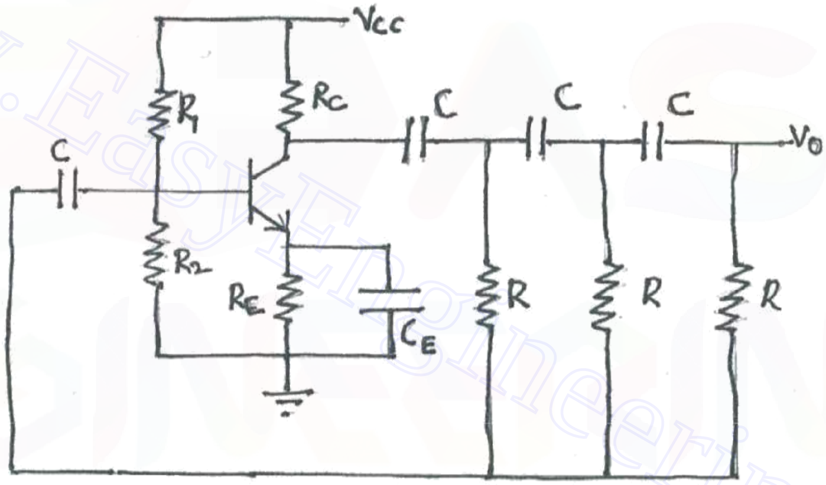
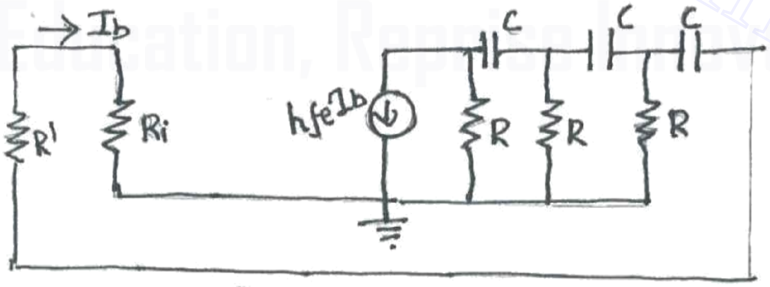
16 Marks Questions

1) Explain the operation of RC phase shift Oscillator and Wein Bridge Oscillator. Derive its frequency of Oscillation.

RC Oscillators :-

i) RC phase shift Oscillator :-

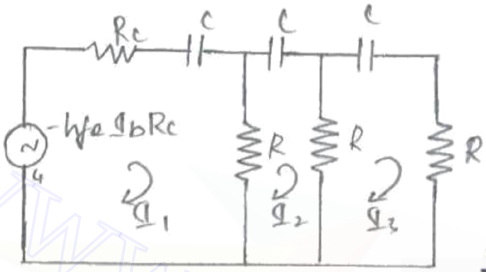




$R_i = R_1 || R_2 || h_{fe}$

→ It is a audio frequency or low frequency Oscillator. It uses a Common emitter amplifier whose Output is given to three RC networks. The phase shift produced by the Common emitter

emitter amplifier is 180°. Since an Oscillator requir a phase shift of 360° and the additional 180° phase shift is Obtained using three RC network With an individual phase shift of 60° each.



At loop B

$$(I_3 - I_2)R + \frac{I_3}{j\omega C} + I_3 R = 0$$

$$I_3(2R - 1/j\omega C) - I_2 R = 0 \rightarrow ①$$

At loop 2 :- $(I_2 - I_1)R + I_2/j\omega C + (I_2 - I_3)R = 0$

$$-I_1 R + I_2(2R + 1/j\omega C) - I_3 R = 0 \rightarrow ②$$

At loop 1 : $(I_1 - I_2)R + I_1/j\omega C + I_1 R_C = -h_{fe} I_b R_C$

$I_1(R + 1/j\omega C) + R_C) - I_1 R = -h_{fe} I_b R_C \Rightarrow h_{fe} I_3 R_C - I_2 R + I_1(R + R_C + 1/j\omega C) = 0 \rightarrow$

$$\begin{vmatrix} 2R + 1/j\omega C & -R & 0 \\ -R & 2R + 1/j\omega C & -R \\ h_{fe} R_C & -R & R + R_C + 1/j\omega C \end{vmatrix} = \begin{array}{l} (2R + 1/j\omega C)\left[(2R + 1/j\omega C) \times (R + R_C + 1/j\omega C)\right] - \\ + R\left[-R(R + R_C + 1/j\omega C) + R h_{fe} R_C\right] \end{array}$$

$$= (2R + 1/j\omega C)\left[2R^2 + 2RR_C + \frac{2R}{j\omega C} + \frac{R}{j\omega C} + \frac{R_C}{j\omega C} - 1/\omega^2 C^2 - R^2\right] + R\left[-R^2 - RR_C - \frac{R}{j\omega C} + R h_{fe} R_C\right]$$

$$= (2R + 1/j\omega C)\left[2R^2 + \frac{3R}{j\omega C} + 2RR_C - 1/\omega^2 C^2 - R^2 + \frac{R_C}{j\omega C}\right] + \left[-R^3 - R^2 R_C - \frac{R^2}{j\omega C} + R^2 h_{fe} R_C\right]$$

$$= 4R^3 + \frac{6R^2}{j\omega c} + 4R^2R_C - \frac{2R}{\omega^2c^2} - 2R^3 + \frac{2RR_C}{j\omega c} - R^3 - R^2R_C - \frac{R^2}{j\omega c} + R^2h_{fe}R_C$$
$$+ \frac{2R^2}{j\omega c} - \frac{3R}{\omega^2c^2} + \frac{2RR_C}{j\omega c} - \frac{1}{j\omega^3c^3} - \frac{R^2}{j\omega c} - \frac{R_C}{\omega^2c^2}$$

$$= R^3 + 3R^2R_C + R^2h_{fe}R_C - 1/j\omega^3c^3 - \frac{5R}{\omega^2c^2} + \frac{6R^2}{j\omega c} + \frac{4RR_C}{j\omega} - \frac{R_C}{\omega^2c^2}$$

$$= \left[R^3 + 3R^2R_C + R^2R_Ch_{fe} - \frac{5R}{\omega^2c^2} - \frac{R_C}{\omega^2c^2}\right] + \left[\frac{6R^2}{j\omega c} + \frac{4RR_C}{j\omega c} - \frac{1}{j\omega^3c^3}\right] \rightarrow (1)$$

Equating imaginary part to zero

ie $\frac{6R^2}{j\omega c} + \frac{4RR_C}{j\omega c} - 1/j\omega^3c^3 = 0$, $\frac{6R^2+4RR_C}{j\omega c} - \frac{1}{\omega^3c^3} = 0$

$$\left[\omega^2c^2(6R^2+4RR_C) - 1\right] = 0 \Rightarrow \omega^2c^2(6R^2+4RR_C) = 1$$

$$\Rightarrow \omega^2c^2 = \frac{1}{6R^2+4RR_C}$$

$$\omega^2 = \frac{1}{c^2(6R^2+4RR_C)} \Rightarrow \frac{1}{c^2R^2\left[6+\frac{4R_C}{R}\right]} \rightarrow$$

$$\omega = \frac{1}{RC\sqrt{6+4K}} \qquad K = R_C/R$$

$$f = \frac{1}{2\pi RC\sqrt{6+4K}} \rightarrow (3)$$

If R_C/R is very small

$$f = \frac{1}{2\pi RC\sqrt{6}}$$

(56)

Equating real part to zero

$$R^3 + 3R^2R_C + R^2R_Ch_{fe} - \frac{5R}{\omega^2C^2} - \frac{R_C}{\omega^2C^2} = 0$$

$$R^3 + 3R^2R_C + R^2R_Ch_{fe} - 5R(6R^2+4RR_C) - R_C(6R^2+4RR_C) = 0$$ from eqn (

$$R^3 + 3R^2R_C + R^2R_Ch_{fe} - 30R^3 - 20R^2R_C - 6R^2R_C - 4RR_C^2 = 0$$

$$-29R^3 - 23R^2R_C + R^2R_C + 4RR_C^2 = 0$$

$$R^2R_Ch_{fe} = 29R^3 + 23R^2R_C + 4RR_C^2$$

$$h_{fe} = \frac{29R}{R_C} + 23 + \frac{4R_C}{R} \rightarrow (4)$$

Let $k = R_C/R \Rightarrow h_{fe} = \frac{29}{k} + 23 + 4k$

diff w.r.t to 'k'. $\frac{dh_{fe}}{dk} = -\frac{29}{k^2} + 4$

$$\frac{dh_{fe}}{dk} = 0$$

$$\frac{29}{k^2} = 4 \Rightarrow k = 2.7 \rightarrow (5)$$

Substituting k value in (4) $h_{fe} = \frac{29}{2.7} + 23 + 4 \times 2.7$

$$= 44.54$$

$h_{fe} \geq 44.54$ for sustained Oscillation

For Barkhausen Criterion $A\beta = 1$, $\beta = -1/29$

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