

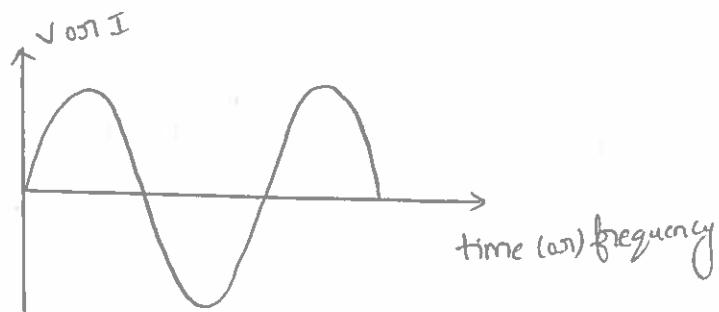
Unit - III  
Oscillators....

Oscillators:-

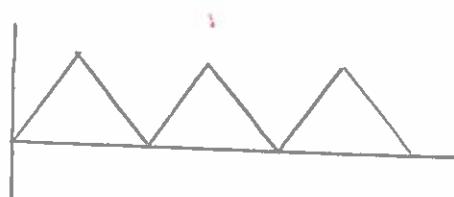
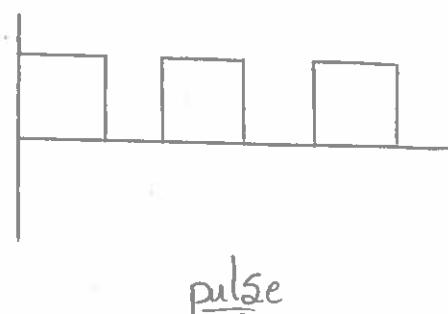
Any circuit which is used to generate an AC voltage without any AC i/p signal is called an oscillator. To generate AC voltage the circuit is supplied with energy from DC source.

Classification of oscillators:-

\* Sinusoidal oscillators.



\* Relaxation oscillators.



According to the frequency generator:-

- i) Audio frequency oscillator :- upto 20kHz.
- ii) Radio frequency oscillator : 20kHz - 30MHz.
- iii) Very high frequency oscillator: 30MHz - 300MHz
- iv) Ultra high frequency oscillator: 300MHz - 3GHz
- v) Microwave frequency oscillator: above 3GHz

According to type of circuit used (sinewave oscillator type):

- i) LC tune oscillators
- ii) RC phase shift oscillators.

Condition for oscillation (or) Barkhausen criteria

\* When the amplifier is tune at a particular frequency the o/p signal caused by noise signals. If a small part of o/p signal is fed back to the i/p then this signal will be amplified by amplifier. This process continues and the o/p goes on increasing but as a signal level increases, the gain of the amplifier decreases and at a particular value of o/p, the gain of amplifier reduced equal to  $\frac{1}{B}$ . Then the o/p voltage remains constant at frequency  $f_r$  called frequency of oscillation.

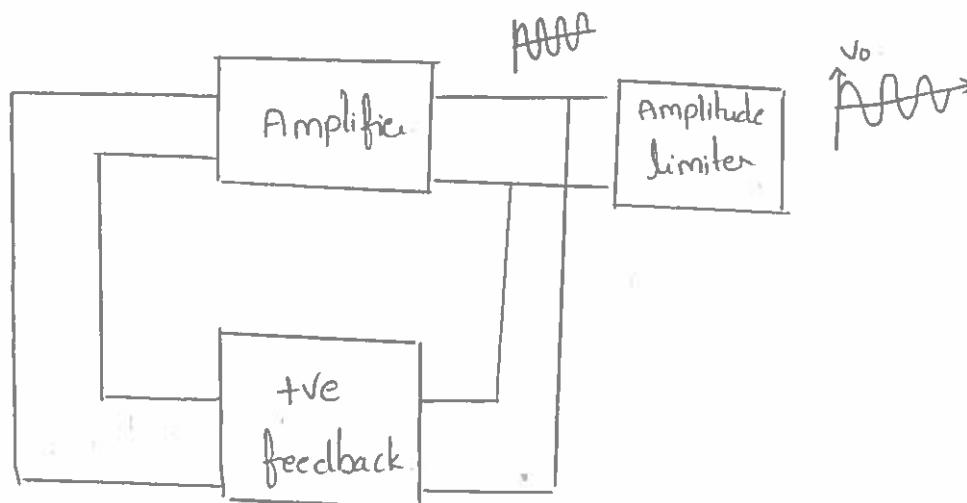
The essential conditions for maintaining oscillations are

\*  $|AB| = 1$  i.e. the magnitude of loop gain must be unity.

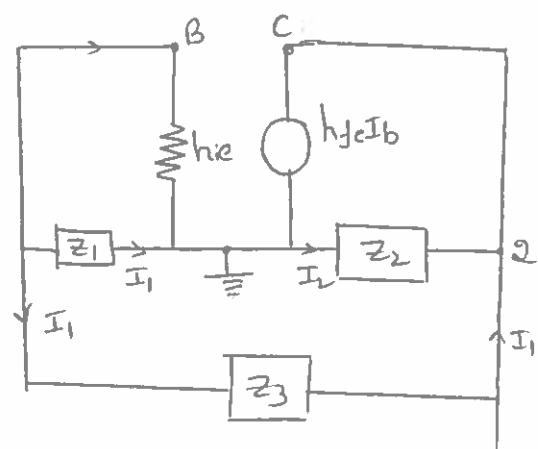
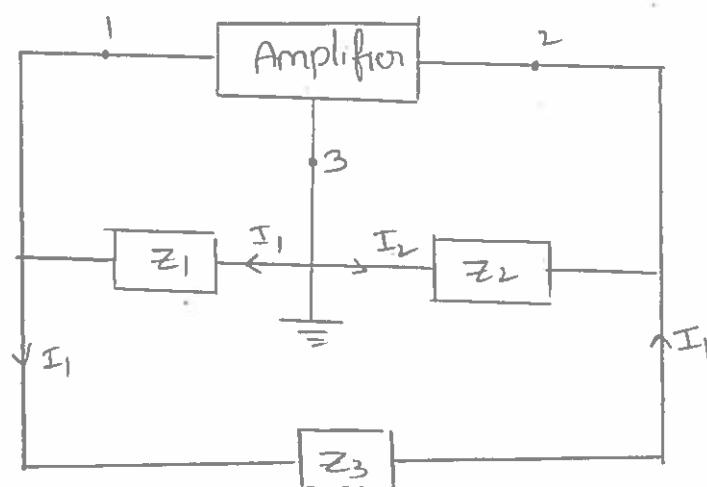
\* The total phase shift around closed loop  $0^\circ$  or  $360^\circ$ .

Practical considerations:-

The condition  $|AB| = 1$  gives single value of AB which should be said through out the operation of oscillator circuit.



General form of an LC oscillator :-



We can use any active device in place of amplifier.  
The reactive elements  $Z_1$ ,  $Z_2$  &  $Z_3$  constituting the

feedback tank circuit which determines the frequency of oscillations. Here  $Z_1$  &  $Z_2$  serves as an AC voltage divider for the output voltage and feedback signal. Therefore the voltage across  $Z_1$  is feedback signal. The inductive or capacitive reactances are represented by  $Z_1$ ,  $Z_2$  and  $Z_3$ .

Analysis:-

Load impedance

$$Z' = Z_1 \parallel h_{ie}$$

$$Z' = \frac{Z_1 h_{ie}}{Z_1 + h_{ie}}$$

The load impedance b/w the o/p terminals af 3. is equivalent to  $Z_L = (Z' + Z_3) \parallel Z_2$

$$= \frac{(Z' + Z_3) Z_2}{(Z' + Z_3) + Z_2}$$

$$= \frac{\left( \frac{Z_1 h_{ie}}{Z_1 + h_{ie}} + Z_3 \right) Z_2}{\frac{Z_1 h_{ie}}{Z_1 + h_{ie}} + Z_3 + Z_2}$$

$$= \frac{Z_1 Z_2 h_{ie} + Z_2 Z_3 (Z_1 + h_{ie})}{Z_1 h_{ie} + Z_3 Z_1 + Z_3 h_{ie} + Z_1 Z_2 + Z_2 h_{ie}}$$

$$= \frac{z_1 z_2 h_{ie} + z_1 z_2 z_3 + z_2 z_3 h_{ie}}{z_1 h_{ie} + z_2 h_{ie} + z_3 h_{ie} + z_1 z_2 + z_1 z_3}$$

$$Z_L = \frac{z_2 [h_{ie}(z_1 + z_3) + z_1 z_3]}{z_1 h_{ie} + z_2 h_{ie} + z_3 h_{ie} + z_1 z_2 + z_1 z_3}$$

Voltage gain without feedback

$$\begin{aligned} A &= -\frac{h_{fe} Z_L}{h_{ie}} \\ &= -h_{fe} \left[ \frac{z_2 (h_{ie}(z_1 + z_3) + z_1 z_3)}{h_{ie}(z_1 + z_2 + z_3) + z_1 z_2 + z_1 z_3} \right] \end{aligned}$$

$$\text{feedback factor } \beta = \frac{V_f}{V_o}$$

$$V_o = I_1 (z' + z_3)$$

$$V_o = I_1 \left( \frac{z_1 h_{ie}}{z_1 + h_{ie}} + z_3 \right)$$

$$= I_1 \left[ \frac{z_1 h_{ie} + z_1 z_3 + z_3 h_{ie}}{z_1 + h_{ie}} \right]$$

$$= I_1 \left[ \frac{h_{ie}(z_1 + z_3) + z_1 z_3}{z_1 + h_{ie}} \right]$$

$$V_f = I_1 z' = \frac{I_1 z_1 h_{ie}}{z_1 + h_{ie}}$$

$$B = \frac{Z_1 Z_{hie}}{Z_{1+hie}} \times \frac{Z_{1+hie}}{Z_1(h_{ie}(Z_1 + Z_3) + Z_1 Z_3)}$$

$$\beta = \frac{Z_{hie}}{h_{ie}(Z_1 + Z_3) + Z_1 Z_3}$$

To work feedback Amplifier as an oscillator the necessary condition is  $|AB| = 1$ ,  $AB = 1$ .

$$\frac{-h_{fe}}{h_{ie}} \left[ \frac{Z_2(h_{ie}(Z_1 + Z_3) + Z_1 Z_3)}{h_{ie}(Z_1 + Z_2 + Z_3) + Z_1(Z_2 + Z_3)} \right] \cdot \frac{\frac{Z_1 h_{ie}}{h_{ie}(Z_1 + Z_3) + Z_1 Z_3}}{= 1}$$

$$\frac{-h_{fe} Z_2 (h_{ie} + (Z_1 Z_3) + Z_1 Z_3)}{h_{ie} (Z_1 + Z_2 + Z_3) + Z_1 (Z_2 + Z_3)} \cdot \frac{\frac{Z_1}{h_{ie}(Z_1 + Z_3) + Z_1 Z_3}}{= 1}$$

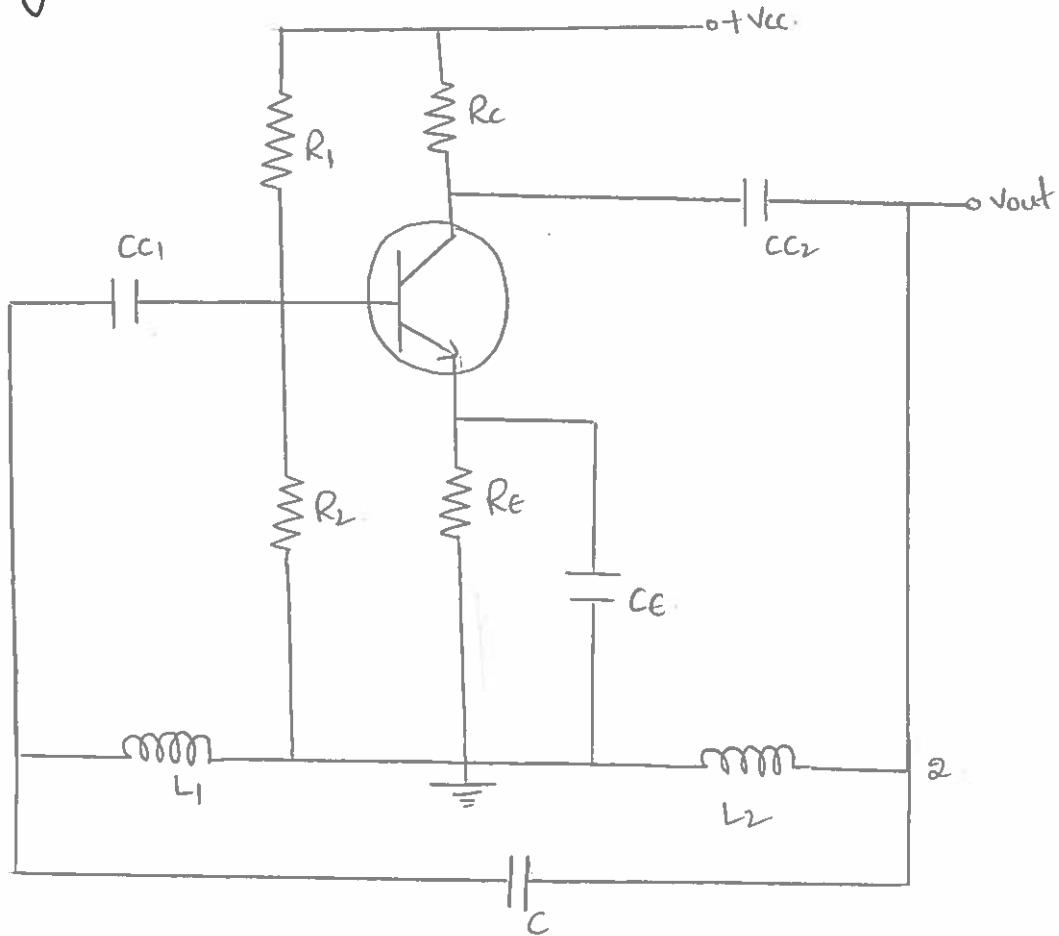
$$= \frac{-h_{fe} Z_1 Z_2}{h_{ie} (Z_1 + Z_2 + Z_3) + Z_1 (Z_2 + Z_3)} = 1$$

$$-h_{fe} Z_1 Z_2 = h_{ie} (Z_1 + Z_2 + Z_3) + Z_1 (Z_2 + Z_3)$$

$$h_{ie} (Z_1 + Z_2 + Z_3) + h_{fe} Z_1 Z_2 + Z_1 Z_2 + Z_1 Z_3 = 0.$$

$$h_{ie} (Z_1 Z_2 + Z_3) + Z_1 Z_2 (1 + h_{fe}) + Z_1 Z_3 = 0.$$

## Hartley oscillator:-



## Hartley oscillator

$Z_1$  and  $Z_2$  are Inductors and  $Z_3$  is capacitor  
Resistors  $R_1$ ,  $R_2$  and  $R_E$  provides necessary bias to the  
transistor  $C_E$  is the bipass capacitor which  
provides low reactance path.  $C_{C1}$  &  $C_{C2}$  are coupling  
Capacitors. The feedback network consisting of  
 $L_1$ ,  $L_2$  and  $C$ .

when the supply voltage  $V_{CC}$  is switched on the  
transient current is produced in the tank circuit  
and harmonic oscillations are setup in the circuit.

The oscillatory current in the tank circuit produces AC voltage across  $L_1$  and  $L_2$ . If the terminal '1' is positive potential wrt to ground and terminal '2' is '-ve' wrt to ground so there is phase difference b/w terminal '1' & '2' is always  $180^\circ$ . In the CE mode, the transistor provides the phase difference of  $180^\circ$  b/w i/p and o/p. Therefore total phase shift is  $360^\circ$ .

If the feedback is adjusted so that, the loop gain  $A_B = 1$ , then the circuit acts as an oscillator.

Analysis:-

$$Z_1 = j\omega L_1 + j\omega M$$

$$Z_2 = j\omega L_2 + j\omega M$$

$$Z_3 = \frac{1}{j\omega C} \text{ (on)} \quad \frac{-j}{\omega C}$$

$$h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 (1 + h_{fe}) + Z_1 Z_3 = 0.$$

$$h_{ie} \left( j\omega L_1 + j\omega M + j\omega L_2 + j\omega M + \frac{1}{j\omega C} \right) + (j\omega L_1 + j\omega M)(j\omega L_2 + j\omega M) \\ (1 + h_{fe}) + (j\omega L_1 + j\omega M) \left( \frac{1}{j\omega C} \right) = 0$$

$$h_{ie} \left( j\omega L_1 + j\omega L_2 + 2j\omega M + \frac{1}{j\omega C} \right) + (-\omega^2 L_1 L_2 - \omega^2 L_1 M - \omega^2 L_2 M - \omega^2 M^2) \\ (1 + h_{fe}) + \frac{L_1}{C} + \frac{M}{C} = 0.$$

$$j\omega L_1 h_{ie} + j\omega L_2 h_{ie} + 2j\omega M h_{ie} + \frac{h_{ie}}{j\omega C} (-\omega^2 L_1 L_2 - \omega^2 M(L_1 + L_2) - \omega^2 M^2)(1 + h_{fe}) \\ 1 \rightarrow 2 \rightarrow \frac{L_1 + M}{C} = 0.$$

$$-\omega^2 L_1 L_2 - \omega^2 M (L_1 + L_2) - \omega M^2 (1 + h_{fe}) + \frac{L_1 + M}{C} + j (\omega h_{ie} (L_1 + L_2) \omega \cdot 2M - \frac{1}{\omega C}) = 0.$$

$$-\omega^2 (L_1 L_2 + M L_1 + M L_2 + M^2) (1 + h_{fe}) + \frac{L_1 + M}{C} + h_{ie} j (\omega (L_1 + L_2) + 2M - \frac{1}{\omega C}) = 0$$

To calculate frequency of LC oscillators, the imaginary part must be equal to '0'.

$$h_{ie} (\omega L_1 + \omega L_2 + 2\omega M - \frac{1}{\omega C}) = 0.$$

$$\omega L_1 + \omega L_2 + 2\omega M - \frac{1}{\omega C} = 0.$$

$$\omega (L_1 + L_2 + 2M - \frac{1}{\omega^2 C}) = 0.$$

$$L_1 + L_2 + 2M = \frac{1}{\omega^2 C}$$

$$\frac{1}{\omega^2 C} = C(L_1 + L_2 + 2M)$$

$$\omega^2 = \frac{1}{C(L_1 + L_2 + 2M)}$$

$$\omega = \frac{1}{\sqrt{C(L_1 + L_2 + 2M)}}$$

$$2\pi f = \frac{1}{\sqrt{C(L_1 + L_2 + 2M)}}$$

$$f = \frac{1}{2\pi \sqrt{C(L_1 + L_2 + 2M)}}$$

$$-\omega^2(L_1L_2 + ML_1 + ML_2 + M^2)(1+h_{fe}) + \frac{L_1+M}{C} = 0.$$

$$-\omega^2 C (L_1L_2 + ML_1 + ML_2 + M^2) (1+h_{fe}) + L_1+M = 0.$$

$$L_1+M = \omega^2 C (L_1L_2 + ML_1 + ML_2 + M^2) (1+h_{fe})$$

$$L_1+M = \omega^2 C (L_1(L_2+M) + M(L_2+M)) (1+h_{fe})$$

$$\cancel{L_1+M} = \omega^2 C [(L_2+M)(L_1+M)] (1+h_{fe})$$

$$(L_2+M)(1+h_{fe})\omega^2 C = 1$$

$$(L_2+M)(1+h_{fe}) = \frac{1}{\omega^2 C}$$

$$(L_2+M)(1+h_{fe}) = L_1 + L_2 + 2M.$$

$$1+h_{fe} = \frac{L_1 + L_2 + 2M}{L_2 + M}$$

$$h_{fe} = \frac{L_1 + L_2 + 2M - L_2 - M}{L_2 + M}$$

$$\boxed{\beta = h_{fe} = \frac{L_1 + M}{L_2 + M}}$$

- \* In the Hartley oscillator  $L_2 = 0.4 \text{ mH}$  and  $C = 0.004 \mu\text{F}$   
If the frequency of oscillator is  $120 \text{ kHz}$ . Find the value of  $L_1$ .

Given

$$L_2 = 0.4 \text{ mH}$$

$$C = 0.004 \mu\text{F}$$

$$F = 120 \text{ kHz}$$

$\therefore L_2 = 120$

$$f = \frac{1}{2\pi\sqrt{C(L_1+L_2)}}$$

$$120 \times 10^3 = \frac{1}{2 \times 3.14 \sqrt{0.004 \times 10^{-6} (L_1 + 0.4 \times 10^{-3})}}$$

$$2\pi f = \frac{1}{\sqrt{C(L_1+L_2)}}$$

$$4\pi^2 f^2 = \frac{1}{C(L_1+L_2)}$$

$$L_1 + L_2 = \frac{1}{4\pi^2 f^2 C}$$

$$L_1 = \frac{1}{4\pi^2 f^2 C} - L_2$$

$$= \frac{1}{4 \times (3.14)^2 \times (120 \times 10^3)^2 \times 0.004 \times 10^{-6}} - 0.4 \times 10^{-3}$$

$$L_1 = 0.04 \text{ mH}$$

- \* In a Hartley oscillator, the two inductances are 2mH and 20mH. If the frequency is changed from 950kHz to 2050kHz. calculate the range over which the capacitor is to be varied.

Given

$$L_1 = 2 \text{ mH}$$

$$L_2 = 20 \text{ mH}$$

$\Delta C = L_2 \cdot n \cdot 1.36$

$$f_1 = 950 \text{ kHz}, f_2 = 2050 \text{ kHz}$$

$$f_1 = \frac{1}{2\pi\sqrt{C(L_1+L_2)}}$$

$$4\pi f_1^2 = \frac{1}{C_1(L_1+L_2)}$$

$$C_1 = \frac{1}{4\pi^2 f_1^2 (L_1+L_2)}$$

$$= \frac{1}{4 \times (3.14)^2 \times (950 \times 10^3)^2 (2 \times 10^{-3}) + 20 \times 10^{-6}}$$

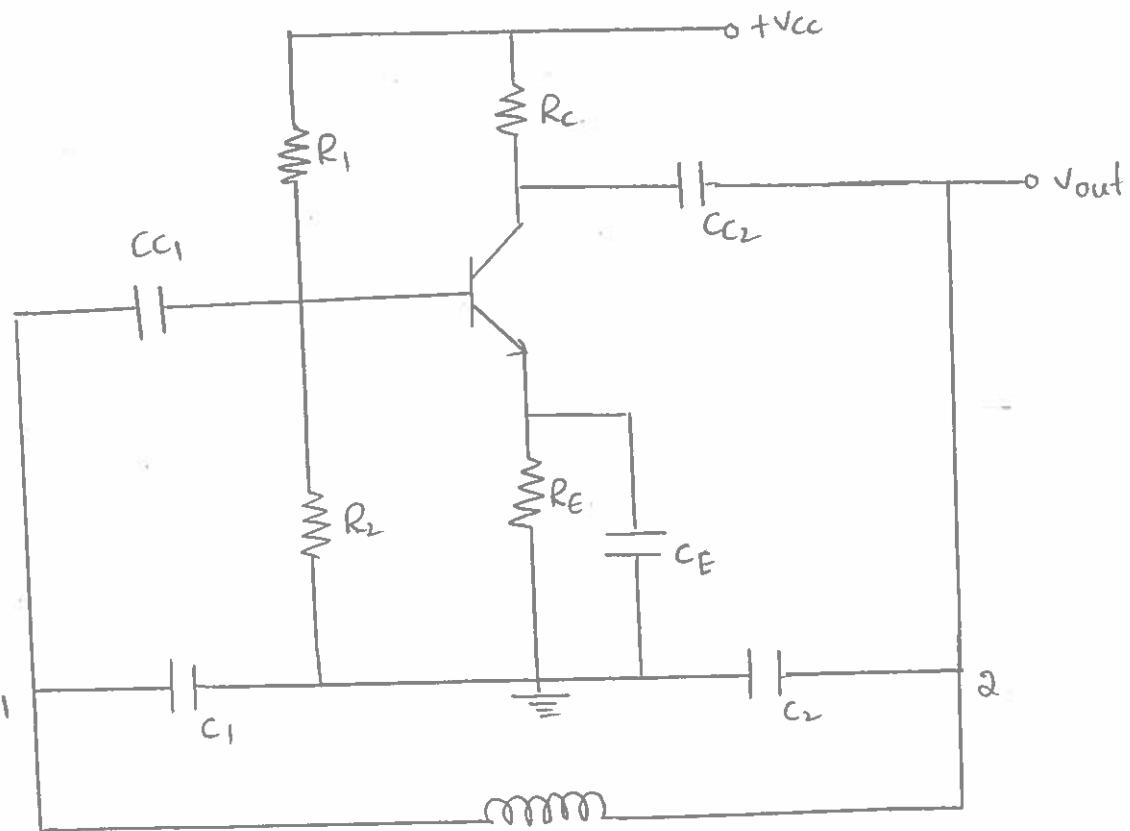
$$C_1 = 1.39 \times 10^{-11} \text{ F}$$

$$C_2 = \frac{1}{4 \times (3.14)^2 (2050 \times 10^3)^2 (2 \times 10^{-3}) + 20 \times 10^{-6}}$$

$$C_2 = 2.98 \times 10^{-12}$$

$$C_2 = 2.98 \text{ pF}$$

## Colpitts Oscillator:-



$$z_1 = \frac{1}{j\omega c_1}$$

$$z_2 = \frac{1}{j\omega c_2}$$

$$z_3 = j\omega L$$

$$h_{ie}(z_1 + z_2 + z_3) + z_1 z_2 (1 + h_{fe}) + z_1 z_3 = 0.$$

$$h_{ie} \left( \frac{1}{j\omega c_1} + \frac{1}{j\omega c_2} + j\omega L \right) + \left( \frac{1}{j\omega c_1} \right) \left( \frac{1}{j\omega c_2} \right) (1 + h_{fe}) + \left( \frac{1}{j\omega c_1} \right) (j\omega L) = 0$$

$$\frac{h_{ie}}{j\omega c_1} + \frac{h_{ie}}{j\omega c_2} + h_{ie} j\omega L - \frac{1}{\omega^2 c_1 c_2} (1 + h_{fe}) + \frac{L}{c_1} = 0.$$

$$\left[ - \frac{(1 + h_{fe})}{\omega^2 c_1 c_2} + \frac{L}{c_1} \right] + h_{ie} j \left[ - \frac{1}{\omega c_1} - \frac{1}{\omega c_2} + \omega L \right] = 0.$$

to calculate frequency of oscillator imaginary part must be equal to '0'.

$$hie \left[ -\frac{1}{wC_1} - \frac{1}{wC_2} + wL \right] = 0.$$

$$-\frac{1}{wC_1} - \frac{1}{wC_2} + wL = 0.$$

$$-wC_2 - wC_1 + wL (w^2 C_1 C_2) = 0.$$

$$-w(C_1 + C_2 + w^2 L C_1 C_2) = 0.$$

$$w^2 L C_1 C_2 = + (C_1 + C_2)$$

$$w^2 = \frac{+ (C_1 + C_2)}{L C_1 C_2}$$

$$\omega = + \sqrt{\frac{C_1 + C_2}{L C_1 C_2}}$$

$$2\pi f = + \sqrt{\frac{C_1 + C_2}{L C_1 C_2}}$$

$$f = + \frac{1}{2\pi} \sqrt{\frac{C_1 + C_2}{L C_1 C_2}}$$

$$\frac{-(1+hfe)}{w^2 C_1 C_2} + \frac{L}{C_1} = 0$$

$$\frac{1+hfe}{w^2 C_1 C_2} = \frac{L}{C_1}$$

$$(1+hfe) = \frac{L w^2 C_1 C_2}{C_1}$$

$$h_{fe} = L \omega^2 C_2 - 1$$

$$= L \left[ + \frac{(C_1 + C_2)}{LC_1 C_2} \right] C_2 - 1$$

$$= \frac{+(C_1 + C_2)}{C_1 C_2} \cdot C_2 - 1$$

$$= \frac{+C_1 + C_2 - 1}{C_1}$$

$$h_{fe} = \frac{C_2}{C_1}$$

- \* In the colpitts oscillator  $C_1 = 0.2\text{mF}$ ,  $C_2 = 0.02\text{mF}$ . If the frequency of the oscillator is  $10\text{kHz}$ . Find the value of Inductor and gain for oscillation.

Given

$$C_1 = 0.2\text{mF}$$

$$C_2 = 0.02\text{mF}$$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$f^2 = \frac{1}{(2\pi)^2 LC}$$

$$L = \frac{1}{(2\pi f)^2 C}$$

$$L = \frac{1}{(2 \times 3.14 \times 10 \times 10^3)^2 C}$$

$$C = \frac{C_1 C_2}{C_1 + C_2} = \frac{0.2 \times 10^{-6} \times 0.2 \times 10^{-6}}{0.2 \times 10^{-6} + 0.02 \times 10^{-6}}$$

$$C = \frac{4 \times 10^{-3} \times 10^{-12}}{0.22 \times 10^{-6}}$$

$$C = \frac{4 \times 10^{-15} \times 10^6}{0.22}$$

$$C = 1.818 \times 10^{-8}$$

$$L = \frac{1}{(2 \times 3.14 \times 10^4)^2 \times 1.818 \times 10^{-8}}$$

$$L = 0.01394$$

- \* In a Colpitts oscillator, the values of inductor  $L = 40\text{mH}$ ,  $C_1 = 100\text{pF}$  and  $C_2 = 500\text{pF}$ , find frequency of oscillations. If the o/p voltage is 10v. find the feedback voltage.

Given  $L = 40\text{mH}$

$C_1 = 100\text{pF}$

$C_2 = 500\text{pF}$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$C = \frac{C_1 C_2}{C_1 + C_2} = \frac{100 \times 10^{-12} \times 500 \times 10^{-12}}{100 \times 10^{-12} + 500 \times 10^{-12}}$$

$$C = \frac{50000 \times 10^{-24}}{600 \times 10^{-12}}$$

$$C = \frac{50000 \times 10^{-12}}{600}$$

$$C = 8.33 \times 10^{-11}$$

$$f = \frac{1}{2 \times 3.14 \sqrt{40 \times 10^3 \times 8.33 \times 10^{-11}}}$$

$$f = 87.2 \text{ kHz}$$

$$\beta = \frac{\sqrt{f}}{V_0} = \frac{C_2}{C_1}$$

$$\sqrt{f} = V_0 \cdot \frac{C_2}{C_1}$$

$$= 10 \cdot \frac{500 \times 10^{-12}}{100 \times 10^{-12}}$$

$$\boxed{\sqrt{f} = 50 \text{ V}}$$

RC oscillators:-

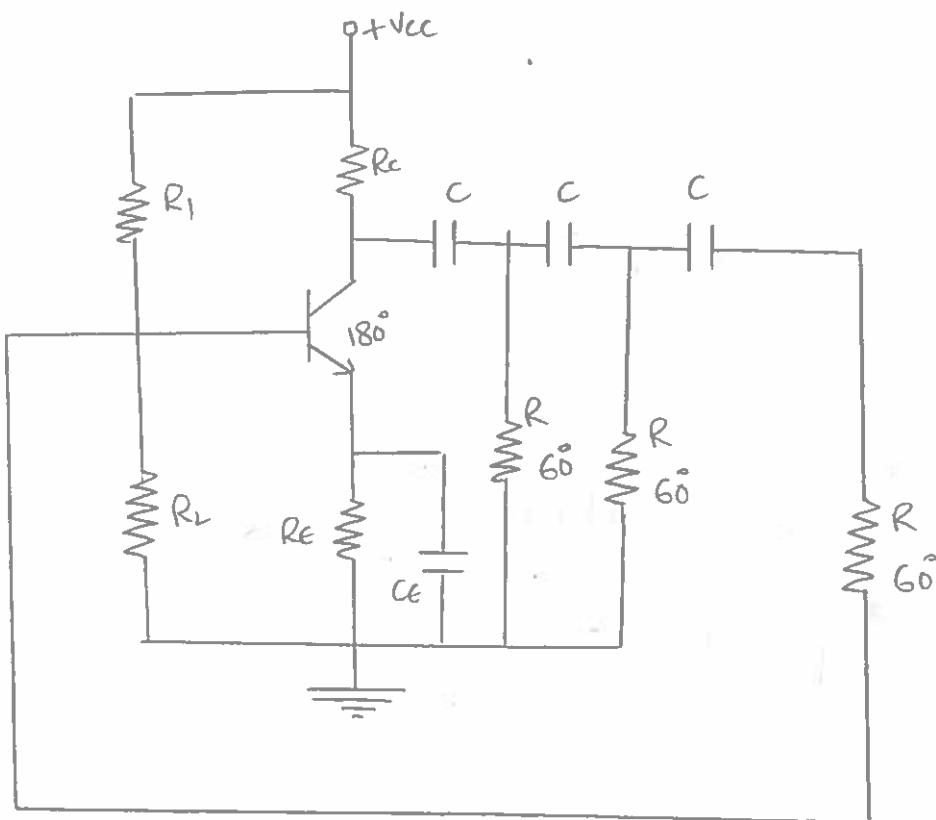
All the oscillators using LC circuits operate at high frequencies. At low frequencies, the inductor and capacitor required for the circuit is

Very bulky. So RC oscillators are used at low frequencies. RC oscillator are two types.

i) RC phase shift oscillator.

ii) Wein bridge oscillator.

\* RC phase shift oscillator:-

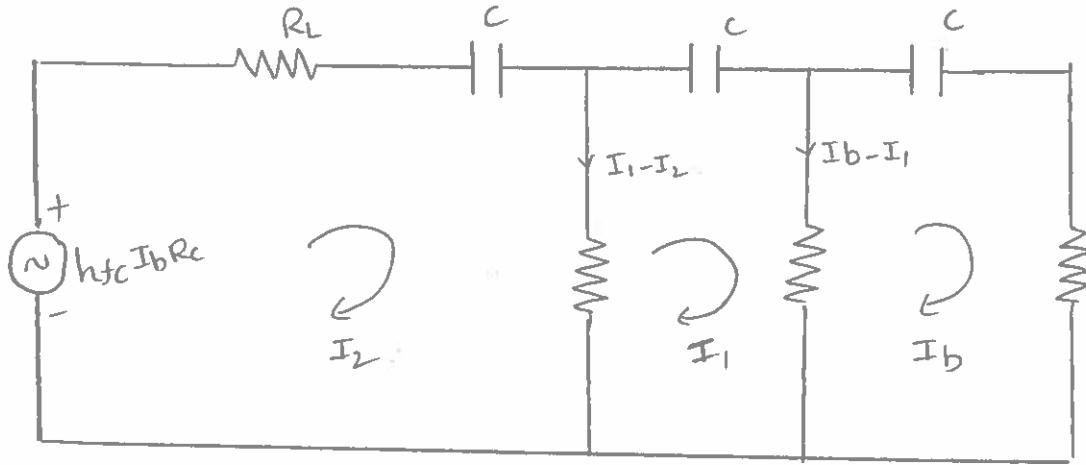


In this oscillator the required phase shift of  $180^\circ$  in the feedback loop from output to input is obtained by using  $R$  &  $C$  components. The common emitter amplifier is followed by 3 sections of RC phase shift network. The output of last section is connected to i/p of the CE amplifier. The phase shift of each RC section provides  $60^\circ$ . So the total phase shift provided by RC sections is  $180^\circ$  and

another  $180^\circ$  is provided in the CE amplifier section.

The total phaseshift from the base of the transistor around circuit is  $360^\circ$ . So, the circuit satisfies Barkhausen criterion.

### H-parameter equivalent circuit for RC phase shift oscillator



Modified phase shift oscillator equivalent circuit.

$$I_b \left( 2R + \frac{1}{j\omega C} \right) - I_1 R = 0 \rightarrow ①$$

$$I_1 \left( 2R + \frac{1}{j\omega C} \right) - I_2 \Rightarrow I_2 R - I_b R = 0 \rightarrow ②$$

$$h_{fe}I_b R_L + I_2 \left( R_L + R + \frac{1}{j\omega C} \right) = I_1 R = 0 \rightarrow ③$$

$I_b \quad I_1 \quad I_2$ .

$$\begin{bmatrix} 2R + \frac{1}{j\omega C} & -R & 0 \\ -R & 2R + \frac{1}{j\omega C} & -R \\ h_{fe}R_L & -R & R_L + R + \frac{1}{j\omega C} \end{bmatrix}$$

$$\Delta = I_b [R^2 - 0] - I_1 \left[ \left( 2R + \frac{1}{jw_c} \right) \left( R_L + R + \frac{1}{jw_c} \right) \right]$$

$$\Delta = \left( 2R + \frac{1}{jw_c} \right) \left[ \left( 2R + \frac{1}{jw_c} \right) \left( R_L + R + \frac{1}{jw_c} \right) - R^2 \right] + R \left[ -R \left( R_L + R + \frac{1}{jw_c} \right) \right. \\ \left. + h_{fe} R_L R \right] + 0.$$

$$= \left( 2R + \frac{1}{jw_c} \right) \left[ 2RR_L + 2R^2 + \frac{2R}{jw_c} + \frac{R_L}{jw_c} + \frac{R}{jw_c} - \frac{1}{w_c^2} - R^2 \right]$$

$$+ R \left[ -RR_L - R^2 - \frac{R}{jw_c} + h_{fe} R_L R \right] + 0.$$

$$= 4R^2 R_L + 4R^3 + \frac{4R^2}{jw_c} + \frac{2RR_L}{jw_c} + \frac{2R^2}{jw_c} - \frac{2R}{w_c^2} - 2R^3 + \frac{2RR_L}{jw_c} + \frac{2R^2}{jw_c}$$

$$+ \frac{2R}{j^2 w_c^2} + \frac{R_L}{j^2 w_c^2} + \frac{R}{j^2 w_c^2} - \frac{1}{jw_c^3} - \frac{R^2}{jw_c} - R^2 R_L - R^3.$$

$$- \frac{R^2}{jw_c} + h_{fe} R_L R^2.$$

$$= 4R^2 R_L + 4R^3 + \frac{4R^2}{jw_c} + \frac{2RR_L}{jw_c} + \frac{2R^2}{jw_c} - \frac{2R}{w_c^2} - 2R^3 + \frac{2RR_L}{jw_c} + \frac{2R^2}{jw_c} - \frac{2R}{w_c^2}$$

$$- \frac{R_L}{w_c^2} - \frac{R}{w_c^2} - \frac{1}{jw_c^3} - \frac{R^2}{jw_c} - R^2 R_L - R^3 - \frac{R^2}{jw_c} + h_{fe} R_L R^2.$$

$$= 3R^2 R_L + 1R^3 + \frac{GR^2}{jw_c} - \frac{5R}{w_c^2} + \frac{4RR_L}{jw_c} - \frac{R_L}{w_c^2} + h_{fe} R_L R^2 - \frac{1}{jw_c^3}$$

$$= (3 + h_{fe}) R^2 R_L + 1R^3 - \frac{5R}{w_c^2} - \frac{R_L}{w_c^2} + j \left[ \frac{GR^2}{-w_c} + \frac{4RR_L}{-w_c} - \frac{1}{jw_c^3} \right]$$

$$\Delta = (3 + h_{fe}) R^2 R_L + R^3 - \left[ \frac{5K + KL}{\omega^2 C^2} \right] + j \left[ \frac{-(6R + 4RR_L)}{\omega C} + \frac{1}{\omega^3 C^3} \right].$$

$$\frac{1}{\omega^3 C^3} - \frac{6R^2}{\omega C} - \frac{4RR_L}{\omega C} = 0.$$

$$1 - 6R^2 \omega^2 C^2 - 4RR_L \omega^2 C^2 = 0.$$

$$1 = \omega^2 C^2 (6R^2 + 4RR_L)$$

$$\omega^2 = \frac{1}{C^2 (6R^2 + 4RR_L)}$$

$$f = \frac{1}{2\pi C \sqrt{6R^2 + 4RR_L}}$$

$$f = \frac{1}{2\pi R_C \sqrt{6 + \frac{4R_L}{R}}}$$

$$3R^2 R_L + h_{fe} R^2 R_L + R^3 - \frac{5R}{\omega^2 C^2} - \frac{R_L}{\omega^2 C^2} = 0.$$

$$h_{fe} R^2 R_L = \frac{5R}{\omega^2 C^2} + \frac{R_L}{\omega^2 C^2} - R^3 - 3R^2 R_L.$$

$$h_{fe} R^2 R_L = \frac{5R + R_L - R_W C - 3R R_L W_C}{\omega^2 C^2}.$$

$$R^2 R_L = 5R(6R^2 + 4RR_L) + R_L(6R^2 + 4RR_L) - R^3 - 3R^2 R_L.$$

$$= 30R^3 + 20R^2 R_L + 6R^2 R_L + 4R R_L^2 - R^3 - 3R^2 R_L.$$

$$h_{fe} R^2 R_L = 29R^3 + 23R^2 R_L + 4RR_L^2$$

$$h_{fe} = \frac{29R^3}{R^2 R_L} + 23 + \frac{4RR_L^2}{R^2 R_L}$$

$$h_{fe} = \frac{29R^3}{R^2 R_L} + 23 + \frac{4RR_L^2}{R^2 R_L}$$

$$h_{fe} = \frac{29R^3}{R^2 R_L} + 23 + \frac{4RL}{R}$$

$$h_{fe} = \frac{29R}{RL} + 23 + \frac{4RL}{R}$$

- \* Determine the frequency of oscillations when RC phase shift oscillator has  $R=10k\Omega$ ,  $C=0.01\mu F$  and  $R_C = 2.2k\Omega$  also find the minimum current gain needed for this purpose.

Given  $R=10k\Omega$ ,  $C=0.01\mu F$ ,  $R_C = 2.2k\Omega$

$$h_{fe} = \frac{29R}{RL} + 23 + \frac{4RL}{R}$$

$$= \frac{29(10 \times 10^3)}{2.2 \times 10^3} + 23 + \frac{4 \times 2.2 \times 10^3}{10 \times 10^3}$$

$$= \frac{290}{2.2} + 23 + \frac{8.8}{10}$$

$$h_{fe} = 155.698$$

Current gain,  $\beta = 155.698$ .

$$f = \frac{1}{2\pi R C \sqrt{6 + \frac{4R_L}{R}}}$$

$$f = \frac{1}{2 \times 3.14 \times 10 \times 10^3 \times 0.01 \times 10^{-6} \sqrt{6 + \frac{4(2.2 \times 10^3)}{10 \times 10^3}}}$$

$$f = 607.08 \text{ Hz}$$

- \* Find the capacitor 'c' and h<sub>fe</sub> for the transistor to provide a frequency of 10kHz. Assume R<sub>1</sub> = 25k $\Omega$ , R<sub>2</sub> = 60k $\Omega$ , R<sub>c</sub> = 40k $\Omega$ , R = 7.1k $\Omega$  & h<sub>ie</sub> = 1.8k $\Omega$ .

SOL

$$f = \frac{1}{2\pi R C \sqrt{6 + \frac{4R_L}{R}}}$$

$$C = \frac{1}{2\pi f R \sqrt{6 + \frac{4R_L}{R}}}$$

$$= \frac{1}{2 \times 3.14 \times 10 \times 10^3 \times 7.1 \times 10^3 \sqrt{6 + \frac{4(40 \times 10^3)}{7.1 \times 10^3}}}$$

$$= 0.041 \times 10^{-9}$$

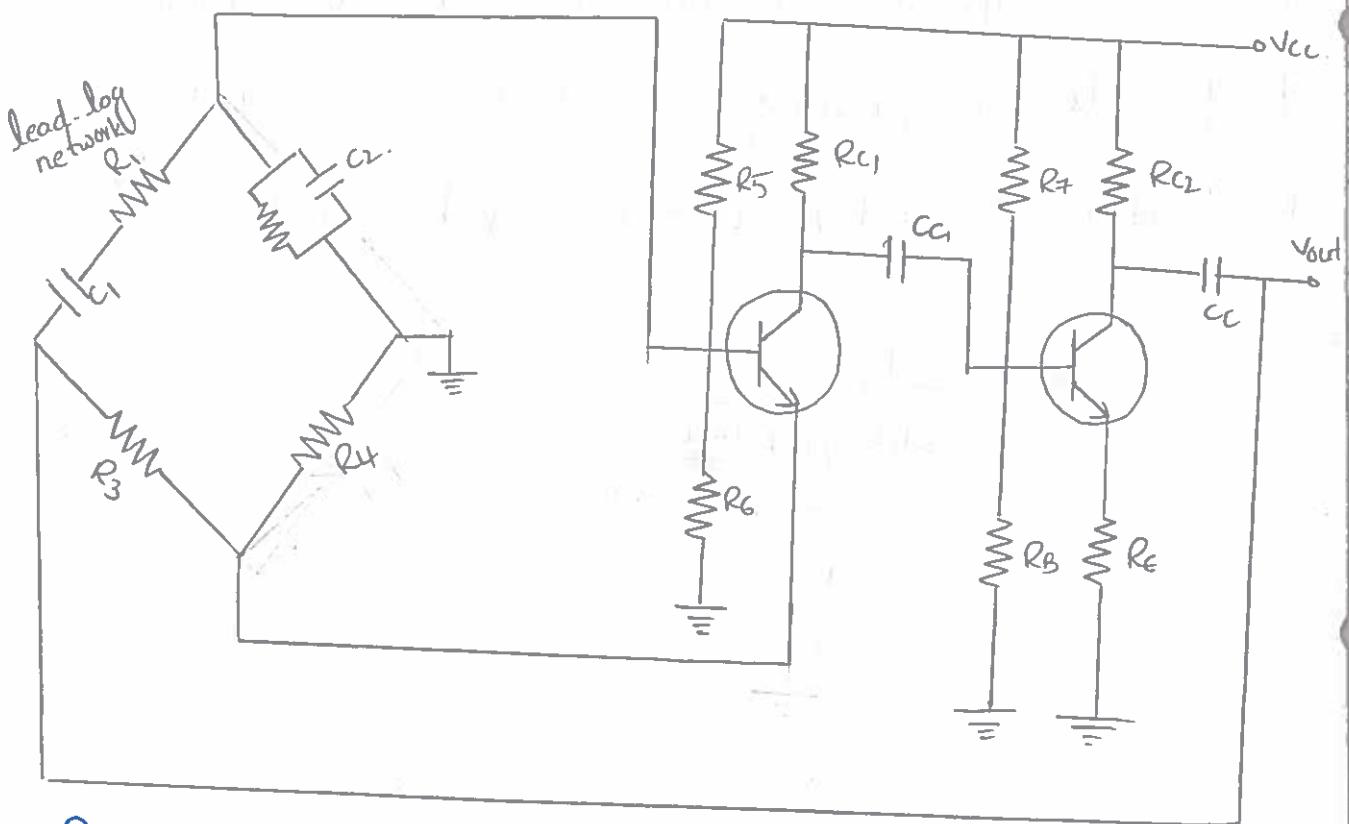
$$\boxed{C = 0.4 \text{ nF}}$$

$$h_{fe} = \frac{29(7.1 \times 10^3)}{40 \times 10^3} + 23 + \frac{4(40 \times 10^3)}{7.1 \times 10^3}$$

$$= \frac{205.9}{40} + 23 + \frac{160}{7.1}$$

$$h_{fe} = 50.68$$

Wein - Bridge oscillator:-



The circuit consisting of two stage RC coupled amplifier which provides phase shift of  $360^\circ$  (or)  $0^\circ$ . The bridge is used as the feedback network which has known into provides any additional phase shift. The feedback network consisting of lead lag Network ( $R_1 C_1$ ) ( $R_2 C_2$ ) and the voltage divider ( $R_3 R_4$ )

The lead-lag network provides +ve feedback to the I/P of the first stage if the bridge is balanced.

$$\frac{R_3}{R_4} = \frac{R_1 + \frac{1}{j\omega C_1}}{R_2 \parallel \frac{1}{j\omega C_2}}$$

$$\frac{R_3}{R_4} = \frac{\frac{j\omega R_1 C_1 + 1}{j\omega C_1}}{\frac{R_2 \frac{1}{j\omega C_2}}{R_2 + \frac{1}{j\omega C_2}}}$$

$$= \frac{j\omega R_1 C_1 + 1}{j\omega C_1} \times \frac{R_2 + \frac{1}{j\omega C_2}}{\frac{R_2}{j\omega C_2}}$$

$$= \frac{j\omega R_1 C_1 + 1}{j\omega C_1} \times \frac{R_2 j\omega C_2 + 1}{j\omega C_2} \times \frac{j\omega C_2}{R_2}$$

$$= \frac{j\omega R_1 C_1 + 1}{j\omega C_1} \times \frac{1 + j\omega R_2 C_2}{R_2}$$

$$\frac{R_3}{R_4} = \frac{(j\omega R_1 C_1 + 1)(j\omega R_2 C_2 + 1)}{j\omega R_2 C_1}$$

$$\frac{R_3}{R_4} = \frac{-\omega^2 R_1 R_2 C_1 C_2 + j\omega R_1 C_1 + j\omega R_2 C_2 + 1}{j\omega R_2 C_1}$$

$$j\omega R_2 R_3 C_1 = -\omega^2 R_1 R_2 C_1 C_2 + j\omega R_1 R_4 C_1 + j\omega R_2 R_4 C_2 + R_4$$

$$-\omega^2 R_1 R_2 R_4 C_1 C_2 + R_4 = 0.$$

$$\omega^2 R_1 R_2 R_4 C_1 C_2 = R_4$$

$$\omega^2 = \frac{1}{R_1 R_2 C_1 C_2}$$

$$4\pi^2 f^2 = \frac{1}{R_1 R_2 C_1 C_2}$$

$$f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

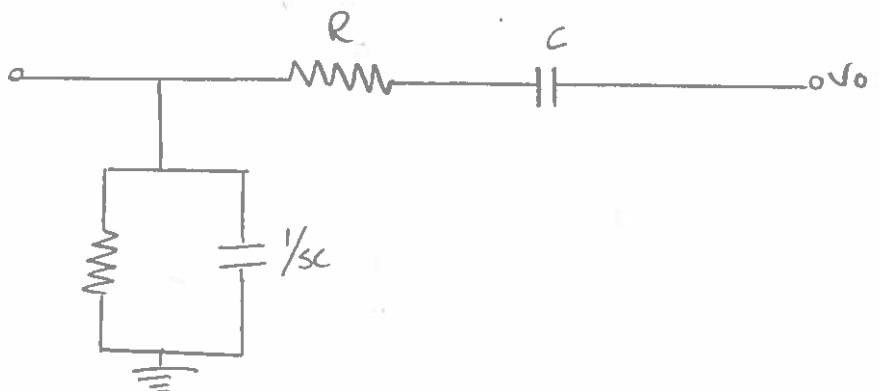
if  $R_1 = R_2 = R$  &  $C_1 = C_2 = C$ .

$$f = \frac{1}{2\pi\sqrt{R^2 C^2}}$$

$$f = \frac{1}{2\pi R C}$$

To determine the gain of Wien bridge oscillator usingBJT Amplifier is assume.

$R_1 = R_2 = R$  &  $C_1 = C_2 = C$ . Then feedback n/w is given as,



$$V_f = V_0 - \frac{R \parallel \frac{1}{sc}}{R \parallel \frac{1}{sc} + R + \frac{1}{sc}}$$

$$\frac{V_f}{V_0} = \frac{R \parallel \frac{1}{sc}}{R \parallel \frac{1}{sc} + R + \frac{1}{sc}}$$

$$= \frac{\frac{R \times \frac{1}{sc}}{R + \frac{1}{sc}}}{\frac{R \times \frac{1}{sc}}{R + \frac{1}{sc}} + R + \frac{1}{sc}}$$

$$= \frac{\frac{R}{sc} \times \frac{sc}{Rsc+1}}{\frac{R}{sc} \times \frac{sc}{Rsc+1} + R + \frac{1}{sc}}$$

$$= \frac{\frac{R}{1+Rsc}}{\frac{R}{1+Rsc} + R + \frac{1}{sc}}$$

$$= \frac{\frac{R}{1+Rsc}}{\frac{R+R+R^2sc}{1+Rsc} + \frac{1}{sc}}$$

$$= \frac{\frac{R}{1+Rsc}}{\frac{2R+R^2sc+1+Rsc}{sc}}$$

.. m:1 z:2, 87/36

$$= \frac{R}{2R + R^2 sC + \frac{1+Rsc}{sc}}$$

$$= \frac{R}{\frac{2Rsc + R^2 s^2 C^2 + 1 + Rsc}{sc}}$$

$$= \frac{Rsc}{3Rsc + R^2 s^2 C^2 + 1}$$

$$\frac{V_f}{V_o} = \frac{Rsc}{3Rsc + R^2 s^2 C^2 + 1}$$

The conditions for is that  $A\beta = 1$

$$A = \gamma_B$$

$$A = \frac{3Rsc + R^2 s^2 C^2 + 1}{Rsc}$$

Substitute  $s = j\omega$  and from frequency of oscillation

$$\omega = 1/Rc$$

$$A = \frac{3Rc(j\omega) + R^2 c^2 (j\omega)^2 + 1}{Rc(j\omega)}$$

$$= \frac{3RCj\omega + R^2 c^2 j^2 \omega^2 + 1}{jRC\omega}$$

$$= \frac{j3RC\omega - R^2 c^2 \omega^2 + 1}{j\omega RC}$$

$$= \frac{j3RC}{Rc} - \frac{R^2C^2}{R^2C^2 + 1}$$

$$\frac{j \cdot RC}{Rc}$$

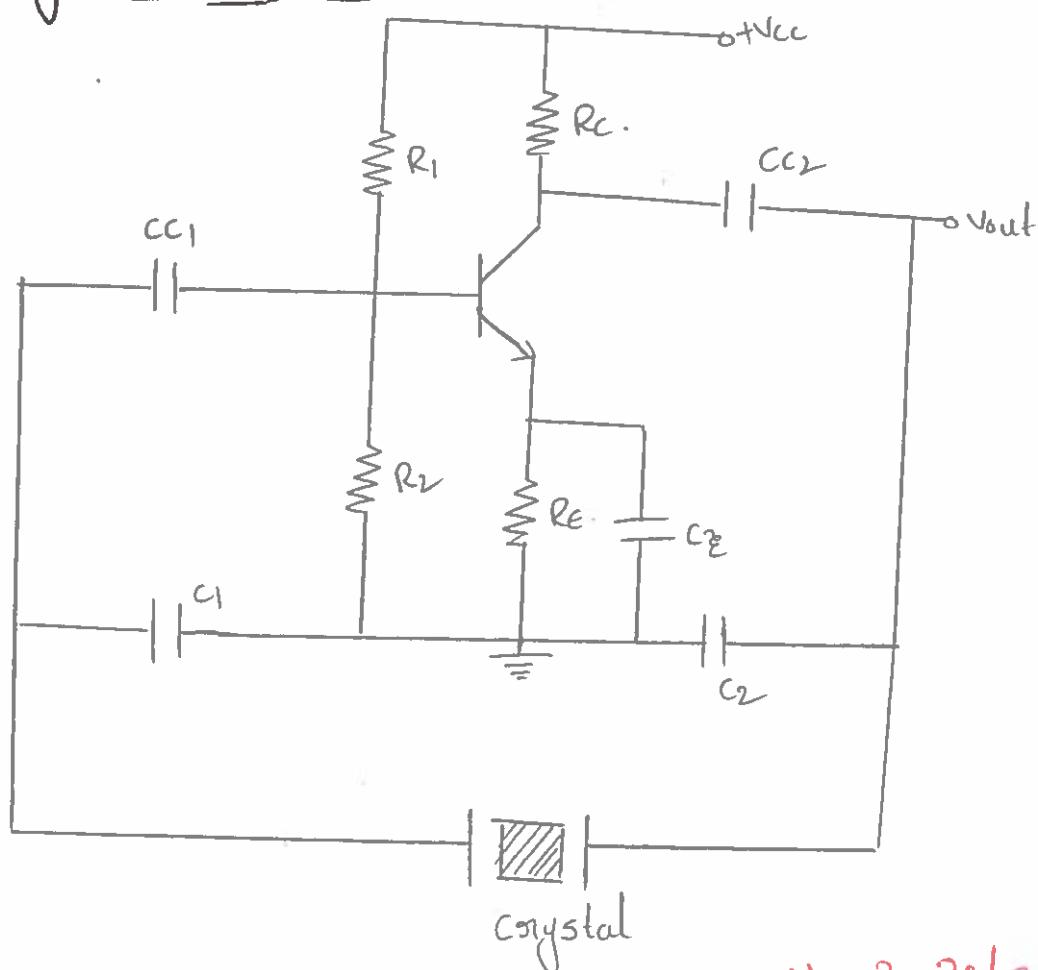
$$= \frac{3j + 1 + j}{j}$$

$$= \frac{3j}{j}$$

$$\boxed{A = 3}$$

Hence, the gain of the wein bridge oscillator using BJT amplifier is atleast equal to '3' for oscillations to occur.

### Crystal oscillator:-

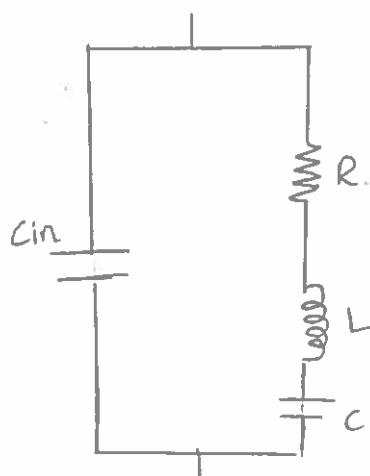


Crystal oscillator is basically a tuned oscillator.

It uses piezo electric crystal as a resonant tank circuit. The crystal provides a high degree of frequency stability. So where we require great stability the crystal oscillators are required.

Ex:- transmitters, digital device

A quartz crystal exhibits a very important property known as piezo electric effect. When an AC voltage is applied across the crystal it vibrates at the frequency of applied voltage. This phenomenon is known as piezo electric effect. To use it in electronic oscillators, the crystal material is mounted between 2 metal plates. The equivalent circuit of crystal is



The crystal has 2 different frequencies.

- \* The inductance 'L' resonates with series capacitance 'C' and produces series resonant frequency  $f_s$ .

$$X_L = X_C$$

$$\omega L = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{LC}$$

$$(2\pi f_s)^2 = \frac{1}{LC}$$

$$f_s = \frac{1}{2\pi\sqrt{LC}}$$

\* parallel resonance  $f_p$ .

$$X_L = X_C + X_m$$

$$\omega L = \frac{1}{\omega C} + \frac{1}{\omega C_m}$$

$$\frac{1}{\omega C_m} = \omega L - \frac{1}{\omega C}$$

$$\frac{1}{\omega C_m} = \frac{\omega^2 LC - 1}{\omega C}$$

$$\omega^2 LC - 1 = \frac{C}{C_m}$$

$$\omega^2 LC = \frac{C}{C_m} + 1$$

$$\omega^2 LC = \frac{C + C_m}{C_m}$$

$$\omega^2 = \frac{1}{LC} \left[ 1 + \frac{C}{C_m} \right]$$

$$(2\pi f_p)^2 = \frac{1}{L} \left[ \frac{1}{C} + \frac{1}{C_m} \right]$$

$$f_p = \frac{1}{2\pi} \sqrt{\frac{1}{L} \left( \frac{1}{C} + \frac{1}{C_m} \right)}$$

The fp frequency crystal has capacitive reactance only. The frequency fs has inductive reactance only between fs & fp crystal acts as inductor. If the crystal is given in the place of inductor the frequency of oscillation lies b/w fs & fp.

- \* A crystal oscillator has the following parameters L = 0.5H, C = 0.06pF, Cm = 1pF and R = 5kΩ, find series and parallel resonant frequencies and quality factor of the crystal.

Given

$$R = 5k\Omega$$

$$L = 0.5H$$

$$C = 0.06pF$$

$$C_m = 1pF$$

Series resonance frequency

$$\begin{aligned} f_s &= \frac{1}{2\pi\sqrt{LC}} \\ &= \frac{1}{2 \times 3.14 \sqrt{0.5 \times 0.06 \times 10^{-12}}} \end{aligned}$$

$$f_s = 919 \text{ kHz}$$

$$\text{Quality factor } Q = \frac{w_s L}{R}$$

$$= \frac{2\pi f_s \times 0.5}{5 \times 10^3}$$

$$= \frac{2 \times 3.14 \times 919 \times 10^3 \times 0.5}{5 \times 10^3}$$

$$Q = 577.13$$

parallel resonance frequency

$$f_p = \frac{1}{2\pi} \sqrt{\frac{1}{L} \left( \frac{1}{C} + \frac{1}{C_m} \right)}$$

$$= \frac{1}{2 \times 3.14} \sqrt{\frac{1}{0.5} \left( \frac{1}{0.06 \times 10^{-12}} + \frac{1}{1 \times 10^{-12}} \right)}$$

$$f_p = 94.6 \text{ kHz}$$

$$Q = \frac{w_p L}{R}$$

$$= \frac{2 \times 3.14 \times 94.6 \times 10^3 \times 0.5}{5 \times 10^3}$$

$$Q = 594.08$$

- \* A crystal oscillator has the following parameters  
 $C_1 = 0.065 \text{ pF}$ ,  $C_2 = 1 \text{ pF}$ ,  $R = 5.5 \text{ k}\Omega$ ,  $f_s = 1.09 \text{ MHz}$  then  
 find inductor value, quality factor and parallel resonance

Given

$$C_1 = 0.065 \text{ pF}$$

$$C_2 = 1 \text{ pF}$$

$$R = 5.5 \text{ k}\Omega$$

$$f_s = 1.09 \text{ MHz}$$

$$f_s = \frac{1}{2\pi\sqrt{LC}}$$

$$f_s^2 = \frac{1}{4\pi^2 LC}$$

$$L = \frac{1}{4\pi^2 f_s^2 C}$$

$$L = \frac{1}{4 \times (3.14)^2 (1.09 \times 10^6)^2 \times 0.065 \times 10^{-12}}$$

$$L = 0.33 \text{ H}$$

quality factor  $Q = \frac{\omega_s L}{R}$

$$= \frac{2 \times 3.14 \times 1.09 \times 10^6 \times 0.33}{5.5 \times 10^3}$$

$$Q = 410.712$$

$$f_p = \frac{1}{2\pi} \sqrt{\frac{1}{L} \left( \frac{1}{C_1} + \frac{1}{C_2} \right)}$$

$$= \frac{1}{2 \times 3.14} \sqrt{\frac{1}{0.33} \left( \frac{1}{0.065 \times 10^{-12}} + \frac{1}{1 \times 10^{-12}} \right)}$$

$$f_p = 1.1 \text{ MHz}$$

$$Q = \frac{WPL}{R} = \frac{2 \times 3.14 \times 1.1 \times 10^6 \times 0.33}{5.5 \times 10^3}$$

$$Q = 414$$

Frequency range of Rc and Lc oscillators:-

The Wien bridge RC oscillator is used in the range of 5Hz to 1MHz.

At high frequencies, due to capacitor and inductor there is no stability in LC & RC oscillators. The crystal oscillators are used whenever accuracy and stability of oscillations are required.

Frequency stability of oscillator:-

The frequency stability of an oscillator is a measure of its ability to maintain the required frequency stable over a long period of time. The main drawback in transistor oscillators is that the frequency of oscillation is not stable during a long time period the following are the factors to change in frequency.

\* Due to change in temperature, the values of frequency components like resistor, inductor and capacitor change.

- \* Due to variation in power supply, unstable transistor parameters, change in climate conditions ~~(x)~~
- \* The effective resistance of tank circuit is change when the load is connected.
- \* Due to variation in biasing conditions and loading conditions.

The variation of frequency, temperature

i.e.

$$S_{W0T} = \frac{\Delta\omega/\omega_0}{\Delta T/T_0}$$

where  $\omega_0, T_0$  are the designed frequency of oscillation and operating temperature.

The loading effect may be minimized if the oscillator is coupled to the load by a circuit with high input resistance and low o/p resistance properties. The frequency stability is given as

$$S_w = \frac{d\phi}{d\omega}$$

where  $d\phi$  is the phase shift introduced for a small frequency change. The circuit giving larger value of  $S_w$  has more stable oscillator frequency.