BASIC ELECTRONICS

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CHAPTER – 2

ELECTRONIC CIRCUITS

Rectifier :

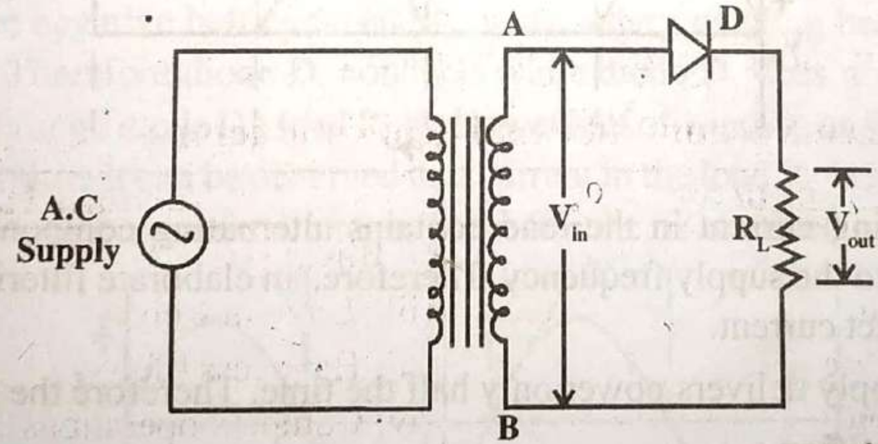
It is a device which converts alternating current and voltage to direct current and voltage.

Rectifiers are of two types.

1. Half-wave Rectifier
2. Full-wave Rectifier

1. Half-wave Rectifier :

In half wave rectification the rectifier conducts current only during positive half cycles of input a.c. supply while the negative half cycle is suppressed i.e., no current is conducted and hence no voltage appears across the load.



Circuit details :

Here a single crystal diode acts as a rectifier. The circuit contains a transformer consisting of two coils namely primary and secondary. The input AC supply is applied between two terminals of the primary coil. A diode D is connected in series with a load resistance 'R_L' to the secondary coil. Here the use of transformer has two advantages.

(i) It allows to step up or step down the a.c. input voltage as the situation demands.

(ii) It isolates the rectifier circuit from power line and thus reduces the risk of electric shock.

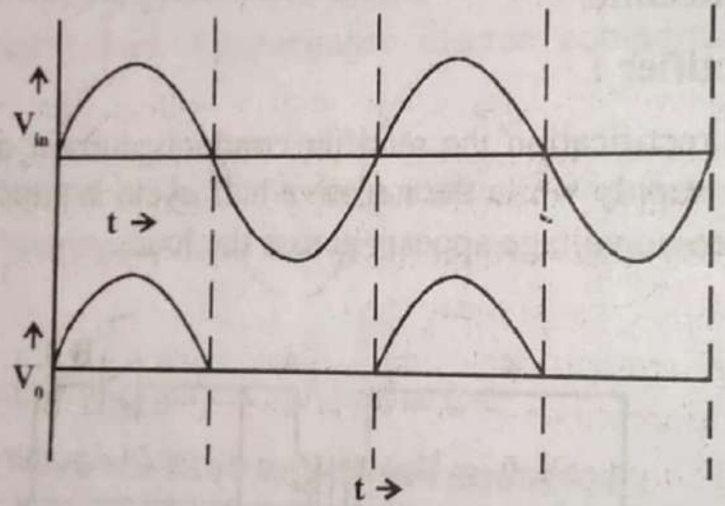
Operation :

The a.c. voltage across the secondary winding AB changes polarities after every half cycle.

During the positive cycle of input a.c. voltage terminal 'A' becomes positive w.r.t B. This makes the diode forward biased and hence it conducts current.

During the negative half cycle of input a.c. voltage and B becomes positive w.r.t. A. This makes the diode reverse biased and its 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 R_L always in the same direction. Hence, d.c. output is obtained across R_L.



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.

2. Full Wave Rectifier :

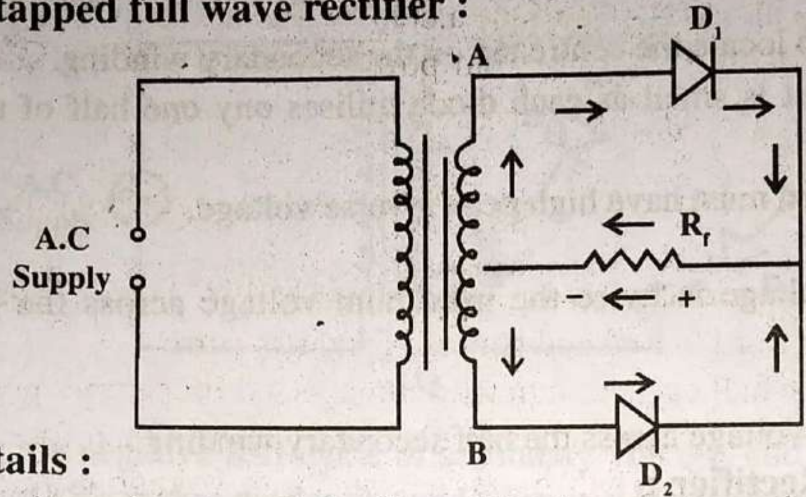
In full wave rectification, current flows through the load in the same direction for both half cycles of input a.c. supply. This can be achieved by using two diodes.

The following two ckts are commonly used for full wave rectification.

(a) Centre tapped full wave rectifier

(b) Full wave bridge rectifier.

(a) Centre tapped full wave rectifier :



Circuits details :

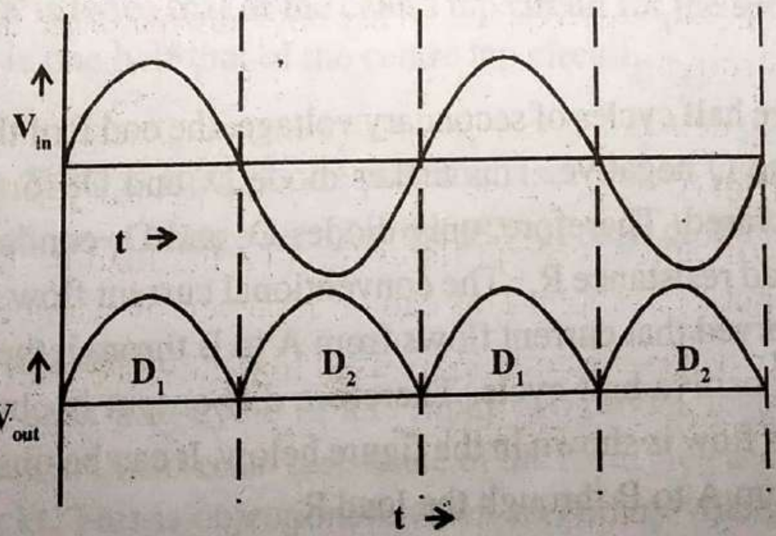
The circuit employs two diodes D_1 and D_2. A centre tapped secondary winding AB is used with two diodes connected so that each uses one half cycle of input a.c. voltage i.e., diode D_1, utilises the a.c. voltage appearing across the upper half OA of secondary winding for rectification while diode D_2 uses the lower half winding OB.

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 rectifier R_L and the upper half of secondary winding, as shown by the arrows.

During the negative half cycle end A of 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 lower half of winding as shown by the arrows.

From the figure it can be observed that current in the load R_L is in the same direction for both half cycles of input a.c. voltage. Therefore d.c. is obtained across load R_L.



Disadvantages :

* It is difficult to locate the centre tap on the secondary winding.
* The d.c. output is small as each diode utilises ony one half of the transforme secondary voltage.
* The diodes used must have high peak inverse voltage.

Note :

Peak inverse voltage is twice the maximum voltage across the half secondar winding i.e.,

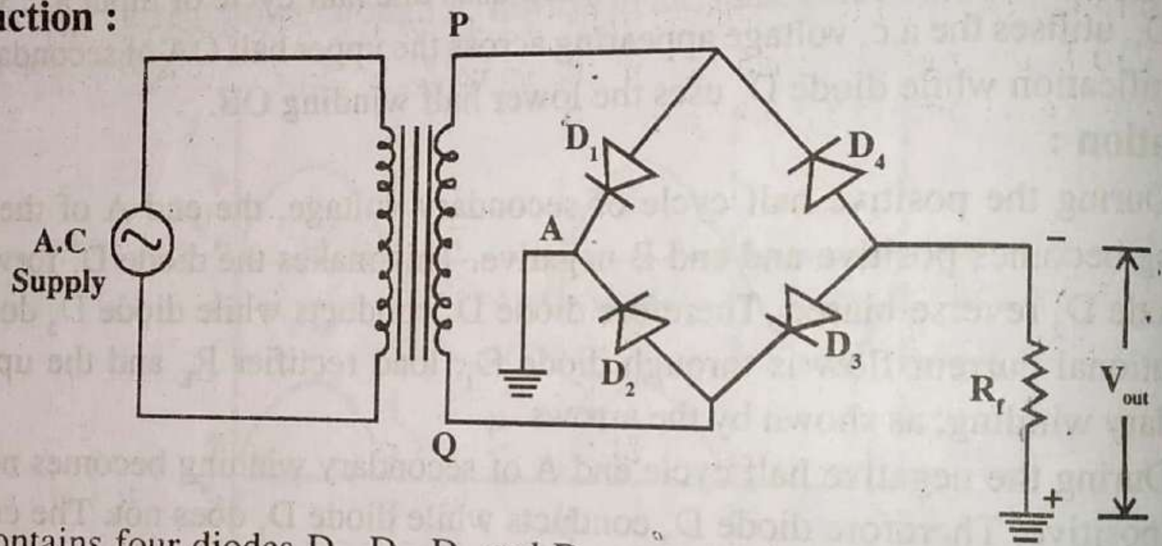
PIV = $2V_m$

V_m = Maximum voltage across the half secondary winding.

Full Wave Bridge Rectifier :

The need for a centre tapped power transmitter is eliminated in the bridge rectifier

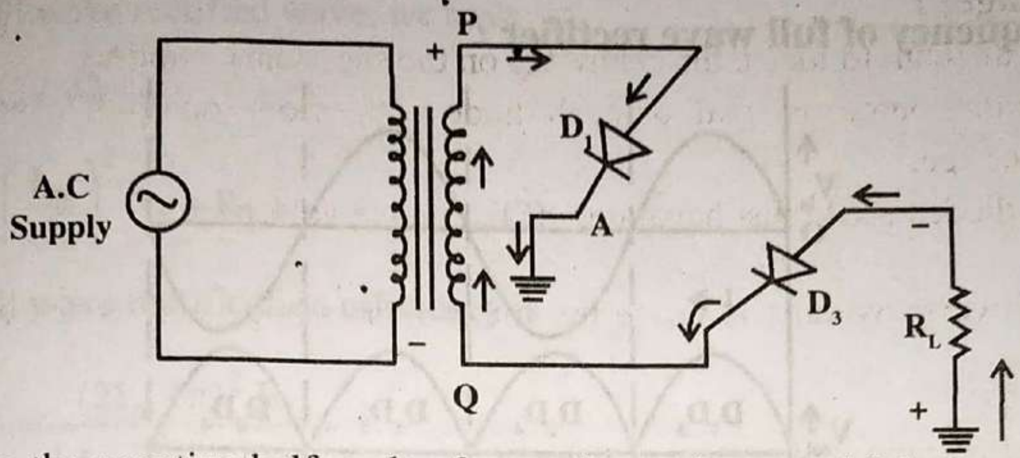
Construction :



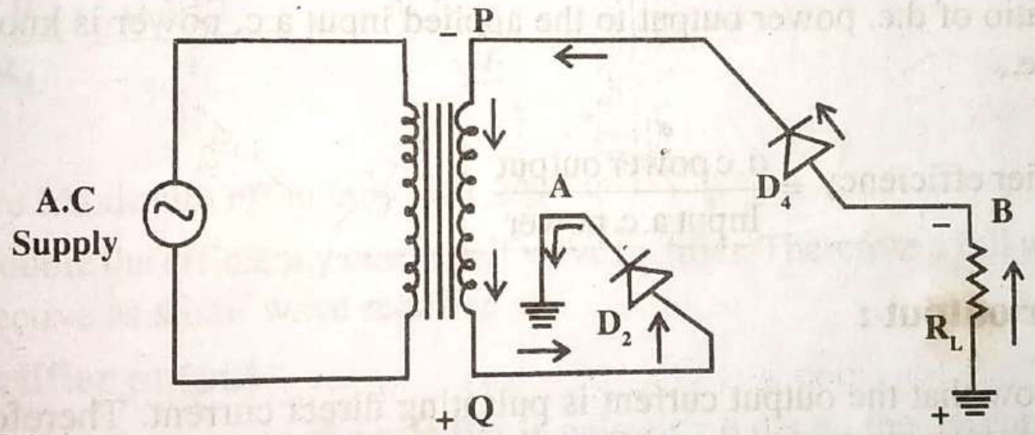
It contains four diodes D_1, D_2, D_3 and D_4 connected to form a bridge as shown in above figure. The a.c. supply to be rectified is applied diagonally opposite ends of the bridge through the transformer. Between other two ends of the bridge, the load resistance R_L is connected.

Operation :

During positive half cycles of secondary voltage, the end P of the secondary winding becomes positive and Q negative. This makes diode D_1 and D_3 forward biased while D_2 and D_4 are reverse biased. Therefore, only diodes D_1 and D_3 conduct. These two diodes will in series with load resistance R_L. The conventional current flow is shown in the figure below. It can be observed that current flows from A to B through the load i.e., in the same direction as for the positive half cycle. Therefore d.c. output is obtained across R_L. The convientional current flow is shown in the figure below. It can be observed from the figure 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 figure below. It can be observed that current flows from A to B through the load i.e., in the same direction as for the positive half-cycle. Therefore d.c output is obtained across R_L.



Advantages :

(i) The need for centre tapped transformer is eliminated.

(ii) 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.

Note :

* PIV of each diode is equal to the maximum secondary voltage of transformer.

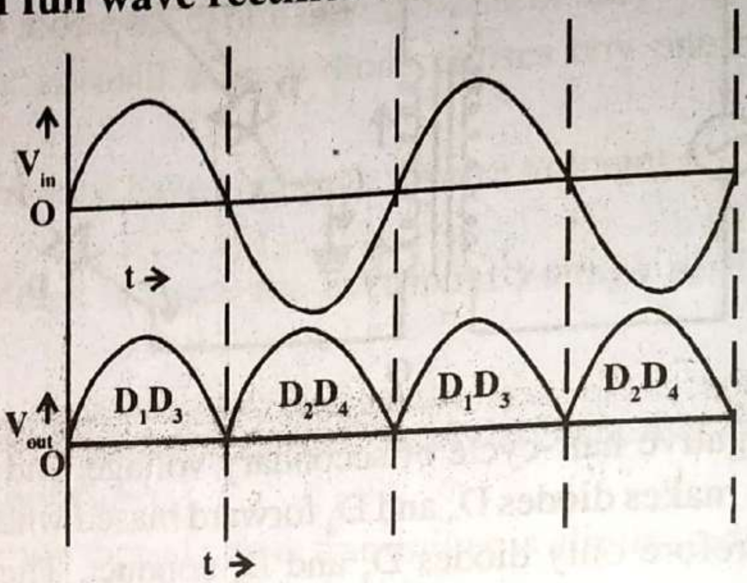
* In case of full wave bridge rectifier the PIV of each diode is V_m.

Disadvantages :

(i) It requires four diodes.

(ii) As during each half cycle of a.c. input two diodes that conduct are in series, therefore voltage drop in the internal resistance of the rectifying unit will be twice as great as in the centre tap ckt. This is objectionble when secondary voltage is small.

Output frequency of full wave rectifier :



Here $f_{out} = 2\,f_{in}$

Efficiency of full wave rectifier :

The ratio of d.c. power output to the applied input a.c. power is known as rectif efficiency i.e.,

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

D.C. power output :

We know that the output current is pulsating direct current. Therefore, in order find the d.c. power, average current has to be found out.

We know that $I_{dc} = \dfrac{2I_m}{\pi}$

∴ d.c. power ~~input~~ o/p. is $P_{dc} = I_{dc}^2 \times R_L = \left(\dfrac{2I_m}{\pi}\right)^2 \times R_L$ ... (1)

Input a.c. power :

The a.c. input power is given by

$$P_{ac} = I_{rms}^2 (r_f + R_L)$$

For a full wave rectified wave, we have

$$I_{rms} = I_m / \sqrt{2}$$

$$\therefore P_{ac} = \left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L) \quad \text{... (2)}$$

Now full wave rectification efficiency is

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{(2I_m/\pi)^2 R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L)}$$

$$= \frac{8}{\pi^2} \times \frac{R_L}{r_f + R_L}$$

$$= \frac{0{\cdot}812\, R_L}{r_f + R_L} = \frac{0{\cdot}812}{1 + \frac{r_f}{R_L}}$$

Therefore Maximum efficiency = 81.2%

This is double the efficiency due to half wave rectifier. Therefore a full wave rectifier is twice as effective as a half wave rectifier.

Nature of rectifier output :

We know that the output of a rectifier is pulsating d.c. i.e., the output contains a.c. component as well as d.c. component. The a.c. component is responsible for the pulsation in the wave.

Ripple factor :

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 i.e.,

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

Ripple factor is very important in determining the effectiveness of a rectifier. The smaller the ripple factor, the lesser the effective a.c. component and hence more effective is the rectifier.

Mathematical Analysis :

The output current of a rectifier contains d.c. as well as a.c. component. The undesired a.c. component has a frequency of 100 Hz and is called the ripple.

By definition we can get

$$I_{rms} = \sqrt{I_{dc}^2 + I_{ac}^2}$$

$$\text{or, } I_{ac} = \sqrt{I_{rms}^2 - I_{dc}^2}$$

$$\text{or, } \frac{I_{ac}}{I_{dc}} = \frac{1}{I_{dc}}\sqrt{I_{rms}^2 - I_{dc}^2}$$

$$\Rightarrow \text{Ripple factor} = \frac{1}{I_{dc}}\sqrt{I_{rms}^2 - I_{dc}^2}$$

$$\Rightarrow \text{Ripple factor} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

For Half wave rectification :

In half wave rectification

$$I_{rms} = I_m / 2$$

$$I_{dc} = I_m / \pi$$

$$\therefore \text{Ripple factor} = \sqrt{\left(\frac{I_m / 2}{I_m / \pi}\right)^2 - 1} = 1 \cdot 21$$

Here a.c. component exceeds the d.c. component in the output of a half wave rectifier. This results in greater pulsation of the output. Therefore half wave rectifier is ineffective for conversion of a.c. into d.c.

For full wave rectification :

In full wave rectification

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$I_{dc} = \frac{dI_m}{\pi}$$

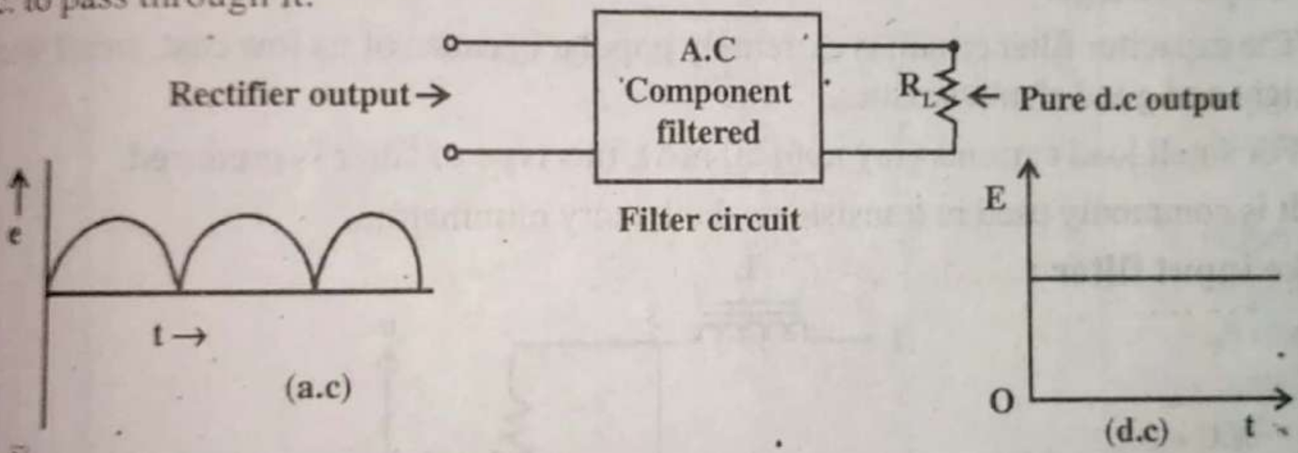
$$\therefore \text{ Ripple factor} = \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1} = 0.48$$

It can be observed that in the output of a full wave rectifier, the d.c. component is more than the a.c. component. Consequently, the pulsations in the output will be less than in half wave rectifier. For this reason, full wave rectification is invariably used for conversion of a.c. into d.c.

Filter circuit :

A filter ckt. is a device which removes the a.c. component of rectifier output but allows the d.c. component to reach the load.

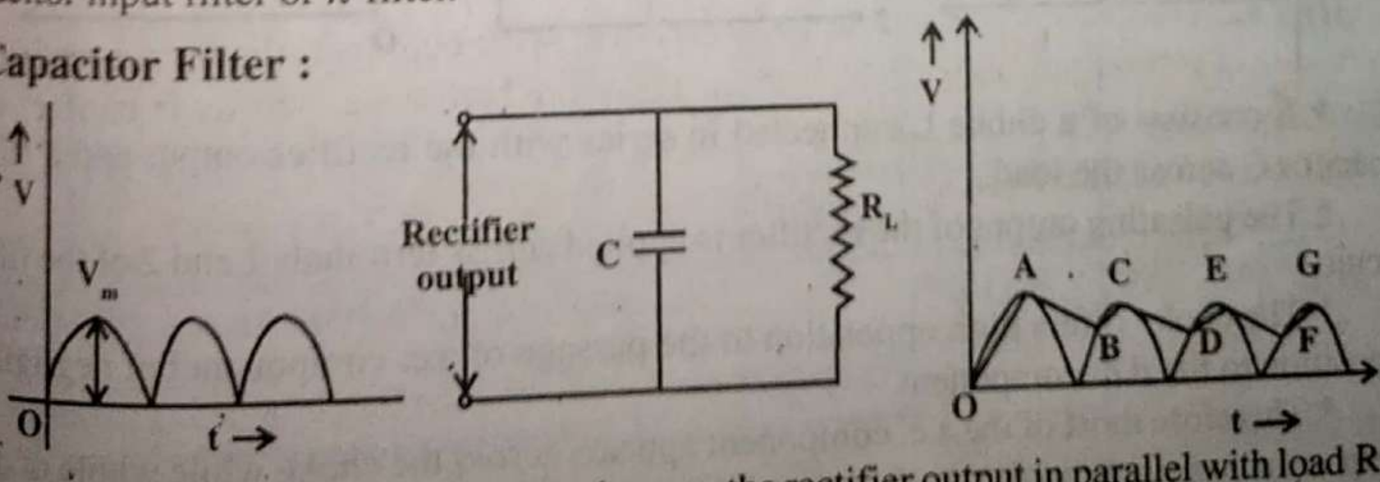
A filter ckt is generally a combination of inductors (L) and capacitors (C). If capacitor passes a.c. readily but does not pass d.c. at all. While an inductor opposes a.c. but allows d.c. to pass through it.



Types of Filter Circuits :

The most commonly used filter circuits are capacitor filter, choke input filter and capacitor input filter or π-filter.

1. Capacitor Filter :



* 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 (point A), the capacitor is recharged to the peak value V_m of the rectifier voltage.

* Now the rectifier voltage starts to decrease. As this occurs, the capacitor discharges through the load and voltage across it decreases as shown by line AB.

* The voltage across load will decrease only slightly because immediately the next voltage peak comes and recharges the capacitor.

* This process is repeated again and again and the output voltage wave form becomes ABCDEFG.

* It can be observed that a very little ripple is left in the output.

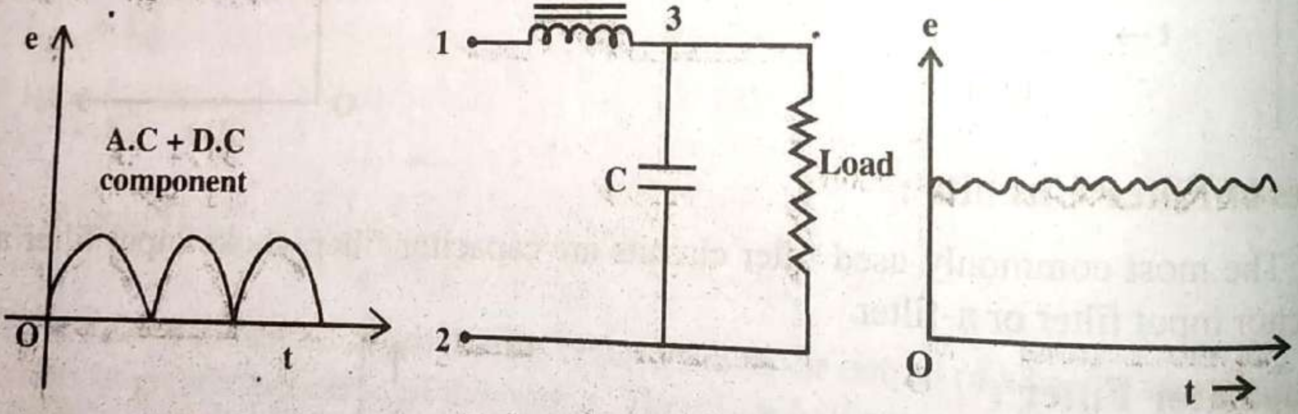
* The output voltage is higher as it remains substantially near the peak value of the rectifier output voltage.

* The capacitor filter circuit is extremely popular because of its low cost, small size, little weight and good characteristics.

* For small load currents (say upto 50 mA), this type of filter is preferred.

* It is commonly used in transistor radio battery eliminators.

2. Choke input filter :



* It consists of a choke L connected in series with the rectifier output and a filter capacitor C across the load.

* The pulsating output of the rectifier is applied across terminals 1 and 2 of the filter circuit.

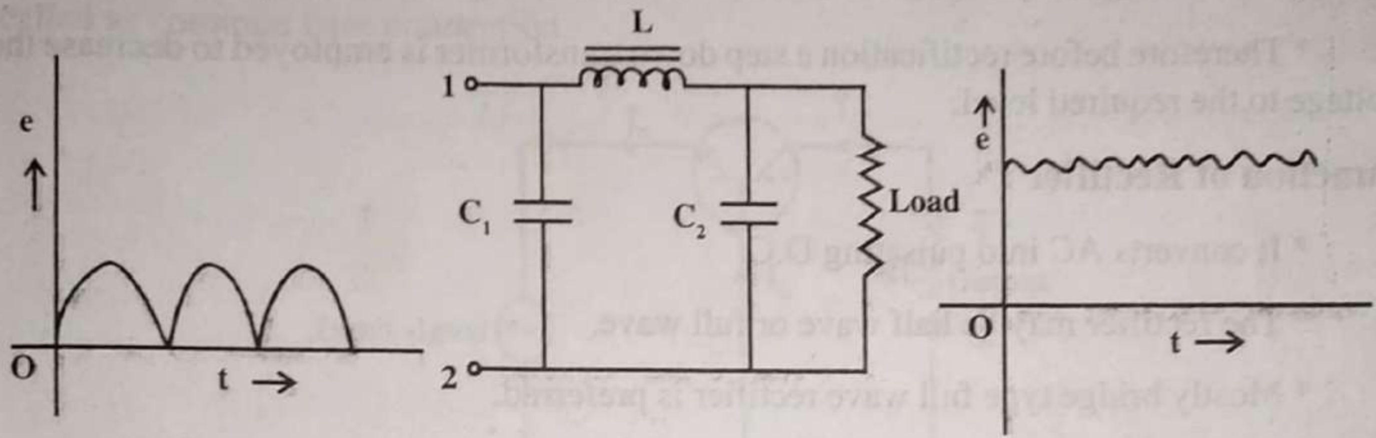
* The choke offers high opposition to the passage of a.c. component but negligible opposition to the d.c. component.

* Therefore 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 and the pulsation is reduced 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 filter capacitor by passes the a.c. component but prevents the d.c. component to flow through it. Therefore only d.c. component reaches the load.

3. 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.

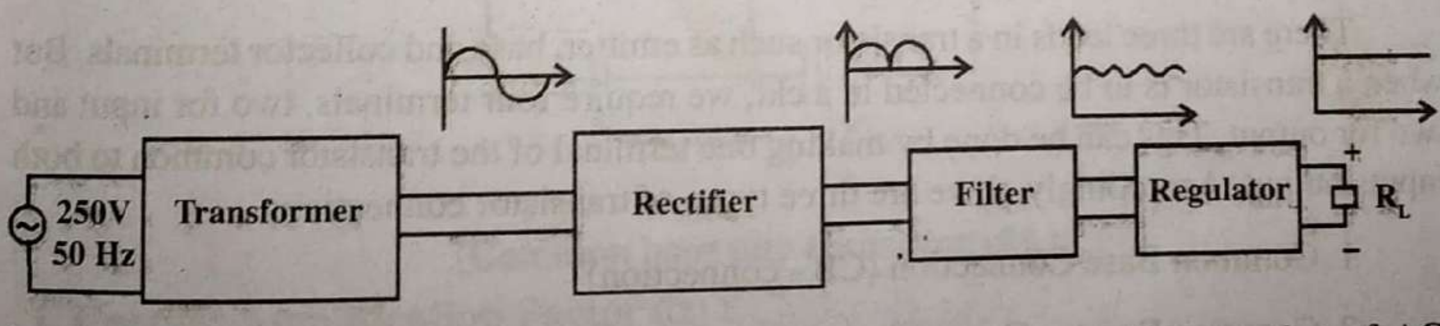
* The pulsating output from the rectifier is applied across the input terminals of the filter.

* 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, C_1 by passes an appreciable amount of a.c. component while the d.c. component reaches at the choke L.

* The choke L offers high reactance to the a.c. component but it offers almost zero reactance to the d.c. component. Therefore, it allows the d.c. component to flow through it, while the un by passed a.c. component is blocked.

* The filter capacitor C_2 by passes the rest of the a.c. component. Therefore, only d.c. component appears across the load.

Regulated power supply with the help of block diagram (DC Power Supply) :



* A power supply that maintains the output voltage constant irrespective of AC mains filtrations or load variations is called as regulated power supply.

Function of transformer :

* Usually, DC voltage is required for the operation of various electronic equipment is 6V, 9V or 12V.

* This voltage is quite small than the all mains voltage (In India it is 230 V, 50 Hz).

* Therefore before rectification a step down transformer is employed to decrease the voltage to the required level.

Function of Rectifier :

* It converts AC into pulsating D.C.

* The rectifier may be half wave or full wave.

* Mostly bridge type full wave rectifier is preferred.

Function of Filter :

* It removes the ripples from the output of rectifier and smooths it out.

* The output received from the filter is constant till the mains voltage and load is kept constant.

* If either of the two is varied, dc voltage received at this point changes.

* Therefore, a regulator is employed at the output stage.

* It is a circuit that keeps the output dc voltage constant even if the AC mains voltage constant even if the AC mains voltage or load varies.

* Usually zener diode or glow tube voltage regulator is used.

Transistor Connections :

There are three leads in a transistor such as emitter, base and collector terminals. But when a transistor is to be connected in a ckt, we require four terminals, two for input and two for output. This can be done by making one terminal of the transistor common to both inputs output. Accordingly, there are three types of transistor connections.

1. Common Base Connection (CB - connection)

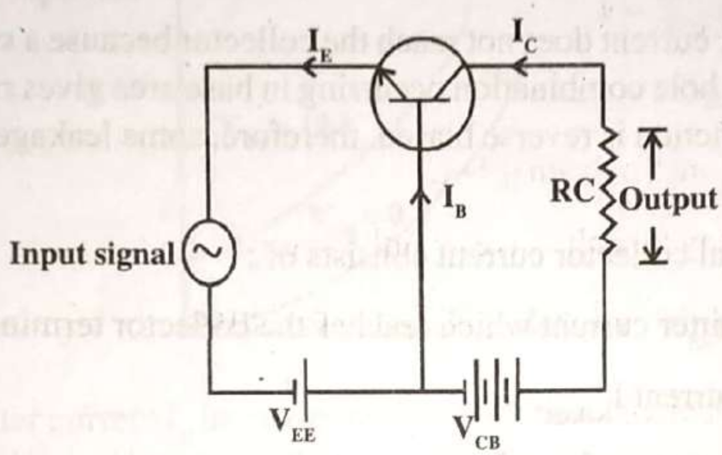
2. Common Emitter Connection (CE - Connection)

3. Common Collector Connection (CE connection)

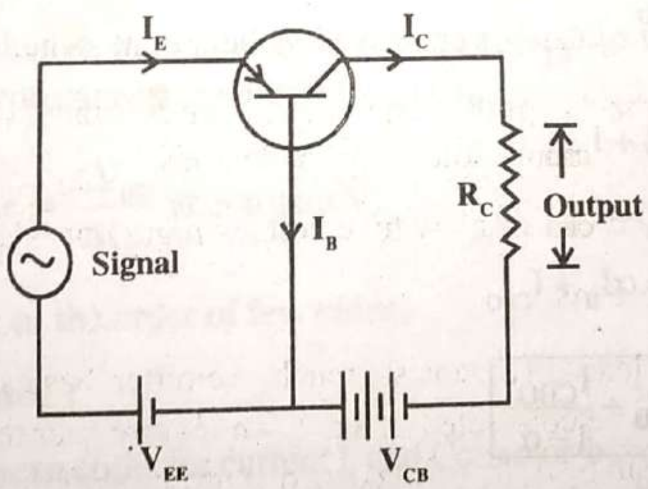
1. Common Base Connection :

* In CB connection input is applied between emitter and base while output is obtained across collector and base.

* Since the base is connected to both input and output, therefore this connection is called as common base connection.



(Common base npn transistor ckt.)



(Common base pnp transistor ckt.)

1. Current Amplification Factor (α) :

It is defined as the ratio of change in collector current to the change in emitter current at constant collector base voltage V_{CB} i.e.,

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \text{ at constant } V_{CB}$$

α is always less than unity practical value of α in commercial transistors range from 0.9 to 0.99.

2. Expression for collector current :

The whole emitter current does not reach the collector because a small percentage of it, as a result of electron hole combination occurring in base area gives rise to base current. As the collector base junction is reverse biased, therefore, some leakage current flows due to minority carriers.

Therefore, the total collector current consists of :

(i) The part of emitter current which reaches the collector terminal i.e., αI_E.

(ii) The leakage current $I_{leakage}$.

$\therefore$ Total Collector current $I_c = \alpha I_E + I_{leakage}$.

If $I_E = 0$, a small leakage current still flows in the collector circuit.

So $I_{leakage} = I_{CBO}$ (Collector-base curent with emitter open)

$\therefore I_c = \alpha I_E + I_{CBO}$

Now $I_E = I_c + I_B$

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

$\Rightarrow I_c = \alpha I_c + \alpha I_B + I_{CBO}$

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

$$\Rightarrow \boxed{I_c = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}}$$

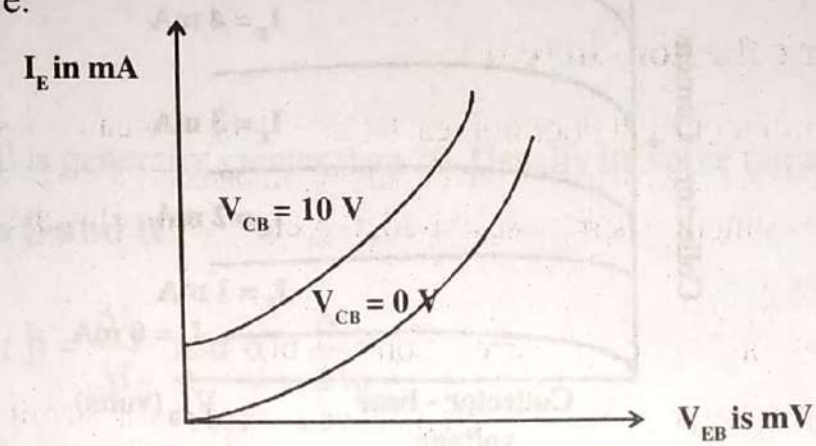
This is the expression for collector current.

Characteristics of Common-Base Connection :

The most important characteristics of common base connection are input characteristics and output characteristics.

1. Input Characteristics :

It is the curve between emitter current I_E and emitterbase voltagte V_{EB} at constant collector-base voltage V_{CB}. The following points may be noted from these characteristic curve.



(i) The emitter current I_E increases rapidly with small increase in emitter-base voltage V_{EB}. i.e Input resistance is very small.

(ii) The emitter current is almost independent of Collector-base voltage V_{CB}. i.e the emitter current is almost independent of collector voltage.

Input-Resistance :

It is the ratio of change in emitter-base voltage (ΔV_{EB}) to the resulting change in emitter current (ΔI_E) at constant-base voltage (V_{CB}) i.e,

$$\text{Input Resistance, } r_i = \frac{\Delta V_{BE}}{\Delta I_E} \text{ at constant } V_{CB}.$$

Input resistance is of the order of few ohms.

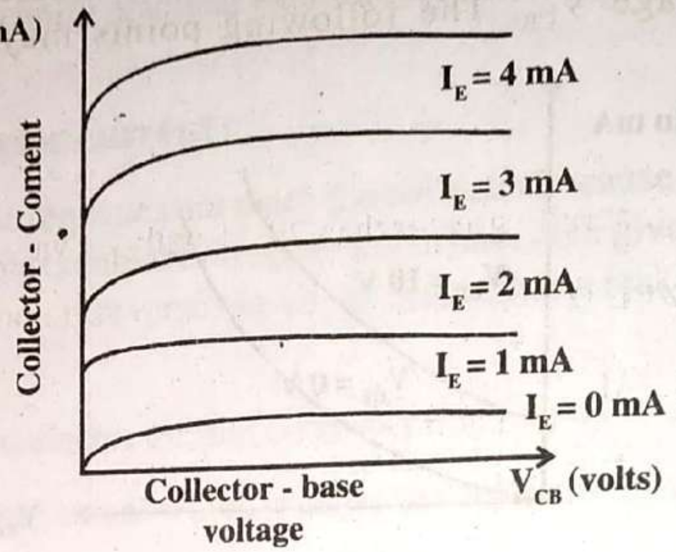
2. Output Resistance :

It is the curve between collector current I_c and Collector-base voltage V_{CB} at constant emitter current I_E. The following points may be noted from the characteristic curve :

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

(ii) When the value of V_{CB} is raised above 1-2 volt, the collector current becomes constant as indicated by straight horizontal curves. i.e Now I_c is independent of V_{CB} and depends upon I_E only. The transistor is always operated in this region.

(iii) A very large change in collector-base voltage produces only a tiny change in collector current. i.e the outpt resistance is very high.



Output Resistance :

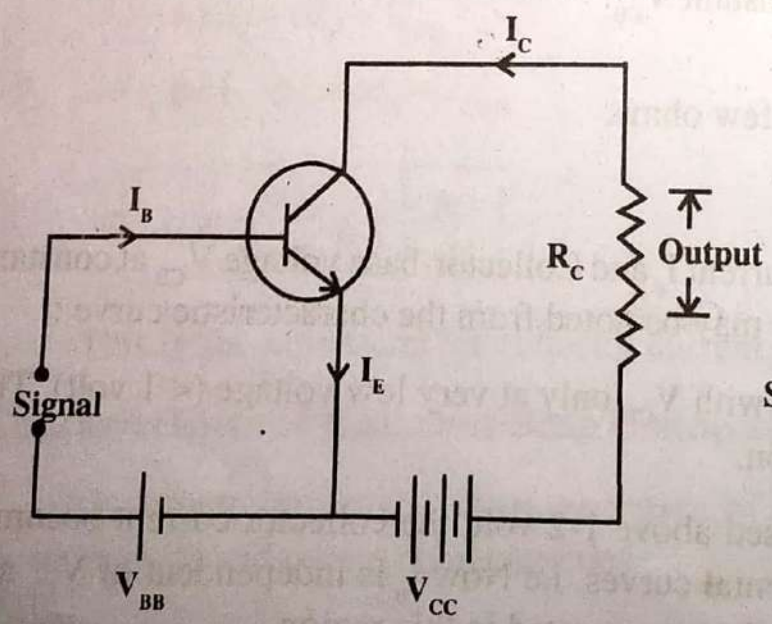
It is the ratio of change in collector-base voltage (ΔV_{CB}) to the resulting change in collector current (ΔI_C) at constant emitter current i.e

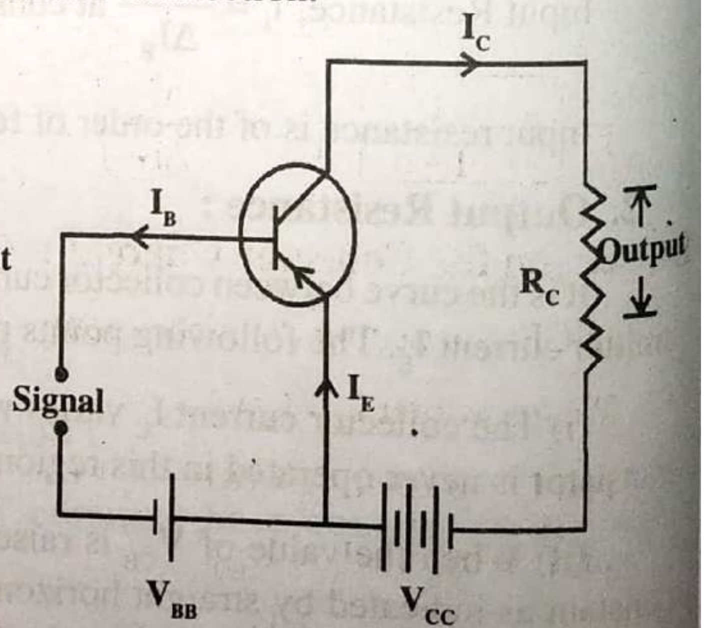
$$r_o = \frac{\Delta V_{CB}}{\Delta I_c} \text{ at constant } I_E.$$

Output resistance is of the order of several terms of kilo-ohms.

2.Common-Emitter Connection :

In CE Connection the input is applied between emitter and base while the output is obtained across collector and emitter. Since emitter is common to both input and output, therefore this connection is called as common emitter connection.





Base Current Amplification Factor (β) :

The ratio of change in collector current (ΔI_C) to the change in base current (ΔI_B) is known as base current amplification factor i.e

$$\beta = \frac{\Delta I_c}{\Delta I_B}$$

The value of β is generally greater than 20. Usually its value ranges from 20 to 500.

Relation between β and α :

We know that $\beta = \frac{\Delta I_c}{\Delta I_B}$ and $\alpha = \frac{\Delta I_c}{\Delta I_E}$

But $I_E = I_B + I_C$

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

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

Now we can write, $\beta = \frac{\Delta I_c}{\Delta I_E - \Delta I_C}$

or $\beta = \frac{\Delta I_c / \Delta I_E}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_c}{\Delta I_E}}$ (Dividing both numerator and denominator of R.H.S by ΔI_E)

$$\Rightarrow \boxed{\beta = \frac{\alpha}{1-\alpha}} \quad \left(\therefore \alpha = \frac{\Delta I_c}{\Delta I_E}\right)$$

Expression for Collector Current :

In CE-Connection, I_B is the Input and Current and I_C is the output current.

We know that $I_E = I_B + I_C$.

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

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

or, $I_C - \alpha I_C = \alpha I_B + I_{CBO}$

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

or, $I_c = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}$

If $I_B = 0$

Then $I_c = \frac{1}{1-\alpha} I_{CBO} = I_{CEO}$ (Collector-emitter current with base opened)

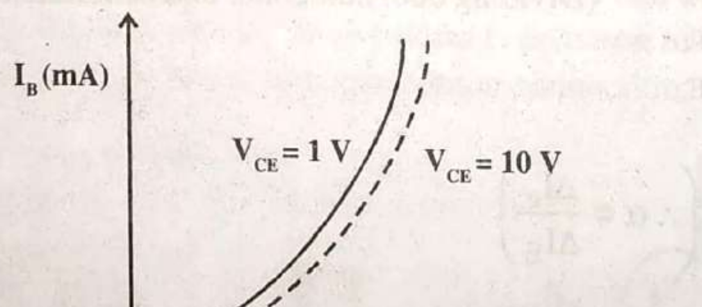
Now we can write $I_c = \frac{\alpha}{1-\alpha} I_B + I_{CEO}$

or, $I_c = \beta I_B + I_{CEO}$ $\left(\therefore \beta = \frac{\alpha}{1-\alpha}\right)$

Characteristics of Common-Emitter Connection :

1. Input characteristic :

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



- The following points may be noted from the characteristic curve :

(i) The characteristic resembles that of a forward biased diode curve, as the base-emitter junction of the transister is a diode.

(ii) 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 ckt.

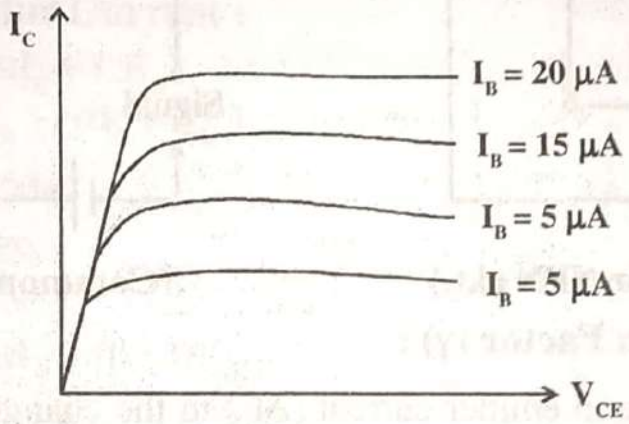
Input Resistance :

It is the ratio of change in base-emitter voltage (ΔV_{BE}) to the change in base current (ΔI_B) at constant V_{CE} i.e., $r_i = \frac{\Delta V_{BE}}{\Delta I_B}$ at constant V_{CE}.

Value of r_i for a CE ckt is of the order of a few hundred ohms.

Output Characteristics :

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



The following points may be noted from the characteristic curve :

(i) The collector current I_C varies with V_{CE} for V_{CE} between OV and IV only. After this, collector current becomes almost constant and independent of V_{CE}.

(ii) The value of V_{CE} upto which collector current I_C changes with V_{CE} is called as knee voltage.

(iii) The transistor is always operated in the region above knee voltage.

(iv) Above knee voltage, I_C is almost constant.

Output resistance :

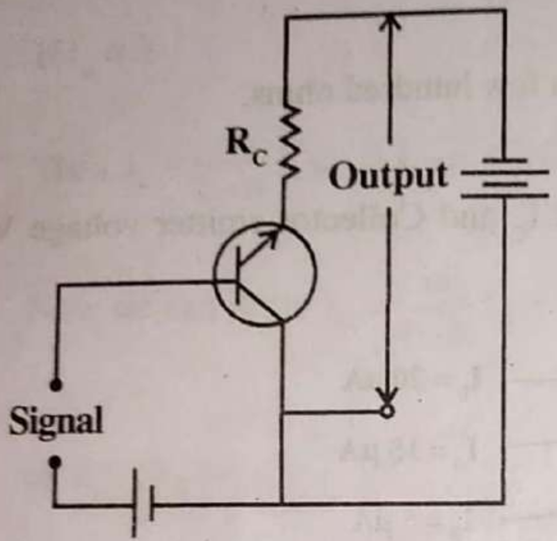
It is the ratio of change in collector emitter voltage (ΔV_{CE}) to the change in collector current (ΔI_C) at constant I_B i.e.,

Output resistance $r_0 = \frac{\Delta V_{CE}}{\Delta I_C}$ at constant I_B.

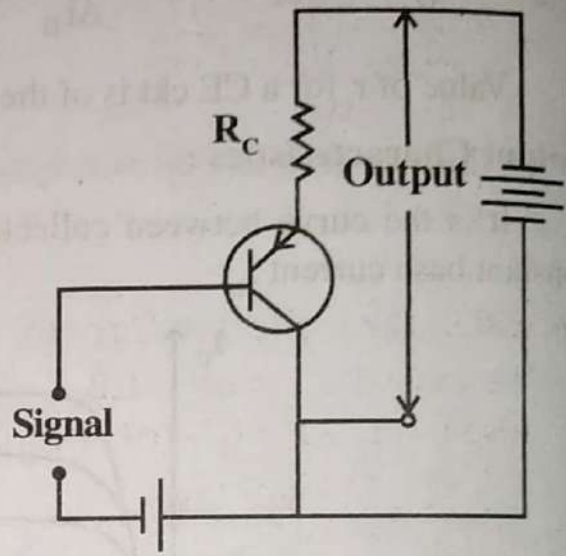
Value of r_0 is of the order of 50 kΩ.

3. Common collector connection :

In CC connection the input is applied between base and collector while output is obtained between emitter and collector. Since collector is common to both input and output, therefore, the connection is called as common collector connection.



(Common collector NPN ckt.)



(Common collector PNP ckt.)

Current Amplification Factor (γ) :

The ratio of change in emitter current (ΔI_E) to the change in base current (ΔI_B) is known as current amplification factor, i.e.,

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

Relation between γ and α :

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

$$\alpha = \frac{\Delta I_c}{\Delta I_E}$$

We know that $I_E = I_B + I_c$

or, $\Delta I_E = \Delta I_B + \Delta I_c$

or, $\Delta I_B = \Delta I_E - \Delta I_c$

Now $\gamma = \dfrac{\Delta I_E}{\Delta I_E - \Delta I_c}$

Dividing both numerator and denominator by I_E we can get

$$\gamma = \frac{\Delta I_E / \Delta I_E}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_c}{\Delta I_E}} = \frac{1}{1-\alpha}$$

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

Expression for Collector Current :

We know that $I_c = \alpha I_E + I_CB_O$

Also $I_E = I_B + I_c = I_B + (\alpha I_E + I_{CBO})$

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

or, $I_E = \dfrac{I_B}{1-\alpha} + \dfrac{I_{CBO}}{1-\alpha}$

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

Transistor Biasing :

The proper flow of zero signal collector current and the maintenance of proper colletor-emitter voltage during the passage of signal is known as transistor biasing.

Need of Biasing :

(i) To keep the base-emitter junction properly forward biased and collector-base junction properly reverse biased during the application of signal.

(ii) It should ensure proper zero signal collector current and V_{CE} i.e it should establish the operating point in the centre load ine curve.

Stabilisation :

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

Need for Stabilisation :

Stabilisation of the operating point is necessary due to the following reasons :

(i) Temperature dependence of I_c.

(ii) Indivisual Variations.

(iii) Thermal Runaway.

Thermal Runway :

The self destruction of an unstablised transistor is known as thermal runaway.

Stability Factor :

The rate of change of collector current I_c w.r.t the collector leakage current I_{CO} at constant β and I_B is called as stability factor i.e,

$$\text{Stability factor} = s = \frac{dI_c}{dI_{CO}} \text{ at constant } I_B \text{ and } \beta.$$

In order to achieve greater thermal stability, it is desirable to have as low stability factor as possible.

The general expression of stability for a C.E configuration can be obtained as

$I_c = \beta I_B + (\beta + 1) I_{CO}$

Differentiating above expression w.r.t I_c, we can get,

$$\frac{d}{dI_c}(I_c) = \frac{d}{dI_c}[\beta I_B + (\beta+1)I_{CO}]$$

$$\Rightarrow 1 = \beta\frac{dI_B}{dI_c} + (\beta+1)\frac{dI_{CO}}{dI_c}$$

$$\text{or, } 1 = \beta\frac{dI_B}{dI_c} + \frac{(\beta+1)}{S} \qquad \left[\because \frac{dI_{CO}}{dI_c} = \frac{1}{s}\right]$$

$$\text{or, } \boxed{S = \frac{\beta+1}{1-\beta\left(\frac{dI_B}{dI_c}\right)}}$$

Types of Biasing :

There are four types of biasing such as

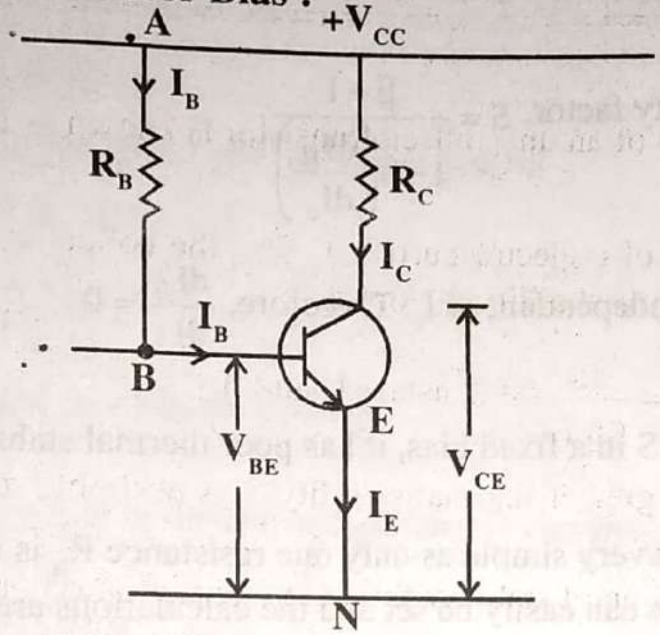
(i) Fixed bias or Base Resister bias.

(ii) Self bias or emitter stabilised method.

(iii) Voltage Divider bias.

(iv) Feed back Bias.

1.Fixed Bias or Base Resistor Bias :



(i) Here, a high resistance R_B is connected between the base and +ve end of supply for npn transistor and between base and negative end of supply for pnp transistor.

(ii) The required zero signal base current is provided by V_{CC} and it flows through R_B. as the base-emitter junction is forward-biased.

Circuit Analysis :

Let I_c = Required zero signal current.

$$\therefore I_B = \frac{I_c}{\beta} \qquad (\because I_c = \beta I_B)$$

In closed ckt. ABENA, applying KVL, we can get

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

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

$$\text{or, } R_B = \frac{V_{cc} - V_{BE}}{I_B} \qquad \text{.... (1)}$$

V_{BE} is generally quite small as compared to V_{CC} therefore we can neglect V_{BE}. Now equation (1) can be reduced to

$$\boxed{R_B = \frac{V_{cc}}{I_B}}$$

Here 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 region, this method is sometimes called as fixed-bias method.

Stability Factor :

We know that, stability factor, $S = \dfrac{\beta + 1}{1 - \beta\left(\dfrac{dI_B}{dI_c}\right)}$.

In this method, I_B is independent of I_c. Therefore, $\dfrac{dI_B}{dI_c} = 0$

So, $S = \beta + 1$

Due to large value of S in a fixed bias, it has poor thermal stability.

Advantages :

(i) This biasing ckt. is very simple as only one resistance R_B is required.

(ii) Biasing conditions can easily be set and the calculations are simple.

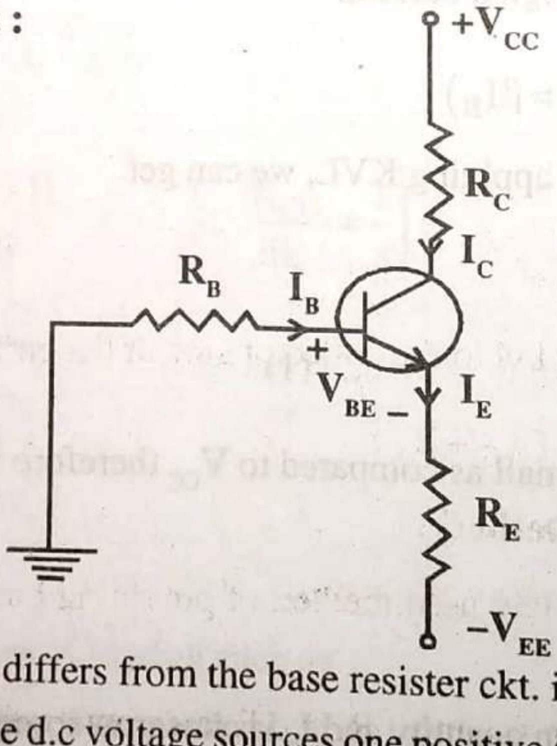
(iii) There is no loading of the source by the biasing ckt. Since no resister is employed across base-emitter junction.

Disadvantages :

(i) Provides poor stabilisation.

(ii) Stability factor is very high. Therefore there are strong chances of thermal runaway.

2. Emitter Bias Circuit :



The emitter bias ckt. differs from the base resister ckt. in two important respects :

(i) It uses two separate d.c voltage sources one positive ($+v_{cc}$) and the other negative ($-v_{EE}$) normally these two supply voltages will be equal.

(ii) There is a resister R_E in the emitter circuit.

Circuit Analysis :

Collector Current (I_C) :

Applying Kvl to the base-emitter ckt. we can get

$-I_B R_B - V_{BE} - I_E R_E + V_{EE} = 0$

or, $V_{EE} = I_B R_B + V_{BE} + I_E R_E$

Now $I_c \cong I_E$ and $I_c = \beta I_B \Rightarrow I_B \cong \frac{I_E}{\beta}$

Substituting $I_B \Rightarrow I_E/\beta$ in the above equation we can get

$$V_{EE} = \left(\frac{I_E}{\beta}\right) R_B + I_E R_E + V_{BE}$$

or, $V_{EE} - V_{BE} = I_E (R_B / \beta + R_E)$

or, $I_E = \frac{V_{EE} - V_{BE}}{R_E + R_B / \beta}$

Since $I_C \cong I_E$, we have

$$I_C = \frac{V_{EE} - V_{BE}}{R_E + R_B / \beta}$$

Alternatively applying kvl to the collector side of the emitter bias ckt, we can get

$$V_{CE} = V_{CC} + V_{EE} - I_C (R_C + R_E)$$

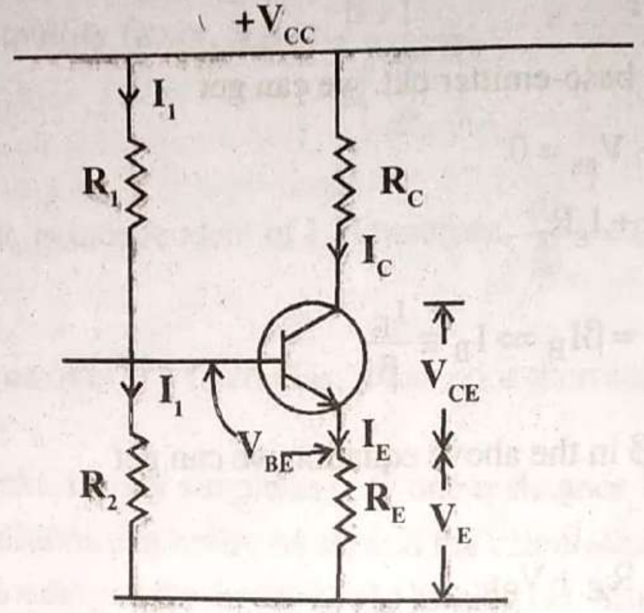
3. Voltage Divider Bias method :

(i) This is the most widely used method of providing biasing and stabilisation to a transistor.

(ii) In this method two resistances R_1 and R_2 are connected across the supply voltage V_{CC} and provide biasing.

(iii) The emitter resistance R_E provides stabilisation.

(iv) The voltage drop across R_2 forward biases the base emitter junction. This causes the base current and hence collector current flow in the zero signal condition.



Circuit Analysis :

Let I_1 = Current flowing through R_1.

Since I_B is very small therefore, it can be assumed with reasonable accuracy that current flowing through R_2 is also I_1.

Collector current I_C :

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

Now voltage across resistance R_2 is

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

Applying KVL to the base circuit we can get

$V_2 = V_{BE} + V_E$

or, $V_2 = V_{BE} + I_E R_E$

or, $I_E = \dfrac{V_2 - V_{BE}}{R_E}$

Since $I_E \cong I_C$

Therefore, $I_C = \dfrac{V_2 - V_{BE}}{R_2}$

From the above equation it is clear that I_C does not depend upon β. Though I_C depends upon V_{BE} but in practice $V_2 >> V_{BE}$. So I_C practically independent of V_{BE}. Thus, I_C is almost independent of transistor parameters and hence stabilisation is good.

Collector emitter voltage V_{CE} :

Applying KVL to the collector side,

$$V_{CC} = I_C R_C + V_{CE} + I_E R_E$$

$$= I_C R_C + V_{CE} + I_C R_E \quad (\because I_E \cong I_C)$$

$$= I_C (R_C + R_E) + V_{CE}$$

or, $V_{CE} = V_{CC} - I_C (R_C + R_E)$

Stability Factor :

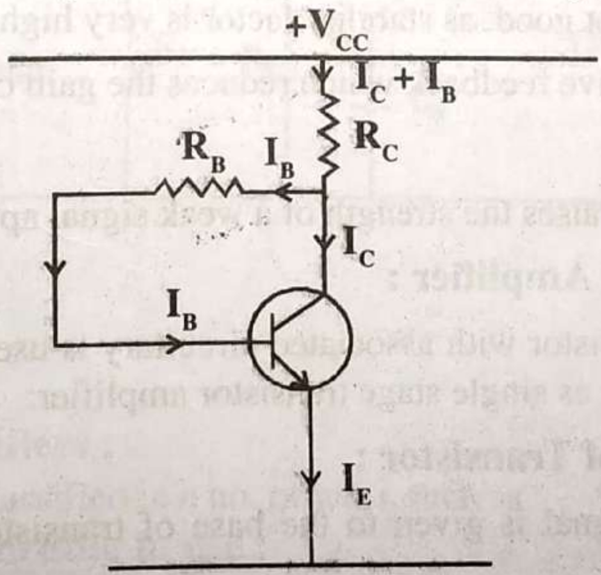
In this method S = 1

This is the smallest possible value of s and leads to the maximum possible thermal stability.

4. Feed back Biasing :

(i) In this method, one end of R_B is connected to the base and the other end is connected to the collector.

(ii) The required zero signal base current is determined by collector base voltage V_{CB}.



(iii) V_{CB} forward biases the base emitter junction and hence base current I_B flows through R_B. This causes zero signal collector current to flow in the ckt.

Circuit Analysis :

From the figure $V_{CC} = I_C R_C + I_B R_E + V_{BE}$

$$\text{or, } R_B = \frac{V_{CC} - V_{BE} - I_C R_C}{I_B}$$

$$= \frac{V_{CC} - V_{BE} - \beta I_B R_C}{I_B} \quad (\because I_C = \beta I_B)$$

Alternatively $V_{CE} = V_{BE} + V_{CB}$

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

$$\text{or, } R_B = \frac{V_{CB}}{I_B} = \frac{V_{CE} - V_{BE}}{I_B} \text{ where } I_B = \frac{I_C}{\beta}$$

Here stability factor $S < \beta + 1$

Therefore, this method provides better thermal stability than the fixed bias.

Advantages :

(i) It is a simple method as it requires only one resistance R_B.

(ii) The ckt. provides some stabilisation of the operating point.

Disadvantages :

(i) Stabilisation is not good, as stability factor is very high.

(ii) Provides a negative feedback which reduces the gain of the amplifier.

Amplifier :

It is a device which raises the strength of a weak signal applied at the input.

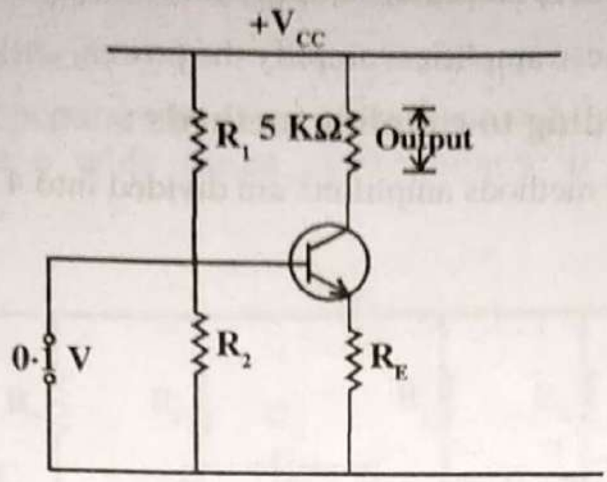
Single Stage Transistor Amplifier :

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

Amplification Process of Transistor :

(i) When a weak signal is given to the base of transistor, a small base current starts flowing.

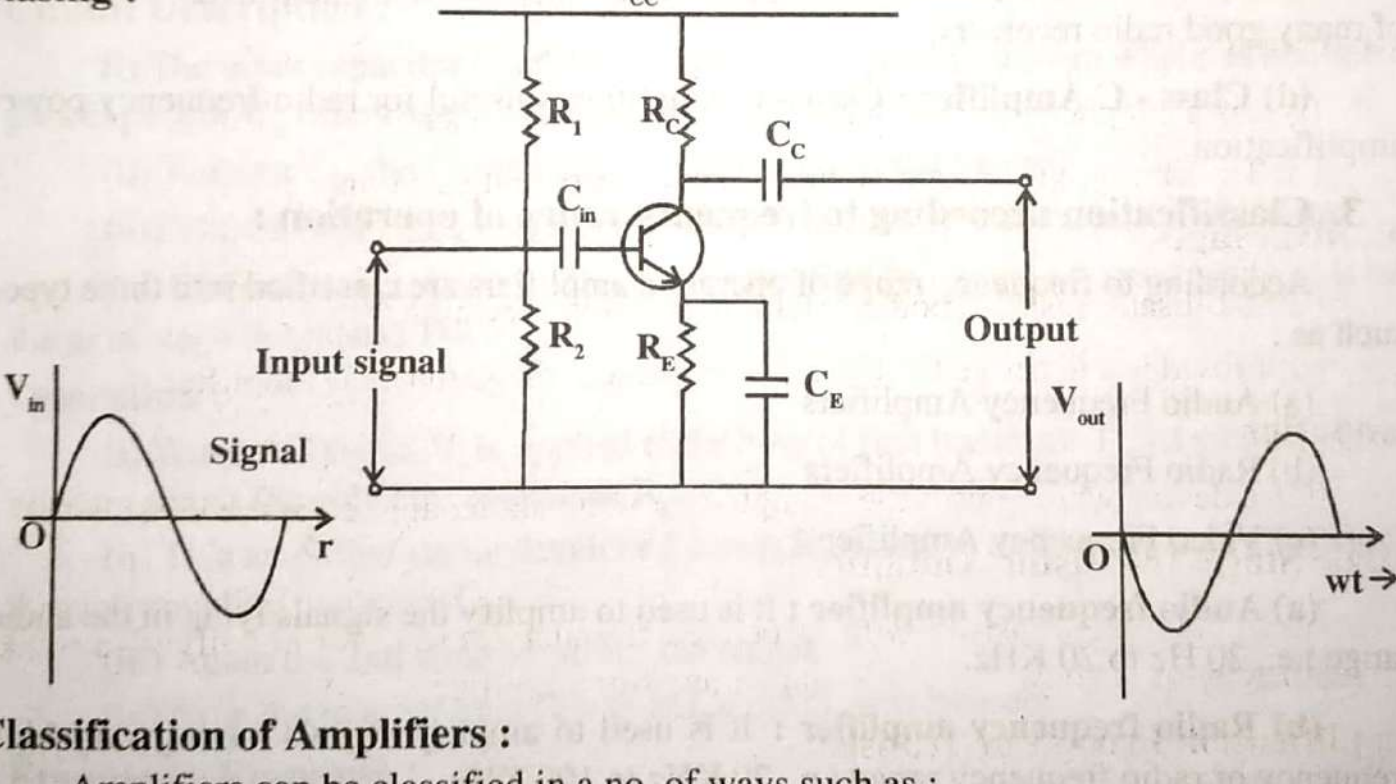
(ii) Due to transistor action, a much large a.c. current flows through the collector load R_C.



(iii) As the value of R_C is quite high (usually 4-10 kΩ), therefore, a large voltage appears across R_C.

(iv) Thus, a weak signal applied in the base ckt. appears in amplified form in collector ckt. In this way a transistor acts as an amplifier.

Working principle of single stage CE transistor Amplifier with voltage divider biasing :



Classification of Amplifiers :

Amplifiers can be classified in a no. of ways such as :

1. Classification according to use :

According to use amplifiers are divided into the following types.

(a) Voltage Amplifier

(b) Power Amplifier

Voltage Amplifier : These amplifiers amplify the voltage.

Power Amplifier : These amplifiers amplify the power.

2. Classification according to coupling methods :

According to coupling methods amplifiers are divided into 4 types such as :

(a) Class A

(b) Class B

(c) Class AB

(d) Class C

(a) Class - A Amplifier : These are used to amplify speech signals from microphone sets.

(b) Class - B Amplifier : These amplifiers produce a large power output and are used at broadcasting stations.

(c) Class - AB Amplifier : This type of amplifier is used in the loudspeaker stages of many good radio receivers.

(d) Class - C Amplifier : Class - C Amplifier is useful for radio frequency power amplification.

3. Classification according to frequency range of operation :

According to frequency range of operation amplifiers are classified into three types such as :

(a) Audio Frequency Amplifiers

(b) Radio Frequency Amplifiers

(c) Video Frequency Amplifier

(a) Audio frequency amplifier : It is used to amplify the signals lying in the audio range i.e., 20 Hz to 20 KHz.

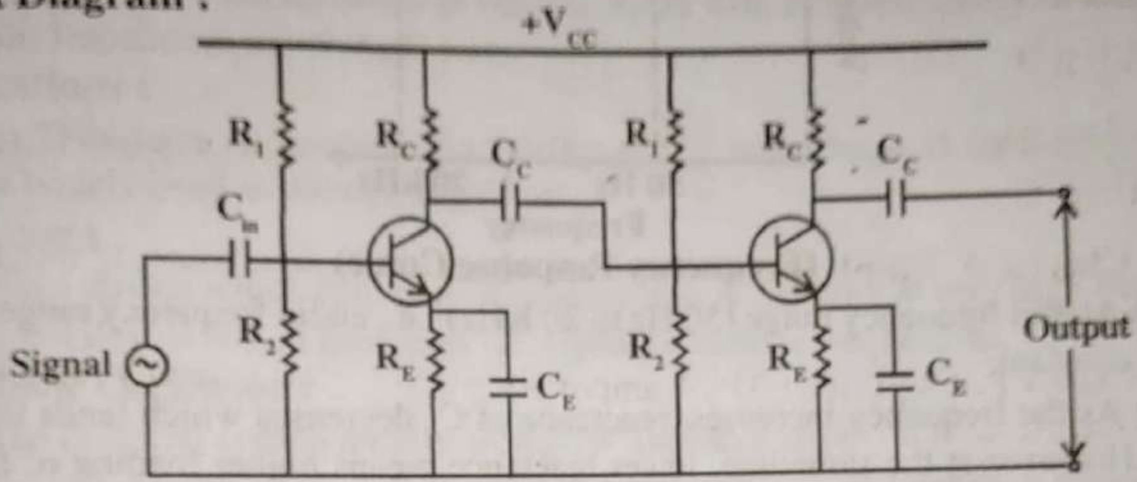
(b) Radio frequency amplifier : It is used to amplify signals having very high frequency or radio frequency range i.e., 20 KHz to 100 KHz.

(c) Video frequency amplifier : Amplifiers that are used to amplify a wide band of frequencies in the range of few cycles per second to a few megacycles per second are called video frequency amplifiers. It is used in TV circuits.

R-C Coupled Amplifier :

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

Circuit Diagram :



Circuit Description :

(i) The input capacitor C_{in} allows only the A.C signal to flow in where as emitter by pass capacitor C_E offers low reactance path to the signal.

(ii) Without C_E, the voltage gain of each stage would be lost.

(iii) The resistor R_1, R_2 and R_E provides the necessary biasing and stabilisation.

(iv) The coupling capacitor CE allows amplified AC signal of one stage to pass into the next stage but blanks D.C.

Operation :

(i) When AC signal V_n is applied to the base of first transistor T_1, its amplified form appears across the collector resistance R_C.

(ii) This amplified signal developed across RC is fed to the base of next transistor T_2 through coupling capacitor C_E.

(iii) Again the 2nd state amplifies the signal.

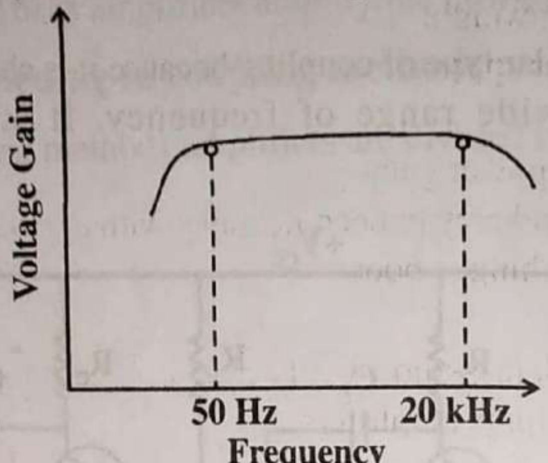
(iv) Now the over all gain $G = G_1 \times G_2 \times \ldots \times G_n$ is increased.

Frequency Response :

(i) The curve between signal frequency and voltage gain of an amplifier is called as frequency response curve.

(ii) At low frequency (< 50 Hz), the voltage gain is small, because (a) the reactance of the coupling capacitor C_C is quite high and hence very small part of signal will pass from one stage to next stage.

(b) C_E cannot shunt the emitter resistance R_E efficiency because of its large reactance at low frequencies.



(Frequency Response Come)

(iii) At mid frequency range (50 Hz to 20 KHz) i.e., audio frequency range, the gain is almost constant.

(iv) As the frequency increases, reactance of C_C decreases which tends to increase the gain. However at the sametime, lower reactance means higher loading of first stage and hence lower gain.

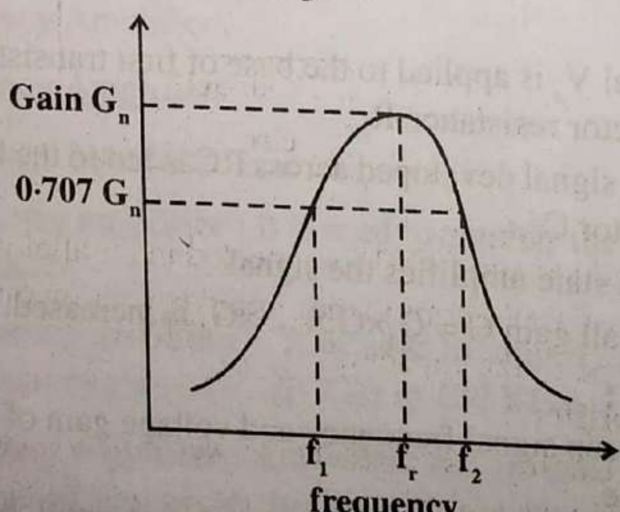
(v) At high frequencies (> 20 KHz) the voltage gain drops off.

Band width :

(i) The range of frequencies over which the gain is equal to 70.7% of the maximum gain is known as band width.

(ii) Here $f_1 - f_2$ is the bandwidth.

(iii) The bandwidth of an amplifier is the range of frequency at the limits of which its voltage gain falls by 3dB from maximum gain.



Advantages :

(i) It has excellent frequency response. The gain is constant over the audio frequency range which is the region of most importance for speech, music etc.

(ii) It has lower cost since it employs resistors and capacitors which are cheap.

(iii) They are light in weight.

(iv) They occupy less space.

Disadvantages :

(i) Low voltage and power gain

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

(iii) Impedence matching is poor.

Applications :

(i) They have excellent audio fidelity over a wide range of frequency. Therefore, they are widely used as voltage amplifiers.

Oscillator :

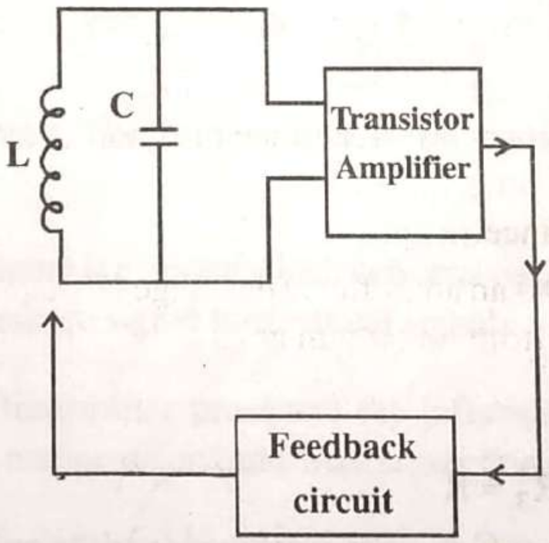
It is a device which converts DC energy into AC energy at very high frequency.

It is a device which generates AC signal of various frequencies.

Transistor Oscillator :

The essential components of transistor oscillator are :

1. Tank circuit 2. Transistor Amplifier 3. Feedback circuit



1. Tank circuit :

(i) It consists of inductance coil (L) connected in parallel with capacitor (C).

(ii) The frequency of oscillations in the circuit depends upon the values of inductance of the coil and capacitance of the capacitor.

2. Transistor Amplifier :

(i) The transistor Amplifier receives d.c. power from the battery and changes it into a.c. power for supplying to the tank circuit.

(ii) The oscillations occurring in the tank circuit are applied to the input of the transistor amplifier for amplification.

3. Feedback circuit :

The feedback circuit supplies a part of collector energy to the tank circuit in correct phase to aid the oscillations i.e:, it provides positive feedback.

Different types of Oscillators :

1. Tuned collector oscillator

$$f = \frac{1}{2\pi\sqrt{L_1C_1}}$$

2. Colpit's oscillator

$$f = \frac{1}{2\pi\sqrt{LC_T}}$$

$$C_T = \frac{C_1C_2}{C_1 + C_2} = \text{Total capacitance}$$

3. Hartley oscillator

$$f = \frac{1}{2\pi\sqrt{CLT}}$$

$$L_T = L_1 + L_2 + 2M$$

M = Mutual inductance

4. Phase shift oscillator

$$f = \frac{1}{2\pi RC\sqrt{6}}$$

where $R_1 = R_2 = R_3 = R$

$C_1 = C_2 = C_3 = C$

5. Wien Bridge Oscillator

$$f = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$

If $R_1 = R_2 = R$ and $C_1 = C_2 = C$ then $f = \frac{1}{2\pi RC}$

6. Crystal oscillator

■