MODULE 2: TUNED VOLTAGE AMPLIFIERS & POWER AMPLIFIERS

TUNED AMPLIFIERS

Need of Tuned Amplifier

- The types of amplifiers that we have discussed so far cannot work effectively at radio frequencies, even though they are good at audio frequencies.
- Also, the gain of these amplifiers is such that it will not vary according to the frequency of the signal, over a wide range.
- This allows the amplification of the signal equally well over a range of frequencies and does not permit the selection of desired frequency while rejecting the other frequencies.
- So, there occurs a need for a circuit which can select as well as amplify. So, an amplifier circuit along with a selection, such as a tuned circuit makes a **Tuned amplifier**.

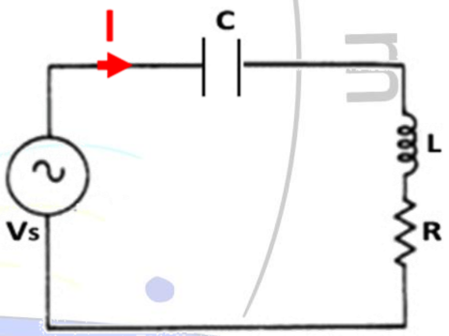
What is a Tuned Amplifier?

- Tuned amplifiers are the amplifiers that are employed for the purpose of **tuning**. Tuning means selecting.
- ***Among a set of frequencies available, if there occurs a need to select a particular frequency, while rejecting all other frequencies, such a process is called <u>selection</u>***. This selection is done by using a circuit called as **Tuned circuit**.
- ***When an amplifier circuit has its load replaced by a tuned circuit, such an amplifier can be called as a <u>Tuned amplifier</u> circuit.***
- The tuner circuit is nothing but a LC circuit which is also called as **resonant** or **tank circuit**. It selects the frequency.
- A tuned circuit is capable of amplifying a signal over a narrow band of frequencies that are cantered at resonant frequency.
- When the reactance of the inductor balances the reactance of the capacitor, in the tuned circuit at some frequency, such a frequency can be called as **resonant frequency**. It is denoted by $\mathbf{f_r}$.

RESONANCE CIRCUIT

1.) <u>SERIES RESONANCE CIRCUIT</u>

Fig (a) shows a series resonant circuit, where an inductor and a capacitor are connected in series to the voltage source (Vs). The resistance (R) represents the resistance of the inductor coil. The reactance of the inductor X_L and reactance of the capacitor X_c at a particular frequency f are given by the expressions

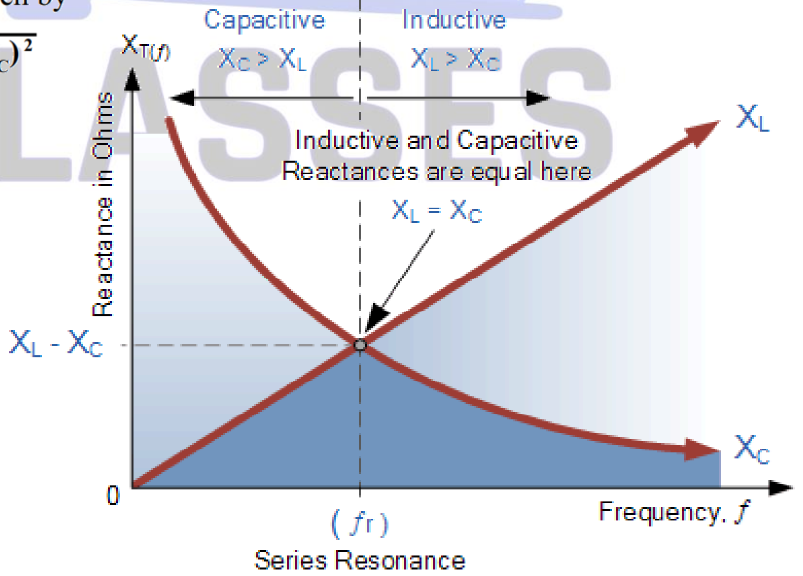


Fig(a)

$$X_L = 2\pi fL$$
$$Xc = 1/2\pi fC$$

The impedance of the circuit (Zs) is given by

$$Zs = \sqrt{R^2+(X_L-X_C)^2}$$



- In a series RLC circuit, when the frequency is below resonant inductive reactance (X_L) is small and capacitive reactance X_c) is large **(Xc> XL).** The reactance of the circuit is then **capacitive**.
- At resonant fequency **(f_r)**, inductive reactance becomes equal to capacitive reactance **(Xc=XL)**. Then the impedance of the circuit becomes purely **resistive** and equal to **R**.
- When the frequency is above resonant frequency XL will exceed Xc **(XL >Xc)** and the reactance of the circuit becomes **inductive.**

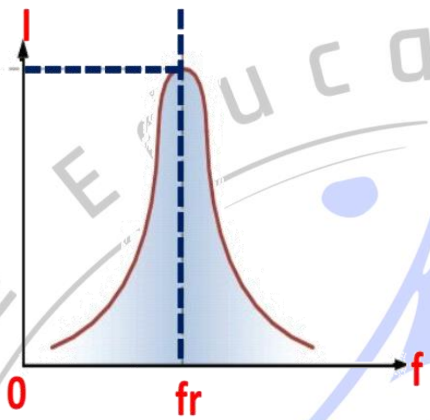
Fig (b) and (c) respectively shows the variation of line current **(I)** and impedance **(Zs)** with source frequency in a series resonant circuit.

At resonance, in series resonant circuit

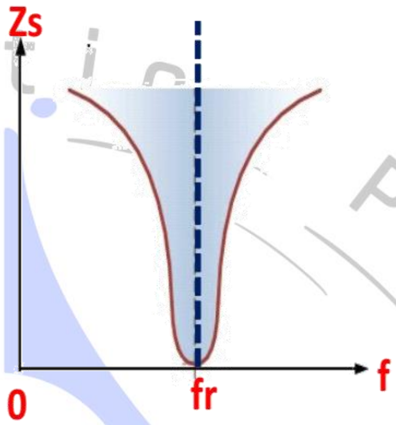
- Inductive reactance equals capacitive reactance (XL =XC)
- Circuit impedance become minimum, equal to the circuit resistance

  i.e. Zs=R (minimum)
- Current through the circuit becomes maximum

  i.e. I=V/R (max)
- Resonant frequency $\mathbf{f_r=1/2\pi\sqrt{LC}}$



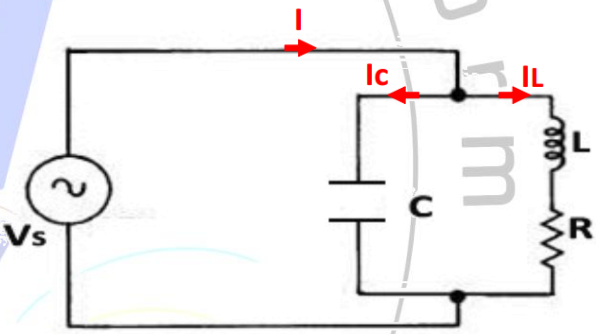
Fig(b)



Ficg(c)

2) <u>PARALLEL RESONANCE CIRCUIT</u>

Fig shows a series resonant circuit, where an inductor and a capacitor are connected in parallel to the voltage source (Vs). The resistance (R) represents the resistance of the inductor coil



<u>Impedance</u>

$$Z_p = \frac{L}{RC}$$

Note: ***In practice, the impedance (Z) of the circuit is maximum and not infinite because of resistance of the coil and hence the r.m.s. current given to the circuit is minimum (tends to zero), this is the condition of parallel resonance.***

Expression for resonant frequency (fr)

At resonance

$$\begin{aligned}
X_L &= X_C \\
\text{or } 2\pi f_r L &= 1/2\pi f_r C \\
\text{or } 2\pi f_r L \times 2\pi f_r C &= 1 \\
\text{or } 4\pi^2 f_r^2 LC &= 1 \\
\therefore \quad f_r^2 &= 1/4\pi^2 LC \\
f_r &= \sqrt{1/4\pi^2 LC} \\
&= 1/2\pi\sqrt{LC} \\
&= \mathbf{0.159/\sqrt{LC}}
\end{aligned}$$

Where:

fr is the resonant frequency in *Hz*

L is the inductance of the inductor in *Henry*

C is the capacitance of the capacitor in *Farad*

Quality factor (Q)

- Quality factor (Q) is a measure of the ability of a resonant circuit to select or reject a band of frequencies.
- It is defined as the ratio of the inductive reactance of the coil to the resistance of the coil used in the resonant circuit

$$Q = \frac{X_L}{R}$$
$$Q = \frac{2\pi f L}{R}$$

Bandwidth (Δf)

- The range of frequencies at which the voltage gain of the tuned amplifier falls to 70.7% of the maximum gain is called its **Bandwidth**.
- The range of frequencies between f_1 and f_2 is called as bandwidth of the tuned amplifier.
- The bandwidth of a tuned amplifier depends upon the Q of the LC circuit i.e., upon the sharpness of the frequency response. The value of Q and the bandwidth are inversely proportional.

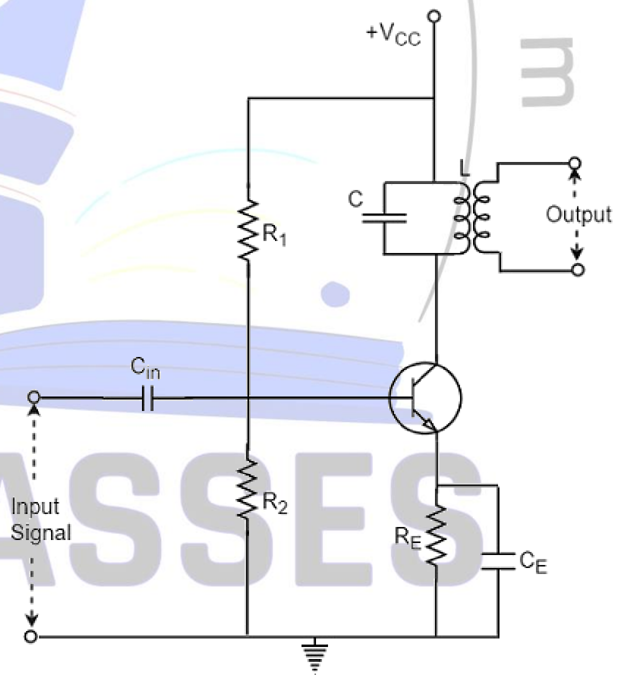
$$.\Delta f = \frac{f_r}{Q}$$

Problems

1. **A parallel tuned circuit is resonant at 455 KHz and it has 20kHz bandwidth and $X_L = 1500\Omega$. Find Q factor**
2. **A parallel resonant circuit has the following C = 100 pf ,L=50mH (with R =l0 ohm) and supply voltage V = 500 V. calculate resonant frequency, Q factor and bandwidth.**
3. **A parallel trued circuit is resonant at 455KHz and has a 10KHz bandwidth and $X_L = 1255\Omega$. Find the Q-factor. Calculate the circuit impedance at resonance**

Single Tuned Amplifier

An amplifier circuit with a single tuner section being at the collector of the amplifier circuit is called as Single tuner amplifier circuit.



CONSTRUCTION

- A simple transistor amplifier circuit consisting of a parallel tuned circuit in its collector load, makes a single tuned amplifier circuit.
- The values of capacitance and inductance of the tuned circuit are selected such that its resonant frequency is equal to the frequency to be amplified.
- The following circuit diagram shows a single tuned amplifier circuit.

OPERATION OF SINGLE TUNED AMPLIFIER:

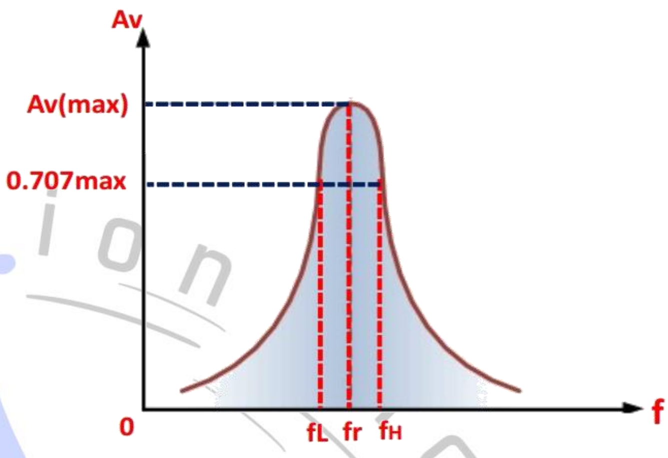
- When the frequency of the input signal becomes equals to the resonant frequency of the tuned circuit, the impedance of the resonant circuit is maximum and a large signal appears across the output terminal.
- If the input signal is a complex wave consisting of many frequencies, then amplifier will select and amplify strongly only those frequencies equal and close to its resonant frequency.
- The other frequencies will be rejected. Thus, the desired signal is selected and amplified by the tuned amplifier

FREQUENCY RESPONSE

The parallel resonance occurs at resonant frequency f_r when the circuit has a high Q. the resonant frequency f_r is given by

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

The graph shows the frequency response of a single tuned amplifier circuit.



- At resonant frequency f_r the impedance of parallel tuned circuit is very high and is purely resistive.
- The voltage across R_L is therefore maximum, when the circuit is tuned to resonant frequency.
- Hence the voltage gain is maximum at resonant frequency and drops off above and below it.
- The higher the Q, the narrower will the curve be.

ADVANTAGES OF A SINGLE TUNED AMPLIFIER

- The power loss is less due to the lack of collector resistance.
- Selectivity is high.
- The voltage supply of the collector is small due to the lack of Rc.

DISADVANTAGES OF A SINGLE TUNED AMPLIFIER

- The product of gain bandwidth is small

APPLICATIONS OF SINGLE TUNED AMPLIFIER

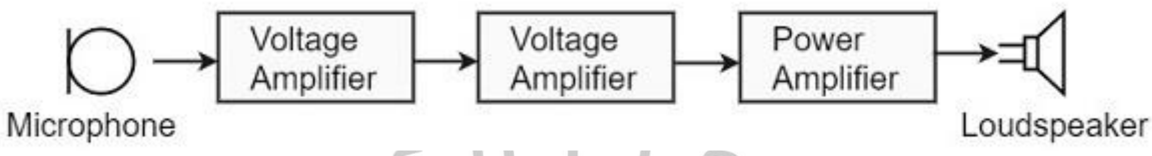
- This amplifier is used in the primary internal stage of the radio receiver wherever the selection of the front end can be done using an RF amplifier.
- This amplifier can be used in television circuits.

COMPARISON OF SERIES AND PARALLEL RESONANCE CIRCUIT

Aspect	Series resonance circuit	Parallel resonance circuit
▪ **Circuit structure**	Inductor and a capacitor are connected in series to the voltage source	An inductor in parallel with a capacitor is connected across the source voltage
▪ **Impedance of the circuit**	$Zs = \sqrt{R^2+(X_L-X_C)^2}$	$Zp=Xc.X_L/Zs$
▪ **Resonant frequency fr**	$1/2\pi\sqrt{LC}$	$1/2\pi\sqrt{LC}$
▪ **Current at resonance**	Maximum (Vs/R)	Minimum (Vs/Zp)
▪ **Impedance at resonance**	Minimum (Zs=R)	Maximum (Zp=L/R)
▪ **Circuit condition at resonance**	Maximum current and minimum impedance	Maximum impedance and minimum current
▪ **Power factor**	Unity	Unity
▪ **Quality facto**	$2\pi f\, L/R$	$2\pi f\, L/R$

POWER AMPLIFIER

- A power amplifier is an electronic amplifier designed to increase the magnitude of power of a given input signal.
- The power of the input signal is increased to a level high enough to drive loads of output devices like speakers, headphones, RF transmitters etc.
- Unlike voltage/current amplifiers, a power amplifier is designed to drive loads directly and is used as a final block in an amplifier chain.



COMPARISON OF VOLTAGE AMPLIFIER AND POWER AMPLIFIER

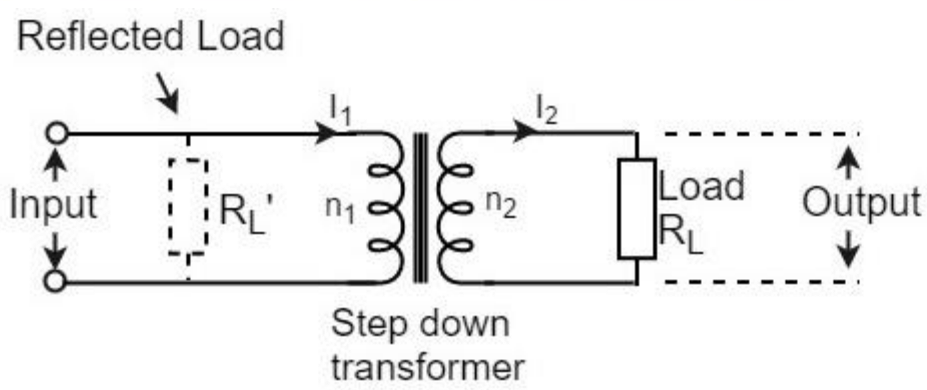
	VOLTAGE AMPLIFIER	POWER AMPLIFIER
Current gain β	High (>100)	Low(5 – 20)
Rc	High (4-10kOhm)	Low(5-20 ohm)
Coupling	RC coupling	Transformer coupling
Input voltage	Low(a few mV)	High(2-4 V)
Collector current	Low (~1mA)	High(>100mA)
Power output	low	High
Output impedance	High(~12kohm)	Low(200 ohm)

IMPEDANCE MATCHING IN POWER AMPLIFIER.

- Power amplifiers are used to drive loads like loud speakers, antenna etc.
- The power generated from the amplifier must be transferred to the load to the maximum extend.
- It is possible only if the output impedance of the amplifier equals the load impedance R_L. Otherwise it results in loss of power output.
- Usually, a transformer called the *output transformer* is used for this purpose.

TRANSFORMER ACTION

- The transformer used in the collector circuit is for impedance matching. R_L is the load connected in the secondary of a transformer. R_L' is the reflected load in the primary of the transformer.
- The number of turns in the primary are n_1 and the secondary are n_2. Let V_1 and V_2 be the primary and secondary voltages and I_1 and I_2 be the primary and secondary currents respectively. The below figure shows the transformer clearly.



$$R'_L = \left(\frac{n_1}{n_2}\right)^2 R_L = n^2 R_L$$

Where

$$n = \frac{number\ of\ turns\ in\ primary}{number\ of\ turns\ in\ secondary} = \frac{n_1}{n_2}$$

A power amplifier may be matched by taking proper turn ratio in step down transformer.

Problem

In a single stage power amplifier the output transformer winding N1=300,N2=25 and loud speaker impedance is 16 ohms. Find the effective load impedance experienced by the transistor amplifier

Solution: **Given :** N1 = 300

N2 = 25

RL =16 ohms

Effective load impedance experienced by the transistor amplifier $R^I L = (N1/N2)^2 RL$

$= (300/25)^2 x16$

= **2.304K**

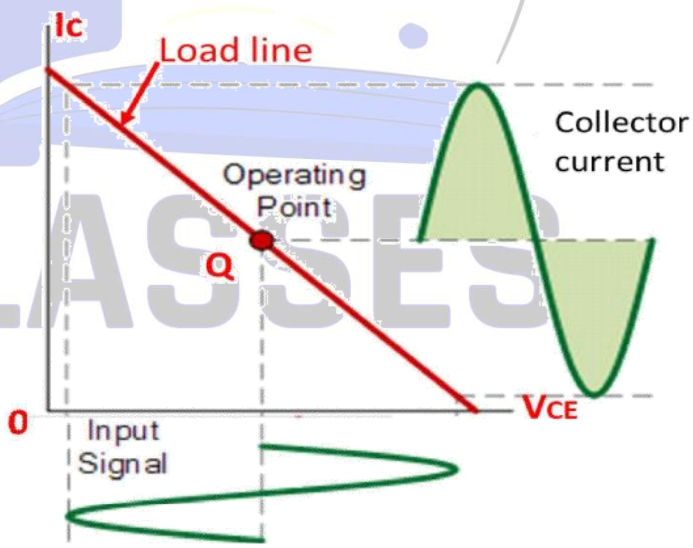
CLASSIFICATION OF POWER AMPLIFIER

On the basis of mode of operation power amplifiers may be classified as

(i) Class **A** (ii) Class **AB** (iii) Class **B** (iii) Class **C**

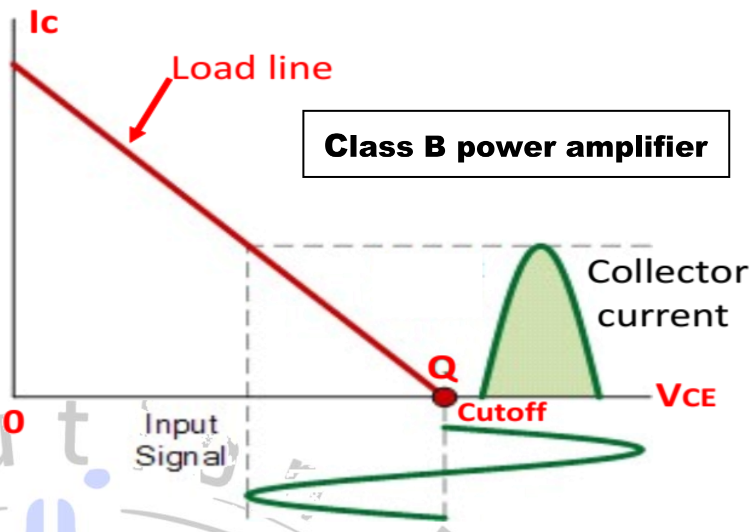
Class A power amplifier

- In class A power amplifier, the collector current flows at all times during the full cycle of the input signal.
- To obtain class A operation the operating point **'Q'** is set in the middle of the load line so that the swing of Q point will be within the active region only



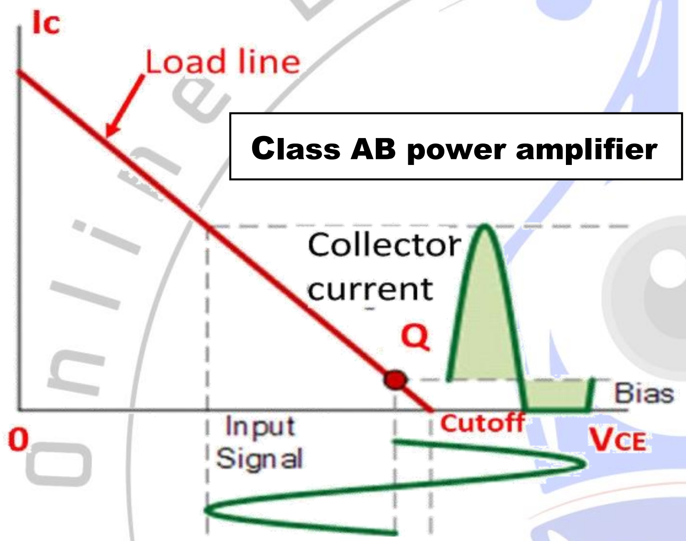
Class B power amplifier

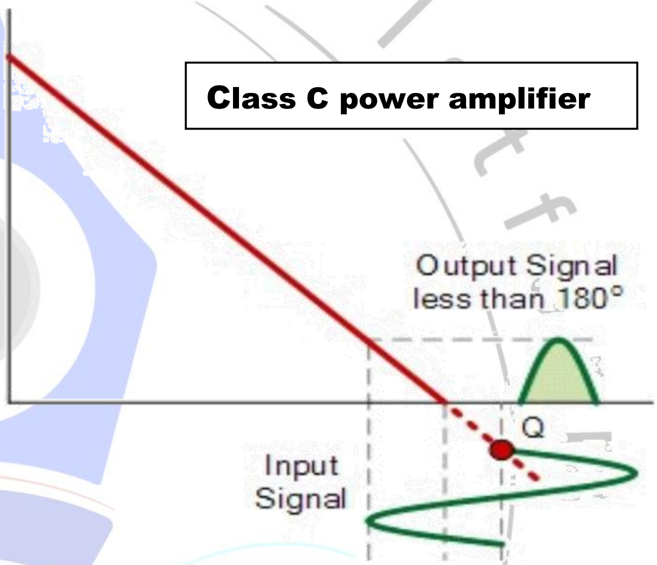
- In class B amplifier the collector current flows only during one half cycle of the input signal.
- For class B operation, the biasing circuit is so adjusted that the operating point **'Q'** lies at the cut off (Ic=0)



Class AB power amplifier

- In this type of power amplifier collector current flows for a period of more than half cycle but less than one cycle of the input signal.
- For class AB operation the operating point is located near cut off.





Class C power amplifier

- In class C amplifier, the collector current flows for less than half cycle of the input signal.
- In this case the 'Q' point is fixed beyond the cutoff point by giving some reverse bias to the base.

Comparison of Class A, Class B and Class C Power Amplifiers

	CLASS A	CLASS B	CLASS C
Transistor is ON for	One full cycle	One half cycle	Less than a half cycle
Period of conduction	360 degree	180 degree	Less than 180 degree
Operating point	Q point is set at the middle of load line	Q point is set at cut off	Q point is set at below cut off
Maximum efficiency	50%	78.5%	85-90%
Output	No distortion	Distorted version of input	Highly distorted version of input
Power dissipation	Very high	Low	Very low