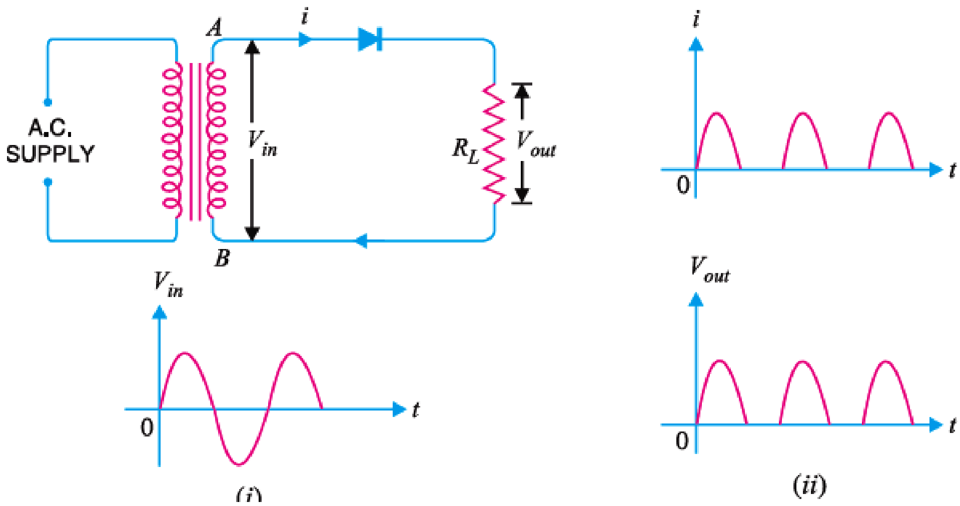
1 Half wave rectifier

As the name suggests, the half wave rectifier is a type of rectifier which converts half of the AC input signal (positive half cycle) into pulsating DC output signal and the remaining half signal (negative half cycle) is blocked or lost. In half wave rectifier circuit, we use only a single diode.

In half-wave rectification, the rectifier conducts current only during the positive half-cycles of input a.c. supply. The negative half-cycles of a.c. supply are suppressed i.e. during negative half-cycles, no current is conducted and hence no voltage appears across the load. Therefore, current always flows in one direction (i.e. d.c.) through the load though after every half-cycle



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 this condition, 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 RL always in the same direction. Hence d.c. output is obtained across RL.

It may be noted that output across the load is **pulsating d.c**. These pulsations in the output are further smoothened with the help of **filter circuits** . The pulsating DC current always flows in one direction like the pure DC current. However, the value of pulsating DC current or pulsating DC voltage slightly changes over a given period. The electric current produced by batteries, power supplies, and solar panels is a pure DC current.

By using the combination of components such as capacitors, inductors, and resistors in the circuit, we can achieve the smoothening of pulsating DC to pure DC.

The output frequency of a half-wave rectifier is equal to the input frequency (50 Hz).

1.1 Efficiency of a Half-Wave Rectifier

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

Rectifier efficiency, = d.c. power output/Input a.c. power

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.

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.

$$P_{dc} = I_{dc}^2 R_L$$

$$P_{dc} = \frac{I_m}{\pi}^2 R_L$$

a.c. power input : The a.c. power input is given by

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

$$P_{ac} = \frac{I_m}{2}^2 (r_f + R_L)$$

$$\begin{aligned} Efficiency &= \frac{P_{dc}}{P_{ac}} \\ &= \frac{\frac{I_m}{\pi}^2 R_L}{\frac{I_m}{2}^2 (r_f + R_L)} \\ &= \frac{0.406}{1 + r_F/R_L} \end{aligned}$$

The efficiency will be maximum if r_f is negligible as compared to R_L. Max. rectifier efficiency = 40.6 %. This shows that in half-wave rectification, a maximum of 40.6 % of a.c. power is converted into d.c. power.

2 Full wave rectifier

The full wave rectifier is a type of rectifier which converts the full AC input signal (positive half cycle and negative half cycle) to pulsating DC output signal. Unlike the half wave rectifier, the input signal is not wasted in full wave rectifier. The efficiency of full wave rectifier is high as compared to the half wave rectifier.

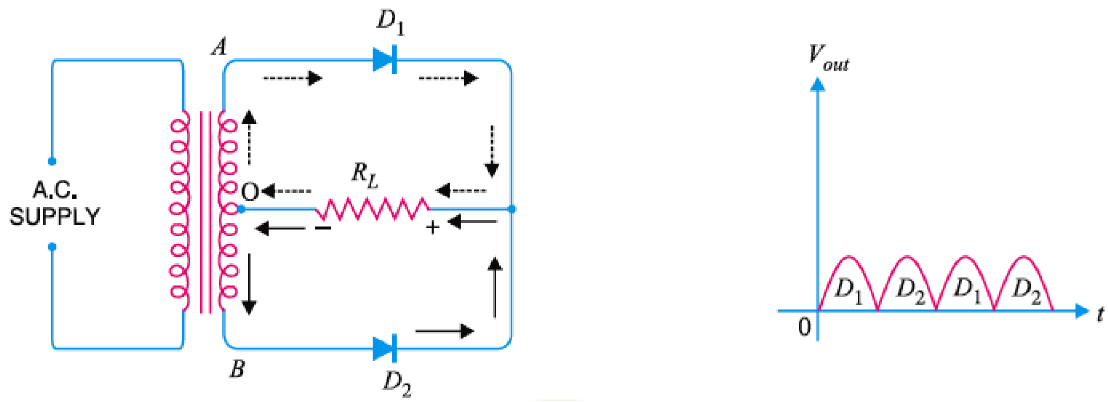
In full-wave rectification, current flows through the load in the same direction for both half-cycles of input a.c. voltage. This can be achieved with two diodes working alternately. For the positive halfcycle of input voltage, one diode supplies current to the load and for the negative half-cycle, the other diode does so ; current being always in the same direction through the load. Therefore, a full-wave rectifier utilises both half-cycles of input a.c. voltage to produce the d.c. output. The following two circuits are commonly used for full-wave rectification - (i) Centre-tap full-wave rectifier (ii) Full-wave bridge rectifier

2.1 Centre-tap full-wave rectifier

The circuit employs two diodes D1 and D2 as shown in Fig. A centre tapped secondary winding AB is used with two diodes connected so that each uses one half-cycle of input a.c. voltage. In other words, diode D1 utilises the a.c. voltage appearing across the upper half (OA) of secondary winding for rectification while diode D2 uses the lower half winding OB.

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 D1 forward biased and diode D2 reverse biased.

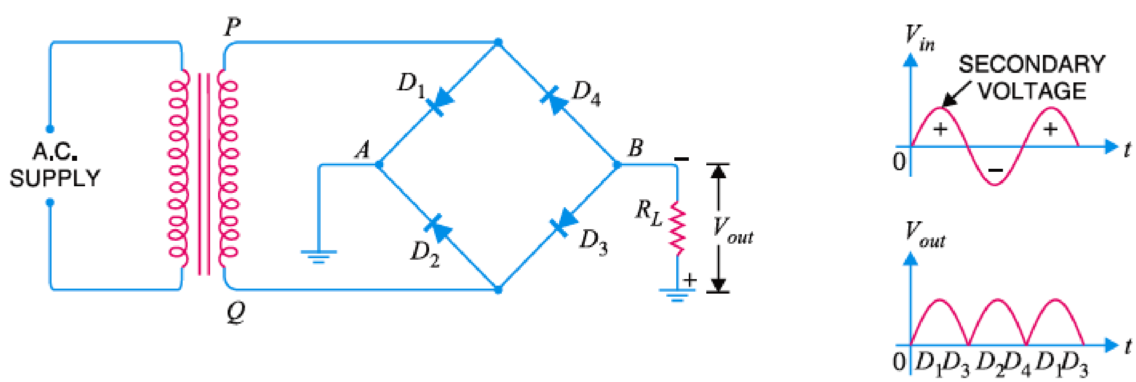
Therefore, diode D1 conducts while diode D2 does not. The conventional current flow is through diode D1, load resistor RL and the upper half of secondary winding as shown by the dotted arrows. During the negative half-cycle, end A of the secondary winding becomes negative and end B positive. Therefore, diode D2 conducts while diode D1 does not. The conventional current flow is through diode D2, load RL and lower half winding as shown by solid arrows. It may be seen that current in the load RL is in the same direction for both half-cycles of input a.c. voltage. Therefore, d.c. is obtained across the load R_L. Also, the polarities of the d.c. output across the load should be noted.



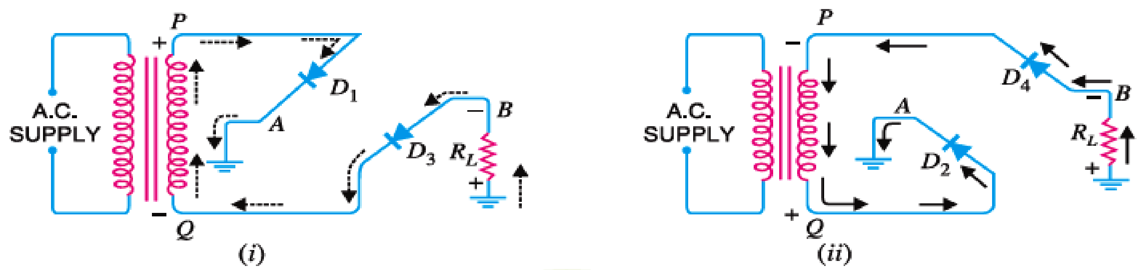
Peak inverse voltage - Suppose V_m is the maximum voltage across the half secondary winding. Fig. 6.25 shows the circuit at the instant secondary voltage reaches its maximum value in the positive direction. At this instant, diode D1 is conducting while diode D2 is non-conducting. Therefore, whole of the secondary voltage appears across the non-conducting diode. Consequently, the peak inverse voltage is twice the maximum voltage across the half-secondary winding i.e. $PIV = 2V_m$

2.2 Full-Wave Bridge Rectifier

The need for a centre tapped power transformer is eliminated in the bridge rectifier. It contains four diodes D1, D2, D3 and D4 connected to form bridge as shown in Fig. 6.26. 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 RL is connected.



During the positive half-cycle of secondary voltage, the end P of the secondary winding becomes positive and end Q negative. This makes diodes D1 and D3 forward biased while diodes D2 and D4 are reverse biased. Therefore, only diodes D1 and D3 conduct. These two diodes will be in series through the load RL as shown in Fig. The conventional current flow is shown by dotted arrows. It may be seen that current flows from A to B through the load RL . During the negative half-cycle of secondary voltage, end P becomes negative and end Q positive. This makes diodes D2 and D4 forward biased whereas diodes D1 and D3 are reverse biased. Therefore, only diodes D2 and D4 conduct. These two diodes will be in series through the load RL as shown in Fig. The current flow is shown by the solid arrows. It may be seen that again 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 load R_L.



In bridge rectifier, the peak inverse voltage is the maximum voltage $PIV = V_m$
The output frequency of a full-wave rectifier is double the input frequency.

2.2.1 Efficiency of a full wave rectifier

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

Rectifier efficiency, = d.c. power output/Input a.c. power

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.

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.

$$P_{dc} = I_{dc}^2 R_L$$
$$P_{dc} = \frac{2I_m}{\pi}^2 R_L$$

a.c. power input : The a.c. power input is given by

$$P_{ac} = I_{rms}^2 (r_f + R_L)$$
$$P_{ac} = \frac{I_m}{\sqrt{2}}^2 (r_f + R_L)$$

$$\begin{aligned} Efficiency &= \frac{P_{dc}}{P_{ac}} \\ &= \frac{\frac{2I_m}{\pi}^2 R_L}{\frac{I_m}{\sqrt{2}}^2 (r_f + R_L)} \\ &= \frac{0.812}{1 + r_F/R_L} \end{aligned}$$

The efficiency will be maximum if r_f is negligible as compared to R_L. Max. rectifier 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

2.3 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.

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.

Ripple factor = r.m.s. value of a.c component of voltage (or current)/ value of d.c. component of voltage (or current) $= \frac{I_{ac}}{I_{dc}}$

The smaller the ripple factor, the lesser the effective a.c. component and hence more effective is the rectifier

$$\begin{aligned} I_{rms} &= \sqrt{I_{ac}^2 + I_{dc}^2} \\ I_{ac} &= \sqrt{I_{rms}^2 - I_{dc}^2} \\ Dividing\ throughout\ by\ I_{dc}, & \\ \frac{I_{ac}}{I_{dc}} &= \frac{1}{I_{dc}}\sqrt{I_{rms}^2 - I_{dc}^2} \\ Ripple\ Factor &= \sqrt{\frac{I_{rms}^2}{I_{dc}^2} - 1} \end{aligned}$$

For half-wave rectification, $I_{rms} = \frac{I_m}{2} =, I_{dc} = \frac{I_m}{\pi}$

So Ripple factor for half-wave rectification is 1.21

It is clear that a.c. component exceeds the d.c. component in the output of a half-wave rectifier. This results in greater pulsations in the output. Therefore, half-wave rectifier is ineffective for conversion of a.c. into d.c.

For full-wave rectification, $I_{rms} = \frac{I_m}{\sqrt{2}}, I_{dc} = \frac{2I_m}{\pi}$

So Ripple factor for half-wave rectification is 0.48

This shows 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.

2.4 Average dc Voltages

The average dc output voltage of a half-wave rectifier is

$$\boxed{V_{dc} = 0.318(V_m - V_T)}$$

where V_m is the maximum value of ac input signal to be rectified and V_T is the barrier potential of Si diode

For a full-wave rectifier,

$$\boxed{V_{dc} = 0.636(V_m - 2V_T)}$$

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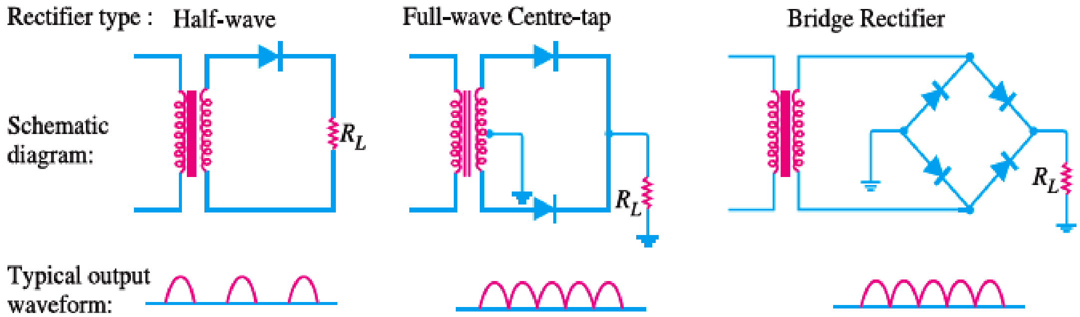
Comparison of Rectifiers

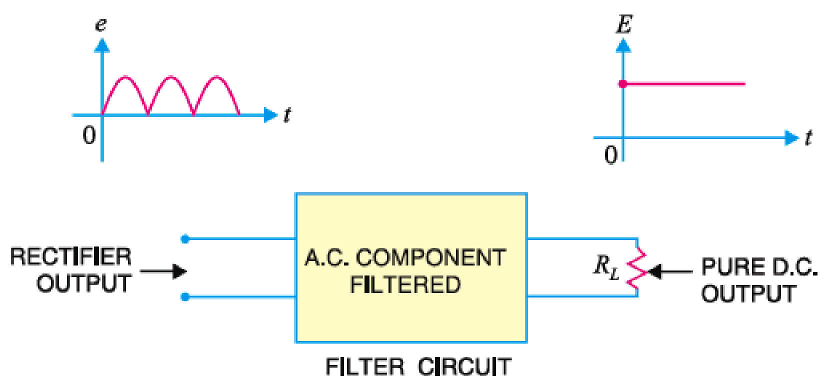


S. No.	Particulars	Half-wave	Centre-tap	Bridge type
1	No. of diodes	1	2	4
2	Transformer necessary	no	yes	no
3	Max. efficiency	40.6%	81.2%	81.2%
4	Ripple factor	1.21	0.48	0.48
5	Output frequency	f_{in}	$2 f_{in}$	$2 f_{in}$
6	Peak inverse voltage	V_m	$2\ V_m$	V_m

3 Filter Circuits

A rectifier is required to produce pure d.c. supply for using at various places in the electronic circuits. However, the output of a rectifier has pulsating *character i.e. 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 (or filters out) the a.c. component and allows only 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.

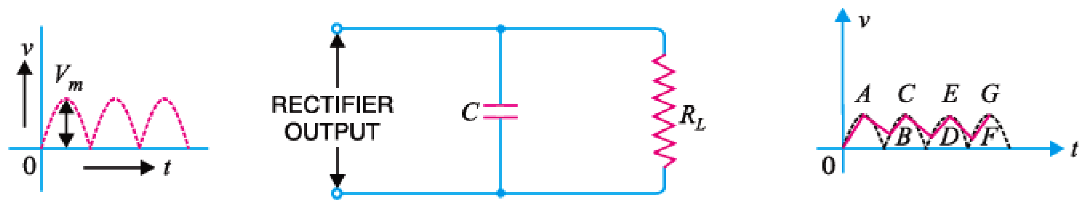


Obviously, a filter circuit should be installed between the rectifier and the load as shown in Fig. A filter circuit is generally a combination of inductors (L) and capacitors (C). The filtering action of L and C depends upon the basic electrical principles. A capacitor passes a.c. readily but does not 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 L and C can effectively remove the a.c. component, allowing the d.c. component to reach the load.

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

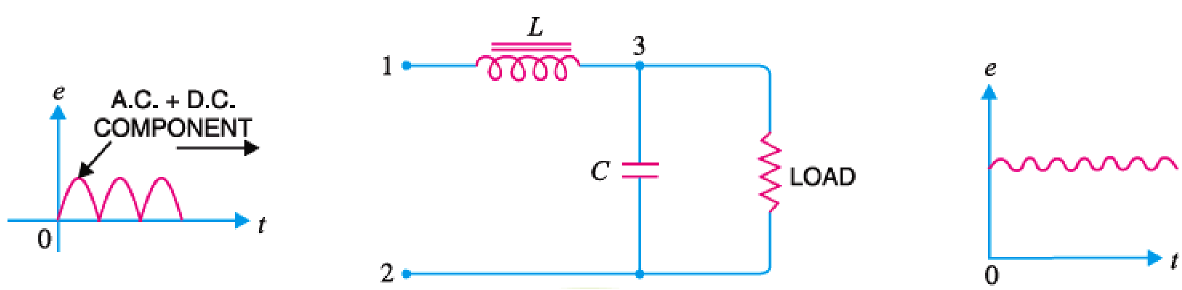
3.1 Capacitor filter

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, 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 discharges through the load and voltage across it (i.e. across parallel combination of R-C) decreases as shown by the line AB in Fig. 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 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.



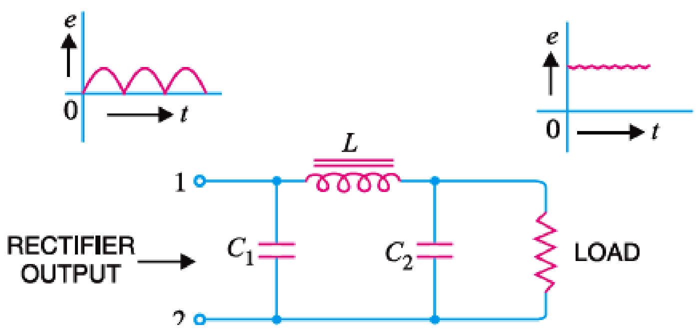
3.2 Choke input filter

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



3.3 Capacitor input filter or π - filter

It consists of a filter capacitor C1 connected across the rectifier output, a choke L in series and another filter capacitor C2 connected across the load. The pulsating output from the rectifier is applied across the input terminals (i.e. terminals 1 and 2) of the filter. The filter capacitor C1 offers low reactance to a.c. component of rectifier output while it offers infinite reactance to the d.c. component. Therefore, capacitor C1 bypasses an appreciable amount of a.c. component while the d.c. component continues its journey to 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 *unbypassed a.c. component is blocked. The filter capacitor C2 bypasses the a.c. component which the choke has failed to block. Therefore, only d.c. component appears across the load and that is what we desire.



4 Transistor

A transistor consists of two pn junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types. Accordingly ; there are two types of transistors, namely;

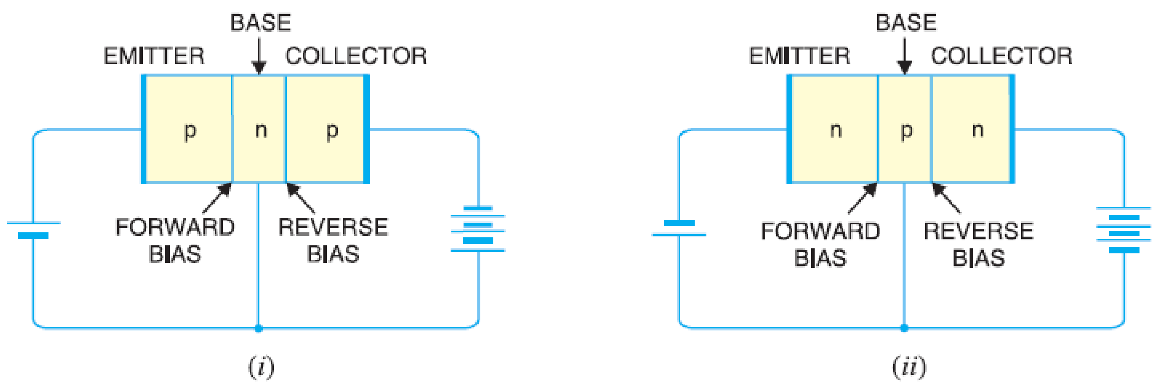
(i) n-p-n transistor (ii) p-n-p transistor

An n-p-n transistor is composed of two n-type semiconductors separated by a thin section of p-type. However, a p-n-p transistor is formed by two p-sections separated by a thin section of n-type.

In each type of transistor, the following points may be noted :
(i) These are two pn junctions. Therefore, a transistor may be regarded as a combination of two diodes connected back to back.
(ii) There are three terminals, one taken from each type of semiconductor.
(iii) The middle section is a very thin layer. This is the most important factor in the function of a transistor.

A transistor (pnp or npn) has three sections of doped semiconductors. 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.
(i) Emitter. The section on one side that supplies charge carriers (electrons or holes) is called the emitter. The emitter is always forward biased w.r.t. base so that it can supply a large number of majority carriers. The emitter (p-type) 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.
(ii) 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.
(iii) Base. The middle section which forms two pn-junctions between the emitter and collector is called the 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.



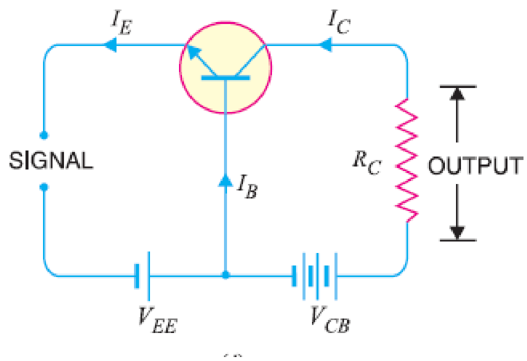
5 Transistor characteristics

There are three leads in a transistor viz., 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 the transistor 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. Accordingly; a transistor can be connected in a circuit in the following three ways :
(i) common base connection (ii) common emitter connection and (iii) common collector connection. Each circuit connection has specific advantages and disadvantages

The complete electrical behaviour of a transistor can be described by stating the interrelation of the various currents and voltages. These relationships can be conveniently displayed graphically and the curves thus obtained are known as the characteristics of transistor

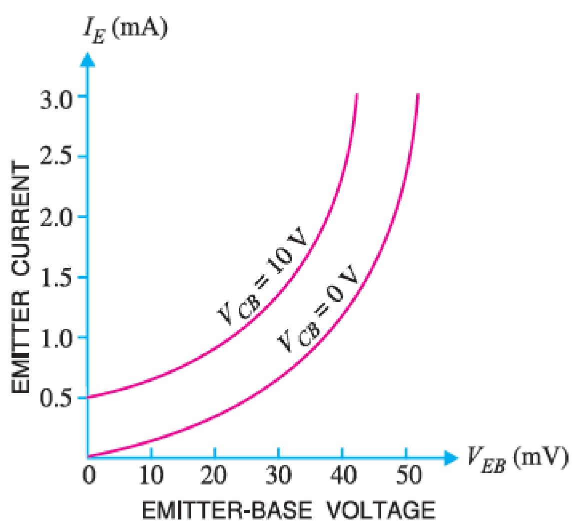
5.1 Characteristics of Common Base Connection

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



5.1.1 Input characteristics

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



Input resistance is the ratio of change in emitter-base voltage (ΔV_{EB}) to the resulting change in emitter current (ΔI_E) at constant collector-base voltage (V_{CB}).

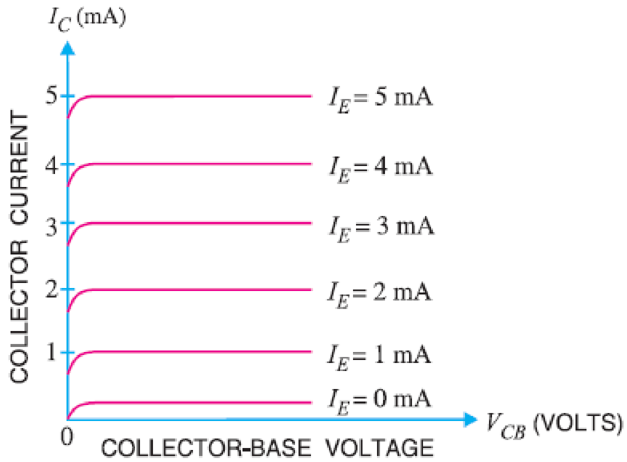
5.1.2 Output characteristics

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. Fig. shows the output characteristics of a typical transistor in CB arrangement.

(i) The collector current I_C varies with V_{CB} only at very low voltages ($< 1V$). The transistor is never operated in this region.
(ii) When the value of V_{CB} is raised above 1 - 2 V, the collector current becomes constant as indicated

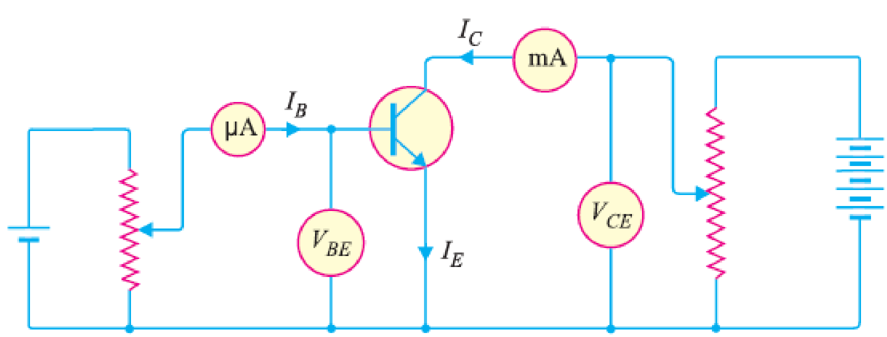
by straight horizontal curves. It means that now I_C is independent of V_{CB} and depends upon I_E only. This is consistent with the theory that the emitter current flows almost entirely to the collector terminal. The transistor is always operated in this region.
(iii) A very large change in collector-base voltage produces only a tiny change in collector current. This means that output 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. The output resistance of CB circuit is very high, of the order of several tens of kilo-ohms since the collector current changes very slightly with the change in V_{CB}



5.2 Common Emitter Connection

In this circuit arrangement, input is applied between base and emitter and output is taken from the collector and emitter. Here, emitter of the transistor is common to both input and output circuits and hence the name common emitter connection.



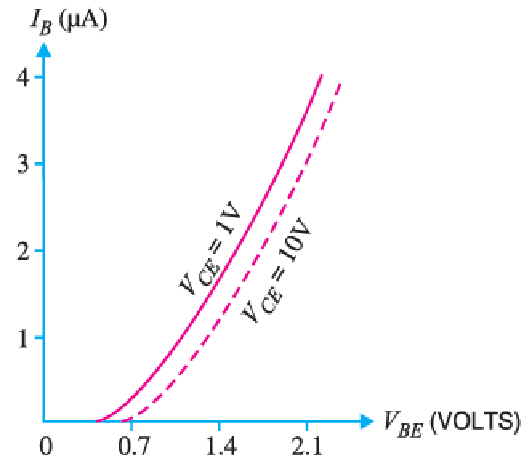
5.2.1 Input characteristics

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

Keeping V_{CE} constant (say at 10 V), note the base current IB for various values of VBE. 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 $V_{CE} = 10$V.

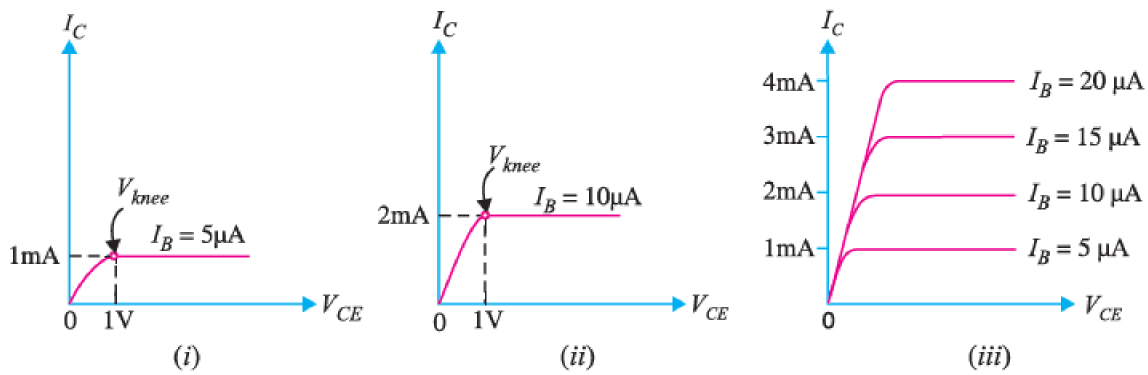
(i) The characteristic resembles that of a forward biased diode curve. This is expected since the base-emitter section of transistor is a diode and it is forward biased.
(ii) As compared to CB arrangement, I_B increases less rapidly with V_{BE}. Therefore, input resistance of a CE circuit is higher than that of CB circuit.

Input resistance is the ratio of change in base-emitter voltage (ΔV_{BE}) to the change in base current (ΔI_B) at constant V_{CE}. The value of input resistance for a CE circuit is of the order of a few hundred ohms



5.2.2 Output characteristic

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



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. The output characteristics of CB circuit are horizontal, they have noticeable slope for the CE circuit. Therefore, the output resistance of a CE circuit is less than that of CB circuit.

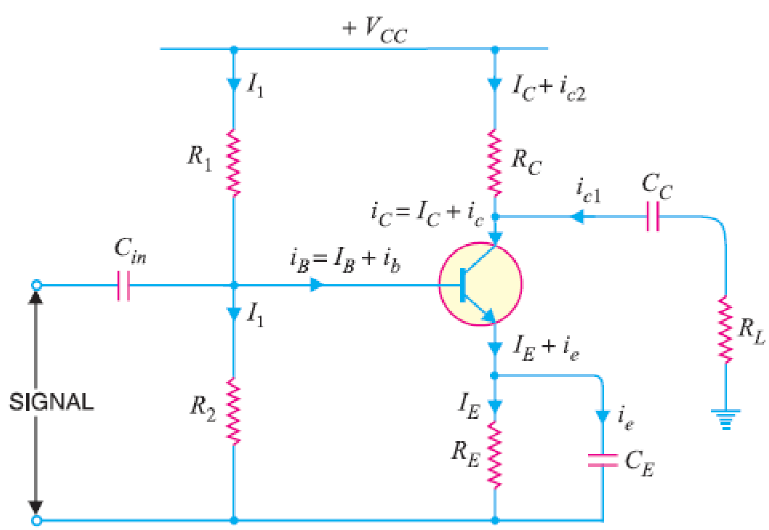
6 Transistor Amplifier

Out of the three transistor connections, 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 arrangement are : (i) High current gain, (ii) High voltage and power gain and (iii) Moderate output to input impedance ratio

A transistor raises the strength of a weak signal and thus acts as an amplifier. As the input circuit has low resistance, therefore, a small change in signal voltage causes an appreciable change in emitter current. This causes almost the same change in collector current due to transistor action. The collector current flowing through a high load resistance produces a large voltage across it. Thus, a weak signal applied in the input circuit appears in the amplified form in the collector circuit. It is in this way that a transistor acts as an amplifier.

The resistances R_1, R_2 and R_E form the biasing and stabilisation circuit. The biasing circuit must establish a proper operating point otherwise a part of the negative half-cycle of the signal may be cut off in the output. Three capacitors - Input capacitor C_{in}, Emitter bypass capacitor C_E and Coupling capacitor C_C are used.

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. 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 i_c also flows. When no signal is applied, a d.c. emitter current I_E flows. With the application of signal, total emitter current i_E flows.



It is important to note that a transistor can accomplish faithful amplification only if proper associated circuitry is used with it. Fig. shows a practical single stage transistor amplifier. The phase difference of 180^0 between the signal voltage and output voltage in a common emitter amplifier is known as phase reversal. When the signal voltage increases in the positive half-cycle, the base current also increases. The result is that collector current and hence voltage drop $i_C R_C$ increases. As V_{CC} is constant, therefore, output voltage v_{CE} decreases. The amplification is not affected by this phase reversal.

The basic function of an amplifier is to **raise the strength of an a.c. input signal. The voltage gain** of the amplifier is the ratio of a.c. output voltage to the a.c. input signal voltage. Therefore, in order to find the voltage gain, we should consider only the a.c. currents and voltages in the circuit.

Voltage gain A_v

$$A_v = \frac{V_{out}}{V_{in}}$$

$$= \frac{i_c R_{AC}}{i_b R_{in}}$$

$$= \beta \frac{R_{AC}}{R_{in}}$$

where $R_{AC} = R_C || R_L$

6.1 Frequency Response

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

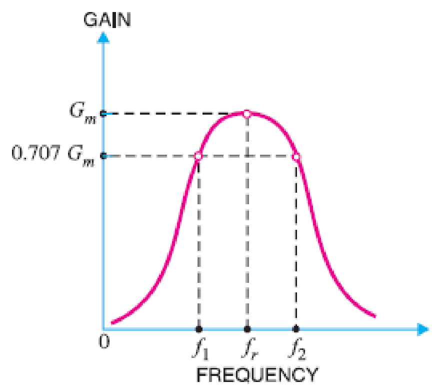


Fig. shows the frequency response of a typical amplifier. The gain of the amplifier increases as the frequency increases from zero till it becomes maximum at f_r, called resonant frequency.

The voltage gain of an amplifier changes with frequency. For any frequency lying 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 former (f_1) is called lower cut-off frequency and the latter (f_2) is known as upper cut-off frequency. For distortionless amplification, it is important that signal frequency range must be within the **bandwidth of the amplifier**.

Bandwidth of an amplifier is the range of frequency at the limits of which its voltage gain falls by **3 db** from the maximum gain. The frequency f_1 or f_2 is also called 3-db frequency or half-power frequency. The 3-db designation comes from the fact that voltage gain at these frequencies is 3db below the maximum value. The term half-power is used because when voltage is down to 0.707 of its maximum value.

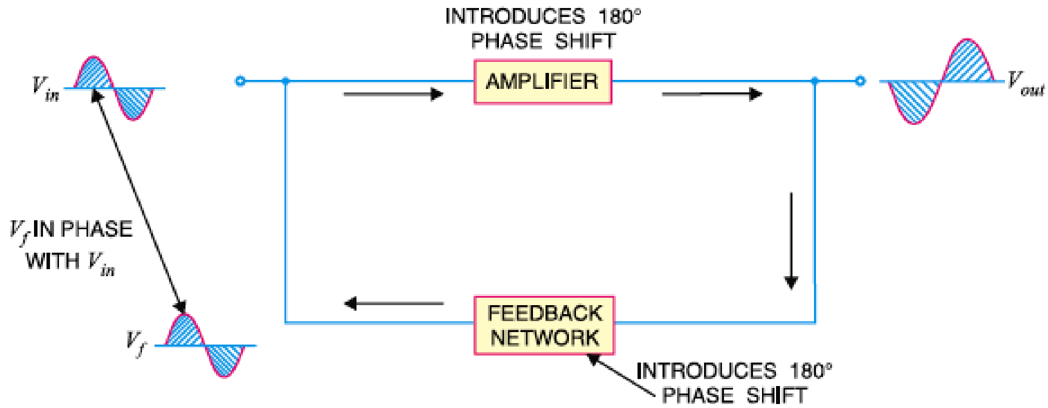
7 Concept of feedback mechanism

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

Feedback has been found very useful in reducing noise in amplifiers and making amplifier operation stable. 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.

7.1 Positive feedback

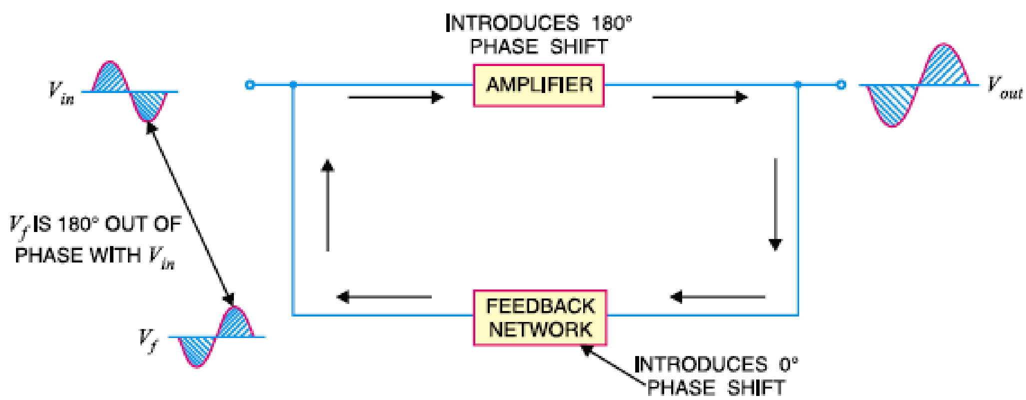
When the feedback energy (voltage or current) is in phase with the input signal and thus aids it, it is called positive feedback. Both amplifier and feedback network introduce a phase shift of 180^0. The result is a 360^0 phase shift around the loop, causing the feedback voltage V_f to be in phase with 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 seldom employed in amplifiers. One important use of positive feedback is in **oscillators**. As we shall see in the next chapter, if positive feedback is sufficiently large, it leads to oscillations. An oscillator is a device that converts d.c. power into a.c. power of any desired frequency.

7.2 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. The amplifier introduces a phase shift of 180^0 into the circuit while the feedback network is so designed that it introduces no phase shift (i.e., 0^0 phase shift). The result is that the feedback voltage V_f is 180^0 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 and improved input and output impedances. It is due to these advantages that negative feedback is frequently employed in **amplifiers**.

8 Oscillators

An electronic device that generates sinusoidal oscillations of desired frequency is known as a sinusoidal oscillator.

An oscillator receives d.c. energy and changes it into a.c. energy of desired frequency. The frequency of oscillations depends upon the constants of the device. Although an alternator produces sinusoidal oscillations of 50Hz, it cannot be called an oscillator. Firstly, an alternator is a mechanical device having rotating parts whereas an oscillator is a non-rotating electronic device. Secondly, an alternator converts mechanical energy into a.c. energy while an oscillator converts d.c. energy into a.c. energy. Thirdly, an alternator cannot produce high frequency oscillations whereas an oscillator can produce oscillations ranging from a few Hz to several MHz.

Although oscillations can be produced by mechanical devices (e.g. alternators), but electronic oscillators have the following advantages :

(i) An oscillator is a non-rotating device. Consequently, there is little wear and tear and hence longer life.

(ii) Due to the absence of moving parts, the operation of an oscillator is quite silent.

(iii) An oscillator can produce waves from small (20 Hz) to extremely high frequencies (¿ 100 MHz).

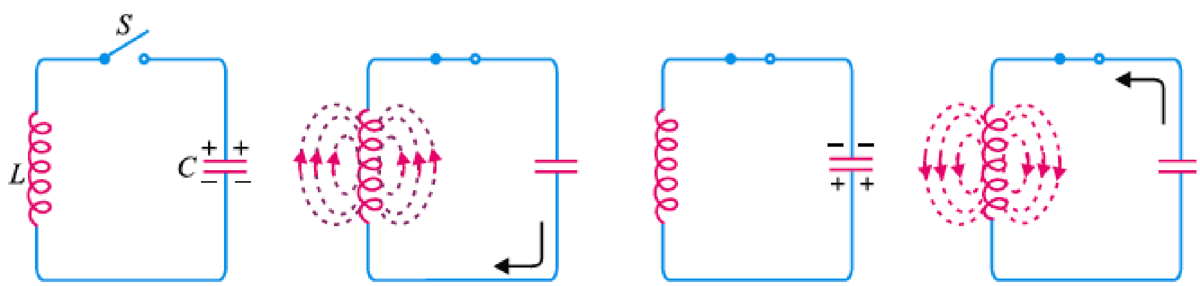
(iv) The frequency of oscillations can be easily changed when desired.

(v) It has good frequency stability i.e. frequency once set remains constant for a considerable period of time.

(vi) It has very high efficiency.

8.1 Tank Circuit

A circuit which produces electrical oscillations of any desired frequency is known as an oscillatory circuit or tank circuit. A simple oscillatory circuit consists of a capacitor (C) and inductance coil (L) in parallel as shown in Fig. This electrical system can produce electrical oscillations of frequency determined by the values of L and C.



The sequence of charge and discharge results in alternating motion of electrons or an oscillating current. The energy is alternately stored in the electric field of the capacitor (C) and the magnetic field of the inductance coil (L). This interchange of energy between L and C is repeated over and again resulting in the production of oscillations.

If there were no losses in the tank circuit to consume the energy, the interchange of energy between L and C would continue indefinitely. In a practical tank circuit, there are resistive and radiation losses in the coil and dielectric losses in the capacitor. During each cycle, a small part of the originally imparted energy is used up to overcome these losses. The result is that the amplitude of oscillating current decreases gradually and eventually it becomes zero when all the energy is consumed as losses. Therefore, the tank circuit by itself will produce **damped oscillations**.

The frequency of oscillations in the tank circuit is determined by the constants of the circuit viz L and C. The actual frequency of oscillations is the resonant frequency (or natural frequency) of the tank circuit given by :

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

8.2 Undamped Oscillations

In order to make the oscillations in the tank circuit undamped, it is necessary to supply correct amount of energy to the tank circuit at the proper time intervals to meet the losses. Any energy which would be applied to the circuit must have a polarity conforming to the existing polarity at the instant of application of energy. If the applied energy is of opposite polarity, it would oppose the energy in the tank circuit, causing stoppage of oscillations. Therefore, in order to make the oscillations in the tank circuit undamped, the following conditions must be fulfilled :

(i)The amount of energy supplied should be such so as to meet the losses in the tank circuit and the a.c. energy removed from the circuit by the load.
(ii) The applied energy should have the same frequency as that of the oscillations in the tank circuit.
(iii) The applied energy should be in phase with the oscillations set up in the tank circuit i.e. it should aid the tank circuit oscillations.

9 Transistor Oscillator

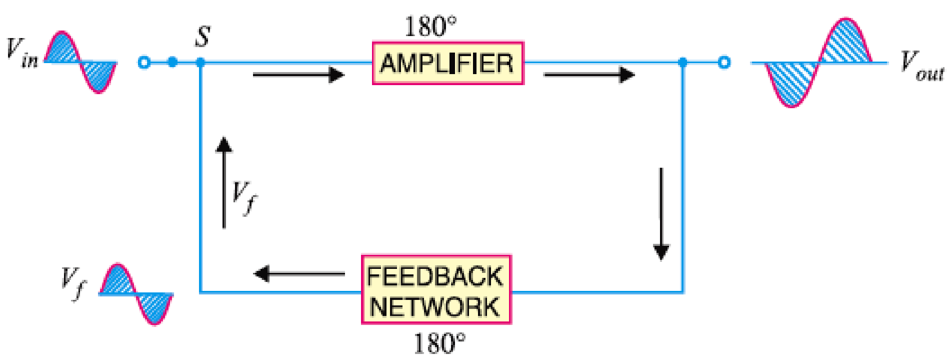
A transistor amplifier with proper positive feedback can act as an oscillator i.e., it can generate oscillations without any external signal source.
The amplifier will produce sinusoidal output with no external signal source.

- A transistor amplifier with proper positive feedback will work as an oscillator.
- The circuit needs only a quick trigger signal to start the oscillations. Once the oscillations have started, no external signal source is needed.
- In order to get continuous undamped output from the circuit, the following condition must be met :

$$m_v A_v = 1$$

where A_v = voltage gain of amplifier without feedback, m_v = feedback fraction

This relation is called **Barkhausen criterion**



9.1 Barkhausen Criterion

Barkhausen criterion is that in order to produce continuous undamped oscillations at the output of an amplifier, the positive feedback should be such that :

$$m_v A_v = 1$$

Once this condition is set in the positive feedback amplifier, continuous undamped oscillations can be obtained at the output immediately after connecting the necessary power supplies.

The voltage gain of a positive feedback amplifier is given by

$$A_{vf} = \frac{A_v}{1 - m_v A_V}$$

If $m_v A_v = 1$, then $A_{vf} \to \infty$. It means that a vanishing small input voltage would give rise to finite (i.e., a definite amount of) output voltage even when the input signal is zero. Thus once the circuit receives the input trigger, it would become an oscillator, generating oscillations with no external signal source.

9.2 Essentials of Transistor Oscillator

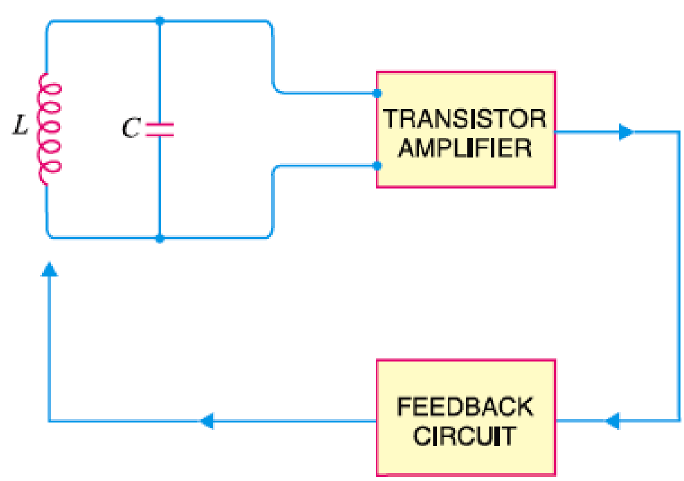
A transistor Oscillator should have

9.2.1 Tank circuit

It consists of inductance coil (L) connected in parallel with capacitor (C). The frequency of oscillations in the circuit depends upon the values of inductance of the coil and capacitance of the capacitor.

9.2.2 Transistor amplifier

The transistor amplifier receives d.c. power from the battery and changes it into a.c. power for supplying to the tank circuit. The oscillations occurring in the tank circuit are applied to the input of the transistor amplifier. Because of the amplifying properties of the transistor, we get increased output of these oscillations. This amplified output of oscillations is due to the d.c. power supplied by the battery. The output of the transistor can be supplied to the tank circuit to meet the losses.



9.2.3 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.

10 Different types of transistor oscillators

A transistor can work as an oscillator to produce continuous undamped oscillations of any desired frequency if tank and feedback circuits are properly connected to it. All oscillators under different names have similar function i.e., they produce continuous undamped output. However, the major difference between these oscillators lies in the method by which energy is supplied to the tank circuit to meet the losses.

The oscillator circuits employing **L-C elements** have two general drawbacks. Firstly, they suffer from frequency instability and poor waveform. Secondly, they cannot be used for very low frequencies because they become too much bulky and expensive. Good frequency stability and waveform can be obtained from oscillators employing resistive and capacitive elements. Such amplifiers are called **R-C or phase shift oscillators** and have the additional advantage that they can be used for very low frequencies.

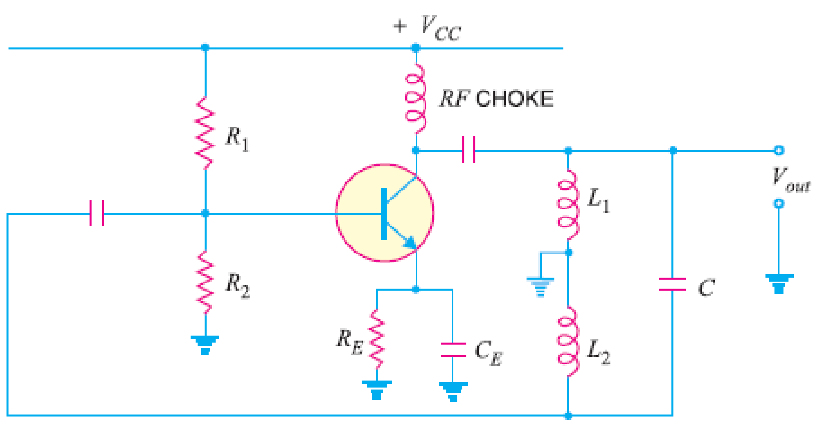
10.1 Hartley oscillator

The Hartley oscillator is a L-C oscillator, two inductors L_1 and L_2 are placed across a common capacitor C and the centre of the inductors is tapped. The tank circuit is made up of L_1, L_2 and C. The frequency of oscillations is determined by the values of L_1, L_2 and C and is given by :

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

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

M = mutual inductance between L_1 and L_2 L_1L_2C is also the feedback network that produces a phase shift of 180^0.



When the circuit is turned on, the capacitor is charged. When this capacitor is fully charged, it discharges through coils L1 and L2 setting up oscillations. The output voltage of the amplifier appears across L1 and feedback voltage across L2. The voltage across L2 is 180^0 out of phase with the voltage developed across L1 (V_{out}). A phase shift of 180^0 is produced by the transistor and a further phase shift of 180^0 is produced by L1 L2 voltage divider.

In Hartley oscillator, the feedback voltage is across L2 and output voltage is across L1.

$$m_v = \frac{L_2}{L_1}$$

11 Modulation

The audio signal cannot be sent directly over the air for appreciable distance. Even if the audio signal is converted into electrical signal, the latter cannot be sent very far without employing large amount of power. The energy of a wave is directly proportional to its frequency. At audio frequencies (20 Hz to 20 kHz), the signal power is quite small and radiation is not practicable.

The radiation of electrical energy is practicable only at high frequencies e.g. above 20 kHz. The high frequency signals can be sent thousands of miles even with comparatively small power. Therefore, if audio signal is to be transmitted properly, some means must be devised which will permit transmission to occur at high frequencies while it simultaneously allows the carrying of audio signal. This is achieved by superimposing electrical audio signal on high frequency carrier. The resultant waves are known as modulated waves or radio waves and the process is called **modulation**. At the radio receiver, the audio signal is extracted from the modulated wave by the process called **demodulation**. The signal is then amplified and reproduced into sound by the loudspeaker. In this chapter, we shall focus our attention on the various aspects of modulation and demodulation.

The process of changing some characteristic (e.g. amplitude, frequency or phase) of a carrier wave in accordance with the intensity of the signal is known as modulation. Modulation means to "change". In modulation, some characteristic of carrier wave is changed in accordance with the intensity (i.e. amplitude) of the signal. The resultant wave is called modulated wave or radio wave and contains the audio signal. Therefore, modulation permits the transmission to occur at high frequency while it simultaneously allows the carrying of the audio signal.

11.1 Types of Modulation

Modulation is the process of changing amplitude or frequency or phase of a carrier wave in accordance with the intensity of the signal. Accordingly, there are three basic types of modulation, namely ;
(i) amplitude modulation (ii) frequency modulation and (iii) phase modulation

In television transmission, frequency modulation is used for sound signal and amplitude modulation for picture signal.

11.1.1 Amplitude Modulation

When the amplitude of high frequency carrier wave is changed in accordance with the intensity of the signal, it is called amplitude modulation. In amplitude modulation, only the amplitude of the carrier wave is changed in accordance with the intensity of the signal. However, the frequency of the modulated wave remains the same i.e. carrier frequency.

11.1.2 Frequency Modulation (FM)

When the frequency of carrier wave is changed in accordance with the intensity of the signal, it is called frequency modulation (FM).

In frequency modulation, only the frequency of the carrier wave is changed in accordance with the signal. However, the amplitude of the modulated wave remains the same i.e. carrier wave amplitude.

11.2 Demodulation

The process of recovering the audio signal from the modulated wave is known as demodulation or detection.

At the broadcasting station, modulation is done to transmit the audio signal over larger distances to a receiver. When the modulated wave is picked up by the radio receiver, it is necessary to recover the audio signal from it. This process is accomplished in the radio receiver and is called demodulation. Necessity of demodulation. It was noted previously that amplitude modulated wave consists of carrier and sideband frequencies. The audio signal is contained in the sideband frequencies which are radio frequencies. If the modulated wave after amplification is directly fed to the speaker, no sound will be heard. It is because diaphragm of the speaker is not at all able to respond to such high frequencies. Before the diaphragm is able to move in one direction, the rapid reversal of current tends to move it in the opposite direction i.e. diaphragm will not move at all. Consequently, no sound will be heard.

12 TV transmission and Reception

The plan of television system is to expand sense of sight beyond its natural limits and to transmit sound associated with scene. Picture signal is generated by Television camera and the sound signal by microphone. The TV receiver has tuned circuits in its input section called 'tuner'. It selects desired channel signal out of the numerous chosen up by antenna.

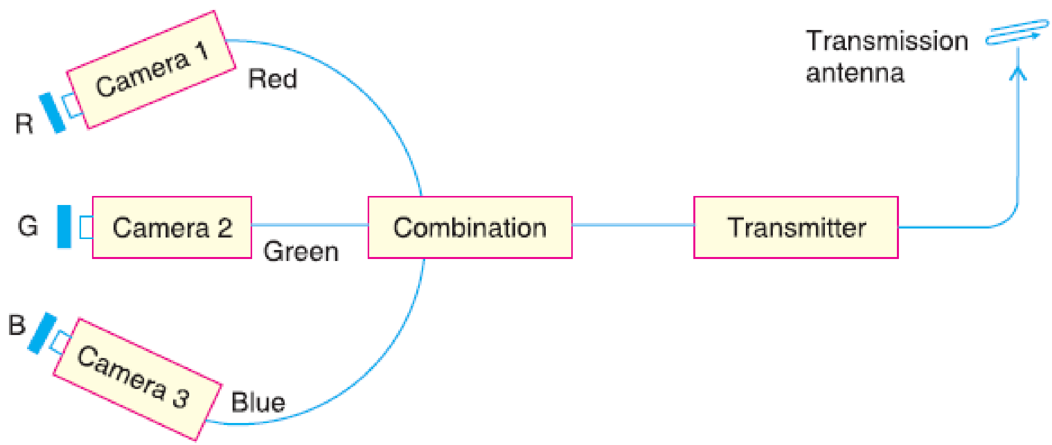
The luminance signal from camera is amplified and synchronizing pulses added before feeding it to modulating amplifier. The synchronizing pulses are transmitted to keep the camera and picture tube beams in step. The allotted picture carrier frequency is generated by a crystal controlled oscillator. The continuous wave sine wave output is given large amplification before feeding to the power amplifier where its amplitude is made to vary in accordance with the modulating signal received from the modulating amplifier.

The picture signal generated as described above can be conveyed over short distances by wire or cable in unaltered form, but for broadcast over the air or transmission over cable networks it must be shifted to appropriately higher frequency channels. Such frequency shifting is accomplished in the transmitter, which essentially performs two functions: (1) generation of very high frequency (VHF) or ultrahigh frequency (UHF) carrier currents for picture and sound, and (2) modulation of those carrier currents by imposing the television signal onto the high-frequency wave. In the former function (generation of the carrier currents), precautions are taken to ensure that the frequencies of the UHF or VHF waves have precisely the values assigned to the channel in use. In the latter function (modulation of the carrier wave), the picture signal wave form changes the strength, or amplitude, of the high-frequency carrier in such a manner that the alternations of the carrier current take on a succession of amplitudes that match the shape of the signal wave form. This process is known as amplitude modulation (AM) The sound program accompanying a television picture signal is transmitted by equipment similar to that used for frequency-modulated (FM) radio broadcasting.

When the band of frequencies in the picture signal is imposed on the high-frequency broadcast carrier current in the modulator of the transmitter, two bands of frequencies are produced above and below the carrier frequency. These are known as the upper and lower side bands, respectively. The side bands are identical in frequency content; that is, both carry the complete picture signal information. One of the side bands is therefore superfluous and, if transmitted, would wastefully consume space in the broadcast spectrum. Therefore, the major portion of one of the side bands (that occupying frequencies below the carrier) is removed by a wave filter, and the other side band (occupying frequencies above the carrier) is transmitted in full. Complete removal of the superfluous side band is possible, but this would complicate receiver design; hence, a vestige of the unwanted side band is retained to serve the overall economy of the system. This technique is known as vestigial side-band transmission. It is universally employed in the television broadcasting systems of the world.

After the signal wave form and carrier current are combined in the modulator, the modulated carrier current is amplified (typically to 10,000 watts or more) and passed to the transmitter antenna, which is designed to direct radio waves along the surface of the Earth and to minimize radiation toward the sky. The antenna must be placed to stand as high and in as exposed a location as possible, since the radio waves tend to be intercepted by solid objects that stand in their path, including the Earth's surface at the horizon. Reception beyond the horizon is possible, but the signal at such distances becomes rapidly weaker as it passes to the limit of the service area.

Figure shows the block diagram of colour TV transmitter

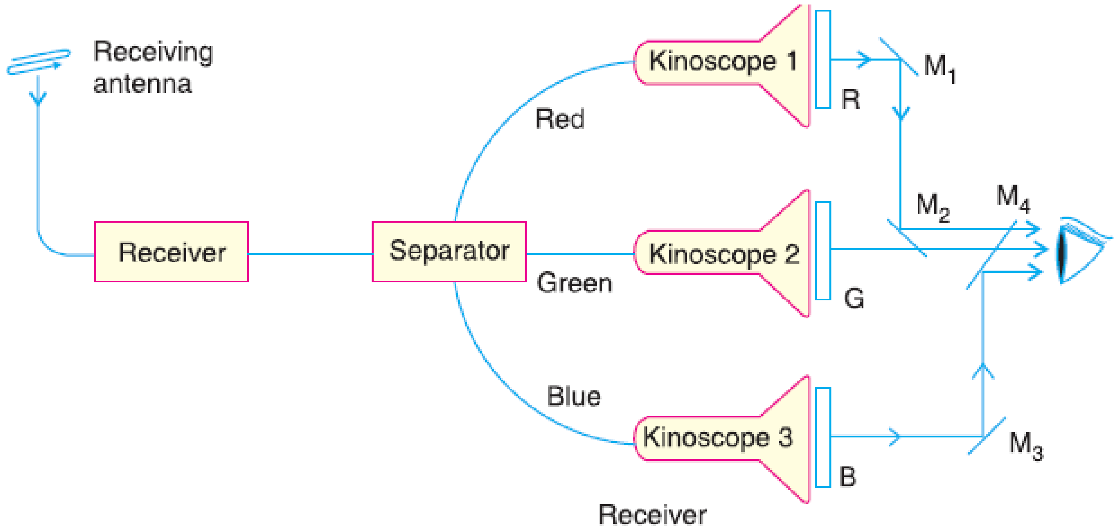


The camera system consists of three ordinary television cameras, all focussed on the object to be televised. The red, green and blue filters are placed in front of the cameras 1, 2 and 3. The signals from the three cameras are combined in a special way and telecast together.

At the receier, the three signals are received together and then separated. Each signal is used to operate a separate kinoscope in front of whose screen is a second filter of the same colour. The camera behind each colour filter responds to parts of the object having the same colour and therefore the corresponding kinoscope of the receiver shows only that colour. A system of mirrors is used to combine the three coloured beams into a single beam, so that the final image is also coloured like the original object.

At the television receiver the sound and picture carrier waves are picked up by the receiving antenna, producing currents that are identical in form to those flowing in the transmitter antenna but much weaker. These currents are conducted from the antenna to the receiver by a lead-in transmission line, typically a 12-mm (one-half-inch) ribbon of plastic in which are embedded two parallel copper wires. This form of transmission line is capable of passing the carrier currents to the receiver, without relative discrimination between frequencies, on all the channels to which the receiver may be tuned. Television signals also are delivered to the receiver over coaxial cable from a cable service provider or from a videocassette recorder. In addition, some television receivers have an input that bypasses the tuner and detector so that an unmodulated video signal can be viewed directly, in effect making the television receiver into a video display terminal.

Figure shows the block diagram of colour TV Receiver


Receiving
antenna
Receiver
Separator
Red
Green
Blue
Kinoscope 1
Kinoscope 2
Kinoscope 3
R
G
B
M1
M2
M3
M4
Receiver

13 Questions

1. What is a rectifier ? Explain the construction and working of a Half wave rectifier
2. What are filter circuits ? Explain the working of a π filter
3. Compare the three types of filters - half wave, center-tap full wave and bridge rectifier
4. What is meant by ripple factor ?
5. What is common emitter bipolar junction transistor ? Explain its characteristics
6. What is meant by a transistor amplifier ?
7. What is frequency response ? Define bandwidth
8. What is positive feedback ?
9. Explain Barkhausen criterion
10. What is an oscillator ? What are the requirements for an amplifier to be an oscillator
11. Explain the construction and working of Hartley oscillator
12. What is meant by modulation ? What are the necessities of modulation ?
13. What are the differences between AM and FM
14. Write a short note on TV transmission and reception