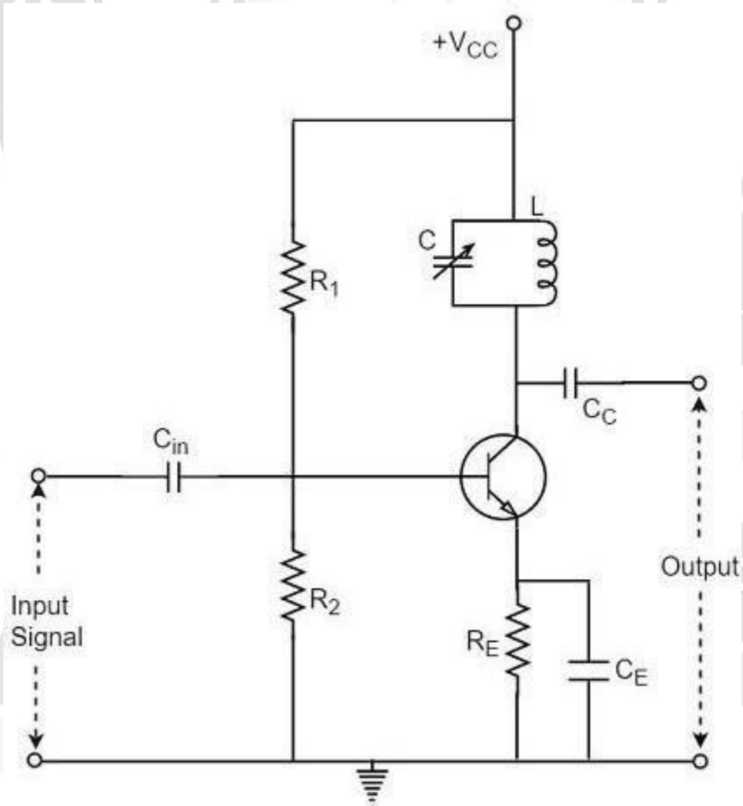
SINGLE TUNED AMPLIFIER

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

CONSTRUCTION

A simple transistor amplifier circuit consisting of a parallel tuned circuit inits 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.In single tuned amplifier circuit the output can be obtained from the couplingcapacitor CC as shown above or from a secondary winding placed at L.



[Ref:Robert L. Boylestad and Louis Nasheresky, "Electronic Devices and Circuit Theory", 10th Edition, Pearson Education / PHI, 2008]

OPERATION

The high frequency signal that has to be amplified is applied at the input of the amplifier. The resonant frequency of the parallel tuned circuit is made equal to the frequency of the signal applied by altering the capacitance value of the capacitor C,in the tuned circuit. At this stage, the tuned circuit offers high impedance to the signal frequency, which helps to offer high output across the tuned circuit.As high impedance is offered only for the tuned frequency, all the other frequencies which get lower impedance are rejected by the tuned circuit. Hence the tuned amplifier selects and amplifies the desired frequency signal.

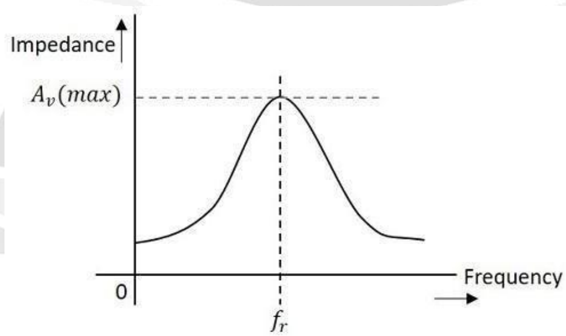
FREQUENCY RESPONSE

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 following 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 be the curve.

$$Y_1 = \frac{1}{r_c + j\omega L} = \frac{r_c - j\omega L}{r_c^2 + \omega^2 L^2}$$

$$\approx \frac{r_c}{r_c^2 + \omega^2 L^2} - \frac{j\omega L}{r_c^2 + \omega^2 L^2}$$

$$Y_1 = \frac{r_c}{\omega^2 L^2} + \frac{1}{j\omega L}$$

$$Y_2 = \frac{1}{R_p} + \frac{1}{j\omega L}$$

$$R_p = r_c Q_c^2 = \omega L Q_c$$

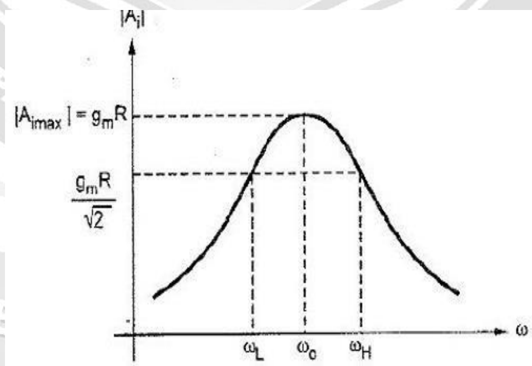
$$R = r_i \parallel R_p \parallel r_{b'e}$$

$$A_i = \frac{-g_m R}{1 + j(\omega RC - R/\omega L)} = \frac{-g_m R}{1 + j\omega_o RC(\omega/\omega_o - \omega_o/\omega)}$$

$$Q_i = \frac{R}{\omega_o L} = \omega_o RC$$

$$A_i = \frac{-g_m R}{1 + jQ_i(\omega/\omega_o - \omega_o/\omega)}$$

$$A_{i\,(max)} = -g_m R$$



At 3 db frequency

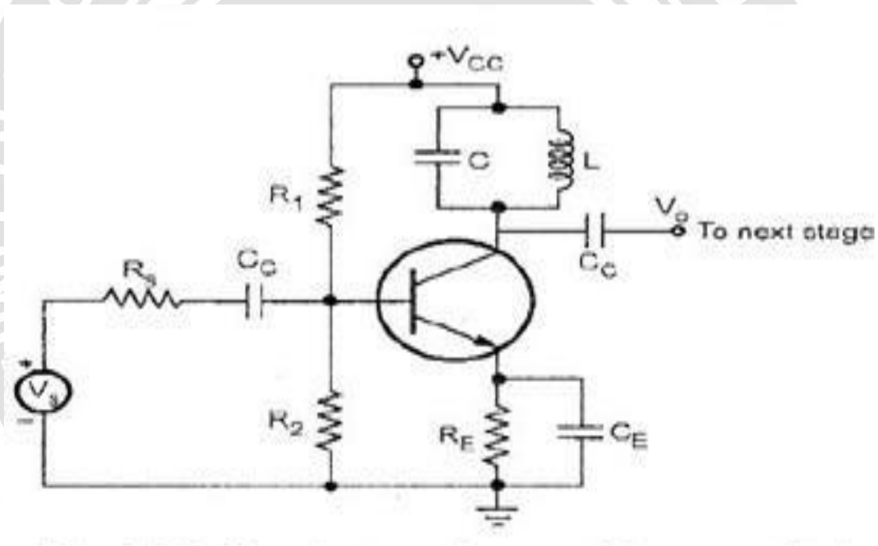
$$|A_i| = \frac{g_m R}{\sqrt{2}}$$

$$1 + Q_i^2\left(\frac{\omega}{\omega_o} - \frac{\omega_o}{\omega}\right)^2 = 2$$

$$BW = \frac{1}{2\pi RC}$$

Single Tuned Capacitive Coupled Amplifier:

Single Tuned multistage amplifier circuit uses one parallel tuned circuit as a load in each stage with tuned circuits in all stages tuned to same frequency. Fig shows a typical single tuned amplifier in CE configuration. As shown in Fig. tuned circuit formed by L and C acts ascollector load and resonates at frequency of operation. Resistors R_1,R_2 and R_E along with capacitor C_E provides self bias for the circuit.



[Robert L. Boylestad and Louis Nasheresky, "Electronic Devices and Circuit Theory", 10th Edition, Pearson Education / PHI, 2008]

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

Equivalent capacitance

Output conductance

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

Admittance

$$= \frac{1}{R_p} + \frac{1}{j\omega L_p}$$

Resonant frequency

$$f_r = \frac{1}{2\pi\sqrt{L_p C_{eq}}}$$

DOUBLE TUNED AMPLIFIER

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

CONSTRUCTION

The construction of double tuned amplifier is understood by having a look at the following figure. This circuit consists of two tuned circuits L_1C_1 and L_2C_2 in the collector section of the amplifier. The signal at the output of the tuned circuit L_1C_1 is coupled to the other tuned circuit L_2C_2 through mutual coupling method. The remaining circuit details are same as in the single tuned amplifier circuit, as shown in the following circuit diagram.

Fig shows double tuned RF amplifier in CE configuration. Here, voltage developed across tuned circuit is coupled inductively to another tuned circuit. Both tuned circuits are tuned to the same frequency. The double tuned circuit can provide a bandwidth of several percent of the resonant frequency and gives steep sides to the response curve. Let us analyze the double tuned circuit. The Fig. shows the coupling section of a transformer coupled double tuned amplifier and equivalent circuit for it, in which transistor is replaced by the current source with its output resistance (R_o).

The C_1 and L_1 are the tank circuit components of the primary side. The resistance R_1 is the series resistance of the inductance L_1. Similarly on the second side L_2 and C_2 represent the tank circuit components of the secondary side and R_2 represents resistance of the inductance L_2. The resistance R_i represents the input resistance of the next stage.

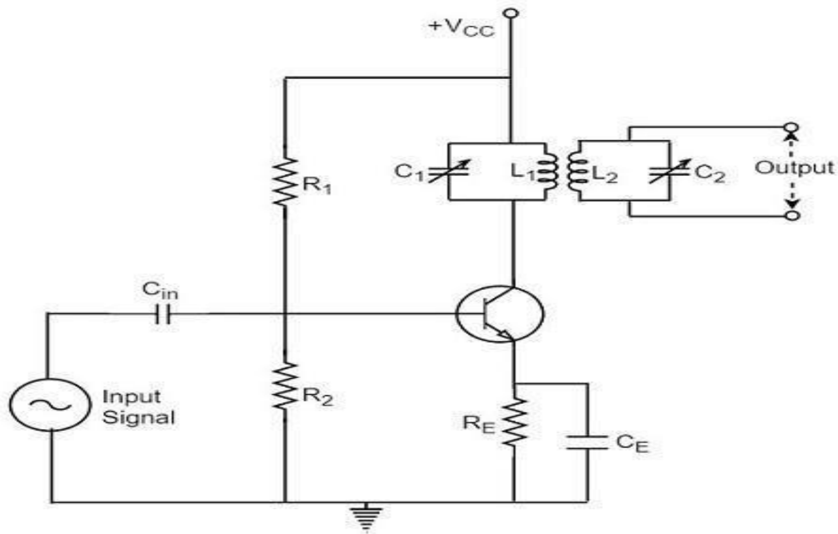


Fig. 2 Double Tuned Amplifier

[Ref:Robert L. Boylestad and Louis Nasheresky, "Electronic Devices and Circuit Theory", 10th Edition, Pearson Education / PHI, 2008]

OPERATION

The high frequency signal which has to be amplified is given to the input of the amplifier. The tuning circuit L_1C_1 is tuned to the input signal frequency. At this condition, the tuned circuit offers high reactance to the signal frequency. Consequently, large output appears at the output of the tuned circuit L_1C_1 which is then coupled to the other tuned circuit L_2C_2 through mutual induction. These double tuned circuits are extensively used for coupling various circuits of radio and television receivers.

FREQUENCY RESPONSE OF DOUBLE TUNED AMPLIFIER

The double tuned amplifier has the special feature of coupling which is important in determining the frequency response of the amplifier. The amount of mutual inductance between the two tuned circuits states the degree of coupling, which determines the frequency response of the circuit. In order to have an idea on the mutual inductance property, let us go through the basic principle.

For an amplifier to be efficient, its gain should be high. This voltage gain depends upon β, input impedance and collector load. The collector load in a tuned amplifier is a tuned circuit.

The voltage gain amplifier is given

$$\text{Voltage gain} = Bz_C/Z_{in}$$

Where Z_C = effective collector load and Z_{in} = input impedance of the amplifier.

The value of Z_C depends upon the frequency of the tuned amplifier. As Z_C is maximum atresonant frequency, the gain of the amplifier ismaximum at this resonant frequency.

COUPLING

Under the concept of mutual inductance coupling will be as shown in the figure below. When the coils are spaced apart, the flux linkages of primarycoil L_1 will not link the secondary coil L_2. At this condition, the coils are said to have Loose coupling.

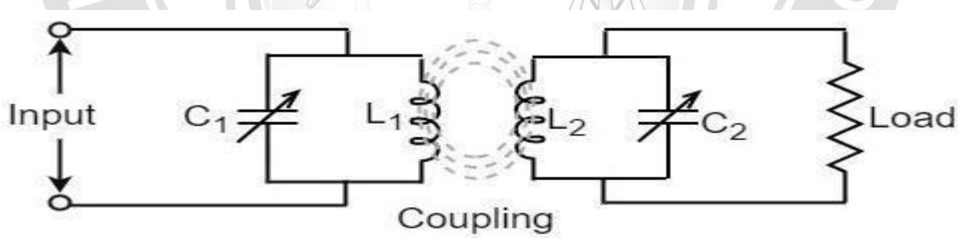
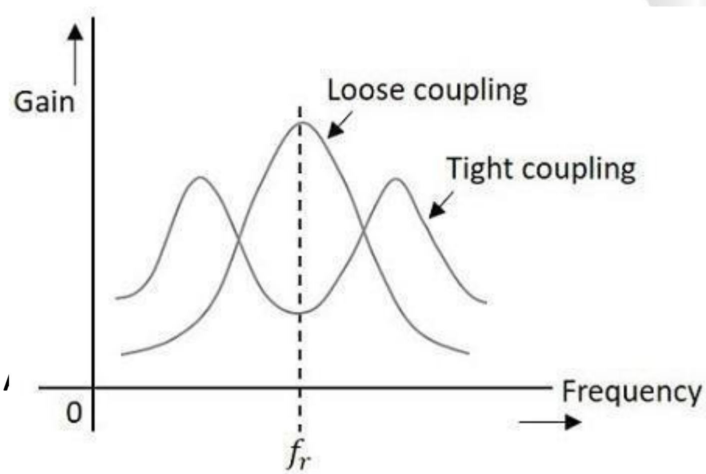


Fig.3. Coupling

The resistance reflected from the secondary coil at this condition is small and the resonance curve will be sharp and the circuit Q is high as shown inthe figure below.



On the contrary, when the primary and secondary coils are brought close together, they have Tight coupling. Under such conditions, the reflected resistance will be large and the circuit Q is lower.Two positions of gain maxima, one above and the other below the resonant frequency are obtained.

BANDWIDTH OF DOUBLE TUNED CIRCUIT

- The above figure clearly states that the bandwidth increases with the degree ofcoupling.
- The determining factor in a double tuned circuit is not Q but the coupling.
- We understood that, for a given frequency, the tighter the coupling the greater thebandwidth will be.
- The equation for bandwidth is given as

$$BW_{dt} = kf_r$$

Where

BW_{dt} = bandwidth for double tuned circuit,

K = coefficient of coupling, andf_r = resonant frequency.

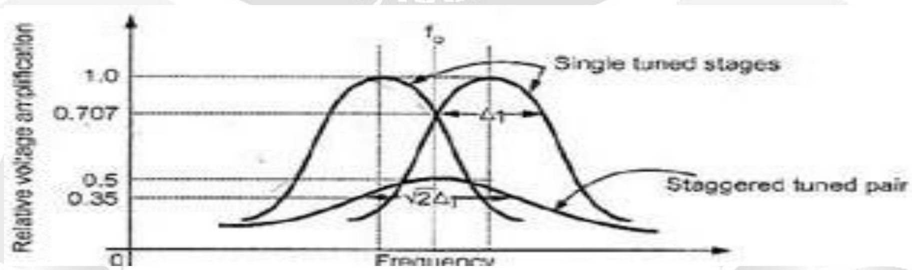


Fig.4 Band width

Q factors of double tuned circuit

$$Q_1 = \frac{\omega_r L_1}{R_{11}} \text{ and } Q_2 = \frac{\omega_r L_2}{R_{22}}$$

Output Voltage

$$V_o = -\frac{j}{\omega_r C_2} I_2$$

Transfer Admittance

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

Voltage Gain (Av)

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

Frequencies

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

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

Gain Magnitude

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

The 3 dB bandwidth for single tuned amplifier is $2f_r$ / Q. Therefore, the 3 dB bandwidth provided by double tuned amplifier (3.1ff / Q) is substantially greater than the 3 dB bandwidth of single tuned amplifier.

Compared with a single tuned amplifier, the double tuned amplifier,

1. Possesses a flatter response having steeper sides.
2. Provides larger 3 dB bandwidth.
3. Provides large gain-bandwidth product.

Effect of cascading Single Tuned Amplifier on Bandwidth:

- In order to obtain a high overall gain, several identical stages of amplifiers can be used in cascade.
- The overall gain is the product of the voltage gains of the individual stages.

Effect of cascading Double Tuned Amplifiers on Bandwidth:

- When a number of identical double tuned amplifier stages are connected in cascade, the overall bandwidth, of the system is thereby narrowed and the steepness of the sides of the response is increased, just as when single tuned stages are cascaded.
- The quantitative relation between the 3 dB bandwidth of n identical double tuned critically coupled stages compared with the bandwidth Δ2 of such a system can be shown to be 3 dB bandwidth for n identical stages double tuned amplifiers is,

$$\Delta_2 \times \left(2^{\frac{1}{n}} - 1\right)^{\frac{1}{4}}$$

where Δ2 is the 3 dB bandwidth of single stage double tuned amplifier. The above equation assumes that the bandwidth Δ2 is small compared with the resonant frequency.