Power Amplifiers

Date: 01 April 2020
Class: BE CSE -3
Faculty: T.Sridher, Asst Professor, ECE Department
Time: 03:20 to 04:20 pm

Lecture Outline

Power Amplifier (PA)

- Performance parameters
- Classification
- DC and AC Load line

Class A

Class B

Class AB

Class C

Practical Examples of PA

Performance Parameters of PA

Amplifier Efficiency

A figure of merit for the power amplifier is its conversion efficiency.

$$\eta = \frac{average\ ac\ power\ delivered\ to\ the\ load}{average\ dc\ power\ drawn\ by\ the\ circuit} = \frac{P_o(ac)}{P_i(dc)}$$

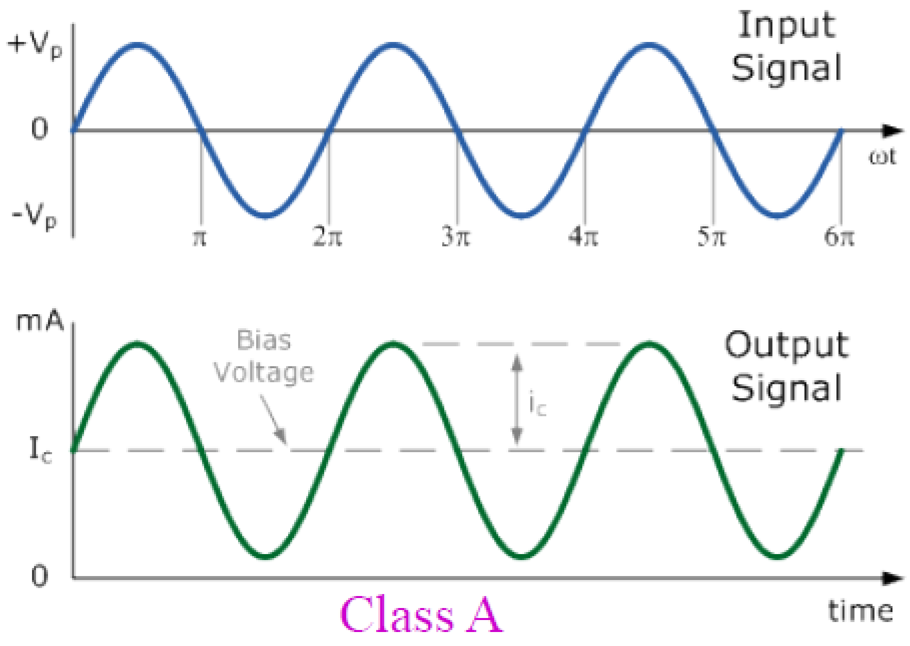
Distortion

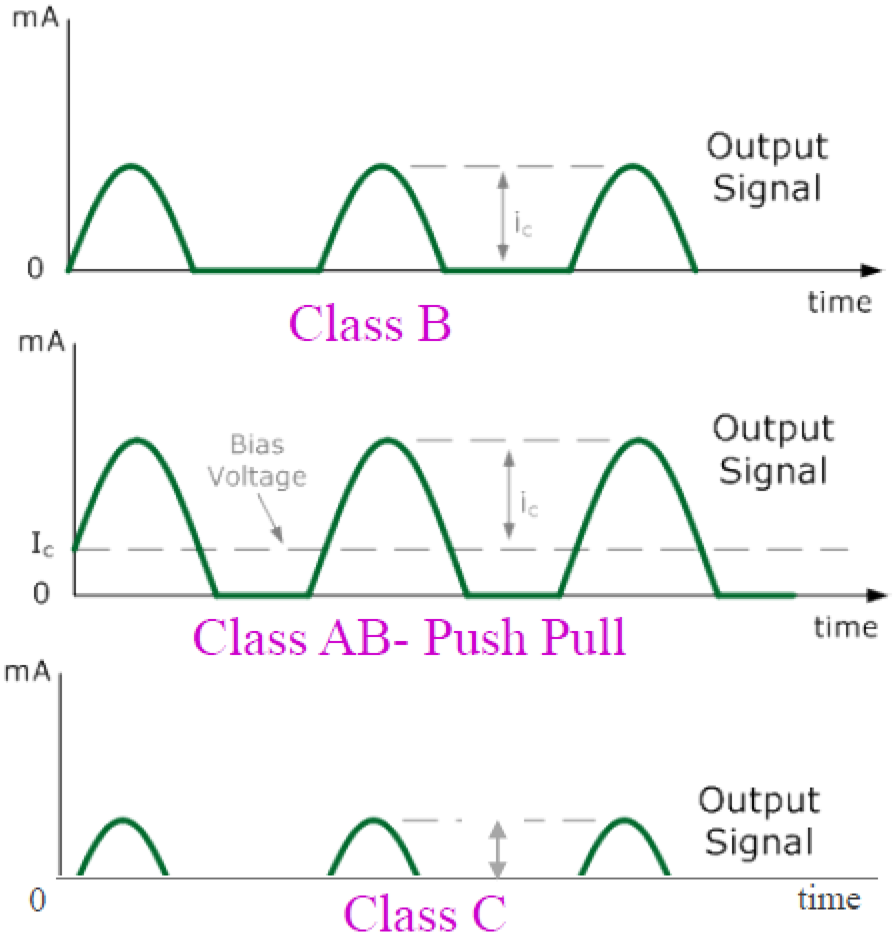
The change in output wave shape from the input wave shape of an amplifier is known as distortion.

Power dissipation capability

The ability of a power amplifier to dissipate heat is known as power dissipation capability.

Classification of Power Amplifier





Conduction Angle:

Class A > Class AB > Class B > Class C

Efficiency:

Class A < Class AB < Class B < Class C

Definitions of Class A Power Amplifier

Amplifier:

An *amplifier* is an electronic device that increases voltage, current or power of a signal.

According to the class of operation, the amplifiers can be classified as:

(i) Class A, (ii) Class B, (iii) Class AB, and (iv) Class C.

Class A: A *class A* amplifier is one in which the operating point and the input signal are such that the current in the output circuit flows at full times.

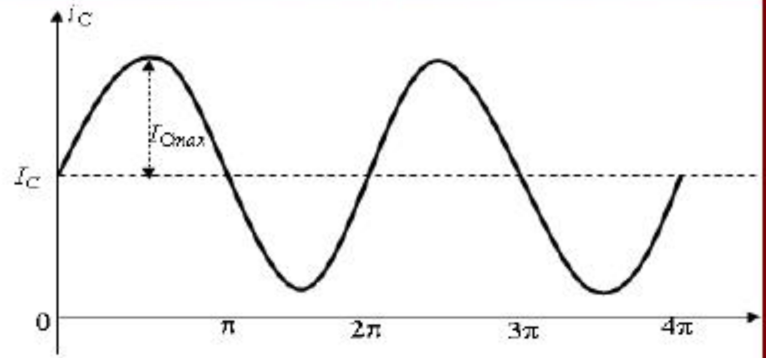


Fig.1(a) Collector current waveform for transistor operating in Class A.

The output signal of *class A* amplifiers varies for a full 360° of the cycle.

Class B , AB Power Amplifier

Class B: A *class B* amplifier is one in which the operating point is at an extreme end of its characteristic, so that the quiescent power is very small. If the signal voltage is sinusoidal, amplification takes place for only one-half a cycle.

A *class B* circuit provides an output signal varying over one-half the input signal cycle, of for 180° of input signal.

Class AB: A *class AB* amplifier is one operating between the two extremes defined for class A and class B. Hence the output signal is zero for part but less than one-half of an input sinusoidal signal.

For class AB operation the output signal swing occurs between 180° and 360° and is neither class A nor class B operation.

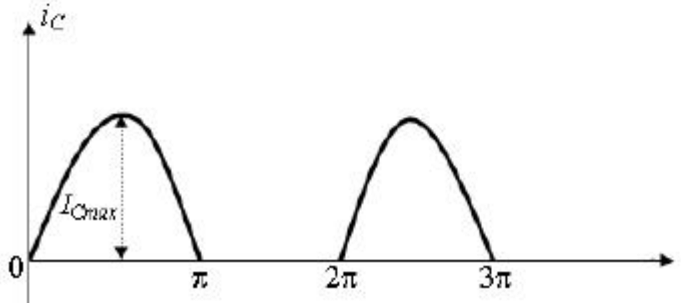


Fig.1(b) Collector current waveform for transistor operating in Class B.

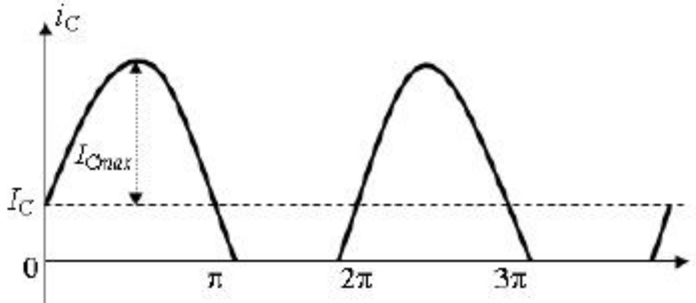


Fig.1(c) Collector current waveform for transistor operating in Class AB.

Class C Power Amplifier

Class C: A *class C* amplifier is one in which the operating point is chosen so that the output current (or voltage) is zero for more than one-half of the input sinusoidal signal cycle.

The output of a class C amplifier is biased for operation at less than 180° of the cycle and will operate only with a tuned (resonant) circuit which provides a full cycle of operation for the tuned or resonant frequency.

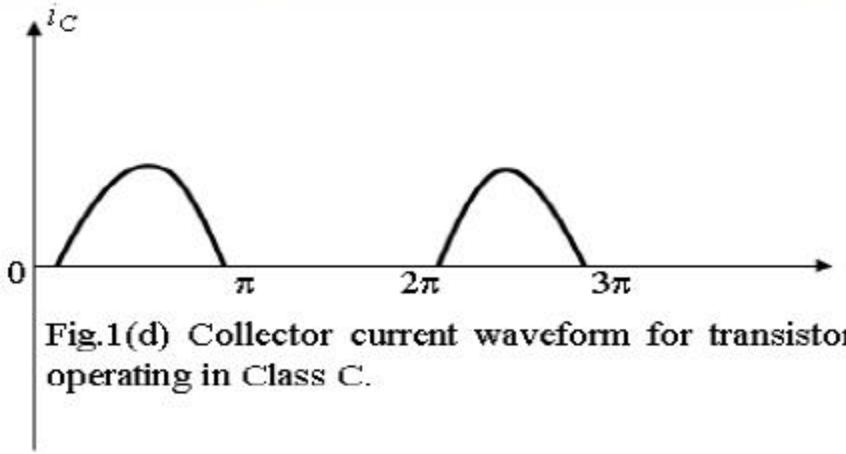
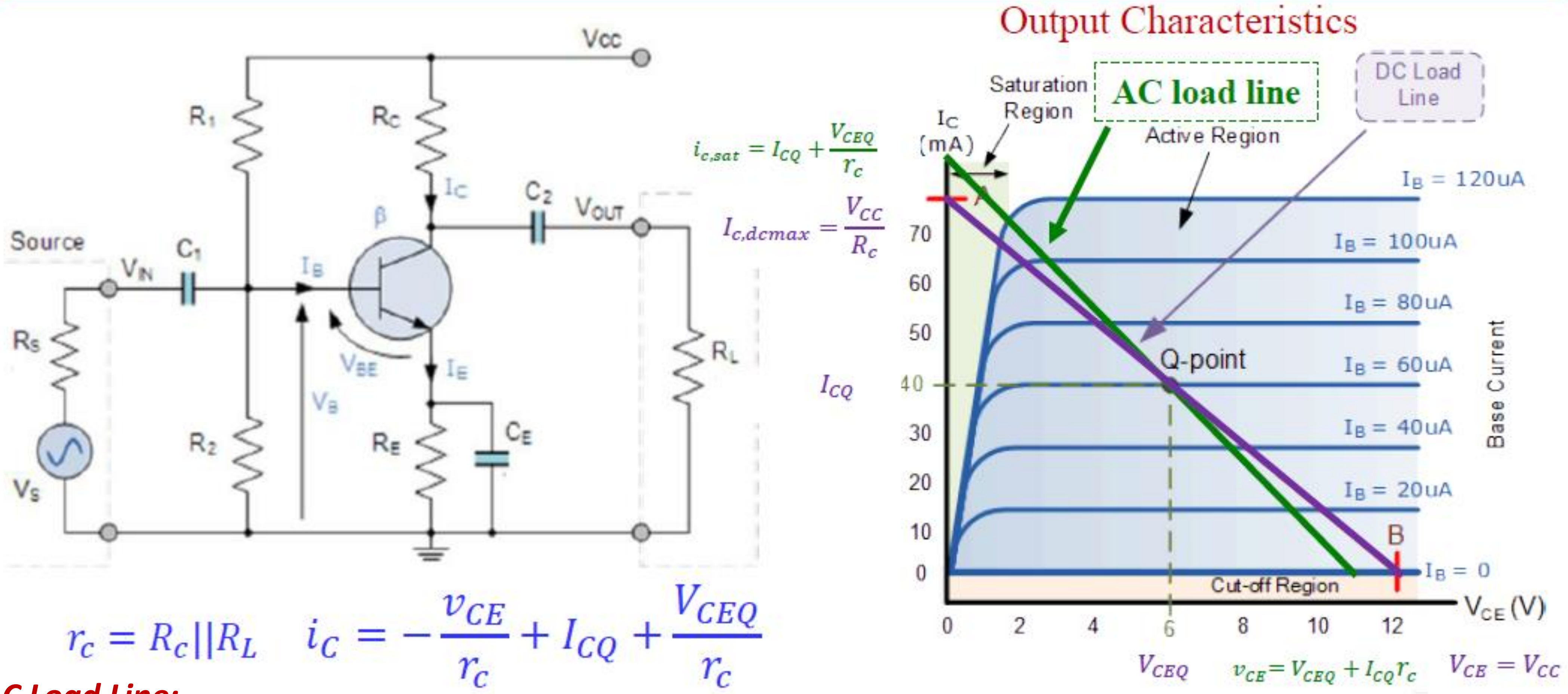


Fig.1(d) Collector current waveform for transistor operating in Class C.

CE Amplifier DC and AC Load Line



DC and AC Load Line:

If this **load line** is drawn only when **DC biasing** is given to the transistor, but no input signal is applied, then such a load line is **called as DC load lilne**.

Whereas the **load line** drawn under the conditions when **an input signal along with the DC voltages** are applied, such a line is called as an **AC load line.**

Class A Power Amplifier

Operation:

Class A power amplifier is a type of power amplifier where the output transistor is ON full time and the output current flows for the entire cycle of the input wave form.

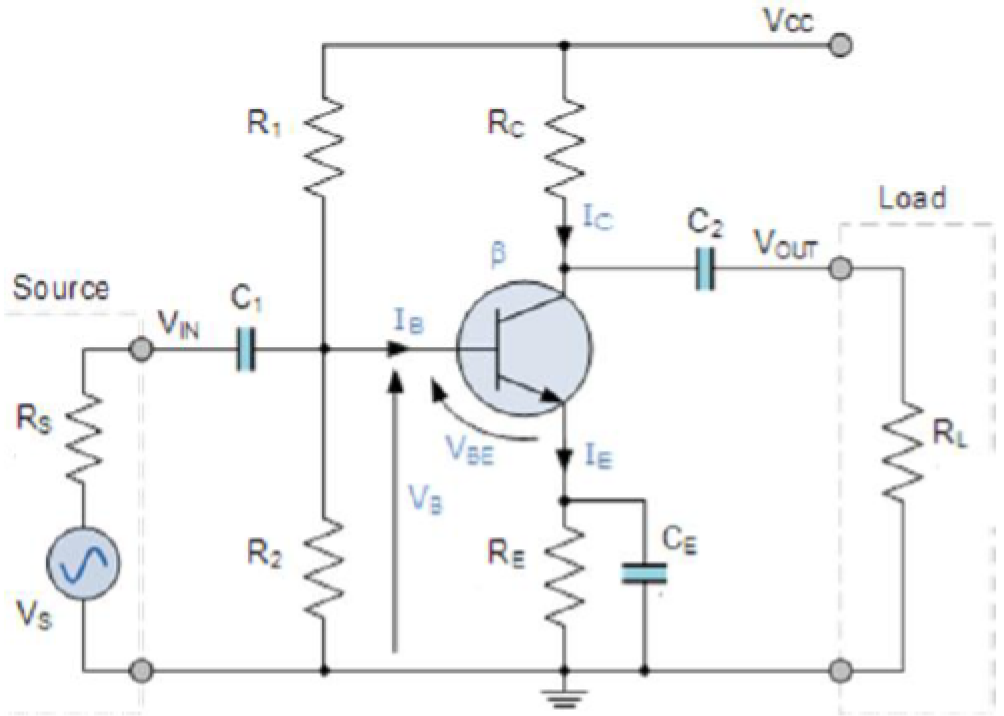
Purpose:

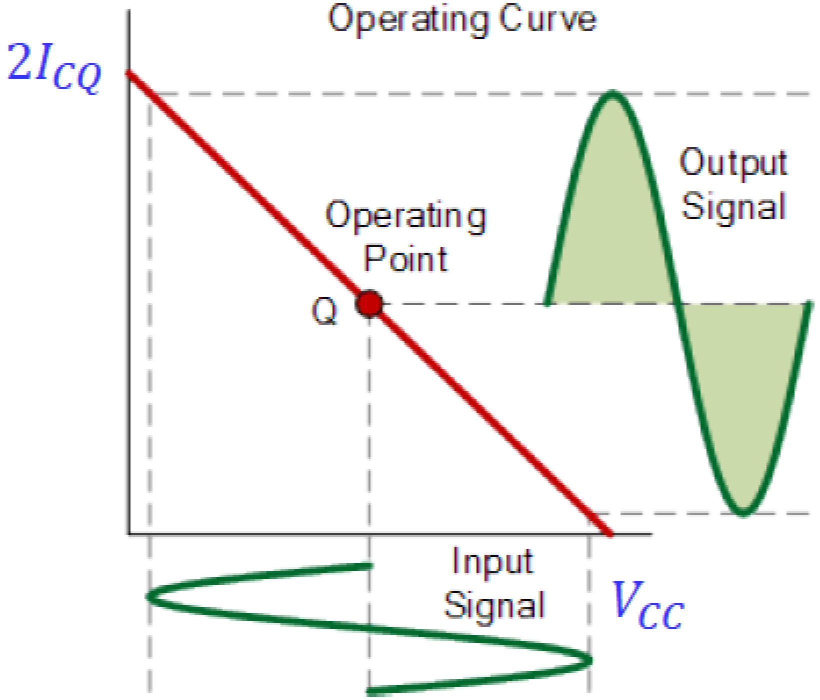
The purpose of class A bias is to make the amplifier relatively free from distortion by keeping the signal waveform out of the region between 0V and about 0.6V where the transistor's input characteristic is non linear.

Class A design produces good linear amplifiers, but consumes lot of input power.

The output power they produce is theoretically 50%, but practically only about 25 to 30%, compared with the DC power they consume from the power supply.

RC Coupled Class A PA





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$$\eta = \frac{P_o(ac)}{P_i(dc)} = \frac{V_{ce}.I_{ce}}{V_{CC}.I_{CQ}} = \frac{\frac{V_{ce(p-p)}}{2\sqrt{2}}.\frac{I_{ce(p-p)}}{2\sqrt{2}}}{V_{CC}.I_{CQ}} = \frac{\frac{V_{CC}}{2\sqrt{2}}.\frac{I_{CQ}}{\sqrt{2}}}{V_{CC}.I_{CQ}} \rightarrow \%\eta = 25\%$$

RC Coupled Class A Power Amplifier

Operation of RC Coupled Amplifier

When an AC input signal is applied to the base of first transistor, it gets amplified and appears at the collector load RL which is then passed through the coupling capacitor CC to the next stage.

This becomes the input of the next stage, whose amplified output again appears across its collector load. Thus the signal is amplified in stage by stage action.

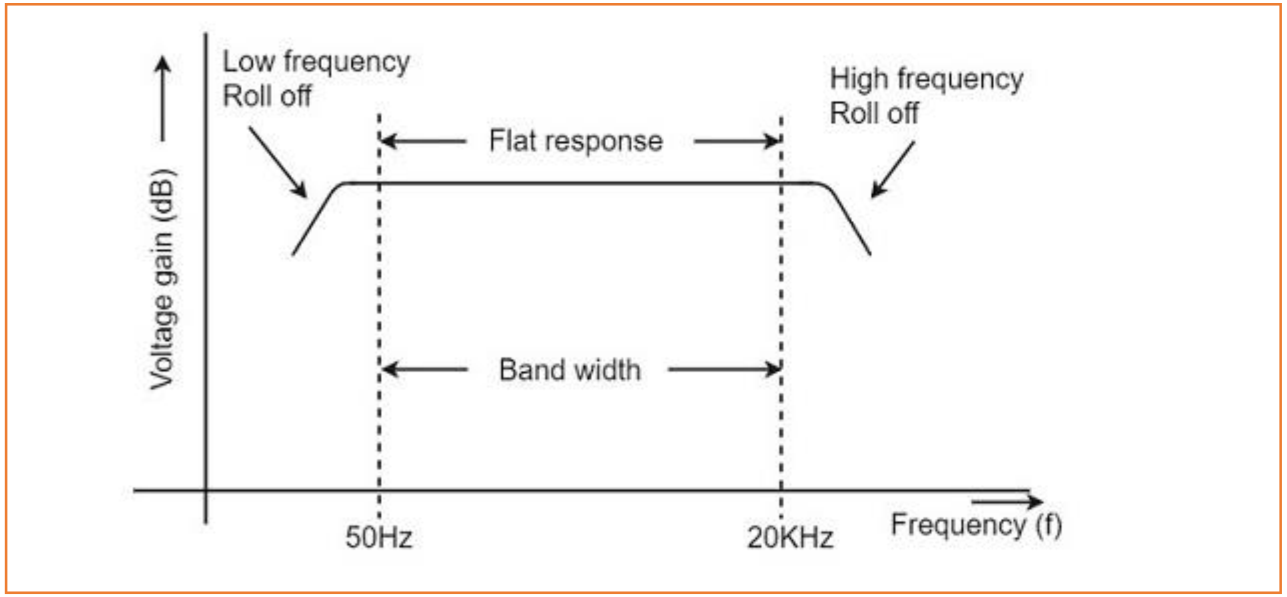
The important point that has to be noted here is that the total gain is less than the product of the gains of individual stages. **This is because when a second stage is made to follow the first stage, the effective load resistance of the overall amplifier is reduced due to the shunting effect of the input resistance of the second stage.**

Frequency Response of RC Coupled Amplifier

Frequency response curve is a graph that indicates relationship between voltage gain and function frequency.

Mathematical expression

$$X_C = \frac{1}{2\pi f_c}$$



Frequency Response of RC Power Amplifier

At Low frequencies (i.e. below 50 Hz)

The capacitive reactance is inversely proportional to the frequency. At low frequencies, the reactance is quite high. The reactance of input capacitor Cin and the coupling capacitor CC are so high that only small part of the input signal is allowed. The reactance of the emitter by pass capacitor CE is also very high during low frequencies. Hence it cannot shunt the emitter resistance effectively. With all these factors, the voltage gain rolls off at low frequencies.

At High frequencies (i.e. above 20 KHz)

Again considering the same point, we know that the capacitive reactance is low at high frequencies. So, a capacitor behaves as a short circuit, at high frequencies. As a result of this, the loading effect of the next stage increases, which reduces the voltage gain. Along with this, as the capacitance of emitter diode decreases, it increases the base current of the transistor due to which the current gain (β) reduces. Hence the voltage gain rolls off at high frequencies.

At Mid-frequencies (i.e. 50 Hz to 20 KHz)

The voltage gain of the capacitors is maintained constant in this range of frequencies, as shown in figure. If the frequency increases, the reactance of the capacitor CC decreases which tends to increase the gain. But this lower capacitance reactive increases the loading effect of the next stage by which there is a reduction in gain.

Due to these two factors, the gain is maintained constant.

RC Coupled Power Amplifier

Advantages of RC Coupled Amplifier

- The frequency response of RC amplifier provides constant gain over a wide frequency range, hence most suitable for audio applications.
- The circuit is simple and has lower cost because it employs resistors and capacitors which are cheap.
- It becomes more compact with the upgrading technology.

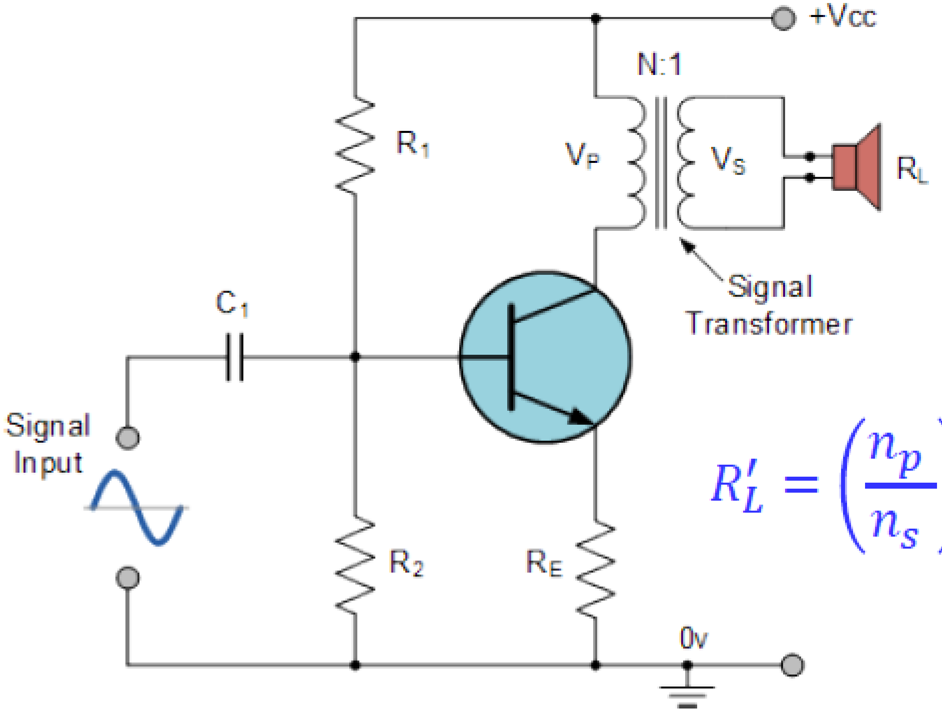
Disadvantages of RC Coupled Amplifier

- The voltage and power gain are low because of the effective load resistance.
- They become noisy with age.
- Due to poor impedance matching, power transfer will be low.

Applications of RC Coupled Amplifier

- They have excellent audio fidelity over a wide range of frequency.
- Widely used as Voltage amplifiers
- Due to poor impedance matching, RC coupling is rarely used in the final stages.

Transformer Coupled Class A PA



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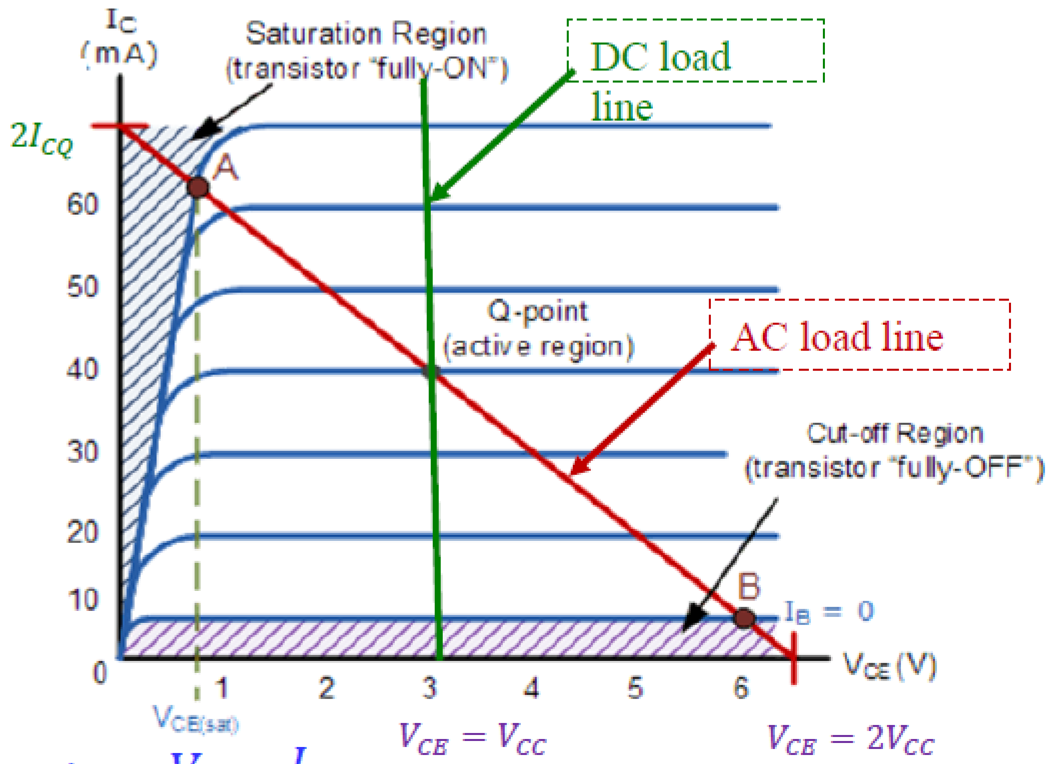
$$R_L' = \left(\frac{n_p}{n_s}\right)^2 R_L$$



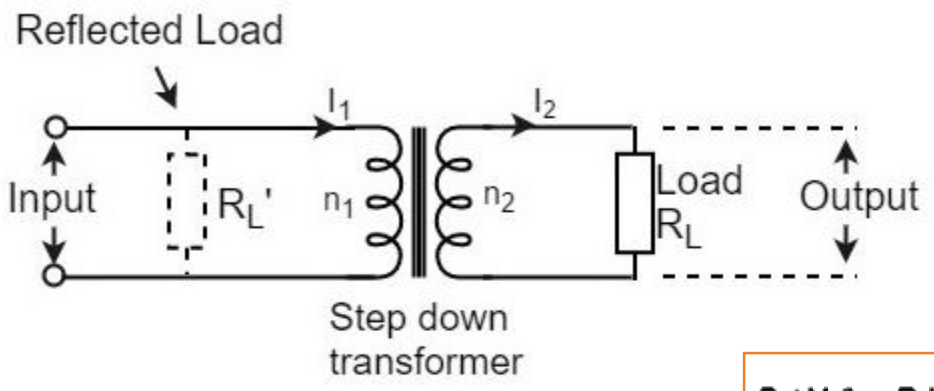
$$\eta = \frac{P_o(ac)}{P_i(dc)} = \frac{V_{ce}.I_{ce}}{V_{CC}.I_{CQ}} = \frac{\frac{V_{ce(p-p)}}{2\sqrt{2}}.\frac{I_{ce(p-p)}}{2\sqrt{2}}}{V_{CC}.I_{CQ}} = \frac{\frac{V_{CC}}{\sqrt{2}}.\frac{I_{CQ}}{\sqrt{2}}}{V_{CC}.I_{CQ}} \rightarrow \%\eta = 50\%$$

Transformer Coupled Class A Power Amplifier

Operation:

Transformer coupled power amplifiers are coming under the category under the multistage amplifiers.
In this type of amplifier one stage of the amplifier is connected to the second stage of amplifiers by coupling the “transformer”. Because we can achieve impedance equality through the transformers. The impedances of the two stages can be equalled if any stage has low or high impedance value by transformers. So, the voltage gain and power gain also increases.

Transformer Action:



We know that

$$\frac{V_1}{V_2} = \frac{n_1}{n_2} \; and \; \frac{I_1}{I_2} = \frac{n_1}{n_2}$$

Or

$$V_1 = \frac{n_1}{n_2} V_2 \; and \; I_1 = \frac{n_1}{n_2} I_2$$

Hence

$$\frac{V_1}{I_1} = \left(\frac{n_1}{n_2}\right)^2 \frac{V_2}{I_2}$$

But $V_1/I_1 = R_L'$ = effective input resistance

And $V_2/I_2 = R_L$ = effective output resistance

Therefore,

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

Class B Power Amplifier

Class B operation is provided when the dc bias transistor biased just off, the transistor turning on when the ac signal is applied.

This is essentially no bias and the transistor conducts current for only one-half of the signal cycle.

To obtain output for the full cycle of signal, it is necessary to use two transistors and have each conduct on opposite half-cycles, the combined operation providing a full cycle of output signal.

Since one part of the circuit pushes the signal high during one-half cycle and the other part pulls the signal low during the other half-cycle, the circuit is referred to as a push-pull circuit.

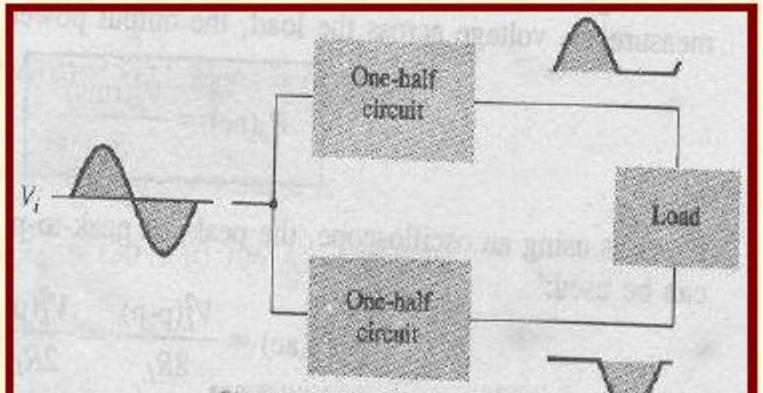
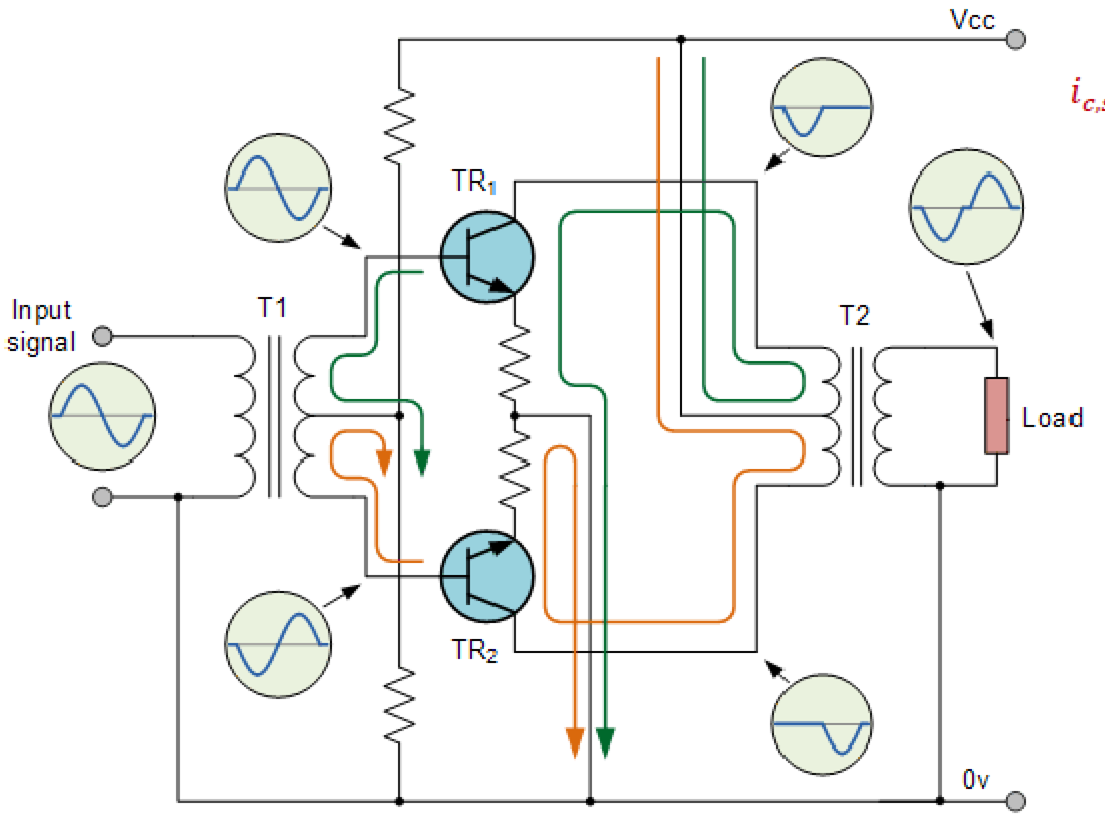


Figure 16.12 Block representation of push-pull operation.

Figure 16.12 shows a diagram for push-pull operation.

Class B Power Amplifier



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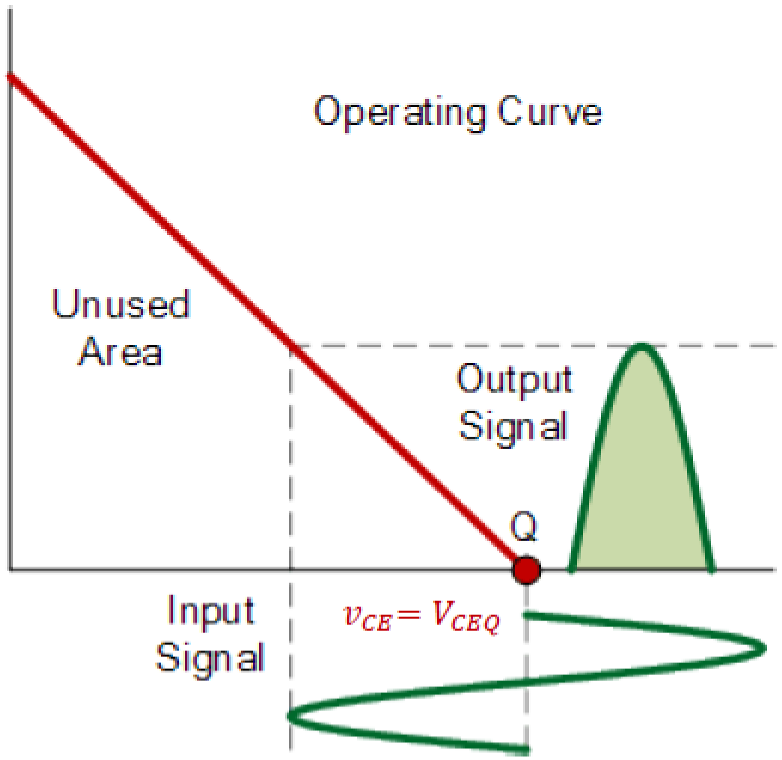


$$\eta = \frac{P_o(ac)}{P_i(dc)} = \frac{V_{ce}.I_{ce}}{V_{CC}.I_{DC}} = \frac{\frac{V_{CC}}{2\sqrt{2}}.\frac{I_{CQ}}{\sqrt{2}}}{V_{CC}.\frac{I_{CQ}}{\pi}} = \frac{\pi}{4} \rightarrow \%\eta = 78.5\%$$

Class B Power Amplifier

The arrangement of a push-pull circuit is shown in **Fig. 18-8**.

When the signal on transistor Q_1 is positive, the signal on Q_2 is negative by an equal amount.

During the first half-cycle of operation, transistor Q_1 is driven into conduction, whereas transistor Q_2 is driven off. The current i_1 through the transformer results in the first half-cycle of signal to the load.

During the second half-cycle of operation, transistor Q_2 is driven into conduction, whereas transistor Q_1 is driven off. The current i_2 through the transformer results in the second half-cycle of signal to the load.

The overall signal developed across the load then varies over the full cycle of signal operation.

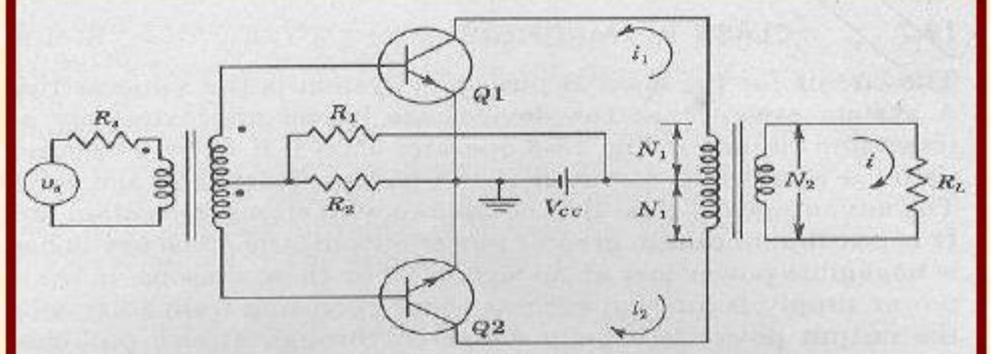


Fig. 18-8 Two transistors in a push-pull arrangement.

Class B Power Amplifier

Class B amplifier operation

The transistor circuit of Fig. 18-8 operates class B if $R_2=0$ because a silicon transistor is essentially at cutoff if the base is shorted to the emitter.

Advantages of Class B as compared with class A operation

1. It is possible to obtain greater power output,
2. The efficiency is higher, and
3. There is negligible power loss at no signal.

Disadvantages of Class B as compared with class A operation

1. The harmonic distortion is higher,
2. Self-bias cannot be used, and
3. The supply voltage must have good regulation.

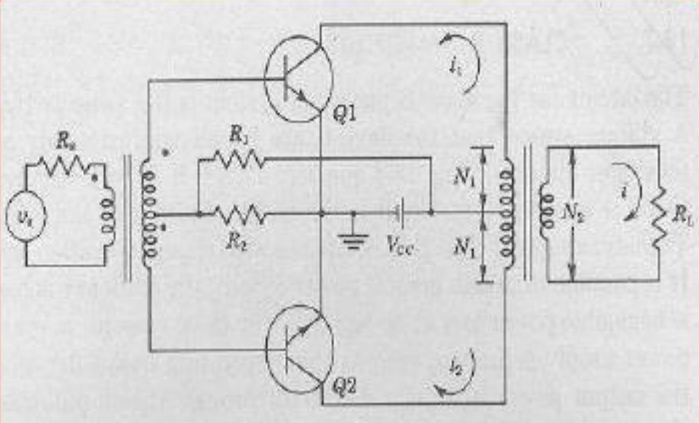


Fig. 18-8 Two transistors in a push-pull arrangement.

Class B Power Amplifier

Crossover distortion

The distortion caused by the nonlinear transistor input characteristic is indicated in **Fig. 18-12**. The i_B-v_B curve for each transistor is drawn, and the construction used to obtain the output current (assumed proportional to the base current) is shown.

In the region of small currents (for $v_B < V_\gamma$) the output is much smaller than it would be if the response were linear. This effect is called *crossover distortion*.

In order to overcome the problem of crossover distortion, the transistor must operate in a class AB mode.

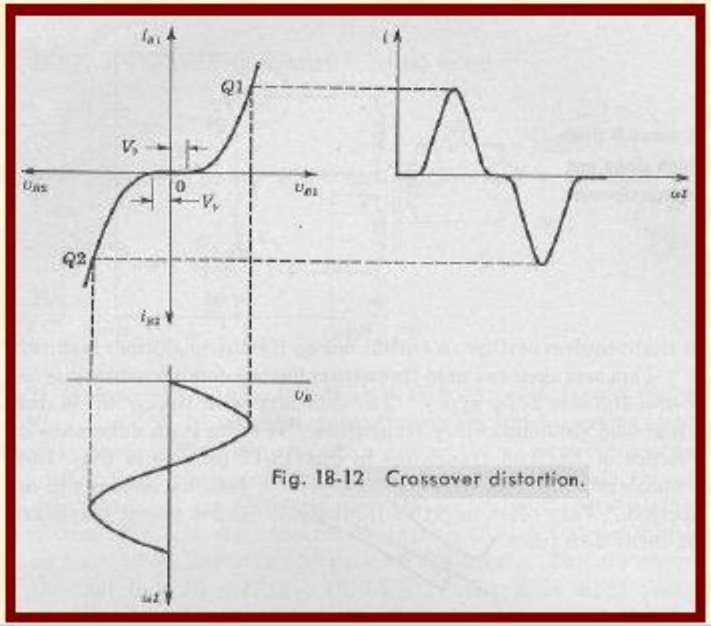
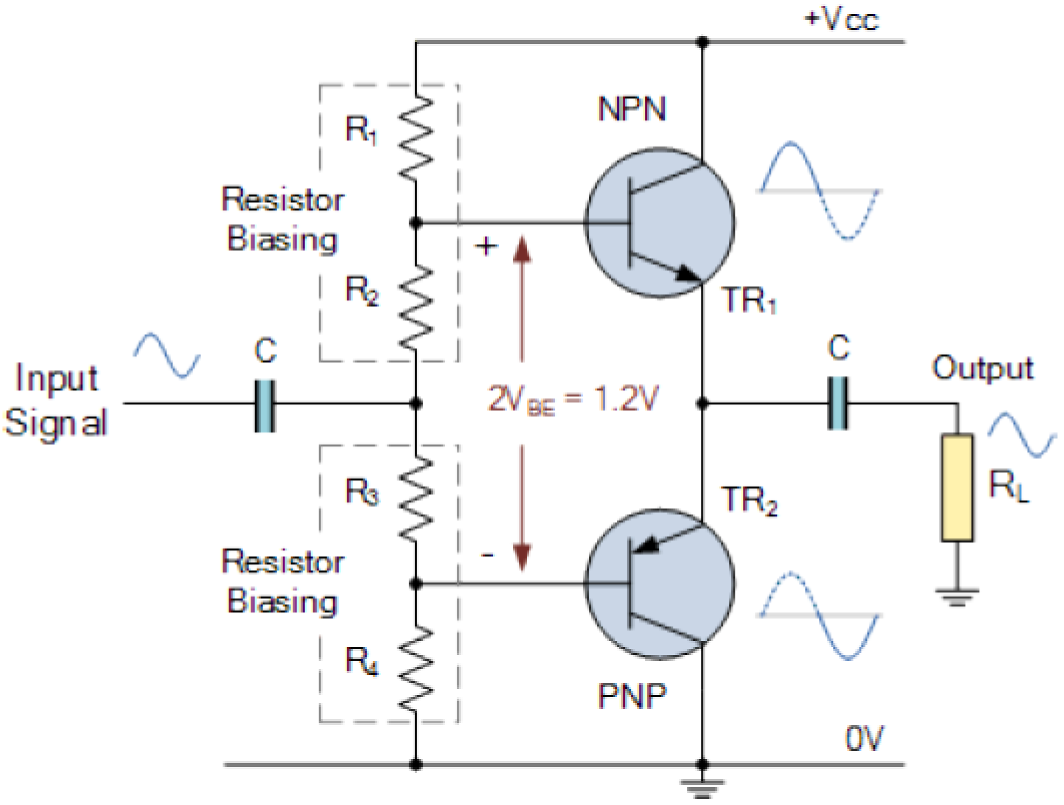


Fig. 18-12 Crossover distortion.

Resistor Biased Class AB – Push Pull PA



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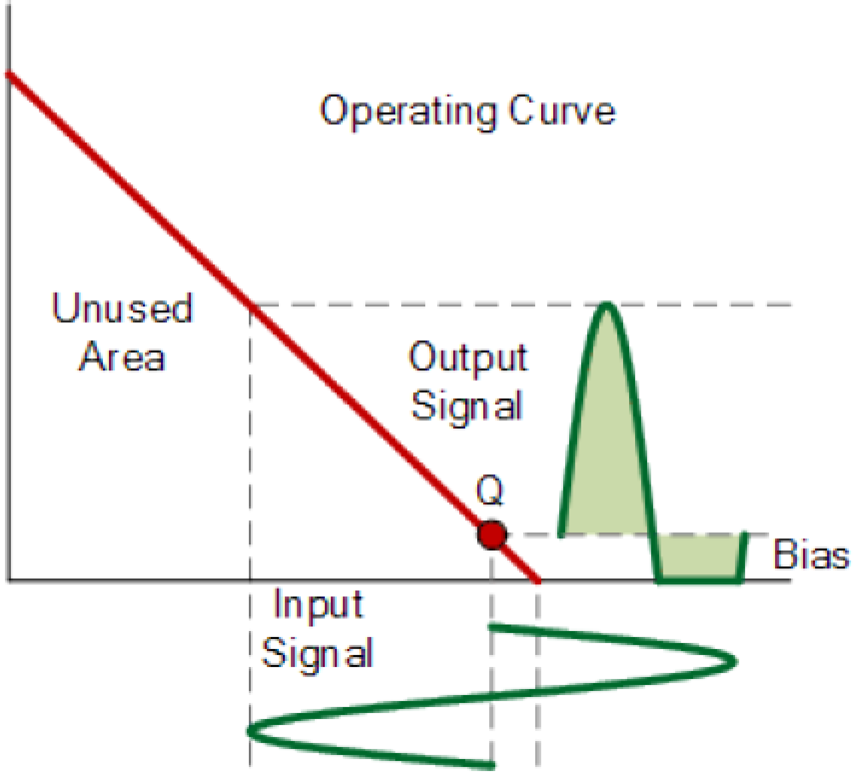


Resistor Biased Class AB Power Amplifier

Operation:

The purpose of any amplifier is to produce an output which follows the characteristics of the input signal but is sufficiently large enough to supply the needs of the load connected to it.

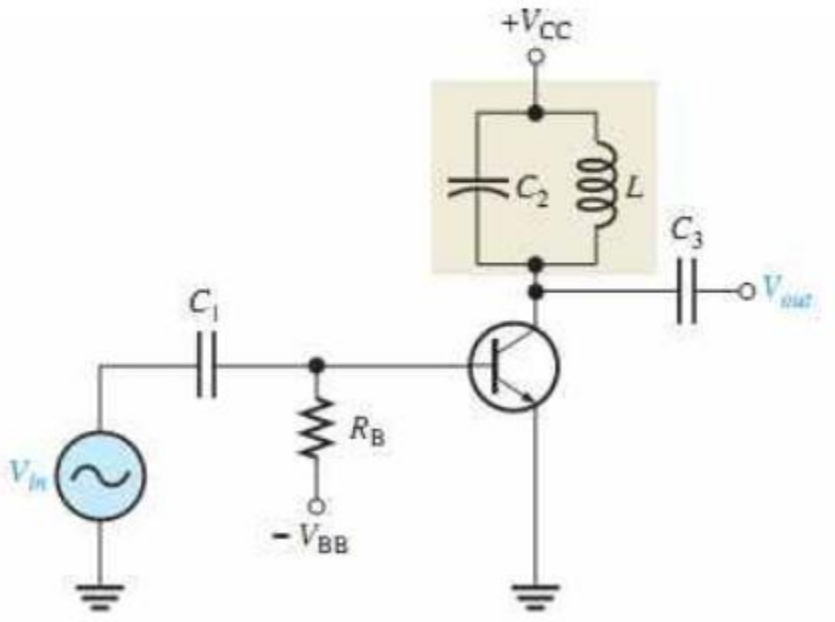
Class AB amplifier output stage combines the advantages of the Class A amplifier and the Class B amplifier while minimising the problems of low efficiency and distortion associated with them.

Class AB Amplifier is a combination of Classes A and B in that for small power outputs the amplifier operates as a class A amplifier but changes to a class B amplifier for larger current outputs.

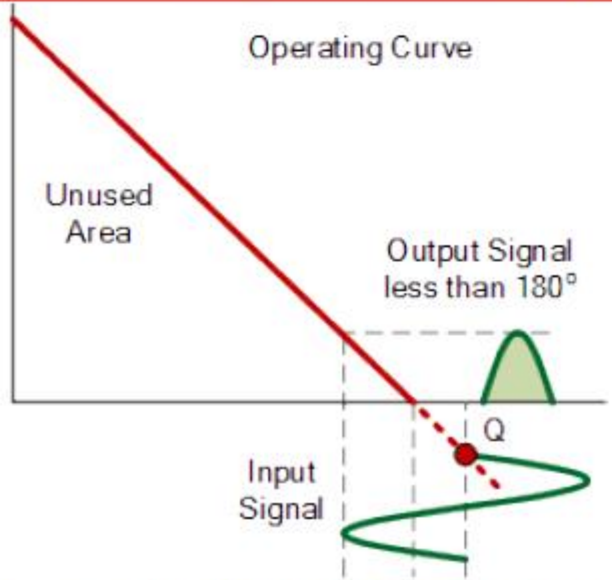
This action is achieved by pre-biasing the two transistors in the amplifiers output stage. Then each transistor will conduct between 180^o and 360^o of the time depending on the amount of current output and pre-biasing. Thus the amplifier output stage operates as a Class AB amplifier.

- Class A: – The amplifiers single output transistor conducts for the full 360^o of the cycle of the input waveform.
- Class B: – The amplifiers two output transistors only conduct for one-half, that is, 180^o of the input waveform.
- Class AB: – The amplifiers two output transistors conduct somewhere between 180^o and 360^o of the input waveform.

Class C PA (Tuned Amplifiers)



(a) Basic circuit



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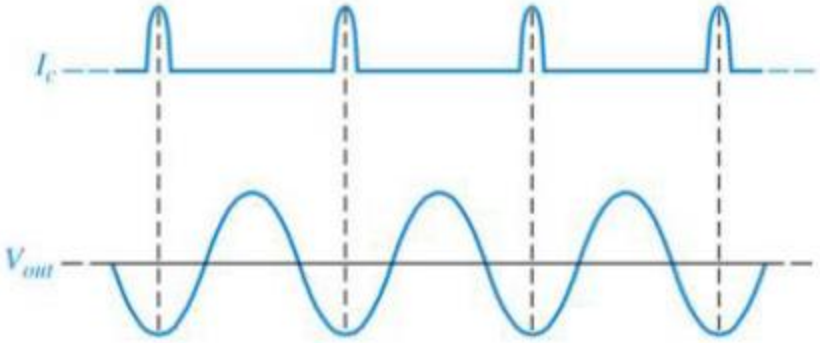
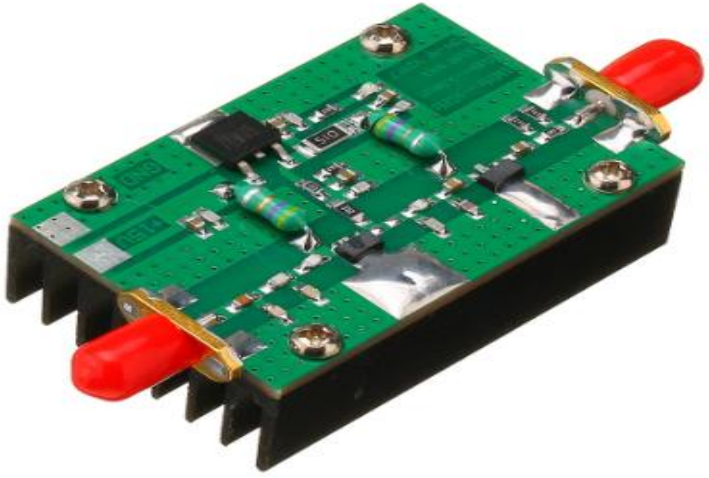


In order to produce a full sine wave output, the class C uses a tuned circuit (LC tank) to provide the full AC sine wave.

Practical Power Amplifiers

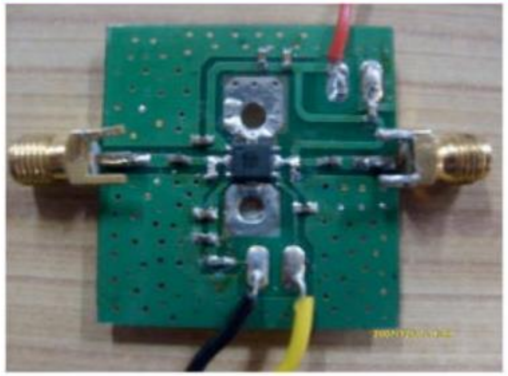
1000MHz 2.5W HF VHF UHF FM Transmitter RF Power Amplifier Practical Durable AMP For Ham Radio

RF Power Amplifier For Ham Radio

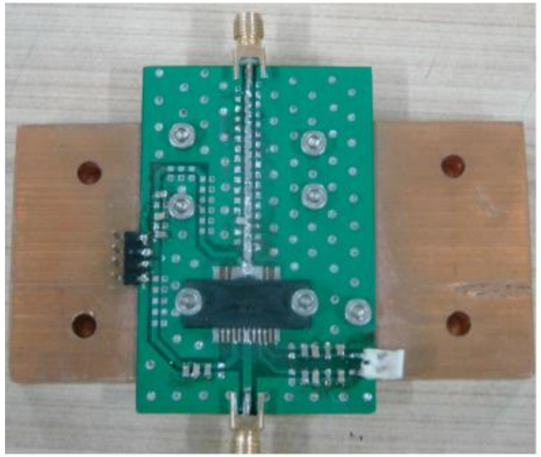


1MHz-1000MHZ 35DB RF Power Amplifier 3W HF VHF UHF FM Transmitter Broadband For Ham Radio

1000M 3W HF FM VHF UHF FM Shortwave Broadband Amplifier Upgrade Improved Version



Class AB Power Amplifier; Supply voltage - 5V, RF input 21.5dBm



Class AB , Supply Voltage - 28 V RF Input – 17 dBm
30 dB attenuator is added at output for measurement.

Summary

1. In this lecture Power amplifier concept is introduced.
2. Discussed various types of power amplifiers
3. Discussed the operating point concept.
4. Given the definitions for DC load Line and AC load line.
5. Analysed the operation of Class A Power amplifier.
6. Analysed the frequency response of simple class A power amplifier
7. Discussed about the Class B power amplifier.
8. Discussed about the cross over distortion in class B power
9. Comparison of class A and B has done in terms of advantages and disadvantages.
10. Later on discussed about Class AB, Class C power amplifier
11. Shown the practical power amplifiers
12. Lecture has concluded with the clarifying the doubts.

Doubts

Thank you