

Analog Electronics and op-AMP

Synabus

1 - P-N Junction.

2 - Special semiconductor devices.

3 - Rectifier circuit and filters.

4 - Transistors.

5 - Transistor circuits.

6 - Transistor amplifiers and oscillators.

7 - field effect transistor.

8 - operational amplifiers.

P-N JUNCTION CHAPTER - ONE

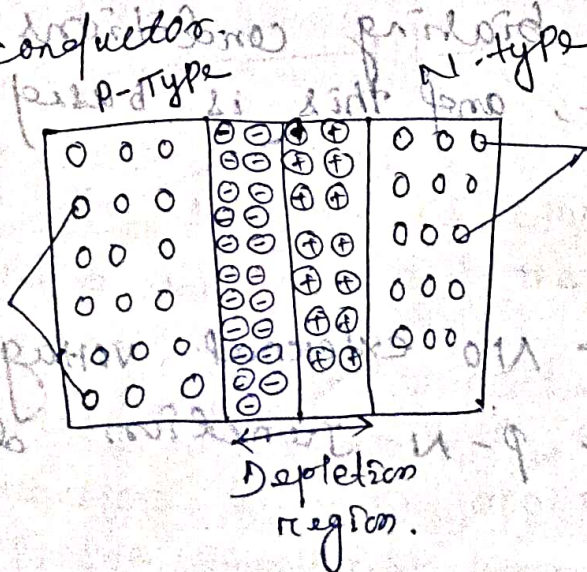
Course Content:-

P-N Junctions

Definition - A P-N Junction is an interface or a boundary between two semiconductor material types namely the p-type and the n-type, which is a

semiconductor.

Empty holes.



When an electron diffuses from the n-side to the p-side, an ionised donor is left behind on the n-side, which is immobile. As the process goes on a layer of positive charge is developed on the n-side of the junction. Similarly, when a hole goes from the p-side to the n-side, an ionized acceptor is left behind on the p-side, resulting in the formation of a layer of negative charge on the p-side of the junction.

Biassing conditions for the p-n junction diode.

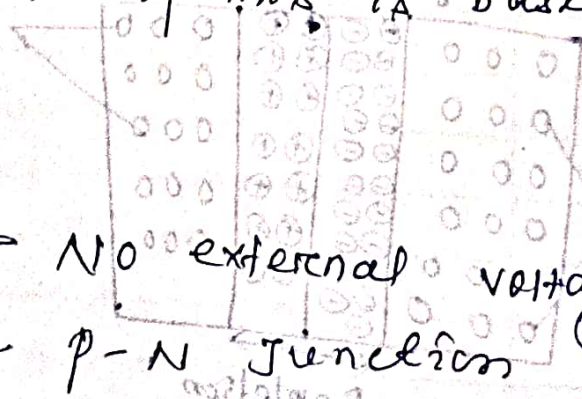
There are two operating regions in the p-n junction diode.

→ p-type

→ n-type

There are three biassing conditions for the p-n junction diode, and this is based on the voltage applied.

→ Zero bias: — No external voltage is applied to the p-n junction diode.



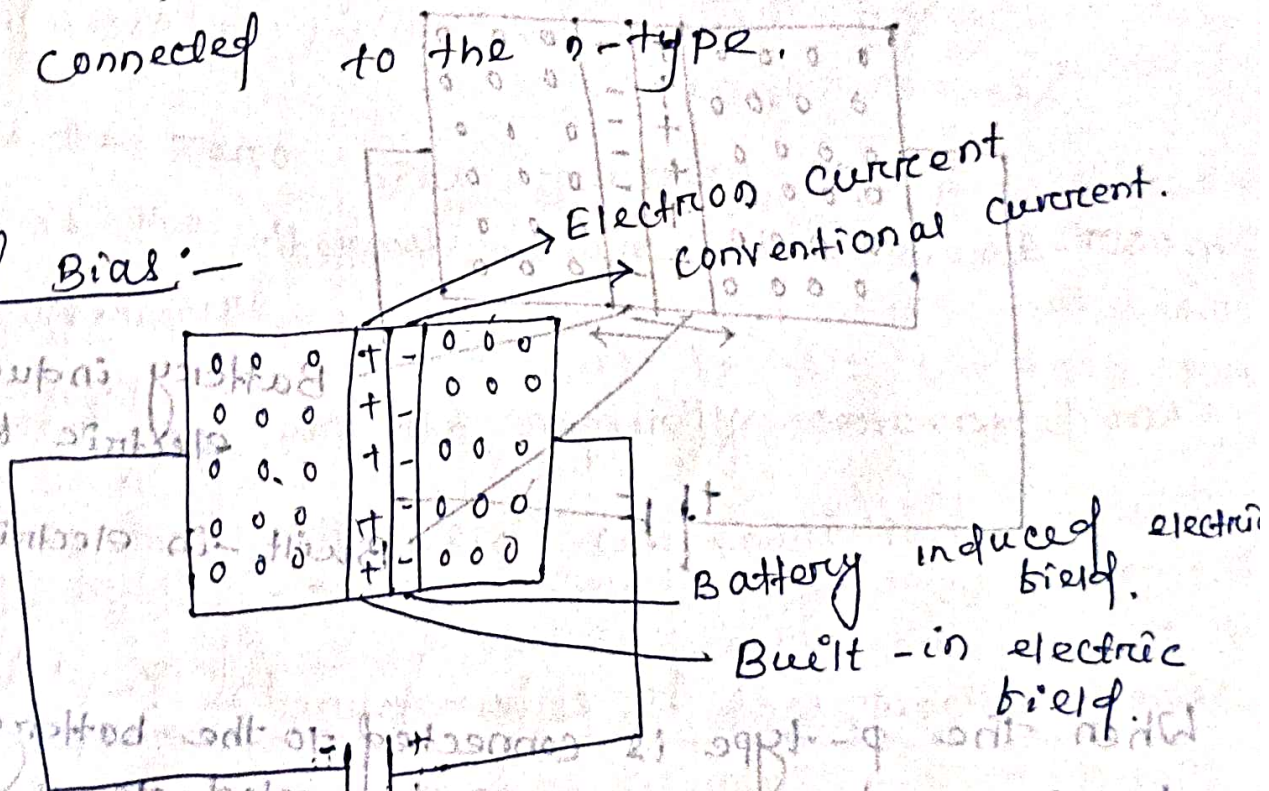
* Forward bias:-

The positive terminal of the voltage potential is connected to the p-type while the negative terminal is connected to the n-type.

* Reverse bias:-

The negative terminal of the voltage potential is connected to the p-type and the positive is connected to the n-type.

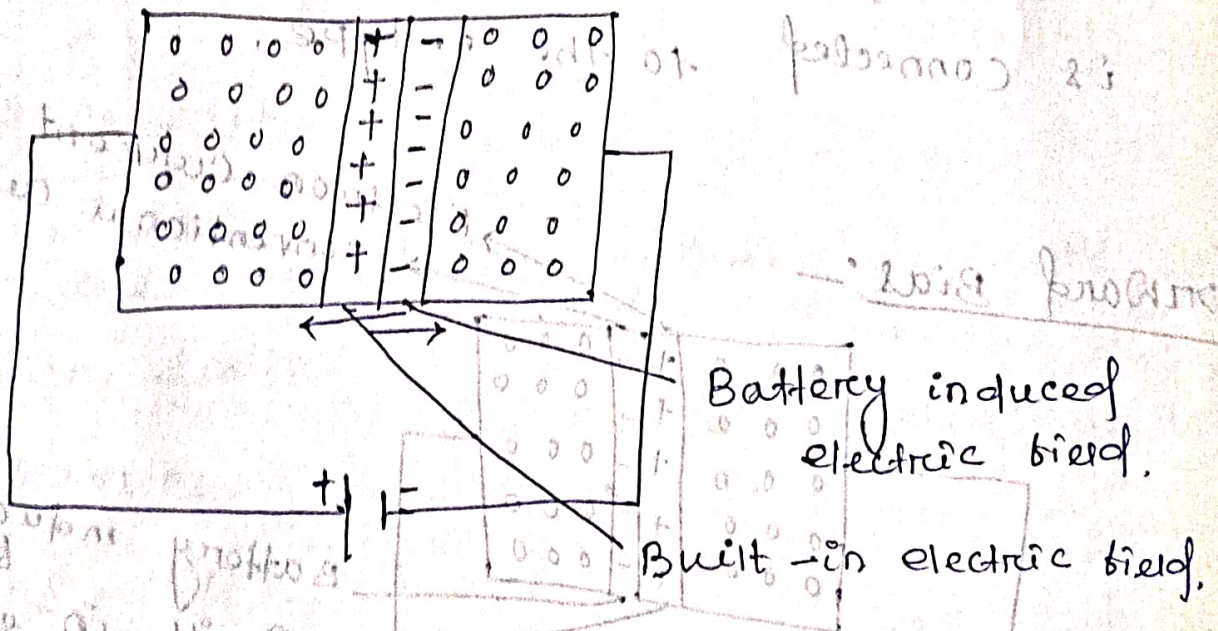
Forward Bias:-



When the p-type is connected to the battery's positive terminal and the n-type to the negative terminal, then the p-n junction is forward biased. The built-in electric field at the p-n junction and the applied electric field are in opposite directions. When both the electric field add up, the resultant electric field has a magnitude less than the built-in electric field.

This results in a less resistive and thinner depletion region. The depletion region's resistance becomes negligible when the applied voltage is large. In Silicon, at the voltage of 0.6V, the resistance of the depletion region becomes completely negligible, and the current flows across it unimpeded.

Reverse Bias:



When the p-type is connected to the battery's negative terminal and the n-type is connected to the positive side, the P-N junction is reverse biased. In this case, the built-in electric field and the applied electric field are in the same direction. When the two fields are added, the resultant electric field is in the same direction as the built-in electric field, creating a more resistive, thicker depletion region. The depletion region becomes

More resistive and thicker is the applied voltage becomes larger.

P-N Junction formula:-

The formula used in the p-n junction depends upon the built-in potential difference created by the electric field is given as

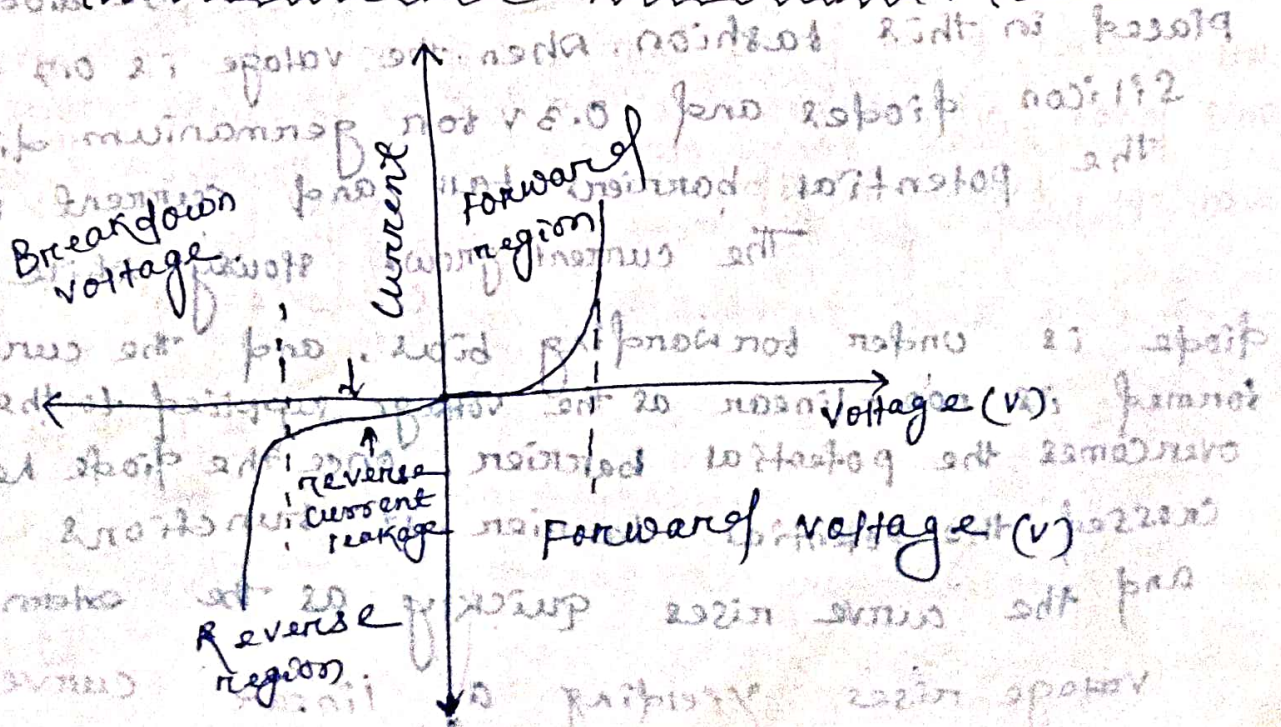
$$E_0 = V_T \ln \left[\frac{N_D \cdot N_A}{n_i^2} \right]$$

Where,

- E_0 is the Zero bias junction voltage.
- V_T is the thermal voltage 1026 mV at room temperature.
- N_D and N_A are the impurity concentrations.

→ n_i is the intrinsic concentration.

V-I Characteristics of p-n Junction diode:-



V-I characteristics of p-n junction diodes is a curve between the voltage and current through the circuit. voltage is taken along the x-axis while the current is taken along the y-axis. The above graph is the V-I characteristic curve of the p-n junction diode. With the help of the curve, we can understand that there are three regions in which the diode works, and they are.

- Zero Bias.
- Forward bias.
- Reverse bias.

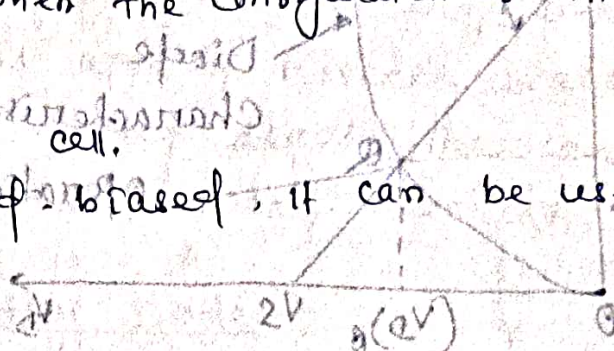
When the p-n junction diode is in zero bias condition. There is no external voltage applied and this means that the potential barrier at the junction does not allow the flow of current.

When the p-n junction diode is in forward bias condition, the p-type is connected to the positive terminal while the n-type is connected to the negative terminal of the external voltage. The potential barrier is reduced when the diode is placed in this fashion. When the voltage is 0.7 V for Silicon diodes and 0.3 V for germanium diode, the potential barrier falls and current flows.

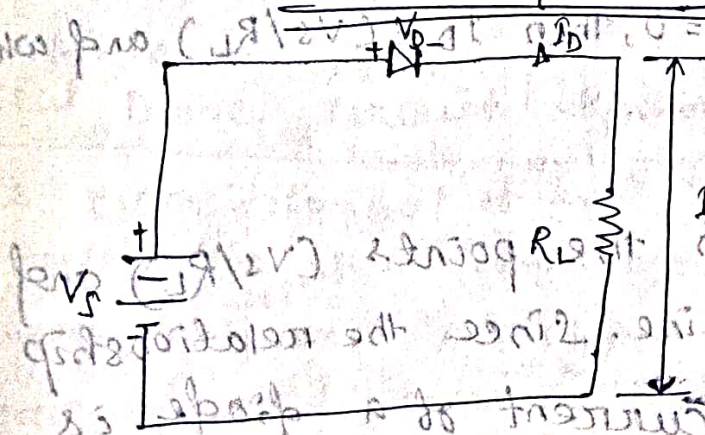
The current grows slowly while the diode is under forward bias, and the curve formed is non-linear as the voltage supplied to the diode overcomes the potential barrier. Once the diode has crossed the potential barrier, it functions normally and the curve rises quickly as the external voltage rises, yielding a linear curve.

Applications of P-N Junction Diode:-

- P-N Junction diode can be used as a photodiode as the diode is sensitive to the light when the configuration of the diode is reverse-biased.
- It can be used as a solar cell.
- When the diode is forward-biased, it can be used in LED lighting applications.
- It is used as rectifier in many electric circuits and as a voltage-controlled oscillator in varactors.



D.C Load Lines



Consider a crystal diode connected in series with a load resistance R_L across a supply voltage V_s . Here, the diode is forward-biased. A line drawn on the characteristics of the device that represents all d.c. conditions that could exist within the circuit for given values of V_s and R_L is called as d.c. load line.

Applying Kirchhoff's voltage law to the diode circuit, we have

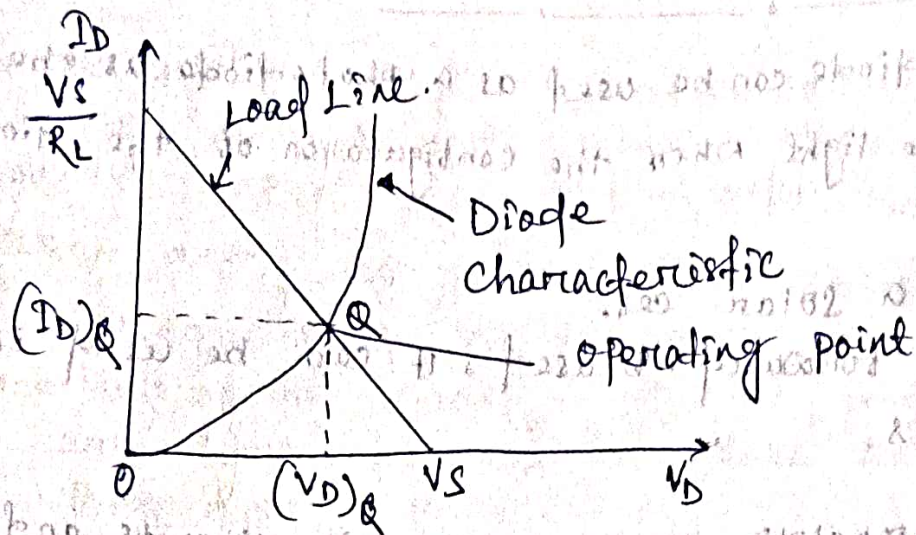
$$V_s - V_D - I_D R_L = 0$$

or,

$$I_D = \frac{V_s - V_D}{R_L}$$

the current can be changed by changing V_s or R_L .

either 1 or 2



So, d.c Load Line is a straight Line.

From above equation, when $V_D = 0$, then $I_D = (V_S/R_L)$ and when $I_D = 0$, $V_D = V_S$.

A Line passing through the points (V_S/R_L) and V_S is called a load line. Since the relationship between voltage and current of a diode is defined by diode characteristic, there is only one point on d.c. load line at which diode voltage and current are compatible with circuit conditions. The point is termed as quiescent point or d.c. bias point and is denoted by Q. Corresponding to quiescent point Q, we have current $(I_D)_Q$ through diode and voltage $(V_D)_Q$ across diode. The load line has a slope given by $-1/R_L$. The quiescent conditions for the circuit can be changed by changing either R_L or V_S .

* important terms such as ideal Diode, knee voltage.

An ideal diode is a diode that acts like a perfect conductor when voltage is applied forward biased and like a perfect insulator when voltage is applied reverse biased. so when positive voltage is applied across the anode to the cathode, the diode conducts forward current instantly.

Modes of operation of ideal Diode:-

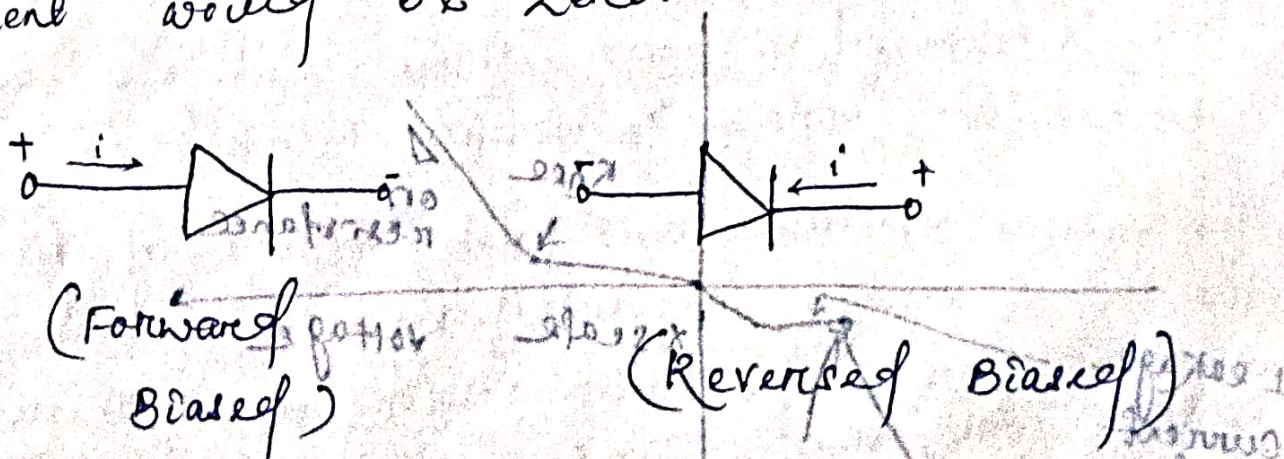
The two modes of operation of the ideal diode are-

- Forward Bias
- Reverse Bias.

Ideal Diode circuit symbol:-

The circuit symbol of an ideal diode is the simple representation of a diode by a triangle device. this symbol becomes a short or open circuit when forward and reverse biased, respectively.

In forward bias, the current flows from p to n side, and in reverse bias, there is supposed to be a small current from n to p, but since we are dealing with an ideal diode, the reverse current would be zero.





Forward Bias
(Switch closed)



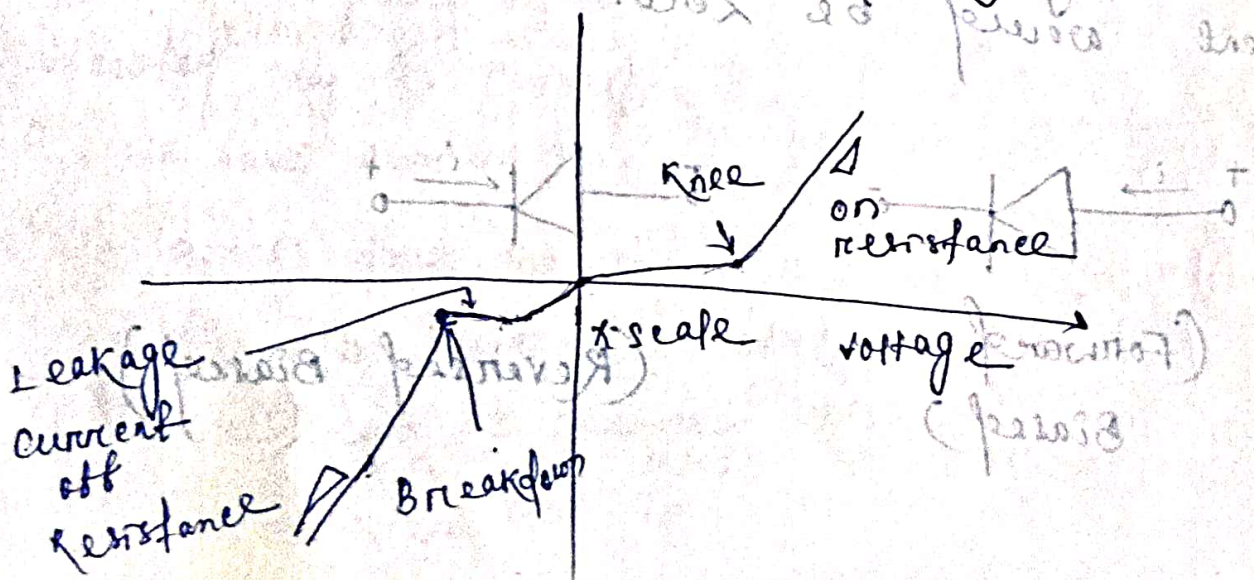
Reverse Bias
(Switch open)

Knee voltage: —

Knee voltage or cut-in voltage of PN Junction diode is the voltage at which the forward biased diode begins to conduct.

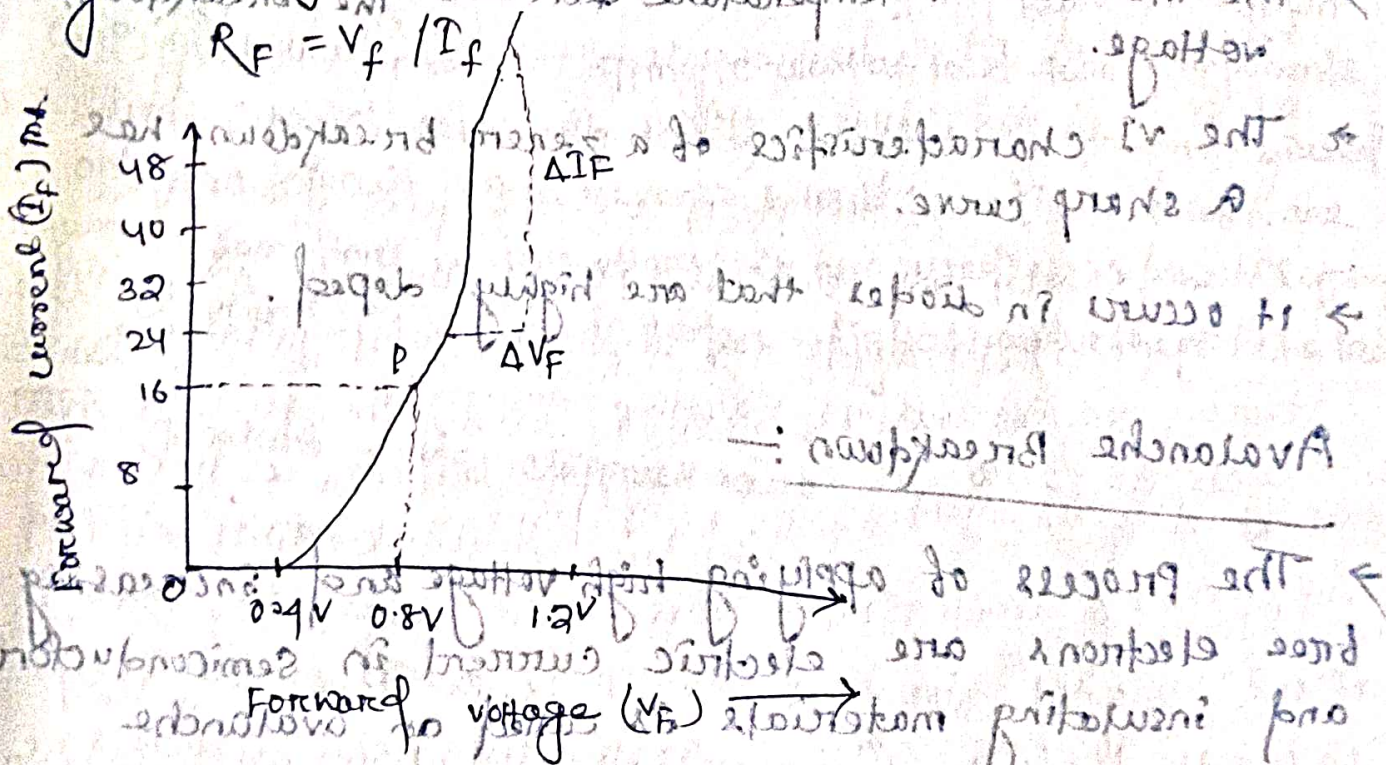
- The barrier potential or built-in potential is created when the p and n-junctions are joined. When the positive terminal of the battery is connected to the anode and the negative terminal is connected to the cathode, the diode is forward biased and will not conduct unless the battery voltage is greater than the barrier potential.

The germanium and silicon diodes have barrier potentials of 0.3 and 0.7V respectively.



* Static and dynamic resistance of a diode.

It has been observed that a real diode does not offer zero resistance when it is forward biased and an infinite resistance when reverse biased. This shows that when a real diode is forward biased has a definite resistance. This resistance is known as static forward resistance of diode. This is defined as the ratio of d.c voltage across the diode to the d.c current flowing through it. If V_f and I_f be the d.c voltage across diode and d.c current flowing through it respectively then the static resistance R_f is given by

$$R_f = V_f / I_f$$


This is observed in reverse bias. Having a zero resistance voltage is greater than 8V. The voltage electrons are pushed to conduction due to the energy imparted by accelerated electrons, which gain their velocity due to their collision with other atoms.

* Zener breakdown:-

- The process in which the electrons move across the barrier from the valence band of p-type material to the conduction band of n-type material is known as Zener breakdown.
- This is observed in zener diodes having a zener breakdown voltage V_z of 5 to 8 volts.
- The valence electrons are pulled into conduction due to the high electric field in the narrow depletion region.
- The increase in temperature decreases the breakdown voltage.
- The $V-I$ characteristics of a zener breakdown has a sharp curve.
- It occurs in diodes that are highly doped.

Avalanche Breakdown:-

- The process of applying high voltage and increasing the free electrons are electric current in semiconductors and insulating materials is called an avalanche breakdown.
- This is observed in zener diode having a zener breakdown voltage V_z greater than 8 volts.
- The valence electrons are pushed to conduction due to the energy imparted by accelerated electrons, which gain their velocity due to their collision with other atoms.

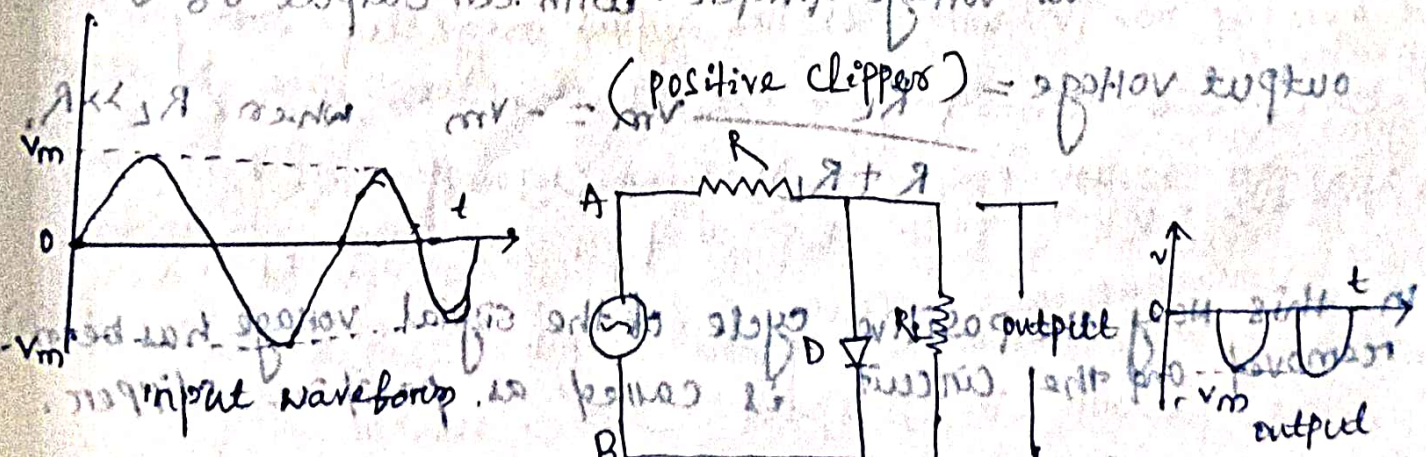
- The increase in temperature increases the breakdown voltage.
 - The $V-I$ characteristic curve of the avalanche breakdown is not as sharp as the Zener breakdown.
 - It occurs in diodes that are highly doped $P-N$ junction diodes.
- ### P-N junction diode clipping circuit:

A wave shaping circuit which controls the shape of out waveform by removing or clipping a portion of the applied wave is known as clipping circuit. For a clipping circuit at least two components of a diode (which acts as a closed switch when forward-biased and an open circuit when reverse-biased) and a resistor are required. Sometimes a dc battery is also used to fix the clipping level. Clippers are used in radar, digital and other electronic devices.

The important diode clippers are:

- (1) Positive clipper
- (2) Biased clipper
- (3) Combination clipper

* Positive clipper: The clipper which removes the positive half cycle of the input voltage is known as positive clipper.



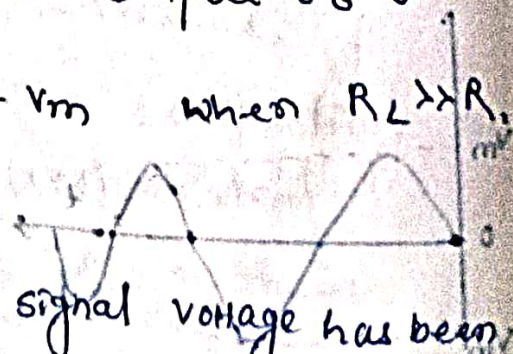
In this diode clipping circuit, the diode is forward biased during the positive half cycle of the sinusoidal input waveform. For the diode to become forward biased, it must have the input voltage magnitude greater. When this happens the diode begins to conduct and holds the voltage across itself constant until the sinusoidal waveform falls value. Thus the output voltage which is taken across the diode can never exceed value during the positive half cycle.

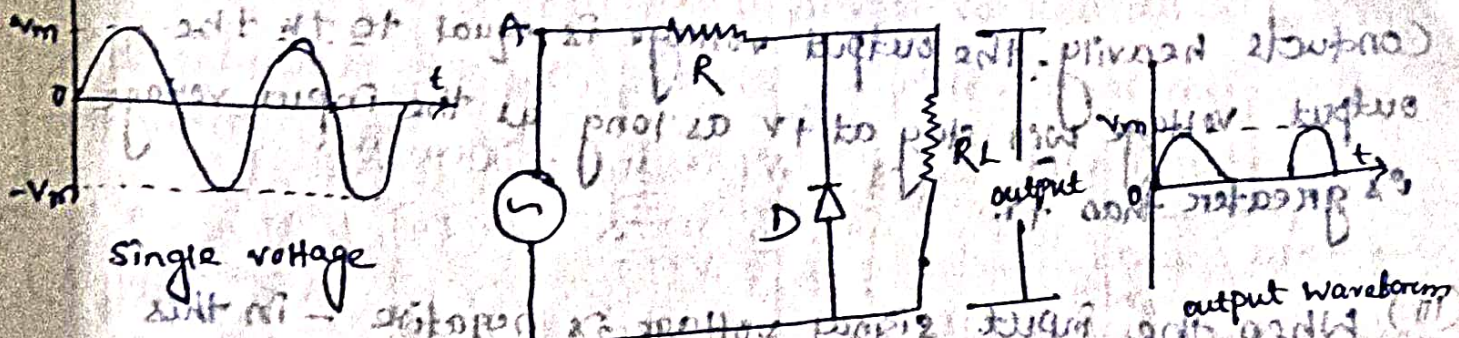
When the negative half cycle of the signal voltage is applied to the clipper. When 'A' is +ve with respect to 'B', the diode 'D' is forward-biased. Hence it acts like a closed switch and conducts heavily. Therefore, the voltage drop across the diode or across the load resistor R_L is zero. So the output voltage during the positive half cycle is zero as is obvious from the output waveform in the negative half cycle.

of the signal voltage. When 'B' is positive with respect to 'A', the diode 'D' is reverse-biased. Hence it acts like an open switch. Consequently, the entire input voltage appears across the diode or across the load resistor R_L . Actually the circuit behaves as voltage divider with an output of

$$\text{output voltage} = \frac{R_L}{R + R_L} V_m = -V_m \quad \text{when } R_L \gg R$$

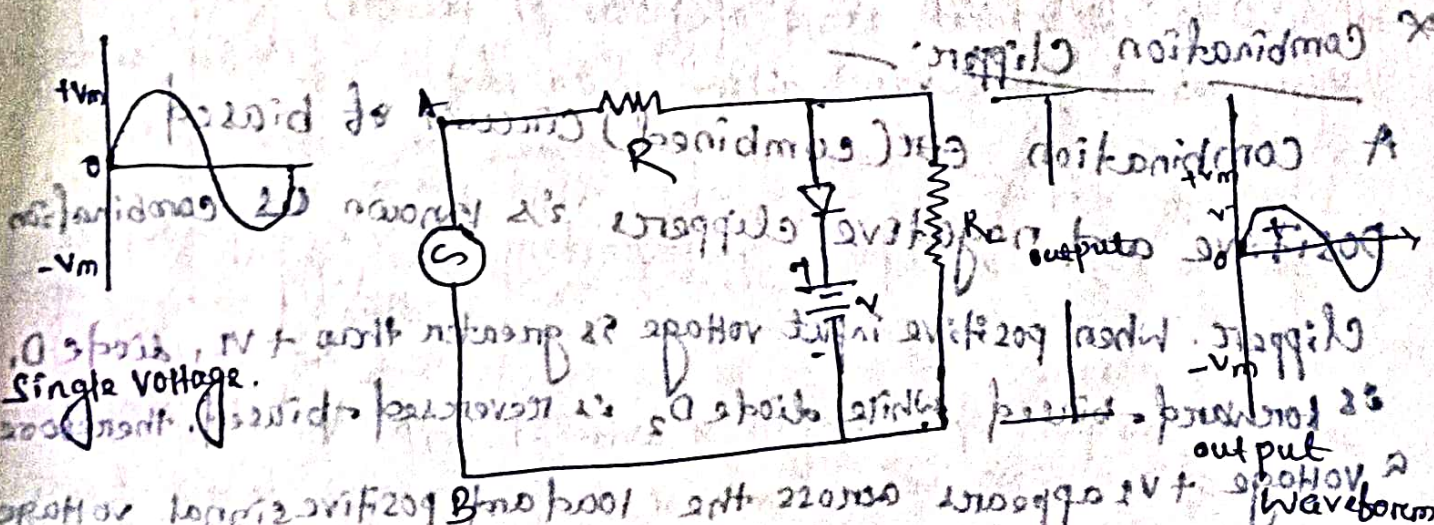
In this way the positive cycle of the signal voltage has been removed and the circuit is called as positive clipper.





Negative clipper: When the diode is reverse-biased, the entire negative half cycle appears across the load. In this way, a biased positive clipper removes input voltage above the value of V . It is referred to as a portion of the negative half-cycle of the input voltage, where the polarity of the voltage is reversed.

*** Biased clipper:** A biased clipper is used when it is desired to remove a small portion of positive or negative half cycle of the signal voltage.



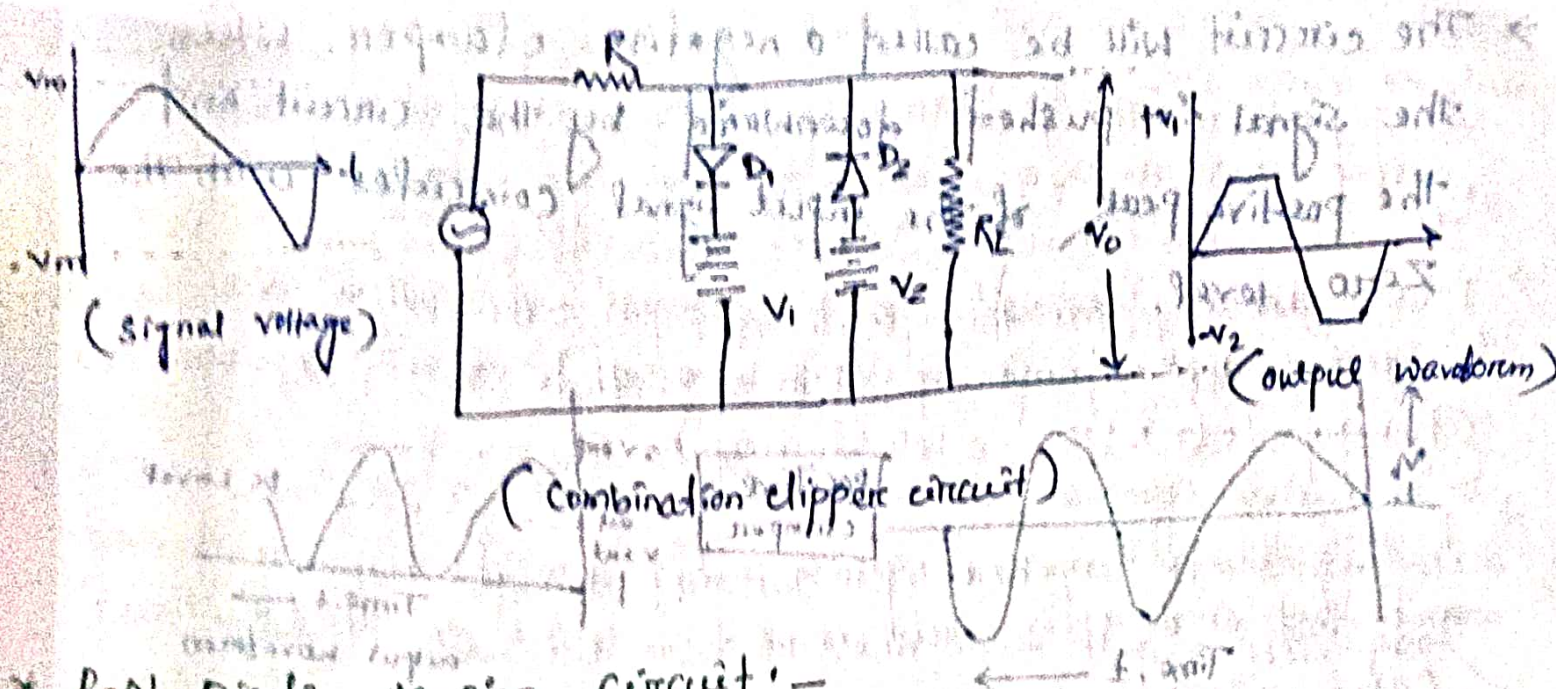
- Biased clipper:**
- (1) When the input signal voltage is less than V for positive half cycle: In this case, the diode D is reverse-biased, acts as an open circuit. Therefore, most of the input voltage appears across the output.
 - (2) When the input signal voltage is greater than V for positive half cycle: In this case, the diode D is forward-biased.

Conducts heavily. The output voltage is equal to $+V$. The output voltage will stay at $+V$ as long as the input voltage is greater than $+V$.

(II) When the input signal voltage is negative :- In this case, the diode D is reverse biased, acts as reverse-biased. Therefore, entire negative half cycle appears across the load. In this way a biased positive clipper removes input voltage above $+V$. When it is desired to clip a portion of the negative half-cycle of the input voltage, either the polarity of the diode or battery is changed. Such a circuit is called as biased negative clipper.

* Combination Clipper :-

A combination or (combined) circuit of biased positive and negative clippers is known as combination clipper. When positive input voltage is greater than $+V_1$, diode D_1 is forward-biased while diode D_2 is reverse-biased. Therefore a voltage $+V_1$ appears across the load and positive signal voltage above $+V_1$ is clipped off. On the other hand, during negative half cycle, the diode D_2 is forward-biased and D_1 is reverse-biased, so long as the input negative voltage is greater than $-V_2$. So the output stays at $-V_2$. Hence signal voltage beyond $-V_2$ volt is clipped off. Between $+V_1$ and $-V_2$ neither diode is on and hence most of the input voltage appears across the load. The output waveform.



* P-N Diode clamping circuit: -

clamping is a process of introducing a dc level into an ac signal. A clamping circuit is a device that places either the positive or negative peak of a signal at a desired level.

- A clamping circuit is used to place either the positive or negative peak of a signal at a desired level. The dc component is simply added or subtracted to/from the input signal.
- The clamper is also referred to as a dc restorer and ac signal level shifter.
- A clamp circuit adds positive or negative dc component to the input signal so as to push it either on the positive side.

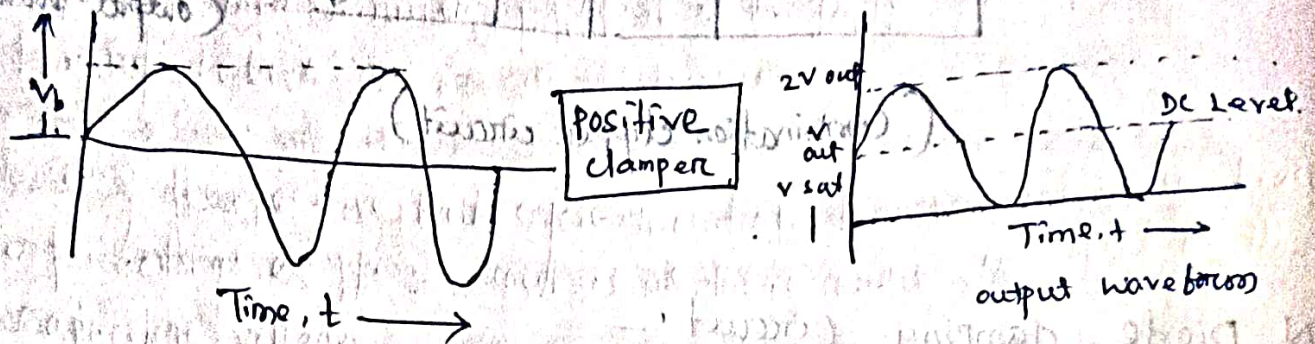
→ The clamper is of two types: -

- 1 - positive clamper
- 2 - Negative clamper.

→ The circuit will be called a positive clamper, when the signal is pushed upward side by the circuit and the negative peak of the signal coincides with the zero level.

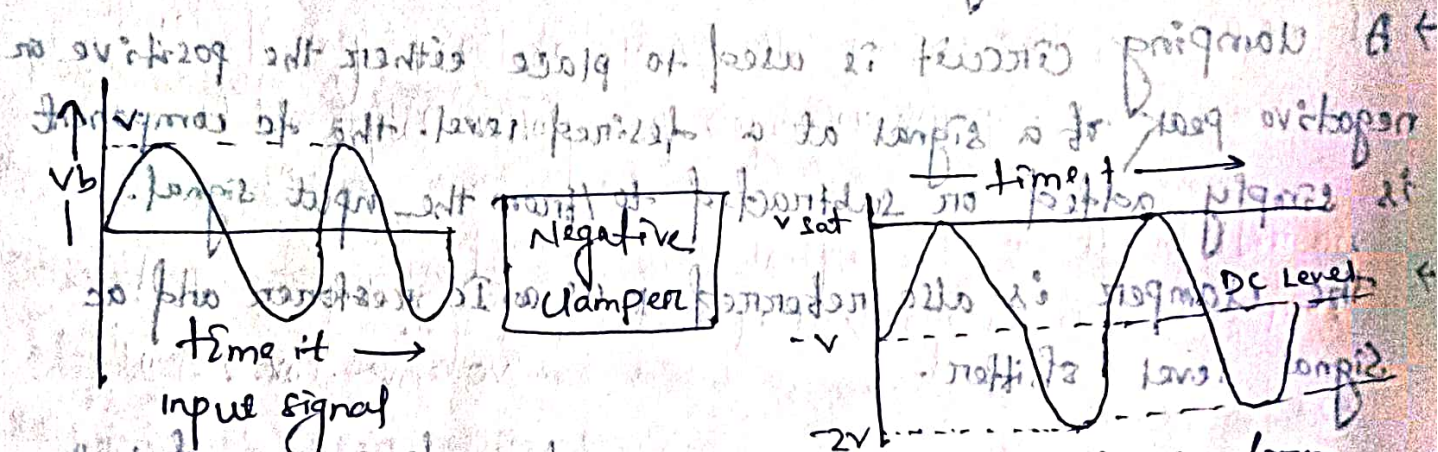
→ The circuit will be called a negative clamper, when the signal is pushed downward by the circuit and the positive peak of the input signal coincides with the

Zero level.



input signal

positive clamper



input signal

→ For a clamping circuit at least three components - a diode, a Capacitor and a resistor are required. Sometimes an independent dc supply is also required to cause an additional shift. The important points regarding clamping circuit are

1 - The shape of the waveform will be the same, but its level is shifted either upward or downward.

2 - There will be no change in the peak-to-peak or R.M.S. value of the waveform due to the clamping circuit. Thus the input waveform and output waveform will have the same peak-to-peak value that is, $2V_{max}$. This is shown in the figure above. It must also be noted that same readings will be obtained in the peak-to-peak voltmeter for the input voltage and the clamped output voltage.

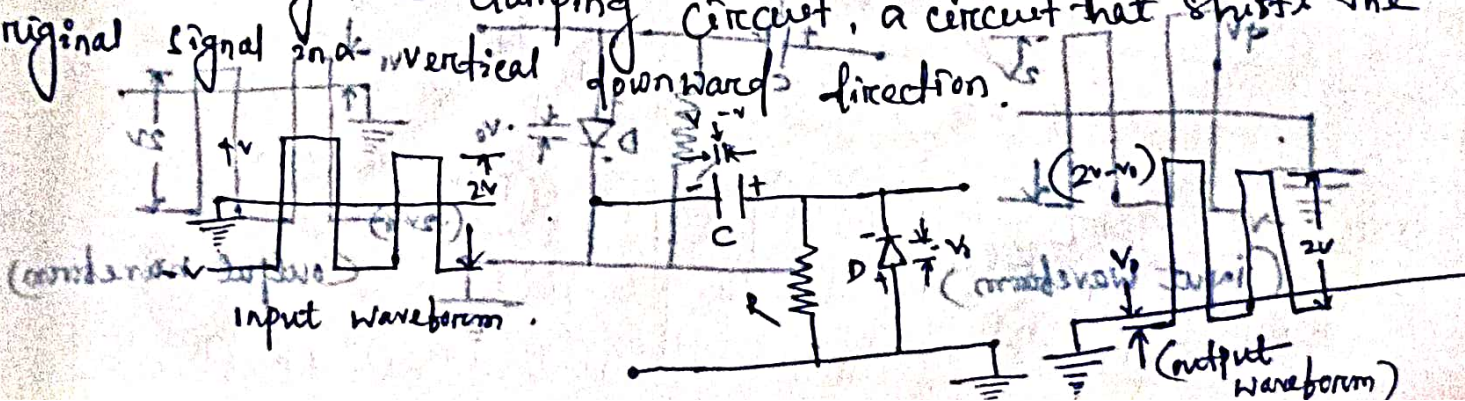
3 - There will be a change in the peak and average values of the waveform. In the figure shown above, the input waveform has a peak value of V_{max} and average value over a complete cycle is zero. Value of the clamped output is $2V_{max}$ and thus the peak value of the clamped output is $2V_{max}$ and average value is V_{max} .

4 - The values of the resistor R and capacitor C affect the waveform.

5 - The values of the resistor R and capacitor C should be determined from the time constant equation of the circuit, $t = RC$, the values must be large enough to make sure that the voltage across capacitor C does not change significantly during the time interval the diode is non-conducting. In a good clamper circuit, the circuit time constant $t = RC$ should be at least ten times the time period of the input signal voltage. It is advantageous to first consider the condition under which the diode becomes forward biased.

Positive clamper:

Consider a negative clamping circuit, a circuit that shifts the original signal in a vertical downward direction.



→ The diode D will be forward biased and the capacitor C is charged with the polarity shown, when an input signal is applied.

→ During the negative half cycle of input, the output voltage will be equal to the barrier potential of the diode V_0 and capacitor is charged to $(V - V_0)$.

→ During the positive half cycle, the diode becomes reverse-biased and acts as an open circuit, thus, there will be no effect on the capacitor voltage.

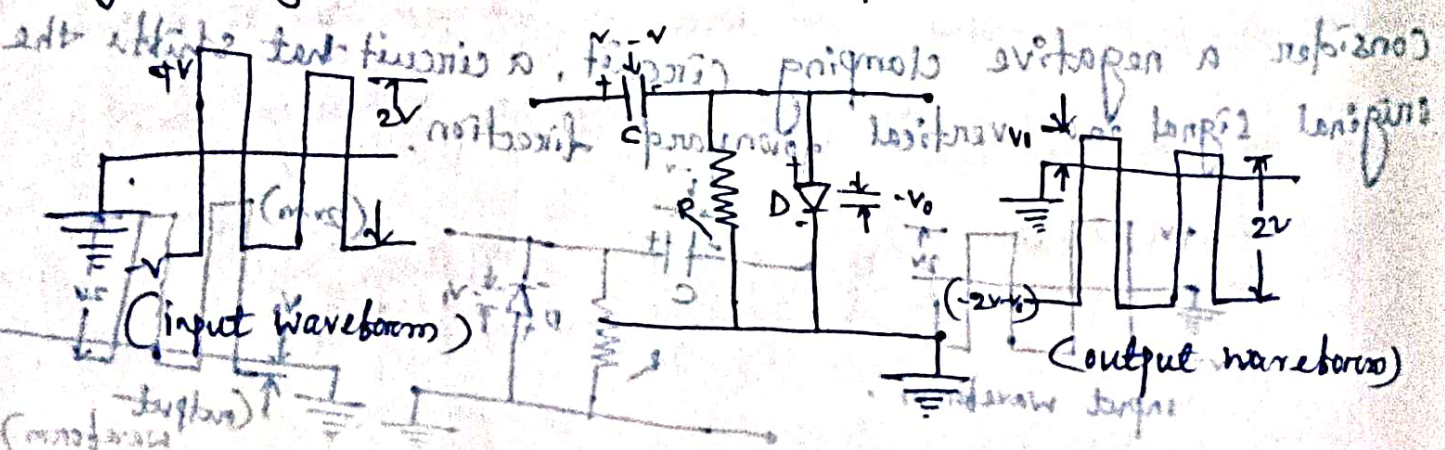
→ The Resistance R_D being of very high value, cannot discharge capacitor during the positive portion of the input waveform.

→ Thus during positive input, the output voltage will be the sum of the input voltage and capacitor voltage $= +V + (V - V_0) = 2V - V_0$.

→ The value of the peak-to-peak output will be the difference between the negative and positive peak voltage levels is equal to $(2V - V_0) - (-V_0) = 2V$.

Negative clamper

Consider a negative clamping circuit, a circuit that shifts the original signal in a vertical downward direction.



→ The diode 'D' will be forward biased and the capacitor 'C' is charged with the polarity shown, when an input signal is applied.

→ During the positive half cycle of input, the output voltage will be equal to the barrier potential of the diode, V_0 and capacitor is charged to $(V - V_0)$.

→ During the negative half cycle, the diode becomes reverse-biased and acts as an open circuit. Thus there will be no effect on the capacitor voltage.

→ The Resistor, being of very high value, cannot discharge. A lot during the negative portion of the input waveform.

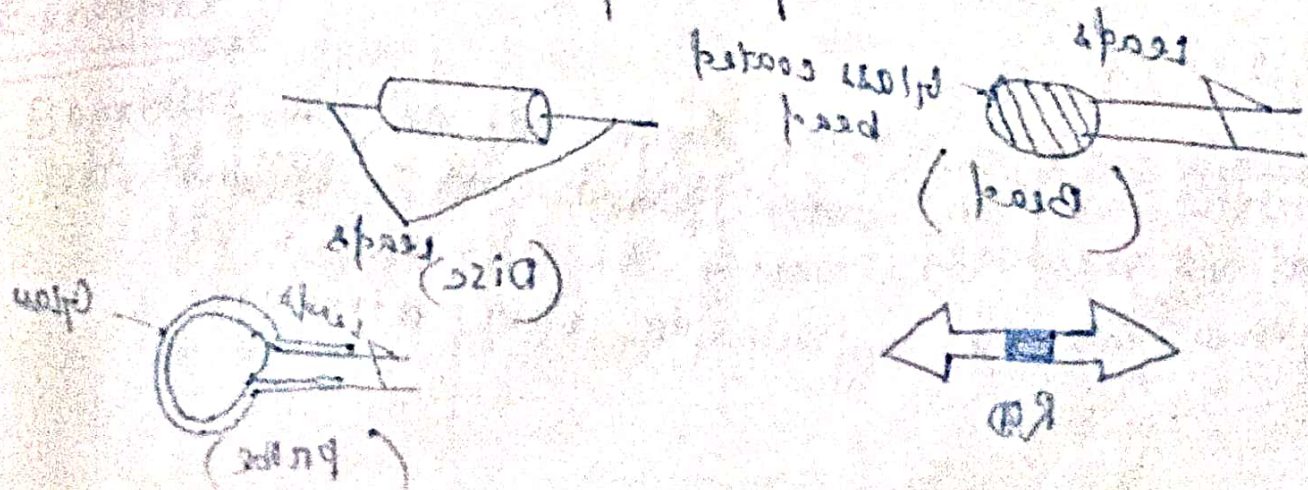
→ Thus during negative input, the output voltage will be the sum of the input voltage and capacitor voltage $= -V - (V - V_0) = -(2V - V_0)$.

→ The value of the peak-to-peak output will be the difference of the negative and positive peak voltage levels is equal to $V_0 - [-(2V - V_0)] = 2V$.

Application of clamper:-

→ Clamping circuit are often used in television receivers as dc restorers in the TV receiver they also find application in storage counters, analog frequency meters, capacitance meters, divider and stair-case waveform generator.

The relation between resistance and absolute temperature of a thermistor can be represented as



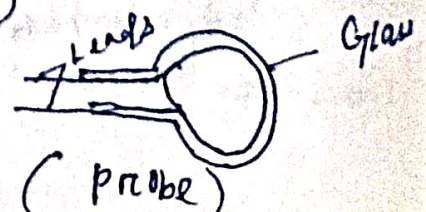
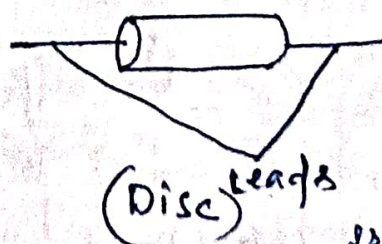
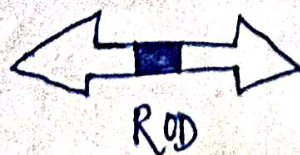
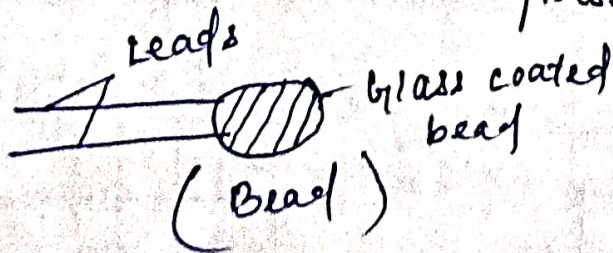
Special Semiconductor device:- Chapter - 2

Thermistor

- Thermistor is the contraction of the term Thermal Resistor.
- It is generally composed of semiconductor materials. Most thermistors have a negative coefficient of temperature that is their resistance decrease with the increase of temperature.
- This high sensitivity to temperature changes makes thermistors extremely useful for precision temperature measurement, control and compensation.
- The temperature measurement of thermistor ranges from -50°C to 150°C and the resistance of thermistors ranges from 0.5Ω to $0.75\text{M}\Omega$. It exhibits highly non-linear characteristics of resistance versus temperature.

Construction

- These thermistors are composed of sintered mixture of metallic oxides such as manganese, nickel, cobalt, copper, iron, and uranium.
- These may be in the form of beads or rods or discs or probes.
- The relation between resistance and absolute temperature of a thermistor can be represented as,



Features:-

- These are compact, rugged and inexpensive and have good stability when properly aged.
- Measuring current is maintained at a value as low as possible so that self-heating of thermistor is avoided otherwise errors are changes of resistance by self-heating.
- The upper operating limit of temperature for thermistor is dependent on physical changes in the material.
- For thermistor the response time can vary from fraction of second to minute depending on the size of detecting mass and thermal capacity of the thermistor.
- Response time varies inversely with dissipation factor.

Application

- It is used for measurements and control of temperature and for temperature compensation.
- It is used for measurement of power at high frequency. It is also used for thermal conductivity.
- Thermistor is used for measurement of level, flow and pressure of liquid, composition of gases and vacuum measurement. It is used for providing time delay.

Barometers

- Barometers are the short length wires with fine diameters with operating range around 150°C.

Sensors —

- A sensor is a device that detects events or changes in quantities and provides a corresponding output, generally as an electrical or optical signal, for example a thermocouple converts temperature to an output voltage.
- Sensors are used in everyday objects such as touch sensitive elevator buttons and lamps which dim or brighten by touching the base, besides innumerable applications of which most people are never aware.
- With advances in micro machinery and easy to use microcontroller platforms, the use of sensors have expanded beyond the more traditional fields of temperature, pressure or flow measurement.
- Moreover, analog sensors such as potentiometers and force-sensing resistors are still widely used, applications include manufacturing and machinery, airplanes and aerospace, cars, medicine and robotics.
- A sensor's sensitivity indicates how much the sensor's output changes when the input quantity being measured changes.
- For instance, if the mercury in a thermometer moves 1 cm when the temperature changes by 1°C the sensitivity is $1\text{ cm}/^{\circ}\text{C}$.
- Sensors need to be designed to have a small effect on what is measured, making the sensor smaller often improves this and may introduce other advantages.

Zener Diode:—

Zener Diodes are semiconductor devices that allow current to flow in both directions but specialize in current flowing in reverse. Also known as breakdown diodes, Zener diodes are the most common electronic components used as stable voltage references for electronic circuits.

There are two types of breakdown in a Zener Diode:

Avalanche Breakdown in Zener Diode and Zener Breakdown

Avalanche Breakdown in Zener Diode:—

Avalanche Breakdown occurs in both normal diodes and Zener Diodes when subjected to high reverse voltage. When a significant reverse voltage is applied to the PN junction, the free electrons gain enough energy to accelerate at high velocities. These high velocity electrons collide with other atoms, causing the ejection of additional electrons. This continuous collision process generates a large number of free electrons, resulting in a rapid increase in electric current through the diode.

Zener Breakdown in Zener Diode:—

When the reverse bias voltage applied to a Zener diode approaches its Zener voltage, the electric field within the depletion region becomes strong enough to attract and remove electrons from their valence band. These valence electrons break free from their parent atoms. This phenomenon takes place in the Zener breakdown region.

Tunnel Diode:

- Under normal forward bias operation, as voltage begins to increase, electrons at first tunnel through the very narrow p-n junction barrier because filled electron states in the conduction band on the n-side become aligned with empty valence band hole states on the p-side of the p-n junction.
- As voltage increases further these states become more misaligned and the current drops this is called negative resistance because current decreases with increasing voltage.
- As voltage increases yet further, the diode begins to operate as a normal diode, where electrons travel by conduction across the p-n junction and no longer by tunneling through the p-n junction barrier.
- The most important operating region for a tunnel diode is the negative resistance region.
- When used in the reverse direction, tunnel diodes are called back diodes and can act as fast rectifiers with zero offset voltage and extreme linearity for power signals.
- Under reverse bias, filled states on the p-side become increasingly aligned with empty states on the n-side and electrons now tunnel through the p-n junction barrier in reverse direction.
- In a conventional semiconductor diode, conduction takes place while the p-n junction is forward biased and blocks current flow when the junction is reverse biased. This occurs up to a point known as the reverse breakdown voltage when conduction begins.

→ In the tunnel diode, the dopant concentrations in the p and n layers are increased to the point where the reverse breakdown voltage becomes zero and the diode conducts in the reverse direction.

→ However, when forward-biased, an odd effect occurs called quantum mechanical tunnelling which gives rise to a region where an increase in forward voltage is accompanied by a decrease in forward current.

→ In the current voltage characteristics of tunnel diode, we can find a negative slope region when forward bias is applied.

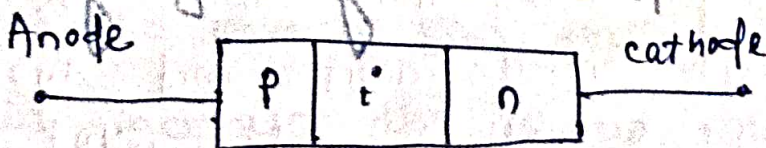
→ Quantum mechanical tunneling is responsible for the phenomenon and thus this device is named as tunnel diode.

→ The doping is very high so at absolute zero temperature the Fermi level lies within the band of the semiconductor. When no bias is applied, any current flows through the junction.

PIN Diode:-

The PIN diode can be a PN junction but with an intrinsic layer between the p and n layers.

- The intrinsic layer of the PIN diode is a layer without doping, and as a result this increases the size of the depletion region - the region between the p and n layers where there are no majority carriers. This change in the structure gives the PIN diode its unique properties.



→ The PIN diode operates in exactly the same way as a normal diode.

→ The only real difference is that the depletion region that normally exists between the p and n regions in an unbiased or reverse biased diode is larger.

→ In any PN junction the p region contains holes as it has been doped to ensure that it has a predominance of holes.

→ Similarly the n region has been doped to contain a excess electrons.

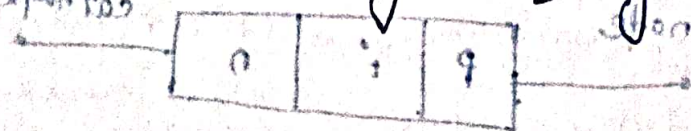
→ The region between the p and n regions contains no charge carriers as any holes or electron combine with the depletion regions. Contains no charge carriers & acts as an insulator.

→ Within a PIN diode the depletion region has no charge but if the diode is forward biased, the carriers enter the depletion region and as the two carrier types meet, current starts to flow.

→ When the diode is forward bias, the carrier concentration, holes and electrons is very much higher than the intrinsic levels carrier concentration.

→ Due to this high level injection level, the electric field extends deeply into the region.

→ This electric field helps in speeding up of the transport of charge carriers from p to n region which result in faster operation of the diode, making it a suitable device for high frequency operations.



→ A PIN diode obeys the standard diode equation too. At low frequency signals, at higher frequencies, the diode looks like an almost perfect linear resistor for large signals, etc.

→ There is a lot of stored charge in the intrinsic region.

→ At low frequencies, the charge can be removed and the diode turns off. The PIN diode has a poor reverse recovery time.

→ The high-frequency resistance is inversely proportional to the DC bias current through the diode.

→ A PIN diode is usually biased, therefore acts like a variable resistor.

→ This high-frequency resistance may vary over a wide range. Some cases the useful range is smaller though.

→ The wide intrinsic region also means that the diode will have a low capacitance when reverse biased.

→ In a PIN diode, the depletion region exists almost completely within the intrinsic region.

→ This depletion region is much larger than in a PN diode, and almost constant-size independent of the reverse bias applied to the diode.

→ This increases the volume where electron-hole pairs can be generated by an incident photon.

* PIN Diode uses and advantages

→ The PIN diode is used in a number of areas as a result of its structure providing some properties which are of particular use.

1 - High voltage Rectifiers: — The PIN diode can be used as a high voltage rectifier. The intrinsic region provides a greater separation between the P and N regions, allowing higher reverse voltage to be tolerated.

2 - RF switch: — The PIN diode makes an ideal RF switch. The intrinsic layer between the P and N regions increases the distance between them. This also decreases the capacitance between them. Thereby increasing the level of isolation when the diode is reverse biased.

3 - Photo detector: — As the conversion of light into current takes place within the depletion region of a photodiode, increasing the depletion region by adding the intrinsic layer improves the performance by increasing the volume in which light conversion occurs.

→ In a PIN diode, the depletion region is much larger than in a PN junction. This is because the intrinsic region is much larger than the P and N regions. The depletion region is almost completely within the intrinsic region. This is because the P and N regions are much thinner than the intrinsic region. The depletion region is almost constant size in a PIN diode. This is because the P and N regions are much thinner than the intrinsic region. The depletion region is almost constant size in a PIN diode. This is because the P and N regions are much thinner than the intrinsic region.

→ This increases the volume where electron-hole pairs are generated by an incident photon. Power can be generated by an incident photon. This increases the volume where electron-hole pairs are generated by an incident photon. Power can be generated by an incident photon.

Rectifiers

A rectifier is an electronic device that converts an alternating current into a direct current by using one or more P-N junction diodes. A diode behaves as a one way valve that allows current to flow in a single direction. This process is known as rectification.

Rectifiers are mainly classified into two types as:

1. uncontrolled Rectifier.
2. Controlled Rectifier.

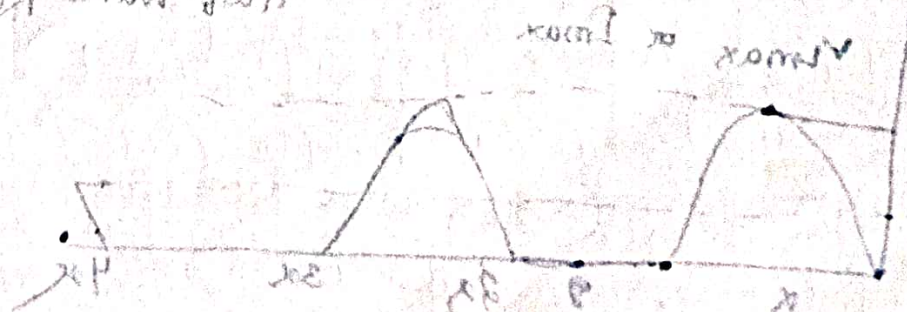
* uncontrolled Rectifier: — The type of rectifier whose voltage cannot be controlled is known as an uncontrolled Rectifier.

1. Half wave Rectifier.
2. Full wave Rectifier.
3. Full wave Bridge Rectifier.

* Controlled Rectifier: — A type of rectifier whose voltage can be varied is known as the controlled rectifier. We use SCRs, MOSFET and IGBTs to make an uncontrolled rectifier a controlled one.

* Silicon Controlled Rectifier: —

A type of controlled rectifier.



Bridge rectifiers

→ Uses a bridge configuration of diodes to rectify alternating current. - among no one point of current flowing in one direction.

* Full wave bridge rectifier:- A diode bridge rectifier is a circuit configuration that has a preferred rectifier circuit configuration that has certain advantages over other rectifier circuits.

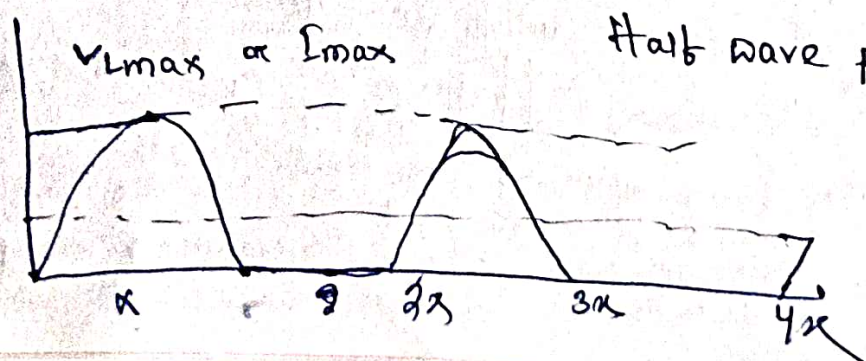
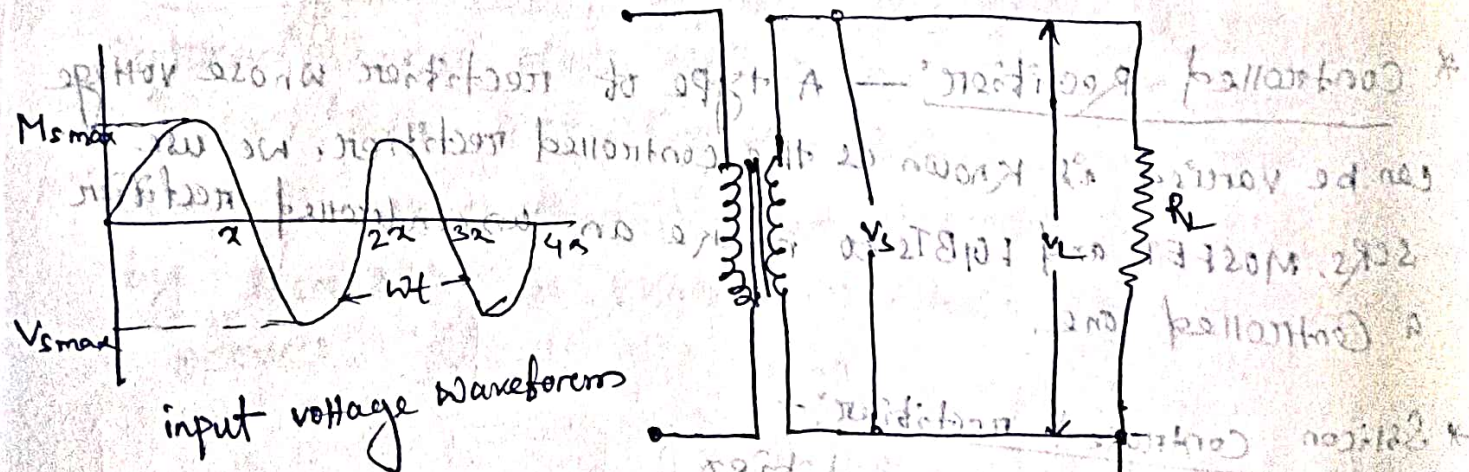
Center tapped full wave rectifier:-

→ Uses a center tapped transformer to convert the complete AC signal into DC signal.

Efficiency:-

→ Rectifier efficiency is the ratio between the output DC power and the input AC power.

Half wave rectifier



A Half-wave rectifier is a circuit that converts alternating current (AC) to direct current (DC) by only allowing the positive half of the AC cycle to pass.

Analysis

Efficiency:-

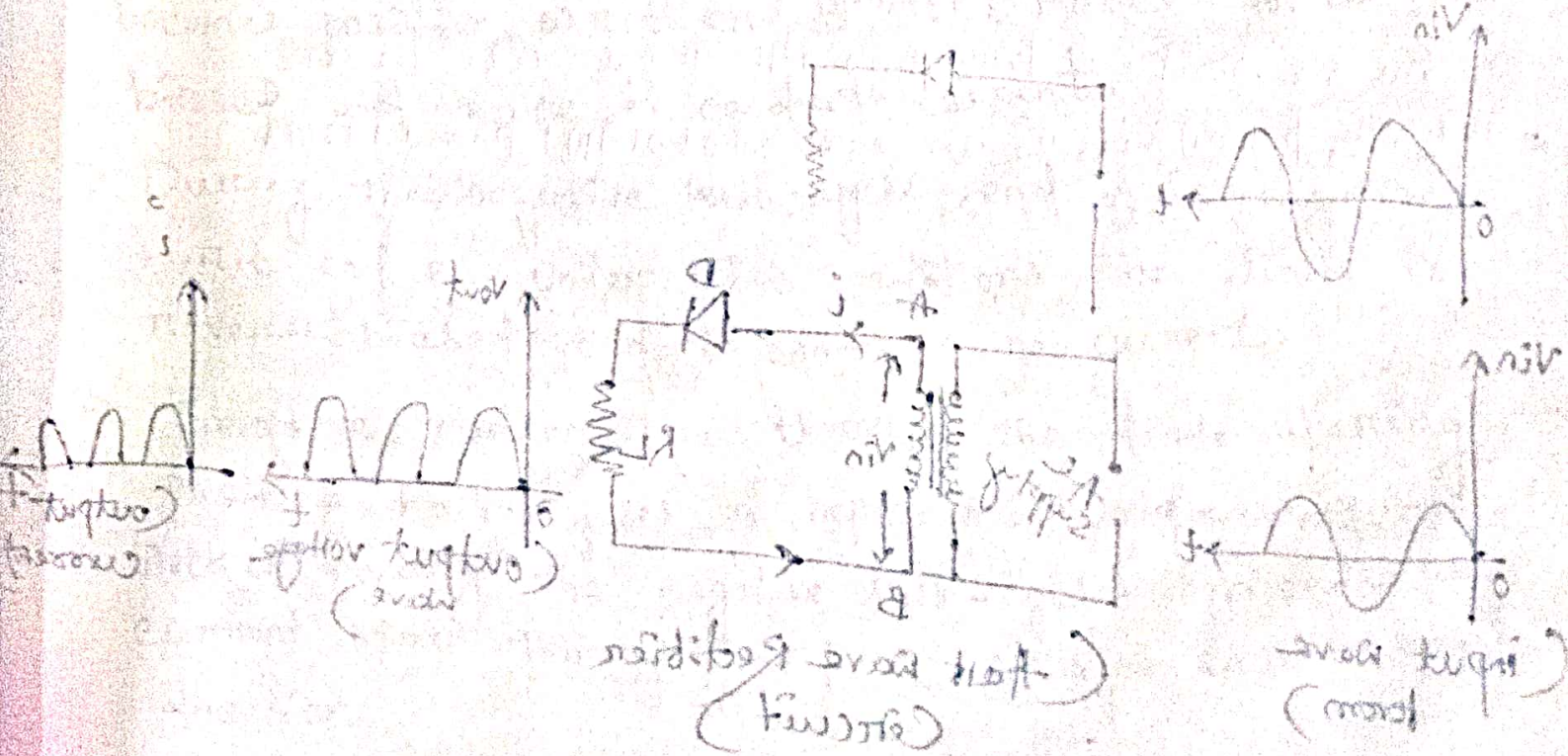
Half-wave rectifiers are less efficient than full-wave rectifiers because they only pass half of the input wave.

output voltage

→ The output voltage of a half-wave rectifier is a pulsating DC voltage.

Ripple:-

The output current of a half-wave rectifier contains a lot of ripple which.



Rectifier

A rectifier is an electrical device that converts alternating current, which periodically reverses direction, to direct current which flows in only one direction. the process is known as rectification.

→ There are two types of rectifier

(i) Half wave rectifier

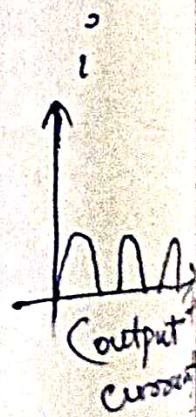
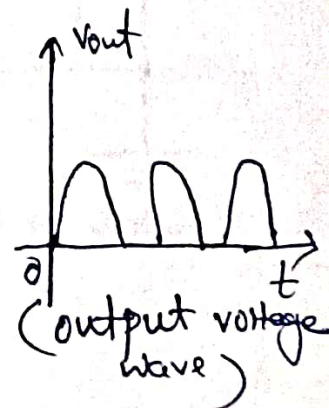
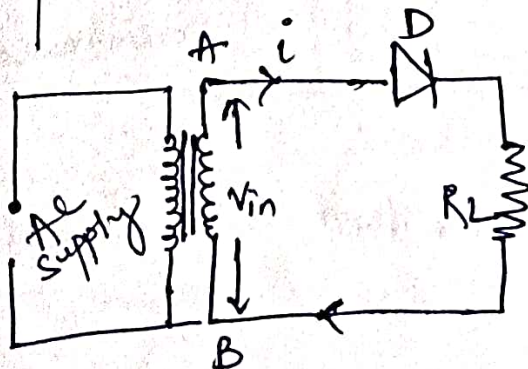
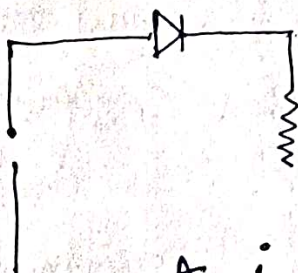
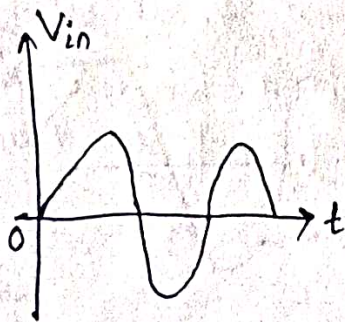
(ii) Full wave rectifier

Half wave rectifier

→ The rectifier conducts current only during the positive half-cycle of input A.C supply.

→ The negative half-cycles of A.C supply is suppressed. during the negative half-cycles, no current is conducted and hence no voltage appears across the load.

→ Therefore current always flows in one direction.



(input wave form)

(Half wave Rectifier Circuit)

- The above bkg shows the circuit where a single crystal diode acts as a half-wave rectifier.
- The A.C supply to be rectified is applied in series with the diode and load resistance R_L . Generally A.C supply is given through a transformer.
- The use of Transformer permits two advantages.
 - Firstly, it allows us to step up or step down the A.C input voltage as the situation demands.
 - Secondly, the transformer isolates the rectifier circuit from power line and thus reduces the risk of electric shock.

Operation

- The A.C voltage across the secondary winding AB changes polarities after every half-cycle.
- During the positive half-cycle of input A.C voltage end A becomes positive w.r.t end B. This makes the diode forward biased and hence it conducts current.
- During the negative half-cycle, end A is negative w.r.t end B. Under these conditions, the diode is reverse biased and it conducts no current.
- Therefore, current flows through the diode during positive half-cycles of input A.C voltage only. It is blocked during the negative half-cycles. In this way current flows through load R_L always in the same direction.

Hence D.C output is obtained across R_L .

→ It may be noted that output across the load is pulsating in the output are further smoothened with the help of filter circuit is obtained.

Disadvantages:-

- The pulsating current in the load contains alternating component whose basic frequency is equal to the supply frequency. Therefore, an elaborate filtering is required to produce steady direct current.
- The A.C supply delivers power only half the time. Therefore the output is low.

Full Wave Rectifier:-

- In full-wave rectification, current flows through the load in the same direction for both half-cycles of input A.C voltage. This can be achieved with two diodes working alternately.
- For the positive half-cycle of input voltage, one diode supplies current to the load and for the negative half-cycle, the other diode does so, current being always in the same direction through the load.
- Therefore, a full-wave rectifier utilizes both half-cycle of input A.C voltage to produce the D.C output.

→ The following two circuit are commonly used for full-wave rectification.

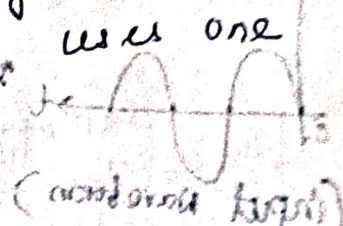
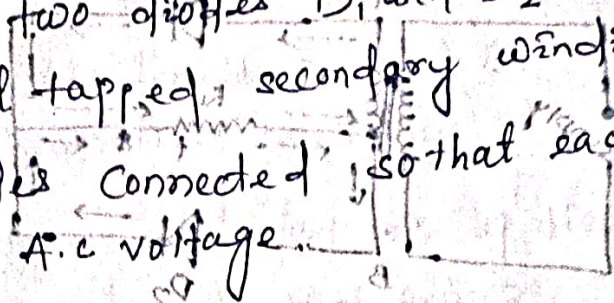
① Centre-Tap full-wave rectifier

② Full wave Bridge rectifier.

* Centre-tap full wave rectifier

Circuit Details. —

→ The circuit employs two diodes D_1 and D_2 as shown in fig below. A current tapped secondary winding AB is used with two diodes connected so that each uses one half-cycle of input A.C. voltage.



→ The Diode D_1 utilizes the A.C. voltage appearing across the upper half (OA) of secondary winding for rectification while diode D_2 uses the lower half winding OB.

Circuit operation

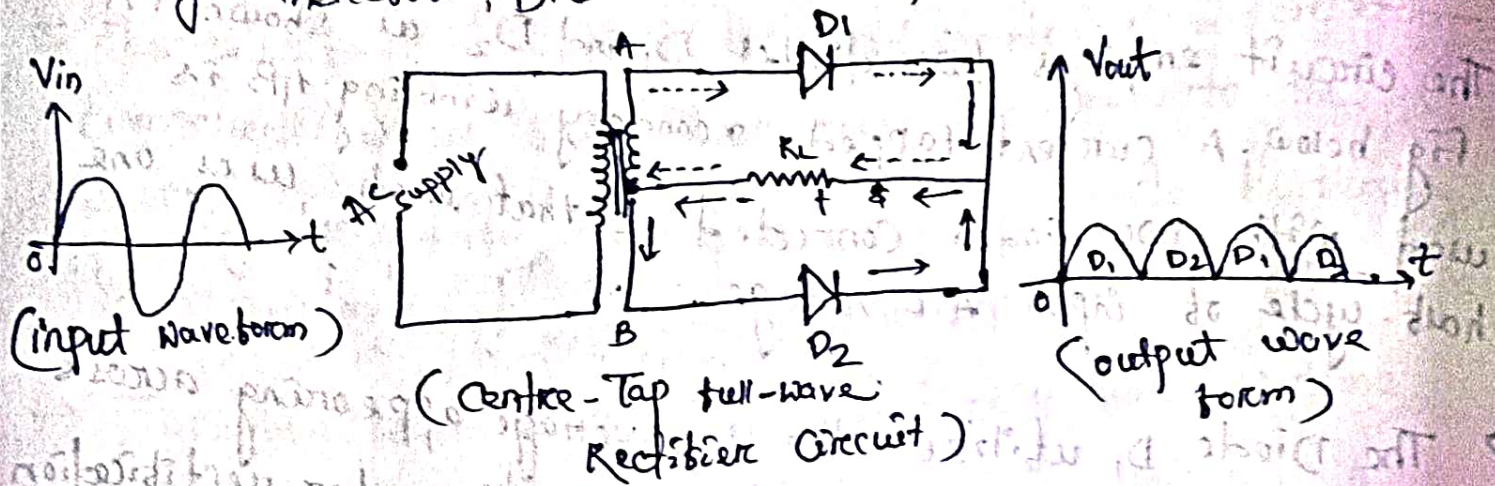
→ During the positive half-cycle of secondary voltage, the end A of the secondary winding becomes positive and end B negative. This makes the diode D_1 forward biased and diode D_2 reverse biased.

→ Therefore diode D_1 conducts while diode D_2 does not, the conventional current flow is through diode D_1 , load resistor R_L and the upper half of secondary winding as shown by the dotted arrows.

→ During the negative half-cycle, end A of the secondary winding becomes negative and end B positive.

→ Therefore, diode D_2 conducts while diode D_1 does not. the conventional current flow is through diode D_2 , load R_L and power half winding shown by solid arrows.

→ It may be seen that current in the load R_L is in the same direction for both half-cycles of input AC. Voltage therefore, D.C. is obtained across the load R_L .



Advantages:

- (i) The D.C. output voltage and load current values are twice than that of a half-wave rectifier.
- (ii) The ripple factor is much less (0.482) than that of half rectifier (1.21).
- (iii) The efficiency is twice (81.2%) than that of half wave rectifier (40.6%).

Disadvantages:

- ① It is difficult to locate the centre tap on the secondary winding.

(ii) The D.C output is small as each diode utilizes only one-half of the transformer secondary voltage.

(iii) The diodes used must have high peak inverse voltage.

* Full-Wave Bridge Rectifier :-

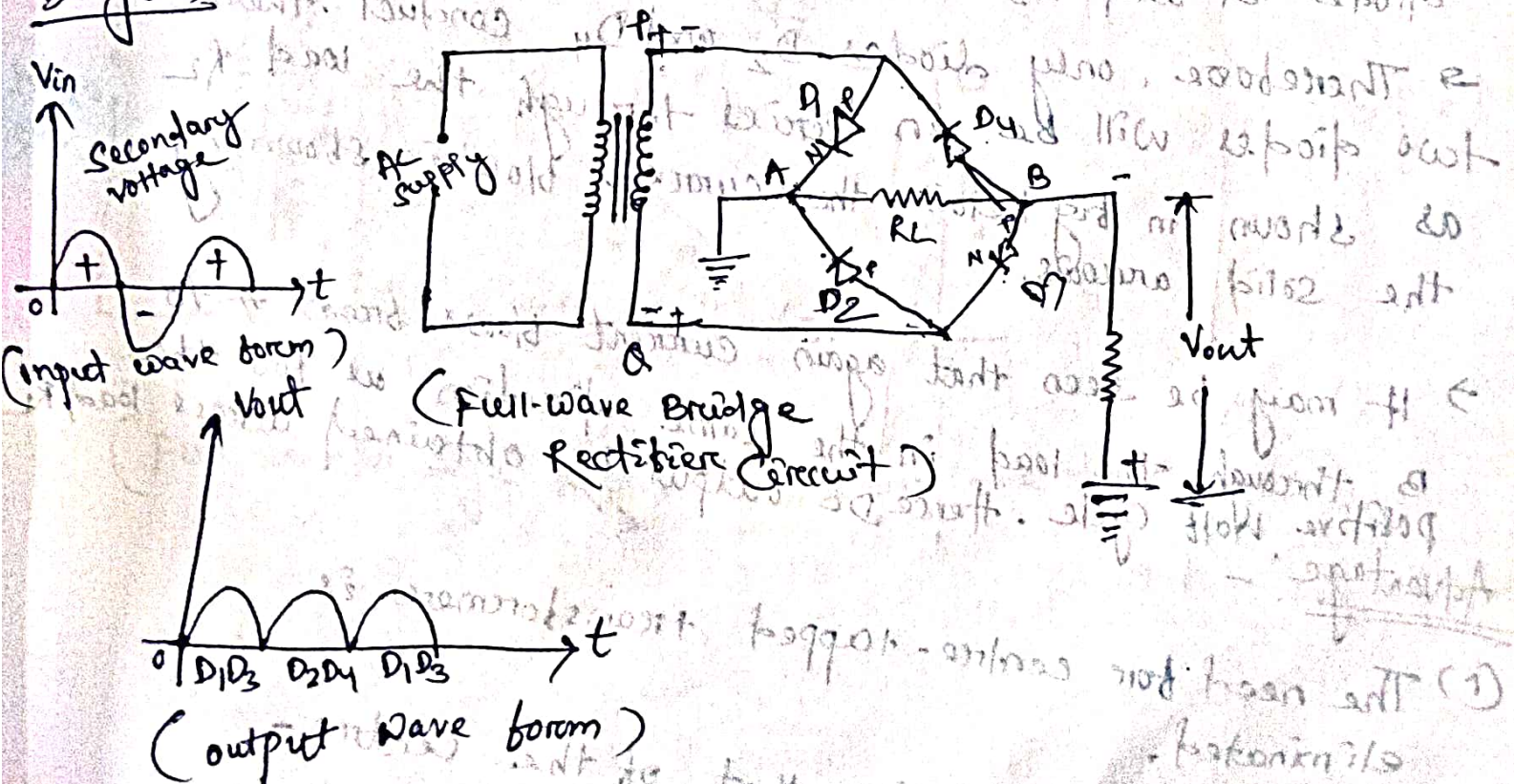
→ The need for a centre tapped power transformer is eliminated in the bridge rectifier.

→ It contains four diodes D_1, D_2, D_3 and D_4 connected to form bridge as shown in fig. below.

→ The A.C supply to be rectified is applied to the diagonally opposite ends of the bridge through the transformer.

→ Between other two ends of the bridge the load resistance R_L is connected.

Diagram



Circuit operation

- During the positive half-cycle of secondary voltage the end P of the secondary winding becomes positive and end Q negative.
- This makes diodes D_1 and D_3 forward biased while diodes D_2 and D_4 are reverse biased.
- Therefore only diode D_1 and D_3 conduct. these two diodes will be in series through the load R_L as shown in fig below. the conventional current flow is shown by dotted arrows. It may be seen that current flows from A to B through the load R_L .
- During the negative half-cycle of secondary voltage end P becomes negative and end Q positive. this makes diodes D_2 and D_4 forward biased whereas diodes D_1 and D_3 are reverse biased.
- Therefore, only diodes D_2 and D_4 conduct. these two diodes will be in series through the load R_L as shown in fig below. the current flow is shown by the solid arrows.
- It may be seen that again current flows from A to B through the load in the same direction as for the positive half cycle. Hence DC output is obtained across load.

Advantage:-

- (1) The need for centre-tapped transformer is eliminated.
- (2) The output is twice that of the centre-tap circuit for the same secondary voltage.

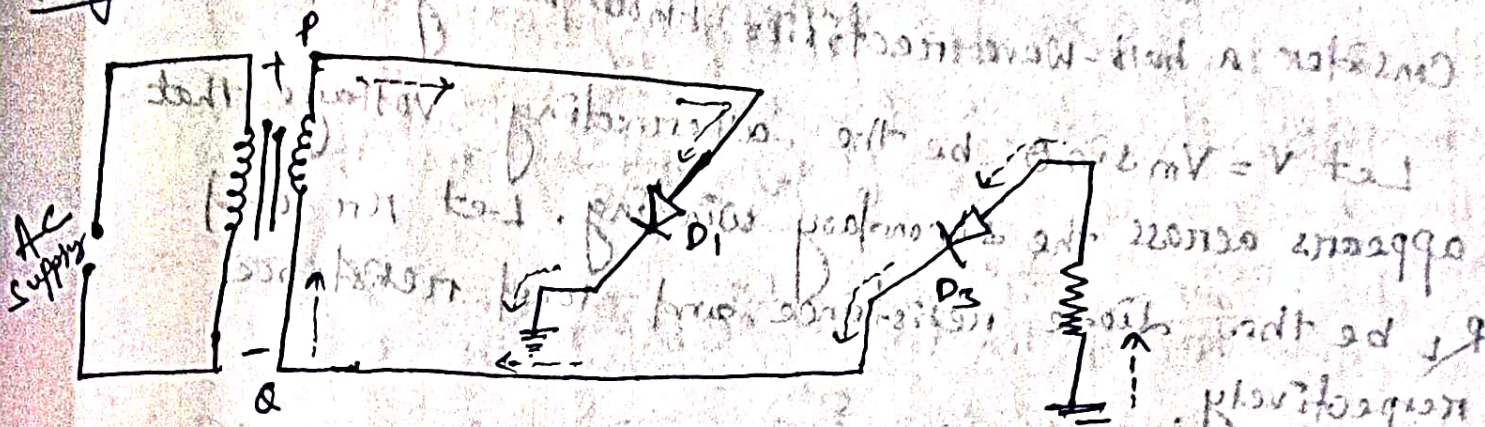
(iii) The PIV is one-half that of the centre-tap circuit

Disadvantage: —

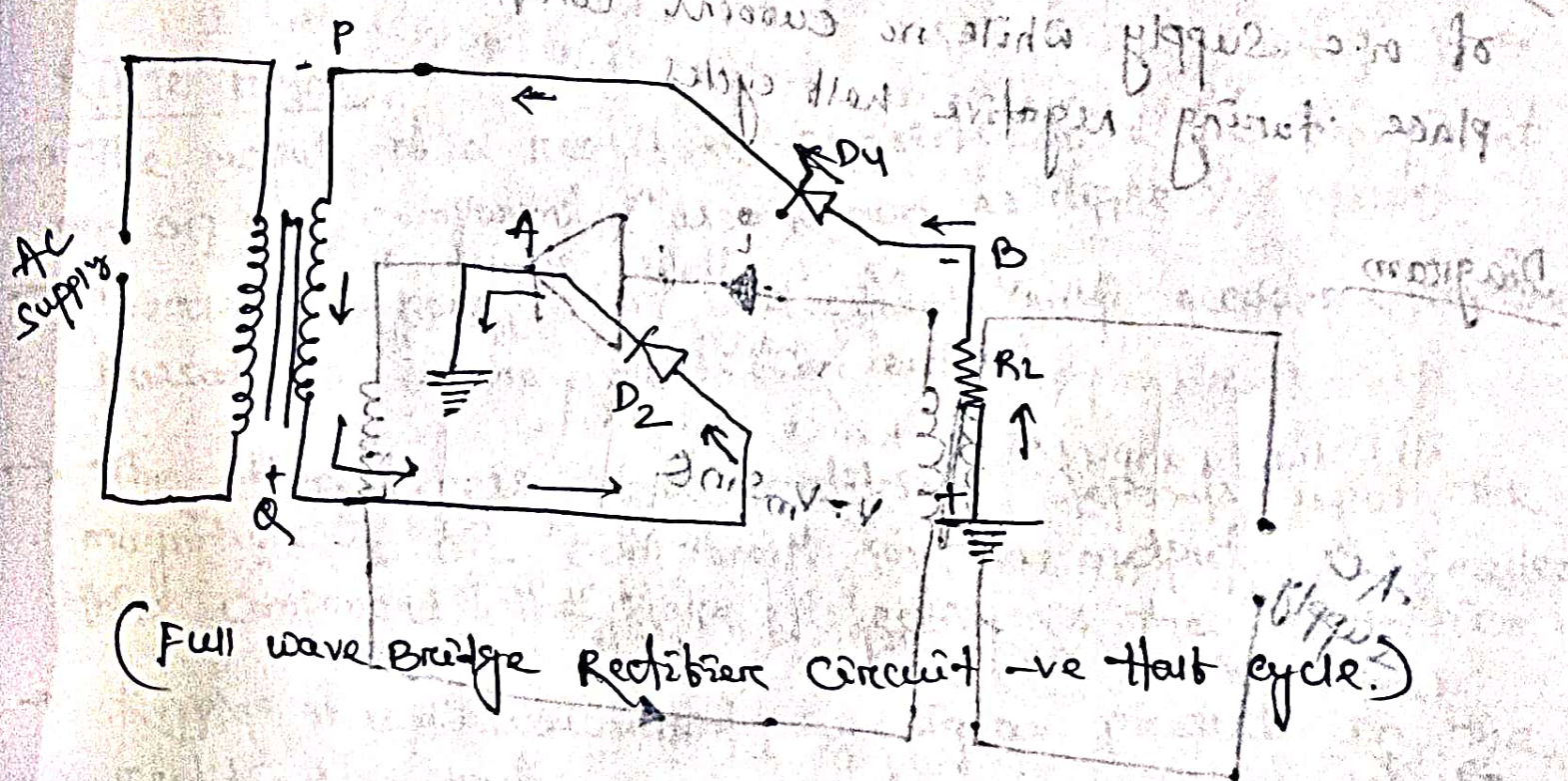
(i) It requires four diodes

(ii) Internal resistance high.

Diagram



(Full wave Bridge Rectifier Circuit in the half cycle)



(Full wave Bridge Rectifier Circuit -ve half cycle)

Mathematical Derivation for rectification efficiency for Half Wave rectifier:-

$$\text{Rectifier efficiency } \eta = \frac{\text{d.c power output}}{\text{input a.c power}}$$

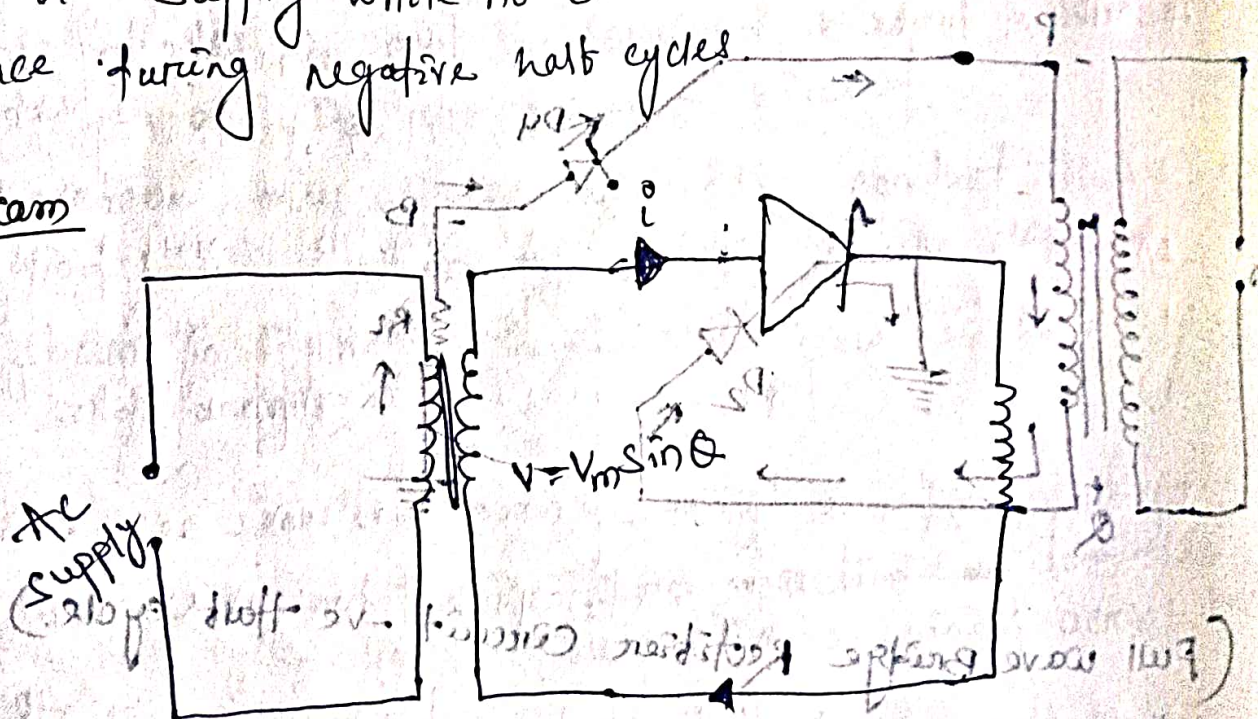
→ The ratio of d.c power output to the applied input a.c power is η .

→ Consider a half-wave rectifier shown in fig

→ Let $V = V_m \sin \theta$ be the alternating voltage that appears across the secondary winding. Let r_f and R_L be the diode resistance and load resistance respectively.

→ The diode conducts during positive half cycles of a.c supply while no current conduction takes place during negative half cycles.

Diagram



output D.C Power :-

→ The output current is pulsating direct current. therefore in order to find D.C power, average current has to be found out.

$$\text{Average value} = \frac{\text{Area under the curve over a cycle}}{\text{Base}} = \frac{\int i_o d\omega}{2\pi}$$

$$\begin{aligned} I_{av} = I_{dc} &= \frac{1}{2\pi} \int i_o d\omega = \frac{1}{2\pi} \int_{\sin^{-1} 0}^{\sin^{-1} 1} V_m \sin \omega d\omega = \int \sin \omega d\omega \\ &= V_m \sin \omega [\cos \omega] = \frac{V_m}{2(\pi/4 - 0)} \times [(-\cos \pi) - (-\cos 0)] \\ &= V_m \times \frac{2}{\pi} = \frac{2}{\pi} V_m \end{aligned}$$

$$\therefore \text{DC power, } P_{dc} = I_{dc}^2 \times R_L = \left(\frac{2}{\pi} V_m\right)^2 \times R_L$$

Ripple factor :-

- The output of a rectifier consists of a d.c component and an a.c component (also known as ripple).
- The a.c component is undesirable and accounts for the pulsations in the rectifier output.
- The effectiveness of a rectifier depends upon the magnitude of a.c component in the output. the smaller this component, the more effective is the rectifier.
- Ripple means unwanted a.c signal present in the rectified output.
- The ratio of R.M.S value of A.C component to the D.C component in the rectifier output is known as ripple factor.

$$\text{Ripple factor} = \frac{\text{r.m.s value of a.c component}}{\text{Value of d.c component}} = \frac{V_{ac}}{V_{dc}}$$

Filter Circuit

- Generally, a rectifier is required to produce pure DC supply for using at various places in the electronic circuit.
- However, the output of a rectifier has pulsating character, it contains A.C and D.C components.
- The A.C component is undesirable and must be kept away from the load.
- To do so, a filter circuit is used which removes the A.C component and allows only the D.C components to reach the load.
- A filter circuit is a device which removes the A.C component of rectifier output but allows the D.C component to reach the load.
- A filter circuit is a device which removes the A.C component of rectifier output but allows the D.C component to reach the load.
- A filter circuit is generally a combination of inductors (L) and capacitors (C).
- The filtering action of L and C depends upon the basic electrical principles.
- A capacitor offers infinite reactance to d.c.
- We know that $X_c = 1/\omega C$ but for d.c $\omega = 0$
 $\therefore X_c = 1/2\pi f C = 1/2\pi \times 0 \times C = \infty$

Hence, a capacitor does not allow d.c to pass through it.

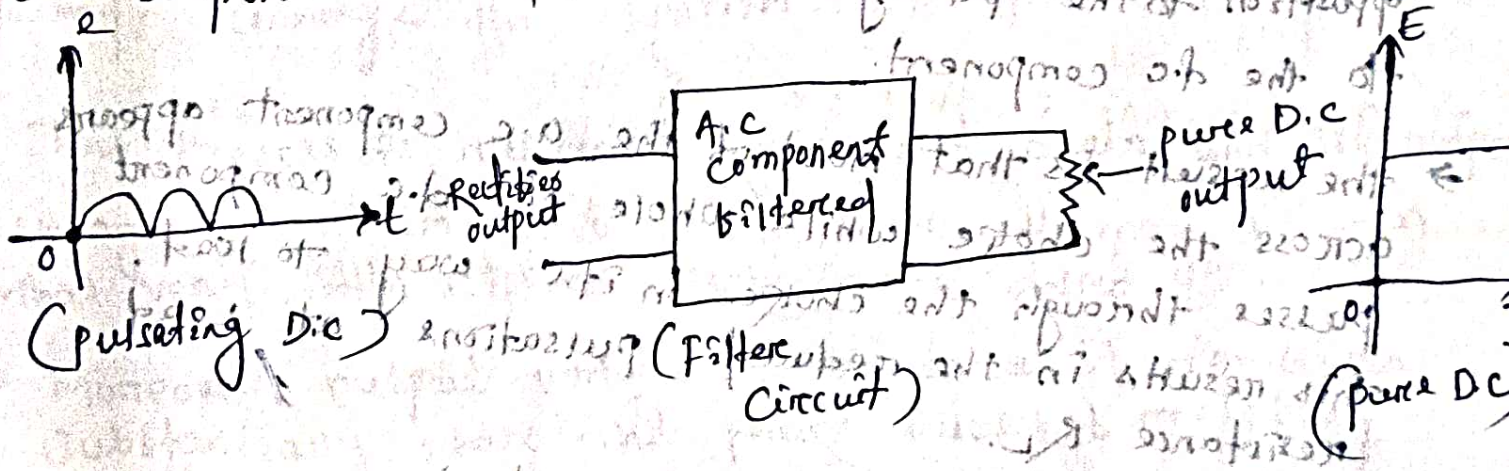
→ We know $X_L = 2\pi fL$. for d.c, $f = 0$

$$\therefore X_L = 2\pi \times 0 \times L = 0$$

Hence inductor passes d.c quite readily.

→ A capacitor passes A.C. but does not pass D.C. at all. on the other hand, an inductor opposes A.C. but allows D.C. to pass through it.

→ It then becomes clear that suitable network of R and C can effectively remove the A.C. component allowing the D.C. component to reach the load.



Types of filter Circuit:-

There are different types of filter circuit according to their construction. the most commonly used filter circuit are.

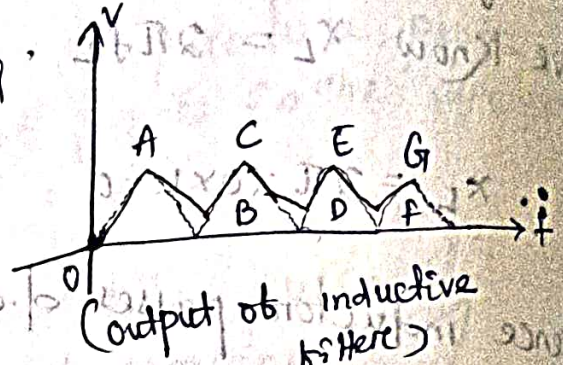
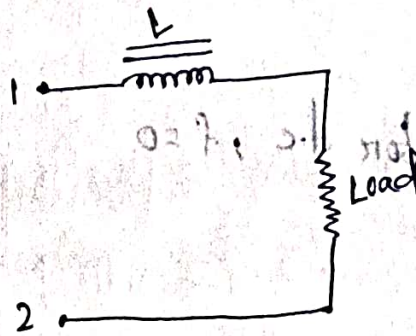
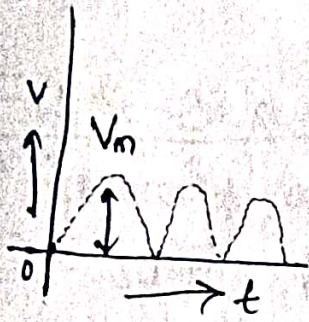
* Inductive filter or series inductor

* Capacitor filter or shunt capacitor

* Choke input filter or LC filter and

* Capacitor input filter or π filter.

* Inductive filter or series inductor:-



(Rectified output pulsating d.c.)

(Inductive filter circuit)

(Output of inductive filter)

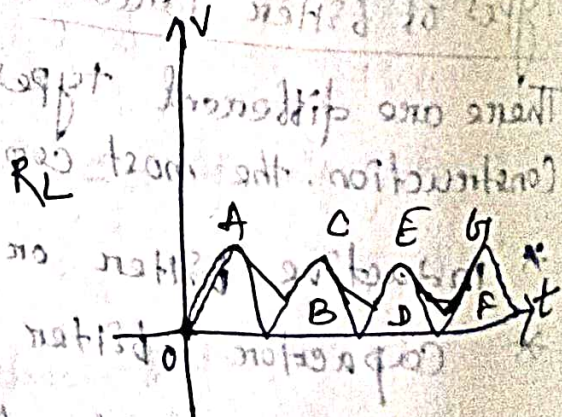
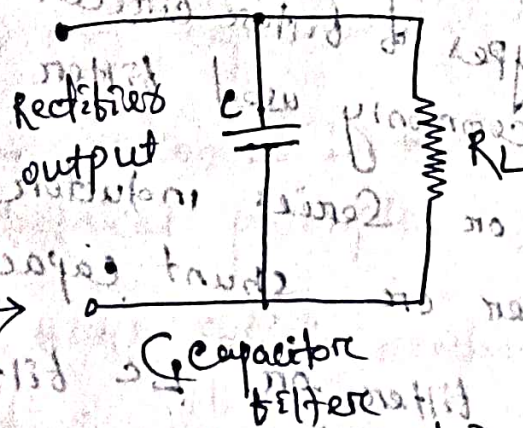
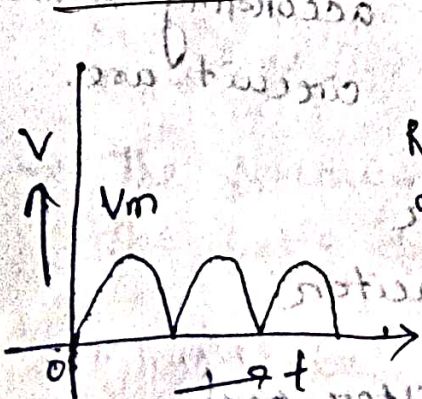
→ A Typical inductive filter circuit. It consists of an inductor placed across the rectifier output in series with load.

→ the choke inductor with iron core offers high opposition to the passage of a.c. component but no opposition to the d.c. component.

→ the result is that most of the a.c. component appears across the choke while whole of d.c. component passes through the choke in its way to load.

(This results in the reduced pulsations at load resistance R_L .)

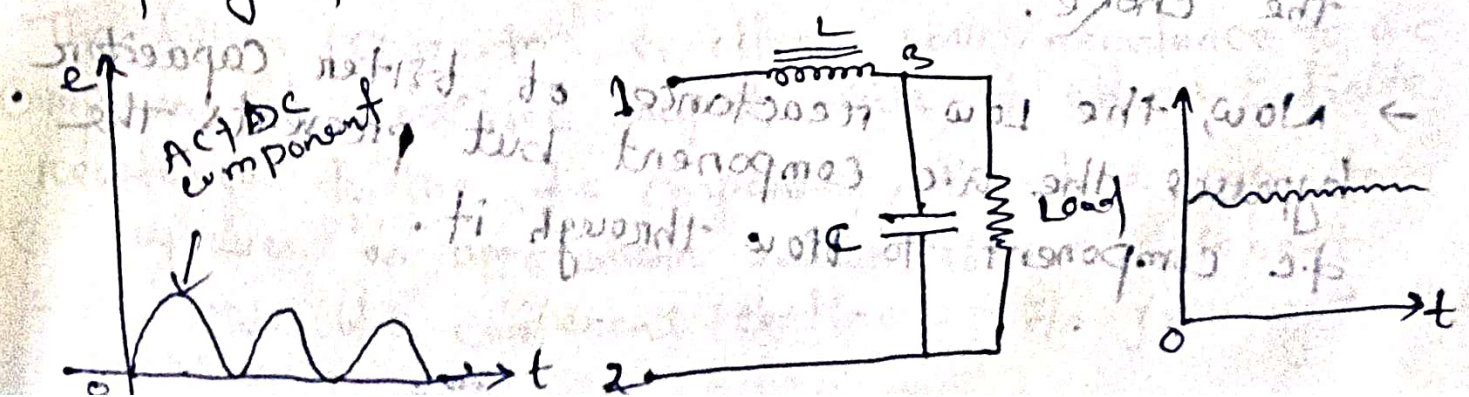
Capacitor filter or shunt capacitor:-



Rectified output

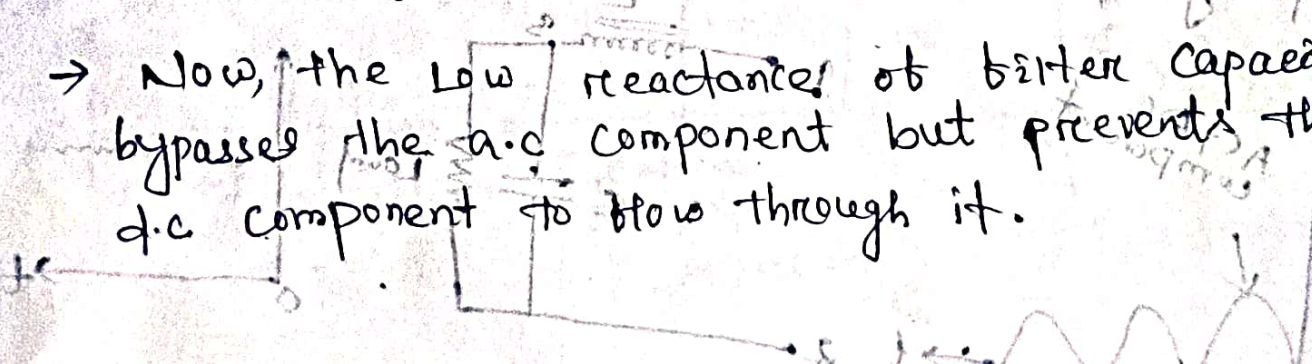
Capacitor filter circuit

- A typical capacitor filter circuit. It consists of a capacitor C placed across the rectifier output in parallel with load R_L .
- The pulsating direct voltage of the rectifier is applied across the capacitor. As the rectifier voltage increases, it charges the capacitor and also supplies current to the load.
- At the end of quarter cycle, the capacitor is charged to the peak value V_m of the rectifier voltage.
- Now, the rectifier voltage starts to decrease. As this occurs, the capacitor discharge through the load, and voltage across it decreases as shown by the line AB in fig (1).
- The voltage across load will decrease only slightly because immediately the next voltage peak comes and recharge the capacitor.
- This process is repeated again and again and the output voltage waveform becomes ABCDEFG. It may be seen that very little ripple is left in the output.
- Moreover, output voltage is higher as it remains substantially near the peak value of rectifier output voltage.
- The capacitor filter circuit is extremely popular because of its low cost, small size, little weight and good characteristics.



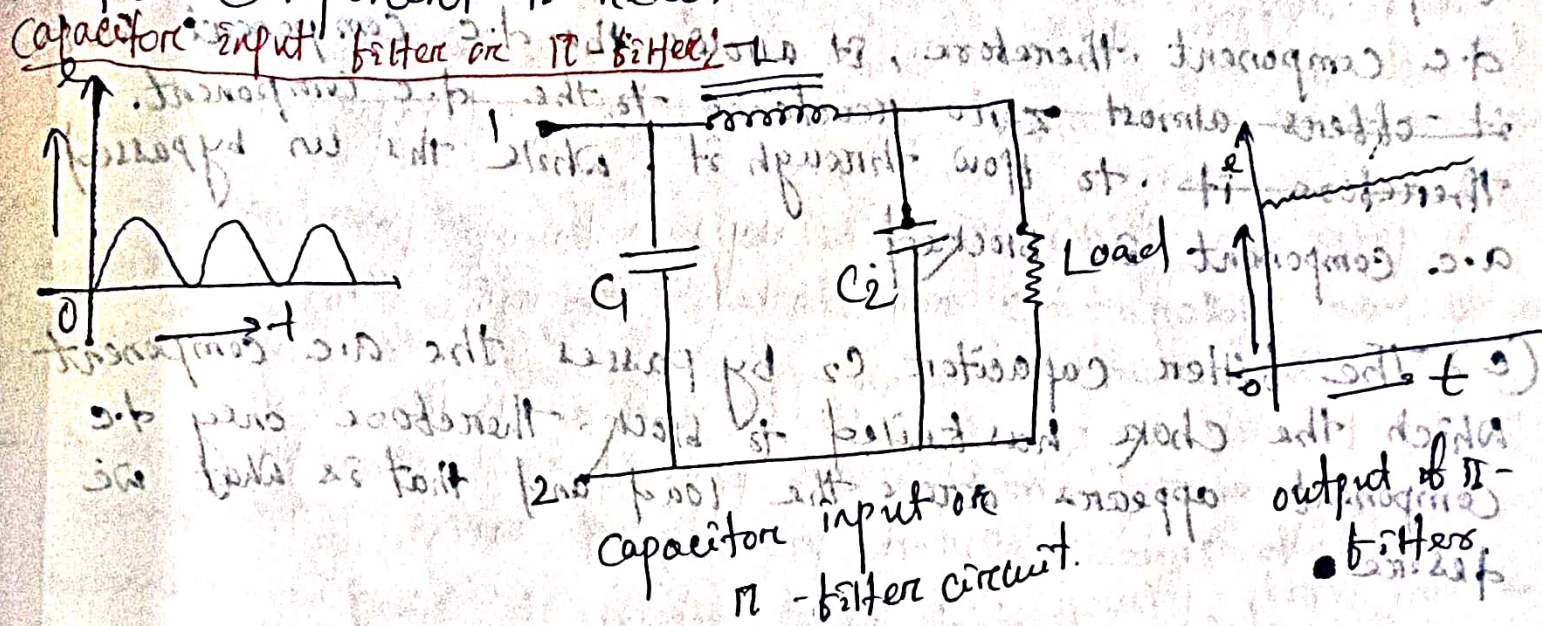
choke input filter or L Filter:

- Fig shows a typical choke input filter circuit. It consists of a choke L connected in series with the rectifier output and a filter capacitor C across the load.
- Only a single filter section is shown, but several identical sections are often used to reduce the pulsations as effectively as possible.
- The pulsating output of the rectifier is applied across terminals 1 and 2 of the filter circuit.
- As the pulsating output of rectifier contains a.c. and d.c. components, the choke offers high opposition to the passage of a.c. component but negligible opposition to the d.c. component.
- The result is that most of the a.c. component appears across the choke while whole of d.c. component passes through the choke on its way to load. This results in the reduced pulsations at terminal 3.
- At terminal 3, the rectifier output contains d.c. component and the remaining part of a.c. component which has managed to pass through the choke.
- Now, the low reactance of filter capacitor bypasses the a.c. component but prevents the d.c. component to flow through it.



Therefore, only d.c component reaches the load.

→ In this way, the filter circuit has filtered out the a.c component from the rectifier output, allowing d.c component to reach the load.



→ Fig shows a typical capacitor input filter or π -filter. It consists of a filter capacitor C_1 connected across the rectifier output, a choke L in series and another filter capacitor C_2 connected across the load.

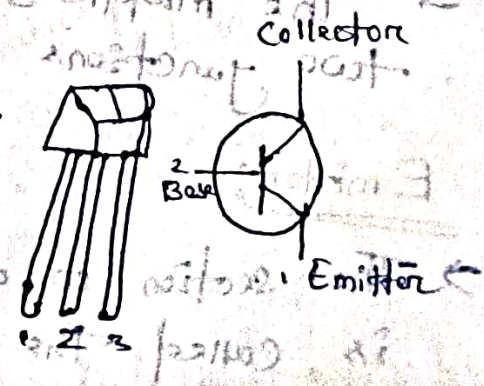
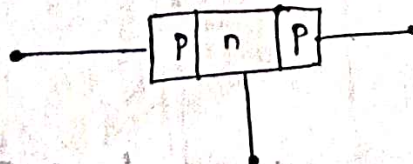
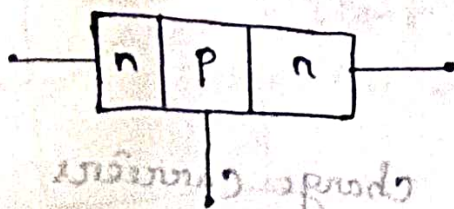
→ only one filter section is shown but several identical sections are often used to improve the smoothing action. The pulsating output from the rectifier is applied across the input terminal of the filter.

→ The filtering action of the three components viz C_1 , L and C_2 of this filter is obtained.

① The filter capacitor C_1 offers low reactance to a.c component of rectifier output while it offers infinite reactance to the d.c component, therefore, capacitor C_1 bypasses an appreciable amount of a.c component while the d.c component continues its journey to the choke L .

Transistor:-

- When a third doped element is added to a crystal diode in such a way that two PN junctions are formed the resulting device is known as a Transistor.
- This is a new type of electronic device which can amplify a weak signal in a fashion comparable and often superior to that realized by vacuum tubes.
- A transistor consists of two PN junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types. Hence Transistor is classified into two types, namely
 - (i) n-p-n-transistor
 - (ii) p-n-p transistor
- An n-p-n transistor is composed of two n-type semiconductor separated by a thin section of p-type.
- However, a p-n-p transistor is formed by two p-section separated by a thin section of n-type as shown in figure below.



NAMING:

- A Transistor has two pn junction. one junction is forward biased, and the other is reverse biased.
 - The forward biased junction has a low resistance path whereas a reverse biased junction has a high resistance path.
 - The weak signal is introduced in the low resistance circuit and output is taken from the high resistance circuit. therefore, a transistor transfers a signal from a low resistance to high resistance.
 - The prefix 'trans' means the signal transfer property of the device while 'istor' classified as a solid element in the same general family with resistors.
- * Naming The transistor Terminals :-

→ A transistor (PNP or NPN) has three sections of doped semiconductor.

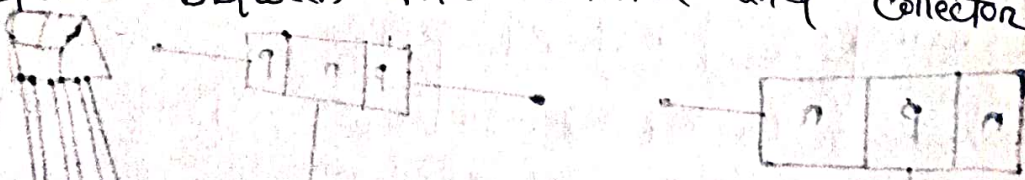
→ The section on one side is the emitter and the section on the opposite side is the collector.

→ The middle section is called the base and forms two junctions between the emitter and collector.

Emitter:

→ The section on one side that supplies charge carriers is called the emitter.

→ The emitter is always forward biased, base so that it can supply a large number of majority carriers.



→ The emitter of PNP Transistor is forward biased and supplies hole charges to its junction with the base. Similarly the emitter (n-type) of NPN transistor has a forward bias and supplies free electrons to its junction with the base.

Collector:-

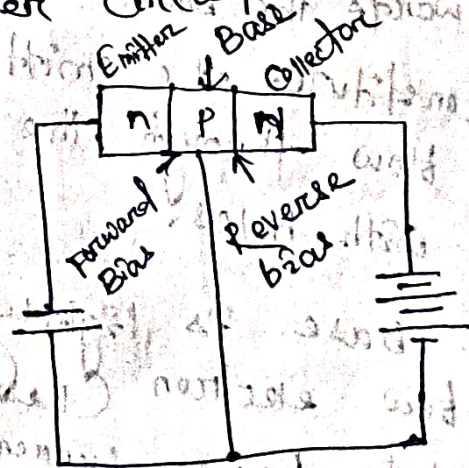
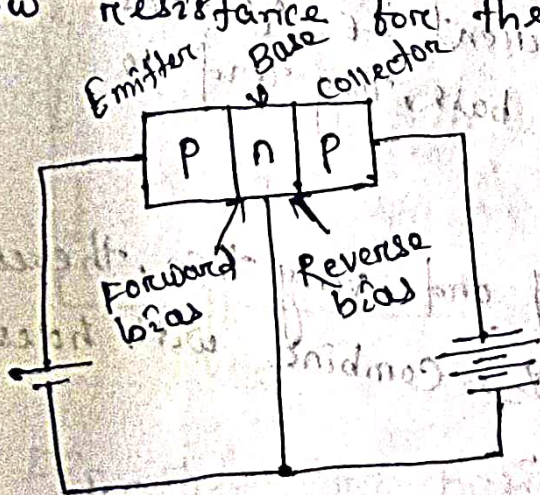
→ The section on the other side that collects the charges is called the collector. The collector is always reverse biased. Its function is to remove charges from its junction with the base.

→ The collector (p-type) of PNP transistor has a reverse bias and receives hole charges that flow in the output circuit. Similarly the collector of NPN transistor has reverse bias & receives electrons.

Base:-

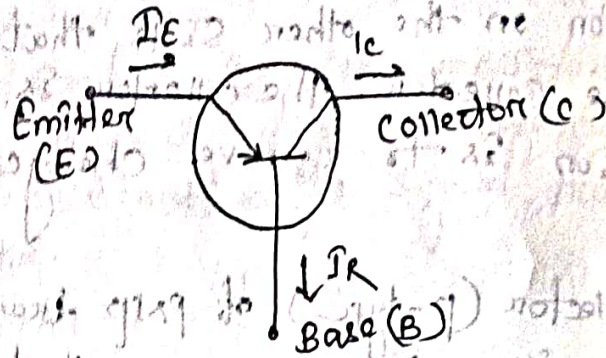
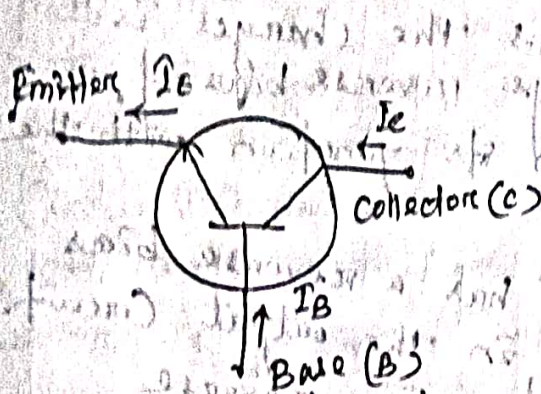
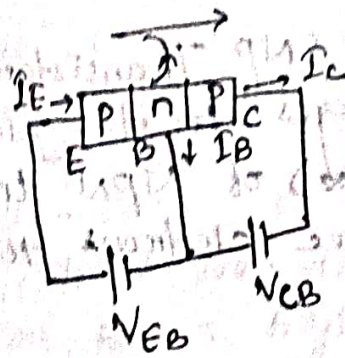
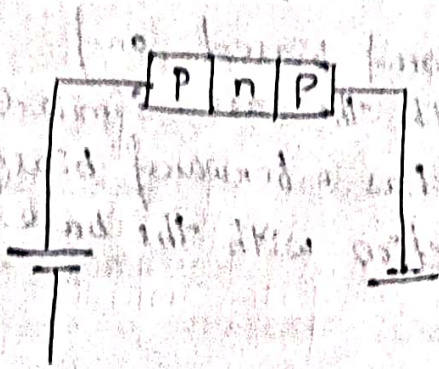
The middle section which forms two PN junctions between emitter & collector is called base.

→ The base-emitter junction is forward biased, allowing low resistance for the emitter circuit.



The base-collector junction is reverse biased and provides high resistance in the collector circuit.

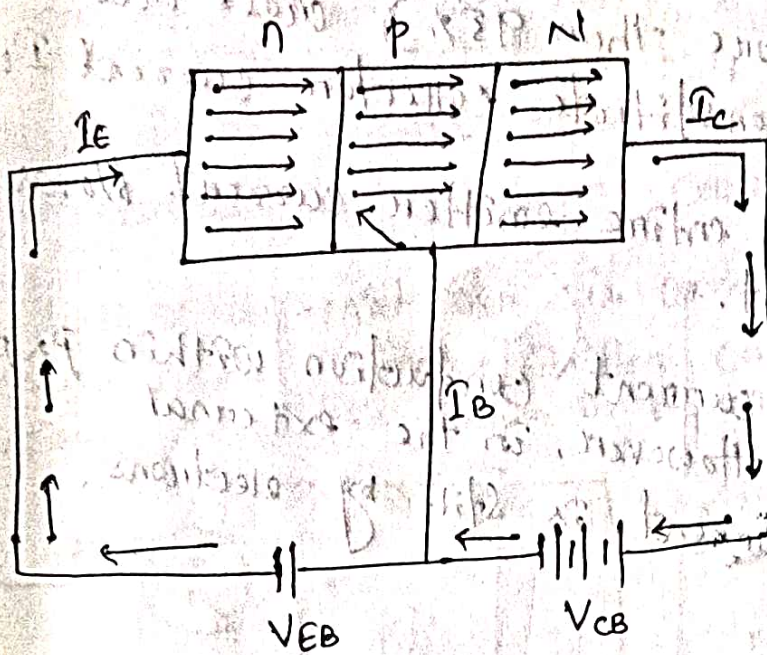
Transistor symbol:-



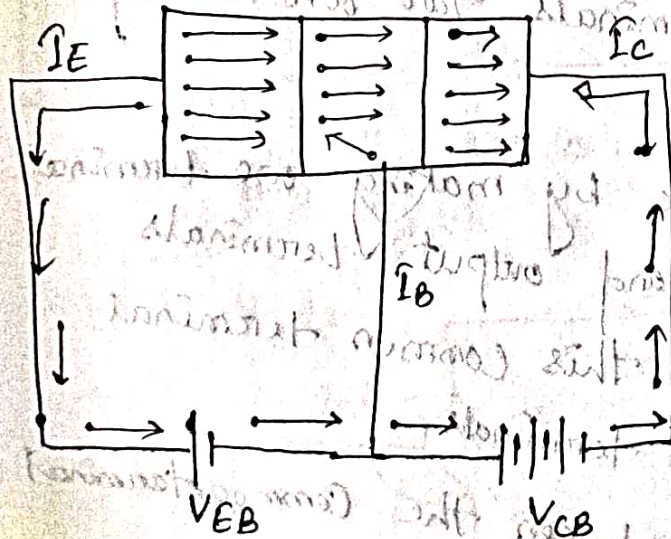
Working of NPN Transistor (NPN)

- The NPN Transistor, with forward bias to emitter-base junction and reverse bias to collector-base junction.
- The forward bias causes the electrons in the n-type emitter to flow towards the base.
- This constitutes the emitter current I_E . As these electrons flow through the p-type base, they tend to combine with holes.
- As the base is lightly doped and very thin, therefore only a few electrons (less than 5%) combine with holes to constitute base current I_B .
- The remainder (more than 95%) cross over into the collector region to constitute Collector Current I_C .

- In this way, almost the entire emitter current flows in the collector circuit.
- It is clear that emitter current is the sum of collector and base current $I_E = I_B + I_C$



Working of PNP transistor (PNP)



- Fig shows the basic connection of a PNP transistor.
- The forward bias causes the holes in the p-type emitter to flow towards the base.
- This constitutes the emitter current I_E .

- As these holes cross into n-type base, they tend to combine with the electrons.
- As the base is lightly doped and very thin, therefore only a few holes (less than 5%) combine with the electrons. the remainder (more than 95%) cross into the collector region to constitute collector current I_c .
- In this way, almost the entire emitter current flows in the collector circuit.
- It may be noted that current conduction within pnp transistor is by holes. However, in the external connecting wires, the current is still by electrons.

Transistor Connections: —

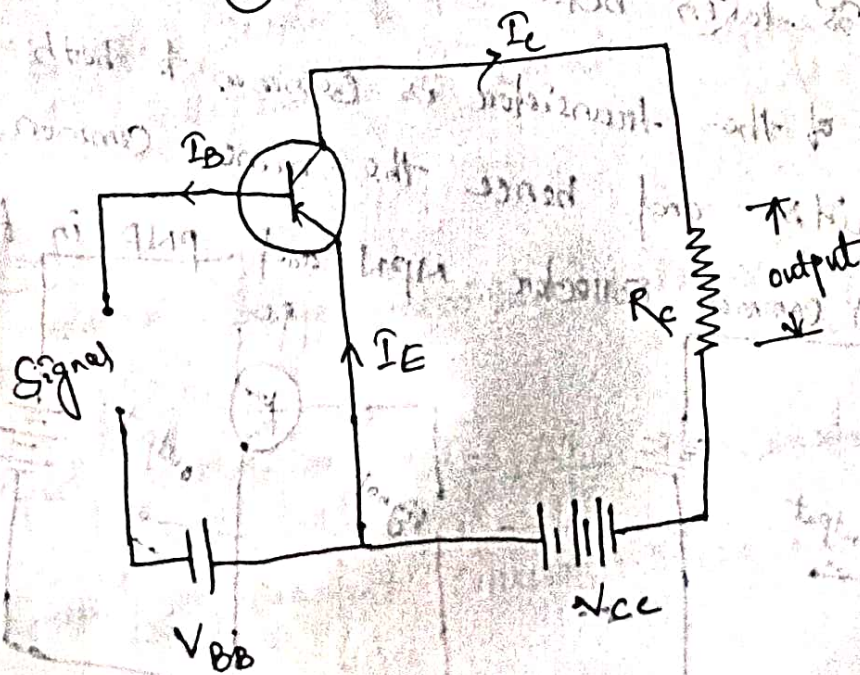
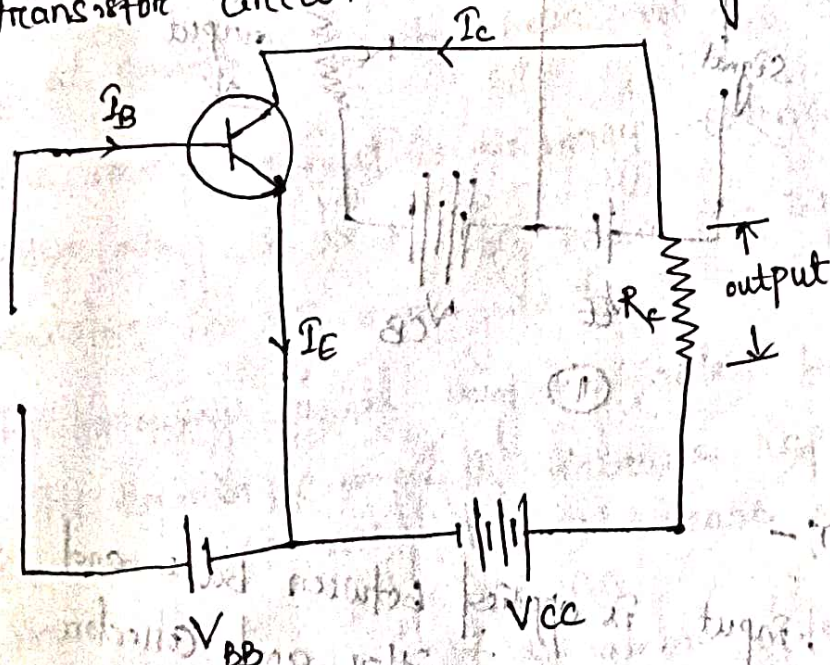
- There are three leads in a transistor such as emitter base and collector terminals.
- However, when a transistor is to be connected in a circuit, we require four terminals two for the input and two for the output.
- This difficulty is overcome by making one terminal of it in common to both input and output terminals.
- The input is fed between this common terminal and one of the other two terminals.
- The output is obtained between the common terminal and the remaining terminal.
- So a transistor can be connected in a circuit in the following ways: —

- (i) Common Base Connection
- (ii) Common Emitter Connection
- (iii) Common Collector

(i) Common Base Connection

In this circuit arrangement, input is applied between ^{base} emitter and output is taken from collector and ~~base~~ emitter.

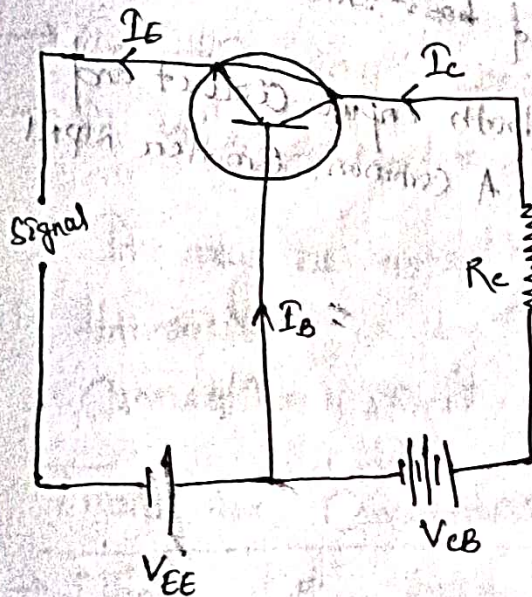
Here, base of the transistor is common to both input circuit and hence the name Common Emitter Connection. A Common Emitter NPN transistor circuit is shown in figure.



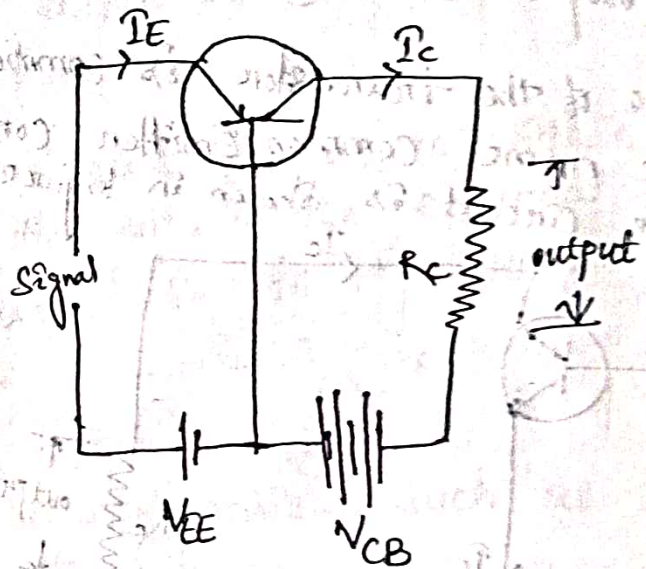
Common Base Connection:-

In this circuit arrangement, input is applied between emitter and base and output is taken from collector and base.

Here, base of the transistor is common to both input and output circuits and hence the name Common Base connection. A Common Base NPN and PNP in figure below.



(i)

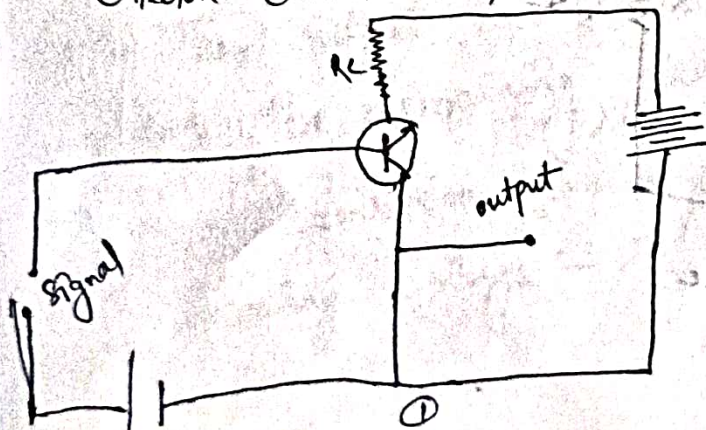


(ii)

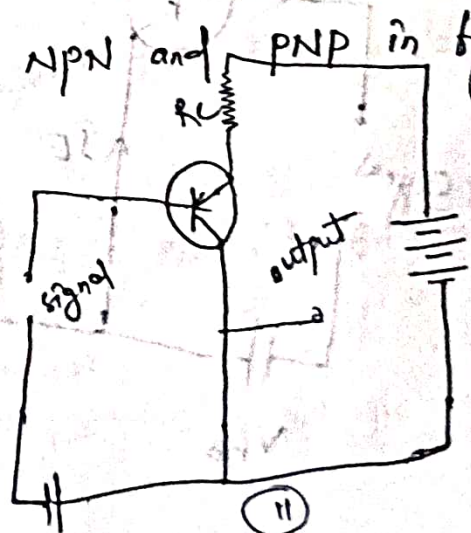
Common Collector Connection:-

In this circuit arrangement, input is applied between base and collector while output is taken between the emitter and collector.

Here, collector of the transistor is common to both input and output circuits and hence the name Common Collector Connection. A common collector NPN and PNP in figure below.



(i)



(ii)

Transistor Characteristics:-

① Characteristics of Common Base Connection:-

- The complete electrical behaviour of a transistor can be described by stating the interrelation of the various current and voltage.
- These relationship can be conveniently displayed graphically and the curves thus obtained are known as the characteristics of transistor.
- The most important characteristics of common base connection are input characteristics.

① Input characteristics:-

- It is the curve between emitter current I_E & emitter-base voltage V_{BE} at constant collector-base voltage V_{CB} .
- The emitter current is generally taken along y-axis and emitter-base voltage along x-axis. It shows the input characteristics of a typical transistor in CB arrangement.
- The following points may be noted from these characteristics:-
 - The emitter current I_E increases rapidly with small increase in emitter-base voltage V_{EB} . It means that input resistance is very small.
 - The emitter current is almost independent of collector-base voltage V_{CB} . This leads to the conclusion that emitter current is almost independent of collector voltage.

Input Resistance:-

- It is the ratio of change in emitter-base voltage to the resulting change in input resistance $r_i = \frac{\Delta V}{\Delta I_E}$ at constant V_{CB} .
- emitter current at constant collector-base voltage.

→ In fact, input resistance is the opposition offered to the signal current. As a very small V_{EB} is sufficient to produce a large flow of emitter current I_E thus, input resistance is quite small, of the order of a few ohms.

(B) output characteristics:—

→ It is the curve between collector current I_C and collector base voltage V_{CB} at constant emitter current I_E .

→ Generally, collector current is taken along y-axis and collector base voltage along x-axis.

→ The fig. shows the input and output characteristics of a typical transistor in CB arrangement.

→ The following points may be noted from characteristics

→ The collector current I_C varies with V_{CB} only at very low voltage ($< 1V$). the transistor is never operated in this region.

→ When the value of V_{CB} is raised above 1-2V, the collector current becomes constant as indicated by straight horizontal curve. It means that now I_C is independent of V_{CB} and depends only upon I_E only. This is consistent with the theory that the emitter current flows almost entirely to the collector terminal. the transistor always operated in this region.

→ A very large change in collector-base voltage produces only a tiny change in collector current. This means that output resistance is very high.

output Resistance:—

→ It is the ratio of change in collector-base voltage to the resulting change

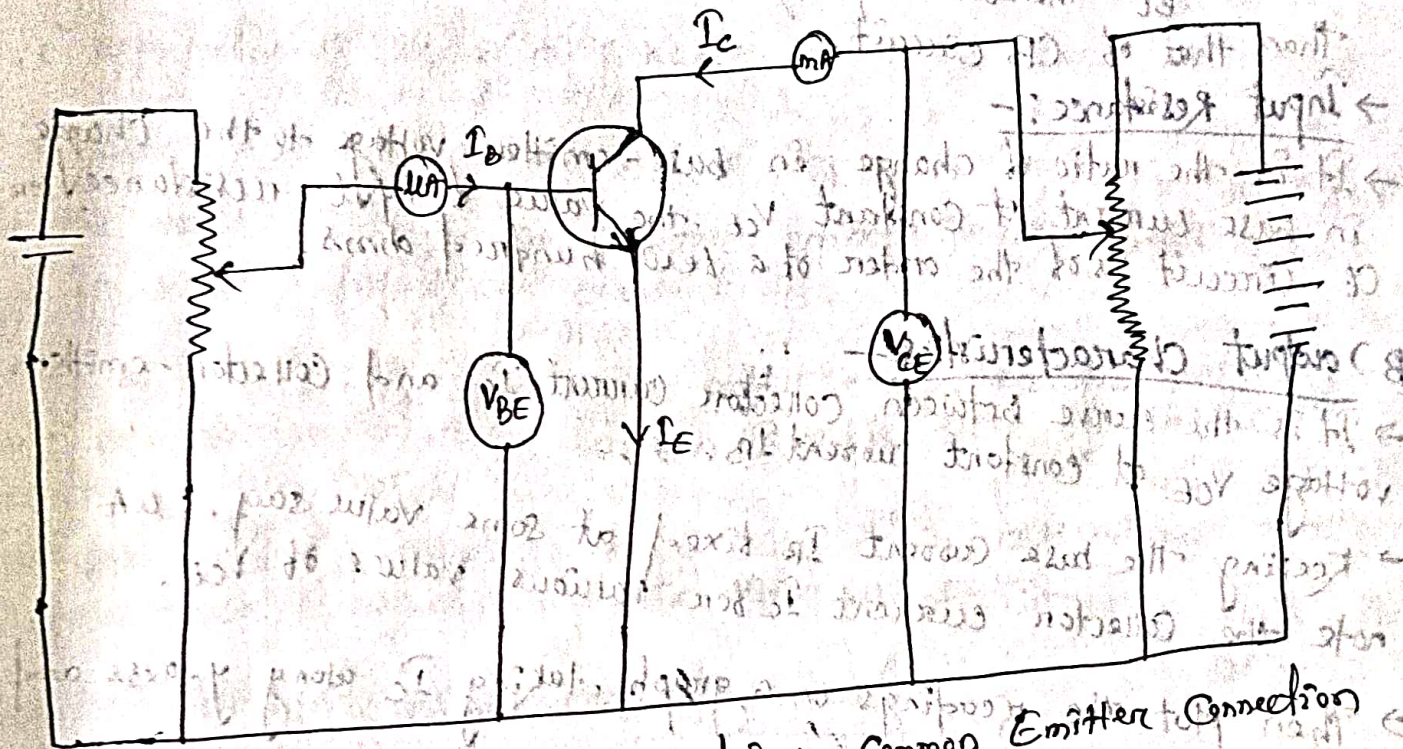
$$\text{output resistance } r_o = \frac{\Delta V_{CB}}{\Delta I_C} \text{ at constant } I_E$$

in collector current of CB circuit is very high, of the order of several tens of Kilo-ohms.

→ The output resistance of CB circuit is very high, of the order of several tens of $k\Omega$ -ohm.

(a) Characteristics of Common Emitter Connection:—

→ The important characteristics of this circuit arrangement are the input characteristic and output characteristics.

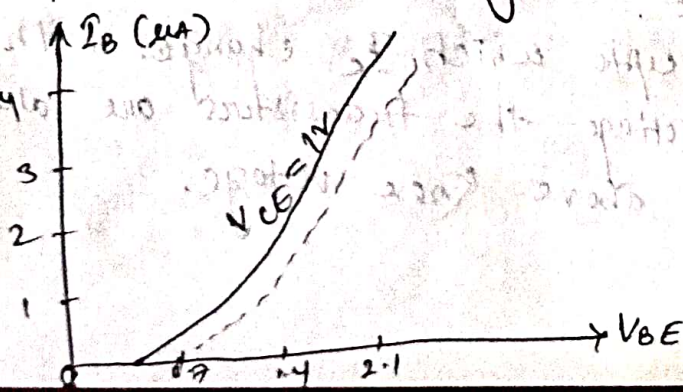


(Circuit Arrangement for studying Common Emitter Connection of transistor)

(A) Input characteristics:—

→ It is the curve between base current I_B & base-emitter voltage V_{BE} at constant collector emitter volt V_{CE} . The input characteristics of a CE connection can be determined by the circuit shown in fig keeping

Can be note the base current I_B for various values of V_{BE} .
 → Then plot the readings obtained on the graph, taking I_B along y-axis and V_{BE} along x-axis this gives the input characteristic at $V_{CE} = 10V$ as shown in fig.



→ The following points may be noted from the characteristics:-
→ The characteristic resembles that of a forward biased diode curve. This is expected since the base-emitter section of transistor is a diode and it is forward biased.

→ As compared to CB arrangement, I_B increases less rapidly with V_{BE} . Therefore input resistance of a CE circuit is higher than that of CB circuit.

→ Input Resistance:-

→ It is the ratio of change in base-emitter voltage to the change in base current at constant V_{CE} . The value of input resistance for CE circuit is of the order of a few hundred ohms.

(B) output characteristics:-

→ It is the curve between collector current I_C and collector-emitter voltage V_{CE} at constant current I_B .

→ Keeping the base current I_B fixed at some value say, 5 μA note the collector current I_C for various values of V_{CE} .

→ Then plot the readings on a graph, taking I_C along y-axis and V_{CE} along x-axis.

→ This gives the output characteristics at $I_B = 5 \mu A$ as shown in fig. The test can be repeated for $I_B = 10 \mu A$ to obtain the new output characteristic as shown in fig.

→ Following similar procedure, a family of output characteristics can be drawn as shown in fig.

→ The following points may be noted from the characteristics

→ The collector current I_C varies with V_{CE} for V_{CE} between 0 and I_V only. After this, I_C becomes almost constant and independent of V_{CE} .

→ This value of V_{CE} upto which I_C changes with V_{CE} is called the knee voltage. The transistors are always operated in the region above knee voltage.

→ Above knee voltage, I_C is almost constant. However a small increase in I_C with increasing V_{CE} is caused by the collector depletion layer getting wider and capturing a few more majority carriers before electron-hole combinations occur in the base area.

→ For any value of V_{CE} above knee voltage, the collector current I_C is approximately equal to $\beta \times I_B$.

output resistance:

→ It is the ratio of change in collector-emitter voltage to the change in collector current at constant I_B .

→ It may be noted that whereas the output characteristics of CE circuit are horizontal, they have noticeable slope for the CE circuit.

→ Therefore, output resistance of CE circuit is less than that of CB circuit. Its value is of the order of $50k\Omega$.

③ Characteristics of Common collector connection:-

→ In a common collector circuit connection the load resistor is connected from emitter to ground, so the collector is tied to ground even though the transistor is connected in a manner similar to the CE connection.

→ Hence there is no need for a set of common-collector characteristics to choose the parameters of the circuit. The output characteristics of the CC configuration is same as CE configuration.

→ For CC connection the output characteristics are plot of I_E versus V_{CE} for a constant value of I_B .

→ There is an almost unnoticeable change in the vertical scale of I_C of the CE connection. It is replaced by I_E for CC connection.

→ The input circuit of CC connection, the CE characteristics is sufficient to obtain the required information.

→ Hence common collector circuit connection is known as Emitter follower.

* Current Amplification factors:—

① Common Base Connection:—

In a common Base connection, the input current is the Emitter current I_E and output current is the collector current I_C .

Hence the ratio of change in collector current to the change in emitter at constant collector base voltage V_{CB} is known as current amplification factor for CB connection and is denoted as α .

→ Practical values of α in commercial transistors range from 0.9 to 0.99.

② Common Emitter Connection:—

In a common emitter connection, the input current is the base current I_B and output current is the collector current I_C .

Hence ratio of change in collector current to the change in base current at constant collector emitter voltage V_{CE} is known as current amplification factor for CE connection and denoted as β (Beta)

→ Usually, its value ranges from 20 to 500.

③ Common Collector Connection:—

In a common collector connection, the input current is the Emitter current I_E and output current is the Emitter current I_E .

Hence the ratio of change in emitter current to the change in base current at constant V_{CC} is known as current amplification factor for CC connection and is denoted as γ (gamma).

→ The circuit provides about the same current gain as the common emitter circuit $\approx A_E \approx A_C$

Comparison of transistor connections:-

- Out of the three transistor connection, the Common Emitter circuit is the most efficient.
- It is used in about 90 to 95 per cent of all transistor applications.
- The main reasons for the widespread use of this circuit are:
 - (i) High current gain
 - (ii) High voltage & power gain
 - (iii) Moderate output to input impedance ratio

Amplifier:-

- The device which increases the strength of a weak signal is known as Amplifier. This can be achieved by use of transistor. It may be classified according to the number of stages of amplification such as.

Single stage transistor Amplifier:-

When only one transistor with associated circuitry is used for amplifying a weak signal, the circuit is known as single stage transistor amplifier.

Multi stage transistor Amplifier:-

When a transistor circuit containing more than one stage of amplification is known as Multi stage transistor amplifier.

Single stage transistor Amplifier:-

- A single stage transistor amplifier has one transistor, bias circuit and other auxiliary components.
- When a weak A.C signal is given to the base of transistor, a small base current starts flowing.
- Due to transistor action, a much larger current flows through the collector load R_C .
- As the value of R_C is quite high, therefore a large voltage appears across R_C .

- Thus, a weak signal applied in the base circuit appears in amplified form in the collector circuit.
- It is in this way that transistor acts as an amplifier.

Chapter-5 (Transistor circuit)

Transistor Biasing:

- The basic function of transistor is to do amplification. The weak signal is given to the base of the transistor and amplified output is obtained in the collector circuit.
- One important requirement during amplification is that only the magnitude of the signal should increase and there should be no change in signal shape.
- This increase in magnitude of the signal without any change in shape is known as faithful amplification.
- For this we have to provide input circuit remains forward biased and output circuit remains reverse biased at all times.
- To achieve faithful amplification the following conditions must be satisfied:
- (i) Proper zero signal collector current
 - (ii) Minimum proper base-emitter voltage at any instant.
 - (iii) Minimum proper collector-emitter voltage at any instant.

- The fulfillment of these will ensure that transistor works over the active region of the output characteristics.
- The proper flow of zero signal collector current and the maintenance of proper collector-emitter voltage during the passage of signal is known as transistor biasing.
- The basic purpose of transistor biasing is to keep the base-emitter junction properly forward biased and collector-base junction properly reverse biased during the application of signal.
- This can be achieved with a bias battery or associating a circuit with a transistor.
- The second method with a bias battery or associating a circuit with a transistor is more efficient and is frequently employed.
- The circuit which provides transistor biasing is known as biasing circuit. The transistor biasing is very essential for the proper operation of transistor in any circuit.

NEED OF TRANSISTOR BIASING:-

- (i) It should ensure proper zero signal collector current.
- (ii) It should ensure that V_{CE} does not fall below 0.5 V for Ge transistors and 1 V for Si transistors.
- (iii) It should ensure the stabilization of operating point.

STABILISATION:-

- The process of making operating point independent of temperature changes or variations in transistor parameters is known as stabilization.

NEED FOR STABILIZATION

→ Stabilization of the operating point is necessary due to the following reasons.

- ① Temperature dependence of I_C
 - ② Individual variation
 - ③ Thermal run away
- The self-destruction of an unsterilized transistor is known as thermal run away.

* Stability factor:—

→ The rate of change of collector current I_C the collector leakage current $I_{C0} = I_{CBO}$ at constant β and I_B is called stability factor.

Stability factor, $S = \frac{dI_C}{dI_{C0}}$ at constant I_B & β

Methods of Transistor Biasing:—

→ In the transistor amplifier circuit drawn so far biasing was done with the aid of a battery V_{BB} , which was separate from the battery V_{CC} used in the output circuit. However, for simplicity and economy, it is desirable that transistor circuit should have a single source of supply the one in the output circuit.

→ The following are the most commonly used methods of obtaining transistor biasing from one source of supply.

- ① Base resistor method
- ② Biasing with collector-feedback resistor
- ③ Voltage-divider bias.

→ In all these methods, the same basic principle is employed required value of base current is obtained from V_{CC} in the zero signal conditions.

→ The value of collector load R_C is selected keeping in view that V_{CE} should not fall below 0.5 V for germanium transistors and 1 V for silicon transistors.

Base Resistor Method:

→ In this Method, a high resistance R_B is connected between the base and the end of supply for npn transistor and between base and negative end of supply for npn transistor.

→ Here, the required zero signal base current is provided by V_{CC} and it flows through R_B . It is because now base is positive emitter base junction is forward biased.

→ The required value of zero signal base current I_B can be made to flow by selecting the proper value of base resistor R_B .

Circuit Analysis:

It is required to find the value of R_B so that required collector current flows in the zero signal conditions.

Let I_C be the required zero signal collector current

$$\therefore I_B = I_C / \beta$$

Considering the closed circuit ABENA and applying KVL we get;

$$V_{CC} = I_B R_B + V_{BE}$$

$$I_B R_B = V_{CC} - V_{BE} \quad \text{--- (1)}$$

$$R_B = \frac{V_{CC} - V_{BE}}{I_B}$$

As $V_{BE} \approx 0.7 \text{ V}$ for silicon and 0.3 V for germanium.

Can be seen from the transition one known and value of R_B can be found.

V_{BE} found from exp ①

Since V_{BE} is generally quite small as compared to V_{CC} , the former can be neglected with little error.

Thus Equation ① becomes $R_B \approx \frac{V_{CC}}{I_B}$

→ It may be noted the V_{CC} is a fixed known quantity and I_B is chosen at some suitable value. Hence R_B can always be found directly, and for this reason, this method is sometimes called fixed-bias Method.

Advantage:—

- This biasing circuit is very simple as only one resistance R_B is required.
- Biasing conditions can easily be set and the calculations are simple.

Disadvantages:—

- ① This method provides poor stabilizations
- ② The stability factor is very high.

Biasing with feedback circuit:—

→ In this method, one end of R_B is connected to the base and other end to the collector. Here the required zero signal base current is determined not by V_{CC} but by the collector-base voltage V_{CB} . It is clear that V_{CB} forward biases the base-emitter junction and hence base current I_B flows through R_B . This causes the zero signal collector current to flow in the circuit.

Circuit Analysis:-

The required value of R_B needed to give the zero signal current I_C can be determined as follows from the above circuit diagram $V_{CE} = I_C R_C + I_B R_B + V_{BE}$

Alternately, $V_{CE} + V_{CB}$ or $V_{CB} = V_{CE} - V_{BE}$

Advantages:-

- (i) It is a simple method as it requires only one resistance R_B .
- (ii) This circuit provides some stabilization of the operating point than fixed bias method.

Disadvantage:-

- (i) The circuit does not provide good stabilization.
- (ii) This circuit provides a negative feedback which reduces the gain of the amplifier.
- (iii) This will reduce the base current and hence collector

Current

Voltage divider Bias Method:-

- This is the most widely used method of providing biasing and stabilization to a transistor. In this method, two resistors R_1 and R_2 are connected across the supply voltage V_{CC} and provide biasing. The emitter resistance R_E provides stabilization. The name voltage divider comes from the voltage divider formed by R_1 and R_2 . The voltage drop across R_2 forward biases the base-emitter junction.

This causes the base current and hence collector current to be zero in the zero signal conditions.

Circuit Analysis:-

→ Suppose that the current flowing through resistance R_1 is I_1 . As base current I_B is very small, therefore it can be assumed with reasonable accuracy that current flowing through R_2 is also I_1 .

$$I_1 = \frac{V_{CC}}{R_1 + R_2}$$

∴ Voltage across resistance R_2 is

$$V_2 = \left(\frac{V_{CC}}{R_1 + R_2} \right) R_2$$

(1) Collector current I_C

Applying Kirchhoff's voltage law to the base circuit

$$V_2 = V_{BE} + V_E = V_{BE} + I_E R_E$$

$$I_E = \frac{V_2 - V_{BE}}{R_E}, \quad I_C = \frac{V_2 - V_{BE}}{R_E}$$

$$\text{Since } I_E = I_C$$

→ Thus I_C in this circuit is almost independent of transistor parameters and hence good stabilization is ensured. Due to this reason the potential divider bias has become universal method for providing transistor biasing.

(11) Collector-emitter voltage (V_{CE})

Applying Kirchhoff's Voltage Law to the collector side, V_{CC}

$$= I_C R_C + V_{CE} + I_E R_E + V_{CE} + I_C R_E \quad (\text{As } I_C \approx I_E)$$

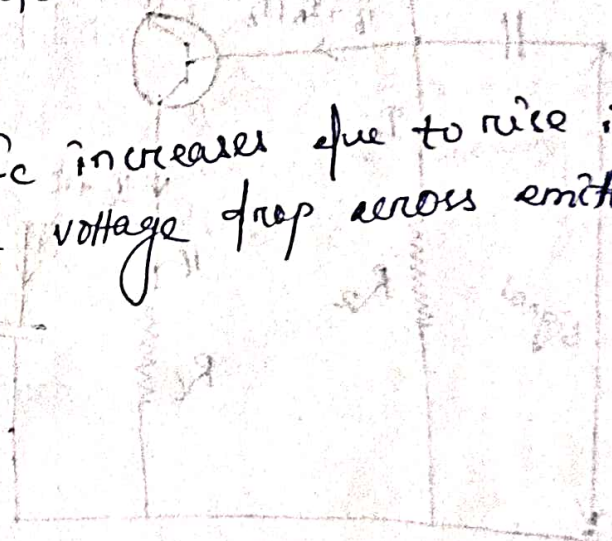
$$\text{So, } V_{CC} = I_C (R_C + R_E) + V_{CE} \Rightarrow V_{CE} = V_{CC} - I_C (R_C + R_E)$$

Advantages:-

→ In this circuit, excellent stabilization is provided by R_E .

Consider the following Equation.

→ Suppose the collector current I_C increases due to rise in temperature, this will cause the voltage drop across emitter resistance R_E to increase.

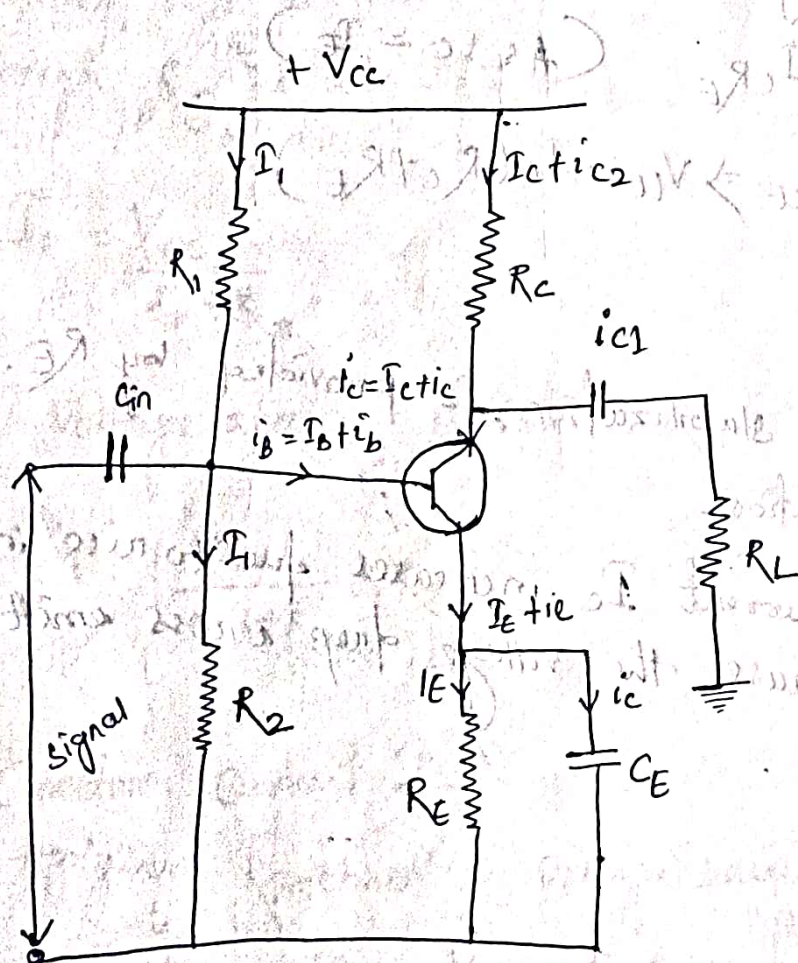


Transistor Amplifiers & Oscillators

Chapter - 6

D.C And A.C Equivalent circuits:

→ Various circuit current. It is useful to mention the various currents in the complete amplifier circuit. These are shown in the circuit of fig.



→ (i) Base Current: - When no signal is applied in the base circuit. D.C base current I_B flows due to biasing circuit. When A.C signal is applied A.C base current i_b also flows.

→ Therefore, with the application of signal total Base current is given by $i_B = I_B + i_b$

(ii) Collector Current: When no signal is applied a D.C collector current I_C flows due to biasing circuit.

When A.C signal is applied A.C collector current is also flows.

→ Therefore, the total collector current i_c is given by $i_c = I_C + i_c$

Where $I_C = \beta I_B$ = zero signal collector current and $i_c = \beta i_b$ = collector current due to signal.

(III) Emitter Current:- When no signal is applied a D.C emitter current I_E flows. When A.C signal is applied, A.C Emitter current i_e also flows. therefore the total Emitter current is

$$i_E = I_E + i_e$$

→ It is useful to keep in mind that $I_E = I_B + I_C$ and $i_e = i_b + i_c$.

→ But base current is usually very small, therefore, as a reasonable approximation, $I_E \approx I_C$ and $i_e \approx i_c$.

D.C Equivalent circuit:-

In order to draw the equivalent D.C circuit, the following two steps are applied to the transistor circuit.

(a) Reduce All A.C source to zero

(b) open all the capacitors

→ Referring D.C Equivalent circuit

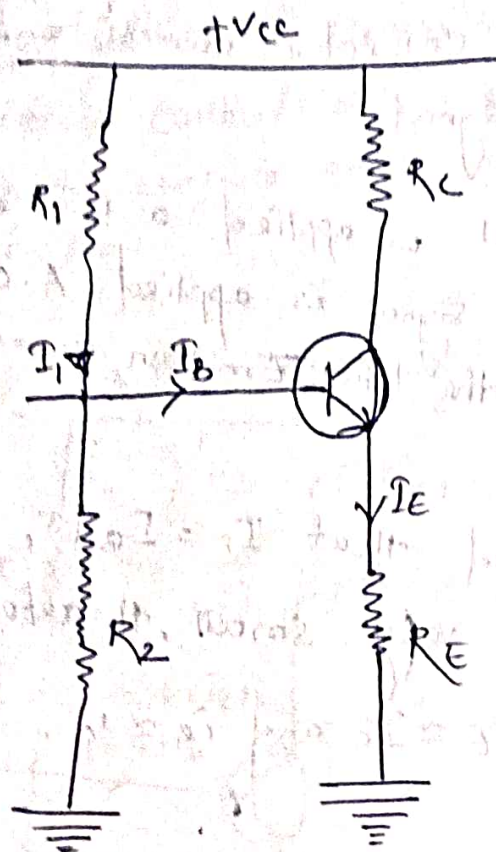
$$\text{D.C load } R_{ic} \approx R_C + R_E \quad \& \quad V_{ce} = V_{CC} - I_C(R_C + R_E)$$

→ The Maximum value of V_{CE} will occur when there is no collector current $I_C = 0$

$$V_{\text{Maximum } V_{CE}} = V_{CC}$$

→ The maximum Collector current will flow when $V_{CE} = 0$

$$\text{Maximum } I_C = V_{CC} / (R_C + R_E)$$



(D.c equivalent circuit)

A.c Equivalent circuit:—

- In order to draw A.c equivalent circuit, the following two steps are applied to the transistor circuit.

(a) Reduce all D.c source to zero (i.e. $V_{CC} = 0$)

(b) Short all the capacitors.

- Referencing A.c Equivalent circuit A.c load equal to $R_C || R_L$.

$$\text{A.c load, } R_{AC} = (R_C || R_L)$$

Maximum positive swing of A.C collector.

$\therefore$ total Maximum collector-emitter voltage, $V_{CE \text{ Max}} = V_{CE} + I_C R_{AC}$
emitter voltage $= I_E R_{AC}$

Maximum positive swing of A.C collector current $= V_{CE} / R_{AC}$

$\therefore$ total Maximum collector current, $I_{C \text{ Max}} = I_C + V_{CE} / R_{AC}$

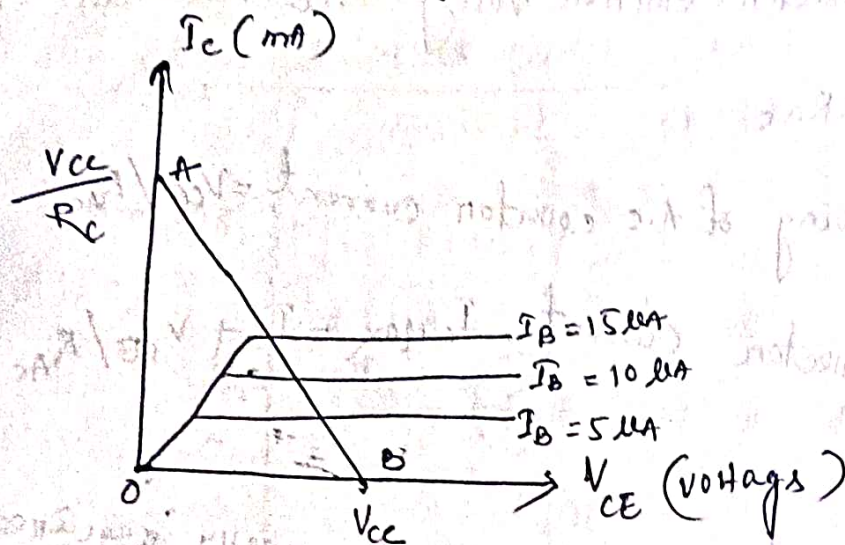
Load Line Analysis:-

- In the transistor circuit analysis, it is generally required to determine the collector current for various collector-emitter voltage.
- One of the methods can be used to plot the output characteristics and determine the collector current at any desired collector-emitter voltage.
- However, a more convenient method, known as load line method can be used to solve such problems.
- This method is quite easy and is frequently used in the analysis of transistor applications.

D.C Load Line - It is the line on the output characteristics of a transistor circuit which gives the value of I_C and V_{CE} corresponding to zero signal or D.C conditions.

- Consider a common emitter NPN transistor circuit where no signal is applied. Therefore, D.C conditions prevail in the circuit.

→ Consider the output characteristics of this circuit are shown in fig.



The value of collector-emitter voltage V_{CE} at any time is given $V_{CE} = V_{CC} - I_C R_C$ or $I_C R_C = V_{CC} - V_{CE}$

$$I_C = V_{CC}/R_C - V_{CE}/R_C$$

$$\text{or } I_C = (-1/R_C) V_{CE} + V_{CC}/R_C \quad (\equiv Y = Mx + c)$$

→ As V_{CC} and R_C are fixed value, therefore, it is a first degree equation and can be represented by a straight line on the output characteristics. This is known as D.C. Load Line.

→ To add Load Line, we need two end points of the straight line. These two points can be located as under

(i) When the collector $I_C = 0$, then collector-emitter voltage is maximum and is equal to V_{CC}
 $\text{Max. } V_{CE} = V_{CC} - I_C R_C \cdot V_{CC} \text{ (As } I_C = 0 \text{)}$

→ This gives the First point B ($OB = V_{CC}$) on the collector-emitter voltage axis as shown in fig.

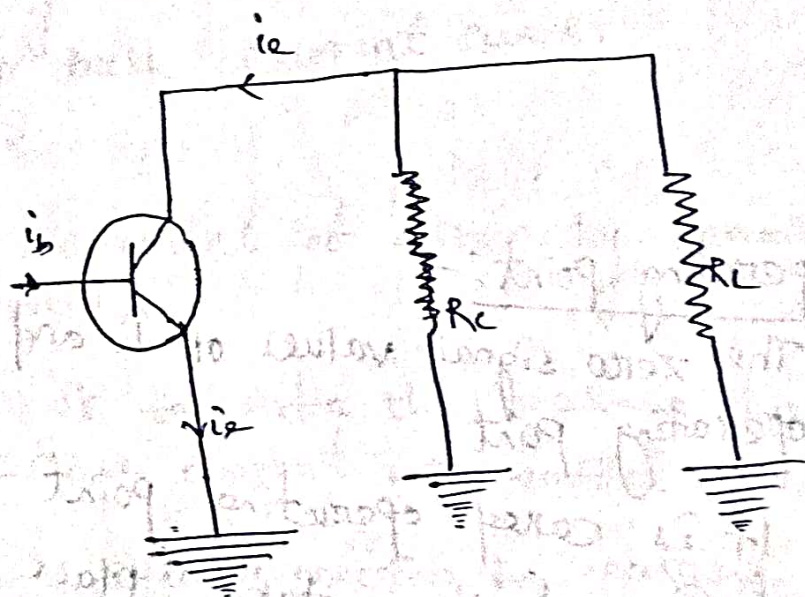
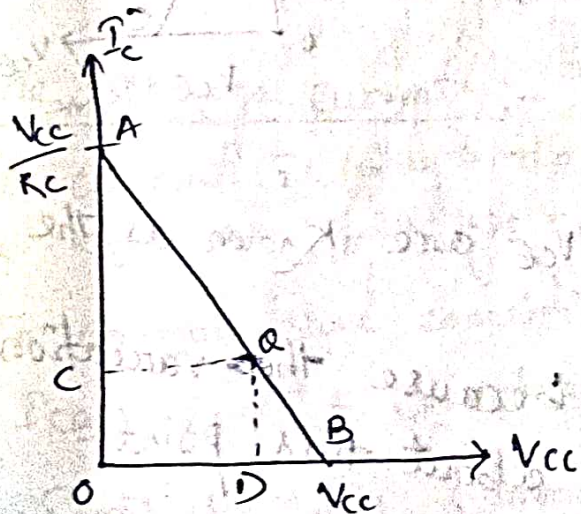
① When Collector-emitter voltage $V_{CE} = 0$, the collector current is maximum and is equal to V_{CC}/R_C

$$i.e. V_{CE} = V_{CC} - I_C R_C \text{ or } 0 = V_{CC} - I_C R_C$$

$$\therefore \text{Max. } I_C = V_{CC}/R_C$$

→ This gives the second point A ($OA = V_{CC}/R_C$) on the Collector Current axis as shown in fig.

→ By joining these two points, DC Load line AB is constructed.



② A.C Load Line

This is the line on the output characteristics of a transistor of a transistor circuit which gives the value of i_c and V_{CE} when signal is applied.

→ Referring back to the transistor amplifier shown in fig its A.C equivalent circuit as for output circuit is connected is as shown in fig.

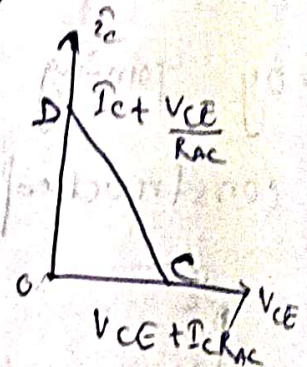
→ To add A.C Load Line to the output characteristics we again require two end points -

- 1 - one maximum collector-emitter voltage point ($V_{CE \max}$)
- 2 - other is maximum collector current point ($I_{C \max}$)

→ Under the application of A.C signal these values are Maximum collector-emitter voltage, $V_{CE \max} = V_{CE} + I_{C \text{ r.m.s.}}$

→ This locates the point C of the A.C Load Line on the collector-current axis

→ By joining point C and D, the A.C Load Line CD is constructed.



Operating point:-

→ The zero signal values of I_c and V_{ce} are known as the operating point.

→ It is called operating point because the variations of I_c and V_{ce} take place about this point when signal is applied.

→ It is called quiescent point or Q-point because it is the point on I_c - V_{ce} characteristics when the transistor is silent i.e. in the absence of the signal.

→ Suppose in the absence of signal, the base current is I_B then I_c and V_{ce} conditions in the circuit must be represented by some point on $I_B = I_{B \text{ r.m.s.}}$ characteristics.

- But I_C and V_{CE} conditions in the circuit should also be represented by some point on the d.c. load line AB.
- The point A where the load line and the characteristics intersect is the only point which satisfies both these conditions. Therefore, the point A describes the actual state of affairs in the circuit in the zero signal conditions and is called the operating point.

$I_B = 5 \mu A$, the zero signal values are

$$V_{CE} = 0.0 \text{ volts}, I_C = 0.0 \text{ mA}$$

- It follows, therefore, that the zero signal values of I_C and V_{CE} are determined by the point where d.c. load line intersects at proper base current curve.

The leakage currents :-

- The current is due to the movement of minority carriers is known as Leakage current.
- In Common Base connection of transistor the leakage current I_{CBO} is the collector-base current with emitter open.
- Similarly, in Common Emitter connection the leakage current I_{CEO} is the collector-emitter current with open base.
- Expression for collector current in Common base connection is given by

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO} \text{ or, } I_C = \frac{\alpha}{1-\alpha} I_B + I_{CEO}$$

Multistage transistor Amplifier:-

- The output from a single stage amplifier is usually insufficient to drive an output device. In other words the gain of a single amplifier is inadequate for practical purposes.
- Consequently, additional amplification over two or three or three stages is necessary. To achieve this, the output of each amplifier stage is coupled in some way to the input of the next stage.
- The resulting system is referred to as multistage amplifier.
- A transistor circuit containing more than one stage of amplification is known as multistage transistor amplifier.
- In a multistage amplifier, a number of single amplifiers are connected in cascade arrangement. The output of first stage is connected to the input of the second stage through a suitable coupling device and so on.
- The purpose of coupling device (e.g. a capacitor or transformer) is:
 - (i) to transfer A.C. output of one stage to the input of the next stage and
 - (ii) to isolate the D.C. conditions of one stage from the next stage.

Name of Coupling

Rc coupling

Transformer Coupling

Direct coupling

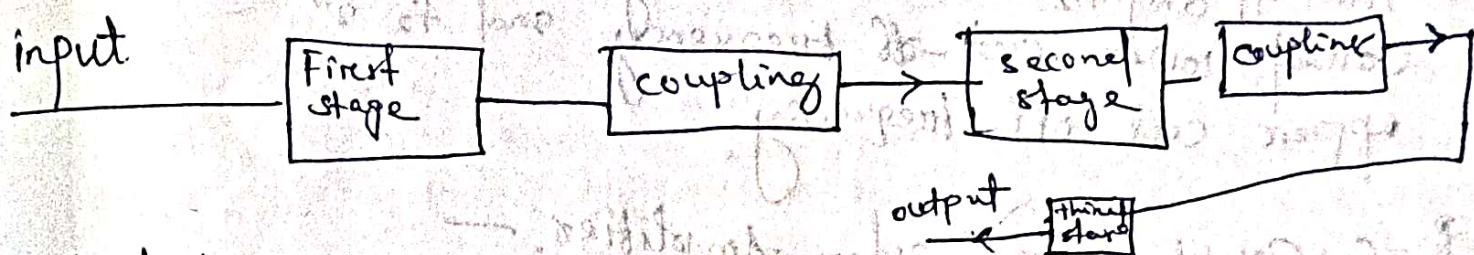
Name of multistage amplifier

R-c coupled amplifier

Transformer coupled amplifier

Direct coupled amplifier

→ The name of the amplifier is usually given after the type of coupling used.



Important terms:-

Gain: - The ratio of the output electrical quantity to the input of the amplifier is called its gain.

→ The gain of a multistage amplifier is equal to the product of gains of individual stages.

Frequency response: - The curve between voltage gain and signal frequency of an amplifier is known as frequency response.

Decibel gain: - Although the gain of an amplifier can be expressed as a number, yet great practical importance to assign it a unit.

→ The unit assigned is bel or decibel (db). The common logarithm of power gain is known as bel power gain.

$$\log \text{ to } \frac{P_{out}}{P_{in}} \text{ bel}$$

Bandwidth: - The range of frequency over which the voltage gain is equal to or greater than 70.7% of the maximum gain is known as bandwidth.

→ From the fig. it is clear that for any frequency varying between f_1 and f_2 the gain is equal to or greater than 70.7% of the maximum gain.

→ Therefore, $f_1 - f_2$ is the bandwidth. It may be seen that f_1 and f_2 are the limiting frequencies. The f_1 is called lower cut-off frequency and f_2 is known as upper cut-off frequency.

R-C Coupled Transistor Amplifiers: -

→ This is the most popular type of coupling it is cheap and provides excellent audio fidelity over a wide range of frequency. It is usually employed for voltage amplification.

→ Fig shows two stages of an R-C coupled amplifier. A coupling capacitor C_c is used to connect the output of first stage to the base of the second stage and so on.

→ As the coupling from one stage to next is achieved by a coupling capacitor followed by a connection to a shunt resistor, therefore, such amplifiers are called Resistance - Capacitance coupled amplifiers.

→ The Resistances R_1 , R_2 and R_E from the biasing and stabilization network. The emitter bypass capacitor offers low reactance path to the signal. Without it the voltage gain of each stage would be lost.

→ The coupling capacitor C_c transmits AC signal

→ It is because when a second stage is made to follow the first stage, the effective load resistance of first stage is reduced due to the shunting effect of the input resistance of second stage.

→ This reduces the gain of the stage which is loaded by the next stage.

Frequency response R-C Coupled Transistor Amplifiers:-

→ Fig shows the frequency response of a typical R-C coupled amplifier. It is clear that voltage gain drops off at low and high frequencies whereas it is uniform over mid frequency range.

→ This behaviour of the amplifier is briefly explained below

(i) At Low frequencies:-

→ AT this stage the reactance of coupling capacitor C_c is quite high and hence very small part of signal will pass from one stage to the next stage. Moreover, C_c cannot shunt the emitter resistance R_E effectively because of its large reactance at low frequencies. These two factors cause a falling of voltage gain at low frequencies.

(ii) At high frequencies:- At this stage the reactance of C_c is very small and it behaves as a short circuit. These increase the loading effect of next stage and serves to reduce the voltage gain.

Moreover, at high frequency, capacitive reactance of base emitter junction is low which increases the base current. This reduces the current amplification factor β . Due to these two reasons, the voltage gain drops off at high frequency.

At-Mid-frequencies:- At this stage the voltage gain of the amplifier is constant. The effect of coupling capacitor in this frequency range is such as to maintain a uniform voltage gain. Thus as the frequency increases in this range, reactance of CC decreases which tends to increase the gain. These two factors almost cancel each other, resulting in a uniform gain at mid-frequency.

Advantages:-

- (i) It has excellent frequency response. The gain is constant over the audio frequency range which is the region of most important for speech, music.
- (ii) It has lower cost since it employs resistors and capacitors which are cheap.
- (iii) The circuit is very compact as the modern resistors and capacitors are small extremely light.

Disadvantage:-

- (i) The RC coupled amplifiers have low voltage and power gain. It is because the low resistance presented by the input of each stage to the preceding stage decreases the effective load resistance and hence the gain.

(ii) They have the tendency to become noisy with age, particularly in moist climates.

(iii) Impedance matching is poor. It is because the output impedance of RC coupled amplifier is several hundred ohms, whereas the input impedance of a speaker is only a few ohms. Hence little power will be transferred to the speaker.

Application :-

→ The RC coupled amplifiers have excellent audio fidelity over a wide range of frequency. Therefore they are widely used as voltage amplifiers in the initial stages of public address systems.

→ If other type of coupling is employed in the initial stages, this results in frequency distortion which may be amplified in next stages.

→ However, because of poor impedance matching, RC coupling is rarely used in the final stage.

particular

Re. coupling

S.L.NO	particular	Re. coupling
1	Frequency response	Excellent in the audio frequency range → poor → best
2	cost	Less → more → least
3	space and weight	Less → more → Least
4	Impedance matching	Not good → Excellent → good
5	Use	For voltage amplification → For power amplification → For amplifying extremely low frequency

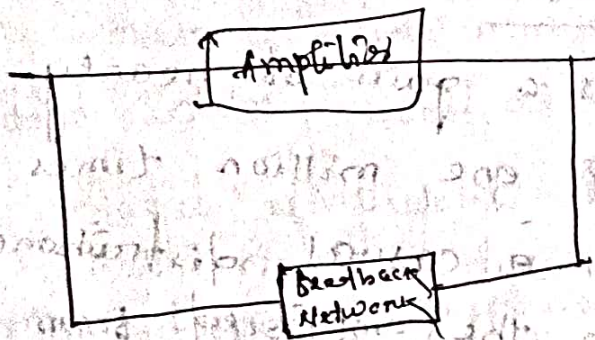
Feedback Amplifiers

- A practical amplifier has a gain of nearly one million i.e. its output is one million times the input. Consequently, even a casual disturbance at the input will appear in the amplified form in the output.
- The noise in the output of an amplifier is undesirable and must be kept to as small a level as possible. The noise level in amplifiers can be reduced considerably by the use of negative feedback. By injecting a fraction of output in phase opposition to the input signal.
- The object of this chapter is to consider the effect and methods of providing negative feedback in transistor amplifiers.

feedback

→ The process of injecting a fraction of output energy of some device back to input is known as feedback.

→ Depending upon whether the feedback energy aids or opposes the input signal, there are two basic types of feedback in amplifiers viz positive feedback and negative feedback. Positive feedback when the feedback energy (voltage or current) is in phase with the input signal and thus aids it. It is called positive feedback. This is illustrated in fig.



→ Both amplifier and feedback network introduce a phase shift of 180° . The result is a 360° phase shift around the loop, causing the feedback voltage V_f to be in phase with the input signal V_{in} .

→ The positive feedback increases the gain of the amplifier. However, it has the disadvantages of increased distortion and instability.

→ Therefore, positive feedback is not often employed in amplifiers.

→ One important use of positive feedback is in oscillators. If positive feedback is sufficiently large, it leads

to oscillations. As a matter of fact, an oscillator is a device that converts d.c power into a.c power of any desired frequency.

(ii) Negative feedback :-

→ When the feedback energy (voltage or current) is out of phase with the input signal and thus opposes it, it is called negative feedback. This is illustrated in fig.

→ As you can see, the amplifier introduces a phase shift of 180° into the circuit while the feedback network is so designed that it introduces no phase shift. The result is that the feedback voltage V_f is 180° out of phase with the input signal V_{in} .

→ Negative feedback reduces the gain of the amplifier. However the advantages of negative feedback are reduction in distortion, stability in gain, increased bandwidth & improved input and output impedances.

→ It is due to these advantages that negative feedback is frequently employed in amplifiers.

Principles of negative voltage feedback in Amplifiers :-

→ A feedback amplifier has main two parts such as an amplifier and a feedback circuit.

→ The feedback circuit usually consists of resistors and returns a fraction of output energy back to the input.

→ Fig shows the principles of negative voltage feedback in an amplifier. Typical values have been assumed to make the treatment more illustrative.

→ The output of the amplifier is 10V. The fraction m_v of this output i.e. 100 mV is feedback to the input where it is applied in series with the input signal of 101 mV.

→ As the feedback is negative, therefore, only 1 mV appears at the input terminals of the amplifier.

→ Referring to bty. we have:

→ Gain of amplifier without feedback $A_v = (10V) / (1mV)$

→ Fraction of output voltage feedback $= (10,000mV) / 10V = 0.01$

→ Gain of amplifier with negative feedback $A_{vf} = 10V / 101mV = 100$

→ The following points are worth noting:-

→ When negative voltage feedback is applied, the gain of the amplifier is reduced. Thus, the gain of above amplifier without feedback is 10,000 whereas with negative, it is only 100.

→ When negative voltage feedback is employed, the voltage actually applied to the amplifier is extremely small. In this case, the signal voltage is 101 mV and the negative feedback is 100 mV so that voltage feedback circuit, the feedback fraction m_v is always between 0 and 1.

→ The gain with feedback is sometimes called closed-loop gain while the gain without feedback is called open-loop gain. These terms come from the fact the amplifier and feedback circuit form a loop.

- When loop is opened by disconnecting feedback circuit from V_p , amplifier's gain A .
- When the loop is closed by connecting the feedback circuit, gain decreases to A_{ft} .
- Gain of negative voltage feedback amplifiers. —
- Consider the negative voltage feedback amplifiers shown in fig.
- The gain of the amplifier without feedback is A_v .
- Negative feedback is then applied by feeding a fraction m_v of the output voltage e_o back to amplifier input.
- Therefore, the actual input to the.