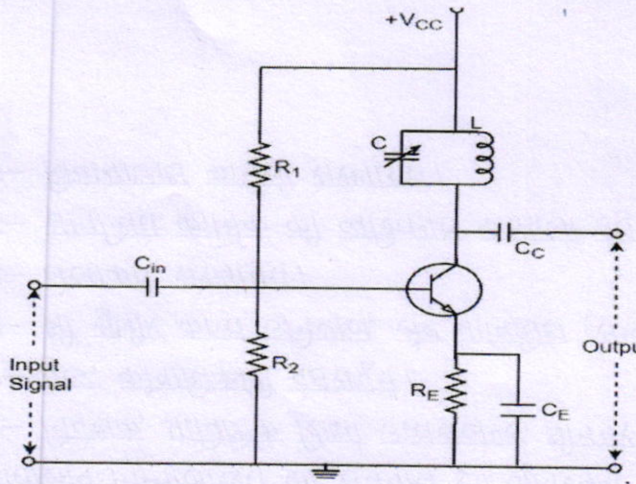
HAND OUT ON TUNED VOLTAGE AMPLIFIER

A- TUNED VOLTAGE AMPLIFIER

⇨ An amplifier used to amplify a selected frequency or a narrow band of frequencies, is known as Tuned voltage Amplifier.
⇨ Here load circuit is a tank circuit so that it can be tuned to pass or amplify selection of a desired frequency or a narrow band of frequencies.
⇨The phenomena of resonance as occurs in the tank circuit which is capable of selecting a particular or relative narrow band of frequencies, is used in such amplifier.
⇨ The resonant frequency of the tuned circuit is centre of selected frequency band .
⇨Basic Circuit of a tuned voltage amplifier is shown below:-



There are two main types of tuned amplifiers.
1- Single tuned amplifier
2- Double tuned amplifier

1- **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.

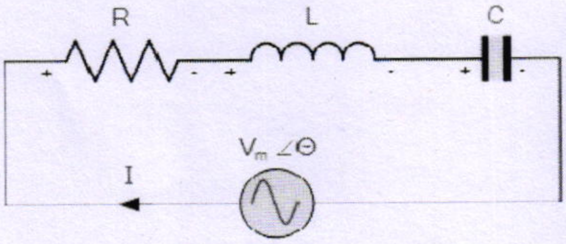
2-**Double tuned amplifier-** When two tuner circuits are used at collector of amplifier circuit, then such an amplifier is known as double tuned amplifier.

B-Resonance Circuits :

⇨ The phenomenon of resonance occurs only in ac circuits containing an inductance L and capacitance C with two element connected in series and parallel. The Circuit also contains resistance R which may the effective resistance of the coil L itself or a resistance deliberately introduced in the circuit for certain reason.
⇨When such a circuit is connected across an ac supply, in normal condition, the above parameters may behave as an inductive circuit or a capacitive circuit. However when at a particular supply frequency the inductive reactance becomes equal to capacitive reactance, the circuit then behaves as purely resistive circuit.
⇨In such situation, current supplied to the circuit is in phase with supply voltage & this phenomenon is called **resonance** and the corresponding frequency as **resonant frequency.**

B-1-Series resonant circuit and its bandwidth

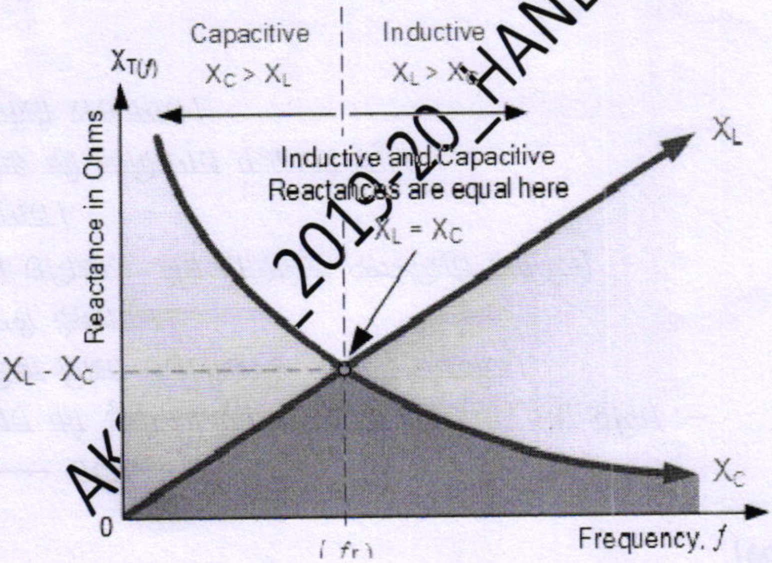
⇨ In a series resonant circuit, an inductor and a capacitor is connected in series across an ac source as shown in the diagram:



⇨At any frequency f of supply voltage, inductive reactance is given as $X_L = 2\pi f L$
Capacitive reactance $X_C = 1/ 2\pi f C$
Whereas total impedance of the circuit is given as

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

⇨As we see that both inductive & capacitive reactance (X_L & X_C) depends on supply frequency f. X_L is directly proportional to frequency f whereas X_C is inversely proportional to supply frequency f.
⇨The variation of X_L & X_C with respect to supply frequency is shown in the below graph:



⇨As we see in the graph, at particular frequency f_r both X_L & X_C are equal & at that point both curves intersect each other. The frequency at which $X_L = X_C$, is known as resonant frequency & value of f_r is calculated as :

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

B-2-Characteristics of Series resonant circuit

1-Impedance of series resonant circuit is minimum at resonant frequency & its value increases when frequency decreases or increases than the resonant frequency.
2- The magnitude of current flowing through series resonant circuit is inversely proportional to resistance of the series resonant circuit.
3- the Q value of series resonant circuit varies inversely with the circuit resistance where Q is known as quality factor of the circuit & defined as the ratio of voltage drop across L or C to the voltage drop across R at series resonance. This quality factor is a figure of merit.

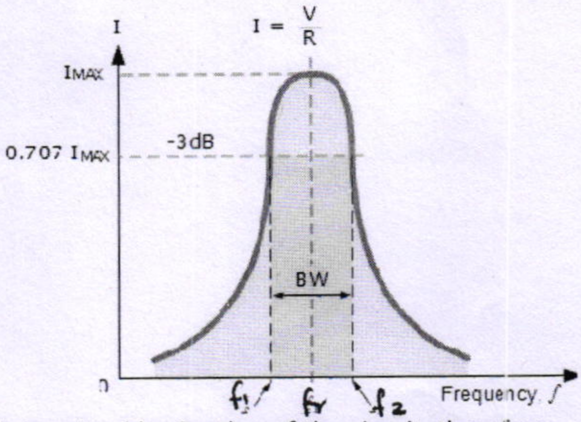
B-3- Bandwidth of series resonant circuit

⇨The range of frequency over which circuit current is equal to more than 70.7% of maximum circuit current at resonance is known as bandwidth of series resonant circuit.

⇨Typical series resonance circuit is shown adjacently. As shown, circuit current is equal to or greater than 70.7% of maximum current (I= V/R) between frequency range f_1 & f_2

Therefore Bandwidth BW= $f_2 - f_1$

⇨ BW represents the frequency range at which the circuit offers low impedance path.



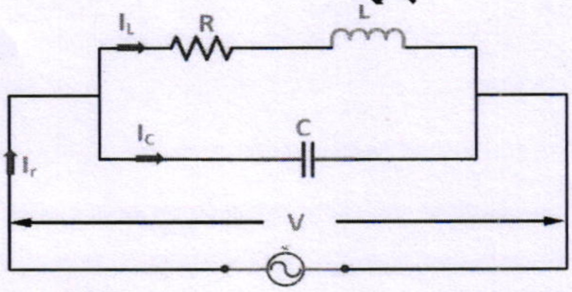
⇨As we know that steepness of the resonance curve is determined by Q value of the circuit, therefore bandwidth of series resonant circuit may also be decided in terms of resonant frequency & Q value by the following relation:

$$BW = f_2 - f_1 = f_r / Q$$

⇨ It shows that higher the value of Q, smaller the value of bandwidth of a series resonant circuit.

C-1-Parallel resonant circuit and its bandwidth

⇨ In a parallel resonant circuit, an inductor and a capacitor is connected in parallel across an ac source as shown in the diagram:



⇨Frequency of supply voltage can be varied and at any stage if this frequency is equal to natural or resonance frequency of LC circuit, then resonance will occur.

⇨In such condition, the impedance of tuned circuit becomes maximum & the circuit draws a minimum current from the source.

⇨Assume that current drawn by inductor is I_L & that by capacitor is Ic & I_L lags behind the voltage by some angle say ϕ_L. At resonance the resultant current I drawn by the circuit must be in phase with the applied voltage.

⇨ If f_r is resonance frequency then in LC parallel tuned circuit, the condition of resonance is obtained when : $I_c = I_L \sin \phi_L$

Where $I_L = V/Z_L$, $\sin \phi_L = X_L/Z_L$ and $I_c = V/X_c$

Therefore, $V/X_c = V/Z_L \times X_L/Z_L$

Or $Z_L^2 = X_L . X_c$

Or $(R^2 + X_L^2) = X_L . X_c$

Or $R^2 + (2\pi f_r L)^2 = 2\pi f_r L/2\pi f_r C = L/C$

$$\text{Or } (2\pi f_r L)^2 = L/C - R^2$$

⇨ Usually value of R being very small, can be neglected & then Resonant frequency for a parallel tuned circuit is given as :

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

C-2-Characteristics of Parallel resonant circuit

1-Impedance of parallel resonant circuit is maximum at resonant frequency & its value decreases rapidly when frequency is changed above or below the resonant frequency. This quality makes parallel resonant circuit good for selecting desired frequency & rejecting unwanted frequency.

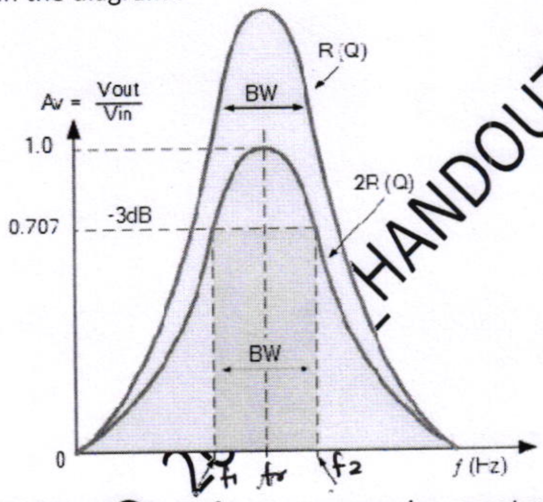
2- The magnitude of current flowing through parallel resonant circuit is very small at resonant frequency & its value changes rapidly when frequency is changed above or below resonant frequency.

3- The most important characteristic of a parallel resonant circuit is its property of selectivity, which in turn depends on the sharpness of resonance curve. Sharpness is decided by Q factor which varies inversely with the circuit resistance. Here Q is defined as the ratio of inductive reactance of coil at resonance to its resistance.

C-3- Bandwidth of Parallel resonant circuit

⇨ The bandwidth of a parallel resonance circuit is defined in exactly the same way as for the series resonance circuit and is given as $BW = f_2 - f_1$

⇨Where f_2 is upper and f_1 is lower cut-off frequencies & are equal to 70.7% of its maximum resonant value, $(0.707 \times I)^2 R$ as shown in the diagram :



⇨As with the series circuit, if the resonant frequency remains constant, an increase in the quality factor, **Q** will cause a decrease in the bandwidth and likewise, a decrease in the quality factor will cause an increase in the bandwidth as defined by:

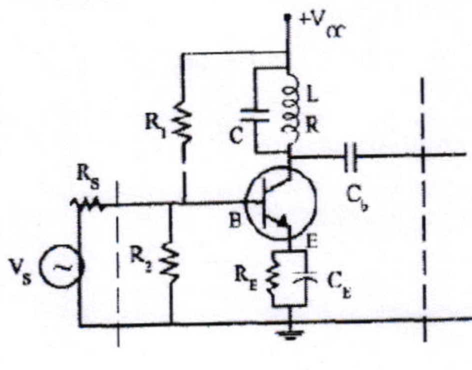
$$BW = f_r / Q \quad \text{or} \quad BW = f_2 - f_1$$

⇨Also changing the ratio between the inductor, L and the capacitor, C, or the value of the resistance, R the bandwidth and therefore the frequency response of the circuit will be changed for a fixed resonant frequency.

⇨ This technique is used extensively in tuning circuits for radio and television transmitters and receivers.

D-Single Tuned Amplifier and its frequency response characteristics

⇨ Single Tuned Amplifier is shown below where a parallel resonant circuit is connected in the collector :



⇨ Usually the capacitor used in resonant circuit is variable & value of L & C is chosen in such a way that resonant frequency is equal to frequency of signal to be amplified.

⇨The biasing network used is designed for class-C operation. The output of the amplifier may be obtained in either of two ways:

1- By a coupling capacitor

2- By a secondary coil magnetically coupled to inductive coil of the resonant circuit.

⇨The voltage gain of a single tuned amplifier is given by the following Expression:

$$A = \beta Z_r / r_i$$

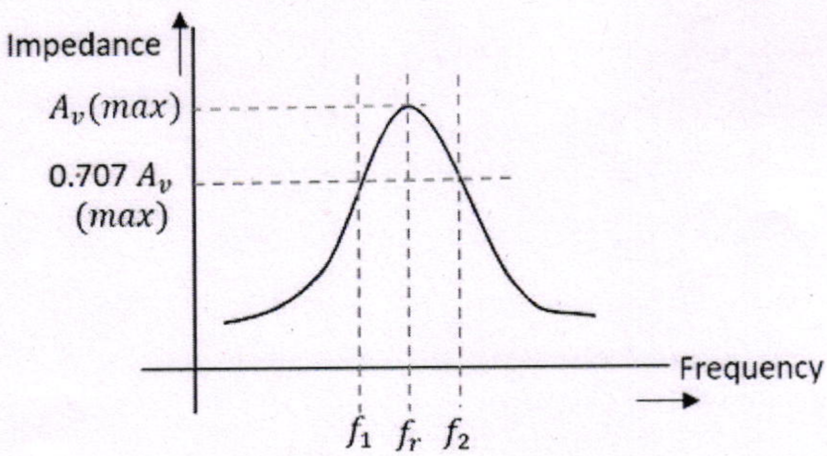
where β = Current amplification factor of transistor

Z_r = Impedance of the resonant circuit at resonant frequency

r_i = Input resistance of the transistor

⇨ The voltage gain of this amplifier is very high since impedance of parallel resonant circuit at resonant frequency .

⇨ **FREQUENCY RESPONSE :** The graph drawn between voltage gain & frequency is known as frequency response curve . The frequency response curve of single tuned amplifier is shown below:



⇨As the impedance of the resonant circuit is maximum at resonant frequency, the voltage gain will also be maximum at this frequency.

⇨The voltage gain decreases when frequency varies on either side of the resonant frequency.

⇨ The range of frequency over which gain of the amplifier is equal to more than 70.7% of maximum value of voltage gain is known as bandwidth & is given as

$$BW = f_r / Q$$

⇨ A high Q- factor circuit will give a high Av but at the same time , it will give much reduced band with because bandwidth is inversely proportional to the Q- factor .

ADVANTAGE OF SINGLE TUNED AMPLIFIER:

1- Less power loss due to the lack of collector resistance.

2- High Selectivity.

DISADVANTAGE OF SINGLE TUNED AMPLIFIER:

Gain bandwidth product is small

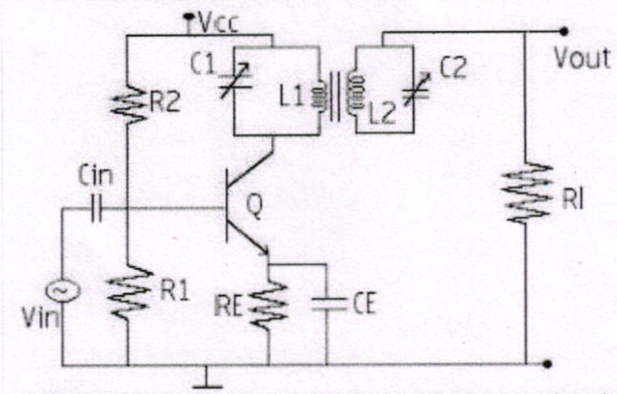
APPLICATIONS OF SINGLE TUNED AMPLIFIER

1-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.

2- This amplifier can be used in television circuits.

E- Double tuned voltage amplifier and its frequency response characteristics

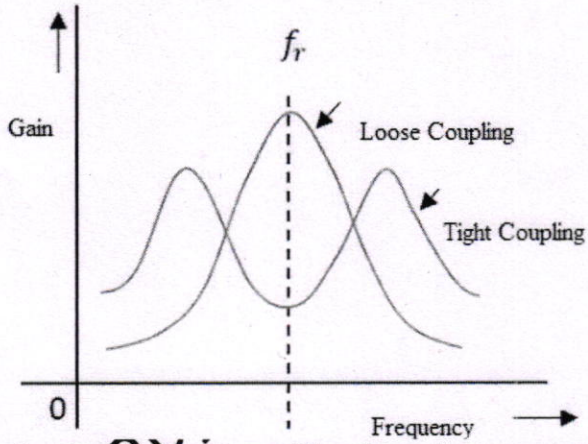
⇨ The circuit arrangement of double tuned voltage amplifier is same as single tuned voltage amplifier except the difference that now instead of one tuned circuit, two tuned circuits - one L_1-C_1 in the collector & other L_2 -C_2 in the output are used as shown in the below diagram:



⇨ 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.

⇨ **FREQUENCY RESPONSE :** The graph drawn between voltage gain & frequency is known as frequency response curve . The frequency response curve of single tuned amplifier is shown below:



⇨The frequency response of a double tuned amplifier depends upon degree of magnetic coupling or coefficient of coupling between the two coils L_1 & L_2 .In fact, the load resistance is transferred to collector through this coupling & it affects frequency response curve.

⇨ In case the two coils are spaced separately, the primary coil's (L_1) flux linkages will not link to the secondary coil (L_2) . At this state, these coils have loose coupling. The reflected resistance from the L2 coil on this state is minute & the resonance curve is sharp.

⇨When the two coils are arranged together, then they have tight coupling. Below these forms, the reflected resistance will be huge & the curve is lesser.

⇨ The bandwidth of this amplifier is shown in the above figure which states that the BW rises by the amount of coupling. In a double-tuned circuit, the determining factor is not Q, rather it is coupling. & also when for certain frequency, the coupling is tighter, the bandwidth will be greater

Advantages of Double Tuned Amplifier

1- Narrow bandwidth.

2- Increased Sensitivity with gain

3- Improved Selectivity

Disadvantages of Double Tuned Amplifier

1- Not suitable for amplification of audio frequencies

2- Due to use of elements like capacitor & inductor, the circuit is costly & bulky.

Applications of Double-tuned Amplifier

1- In super heterodyne receiver & satellite transponder as an IF (intermediate frequency) amplifier.

2- Used within UHF radio relay systems.

3- Used as extremely narrow-band intermediate frequency amplifier in a spectrum analyzer.