8th April

UNIT-5 TUNED AMPLIFIER

Introduction:

Voltage amplifiers are used at short distance communication because it handles small signals (audio frequency)

For long distance communications we use tuned amplifier.

It is an amplifier which amplifies band of frequencies, other than this band, signals will get distorted.

Tuned amplifiers are also called as narrow band frequency amplifiers

Types of Tuned Amplifiers:

i) single Tuned Amplifier
- single tuned capacitive coupled Amplifier
- Single tuned transformer coupled amplifier

ii) Double tuned amplifier

iii) stagger tuned amplifier

Single Tuned Amplifier:

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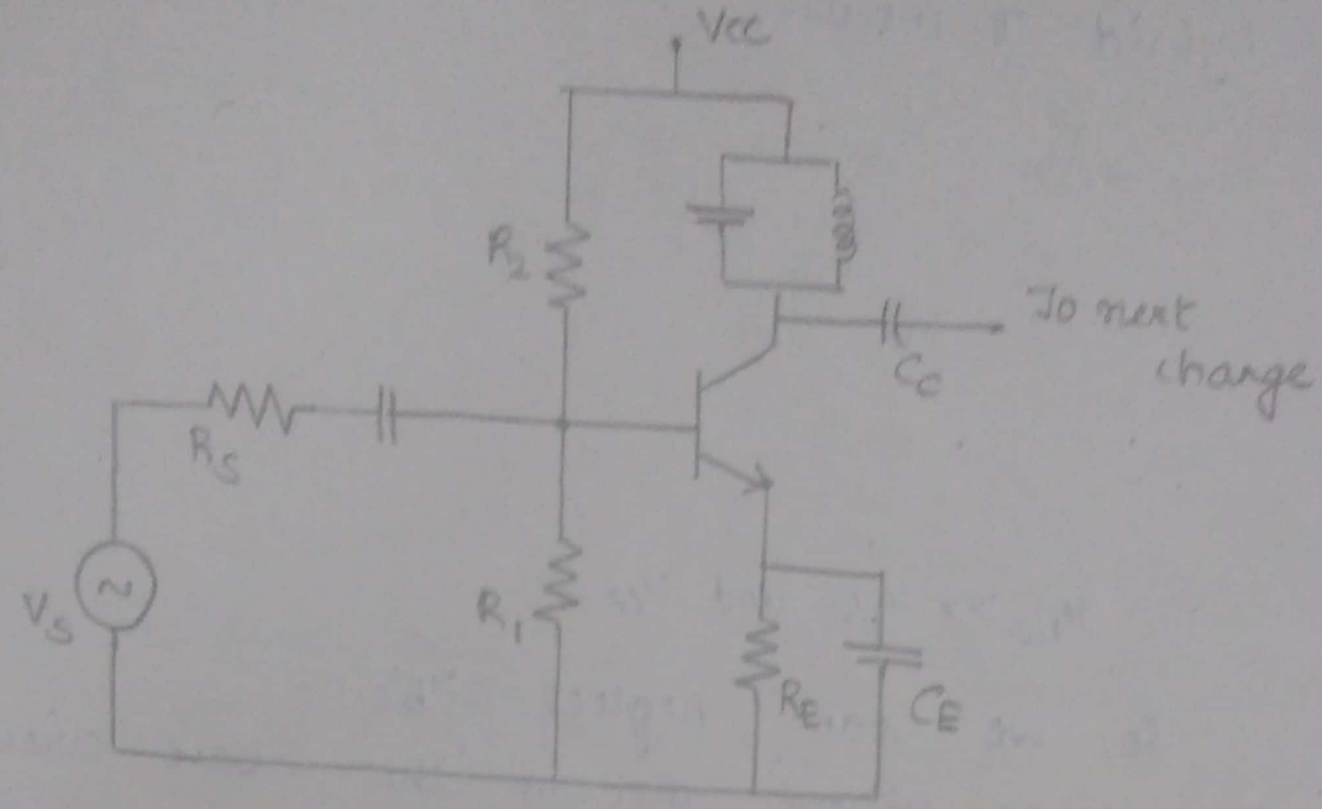
It is a tuned amplifier which consists of only one tank circuit or one tuned circuit. (1 inductor, 1 capacitor).

There are of two types

i) single tuned Capacitive coupled Amplifier

ii) single tuned transformer coupled amplifier



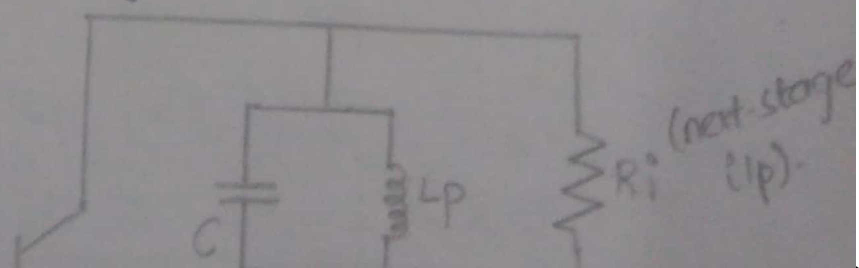
Above circuit shows single tuned amplifier. It consists of one tank circuit.

Here R_1 and R_2 provides proper biasing to the circuit, and R_E provides stability to the circuit.

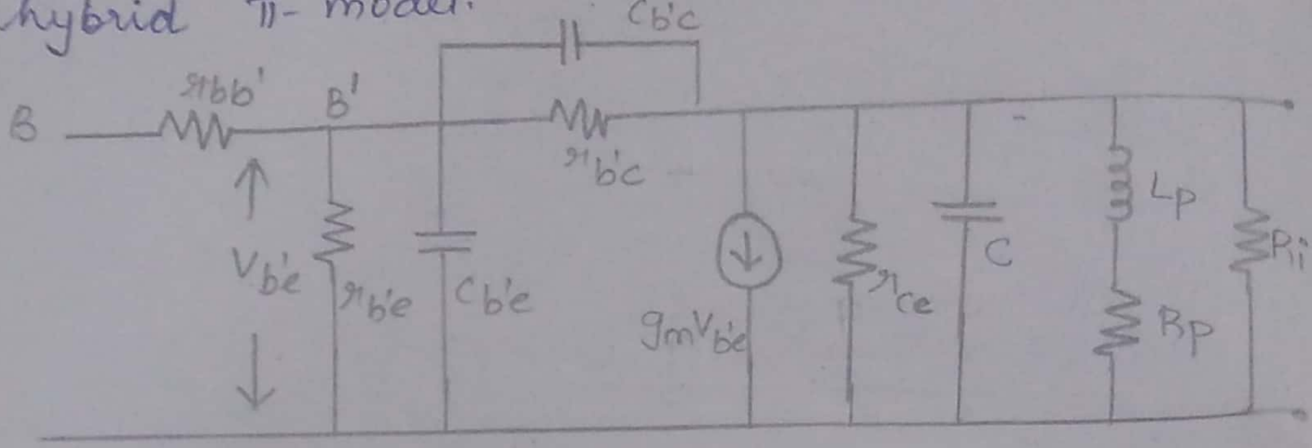
When input signal frequency is equal to tank circuit frequency, then the input signal gets amplified and appeared across output terminals.

If input signal frequency ≠ tank circuit frequency, input signal gets distorted.

Analysis:



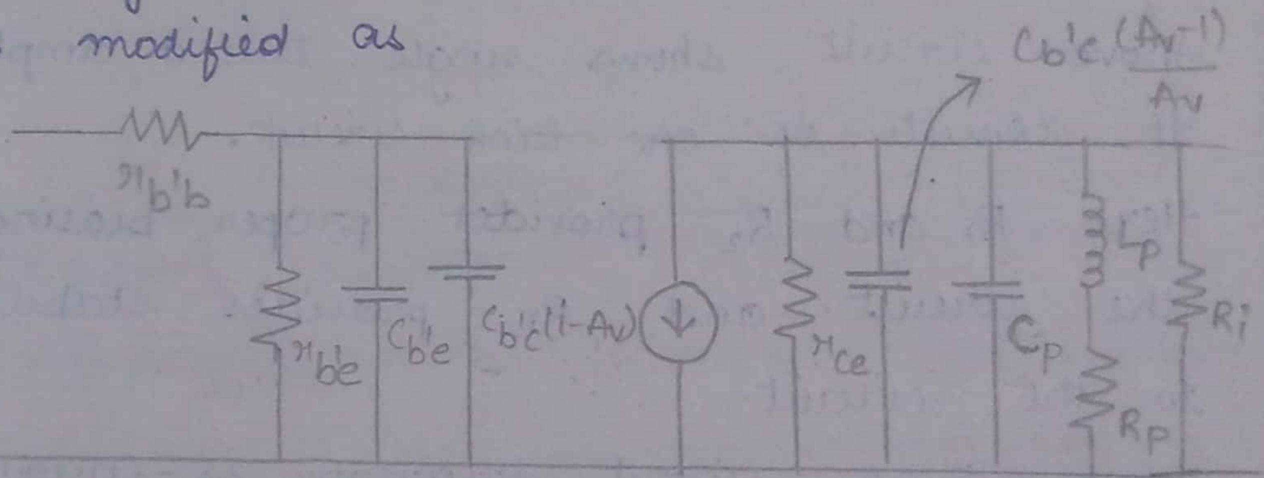
By replacing transistor with its equivalent hybrid π- model.



$r_{b'c} >> r_{b'e}$ and r_{ce}

So, we can neglect $r_{b'c}$

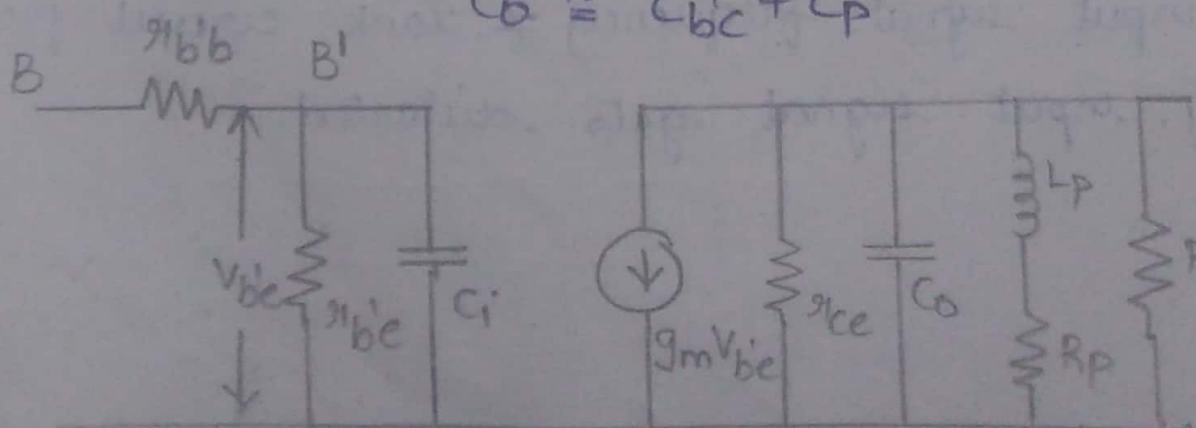
By using Millers theorem the above circuit is modified as



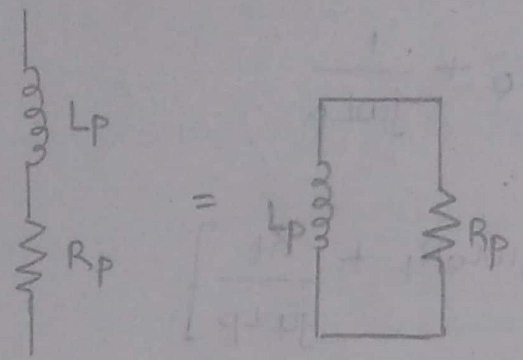
$$C_i = C_{b'e} + C_{b'c}(1-A_V)$$

$$C_o = C_{b'c}\left(\frac{A_V-1}{A_V}\right) + C_p$$

$$C_o \cong C_{b'c} + C_p$$



By converting series inductance, resistance into parallel inductance and resistance (by using admittance).



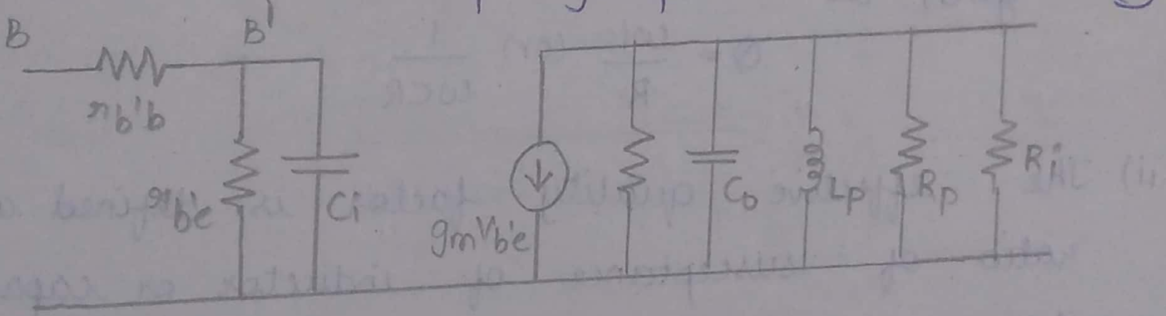
$$Y = \frac{1}{R + j\omega L}$$

$$= \frac{R - j\omega L}{(R + j\omega L)(R - j\omega L)}$$

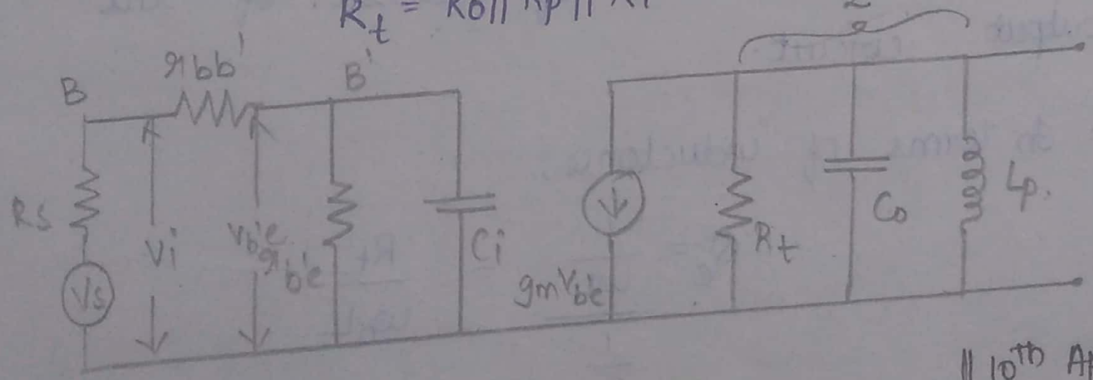
$$= \frac{R - j\omega L}{R^2 + \omega^2 L^2}$$

$$= \frac{R}{R^2 + \omega^2 L^2} - \frac{j\omega L}{R^2 + \omega^2 L^2} = \frac{1}{R_p} + \frac{1}{j\omega L_p}$$

$$L_p = \frac{R^2 + \omega^2 L^2}{\omega^2 L} \sim (1) \qquad Y = \frac{1}{R_p} + \frac{1}{j\omega L_p} \qquad R_p = \frac{R^2 + \omega^2 L^2}{R} \sim (2)$$



$$R_t = R_o \| R_p \| R_i$$



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Voltage gain:

$$A_v = \frac{\text{output voltage}}{\text{input voltage}}$$

output voltage $(V_o) = -g_m V_{b'e} Z$

$$\frac{1}{Z} = \frac{1}{R_t} + \frac{1}{\frac{1}{j\omega C_o}} + \frac{1}{j\omega L_p}$$

$$\frac{1}{Z} = \frac{1}{R_t} + j\omega C_o + \frac{1}{j\omega L_p}$$

$$\frac{1}{Z} = \frac{1}{R_t}\left[1 + j\omega C_o R_t + \frac{R_t}{j\omega L_p}\right]$$

$$\frac{1}{Z} = \frac{1}{R_t}\left[1 + j\omega C_o R_t \frac{\omega_o}{\omega_o} + \frac{R_t}{j\omega L_p}\frac{\omega_o}{\omega_o}\right] \quad \text{③}$$

$\omega_o \rightarrow$ resonant frequency

NOTE: i) In tuned circuits quality factor is given as

$$\boxed{Q = \frac{\omega L}{R} \text{ (or) } \frac{1}{\omega C R}}$$

ii) The effective quality factor is defined as ratio of susceptance of inductor or capacitor to conductance of resistor of the output circuit.

In terms of inductanse,

$$\boxed{Q_e = \frac{\frac{1}{\omega_o L}}{\frac{1}{R_t}} = \frac{R_t}{\omega_o L}}$$

In terms of capacitance,

$$\boxed{Q_e = \omega_o C R_t}$$

∴ equatⁿ ③ can be written as,

$$\frac{1}{Z} = \frac{1}{R_t}\left[1 + jQ_e\left[\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right]\right] \quad \text{—④}$$

Let us consider, frequency variation factor

$$\delta = \frac{\omega - \omega_0}{\omega_0} = \frac{\omega}{\omega_0} - 1$$

$$\boxed{\frac{\omega}{\omega_0} = 1 + \delta} \quad \text{—⑤}$$

Substitute eqⁿ ⑤ in eqⁿ ④, we get

$$\frac{1}{Z} = \frac{1}{R_t}\left[1 + jQ_e\left(1 + \delta - \frac{\omega_0}{\omega}\right)\right]$$

$$= \frac{1}{R_t}\left[1 + jQ_e\left(1 + \delta - \frac{1}{1+\delta}\right)\right]$$

$$= \frac{1}{R_t}\left[1 + jQ_e\left(\frac{(1+\delta)^2 - 1}{1+\delta}\right)\right]$$

$$= \frac{1}{R_t}\left[1 + jQ_e\left(\frac{\delta^2 + 2\delta}{1+\delta}\right)\right]$$

$$= \frac{1}{R_t}\left[1 + 2\delta jQ_e\left(\frac{\delta/2 + 1}{1+\delta}\right)\right]$$

generally, frequency variation factor $\delta << 1$,

$$\therefore \frac{1}{Z} = \frac{1}{R_t}\left[1 + 2\delta jQ_e\right]$$

$$\boxed{Z = \frac{R_t}{1 + 2\delta jQ_e}}$$

$$V_o = \frac{-g_m V_{b'e} R_t}{1+2\delta j Q_e}$$

$$V_{b'e} = V_i \times \frac{r_{b'e}}{r_{b'e}+r_{b'b}}$$

$$\therefore \quad V_o = \frac{-g_m V_i r_{b'e}}{r_{b'e}+r_{b'b}} \times \frac{R_t}{1+2\delta j Q_e}$$

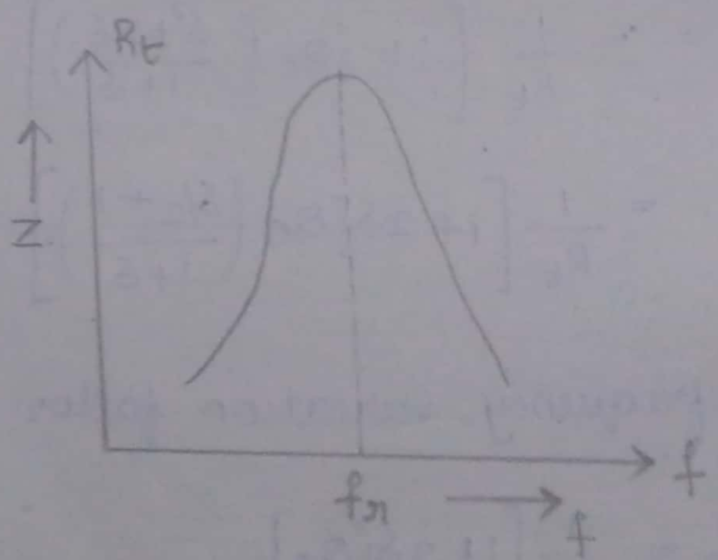
$$\boxed{A = \frac{V_o}{V_i} = \frac{-g_m r_{b'e}}{r_{b'e}+r_{b'b}} \cdot \frac{R_t}{1+2\delta j Q_e}}$$

At resonance,

$$\delta = 0,$$

then

$$\boxed{A_{V(res)} = \frac{-g_m r_{b'e} R_t}{r_{b'e}+r_{b'b}}}$$



$$\frac{A_v}{A_{v(res)}} = \frac{\dfrac{-g_m r_{b'e}}{r_{b'e}+r_{b'b}} \cdot \dfrac{R_t}{1+2j\delta Q_e}}{\dfrac{-g_m r_{b'e}}{r_{b'e}+r_{b'b}} \cdot R_t}$$

$$\boxed{\frac{A_v}{A_{v(res)}} = \frac{1}{1+2jQ_e\delta}}$$

$$\left|\frac{A_v}{A_{v(res)}}\right| = \frac{1}{\sqrt{1+(2j\delta Q_e)^2}}$$

$$\boxed{\left|\frac{A_v}{A_{v(res)}}\right| = \frac{1}{\sqrt{1+(2\delta Q_e)^2}}}$$

Bandwidth:

By looking at output circuit, bandwidth is equal to,

$$B/N = \frac{1}{2\pi R_t C}$$

as we know that, $Q_e = \omega_0 R_t C$

$$\boxed{BW = \frac{\omega_0}{2\pi Q_e} = \frac{f_0}{Q_e}}$$