Chapter 1

MULTISTAGE AMPLIFIER

Learning Objectives

To study

- Need for multistage amplifier
- Gain of multistage amplifier
- Different types of multistage amplifier like RC coupled, transformer coupled, direct coupled, and their frequency response and bandwidth

Amplifier

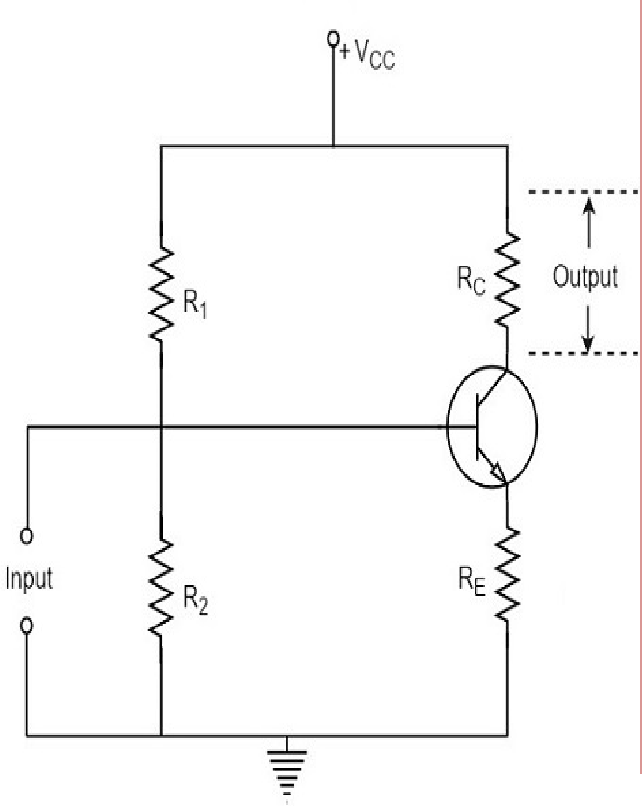
- An amplifier is the basic building block of most electronic system.
- An amplifier increases the strength of the input signal.
- e.g the signal that is obtained from a microphone is not strong enough to be reproduced in a speaker. It has to be amplified.

Gain,A = Vo/Vin

Gain in dB =20log(Vo/Vin)

Single Stage Amplifier

- Let us first have a view of single stage amplifier.



- It consists of a transistor And resistances-R_1,R_2,R_c,R_E
- The resistances provide the necessary biasing for faithful amplification.
- Voltage gain of amplifier $A_v = \frac{\text{output}}{\text{input}}$

Need for Multistage Amplifier

- For most systems, a single transistor amplifier does not provide sufficient gain
- To increases the voltage gain of the **amplifier**, multiple **amplifier** are connects in cascade. The output of one **amplifier** is coupled to the input to next stage. In this way the overall voltage gain can be increased. when number of **amplifier** stages are used in succession it is called a **multistage amplifier**

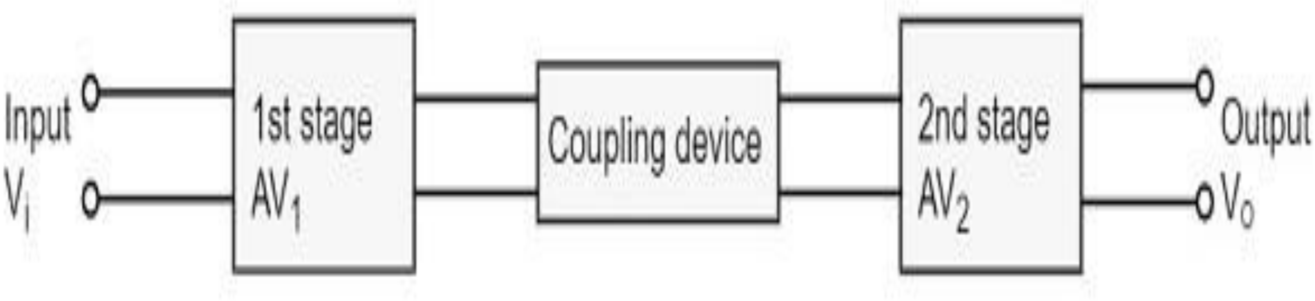
.

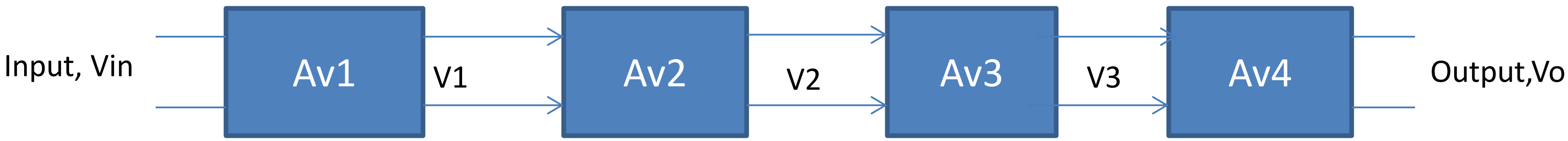
Multi stage amplifier

In Multi-stage amplifiers, the output of first stage is coupled to the input of next stage using a coupling device. These coupling devices can usually be a capacitor or a transformer. This process of joining two amplifier stages using a coupling device can be called as **Cascading**.

Two Stage Amplifier

Total Gain A = Av1 x Av2





Total Gain A= Av1 x Av2 x Av3 x Av4

Gain of a Multi stage amplifier

The overall gain is the product of voltage gain of individual stages.

A=Av1×Av2xAv3x…

Where A_V = Overall gain,

A_{V1} = Voltage gain of 1st stage,

and A_{V2} = Voltage gain of 2nd stage.

A_{V3} = Voltage gain of 3rd stage.

If there are **n** number of stages, the product of voltage gains of those **n** stages will be the overall gain of that multistage amplifier circuit.

Gain of a multistage Amplifier in db

Let the gain of the different stages of multistage amplifier be

$A_{v1}, A_{v2}, A_{v3}....$

Then the gain of multistage amplifier is

$$A = A_{v1} \times A_{v2} \times A_{v3}$$

Taking Log of both sides

$$\text{Log } A = \log A_{v1} + \log A_{v2} + \log A_{v3}$$

$$\mathbf{20 \text{Log } A = 20 \log A_{v1} + 20 \log A_{v2} + 20 \log A_{v3}}$$

$$\mathbf{A_{dB} = A_{dB1} + A_{dB2} + A_{dB3}}$$

Thus the logarithmic gain(or gain in db)of a multistage amplifier is simply the addition of logarithmic gains of individual stages.

Contd…

- So if you are given the gain of individual stages in db you can simply add it to find the overall gain
- e.g. if voltage gain of first stage is 15 db,2nd stage is 10 db 3rd stage id 20 db then overall gain of a multistage amplifier is 45 db

Advantages of Gain in dB

- It allows the gains of all the stages to be directly added to compute the overall gain of a multistage amplifier.
- It represents very large and very small values of gain by small figures.
- Our ear responds to sound on a logarithmic scale. e.g if sound increases from 4 to 64 our ear will feel the increase only 3 times.

How to couple two stages

- In a multistage amplifier, the output of one stage is the input of next stage.
- We must connect the output of one stage to the input of next stage through a suitable coupling device so that minimum loss occurs when signal passes from one stage to other.

Purpose of coupling device

- The basic purposes of a coupling device are
- To transfer the AC from the output of one stage to the input of next stage.
- To block the DC to pass from the output of one stage to the input of next stage, which means to isolate the DC conditions.

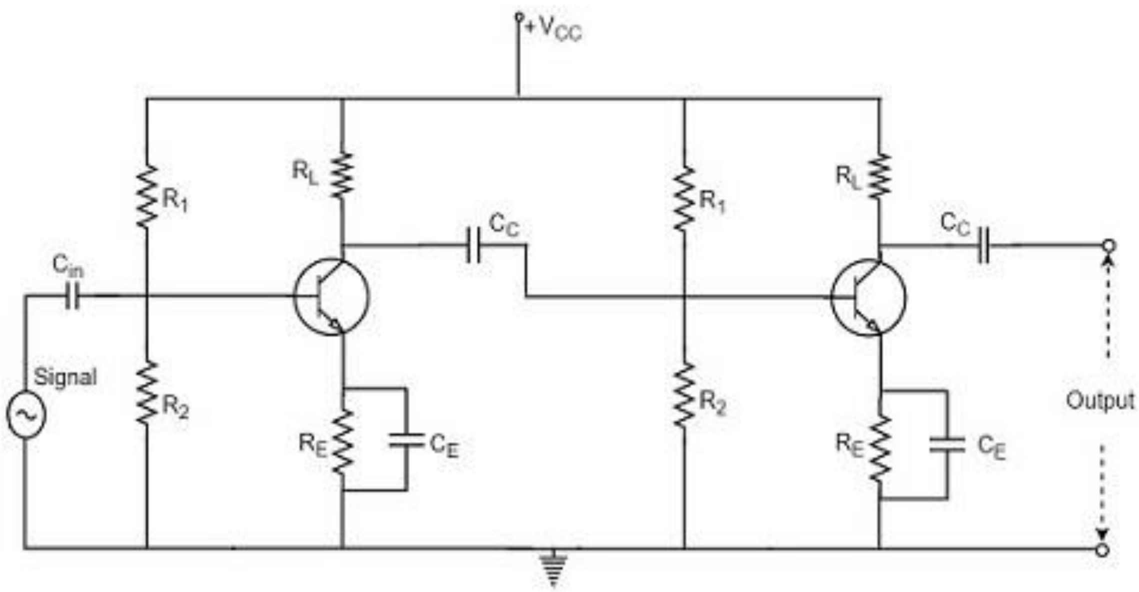
Types of Coupling

- Resistance-Capacitance Coupling
- Transformer Coupling
- Direct Coupling

Resistance-Capacitance Coupling

- This is the most commonly used method of coupling, formed using simple **resistor-capacitor** combination. The output of one stage is coupled to the next stage through a coupling capacitor.
- The coupling capacitor passes the AC from the output of one stage to the input of its next stage. While blocking the DC components from DC bias voltages to effect the next stage,it couples tha ac to next stage.

RC coupled Amplifier: The output of one stage is coupled to the next stage through a coupling capacitor



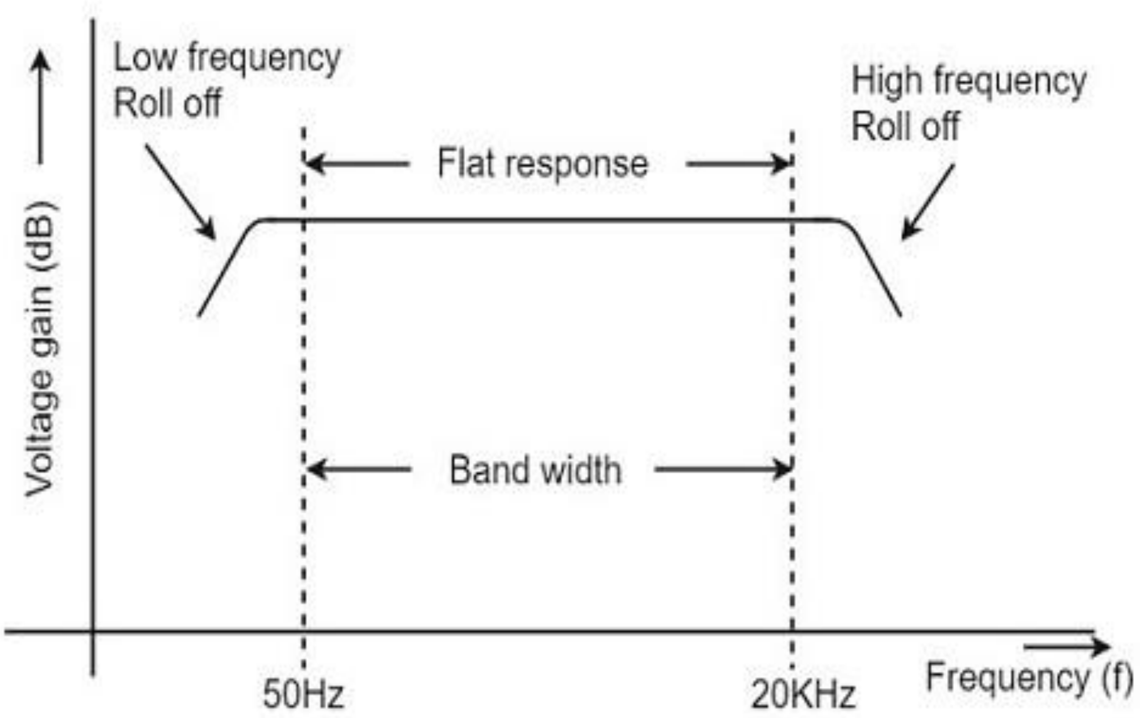
Operation of RC Coupled Amplifier

When an AC input signal is applied to the base of first transistor, it is amplified and appears at the collector load R_L which is then passes through the coupling capacitor C_C to the next stage. This becomes the input of the next stage, whose amplified output again appears across its collector load, Rc.

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 first stage is reduced due to the shunting effect of the input resistance of the second stage. Hence, in a multistage amplifier, only the gain of the last stage remains unchanged

Frequency Response of RC Coupled Amplifier

Frequency response curve is a graph that indicates the relationship between voltage gain and function of frequency. The frequency response of a RC coupled amplifier is as shown in the following graph.



Advantages and disadvantages of RC coupled amplifier

The following are the advantages of RC coupled amplifier.

1) The frequency response of RC amplifier provides constant gain over a wide frequency range, hence most suitable for audio applications
2) The circuit is simple and has lower cost because it employs resistors and capacitors.
3) It has become 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 is low.

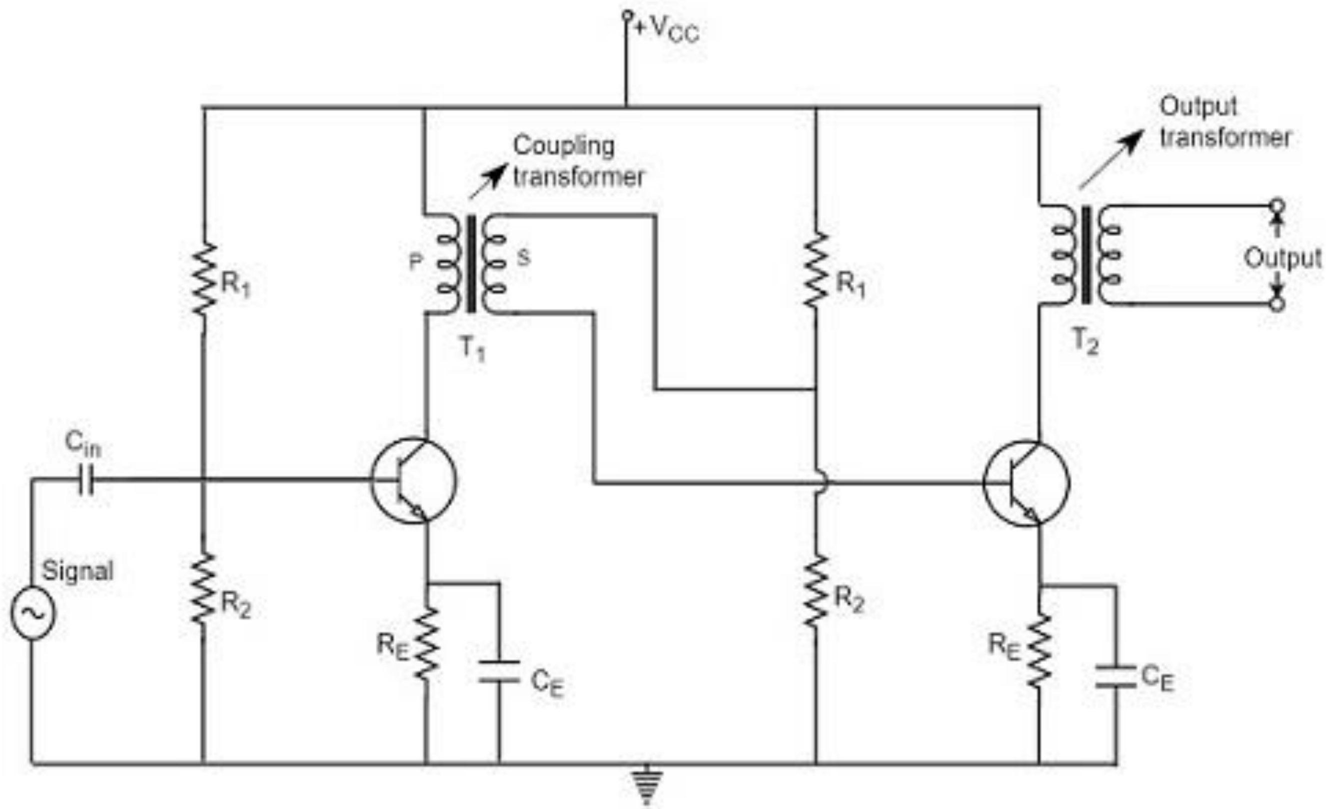
Applications of RC Coupled Amplifier

- RC coupled amplifier have excellent audio fidelity over a wide range of frequency.
- They are widely used as Voltage amplifiers

Transformer Coupling

- The coupling method that uses a **transformer as the coupling** device can be called as Transformer coupling. There is no capacitor used in this method of coupling because the transformer itself couples the AC component directly to the base of second stage.
- The secondary winding of the transformer provides a base return path and hence there is no need of base resistance. This coupling is popular for its efficiency and its impedance matching and hence it is mostly used.

Transformer coupled amplifier

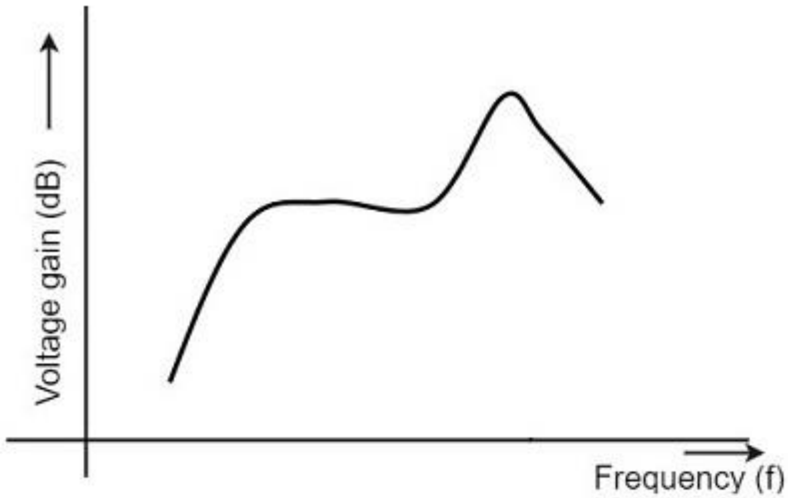


Transformer coupled amplifier

- The amplifier circuit in which, the previous stage is connected to the next stage using a coupling transformer, is called as Transformer coupled amplifier.
- The coupling transformer T_1 is used to feed the output of 1^{st} stage to the input of 2^{nd} stage. The collector load is replaced by the primary winding of the transformer. The secondary winding is connected between the potential divider and the base of 2^{nd} stage, which provides the input to the 2^{nd} stage. Instead of coupling capacitor like in RC coupled amplifier, a transformer is used for coupling any two stages, in the transformer coupled amplifier circuit.

Frequency Response of Transformer Coupled Amplifier

The figure shows the frequency response of a transformer coupled amplifier.



The gain of the amplifier is constant only for a small range of frequencies. So, the amplification of audio signals will not be proportionate and some distortion will also get introduced, which is called as **Frequency distortion**.

Advantages of Transformer Coupled Amplifier

- It provides excellent impedance matching .This helps in transferring maximum power to the load.
- Gain achieved is higher.
- There will be no power loss in collector and base resistors.
- Efficient in operation.

Disadvantages of Transformer Coupled Amplifier

- The transformer used are different from ideal one. Due to leakage inductance and interwinding capacitance , the gain varies considerably with frequency. It does amplify the signals of different frequencies equally.Hence it has a poor frequency response.
- Frequency distortion is higher.
- Transformers produce hum noise.
- Transformers are bulky and costly.

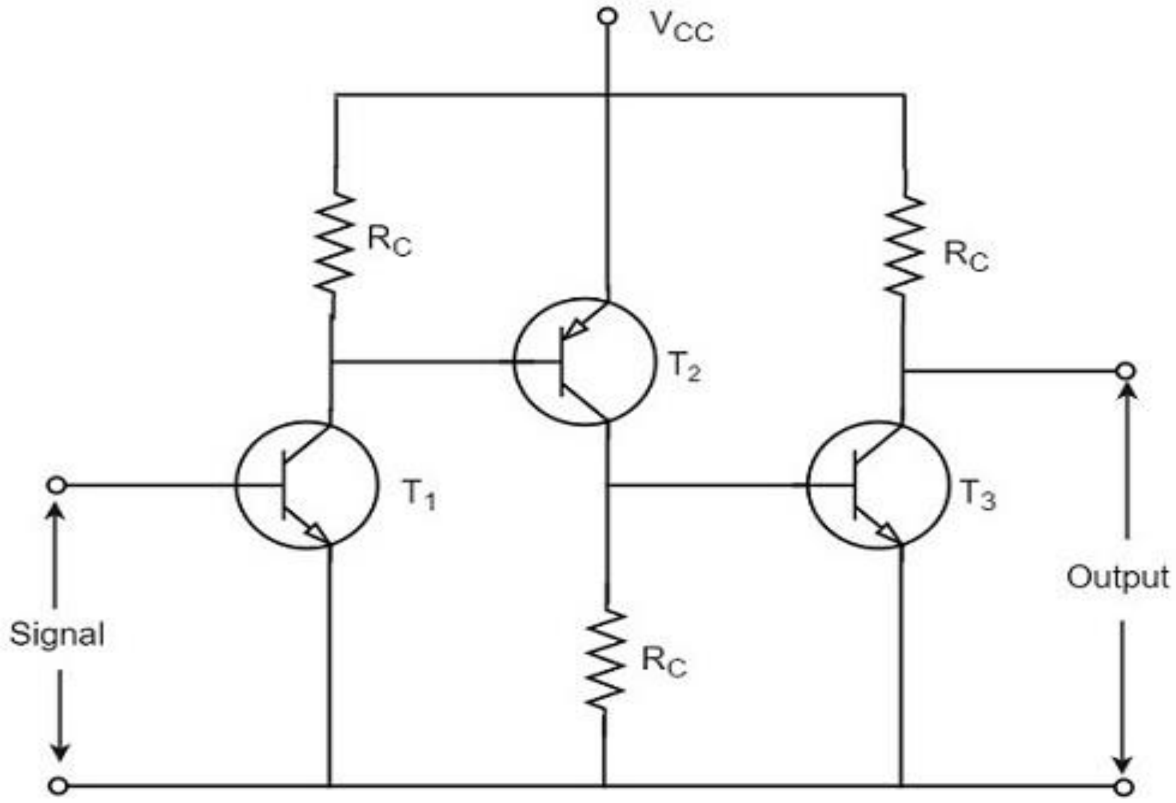
Transformer Coupled amplifier

- Transformer coupled amplifiers are used widely for the amplification of radio frequency signals i.e. above 20 KHz

Applications of Transformer coupled amplifier

1.Mostly used for impedance matching purposes.
2.Used for Power amplification.
3.Used where maximum power transfer is needed.

Direct Coupled Amplifier: The output of one stage is directly coupled to the next stage through a simple wire without any coupling device.



Direct Coupled Amplifier

- If the previous amplifier stage is connected to the next amplifier stage directly, it is called as **direct coupling**. The individual amplifier stage bias conditions are so designed that the stages can be directly connected without DC isolation.
- The direct coupling method is mostly used when the load is connected in series, with the output terminal of the active circuit element. For example, head-phones, loud speakers etc.

Advantages and disadvantages of DC amplifier

Advantages

The advantages of direct coupled amplifier are as follows.

- The circuit arrangement is simple because of minimum use of resistors.
- The circuit is of low cost because of the absence of expensive coupling devices.

Disadvantages

The disadvantages of direct coupled amplifier are as follows.

- It cannot be used for amplifying high frequencies.
- The operating point is shifted due to temperature variations.

Applications and Frequency Response

- The **applications** of direct coupled amplifier are as follows.
- Low frequency amplifications.
- Low current amplifications.

Chapter 2

LARGE SIGNAL AMPLIFIERS

Learning Ojectives

- Difference between voltage and power amplifiers
- Importance of impedance matching in amplifiers
- Class A, Class B, Class AB, and Class C amplifiers, collector efficiency and Distortion in class A,B,C
- Single ended power amplifiers
- Push-pull amplifier, and complementary symmetry push-pull amplifier

Difference between voltage and power amplifiers

- The Small Signal Amplifier is generally referred to as a ‘ **Voltage amplifier’** because they usually convert a small input voltage into a much larger output voltage.
- A ’**power amplifier’** is an electronic amplifier designed to increase the magnitude of power of a given input signal.

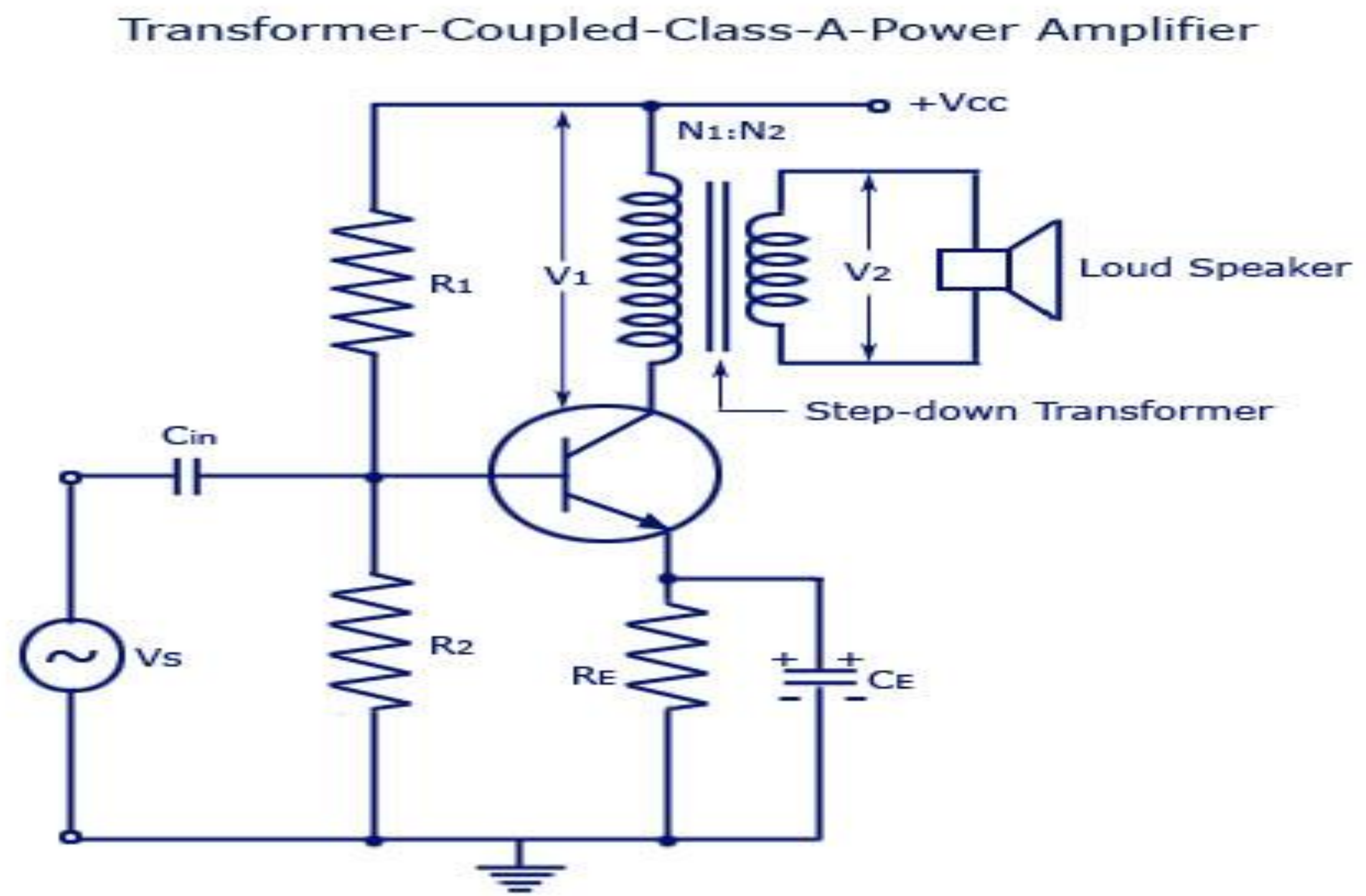
Difference between voltage and power amplifiers

A voltage amplifier is a small signal amplifier where as a power amplifier is a large signal amplifier. So a power amplifier is always preceded by voltage amplifier.

Difference between voltage and power amplifiers

- While designing the voltage amplifier the objective is to obtain a better voltage gain where as in power amplifiers the objective is power gain
- A Voltage amplifier increases the strength of the input signal but a power amplifier converts the dc power into useful ac power.
- The transistor used in voltage amplifiers have low power dissipation ratings whereas the transistors used in power amplifiers have high power dissipation ratings.

Single ended power amplifier.



A single ended power amplifier has a single transistor controlling a current through a load. The ac signal is input at RI to the base of Q1 the output signal is across load in the secondary coil of the transformer T1. The transformer is used as an impedance matching device. T1 matches the relatively high impedance of the Q1 collector circuit in the T1 primary coil with a low impedance load in the T1 secondary coil .In the single ended power amplifier circuit, the transformer matches the low impedance load with the high impedance of the Q1 collector circuit

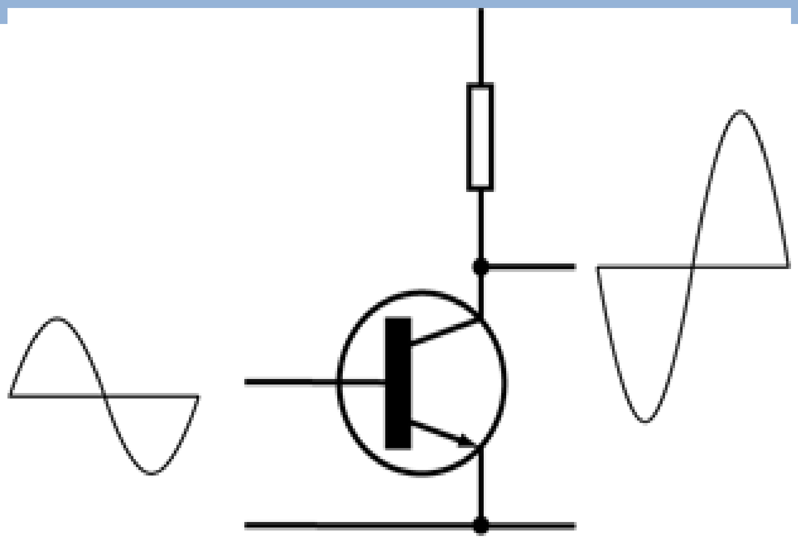
Power gain is determined by the ratio of the output power to the input power or the product of voltage gain and current gain.

Power amplifiers have high power gain but low voltage gain. Power gain is the product of voltage gain and current gain because the current gain is high.

Class A Power Amplifier: -

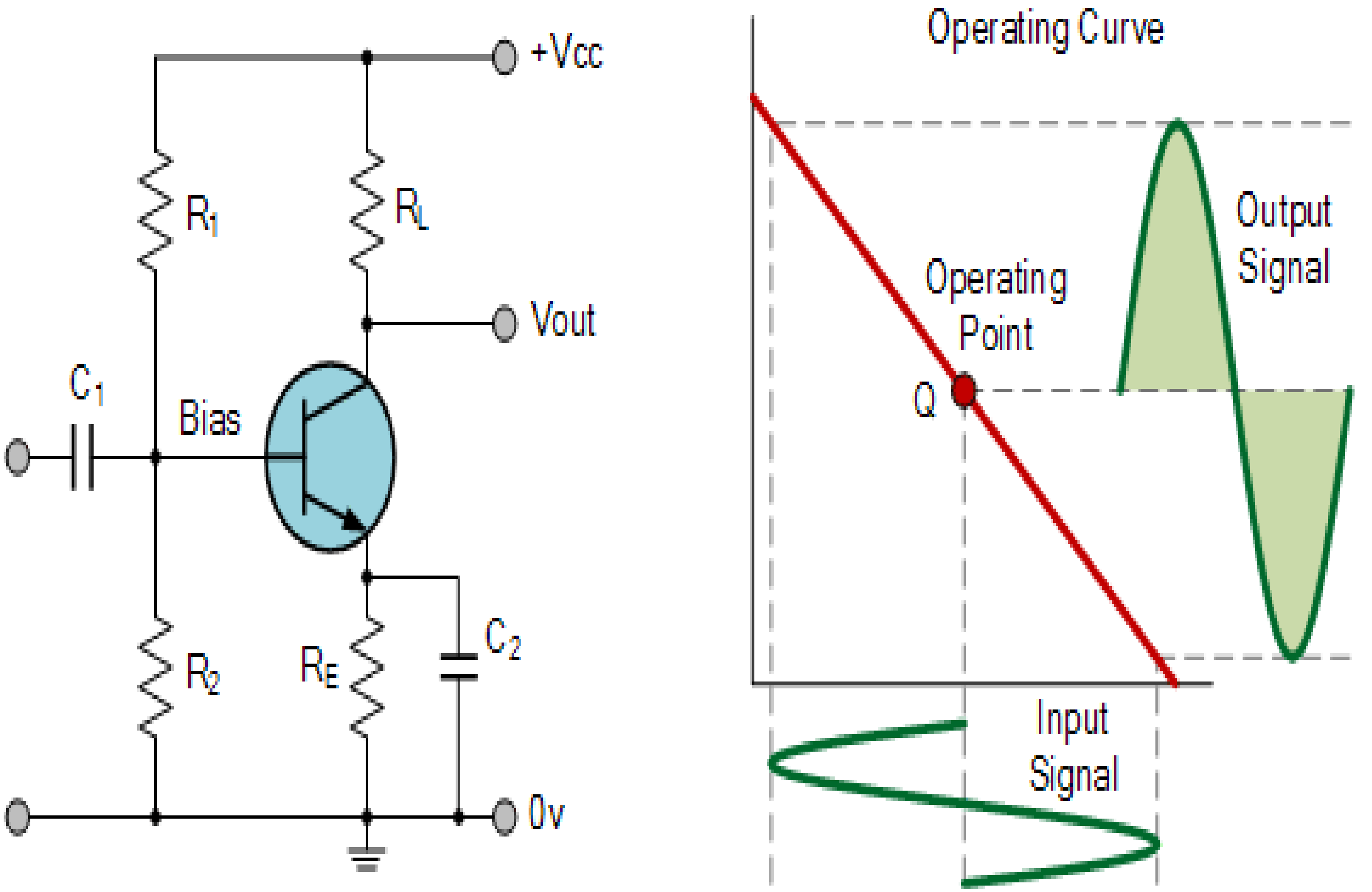
In a Class A amplifier, 100% of the input signal is used (conduction angle Θ = 360°). The Transistor remains conducting all of the time.

Amplifying devices operating in class A conduct over the entire range of the input cycle.



Class A Amplifier

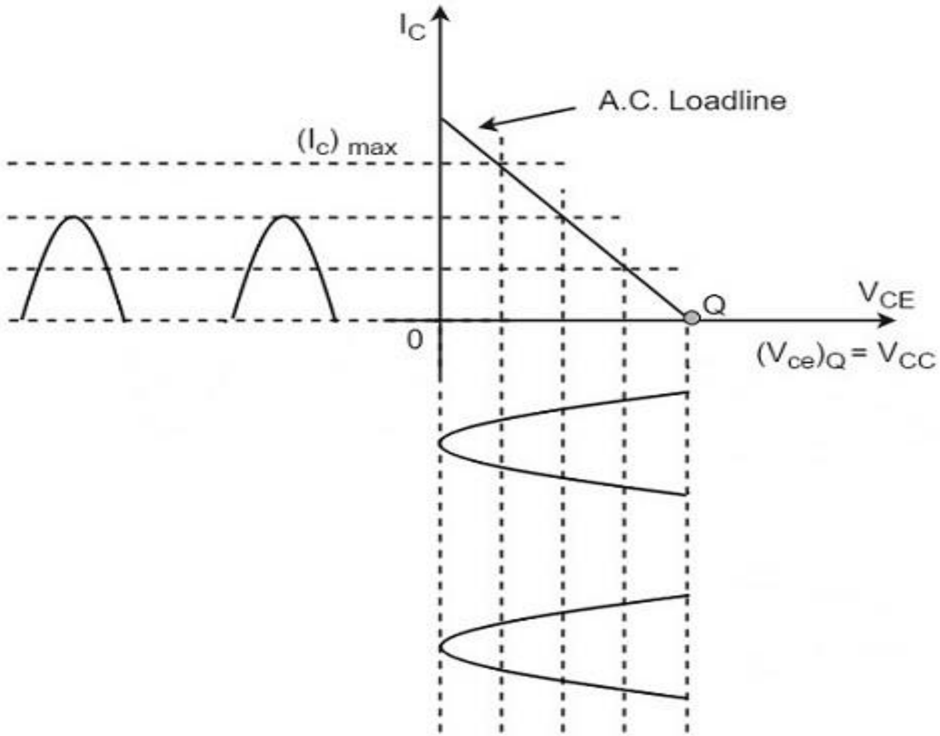
Class-A amplifiers are inefficient. A maximum theoretical efficiency of 50% is obtainable.


+Vcc
R1
RL
Vout
C1
Bias
R2
RE
C2
0v
Operating Curve
Output
Signal
Operating
Point
Q
Input
Signal

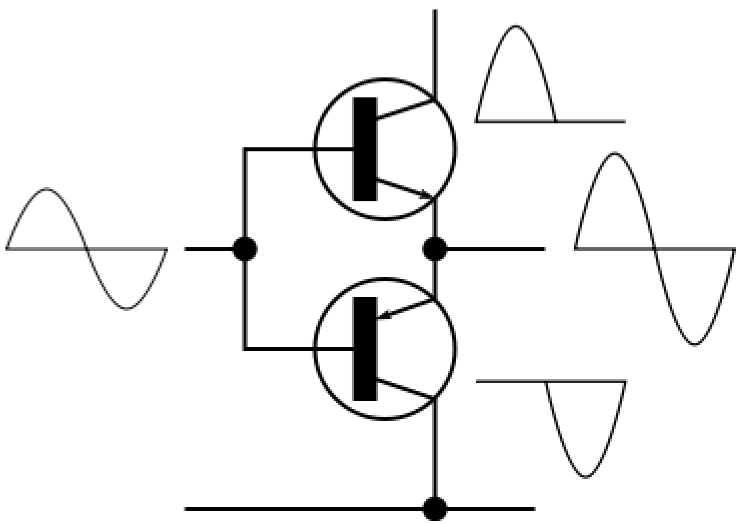
Class B Amplifier

- In a class-B amplifier, the active device conducts for 180 degrees of the cycle. Distortion is more .
- At radio frequency, if the load of the class-B amplifier is a tuned circuit, a single device in class B can be used.. Such amplifiers have an efficiency around 60%
- This would cause distortion if there were only one device, so two devices are used, each conducts for one half (180°) of the signal cycle, and the device currents are combined so that the load current is continuous.

Class B Amplifier: The biasing of the transistor in class B operation is in such a way that at zero signal condition, there will be no collector current. The **operating point** is selected to be at collector cut off voltage. Hence, when the signal is applied, **only the positive half cycle** is amplified at the output.



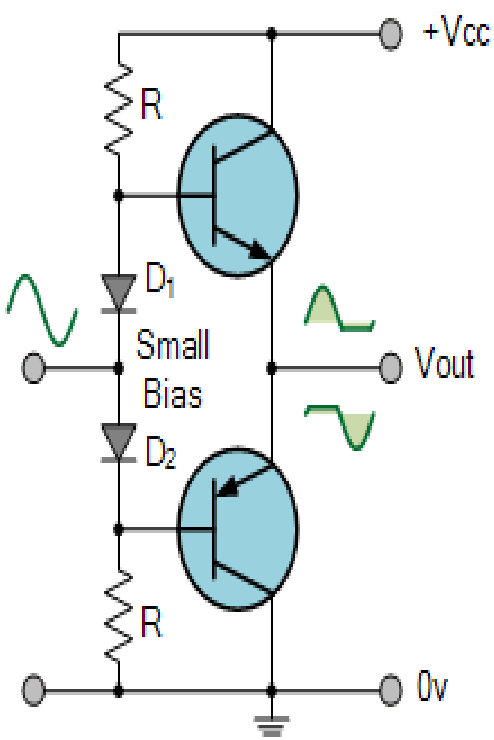
Class B Push Pull amplifier

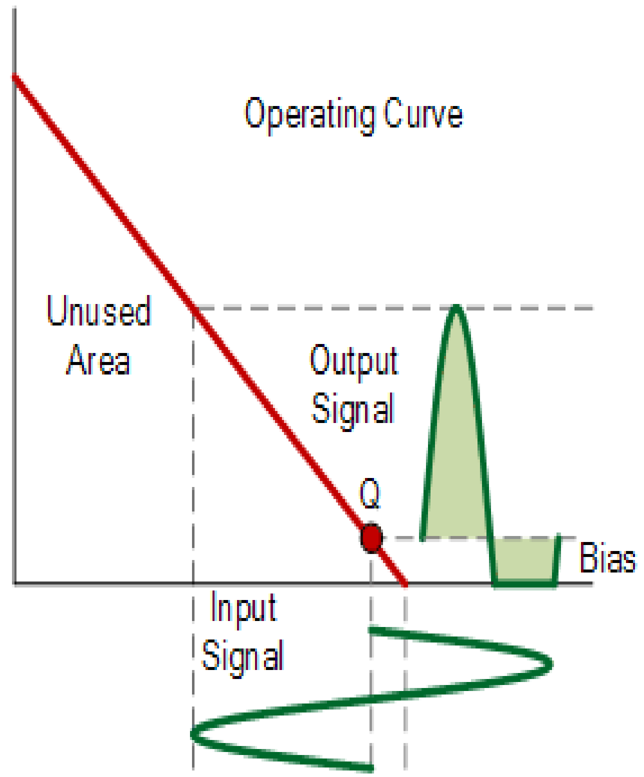


Class AB Amplifier

- In a class-AB amplifier, the conduction angle is intermediate between class A and B;
- the two active elements conduct more than half of the time.
- Class AB is widely considered a good compromise for amplifiers, since much of the time the music signal is quiet enough that the signal stays in the "class-A" region, where it is amplified with good fidelity.
- The distortion of class B are relatively small.

Class AB Amplifier

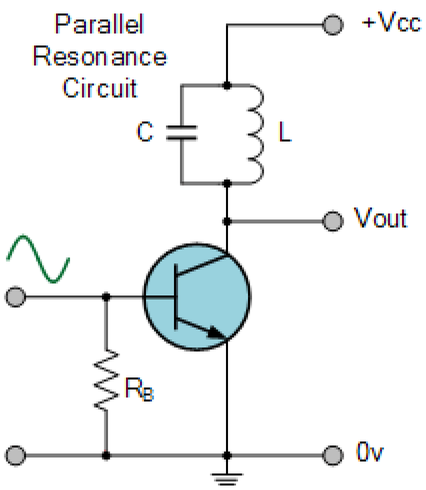


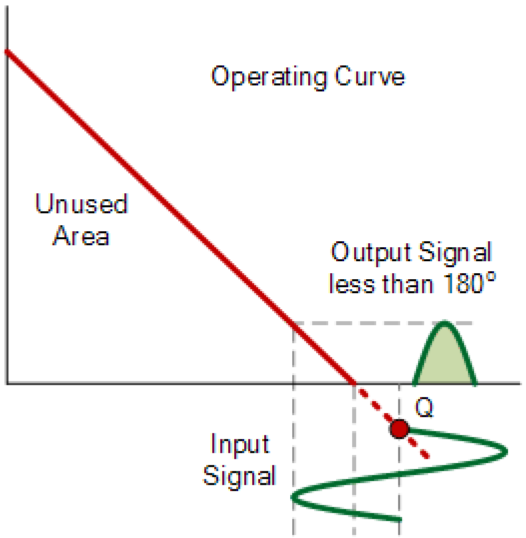


Class-C amplifier

In a class-C amplifier, less than 50% of the input signal is used (conduction angle < 180°). Distortion is high and practical use requires a tuned circuit as load. Efficiency can reach 80% in radio-frequency applications.

Class C Amplifier





Single – ended Power Amplifier

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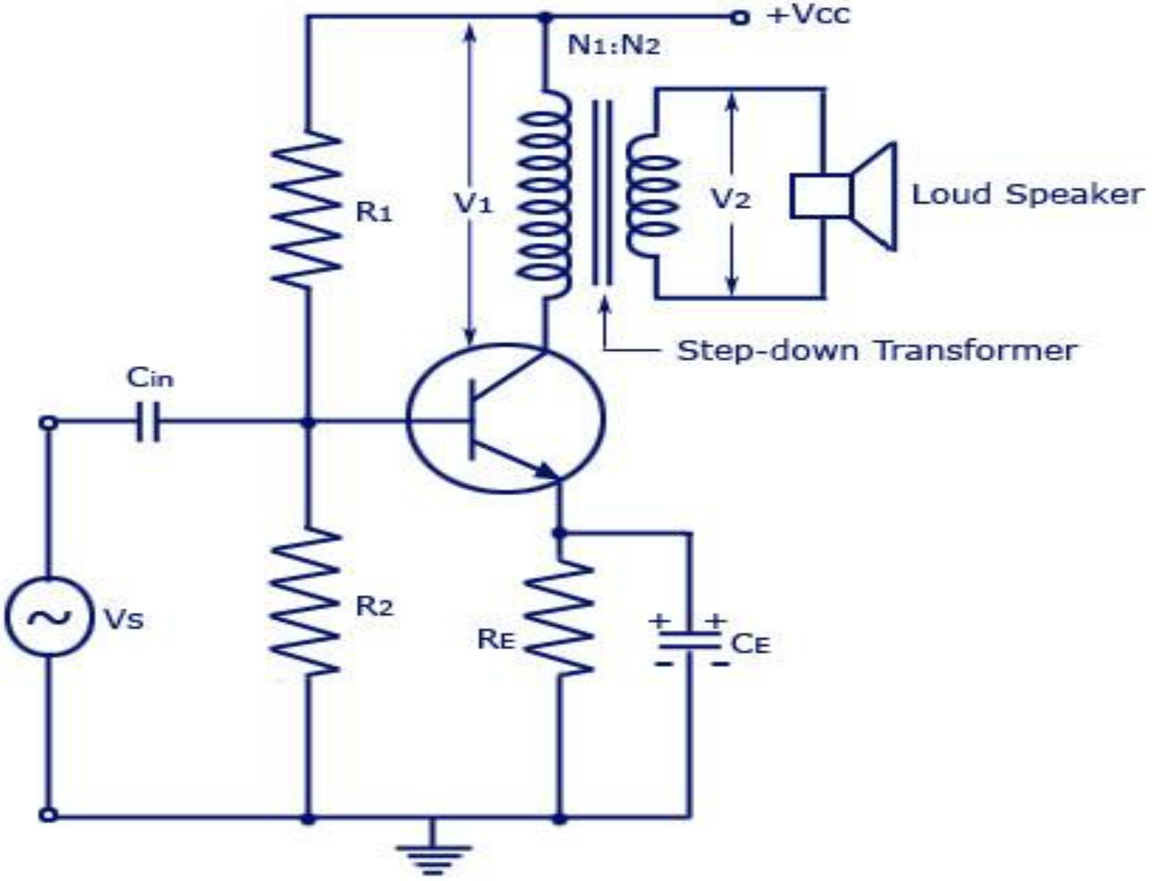
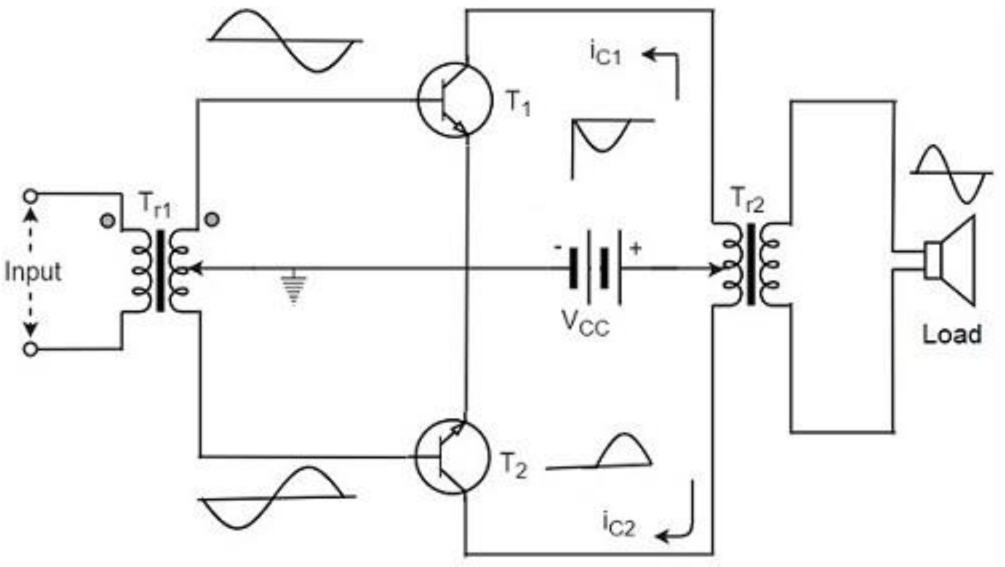
Transformer-Coupled-Class-A-Power Amplifier



Push-pull class B power amplifier

The circuit of a push-pull class B power amplifier consists of two identical transistors T_1 and T_2 whose bases are connected to the secondary of the center-tapped input transformer T_{r1}. The emitters are shorted and the collectors are given the V_{CC} supply through the primary of the output transformer T_{r2}.



Chapter 3

FEEDBACK IN AMPLIFIERS

Feedback in Amplifiers

Objectives:

- Basic principles and types of feedback
- Derivation of expression for gain of an amplifier employing feedback
- Effect of feedback (negative) on gain, stability, distortion and bandwidth of an amplifier
- RC coupled amplifier with emitter bypass capacitor
- Emitter follower amplifier and its application

Feedback

- In feedback amplifiers , a part of the output signal is fed back to the input signal. The signal fed back may be in phase or out of phase with the input signal.

Types of feedback

- Positive Feedback: The signal fedback from the output of the amplifier is in phase with the input signal.
- Negative feedback: The signal fedback from the output of the amplifier is out of phase with the inptu signal

Amplifier without feedback

Gain without Feedback,

$$Av = Vo/Vi$$

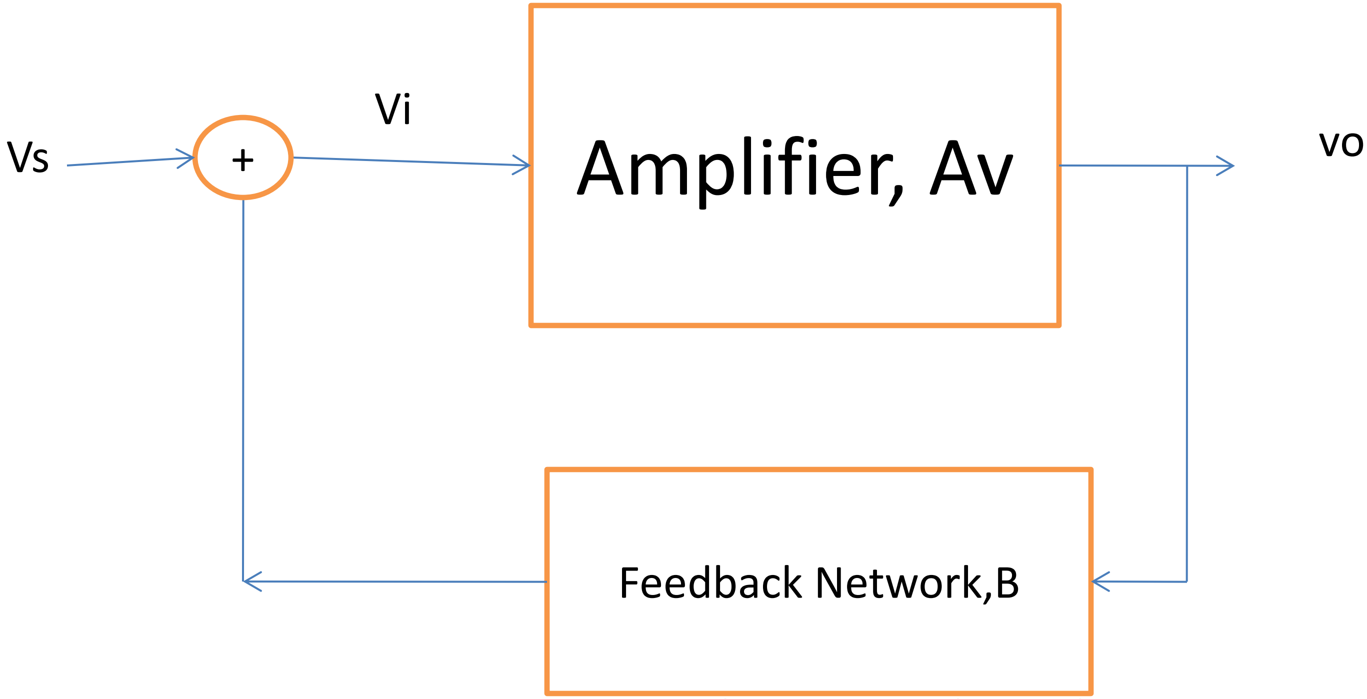
Gain

- Positive Feedback

  Gain, $A_f = A/(1 - A\beta)$
- Negative Feedback

  Gain, $A_f = A/(1 + A\beta)$

Amplifier without feedback



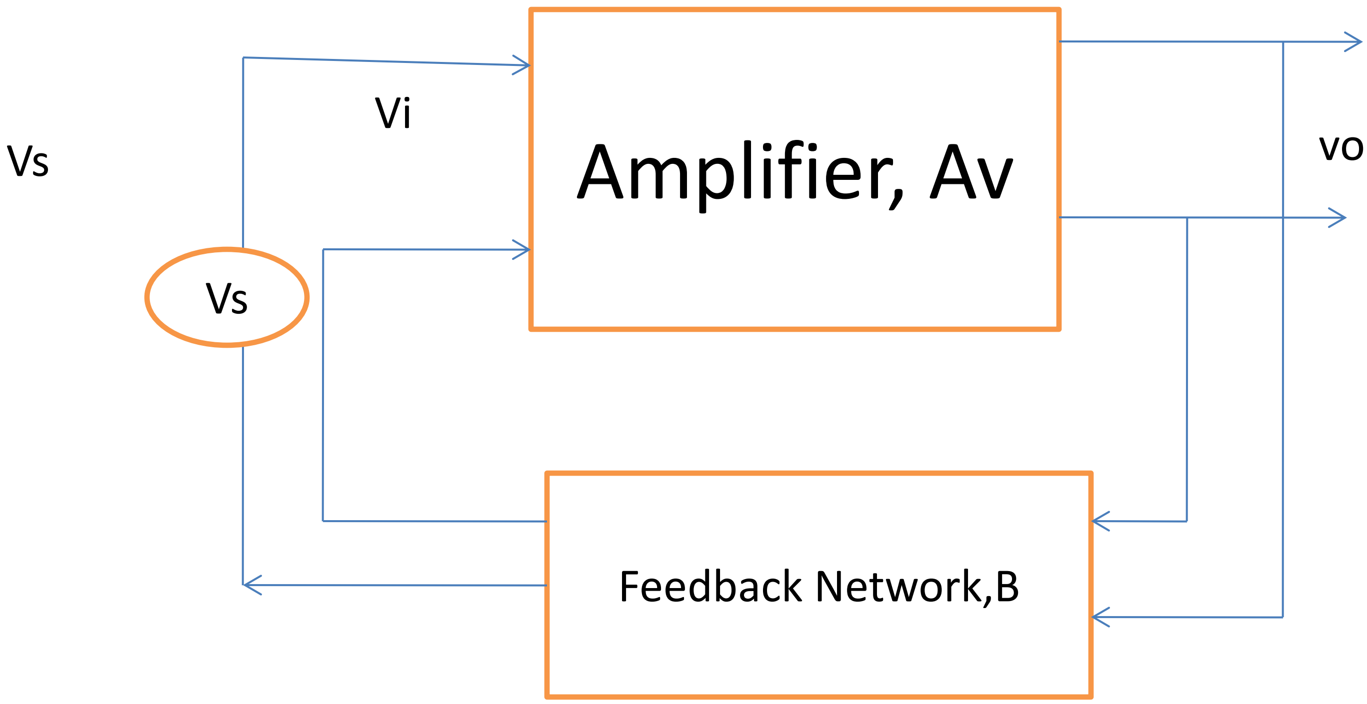
Gain with Feedback,

Af=Vo/Vi

Types of Negative Feedback

- Voltage Series Feedback
- Current Series Feeback
- Voltage shunt feedback
- Current shunt Feedback

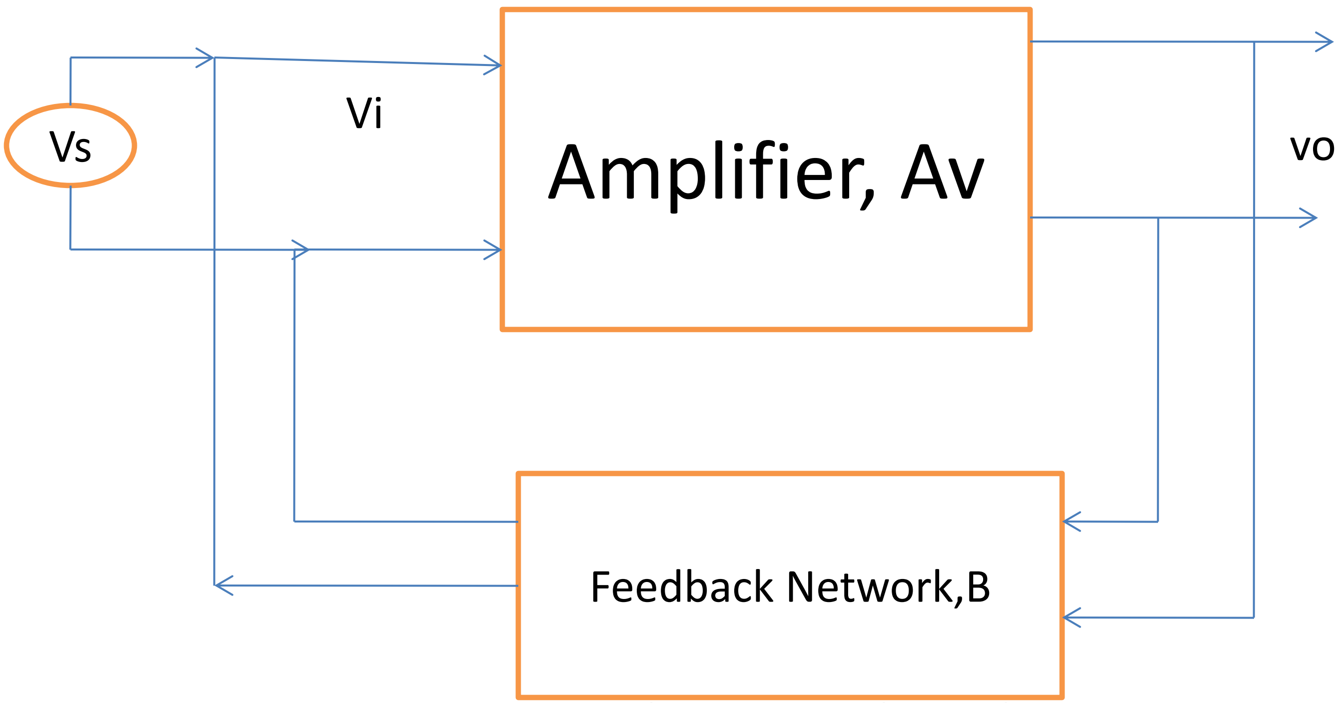
Voltage series Feedback In the voltage series feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit.



Gain with Feedback,

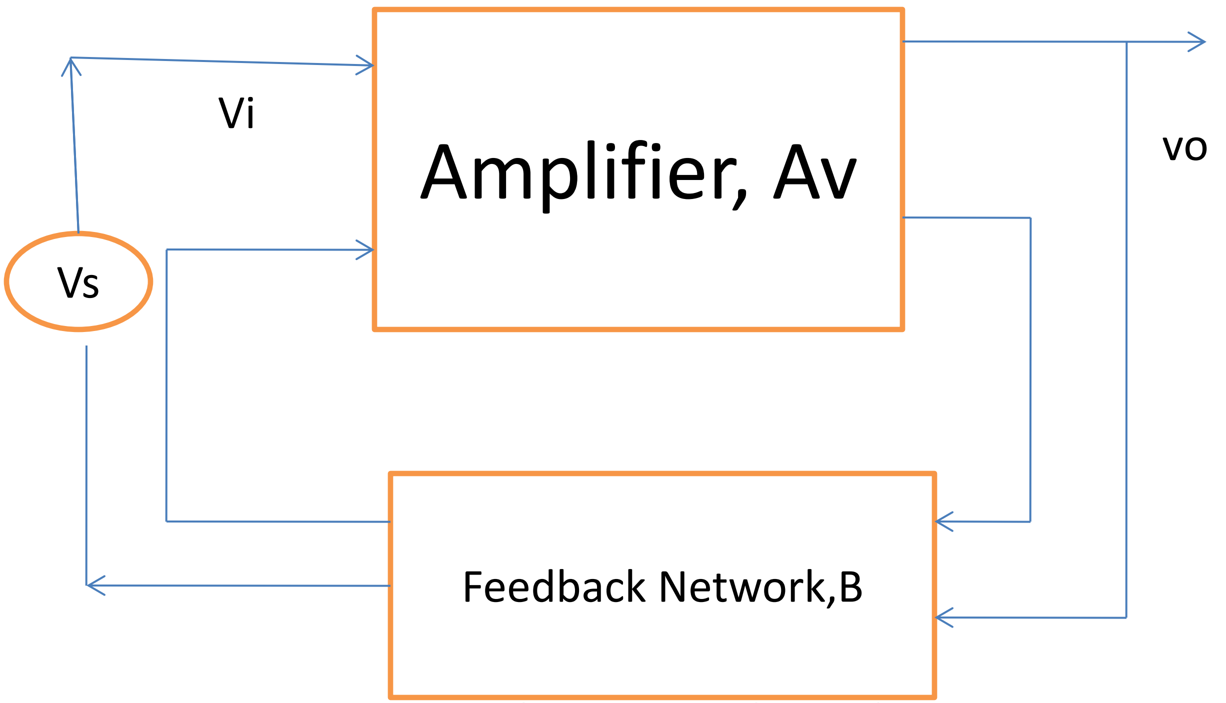
Af=Vo/Vs

Voltage shunt Feedback : In the voltage shunt feedback circuit, a fraction of the output voltage is applied in parallel with the input voltage through the feedback network.



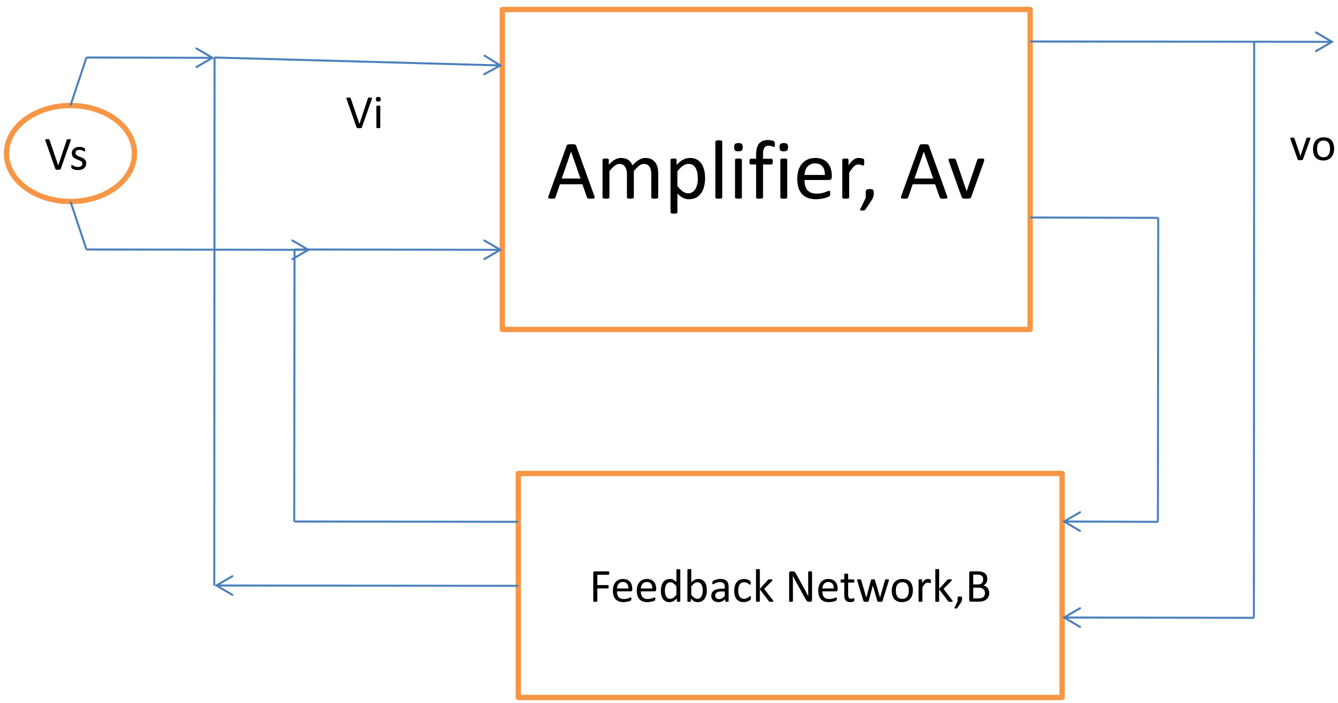
- Gain with Feedback,
- Af=Vo/Vs

Current Series Feedback



- Gain with Feedback,
- Af=Vo/Vs

current shunt Feedback



- Gain with Feedback,
- Af=Vo/Vs

Advantages of voltage series feedback

Increase in input impedance

$Z_{if} = Z_i(1+A\beta)$

Decrease in output impedance

$Z_{of} = Z_o/(1+A\beta)$

Reduction in total distortion

Noise decreases

Increases the bandwidth.

Chapter 4

Sinusoidal Oscillators

Sinusoidal Oscillators

Objectives

- Use of positive feedback
- Barkhausen criterion for oscillations
- Different oscillator circuits-tuned collector, Hartley, Colpitts, phase shift, Wien’s bridge, and crystal oscillator.

Use of positive feedback

- An Oscillator is an amplifier ckt. With positive feedback.
- The Circuit must have positive feedback

When positive feedback is used in the circuit, the overall circuit gain is given by,

$Af=A/(1-A\beta)$

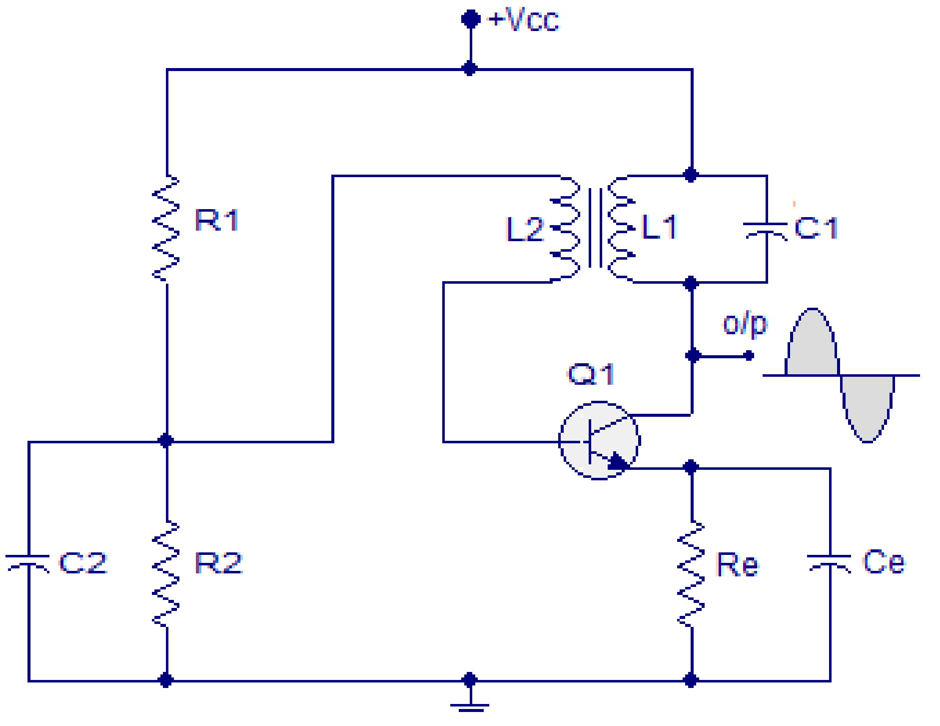
Barkhausen criterion for oscillations

To start the oscillation with the constant amplitude, Oscillator circuit must satisfy the following two conditions known as **Barkhausen** conditions:

1. The first condition is that the magnitude of the loop gain ($A\beta$) must be unity. This means the product of gain of amplifier 'A' and the gain of feedback network 'β' has to be unity.

2. The second condition is that the phase shift around the loop must be 360° or 0°. This means, the phase shift through the amplifier and feedback network has to be 360° or 0°.

Tuned collector Oscillator

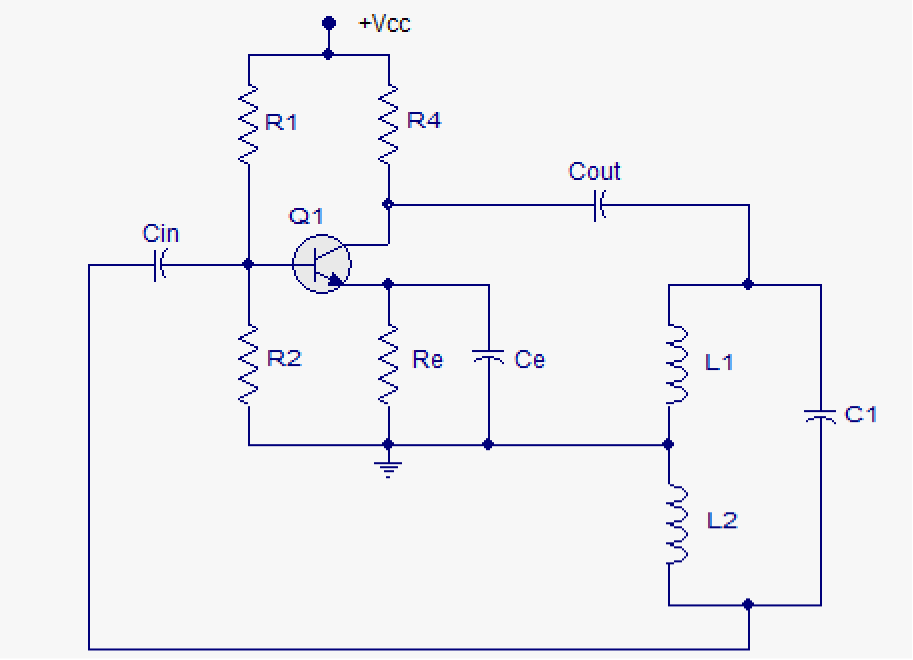


$$F = \frac{1}{2\pi\sqrt{LC}}$$

Tuned collector Oscillator

Tuned collector oscillation is a type of transistor LC oscillator where the tuned circuit (tank) consists of a transformer and a capacitor is connected in the collector circuit of the transistor. Tuned collector oscillator is of course the simplest and the basic type of LC oscillators. The tuned circuit connected at the collector circuit behaves like a purely resistive load at resonance and determines the oscillator frequency.The common applications of tuned collector oscillator are RF oscillator circuits, mixers, frequency demodulators, signal generators etc.

Hartley Oscillator



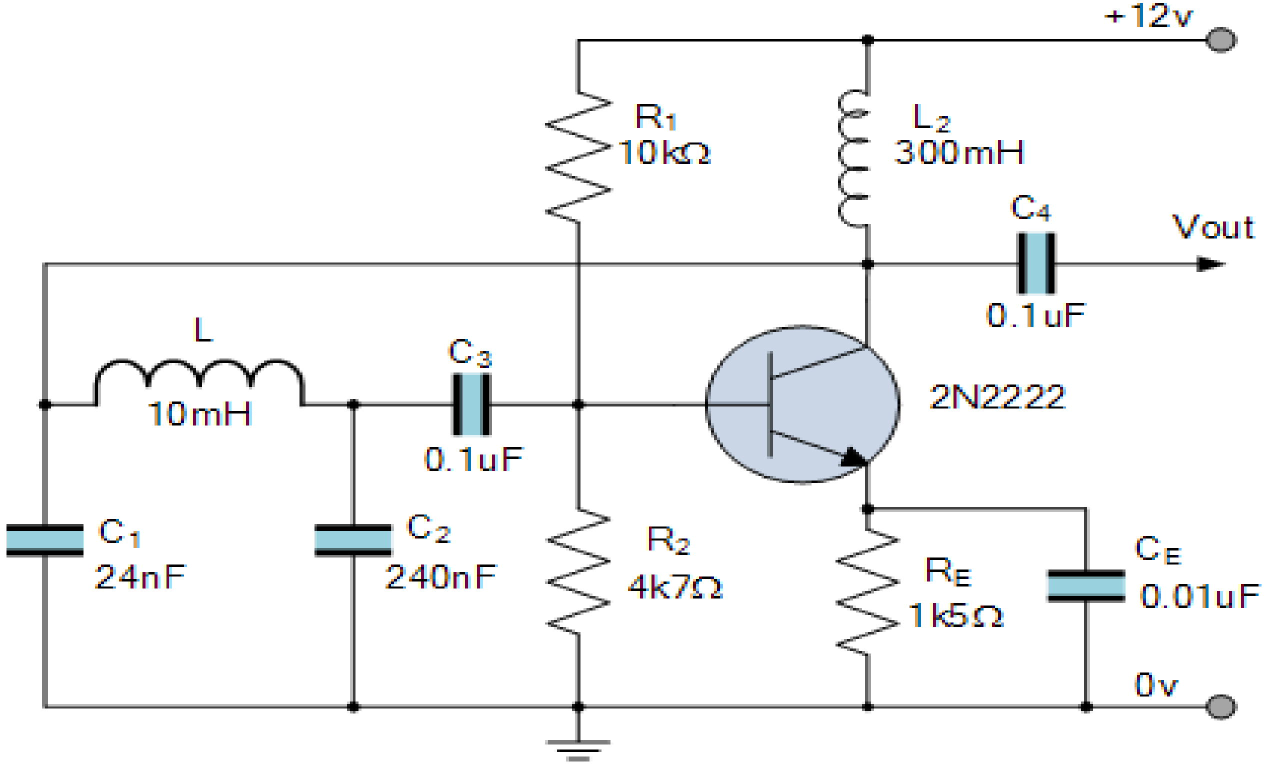
Hartley Oscillator

In the **Hartley Oscillator** the tuned LC circuit is connected between the collector and the base of a transistor amplifier. As far as the oscillator voltage is concerned, the emitter is connected to a tapping point on the tuned circuit coil.

The feedback part of the tuned LC tank circuit is taken from the centre tap of the inductor coil or even two separate coils in series which are in parallel with a variable capacitor, C .

The Hartley circuit is often referred to as a split-inductance oscillator because coil L is centre-tapped. In effect, inductance L acts like two separate coils in very close proximity with the current flowing through coil

Colpitts Oscillators

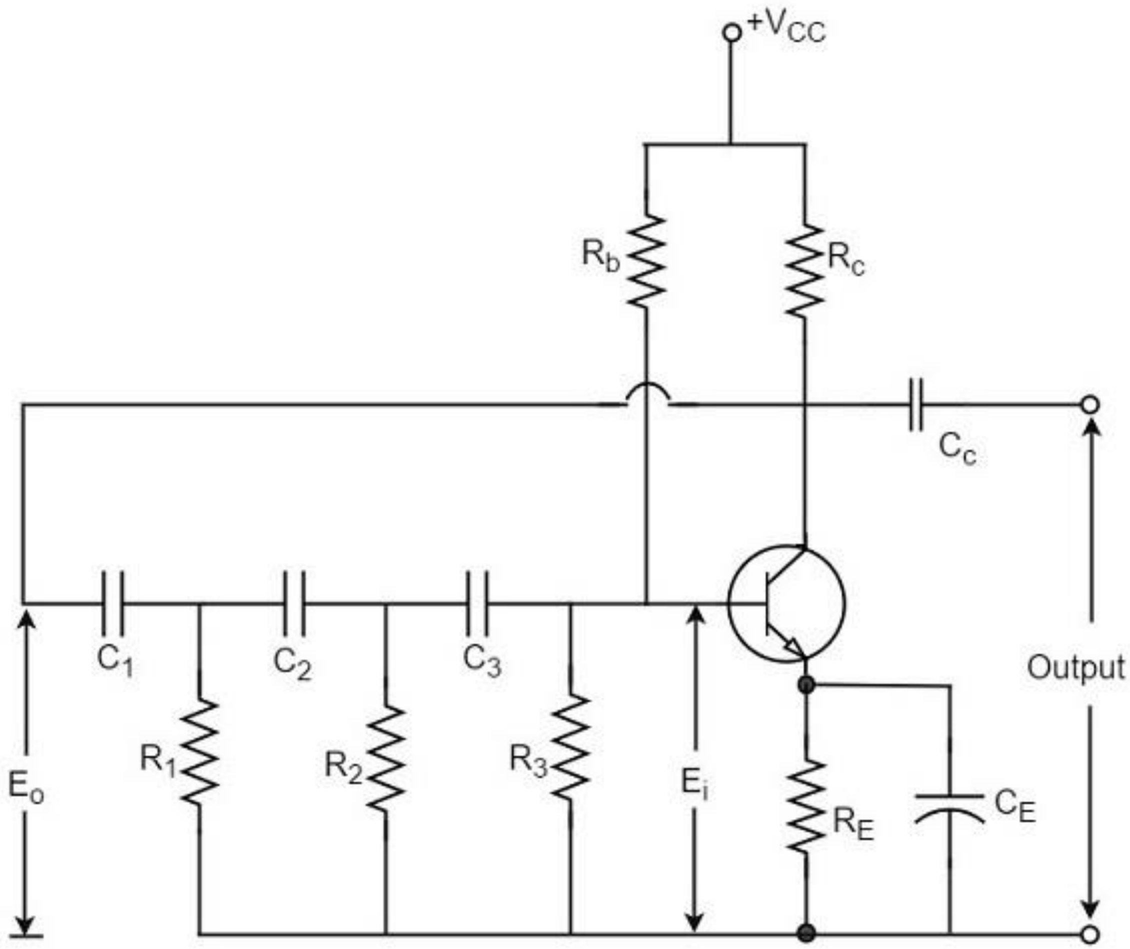


Colpitts Oscillators

In the C**olpitt oscillator** the tuned LC circuit is connected between the collector and the base of a transistor amplifier. As far as the oscillator voltage is concerned, the emitter is connected to a center point on the two capacitors.

The feedback part of the tuned LC tank circuit is taken from the centre point on the two capacitors which are in parallel with a variable inductor L .

Phase Shift Oscillator



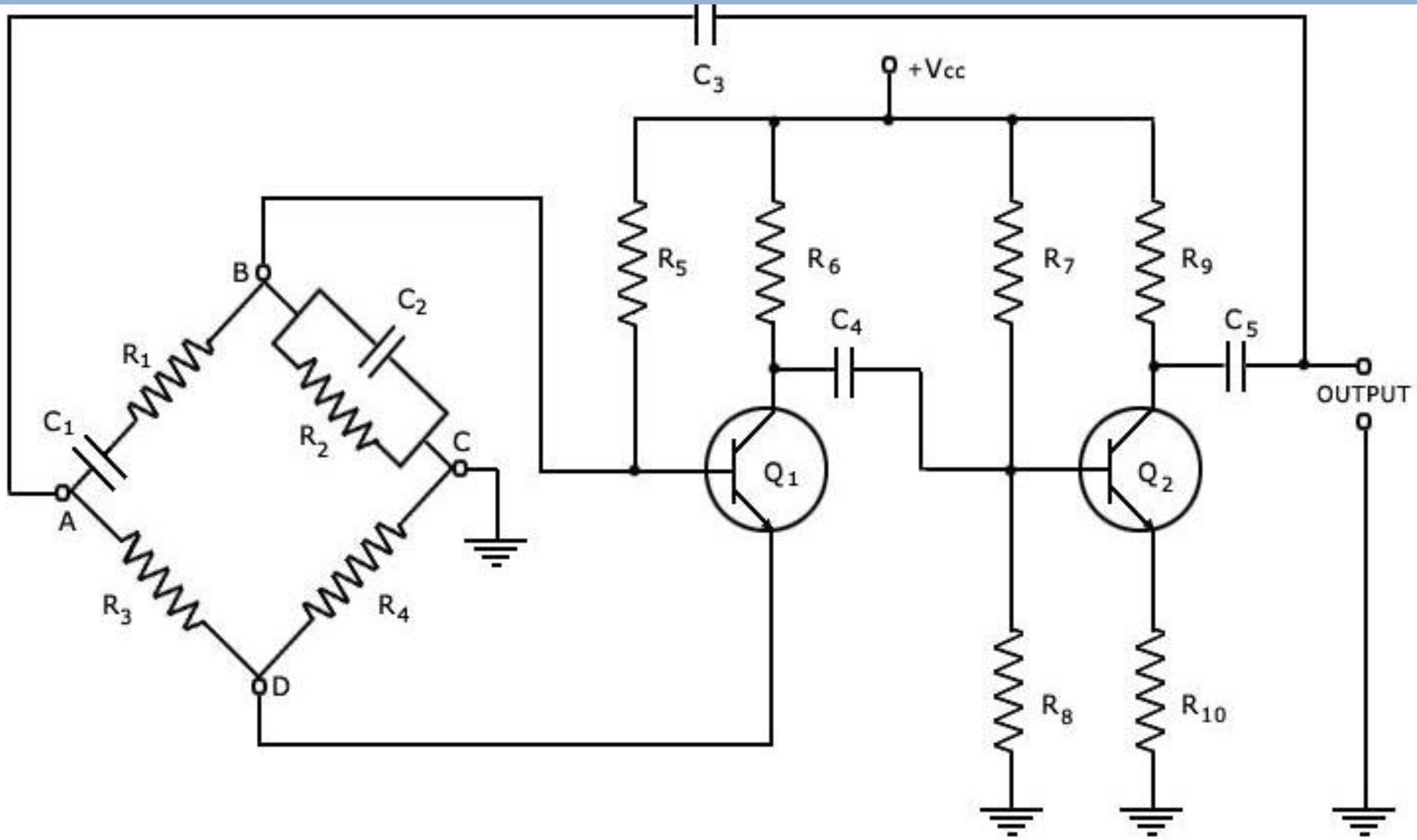
Phase shift Oscillator

- A phase-shift oscillator is a linear electronic oscillator circuit that produces a sine wave output. It consists of an inverting amplifier using a transistor or op amp with its output fed back to its input through a phase-shift network consisting of resistors and capacitors in a ladder network. The feedback network 'shifts' the phase of the amplifier output by 180 degrees at the oscillation frequency to give positive feedback. Phase-shift oscillators are often used at audio frequency as audio oscillators.

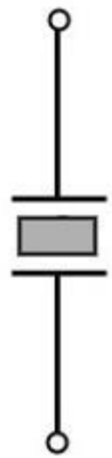
Wein Bridge Oscillator

- **Wien bridge oscillator** is a type of electronic oscillator that generates sine waves. It can generate a large range of frequencies. The oscillator is based on a bridge circuit. The bridge comprises four resistors and two capacitors. The oscillator can also be viewed as a positive gain amplifier combined with a bandpass filter that provides positive feedback.

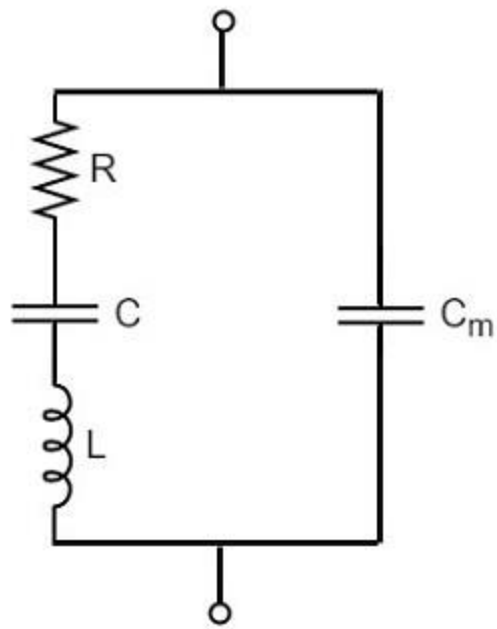
Wein Bridge Oscillator



Crystal Oscillator



Symbol of a Crystal



Equivalent circuit of a crystal

Crystal Oscillator

The principle of crystal oscillators depends upon the **Piezo electric effect**.

The crystal used in crystal oscillator exhibits a property called as Piezo electric property.

Piezo Electric Effect

The crystal exhibits the property that when a mechanical stress is applied across one of the faces of the crystal, a potential difference is developed across the opposite faces of the crystal. Reverse of which is also true. when a potential difference is applied across one of the faces, a mechanical stress is produced along the other faces. This is known as **Piezo electric effect**.

Certain crystalline materials like Rochelle salt, quartz and tourmaline exhibit piezo electric effect and such materials are called as **Piezo electric crystals**. Quartz is the most commonly used piezo electric crystal because it is inexpensive and readily available in nature.

CHAPTER 5
Tuned Voltage Amplifiers

Tuned Voltage Amplifiers

Objectives of study:

- Series and parallel resonant circuits and bandwidth of resonant circuits.
- Single and double tuned voltage amplifiers and their frequency response characteristics

Tuned Voltage Amplifiers

- The amplifiers which amplify a specific band of frequencies is called as tuned voltage amplifier.

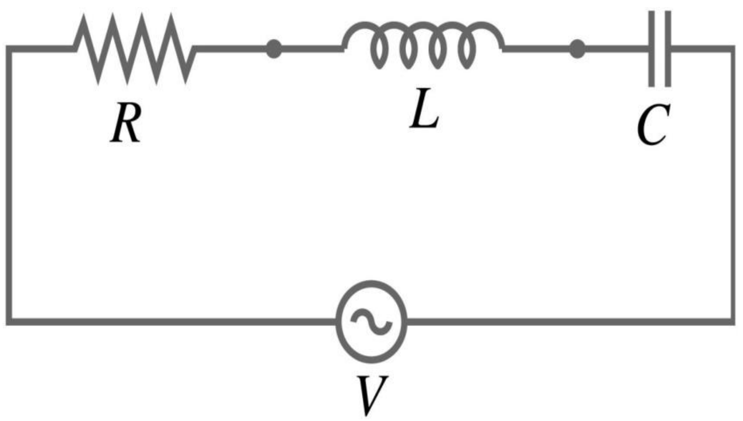
- Tuned voltage amplifiers are widely used in all types of receivers. The selectivity of receivers depends on the resonant circuit used.

The types of resonant circuits are

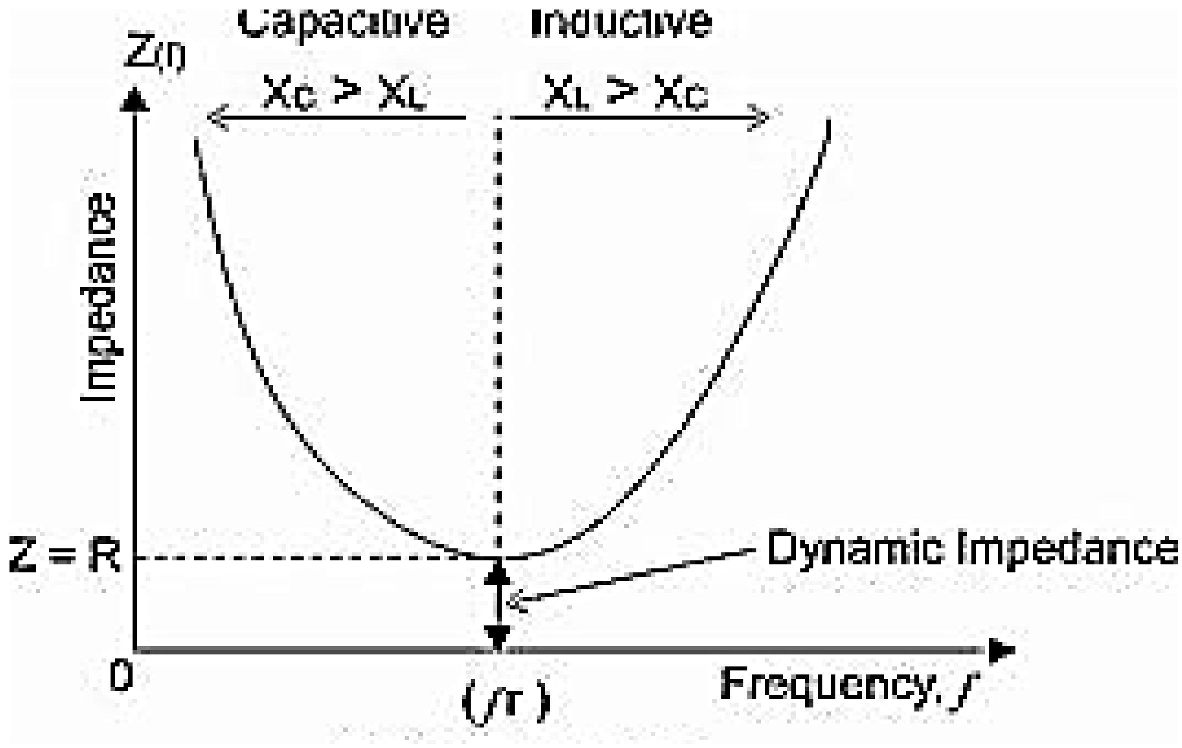
1.Series Resonant circuit

2.Parallel Resonant circuit

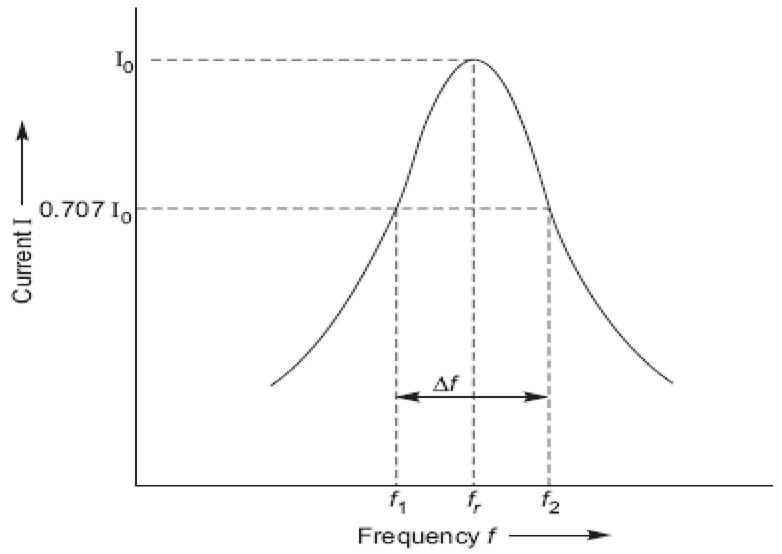
Series Resonant Circuit: The circuit consists of resistance , capacitance and inductance connected in series.



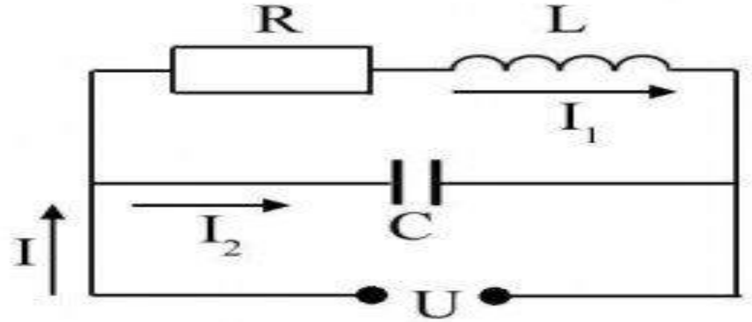
Frequency response of Series Resonant ckt : At resonance, the value of current is maximum and impedance is minimum and purely resistive



Bandwidth : The range of frequencies over which the circuit current is equal to 70.7% of the maximum current at resonance is called bandwidth. Bandwidth = $f_2 - f_1$



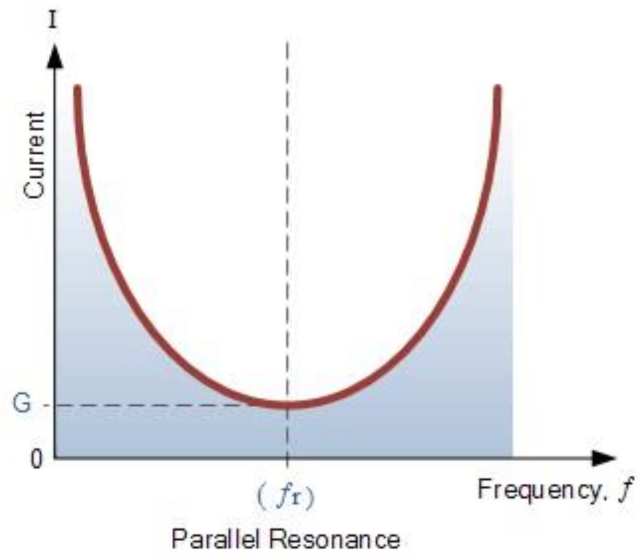
Parallel resonant circuit: It consists of an inductor connected parallel to capacitor. When such a circuit is connected to ac voltage of varying frequency, the resonance occurs at a frequency where impedance is maximum and cuerrent is minimum



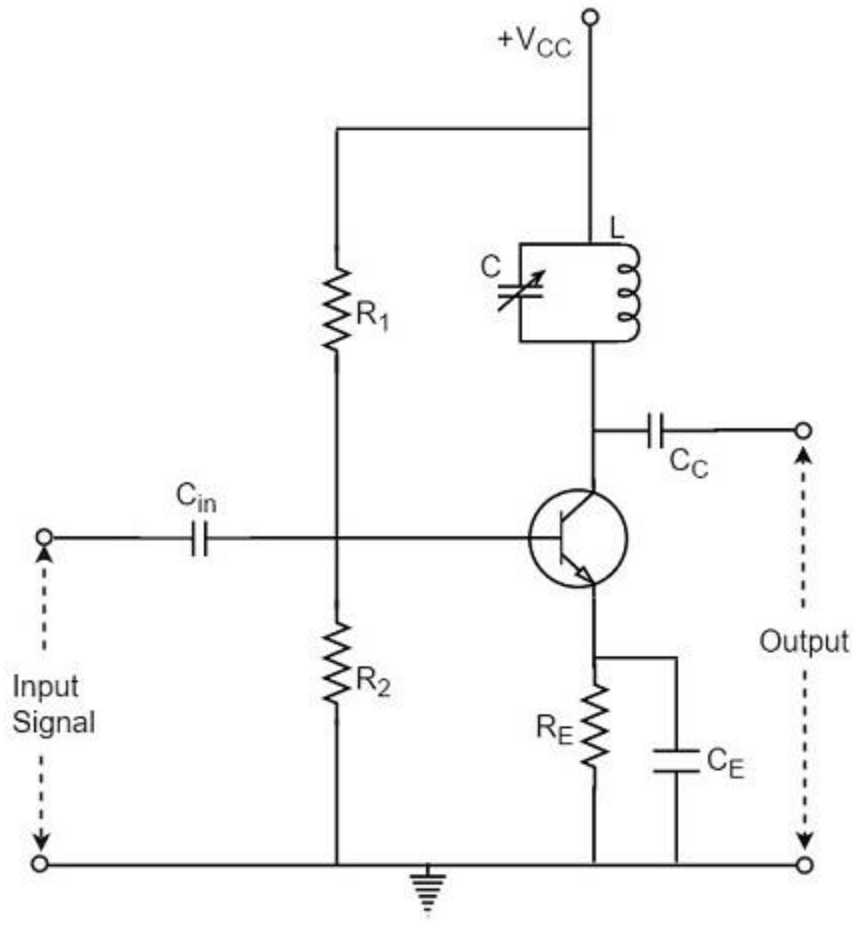
Parallel Resonant circuit

$$W=1/\sqrt{LC}$$

Frequency Response of Parallel Resonant circuit: At resonance, the value of current is maximum and impedance is minimum and purely resistive

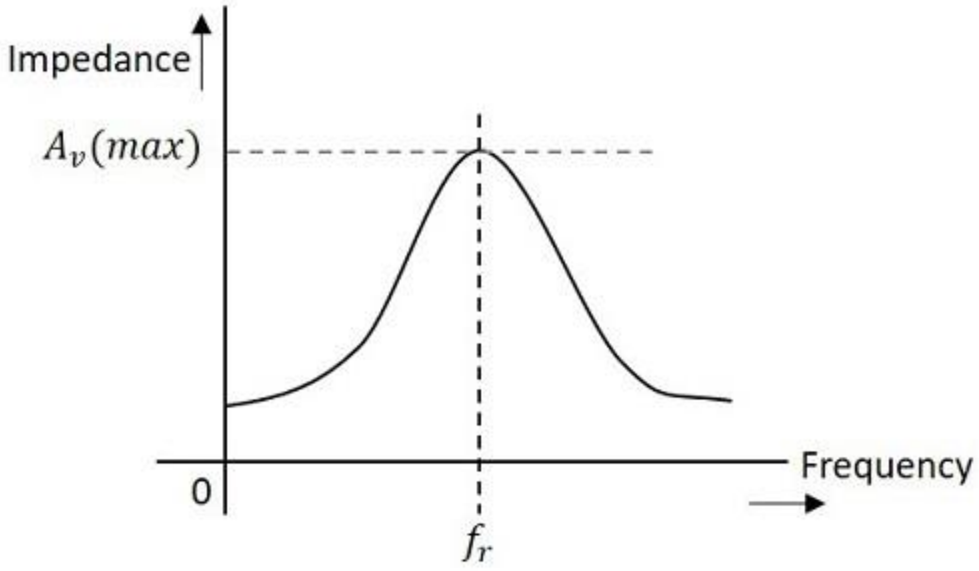


Single Tuned Voltage amplifier

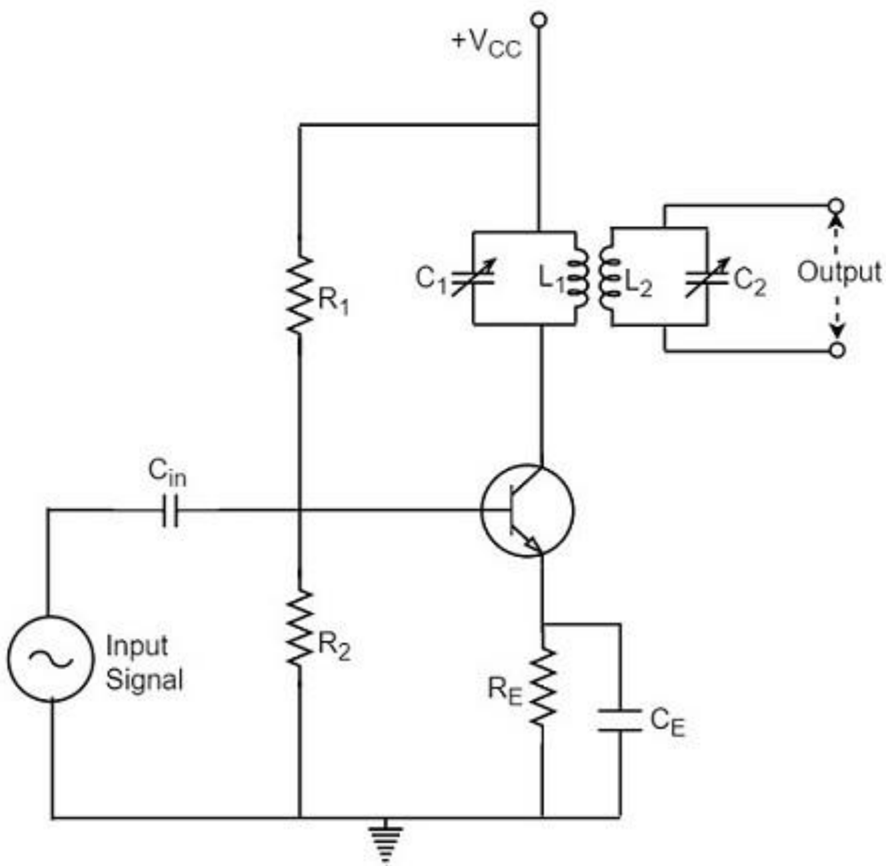


A **single tuned voltage amplifier** circuit consisting of a **parallel** tuned circuit in its collector load in a simple transistor amplifier. The values of capacitance and inductance of the tuned circuit are selected such that the resonant frequency of the tuned circuit is equal to the frequency to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

Frequency response of a single tuned amplifier circuit



Double tuned Amplifier: It consists of double tuned circuit in collector to obtain better selectivity, gain and bandwidth



Double tuned Amplifier

- A **double-tuned amplifier** is a tuned amplifier with transformer coupling between the amplifier stages in which the inductances of both the primary and secondary windings are tuned separately with a capacitor across each. The scheme results in a wider bandwidth.

Bandwidth of Double tuned Amplifier

- The equation for bandwidth is given as

$$B = k.fr$$

Where

B = bandwidth for double tuned circuit,

K = coefficient of coupling,

f_r = resonant frequency.

References

Basic Electronics and Linear Circuits by NN Bhargava; Tata McGraw Hill, New Delhi

Electronic Principles by Sahdev; Dhanpat Rai and Sons, New Delhi.

Electronics Devices and Circuits by Bhupinderjit Kaur; Modern Publishers, Jalandhar

Electronic Devices and Circuits by BL Theraja; S Chand and Co Ltd. New Delhi

Operational Amplifiers and Linear Integrated Circuits by Ramakant A. Gaykwad

www.circuitstoday.com

www.tutorialspoint.com

Thank You