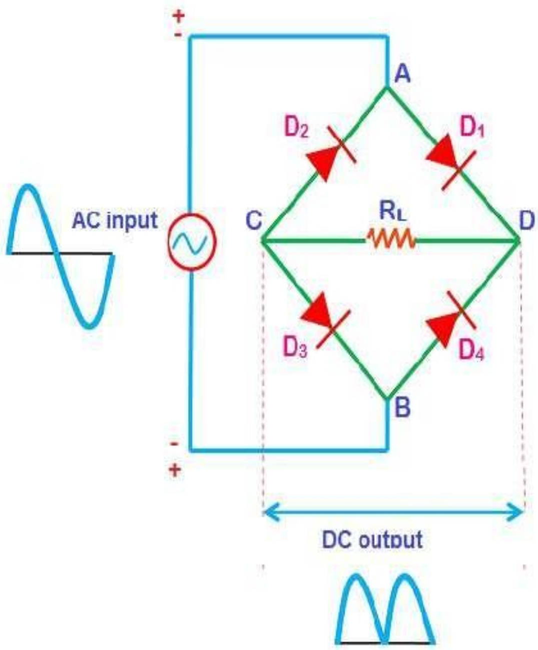


Figure 1.24:Circuit diagram of full wave bridge rectifier

The input AC signal is applied across two terminals A and B and the output DC signal is obtained across the load resistor R_L which is connected between the terminals C and D.

During the positive half cycle, the terminal A becomes positive while the terminal B becomes negative. This causes the diodes D_1 and D_3 forward biased and at the same time, it causes the diodes D_2 and D_4 reverse biased. The current flow direction during the positive half cycle is shown in the figure A (I.e. A to D to C to B).

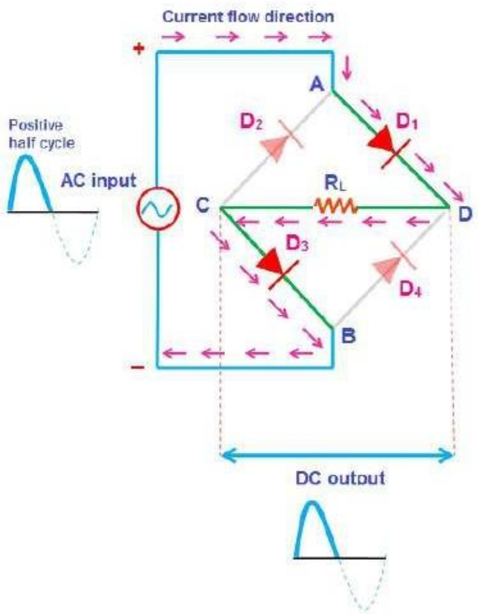


Figure 1.25:During positive half cycle- full wave bridge rectifier

During the negative half cycle, the terminal B becomes positive while the terminal A becomes negative. This causes the diodes D_2 and D_4 forward biased and at the same time, it causes the diodes D_1 and D_3 reverse biased.The current flow direction during negative half cycle is shown in the figure B (I.e. B to D to C to A).

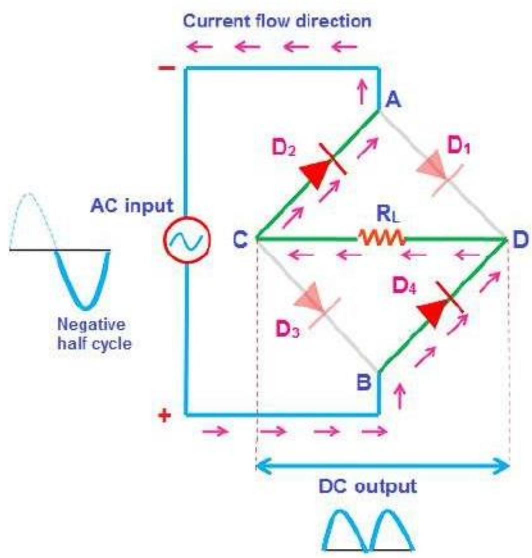


Figure 1.26:During negative half cycle- full wave bridge rectifier

The output waveforms of the bridge rectifier is shown in the below figure.

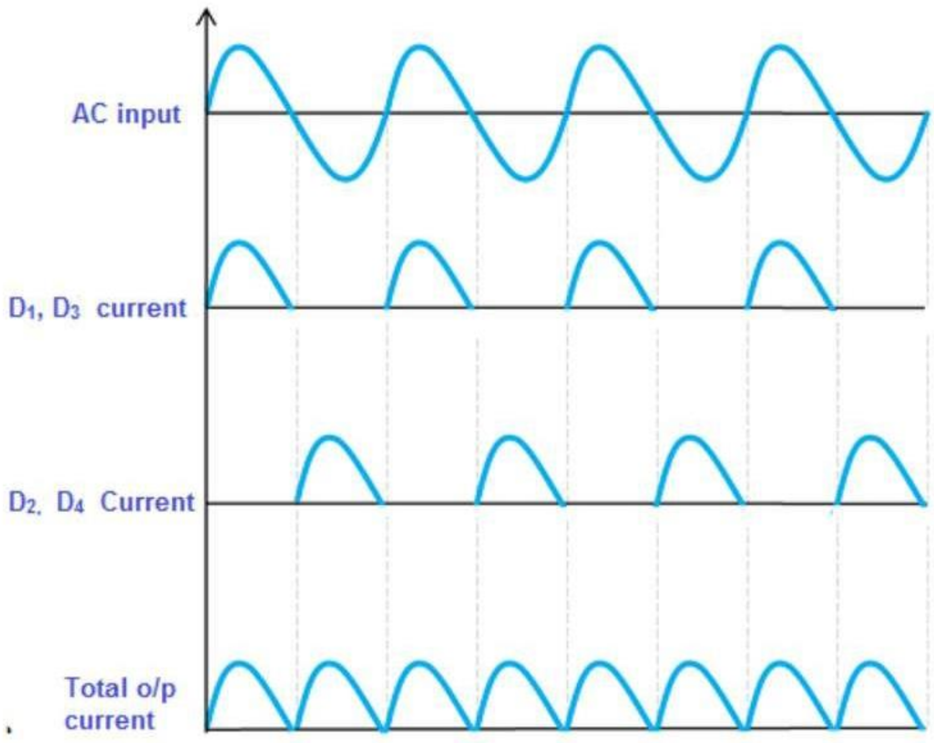


Figure 1.27:Input and Output waveforms of full wave bridge rectifier

Advantages and disadvantages of bridge rectifier

The following are advantages

1. No centre tap is needed in the transformer secondary.
2. The output is twice that of the centre tap circuit for the same secondary voltage.
3. The peak inverse voltage is one half that of the centre tap circuit.

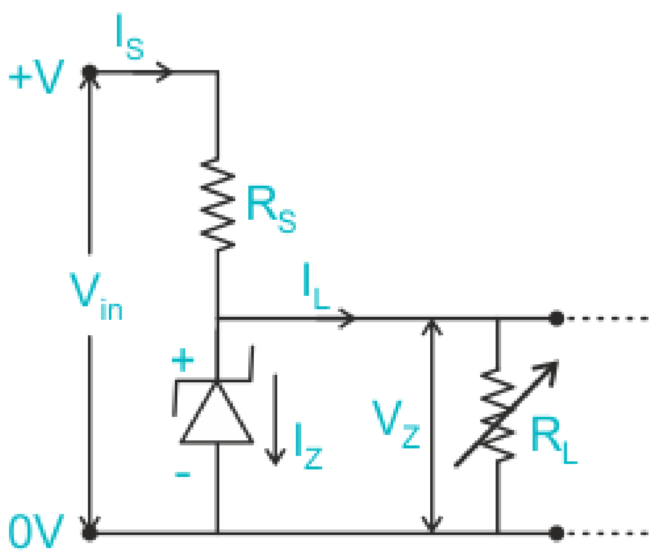
The following are disadvantages

1. It requires four diodes.
2. As during each half cycle of a.c input two diodes that conduct are in series, therefore voltage drop in the internal resistance of the rectifying unit will be twice. This is objectionable when secondary voltage is small.

Working of Zener Diode as a Voltage Regulator

The capacity of a Zener diode to keep a constant voltage regardless of changes in source or load current is critical in this application. A voltage regulation device’s general role is to give a constant output voltage to a load connected in parallel to it, regardless of variations in the load’s energy drawn (Load current) or fluctuations and instability in the supply voltage. If the current remains within the limit of the min and max reverse currents, the Zener diode will produce a constant voltage.

To restrict the current that flows through the Zener diode, a resistor RsRs is connected in series with the diode, and also the input voltage VinVin is connected across as shown in the image, and the output voltage VoutVout is chosen to take across the Zener diode with Vout=VzVout=Vz. Because the reverse bias features of the Zener diode are required to control the voltage, it is wired in reverse bias mode, and with a cathode linked to the circuit’s positive rail.



Whenever the load is connected, a small valued resistor would result in a big diode current and electricity, which would raise the power dissipation need of the diode, which could exceed the Zener’s maximum power rating and harm it.

The value of the resistor can be determined by the formula

$RS=(Vin-VZ)Iz$

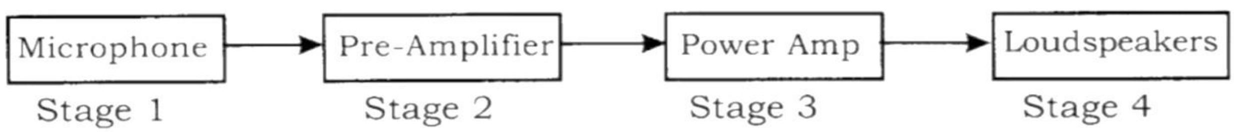
Where, RS is the value of series resistance and Vin is the input voltage and Vz is Zener voltage.

Using this method, it is simple to assure that the resistor value chosen does not result in a current flow greater than the Zener can tolerate.

One minor issue with Zener diode-based regulatory circuits is that although attempting to moderate the input voltage, the Zener might generate electrical noise just on the supply rail. Although it may not be a problem in most cases, a big value decoupling capacitor placed across the diode may address the problem. This helps to keep the Zener's output stable.

Block diagram of Public Address system

- A "Public Address" system is anything that amplifies sound so more people can hear it.
- A simple public address system (or PA system) is shown in the following block diagram.



Stage 1: Microphone (Transducer)

- ✓ The microphone converts sound waves into electrical signals that can be processed by the rest of the system.
- ✓ It is important that the microphone **creates a faithful reproduction of the sound wave as an electrical signal.**

Stage 2: Pre-Amplifier

- ✓ It is basically a voltage amplifier.
- ✓ **Its purpose is to take the small electrical signals from the microphone and increase the amplitude of the signal voltage.**

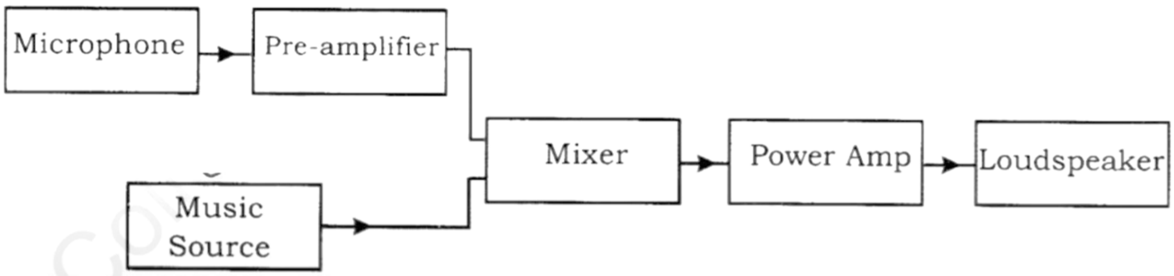
Stage 3: Power Amplifier

- ✓ The power amplifier **takes this enlarged voltage signal, and boosts the current so that it is strong enough to drive the, loudspeaker.**

Stage 4: Loud Speaker

- ✓ The loudspeaker is the final part of the system where the electrical signal is transformed back into a sound wave.

- If the system has carried out its function correctly, the emerging sound wave will be an undistorted but amplified version of the original.
- A more sophisticated PA system would allow a number of inputs to be connected
- For eg., a band would have several microphone inputs and guitar pick-up inputs. These inputs would need to be faded in or out individually.
- Consider the following block diagram



- It can be noticed that there are two additions to the simple PA system. The first is a music source and the second is a mixer.
- **Mixer:** Its function is to add together electrical signals from microphones or pick-ups from electric guitars or sound tracks from a CD player.
- Most music sources produce a much larger signal than a microphone and do not need a pre-amplifier.
- **In a real system, each microphone would have its own pre-amplifier.**
- **Clipping:** If we try to amplify the signal too much the system will not be able to provide the voltage required. This results in distortion of the output signal, called **clipping distortion.**

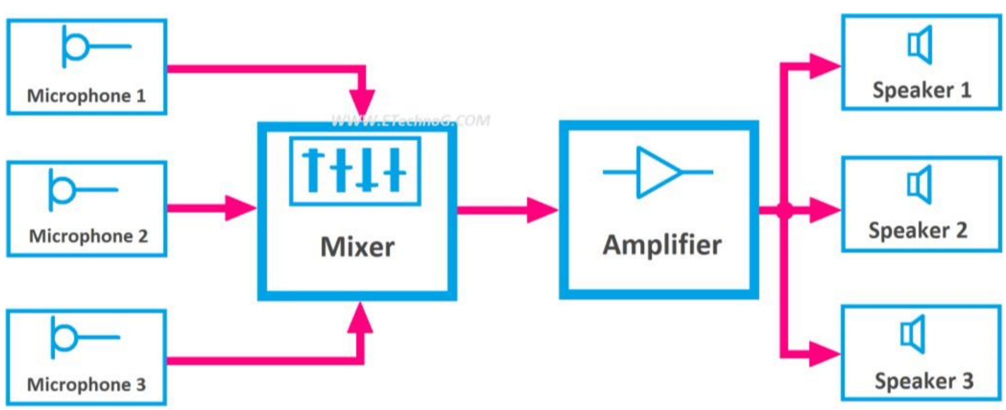
Public Address System or PA system Explained with Diagram

A public Address System or PA system is an electronic system that includes acoustic signal converting, mixing, amplifying, and playing. A PA system has microphones, amplifiers, and loudspeakers as its main components or equipment. We know that the intensity of the sound decreases with the distance. Also, a particular sound can be affected or distorted by the other sound if the level or volume of the sound is the same. So, if we want to deliver sound energyover a long distance or highlight a particular sound or voice in a large crowd or gathering then we need a PA system. Because the PA systems provide the amplification of the sound for comfortable listening.

The range of amplification is required for the sound is to be delivered to the distance, size of the gathering or gathering, etc. Sound quality is also a very important factor with amplification because it improves the listening experience. The PA system helps to amplify as well as record the voice of any human being or the sound of any musical instrument. Also, it helps to communicate between a group.

Basic Block Diagram of PA System

Here, you can see the public address system block diagram and its important blocks.



Public Address System or PA System Block Diagram

Components of a PA System

There are so many devices or components are used in PA system that depends upon their applications and other factors. But the main three components of any public address system are explained below.

1. Microphone

The microphone is a very important part or component of a PA system. The microphonebasically is a transducer that converts acoustic energy or sound energy into electrical energy. It continuously generates the pulsating electrical voltage according to the frequency of the sound energy applied to it. Various types of microphones are used in the PA system. The main basic two types of microphones are,

1. Handheld Microphone
2. Lapel Microphone

Other different types of microphones are,

- Wired Microphone
- Wireless Microphone

A wired microphone can be connected by a wire to the mixer or amplifier. It is very simple. But the wireless microphone needs a battery and the frequency of its signal is also a very important factor. The wireless microphone cannot be connected directly to the mixer or amplifier. A receiver is required that can receive the signals sent by the microphone. This receiver is to be connected to the amplifier.

2. Amplifier

The amplifier is the second part of a PA system. The main function of the amplifier is to amplify or increase the volume level of the audio signal that can drive a loudspeaker. The requirement or size of the amplifier depends upon the number and size of the loudspeaker. If the size of the loudspeaker is very large or so many loudspeakers are to be connected then a very powerful amplifier is required. The output of the amplifier is measured in watts or kilowatts.

3. LoudSpeaker

Loudspeakers play a very important role in the PA system. It converts electrical energy into acoustic energy or sound energy. The loudspeakers are generally connected to the amplifier and it generates sound according to the audio signal provided by the amplifier. There are different types of loudspeakers are available according to their operating frequency.

1. Woofer - it operates at the lowest frequency audio signal such as Bass
    1. Subwoofer - it also operates with low frequency but more than the woofer such as bass and deep vocals
2. Squawker - it operates with medium-frequency audio signals such as vocals
3. Tweeter - it operates with high-frequency audio signals such as tone

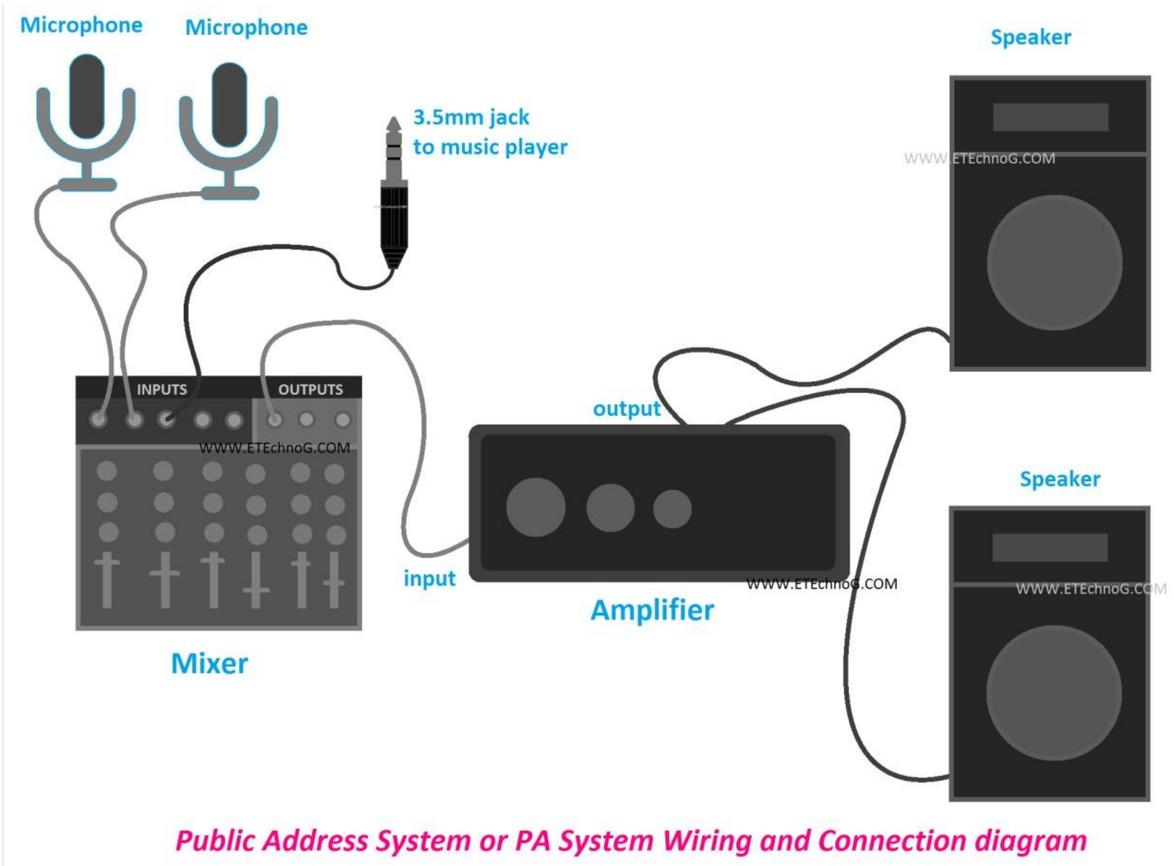
4. Mixer

A mixer is not a necessary part of a PA system. But if there are multiple audio sources or multiple microphones used in the PA system then a mixer is must required. The mixer is an electronic device that can control multiple sound sources simultaneously. It can mix all the sound sources together and play with a single loudspeaker with the help of an amplifier. So the mixer is generally connected before the amplifier. Nowadays, there are so many amplifiers are available in the market that already have an inbuilt mixer. So there is no need for an external additional mixer. All the microphones or sound sources can be connected directly to the amplifier.

(Extra information about Electronic Instrumentation System For your understanding)

PA System Wiring and Connection Diagram

Here, you can see a basic wiring diagram of public address system. This will help you understand how microphones, mixers, amplifiers, and speakers are connected together.



Here, you can see, that multiple audio or sound sources such as microphones and music players are connected to the mixer. Then the mixer output is connected to the amplifier input. And the amplifier output is connected to the speaker.

Important Factors in a Public Address System

Acoustic Feedback

When the microphone picks up sound from the speaker and re-amplifies and sends it again to the speaker then it is called Acoustic feedback. The objective of any PA system should be to minimize as much as possible. It distorts the actual sound and creates a bad experience of listening. It generally happens more when the volume of the system is turned up to the highest level.

This can be reduced by the different procedures,

- by keeping microphones at a distance from the speaker
- changing the direction of the microphone from the point towards the speaker
- lowering the gain level of the feedback sound
- using some devices like notch filter, graphic equalizer, parametric equalizer, etc

Cables and Wires

The size and quality of cables used in the PA system is a very important factor. Using the proper size and good quality cables and wire improves the sound quality very much.

Types of PA System

The PA system can be classified such as,

- Personal PA System
- Medium Size PA System
- Large Size PA System
- Portable PA System

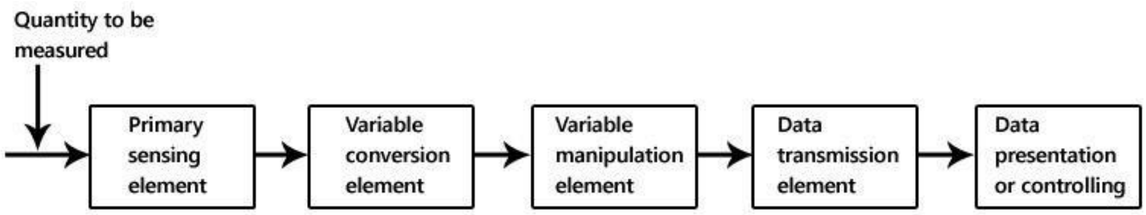
Applications and Uses of PA System

1. The PA system is used in group meetings, presentations, concerts, theaters, large halls, etc.

2. PA systems are also used in sports, stadiums, travel systems, security systems, conference systems, etc.

Block diagram of Instrumentation system

Instrumentation system is branch of engineering which deals with various types of instrument to record, monitor, indicate and control various physical parameters such as pressure, temperature, etc.



Block diagram of instrumentation system

The block diagram shown above is of basic instrumentation system. It consist of primary sensing element, variable manipulation element, data transmission element and data presentation element.

Primary sensing element

The primary sensing element is also known as sensor. Basically transducers are used as a primary sensing element. Here, the physical quantity (such as temperature, pressure etc.) are sensed and then converted into analogues signal.

Variable conversion element

It converts the output of primary sensing element into suitable form without changing information. Basically these are secondary transducers.

Variable manipulation element

The output of transducer may be electrical signal i.e. voltage, current or other electrical parameter. Here, manipulation means change in numerical value of signal. This element is usedto convert the signal into suitable range.

Data transmission element

Sometimes it is not possible to give direct read out of the quality at a particular place (Example – Measurement of temperature in the furnace). In such a case, the data should transfer from one place to another place through channel which is known as data transmission element. Typically transmission path are pneumatic pipe, electrical cable and radio links. When radio link is used, the electronic instrumentation system is called as telemetry system.

Data presentation or controlling element

Finally the output is recorded or given to the controller to perform action. It performs different functions like indicating, recording or controlling.

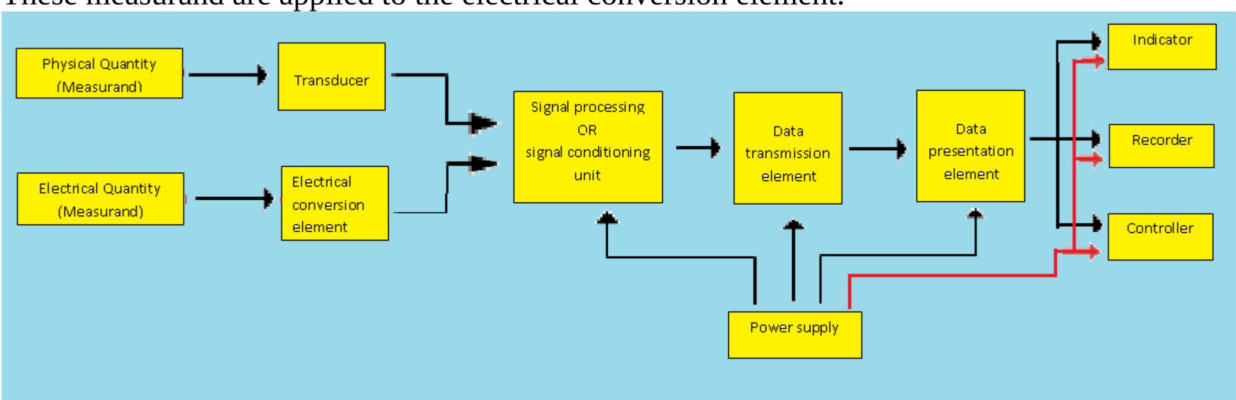
(Extra information about Electronic Instrumentation System For your understanding)

Electronic Instrumentation System

- Fig shows block diagram of generalized electronics instrumentation system, in which number of element worked together to perform a desired function accurately i.e. to measure the measurand quantity and display it or record it.
- We will discuss the different element separately so it is easy for us to understand the system in detail.

Measurand (physical quantity or electrical quantity) :

- The physical or electrical quantity which is to be measurand is called as measurand. If the input to the instrumentation is parameter like pressure, force, level, strain, displacement, temperature, flow, velocity etc. then these parameters is physical measurand. These measurand are applied to the transducer element.
- If the input is current, voltage and frequency then these parameter are called electrical measurand. These measurand are applied to the electrical conversion element.



BLOCK DIAGRAM OF GENERALIZED ELECTRONIC INSTRUMENTATION SYSTEM

Transducer and electrical conversion elements:

- If the measurand is physical quantity then it is converted into equivalent electrical signal with help of element which is called transducer. Transducer is a device which convert one form of energy into another. (phiysical to electrical).
- Most of the transducer is primary sensors which sense the measurand then convert it intoelectrical signal with the help of conversion element.
- If the measured is already electrical signal like voltage, current or frequency then it is give to the electrical conversion element which convert the signal into more suitable form of signals such as 4-20mA, 1-5VDC, 1-10VDC etc.

Signal processing or signal conditioning:

- The output from the transducer elements is given to the signal processing or signal conditioning elements. Sigmal conditioning is a process to modify the output of transducer so that it can be mesurand, controlled and acceptable by next stages.
- In electronic instrumentation system, filter, modulator, A/D converters, D/A converter, amplifiers, integrators, differentiators are the important signal conditioning circuits.

- This stage is required to convert the transducer output into an electrical quantity suitable for proper operation of the last stage or indicator.

Data transmission element:

- If the sensing element and data presentation element of the instrumentation system are awayfrom each other (physically separated) in that case data transmission element is very important .
- This element provides a transmission path for the modified signals to travel from transducer element to the rest of instrumentation elements like recorders, controllers, displays etc.
- In electronic instrumentation system, typically the transmission path is a conducting lines (i.e. electrical cables). In electronic instrumentation system some time radio link is used as a transmission path them the system is called telemetry system.
- This element transmits the data to the remote located control room.

Data presentation element:

- The signal from the data lines are provided to the data presentation element. This element converts the signal into such from that it can be presented by some visual or audible means.
- Function performed by this stage may be demodulation, amplification, filtering, A/D conversion etc.
- This element modifies the signals in such a way that the signals are accepted by recorders, displays, indicators, printers, announcing systems etc. The output of the data presentation element is provided to the recorders, controllers, and indicators as per the requirement of the useror operator or observer.

Output devices:

- The last stage of instrumentation system is required to provide the information about the measurand for immediate reorganization by the operator whatever output is presented on indicator.
- For example, if the system is simple instrumentation with display then measured parameter is displayed directly on the display. If it is required to produce alarm for the over range then indicator or buzzer is used. If the recorder like strip-chart or X-Y recorder etc. To record the data.
- If the system is control system in that case the measured data not only displayed or recorded but also compared with some reference value and control action is generated which is used toremove the error.

Power supply:

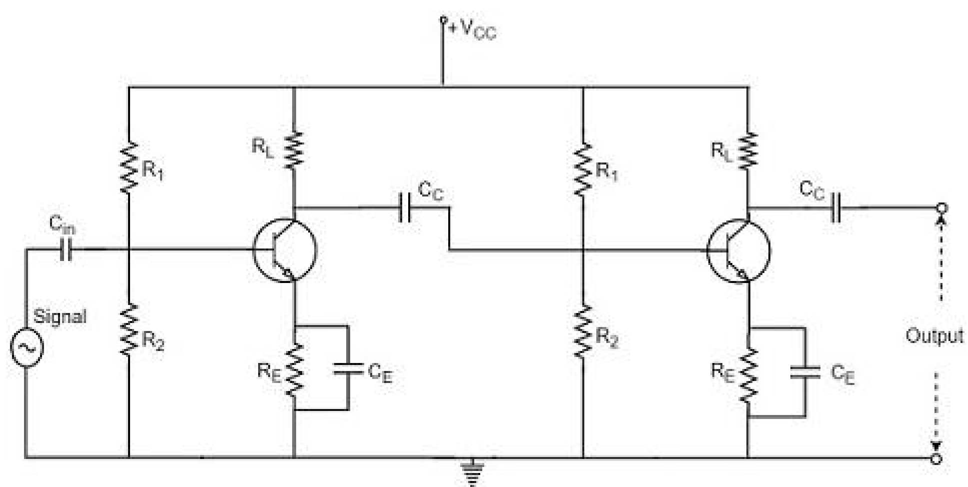
- This is a common unit for all instrumentation system. This provides power to all elements working in the instrumentation setup.
- If the transducer is active transducer (self-generating), in that case power supply is not required.For example if that transducer is thermocouple or piezoelectric crystal.
- For passive transducer power supply is required, for example if the transducer is thermistor orRTD, in that case power supply is important to the transducer block.

The resistance-capacitance coupling is, in short termed as RC coupling. This is the mostly used coupling technique in amplifiers.

Construction of a Two-stage RC Coupled Amplifier

The constructional details of a two-stage RC coupled transistor amplifier circuit are as follows. The two stage amplifier circuit has two transistors, connected in CE configuration and a common power supply V_{CC} is used. The potential divider network R_1 and R_2 and the resistor R_e form the biasing and stabilization network. The emitter by-pass capacitor C_e offers a low reactance path to the signal.

The resistor R_L is used as a load impedance. The input capacitor C_{in} present at the initial stage of the amplifier couples AC signal to the base of the transistor. The capacitor C_C is the coupling capacitor that connects two stages and prevents DC interference between the stages and controls the shift of operating point. The figure below shows the circuit diagram of RC coupled amplifier.



Operation of RC Coupled Amplifier

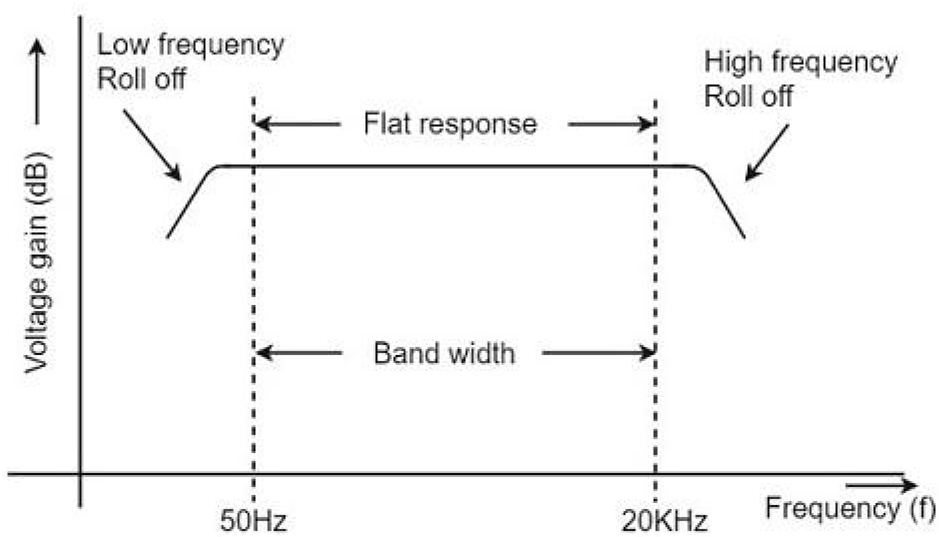
When an AC input signal is applied to the base of first transistor, it gets amplified and appears at the collector load R_L which is then passed through the coupling capacitor C_C to the next stage. This becomes the input of the next stage, whose amplified output again appears across its collector load. Thus the signal is amplified in stage by stage action.

The important point that has to be noted here is that the total gain is less than the product of the gains of individual stages. This is because when a second stage is made to follow the first stage, the **effective load resistance** of the first stage is reduced due to the shunting effect of the input resistance of the second stage. Hence, in a multistage amplifier, only the gain of the last stage remains unchanged.

As we consider a two stage amplifier here, the output phase is same as input. Because the phase reversal is done two times by the two stage CE configured amplifier circuit.

Frequency Response of RC Coupled Amplifier

Frequency response curve is a graph that indicates the relationship between voltage gain and function of frequency. The frequency response of a RC coupled amplifier is as shown in the following graph.



From the above graph, it is understood that the frequency rolls off or decreases for the frequencies below 50Hz and for the frequencies above 20 KHz. whereas the voltage gain for the range of frequencies between 50Hz and 20 KHz is constant.

We know that,

$$XC=12\pi fc$$

It means that the capacitive reactance is inversely proportional to the frequency.

At Low frequencies (i.e. below 50 Hz)

The capacitive reactance is inversely proportional to the frequency. At low frequencies, the reactance is quite high. The reactance of input capacitor C_{in} and the coupling capacitor C_C are so high that only small part of the input signal is allowed. The reactance of the emitter by pass capacitor C_E is also very high during low frequencies. Hence it cannot shunt the emitter resistance effectively. With all these factors, the voltage gain rolls off at low frequencies.

At High frequencies (i.e. above 20 KHz)

Again considering the same point, we know that the capacitive reactance is low at high frequencies. So, a capacitor behaves as a short circuit, at high frequencies. As a result of this, the loading effect of the next stage increases, which reduces the voltage gain. Along with this, as the capacitance of emitter diode decreases, it increases the base current of the transistor due to which the current gain (β) reduces. Hence the voltage gain rolls off at high frequencies.

At Mid-frequencies (i.e. 50 Hz to 20 KHz)

The voltage gain of the capacitors is maintained constant in this range of frequencies, as shown in figure. If the frequency increases, the reactance of the capacitor C_C decreases which tends to increase the gain. But this lower capacitance reactive increases the loading effect of the next stage by which there is a reduction in gain.

Due to these two factors, the gain is maintained constant.

Advantages of RC Coupled Amplifier

The following are the advantages of RC coupled amplifier.

- The frequency response of RC amplifier provides constant gain over a wide frequency range, hence most suitable for audio applications.

- The circuit is simple and has lower cost because it employs resistors and capacitors which are cheap.
- It becomes more compact with the upgrading technology.

Disadvantages of RC Coupled Amplifier

The following are the disadvantages of RC coupled amplifier.

- The voltage and power gain are low because of the effective load resistance.
- They become noisy with age.
- Due to poor impedance matching, power transfer will be low.

Applications of RC Coupled Amplifier

The following are the applications of RC coupled amplifier.

- They have excellent audio fidelity over a wide range of frequency.
- Widely used as Voltage amplifiers
- Due to poor impedance matching, RC coupling is rarely used in the final stages.

Advantages of Digital system over Analog system

1. Ease of programmability

The digital systems can be used for different applications by simply changing the program without additional changes in hardware.

2. Reduction in cost of hardware

The cost of hardware gets reduced by use of digital components and this has been possible due to advances in IC technology. With ICs the number of components that can be placed in a given area of Silicon are increased which helps in cost reduction.

3.High speed

Digital processing of data ensures high speed of operation which is possible due to advances in Digital Signal Processing.

4. High Reliability

Digital systems are highly reliable one of the reasons for that is use of error correction codes.

5. Design is easy

The design of digital systems which require use of Boolean algebra and other digital techniques is easier compared to analog designing.

6. Result can be reproduced easily

Since the output of digital systems unlike analog systems is independent of temperature, noise, humidity and other characteristics of components the reproducibility of results is higher in digital systems than in analog systems.

Disadvantages of Digital Systems

- Use more energy than analog circuits to accomplish the same tasks, thus producing more heat as well.
- Digital circuits are often fragile, in that if a single piece of digital data is lost or misinterpreted the meaning of large blocks of related data can completely change.
- Digital computer manipulates discrete elements of information by means of a binary code.
- Quantization error during analog signal sampling.

NUMBER SYSTEM

Number system is a basis for counting varies items. Modern computers communicate and operate with binary numbers which use only the digits 0 &1. Basic number system used by humans is Decimal number system.

For Ex: Let us consider decimal number 18. This number is represented in binary as 10010.

We observe that binary number system take more digits to represent the decimal number. For large numbers we have to deal with very large binary strings. So this fact gave rise to three new number systems.

i) Octal number systems

ii) Hexa Decimal number system

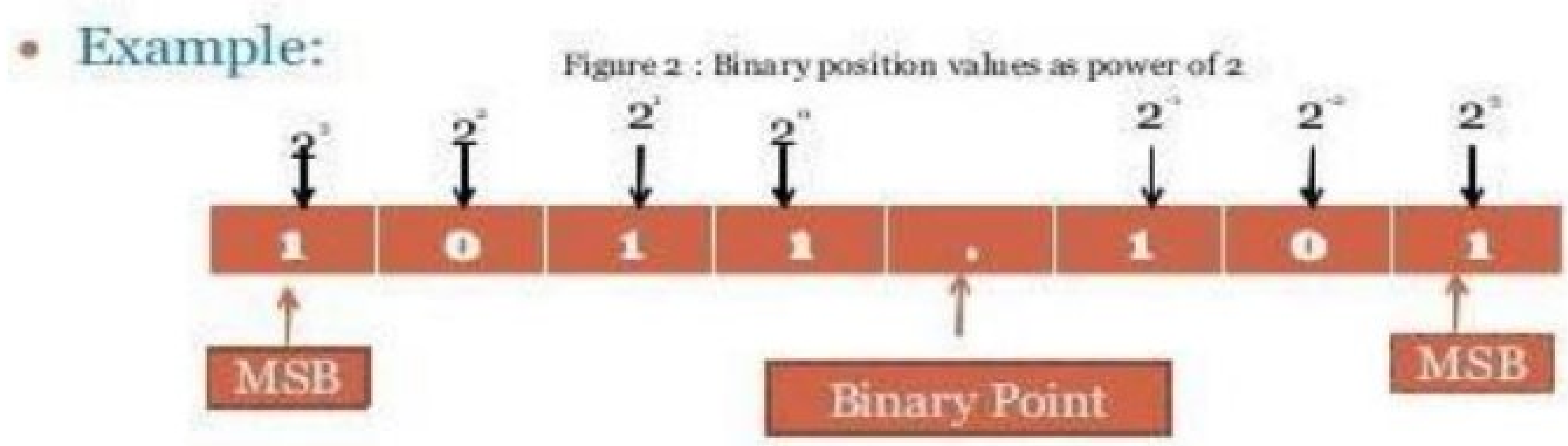
iii) Binary Coded Decimal number(BCD) system

To define any number system we have to specify

- Base of the number system such as 2,8,10 or 16.
- The base decides the total number of digits available in that number system.
- First digit in the number system is always zero and last digit in the number system is always base-1.

Binary number system:

The binary number has a radix of 2. As r = 2, only two digits are needed, and these are 0 and 1. In binary system weight is expressed as power of 2.



The left most bit, which has the greatest weight is called the Most Significant Bit (MSB). And the right most bit which has the least weight is called Least Significant Bit (LSB).

For Ex: $\mathbf{1001.01_2 = [(1) \times 2^3] + [(0) \times 2^2] + [(0) \times 2^1] + [(1) \times 2^0] + [(0) \times 2^{-1}] + [(1) \times 2^2]}$

$\mathbf{1001.01_2 = [1 \times 8] + [0 \times 4] + [0 \times 2] + [1 \times 1] + [0 \times 0.5] + [1 \times 0.25]}$

$\mathbf{1001.01_2 = 9.25_{10}}$

Decimal Number system

The decimal system has ten symbols: 0,1,2,3,4,5,6,7,8,9. In other words, it has a base of 10.

Octal Number System

Digital systems operate only on binary numbers. Since binary numbers are often very long, two shorthand notations, octal and hexadecimal, are used for representing large binary numbers. Octal systems use a base or radix of 8. It uses first eight digits of decimal number system. Thus it has digits from 0 to 7.

Hexa Decimal Number System

The hexadecimal numbering system has a base of 16. There are 16 symbols. The decimal digits 0 to 9 are used as the first ten digits as in the decimal system, followed by the letters A, B, C, D, E and F, which represent the values 10, 11,12,13,14 and 15 respectively.

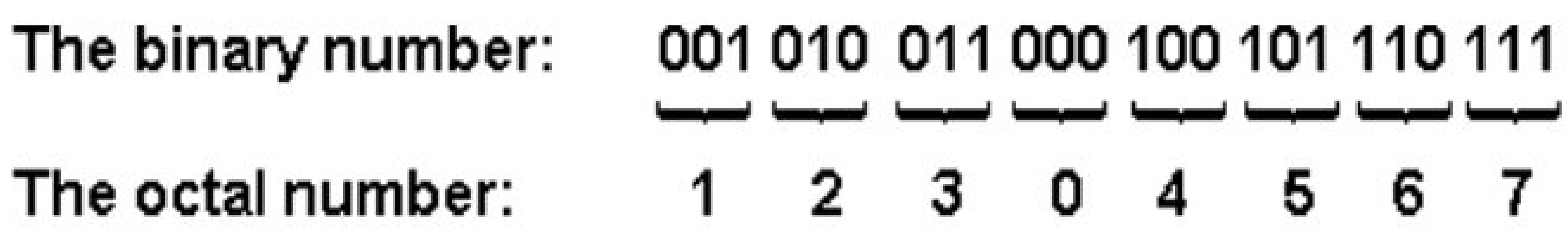
Decimal	Binary	Octal	Hexadecimal
0	0000	0	0
1	0001	1	1
2	0010	2	2
3	0011	3	3
4	0100	4	4
5	0101	5	5
6	0110	6	6
7	0111	7	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

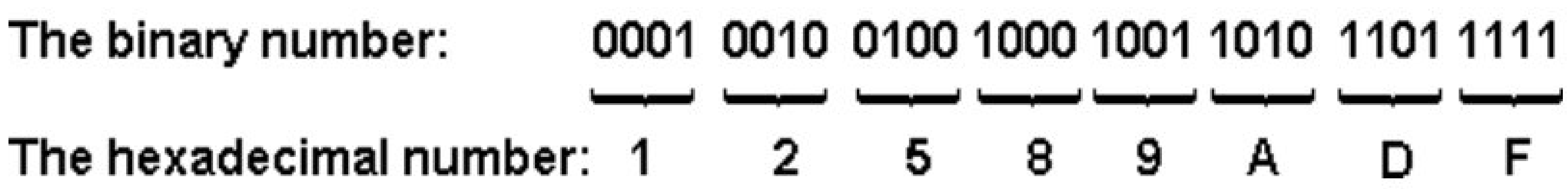
Number Base conversions

The human beings use decimal number system while computer uses binary number system. Therefore it is necessary to convert decimal number system into its equivalent binary.

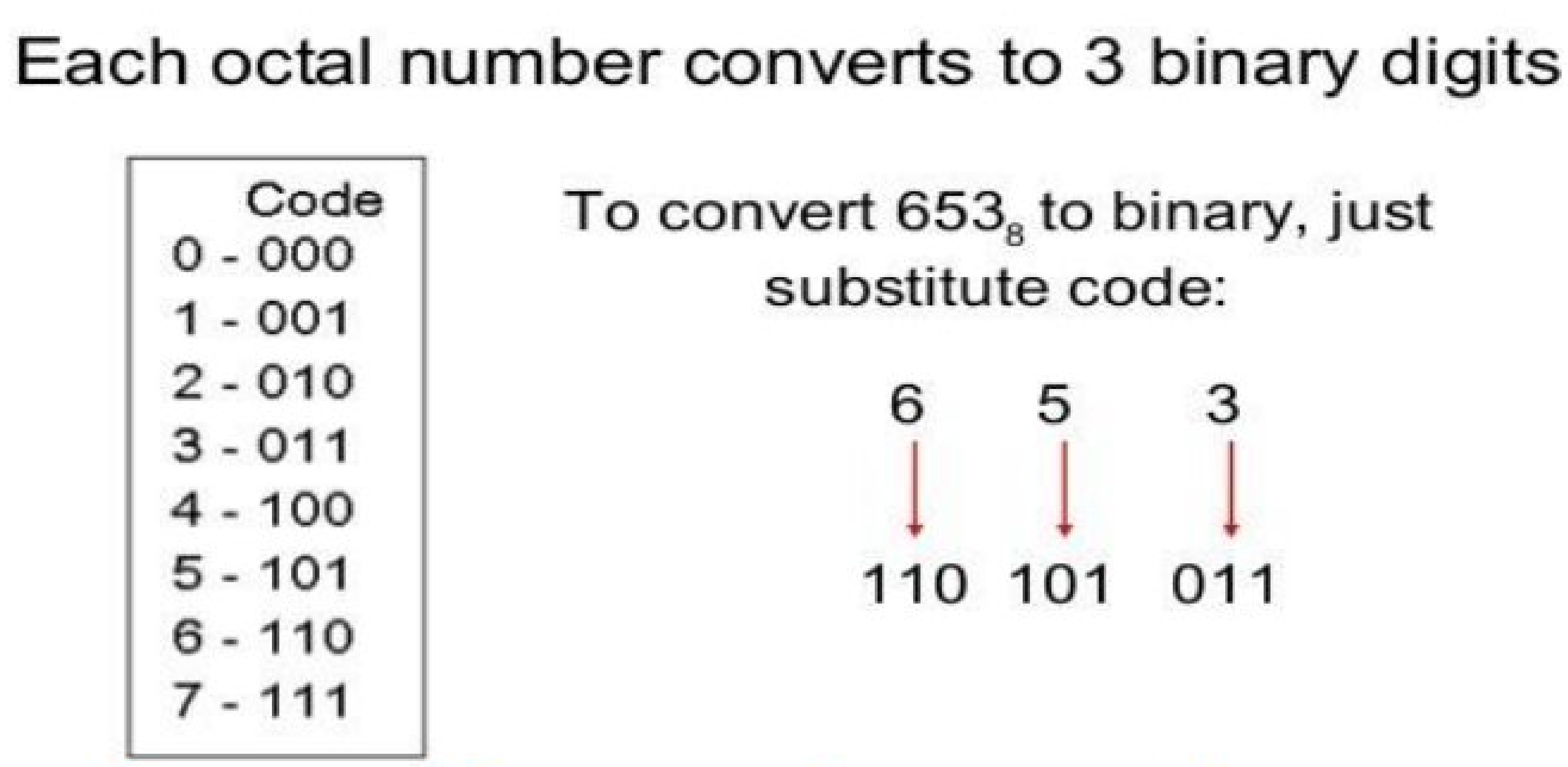
i) Binary to octal number conversion

ii) Binary to hexa decimal number conversion





iii) Octal to binary Conversion



iv) Hexa to binary conversion

v) Octal to Decimal conversion

Ex: convert 4057.06_8 to octal

$=4x8^3+0x8^2+5x8^1+7x8^0+0x8^{-1}+6x8^{-2}$

=2048+0+40+7+0+0.0937

$=2095.0937_{10}$

vi) Decimal to Octal Conversion

Ex: convert 378.93_{10} to octal

378_{10} to octal: Successive division:

```
8 | 378
  |____
8 |47 ---   2
  |________
8 |5  ---   7      ↑
  |_______
   0  ---   5
```

$=572_8$

0.93_{10} to octal :

0.93x8=7.44

0.44x8=3.52 ↓

0.53x8=4.16

0.16x8=1.28

$=0.7341_8$

$378.93_{10}=572.7341_8$

vii) Hexadecimal to Decimal Conversion

Ex: $5C7_{16}$ to decimal

$=(5x16^2)+(C\ x16^1)+(7\ x16^0)$

=1280+192+7

$=147_{10}$

viii) Decimal to Hexadecimal Conversion

Ex: 2598.67510

```
 1 6 |2598
     |_____
16 16|2        -6
     10        -2
```

= $A26_{(16)}$

0.67510=0.675x16 -- 10.8

=0.800x16 -- 12.8 ↓

=0.800x16 -- 12.8

=0.800x16 -- 12.8

$=0.ACCC_{16}$

$2598.675_{10} = A26.ACCC_{16}$

ix) Octal to hexadecimal conversion:

The simplest way is to first convert the given octal no. to binary & then the binary no. to hexadecimal.

Ex: 756.603_8

7	5	6	.	6	0	3
111	101	110	.	110	000	011
0001	1110	1110	.	1100	0001	1000
1	E	E	.	C	1	8

x) Hexadecimal to octal conversion:

First convert the given hexadecimal no. to binary & then the binary no. to octal.

Ex: B9F.AE16

B	9	F	.	A	E		
1011	1001	1111	.	1010	1110		
101	110	011	111	.	101	011	100
5	6	3	7	.	5	3	4

=5637.534

Complements:

In digital computers to simplify the subtraction operation & for logical manipulation complements are used. There are two types of complements used in each radix system.

i) The radix complement or r's complement
ii) The diminished radix complement or (r-1)'s complement

Ex: Subtract 14 from 25 using 8 bit 1‘s EX: ADD -25 to +14

25	=	00011001	+14	= 00001110
-45	=	11110001	-25	=+11100110
+11		(1)00001010	-11	11110100
	+1			
			No carry	MSB =1
		00001011		result=-ve=-11_{10}

MSB is a 0 so result is +ve (binary)

=+11_{10}

Binary codes

Binary codes are codes which are represented in binary system with modification from the original ones.

- Weighted Binary codes
- Non Weighted Codes

Weighted binary codes are those which obey the positional weighting principles, each position of the number represents a specific weight. The binary counting sequence is an example.

Decimal	BCD 8421	Excess-3	84-2-1	2421	5211	Bi-Quinary 5043210			5	0	4	3	2	1	0
0	0000	0011	0000	0000	0000	0100001		0		X					X
1	0001	0100	0111	0001	0001	0100010		1		X				X	
2	0010	0101	0110	0010	0011	0100100		2		X			X		
3	0011	0110	0101	0011	0101	0101000		3		X		X			
4	0100	0111	0100	0100	0111	0110000		4		X	X				
5	0101	1000	1011	1011	1000	1000001		5	X						X
6	0110	1001	1010	1100	1010	1000010		6	X					X	
7	0111	1010	1001	1101	1100	1000100		7	X				X		
8	1000	1011	1000	1110	1110	1001000		8	X			X			
9	1001	1111	1111	1111	1111	1010000		9	X		X				

Reflective Code

A code is said to be reflective when code for 9 is complement for the code for 0, and so is for 8 and 1 codes, 7 and 2, 6 and 3, 5 and 4. Codes 2421, 5211, and excess-3 are reflective, whereas the 8421 code is not.

Sequential Codes

A code is said to be sequential when two subsequent codes, seen as numbers in binary representation, differ by one. This greatly aids mathematical manipulation of data. The 8421 and Excess-3 codes are sequential, whereas the 2421 and 5211 codes are not.

Non weighted codes

Non weighted codes are codes that are not positionally weighted. That is, each position within the binary number is not assigned a fixed value. Ex: Excess-3 code

Excess-3 Code

Excess-3 is a non weighted code used to express decimal numbers. The code derives its name from the fact that each binary code is the corresponding 8421 code plus 0011(3).

Gray Code

The gray code belongs to a class of codes called minimum change codes, in which only one bit in the code changes when moving from one code to the next. The Gray code is non-weighted code, as the position of bit does not contain any weight. The gray code is a reflective digital code which has the special property that any two subsequent numbers codes differ by only one bit. This is also called a unit- distance code. In digital Gray code has got a special place.

Decimal Number	Binary Code	Gray Code	Decimal Number	Binary Code	Gray Code
0	0000	0000	8	1000	1100
1	0001	0001	9	1001	1101
2	0010	0011	10	1010	1111
3	0011	0010	11	1011	1110
4	0100	0110	12	1100	1010
5	0101	0111	13	1101	1011
6	0110	0101	14	1110	1001
7	0111	0100	15	1111	1000

Binary to Gray Conversion

- Gray Code MSB is binary code MSB.
- Gray Code MSB-1 is the XOR of binary code MSB and MSB-1.
- MSB-2 bit of gray code is XOR of MSB-1 and MSB-2 bit of binary code.
- MSB-N bit of gray code is XOR of MSB-N-1 and MSB-N bit of binary code.

8421 BCD code (Natural BCD code):

Each decimal digit 0 through 9 is coded by a 4 bit binary no. called natural binary codes. Because of the 8,4,2,1 weights attached to it. It is a weighted code & also sequential . it is useful for mathematical operations. The advantage of this code is its case of conversion to & from decimal. It is less efficient than the pure binary, it require more bits.

Ex: 14→1110 in binary

But as 0001 0100 in 8421 ode.

The disadvantage of the BCD code is that , arithmetic operations are more complex than they are in pure binary . There are 6 illegal combinations 1010,1011,1100,1101,1110,1111 in these codes, they are not part of the 8421 BCD code system . The disadvantage of 8421 code is, the rules of binary addition 8421 no, but only to the individual 4 bit groups.

BCD Addition:

It is individually adding the corresponding digits of the decimal no,s expressed in 4 bit binary groups starting from the LSD . If there is no carry & the sum term is not an illegal code , no correction is needed .If there is a carry out of one group to the next group or if the sum term is an illegal code then 6_{10}(0100) is added to the sum term of that group & the resulting carry is added to the next group.

Ex: Perform decimal additions in 8421 code

(a)25+13

In BCD 25= 0010 0101

In BCD +13 =+0001 0011

——— ——————

38 0011 1000

No carry , no illegal code .This is the corrected sum

Error Position	For 15 bit code $C_4 C_3 C_2 C_1$	For 12 bit code $C_4 C_3 C_2 C_1$	For 7 bit code $C_3 C_2 C_1$
0	0 0 0 0	0 0 0 0	0 0 0
1	0 0 0 1	0 0 0 1	0 0 1
2	0 0 1 0	0 0 1 0	0 1 0
3	0 0 1 1	0 0 1 1	0 1 1
4	0 1 0 0	0 1 0 0	1 0 0
5	0 1 0 1	0 1 0 1	1 0 1
6	0 1 1 0	0 1 1 0	1 1 0
7	0 1 1 1	0 1 1 1	1 1 1
8	1 0 0 0	1 0 0 0	
9	1 0 0 1	1 0 0 1	
10	1 0 1 0	1 0 1 0	
11	1 0 1 1	1 0 1 1	
12	1 1 0 0	1 1 0 0	
13	1 1 0 1		
14	1 1 1 0		
15	1 1 1 1		

7-bit Hamming code:

To transmit four data bits, 3 parity bits located at positions 2^0 21&2^2 from left are added to make a 7 bit codeword which is then transmitted.

The word format

P_1	P_2	D_3	P_4	D_5	D_6	D_7

D—Data bits P-
Parity bits

Decimal Digit	For BCD P1P2D3P4D5D6D7	For Excess-3 P1P2D3P4D5D6D7
0	0 0 0 0 0 0 0	1 0 0 0 0 1 1
1	1 1 0 1 0 0 1	1 0 0 1 1 0 0
2	0 1 0 1 0 1 1	0 1 0 0 1 0 1
3	1 0 0 0 0 1 1	1 1 0 0 1 1 0
4	1 0 0 1 1 0 0	0 0 0 1 1 1 1
5	0 1 0 0 1 0 1	1 1 1 0 0 0 0
6	1 1 0 0 1 1 0	0 0 1 1 0 0 1
7	0 0 0 1 1 1 1	1 0 1 1 0 1 0
8	1 1 1 0 0 0 0	0 1 1 0 0 1 1
9	0 0 1 1 0 0 1	0 1 1 1 1 0 0

Ex: Encode the data bits 1101 into the 7 bit even parity Hamming Code

The bit pattern is

P1P2D3P4D5D6D7

1 1 0 1

Bits 1,3,5,7 (P_1 111) must have even parity, so P_1 =1

Bits 2, 3, 6, 7(P_2 101) must have even parity, so P_2 =0

Bits 4,5,6,7 (P_4 101)must have even parity, so P_4 =0

The final code is 1010101

EX: Code word is 1001001

Bits 1,3,5,7 (C_1 1001) →no error →put a 0 in the 1's position→C1=0

Bits 2, 3, 6, 7(C_2 0001)) → error →put a 1 in the 2's position→C2=1

Bits 4,5,6,7 (C_4 1001)) →no error →put a 0 in the 4's position→C3=0

15-bit Hamming Code: It transmit 11 data bits, 4 parity bits located 2^0 2^1 2^2 2^3

Word format is

P_1	P_2	D_3	P_4	D_5	D_6	D_7	P_8	D_9	D10	D11	D12	D13	D14	D15

12-Bit Hamming Code: It transmit 8 data bits, 4 parity bits located at position 2^0 2^1 2^2 2^3

Word format is

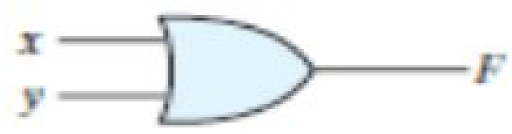
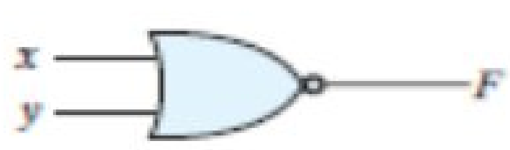
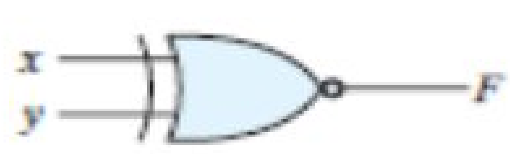
P_1	P_2	D_3	P_4	D_5	D_6	D_7	P_8	D_9	D10	D11	D12

Alphanumeric Codes:

These codes are used to encode the characteristics of alphabet in addition to the decimal digits. It is used for transmitting data between computers & its I/O device such as printers, keyboards & video display terminals.Popular modern alphanumeric codes are ASCII code & EBCDIC code.

Digital Logic Gates

Boolean functions are expressed in terms of AND, OR, and NOT operations, it is easier to implement a Boolean function with these type of gates.

Name	Graphic symbol	Algebraic function	Truth table
AND		$F = x \cdot y$	x y F 0 0 0 0 1 0 1 0 0 1 1 1
OR		$F = x + y$	x y F 0 0 0 0 1 1 1 0 1 1 1 1
Inverter		$F = x'$	x F 0 1 1 0
Buffer		$F = x$	x F 0 0 1 1
NAND		$F = (xy)'$	x y F 0 0 1 0 1 1 1 0 1 1 1 0
NOR		$F = (x + y)'$	x y F 0 0 1 0 1 0 1 0 0 1 1 0
Exclusive-OR (XOR)		$F = xy' + x'y$ $= x \oplus y$	x y F 0 0 0 0 1 1 1 0 1 1 1 0
Exclusive-NOR or equivalence		$F = xy + x'y'$ $= (x \oplus y)'$	x y F 0 0 1 0 1 0 1 0 0 1 1 1

Properties of XOR Gates

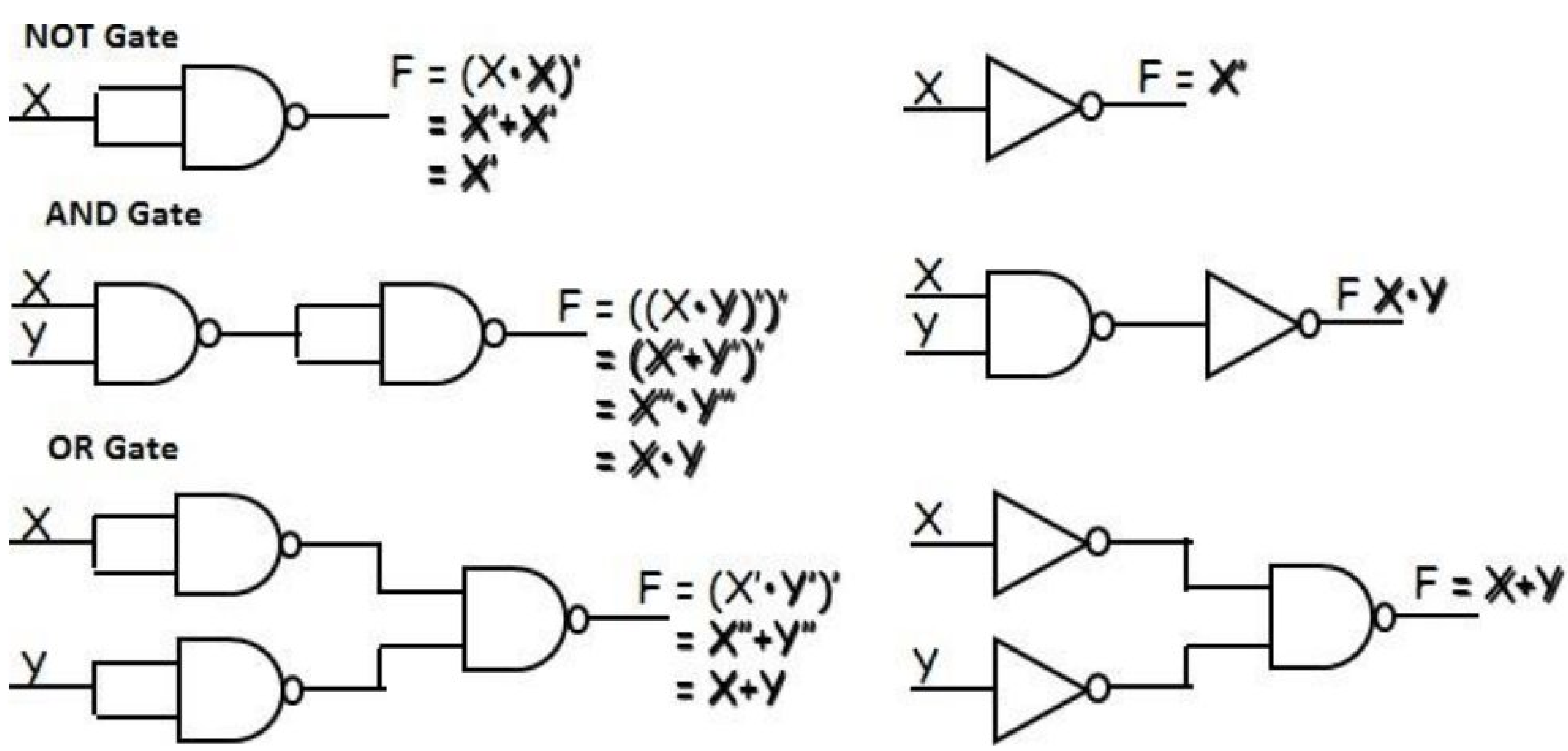
- XOR (also ⊕) : the “not-equal” function
- XOR(X,Y) = $X \oplus Y = X'Y + XY'$
- Identities:
  - $X \oplus 0 = X$
  - $X \oplus 1 = X'$
  - $X \oplus X = 0$
  - $X \oplus X' = 1$
- Properties:
  - $X \oplus Y = Y \oplus X$
  - $(X \oplus Y) \oplus W = X \oplus (Y \oplus W)$

Universal Logic Gates

NAND and NOR gates are called Universal gates. All fundamental gates (NOT, AND, OR) can be realized by using either only NAND or only NOR gate. A universal gate provides flexibility and offers enormous advantage to logic designers.

NAND as a Universal Gate

NAND Known as a “universal” gate because ANY digital circuit can be implemented with NAND gates alone.
To prove the above, it suffices to show that AND, OR, and NOT can be implemented using NAND gates only.



Boolean Algebra: In 1854, George Boole developed an algebraic system now called Boolean algebra. In 1938, Claude E. Shannon introduced a two-valued Boolean algebra called switching algebra that represented the properties of bistable electrical switching circuits. For the formal definition of Boolean algebra, we shall employ the postulates formulated by E. V. Huntington in 1904.

Boolean algebra is a system of mathematical logic. It is an algebraic system consisting of the set of elements (0, 1), two binary operators called OR, AND, and one unary operator NOT. It is the basic mathematical tool in the analysis and synthesis of switching circuits. It is a way to express logic functions algebraically.

Boolean algebra, like any other deductive mathematical system, may be defined with aset of elements, a set of operators, and a number of unproved axioms or postulates. A *set* of elements is anycollection of objects having a common property. If **S** is a set and ***x*** and ***y*** are certain objects, then **x Î S**denotes that ***x*** is a member of the set **S**, and ***y*** **ÏS** denotes that ***y*** is not an element of **S**. A set with adenumerable number of elements is specified by braces: **A** = {1,2,3,4}, *i.e.* the elements of set **A** are thenumbers 1, 2, 3, and 4. A *binary operator* defined on a set S of elements is a rule that assigns to each pair ofelements from S a unique element from S._ Example: In *a***b*=*c*, we say that * is a binary operator if it specifies a rule for finding *c* from the pair (*a*,*b*)and also if *a*, *b*, *c* Î S.

Axioms and laws of Boolean algebra

Axioms or Postulates of Boolean algebra are a set of logical expressions that we accept without proof and upon which we can build a set of useful theorems.

	AND Operation	OR Operation	NOT Operation
Axiom1 :	0.0=0	0+0=0	$\overline{0}$=1
Axiom2:	0.1=0	0+1=1	$\overline{1}$=0
Axiom3:	1.0=0	1+0=1	
Axiom4:	1.1=1	1+1=1	

AND Law	OR Law
Law1: A.0=0 (Null law)	Law1: A+0=A
Law2: A.1=A (Identity law)	Law2: A+1=1
Law3: A.A=A (Impotence law)	Law3: A+A=A (Impotence law)

CLOSURE: The Boolean system is *closed* with respect to a binary operator if for every pair of Boolean values,it produces a Boolean result. For example, logical AND is closed in the Boolean system because it accepts only Boolean operands and produces only Boolean results.

_ A set *S* is closed with respect to a binary operator if, for every pair of elements of *S*, the binary operator specifies a rule for obtaining a unique element of *S*.

_ For example, the set of natural numbers N = {1, 2, 3, 4, … 9} is closed with respect to the binary operator plus (+) by the rule of arithmetic addition, since for any *a*, *b* Î N we obtain a unique *c* Î N by the operation *a* + *b* = c.

ASSOCIATIVE LAW:

A binary operator * on a set *S* is said to be associative whenever $(x * y) * z = x * (y * z)$ for all *x, y, z* Î S, forall Boolean values x, y and z.

COMMUTATIVE LAW:

A binary operator * on a set *S* is said to be commutative whenever $x * y = y * x$ for all *x, y, z* ϵ S

IDENTITY ELEMENT:

A set ***S*** is said to have an identity element with respect to a binary operation * on S if there exists an element $e \epsilon$ S with the property $e * x = x * e = x$ for every x ϵ S

BASIC IDENTITIES OF BOOLEAN ALGEBRA

- *Postulate 1(Definition)*: A Boolean algebra is a closed algebraic system containing a set *K* of two or more elements and the two operators · and + which refer to logical AND and logical OR •$x + 0 = x$
- $x \cdot 0 = 0$
- $x + 1 = 1$
- $x \cdot 1 = 1$
- $x + x = x$
- $x \cdot x = x$
- $x + x' = x$
- $x \cdot x' = 0$
- $x + y = y + x$
- $xy = yx$
- $x + (y + z) = (x + y) + z$
- $x (yz) = (xy) z$
- $x (y + z) = xy + xz$
- $x + yz = (x + y)(x + z)$
- $(x + y)' = x' y'$
- $(xy)' = x' + y'$

- $(x')' = x$

DeMorgan's Theorem

(a) $(a + b)' = a'b'$

(b) $(ab)' = a' + b'$

Generalized DeMorgan's Theorem

(a) $(a + b + \dots z)' = a'b' \dots z'$
(b) $(a.b \dots z)' = a' + b' + \dots z'$

Basic Theorems and Properties of Boolean algebra Commutative law

Law1: A+B=B+A Law2: A.B=B.A

Associative law

Law1: A + (B +C) = (A +B) +C Law2: A(B.C) = (A.B)C

Distributive law

Law1: A.(B + C) = AB+ AC Law2: A + BC = (A + B).(A +C)

Absorption law

Law1: A +AB =A Law2: A(A +B) = A

Solution: A(1+B)
A

Solution: A.A+A.B
A+A.B
A(1+B)
A

Consensus Theorem

Theorem1. AB+ A'C + BC = AB + A'C Theorem2. (A+B). (A'+C).(B+C) =(A+B).(A'+C)

The BC term is called the consensus term and is redundant. The consensus term is formed from a PAIR OF TERMS in which a variable (A) and its complement (A') are present; the consensus term is formed by multiplying the two terms and leaving out the selected variable and its complement

Consensus Theorem1 Proof:

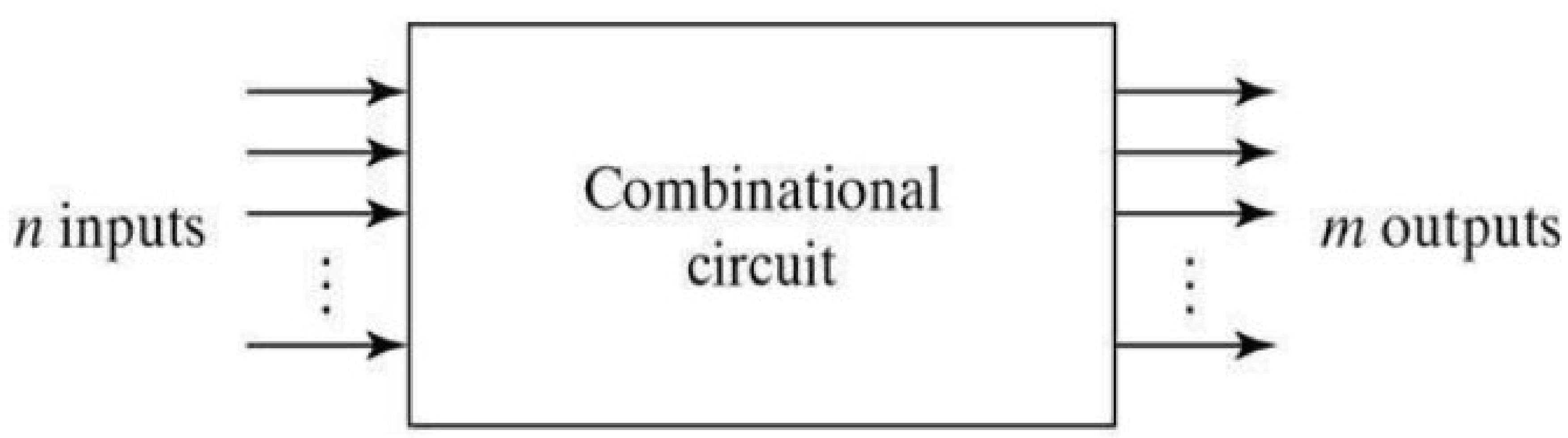
AB+A'C+BC=AB+A'C+(A+A')BC
=AB+A'C+ABC+A'BC

UNIT-III

COMBINATIONAL CIRCUITS

Combinational Logic

- Logic circuits for digital systems may be combinational or sequential.
- A combinational circuit consists of input variables, logic gates, and output variables.



For n input variables,there are 2^n possible combinations of binary input variables .For each possible input Combination ,there is one and only one possible output combination.A combinational circuit can be described by m Boolean functions one for each output variables.Usually the input s comes from flip-flops and outputs goto flip-flops.

Design Procedure:

1. The problem is stated
2. The number of available input variables and required output variables is determined. 3.The input and output variables are assigned lettersymbols.
4.The truth table that defines the required relationship between inputs and outputs is derived.
5.The simplified Boolean function for each output is obtained.

Adders:

Digital computers perform variety of information processing tasks,the one is arithmetic operations.And the most basic arithmetic operation is the addition of two binary digits.i.e, 4 basic possible operations are:

$$0+0=0, 0+1=1, 1+0=1, 1+1=10$$

The first three operations produce a sum whose length is one digit, but when augends and addend bits are equal to 1,the binary sum consists of two digits.The higher significant bit of this result is called a carry.A combinational circuit that performs the addition of two bits is called a half-adder. One that performs the addition of 3 bits (two significant bits & previous carry) is called a full adder.& 2 half adder can employ as a full-adder.

The Half Adder: A Half Adder is a combinational circuit with two binary inputs (augends and addend bits and two binary outputs (sum and carry bits.) It adds the two inputs (A and B) and produces the sum (S) and the carry (C) bits. It is an arithmetic operation of addition of two single bit words.

Inputs		Outputs	
A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

(a) Truth table

(b) Block diagram

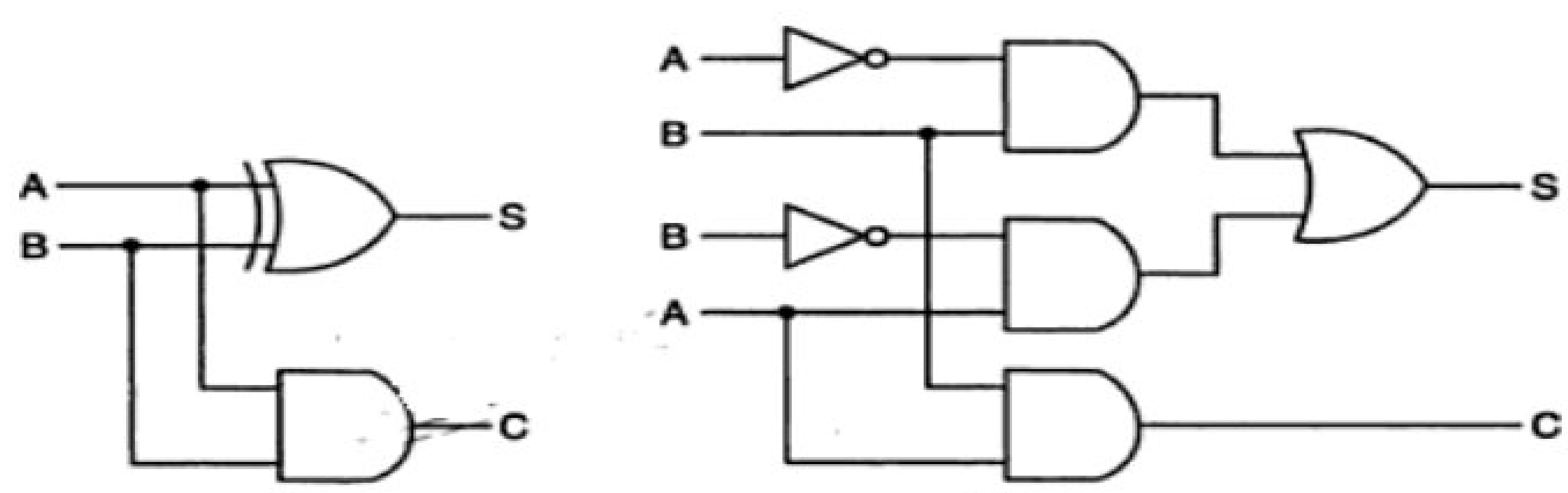
The Sum(S) bit and the carry (C) bit, according to the rules of binary addition, the sum (S) is the X-OR of A and B (It represents the LSB of the sum). Therefore,

$$S=A B+A A \oplus B$$

The carry (C) is the AND of A and B (it is 0 unless both the inputs are 1).Therefore,

$$C=AB$$

A half-adder can be realized by using one X-OR gate and one AND gate a

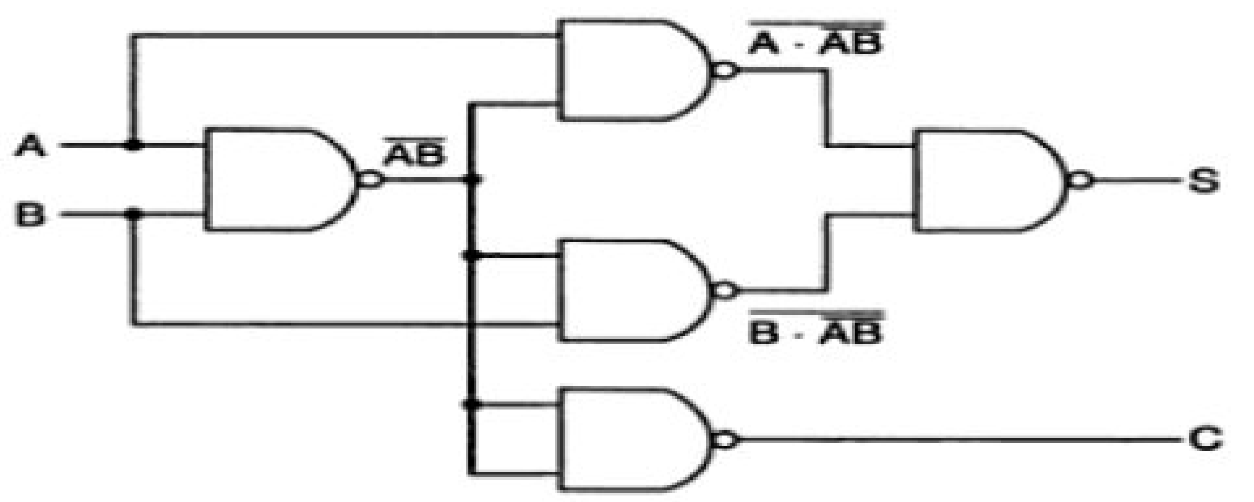


(a) (b)

Logic diagrams of half-adder

NAND LOGIC:

$$S = A\bar{B} + \bar{A}B = A\bar{B} + A\bar{A} + \bar{A}B + B\bar{B}$$
$$= A(\bar{A} + \bar{B}) + B(\bar{A} + \bar{B})$$
$$= A \cdot \overline{AB} + B \cdot \overline{AB}$$
$$= \overline{\overline{A \cdot \overline{AB}} \cdot \overline{B \cdot \overline{AB}}}$$
$$C = AB = \overline{\overline{AB}}$$

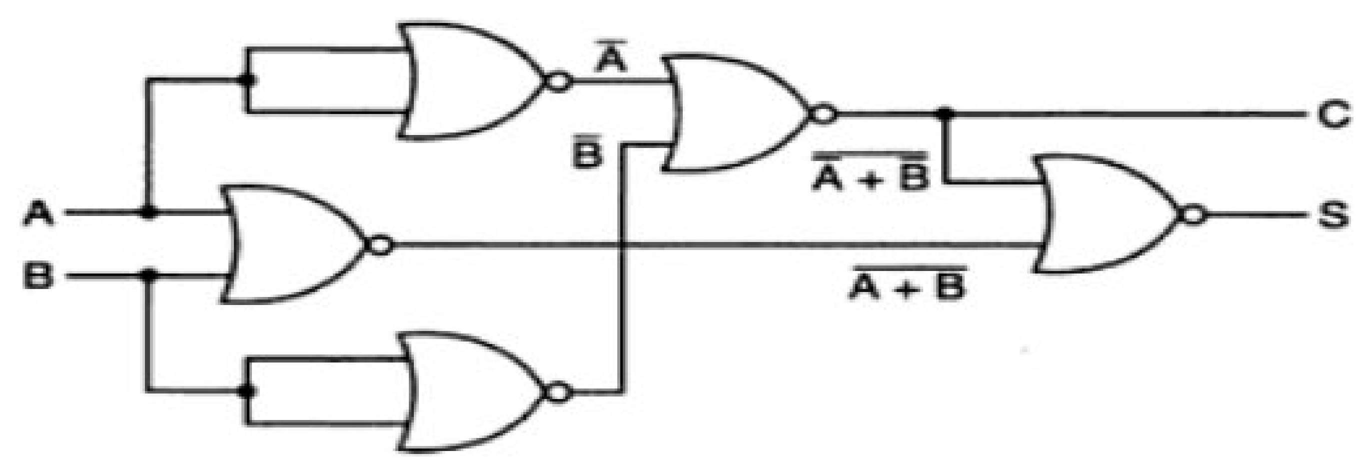


Logic diagram of a half-adder using only 2-input NAND gates.

NOR Logic:

$$S = A\bar{B} + \bar{A}B = A\bar{B} + A\bar{A} + \bar{A}B + B\bar{B}$$
$$= A(\bar{A} + \bar{B}) + B(\bar{A} + \bar{B})$$

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



Logic diagram of a half-adder using only 2-input NOR gates.

The Full Adder:

A Full-adder is a combinational circuit that adds two bits and a carry and outputs a sum bit and a carry bit. To add two binary numbers, each having two or more bits, the LSBs can be added by using a half-adder. The carry resulted from the addition of the LSBs is carried over to the next significant column and added to the two bits in that column. So, in the second and higher columns, the two data bits of that column and the carry bit generated from the addition in the previous column need to be added.

The full-adder adds the bits A and B and the carry from the previous column called the carry-in C_{in} and outputs the sum bit S and the carry bit called the carry-out C_{out} . The variable S gives the value of the least significant bit of the sum. The variable C_{out} gives the output carry.The eight rows under the input variables designate all possible combinations of 1s and 0s that these variables may have. The 1s and 0s for the output variables are determined from the arithmetic sum of the input bits. When all the bits are 0s , the output is 0. The S output is equal to 1 when only 1 input is equal to 1 or when all the inputs are equal to 1. The C_{out} has a carry of 1 if two or three inputs are equal to 1.

Inputs			Sum	Carry
A	B	C_{in}	S	C_{out}
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

(a) Truth table

(b) Block diagram

Full-adder.

From the truth table, a circuit that will produce the correct sum and carry bits in response to every possible combination of A,B and C_{in} is described by

$$S = \overline{A}\,\overline{B}C_{in} + A\overline{B}C_{in} + \overline{A}BC_{in} + \overline{A}BC_{in}$$

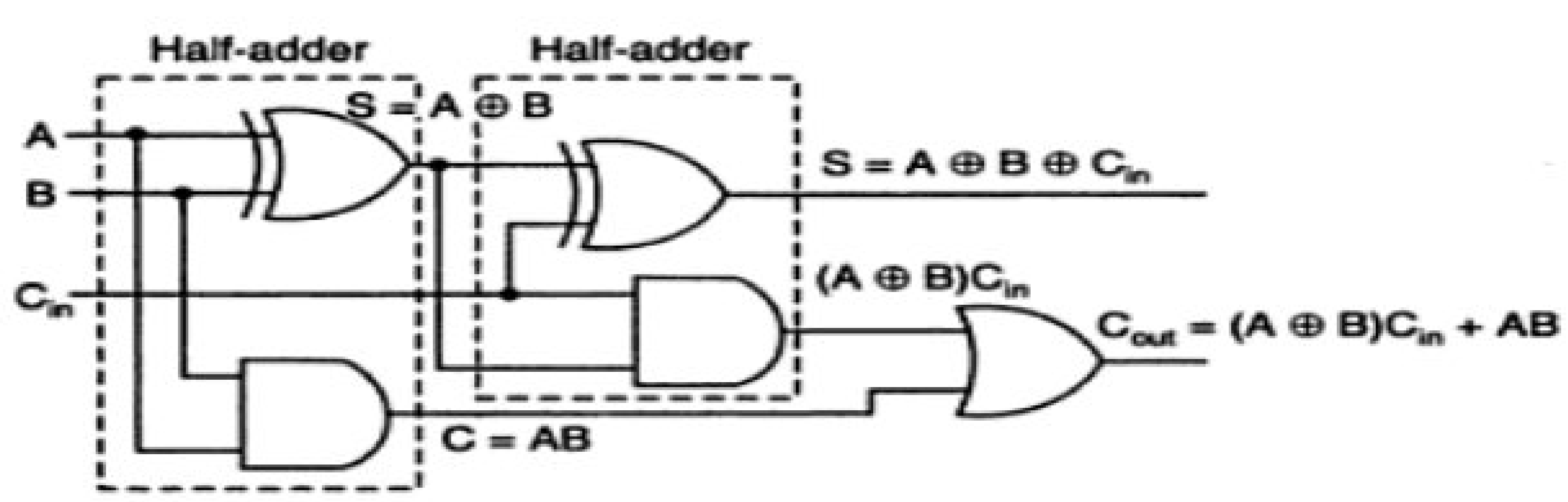
$$C_{out} = A\overline{B}C_{in} + AB\overline{C_{in}} + ABC_{in} + \overline{A}BC_{in}$$

and

$$S = A \oplus B \oplus C_{in}$$

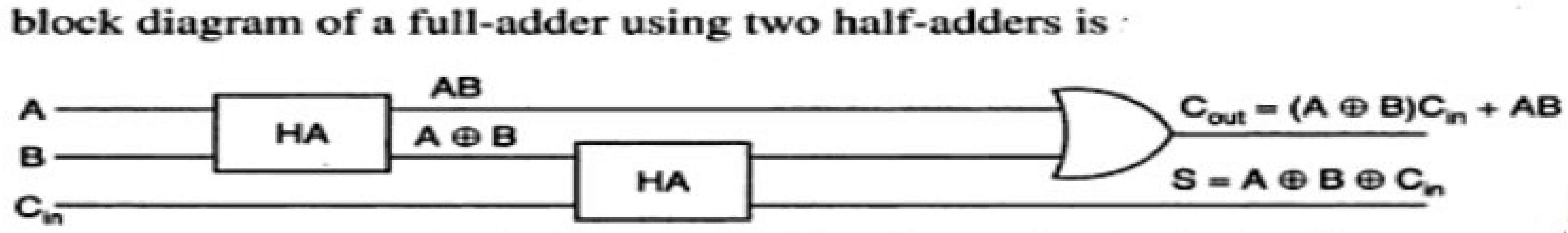
$$C_{out} = AC_{in} + BC_{in} + AB$$

The sum term of the full-adder is the X-OR of A,B, and C_{in}, i.e, the sum bit the modulo sum of the data bits in that column and the carry from the previous column. The logic diagram of the full-adder using two X-OR gates and two AND gates (i.e, Two half adders) and one OR gate is



Logic diagram of a full-adder using two half-adders.

The block diagram of a full-adder using two half-adders is



Block diagram of a full-adder using two half-adders.

Even though a full-adder can be constructed using two half-adders, the disadvantage is that the bits must propagate through several gates in accession, which makes the total propagation delay greater than that of the full-adder circuit using AOI logic.

The Full-adder neither can also be realized using universal logic, i.e., either only NAND gates or only NOR gates as

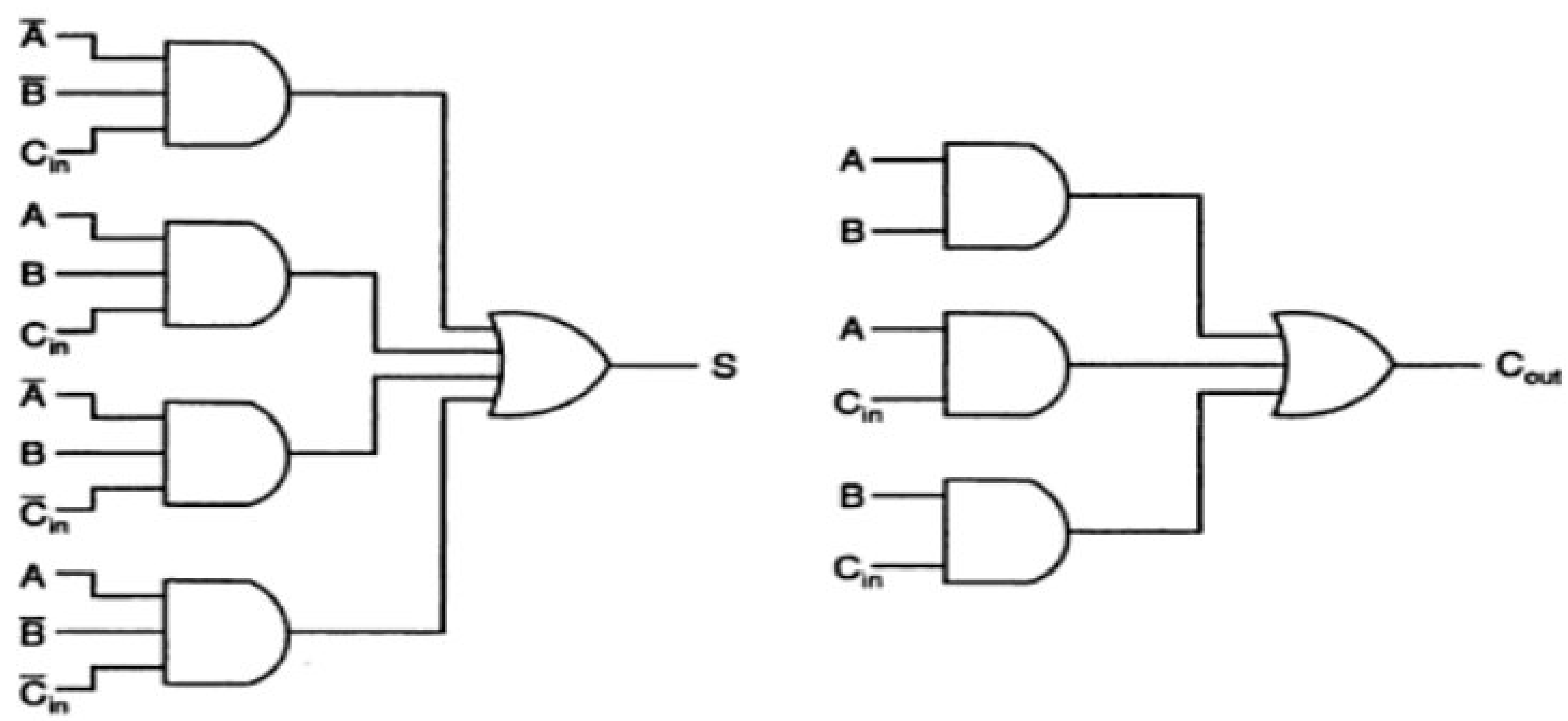
$$A \oplus B = \overline{\overline{A \cdot \overline{AB}} \cdot \overline{B \cdot \overline{AB}}}$$

Then

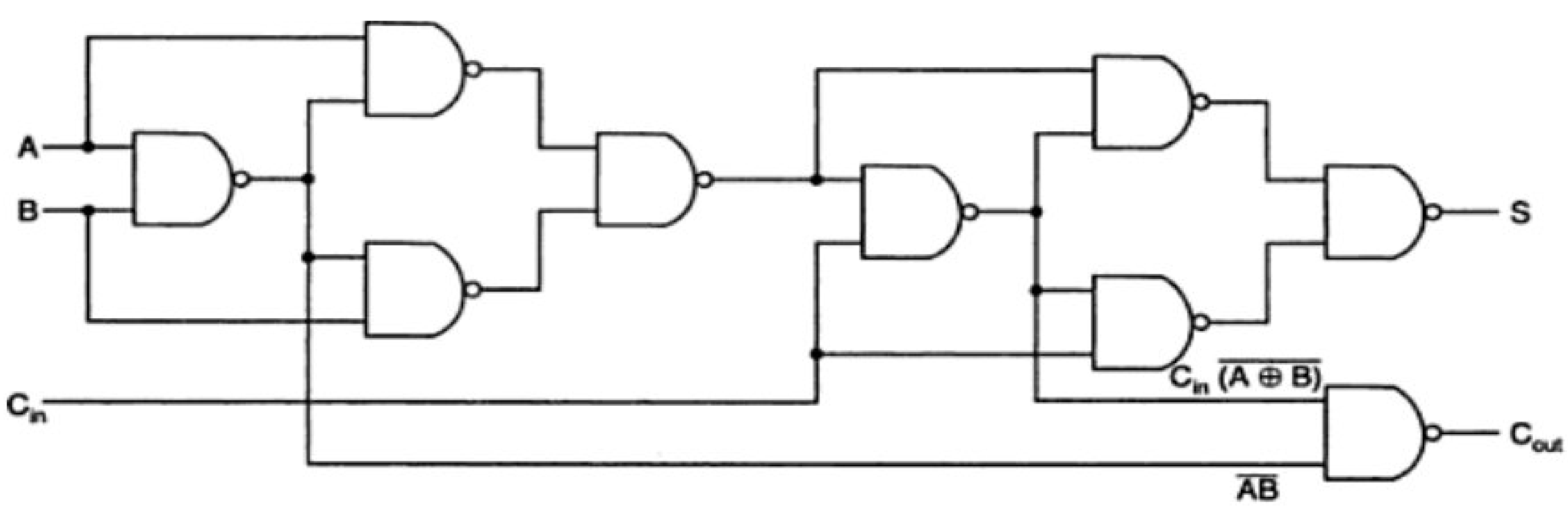
$$S = A \oplus B \oplus C_{in} = \overline{\overline{(A \oplus B) \cdot \overline{(A \oplus B)C_{in}}} \cdot \overline{C_{in} \cdot \overline{(A \oplus B)C_{in}}}}$$

NAND Logic:

$$C_{out} = C_{in}(A \oplus B) + AB = \overline{\overline{C_{in}(A \oplus B)} \cdot \overline{AB}}$$



Sum and carry bits of a full-adder using AOI logic.



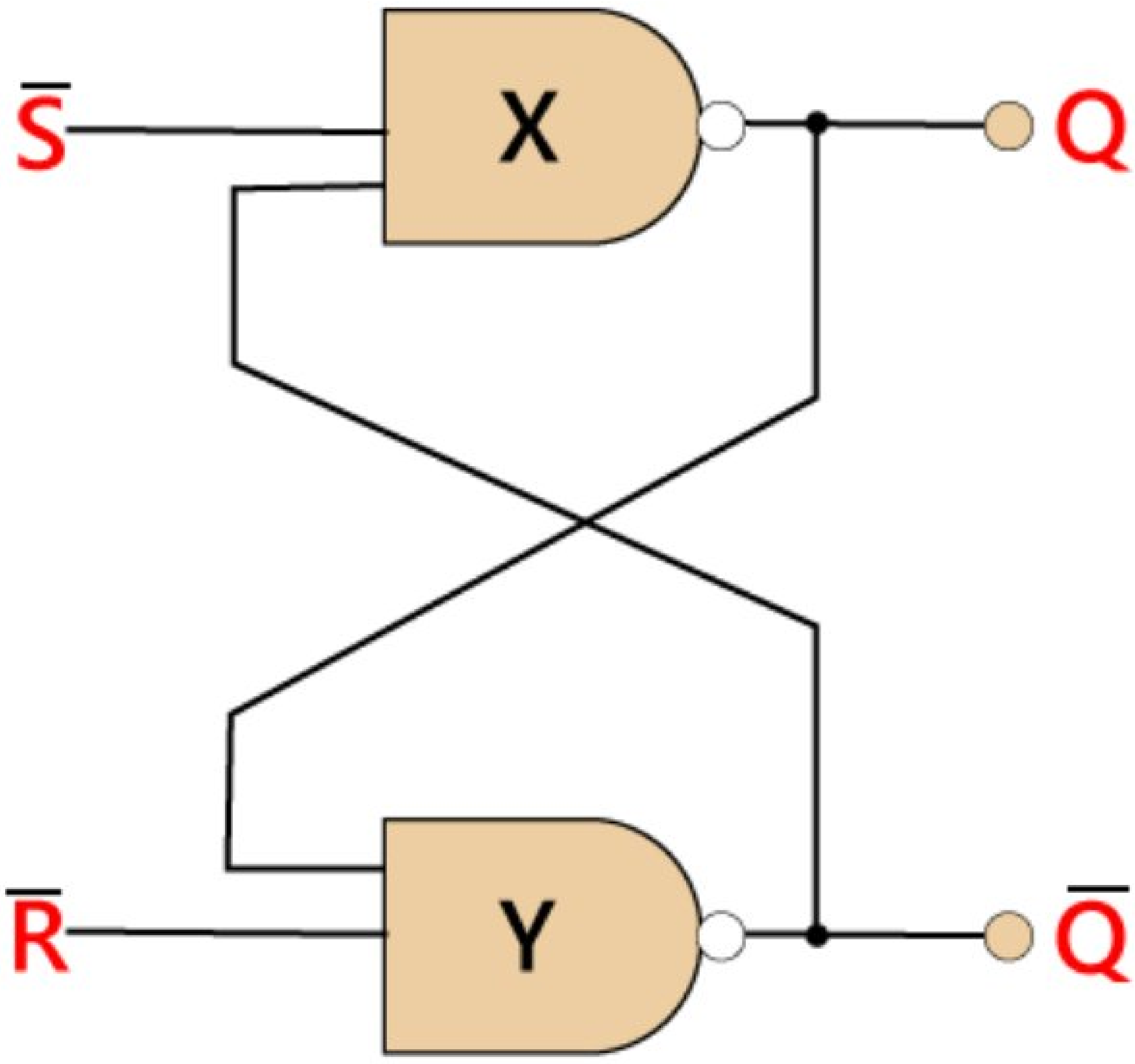
Logic diagram of a full-adder using only 2-input NAND gates.

Basics of Flip Flop

A circuit that has two stable states is treated as a **flip flop**. These stable states are used to store binary data that can be changed by applying varying inputs. The flip flops are the fundamental building blocks of the digital system. Flip flops and latches are examples of data storage elements. In the sequential logical circuit, the flip flop is the basic storage element. The latches and flip flops are the basic storage elements but different in working. There are the following types of flip flops:

SR Flip Flop

The S-R flip flop is the most common flip flop used in the digital system. In SR flip flop, when the set input "S" is true, the output Y will be high, and Y' will be low. It is required that the wiring of the circuit is maintained when the outputs are established. We maintain the wiring until set or reset input goes high, or power is shutdown.



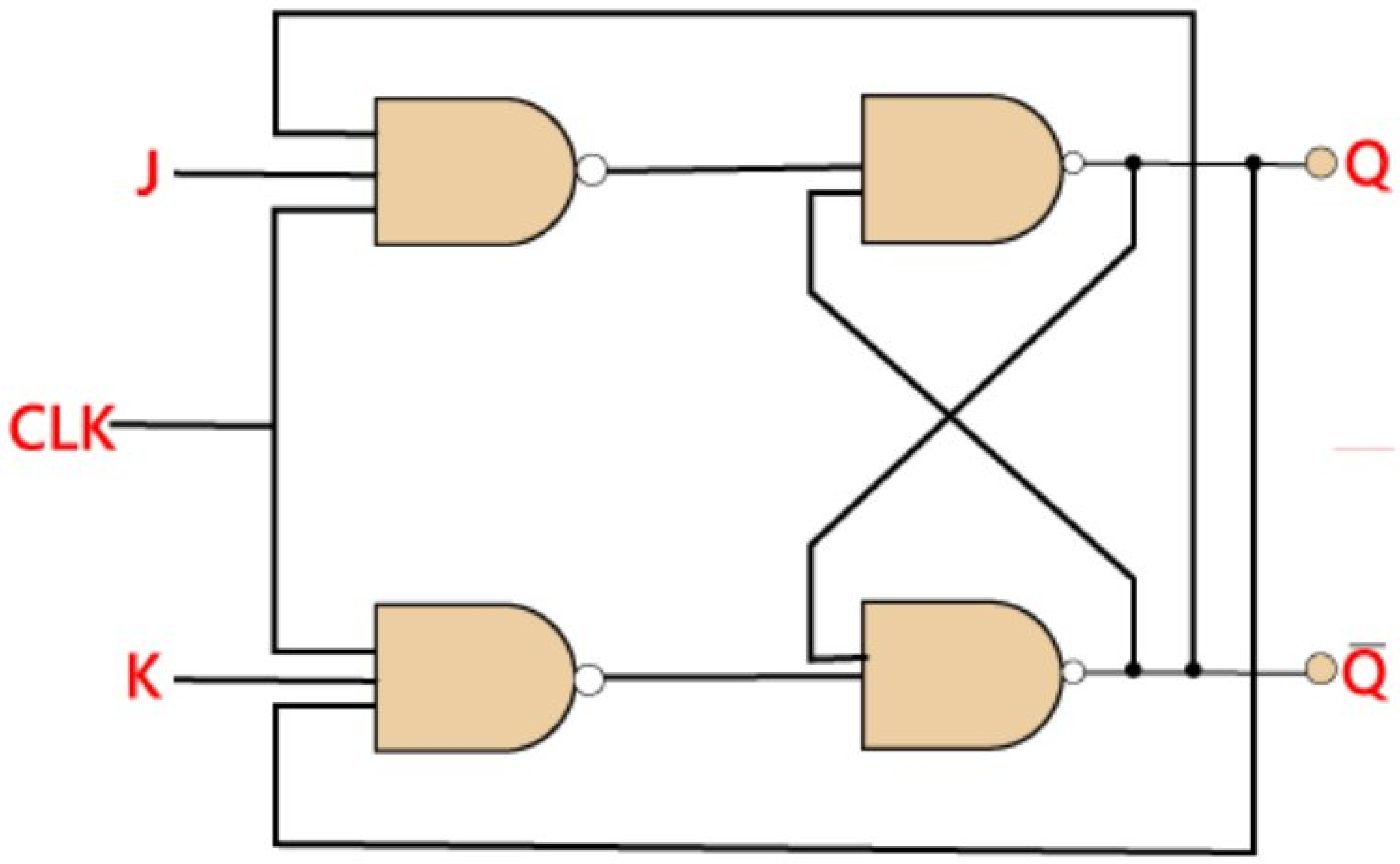
The S-R flip flop is the simplest and easiest circuit to understand.

Truth Table:

S	R	Y	Y'
0	0	0	1
0	1	0	1
1	0	1	0
1	1	∞	∞

J-K Flip-flop

The JK flip flop is used to remove the drawback of the S-R flip flop, i.e., undefined states. The JK flip flop is formed by doing modification in the SR flip flop. The S-R flip flop is improved in order to construct the J-K flip flop. When S and R input is set to true, the SR flip flop gives an inaccurate result. But in the case of JK flip flop, it gives the correct output.



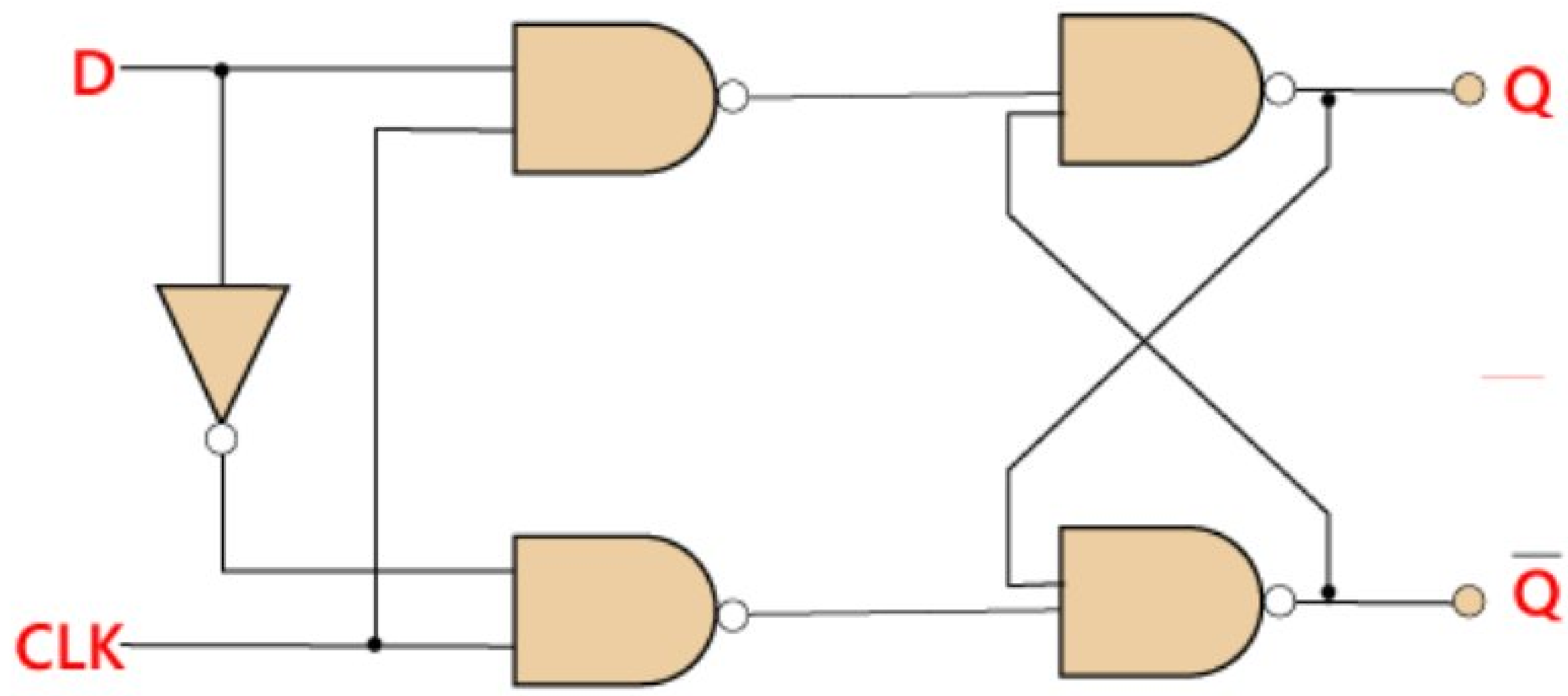
In J-K flip flop, if both of its inputs are different, the value of J at the next clock edge is taken by the output Y. If both of its input is low, then no change occurs, and if high at the clock edge, then from one state to the other, the output will be toggled. The JK Flip Flop is a Set or Reset Flip flop in the digital system.

Truth Table:

J	K	Y	Y'
0	0	0	0
0	1	0	0
1	0	0	1
1	1	0	1
0	0	1	1
0	1	1	0
1	0	1	1
1	1	1	0

D Flip Flop

D flip flop is a widely used flip flop in digital systems. The D flip flop is mostly used in shift-registers, counters, and input synchronization.

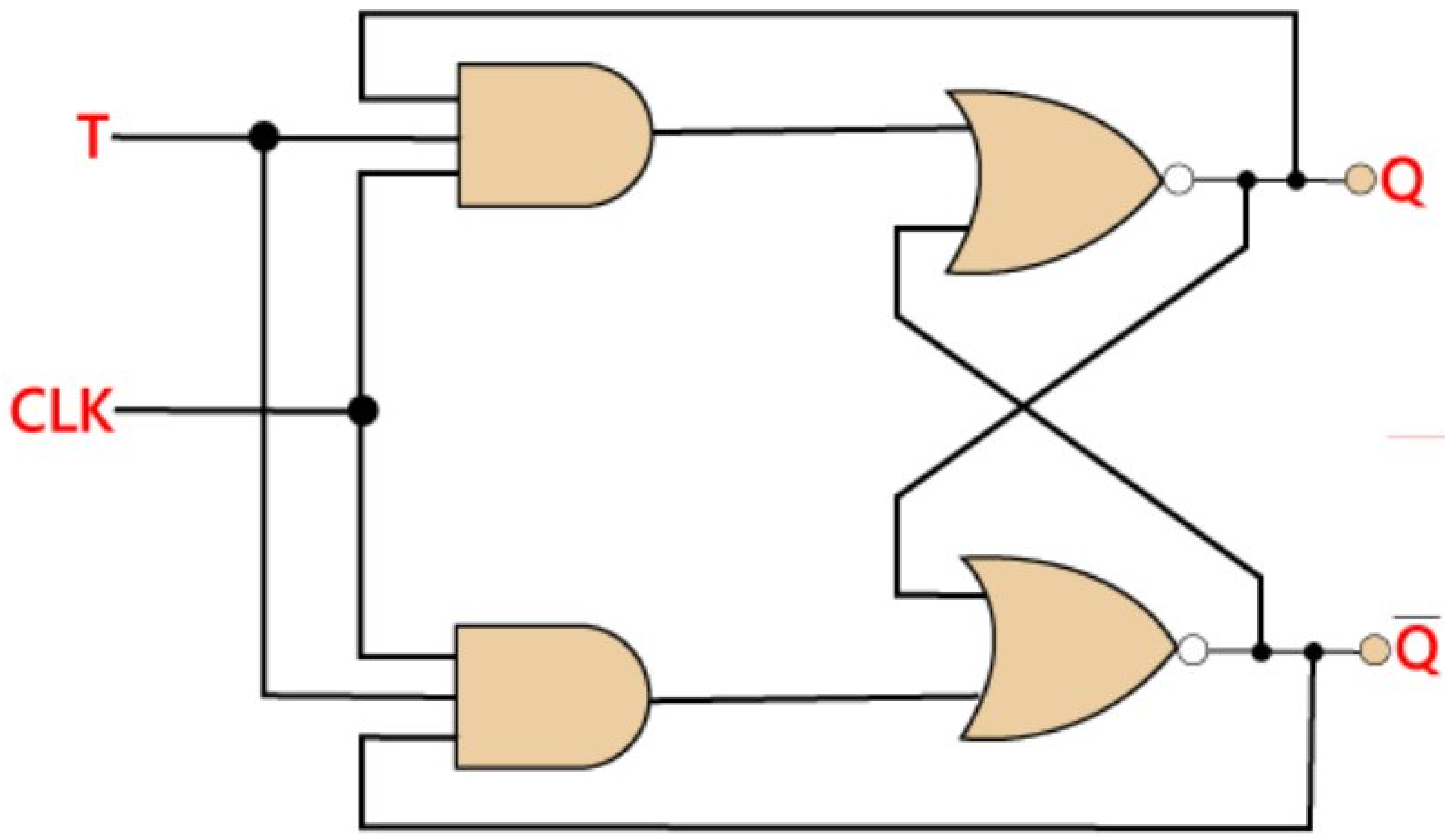


Truth Table:

Clock	D	Y	Y’
↓ » 0	0	0	1
↑ » 1	0	0	1
↓ » 0	1	0	1
↑ » 1	1	1	0

T Flip Flop

Just like JK flip-flop, T flip flop is used. Unlike JK flip flop, in T flip flop, there is only single input with the clock input. The T flip flop is constructed by connecting both of the inputs of JK flip flop together as a single input.



The T flip flop is also known as **Toggle flip-flop**. These T flip-flops are able to find the complement of its state.

Truth Table:

T	Y	Y (t+1)
0	0	0
1	0	1
0	1	1
1	1	0

Registers & Need for a Register:

* A group of FF's is known as register. It is used to store binary information.
* An 'n' bit register requires 'n'-flipflops.

Need for registers :- Registers are used for:

1) temporary storage of digital data
2) Transfer of digital data (shifting capability).

Types of registers:-

There are 4 basic types of shift registers. They are:-

1) Serial In Serial Out shift registers (SISO)
2) " " Parallel out " " (SIPO)
3) Parallel In Serial out " " (PISO)
4) " " Parallel " " . (PIPO).

4-Bit Shift Right Register:-

A shift register which moves the stored bits towards right side is known as shift right register. The 4-bit shift right register implemented with D-FF's is shown b

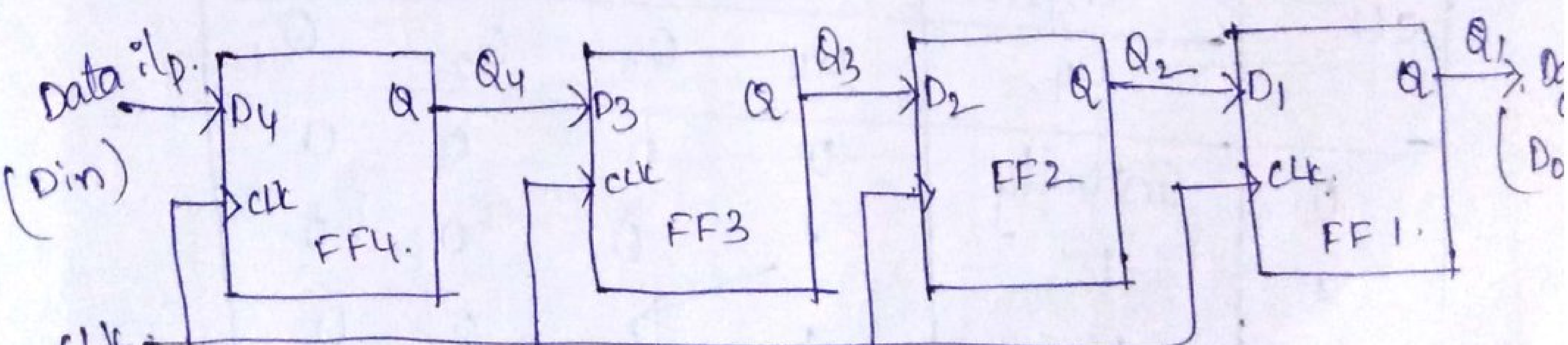


fig: shift right register.

* The Delay(D) FF simply transfers the data from the i/p to the o/p Q after a delay of one clock pulse.

operation:-

→) Consider an example of a 4-bit binary number 1111 into register. To begin the operation, initially the register is CLEARed by giving its data o/p as:

$Q = Q_4Q_3Q_2Q_1 = 0000$.

Let us begin with MSB of 4-bit binary number ie, 1 is p onto the data i/p (D_{in}) of the FF.

1) when a first clock pulse is applied, the left most FF i and the stored word becomes as

$Q_4Q_3Q_2Q_1 = 1000$.

2) when 2nd pulse is applied, the 2nd MSB bit entered into left most FF and 1st clock pulse o/p of leftmost FF is given as an i/p to the next FF. [FF4 o/p as i/p to FF3]. Then the stored word Becomes $Q_4Q_3Q_2Q_1 = 1100$.

3) Similarly After applying 3rd pulse, the o/p is

$Q_4Q_3Q_2Q_1 = 1110$.

Similarly After 4th pulse, $Q_4Q_3Q_2Q_1 = 1111$.

CLK	Input D_4.	outputs Q_4	Q_3	Q_2	Q_1
0.	Initially	0	0	0	0
1	1.	1	0	0	0
2	1	1	1	0	0
3	1	1	1	1	0
4	1	1	1	1	1

Shift Left register:-

A Shift register which moves the stored bits towards left side is known as "Shift left register". The 4-bit shift left register is shown below.

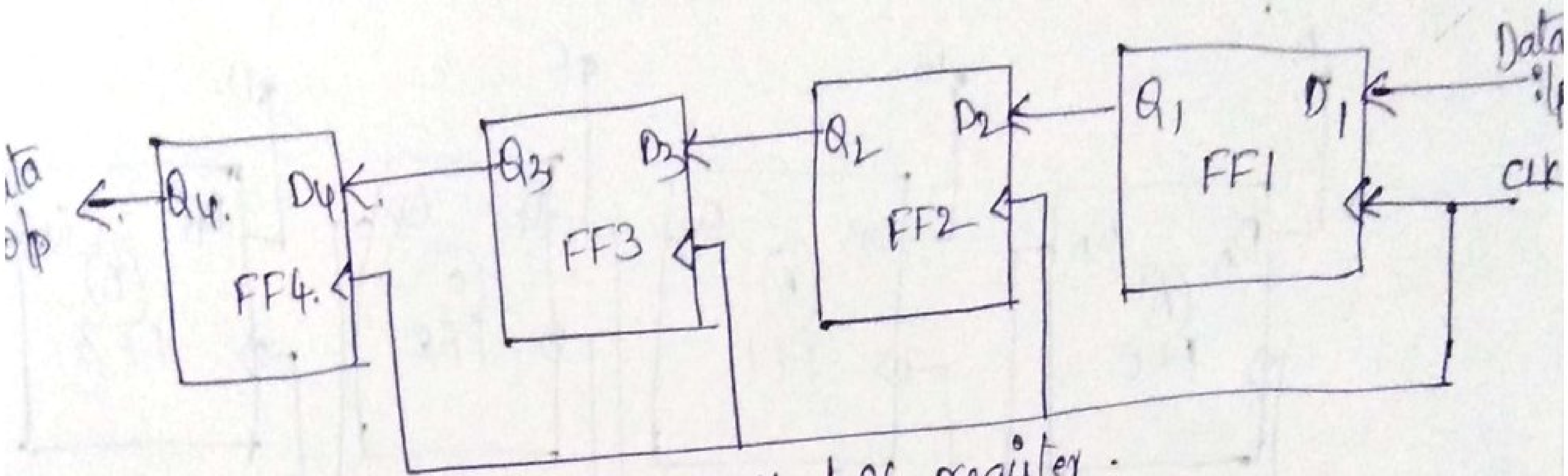


fig: 4-bit Shift left register.

operation:-

* Consider a 4 bit binary number 1111 into the register $Q_4Q_3Q_2Q_1$.
* Initially the register is CLEARed at the data o/p is 0000

→ when the 1st clock pulse is applied, then the LSB bit of 4-bit binary number is given as i/p. & the o/p is $Q_4Q_3Q_2Q_1$ = 0001.

→ when 2nd pulse is applied ; Dout is $Q_4Q_3Q_2Q_1$ = 0011

→ " 3rd pulse " " ; then $Q_4Q_3Q_2Q_1$ = 0111

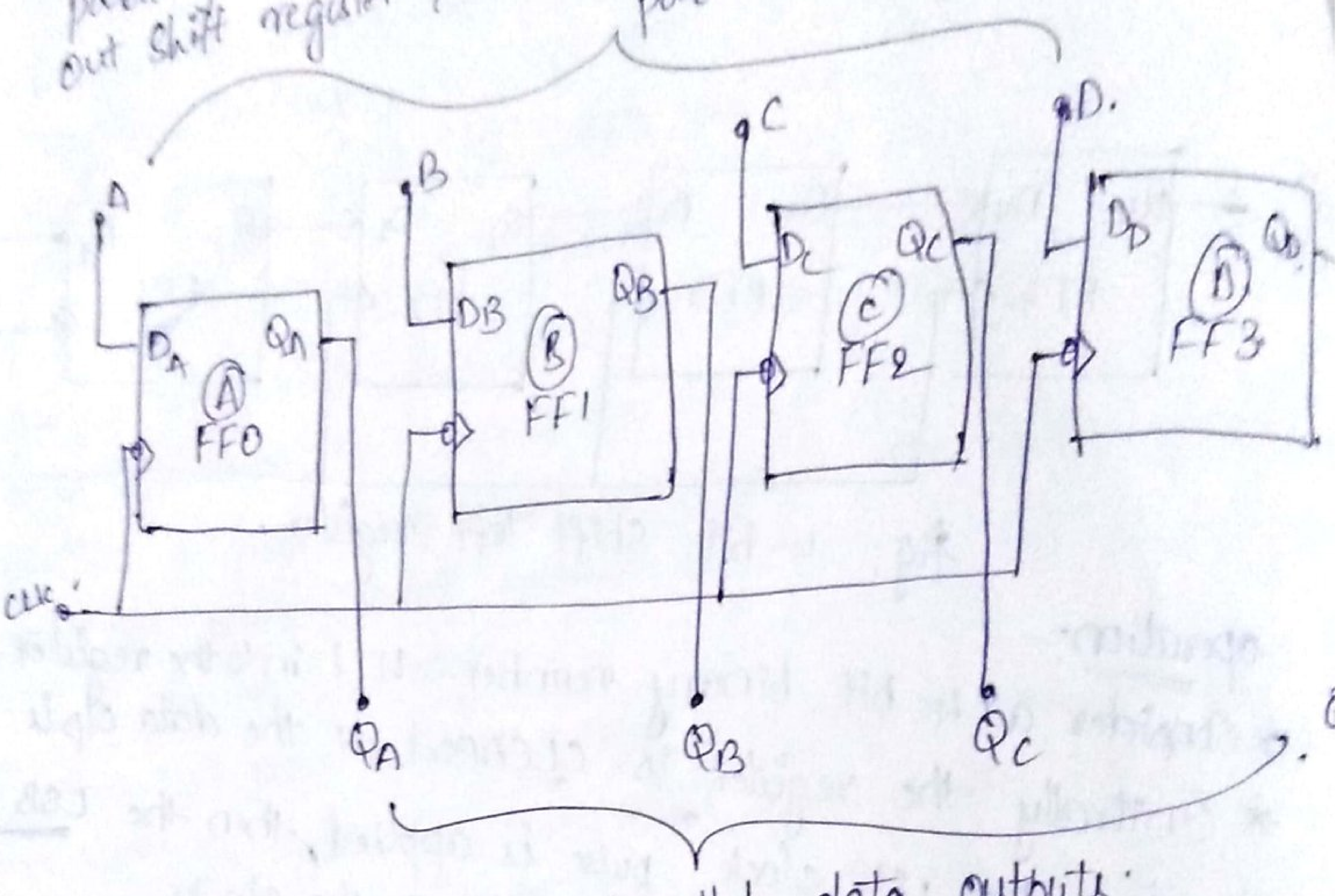
→ " 4th pulse " " ; then $Q_4Q_3Q_2Q_1$ = 1111.

Table:- Data transfer in 4-bit SHL Register.

CLK	Input D_1	outputs Q_4	Q_3	Q_2	Q_1
0	Initially	0	0	0	0
1	1	0	0	0	1
2	1	0	0	1	1
3	1	0	1	1	1
4	1	1	1	1	1

Parallel In Parallel Out Shift Register :-

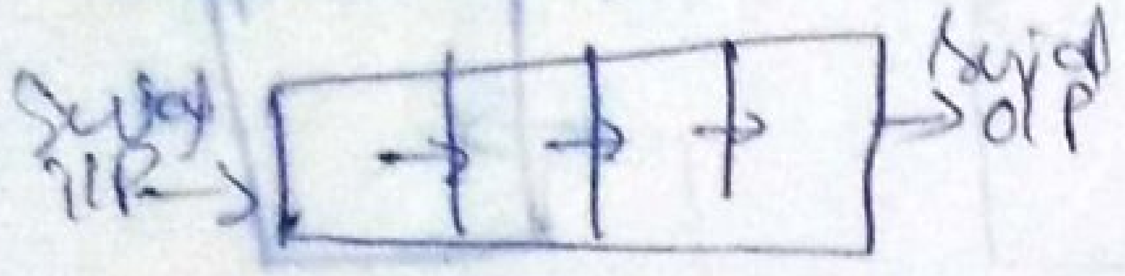
* In this type of register the data inputs can be shifted parallely to the data outputs. The 4-bit parallel-in out shift register is shown in below fig.



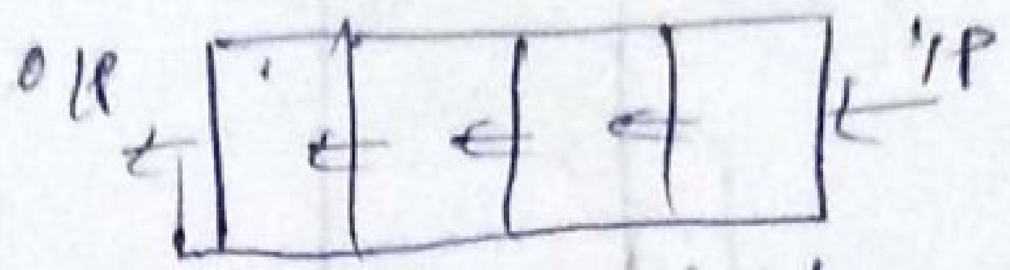
* In this register, there is no inter Connection b/w successive flipflops since no Serial Shifting is required.
* If you enter (load) the data at the i/p terminals of each FF then you can read the data at the o/p termin
* The process of loading the data into register is known as "Write Operation".
* The process of reading the data from the register is known as Read Operation.

Shift registers: A reg. capable of shifting binary info. in one or both direction is called "shift reg.".

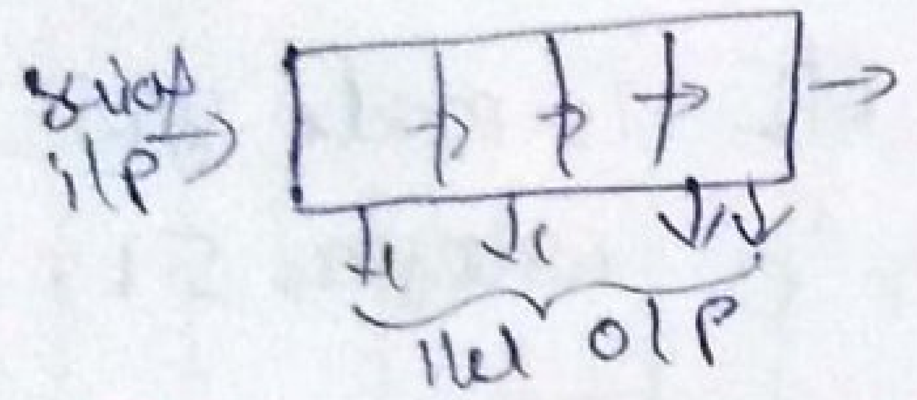
Data txion in shift registers: Data may be shifted into & out of reg. either in serial form & in ||el form. Basic types of S.Rs are: a) Serial-in serial-out b) Serial-in, ||el-out c) ||el-in, serial-out d) ||el-in, ||el-out.

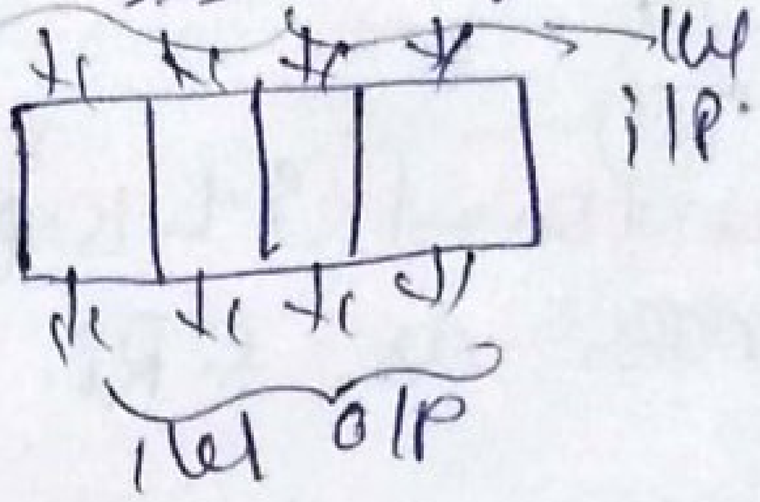


SISO, Shift right

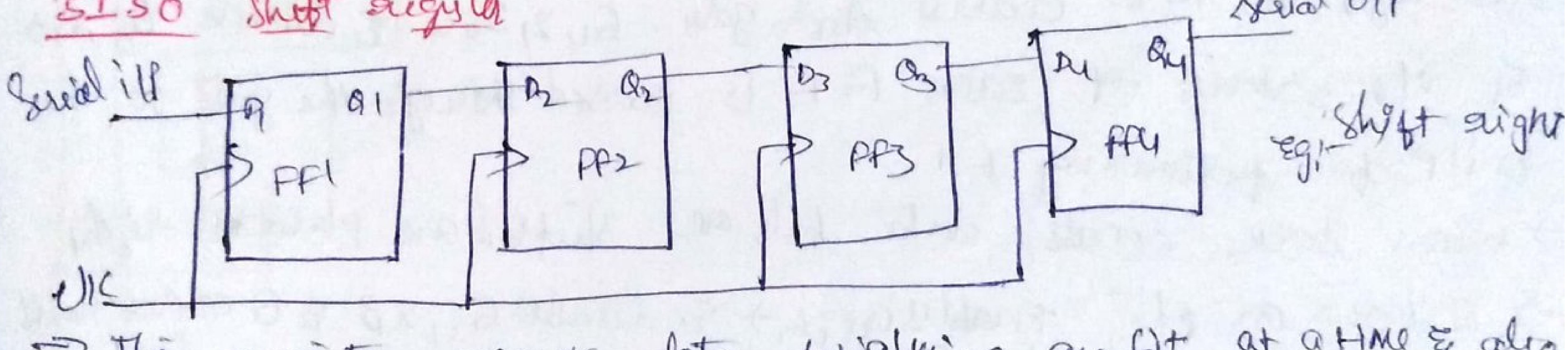


SISO Shift left



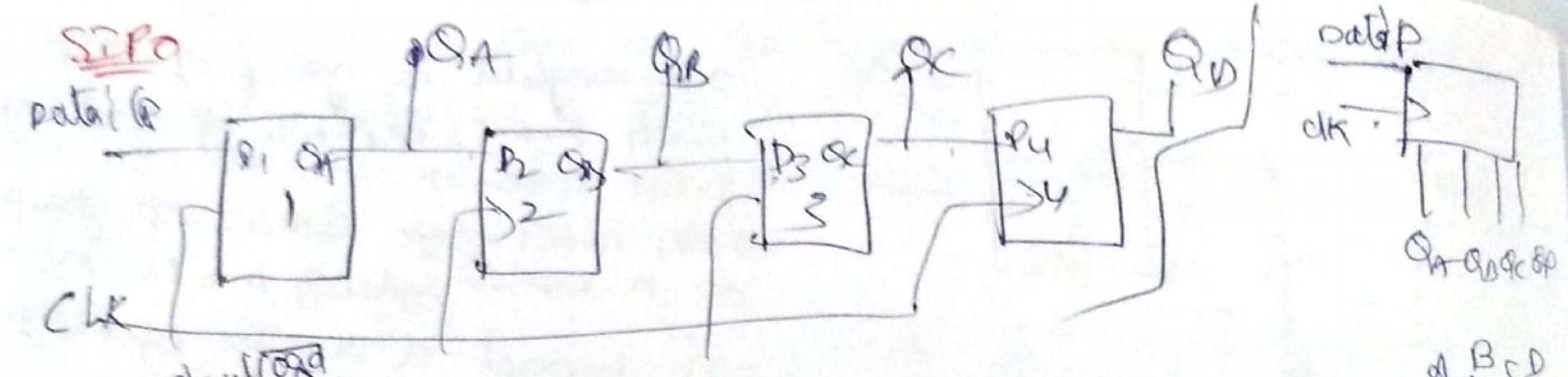


SISO Shift register

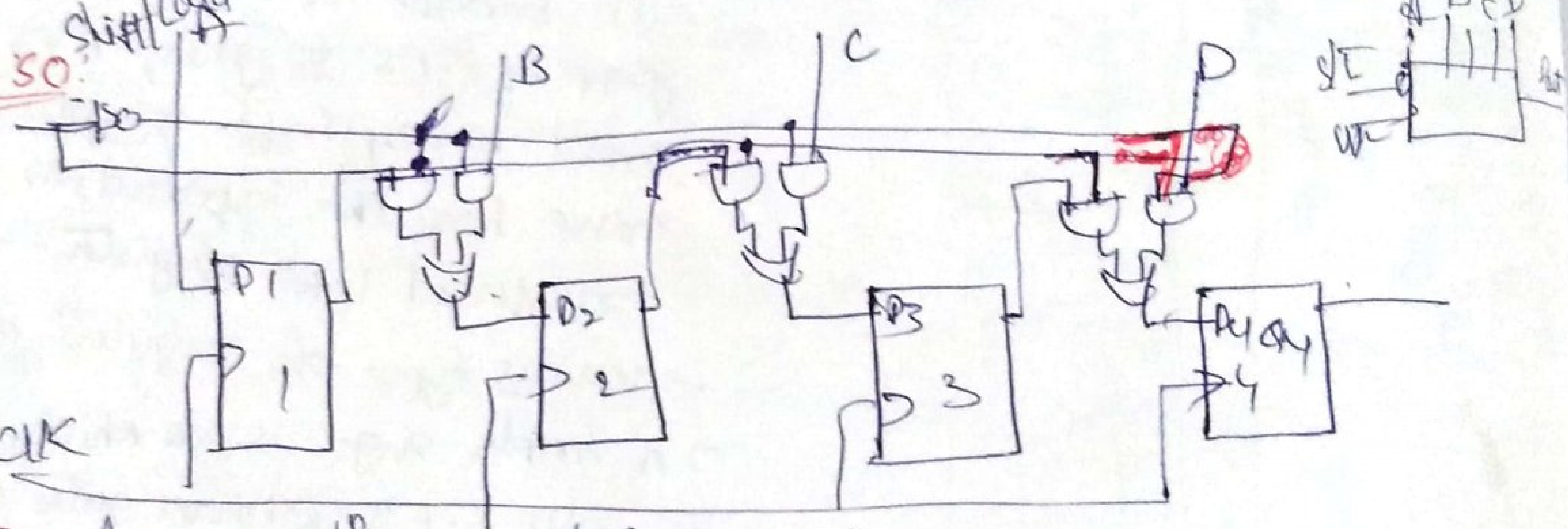


→ The register accepts data serially i.e one bit at a time & also O/Ps data serially

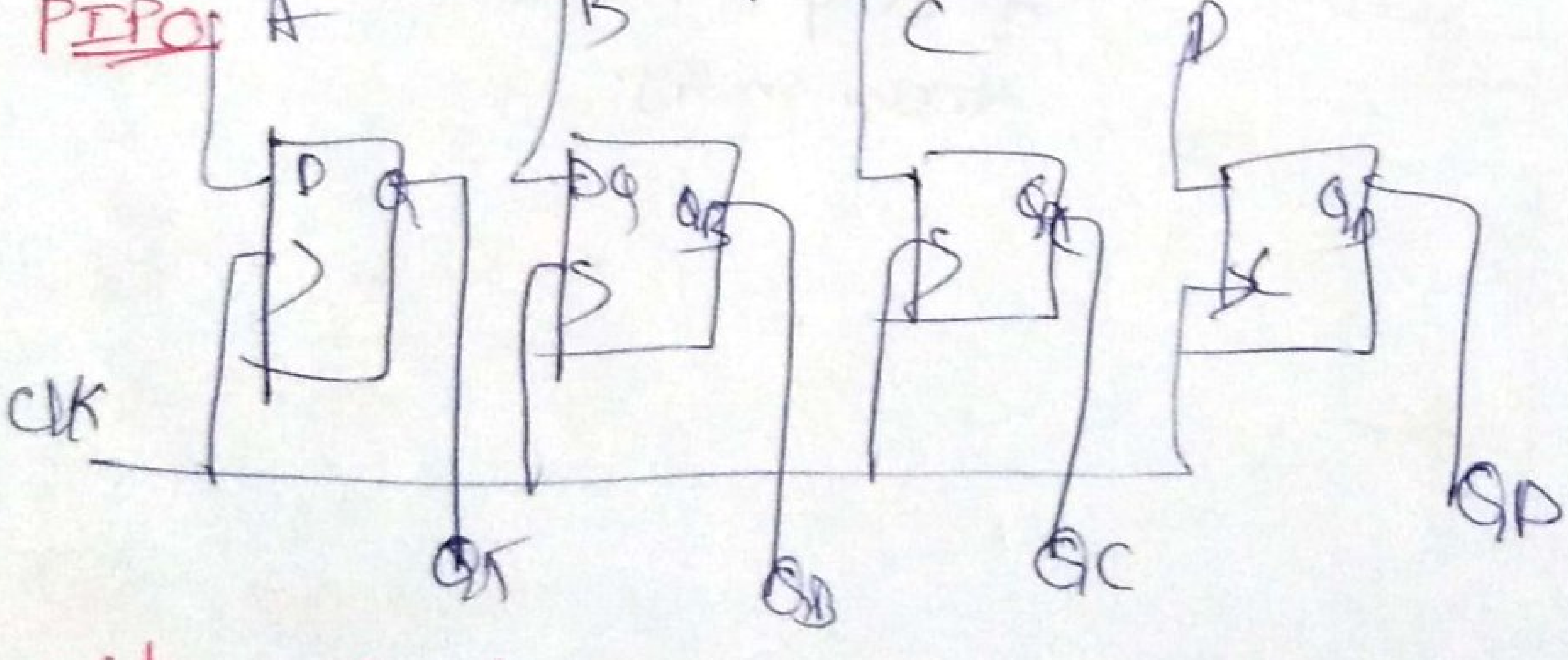
SIPO



PISO:



PIPO:



Counters :-

* A counter is capable of counting the number of clock pulses that arrives at its clock input.
* Flip Flops connected together to perform counting operation.
* counters are mostly constructed using JK FF in Toggle mode (or) T-Flip Flops.

* A/c to Mode of applying clock pulse, counters are classified into 2 types.
  1) Asynchronous Counters. (Ripple counters).
  2) Synchronous Counters.

Asynchronous Counters	Synchronous Counters.
1) All FFs are triggered by different clock sources at different times.	1) All FF are triggered by same clock source at same time.
2) Propogation delay is more	2) Propogation delay is less.
3). Circuit is Simple.	3) Complex circuitry.
4). Max. Freq^n depends on Modulus.	4) does n't depends on Modulus.
5). Frequency of operation is lesser than in a Synchronous counter.	5). Frequency of operation can be much higher than in Asynchronous Counter.
6) Less costly.	6) More costly.

4-Bit Asynchronous Counter & its Timing diagrams

* A 4 bit asynchronous counter is also called Ripple counter because of the clock pulse ripples through the circuit,
* A Ripple counter is a cascaded arrangement of flipflops where the o/p of first flipflop drives the clock input of the following flipflops.
* An n-Mod ripple counter contains n-no-of FF's and the circuit can count upto 2^n values before it resets itself to the initial value.
* 4-bit Asynchronous counter circuit implemented with negative edge triggered JK flip-flop in 'Toggle' mode is shown in the fig below.

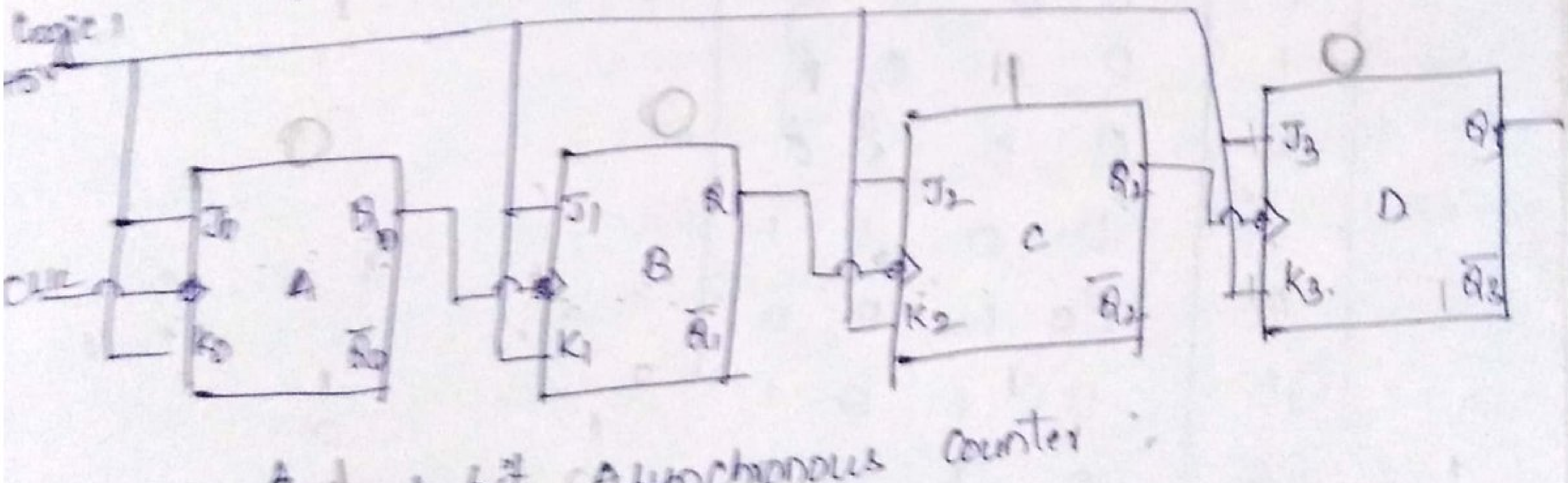


fig: 4-bit Asynchronous counter (Mod-16)

* J & K inputs of all FF's are connected to logic '1', they act as a toggle FF. Here the o/p of each flipflop toggles at negative transition of the clock i/p.
* Initially all the FF's are cleared i.e., $Q_3Q_2Q_1Q_0 = 0000$. With the application of 1st clock pulse, Q_0 changes from 0 to 1, where as Q_1, Q_2 & Q_3 remains uneffected. i.e., $Q_3Q_2Q_1Q_0 = 0001$

* When the 2nd clock pulse is given A toggles i.e., it goes from 1 to 0. this is a negative change. So, B FF o/p goes from 0 to 1 & Q_2 & Q_3 remains unchanged.

i.e., $Q_3 Q_2 Q_1 Q_0$ = 0010.

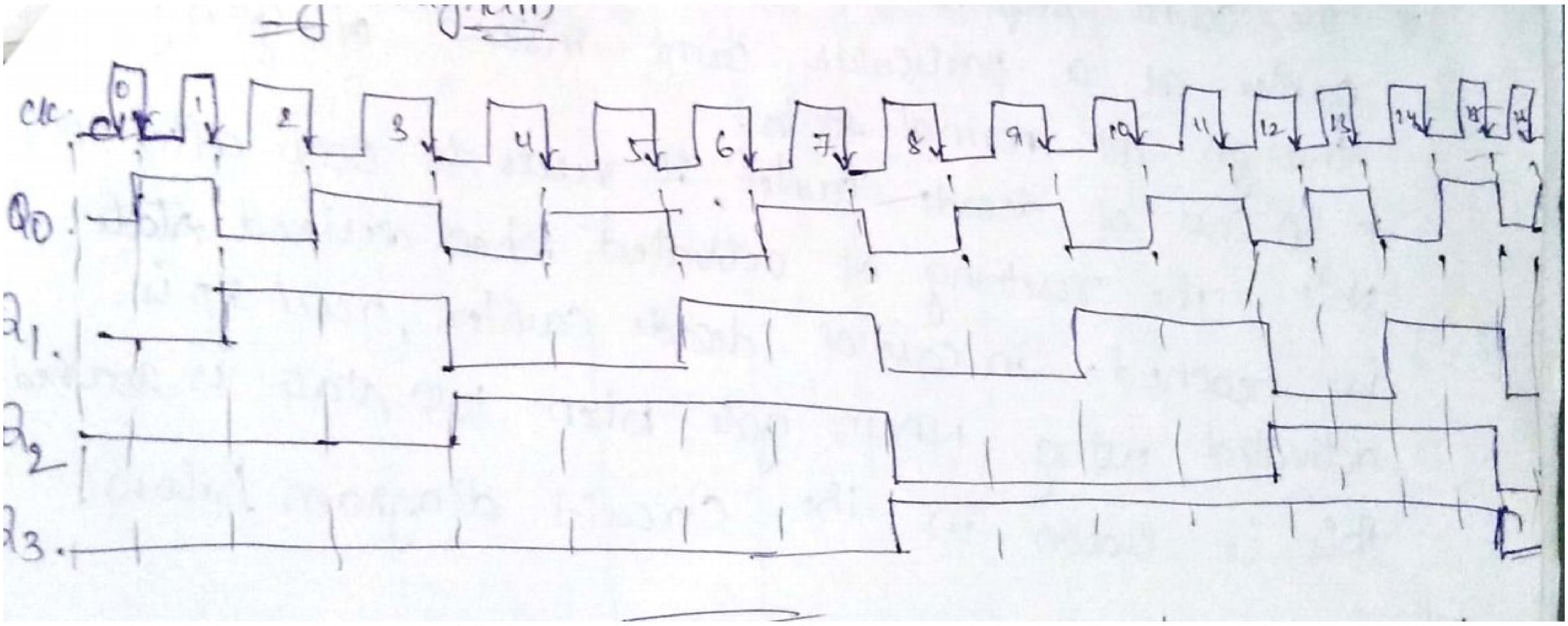
* This continues for each clock pulse until 15th clock pul when 16th clock pulses all the FF's are toggles. i.e., changing all the o/p's from 1 to 0.

$Q_3 Q_2 Q_1 Q_0$ = 0000.

* The below table shows the clock pulse & o/p's at eac clock pulse.

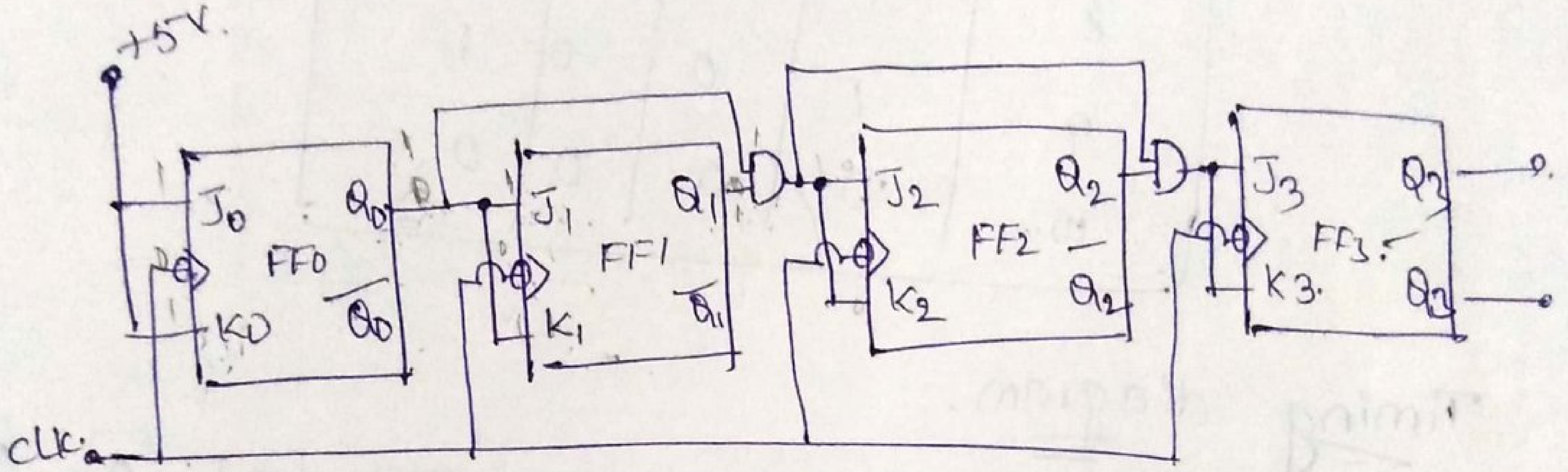
CLK.	D (Q_3)	C (Q_2)	B (Q_1)	A (Q_0)
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4.	0	1	0.	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0
13	1	1	0	1
14	1	1	1	0

CLK	D	C	B	A
15	1	1	1	1
16	0	0	0	0.


Clk
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Q0
Q1
Q2
Q3

4-bit Synchronous Counter :-

* In Synchronous Counter, the clock is given to all FF's and when the FF toggles, they do simultaneously. The J & K i/p's of the first flipflop are connected to high. Therefore the first FF would toggle for each clock pulse.
* In Synchronous Counters, all FF's are clocked at the same time that's why they change their states at same time.
* A 4-bit synchronous counter is shown below.



* The J & K i/p's of first FF connected to high (+5v). Therefore the FF0 would toggle for each clock pulse.

  i.e., J=K=1 , FF1 toggles for every clock pulse.
* FF1 toggles ; when $Q_0=1$.
* FF2 Toggles ; when $Q_0=Q_1=1$; so $Q_0 Q_1$ is connected to J_2 and K_2.
* FF3 toggles ; when $Q_0=Q_1=Q_2=1$; so $Q_0 Q_1 Q_2$ is connected to J_3 & K_3.

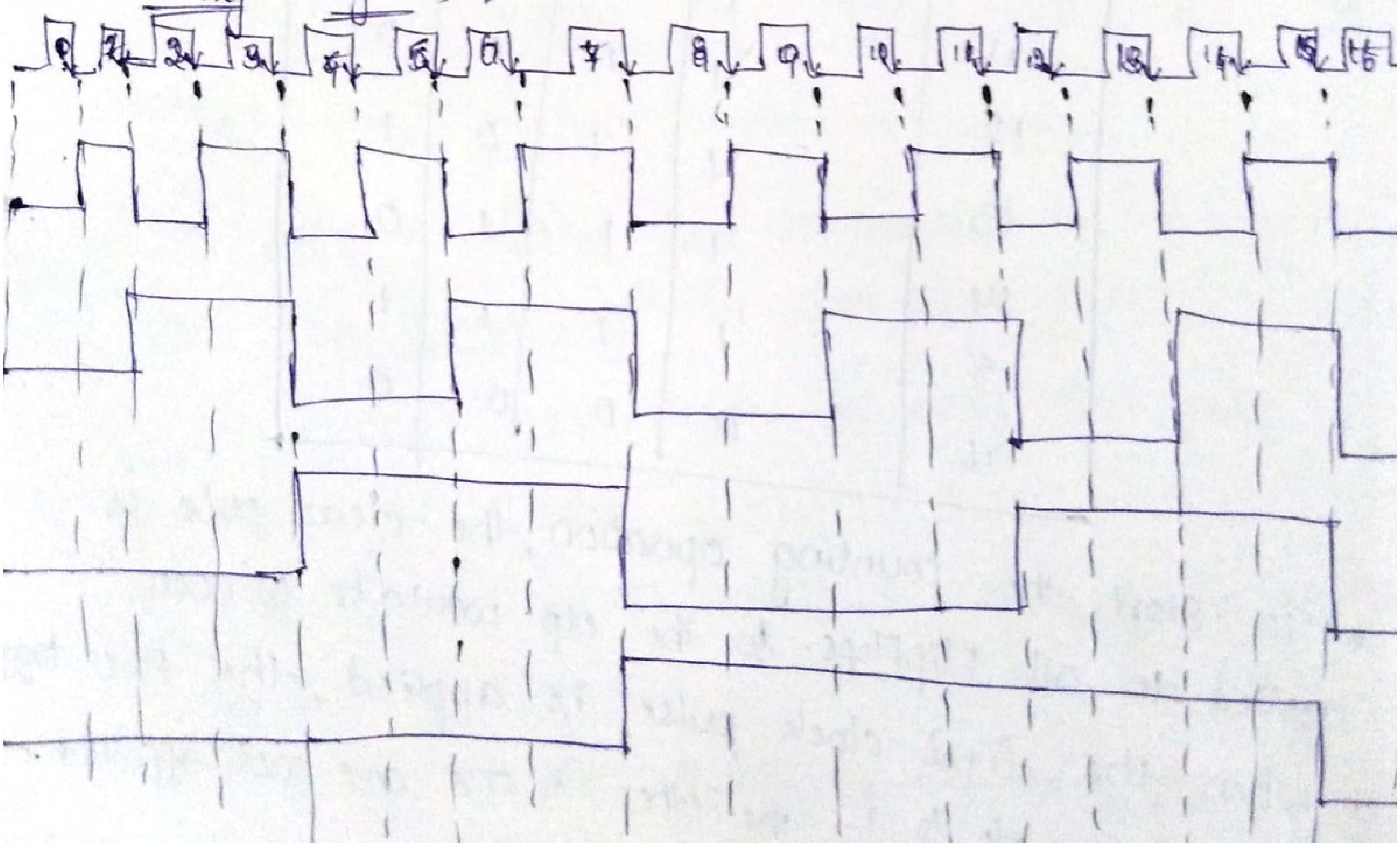
CLK	Q_3	Q_2	Q_1	Q_0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0
13	1	1	0	1
14	1	1	1	0
15	1	1	1	1
16	0	0	0	0

* To start the counting operation, the clear pulse is applied to all FlipFlops. So the o/p would be Q=0000.
* when the first clock pulse is applied, the FF0 toggles changing the o/p to 1. The other 3 FF's are not affected. The o/p now is Q=0001.

* As the o/p of Q0 is 1, the J&K of FF-1 are at 1 i.e. FF0 & FF1 are in toggle mode.
* When the 2nd clock pulse is applied, the FF0 goes low & FF1 goes high. Hence the o/p would now be 0010.
* For the 3rd clock pulse, FF0 toggles giving the o/p's Q = 0011. Now both Q0 & Q1 are 1. Hence the o/p of first AND gate is 1. & this is connected to J&K of FF2. The FF2 is now in toggle mode. Therefore we find the first 3 FF's are in toggle mode.

* When the 4th clock pulse is applied, all these 3 FF's toggle giving the o/p = 0100. This continuing action will continue ~~this~~ for 15th clock pulse and get the o/p Q = 1111.
* For the next clock pulse, all FF's would reset.

Timing diagram :-



UNIT - I

DC & AC CIRCUITS

SYLLABUS:

UNIT - I : DC & AC CIRCUITS

DC CIRCUITS:

Electrical circuit elements (R, L & C), Ohm's law & its limitations, KCL & KVL, Series-parallel circuits, super position theorem, simple numerical problems.

AC CIRCUITS:

AC Fundamentals : Equation of AC voltage and current, waveform, time period, frequency, amplitude, phase, phase difference, average value, RMS value, Form factor, peak factor, voltage and current relationship with phasor diagrams in R, L and C circuits. Concept of impedance, Active power, reactive power and apparent power, concept of power factor (Simple Numerical problems).

BASIC DEFINITIONS:

CIRCUIT: A circuit is a conducting path through which either an electric current flows (or) is intended to flow.

Circuits are of two types

(a) Active circuit

(b) passive circuit

ELECTRIC NETWORK: A combination of various electric elements connected in any manner is known as electric network. A circuit may be a network (or) a part of the network.

ACTIVE ELEMENTS: The sources may be voltage / current sources which supply energy to a circuit / network are known as active elements.

Ex: Generators, Batteries etc..

PASSIVE ELEMENTS: The various elements like resistance, inductance and capacitance are called passive elements (or) circuit elements.

LINEAR CIRCUIT: A linear circuit is one whose parameters are constant, i.e., they do not change with voltage (or) current.

NON-LINEAR CIRCUIT: A circuit in which the parameters change with voltage (or) current is known as non-linear-circuit.

UNILATERAL CIRCUIT: A circuit whose properties (or) characteristics change with the change of direction of its operating current is known as unilateral circuit.

Ex : Rectifier

BILATERAL CIRCUIT: A circuit whose properties (or) characteristics are same in either direction is known as bilateral-circuit.

Ex: A Transmission line

ACTIVE CIRCUIT: A closed electric circuit in which active elements like voltage sources (or) current sources are are found along with passive elements is known as active-circuit.

PASSIVE CIRCUIT: A closed electric circuit in which only passive elements are present is known as passive circuit.

JUNCTION (OR) NODE: In a network/circuit, a point at which two (or) more elements are connected and where division of current takes place is known as a junction (or) node.

BRANCH: A part of the network/circuit connected between two junctions is called a branch.

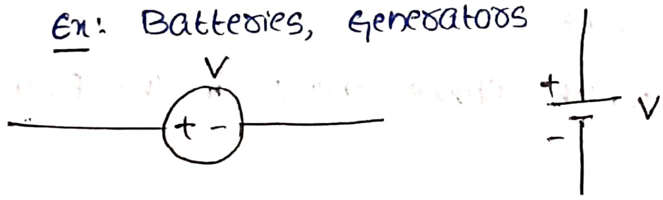
LOOP (OR) MESH: A loop is a closed path and may contain active (or) passive elements (or) both. A loop may be a part of a circuit / Network.

A Mesh is the simplest possible loop (or) is a closed path in a circuit / Network. Mesh doesn't contain any other inner loops in it.

∴ "All Meshes are loops, but all loops are not Meshes."

ELECTRIC VOLTAGE: The potential difference between two points (or) voltage in an electric circuit is the amount of energy required to move a unit charge between two points. It is measured in "Volts" and indicated with a letter 'V'.

Ex: Batteries, Generators

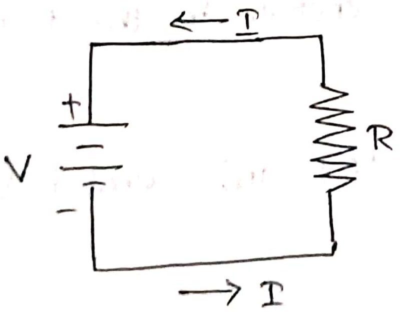


ELECTRIC CURRENT:

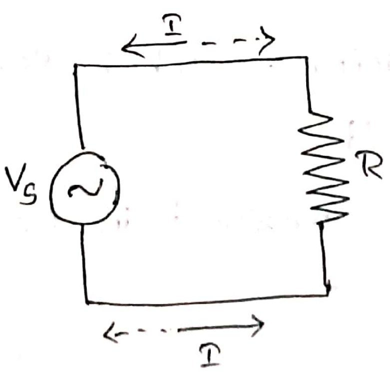
It is the flow of electrons (or) electric charge. It is measured in Amperes and denoted by the letter 'I'.

Ex of DC current: batteries, solar cells, thermocouples etc.

In AC, current (or) electric charge movement periodically changes with respect to time.



(a) DC Circuit



(b) AC Circuit

RESISTANCE (R):

The resistance of a conducting material opposes the flow of electrons. It is measured in ohms and denoted by the Greek symbol Ω.

(a) Fixed Resistor (b) Variable Resistor.

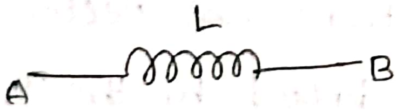
INDUCTANCE (L):

Inductance is the ability of a device to generate a voltage when the current through it changes. (or)

Inductance is the ability of a device which oppose the change in current. (or)

Inductance which stores energy in the form of a magnetic field.

It is measured in henrys (H) and denoted by letter 'L'.

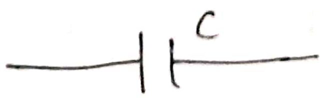


CAPACITANCE (C):

Capacitance is the ability of a device which oppose the change in voltage. (or)

Capacitance which stores energy in the form of a electric field.

It is measured in Farads (F) and denoted by letter 'C'.



POWER (P):

Power is the rate at which work is being done.

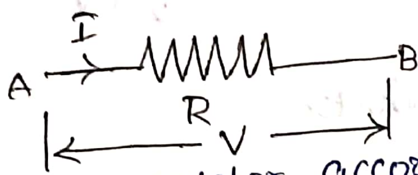
(or) power in a DC circuit is the product of voltage and the current. It is measured in 'watts' (W) and is denoted by 'P'.

$$\boxed{P = V \times I} \text{ Watts.}$$

VOLTAGE & CURRENT EQUATIONS IN DC PARAMETERS:

RESISTORS:

The symbol for a resistor:



Voltage across resistor, according to ohm's law is given by:

$$\boxed{V = IR} \text{ Volts}$$

where, V = Voltage across Resistor in Volts

I = current through Resistor in Amps

R = Resistance of the conductor in ohms

power, $P = VI$

$= V \times \frac{V}{R}$ $\quad (I = \frac{V}{R})$

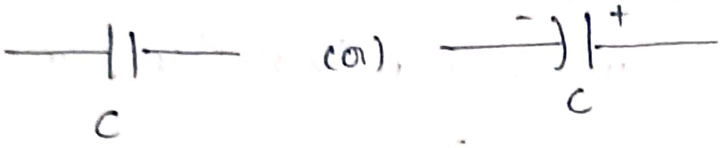
$$\boxed{P = \frac{V^2}{R}} \text{ W (or)}$$

$P = IR \times I$ $\quad (V = IR)$

$$\boxed{P = I^2 R} \cdot W$$

CAPACITORS:

The symbol for a capacitor:



1 unit of Farad = 1 coulomb/volt

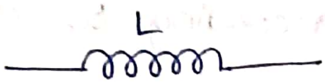
current is given by $i(t) = C\frac{dv}{dt}$

voltage is given by $v(t) = \frac{1}{C}\int i(t)\,dt$

$w_C(t) = \frac{1}{2}CV^2$

INDUCTORS:

The symbol for a inductor:



voltage is given by $v(t) = L\frac{di}{dt}$

current is given by $i(t) = \frac{1}{L}\int v\,dt$

Energy stored in inductor is given by:

$w_L(t) = \frac{1}{2}Li^2$

OHM'S LAW:

STATEMENT: Ohm's law states that the voltage across a conductor is directly proportional to the current flowing through it, provided all physical conditions and temperature remains constant.

OHM's law Caluation:

$$V = IR$$

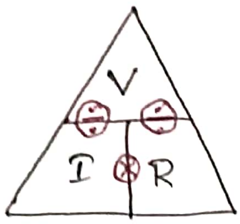
where,

V = voltage across the conductor

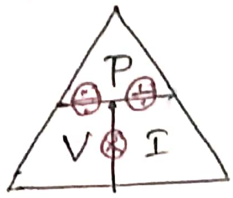
I = current flowing through the conductor

R = Resistance provided by the conductor to the flow of current.

OHM's law Magic Triangle:



POWER TRIANGLE:



NUMERICAL PROBLEMS ON OHM'S LAW:

(1) If the resistance of an electric iron is 50Ω and a current of 3.2A flows through the resistance. Find the voltage between two points.

Given

Resistance, $R = 50\ \Omega$

current, $I = 3.2A$

Find

voltage, $V = ?$

From ohm's law, $V = IR$

$$= 3.2 \times 50$$

$$\boxed{V = 160V}$$

(2) An EMF source of 8.0V is connected to a purely resistive electrical appliance (a light bulb). An electric current of 2.0A flows through it. Calculate the resistance offered by the electrical appliance.

Given

Voltage, $V = 8\ V$

current, $I = 2\ A$

Find

Resistance, $R = ?$

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

$$= \frac{8}{2}$$

$$\boxed{R = 4\ \Omega}$$

OHM'S LAW APPLICATIONS:

The main applications of ohm's law are:

(1) To determine the voltage, resistance (or) current of an electric circuit.

(2) ohm's law maintains the desired voltage drop across the electronic components.

(3) ohm's law is also used in DC ammeter and other DC shunts to divert the current.

LIMITATIONS OF OHM'S LAW :

Following are the limitations of ohm's law :

(1) ohm's law is not applicable for unilateral electrical - elements like diodes and transistors as they allow the current to flow through in one direction only.

(2) For non-linear electrical elements with parameters like capacitance, resistance etc the ratio of voltage and current won't be constant with respect to time making it difficult to use ohm's law.

KIRCHHOFF'S LAWS:

In 1847, Gustav Robert Kirchhoff's introduced a pair of laws based on the law of conservation of charge and energy in an electrical circuit. These laws are valid in AC and DC networks at low frequencies.

(1) Kirchhoffs current law (KCL)

(2) Kirchhoffs voltage law (KVL)

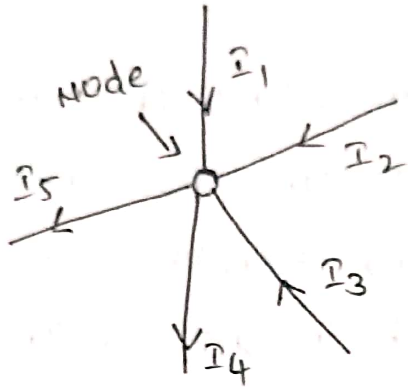
(1) KIRCHHOFFS CURRENT LAW (KCL):

Kirchhoffs current law (or) KCL, states that the "total current (or) charge entering a junction (or) node is exactly equal to the charge leaving the node".

In other words the algebraic sum of All the currents entering and leaving a node must be equal to zero.

$$\Sigma i_{entering} = \Sigma i_{leaving}$$

$$\Sigma i_{entering} + \Sigma i_{leaving} = 0$$



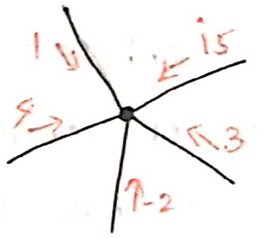
$$I_1 + I_2 + I_3 + (-I_4 - I_5) = 0$$

where,

I_1, I_2, I_3 are entering currents

I_4, I_5 are leaving currents

Ex: ① what is i_5 ?

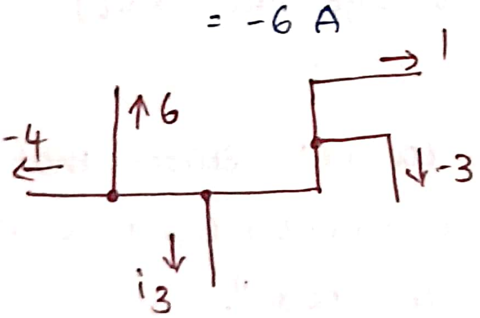


$$1 + 4 - 2 + 3 + i_5 = 0$$

$$i_5 = 8 - 2$$

$$= -6 \text{ A}$$

②



$$-4 + 6 + i_3 + 1 + (-3) = 0$$

$$i_3 = -[-4 + 6 + 1 + (-3)]$$

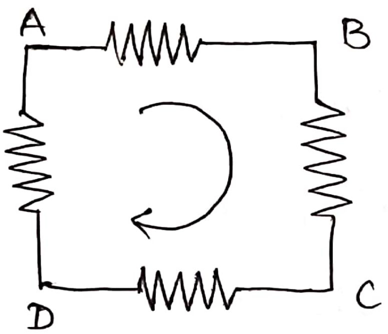
$$= 0 \text{ A}$$

KIRCHHOFFS VOLTAGE LAW (KVL):

Kirchhoffs voltage law (or) KVL, states that "in any closed loop network being driven by a voltage source, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop" which is equal to zero.

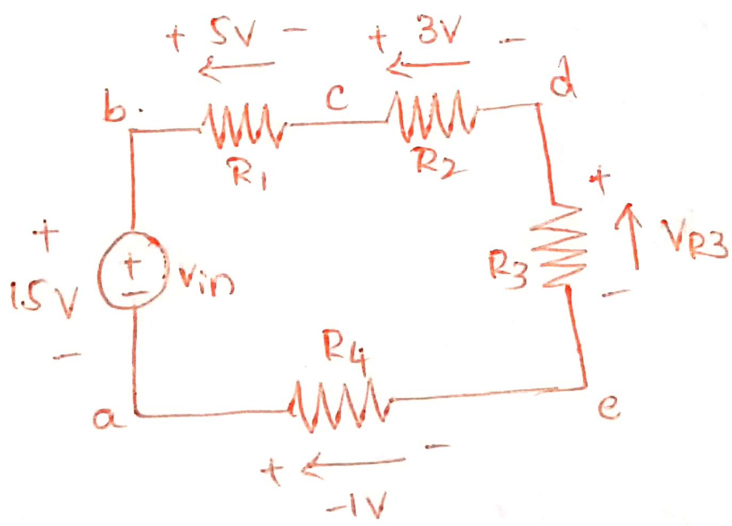
In other words the algebraic sum of all voltage sources and the voltage drops within a closed loop must be equal to zero.

$$\sum_{n} V_n = 0$$



$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

Ex: 1

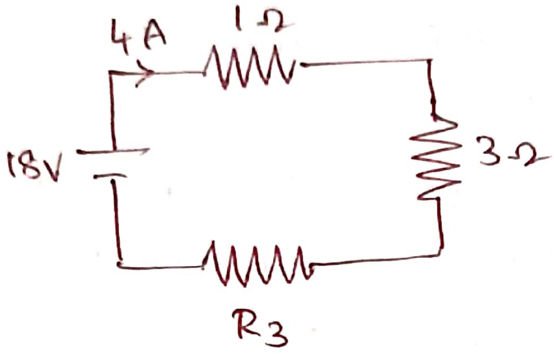


$$\Sigma V = 15 - 5 - 3 - V - 1 = 0$$

$$\boxed{V = 6V}$$

NUMERICAL PROBLEMS ON KCL & KVL:

(1) what is the magnitude of the electric potential difference across resistor R_3?



By applying KVL to the circuit

$$-18 + 4\times1 + 4\times3 + 4\times R_3 = 0$$

$$-18 + 4 + 12 + 4R_3 = 0$$

$$4R_3 = +18 - 16$$

$$4R_3 = 2$$

$$R_3 = \frac{2}{4}$$

$$R_3 = 0.5\,\Omega$$

$$V_{R_3} = I \times R_3$$

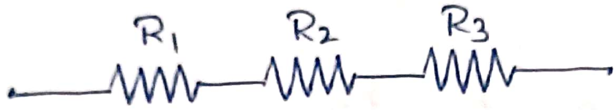
$$= 4 \times 0.5$$

$$\boxed{V_{R_3} = 2\,V}$$

SERIES - PARALLEL CIRCUITS:

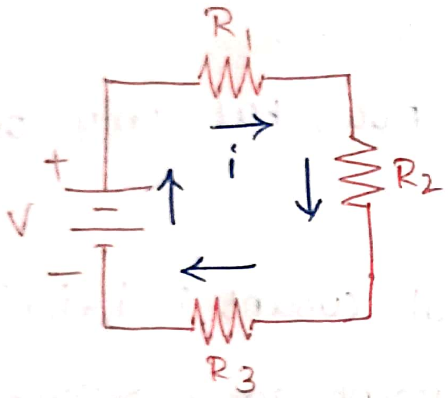
SERIES CIRCUIT:

It is a circuit where the components are connected end-to-end in a line is called series circuit.



only one path for current to flow

Ex:



Voltage drop across, $R_1 = V_{R1}$

$V_{R1} = iR_1$

Voltage drop across, $R_2 = V_{R2}$

$V_{R2} = iR_2$

Voltage drop across $R_3 = V_{R3}$

$V_{R3} = iR_3$

$$\therefore V = V_{R1} + V_{R2} + V_{R3}$$

$$iR = iR_1 + iR_2 + iR_3$$

$$iR = i(R_1 + R_2 + R_3)$$

$$\therefore R_{eq} = R_1 + R_2 + R_3$$

If there are 'n' resistors, then

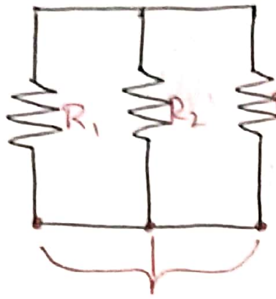
$$R_{eq} = R_1 + R_2 + R_3 + \cdots + R_n$$

current, $i = \dfrac{V}{R_{eq}}$

voltage, $V = iR_{eq}$

PARALLEL CIRCUIT:

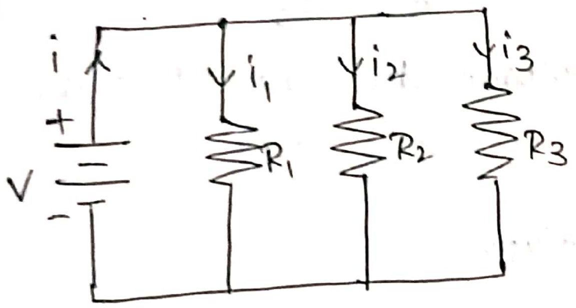
Parallel circuit is a circuit where all components are connected across each other.



These points are electrically common

There are many paths for current flow, but only one voltage across all components.

Ex:



Total current, $i = i_1 + i_2 + i_3$

Current across resistor, $i_1 = \frac{V}{R_1}$

Current across resistor, $i_2 = \frac{V}{R_2}$

current across resistor, $i_3 = \frac{V}{R_3}$

$$\therefore \quad i = i_1 + i_2 + i_3$$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R} = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

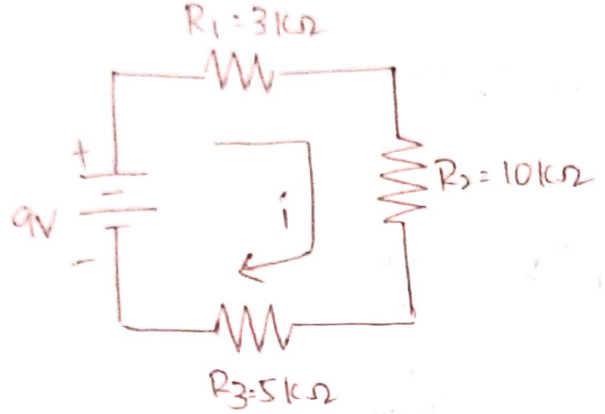
$$\frac{1}{R} = \left[\frac{R_2 R_3 + R_1 R_3 + R_1 R_2}{R_1 R_2 R_3}\right]$$

$$R_{eq} = \frac{R_1 R_2 R_3}{R_1 R_2 + R_2 R_3 + R_3 R_1}$$

$\therefore$ current, $i = \frac{V}{R_{eq}}$, $V = i R_{eq}$

NUMERICAL PROBLEMS ON SERIES - PARALLEL CIRCUITS:

(1) Find the current to the given circuit & voltage drops.



Total resistance, $R_{eq} = R_1 + R_2 + R_3$

$R_{eq} = 3 + 10 + 5$

$= 18\,k\Omega$

$V = 9V$

From ohm's law,

we know, $V = i . R_{eq}$

$$i = \frac{V}{R_{eq}}$$

$$= \frac{9}{18 \times 1000}$$

$$\boxed{i = 500\,\mu A}$$

voltage drop across Resistor, R_1, $V_{R1} = iR_1$

$= 500 \times 10^{-6} \times 3 \times 1000$

$= 1.5\ V$

voltage drop across Resistor, R_2, $V_{R2} = iR_2$

$= 500 \times 10^{-6} \times 10 \times 1000$

$= 5\ V$

voltage drop across Resistor R_3, $V_{R3} = iR_3$

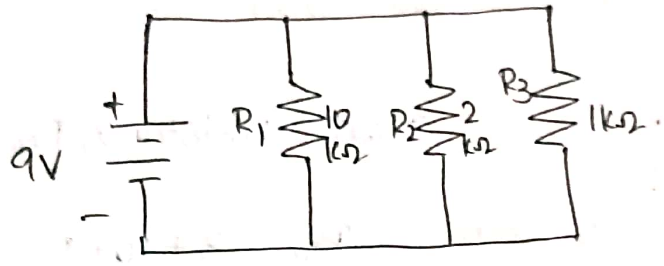
$= 500 \times 10^{-6} \times 5 \times 1000$

$= 2.5\ V$

$\therefore V = V_{R1} + V_{R2} + V_{R3} \Rightarrow 1.5 + 5 + 2.5$

$= 9V$

(2) what is the voltage and total current in a parallel circuit.



current across resistor R_1, $I_{R_1} = \frac{V}{R_1}$

$= \frac{9}{10k\Omega}$

$= 0.9 mA$

current across resistor R_2, $I_{R_2} = \frac{V}{R_2}$

$= \frac{9}{2k\Omega}$

$= 4.5 mA$

current across resistor R_3, $I_{R_3} = \frac{V}{R_3}$

$= \frac{9}{1 \times 1000}$

$= 9 mA$

$I = I_{R_1} + I_{R_2} + I_{R_3}$

$= 0.9 + 4.5 + 9$

$= 14.4 mA$

$R = \frac{R_1 R_2 R_3}{R_1R_2 + R_2R_3 + R_3R_1} = \frac{10 \times 2 \times 1}{10\times2 + 2\times1 + 1\times10}$

$= \frac{20}{20+2+10} = \frac{20}{32}$

$= 0.625\,\Omega$

$V = I \times R = 14.4 \times 0.625$

$= 9 V$

SERIES CIRCUITS FUNDAMENTALS:

→ All components in a series circuit conduct the same current

i.e. $I_{total} = I_1 = I_2 = \cdots I_n$.

→ The total equivalent resistance of a series circuit is equal to the sum of the individual resistances.

$$R_{total} = R_1 + R_2 + \cdots + R_n$$

→ The total voltage drop in a series circuit is equal to the sum of the individual voltage drops.

$$V_{total} = V_1 + V_2 + \cdots + V_n$$

PARALLEL CIRCUIT FUNDAMENTALS:

→ The voltage is the same for all components in a parallel-circuit.

$$V_1 = V_2 = \cdots V_n$$

→ The total parallel circuit current is the sum of the individual branch currents.

$$I_{total} = I_1 + I_2 + \cdots + I_n$$

→ The total resistance of a parallel circuit is less than any of the individual branch resistances.

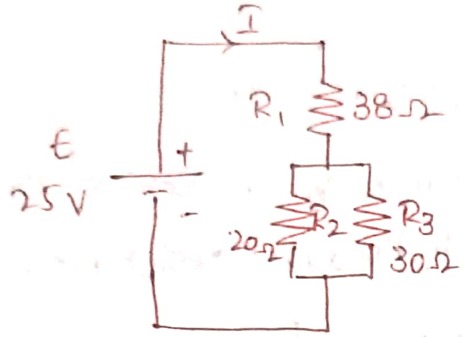
$$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \cdots + \frac{1}{R_n}}$$

(or)

$$R_{total} = \frac{R_1 R_2 R_3 \cdots R_n}{R_1R_2 + R_2R_3 + R_3R_1 + \cdots R_1R_n}$$

PROBLEMS ON SERIES - PARALLEL CIRCUITS:

(1) Find the current in the given circuit



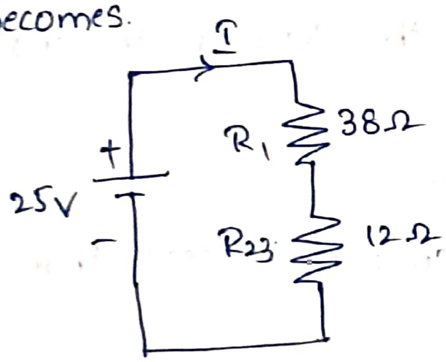
In the given circuit the Resistors R_2 & R_3 are in parallel,

$$\therefore R_{23} = \frac{R_2 R_3}{R_2 + R_3}$$

$$= \frac{20 \times 30}{20 + 30}$$

$$= 12\,\Omega$$

The resistor R_{23} is in series with R_1, hence the circuit becomes.



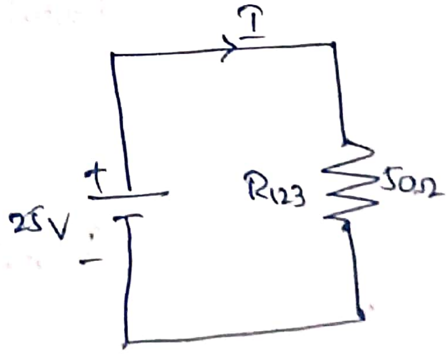
R_1 & R_{23} are in series

$$\therefore R_{123} = R_1 + R_{23}$$

$$= 38 + 12$$

$$= 50\,\Omega$$

hence the equivalent circuit is



From ohm's law,

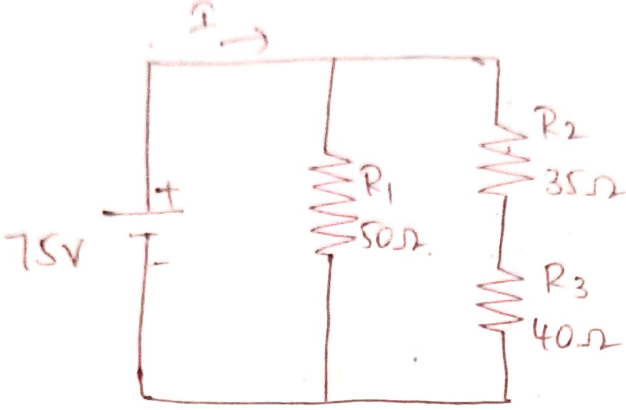
we know, $V = IR$

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

$$= \frac{25}{50}$$

$$\boxed{I = 0.5\,A}$$

Q) Find the current to the following circuit



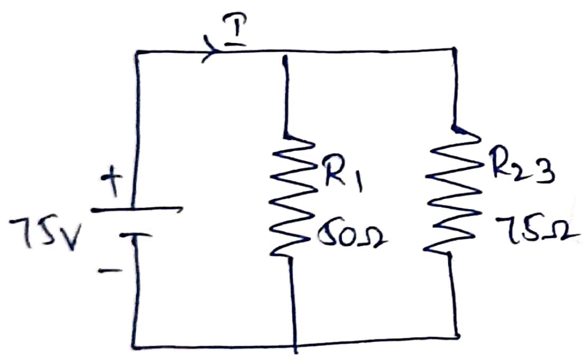
In the given circuit R_2 & R_3 are in series, hence

$$R_{23} = R_2 + R_3$$

$$= 35 + 40$$

$$= 75\ \Omega$$

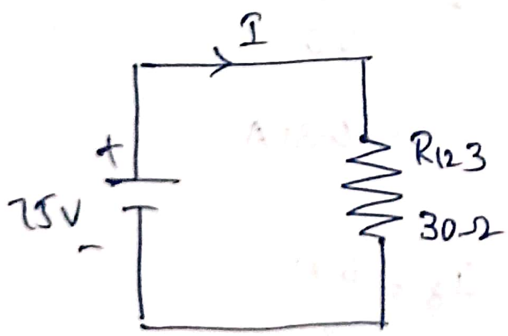
The resistance R_{23} is in parallel with R_1, hence the circuit becomes



$$R_{123} = \frac{R_1 \times R_{23}}{R_1 + R_{23}}$$

$$= \frac{50 \times 75}{50 + 75}$$

$$= 30\ \Omega$$

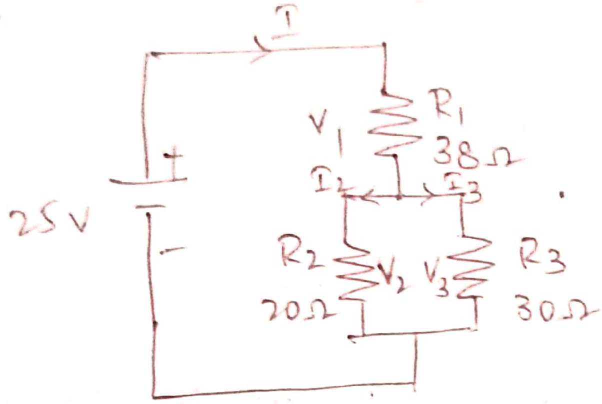


$$I = \frac{V}{R}$$

$$= \frac{75}{30}$$

$$I = 2.5A$$

(3) Determine the resistor voltage drops and the branch currents.



$R_{123} = 50\Omega$

$I = 0.5A$

$V_1 = I R_1$

$= 0.5 \times 38$

$= 19V$

$I = I_2 + I_3$

$0.5 = \frac{V_2}{R_2} + \frac{V_3}{R_3}$ $[V_2 = V_3 = V]$

$0.5 = \frac{V}{20} + \frac{V}{30}$

$0.5 = 0.05V + 0.03V$

$0.5 = 0.08V$

$V = \frac{0.5}{0.08}$

$= 6.25V$

$I_2 = \frac{6.25}{20}$

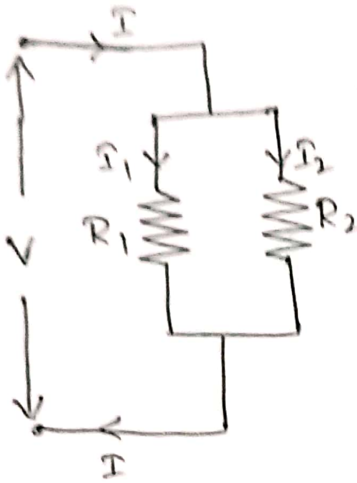
$= 0.31A$

$I_3 = \frac{6.25}{30}$

$= 0.2A.$

CURRENT DIVISION RULE :

A parallel circuit acts as a current divider as the current divides in all the branches in a parallel circuit, and the voltage remains the same across them.



Current I, has been divided into I_1 & I_2 into two parallel branches with the resistance R_1 & R_2, V is the voltage drop across the resistance R_1 & R_2.

As we know,

$$V = IR \longrightarrow (1)$$

$$I_1 = \frac{V}{R_1} \quad \& \quad I_2 = \frac{V}{R_2}$$

Let the total resistance of the circuit be 'R' & is given by,

$$R = \frac{R_1 R_2}{R_1 + R_2} \longrightarrow (2)$$

Eq (1) can also be written as,

$$I = \frac{V}{R} \longrightarrow (3)$$

Substitute (2) in (3)

$$\therefore I = \frac{V(R_1+R_2)}{R_1 R_2} \longrightarrow (4)$$

but

$$V = I_1 R_1 = I_2 R_2 \longrightarrow (5)$$

Substitute $V = I_1 R_1$ in (4)

$$\therefore I = \frac{I_1 \cancel{R_1}(R_1+R_2)}{\cancel{R_1} R_2}$$

$$\therefore I_1 = \frac{I R_2}{R_1 + R_2} \longrightarrow (6)$$

Substitute $V = I_2 R_2$ in (4)

$$\therefore I = \frac{I_2 R_2 (R_1 + R_2)}{R_1 R_2}$$

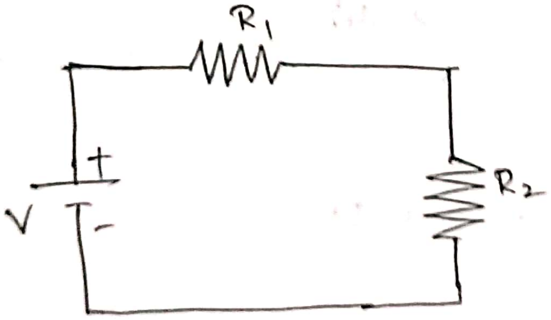
$$I_2 = I \frac{R_1}{R_1 + R_2} \longrightarrow (7)$$

$$\therefore \boxed{I_1 = \frac{I R_2}{R_1 + R_2}}, \quad \boxed{I_2 = \frac{I R_1}{R_1 + R_2}}$$

Thus, in the current division rule, it is said that the current in any of the parallel branches is equal to the ratio of opposite branch resistance to the total resistance, multiplied by the total current.

VOLTAGE DIVISION RULE:

The voltage division rule can be understood by considering a series circuit shown below. In a series circuit, voltage is divided, whereas the current remains the same.



Let us consider a voltage source E with the resistance R_1 & R_2 connected in series across it.

As we know,

$$I = \frac{V}{R} \longrightarrow (1)$$

$$R = R_1 + R_2 \longrightarrow (2)$$

Substitute ② in ①

$$I = \frac{V}{R_1+R_2} \rightarrow (3)$$

$$I = \frac{V_1}{R_1} = \frac{V_1}{R_2}$$

Substitute $I = \frac{V_1}{R_1}$ in ③

$$\frac{V_1}{R_1} = \frac{V}{R_1+R_2}$$

$$\boxed{V_1 = \frac{V R_1}{R_1+R_2}} \rightarrow (4)$$

Substitute $I = \frac{V_2}{R_2}$ in ③

$$\frac{V_2}{R_2} = \frac{V}{R_1+R_2}$$

$$\boxed{V_2 = \frac{V R_2}{R_1+R_2}} \rightarrow (5)$$

Thus, "voltage across a resistor in a series circuit is equal to the value of that resistor times the total impressed voltage across the series elements divided by the total resistance of the series elements."

SUPERPOSITION THEOREM:

STATEMENT:

Superposition theorem states that "in any linear, bilateral network where more than one source is present, the response across any element in the circuit is the sum of the responses obtained from each source acting alone. while, other sources are replaced by their internal resistance.

PROCEDURE TO APPLY SUPERPOSITION THEOREM:

→ The first step is to select one among the multiple sources present in the bilateral network. Among the various sources in the circuit, any one of the sources can be considered first.

→ Except for the selected source, all the sources must be replaced by their internal resistance. If internal resistance is zero then voltage source is repla short circuited & current source is open circuited.

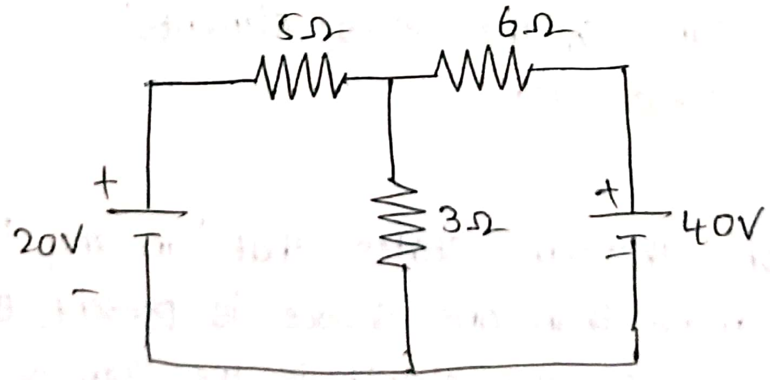
→ Using a network simplification approach, evaluate the current flowing through or the voltage drop across a particular element in the network.

→ The same considering a single source is repeated for all the other sources in the circuit.

→ Upon obtaining the respective response for individual source, perform the summation of all responses to get the overall voltage drop (or) current through the circuit element.

PROBLEMS ON SUPERPOSITION THEOREM:

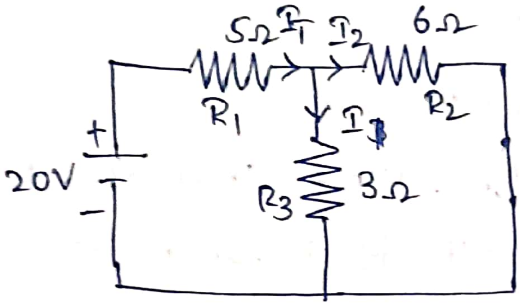
① Find the current through 3Ω resistor using superposition theorem.



Let I_1 & I_2 are the currents flowing through the 3Ω resistor, due to the voltage sources 20V & 40V respectively.

→ To Find : I_1

Consider 20V voltage source alone. Hence short circuit the other voltage source and the circuit is redrawn as below.



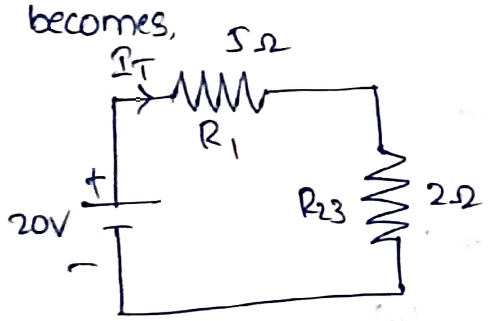
R_2 & R_3 are in parallel

$$R_{23} = \frac{R_2 R_3}{R_2 + R_3}$$

$$= \frac{6 \times 3}{6+3}$$

$$= \frac{18}{9} = 2\Omega$$

The resistor R_{23} is in series with R_1 then the circuit becomes,



$$R_{123} = 5 + 2$$

$$= 7\Omega$$

$$I_T = \frac{V}{R_{123}} = \frac{20}{7}$$

$$= 2.85A$$

Now, the current through 3Ω resistor is determined by current division rule

$$I_1 = I_T \times \frac{6}{6+3}$$

$$= 2.85 \times 0.667$$

$$= 1.9 \text{ A}.$$

LIMITATIONS OF SUPERPOSITION THEOREM:

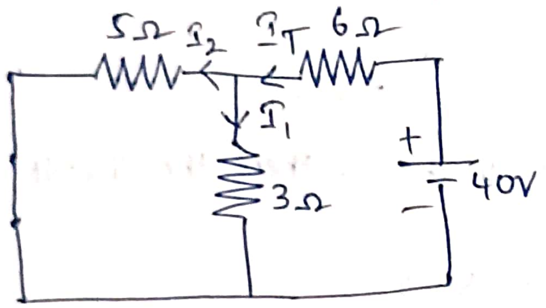
→ Superposition theorem is not apply to non-linear circuits.

→ It is only applicable to determine voltage and current but not power.

→ The application of the superposition theorem realizes two (or) more sources in the circuit.

→ To find I_2 (continuation of problem ①)

Consider 40V voltage source alone. Hence, short circuit the other voltage source and the circuit is redrawn as follows:



$R_T = 6 + \frac{5\times3}{5+3}$

$= 7.875\,\Omega$

$I_T = \frac{V}{R_T}$

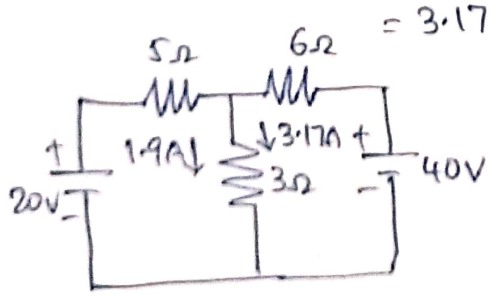
$= \frac{40}{7.875}$

$= 5.079\,A$

$I_1 = I_T \times \frac{5}{5+3}$

$= 5.079 \times 0.625$

$= 3.17\,A$

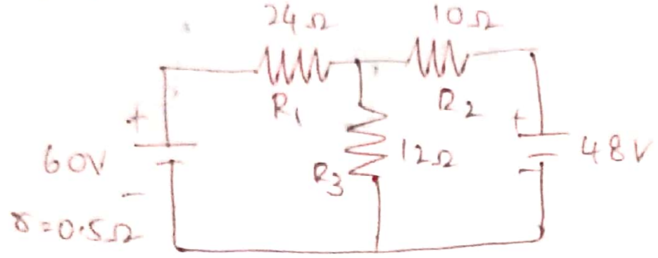


$I_2 = 1.904 + 3.174$

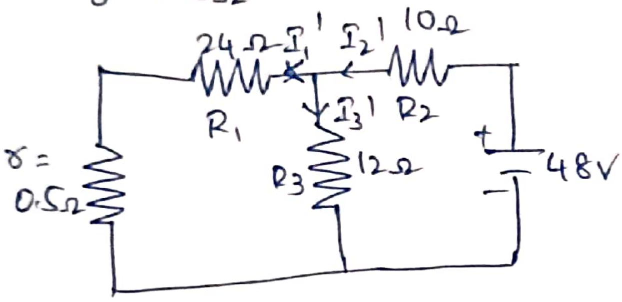
$= 5.078\,A$

[(2) Find the voltage across through 15Ω resistor using Superposition theorem.]

(2) Determine the current in each branch of the network using superposition theorem



→ Replace 60V voltage source with internal resistance of 0.5Ω



$$R_T = \frac{(R_1+r)\times R_3}{(R_1+r)+R_3} + 10$$

$$= 14.1\,\Omega$$

$$I_2' = \frac{V_2}{R_2} = \frac{48}{14.1}$$

$$= 3.4\text{ A}$$

$$I_3' = I_2' \times \frac{V+R_1}{V+R_1+R_2}$$

$$= 3.4 \times \frac{0.5+24}{0.5+24+12}$$

$$= 3.4 \times 0.6$$

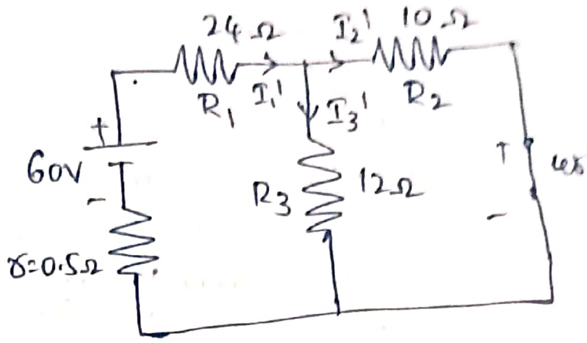
$$= 2.278\text{ A}$$

$$I_1' = I_2' - I_3'$$

$$= 3.4 - 2.278$$

$$= 1.122\text{ A}$$

→ Replace 48V voltage source with short circuit



$R_T = 0.5 + 24 + \frac{12}{110}$

$= 29.95\Omega$

$I_2'' = 2 \times \frac{10}{22}$

$= 0.91$

$I_2 = 2 \times \frac{12}{22}$

$= 1.091$

$I_1 = 1.091 - 2.66$

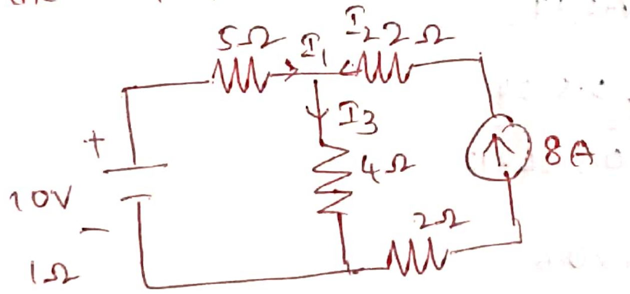
$= 1.569$ A.

$I_{12} = I_{12}' + I$

$= 0.91 + 1.785$

$= 2.695$ A

→ Find the current in each branch of the circuit by applying the superposition theorem.



$I_1 = I_1'' - I_1'$

$= 3.2 - 1$

$= 2$ A

$I_2 = I_2'' - I_2'$

$= 8 - 0$

$= 8$ A.

$I_3 = I_3'' - I_3'$

$= 1 + 4.8$

$= 5.8$ A.

A.C. CIRCUITS:

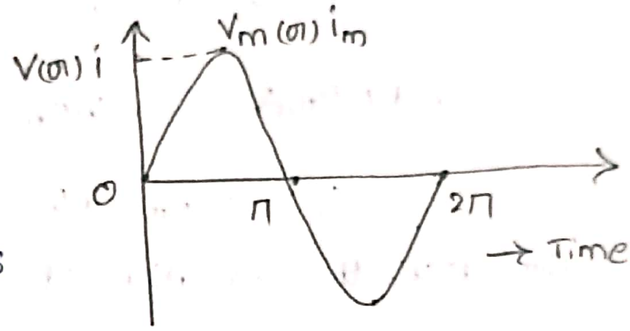
A.C. QUANTITY:

An alternating quantity is one which acts in alternate directions and whose magnitude undergoes a definite cycle of changes in definite intervals of time.

EQUATION OF A.C. VOLTAGE & A.C. CURRENT:

A.C. VOLTAGE:

Voltage that fluctuates sinusoidally with time at a fixed frequency is known as "A.C. voltage."



A.C. CURRENT:

Current that fluctuates sinusoidally with time at a fixed frequency is known as "A.C. current."

According to Faraday's Laws of Electromagnetic Induction, the e.m.f. induced in the coil is

$$e = -N\frac{d\phi}{dt} \quad V$$

$$= -N\frac{d}{dt}(\phi_m \cos\omega t)$$

$$= -N\phi_m(-\sin\omega t)\times\omega \qquad (\theta = \omega t)$$

$$= N\omega\phi_m \sin\omega t$$

$$= N\omega\phi_m \sin\theta \longrightarrow (1)$$

Hence, 'e' has maximum value, i.e E_{max} when $\theta = 90°$

i.e. $\sin\theta = \sin 90° = 1$

From eq (1) we get,

$$E_m = N\omega\phi_m \times 1 \quad V$$

$$= N \times 2\pi f \times B_m A \quad V$$

$[\because \omega = 2\pi f \;\&\; \phi_m = B_m A]$

$$\therefore E_m = 2\pi f N B_m A \quad V \rightarrow ②$$

Substitute ② in ①

$$2\pi f N B_m A = N\omega\phi_m \sin\theta$$

$$\therefore e = E_m \sin\theta \rightarrow ③$$

Similarly, the equation of the induced current is

$$i = I_m \sin\theta$$

$$\therefore e = E_m \sin\theta$$
$$i = I_m \sin\theta$$

A.C. WAVEFORM:

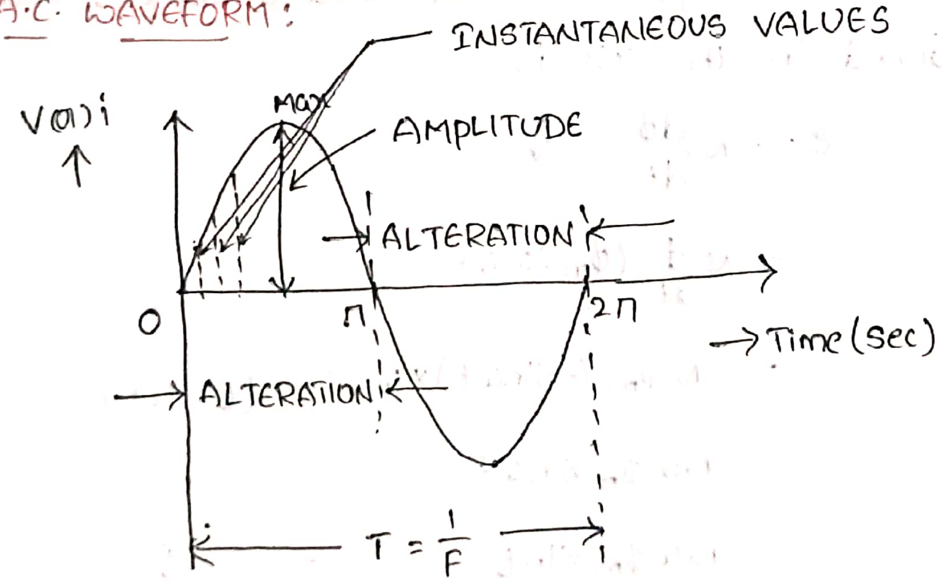


Fig. A.C. waveform

Cycle: one complete set consisting of all positive and all negative values of an alternating quantity is known as a cycle.

TIME PERIOD:

The time period of an alternating quantity is the time required to complete one cycle.

FREQUENCY:

The "Frequency" of an alternating quantity is the number of cycles per second, thus the frequency of an alternating quantity is the reciprocal of the time period. The most common power frequency in India is 50 c/sec (Hertz).

AMPLITUDE:

The maximum / peak value, either positive (or) negative of an alternating quantity is called its "amplitude."

ALTERATIONS:

one-half of the cycle is called an alteration, whether it may be positive (or) negative value.

INSTANTANEOUS VALUES:

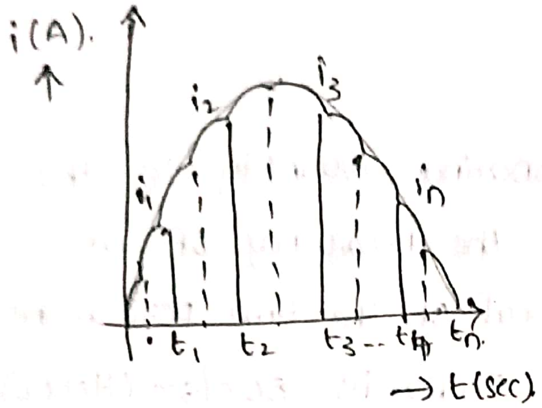
The strength of an alternating quantity existing in a circuit at a given instant.

ANGULAR VELOCITY:

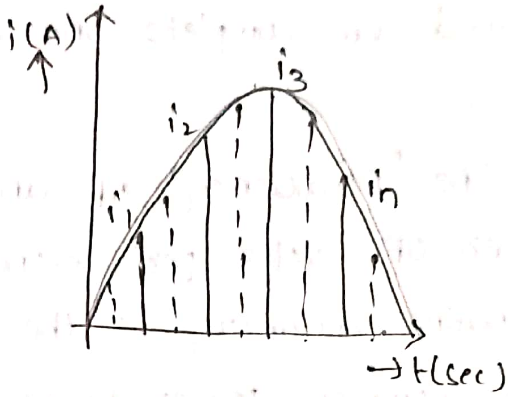
The angle through which any radius of a body turns in a second. usually represented by 'ω' and is measured in radians per second.

MEAN OR AVERAGE VALUE:

"The average value of an alternating current is given by that steady (d.c.) current which transfers across any circuit the same amount of charge as is transferred by that alternating current during the same time."



(a) Non- sinusoidal



(b) Sinusoidal

For finding the average value of symmetrical sinusoidal a.c. either mid- ordinate method (or) analytical method may be used, although for symmetrical but non-sinusoidal wave, the mid- ordinate method is more convenient.

(a) Non- sinusoidal

Let the average value of instantaneous currents during these intervals be $i_1, i_2, \ldots i_n$ respectively.

$$\therefore \text{Average current, } I_{avg} = \frac{i_1 + i_2 + \cdots + i_n}{n}$$

$$\text{Average e.m.f, } E_{avg} = \frac{e_1 + e_2 + \cdots + e_n}{n}$$

(b) Sinusoidal

we know the equation of alternating current is,

$$i = I_m \sin\theta$$

$$I_{avg} = \int_0^{\pi} \frac{I_m}{\pi} \sin\theta \, d\theta$$

$$\boxed{\therefore I_{avg} = \frac{1}{T}\int_0^T i \, dt}$$

$$= \frac{I_m}{\pi} \int_0^{\pi} \sin\theta \, d\theta$$

$$= \frac{I_m}{\pi} \left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{I_m}{\pi} \left[(-\cos\pi) - (-\cos 0^\circ)\right]$$

$$= \frac{I_m}{\pi} \left[1 - (-1)\right]$$

$$= \frac{2 I_m}{\pi}$$

$$\boxed{I_{avg} = 0.637\, I_m} \qquad \boxed{E_{avg} = 0.637\, E_m}$$

R.M.S VALUE:

"The r.m.s value of an alternating current is given by that steady (d.c.) current which when flowing through a given circuit for a given time produces the same amount of heat as produced by the a.c, when flowing through the same circuit for the same time."

For non-sinusoidal:

$$I_{r.m.s} = \sqrt{\left(\frac{i_1^2 + i_2^2 + \cdots + i_n^2}{n}\right)}$$

$$E_{r.m.s} = \sqrt{\left(\frac{e_1^2 + e_2^2 + \cdots + e_n^2}{n}\right)}$$

For sinusoidal:

$$I_{r.m.s} = 0.707\, I_m \text{ (or) } \frac{I_m}{\sqrt{2}}$$

$$E_{r.m.s} = 0.707\, E_m \text{ (or) } \frac{E_m}{\sqrt{2}}$$

FORM FACTOR:

The ratio of the r.m.s. value to the average value of an a.c. is known as Form Factor and is denoted by the letter K_F.

$$\text{Form factor, } K_F = \frac{\text{r.m.s value}}{\text{average value}}$$

$$= \frac{0.707\, I_m}{0.637\, I_m}$$

$$= 1.11 \quad \text{(For sinusoidal only)}$$

PEAK (or) CREST (or) AMPLITUDE FACTOR:

It is defined as the ratio of maximum value to r.m.s value.

$$\text{Peak Factor} = \frac{\text{maximum value}}{\text{r.m.s value}}$$

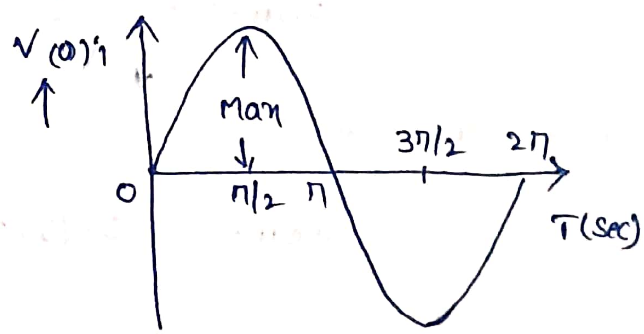
$$= \frac{I_m}{I_m/\sqrt{2}}$$

$$= \sqrt{2}$$

$$= 1.414 \quad \text{(For sinusoidal a.c. only)}$$

PHASE:

The angle turned through by an alternating current (or) voltage from a given instant is known as "phase."



PHASE DIFFERENCE:

The angle between the phases of two alternating quantities of the same frequency as measured in degrees is known as "phase difference."

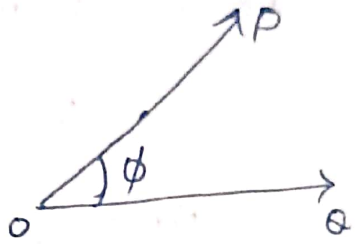
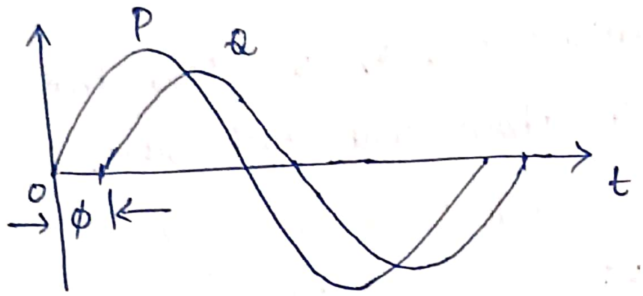
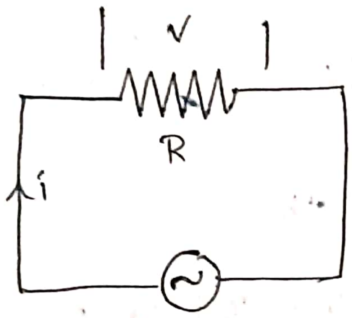


Fig (a)

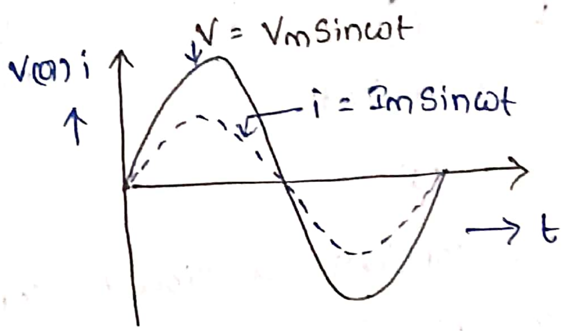


(b).

A.C. through pure Resistance only:



(a)



(b)

Let the applied voltage be,

$$V = V_m \sin\omega t \quad \longrightarrow (1)$$

$$\& \quad i = \frac{V}{R} \quad \longrightarrow (2)$$

Substitute (1) in (2)

$$i = \frac{V_m \sin\omega t}{R}$$

$$i = \frac{V_m}{R} \sin\omega t \quad \longrightarrow (3)$$

current 'i' is maximum when $\sin\omega t$ is unity ($\omega t = 90$)

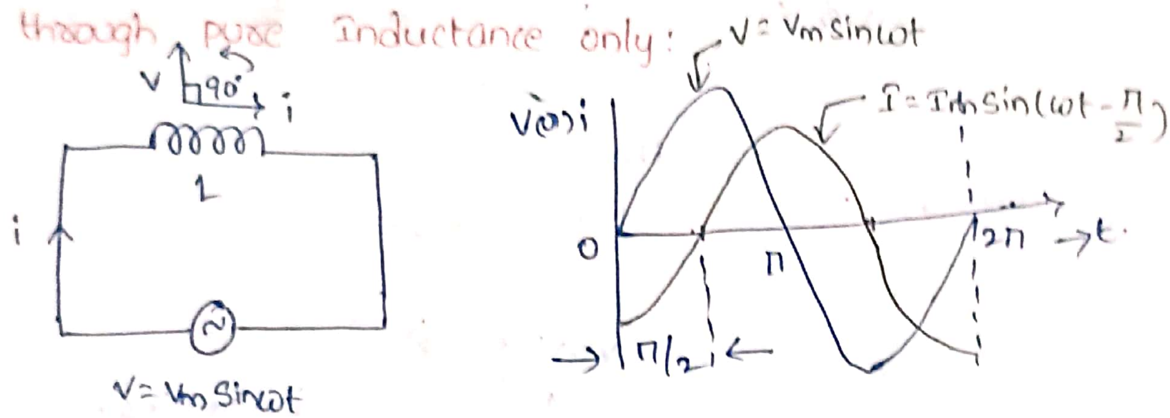
$$\therefore I_m = \frac{V_m}{R}$$

Hence equation (3) becomes

$$i = I_m \sin\omega t \rightarrow (4)$$

Comparing equations (1) & (4), we find that the voltage and current are in phase with each other.

A.C. through pure Inductance only:



(a) (b)

Let us consider a circuit containing coil of pure inductance as shown in fig (a).

$$V = L\frac{di}{dt}$$, voltage across inductor $\rightarrow (1)$

$$V = V_m \sin\omega t \rightarrow (2)$$

L = self inductance in henry.

(1) = (2)

$$L\frac{di}{dt} = V_m \sin\omega t$$

$$di = \frac{V_m}{L}\sin\omega t \, dt$$

Integrating both sides we have

$$\int di = \int \frac{V_m}{L}\sin\omega t \, dt$$

$$i = \frac{V_m}{L}\left(-\frac{\cos\omega t}{\omega}\right)$$

$$i = \frac{V_m}{\omega L}\sin(\omega t - 90^\circ)$$

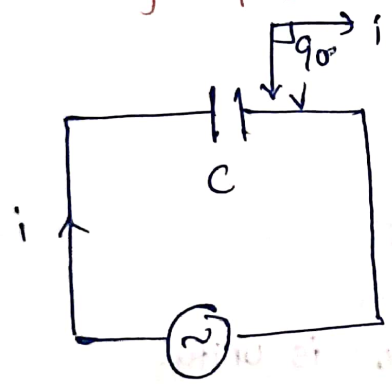
current 'i' is max I_{max}, when $(\omega t - 90^\circ)$ is unity.

$$\therefore I_m = \frac{V_m}{\omega L}$$

$$\therefore i = I_m \sin(\omega t - 90^\circ) \longrightarrow (3)$$

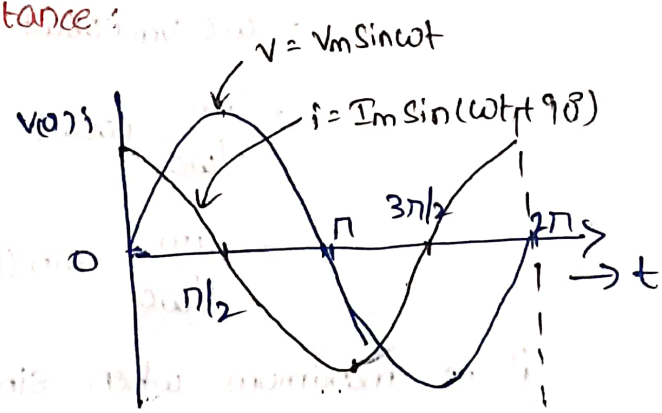
Comparing equations (2) & (3), we find that the current lags behind the applied voltage by 90° (or) the phase difference between the two is $\pi/2$ radian as shown in fig.(b).

A.C. through pure capacitance :



$V = V_m \sin\omega t$

(a)



(b)

Consider a circuit consisting of capacitance 'c' alone as shown in fig (a).

Let, V = potential difference between plates at any instant (V)

q = charge on plates at the instant (coulomb)

C = capacitance of the capacitor (farad) when an alternating e.m.f. is applied to a capacito, the p.d between the plates is given by,

$$V = \frac{q}{C}$$

$$V_m \sin\omega t = \frac{q}{C}$$

$$q = C \cdot V_m \sin\omega t$$

'i' is given by rate of flow of charge.

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

$$= \frac{d}{dt}(C\, V_m \sin\omega t)$$

→ differentiating.

$$= \omega C\, V_m \cos\omega t$$

$$= \frac{V_m}{1/\omega C} \cos\omega t$$

$$= \frac{V_m}{1/\omega C} \sin(\omega t + 90)$$

'i' is maximum when $\sin(\omega t+90)$ is unity.

$$I_m = \frac{V_m}{1/\omega C}$$

$$i = I_m \sin(\omega t + 90) \ \&$$

$$V = V_m \sin\omega t$$

comparing the above two equations, current in a capacitive circuit leads the applied voltage by $90°$ (or) $\pi/2$ radian as shown in fig (b).

ELECTRICAL POWER:

Electrical power is the rate of per unit of time at which the amount of electrical energy is transformed into some other form of energy (such as heat, light, mechanical power, etc..). Unit of electrical power is watt (or) Joule/sec.

CLASSIFICATION OF POWER:

Electrical power is classified into two types.

(i) DC power

(ii) AC power

(i) DC POWER: power consumed in the DC circuit is known as DC power. It is produced by a fuel cell, batteries, DC generators, etc..

$$\boxed{P = VI} \text{ watt}$$

(ii) AC POWER: The electrical power associated with an AC circuit is known as complex power. whereas complex power is the combined form of Active, Reactive & Apparent power. So AC power is of three parts.

(1) Active power

(2) Reactive power

(3) Apparent power

(1) ACTIVE POWER:

The power that is actually consumed (or) utilized in an AC circuit is known as Active power. It is the true power transmitted to the load for energy conversion. That's why it is also known as True power (or) Real power. It is represented by the letter 'P' & measured in watt (W), kW (or) MW.

$$\boxed{\therefore P = VI \cos\phi}$$

'ϕ' is the angle between V & I.

1)

(2) REACTIVE POWER:

The power associated with reactive components (Inductors & capacitors) of the circuit is known as Reactive power. It flows in both (back & forth) directions of the circuit.

Reactive power is not a useful power for consumers so it is represented as wattless power. But it is required in the circuit to produce the electric and magnetic field for the working of capacitors & inductors in the circuit.

It only exists in the electrical system when voltage & current in an AC circuit are not in phase.

It is represented by the letter 'Q' & measured in VAR, KVAR (or) MVAR.

$$\therefore Q = VI \sin\phi$$

ϕ = angle between V & I

(3) APPARENT POWER:

The combination of Active power and Reactive power is known as Apparent power. It is the total power of the circuit. It is denoted by 'S' & is measured in kVA, MVA.

$$S = VI$$

$$S = P + jQ$$

(or)

$$S = \sqrt{P^2 + Q^2}$$

POWER TRIANGLE:

Power triangle is the geometrical representation of Active power, Reactive power, and Apparent power.

It is used to find the power factor of electrical circuits.

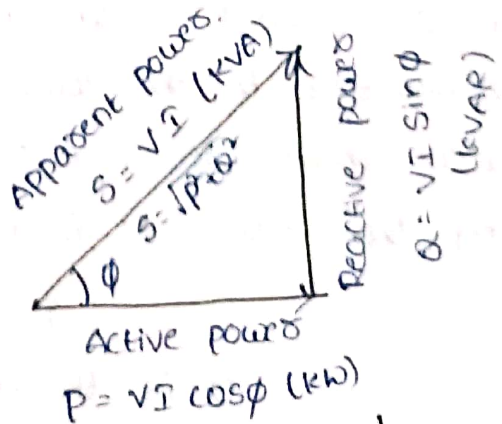


Fig. Power Triangle

Scanned with OKEN Scanner

From the power triangle,

POWER FACTOR:

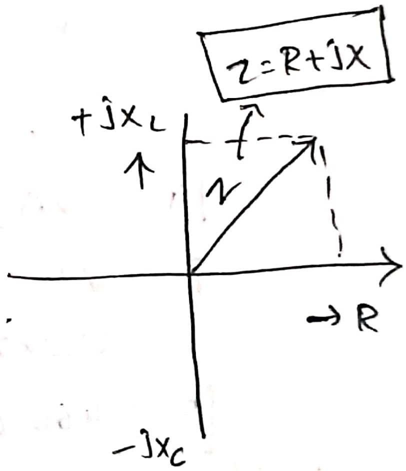
power factor, $\cos\phi$ is the ratio of Active power to the apparent power.

For resistive loads, such as electric heaters & most lighting systems, Reactive power (kVAR) is smaller proportion of apparent power, hence power factor is closer to 1.

For loads like motors, generators and ballasts use inductive loads, in these loads reactive power (kVAR) is larger proportion of apparent power, hence power factor is closer to '0'.

$$\text{power factor}, \cos\phi = \frac{\text{Active power (kW)}}{\text{Apparent power (kVA)}}$$

CONCEPT OF IMPEDANCE (Z):



Impedance is the opposition to alternating current developed by the combined effect of resistance and reactance in a circuit. It is denoted by letter 'Z' & is measured in 'Ω' (ohms).

$$\text{Impedance}, \boxed{Z = R + jX}$$

$$Z = \sqrt{R^2 + X^2}$$

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

$$\text{Inductive Reactance}, X_L = 2\pi FL$$

$$\text{capacitive Reactance}, X_C = \frac{1}{2\pi FC}$$

$$\boxed{X = X_L - X_C}$$

NUMERICAL PROBLEMS ON R, L & C ALONE:

(1) An incandescent lamp having a resistance of 115 ohm is connected to a 230V (r.m.s.) supply. Determine the current taken by the lamp and the power dissipated.

Given data

Resistance, $R = 115\Omega$

Voltage, $V = 230V$

To Find

Current, $I = ?$

power, $P = ?$

we know,

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

$$= \frac{230}{115}$$

$$\boxed{I = 2A}$$

$$P = VI$$

$$= 230 \times 2$$

$$\boxed{P = 460\ W}$$

(2) What is the inductive reactance of an a.c. circuit 0.08 H inductance, if the frequency is 60Hz?

Given

Inductance, $L = 0.08\ H$

Frequency, $f = 60Hz$

To Find

Inductive reactance, $X_L = ?$

we know,

$$X_L = 2\pi f L$$

$$= 2 \times \pi \times 60 \times 0.08$$

$$\boxed{\therefore X_L = 30.16\ \Omega}$$

(3) An inductive coil of negligible resistance takes 12.5A. when connected to 100V, 50Hz supply. Calculate its inductance.

Given

Current, $I = 12.5A$

Voltage, $V = 100V$

Frequency, $F = 50Hz$

To Find

Inductance, $L = ?$

we know,

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

$$= \frac{100}{12.5}$$

$$= 8\Omega$$

$$Z = X_L$$

$$X_L = 2\pi F L$$

$$L = \frac{X_L}{2\pi F}$$

$$= \frac{8}{2\pi \times 50}$$

$$\boxed{L = 0.0255\ H}$$

(4) what is the capacitive reactance of an a.c. circuit containing 35μF capacitance, if the frequency is 60Hz?

Given

Capacitance, $C = 35\mu F$

Frequency, $F = 60Hz$

To Find

Capacitive reactance, $X_C = ?$

we know,

$$X_C = \frac{1}{2\pi F C}$$

$$= \frac{1}{2\pi \times 60 \times 35 \times 10^{-6}}$$

$$\boxed{X_C = 75.79\Omega}$$

NUMERICAL PROBLEMS ON AC WAVE FORM:

(1) Determine the instantaneous value of an e.m.f of 141.4 Volt maximum, after 0.001 sec has elapsed. The voltage starts from zero & the frequency is 50Hz.

Given

$E_m = 141.4\ V$

$t = 0.001\ Sec$

$f = 50\ HZ$

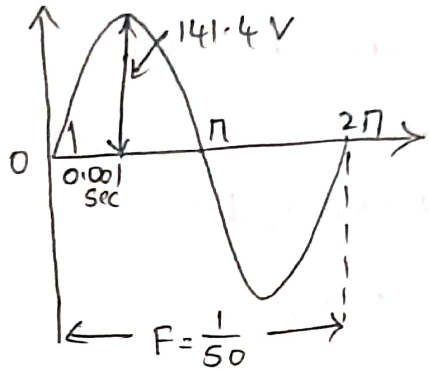


fig.

To Find

$e = ?$

we know,

$e = E_m \sin \omega t$

$= E_m \sin 2\pi f t$

$= 141.4 \times \sin \times 2 \times 180 \times 50 \times 0.001$

$= 141.4 \sin 18^\circ$

$= 141.4 \times 0.309$

$\boxed{e = 43.7\ V}$

(2) The current in a circuit obeys the load $i = 100 \sin \omega t$. If the frequency is 25Hz how long will it take for the current to rise to 50 A?

Given

$i = 100 \sin \omega t$

$F = 25\ HZ$

$i = 50 A.$

To Find

$t = ?$

we know,

$i = 100 \sin \omega t$

$50 = 100 \sin 2 \times \pi \times F \times t$

$\frac{50}{100} = \sin 2 \times 180 \times 25 \times t$

$\frac{1}{2} = \sin(180 \times 50t)$

$180 \times 50t = \sin^{-1}(\frac{1}{2})$

$t = \frac{30}{180 \times 50}$

$\boxed{t = \frac{1}{300}\ Sec}$

(B) The equation of an a.c. is $i = 42.42 \sin 628t$. Determine its (a) r.m.s. value (b) average value. (c) Frequency (d) Form Factor & peak Factor.

Given

$i = 42.42 \sin 628t$

Find

(a) r.m.s. value

(b) average value

(c) Frequency

(d) Form Factor & peak Factor.

We know

$i = I_m \sin \omega t$

Comparing the given equation with standard equation.

$I_m = 42.42$ A.

$\omega = 2\pi f = 628$

(a) r.m.s value, $I_{r.m.s} = 0.707 I_m$

$= 0.707 \times 42.42$

$= 30A$

(b) average value, $I_{avg} = 0.637 I_m$

$= 0.637 \times 42.42$

$= 27 A$

(c) Frequency,

$\omega = 2\pi f = 628$

$$f = \frac{628}{2\pi} = 100 \text{ Hz}$$

(d) Form Factor $= \frac{I_{r.m.s}}{I_{avg}}$

$= \frac{30}{27}$

$= 1.11$

Peak Factor $= \frac{I_m}{I_{r.m.s}}$

$= \frac{42.42}{30}$

$= 1.414.$

NUMERICAL PROBLEMS ON AC POWERS:

(1) The active and reactive power of an inductive circuit are 60W & 80 VAR respectively. Determine the power factor of the circuit.

Given

Active power, $P = 60W$

Reactive power, $Q = 80VAR$

To Find

Power Factor, $\cos\phi = ?$

We know,

$$\cos\phi = \frac{P}{S}$$

$$S = \sqrt{P^2 + Q^2}$$

$$= \sqrt{60^2 + 80^2}$$

$$= 100 \text{ KVA}$$

$$\cos\phi = \frac{60}{100}$$

$$= 0.6 \text{ lag.}$$

(2) Find the true power when apparent power = 10W & power factor = 0.5

Given

Apparent power, $S = 10\ W$

power factor, $\cos\phi = 0.5$

To Find

True power, $P = ?$

we know,

$$\cos\phi = \frac{\text{True power}}{\text{Apparent power}}$$

$$0.5 = \frac{P}{10}$$

$$\boxed{P = 5\ W}$$

(3) For a certain load, the true power is 150W and the reactive power is 125W. Find the apparent power.

Given

Active power, $P = 150\ W$

Reactive power, $Q = 125\ W$

To Find

Apparent power, $S = ?$

we know,

$$S = \sqrt{P^2 + Q^2}$$

$$= \sqrt{(150)^2 + (125)^2} \quad \boxed{S = 195.2\ W}$$

UNIT-2

Machines and Measuring Instruments

Machines: Construction, principle and operation of (1) DC Motor, (ii) DC Generator, (iii) Single Phase Transformer, (iv) Three Phase Induction Motor and (v) Alternator, Applications of electrical machines.

Measuring Instruments: Construction and working principle of Permanent Magnet Moving Coil (PMMC), Moving Iran (MI) Instruments and Wheat Stone bridge.

DC MOTOR

DC motors convert electrical energy into mechanical energy. The fundamental principles and construction of the DC motor are identical with DC generators. A machine that runs as a motor will also operate as a generator operation of DC motor.

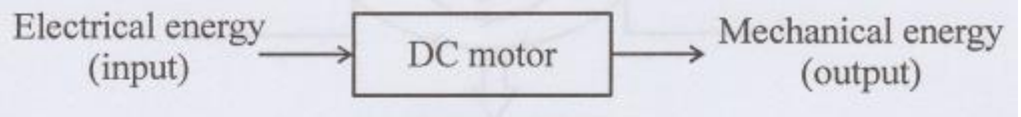


Figure 3.22

PRINCIPLE OF OPERATION

The basic principle is whenever a current carrying conductor is placed in a magnetic field the conductor experiences a force whose direction is given by Fleming's left-hand rule. If a current carrying conductors is placed between two magnetic poles as shown in fig 3.23, both the fields will be distorted flux (less flux)

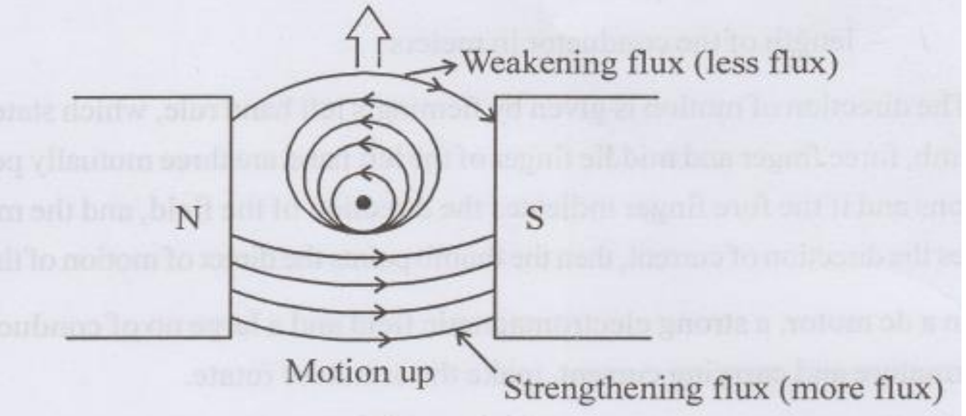


Figure 3.23

From the fig 3.23 above the conductor the field is weakened and below the conductor the field is strengthened. Therefore, the conductor moves upwards. The force exerted upwards depends upon the intensity of the main field flux and the magnitude of the current.

The direction of the current through the conductor is reversed as shown in fig 3.24. Here, below the conductor field is less weakened and above the conductor the field is strengthened. Then the conductor tends to move downwards.

The magnitude of the force experienced by the conductor is

$F = BI\,l$

Where

B - magnetic field density in wb/m^2

I - current in ampere

l - length of the conductor in meters

The direction of motion is given by Fleming's left-hand rule, which states that, if the left thumb, force finger and middle finger of the left hand are three mutually perpendicular directions and if the fore finger indicates the direction of the field, and the middle finger indicates the direction of current, then the thumb points the direct of motion of the conductor.

In a dc motor, a strong electromagnetic field and a large no of conductors housed in an armature and carrying current, make the armature rotate.

APPLICATIONS OF DC MOTORS

DC shunt motors

They are used where the speed has to remain nearly constant with load and where a high starting torque is not required. These are used for driving centrifugal pumps and light machine tools, wood working machines, lathe etc.

Series motor:

These types of motors used where the load is directly attached to the shaft or through a gear arrangement and where there is no danger of the load being through off. These are used in electric trains, cranes, hoists, fans, blowers, conveyours, lifts etc., where the stating torque requirement is high.

Compound Motors

They are used for driving heavy machine tools for intermittent loads. Shafts, punching machines etc.

INTRODUCTION OF DC GENERATOR

An electrical generator is a rotating machine which converts mechanical energy in to electrical energy. This energy conversion is based on the principle of electromagnetic induction.

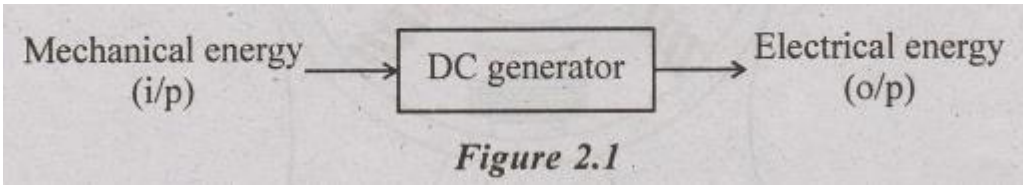


Figure 2.1

According to faraday's laws of electromagnetic induction, whenever a conductor is moved in a magnetic field, dynamically induced emf is produced in the conductor when an external load is connected to the conductor the induced emf causes a current to flow in the load.

CONSTRUCTIONAL DETAILS

The major parts of the DC generator is given below and also shown in fig.2.2

1. Magnetic frame or yoke

2. Poles, interpoles, windings, pole shoes

3. Armature

4. Commutator

5. Brushes, bearings and shaft

Yoke

The outer frame or yoke serves two purposes.

(i) It provides mechanical support for the poles and acts as a protecting cover for the whole machine.

(ii) It carries the magnetic flux produced by the poles.

In small machines where cheapness is the main consideration and weight is not a critical factor. The yoke is made up of cast iron. But for larger machines cast steel or rolled steel is used.

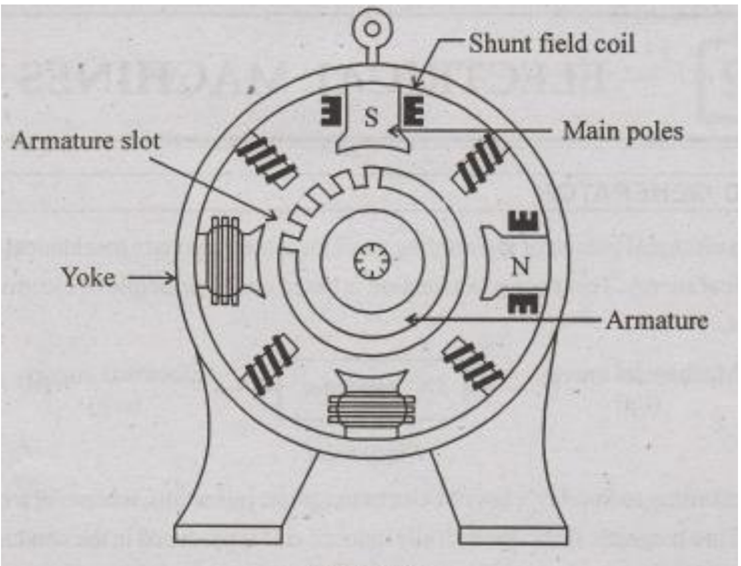


Figure 2.2

Poles

The poles consist of pole cores, pole shoes and pole coils. The pole cores and pole shoes form the field magnet. The pole shoes used to spread out the flux in the air gap and also reduce the reluctance of the magnetic path. The pole shoes also support the exciting coils or field coils. The pole core is made up of cast iron or cast steel. To minimize the eddy current losses the pole cores and pole shoes are laminated. Annealed steel is used for laminations. The thickness of laminations varies from 1 mm to 0.25 mm.

The pole coils are made up of copper wire or strip. When current is passed through these coils, the pole becomes an electromagnet and starts establishing a magnetic field in the machine. The flux distribution through the pole, air gap, armature core and yoke is shown in fig.2.3.

Interpoles

In modern DC machines commutating poles or interpoles are provided to improve commutation. Like the field winding the commutating poles also have exciting coils which are connected in series with the armature.

Armature

The armature consists of an armature core and armature windings. The armature core houses the armature conductors or coils and causes them to rotate and cut the magnetic flux of the field magnets.

The armature core is cylindrical or drum shaped. It is made up of circular sheet steel. The armature core is laminated with the thickness of 0.5 mm. the lamination is used to minimize the eddy current loss. The laminations are known as stampings. In small machines these stampings are directly keyed on the shaft. In larger machines the stampings are first assembled and then keyed on an armature spider and the armature spider is then keyed on to the shaft.

The armature conductors are housed in the slots. The slots are rectangular in shape for large machines and circular for small machines.

The conductors are housed in slots in two layers. The slots are closed by fiber or wooden wedges to prevent the conductors from flying out due to centrifugal force when the armature rotates. The arrangement is shown in fig.2.3 and 2.4.

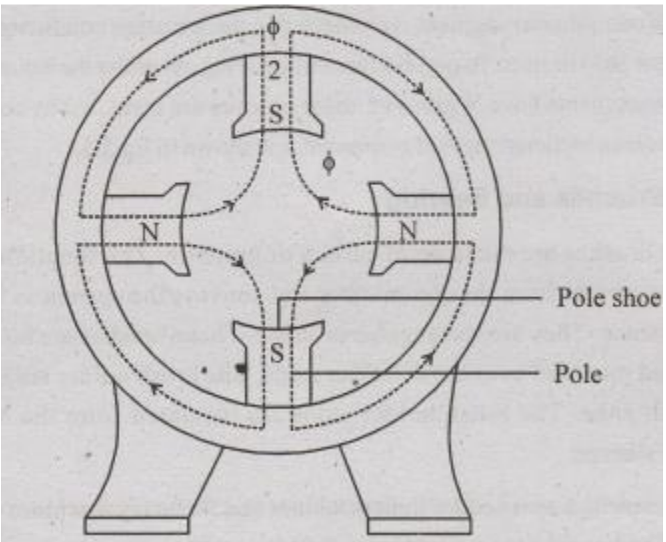


Figure 2.3

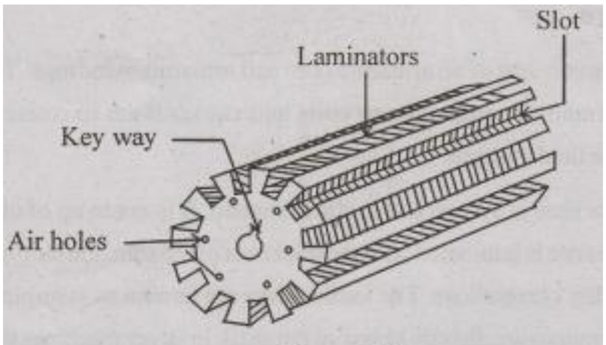


Figure 2.4

Commutator

The function of commutator is collection of current from the armature conductors and converts the alternating current induced in the armature conductors into unidirectional current in the external load circuit. It is cylindrical in structure and is built up of wedge-shaped segments of high conduction hard-drawn copper. These segments are insulated from each other by thin layers of mica. The number of segments is equal to the number of armature coils.

Each commutator segment is connected to the armature conductor by means of a copper lag or strip or riser. To prevent them from flying out under the action of centrifugal forces, the segments have V-grooves, these grooves are insulated by conical Meccanite rings. The cross-sectional view of commutator is shown in fig.2.5.

Brushes and Bearing

The brushes are made up of carbon or graphite. The function of brushes is collecting the current from the commutator and conveys the current in to the external load resistance. They are rectangular in shape. These brushes are housed in brush- holders and mounted over brush holder studs. The brush holder studs are mounted on a brush yoke. The brush holder studs are insulated from the brush yoke by insulation sleeves.

Ball bearings are used for light machines and for heavy machines roller bearings are used. The bearings are packed in hard oil for quieter operation.

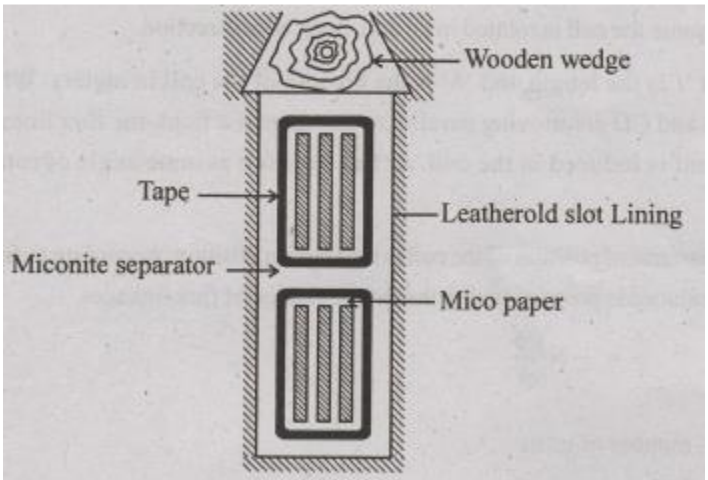


Figure 2.5

PRINCIPLE OF OPERATION

Let us consider a single turn rectangular coil ABCD rotating about its own axis (Fig.2.6) in a magnetic field provided by either permanent magnet or electromagnets. The two ends of the coil are joined by two slip rings 'a' and 'b' which are insulated from each other and from the central shaft. Two collecting brushes made up of carbon or copper press against the slip-rings. Their function is to collect the current induced in the coil and to convey it to the external load resistance R. The rotating coil is called as armature and the magnetic as field magnets.

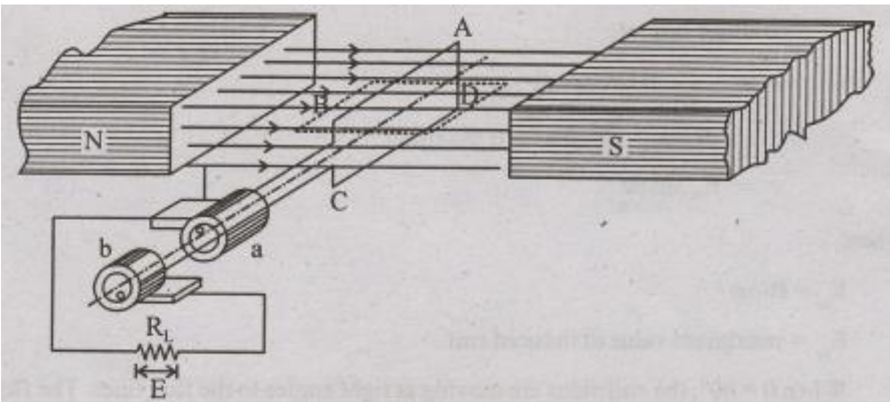


Figure 2.6

Assume the coil is rotated in an anti-clock wise direction.

Let 'l' is the length and 'b' is the breadth of the coil in meters. When the coil sides AB and CD are moving parallel to the magnetic field, the flux lines are not cut and no emf is induced in the coil. At this position assume angle of rotation 'ϴ' as zero.

This vertical position of the coil is the starting position. According to faraday's law, the emf induced is proportional to the rate of change of flux linkages.

Where

$e = - N\, d\phi/dt$ …………(1)

N - number of turns

Φ - flux

t - time

If N = 1,

$e = - d\phi/dt$

Initially, the coil is moving parallel to the flux lines, no flux line is cut. So

$d\phi/dt = 0$, and $e = 0$

After 't' seconds, the coil has rotated through an angle 'ωt' radians in the anticlockwise direction. The flux linking with the coil is

$B\ l\ b \cos \omega t$.

$e = - d/dt\ (B\ l\ b \cos \omega t)$

$= - B\ l\ b\ \omega(- \sin \omega t) = B\ l\ b\ \omega \sin \omega t$

$e = E_m \sin \omega t$ ……....(2)

Where

$E_m = B\ l\ b\ \omega$

E_m = maximum value of induced emf

When Θ = 90°, the coil sides are moving at right angles to the flux lines. The flux

lines are cut at the maximum rate and the emf induced is maximum.

When Θ = 180°, the coil sides are moving parallel to flux lines (AB and CD have exchanges positions) and the emf induced is zero.

When Θ = 270°, the coil sides again move at right angles to the flux lines but their position reversed. The induced emf is maximum in the opposite directs.

When Θ = 360°, the coil sides again move parallel to the magnetic field and the emf induced is zero. The coil has now come back to the starting point.

If the rotation of the coil is continued the changes in the emf are again repeated. The changes in voltage 'e', with respect to the angle 'Θ' can be plotted as shown in fig.2.7.

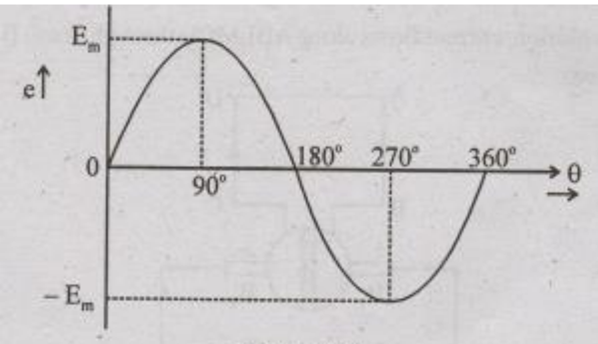


Figure 2.7

The emf changes from instant to instant and becomes alternatively positive and negative. This emf is called as an alternating emf.

The induced emf in the coil can be increased by

i) Increasing the flux density (B)

ii) Increasing the angular velocity (ω)

In commercial generators a large number of coils are used and they are housed in the armature.

The current flowing in the external resistance to a DC generator is made unidirectional by replacing the slip rings by a split rings as shown in fig 2.8.

The ring is split into two equal segments P and Q and the segments are insulated from each other and also from the shaft.

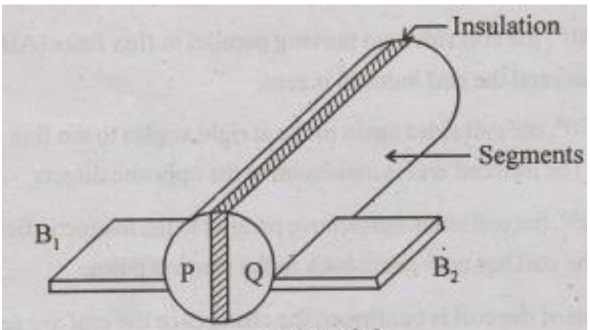


Figure 2.8

The coil side AB is always attached to the segment P and CD to Q. It is shown in fig.2.9. The brushes B_1 and B_2 touch these segments and to collect the current. During the first half revolution, current flows along ABLMCD through brush B_1(Positive) and into B_2 (Negative).

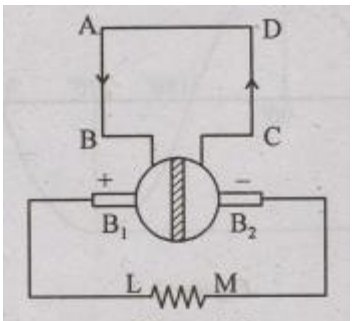


Figure 2.9

After half a cycle AB and CD have exchanged positions along with the segments P and Q and current flows through DCLMBA. B1 is in contact with for each half revolution the positions of segments P and Q also reverse shown in fig.2.10.

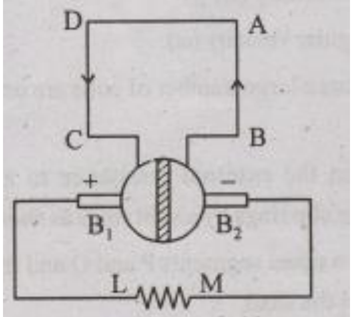


Figure 2.10

The current in the load is always unidirectional is shown in fig.3.11.

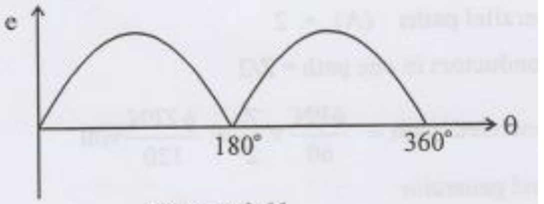


Figure 3.11

In a generator, the split rings are called commutator.

APPLICATIONS OF DC GENERATORS

Shunt generators are used for supplying nearly constant loads. They are used for battery charging, for supplying the fields of synchronous machines and separately excited DC machines.

Series generators are used as boosters for adding a voltage to the transmission line and to compensate for the line drop.

Cumulatively compound generators maintain better voltage regulation and used where constant of voltage is required like lamp loads etc. The differential compound generator is widely used in arc welding.

CONSTRUCTION OF TRANSFORMER

The simple elements of a transformer consist of two coils having mutual inductance and a laminated steel core. The two coils are insulated from each other and the steel core other necessary parts are core and windings. In all types of transformers, the core is constructed of transformer sheet steel laminations assembled to provide a continuous magnetic path with a minimum of air-gap included.

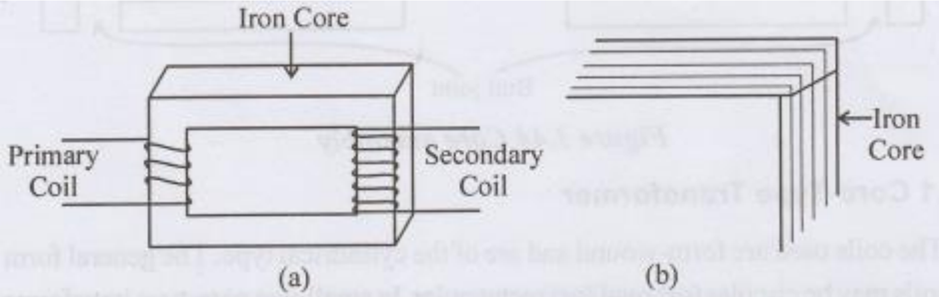


Figure 3.42 Construction of transformer

The steel used is of high silicon content, sometimes heat treated to produce a high permeability and a low hysteresis loss at the usual operating flux densities. The eddy current loss is minimized by laminating the core, the laminations being insulated from each other by a light coat of core-plate varnish (or) by an oxide layer on the surface. The thickness of laminations varies from 0.35 mm to 0.5 mm. The core laminations are joined as shown in Figure 3.42 (b).

Construction ally, the transformers are of two general types, distinguished from each other by in which the primary and secondary coils are placed around the laminated core. The two types are known as

(i) Core type

(ii) Shell type

In both core and shell type transformers, the individual laminations are cut in the form of long strips of 'L', 'E' and 'I' as shown in Figure 2.30.

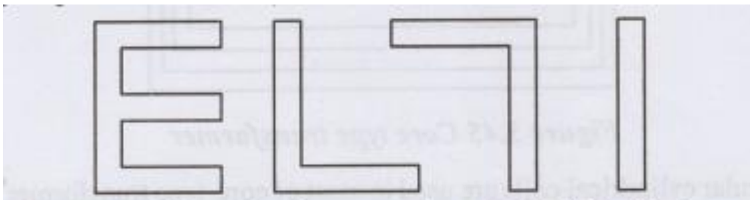


Figure 3.43 Lamination cut strips of 'E', 'T', 'I' shape

The assembly of the complete core for the two types of transformers as shown on Figure 3.43.

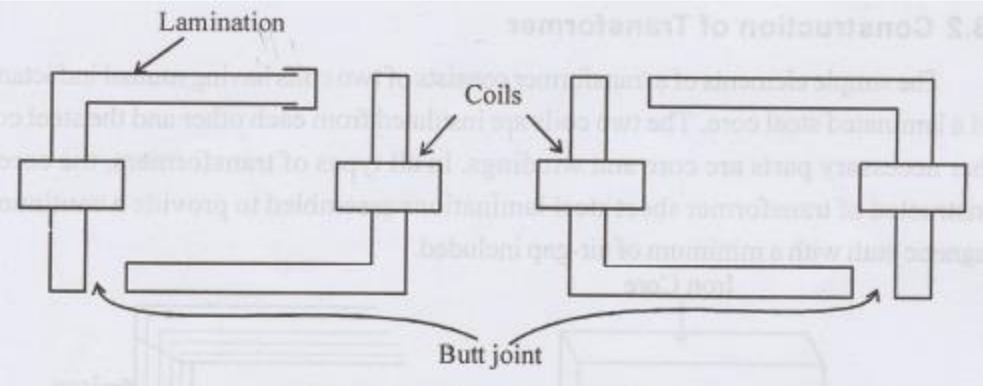


Figure 3.44 Core assembly

Core-Type Transformer

The coils used are form-wound and are of the cylindrical type. The general form of these coils may be circular (or) oval (or) rectangular. In small size core-type transformers, a simple rectangular core is used with cylindrical coils which are either circular (or) rectangular in form.

But for large size core type transformers, round (or) circular cylindrical coils are used which are so wound as to fit over a cruciform core section as shown in Figure 2.32.

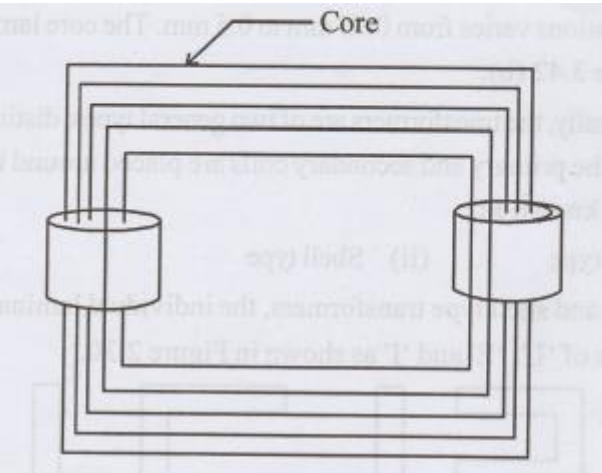


Figure 3.45 Core type transformer

The circular cylindrical coils are used in most of core-type transformer because of their mechanical strength. Such cylindrical coils are wound in helical layers with the different layers insulated from each other by paper, cloth, mica board (or) cooling ducts.

Shell-Type Transformers

In these case also, the coils are form-wound but are multi-layer disc type usually wound in the form of pancakes. The different layers of such multi-layer disc are insulated from each other by paper. The complete winding consists of stacked disc with insulation space between the coils-the spaces forming horizontal cooling and insulating ducts. A shell type transformer may have a simple rectangular form as shown in Figure 2.33.

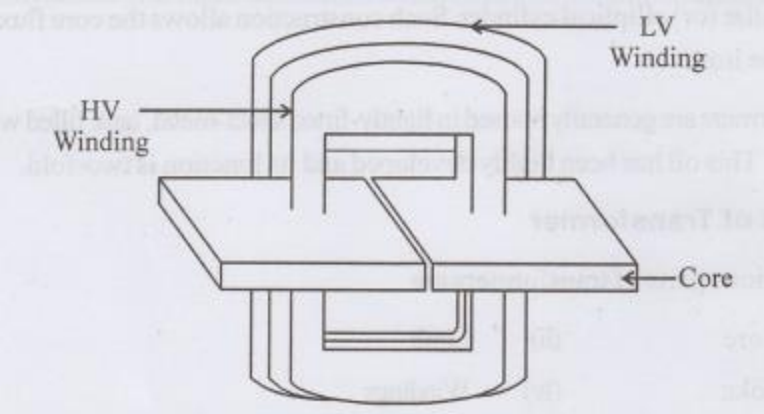


Figure 3.46 Shell type transformer

A very commonly used shell type transformer is the one known as Berry Transformer so called after the name of its designer and is cylindrical in form. The transformer core consists of laminations arranged in groups which radiate out from the centre as shown in Figure 3.47.

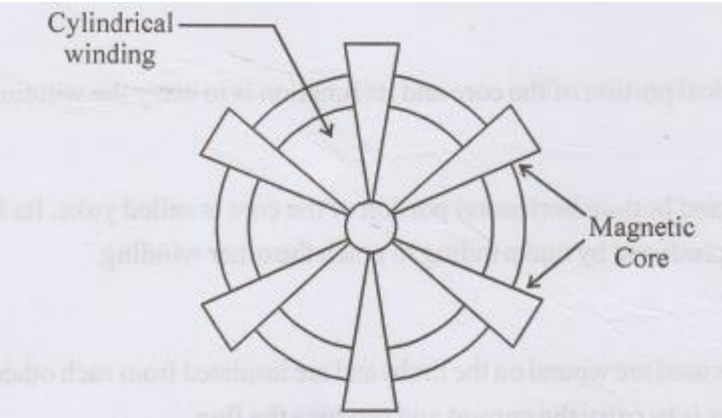


Figure 3.47 Berry type transformer

It may be pointed out that cores and coils of transformers must be provided with rigid mechanical bracing in order to prevent movement and possible insulation damage.

Good bracing reduces vibration and the objectionable noise-a humming sound- during operation.

The spiral-core transformer employs the newest development in core construction. The core is assembled of a continuous strip (or) ribbon of transformer steel wound in the form of a circular (or) elliptical cylinder. Such construction allows the core flux to follow the grain of the iron.

Transformers are generally housed in lightly-fitted sheet-metal, tank filled with special insulating oil. This oil has been highly developed and its function is two-fold.

SINGLE PHASE TRANSFORMER

A transformer is a static device, which transfer electric power from one circuit to another circuit without change in frequency.

Principle of Operation

The transformer operates on mutual induction principle. It states that when two coils are inductively coupled and if current in the one coil is changed uniformly then an emf induced in the other coil.

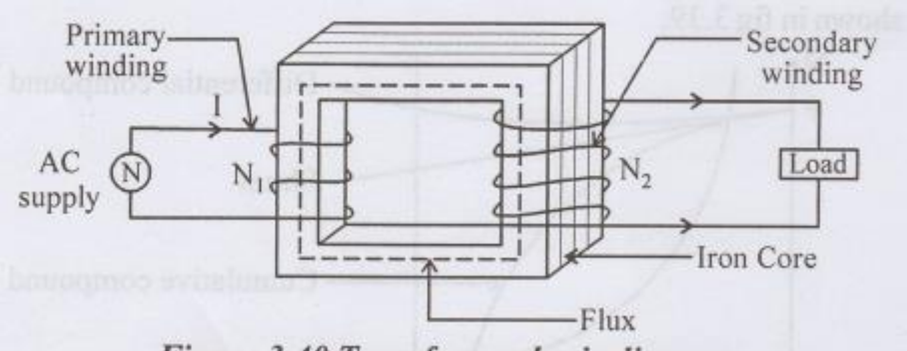


Figure 3.40 Transformer basic diagram

The Figure 3.40 shows the basic transformer diagram. It consists of two coils they are primary and secondary windings. The primary winding is connected in the input power supply and other winding is connected to the load. This winding is secondary winding. The primary winding has N_1 number of turns while secondary winding has N_2 number of turns.

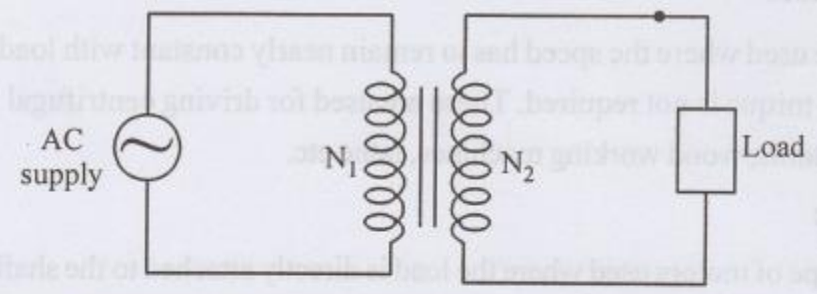


Figure 3.41 Electrical diagram of transformer

When the primary winding is excited by an AC voltage, it circulated an AC current. This current produces a flux (ϕ) which completes its path through common magnetic core. This alternating flux links with the secondary winding. According to Faraday's law of an electromagnetic induction, the secondary winding induces the emf. There is no electrical contact between the two windings.

CONSTRUCTION OF THREE PHASE INDUCTION MOTORS

The induction motor consists of two main parts (i) Stator (ii) Rotor

Stator

The stator is made up of a number of stampings with alternate slot and tooth. Stampings are insulated from each other. Each stamping is 0.4 to 0.5 mm thick. Number of stampings are stamped together to build the stator core. The stator core is then fitted in a casted or fabricated steel frame. The slots house the three-phase winding called stator winding.

It may be connected either in star or delta. The stator winding is made for a fixed no of poles. Fig.3.85 shows the stator lamination.

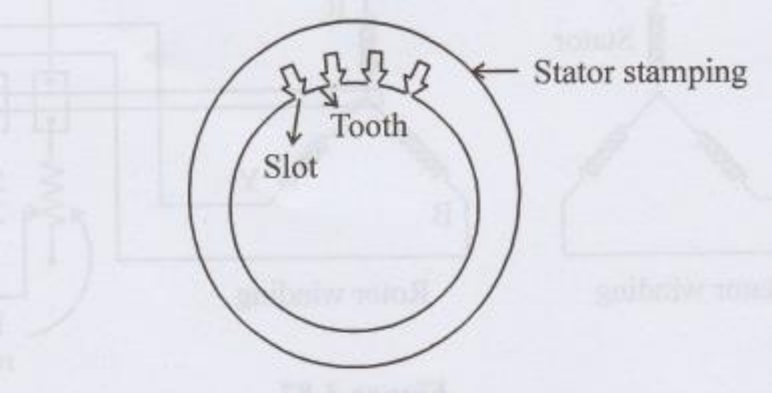


Figure 3.85

Rotor

Two types of rotors are

i) Squirrel cage rotor

ii) Slip ring or wound rotor

i) Squirrel cage rotor

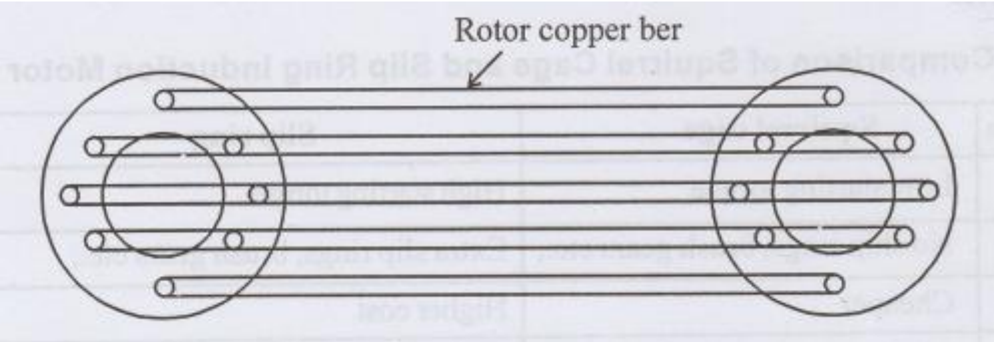


Figure 3.86

Fig.3.86 shows a squirrel cage rotor. This is made up of a cylindrical laminated core with slots to carry the rotor conductors.

The rotor conductors are heavy bars of copper or aluminium short circuited at both ends by end rings. Hence this rotor is called short circuited rotor. The entire rotor resistance is very small. External resistance cannot be connected in the rotor circuit such motors are extremely rugged in construction.

ii) Slip ring or wound rotor

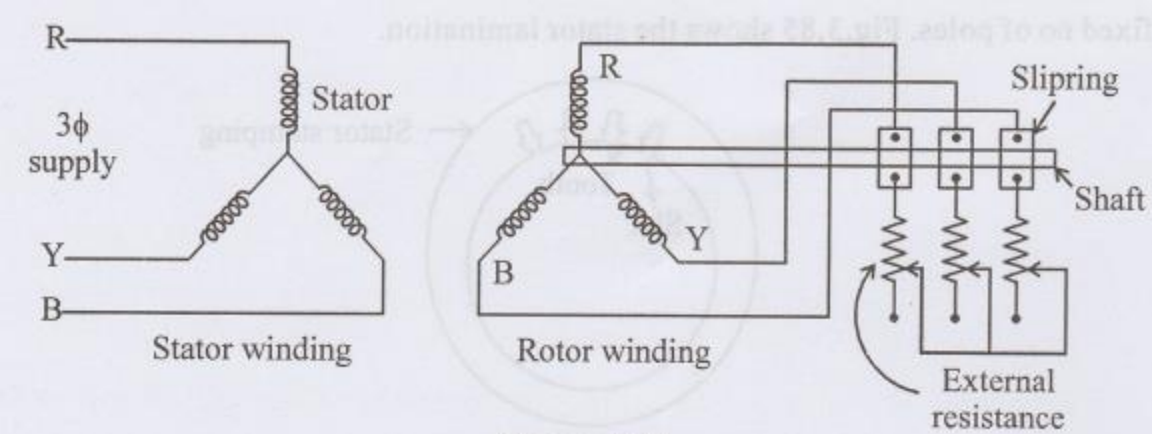


Figure 3.87

Fig. 3.87 shows a slip ring or wound rotor. In this of rotor windings are similar to the stator winding. The rotor winding may be star of delta connected, distributed winding, wound for as many numbers of poles as the stator. The three phases are brought out and connected to slip rings mound on the rotor shaft. Variable external resistance can be connected in the rotor circuit with the help of blushes and slip rings arrangements. By varying the external resistance in the rotor circuit, the motor speed and torque can be controlled.

PRINCIPLE OF OPERATION OF 3Φ INDUCTION MOTOR

Three phase supply is given to the stator windings. Due to this, current flows through the stator winding. This current is called stator current. It produces a rotating magnetic field in the space between stator and rotor. Synchronous speed is produced by this field.

$N_s = 120f/P$

The rotating magnetic field cutting the rotor conductors, an emf is induced in the rotor. If the rotor winding is shorted then the induced emf produces current. this current produces a rotor field.

The interaction of stator and rotor field develops torque. Then the rotor rotates in the same direction as the rotating magnetic field. When the rotor is standstill, the frequency rotor emf is equal to the supply frequency.

As the rotor speed increases, the frequency of rotor emf and the magnitude of rotor emf decreases.

The rotor tries to each up with the rotating magnetic field. But the rotor could not rotate at the synchronous speed. Therefore, the rotor runs at a speed slightly less than the synchronous speed.

The difference between synchronous speed and rotor speed is called the slip speed.

Slip speed = $N_S - N$

Slip (S) = $N_S - N / N_S$

$N = N_S (1-S)$

% Slip = $N_S - N/N_S \times 100$

At no load the difference between synchronous speed and rotor is only about 1%

Squirrel cage induction motor

Advantages

Cheaper, light weight, higher efficiency, less maintenance

Disadvantages

Moderate starting torque, there is no external resistance in the rotor circuit, so the starting torque cannot be controlled.

Applications

Lathes, drilling machines, fans, blowers, water pumps, grinders, printing machines etc

Slip ring induction motor

Advantages

Starting torque can be controlled by varying the rotor circuit resistance, speed is also controlled

Disadvantages

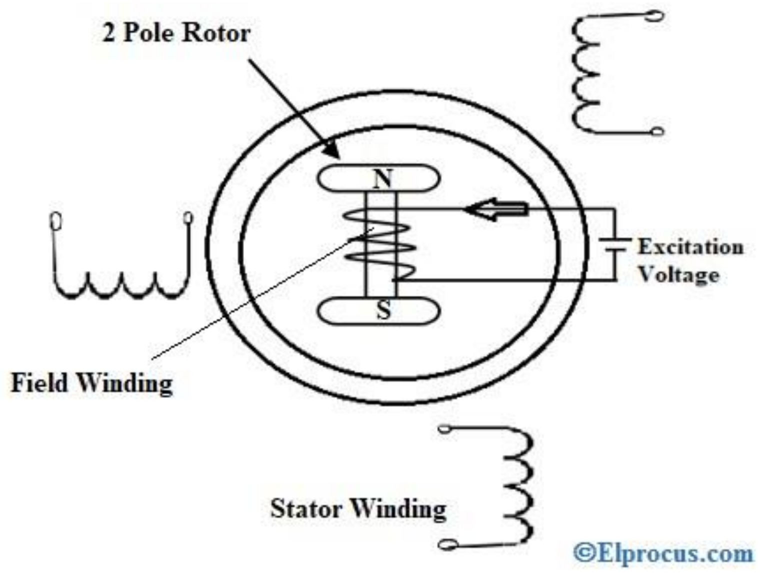
Heavier in size, high cost, high rotor inertia, high speed lamination, maintenance and reliability problems due to brushes and slip rings.

Applications

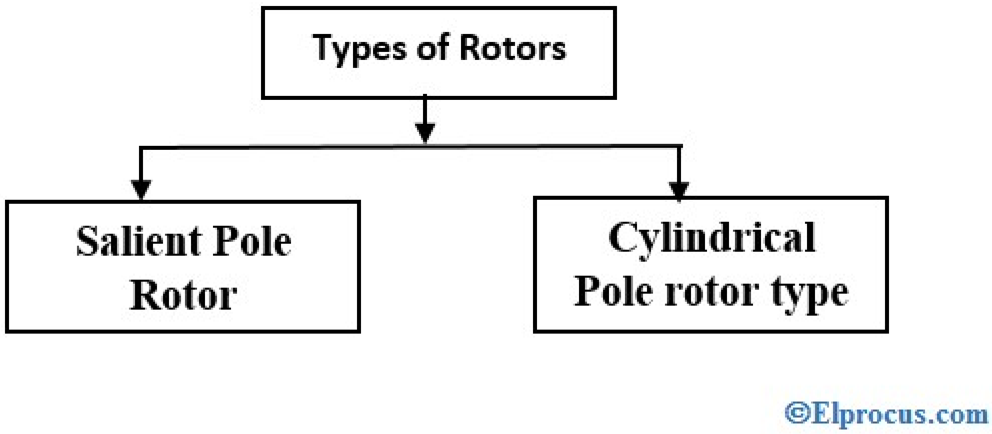
Lifts, hosts, cranes, elevators, compressors etc

Construction of an Alternator

The main components of an alternator or synchronous generator are rotor and stator. The main difference between rotor and stator is, the rotor is a rotating part and stator is not a rotating component means it is a stationary part. The motors are generally run by rotor and stator.



The stator word based on the stationary and the rotor word based on the rotating. The construction of the stator of an alternator is equal to the construction of the stator of an induction motor. So induction motor construction and synchronous motor construction are both are same. Thus the stator is the stationary part of the rotor and the rotor is the component that rotates inside of the stator. The rotor is located on the stator shaft and the series of the electromagnets arranged in a cylinder causing the rotor to rotate and create a magnetic field. There are two types of rotors they are shown in the below figure.



Salient Pole Rotor

The meaning of the salient is projecting outward, which means the poles of the rotor are projecting outward from the centre of the rotor. There is a field winding on the rotor and for this field winding will use DC supply. When we pass the current through this field winding N and S poles are created. The salient rotors are unbalanced so the speeds are restricted. This type of rotor used in hydro stations and diesel power stations. The salient pole rotor used for low-speed machines approximately 120-400rpm.

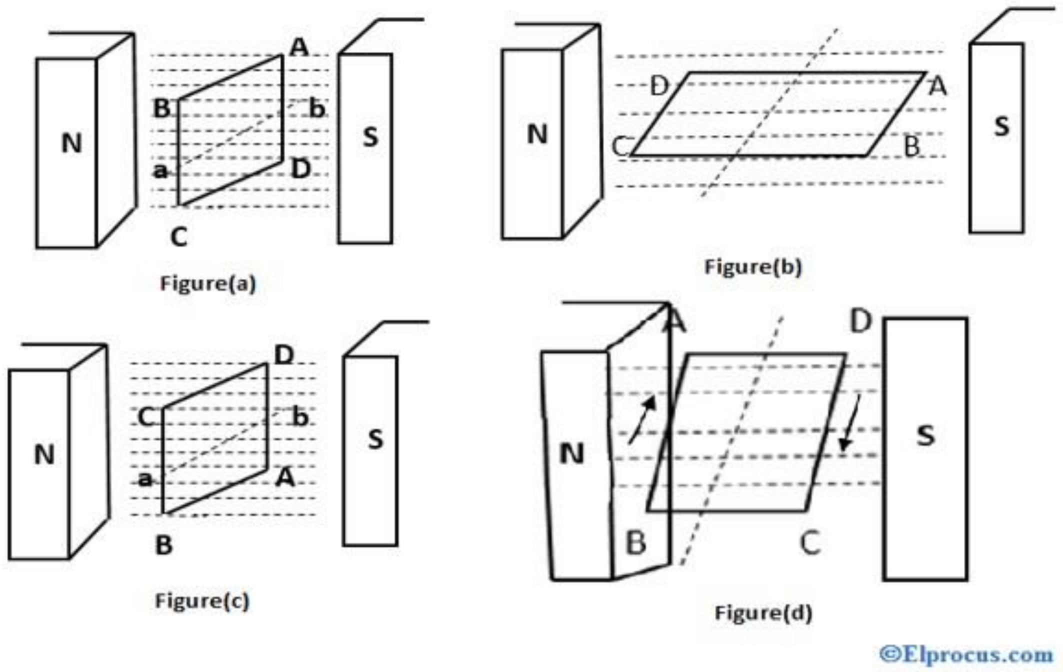
Cylindrical Rotor

The cylindrical rotor is also known as a non-salient rotor or round rotor and this rotor is used for high-speed machines approximately 1500-3000 rpm and the example for this is a thermal power plant. This rotor is made up of a steel radial cylinder having the number of slots and in these slots, the field winding is placed and these field windings are always connected in series. The advantages of this are mechanically robust, flux distribution is uniform, operates at high speed and produces low noise.

An AC motor comes in many shapes and sizes, but we can't have an AC without a rotor and stator. The rotor is made up of a cast iron and the stator is made up of silicon steel. The prices of the rotor and stator depend on the quality.

Working Principle of Alternator

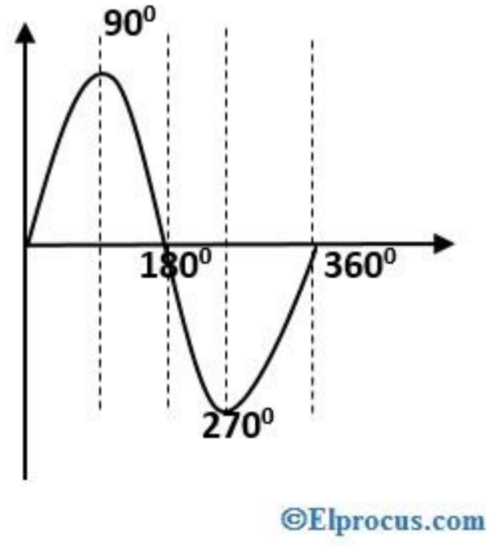
All the alternators work on the principle of electromagnetic induction. According to this law, for producing the electricity we need a conductor, magnetic field and mechanical energy. Every machine that rotates and reproduces Alternating Current. To understand the working principle of the alternator, consider two opposite magnetic poles north and south, and the flux is traveling between these two magnetic poles. In the figure (a) rectangular coil is placed between the north and south magnetic poles. The position of the coil is such that the coil is parallel to the flux, so no flux is cutting and therefore no current is induced. So that the waveform generated in that position is Zero degrees.



If the rectangular coil rotates in a clockwise direction at an axis a and b, the conductor side A and B comes in front of the south pole and C and D come in front of a north pole as shown in figure (b). So, now we can say that the motion of the conductor is perpendicular to the flux lines from N to S pole and the conductor cuts the magnetic flux. At this position, the rate of flux cutting by the conductor is maximum because the conductor and flux are perpendicular to each other and therefore the current is induced in the conductor and this current will be in maximum position.

The conductor rotates one more time at 90^0 in a clockwise direction then the rectangular coil comes in the vertical position. Now the position of the conductor and magnetic flux line is parallel to each other as shown in figure (c). In this figure, no flux is cutting by the conductor and therefore no current is induced. In this position, the waveform is reduced to zero degrees because the flux is not cutting.

In the second half cycle, the conductor is continued to rotate in a clockwise direction for another 90^0. So here the rectangular coil comes to a horizontal position in such a way that the conductor A and B comes in front of the north pole, C and D come in front of the south pole as shown in the figure (d). Again, the current will flow through the conductor that is currently induced in the conductor A and B is from point B to A and in conductor C and D is from point D to C, so the waveform produced in opposite direction, and reaches to the maximum value. Then the direction of the current indicated as A, D, C and B as shown in figure (d). If the rectangular coil again rotates in another 90^0 then the coil reaches the same position from where the rotation is started. Therefore, the current will again drop to zero.
In the complete cycle, the current in the conductor reaches the maximum and reduces to zero and in the opposite direction, the conductor reaches the maximum and again reaches zero. This cycle repeats again and again, due to this repetition of the cycle the current will be induced in the conductor continuously.



This is the process of producing the current and EMF of a single-phase. Now for producing 3 phases, the coils are placed at the displacement of 120^0 each. So the process of producing the current is the same as the single-phase but only the difference is the displacement between three phases is 120^0. This is the working principle of an alternator.

Applications

The applications of an alternator are

- Automobiles
- Electrical power generator plants

- Marine applications
- Diesel electrical multiple units
- Radiofrequency transmission

PERMANENT MAGNET MOVING COIL (PMMC)

It is used only for the measurement of DC.

It consists of 'U' shaped permanent magnet, Aluminium former is placed in the gap between the poles. Former is cylindrical or rectangular in shape. current carrying coil is wound on the former coil is made from enamelled or silk covered 'cu'. Iron core is located inside the former core is used to provide a low reluctance flux path, so it helps to produce strong magnetic field for the coil to move.

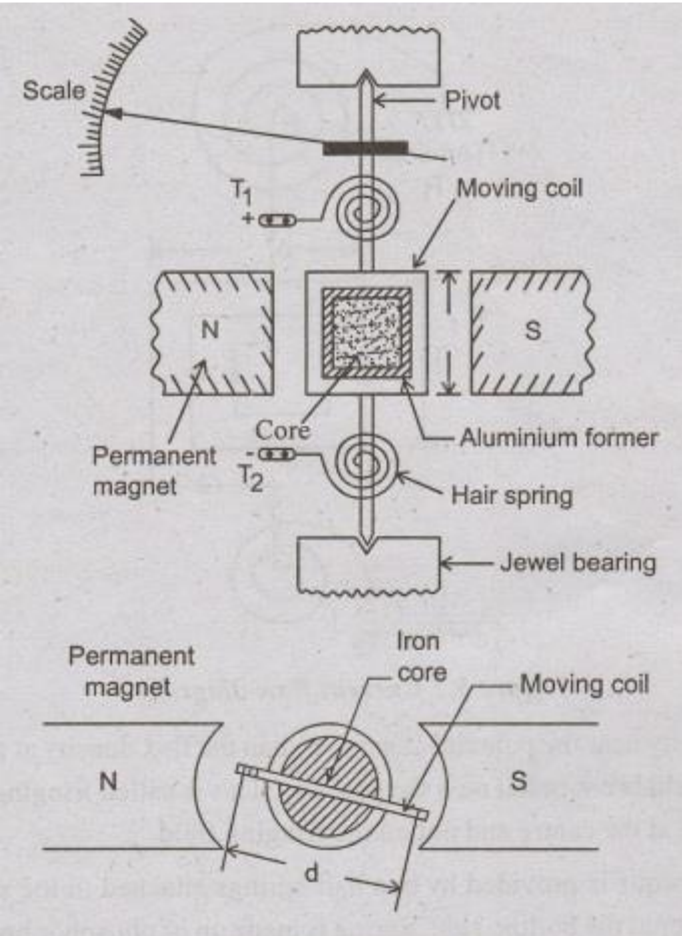


Figure 5.6 PMMC

This arrangement increases the deflecting Torque (T_d) and also the sensitivity of the instrument.

Nowadays permanent magnet is replaced by Alcomax or Alnico. This magnetic material has small length and high field intensities. These materials also serve as core.

The spindle is supported by Jewel bearing. In some case, to eliminate bearing friction, ribbon suspension is used.

The construction of PMMC is similar to d'Arsonval galvanometer with a difference. The lamp & mirror arrangement is replaced by a pointer and a scale in PMMC.

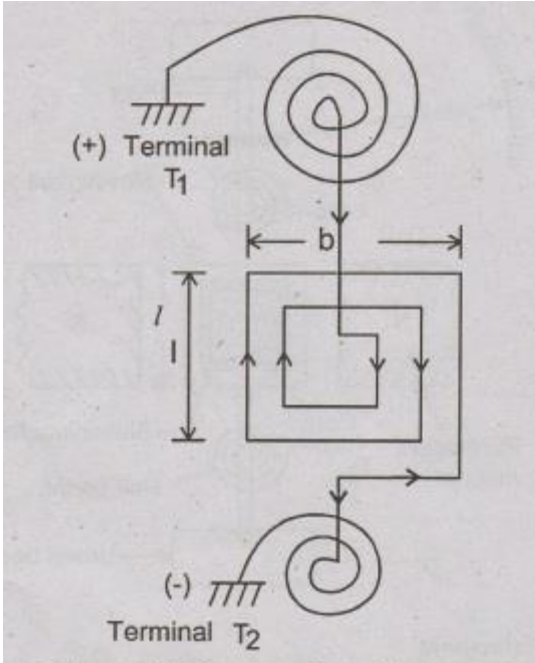


Figure 5.7 Current flow diagram

Flux density near the pole tips is smaller than the flux density at the centre and the magnetic field is not radial near the pole tips. This is called fringing field. So the coil is alligmed at the centre and not on the fringing field.

Control torque is provided by two hair springs attached to the spindle one at the top & another at the bottom side. Spring is made up of phosphor bronze. Current enters and leaves the instrument through these springs.

Damping torque is produced by the eddy current in the Aluminium former in the case where PMMC is used for voltage measurement.

In case of ammeter measurement, PMMC is made from non-metallic former, so damping torque is provided by low resistance, connected across the coil.

When the polarity is reversed, the torque is developed in the opposite direction the meter does not allow the deflection in the opposite direction and the pointer reads zero. Therefore, polarity should be maintained with this PMMC instrument.

Principle:

When supply is given to the coil, current flows through it. The current carrying coil is placed in a magnetic field, by faraday's law the coil experiences a force. This force produces a torque and deflects the coil.

Meter range:

If the measuring current is less than 20mA, the whole current is allowed to pass through the coil, otherwise coil is shunted with a resistor.

The voltage drop across the DC ammeter is 0.50mV, or 0 to 100mV.

DC voltmeter: Normally allows mA to pass through for full scale deflection.

MOVING IRON (MI) INSTRUMENT

It is the commonly used, accurate instrument for both AC and DC measurement. It is divided into two types 1. attraction type and 2. Repulsion type. Moving Iron Instrument consist of a stationary coil which is excited by the current or voltage under measurement. It also consists of a plate or vane of soft iron in case of attraction type in case of repulsion type, two vanes are present.

Vane forms the moving element of the instrument and moves in a magnetic field produced by a stationary coil.

Principle:

Supply is given to the stationary coil it becomes Electromagnet vane moves to increase the flux of the electromagnet because vane tries to occupy a position of minimum reluctance.

Inductance α 1/reluctance

Thus, a force is developed for getting high inductance. This force gives the deflecting torque.

Types:

Attraction type MI instrument

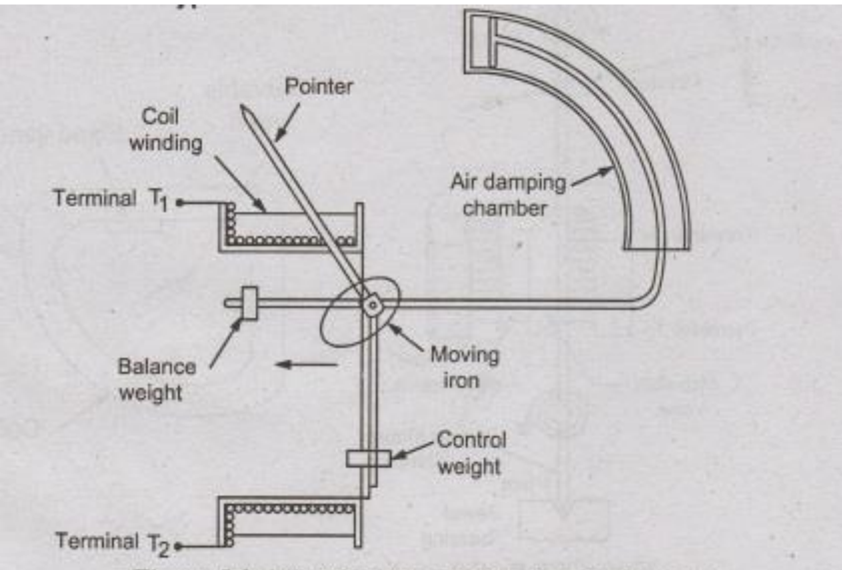


Figure 5.8 Attraction type moving iron instrument

The flat stationary coil forms the narrow slot like opening. moving element is a flat disc or plate.

When current flows through the coil, magnetic field is produced around the coil. moving Iron moves from weaker field to stronger field side.

For control torque this instrument uses spring. In panel type, vertical mounted case uses gravity control for T. Damping is provided by air friction damping.

Repulsion Type

Two vanes are present inside the stationary coil, one vane is fixed and another vane is movable.

Both vanes are similarly magnetised when the current flows through the stationary coil, so repulsion occurs between the two vanes.

This type is divided into two

1. Radial vane type and

2. Co-axial vane type.

In radial vane type, vanes are radial strips of Iron.

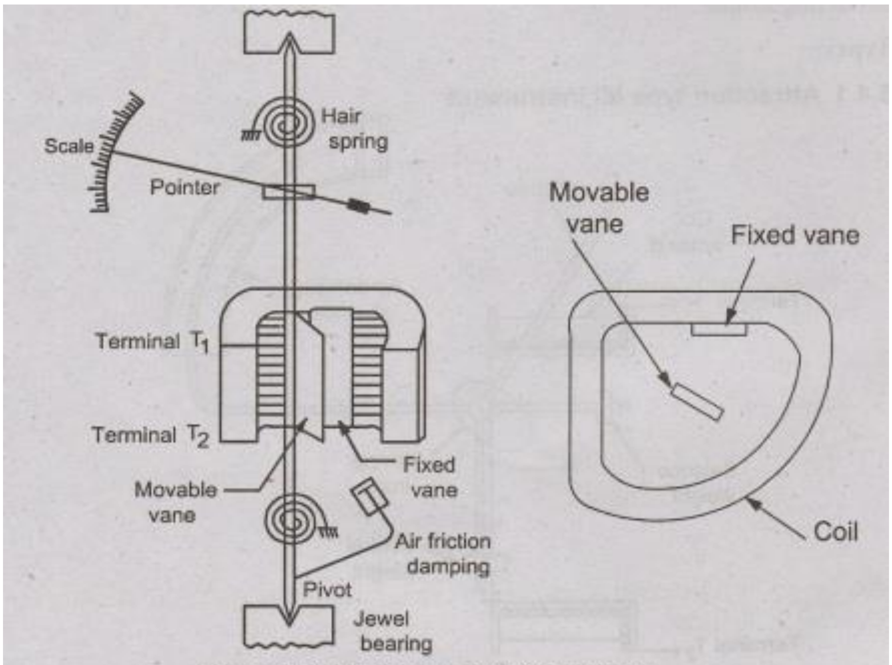


Figure 5.9 Radial vane type instrument

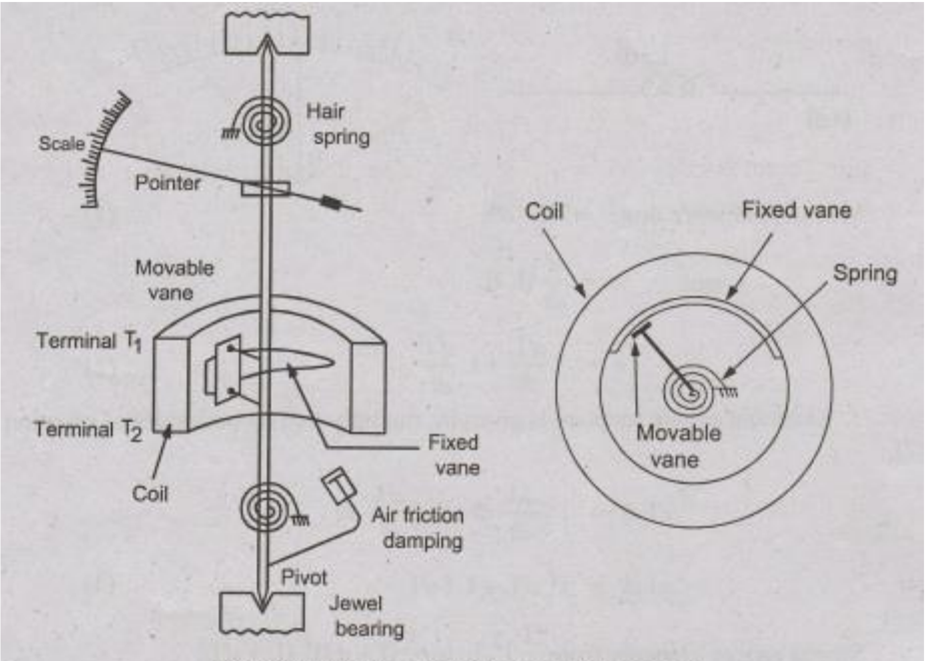


Figure 5.10 Co-axial vane type instrument

In co-axial vane type, vanes are sections of co-axial cylinders.

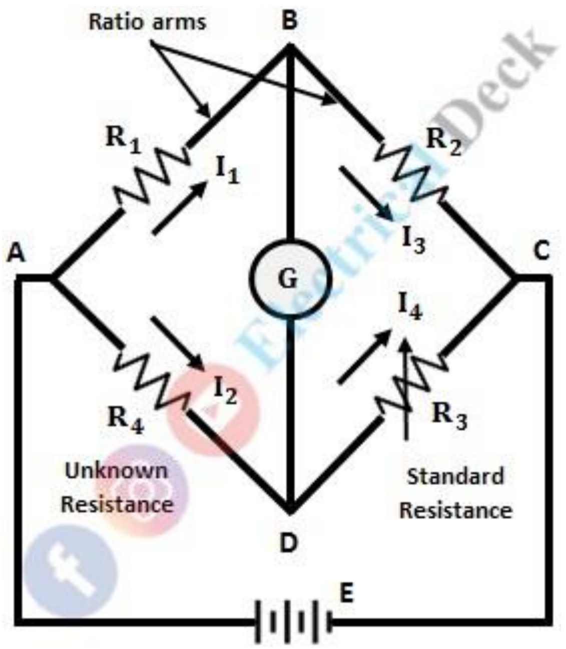
T_c is provided by spring and by gravity control for vertically mounted instrument.

Air friction damping is used.

Eddy current damping is not used because operating magnetic field is very weak.

Construction of Wheatstone Bridge:

The below shows the circuit connections of Wheatstone Bridge. It consists of four arms in which four resistances are connected (one in each arm). A source emf and null detector (galvanometer) are connected between points AC and BD respectively.

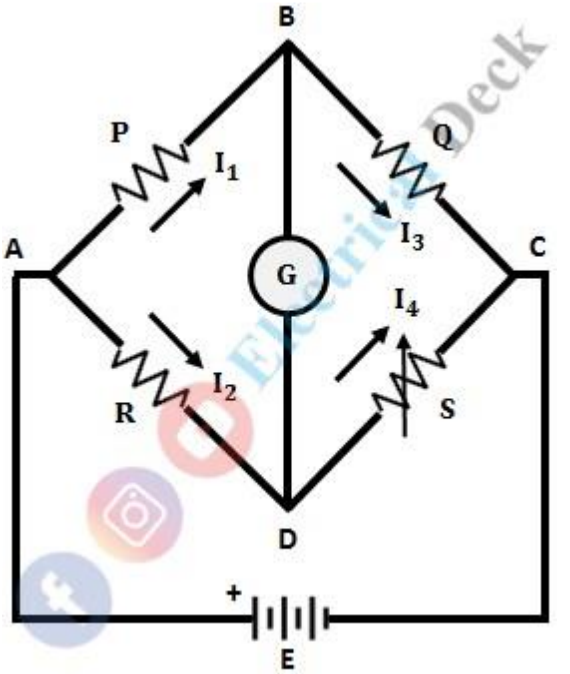


The arms with resistances R_1 and R_2 are called ratio arms. The resistance R_3 is the standard arm resistance and R_4 is the unknown resistance to be measured.

Working of Wheatstone Bridge:

The principle of working of Wheatstone Bridge is on the null deflection or null indication i.e., when the bridge is balanced the ratio of their resistances are equal and no current flows through the galvanometer.

If the bridge is unbalanced there will be a potential difference between B and D, which causes a current to flow through the galvanometer. In order to achieve a balanced condition, the known resistance and variable resistance should be varied. The basic circuit of the Wheatstone bridge is shown below.



let,

- ***P = Resistance of arm AB***
- ***Q = Resistance of BC***
- ***R = Resistance of AD***
- ***S = Resistance of CD***
- ***E = Source (battery)***
- ***G = Galvanometer (detector).***

The bridge is said to be balanced, when the potential difference between points A and B is equal to the voltage across points A and D (i.e., the potential difference across the galvanometer or BD is zero). Hence, no current flows through the galvanometer, thus the no deflection in it (null-deflection).

UNIT III
ENERGY RESOURCES, ELECTRICITY BILL & SAFETY MEASURES

Energy Resources: *Conventional and non-conventional energy resources; Layout and operation of various Power Generation systems: Hydel, Nuclear, Solar & Wind power generation.*

Electricity bill: *Power rating of household appliances including air conditioners, PCs, Laptops, Printers, etc. Definition of "unit" used for consumption of electrical energy, two-part electricity tariff, calculation of electricity bill for domestic consumers.*

Equipment Safety Measures: *Working principle of Fuse and Miniature circuit breaker (MCB), merits and demerits. Personal safety measures: Electric Shock, Earthing and its types, Safety Precautions to avoid shock.*

ENERGY RESOURCES

Generation of Electrical Energy:

Conversion of energy available in different forms in nature into electrical energy is known as **"Generation of Electrical Energy**".

Sources of Energy:

Since electrical energy is produced from energy available in various forms in nature, it is desirable to look into the various sources of energy. These sources of energy are:

1. Non-Renewable or Conventional Energy Sources
2. Renewable or Non-Conventional Energy Sources

Non-Renewable or Conventional Energy Sources:

The Energy Sources which are Eventually Exhausted or run out are called Non-Renewable or Conventional Energy Sources. Hence Non-renewable resources *are the resources found by humans as a source of energy, and such resources cannot be replenished*.

Eg: Fossil Fuels such as Coal, Gas, Oil, Petroleum etc.

Renewable or Non-Conventional Energy Sources:

The Energy Sources which are Eventually cannot Exhausted or run out are called Renewable or Non-Conventional Energy Sources. Hence Renewable *energy comes from sources or processes that are constantly replenished*.

Eg: Solar Energy, Wind Energy, Tidal Energy, Geothermal Energy, Ocean thermal Energy, Biogas and Wave Energy.

GENERATING STATIONS:

Bulk electric power is produced by special plants known as **Generating Stations** or **Power Plants.** A generating station essentially employs a prime mover coupled to an alternator for the production of electric power. The prime mover (*e.g.*, steam turbine, water turbine etc.) converts energy from some other form into mechanical energy. The alternator converts mechanical energy of the prime mover into electrical energy. The electrical energy produced by the generating station is transmitted and distributed with the help of conductors to various consumers. It may be emphasised here that apart from prime mover-alternator combination, a modern generating station employs several auxiliary equipment and instruments to ensure cheap, reliable and continuous service.

Depending upon the form of energy converted into electrical energy, the generating stations are classified as under:

(*i*) Steam power stations or Thermal Power Plant
(*ii*) Hydroelectric power stations
(*iii*) Diesel power stations
(*iv*) Nuclear power stations

HYDRO-ELECTRIC POWER STATION (OR) HYDEL POWER PLANT:

A generating station which utilises the potential energy of water at a high level for the generation of electrical energy is known as a **hydro-electric power station.**

The constituents of a hydro-electric plant are

1. Hydraulic structures

(a) Dams (b) Spillways (c) Head works (d) Surge Tank (e) Penstocks

2. Water turbines and

3. Electrical equipment

Hydro-electric power stations are generally located in hilly areas where dams can be built conveniently and large water reservoirs can be obtained. In a hydro-electric power station, water head is created by constructing a dam across a river or lake. From the dam, water is led to a water turbine.

The water turbine captures the energy in the falling water and changes the hydraulic energy (*i.e.*, product of head and flow of water) into mechanical energy at the turbine shaft. The turbine drives the alternator which converts mechanical energy into electrical energy. Hydro-electric power stations are becoming very popular because the reserves of fuels (*i.e.*, coal and oil) are depleting day by day. They have the added importance for flood control, storage of water for irrigation and water for drinking purposes.

Spillways: There are times when the river flow exceeds the storage capacity of the reservoir. Such a situation arises during heavy rainfall in the catchment area. In order to discharge the surplus water from the storage reservoir into the river on the down-stream side of the dam, spillways are used.

***Head works*:** The head works consists of the diversion structures at the head of an intake. They generally include booms and racks for diverting floating debris, sluices for by-passing debris and sediments and valves for controlling the flow of water to the turbine.

Surge Tank: A surge tank (open from top) is built just before the valve house and protects the penstock from bursting in case the turbine gates suddenly close due to electrical load being thrown off. When the gates close, there is a sudden stopping of water at the lower end of the penstock and consequently the penstock can burst like a paper log. The surge tank absorbs this pressure swing by increase in its level of water.

Although a hydro-electric power station simply involves the conversion of hydraulic energy into electrical energy, yet it embraces many arrangements for proper working and efficiency. The schematic arrangement of a modern hydro-electric plant is shown in Fig (1). The dam is constructed across a river or lake and water from the catchment area collects at the back of the dam to form a reservoir. A pressure tunnel is taken off from the reservoir and water brought to the valve house at the start of the penstock. The valve house contains main sluice valves and automatic isolating valves. The former controls the water flow to the power house and the latter cuts off supply of water when the penstock bursts. From the valve house, water is taken to water turbine through a huge steel pipe known as *penstock*. The water turbine converts hydraulic energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy.

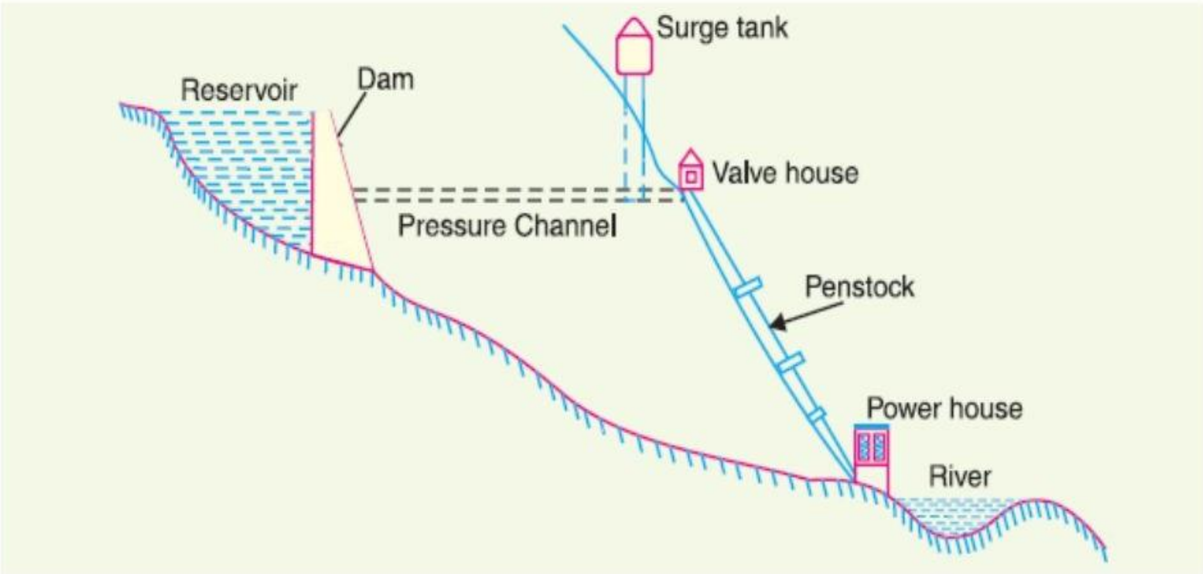


Fig (1): Schematic Arrangement (or) Layout of Hydro Power Plant

Advantages:

1. It requires no fuel as water is used for the generation of electrical energy.
2. It is quite neat and clean as no smoke or ash is produced.
3. It requires very small running charges because water is the source of energy which is avail-able free of cost.
4. It is comparatively simple in construction and requires less maintenance.
5. It does not require a long starting time like a steam power station. In fact, such plants can be put into service instantly.
6. It is robust and has a longer life.
7. Such plants serve many purposes. In addition to the generation of electrical energy, they also help in irrigation and controlling floods.
8. Although such plants require the attention of highly skilled persons at the time of construction, yet for operation, a few experienced persons may do the job well.

Disadvantages:

1. It involves high capital cost due to construction of dam.
2. There is uncertainty about the availability of huge amount of water due to dependence on weather conditions.
3. Skilled and experienced hands are required to build the plant.
4. It requires high cost of transmission lines as the plant is located in hilly areas which are quite away from the consumers.

Choice of Site for Hydro-electric Power Stations:

The following points should be taken into account while selecting the site for a hydro-electric power station:

1. Availability of water:
Since the primary requirement of a hydro-electric power station is the availability of huge quantity of water, such plants should be built at a place *such as* river, canal where adequate water is available at a good head.

2. Storage of water:

There are wide variations in water supply from a river or canal during the year. This makes it necessary to store water by constructing a dam in order to ensure the generation of power throughout the year. The storage helps in equalising the flow of water so that any excess quantity of water at a certain period of the year can be made available during times of very low flow in the river. This leads to the conclusion that site selected for a hydro-electric plant should provide adequate facilities for erecting a dam and storage of water.

3. Cost and type of land:

The land for the construction of the plant should be available at a reasonable price. Further, the bearing capacity of the ground should be adequate to with-stand the weight of heavy equipment to be installed.

4. Transportation facilities:

The site selected for a hydro-electric plant should be accessible by rail and road so that necessary equipment and machinery could be easily transported.

NUCLEAR FISSION:

Nuclear Fission is a reaction in which the nucleus of a heavy atom bombarded with neutron, splits in to two or more light nuclei with a release of huge amount of energy in the form of heat.

Eg:

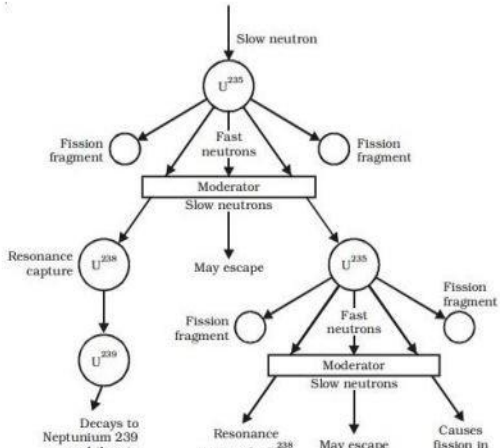
$$^{235}_{92}U + ^{1}_{0}n = ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n + Q$$

$$^{235}_{92}U + ^{1}_{0}n = ^{147}_{57}La + ^{87}_{35}Br + 2^{1}_{0}n + Q$$

CHAIN REACTION:

A *chain reaction* is a sequence of Nuclear Fission reactions where a reactive product or by-product causes additional reactions to take place.

A chain reaction refers to a process in which neutrons released in fission produce an additional fission in at least one further nucleus. This nucleus in turn produces neutrons, and the process repeats. The process may be controlled (nuclear power) or uncontrolled (nuclear weapons).



Fig(2):Controlled Chain Reaction

Nuclear Power Station:

A generating station in which nuclear energy is converted into electrical energy is known as a nuclear power station.

In nuclear power station, heavy elements such as Uranium (U235) or Thorium (Th232) are subjected to nuclear fission in a special apparatus known as a reactor. The heat energy thus released is utilized in raising steam at high temperature and pressure. The steam runs the steam turbine which converts steam energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy. The most important feature of a nuclear power station is that huge amount of electrical energy can be produced from a relatively small amount of nuclear fuel as compared to other conventional types of power stations. It has been found that complete fission of 1 kg of Uranium (U235) can produce as much energy as can be produced by the burning of 4,500 tons of high grade coal. Although the recovery of principal nuclear fuels (i.e., Uranium and Thorium) is difficult and expensive, yet the total energy content of the estimated world reserves of these fuels are considerably higher than those of conventional fuels, viz., coal, oil and gas. At present, energy crisis is gripping us and, therefore, nuclear energy can be successfully employed for producing low cost electrical energy on a large scale to meet the growing commercial and industrial demands.

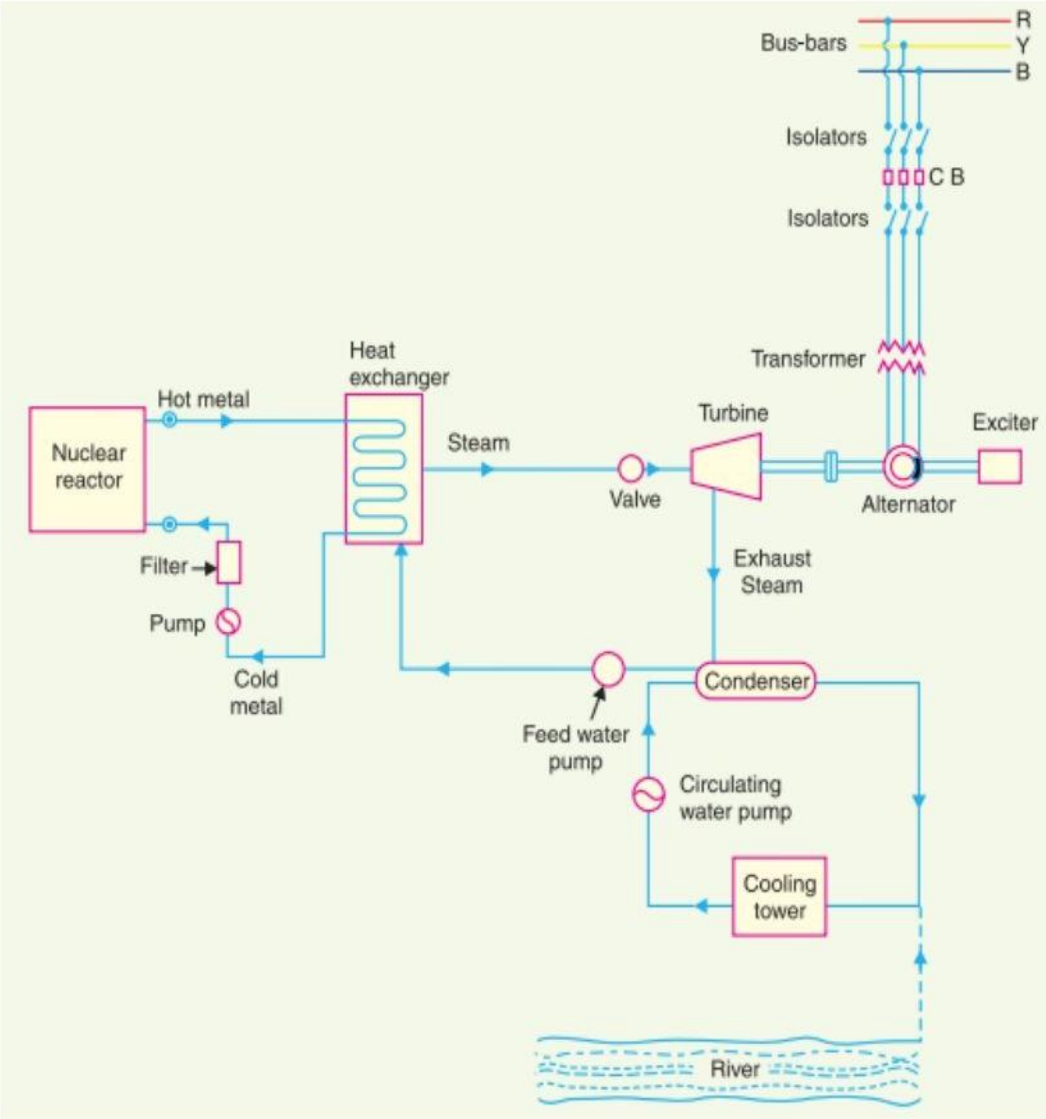
The schematic arrangement of a nuclear power station is shown in Fig(3). The whole arrangement can be divided into the following main stages:

(i) Nuclear reactor (ii) Heat exchanger (iii) Steam turbine (iv) Alternator

(i) Nuclear reactor:

It is an apparatus in which nuclear fuel (U235) is subjected to nuclear fission. It controls the chain reaction that starts once the fission is done. If the chain reaction is not controlled, the result will be an explosion due to the fast increase in the, energy released. A nuclear reactor is a cylindrical stout pressure vessel and houses fuel rods of Uranium, moderator and control rods as shown in Fig(4). The fuel rods constitute the fission material and release huge amount of energy when bombarded with slow moving neutrons. The moderator consists of graphite rods which enclose the fuel rods. The moderator slows down the neutrons before they bombard the fuel rods. The control rods are of cadmium and are inserted into the reactor. Cadmium is strong neutron absorber and thus regulates the supply of neutrons for fission. When the control rods are pushed in deep enough, they absorb most of fission neutrons and hence few are available for chain reaction which, therefore, stops.

However, as they are being withdrawn, more and more of these fission neutrons cause fission and hence the intensity of chain reaction (or heat produced) is increased. Therefore, by pulling out the control rods, power of the nuclear reactor is increased, whereas by pushing them in, it is reduced. In actual practice, the lowering or raising of control rods is accomplished automatically according to the requirement of load. The heat produced in the reactor is removed by the coolant, generally a sodium metal. The coolant carries the heat to the heat exchanger.



Fig(3):Schematic Arrangement (or) Layout of Nuclear Power Station

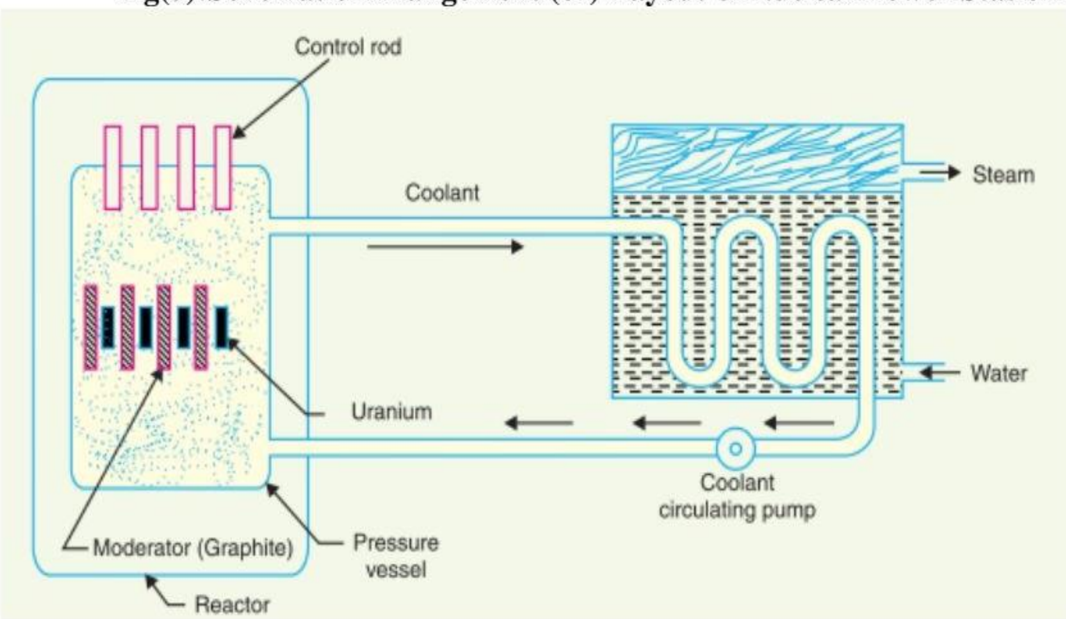


Fig (4): Schematic Arrangement of Nuclear Reactor

(ii) Heat exchanger: The coolant gives up heat to the heat exchanger which is utilised in raising the steam. After giving up heat, the coolant is again fed to the reactor.

(iii) Steam turbine: The steam produced in the heat exchanger is led to the steam turbine through a valve. After doing a useful work in the turbine, the steam is exhausted to condenser. The condenser condenses the steam which is fed to the heat exchanger through feed water pump.

(iv)Alternator: The steam turbine drives the alternator which converts mechanical energy into electrical energy. The output from the alternator is delivered to the bus-bars through transformer, circuit breakers and isolators.

Advantages:

(i) The amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation.
(ii) A nuclear power plant requires less space as compared to any other type of the same size.
(iii) It has low running charges as a small amount of fuel is used for producing bulk electrical energy.
(iv) This type of plant is very economical for producing bulk electric power.
(v) It can be located near the load centres because it does not require large quantities of water and need not be near coal mines. Therefore, the cost of primary distribution is reduced.
(vi)There are large deposits of nuclear fuels available all over the world. Therefore, such plants can ensure continued supply of electrical energy for thousands of years.
(vii) It ensures reliability of operation.

Disadvantages:

(i) The fuel used is expensive and is difficult to recover.
(ii) The capital cost on a nuclear plant is very high as compared to other types of plants.
(iii) The erection and commissioning of the plant requires greater technical know-how.
(iv)The fission by-products are generally radioactive and may cause a dangerous amount of radioactive pollution.
(v) Maintenance charges are high due to lack of standardization. Moreover, high salaries of specially trained personnel employed to handle the plant further raise the cost.
(vi) Nuclear power plants are not well suited for varying loads as the reactor does not respond to the load fluctuations efficiently.
(vii) The disposal of the by-products, which are radioactive, is a big problem. They have either to be disposed off in a deep trench or in a sea away from sea-shore.

Selection of Site for Nuclear Power Station:

The following points should be kept in view while selecting the site for a nuclear power station:

(i) Availability of water: As sufficient water is required for cooling purposes, therefore, the plant site should be located where ample quantity of water is available, e.g., across a river or by sea-side.

(ii) Disposal of waste: The waste produced by fission in a nuclear power station is generally radioactive which must be disposed off properly to avoid health hazards. The waste should either be buried in a deep trench or disposed off in sea quite away from the sea shore. Therefore, the site selected for such a plant should have adequate arrangement for the disposal of radioactive waste.

(iii) Distance from populated areas: The site selected for a nuclear power station should be quite away from the populated areas as there is a danger of presence of radioactivity in the atmosphere near the plant. However, as a precautionary measure, a dome is used in the plant which does not allow the radioactivity to spread by wind or underground waterways.

(iv)Transportation facilities: The site selected for a nuclear power station should have adequate facilities in order to transport the heavy equipment during erection and to facilitate the movement of the workers employed in the plant.

POWER RATING (OR) WATTAGE:

Power rating of household appliances The Rating of an electrical appliance indicates the voltage at which the appliance is designed to work and the current consumption at that voltage. The Power rating of the appliance is related the power it consumes. Every electrical appliance has a power rating which indicates the amount of electricity required to do work. This is usually given in watts (W) or kilowatts (kW).

WATTAGE (OR) POWER RATING OF HOME APPLIANCES:

Power consumption is measured in watts. Technically speaking, the more power an appliance consumes, the higher will be its operating cost. A comprehensive list of the common household appliances with their minimum and maximum wattage.

APPLIANCE	MINIMUM WATTAGE	MAXIMUM WATTAGE
2 Ton Air Conditioner	1300W	2000W
2 Ton Inverter Air Conditioner	1000W	2000W
42 Inch LCD TV	110W	130W
42 Inch LED TV	70W	90W
Air Fryer	1500W	1500W
Air Purifier	25W	30W
Amazon Echo	3W	3W
Bread Toaster (4 Slice)	1200W	2500W
Ceiling Fan (48 Inch)	60W	80W
Coffee maker	800W	1400W
Computer Monitor	25W	30W
Deep Freezer	19W	19W
Dehumidifier	240W	240W
Desktop Computer	100W	450W
Dishwasher	1200W	1500W
Domestic Water Pump	200W	1500W

Electric Heater Fan	2000W	3000W
Electric Iron	800W	1500W
Electric Kettle	1200W	3000W
Electric Stove	2000W	2000W
Espresso Coffee Machine	1300W	1500W
Exhaust Fan	12W	12W
Food Blender	300W	400W
Fridge	150W	450W
Front Load Washing Machine	500W	2200W
Fryer	1000W	1000W
Gaming PC	300W	600W
Guitar Amplifier	20W	30W
Hair Blow Dryer	1000W	3000W
Hair Straightening Iron	75W	300W
Home Internet Router	5W	15W
Home Phone	3W	5W
Hot Water Dispenser	1200W	1300W
Humidifier	35W	40W
Induction Cooktop	1400W	2000W
Inkjet Printer	20W	30W
Iron	1000W	1000W
Laptop Computer	40W	120W
Washing Machine	500W	500W
Water Filter and Cooler	70W	100W

LED Light Bulb	7W	10W
Oven	1000W	2150W
Phone Charger	4W	7W
Projector	220W	270W
Refrigerator	100W	200W
Scanner	10W	18W
Set Top Box	27W	30W
Sewing Machine	70W	80W
Steam Iron	2200W	2800W
Table Fan	10W	25W
Top Loading Washing Machine	500W	2500W
Treadmill	280W	900W
Tube Light	22W	22W
Vacuum Cleaner	450W	900W

ELECTRICAL ENERGY CONSUMPTION:

The Energy consumption of a device is calculated by multiplying the wattage of a device and operational hours.

Energy consumption = Wattage X operational hours

(OR)

Energy consumption = Power Rating X operational hours

UNIT: The unit of electrical energy consumed is kWh. One kilowatt-hour is the electrical energy consumed by an electrical appliance of power 1 kW when it is used for one hour. Therefore,

1kwh =1 unit

CALCULATION OF ELECTRICAL ENERGY CONSUMPTION OF ELECTRICAL HOME APPLIANCES:

Let us consider different home appliances to calculate approximate total energy consumption of house per month.

S.No.	Appliance	watts	Number	Operating Hours/day	Total wattage	Electrical Energy Consumption(kwh)= TotalwattageXOperating Hours/1000
1	Tube Light	60	10	5	600	=600X 5/1000=3
2	Fan	75	4	8	300	=300X 8/1000=2.4
3	Refrigerator	200	1	24	200	=200X 24/1000=4.8
4	AC	1000	1	5	1000	=1000X 5/1000=5
5	Laptop	50	1	2	50	=50X 2/1000=0.1
6	Television	50	1	3	50	=50X 3/1000=0.15
7	Grinders	1000	1	½	1000	=1000X0. 5/1000=0.5
8	Printers	50	1	½	50	=50X0. 5/1000=0.025
9	Washing Machine	2000	1	1	2000	=2000X 1/1000=2
10	Micro Wave	1000	1	1	1000	=1000X 1/1000=1
						Total=18.9=19Units or kwh

Total Electrical Energy Consumption/day=19 kwh
Total Electrical Energy Consumption/month= Total Electrical Energy Consumption/day X No.of days in month

=19 X 30 =570 kwh

ELECTRICITY BILL:

Electricity Bill/month= Electrical Energy Consumption/month X rate of charge

(OR)

Electricity Bill/month= Electrical Energy Consumption/month X rate of charge + meter rent/month

Problems

1. A consumer uses a 10 kW geezer, a 6 kW electric furnace and five 100 W bulbs for 15 hours. (a) How many units (kWh) of electrical energy have been used.(b) Find Electricity Bill if cost per unit is Rs.2.5.

Solution:

Given that
Load – 1 = 10 kW geezer
Load – 2 = 6 kW electric furnace
Load – 3 = 500 watt (five 100 watt bulbs)
Total load = 10kW + 6kW + 0.5kW = 16.5kW
Time taken = 15 hours
Energy consumed = Power in kW × Time in hours
= 16.5 × 15 = 247.5 kWh
So, the total energy consumption = 247.5 units
If the cost per unit is 2.5, then the total cost of energy consumption or Electricity Bill is

Electricity Bill =247.5 × 2.5 = Rs 618.75/-

2. Calculate the monthly electric bill at 50 p/unit for a residential billing with the following load. Meter rent per month is Rs. 5/-

1) 6 no. of 60 W lamps used 3 h/day

ii) 2 no. of 80 W fans used 6 h/day

iii) 1 no. of 500 W refrigerator works at 80%, 4 h/day

iv) 1 no. of 3/4 h.p motor working at 80% efficiency working 3 h/day to pump water.

Solution:

Motor Output=3/4 H.P.=0.75 H.P.

=0.75 X 736.36w

=552.27w

=0.55227kw

%Efficiency of a Motor = Output/Input X 100

80= 552.27/Input X 100

Input=552.27 X 100/80

=690.3375w

=0.6903375kw

S.No.	Appliance	Wattage (w)	Number	Operating Hours (hr's)	Total Wattage(w)	Electrical Energy (or)Total Units consumed(kwh)= Total Wattage X Operating Hours/1000
1.	Lamps	60	6	3	360	360 X3/1000=1.08
2.	Fans	80	2	6	160	160 X6/1000=0.96
3.	Refrigerator	500	1	4	500	500 X4/1000=2
4.	Motor	690.3375	1	3	690.3375	690.3375 X3/1000=1.882
Electrical Energy (or)Total Units consumed(kwh)/day						5.922kwh/day

Electrical Energy (or)Total Units consumed(kwh)/day=5.922kwh

Electrical Energy (or)Total Units consumed(kwh)/month=5.922 X30

=177.66kwh

Monthly Electricity Bill= Electrical Energy Consumption/month X rate of charge + meter rent/month

=177.66 X0.5+5

=Rs.93.83/-

3. A residential house has the following loads:
i) 10 lamps of 60 W, working for 8 h/day
ii) 6 lamps of 100 W, working for 5 h/day
iii) 5 fans of 80 W, working for 12 h/day
iv) 2 heaters of 100 W, working for 3 h/day
v) 1 1/2 h.p pump set of efficiency 85%, running 2 h/day.
Calculate the monthly electricity bill with rate of rupees 1.35 for first 50 units and 2.15 p for the remaining added Rs. 10 as a meter rent per month.

Solution:

Motor Output=1 $\frac{1}{2}$ H.P.=1.5 H.P.
=1.5 X 736.36w
=1104.90w
=1.10490kw

%Efficiency of a Motor = Output/Input X 100
85= 1104.90/Input X 100
Input=1104.90 X 100/85
=1299.88w
=1.299kw

S.No.	Appliance	Wattage (w)	Number	Operating Hours (hr's)	Total Wattage (w)	Electrical Energy (or)Total Units consumed(kwh)= Total Wattage X Operating Hours/1000
1.	Lamps	60	10	8	600	600 X8/1000=4.8
2.	Lamps	100	6	5	600	600 X5/1000=3
2.	Fans	80	5	12	400	400X12/1000=4.8
3.	Heater	100	2	3	200	200 X3/1000=0.6
4.	Pump set	1299.88	1	2	1299.88	1299.88 X2/1000=2.599
Electrical Energy (or)Total Units consumed(kwh)/day						15.799kwh/day

Electrical Energy (or)Total Units consumed(kwh)/day=15.799kwh
Electrical Energy (or)Total Units consumed(kwh)/month=15.799 X30
=473.992kwh

Monthly Electricity Bill= Electrical Energy Consumption/month X rate of charge + meter rent/month
=50 X1.35+423.992 X2.15+10
=Rs.989.082/-

Tariff: The electrical energy generated in generating station is delivered to a large number of consumers at reasonable rates. The rate at which the electrical energy is supplied to a consumer is known as tariff.

The objectives of tariff should include:

1. Recovery of cost of generating electrical energy in power stations
2. Recovery of cost of capital investment in transmission and distribution.
3. Recovery of operation and maintenance of supply of electrical energy.
4. A suitable profit on capital investment.

Types of Tariff:

1. Simple Tariff
2. Flat Rate Tariff
3. Blocked Tariff
4. Two-Part Tariff
5. Three-Part Tariff

TWO PART TARIFF:

There are different types of tariff. The consumers who have appreciable maximum demand for them two-part tariff method is employed. Two Part Tariff When the rate of electricity energy is charged on the maximum demand of the consumer and the units consumed is called two part tariff. In this tariff scheme, the total costs charged to the consumers consist of two components: fixed charges and variable charges. It can be expressed as:

Total Cost =Rs [A X kW + B X kWh]

Where, Fixed charges - A = charge per kW of max demand
Variable charges - B = charge per kWh of energy consumed.

The fixed charges will depend upon maximum demand of the consumer and the variable charge will depend upon the energy (units) consumed. The fixed charges are due to generation, transmission and maintenance.

Advantages:

- It is easily understood by the consumers.
- If a consumer does not consume any energy in a particular month, the supplier will get the return equal to the fixed charges.

Disadvantages:

- If a consumer does not use any electricity, he has to pay the fixed charges regularly. The maximum demand of the consumer is not determined. Hence, there is error of assessment of max demand.
- There is always error in assessing maximum demand of the consumer.

Electricity Bill Calculation of electricity bill for low tension domestic consumer is as follows:

The electricity bill consists of two components: fixed charges and variable charges (running charges). It can be expressed as:

Total Electricity Bill = A+ B+ Tax
= [b X kW + c X kWh] + Tax

Where, b = charge per kW of max demand
Fixed charges A= Total kW X charge per kW
c = charge per kwh of energy consumed
Variable charges B = No of units consumed X rate per unit

Problems

1. A consumer has a maximum demand of 30KW and No.of units consumed is 120kwh.Calcultae the Total Electricity Bill if Rs 2 per kwh and Rs 10 per kw.

Solution:

Fixed charges A= 10x30=Rs300/-

Variable charges B= 2 x120=Rs240/-

Total Electricity Bill=A+B

=300+240=Rs540/-

2. If the sanctioned load is 3KW then for 1kw it is Rs 85 and above 1kw it Rs 95 per kw. If the no of units consumed is 120 units for 0- 50 units – Rs 4.1 per unit, 50- 100 units – Rs 5.55 per unit, 100- 200 units – Rs 7.1 per unit and the Tax is Rs 50.Then find the Total Electricity Bill.

Solution:

Fixed charges A= 1x85 + 2x95=Rs 275

Variable charges B= 50 x4.1 + 50 x 5.55+ 20 x 7.1=Rs 624

Tax=Rs 50

Total Electricity Bill = A+ B+ Tax

= 275+624+50=Rs 949/-

3. Calculate the monthly electric bill at 50 p/unit and Rs10 per Kw for a residential billing with the following load.

1) 6 no. of 60 W lamps used 3 h/day

ii) 2 no. of 80 W fans used 6 h/day

iii) 1 no. of 500 W refrigerator works at 80%, 4 h/day

iv) 1 no. of 3/4 h.p motor working at 80% efficiency working 3 h/day to pump water.

Solution:

Motor Output=3/4 H.P.=0.75 H.P.

=0.75 X 736.36w

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%Efficiency of a Motor = Output/Input X 100

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S.No.	Appliance	Wattage (w)	Number	Operating Hours (hr's)	Total Wattage(w)	Electrical Energy (or)Total Units consumed(kwh)= Total Wattage X Operating Hours/1000
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Electrical Energy (or)Total Units consumed(kwh)/day						5.922kwh/day

Electrical Energy (or)Total Units consumed(kwh)/day=5.922kwh
Electrical Energy (or)Total Units consumed(kwh)/month=5.922 X30
=177.66kwh

Monthly Electricity Bill= Fixed charges+Variable charges
=b XKw+c XKwh
=10 X0.69.3375+ 0.5 X 177.66
=Rs.95.76/-

FUSE:
The electrical equipment is designed to carry a particular rated value of current under normal conditions. Under abnormal conditions such as short circuits, overload, or any fault; the current rises above this value, damaging the equipment and sometimes resulting in fire hazard. Fuses come into operation under fault conditions.

A Fuse is a short piece of metal, inserted in the circuit, which melts when excessive current flows through it and thus breaks the circuits. Under normal operating conditions it designed to carry the full load current. If the current increases beyond this designed value due to any of the reasons mentioned above, the fuse melts, isolating the power supply from the load.

(a) Desirable characteristics of a Fuse Element:
The material used foe fuse wires must have the following characteristics:
1. Low melting point e.g., tin, lead.
2. High conductivity e.g., copper.
3. Free from deterioration due oxidation e.g., silver.
4. Low cost e.g., tin, copper.

(b) Materials:
Materials used are tin lead or silver having low melting points. Use of copper or iron is dangerous, though tinned copper may be used.

(c) Types of Fuses: 1.DC Fuses 2.AC Fuses
AC Fuses are classified into following types 1.Low Voltage Fuses
2. High Voltage Fuses

Low Voltage Fuses are classified as

(i)Round Type Fuse Unit
(ii) Re-wireable or kit-Kat Fuse
(iii) High Rupturing Capacity (H.R.C) Cartridge Fuse

High Voltage Fuses are classified as

(i) Cartridge Fuse
(ii) Liquid Type Fuse
(iii) Metal Type Fuse
(iv) Semiconductor Fuse Units

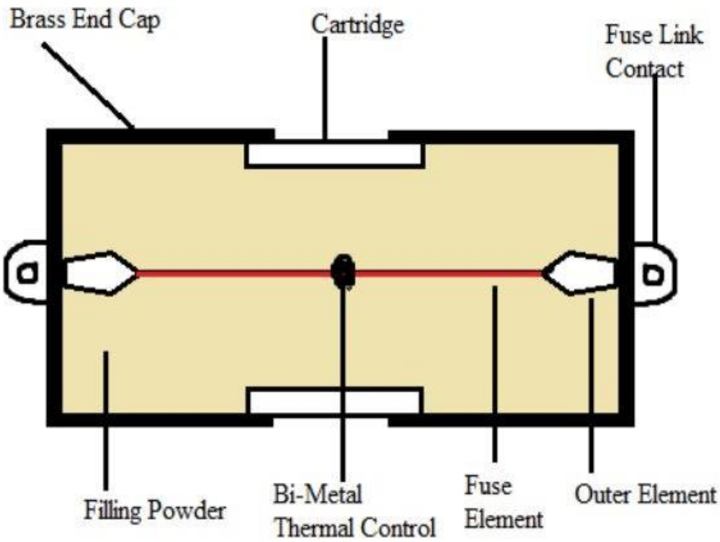


Fig (5): Schematic Diagram of Fuse

A Fuse consists of conducting wire, which has high resistivity and low melting point. The thickness of the Fuse wire is determined based on the amount of current flow in the circuit. If a fault causes a flow of excess Current then a Conductor break the Circuit by melting or separating it, the thin Conductor used is known as an Electric Fuse. The wire inside the Fuse melts if there is an occurrence of high Current due to a short Circuit or an overloaded Circuit. As a result of which the Current stops flowing since the wire has broken. In order to stop the flow of electricity. Once a Fuse melts, it can be changed or replaced with a new Fuse. A Fuse is normally made up of elements like zinc, copper, aluminium and silver.

The space within the body surrounding the element is completely packed with a filling power which may be a chalk, plaster of paris, quartz or marble dust. This filling material acts as an arc quenching and cooling medium.

Fuse Law:

Fuse law determines the current carrying capacity of a fuse wire. We can establish the law in the following way.

At steady-state condition that is when fuse carries normal current without increasing its temperature to the melting limit. That means at this steady state condition, the heat generated due to the current through fuse wire is equal to heat dissipated from it.

Heat generated = I^2R

Where R is the resistance of the fuse wire.

$$\text{Heat generated} = I^2 \rho \frac{l}{a}$$

Where, **ρ** is the resistivity, $\boldsymbol{l}$ is the length and **a** is the cross-sectional area of fuse wire.

$$\text{Heat generated} = I^2 \rho \frac{l}{\frac{\pi d^2}{4}}$$

Where, d is the diameter of fuse wire.

Heat generated = $I^2 k_1 \frac{l}{d^2}$ …….. (1)

Where, K_1 is a constant.

Heat lost ∝ surface area of fuse wire ∝ $\pi d l$

Therefore, Heat Lost= $k_2 dl$…………..(2)

Where, K_2 is a constant.

Now, Equating (1) and (2), we get,

$$I^2 k_1 \frac{l}{d^2} = k_2 dl$$

$$I^2 = kd^3 \text{……..(3)}$$

Where, $k = constant = \frac{k_2}{k_1}$

From Equation (3)

$$I = kd^{3/2}$$

$$I = kd^{1.5}$$

This is known as **fuse law**

Advantages of an Electrical Fuse:

- It is the cheapest form of protection, and it does need any maintenance.
- Its operation is completely automatic and requires less time as compared to circuit breakers.
- The smaller sizes of fuse element impose a current limiting effect under short-circuit conditions.
- Its inverse time-current characteristic enables its use for overload protection.

Disadvantages of an Electrical Fuse:

- Considerable time is required in replacing a fuse after the operation.
- The current-time characteristic of a fuse cannot always be correlated with that of the protective device.

CIRCUIT BREAKER:

A circuit breaker essentially consists of fixed and moving contacts, called electrodes. Under normal operating conditions, these contacts remain closed and will not open automatically until and unless the system becomes faulty. The contacts can be opened manually or by remote control whenever desired. When a fault occurs in any part of the system, the trip coils of the breaker get energized and the moving contacts are pulled apart by some mechanism, thus opening the circuits.

The main types of Circuit Breakers are

1. Miniature Circuit Breakers (MCB)
2. Earth Leakage Circuit Breakers (ELCB) or Residual Current Circuit Breaker (RCCB)
3. Oil Circuit Breakers (OCB)
4. Air Blast Circuit Breakers (ACB)
5. Molded Case Circuit Breakers (MCCB)
6. Vacuum Circuit Breakers (VCB)
7. SF6 Circuit Breakers

MINIATURE CIRCUIT BREAKER (MCB):

Minimum Circuit Breakers are electromechanical devices which protect an electrical circuit from over currents. Over currents in an electrical circuit may results from short circuits overload, or faulty design. An MCB is better alternative than fuse, since it does not require replacement once an overload is detected. AMCB functions by interrupting the continuity of electrical flow through the circuits once a fault is detected. In simple terms, MCB is a switch which automatically turns off when the current flowing through it passes the maximum allowable limit. Generally, MCB is designed to protect against over current and over temperature faults (over heating).

Working Principle:

There are two contacts - one is fixed and the other is moveable. When the current exceeds the predefined limit, a solenoid forces the moveable contact to open (i.e., disconnect from the fixed contact) and the MCB turns off, thereby stopping the current from flowing in the circuits.

Operation (or) working:

Internal parts of an MCB are shown in Figure (6). It mainly consists of one bi-metallic strip, one trip coil and one hand operated on-off lever. When the overflow of current takes place through MCB, the bimetallic strip gets heated and it deflects by bending. The deflection of the bi-metallic strip or trip bar releases a latch. The latch causes the MCB to turn off by stopping the flow of the current in the circuit. This process helps to safeguard the appliances or devices from the hazards happening due to over load or over current. To restart the flow of current, MCB must be turned ON manually.

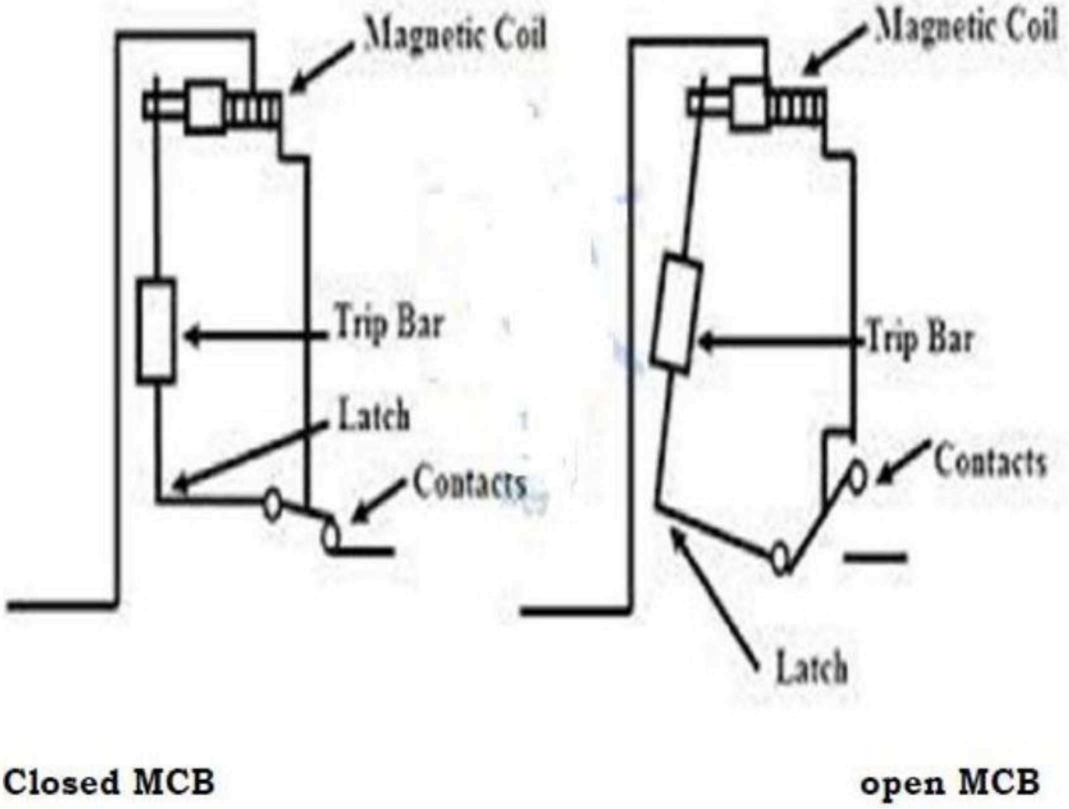


Fig (6):Internal Parts of MCB

If circuits are overload for a long time, the bi -metallic strip becomes over heated and deformed. This deformation of bi-metallic strip causes displacement of latch point. The moving contact of the MCB is so arranged by means of spring, with this latch point, that a little displacement of latch causes releases of spring and makes the moving contact to move for opening the MCB. The current coil or trip coil placed in such a manner that during SC faults, the MMF of that coil causes its plunger to hit the same latch point and force the latch to be displaced. Hence, the MCB will open in the same manner.

In the case of short circuit conditions, the current rises suddenly in an unpredictable way, leading to the electromechanical displacement of the plunger associated with a solenoid. The plunger hits the trip lever, it causes the automatic release of the latch mechanism by opening the circuit breaker contacts.

Advantages:

1. MCBs are replacing the re-wireable switch i.e., fuse units for low power domestic and industrial applications.
2. The MCB is quick work against short circuit up to 10kA,but fuse up to only 3kA.
3. MCB's is work quickly on overloading and under voltage.
4. The performance of MCB is good in case of Earth Leakage.
5. MCB is reliable.
6. In case of surge current, the MCB has time-delay characteristics, therefore it works properly.

Disadvantages:

1. The cost of MCB is greater than fuse.
2. The cost of on MCB distribution board is greater than rewire-able fuse board.
3. The risk of overloading of circuits due to unqualified persons operating than is completely removed.

Comparison between Fuse and Circuit Breaker:

Fuse	Circuit Breaker
Its working principle is based on the electrical or thermal properties of the conducting materials.	It works on the electromagnetism or switching principle.
In case of overload, an indication is not provided.	An indication is provided whenever there is an overload.
These are used only once.	It can be used several times.
The detection and interruption are done by the fuse itself.	It performs only the interruption operation whereas the detection is done relay system.
Perform automatically.	These perform manually or automatically.
It has a low breaking capacity.	High breaking capacity.
It has a low cost.	It has a high cost.

EARTHING (or) GROUNDING:

The process of connecting the metallic frame (i.e., non- current carrying part) of electrical equipment or some electrical part of the system (e.g., neutral point in a star-connected system, one conductor of the secondary of a transformer, etc.) to the earth (i.e., soil) is called grounding or Earthing. **Connection of the body of electric equipment to the general mass of the earth by wire of negligible resistance is called Earthing.** It brings the body of the equipment to the zero potential during electric shock. Necessity of Earthing

1. To protect the human beings from danger of shock in case they come in contact with the charged frame due to defective insulation.
2. It guarantees the safety of electrical appliances and devices from the excessive amount of electric current.
3. It protects the appliances from high voltage surges and lightning discharge.
4. It provides an alternative path for leakage of current hence protects the equipment.
5. It keeps the voltage constant in the healthy phase
6. It protects the Electric system and buildings from lightning.
7. It avoids the risk of fire in the electrical installation system.
8. To maintain the line voltage constant under unbalanced load condition.

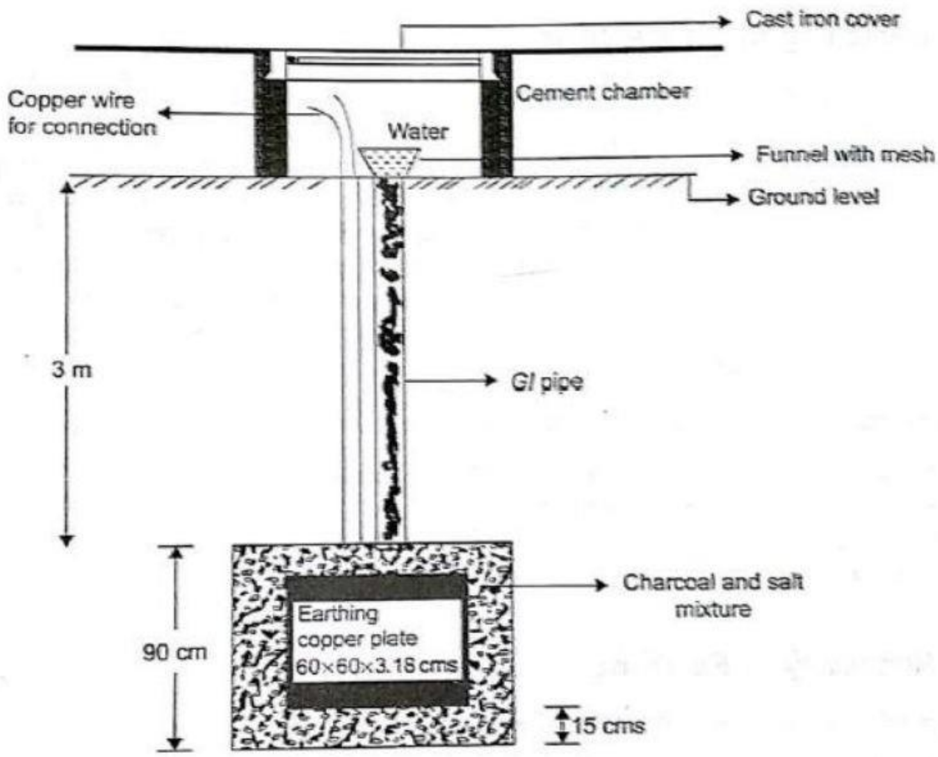
Methods of Earthing:

The various methods of Earthing in common use are

(i) Plate Earthing
(ii) Pipe Earthing
(iii) Rod Earthing
(iv) Strip or Wire Earthing

(i) Plate Earthing:

In this method either a copper plate of 60cm × 60cm ×3.18 or GI plate of 60cm × 60cm × 6.35 is used forearthing. The plate is buried into the ground not less than 3m from the ground level. The earth plate isembedded in alternate layers of coal and salt for a thickness of 15cm as shown in Fig (7). In addition,water is poured for keeping the earth's electrode resistance value below a maximum of 5Ω. The earth wire issecurely bolted to the earth plate. A cement masonry chamber is built with a cast iron cover for easy regular maintenance.



Fig(7):Plate Earthing

(ii) Pipe Earthing:

Earth electrode made of a GI (galvanized iron) pipe of 38mm in diameter and length of 2m (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75cm in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area (15 cm) surrounding the GI pipe is filled with a mixture of salt and coal. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross-sectional area are run through a12.7mm diameter pipe (at 60cm below) from the 19mm diameter pipe and secured tightly at the top as shown in Figure (8).

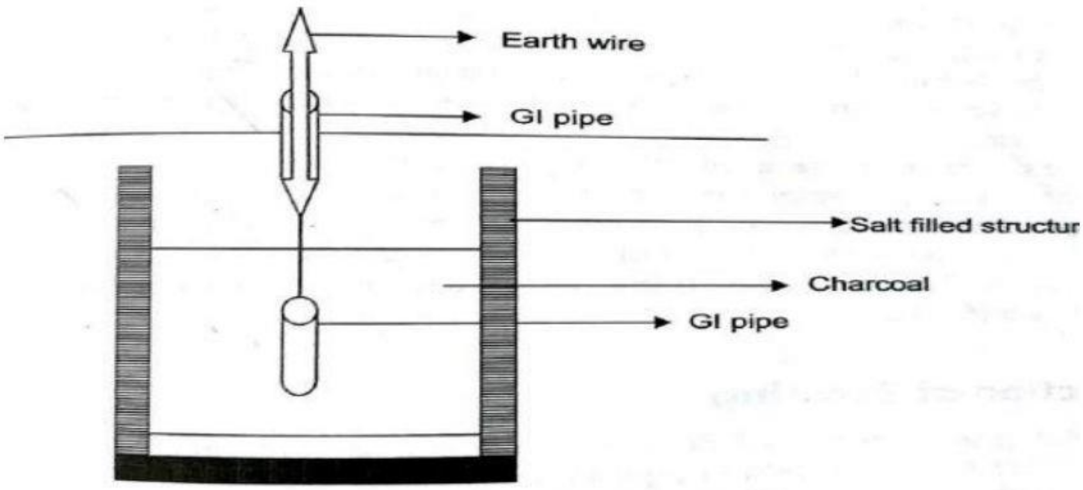


Fig (8):Pipe Earthing

When compared to the plate earth system the pipe earth system can carry larger leakage currents due to larger surface area is in contact with the soil for given electrode size. This system also enables easy maintenance as the earth wire connection is housed at the ground levels.

(iii) Rod Earthing:

It is the same method as pipe earthing, A copper rod of 12.5cm (1/2 inch) diameter or 16mm (0.6in)diameter of galvanized steel or hollow section 25mm (1 inch) of GI pipe of length above 2.5m (8.2 ft) are buried upright in the earth manually or with the help of a pneumatic hammer. The length of embedded electrodes in the soil reduces earth resistance to a desired value.

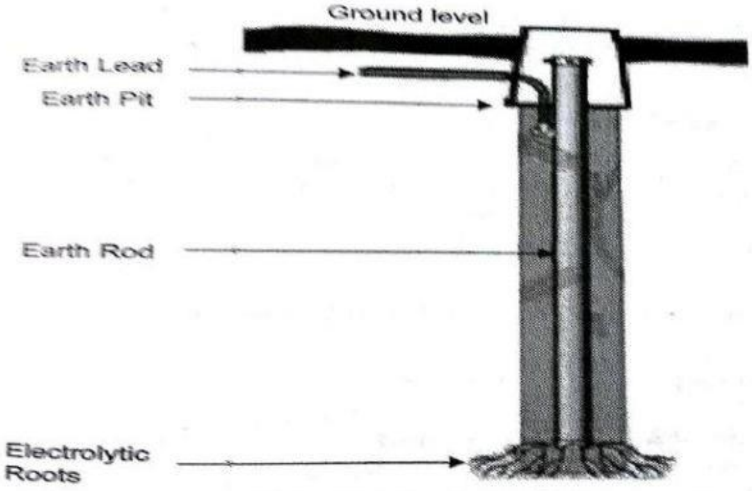


Fig (9):Rod Earthing

(iv) Strip or Wire Earthing:

In this method of earthing strip electrodes of cross- section not less than 25mm × 1.6mm (1 in × 0.06in) is buried in a horizontal trench of a minimum depth of 0.5m. If copper with a cross-section of 25mm × 4mm(1in × 0.15in) is used and a dimension of 3.0 mm2 if it's a galvanized iron or steel. If at all round conductors are used, their cross-section area should not be too small, say less than 6.0mm2 if it's a galvanized iron or steel. The length of the conductor buried in the ground would give a sufficient earth resistance and this length should not be less than 15m. The electrodes shall be as widely distributed as possible in a single straight or circular trench radiating from a point. This type of earthing is used where the earth bed has a rocky soil and excavation work is difficult.

Selection of Earthing or Applications:

The type of earthing to be provided depends on many factors such as type of soil, type of installation, etc..

The following table helps in selecting a type of earthing for a particular application

S.No	Type of Earthing	Application
01	Plate earthing	Large installations such as transmission towers, all sub-stations generating stations
02	Pipe earthing	• For domestic installations such as heaters, coolers, refrigerators, geysers, electric iron, etc. • For 11kV/400V distribution transformers • For induction motors rating upto 100HP • For conduit pipe in a wall, all wall brackets
03	Rod earthing	In areas where the soil is loose or sandy
04	Strip of wire earthing	In rocky ares

PERSONAL SAFETY MEASURES:

Electric shock and precautions

An electric shock is the sudden discharge of electricity through a part of the body when a person comes in contact with electrical equipment. The factors affecting the severity of shock are

1. Magnitude of the current through the body
2. Path of the current through the body
3. Time for which current is passed through the body
4. Frequency of the current
5. Physical and physiological condition

Precautions against Electric shock

- Avoid water at all times when working with electricity. Never touch or try repairing any electrical equipment or circuits with wet hands. It increases the conductivity of the electric current.
- Never use equipment with damaged insulation. The insulation of conductors must be proper and in good condition.
- Earth connection should be maintained in proper condition
- Use of the fuses and cables of proper rating.
- Use the rubber soled shoes while working.

- Megger tests should be done to check the insulation.
- Never touch two different terminals at the same time.
- Never remove the plug by pulling wire.
- The sockets should be placed at a proper height
- Switch off supply and remove the fuses before starting the work with any installation.
- Always use insulated screw drivers, and line testers.

SOLAR AND WIND POWER GENERATION

SOLAR ENERGY:

Solar energy has the greatest potential of all the sources of renewable energy and if only a small amount of this form of energy could be used, it will be one of the most important supplies of energy specially when other sources in the country have depleted. Energy comes to the earth from the sun. This energy keeps the temperature of the earth above that in colder space, causes current, in the atmosphere and in ocean, causes the water cycle and generates photosynthesis in plants.

Applications of Solar Energy:

(1) Heating and cooling of residential building.
(2) Solar water heating.
(3) Solar drying of agricultural and animal products.
(4) Solar distillation on a small community scale.
(5) Salt production by evaporation of seawater or inland brines.
(6) Solar cookers.
(7) Solar engines for water pumping.
(8) Food refrigeration.
(9) Bio conversion and wind energy, which are indirect source of solar energy.
(10) Solar furnaces.
(11) Solar electric power generation by
  (i) Solar ponds.
  (ii) Steam generators heated by rotating reflectors (heliostat mirrors), or by tower concept.
  (iii) Reflectors with lenses and pipes for fluid circulation (cylindrical parabolic reflectors).
(12) Solar photovoltaic cells, which can be used for conversion of solar energy directly into electricity or for water pumping in rural agricultural purposes.

SOLAR POWER GENERATION:

This power plant has photovoltaic cells, as name suggest for power generation. This power system generates electricity for medium and small size applications like for domestic purposes, street lights or at some mobile area where electricity supply lines can't reach. The main drawback of its initial cost because PV cells are made up silicon as we know silica/sand is available in abundant on earth but the extraction process is very costly, which increases the cost of PV cells.

Working Principle:

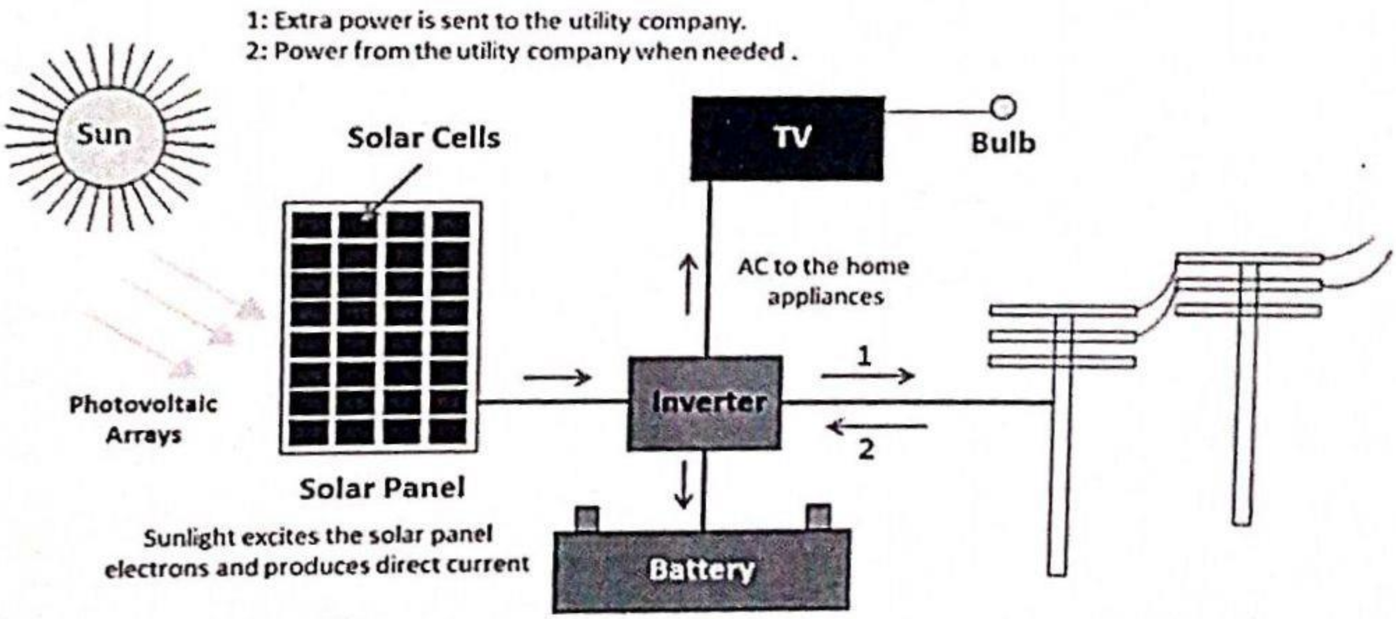
The sun rays come from the sun in the form of small- small energy packets known as Quanta's or photons. These radiations fall on the solar panels. Solar panels are the combinations of solar cells. A solar cell is the combination of both p-type and n-type semiconductors both are in contact with each other. When sun rays fall on to the solar cell then electron from the high concentration region i.e. from n-type semiconductor jumps towards the low concentration of electron region or electron valency region i.e. p-type semiconductor region. The diffusion of the electron continuously takes place into the p-n junction and creates electric field in the form of potential difference. This potential difference carries out by using some circuits, connecting p-type semiconductor with positive terminal and n-type with negative terminal.

This power comes out into the form of direct current to convert it into AC inverter comes into play which converts the DC into AC after that power generated by solar cell transferred to supply. The supply can be utilized directly or may be stored for later use by using Li-ion batteries. The working of solar plant continuously done until the sun light available after that alternative source or emergency systems comes into play like generators or power stored systems.

This is the working of solar power plants having photovoltaic's cells. A domestic solar power plant has various components which are arranged in proper sequence for generation and consumption of electricity as shown in Fig(1).

Following are the major components of solar power plant.

1.Solar Panel
2.Inverter
3.Power Storage Device i.e. Battery



Fig(1):Working of Solar Power Plant

Solar Panel:

Solar panel is made up of solar cell or small photovoltaic cells or we can say that the combinations of PV cells are known as solar panel. This is the main component in the solar power plant. All the solar radiation falls on solar panel which converts into electricity. Generally a solar power plant consists of 30-35 solar cells. We use combination of PV cells because a single PV cell is not capable to produce high power, Solar cells are made up of semiconductor material i.e. which is neither metal nor non-metal. Silicon is best semiconductor used in the solar cell having properties of both metals and non-metals. Solar cells are made up of p-type and n-type silicon semiconductor. Silicon is doped by pentavalent impurity to convert it into p-type semiconductor which has excess number of holes or positive charge, this p-type semiconductor joint with n-type i.e. negative charged semiconductor. These p-type and n-type semiconductor together forms a diode. These cells start working when sun rays fall on solar panel which we will study in working procedure. For large power generation number of solar panels joins together at large area. The output electricity is transferred through the transmission line at the desired location.

Inverter:

Solar panel generated D.C. power but most of the time we require AC power because our most of the electric works better on AC supply so to convert DC into AC we need some equipment. So, inverter comes into the play which converts DC power supply from the solar panel into the alternating current supply.

Power Storage Device:

Sun is not available at 24 hours it is the major drawback of the solar power generation. So, the major requirement of power at night as compare to day that's why the power storage system or device is required. Most of the time Lithium-ion batteries are used for power storage. In day time sun is available most of the time and power consumption are less. Another method to store energy is to lift the water at high altitude by using solar power and then used it to run turbine when it requires. The potential energy of stored water at higher altitude will run the turbine and generates electricity.

SOLAR CELL:

A **solar cell** (also known as a photovoltaic cell or PV cell) is defined as an electrical device that converts light energy into electrical energy through the photovoltaic effect. A solar cell is basically a p-n junction diode. Solar cells are a form of photoelectric cell, defined as a device whose electrical characteristics – such as current, voltage, or resistance vary when exposed to light.

Individual solar cells can be combined to form modules commonly known as solar panels. The common single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts.

Construction of Solar Cell:

A solar cell is basically a junction diode, although its construction it is little bit different from conventional p-n junction diodes. A very thin layer of N-type semiconductor is grown on a relatively thicker P-type semiconductor. A solar cell is essential a PN junction with a large surface area. The N-type material is kept thin to allow light to pass through to the PN junction.

These electrodes do not obstruct light to reach the thick p-type layer. Just below the p-type layer there is a p-n junction. We also provide a current collecting electrode at the bottom of the n-type layer. We encapsulate the entire assembly by thin glass to protect the **solar cell** from any mechanical shock.

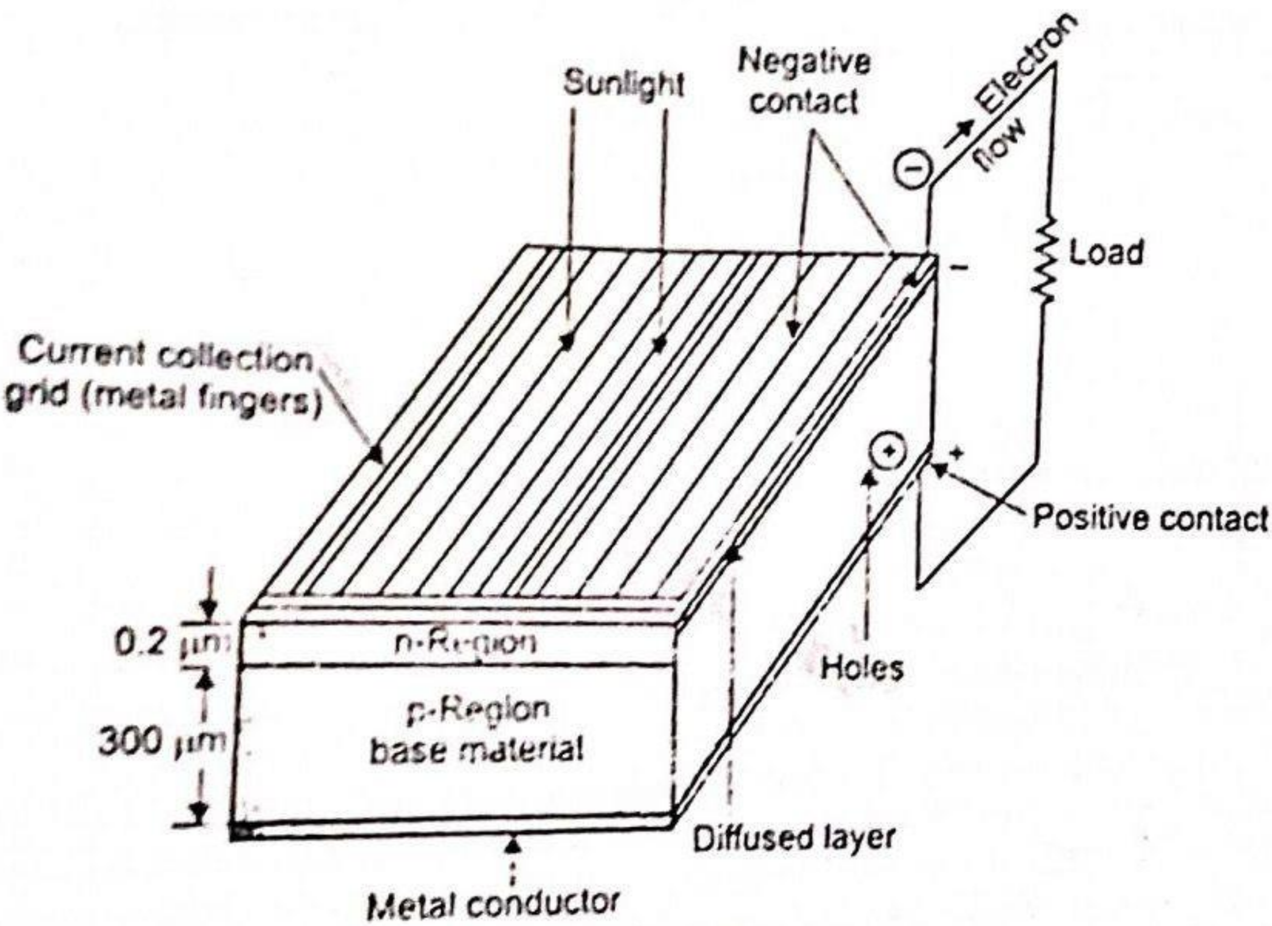


Fig (3): Construction of Solar Cell

Working Principle of Solar Cell:

A solar cell is essential a PN junction with a large surface area. The N-type material is kept thin to allow light to pass through to the PN junction. The light energy, in the form of photons, supplies sufficient energy to the junction to create a number of electron-hole pairs. The incident light breaks the thermal equilibrium condition of the junction. The free electrons in the depletion region can quickly come to the p-type side of the junction.

Light travels in packets of energy called photons. The generation of elec current happens inside the depletion zone of the PN junction. The depletion region explained previously with the diode is the area around the PN junction where electrons from the N-type silicon, have diffused into the holes of the P-type mate When a photon of light is absorbed by one of these atoms in the N-Type silicon it dislodge an electron, creating a free electron and a hole. The free electron and hole sufficient energy to jump out of the depletion zone. If a wire is connected from cathode (N-type silicon) to the anode (P-type silicon) electrons will flow through wire. The electron is attracted to the positive charge of the P-type material and trav through the external load (meter) creating a flow of electric current. The hole created the dislodged electron is attracted to the negative charge of N-type material and migrat to the back electrical contact. As the electron enters the P-type silicon from the bac electrical contact it combines with the hole restoring the electrical neutrality.

Advantages of Solar Cell:

1. No pollution associated with it.
2. It must last for a long time.
3. No maintenance cost.

Disadvantages of Solar Cell:

1. It has high cost of installation.
2. It has low efficiency.
3. During cloudy day, the energy cannot be produced and also at night we will not get solar energy.

Uses of Solar Generation Systems:

1. It may be used to charge batteries.
2. Used in light meters.
3. It is used to power calculators and wrist watches.
4. It can be used in spacecraft to provide electrical energy.

WIND POWER GENERATION:

Wind power or wind energy is the use of wind to provide mechanical power through wind turbines to operate electric generators.

Wind power is sustainable and renewable energy. Wind possesses energy by virtue of its motion. The wind is caused by the uneven heating of the atmosphere by the sun, variations in the earth's surface, and rotation of the earth. Mountains, bodies of water, and vegetation influence wind flow patterns. Wind speeds vary based on geography, topography and season. As a result, there are some locations better suited for wind energy generation.

Wind power is the conversion of wind energy into electricity or mechanical energy using wind turbines. The Schematic Arrangement of Wind Power Generation is shown in Fig(5).

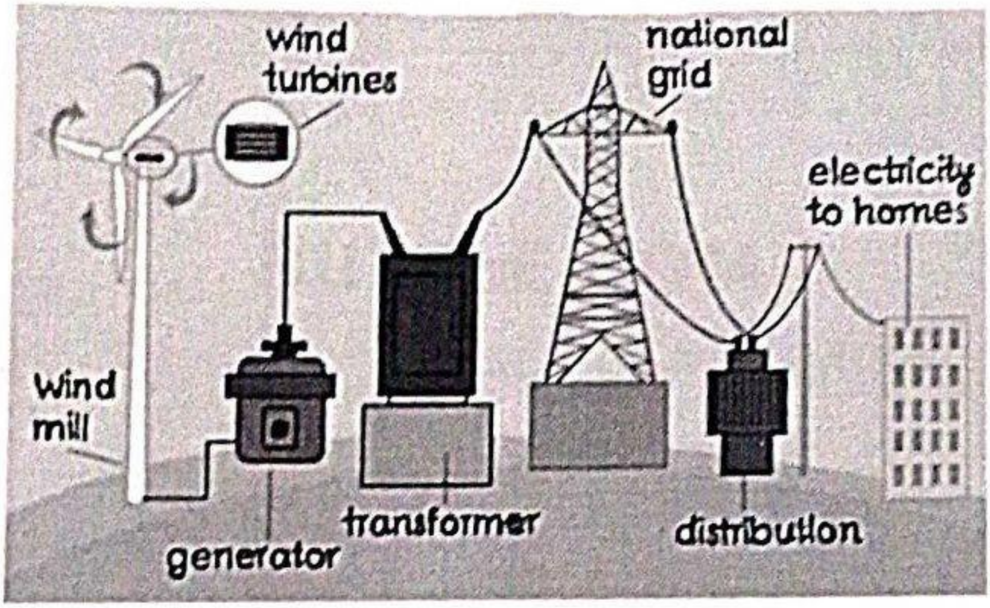


Fig (5):The Schematic Arrangement of Wind Power Generation

The device capable of slowing down the mass of moving air is called **"Rotor"**, like a sail or propeller, can extract part of the energy and convert it into useful work.The spinning blades, attached to a hub and a low-speed shaft, turn along with the blades.The rotating low-speed shaft is connected to a gearbox that connects to a high-speed shaft on the opposite side of the gearbox. The rotor turns the drive shaft, which turns an electric generator. The amount of power transferred is dependent on the rotor size and the wind speed.

This high-speed shaft connects to an electrical generator that converts the mechanical energy from the rotation of the blades into electrical energy. Modern wind turbines are highly evolved machines with more than 8,000 parts that harness wind's kinetic energy and convert it into electricity. The generated power transferred to domestic purpose through grid and distribution system.

WIND TURBINES:

Wind turbines are broadly classified into two categories. They are

1. Horizontal Axis Wind Turbine (HAWT)
2. Vertical Axis Wind Turbine (VAWT)

Working principle of wind power generation

As the free wind stream interacts with turbine rotor, it transfers a part of the kinetic energy to the rotor due to which its speed decreases. This difference in kinetic energy is converted into mechanical power. This mechanical energy is then converted to electrical energy using generator.

* Characteristics of wind energy

1. It is readily available in nature & does not cause any Pollution
2. It is clean & mostly available in many offshore, onshore & remote areas
3. The wind energy obtained is cost effective & reliable for power generation, pumping of water.
4. Desired winds are available only in few locations away from cities & forests.
5. Wind energy is unsteady, irregular, intermittent.
6. Direction of wind continuously changes.

* Advantages & Disadvantages of wind Powerplant :-

Advantages :-

1. There is no requirement of fuel supply
2. It consumes less time for its construction
3. It is non-polluting power system,
4. Wind turbines occupies very small floor area.

* Disadvantages :-

1. This system is noise in operation.
2. Only limited amount of power is produced.
3. It involves very high initial cost.
4. The overall weight of the wind power system is high

Types of Wind turbines and their Construction

Wind turbines are broadly classified into two categories. When When the axis of rotation is parallel to the air stream (i.e., horizontal), the turbine is said to be a Horizontal Axis Wind turbine (HAWT), and when it is perpendicular to the air stream (i.e., vertical), it is said to be a vertical Axis Wind turbine (VAWT).

HORIZONTAL AXIS WIND TURBINE (HAWT)

Horizontal axis wind turbine's are emerged as the most Successful type of turbines. These are being used for commercial energy generation in many parts of the world

Main Components :-

The Constructional details of the most common, three blade rotor, horizontal axis wind turbine is shown in figure.

* TURBINE BLADES :-

Turbine blades are made of high density wood (or) glass fibre and epoxy composites. They have an airfoil type of cross section The blades are slightly twisted from the outer tip to the root to reduce the tendency to stall. In addition to centrifugal force and fatigue due to continuous vibrations, there are many extraneous forces arising from wind turbulence, gust, gravitational forces and directional changes in the wind. All these factors are to be taken care off at the designing stage. The diameter of a typical, MW range, modern rotor may be the of 100m.

Modern wind turbines have two (or) three blades. Two/three blades rotor HAWT are also known as propeller type wind turbines

Owing to their Similarity with propellers of old aeroplanes. However, the rotor rpm is case of a wind turbine is very low as compared to that for propellers. The relative merits and demerits of two and three blade rotors are as follows.

* Compared to the two blade design, the three blade machine has smoother power output and balanced gyroscopic force
* There is no need to teeter the rotor, allowing the use of a simple rigid hub. The blades may be cross-linked for greater rigidity.
* Adding a third blade increases the power output by about 5% only, while the weight and cost of a rotor increases by 50% and additional 50% weight and cost.
* The two blade rotor is also simpler to erect, since it can be assembled on the ground and lifted to the shaft without complicated maneuvers during the lift.

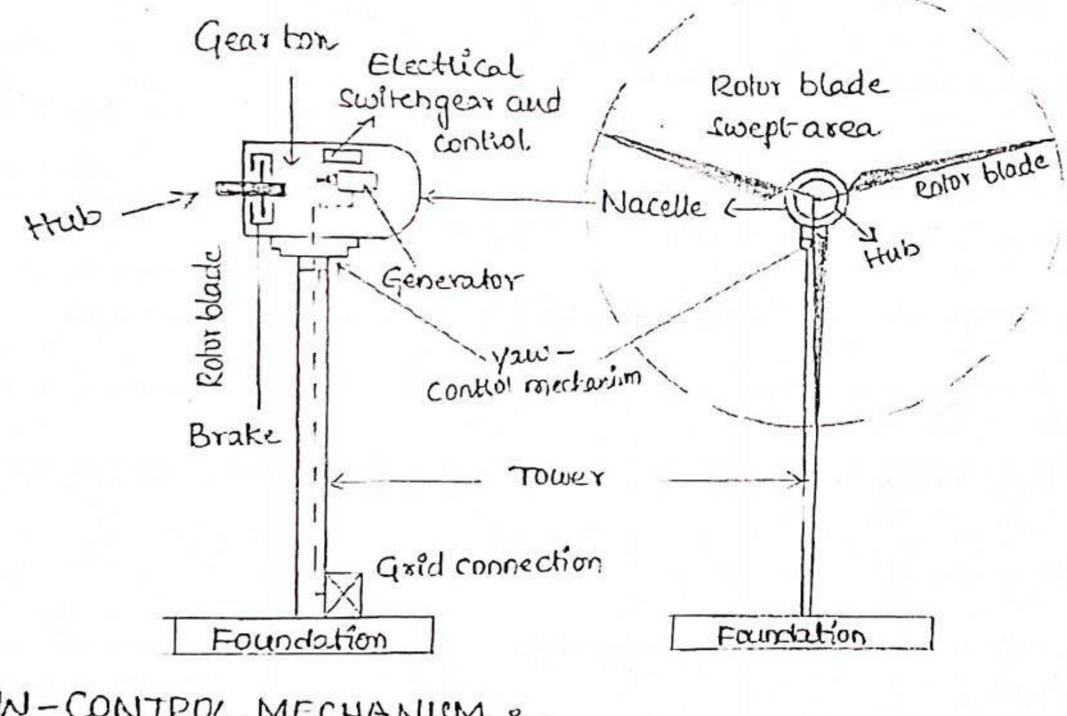
HUB :-

The central solid portion of the rotor wheel is known as HUB. All blades are attached to the Hub. The mechanism for pitch angle control is also provided inside the hub.

NACELLE :-

* The term Nacelle is derived from the name for housing containing the engines of an aircraft. The rotor is attached to the nacelle, and mounted at the top of a tower.

* It contains rotor brakes, gearbox, generator and electrical switchgear and control. Brakes are used to stop the rotor when power generation is not desired. The gearbox steps up the shaft rpm to suit the generator.
* protection and control functions are provided by switchgear and control block. The generated electrical power is conducted to ground terminals through a cable.



YAW-CONTROL MECHANISM :-

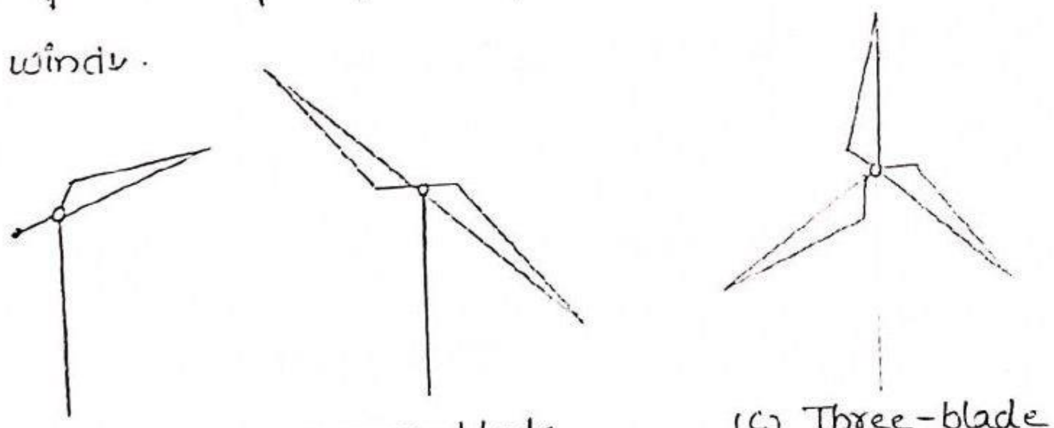
The mechanism to adjust the nacelle around the vertical axis to keep it facing the wind is provided at the base of nacelle.

TOWER :-

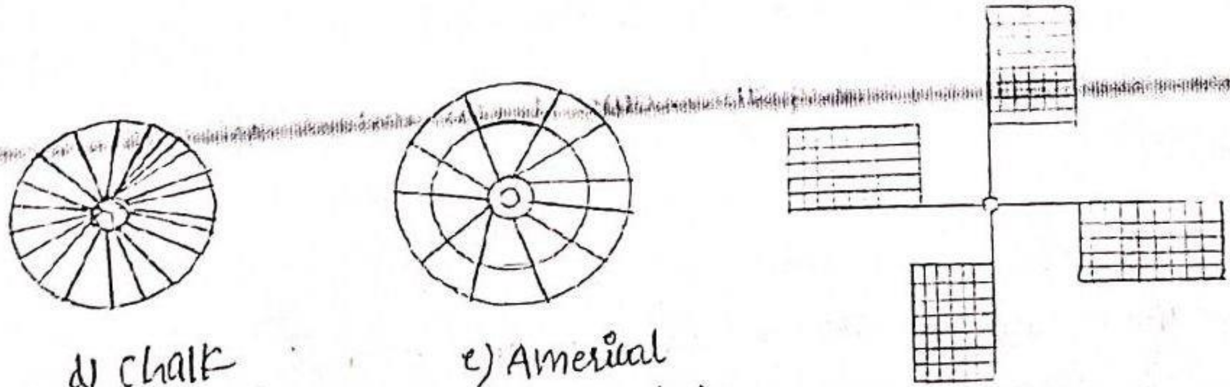
The tower supports the nacelle and rotor. For medium and large sized turbines, the tower is slightly taller than the rotor diameter. In case of a small sized turbine, the tower is much larger than the rotor diameter as the air erratic at lower heights Both steel and concrete towers are being used. The construction can be either tubular (or) lattice type.

TYPES OF ROTORS :-

Large HAWT's have been manufactured with two and three blades. A single blade rotor, with a balancing counterweight is economical, has simple controls but it is noiser and produces unbalanced forces. It is used for low-power applications. The low speed rotors are most suited for water-lifting applications, which require a high starting torque. They can capture power even from very slow winds.



(a) Single blade rotor (b) Two-blade rotor (c) Three-blade rotor.



d) Chalk multiblade rotor. e) American multibladed rotor (f) Dutch type rotor

VERTICAL AXIS WIND TURBINE (VAWT)

VAWT's are in the development stage and many models
undergoing field trial. The main attractions of a VAWT are

* It can accept wind from any direction, eliminating th
yaw control
* The gearbox, generator, etc., are located at the groun
nating the heavy nacelle at the top of the tower, thu
the design and installation of whole structure includin
* The inspection and maintenance also gets easier, and
* It also reduces the overall cost.

MAIN COMPONENTS

The constructional details of a Vertical a
type rotor). The details of main components are

TOWER (OR) ROTOR SHAFT :-

* The tower is a hollow vertical rotor sh

the vertical axis between the top and bottom bearings. It is installed above a support structure. In the absence of any load at the top, a very strong tower is not required, which greatly simplifies its design

*. The upper part of the tower is supported by guy ropes. The height of the tower of a large turbine is around 100m.

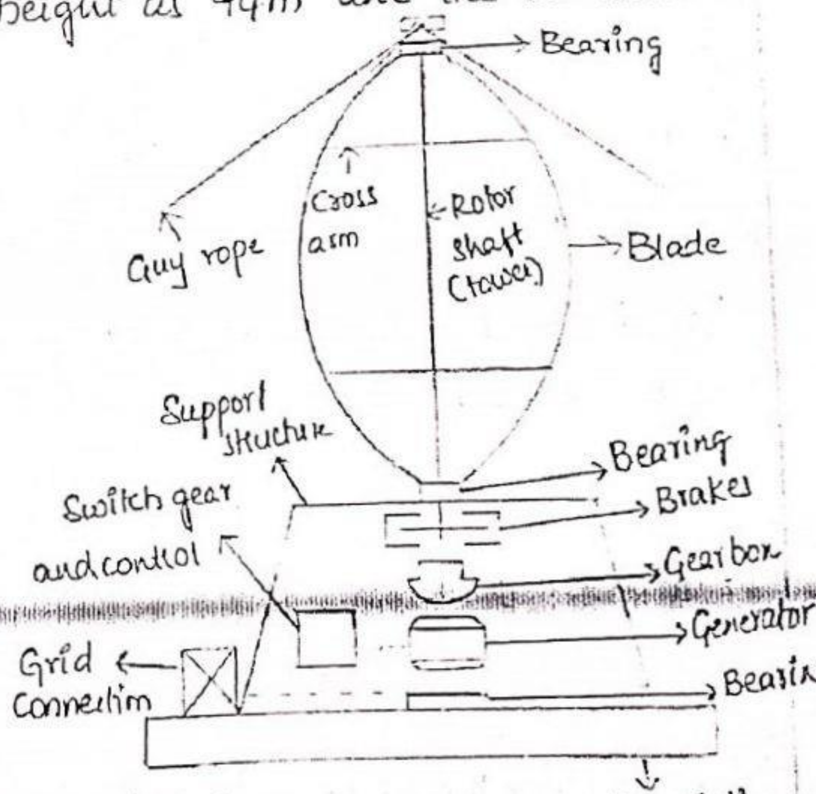
BLADES :-

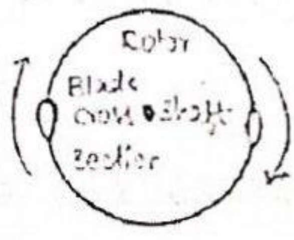
* It has two (or) three thin, curved blades shaped like an egg beater in a profile, with blades curved in a form that minimizes the bending stress caused by centrifugal forces – the so called 'Troposkien' profile. The blades have an airfoil cross section with constant chord length.

* The pitch of the blades cannot be changed. The diameter of rotor is slightly less than the tower height. The first large, darrieus type, Canadian machine has a rotor height as 94m and the diameter as 65m with a chord of 2.4m.

SUPPORT STRUCTURE :-

The support structure is provided at the ground to support the weight of the rotor. Gearbox, generator, brakes electrical switch-gear and controls are housed within this structure.





λ 70.48 μm.

Comparison b/w Convention and Non Conventional Energy sources:-

Conventional Energy Sources (Non Renewable Sources)	Non-Conventional Energy Sources. (Renewable Sources)
* These energy sources are also known as non renewable energy sources.	* These are also called as renewable energy sources.
* These resources available in limited quantity only.	* These sources are aviable in required quantity.
* The Conventional Energy sources are Common and widely used sources	* These are relatively new and hence are not commonly used.
* More fuel cost, Causes pollution when used	* No fuel cost, causes no pollution when used.
* The Conventional Energy sources are not eco friendy in nature.	* The non-conventional energy sources are eco-friendy in nature.
* Comparatively expensive to maintain, Store and transport.	* Initial cost for energy generation is high but cheaper in the long run
* Causes greenhouse effect and major culprit in climate change and has serious heath effects.	* No such issues as energy source is ecologically safe.
* These energy sources are used for commercial and industrial purpose.	* These energy sources are mainly used for house hold purpose.
* Examples: Fossile fuels like coal, petroleum and burning wood etc.	* Examples: Solar Energy, Nuclear energy, Geothermal Energy, Biomass Energy, Energy from oceans.