BEEE-UNIT 3

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HOUSE WIRING

- House wiring is to deal with the distribution system within the domestic premises.
- The wiring requirements may vary among the different consumers.
- House wiring is generally done for consumption of electrical energy at 230 V, 1-phase or at 400 V,3-phase.
- In the three phase system, the total load in the house is expected to be divided among the three phases.
- An earth wire is also run connecting all the power plugs from where large quantity of electrical energy is tapped by using electrical appliances like heater, electric iron, hot plate, etc. This chapter deals with the wiring materialsand accessories, different systems of wiring and earthing methods.

WIRING MATERIALS AND ACCESSORIES

1. **Switches:** A switch is used to make or break the electric circuit.
2. **Lamp Holders**: A lamp holder is used to hold the lamp for lighting purposes.
3. **Power point:** Power points (plugs, wall sockets) need to be installed throughout the house in locations where power will be required.
4. **Main Switch:** This is used at the consumer's premises so that he may have self-control of the entire distribution circuit.

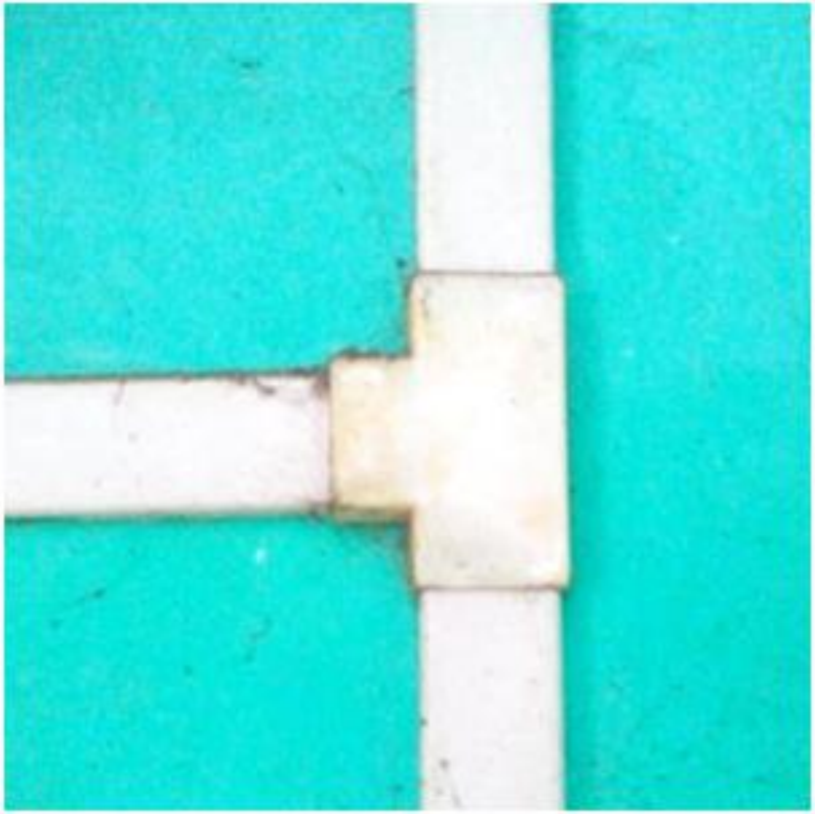
5.Circuit Breakers: Domestic Electrical Circuit Breakers provide essential protection to house from electrical hazards. It is essential to use domestic circuit breakers to get protected from electrical overloads and short circuit conditions. The most widely used electrical circuit breakers are Miniature circuit breakers (MCBs) , Residual current circuit breaker (RCCB) and Mounded Case Circuit Breaker (MCCB)

Electrical wiring system is classified into five categories:

1. Cleat wiring
2. Casing wiring
3. Batten wiring
4. Conduit wiring
5. Concealed wiring

1. Cleat wiring

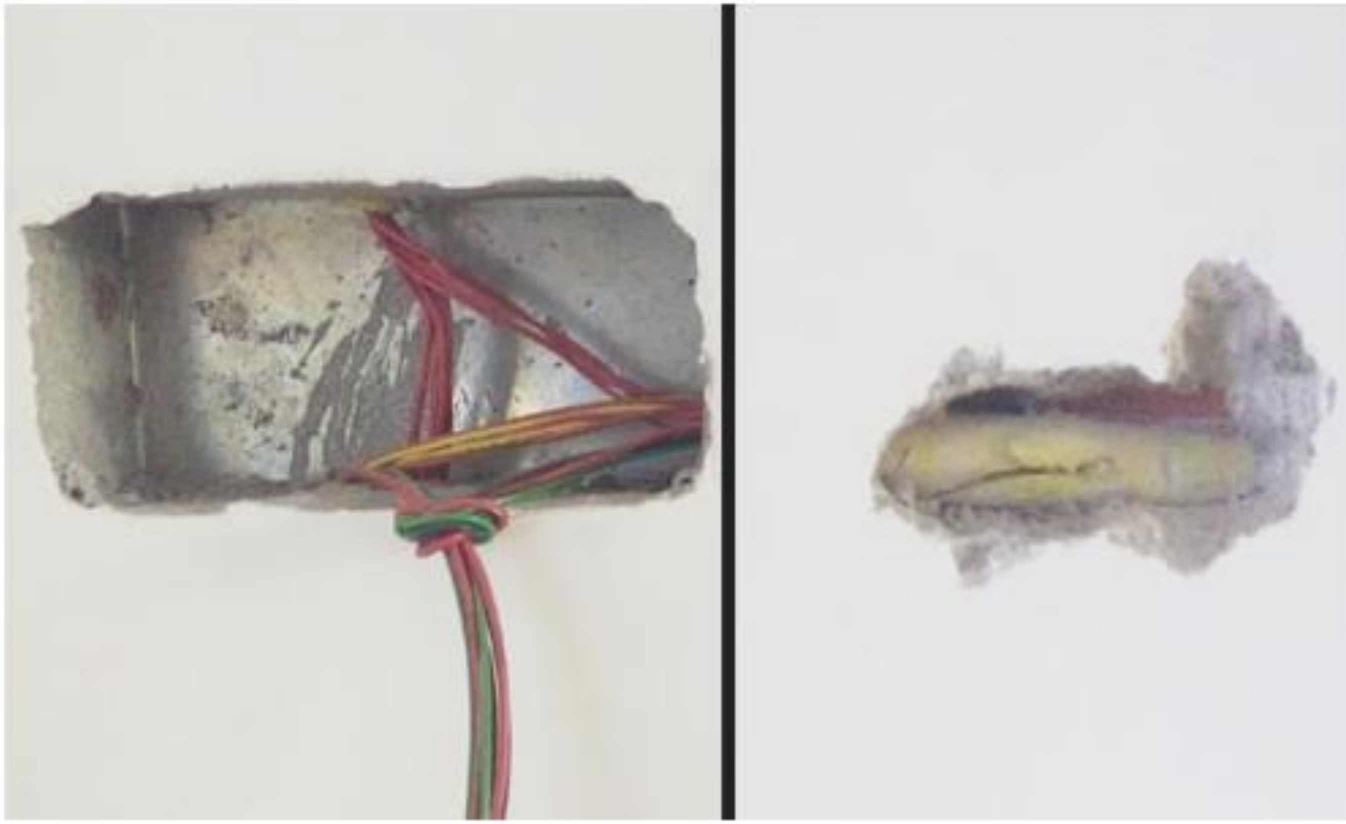
2. Casing wiring



3.Batten wiring

4. Conduit wiring

5. Concealed wiring

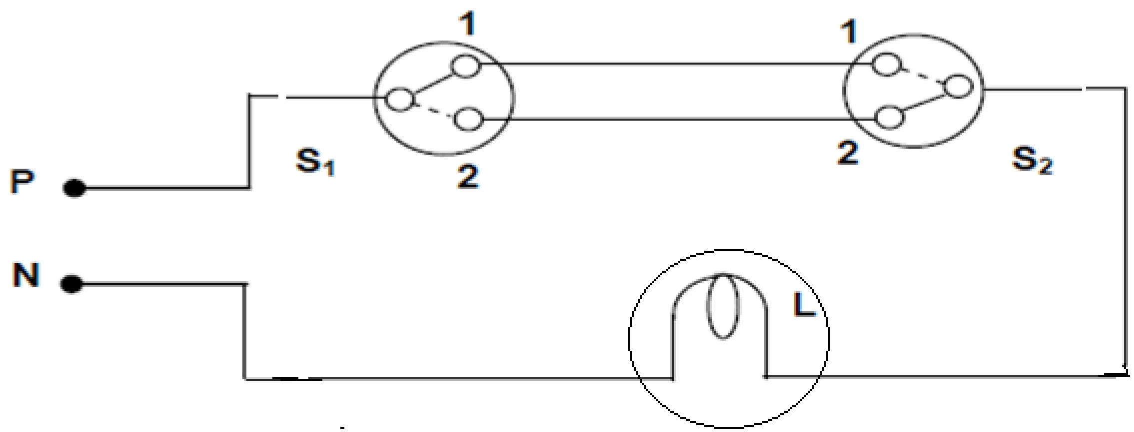


1-WAY SWITCH

2-WAY SWITCH

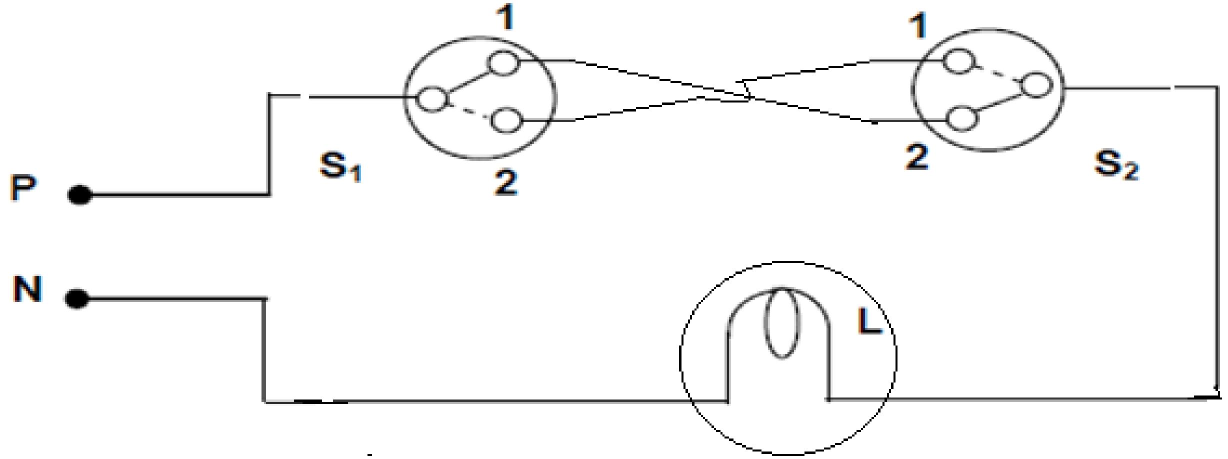
STAIRCASE WIRING

In staircase wiring a single lamp, placed at the middle of the staircase, is controlled by switches at two places, one at the beginning of the staircase and the other at the end of the staircase. For this purpose two-way switches are required. The wiring circuit is shown below.



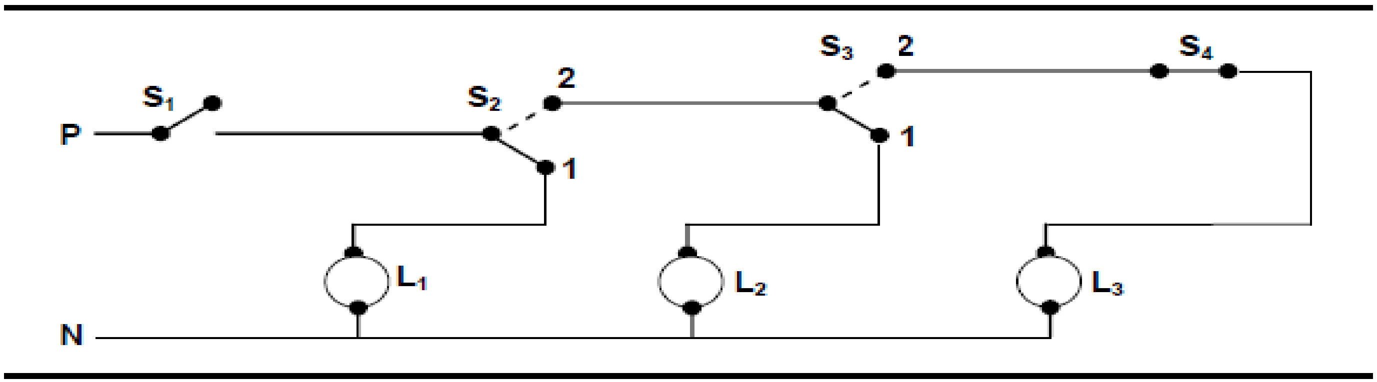
Position of switch S_1	Position of switch S_2	Condition of lamp
1	1	ON
1	2	OFF
2	1	OFF
2	2	ON

STAIRCASE WIRING- Another type of connection



Position of switch S_1	Position of switch S_2	Condition of lamp
1	1	OFF
1	2	ON
2	1	ON
2	2	OFF

CORRIDOR WIRING



Moving from left to right:

Enters	Closes S_1	L_1 ON
Reaches S_2	Put S_2 to 2	L_1 OFF and L_2 ON
Reaches S_3	Put S_3 to 2	L_2 OFF and L_3 ON
Reaches S_4	Opens S_4	L_3 OFF

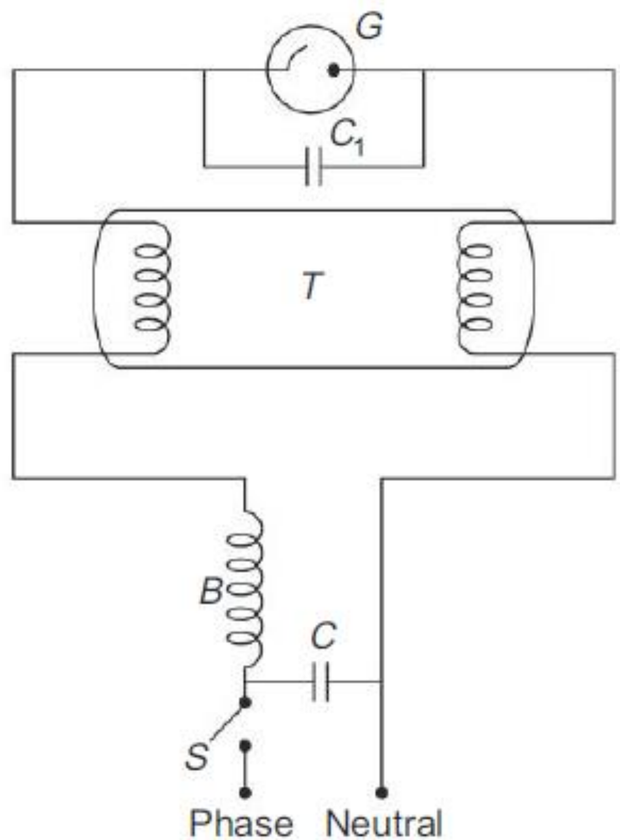
Moving from right to left:

Enters	Closes S_4	L_3 ON
Reaches S_3	Put S_3 to 1	L_2 ON and L_3 OFF
Reaches S_2	Put S_2 to 1	L_1 ON and L_2 OFF
Leaves	Opens S_1	L_1 OFF

FLUORESCENT LAMP

A fluorescent lamp or fluorescent tube is a gas-discharge lamp that uses electricity to excite mercury vapor. The excited mercury atoms produce short-wave ultraviolet light that then causes a phosphor to fluoresce, producing visible light. A fluorescent lamp converts electrical power into useful light more efficiently than an incandescent lamp. Lower energy cost typically offsets the higher initial cost of the lamp. The lamp is more costly because it requires a ballast to regulate the flow of current through the lamp.

While larger fluorescent lamps have been mostly used in commercial or institutional buildings, the compact fluorescent lamp is now available in the same popular sizes and is used as an energy-saving alternative in homes.



T – Fluorescent tube
G – Glow switch starter
B – Ballast or choke
S – Switch
C – Capacitor for P.F. improvement
C_1 – Capacitor to suppress radio interference

LED lamp

An LED lamp or LED light bulb is an electric light for use in light fixtures that produces light using one or more light-emitting diodes (LEDs). LED lamps have a **lifespan** many times longer than equivalent incandescent lamps, and are significantly **more efficient** than most fluorescent lamps, with a luminous efficacy of up to 303 lumens per watt. However, LED lamps require an electronic LED driver circuit when operated from mains power lines. Many LEDs use only about **10%** of the energy an incandescent lamp requires.

Safety Precautions when Working with Electricity

1. Never touch or try repairing any electrical equipment or circuits with **wet hands**. It increases the conductivity of electric current.

2. Never use equipment with **damaged insulation** or **broken plugs**.

3. If you are working on any electrical socket at your home then always **turn off the mains**.

4. Always **use insulated tools while working**.(never_use aluminium or steel ladder)

5. Electrical hazards include exposed **energized parts** and unguarded electrical equipment which may become **energized unexpectedly** -carries warning signs like "**Shock Risk**". Always be observant such electrical signs.

6. when working electrical circuit always use appropriate insulated rubber gloves and goggles.

7. Never try repairing energized equipment. Always check that it is de-energized first by using a tester. When an electric tester touches a live or hot wire, the bulb inside the tester lights up showing that an electrical current is flowing through the respective wire.

8. Know the wire code of your country.

9. Always use a circuit breaker or fuse with the appropriate current rating. Circuit breakers and fuses are protection devices that automatically disconnect the live wire when a condition of short circuit or over current occurs. The selection of the appropriate fuse or circuit breaker is essential.

BASIC PRINCIPLES OF EARTHING

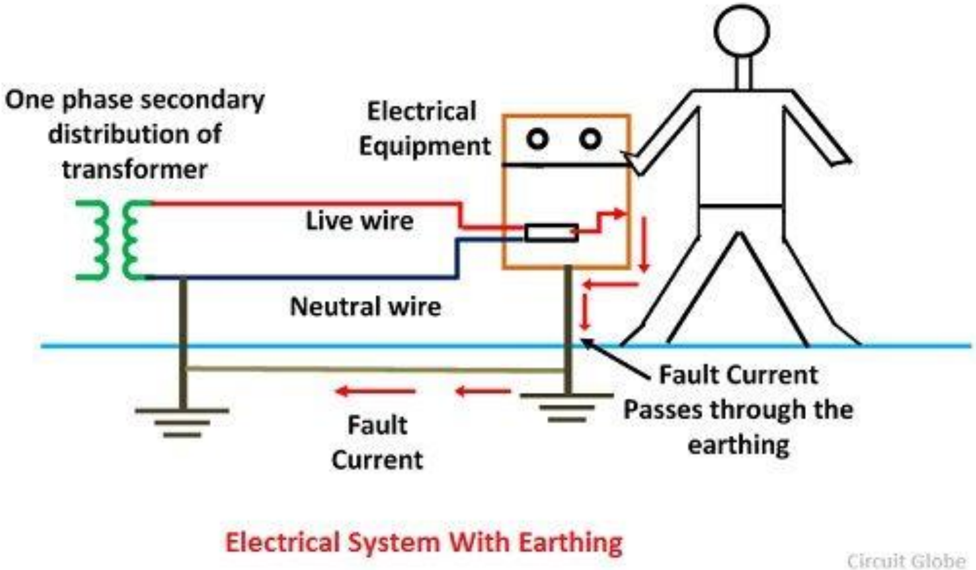
Earthing and its Necessity

Earthing means generally connected to the mass of the earth. It shall be in such a manner as to ensure at all times an immediate and safe discharge of electric current due to leakages, faults, etc.

All metallic parts of every electrical installation such as conduit, metallic sheathing, armouring of cables, metallic panels, frames, iron clad switches, instrument frames, household appliances, motors, starting gears, transformers, regulators etc, shall be earthed using one continuous bus (barewire). If one earth bus for the entire installation is found impracticable, more than one earthing system shall be introduced. Then, the equipment and appliances shall be divided into sub-groups and connected to the different earth buses.

The earthing conductors, when taken out doors to the earthing point, shall be encased in pipe securely supported and continued up to a point not less than 0.3 more below ground level. No joints are permitted in an earth bus. Whenever there is a lightning conductor system installed in a building, its earthing shall not be bonded to the earthing of the electrical installation.

Before electric supply lines or apparatus are energized, all earthing system shall be tested for electrical resistance to ensure efficient earthing. It shall not be more than two ohms including the ohmic value of earth electrode.


One phase secondary distribution of transformer
Electrical Equipment
Live wire
Neutral wire
Fault Current Passes through the earthing
Fault Current
Electrical System With Earthing
Circuit Globe

.1 Earthing through a G.I. Pipe

In this method a G.I. pipe used as an earth electrode. The size of the pipe depends upon the current to be carried and type of soil in which the earth electrode is buried.

For ordinary soils the length of the G.I. pipe used as an earth elctrode is 2 m long and 38 mm in diameter or 1.37 m long and 51 mm in diameter. For dry and

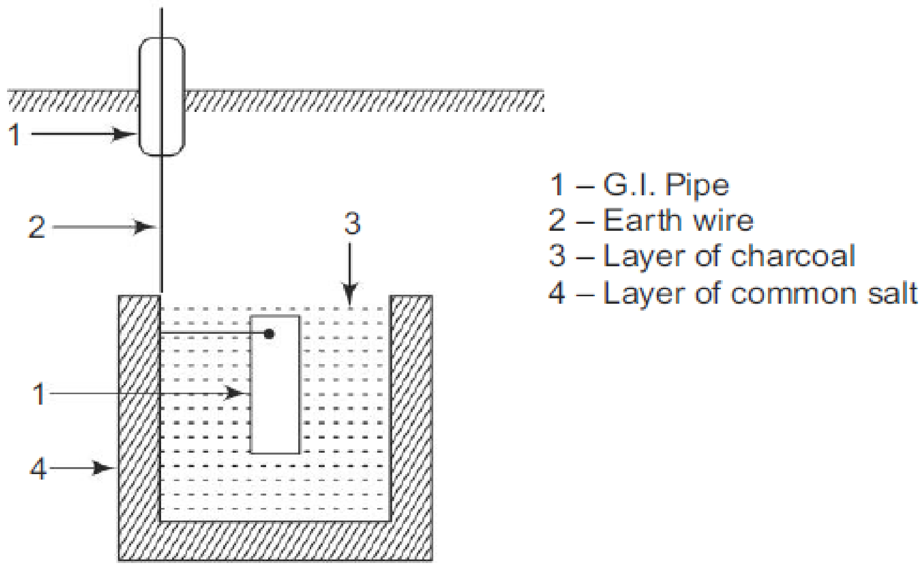
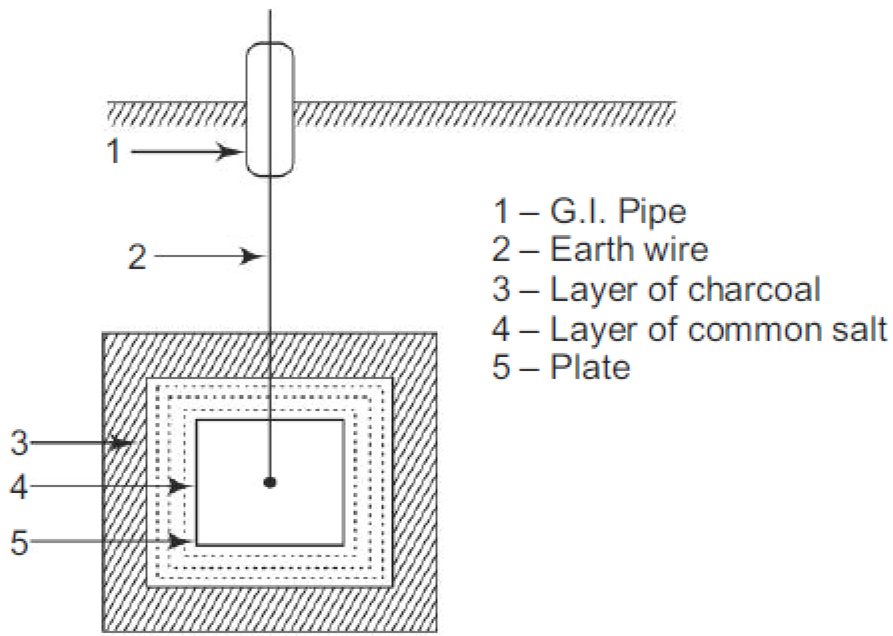


Fig. 8.3

rocky soils the length may be increased to about 2.75 metres and 1.85 metres respectively. The pipe is placed vertically, burying to a depth not less than 2 metres in as moist a place as possible, preferably in close proximity of water tap, water pipe or water drain and at least 0.6 metre away from all building foundations, etc as shown in Fig. 8.3. The pipe shall be completely covered by 80 mm of Charcoal with the layer of common salt 30 mm all around it. The charcoal and salt decreases the earth resistance.

.2 Earthing through a Plate

A G.I. or copper plate is used as an earth electrode. If a G.I. plate is used it shall be of dimensions 0.3 m × 0.3 m and 6.35 mm thick and if a copper plate is used it shall be of dimensions 0.3 m × 0.3 m and 3.2 mm thick. The plate is buried to a depth of not less than 2 m in as moist a place as possible preferably in close proximity of water tap, water pipe or water drain and at least 0.6 m away from all building foundations, etc. The plate shall be completely covered by 80 mm of charcoal with a layer of common salt of 30 mm all around it, keeping the faces of the vertical as shown in Fig. 8.4.



CLASSIFICATION OF INSTRUMENTS

Electrical measuring instruments are classified as follows:

I. Depending on the quantity measured	e.g.	Voltmeter, Ammeter, Wattmeter, Energymeter, Ohmmeter.
II. Depending on the different principles used for their working	e.g.	Moving Iron type, Moving coil type, Dynamometer type, Induction type.
III. Depending on how the quantity is measured?	e.g.	Deflecting type, Integrating type, Recording type.

The different types of torques associated with measuring instruments

1.Deflecting Torque

This torque acts on the moving system of the instrument to give the required deflection. It exists as long as the instrument is connected to the supply.The deflecting torque shall ensure a deflection proportional to the magnitude of the quantity being measured.

2. Opposing Torque

This torque always opposes the deflecting torque. The moving system attains a steady deflected position when the opposing torque equals the deflecting torque. The components of the opposing torque are inertia torque, control torque and damping torque.

2 (a) Inertia Torque

This is due to the inertia of the moving system. The deflecting has to overcome this and make the moving system move from its rest position.

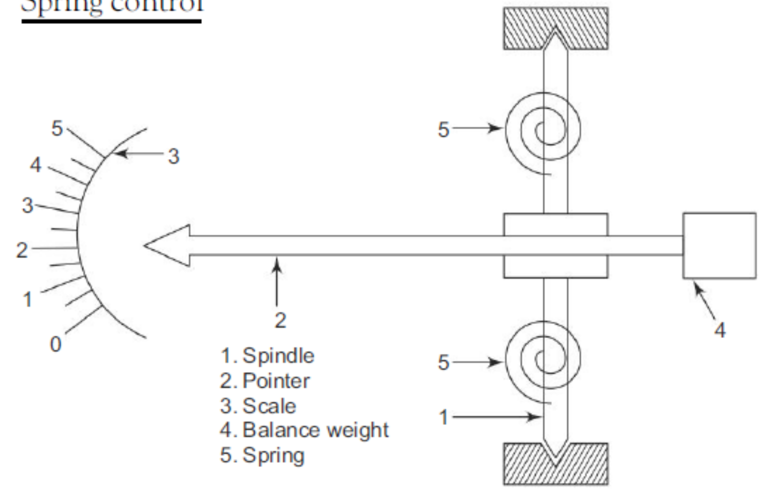
2 (b) Control Torque

This torque is always present in the instrument whether it is connected to the supply or not. The control torque increases with the deflection of the moving system. **It opposes the deflecting torque**. The moving system is brought to a steady deflected position when the control torque is balanced by the deflecting torque. The control torque is also essential to bring back the moving system to its initial or rest or zero position once the instrument is disconnected from the supply.

The control torque can be produced using spring or gravity:

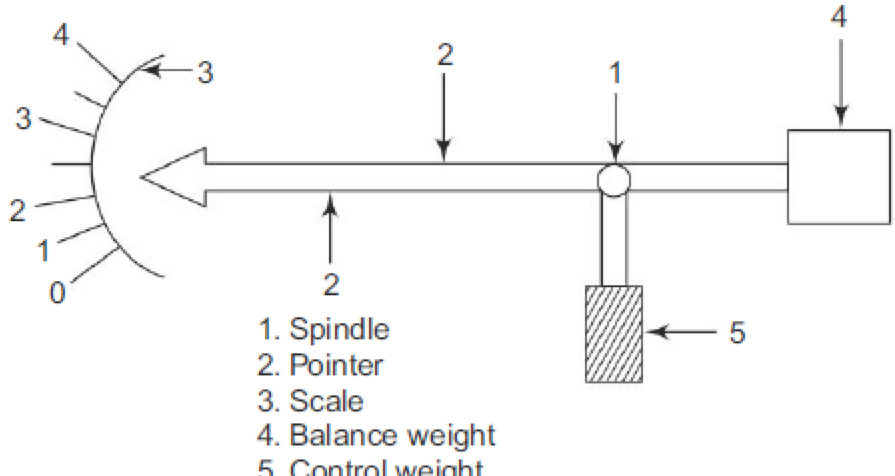
2 (b) (i) Spring control (Refer Fig.). Two helical springs of rectangular cross section are connected to the spindle of the moving system. With the movement of the pointer, the springs bet twisted in the opposite direction. Thus, the required amount of control is affected on the moving system. Also, once the instrument is disconnected from the supply, the pointer (moving system) is brought back to its initial position due to the twisted spring.

Spring control



2 (b) (ii) Gravity control

(Refer Fig.). In this method, adjustable small weights are added to some part of the moving system. When the pointer deflects, this weight also takes a deflected position. The gravitational force acting on the moving weight produces the required control torque



2 (c) ***Damping Torque*** This torque is produced only when the instrument is in operation. This ensures that the moving system takes just the required time to reach its final deflected position.

Electrical measuring instruments

- MOVING COIL INSTRUMENTS
  - PERMANENT MAGNET TYPE
  - DYNAMOMETER TYPE
- MOVING IRON INSTRUMENTS
  - ATTRACTION TYPE
  - REPULSION TYPE

1 MOVING COIL INSTRUMENTS

1 A. PERMANENT MAGNET MOVING COIL INSTRUMENT [PMMC]

Principle A current carrying coil is placed in a magnetic field, a force is exerted. It tends to act on the coil and moves it away from the field. This movement of the coil is used to measure current or voltage.

Construction (Refer Figs. 7.9 and 7.10). N and S refer to the pole pieces of a permanent magnet. A soft iron core in the form of a cylinder is placed in the space between the poles (C). In the permanent magnetic field is placed a rectangular coil of many turns (MC) wound on a former (AF). The former is made of aluminium or copper. To the moving coil is attached the spindle (S_p). Two helical springs (S_g) are connected to the spindle to give the necessary control torque. A pointer (p) attached to the spindle is made to move over a calibrated scale.

Working A magnetic field of sufficient density is produced by the permanent magnet. The moving coil carries the current or a current proportional to the voltage to be measured. Hence, an electromagnetic force is produced which tends to act on the moving coil and moves it away from the field. This movement makes the spindle move and so the pointer gives a proportionate deflection.

PMMC

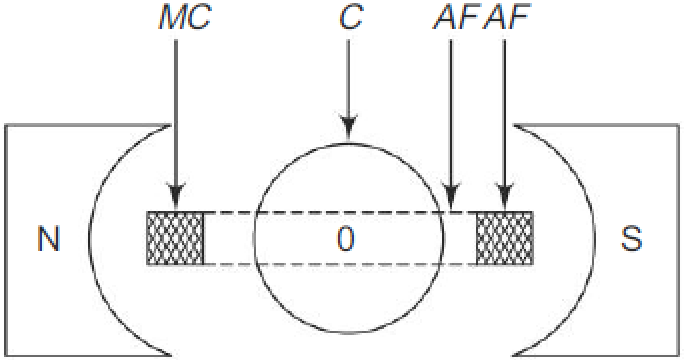


Fig. 7.9

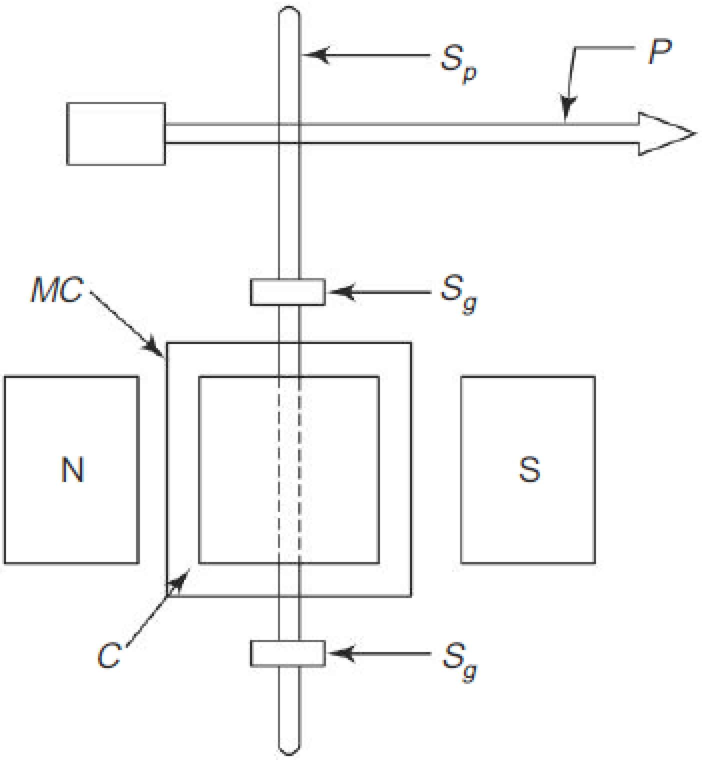


Fig. 7.10

Deflecting torque	...	It is directly proportional to the current or the voltage to be measured. So, the instrument can be used to measure direct current and dc voltage.
Control torque	...	Spring control
Damping torque	...	Eddy current damping. When the moving coil made of aluminium former is moved due to the force exerted on it, it cuts the magnetic flux lines produced by the permanent magnet. Hence, eddy currents are induced in the former.

As per Lenz's law, these eddy currents produce the required damping torque opposing the motion of the moving coil.

1 B DYNAMOMETER TYPE MOVING COIL INSTRUMENT

Principle Working principle of this type of instrument is same as that of permanent magnet moving coil type. But, the difference is that there is no permanent magnet in this instrument. Both the operating fields are produced by the current and/or the voltage to be measured.

Construction (Refer Fig. 7.11). The fixed coil (*FC*) is made in two sections. In the space between these two sections, a moving coil (*MC*) is placed. The moving coil is attached to the spindle to which is attached a pointer. The pointer is allowed to move over a calibrated scale. Two helical springs are attached to the spindle to give the required control torque. A piston attached to the spindle is arranged to move inside an air chamber.

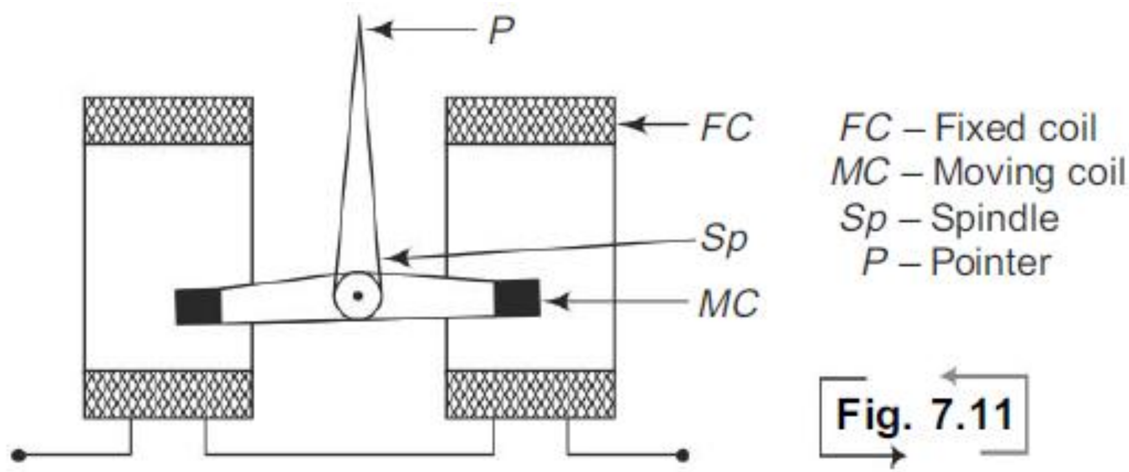


Fig. 7.11

Working The fixed coil and the moving coil carry currents. Thus, two magnetic field are produced. Hence, an electromagnetic force tends to act on the moving coil and makes it move. This makes the pointer give a proportionate deflection.

Deflecting Torque

(a) *As voltmeter* The two coils are electrically in series. They carry a current proportional to the voltage to be measured. The deflecting torque is proportional to $(\text{voltage})^2$. Hence, the instrument can be used for measuring dc and ac voltages.

(b) *As ammeter* The two coils are electrically in series. They carry the current to be measured. The deflecting torque is proportional to $(\text{current})^2$. Hence, the instrument can be used for measuring dc and ac.

(c) *As wattmeter* Fixed coils carry the system current. Moving coil carrys a current proportional to the system voltage. The design is such that the deflecting torque is proportional to $VI \cos \phi$, i.e power to be measured.

Control torque: Spring Control

Damping torque: Air damping

2 MOVING IRON INSTRUMENTS

2A ATTRACTION TYPE

Moving Iron Instruments are used mainly to measure voltage or current.

Principle It is well known that a soft iron piece gets magnetised when it is brought into a magnetic field produced by a permanent magnet. The same phenomenon happens when the soft iron piece is brought near either of the ends of a coil carrying current. The iron piece is attracted towards that portion where the magnetic flux density is more. This movement of the soft iron piece is used to measure the current or voltage which produces the magnetic field.

Construction (Refer Fig. 7.7). The instrument consists of a working coil. It carries the current to be measured or a current proportional to the voltage to be measured. A soft iron disc is attached to the spindle. To the spindle, a pointer is also attached. The pointer is made to move over a calibrated scale. The moving iron (soft iron disc) is pivoted such that it is attracted towards the centre of the coil where the magnetic field is maximum.

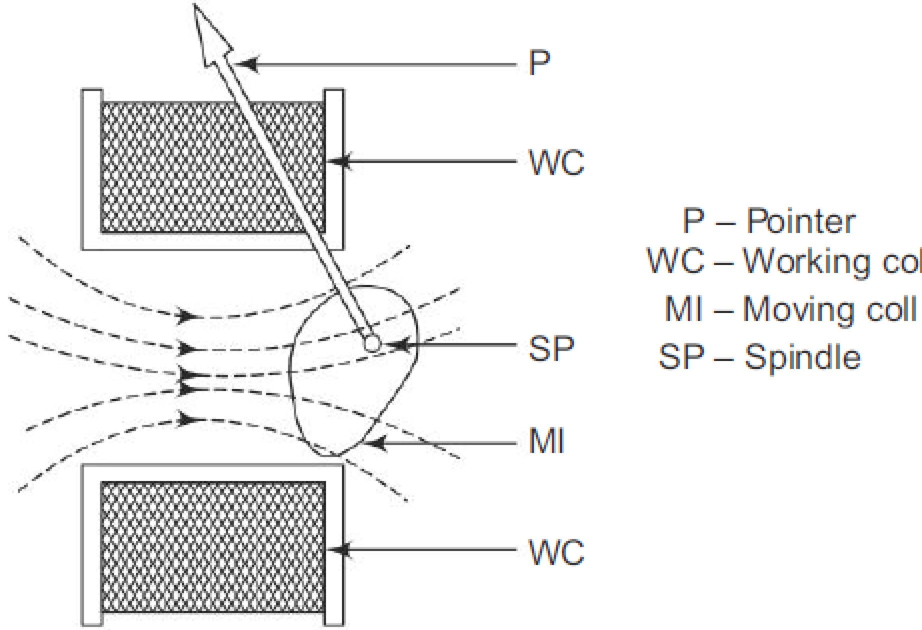


Fig. 7.7

Working The working coil carries a current which produces a magnetic field. The moving disc is attracted towards the centre of the coil where the flux density is maximum. The spindle is, therefore, moved. Thus, the pointer, attached to the spindle gives a proportional deflection.

Deflecting Torque Produced by the current or the voltage to be measured. It is proportional to the square of the current or voltage. Hence, the instrument can be used to measure d.c. or a.c scale is non-uniform.

Control torque: Spring or gravity

Damping: Air friction damping

2B REPULSION TYPE MOVING IRON INSTRUMENT

Principle Two iron pieces kept with close proximity in a magnetic field get magnetized to the same polarity. Hence, a repulsive force is produced. If one of the two pieces is made movable, the repulsive force will act on it and move it on to one side. This movement is used to measure the current or voltage which produces the magnetic field.

Construction (Refer Fig. 7.8). The instrument consists of a working coil which carries a current proportional to voltage or the current to be measured. There are two iron pieces-fixed and moving. The moving iron is connected to the spindle to which is attached a pointer. It is made to move over a calibrated scale.

Working When the operating coil carries current, a magnetic field is produced. This field magnetises similarly both the soft iron pieces. Thus, a repulsive force is produced which acts on the moving iron and pushes it away from its rest position. Thus, the spindle moves and hence the pointer gives a proportionate deflection. Whatever be the direction of current in the coil, the two irons are always similarly magnetised.

Deflecting Torque Produced by the current or the voltage to be measured it is proportional to the square of the current or voltage. Hence, the instrument can be used for dc and ac.

Control torque: Spring or Gravity

Damping: Pneumatic (i.e air damping)

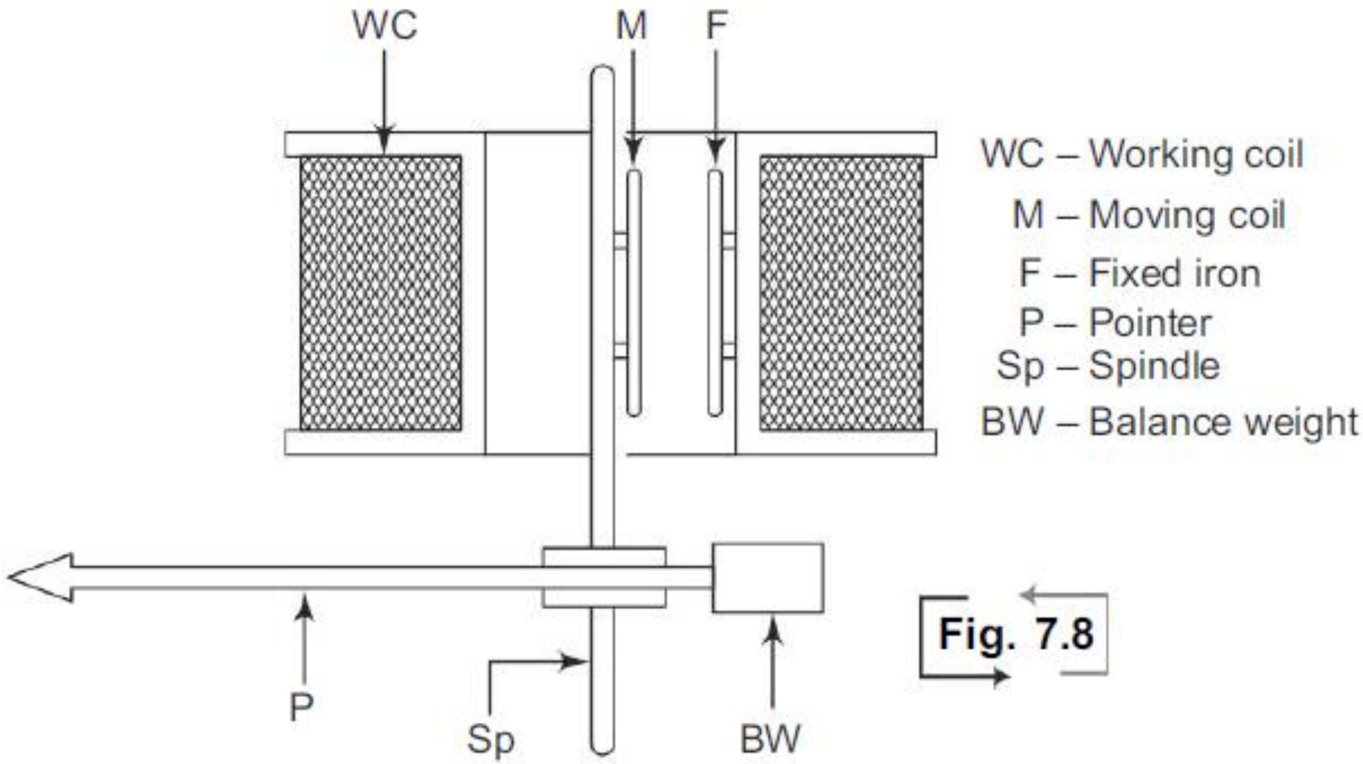


Fig. 7.8

NOTE:

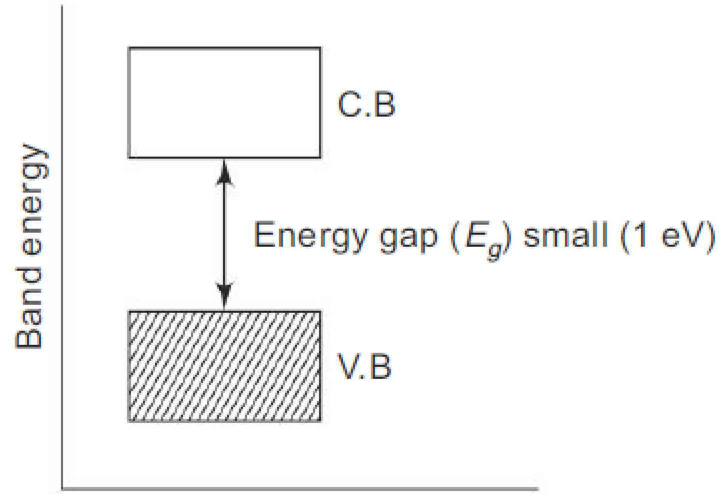
1. MC instruments are used for the measurement of DC Quantities only.
2. MI instruments are used for the measurement of both DC & AC Quantities.

OVERVIEW OF SEMICONDUCTORS

- Depending on their conductivity, materials can be classified into three types as conductors, semiconductors and insulators. Conductor is a good conductor of electricity. Insulator is a poor conductor of electricity. Semiconductor has its conductivity lying between these two extremes.

Energy Band of Semiconductor

In terms of energy band shown in Fig., the valence band is almost filled (partially filled) and conduction band is almost empty.



A comparatively smaller electric field (smaller than required for insulator) is required to push the electrons from the valence band to conduction band. At low temperatures, the valence band is completely filled and the conduction band is completely empty. Therefore a semiconductor virtually behaves as an insulator at low temperature. However even at room temperature some electrons crossover to the conduction band giving conductivity to the semiconductor. As temperature increases, the number of electrons crossing over to the conduction band increases and hence electrical conductivity increases. Hence a semiconductor has negative temperature coefficient of resistance.

Classifications of Semiconductors

Intrinsic Semiconductor: A pure semiconductor is called intrinsic semiconductor.

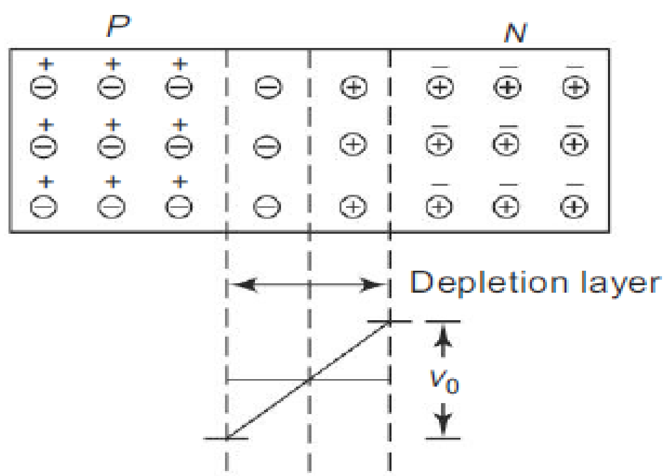
Extrinsic Semiconductor: Due to the poor conduction at room temperature, the intrinsic semiconductor, as such, is not useful in the electronic devices. Hence the current conduction capability of the intrinsic semiconductor should be increased. This can be achieved by adding a small amount of impurity to the intrinsic semiconductor, so that it becomes impurity semiconductor or extrinsic semiconductor. This process of adding impurity is known as **doping**.

N-type Semiconductor: A small amount of **pentavalent** impurities such as arsenic, antimony or phosphorus is added to the pure semiconductor (germanium or silicon crystal) to get N-type semiconductor. Thus, the addition of pentavalent impurity (antimony) increases the number of electrons in the conduction band thereby increasing the conductivity of N-type semiconductor. As a result of doping, the number of free electrons far exceeds the number of holes in an N-type semiconductor. So electrons are called majority carriers and holes are called minority carriers

P-type Semiconductor: A small amount of trivalent impurities such as aluminium or boron is added to the pure semiconductor to get the P-type semiconductor. The number of holes is very much greater than the number of free electrons in a P-type material, holes are termed as majority carriers and electrons as minority carriers.

THEORY OF PN JUNCTION DIODE

In a piece of semiconductor material, if one half is doped by P-type impurity and the other half is doped by N-type impurity, a PN junction is formed. The plane dividing the two halves or zones is called PN junction. As shown in Fig., the N-type material has high concentration of free electrons while P-type material has high concentration of holes. Therefore at the junction there is a tendency for the free electrons to diffuse over to the P-side and holes to the N-side. This process is called diffusion.



Formation of PN Junction

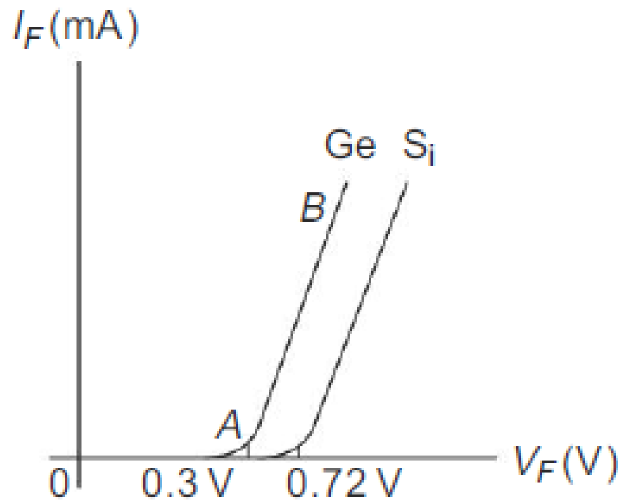
As the free electrons move across the junction from N-type to P-type, the donor ions become positively charged. Hence a positive charge is built. on the N-side of the junction. The free electrons that cross the junction uncover the negative acceptor ions by filling in the holes. Therefore a net negative charge is established on the P-side of the junction. This net negative charge on the P-side prevents further diffusion of electrons into the P-side. Similarly, the net positive charge on the N-side repels the holes crossing from P-side to N-side. Thus a barrier is set up near the junction which prevents further movement of charge carriers, i.e. electrons and holes. This is called potential barrier or junction barrier V_0. V_0 is 0.3 V for germanium and 0.72 V for silicon. The electrostatic field across the junction caused by the positively charged N-type region tends to drive the holes away from the junction and negatively charged P-type region tends to drive the electrons away from the junction. Thus the junction region is depleted to mobile charge carriers. Hence it is called **depletion layer.**

Under Forward Bias Condition

When positive terminal of the battery is connected to the P-type and negative terminal to the N-type of the PN junction diode, the bias applied is known as forward bias. Under the forward bias condition, the applied positive potential repels the holes in P-type region so that the holes move towards the junction and the applied negative potential repels the electrons in the N-type region and the electrons move towards the junction. Eventually when the applied potential is more than the internal barrier potential, the depletion region and internal potential barrier disappear.

V–I Characteristics of a Diode under Forward Bias

For $V_F > V_0$, the potential barrier at the junction completely disappears and hence, the holes cross the junction from P-type to N-type and the electrons cross the junction in the opposite direction, resulting in relatively large current flow in the external circuit.

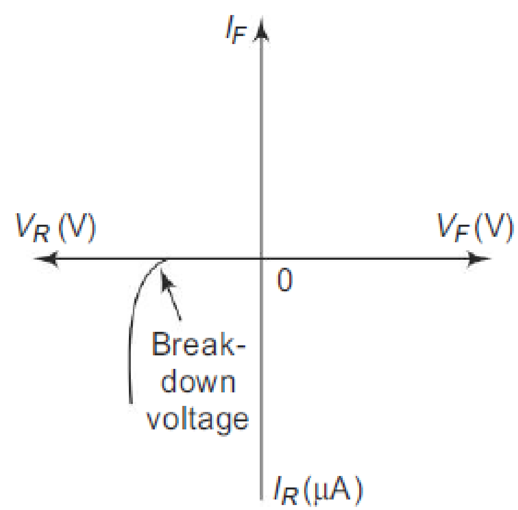


Under Reverse Bias Condition

When the negative terminal of the battery is connected to the P-type and positive terminal of the battery is connected to the N-type of the PN junction, the bias applied is known as reverse bias. Under applied reverse bias, holes which form the majority carriers of the P-side move towards the negative terminal of the battery and electrons which form the majority carrier of the N-side are attracted towards the positive terminal of the battery. Hence the width of the depletion region which is depleted of mobile charge carriers increases. Thus the electric field produced by applied reverse bias, is in the same direction as the electric field of the potential barrier. Hence, the resultant potential barrier is increased, which prevents the flow of majority carriers in both directions. Therefore, theoretically no current should flow in the external circuit. But in practice, a very small current of the order of a few microamperes flows under reverse bias.

V–I Characteristics of a Diode under Reverse Bias

For large applied reverse bias, the free electrons from the N-type moving towards the positive terminal of the battery acquire sufficient energy to move with high velocity to dislodge valence electrons from semiconductor atoms in the crystal. These newly liberated electrons, in turn, acquire sufficient energy to dislodge other parent electrons. Thus, a large number of free electrons are formed which is commonly called as an avalanche of free electrons. This leads to the breakdown of the junction leading to very large reverse current. The reverse voltage at which the junction breakdown occurs is known as **breakdown voltage**.



PN DIODE APPLICATIONS

An ideal PN junction diode is a two terminal polarity sensitive device that has zero resistance (diode conducts) when it is forward biased and infinite resistance (diode does not conduct) when reverse biased. Due to this characteristic the diode finds a number of applications as follows.

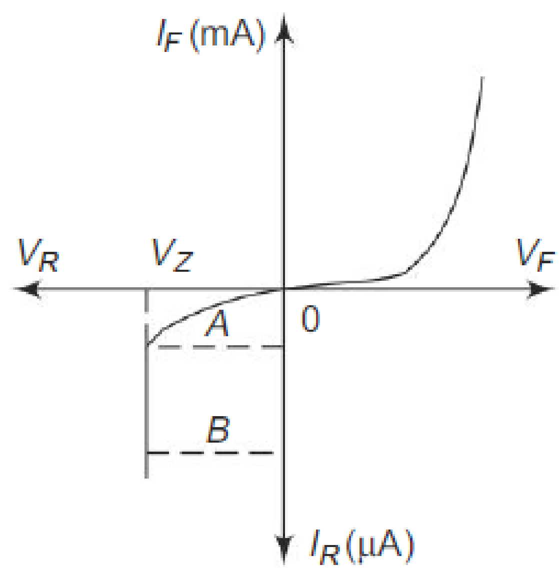
(i) rectifiers in dc power supplies
(ii) switch in digital logic circuits used in computers
(iii) clamping network used as dc restorer in TV receivers and voltage multipliers
(iv) clipping circuits used as wave shaping circuits used in computers, radars, radio and TV receivers
(v) demodulation (detector) circuits.

The same PN junction with different doping concentration finds special applications as follows:

(i) detectors (APD, PIN photo diode) in optical communication circuits
(ii) Zener diodes in voltage regulators
(iii) varactor diodes in tuning sections of radio and TV receivers
(iv) light emitting diodes in digital displays
(v) LASER diodes in optical communications
(vi) Tunnel diodes as a relaxation oscillator at microwave frequencies.

ZENER DIODE

Zener diode is heavily doped than the ordinary diode. From the V–I characteristics of the Zener diode, shown in Fig., it is found that the operation of Zener diode is same as that of ordinary PN diode under forward biased condition. Whereas under reverse-baised condition, breakdown of the junction occurs. The breakdown voltage depends upon the amount of doping.



If the diode is heavily doped, depletion layer will be thin and, consequently, breakdown occurs at lower reverse voltage and further, the breakdown voltage is sharp. Whereas a lightly doped diode has a higher breakdown voltage. Thus breakdown voltage can be selected with the amount of doping. The sharp increasing current under breakdown conditions are due to the following two mechanisms.

(1) Avalanche breakdown

(2) Zener breakdown.

Avalanche Breakdown

As the applied reverse bias increases, the field across the junction increases correspondingly. Thermally generated carriers while traversing the junction acquire a large amount of kinetic energy from this field. As a result the velocity of these carriers increases. These electrons disrupt 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. This process is cumulative in nature and results in generation of avalanche 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.

Zener Breakdown

When the P and N 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 increase the reverse current in a reverse biased PN diode. The increase in current takes place at a constant value of reverse bias typically below 6 V for heavily doped diodes. As a result of heavy doping of P and N regions, the depletion region width becomes very small and for an applied voltage of 6 V or less, the field across the depletion region becomes very high, of the order of 107 V/m, making conditions suitable for Zener breakdown. For lightly doped diodes, Zener breakdown voltage becomes high and breakdown is then predominantly by Avalanche multiplication. Though Zener breakdown occurs for lower breakdown voltage and Avalanche breakdown occurs for higher breakdown voltage, such diodes are normally called Zener diodes.

Applications of Zener diode: Used as Voltage Regulator or Stabilizer.

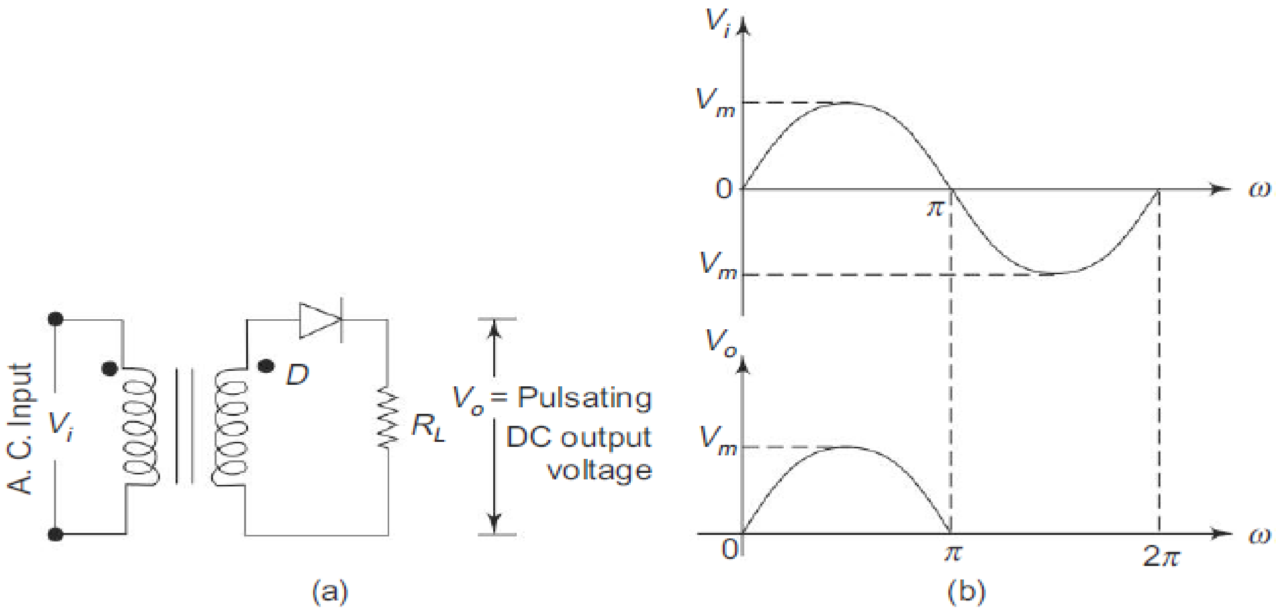
APPLICATIONS OF PN JUNCTION DIODE

RECTIFIERS, CLIPPERS, CLAMPERS ect..

RECTIFIERS-Rectifier is defined as an electronic device used for converting ac voltage into dc voltage

Half-wave Rectifier

It converts an ac voltage into a pulsating dc voltage using only one half of the applied ac voltage. The rectifying diode conducts during one half of the ac cycle only. Figure shows the basic circuit and waveforms of a half wave rectifier.



(a) Basic circuit of a Half-wave Rectifier and (b) Input and Output Waveforms of Half-wave Rectifier

Let V_i be the voltage to the primary of the transformer and given by the equation

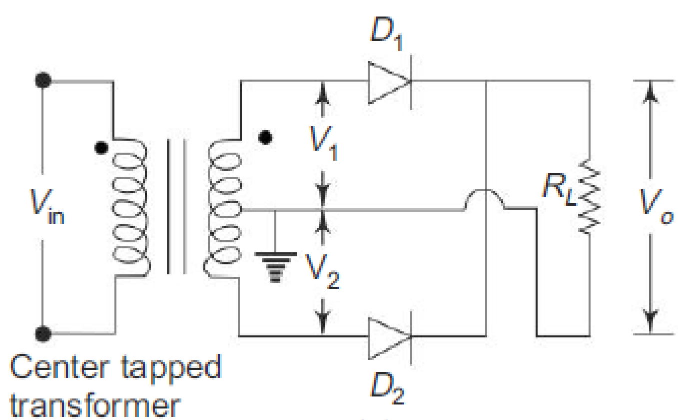
$$V_i = V_m \sin \omega t; \; V_m >> V_r$$

where V_r is the cut-in voltage of the diode. During the positive half-cycle of the input signal, the anode of the diode becomes more positive with respect to the cathode and hence, diode D conducts. For an ideal diode, the forward voltage drop is zero. So the whole input voltage will appear across the load resistance, R_L.

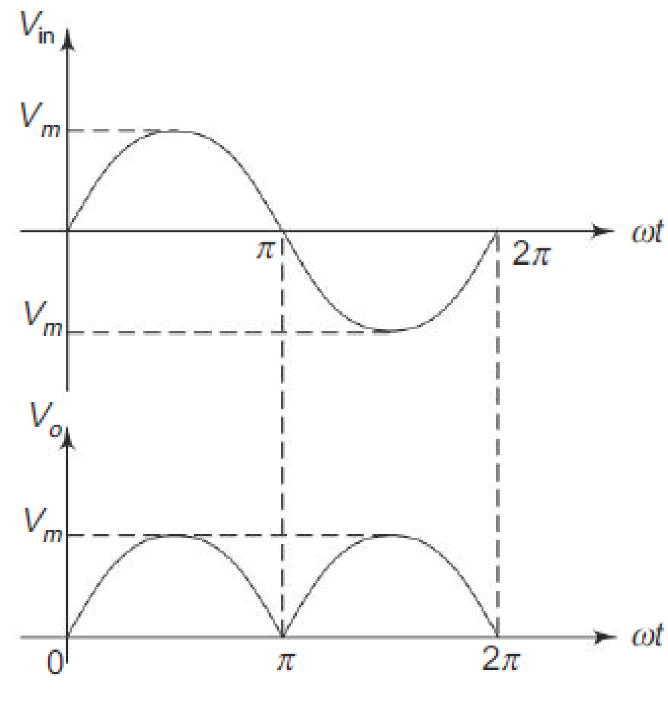
During negative half-cycle of the input signal, the anode of the diode becomes negative with respect to the cathode and hence, diode D does not conduct. For an ideal diode, the impedance offered by the diode is infinity. So the whole input voltage appears across diode D. Hence, the voltage drop across R_L is zero.

Full-wave Rectifier -Center Tapped

It converts an ac voltage into a pulsating dc voltage using both half cycles of the applied ac voltage. It uses two diodes of which one conducts during one half-cycle while the other diode conducts during the other half-cycle of the applied ac voltage. Figure shows the basic circuit and waveforms of full-wave rectifier.



(a)



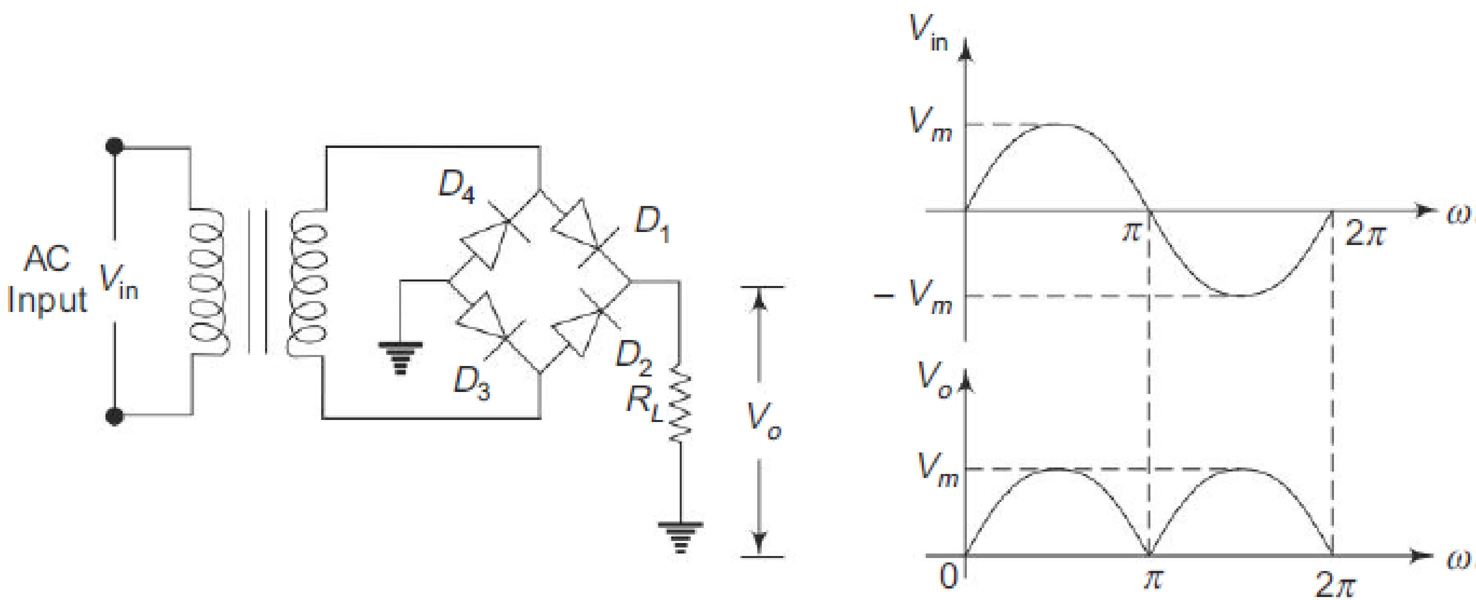
(b)

During positive half of the input signal, anode of diode D_1 becomes positive and at the same time the anode of diode D_2 becomes negative. Hence D_1 conducts and D_2 does not conduct. The load current flows through D_1 and the voltage drop across R_L will be equal to the input voltage.

During the negative half-cycle of the input, the anode of D_1 becomes negative and the anode of D_2 becomes positive. Hence, D_1 does not conduct and D_2 conducts. The load current flows through D_2 and the voltage drop across R_L will be equal to the input voltage.

Full-wave Rectifier - Bridge Rectifier

The need for a center tapped transformer in a full-wave rectifier is eliminated in the bridge rectifier. As shown in Fig. the bridge rectifier has four diodes connected to form a bridge. The ac input voltage is applied to diagonally opposite ends of the bridge. The load resistance is connected between the other two ends of the bridge.



(a) (b)

For the positive half-cycle of the input ac voltage, diodes D_1 and D_3 conduct, whereas diodes D_2 and D_4 do not conduct. The conducting diodes will be in series through the load resistance R_L. So the load current flows through R_L.

During the negative half-cycle of the input ac voltage, diodes D_2 and D_4 conduct, whereas diodes D_1 and D_3 do not conduct. The conducting diode D_2 and D_4 will be in series through the load R_L and the current flows through R_L in the same direction as in the previous half-cycle. Thus a bidirectional wave is converted into a unidirectional one.

The average values of output voltage and load current for bridge rectifier are the same as for a center-tapped full wave rectifier. Hence

Advantages of the bridge rectifier

The bulky center tapped transformer is not required.
Transformer utilisation factor is considerably high.

FILTERS

The output of a rectifier contains dc component as well as ac component. Filters are used to minimise the undesirable ac, i.e. ripple leaving only the dc component to appear at the output.

Some important filters are:

(i) Inductor filter

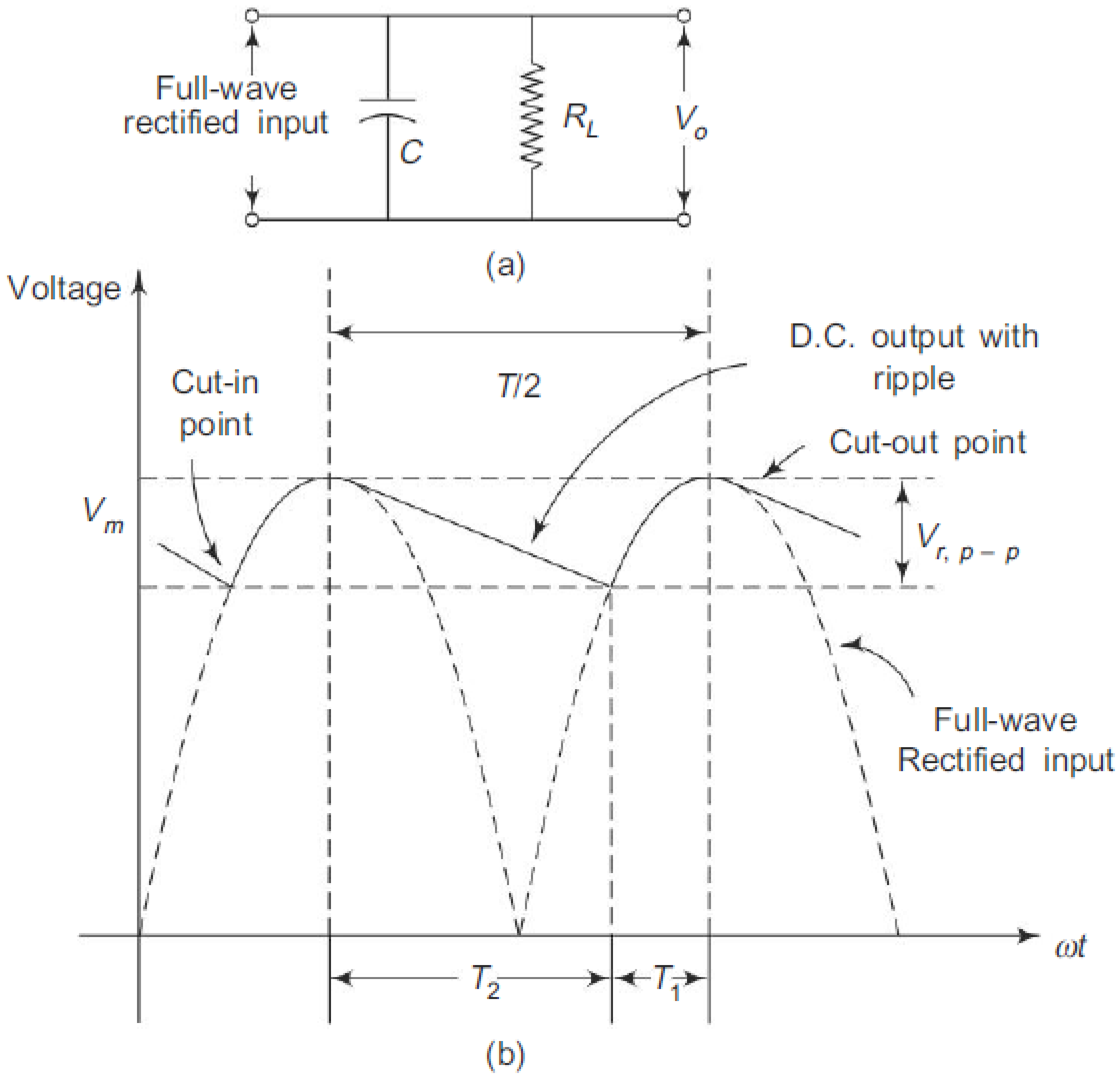
(ii) Capacitor filter

(iii) LC or L-section filter, and

(iv) CLC or π-type filter

Capacitor Filter

An inexpensive filter for light loads is found in the capacitor filter which is connected directly across the load, as shown in Fig. (a). The property of a capacitor is that it allows ac component and blocks the dc component. The operation of a capacitor filter is to short the ripple to ground but leave the dc to appear at the output when it is connected across a pulsating dc voltage.



(a) Capacitor Filter, (b) Ripple Voltage Triangular Waveform

During the positive half-cycle, the capacitor charges up to the peak value of the transformer secondary voltage, V_m, and will try to maintain this value as the full-wave input drops to zero. The capacitor will discharge through R_L slowly until the transformer secondary voltage again increases to a value greater than the capacitor voltage. The diode conducts for a period which depends on the capacitor voltage (equal to the load voltage). The diode will conduct when the transformer secondary voltage becomes more than the 'cut-in' voltage of the diode. The diode stops conducting when the transformer voltage becomes less than the diode voltage. This is called cut-out voltage.

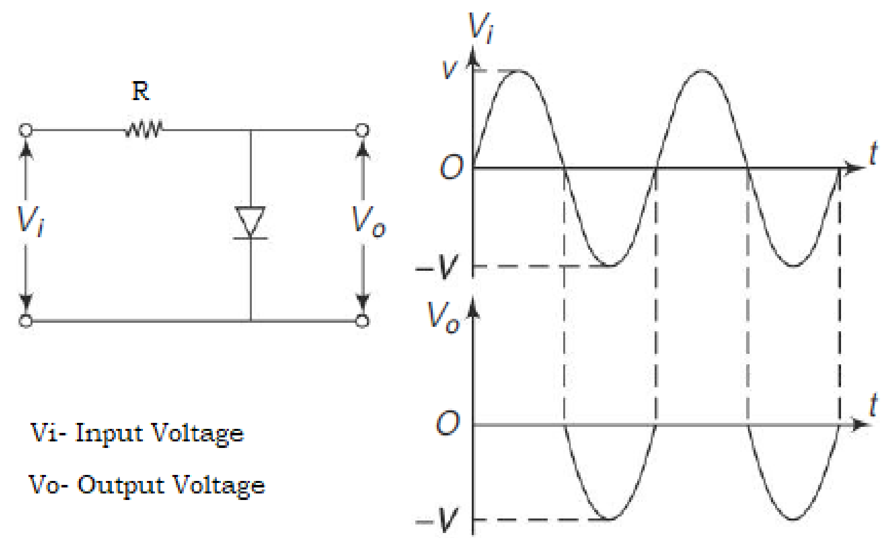
Referring to Fig. (b) with slight approximation, the ripple voltage waveform can be assumed as triangular. From the cut-in point to the cut-out point, whatever charge the capacitor acquires is equal to the charge the capacitor has lost during the period of non-conduction, i.e. from cut-out point to the next cut-in point.

The ripple may be decreased by increasing C or R_L (or both) with a resulting increase in dc output voltage.

CLIPPERS

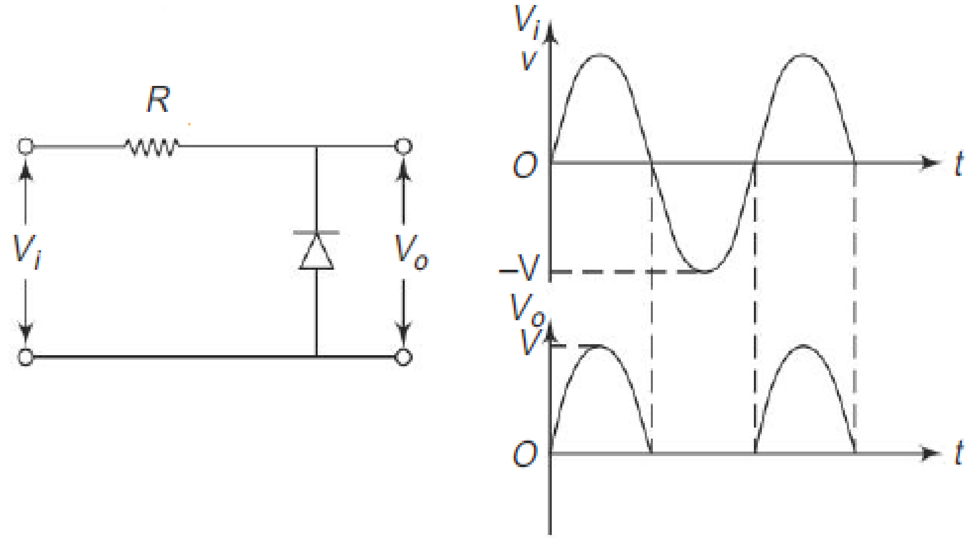
The circuit with which the waveform is shaped by removing (or clipping) a portion of the input signal without distorting the remaining part of the alternating waveform is called a clipper. These circuits find extensive use in radars, digital computers, radio and television receivers etc.

1.Positive clipper



When the input voltage is positive, diode conducts and acts as short-circuit and hence there is zero signal at the output, i.e. the positive half cycle is **clipped off**. When the input signal is negative, the diode does not conduct and acts as an open switch, the negative half cycle appears at the output as shown in Fig.

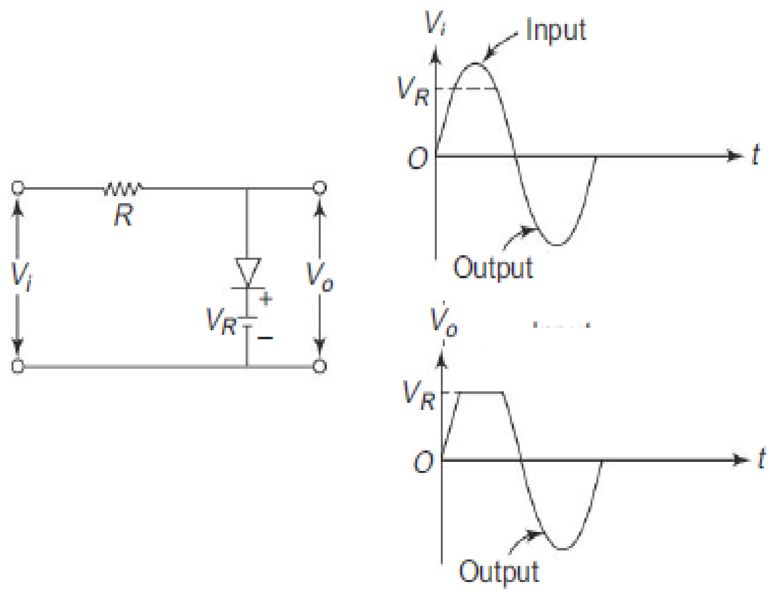
2.Negative clipper



When the input signal is positive, the diode does not conduct and acts as an open switch, the positive half cycle appears at the output as shown in Fig.. When the input voltage is negative, diode conducts and acts as short-circuit and hence there is zero signal at the output, i.e. the negative half cycle is **clipped off**.

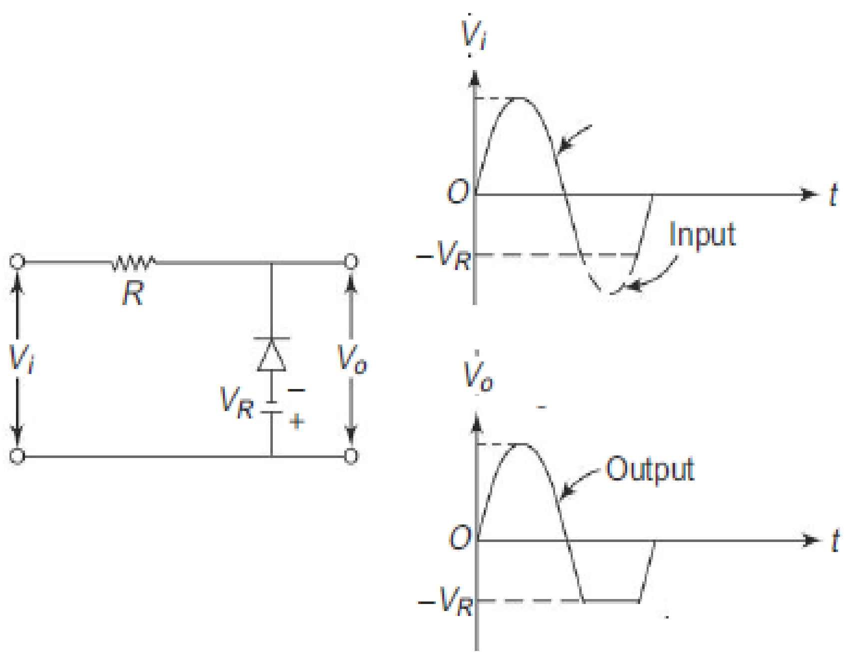
3.Biased Positive clipper

In the biased positive clipper as shown in Fig., the diode conducts as long as the input voltage is greater than $+V_R$ and the output remains at $+V_R$ until the input voltage becomes less than $+V_R$. When the input voltage is less than $+V_R$, the diode does not conduct and acts as an open switch. Hence all the input signal having less than $+ V_R$ as well as negative half cycle of the input wave will appear at the output, shown in Fig



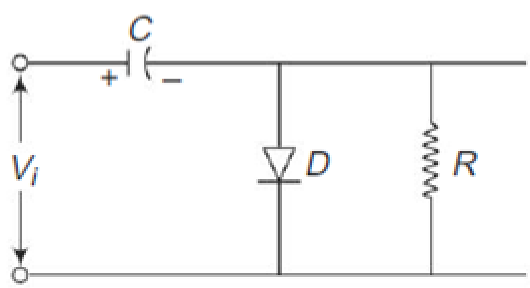
4.Biased Negative clipper

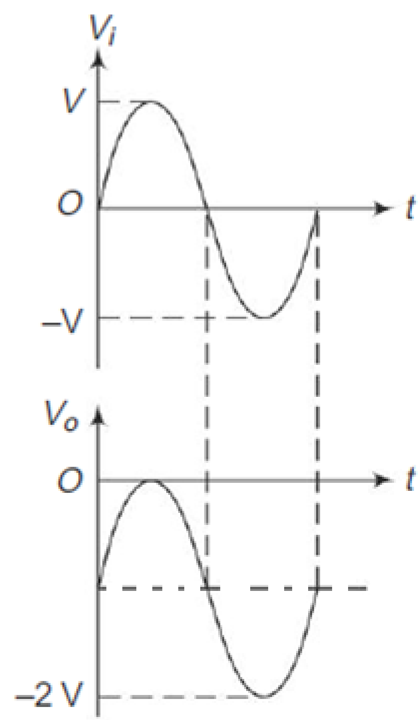
In the biased negative clipper shown in Fig. , when the input voltage $V_i \leq V_R$ the diode conducts and clipping takes place. The clipping level can be shifted up and down by varying the bias voltage $(-V_R)$.



CLAMPERS

Clamping network shifts (clamps) a signal to a different dc level, i.e. it introduces a dc level to an ac signal. Hence, the clamping network is also known as dc restorer. These circuits find application in television receivers to restore the dc reference signal to the video signal.





Negative Clamper circuit

Consider the clamper circuit shown in Fig. A sine wave with maximum amplitude of V is given as the input to the network. During the positive half cycle, the diode conducts, i.e. it acts like a short circuit. The capacitor charges to V volts. During this interval, the output which is taken across the short circuit will be Vo = 0 V. During the negative half cycle, the diode is open. The output voltage can be found out by applying Kirchhoff's law.

$$-V - V - V_0 = 0$$

$$\text{Therefore, } V_0 = -2\text{ V}$$

The analysis of the clamper circuit can be done as follows.

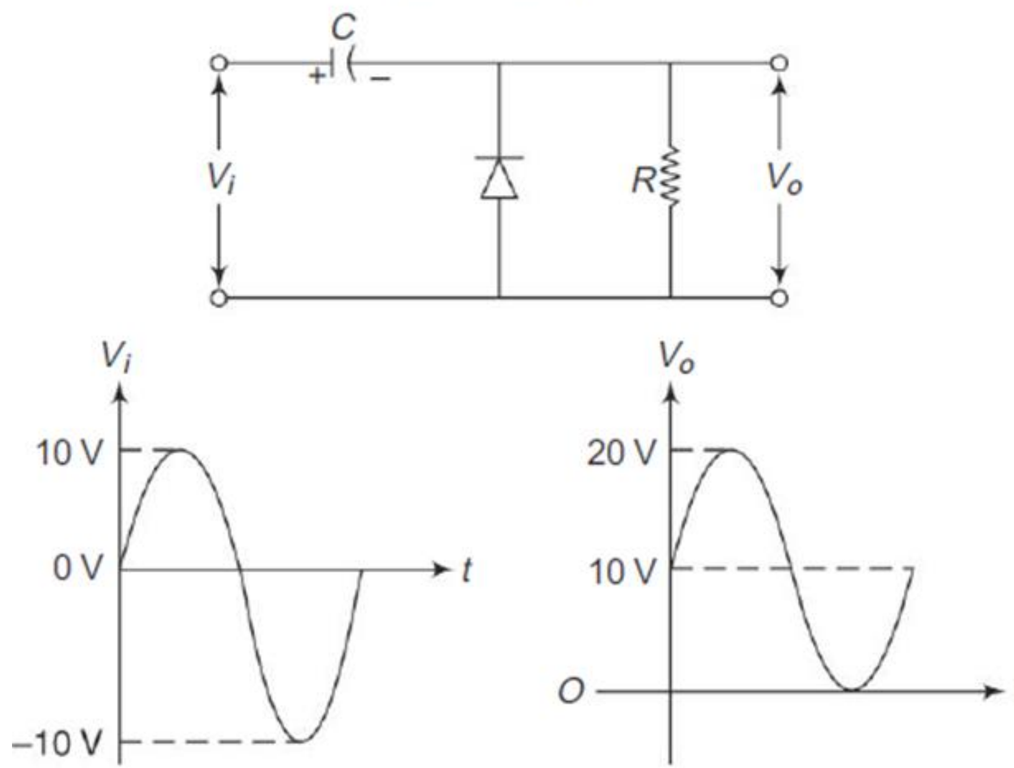
Determine the portion of the input signal that forward biases the diode. When the diode is in short circuit condition, the capacitor charges up to a level determined by the voltage across the capacitor in its equivalent open circuit state. During the open circuit condition of the diode, it is assumed that the capacitor will hold on to all its charge and therefore voltage. In the clamper networks, the total swing of the output is equal to the total swing of the input signal. **This is negative clamper**.

Positive clamper: Consider the clamper circuit shown in Fig. A sine wave with maximum amplitude of 10 V is given as the input to the network. During the negative half cycle, the diode conducts, i.e. it acts like a short circuit. The capacitor charges to10 V volts. During this interval, the output which is taken across the short circuit will be Vo = 0 V. During the positive half cycle, the diode is open. The output voltage can be found out by applying Kirchhoff's law.

$10V + 10\ V - V_0 = 0$

Therefore, $V_0 = 20\ V$

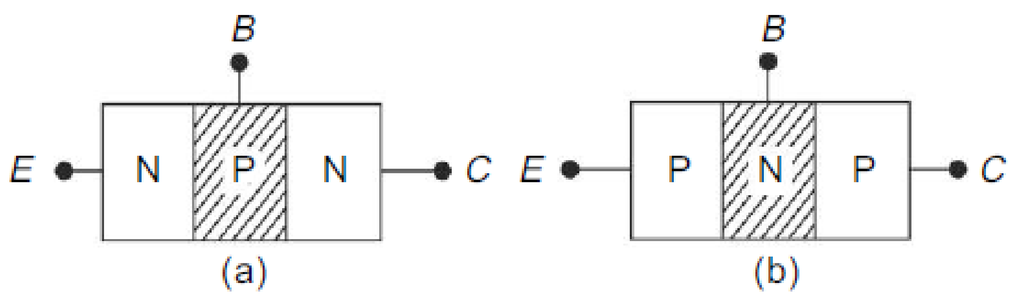
Positive Clamper



BIPOLAR JUNCTION TRANSISTOR [BJT]

A Bipolar Junction Transistor (BJT) is a three terminal semiconductor device in which the operation depends on the interaction of both majority and minority carriers and hence the name Bipolar. It is used in amplifier and oscillator circuits, and as a switch in digital circuits. It has wide applications in computers, satellites and other modern communication systems.

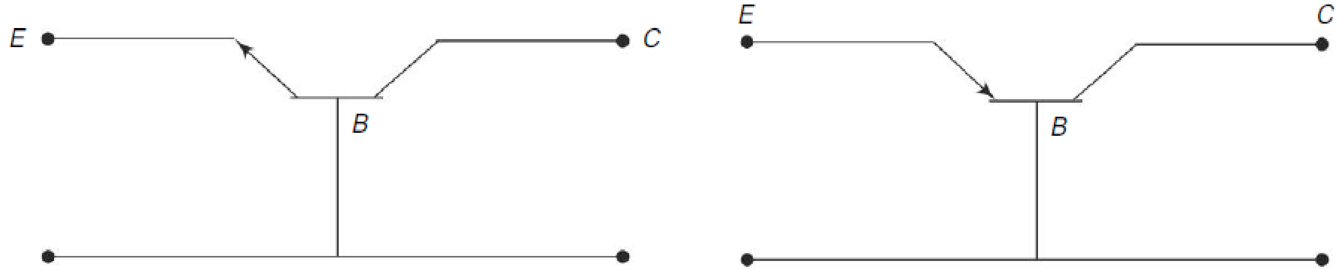
The BJT consists of a silicon (or germanium) crystal in which a thin layer of N-type Silicon is sandwiched between two layers of P-type silicon. This transistor is referred to as PNP. Alternatively, in a NPN transistor, a layer of P-type material is sandwiched between two layers of N-type material. The two types of the BJT are represented in Fig.



Transistor (a) NPN and (b) PNP

E- Emitter
B-Base
C-Collector

Circuit symbol

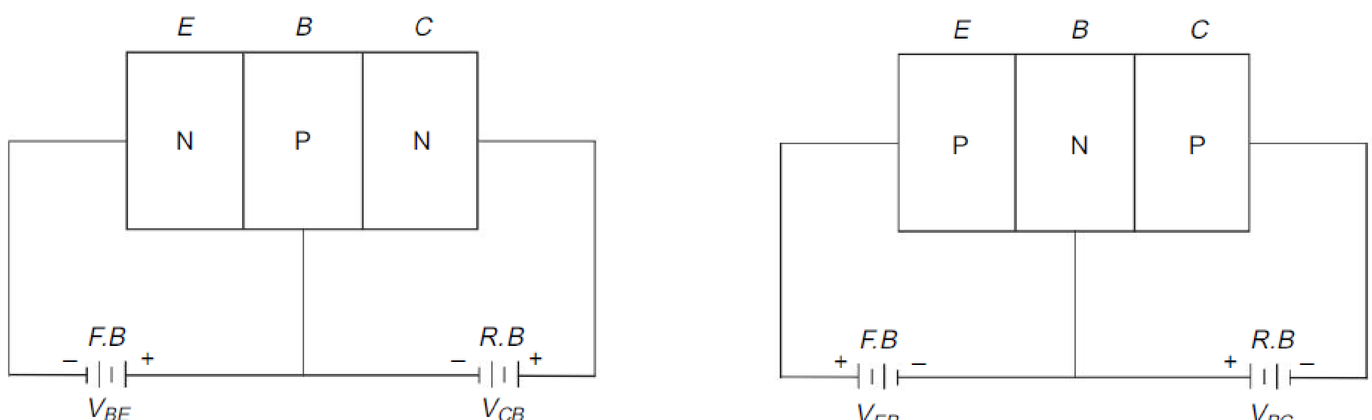


NPN transistor

PNP transistor

TRANSISTOR BIASING

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



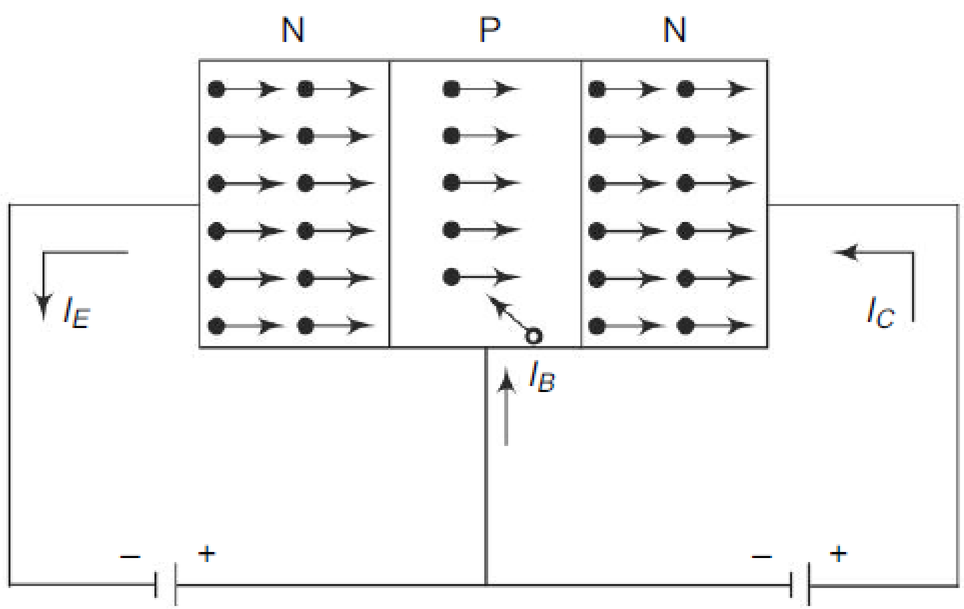
NPN transistor

PNP transistor

OPERATION OF NPN TRANSISTOR

As shown in Fig. 13.4, the forward bias applied to the emitter base junction of an NPN transistor causes a lot of electrons from the emitter region to crossover to the base region. As the base is lightly doped with P-type impurity, the number of holes in the base region is very small and hence the number of electrons that combine with holes in the P-type base region is also very small. Hence a few electrons combine with holes to constitute a base current I_B. The remaining electrons (more than 95%) crossover into the collector region to constitute a collector current I_C. Thus the base and collector current summed up gives the emitter current, i.e. $I_E = -(I_C + I_B)$.

In the external circuit of the NPN bipolar junction transistor, the magnitudes of the emitter current I_E, the base current I_B and the collector current I_C are related by $I_E = I_C + I_B$.



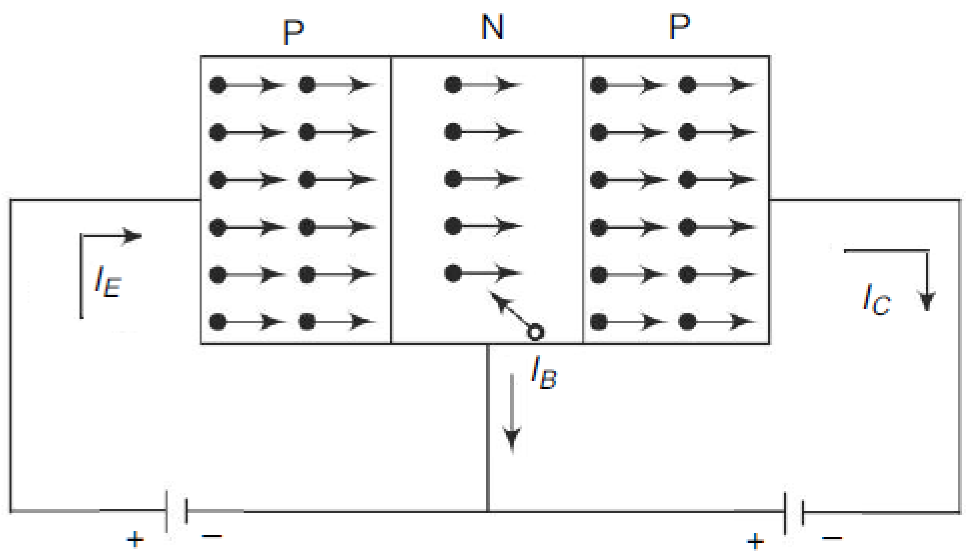
OPERATION OF PNP TRANSISTOR

As shown in Fig. 13.5, the forward bias applied to the emitter-base junction of a PNP transistor causes a lot of holes from the emitter region to crossover to the base region as the base is lightly doped with N-types impurity. The number of electrons in the base region is very small and hence the number of holes combined with electrons in the N-type base region is also very small. Hence a few holes combined with electrons to constitute a base current I_B. The remaining holes (more than 95%) crossover into the collector region to constitute a collector current I_C. Thus the collector and base current when summed up gives the emitter current, i.e. $I_E = -(I_C + I_B)$.

In the external circuit of the PNP bipolar junction transistor, the magnitudes of the emitter current I_E, the base current I_B and the collector current I_C are related by

$$I_E = I_C + I_B$$

This equation gives the fundamental relationship between the currents in a bipolar transistor circuit.

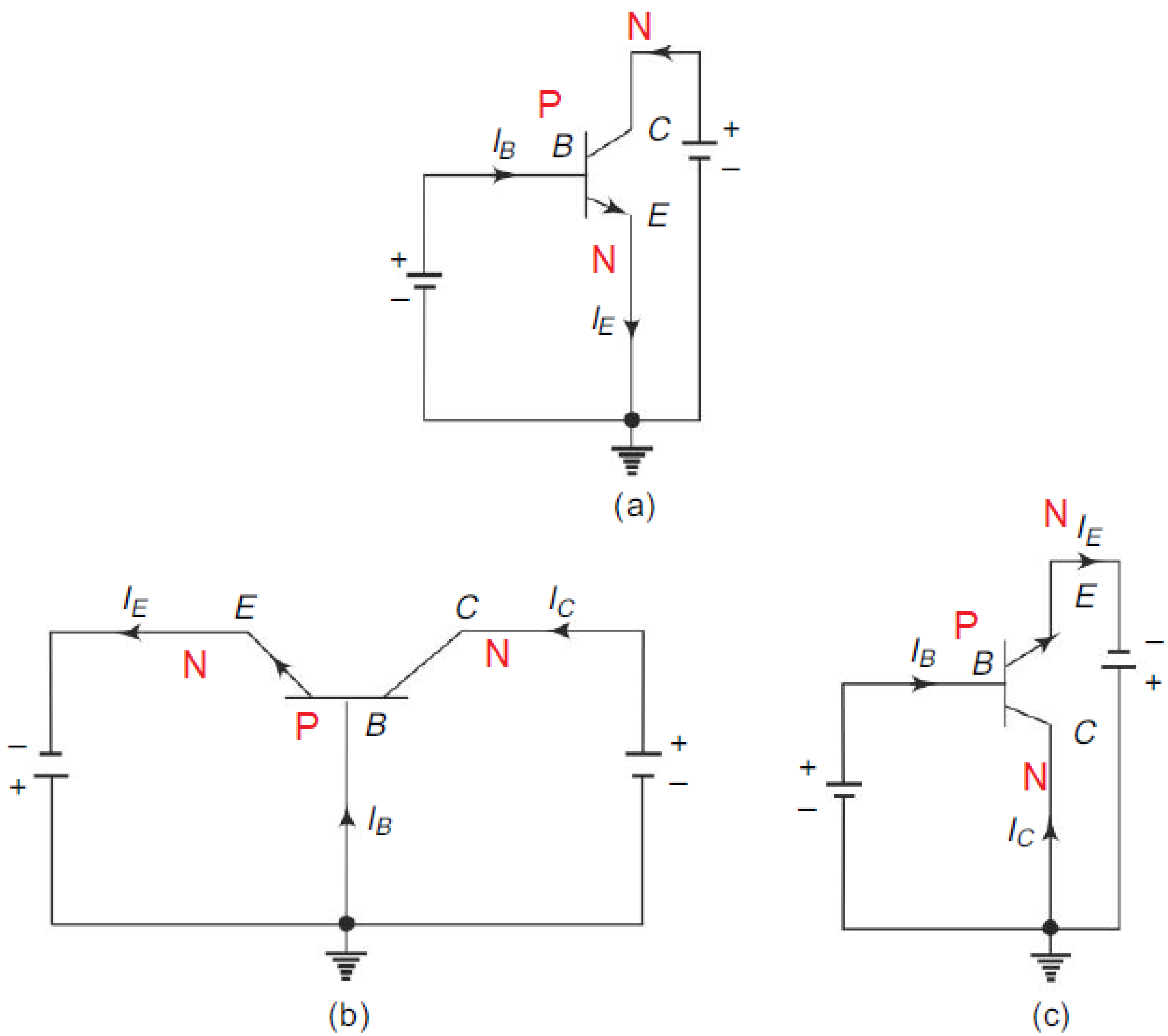


TYPES OF TRANSISTOR AMPLIFIER CONFIGURATION

(i) CE configuration This is also called grounded base configuration. In this configuration, emitter is the input terminal, collector is the output terminal and base is the common terminal.

(ii) CB configuration This is also called grounded emitter configuration. In this configuration, base is the input terminal, collector is the output terminal and emitter is the common terminal.

(iii) CC configuration This is also called grounded collector configuration. In this configuration, base is the input terminal, emitter is the output terminal and collector is the common terminal.



NPN Transistor configuration: (a) common base (b) common emitter and (c) common collector

CB Configuration

The circuit diagram for determining the static characteristics curves of an NPN transistor in the common base configuration is shown in Fig. 13.7.

Input characteristics To determine the input characteristics, the collector-base voltage V_{CB} is kept constant at zero volt and the emitter current I_E is increased from zero in suitable equal steps by increasing V_{EB}. This is repeated for higher fixed values of V_{CB}. A curve is drawn between emitter current I_E and emitter-base voltage V_{EB} at constant collector-base voltage V_{CB}. The input characteristics thus obtained are shown in Fig. 13.8.

When V_{CB} is equal to zero and the emitter-base junction is forward biased as shown in the characteristics, the junction behaves as a forward biased diode so that emitter current I_E increases rapidly with small increase in emitter-base voltage V_{EB}. When V_{CB} is increased keeping V_{EB} constant, the width of the base region will decrease. This effect results in an increase of I_E. Therefore, the curves shift towards the left as V_{CB} is increased.

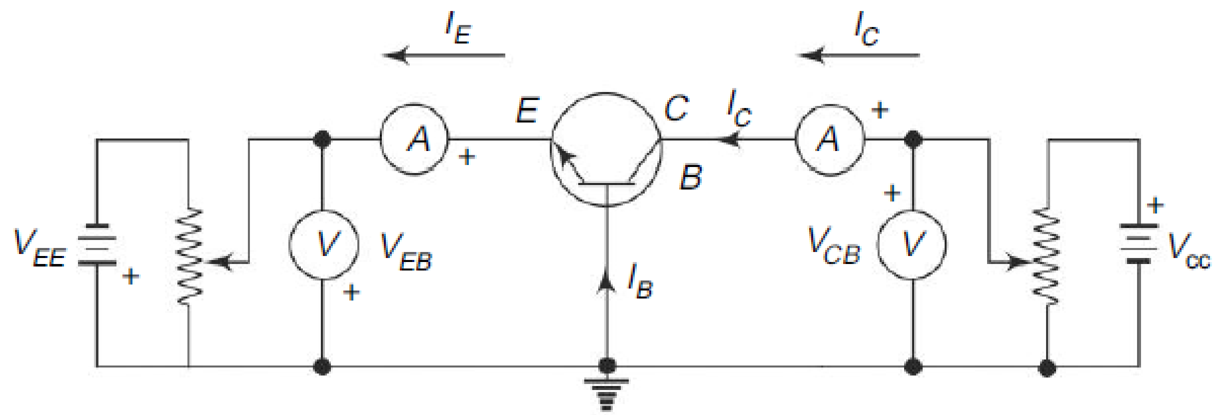


Fig. 13.7 Circuit to determine CB static characteristics

Output characteristics To determine the output characteristics, the emitter current I_E is kept constant at a suitable value by adjusting the emitter-base voltage V_{EB}. Then V_{CB} is increased in suitable equal steps and the collector current I_C is noted for each value of I_E. This is repeated for different fixed values of I_E. Now the curves of I_C versus V_{CB} are plotted for constant values of I_E and the output characteristics thus obtained is shown in Fig. 13.9.

From the characteristics, it is seen that for a constant value of I_E, I_C is independent of V_{CB} and the curves are parallel to the axis of V_{CB}. Further, I_C flows even when V_{CB} is equal to 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 the action of the 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.

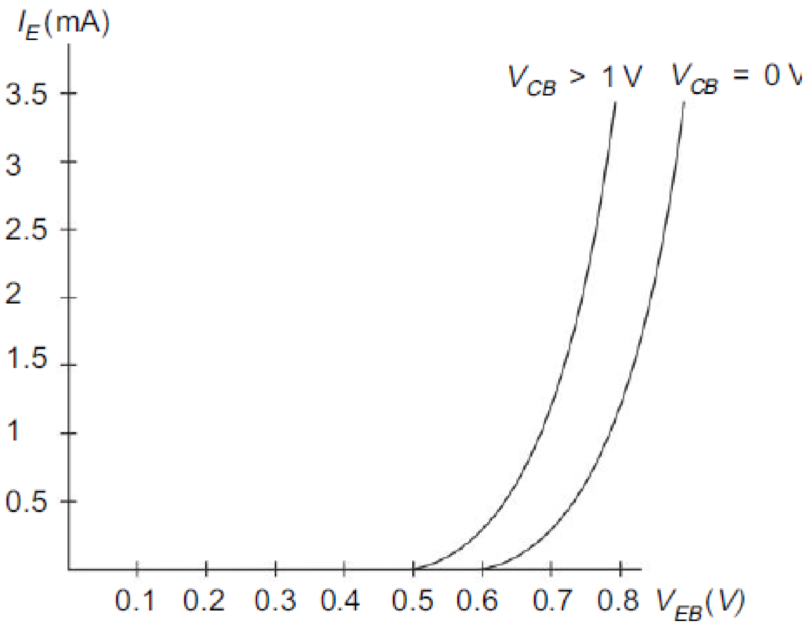


Fig. 13.8 CB Input characteristics

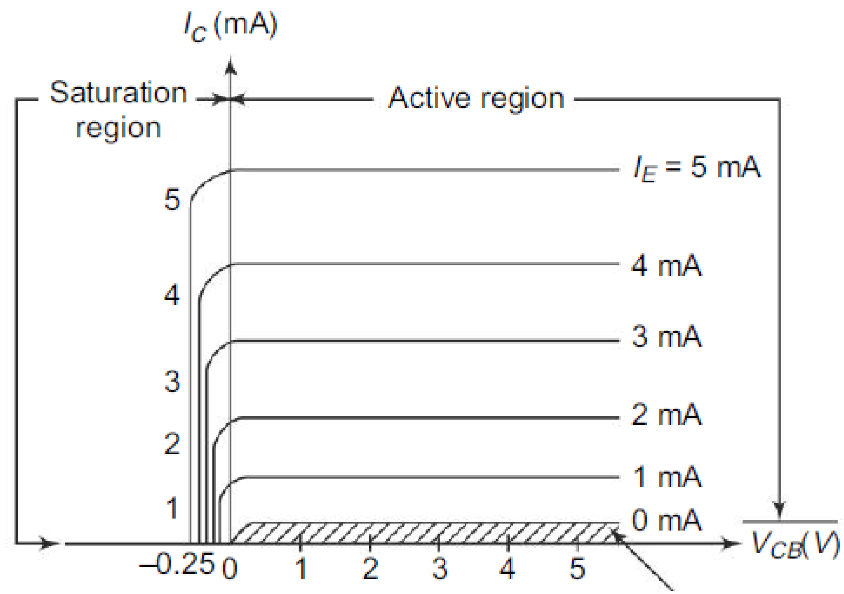


Fig. 13.9 CB Output Characteristics

CE Configuration

Input characteristics 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 V_{BE} in the circuit shown in Fig. 13.10.

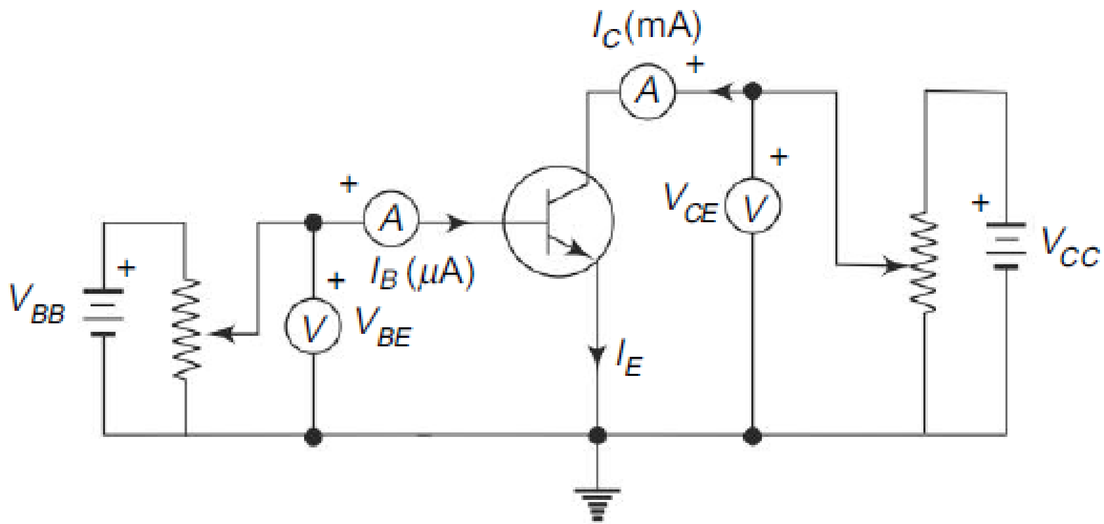


Fig. 13.10 Circuit to determine CE static characterisics

The value of V_{BE} is noted for each setting of I_B. This procedure is repeated for higher fixed values of V_{CE}, and the curves of I_B V_s V_{BE} are drawn. The input characteristics thus obtained are shown in Fig. 13.11.

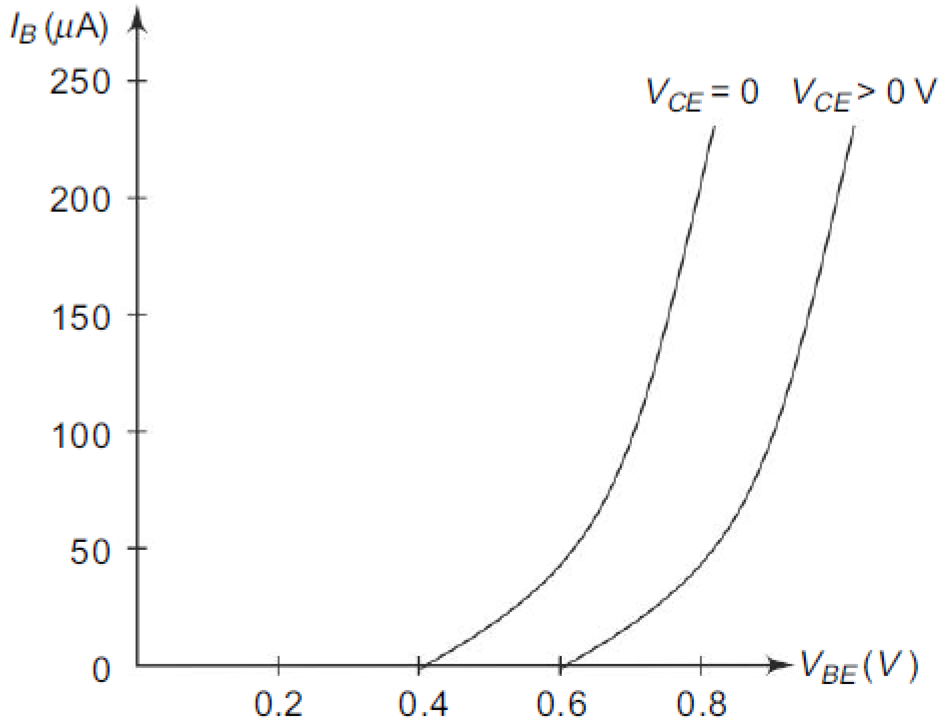


Fig. 13.11 CE input characteristics

When $V_{CE} = 0$, the emitter-base junction is forward biased and the junction behaves as a forward biased diode. Hence the input characteristic for $V_{CE} = 0$ is similar to that of a forward-biased diode. When V_{CE} is increased, the width of the depletion region at the reverse biased collector-base junction will increase. Hence the effective width of the base will decrease. This effect 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 I_B 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 equal steps from zero and the collector current I_C is noted for each setting of V_{CE}. Now the curves of I_C versus V_{CE} are plotted for different constant values of I_B. The output characteristics thus obtained are shown in Fig. 13.12.

The output characteristics have three regions, namely, saturation region, cutoff region and active region. The region of curves to the left of the line OA is called the *saturation region* (hatched), and the line OA is called the saturation line. In this region, both junctions are forward biased and an increase in the base current does not cause a corresponding large change in I_C. The ratio of $V_{CE(\text{sat})}$ to I_C in this region is called saturation resistance.

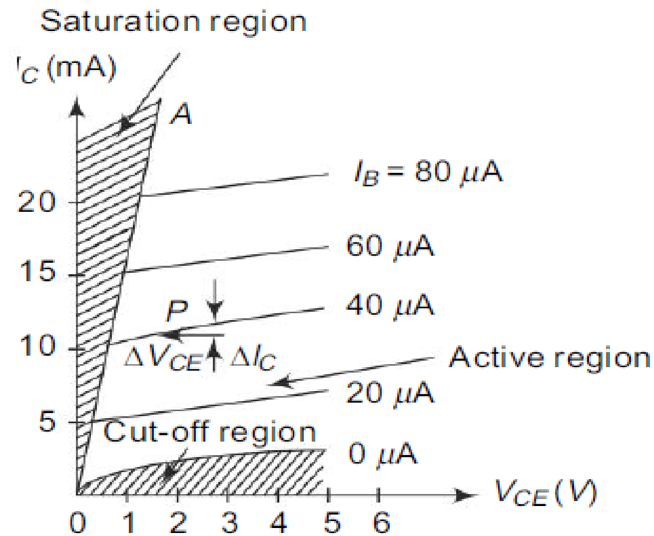


Fig. 13.12 CE output characteristics

The region below the curve for $I_B = 0$ is called the *cut-off region* (hatched). In this region, both junctions are reverse biased. When the operating point for the transistor enters the cut-off region, the transistor is OFF. Hence, the collector current becomes almost zero and the collector voltage almost equals V_{CC}, the collector supply voltage. The transistor is virtually an open circuit between collector and emitter.

The central region where the curves are uniform in spacing and slope is called the *active region* (unhatched). In this region, emitter-base junction is forward biased and the collector-base junction is reverse biased. If the transistor is to be used as a linear amplifier, it should be operated in the active region.

FIELD EFFECT TRANSISTOR

FET is a device in which the flow of current through the conducting region is controlled by an electric field. Hence the name Field Effect Transistor (FET). As current conduction is only by majority carries, FET is said to be a unipolar device.

Based on the construction, the FET can be classified into two types as Junction FET (JFET) and Metal Oxide Semiconductor FET (MOSFET).

Depending upon the majority carriers, JFET has been classified into two types named as (1) N-channel JFET with electrons as the majority carriers and (2) P-channel JFET with holes as the majority carriers.

Construction of N-Channel JFET

It consists of an N-type bar which is made of silicon. Ohmic contacts, (terminals) made at the two ends of the bar, are called Source and Drain.

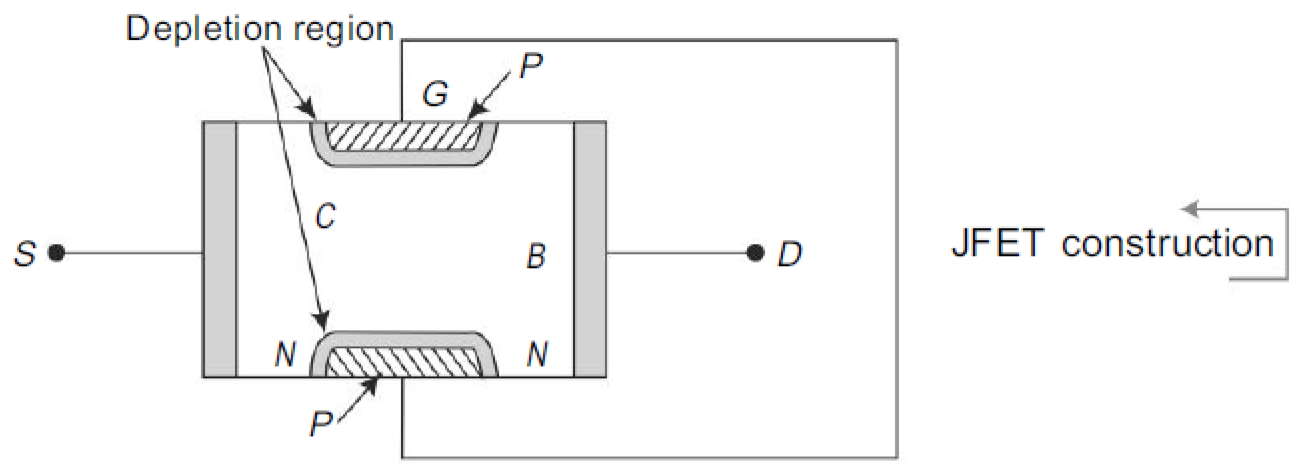
Source (S) This terminal is connected to the negative pole of the battery. Electrons which are the majority carriers in the N-type bar enter the bar through this terminal.

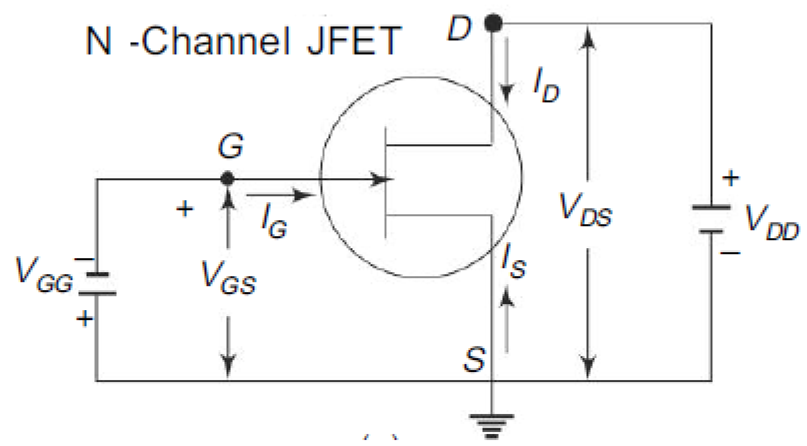
Drain (D) This terminal is connected to the positive pole of the battery. The majority carriers leave the bar through this terminal.

Gate (G) Heavily doped P-Type silicon is diffused on both sides of the N-type silicon bar by which PN junctions are formed. These layers are joined together and the called Gate *G*.

Operation of N-channel JFET

1. *When* $V_{GS} = 0$ *and* $V_{DS} = 0$ When no voltage is applied between drain and source, and gate and source, the thickness of the depletion regions around the PN junction is uniform as shown in Fig.





2. ***When $V_{DS} = 0$ and V_{GS} is decreased from zero*** In this case PN junctions are reverse biased and hence the thickness of the depletion region increases. As V_{GS} is decreased from zero, the reverse bias voltage across the PN junction is increased and hence the thickness of the depletion region in the channel increases until the two depletion regions make contact with each other. In this condition, the channel is said to be cutoff. The value of V_{GS} which is required to cutoff the channel is called the cutoff voltage V_C.

3. ***When $V_{GS} = 0$ and V_{DS} is increased from zero*** Drain is positive with respect to the source with $V_{GS} = 0$. Now the majority carriers (electrons) flow through the N-channel from source to drain. Therefore the conventional current I_D flows from drain to source.

Because the resistance of the channel and the applied voltage V_{DS}, there is a gradual increase of positive potential along the channel from source to drain. Thus the reverse voltage across the PN junctions increases and hence the thickness of the depletion regions also increases. Therefore the channel is wedge shaped, as shown in Fig. 13.20.

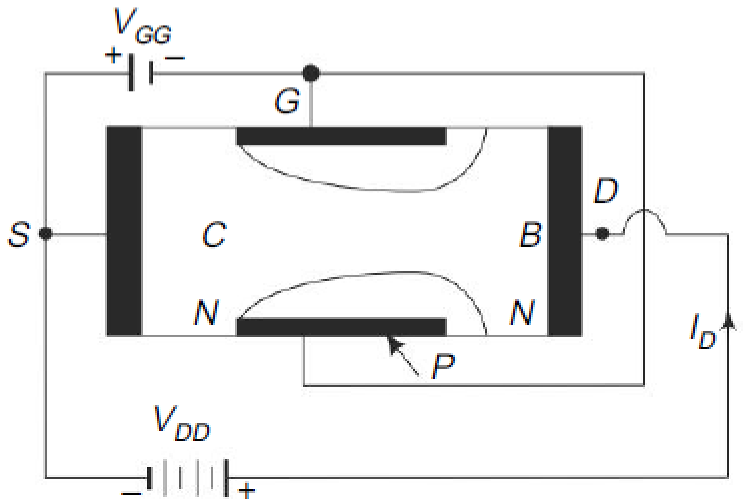


Fig. 13.20 JEFT Under Applied Bias

As V_{DS} is increased, the cross-sectional area of the channel will be reduced. At a certain value V_P of V_{DS}, the cross-sectional area at B becomes minimum. At this voltage, the channel is said to be pinched off and the drain voltage V_P is called the pinch-off voltage.

4. ***When V_{GS} is negative and V_{DS} is increased*** When the gate is maintained at a negative voltage less than the negative cutoff voltage, the reverse voltage across the junction is further increased. Hence for a negative value of V_{GS}, the curve of I_D versus V_{DS} is similar to that for $V_{GS} = 0$, but the values of V_P and BV_{DGO} are lower, as shown in Fig. 13.21.

From the curves, it is seen that above the pinch-off voltage, at a constant value of V_{DS}, I_D increases with an increase of V_{GS}. Hence a JFET is suitable for use as a voltage amplifier, similar to a transistor amplifier.

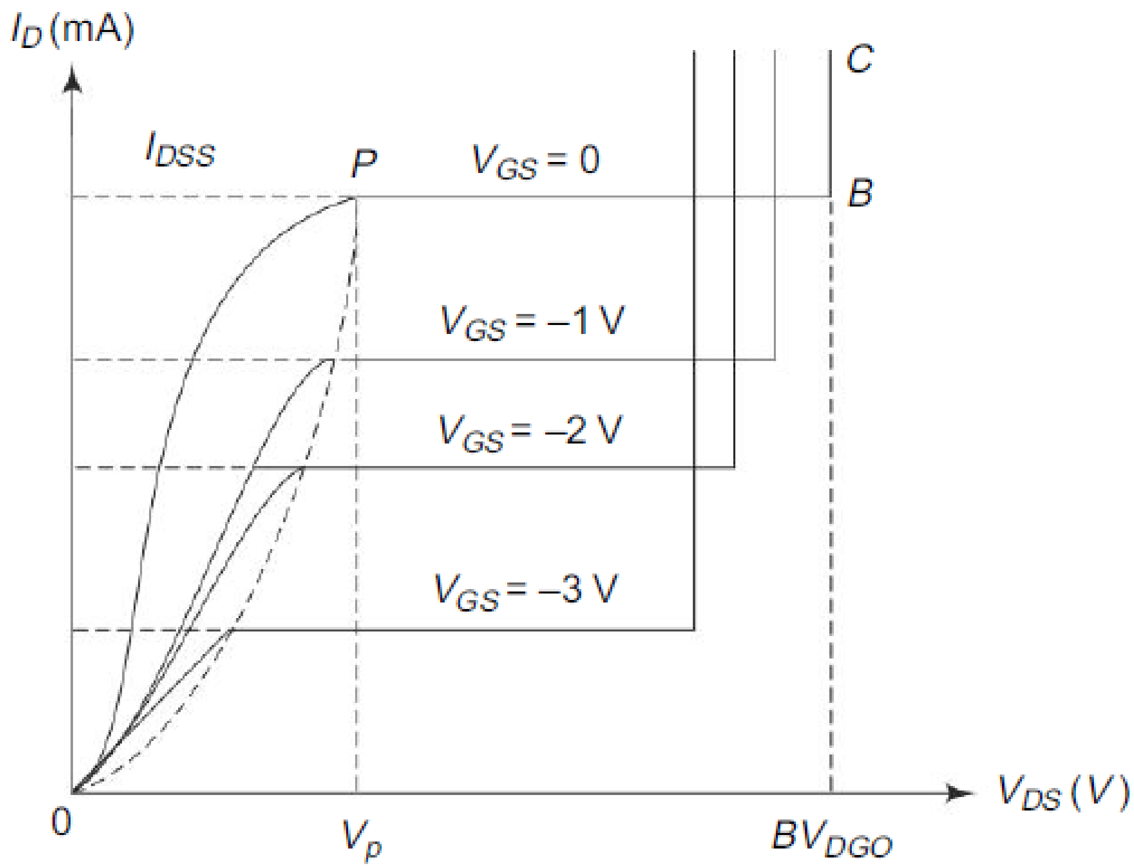


Fig. 13.21 Drain Characteristics

Comparison of JFET and BJT

1. FET operation depends only on the flow of majority carriers—holes for P-channel FETs and electrons for N-channel FETs. Therefore they are called Unipolar devices. Bipolar transitor (BJT) operation depends on both minority and majority current carriers.
2. FETs are less noisy than BJTs.
3. FETs exhibit a much higher input impedance (> 100 MΩ) than BJTs.
4. FETs are much easier to fabricate and are particularly suitable for ICs because they occupy less space than BJTs.
5. FET is normally less sensitive to temperature.
6. FET amplifiers have less voltage gain and produce more signal distortion except for small signal operation.

Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

MOSFET is the common term of the Insulated Gate Field Effect Transistor (IGFET). There are two forms of MOSFET: (i) Enhancement MOSFET and (ii) Depletion MOSFET.

Principle By applying a transverse electric field across an insulator, deposited on the semiconducting material, the thickness and hence the resistance of a conducting channel of a semiconducting material can be controlled.

Enhancement MOSFET

Construction The construction of an N-channel Enhancement MOSFET is shown in Fig. 13.23. Two highly doped N^+ regions are diffused in a lightly doped substrate of P-type silicon substrate. One N^+ region is called the source S and the other one is called the drain D. They are separated by 1 mil (10^{-3} inch). A thin insulating layer of SiO_2 is grown over the surface of the structure and holes are cut into the oxide layer, allowing contact with source and drain. Then a thin layer of metal aluminum is formed over the layer of SiO_2. This metal layer covers the entire channel region and it forms the gate G.

The metal area of the gate, in conjunction with the insulating oxide layer of SiO_2 and the semiconductor channel forms a parallel plate capacitor. This device is called the insulated gate FET because of the insulating layer of SiO_2. This layer gives an extremely high input resistance for the MOSFET.

Operation If the substrate is grounded and a positive voltage is applied at the gate, the positive charge on G induces an equal negative charge on the substrate side between the source and drain regions. Thus an electric field is produced between the source and drain regions. The direction of the electric field is perpendicular to the plates of the capacitor through the oxide. The negative charge of electrons which are minority carriers in the P-type substrate forms an inversion layer. As the positive voltage on the gate increases, the induced negative charge in the semiconductor

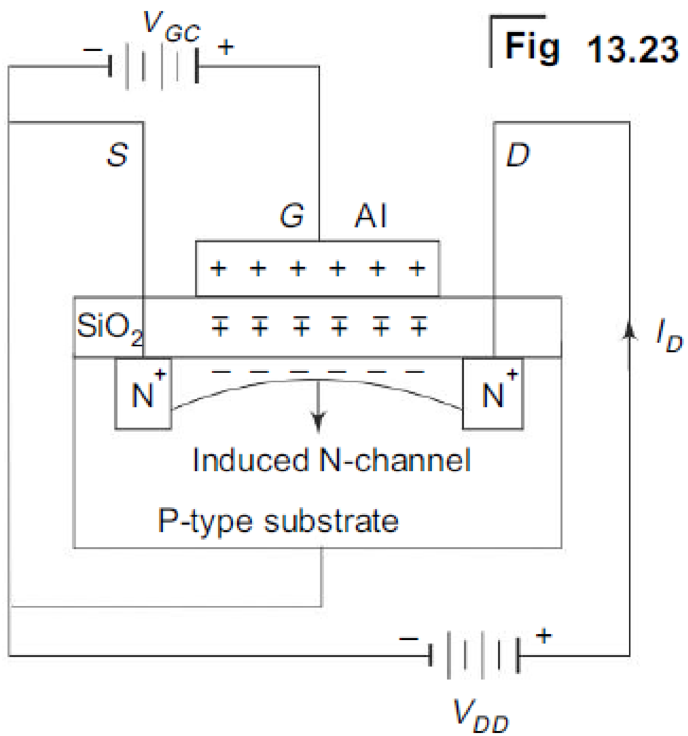


Fig 13.23 N-Channel Enhancement MOSFET

increases. Hence the conductivity increases and current flows from source to drain through the induced channel. Thus the drain current is enhanced by the positive gate voltage as shown in Fig. 13.25.

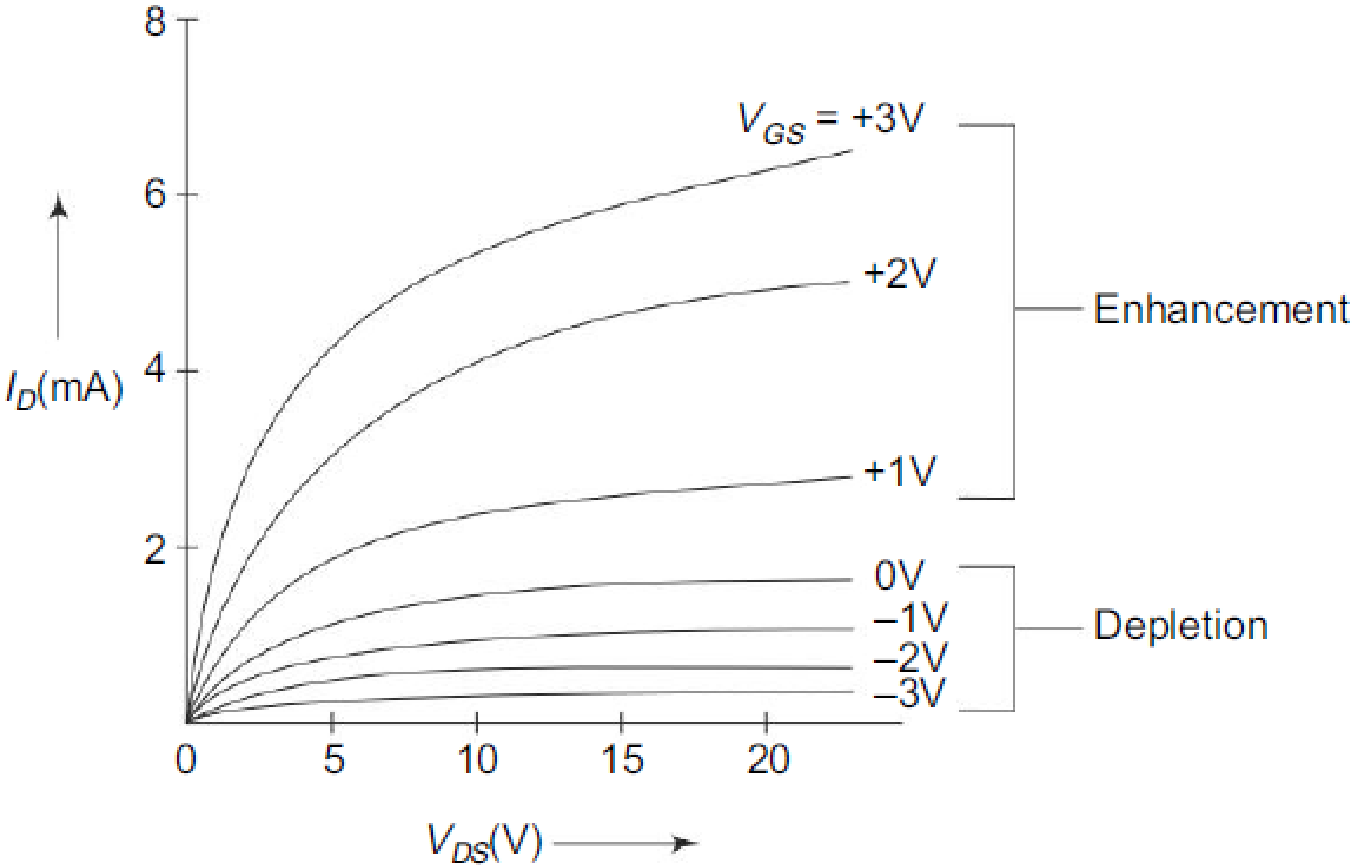


Fig. 13.25 Volt-Ampere Characteristics of MOSFET