UNIT III  TUNED AMPLIFIERS

Coil losses, unloaded and loaded Q of tank circuits, small signal tuned amplifiers - Analysis of capacitor coupled single tuned amplifier - Double tuned amplifier - Effect of cascading single tuned and double tuned amplifiers on bandwidth - Stagger tuned amplifiers - Stability of tuned amplifiers - Neutralization - Hazeltine neutralization method.

3.3. Classification of Tuned Amplifier:

We know that, multistage amplifiers are used to obtain large overall gain. The cascaded stages of multistage tuned amplifiers can be categorized as given below:

1. Single Tuned Amplifiers
2. Double Tuned Amplifiers
3. Stagger Tuned Amplifiers

These amplifiers are further classified according to coupling used to cascade the stages of multistage amplifier. They are,

1. Capacitive Coupled
2. Inductive Coupled
3. Transformer Coupled

3.3.1. 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 L₁C₁ and L₂C₂ in the collector section of the amplifier.

- The signal at the output of the tuned circuit L₁C₁ is coupled to the other tuned circuit L₂C₂ 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.

- The Fig. shows the equivalent circuit for it, in which transistor is replaced by the current source with its output resistance (R_o). The C_i and L_i are the tank circuit components of the primary side.

- The resistance R_i is the series resistance of the inductance L_i. 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_e represents the input resistance of the next stage.

Fig 3.3.1 Double Tuned Amplifier

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.

3.3.2. 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 \( \beta \), input impedance and collector load. The collector load in a tuned amplifier is a tuned circuit.

The voltage gain amplifier is given

\[
\text{Voltage gain} = \frac{B_{zc}}{Z_{in}}
\]

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 at resonant frequency, the gain of the amplifier is maximum at this resonant frequency.

3.3.3. MUTUAL INDUCTANCE

As the current carrying coil produces some magnetic field around it, if another coil is brought near this coil, such that it is in the magnetic flux region of the primary, then the varying magnetic flux induces an EMF in
the second coil. If this first coil is called as Primary coil, the second one can be called as a Secondary coil.

- When the EMF is induced in the secondary coil due to the varying magnetic field of the primary coil, then such phenomenon is called as the Mutual Inductance.

- The figure below gives an idea about this.

![Fig.3.3.3. Mutual Inductance](image)

- The current $i_s$ in the figure indicate the source current while $i_{ind}$ indicates the induced current.

- The flux represents the magnetic flux created around the coil. This spreads to the secondary coil also.

- With the application of voltage, the current $i_s$ flows and flux gets created.

- When the current is varies the flux gets varied, producing $i_{ind}$ in the secondary coil, due to the Mutual inductance property.

### 3.3.4. 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 primary coil $L_1$ will not link the secondary coil $L_2$. At this condition, the coils are said to have Loose coupling.

![Fig.3.3.4. Coupling](image)
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 in the 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.

3.3.5. BANDWIDTH OF DOUBLE TUNED CIRCUIT

The above figure clearly states that the bandwidth increases with the degree of coupling.

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 the bandwidth 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, and \( f_r \) = resonant frequency.
Q factors of double tuned circuit

\[ \frac{Q_1}{Q} = \frac{\alpha_1}{L_1} \quad \text{and} \quad \frac{Q_2}{Q} = \frac{\omega_2}{L_2} \]

Output Voltage

\[ V_o = -\frac{j}{\omega_c C_2 I_2} \]

Transfer Admittance

\[ Y_1 = \frac{kQ^2}{\omega_c \sqrt{L_1 L_2}} \left[ \frac{4Q \delta - j (1 + k^2Q^2 - 4 Q^2 \delta^2)}{4 Q \delta - j (1 + k^2Q^2 - 4 Q^2 \delta^2)} \right] \]

Voltage Gain (Av)

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

Frequencies

\[ f_1 = f_r \left( 1 - \frac{1}{2Q} \sqrt{k^2Q^2 - 1} \right) \quad \text{and} \]
\[ f_2 = f_r \left( 1 + \frac{1}{2Q} \sqrt{k^2Q^2 - 1} \right) \]

Gain Magnitude

\[ |A_v| = \frac{g_m \omega_c \sqrt{L_1 L_2} kQ}{2} \]

➢ We know that, the 3 dB bandwidth for single tuned amplifier is \( 2f_r / Q \). Therefore, the 3 dB bandwidth provided by double tuned amplifier \( (3.1f_r / Q) \) 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.

### 3.3.6. 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. Let us see the effect of cascading of stages on bandwidth.

### 3.3.7. 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 $\Delta_2$ of such a system can be shown to be 3 dB bandwidth for n identical stages double tuned amplifiers is,

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

where $\Delta_2$ is the 3 dB bandwidth of single stage double tuned amplifier. The above equation assumes that the bandwidth $\Delta_2$ is small compared with the resonant frequency.