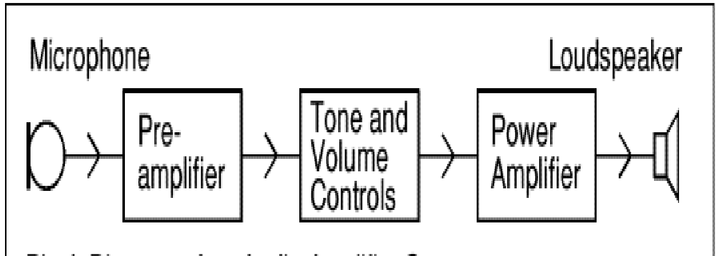
Chapter 7

Large Signal Amplifiers

Analysis of large signal model

- In practical cases we need multistage amplification
- I/p stage to a multistage amplifier is small signals need voltage amplification
- Last stage is design to provide maximum power to load (antenna, speaker etc.)
- Small signal amplifier takes small I/p ac signal as I/p where as large signal amplifiers are designed to provide large amount of ac power
- Microphone - a transducer which converts sound to voltage.
- Pre-Amplifier - amplifies the small audio signal (voltage) from the microphone.
- Tone and Volume Controls - adjust the nature of the audio signal.
- power Amplifier - increases the strength (power) of the audio signal.
- Loudspeaker - a transducer which converts the audio signal to sound.



Block Diagram of an Audio Amplifier System

Series-Fed Class A amplifier

Fig.1 shows a series-fed class A amplifier . This circuit is rarely used for power amplification due to its poor collector efficiency .

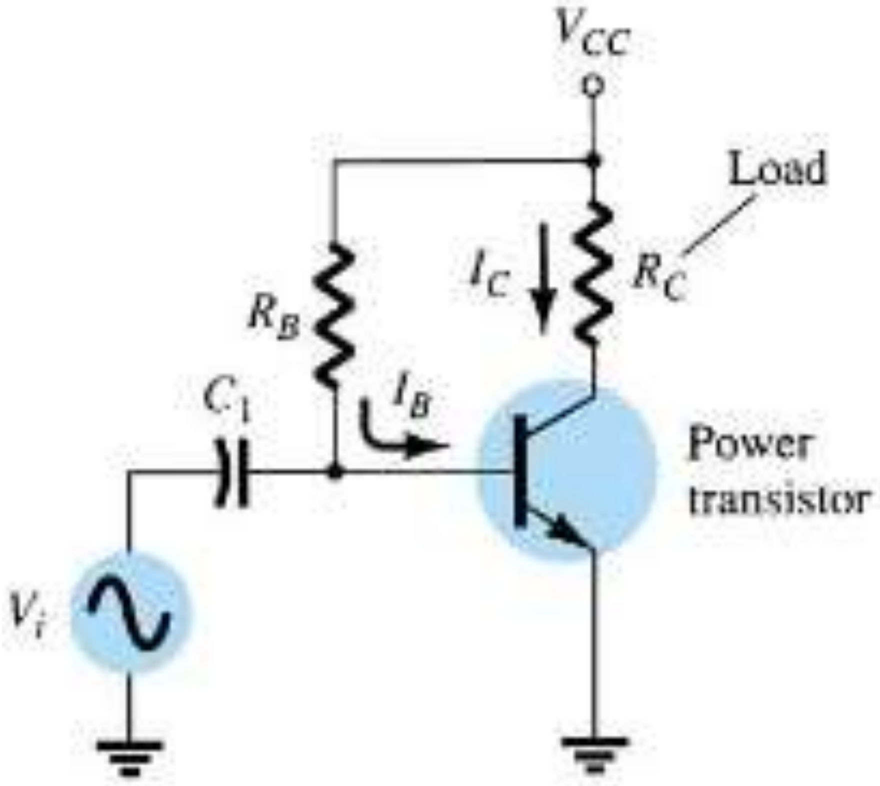


Fig.1: Series-fed Class A Amplifier

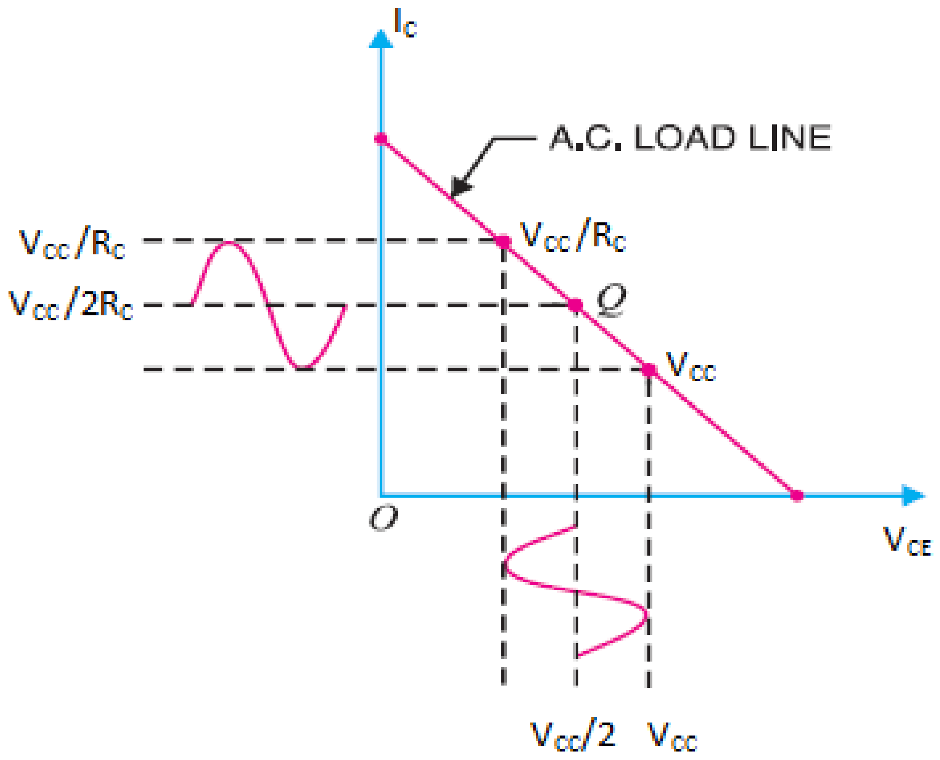


Fig: 2

When an ac signal is applied to the amplifier, the output current and voltage will vary about the operating point Q . In order to achieve the maximum symmetrical swing of current and voltage (to achieve maximum output power), the Q point should be located at the center of the dc load line.

In that case, operating point is :

ICQ = VCC/2RC

and VCEQ= VCC/2

Maximum vce (p-p) = VCC

Maximum ice (p-p) = VCC/RC

We have, $V_{max} = V_{ce}(p\text{-}p)/2$

$V_{rms} = v_{ce} = \frac{v_{ce\,(p-p)}}{2\sqrt{2}}$

Vrms = (VCC – 0)/2**√2= VCC/2√2, same for current i_{ce} .**

Max. ac output power, $P_{o(max)} = v_{ce} \times i_{ce}$

where *vce* and *ice* represents the rms value of the signals .

$$v_{ce} = \frac{v_{ce\,(p-p)}}{2\sqrt{2}} \qquad i_{ce} = \frac{i_{ce\,(p-p)}}{2\sqrt{2}}$$

$$\text{Max. ac output power, } P_{o(max)} = \frac{v_{ce\,(p-p)} \times i_{c(p-p)}}{8} = \frac{V_{CC} \times {}^{V_{CC}}/_{R_C}}{8} = \frac{V_{CC}^2}{8R_C}$$

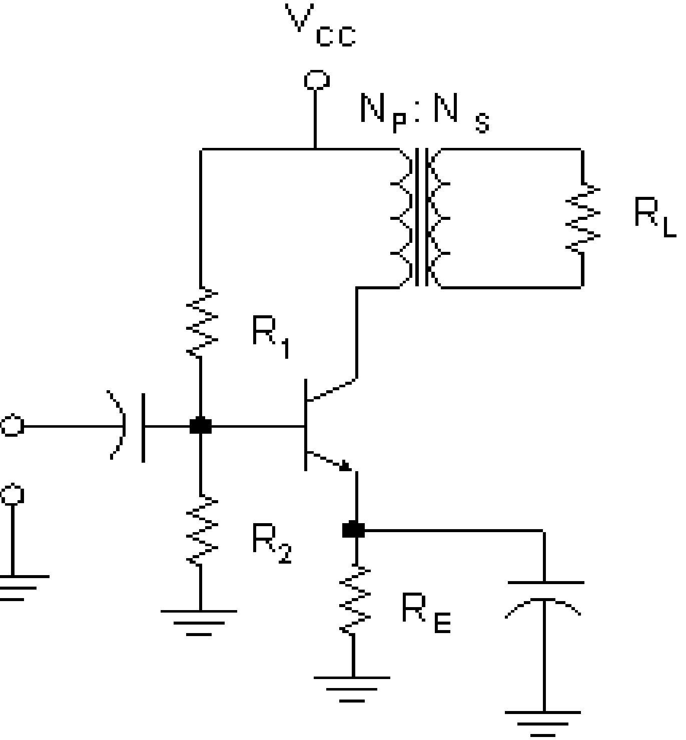
$$\text{D.C. power supplied, } P_{dc} = V_{CC} I_C = V_{CC}\left(\frac{V_{CC}}{2R_C}\right) = \frac{V_{CC}^2}{2R_{CC}}$$

$$\text{So, Maximum Collector Efficiency } \eta = \frac{P_{o(max)}}{P_{dc}} \times 100 = \frac{V_{CC}^2/8R_C}{V_{CC}^2/2R_C} \times 100 = 25\%$$

Thus, the maximum collector efficiency of a class A series-fed amplifier is 25% . In actual practice, the collector efficiency is far less than this value

Transformer Coupled Class A Power Amplifier

In class A amplifier , the load can be either connected directly in the collector or it can be transformer coupled .
Transformer coupling permits impedance matching and it keeps the dc power loss small because of the small resistance of the transformer primary winding .



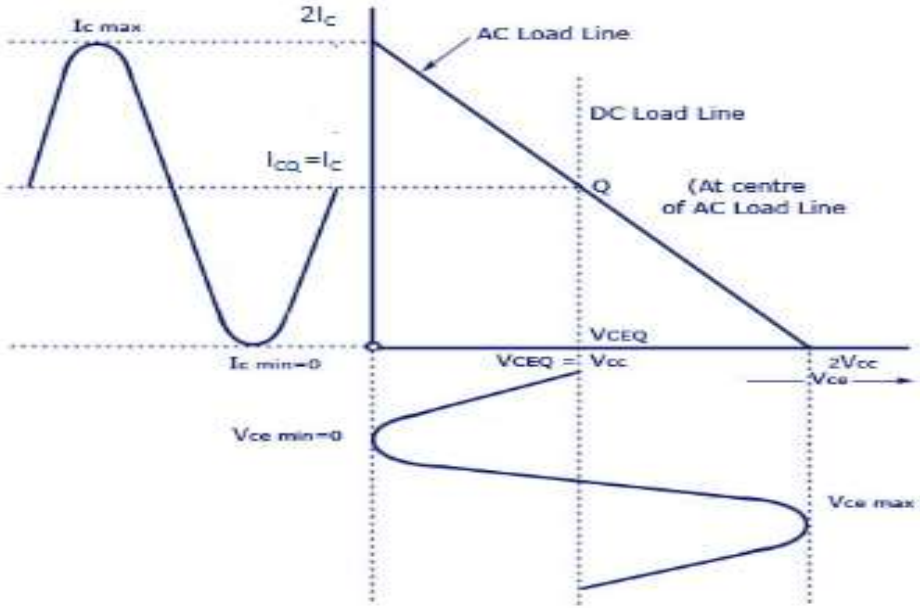


Fig.1 : Transformer coupled class A amplifier

Under zero signal condition, the effective resistance in the collector circuit is that of the primary winding of the transformer. The primary resistance has a very small value and is assumed zero .
Therefore, d.c. load line is a vertical line rising from VCC as shown in figure above.

During the peak of the positive half-cycle of the signal, the total collector current is 2 I_C and $v_{ce} = 0$.
During the negative peak of the signal, the collector current is zero and $v_{ce} = 2\ V_{CC}$
So, Peak-to peak collector – emitter voltage is

$$v_{ce(p-p)} = 2V_{CC}$$

Peak-to-peak collector current is :

$$i_{ce(p-p)} = 2\ I_C = \frac{v_{ce(p-p)}}{\acute{R}_L} = \frac{2V_{CC}}{\acute{R}_L}$$

Where R′L is the reflected value of load RL and appears in the primary of the transformer .
If n= (Np/Ns) is the turn ratio of the transformer, then

$$\acute{R}_L = n^2 R_L$$

d.c. power ,

$$P_{dc} = V_{CC} I_C = {I_C}^2 \acute{R}_L$$

Max. a.c. output power,Po*(max)* is:

$$P_{o(max)} = \frac{v_{ce(p-p)} \times i_{c(p-p)}}{8}$$

$$= \frac{2V_{CC} \times 2I_C}{8}$$

$$= \frac{1}{2} V_{CC} I_C$$

Here i_{ce} (p-p) = i_c (p-p)

$$= \frac{1}{2} {I_C}^2 \acute{R}_L$$

Hence,

$$Max.\,collector\,efficiency\,\eta = \frac{P_{o(max)}}{P_{dc}} \times 100$$

$$= \frac{(1/2) I_C^{\,2} R_L'}{I_C^{\,2} R_L'} \times 100 = 50\%$$

Therefore the maximum efficiency of class A transformer coupled amplifier is 50%, double of direct coupled amplifier.

Here,

$P_{o(ac)} = V_{rms} \cdot I_{rms}$

We have,

$V_{rms} = \frac{V_m}{\sqrt{2}}$, $I_{rms} = \frac{I_m}{\sqrt{2}}$

When, $V_m = \frac{V_{p\text{-}p}}{2}$ $\therefore$ $V_{rms} = \frac{V_{pp}}{2\sqrt{2}}$

$\therefore$ $V_{rms} = \frac{2V_{cc} - 0}{2\sqrt{2}} = \frac{V_{cc}}{\sqrt{2}}$

For I_{rms},

$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{I_{p\text{-}p}}{2\sqrt{2}} = \frac{V_{cc}}{R_L \cdot 2\sqrt{2}}$

Now,

$P_{ac} = I_{rms} \cdot V_{rms} = \frac{V_{cc}^2}{4R_L}$

We have, $I_{dc} = \frac{V_{cc}}{2R_L}$, $V_{dc} = V_{cc}$

$\therefore$ $P_{in(dc)} = \frac{V_{cc}^2}{2R_L}$

$\therefore$ Efficiency $(\eta) = \frac{P_{ac}}{P_{in\,dc}} = 50\%$

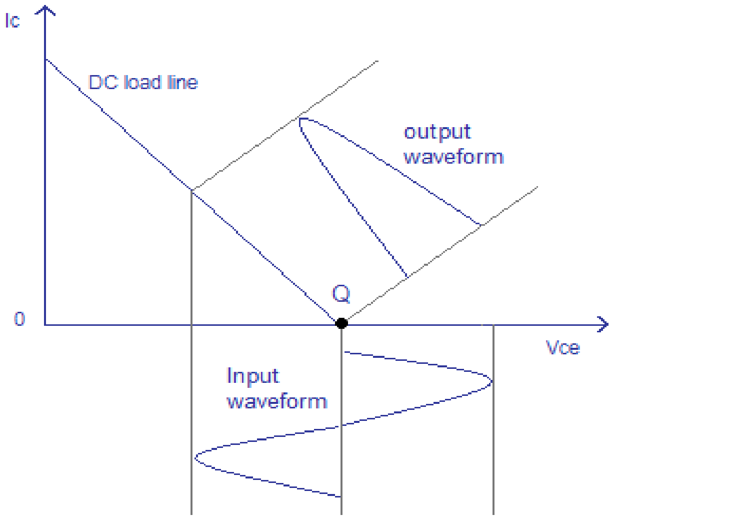
Class B Amplifier

Class B amplifier is a type of power amplifier where transistor conducts only for one half cycle of the input signal. That means the conduction angle is 180° for a Class B amplifier. Since transistor is switched off for of half the input cycle.

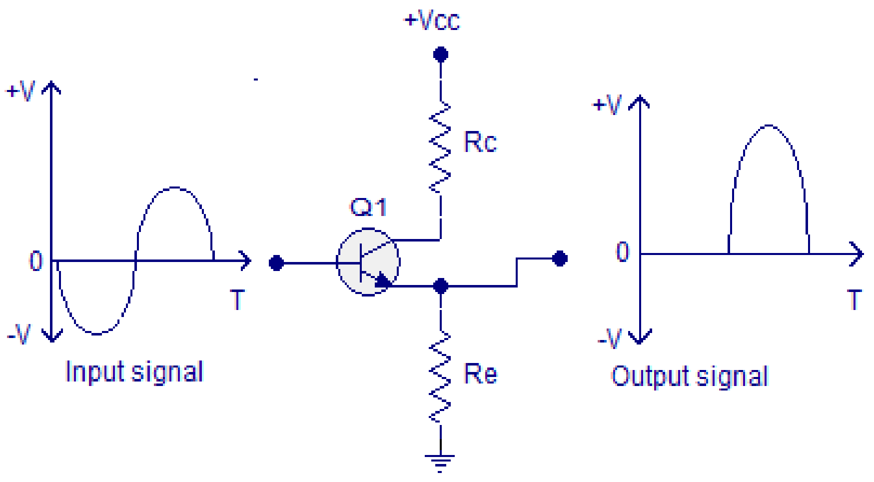
The transistor dissipates less power and hence the efficiency is improved. Theoretical maximum efficiency of Class B power amplifier is 78.5%

Only half the information present in the input will be available in the output

Output characteristics of a single ended Class B power amplifier is shown in the figure

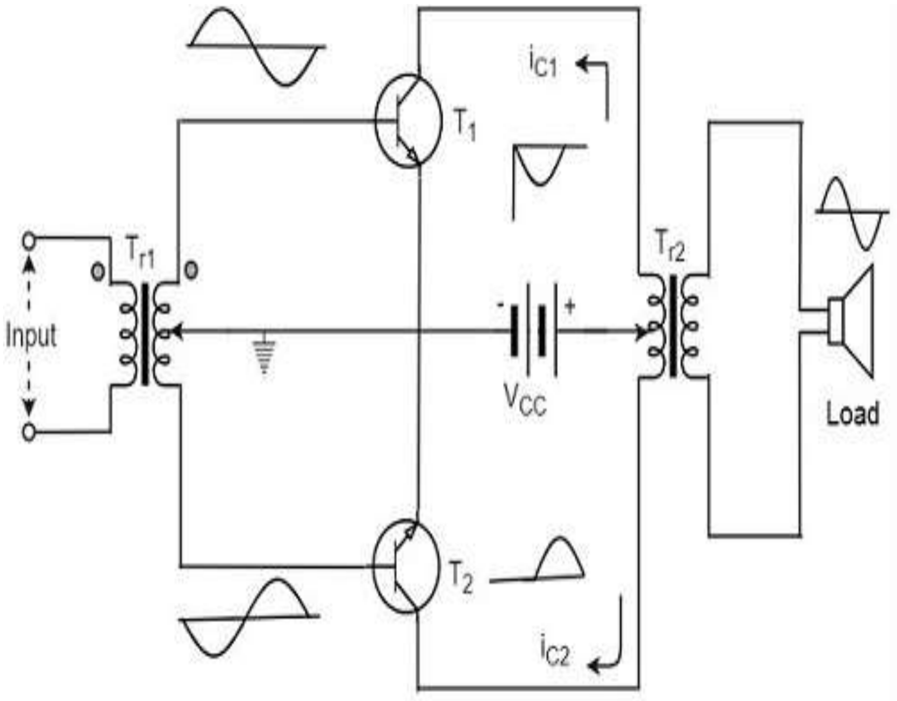


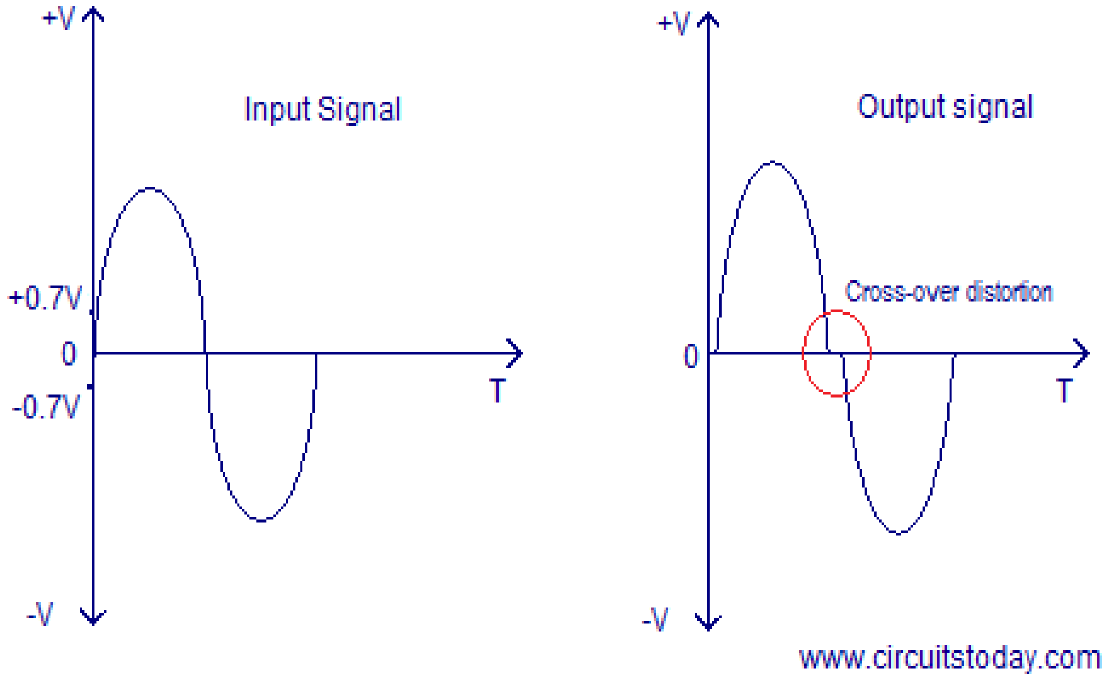
Class B power amplifier output characteristics wwww.circuitstoday.com



Single ended Class B amplifier www.circuitstoday.com

Hence only the positive half cycle is amplified at the output .As the negative half cycle is completely absent, the signal distortion will be high. In order to minimize the disadvantages and achieve low distortion, high efficiency and high output power, the push-pull configuration is used in this class B amplifier.





Here cross over distortion occur at o/p.

Operation

The circuit of class B push-pull amplifier shown in the above figure clears that both the transformers are center-tapped. When no signal is applied at the input, the transistors T_1 and T_2 are in cut off condition and hence no collector currents flow. As no current is drawn from V_{CC}, no power is wasted.

When input signal is given, it is applied to the input transformer T_{r1} which splits the signal into two signals that are 180^o out of phase with each other. These two signals are given to the two identical transistors T_1 and T_2. For the positive half cycle, the base of the transistor T_1 becomes positive and collector current flows. At the same time, the transistor T_2 has negative half cycle, which throws the transistor T_2 into cutoff condition and hence no collector current flows.

For the next half cycle, the transistor T_1 gets into cut off condition and the transistor T_2 gets into conduction, to contribute the output. Hence for both the cycles, each transistor conducts alternately. The output transformer T_{r2} serves to join the two currents producing an almost undistorted output waveform.

We assume that,

Two transistors are perfectly matched, transformer windings has zero resistance.

The current in each transistor is the average value of half sine loop.

For half sine loop, I_{dc} is given by

$$I_{dc} = \frac{(I_C)_{max}}{\pi}$$

Therefore,

$$(p_{in})_{dc} = 2 \times \left[\frac{(I_C)_{max}}{\pi} \times V_{CC}\right]$$

Here factor 2 is introduced as there are two transistors in push-pull amplifier.

R.M.S. value of collector current = $(I_C)_{max}/\sqrt{2}$

R.M.S. value of output voltage = $VCC/\sqrt{2}$

Under ideal conditions of maximum power

Therefore,

$$(P_O)_{ac} = \frac{(I_C)_{max}}{\sqrt{2}} \times \frac{V_{CC}}{\sqrt{2}} = \frac{(I_C)_{max} \times V_{CC}}{2}$$

Now overall maximum efficiency

$$\eta_{overall} = \frac{(P_O)_{ac}}{(P_{in})_{dc}}$$

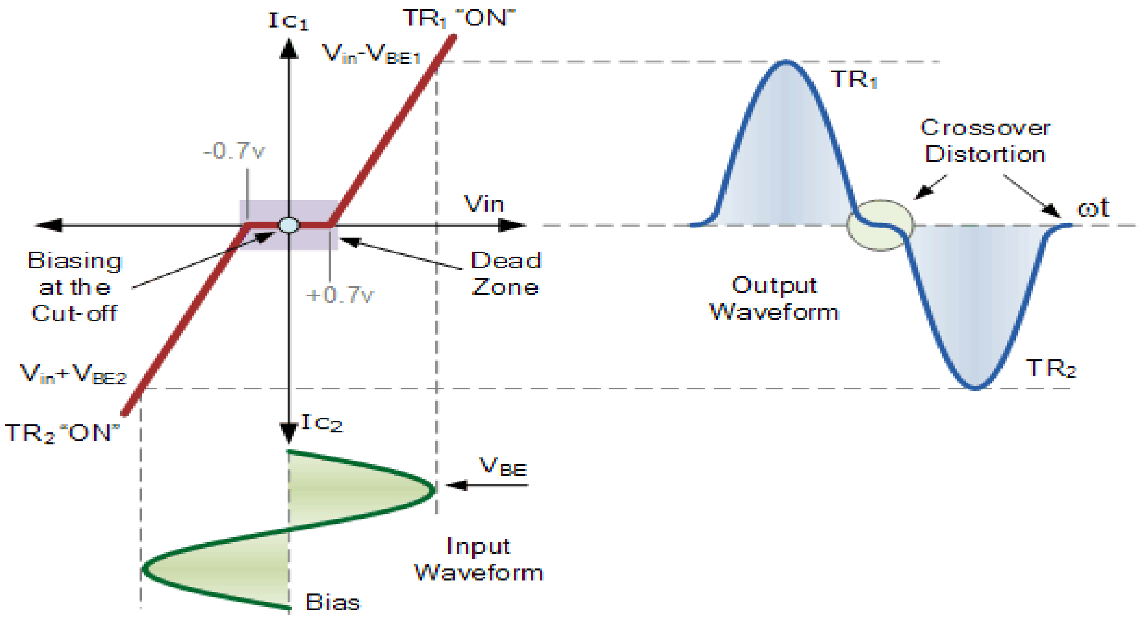
$$= \frac{(I_C)_{max} \times V_{CC}}{2} \times \frac{\pi}{2(I_C)_{max} \times V_{CC}}$$

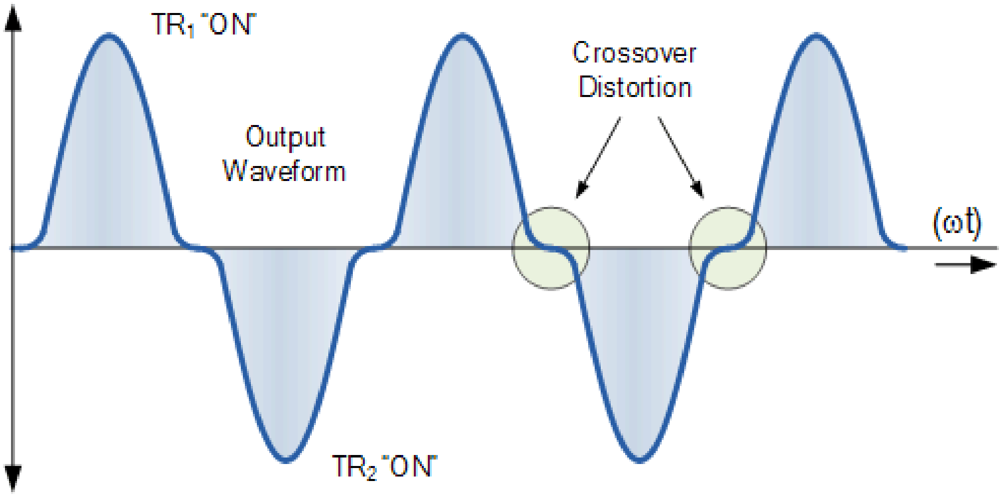
$$= \frac{\pi}{4} = 0.785 = 78.5\%$$

Hence maximum efficiency of transformer coupled class B push pull amplifier is 78.5%.

Crossover Distortion in Amplifiers

Crossover Distortion is a common feature of Class-B amplifiers where the non-linearities of the two switching transistors do not vary linearly with the input signal.





one main fundamental problem with push-pull amplifiers in that the two transistors do not combine together fully at the output both halves of the waveform due to their unique zero cut-off biasing arrangement. As this problem occurs when the signal changes or “crosses-over” from one transistor to the other at the zero voltage point it produces an amount of “distortion” to the output wave shape. This results in a condition that is commonly called **Crossover Distortion**.

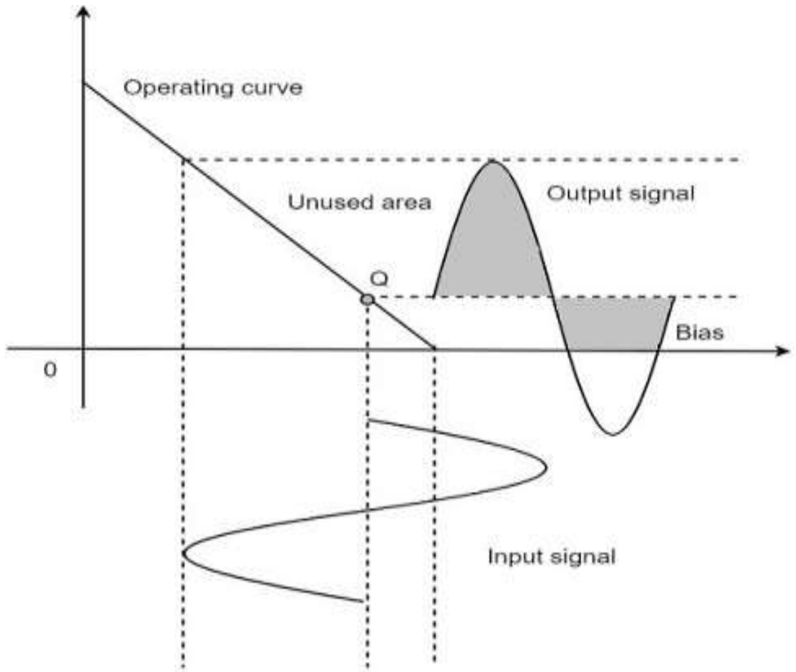
Crossover Distortion produces a zero voltage "dead band” on the output wave shape as it crosses over from one half of the waveform to the other. The reason for this is that the transition period when the transistors are switching over from one to the other, does not stop or start exactly at the zero crossover point thus causing a small delay between the first transistor turning “OFF” and the second transistor turning “ON”. This delay results in both transistors being switched “OFF” at the same instant in time.

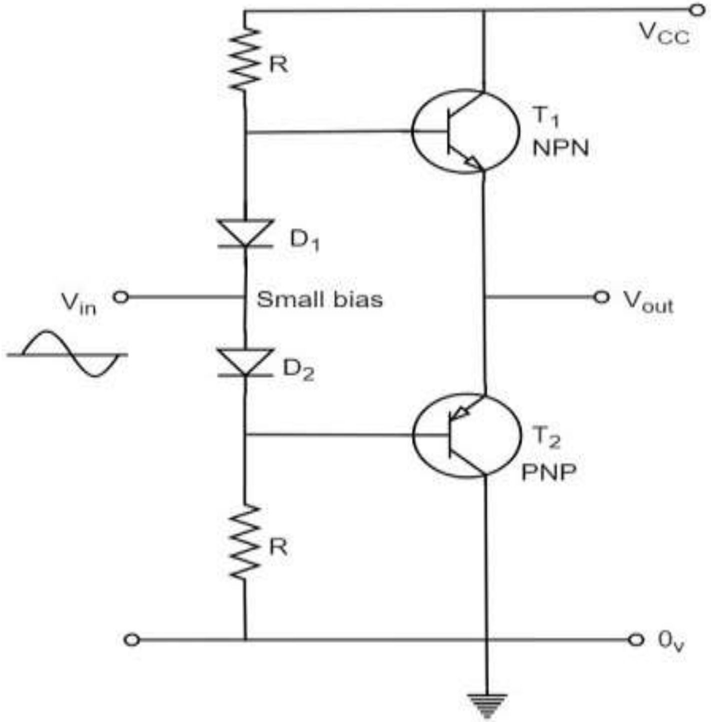
The problem of Crossover Distortion can be reduced considerably by applying a slight forward base bias voltage to the bases of the two transistors via the center-tap of the input transformer, thus the transistors are no longer biased at the zero cut-off point but instead are “Pre-biased” at a level determined by this new biasing voltage ,as in Class AB Amplifier and its biasing arrangement .

Class AB Amplifier

Class AB is a combination of class A and class B type of amplifiers. As class A has the problem of low efficiency and class B has distortion problem, this class AB is emerged to eliminate these two problems, by utilizing the advantages of both the classes.

The cross over distortion is the problem that occurs when both the transistors are OFF at the same instant, during the transition period. In order to eliminate this, the condition has to be chosen for more than one half cycle. Hence, the other transistor gets into conduction, before the operating transistor switches to cut off state. This is achieved only by using class AB configuration, as shown in the following circuit diagram.



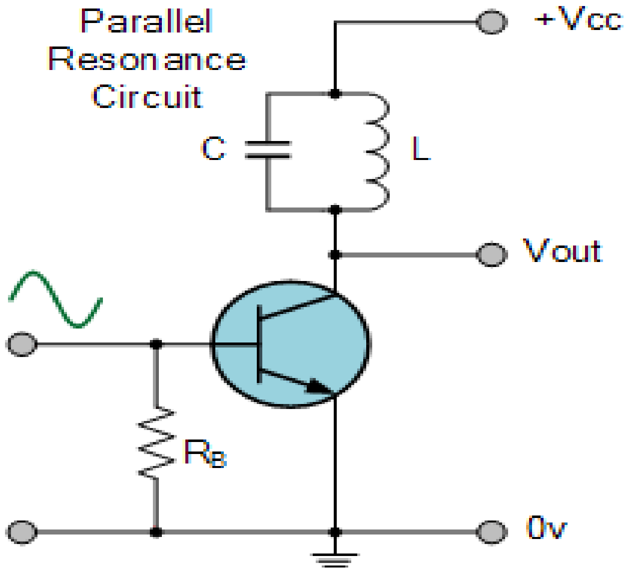


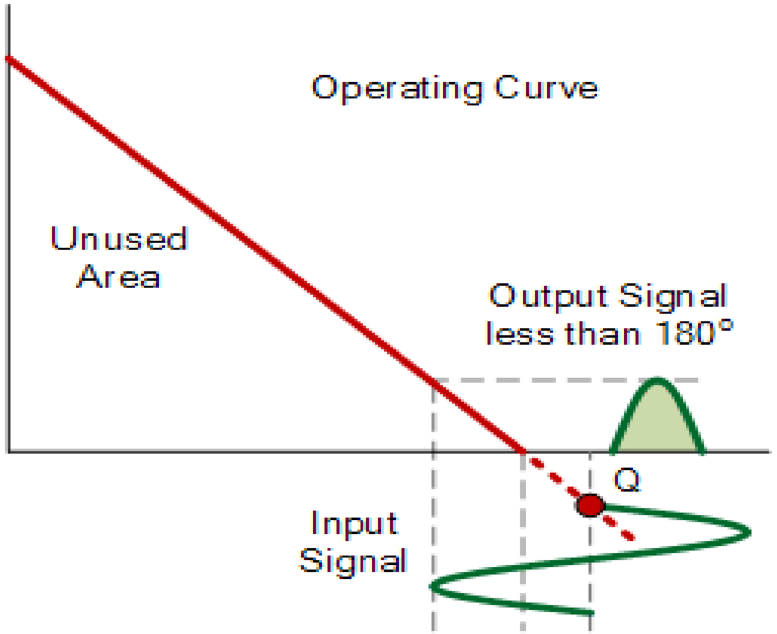
In class AB amplifier design, each of the push-pull transistors is conducting for slightly more than the half cycle of conduction in class B.The conduction angle of class AB amplifier is somewhere between 180^o to 360^o depending upon the operating point selected.

The small bias voltage given using diodes D_1 and D_2, as shown in the above figure, helps the operating point to be above the cutoff point. Hence the output waveform of class AB results as seen in the above figure. The crossover distortion created by class B is overcome by this class AB.

So, the class AB is a good compromise between class A and class B in terms of efficiency and linearity having the efficiency reaching about 50% to 60%.

Class C Amplifier





Biasing resistor Rb pulls the base of transistor further downwards and the Q-point will be set some way below the cut-off point in the DC load line. As a result the transistor will start conducting only after the input signal amplitude has risen above the base emitter voltage (Vbe~0.7V) plus the downward bias voltage caused by RB. That is the reason why the major portion of the input signal is absent in the output signal.

Inductor L and capacitor C forms a tank circuit. Since the resonant circuit(LC) oscillates in one frequency (generally the carrier frequency) all other frequencies are attenuated and the required frequency can be squeezed out using a suitably tuned load. Harmonics or noise present in the output signal can be eliminated using additional filter.

Conduction angle is less than 120 degree, used in high frequency, efficiency is more than 90%.

Power dissipation and Heat sinks

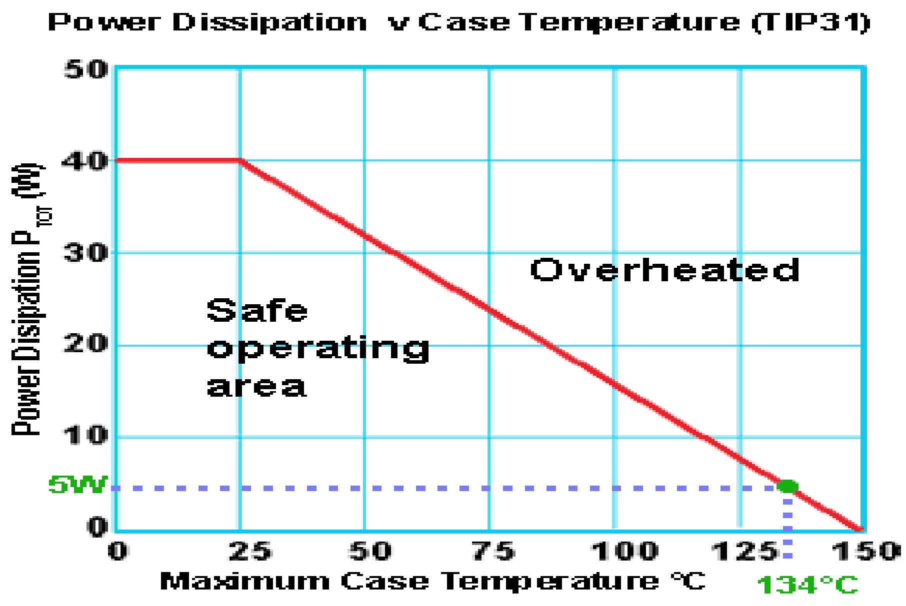
Power transistors can be categorized as those than can handle more than 1 Ampere of collector current. The maximum power rating of a transistor is largely governed by the temperature of the collector/base junction. If too much power is dissipated, this junction gets too hot and the transistor will be destroyed, a typical maximum temperature is between 100°C and 150°C, although some devices can withstand higher maximum junction temperatures.

Minimizing the problem of heat is approached in two main ways:

- 1. By operating the transistor in the most efficient way possible,

that is by choosing a class of biasing that gives high efficiency and is least wasteful of power.

- 2. By ensuring that the heat produced by the transistor can be removed and effectively transferred to the surrounding air as quickly as possible. (Heat Sink).



Heat Sink

A device attached to the transistor for the purpose of removing heat. The physical construction of power transistors is therefore designed to maximize the transfer of heat to the heat sink.

A heat-sink is designed to remove heat from a transistor and dissipate it into the surrounding air as efficiently as possible. Heat-sinks take many different forms, such as finned aluminum or copper sheets.

Good physical contact between the transistor and heat-sink is essential, and a heat transmitting grease (heat-sink compound) is smeared on the contact area before clamping the transistor to the heat-sink.