4.3 INTRODUCTION TO POWER AMPLIFIERS

An Amplifier system has more than one stage as shown in Fig. 4.11. Voltage amplifiers, as middle stages to handle small signals. The final stage (called power amplifier) drives a load like loud speaker and has to handle considerable amount of power. So large swing of voltage or current is needed for obtaining sufficient power. Voltage amplifiers are actually small signal amplifiers, they amplify input voltage. So, they raise only voltage level.

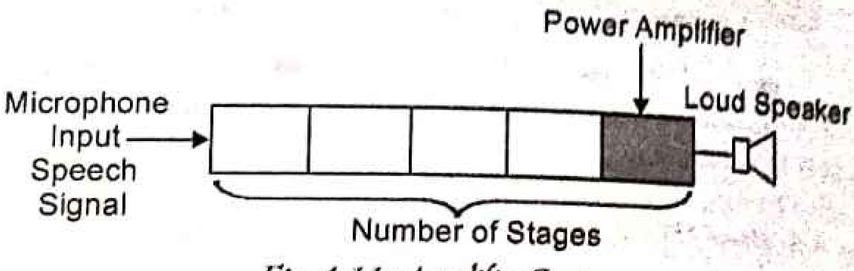


Fig. 4.11 : Amplifier System

Power amplifiers need large current. So they are known as large signal amplifier. Power amplifiers draw power from d.c. source and convert it to a.c. power to drive voice coil of loud speaker. In power amplifier, transformer primary winding is in series with collector. d.c. power loss in primary winding is very less as its resistance is small. Power transferred to secondary winding is a.c.

Power amplifiers find their application in the public address system, radio receivers, T.V. receivers, Tape players, CRTs and driving servomotors in industrial control system.

4.3.1 Classification Of Power Amplifiers

On the basis of period of conduction i.e. the portion of the input cycle during which output current (I_C) flows, the power amplifiers may be classified as

(i) Class-A Amplifiers

(ii) Class-B Amplifiers

(iii) Class-AB Amplifiers

(iv) Class-C Amplifiers

(i) Class-A Amplifiers:

In this type, the transistor is so biased that the output current flows for the full cycle of the input signal, as shown in Fig. 4.12. This means that the transistor remains forward biased throughout the input cycle. From Fig. 4.12 it is seen that the operating point Q is located at the centre of the load line. So that the output current flows for complete cycle of the input signal.

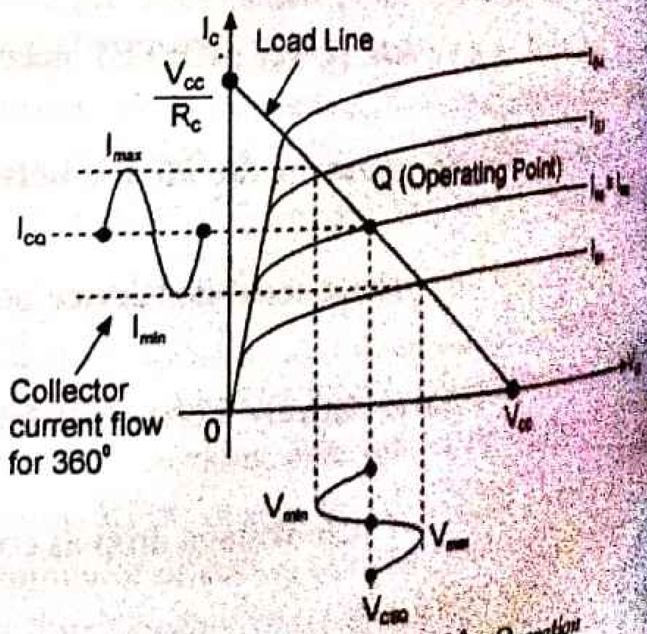


Fig. 4.12 : Class-A Amplifier Operation

As the collector current flows for 360° (full cycle) of the input signal. We can say that the angle of the collector current flow is 360°.

In class A operation, signal is faithfully reproduced at the output without any distortion. This is an important feature of class-A operation. The efficiency of class-A operation is very small.

(ii) Class-B Amplifiers:

In class-B power amplifiers, the transistor is so biased that the output current flows only for half cycle of the input signal. It means that the transistor is forward biased for half of the input cycle. In the negative half cycle of the input signals, the transistor enters in to cut-off region and no signal is produced at the output.

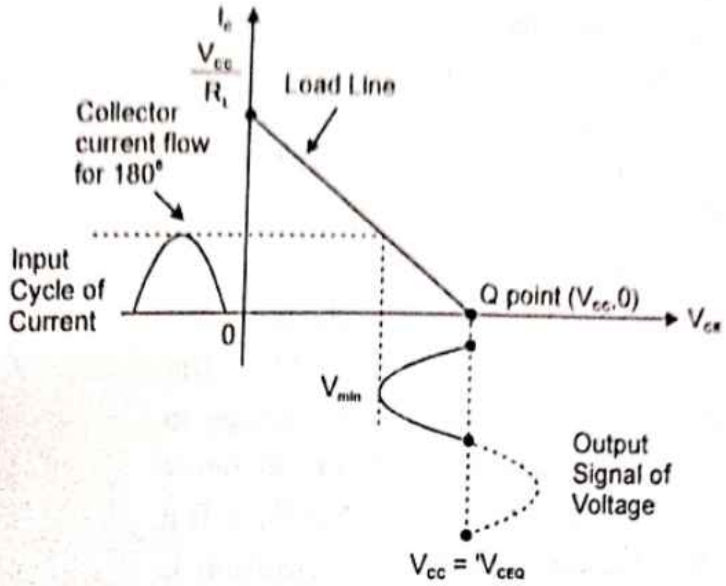


Fig. 4.13 : Class-B Amplifier Operation

As the collector current flows only for 180° (half cycle) of the input signal. In this case the transistor conduction angle is equal to 180° as shown in Fig. 4.13. The operation point Q is located at (V_{CC}, 0) on the load line.

As only a half cycle is obtained at the output, for full input cycle, the output signal is said to be 'distorted' in class B operation. The efficiency of class-B amplifier is much higher than the class A amplifier.

(iii) Class-AB Amplifiers:

In this type, the transistor is so biased that the output current flows for more than half but less that the full cycle. The transistor conduction angle is between 180° and 360° such a condition is shown in Fig. 4.14. The Q point is very close to cut-off value but well above X-axis.

The output signal obtained in the class AB operation is distorted. The efficiency of class AB amplifier is more than class A but less than class B operation.

The class AB operation is important in eliminating the crossover distortion. This is discussed later in this chapter.

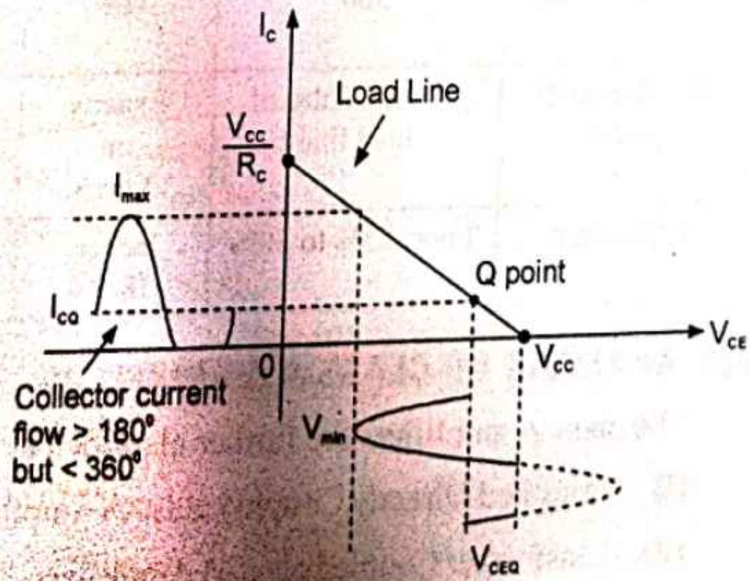


Fig. 4.14 : Class-AB Amplifier Operation

(iv) Class C Amplifier:

In class C Power Amplifier, the transistor bias and signal amplitude are such that the output current flows for appreciably less than half cycle of the input signal. Hence its conduction angle is upto 120° or 150° that is the transistor remains forward biased for less than half the cycle. Such a condition is shown in Fig. 4.15 For this operation the Q point is shifted below X-axis.

In class C operation as the collector current flows for less than 180°, the output is much more distorted. Due to this reason Class C Amplifiers are never used for audio frequency amplifiers. But the efficiency of class C operation is much higher and can reach very close to 100%.

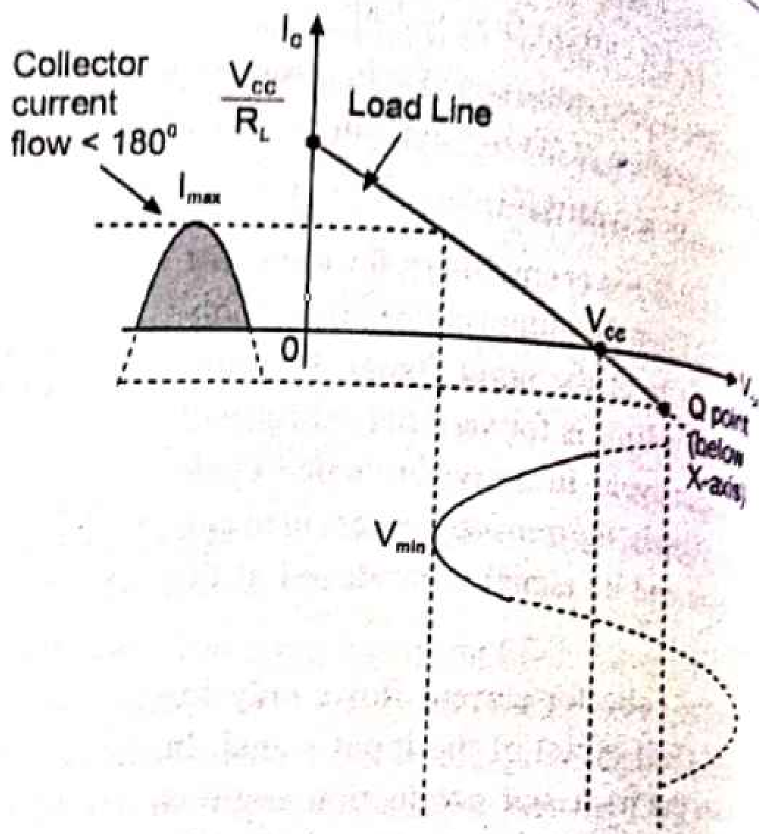


Fig. 4.15 : Class-C Operation

Students may note here that, as the Q point moves away from the centre of load line below towards the X-axis, the efficiency of class of operation increases. Table below shows a summary of different classes of operation of power amplifiers.

Table : Comparison of Power Amplifiers

Class	A	B	AB	C
Operating cycle	360°	180°	180° to 360°	Less than 180°
Position of Q point	At the Centre of load line	Exactly on X-axis	Above X-axis but below the centre of load line	Below X-axis
Efficiency	Poor, 25% to 50%	Better, 78.5%	Higher than A but less than B (50% to 78.5%)	Very high

4.4 ANALYSIS OF CLASS-A AMPLIFIERS

The class-A amplifiers are further classified as

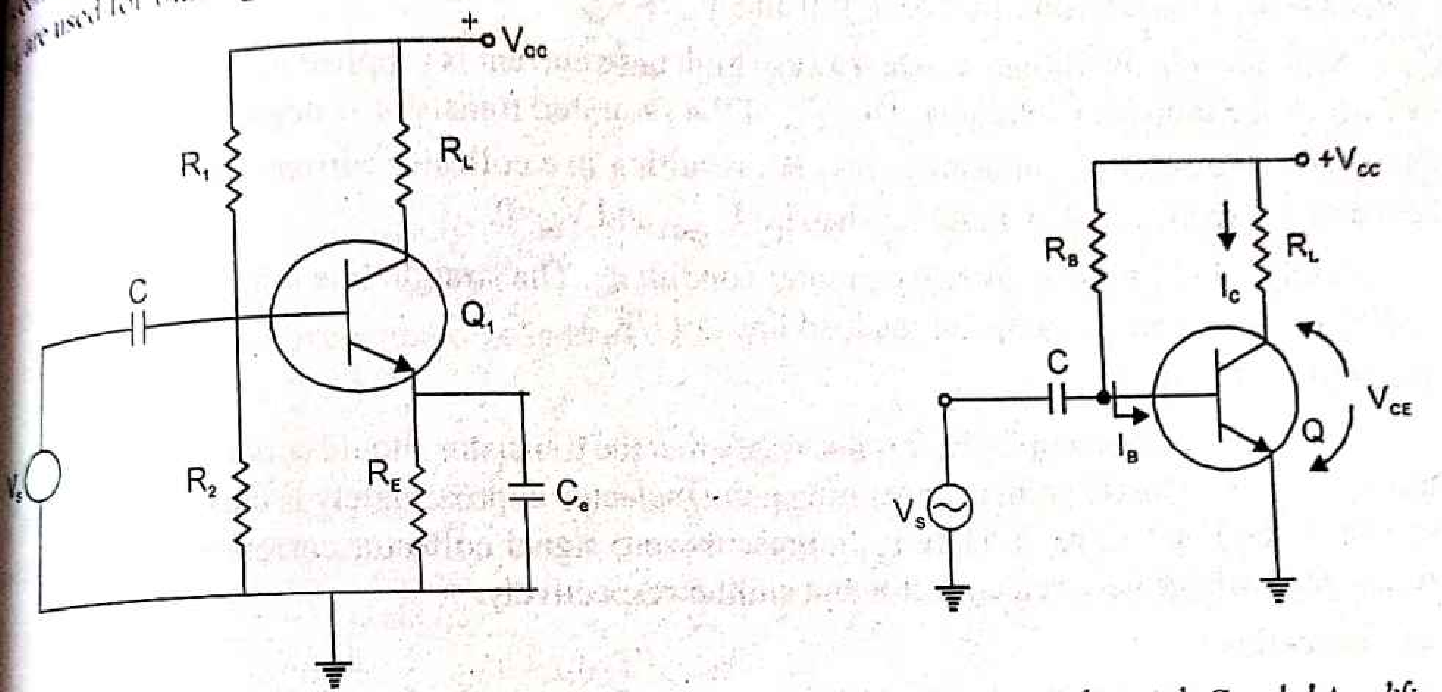
(i) Series Fed Directly Coupled class-A Amplifiers

(ii) Transformer Coupled class-A Amplifiers

In directly coupled type, the load is connected directly to the collector. While in the transformer coupled type, the load is coupled to the collector Through a transformer.

...1 Series Fed Directly Coupled Class A Amplifiers

Fig. 4.16 (a) shows a Class A series fed amplifier. It is so named because the load resistance R_L ...connected directly in series with collector of the transistor Q. Resistor R_1 , R_2 , R_E and capacitor ...are used for biasing.



...(a) Series Fed Directly Coupled Amplifier (b) Schematic Diagram to Series Fed Directly Coupled Amplifier

Fig. 4.16

...Fig. 4.16 (b) shows a schematic diagram of the circuit shown in Fig. 4.16 (a) where in a detailed ...biasing arrangement has been symbolically shown by single biasing resistance R_B.

To understand the operation of the circuit, we take help of graphical method. Fig. 4.17 shows the ...output characteristics (i.e. I_C Versus V_{CE}) of the transistor Q.

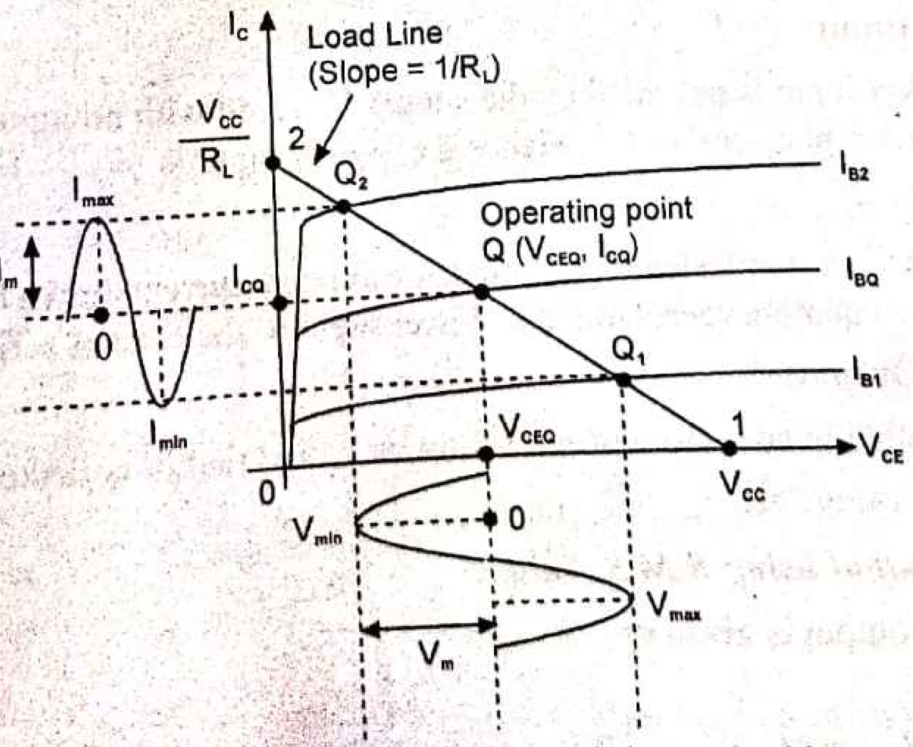


Fig. 4.17 : Graphical Representation of Class A Amplifier

(a) Drawing of Load Lines:

When the base current I_b is zero, the collector current I_c is also equal to zero (neglecting saturation current I_{co}). Therefore the voltage drop across load resistance is also equal to zero and hence the collector-emitter voltage V_{ce} becomes equal to V_{ce}. Thus we get the point 1 which represents the condition of $I_c = 0$ and $V_{ce} = V_{ce}$.

Now consider the situation when a very high base current is supplied to the transistor of which the transistor saturates. The V_{ce} of the saturated transistor is negligible (0.1 or 0.2) and hence the entire V_{cc} appears across R_L, resulting in a collector current $I_{C\,sat} = V_{CC}/R_L$. This condition is represented by Point 2, when $I_C = I_{C(sat)}$ and $V_{ce} = 0$.

Points 1 and 2 represents two extremes conditions. The straight line joining these two points is called the load line. The slope of the load line is $(1/R_L)$.

(b) The Q Point:

For class-A power amplifier, it is necessary that the transistor should conduct for the full input cycle. Thus Q point (or operating point) selected approximately is the mid of load line shown in the Fig.4.13 as Q. Here I_{cQ} represents zero signal collector current and V_{ceQ} represents zero signal voltage between collector and emitter respectively.

(c) Operation:

Let us assume that the input signal applied to the amplifier is sinusoidal which results in a sinusoidal variation of base current I_b. This inturn will cause the collector current I_C and collector-emitter voltage V_{ce} to vary sinusoidally around the Q point.

When the base current goes up to a value of I_{b2}, the collector current goes up to a value of ... Similarly when the base current goes down to a value of I_{b1} the collector current goes down ... Correspondingly the collector-emitter voltage are V_{min} and V_{max}, and Q point shifts new positions Q_2 and Q_1.

(d) D.C. Power Input:

The D.C. power input is provided by the supply V_{cc}. And with no input signal, the d.c. current drawn is the collector bias current I_{CQ}. Hence d.c. power input is

$$P_{DC} = V_{CC} \cdot I_{CQ}$$

Note that even if a.c. input signal is applied, the average current drawn from the supply remains same. Hence above equation represents d.c. power input to the class A series fed amplifier.

(e) A.C. Power Output:

Let the peak value of collector current swing be I_m and that of collector voltage swing be ... Hence there r.m.s. values are $I_m/\sqrt{2}$ and $V_m/\sqrt{2}$.

(i) A.C. Power Output using R.M.S. Values

The a.c. power output is given by

$$P_{ac} = V_{rms} I_{rms} = I_{rms}^2 R_L = \frac{V_{rms}^2}{R_L}$$

A.C. Power Output using Maximum Values

The a.c. power output is given by

$$P_{ac} = V_{rms}.I_{rms}$$

$$= \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}$$

$$= \frac{V_m I_m}{2} \qquad \text{... (4.2)}$$

Since $I_m = \frac{V_m}{R_L}$ the above equation can be rewritten as:

$$\boxed{P_{ac} = \frac{V_m^2}{2R_L}} \qquad \text{...(4.3)}$$

or $$\boxed{P_{ac} = \frac{I_m^2 R_L}{2}} \qquad \text{...(4.4)}$$

Equation (4.3) and (4.4) represents a.c. power output using peak values.

(iii) *A.C. Power Output using Peak to Peak Values*

We have from Equation (4.2)

$$P_{ac} = \frac{V_m I_m}{2}$$

But as $$V_m = \frac{V_{pp}}{2} = \frac{V_{max} - V_{min}}{2} \text{ and}$$

$$I_m = \frac{I_{pp}}{2} = \frac{I_{max} - I_{min}}{2}$$

we get $$P_{ac} = \frac{\left(\frac{V_{pp}}{2}.\frac{I_{pp}}{2}\right)}{2} = \frac{V_{pp}.I_{pp}}{8} \qquad \text{... (4.5)}$$

or $$= \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8} \qquad \text{... (4.6)}$$

(f) Efficiency:

The efficiency of an amplifier represents the a.c. power delivered to the load from the source. The generalised expression for efficiency of an amplifier is given as

$$\%\eta = \frac{P_{ac}}{P_{DC}} \times 100$$

$$\%\eta = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8V_{cc}I_{CQ}} \times 100$$

This efficiency is also called as **conversion efficiency of an amplifier.**

(g) Maximum Efficiency:

From Fig. 4.13, we can see that minimum voltage possible is zero and maximum voltage is V_{cc} for a maximum swing. Similarly the minimum current is zero and the maximum current is $2I_{CQ}$ for a maximum swing i.e.

$$V_{max} = V_{CC} \text{ and } V_{min} = 0$$

$$I_{max} = 2I_{CQ} \text{ and } I_{min} = 0$$

Using Equation (4.8) we can write

$$\%\eta_{max} = \frac{(V_{cc} - 0)(2I_{CQ} - 0)}{8V_{CC}.I_{CQ}} \times 100$$

$$= \frac{2V_{CC}I_{CQ}}{8V_{CC}I_{CQ}} \times 100 = 25\%$$

Thus the maximum efficiency possible in directly coupled series fed class-A amplifier is 25% (ideally). In a practical circuit it is less than 25%, i.e. of the order of 10 to 15%

(h) Power Dissipation:

The amount of power that must be dissipated by the transistor is the difference between the power input P_{DC} and the a.c. Power delivered to the load P_{ac}.

Power dissipation

$$P_d = P_{DC} - P_{ac}$$

Maximum power dissipation occurs when there is zero a.c. input signal, the a.c. power output (P_{ac}) is also zero.

$$P_{ac} = 0$$

Then $$P_d = P_{DC}$$

or $$\boxed{P_d = V_{cc}I_{CQ}}$$

Equation (4.11) gives the maximum power di...

...antages :

1. The circuit is simpler to design and to implement.
2. The load is directly connected in the collector circuit hence no output transformer is required.

...advantages :

1. The load resistance is directly connected in the collector, therefore the quiescent collector current flows through it, there will be considerable power loss in the load resistance.
2. Power dissipation is more, hence use of heat sink is essential.
3. The efficiency is very poor due to large power dissipation.
4. The output impedance is high so circuit can not be used for low impedance load like loud speaker.

...2 Transformer Coupled Class-A Amplifier

Due to load resistance R_L is directly coupled to the output circuit of amplifier the overall efficiency ...ries fed directly coupled class-A amplifier does not exceed 25%. Due to this I_{CQ} passes through ...esistance. This current is representing a considerable waste of power $= I_{CQ}^2 R_L$ because it does ...ntribute to useful ac power. This problem is solved by using a transformer as a coupling device ...een the output of transistor and load.

Circuit Diagram:

Fig. 4.18 shows the basic circuit of transformer coupled amplifier. It is also called as single ended ...A amplifier because single transistor is used for amplification. The primary of the transformer, ...ng negligible d.c. resistance, is connected in the collector circuit. The secondary of transformer ...nnected to load R_L (loud speaker acts as a load).

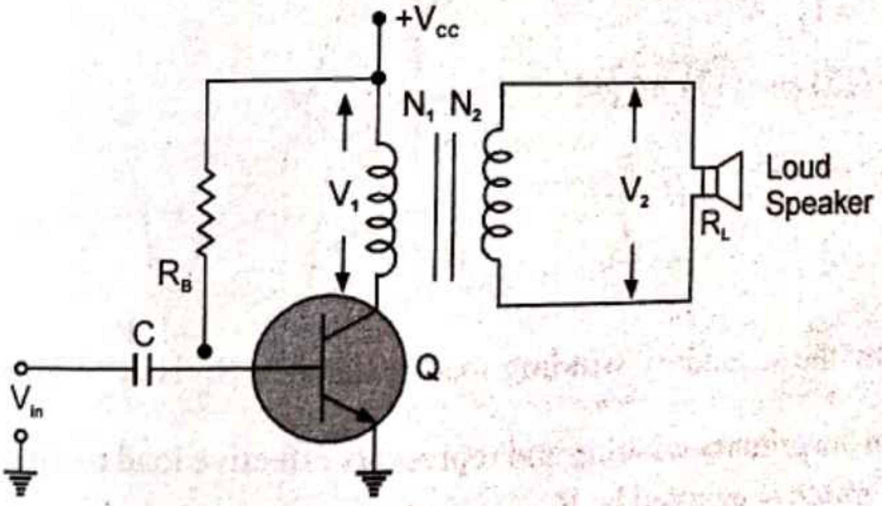


Fig. 4.18 : Transformer Class-A Amplifier

...mpedance Matching:

...he function of transformer is to match the low impedance load to the high output impedance of ...fier. Impedance matching is necessary to ensure that maximum power is transferred from primary to secondary ... minimised. Since the voltage current can be changed by a transformer according to turns ratio. In addition, an impedance from either side (primary or secondary) can also be changed depending on the square of transformer ratio (N^2).

Let us consider only the transformer and the load R_L.

As shown in Fig. 4.19 impedance R_L is connected across the transformer secondary impedance is changed by the transformer when viewed at the primary side (R_L'). This is explained below.

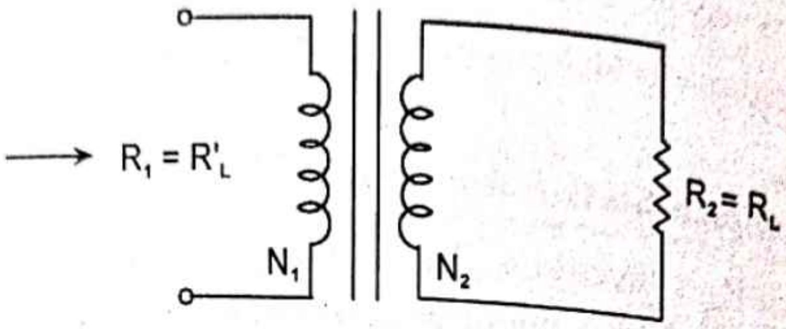


Fig. 4.19 : Transformer with Load

Let the turns ratio between the primary and the secondary of the transformer be N. Therefore the voltage ratio and current ratio can be written as

$$\frac{V_1}{V_2} = N \ \ and \ \ \frac{I_2}{I_1} = N \qquad \left[N = \frac{N_1}{N_2}\right]$$

Therefore, $V_1 = N.V_2$ ...(4.12)

and $I_1 = I_2 / N$ ...(4.13)

From Equation (12) and (13) we get

$$\frac{V_1}{I_1} = \frac{NV_2}{I_2 / N} = N^2 \frac{V_2}{I_2} \qquad ...(4.14)$$

From ohm's law the secondary winding load resistance R_L is $\frac{V_2}{I_2}$. Therefore $\frac{V_1}{I_1}$ is a kind of 'reflection' of R_L in the primary winding and represents effective load resistance on the primary side of the transformer which is denoted by R_L'

Therefore from Equation (4.14) we can write

$$\boxed{R_L' = N^2 R_L} \qquad ...(4.15)$$

where

$N = \frac{N_1}{N_2}$

R_L = actual load resistance

R_L' = resistance presented by the primary winding to the supply source.

Equation (4.15) indicates that the effective load resistance viewed at the primary side (R_L') appearing at the collector side of transistor is N^2 times the load resistance (R_L) connected to the secondary. In other words, the primary winding acts like a resistance equal to the load resistance across the secondary multiplied by the square of turns ratio.

Therefore by choosing proper turns ratio N we can match the actual load resistance R_L to any desired value of R_L'.

(c) DC Operation:

Since the primary of the transformer has negligible d.c. resistance (0 Ω), There will be no voltage drop across the primary winding of the transformer under quiescent condition.

The slope of d.c. load line is given as reciprocal of the d.c. resistance in the collector circuit. The d.c. resistance in this case is zero. Hence slope of d.c. load line will be infinite (ideally). In other words the d.c. load line in ideal condition is a vertically straight line.

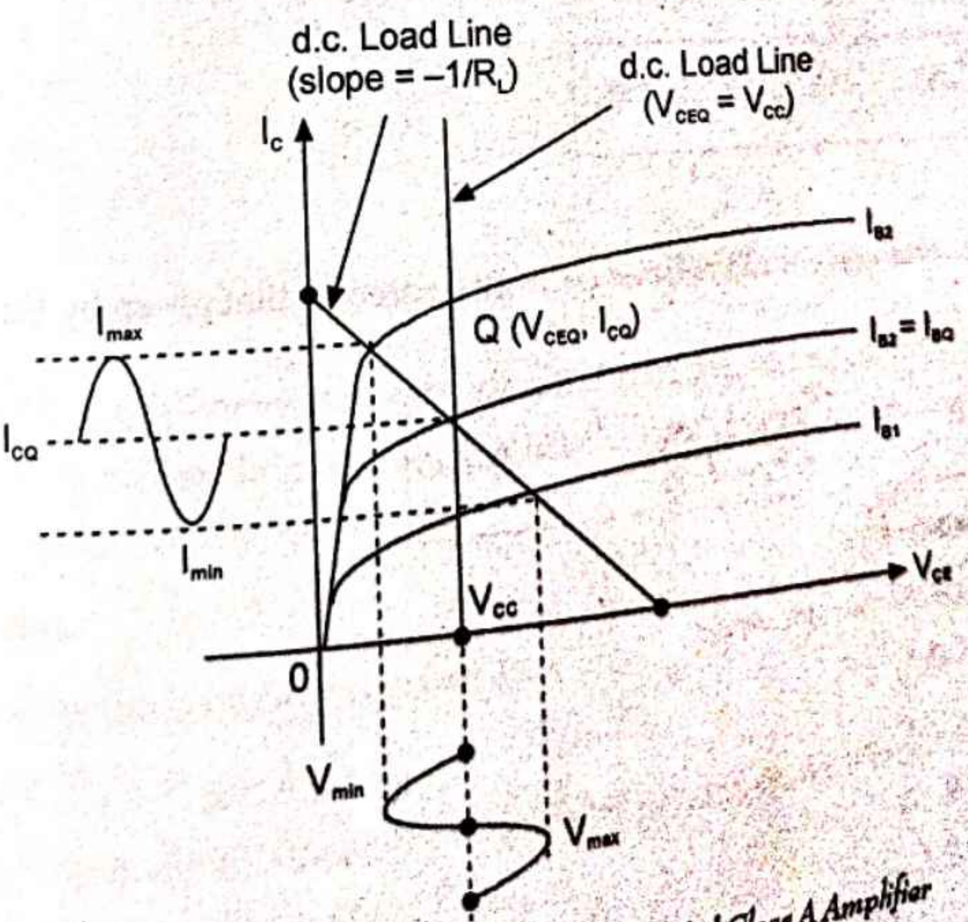


Fig. 4.20 : Load lines for Transformer Coupled Class A Amplifier

(d) DC Power Input:

The D.C. power input is given by

$$\boxed{P_{DC} = V_{CC}\, I_{CQ}}$$

This expression is same as for series fed directly coupled class A amplifier.

(e) AC Operation:

In class A operation the Q point is located at the centre of the load line.

The a.c. load line is obtained by drawing a line through the operating point or quiescent p... (Q-point). Slope of a.c. load line is equal to

$$\left(\frac{-1}{R_L'}\right)$$

When a.c. signal is applied, collector current varies with input signal and accordingly opera... point Q shift its position up and down on load line. Collector voltage varies between V_{max} and ... This varies in opposite phase to the collector current. The variation of collector voltage appe... across the primary of the transformer due to this a.c. voltage is induced in the secondary wi... inturn develops a.c. power in the load.

AC Output Power:

Generalised expression for a.c. output power (delivered to load) for transformer coupled amplifi... is same as represented by Equation (4.6) i.e.

$$\boxed{P_{ac} = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8}} \quad \text{...(4.16)}$$

Efficiency :

The general expression for the efficiency is also same as that given by Equation (4.7) and (4.8) i.e.

$$\boxed{\%\eta = \frac{P_{ac}}{P_{DC}} = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8\, V_{CC} . I_{CQ}} \times 100} \quad \text{...(4.17)}$$

Maximum Efficiency :

Looking at Fig.4.11 we can write

$$V_{min} = 0$$

and $\quad V_{max} = 2\, V_{CC}$

$$I_{min} = 0$$

and $\quad I_{max} = 2\, I_{CQ}$

Using Equation (4.1...)

$$\eta_{max} = \frac{(2V_{CC}-0)(2I_{CQ}-0)}{8V_{CC} \cdot I_{CQ}}$$

$$= \frac{4V_{cc} \cdot I_{cQ}}{8V_{cc} I_{cQ}} \times 100$$

$$= 50\%$$

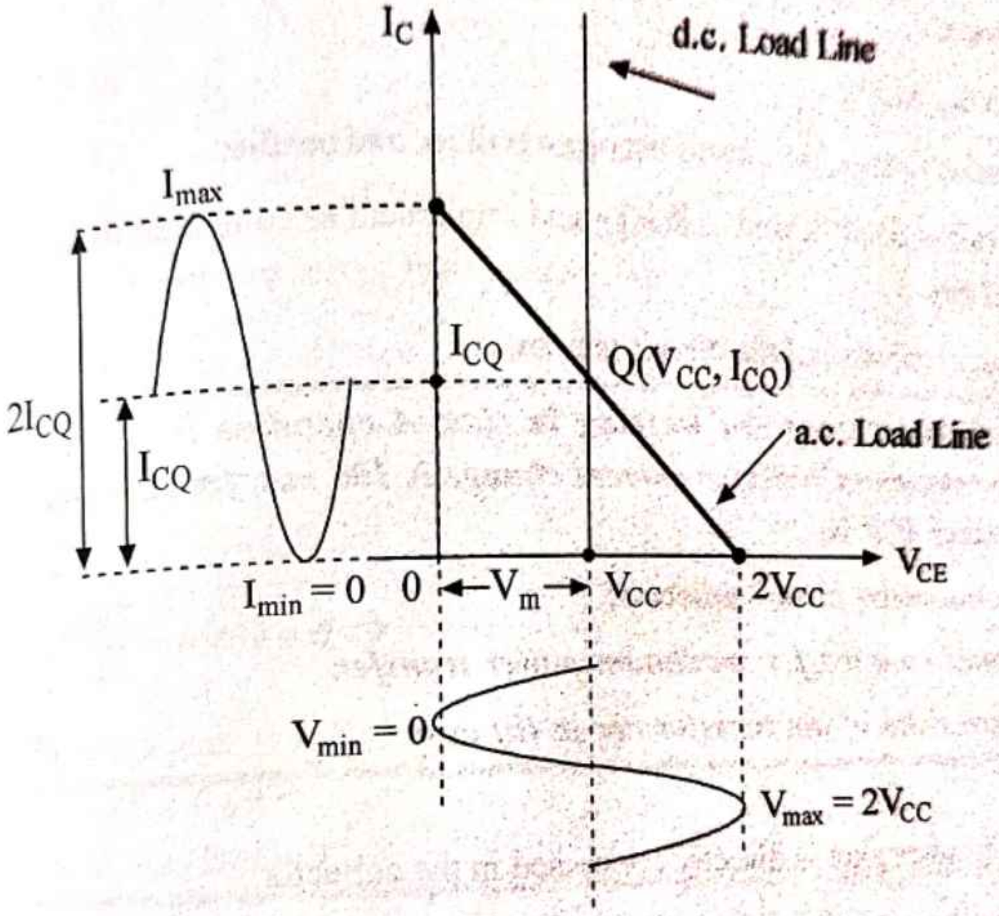


Fig.4.15 : Operating point for transformer coupled class A amplifier

Hence maximum efficiency in case of a transformer coupled class-A amplifier is 50%. For practical circuits it is about 30 to 35%.

(f) Power Dissipation:

Power dissipation by the transistor is given by

Power dissipation $P_d = P_{DC} - P_{ac}$

When there is no input signal, the entire d.c. power gets dissipated in the form of heat (P_{ac}=0), which is the *maximum power dissipation.* ...(4.18)

$$(P_d)_{max} = P_{DC} = V_{CC} I_{CQ}$$

HARMNIC DISTORTION IN POWER AMPLIFIER

One of the important requirements of an amplifier is that the waveform of the amplified output should be enlarged but faithful reproduction of the input waveform.

However in practice this is often not the case due to the *non-linear characteristics of transistor*. Since power amplifier are to handle large signals, distortion is always introduced in the output i.e. the wave shape of output is never exact replica of the waveshape of the input signal. Harmonic distortion is prominent one.

Harmonic distortion means the presence of frequency components in the output waveform, which are not present in the input signal.

When an input signal is applied to a transistor, the non linear characteristics causes the positive half of the signal to be amplified more than negative half cycle. Due to this the output signal contains fundamental frequency component and some undesired frequency components, which are integral multiple of input signal frequency. These additional frequency components are called harmonics. Since the output is said to be distorted, this is called harmonic distortion.

For example if the fundamental frequency is f Hz, then the output signal contains fundamental frequency component at f Hz and additional frequency components at 2 f Hz, 3 f Hz and so on. The 2f component is called second harmonic, the 3f component is called as third harmonic and so on. The fundamental frequency component is not considered as a harmonic because it has the frequency same as the input signal.

Out of all the harmonic components, the second harmonic has the largest amplitude. As the order of the harmonic increases, its amplitude decreases. Since the second harmonic amplitude is largest, second harmonic distortion is more important in the analysis of A.F. amplifier.

Percentage Harmonic Distortion:

The percentage harmonic distortion due to each order (2^{nd}, 3^{rd} and so on) can be calculated by comparing the amplitude of each order of harmonic with the amplitude of the fundamental frequency component.

If the fundamental frequency component has an amplitude of B_1 and the n^{th} harmonic component has an amplitude of B_n then the percentage harmonic distortion due to n^{th} harmonic component is expressed as

$$\boxed{\%D_n = \frac{|B_n|}{|B_1|}\times 100} \qquad ...(4.19)$$

$$\%D_2 = \frac{|B_2|}{|B_1|}$$

$$\%D_3 = \frac{|B_3|}{|B_1|} \text{ and so on}$$

Total harmonic Distortion:

Total harmonic distortion, D which is the effective distortion due to all the individual comp...

$$\boxed{\% D = \sqrt{D_2^2 + D_3^2 + D_4^2 + \ldots} \times 100}$$

CLASS-A PUSH-PULL AMPLIFIER

The distortion introduced by non-linearity discussed earlier can be minimized by the circuit known push-pull configuration. The amplifier is then known as push-pull amplifier. Fig. 4.24 shows a circuit arrangement for class-A push-pull amplifier.

Two transistor T_1 and T_2 are used, both of these transistors are identical. Their emitters are connected together. But bases and collectors are connected to opposite ends of input and output transformers (i.e. T_{r1} and T_{r2}). Both the transformers T_{r1} and T_{r2} are centre-tapped transformers. Resistors R_1 and R_2 provides biasing arrangement. Load is connected across secondary of T_{r2} (output transformer). To ensure that maximum power is delivered to the load from amplifier, turns ratio of T_{r2} is so choosen that output impedance of transistor matches to that of load impedance.

Operation:

Looking at the Fig. 4.24, i_{c1} and i_{c2} flows in opposite direction through the primary of transformer (T_{r2}). In addition i_{c1} and i_{c2} are equal in magnitude. So there is no net d.c. component of collector current in the primary of transformer T_{r2}. Hence there is no DC saturation in the transformer core. This results in increase in a.c. power output compared with single transistor operation.

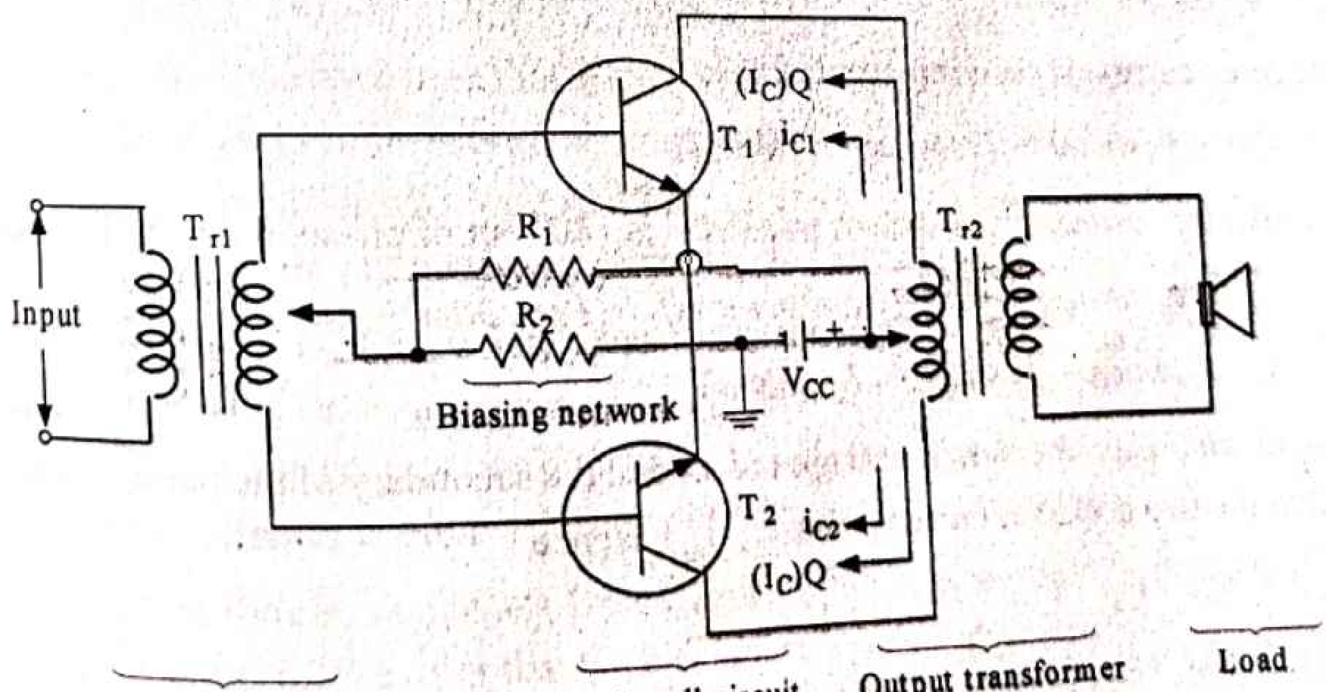


Fig. 4.24 : Class-A Push-Pull Amplifier

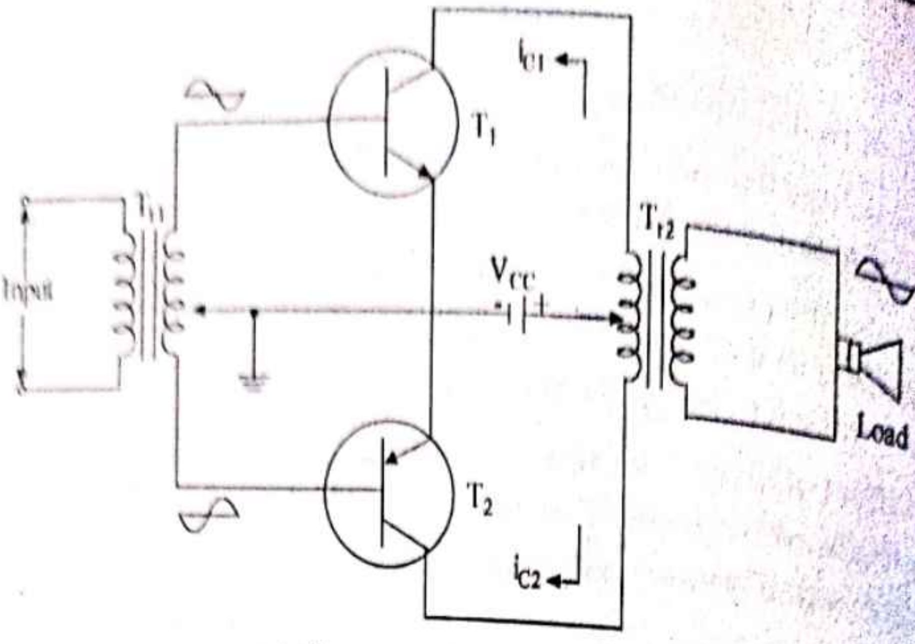
and hence the ...

CLASS-B PUSH-PULL AMPLIFIER

In the earlier section, we have seen that though the class-A push-pull amplifier removes some of e drawbacks of single-ended transistors coupled amplifier, but the efficiency is only limited to 50%. he class-B push-pull amplifier which we will see in this section, helps in getting higher efficiency nd consequently a higher output power for a given type transistor.

Need for Push-pull : In class B amplifiers output current flows for only one half cycle. So ither positive or negative half cycle is missing in the output. This type of output produces large istortion. To avoid this, a push-pull configuration is used. Here one transistor conducts during one alf cycle and other transistor conducts during second half cycle of the input.

Fig. 4.25(a) shows the circuit of class-B push-pull amplifier. This circuit is similar to the class-A push-pull amplifier (Fig. 4.24) except that the biasing resistors R_1 and R_2 are absent so no biasing is provided for two transistors. This is because two transistors are to work in class-B operation. In this operation, operating point is set at cut off region (on X-axis) for which no biasing is required.



(a) Class-B Push-Pull Amplifier

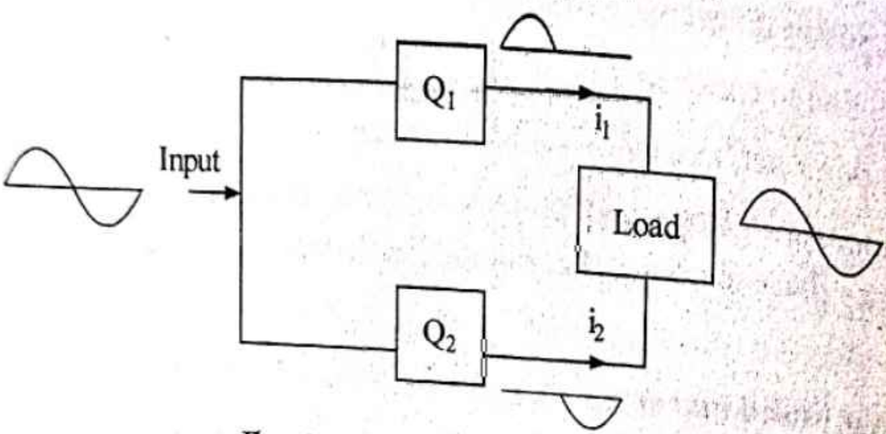


Fig. 4.25 Push-Pull Operation

Operation:

The input transformer is a phase splitter providing two signals 180° out of phase, one going to the base of each transistor. When there is no signal, both the transistors are cut-off and hence no current is drawn by either of them. Thus there is no power wasted during the no signal condition.

Now let us consider that an a.c. signal ($V_S = V_m \sin \omega t$) is applied at the input. During the positive half cycle of input signal i.e. when V_s goes positive, the induced voltage on the secondary of the input transformer becomes positive for the base of T_1 and is negative for T_2. Thus T_1 conducts during positive half cycle and during this time T_2 does not conduct.

In the negative half cycle, when V_s goes negative T_1 does not conduct but T_2 conducts. In Fig.4.25(b) the wave shapes for i_1 and i_2 are shown, each remaining zero for 180° and conducting for next 180° (similar to rectified half waves). Due to transformer action the current induced in the secondary is a full wave.

D.C. power input:

The d.c. power input to the two transistors,

$$P_{dc} = 2 \times \text{power input to the transistor} = 2[I_{dc} \times V_{cc}]$$

$$I_{dc} = \frac{I_m}{\pi} \text{(for half wave)}$$

$$\boxed{P_{dc} = \frac{2I_m}{\pi} V_{CC}} \quad ...(4.57)$$

A.C. power output:

The a.c. power output using peak values is expressed as

$$P_{ac} = \frac{V_m I_m}{2}$$

$$\boxed{P_{ac} = \frac{I_m}{2}(V_{CC} - V_{min})} \quad ...(4.58)$$

Efficiency:

The efficiency of the class-B amplifier can be calculated using basic equation.

$$\%\eta = \frac{P_{ac}}{P_{dc}} \times 100$$

$$= \frac{\frac{I_m}{2}(V_{CC} - V_{min})}{\frac{2}{\pi} I_m V_{CC}} \times 100$$

$$\%\eta = \frac{\pi}{4} \frac{(V_{CC} - V_{min})}{V_{CC}} \times 100 \quad ...(4.59)$$

Maximum efficiency:

The maximum efficiency arises when $V_{min} = 0$

Therefore

$$\%\eta_{max} = \frac{\pi}{4} \frac{V_{CC}}{V_{CC}} \times 100 \quad ...(4.60)$$

$$\%\eta_{max} = 78.5\%$$

Thus maximum possible efficiency for push-pull class-B amplifier is 78.5%. This value is more than class-A where the efficiency is maximum 50%. This increase in efficiency is due to the standing current being zero and hence no loss of power during the cut off half cycle.

4.8 TRANSFORMER LESS CLASS-B AMPLIFIERS

The circuit of class-B push-pull amplifier discussed earlier (Fig. 4.26) uses two transformers, one at the input and one at the output. However, transformers are costly and make the amplifier circuit heavier. We now present complimentary symmetry circuits wherein the transformers are not required.

Complimentary symmetry circuit:

This amplifier circuit shown in Fig. 4.20 does not use an input or output transformer.

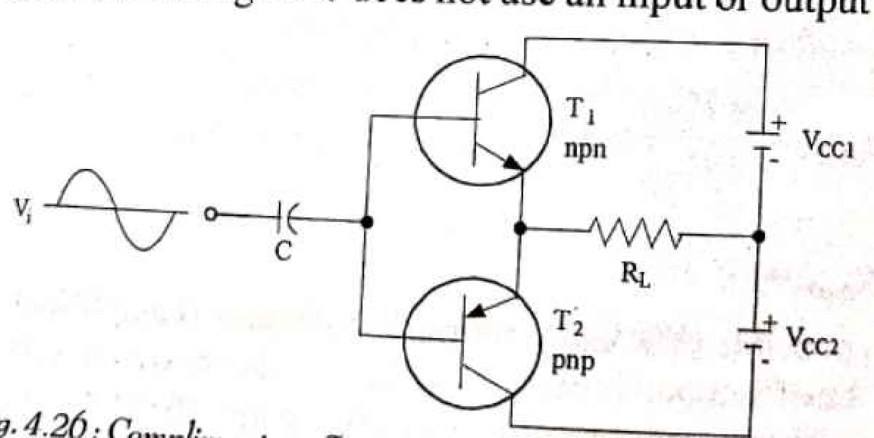


Fig. 4.26 : Complimentary Symmetry Class-B Push-Pull Amplifier

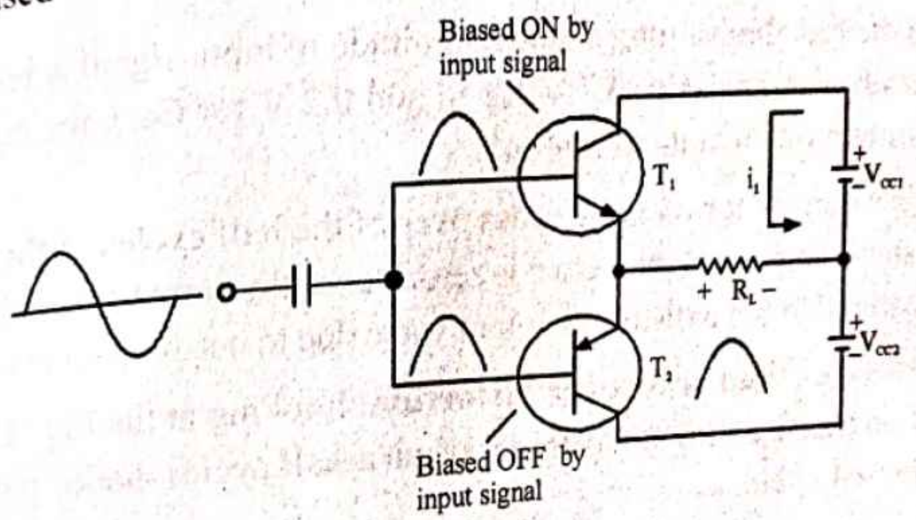
The input transformer used in push-pull amplifier circuit has the function of providing two input signals 180° out of phase, which makes only one transistor (either T_1 or T_2) to conduct at a time. However using complimentary transistors (one N-P-N and other P-N-P), if we introduce same base input to these transistors, the two collector current of transistors would be 180^0 out of phase. Thus no input transformer in the push-pull amplifier circuit. Perfectly matched pair of complimentary transistors are available in the market.

Also the output transformer is avoided using two separate but equal power supplies (V_{cc1} and V_{cc2}).

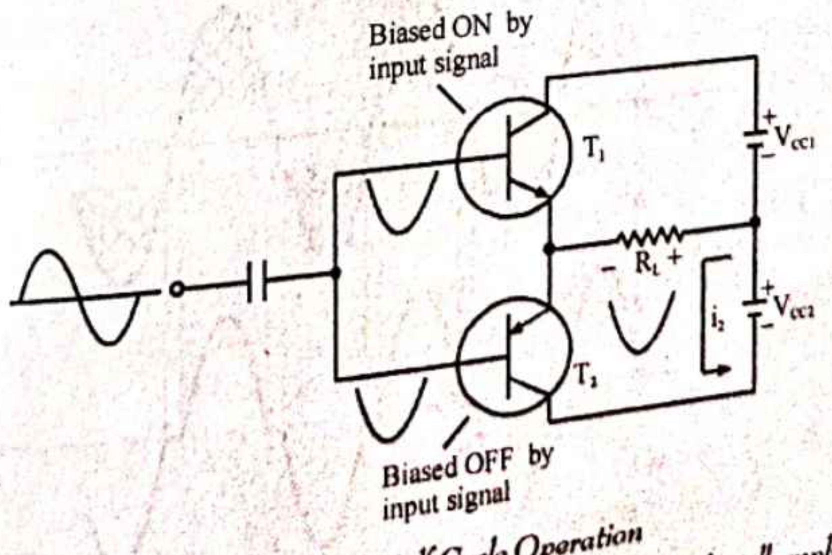
Operation:

In the positive half cycle of input signal, transistor T_1 is forward biased and therefore it conducts, T_2 being P-N-P, is reverse biased and therefore does conduct. This results into positive half cycle across the load R_L, this is shown is Fig. 4.27.

Just the opposite takes place during negative half cycle of input signal. i.e. only T_2 conducts and T_1 being reverse biased does not conduct. This result in to negative half cycle across load R_L.



(a) Positive Half Cycle Operation



(b) Negative Half Cycle Operation

Fig. 4.27 : Operation of complimentary symmetry class B push-pull amplifier

Thus the current i_1 and i_2 flow in one half cycle each but flow through R_L. Therefore the total current through R_L is in both half-cycles.

Following are the advantage and disadvantages of this circuit :

Advantages :

(i) As the circuit is transformerless, its weight, size and cost are less.

(ii) The frequency response improves due to transformerless circuit.

Disadvantages :

(i) The circuit needs two separate voltage supplies. (V_{cc1} and V_{cc2})

(ii) The output is distorted to cross over distortion. i.e. during the cross over from positive to negative both the transistors are OFF, resulting in no output signal.

4.9 CROSSOVER DISTORTION

Cross over distortion in output signal refers to the fact that during the time when input signal crosses over from positive to negative (or negative to positive), there is some non-linearity in output signal.

This is due to the fact that as long as the magnitude of input signal is less than cut-in voltage of base emitter junction of transistor (0.7 V for Si and 0.2 V for Ge), the collector current remains zero, and transistor remains in cut-off region.

Hence there is a period between the cross over of the half cycles of the input signal, for which none of the transistor is active and the output is zero. Hence the output signal does not follows the input signal and gets distorted. Such a distorted output wave due to cut-in voltage is shown in Fig. 4.28.

Such a distortion is called **cross over distortion**. Looking at the Fig. 4.28 it is seen that due to cross over distortion transistor conducts for less than a half cycle (shaded portion in Fig. 4.22) rather than the complete half cycle.

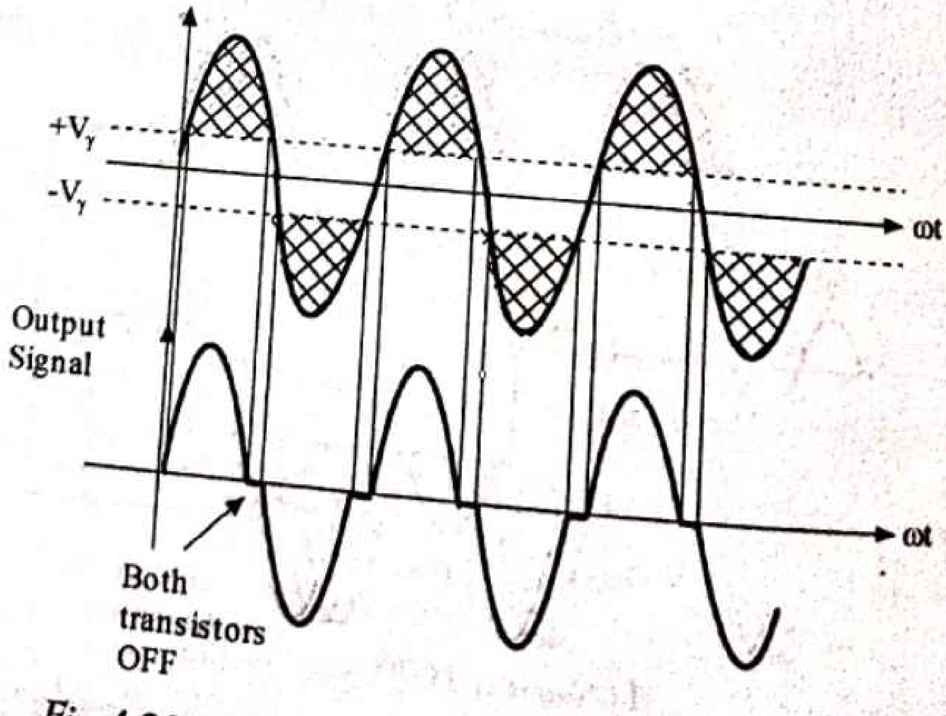


Fig. 4.28 : Cross Over Distortion in Class-B Amplifiers

Crossover distortion is eliminated in class-AB amplifiers where both the transistors are biased to be ON for more than half a cycle.

4.11 CLASS-AB AMPLIFIER

In class-B amplifier, distortions are introduced due to cross over distortion, mismatch of tr... and non-linearity of input and output characteristics. These distortions can be reduced by some modification. The basic reason for cross over distortion is the cut-in voltage of the ... junction. To over come this cut-in voltage, a small forward bias equal to cut-in voltage is app... both the transistors. So that when an a.c. signal is applied to the base, collector circuit star... immediately i.e. no crossover distortion. So in class-AB mode, the base bias during quiescent ... is such that current flows for more than 180° (class-B) but less than 360° (class-A) and hen... name class-AB. Class-AB amplifier gives less distortion than class-B but efficiency is le... class-B.

4.12 CLASS C AMPLIFIERS

A basic class C amplifier with tank circuit as load is shown in Fig. 4.24. A class C power amplifier is biased to operate for less than 180° of the input signal cycle. The tuned circuit in the output however, will provide a full cycle of output signal for the fundamental or resonant frequency of the tuned circuit (L and C tank circuit) of the output.

The used of such amplifiers is therefore limited for a fixed frequency, as occurs in communication circuits. Operation of a class C circuit is not intended primarily for large signal or power amplifiers

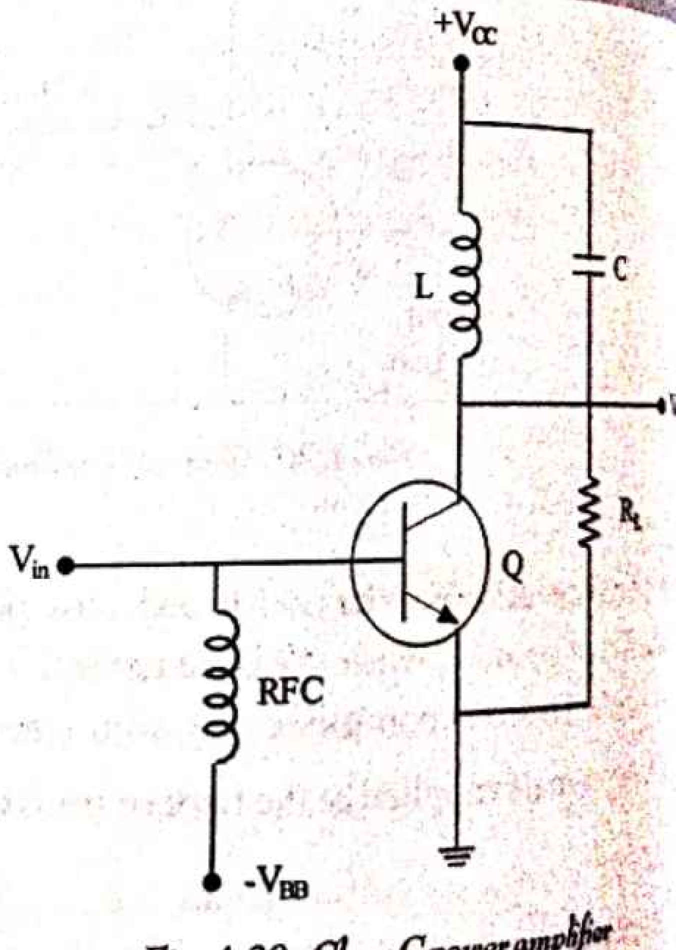


Fig. 4.30: Class C power amplifier

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