UNIT III
TUNED AMPLIFIERS

Introduction to tuned circuits

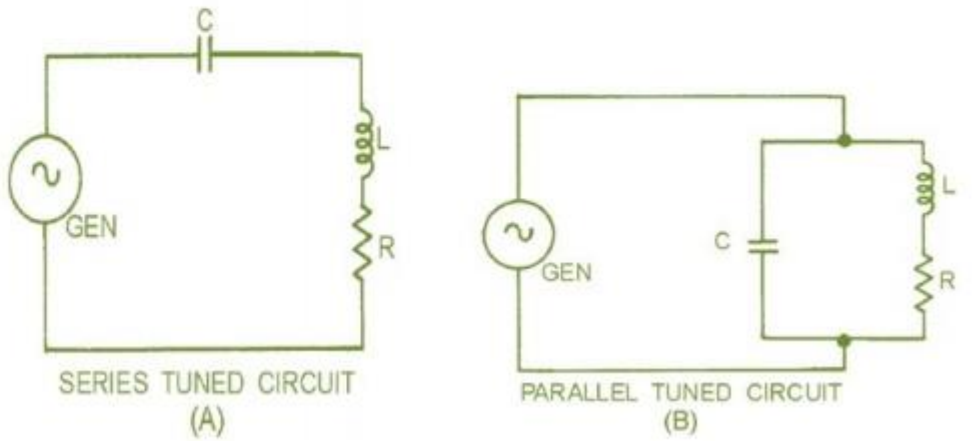
When a radio or television set is turned on, many events take place within the "receiver" before we hear the sound or see the picture being sent by the transmitting station. Many different signals reach the antenna of a radio receiver at the same time. To select a station, the listener adjusts the tuning dial on the radio receiver until the desired station is heard. Within the radio or TV receiver, the actual "selecting" of the desired signal and the rejecting of the unwanted signals are accomplished by means of a tuned circuit.

A tuned circuit consists of a coil and a capacitor connected in series or parallel. Whenever the characteristics of inductance and capacitance are found in a tuned circuit, the phenomenon as RESONANCE takes place.

Resonance circuits

The frequency applied to an LCR circuit causes XL and XC to be equal, and the circuit is RESONANT. If XL and XC are equal ONLY at one frequency (the resonant frequency). This fact is the principle that enables tuned circuits in the radio receiver to select one particular frequency and reject all others.

This is the reason why so much emphasis is placed on XL and X C . figure 1-1 Shows that a basic tuned circuit consists of a coil and a capacitor, connected either in series, view (A), or in parallel, view (B). The resistance (R) in the circuit is usually limited to the inherent resistance of the components (particularly the resistance of the coil).



Tuned amplifier

ü Communication circuit widely uses tuned amplifier and they are used in MW & SW radio frequency 550 KHz – 16 MHz, 54 – 88 MHz, FM 88 – 108 MHz, cell phones 470 - 990 MHz
ü Band width is 3 dB frequency interval of pass band and –30 dB frequency interval

ü Tune amplifiers are also classified as A, B, C similar to power amplifiers based on conduction angle of devices.

Series resonant circuit

Series resonant features minimum impedance (RS) at resonant.

ü f r = ½ √LC; q = L/Rs at resonance L=1/c, BW=fr/Q

ü It behaves as purely resistance at resonance, capacitive below and inductive above resonance

Paralel resonant circuit

ü Paralel resonance features maximum impedance at resonance = L/RsC

ü At resonance Fr=1/2√1/(LC-Rs2/L2); if Rs=0, fr=1/2√(LC)

ü At resonance it exhibits pure resistance and below fr parallel circuit exhibits inductive and above capacitive impedance

Need for tuned circuits:

To understand tuned circuits, we first have to understand the phenomenon of self-induction. And to understand this, we need to know about induction. The first discovery about the interaction between electric current and magnetism was the realization that an electric current created a magnetic field around the conductor. It was then discovered that this effect could be enhanced greatly by winding the conductor into a coil. The effect proved to be two-way: If a conductor, maybe in the form of a coil was placed in a changing magnetic field, a current could be made to flow in it; this is called induction.

So imagine a coil, and imagine that we apply a voltage to it. As current starts to flow, a magnetic field is created. But this means that our coil is in a changing magnetic field, and this induces a current in the coil. The induced current runs contrary to the applied current, effectively diminishing it. We have discovered self-induction. What happens is that the self-induction delays the build-up of current in the coil, but eventually the current will reach its maximum and stabilize at a value only determined by the ohmic resistance in the coil and the voltage applied. We now have a steady current and a steady magnetic field. During the buildup of the field, energy was supplied to the coil, where did that energy go? It went into the magnetic field, and as long as the magnetic field exists, it will be stored there.

Now imagine that we remove the current source. Without a steady current to uphold it, the magnetic field starts to disappear, but this means our coil is again in a variable field which induces a current into it. This time the current is in the direction of the applied current, delaying the decay of the current and the magnetic field till the stored energy is spent. This can give a funny effect: Since the coil **must** get rid of the stored energy, the voltage over it rises indefinitely until a current can run somewhere! This means you can get a surprising amount of sparks and arching when coils are involved. If the coil is large enough, you can actually get an electric shock from a low-voltage source like an ohmmeter.

Applications of tuned amplifier

A tuned amplifier is a type of electronic device designed to amplify specific ranges of electrical signals while ignoring or blocking others. It finds common use in devices that work with radio frequency signals such as radios, televisions, and other types of communication equipment; however, it also can be useful in many other applications. Tuned amplifiers can be found in aircraft autopilot systems, audio systems, scientific instruments, spacecraft, or anywhere else there is a need to select and amplify specific electronic signals while ignoring others.

The most common tuned amplifiers an average person interacts with can be found in home or portable entertainment equipment, such as FM stereo receivers. An FM radio has a tuned amplifier that allows listening to only one radio station at a time. When the knob is turned to change the station, it adjusts a variable capacitor, inductor, or similar device inside the radio, which alters the inductive load of the tuned amplifier circuit. This retunes the amplifier to allow a different specific radio frequency to be amplified so a different radio station can be heard.

CLASSIFICATION:

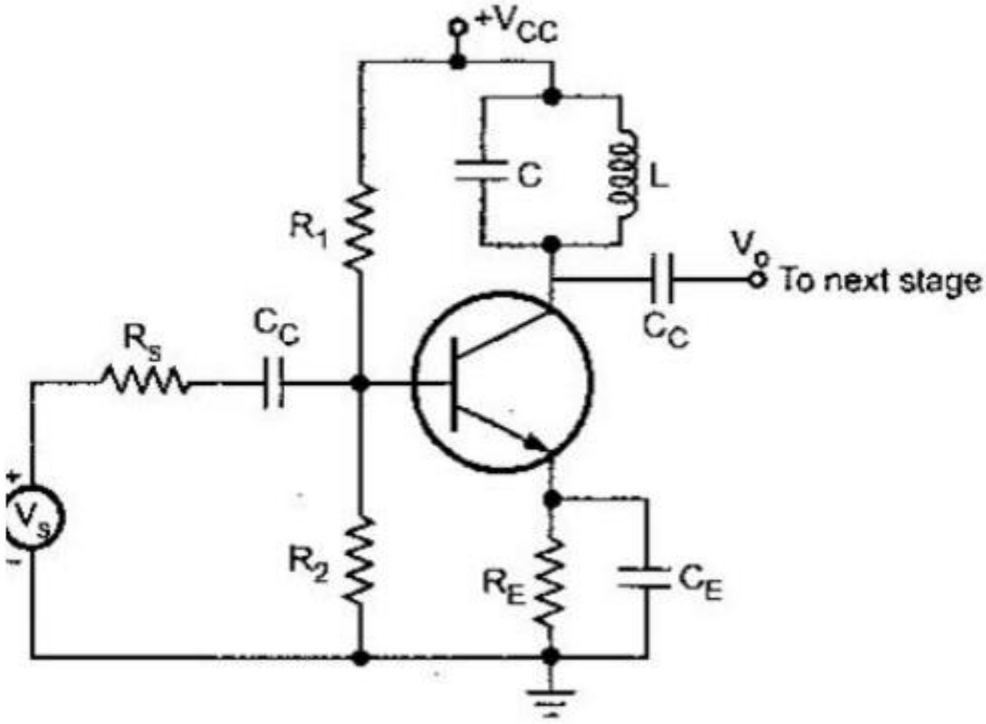
1. Single tuned amplifier

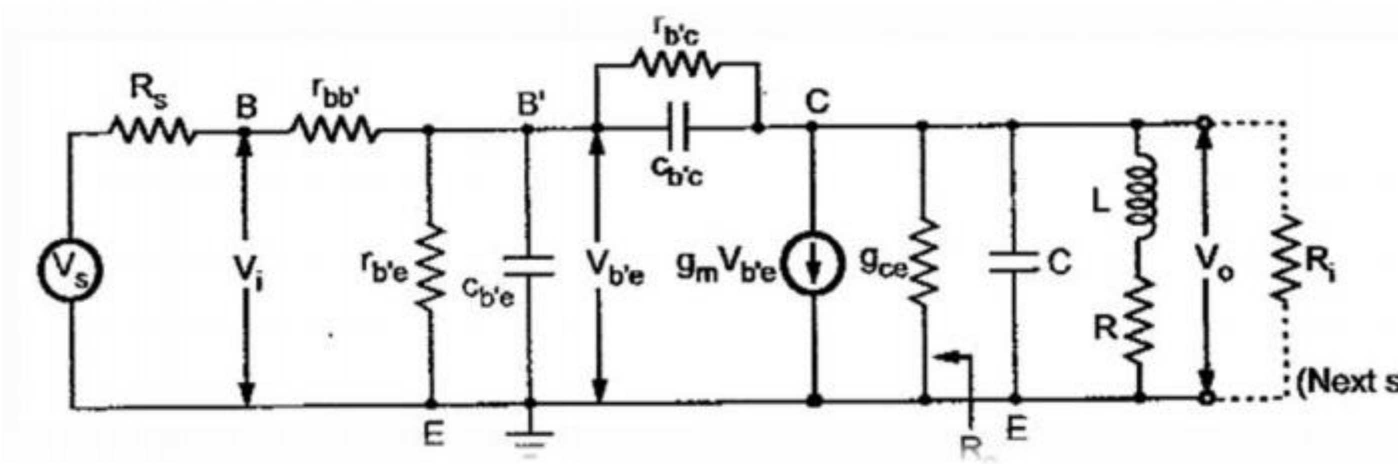
2. Double tuned amplifier

3. Stagger tuned amplifier

1. Single tuned amplifier

Single Tuned Amplifiers consist of only one Tank Circuit and the amplifying frequency range is determined by it. By giving signal to its input terminal of various Frequency Ranges. The Tank Circuit on its collector delivers High Impedance on resonant Frequency, Thus the amplified signal is Completely Available on the output Terminal. And for input signals other than Resonant Frequency, the tank circuit provides lower impedance, hence most of the signals get attenuated at collector Terminal.



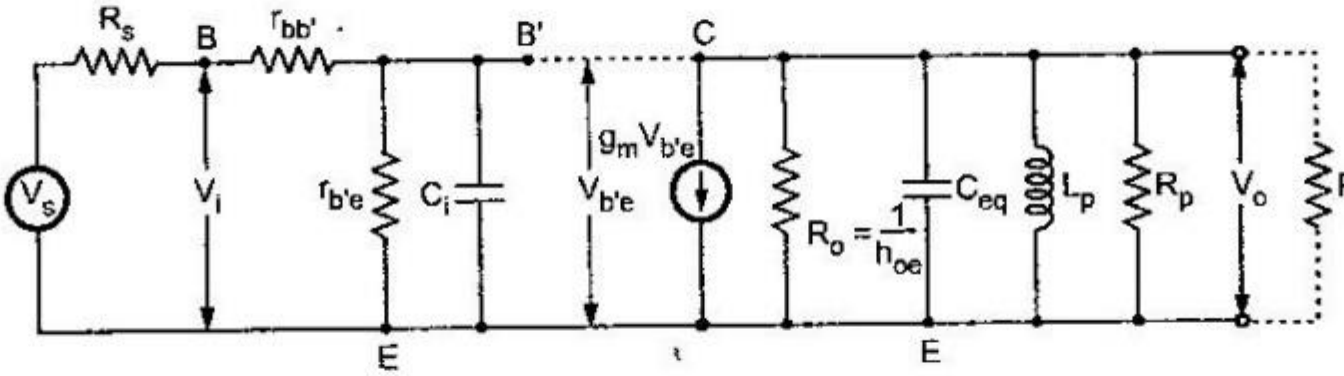


R_i- input resistance of the next stage

R_0-output resistance of the generator g_mVb'e

C_c & C_E are negligible small

The equivalent circuit is simplified by



Simplified equivalent circuit

$$C_i = C_{b'e} + C_{b'c}(1 - A)$$

$$C_{eq} = C_{b'c}\left(\frac{A-1}{A}\right) + C$$

Where,

A-Voltage gain of the amplifier

C-tuned circuit capacitance

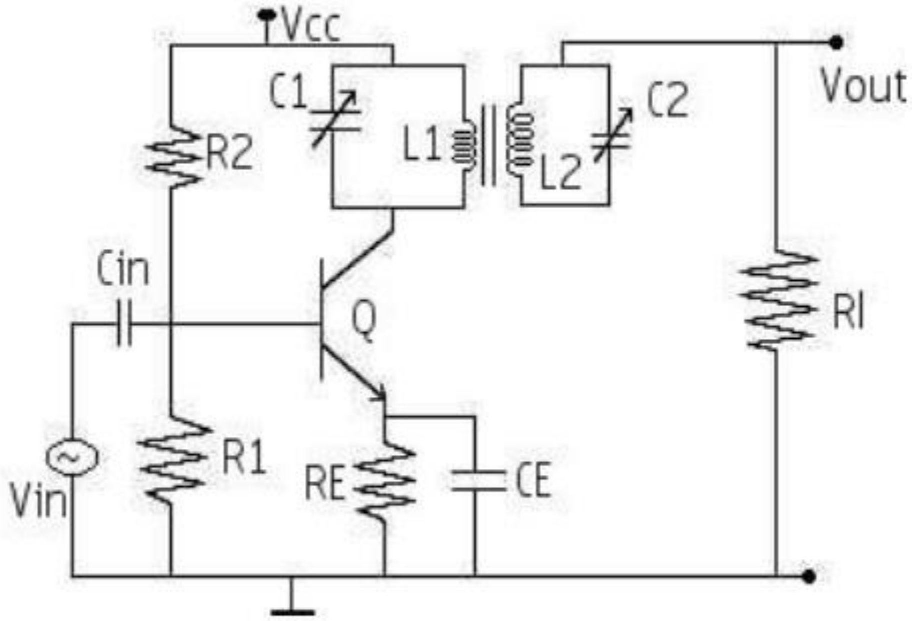
$$g_{ce} = \frac{1}{r_{ce}} = h_{oe} - g_m h_{re} \approx h_{oe} = \frac{1}{R_o}$$

2. Double tuned amplifier

An amplifier that uses a pair of mutually inductively coupled coils where both primary and secondary are tuned, such a circuit is known as "double tuned amplifier". Its response will provide

substantial rejection of frequencies near the pass band as well as relative flat pass band response. The disadvantage of POTENTIAL INSTABILITY in single tuned amplifiers can be overcome in Double tuned amplifiers.

A double tuned amplifier consists of inductively coupled two tuned circuits. One L1, C1 and the other L2, C2 in the Collector terminals. A change in the coupling of the two tuned circuits results in change in the shape of the Frequency response curve.

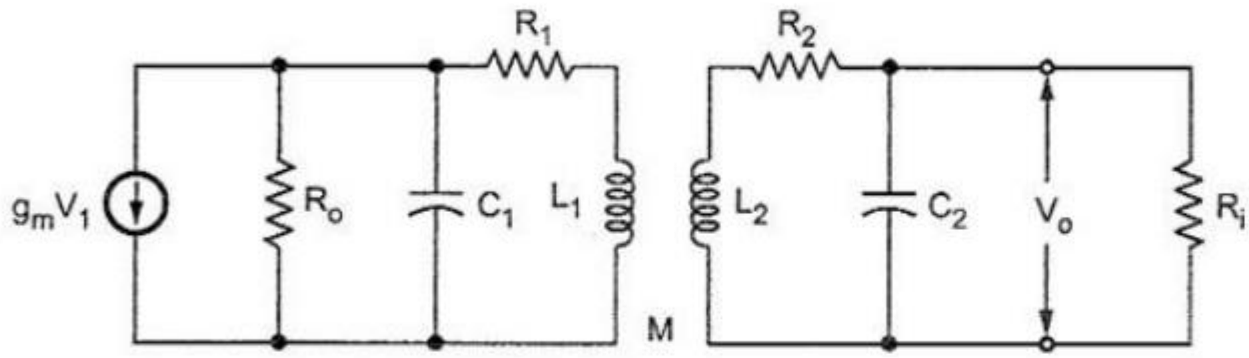


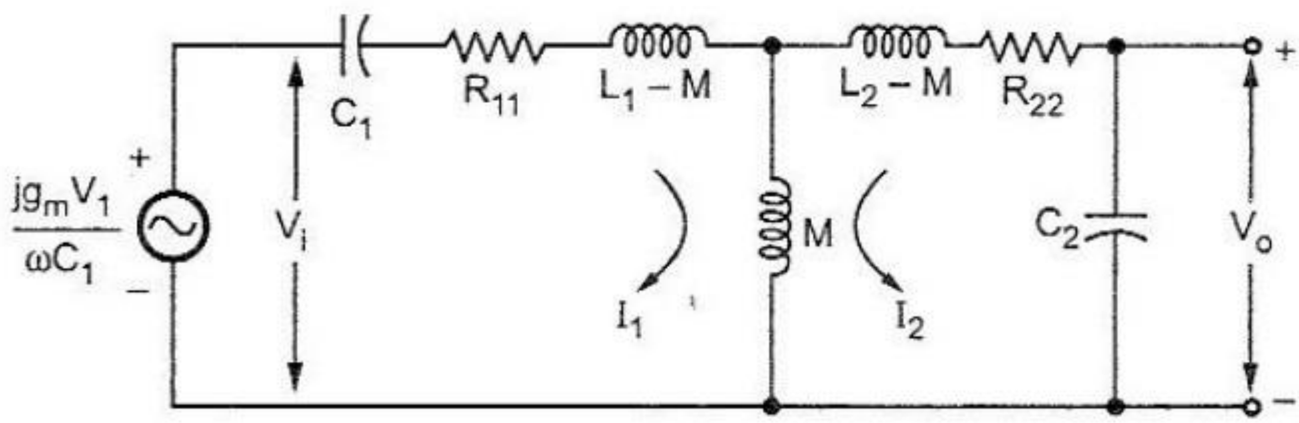
By proper adjustment of the coupling between the two coils of the two tuned circuits, the required results (High selectivity, high Voltage gain and required bandwidth) may be obtained.

Operation:

The high Frequency signal to be amplified is applied to the input terminal of the amplifier. The resonant Frequency of TUNED CIRCUIT connected in the Collector circuit is made equal to signal Frequency by varying the value of C1. Now the tuned circuit L1, C1 offers very high Impedance to input signal Frequency and therefore, large output is developed across it. The output from the tuned circuit L1,C1 is transferred to the second tuned circuit L2, C2 through Mutual Induction. Hence the Frequency response in Double Tuned amplifier depends on the Magnetic Coupling of L1 and L2

Equivalent circuit of double tuned amplifier:





$$\dot{Y}_T = \frac{kQ^2}{\omega_r \sqrt{L_1 L_2}\left[4Q\delta - j(1 + k^2Q^2 - 4Q^2\delta^2)\right]}$$

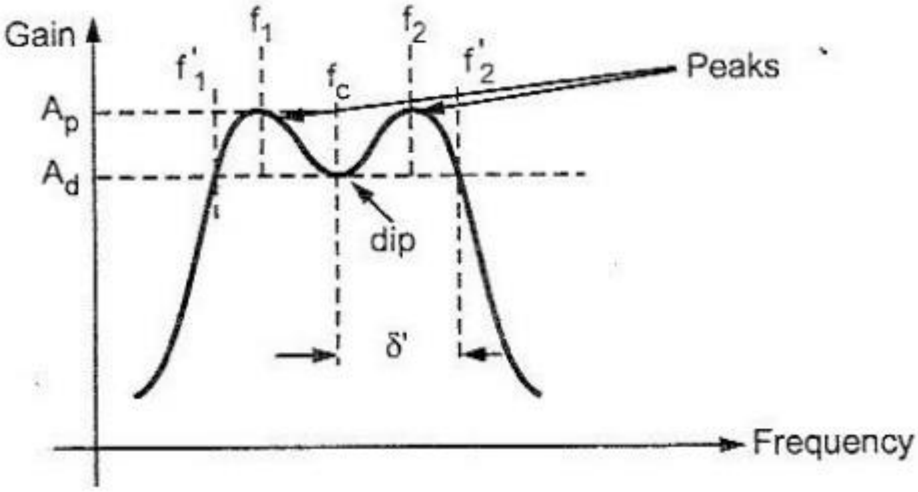
$$|A_v| = g_m \omega_r \sqrt{L_1 L_2}\, Q \frac{kQ}{\sqrt{1 + k^2Q^2 - 4Q^2\delta^2 + 16Q^2\delta^2}}$$

Two gain peaks in frequencies f_1 and f_2

$$f_1 = f_r\left(1 - \frac{1}{2Q}\sqrt{k^2Q^2 - 1}\right) \text{ and}$$

$$f_2 = f_r\left(1 + \frac{1}{2Q}\sqrt{k^2Q^2 - 1}\right)$$

This condition is known as critical coupling.



AT

$$k^2Q^2 = 1, \text{ i.e. } k = \frac{1}{Q}, f_1 = f_2 = f_r$$

For the values of k<1/Q the peak gain is less than the maximum gain and the coupling is poor. For the values k> 1/Q, the circuit is overcoupled and the response shows double peak. This double peak is useful when more bandwidth is required

The gain magnitude at peak is given as,

$$|A_p| = \frac{g_m \omega_o \sqrt{L_1 L_2}\ kQ}{2}$$

And gain at the dip at $\delta = 0$ is given as,

$$|A_d| = |A_p| \frac{2\,kQ}{1 + k^2Q^2}$$

The ratio of peak and dip gain is denoted as γ and it represents the magnitude of the ripple in the gain curve.

$$\gamma = \left|\frac{A_P}{A_d}\right| = \frac{1+k^2Q^2}{2\,kQ}$$

Using quadratic simplification and positive sign

$$kQ = \gamma + \sqrt{\gamma^2 - 1}$$

Bandwidth:

$$BW = 2\,\delta' = \sqrt{2}\,(f_2 - f_1)$$

At 3dB Bandwidth

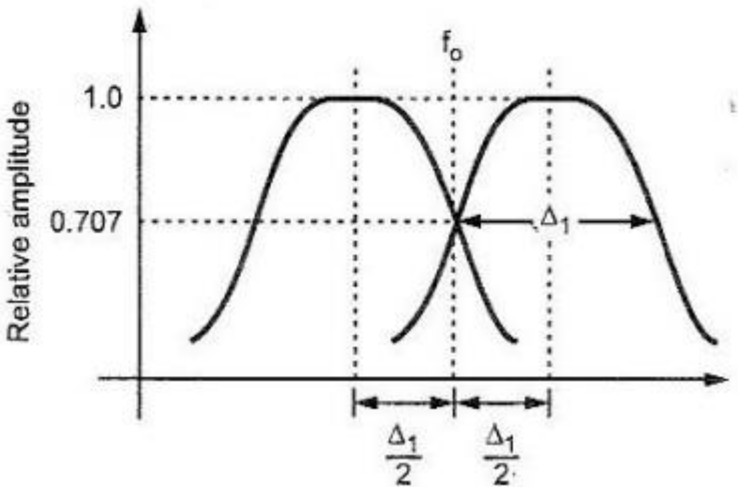
$$3\text{ dB BW} = \frac{3.1\,f_r}{Q}$$

3. Staggered tuned amplifier

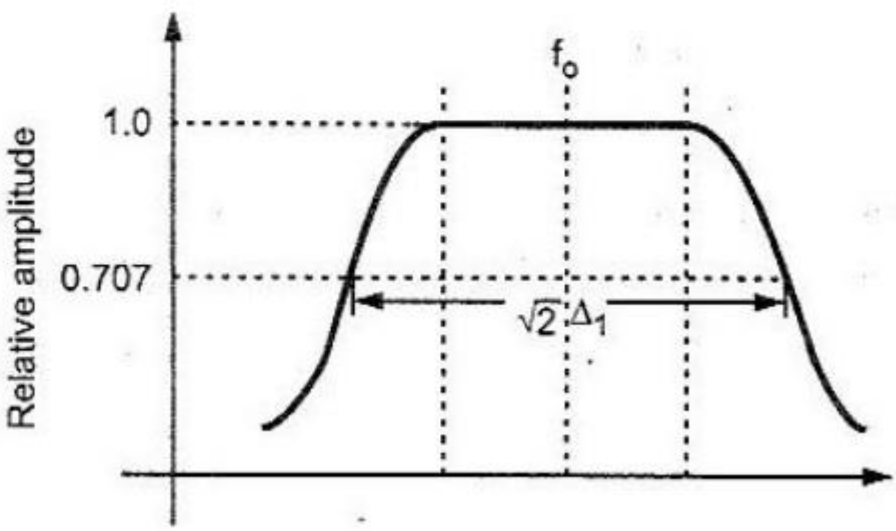
Double tuned amplifier gives greater 3 dB bandwidth having steeper sides and flat top. But alignment of double tuned amplifier is difficult.

To overcome this problem two single tuned cascaded amplifiers having certain bandwidth are taken and their resonant frequencies are so adjusted that they are separated by an amount equal to the bandwidth of each stage. Since the resonant frequencies are displaced or staggered, they are known as staggered tuned amplifiers. If it is desired to build a wide band high gain amplifier, one procedure is to use either single tuned or double tuned circuits which have been heavily loaded so as to increase the bandwidth.

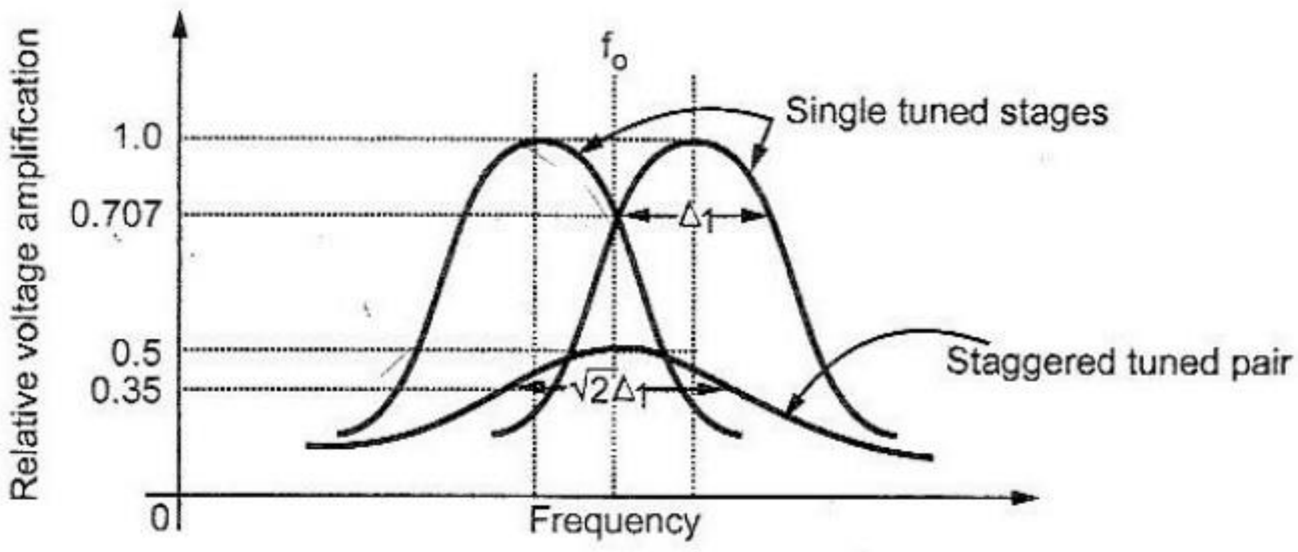
The gain per stage is correspondingly reduced, by virtue of the constant gain-bandwidth product. The use of a cascaded chain of stages will provide for the desired gain. Generally, for a specified gain and bandwidth the double tuned cascaded amplifier is preferred, since fewer tubes are often possible, and also since the pass-band characteristics of the double tuned cascaded chain are more favorable, falling more sensitive to variations in tube capacitance and coil inductance than the single tuned circuits.



Response of individual stages

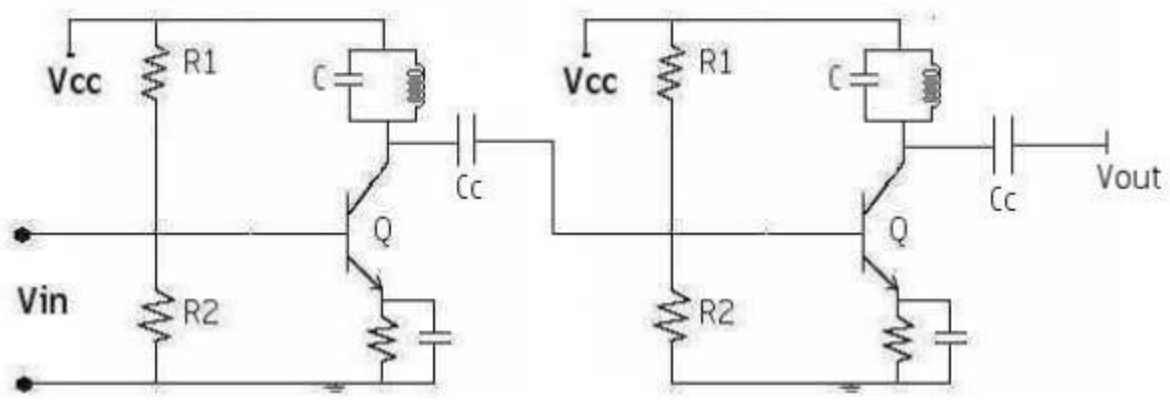


Overall response of synchronous amplifier



Comparison of single and synchronously tuned amplifier

Circuit diagram:



Stagger Tuned Amplifiers are used to improve the overall frequency response of tuned Amplifiers. Stagger tuned Amplifiers are usually designed so that the overall response exhibits maximal flatness around the centre frequency. It needs a number of tuned circuits operating in union. The overall frequency response of a Stagger tuned amplifier is obtained by adding the individual response together.

Since the resonant Frequencies of different tuned circuits are displaced or staggered, they are referred as STAGGER TUNED AMPLIFIER.

The main advantage of stagger tuned amplifier is increased bandwidth. Its Drawback is Reduced Selectivity and critical tuning of many tank circuits. They are used in RF amplifier stage in Radio Receivers.

Analysis:

Gain of the single tuned amplifier:

$$\frac{A_v}{A_v\ (\text{at resonance})_1} = \frac{1}{1 + j(X+1)}$$

$$\frac{A_v}{A_v\ (\text{at resonance})_2} = \frac{1}{1 + j(X-1)}$$

where $X = 2\,Q_{eff}\,\delta$

Gain of the cascaded amplifier:

$$\frac{A_v}{A_v\ (\text{at resonance})_{cascaded}} = \frac{A_v}{A_v\ (\text{at resonance})_1} \times \frac{A_v}{A_v\ (\text{at resonance})_2}$$

$$\left|\frac{A_v}{A_v\ (\text{at resonance})}\right|_{cascaded} = \frac{1}{\sqrt{4 + (2Q_{eff}\,\delta)^4}} = \frac{1}{\sqrt{4 + 16\,Q_{eff}^4\,\delta^4}}$$

$$= \frac{1}{2\sqrt{1 + 4\,Q_{eff}^4\,\delta^4}}$$

PART A

1. **What is a tuned amplifier?**

   [M/J – 10]

   The amplifier that amplifies only selected range of frequencies with the help of tuned circuits is called tuned amplifiers. In tuned amplifier circuit a single parallel tuned circuit acts as a load.

2. **Define unloaded Q.**

   [N/D – 10]

   When the tank circuit is not connected to any external circuit or load, Q accounts for the internal losses and it is known as unloaded quality factor Q_U .

   $Q_U = 2\pi \frac{Maximum\ energy\ stored\ per\ cycle}{Energy\ dissipated\ per\ cycle\ in\ tank\ circuit}$

3. **Define loaded Q.**

   [N/D – 10]

   When the tank circuit is connected to any external circuit or load, energy dissipation takes place in the tank circuit as well as in the external load, it is known as loaded quality factor Q_L.

   $Q_L = 2\pi \frac{Maximum\ energy\ stored\ per\ cycle}{(Energy\ dissipated\ per\ cycle\ in\ tank\ circuit + Energy\ dissipated\ per\ cycle\ due\ to\ the\ presence\ of\ external\ load)}$

4. **A tuned amplifier is designed to receive AM broadcast of speech signal at 650 kHz. What is needed Q for amplifier?**

   [N/D – 09]

   Given f_r = 650 kHz

   For AM broadcast speech signal = 3kHz

   Bandwidth = 2 f_m = 2 * 3 kHz = 6 kHz

   Therefore $Q = \frac{f_r}{BW} = \frac{650\ kHz}{6\ kHz} = 108.33$

5. **A tuned amplifier has resonant frequency of 1600kHz and bandwidth of 10kHz. What is needed Q for amplifier?**

   [M/J – 12]

   Given f_r = 1600 kHz BW = 10kHz

Therefore Q = $\frac{f_r}{BW} = \frac{1600kHz}{10\ kHz}$ = 160

6. What are the advantages and disadvantage of tuned amplifiers?

[M/J – 12]

The advantages of tuned amplifiers are

(i) They amplify defined frequencies.

(ii) Signal to noise ratio at output is good

(iii)They are suited for radio transmitters and receivers

The disadvantages of tuned amplifiers are

(i) The circuit is bulky and costly

(ii) The design is complex.

(iii)They are not suited to amplify audio frequencies.

7. What is a stagger tuned amplifier?

[N/D – 11]

Stagger tuned amplifiers use a number of single tuned stages in cascade, the successive tuned circuits being tuned to slightly different frequencies. It is a circuit in which two single tuned cascaded amplifiers having certain bandwidth are taken and their resonant frequencies are adjusted such that they are separated by an amount equal to the bandwidth of each stage. Since resonant frequencies are displaced it is called stagger tuned amplifier.

8. What is the effect of Q on the resonance circuit?

[N/D – 07]

Increase in Q reduces bandwidth and increases selectivity of the resonance circuit.

9. What are the various components of coil losses?

The various components of coil losses are

(i) Copper loss

(ii) Eddy current loss

(iii) Hysteresis loss

10. Define – Q factor

Q factor is the ratio of reactance to resistance. It is defined as the measure of efficiency with which a inductor can store energy.

Q = 2 π * (Maximum energy stored per cycle/ Energy dissipated per cycle)

11. What are the various types of tuned amplifiers?

(i) Small signal tuned amplifiers

a. Single tuned amplifiers

(1) Capacitive coupled

(2) Inductively coupled (or) Transformer coupled

b. Double tuned amplifiers

c. Stagger tuned amplifiers

(ii) Large signal tuned amplifiers

12. What are single tuned amplifiers?

Single tuned amplifiers use one parallel resonant circuit as the load impedance in each stage and all the tuned circuits are tuned to the same frequency.

13. What are double tuned amplifiers?

Double tuned amplifiers use two inductively coupled tuned circuits per stage, in which both tuned circuits are tuned to the same frequency.

14. What are the different types of neutralization?

The different types of neutralization are

1. Hazeltine neutralization
2. Rice neutralization
3. Neutrodyne neutralization.

15. What is the need for neutralization in tuned amplifiers? [N/D − 08]

Due to internal feedback in amplifier circuits, the overall gain of the amplifier reduces. Neutralization is one of the methods to make the amplifier unilateral i.e. to remove internal feedback of the amplifier. It is done to obtain the maximum gain from an amplifier. Neutralization is needed to remove this feedback and improve efficiency. The capacitance between the output element and the input element in the circuit will cause the output circuit to couple back to the input. If large enough, this regenerative feedback could cause a loss of efficiency.

16. What are the advantages of double tuned over single tuned?

The advantages of double tuned amplifier over single tuned amplifier are

(i) It possess flatter response having steeper sides

(ii) It provides larger 3 db bandwidth

(iii)It provides large gain-bandwidth product.