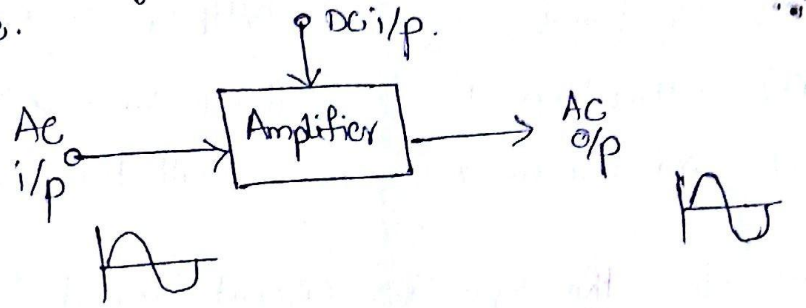
Unit-VI Oscillators

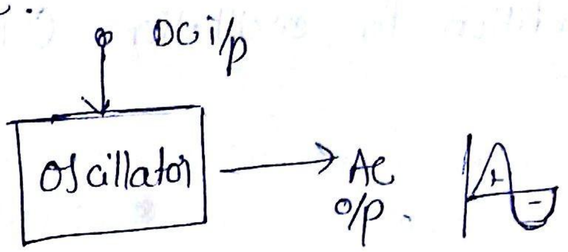
⇒ An Amplifier to amplify the signal it requires AC i/p and DC i/p as shown in figure.



⇒ Oscillator:- which circuit is used to provide or generate a periodic voltage with out an ac input signal is called oscillator.

→ To generate the periodic voltage, the circuit is supplied with energy from a dc source..

→ It is also called DC to AC Converter.



* Classification of oscillators:-

Oscillators can be classified in different ways.

1. According to the waveforms generated:
   a) Sinusoidal oscillators (or) Harmonic oscillators
   b) Non-Sinusoidal oscillators (or) Relaxation Oscillators.

2. According to the fudamental mechanism used.
   a) feedback oscillators
   b) -Ve resistance oscillators.
   [Tunnel diode, UJT oscillators]

3. According to frequency generated.

i) Audio frequency oscillator (AFO) → upto 20 kHz

ii) Radio " " RFO → 20k – 30MHz

iii) Very high " " (VHF)os → 30M – 300MHz

iv) Ultra high " " (UHF)os → 300M – 3GHz

v) microwave " " oscillator → above 3GHz.

4. According to the type of circuit used.

i) LC oscillators

ii) RC oscillators.

—o—

* Condition for oscillation (Barkhausen Condition)

⇒ oscillator produce continous waveform with out any ac signal. Even when no external signal is applied, any conductor or active device produce ever present noise will cause some small signal at the output of the amplifier.

⇒ A small feedback network (β) is used to give that small noise signal on the i/p side which is nearest frequency of tank circuit 'fo'. then this feedback signal is amplified by amplifier.

→ If the amplifier gain hays is more than 1/β, then the o/p increases and there by the feedback signal becomes larger.

→ This process continues and the o/p goes on increasing. But as the signal level increases, the gain of the amplifier decreases and equal to 1/β. Then o/p voltage remains constant at frequency fo, called frequency of oscillation.

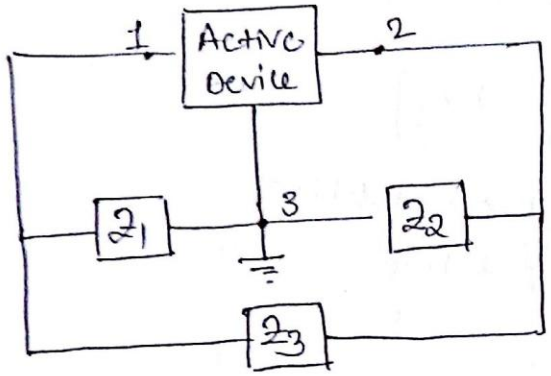
⇒ The essential conditions for maintaining oscillations are:

1) $|A\beta| = 1$. i.e. the magnitude of loop gain must be unity.

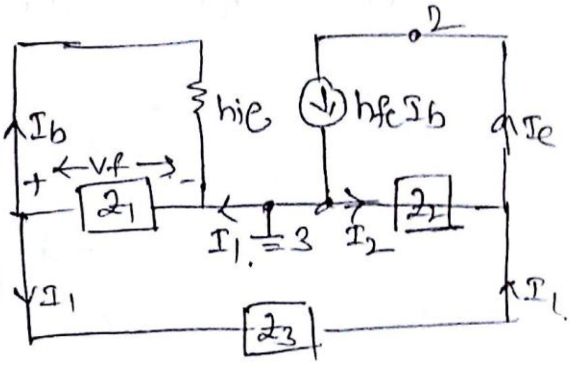
2) The total phase shift around the closed loop is zero or 360°

—o—

* General form of An LC Oscillator:-



$\Rightarrow$



$$\Rightarrow \quad Z' = Z_1 \parallel hie \Rightarrow Z' = \frac{Z_1 hie}{Z_1 + hie}.$$

$\Rightarrow$ Total Load impedance Z_L b/w 2 & 3 is $Z_2 \parallel (Z' + Z_3)$

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

$$= \frac{Z_2\left(\frac{Z_1 hie}{Z_1 + hie} + Z_3\right)}{Z_2 + \frac{Z_1 hie}{Z_1 + hie} + Z_3}.$$

$$= \frac{\frac{Z_1 Z_2 hie + Z_1 Z_2 Z_3 + Z_3 Z_2 hie}{\cancel{Z_1 + hie}}}{\frac{Z_1 Z_2 + Z_2 hie + Z_1 hie + Z_1 Z_3 + Z_3 hie}{\cancel{Z_1 + hie}}}$$

$$= \frac{Z_2[Z_1 hie + Z_1 Z_3 + Z_3 hie]}{hie(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3}.$$

$$A = \frac{-hfe\, Z_L}{hie}.$$

$$= \frac{-hfe \cdot \frac{Z_2(Z_1 hie + Z_1 Z_3 + Z_3 hie)}{hie(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3}}{hie}$$

$$\beta = \frac{V_f}{V_o}.$$

where $V_o = -I_1 (Z' + Z_3)$

$$= -I_1 \left[\frac{Z_1 h_{ie}}{Z_1 + h_{ie}} + Z_3 \right]$$

$$= -I_1 \left[\frac{Z_1 h_{ie} + Z_1 Z_3 + Z_3 h_{ie}}{Z_1 + h_{ie}} \right]$$

$$V_f = -I_1 Z'$$

$$= -I_1 \left[\frac{Z_1 h_{ie}}{Z_1 + h_{ie}} \right]$$

$$\beta = \frac{\cancel{-I_1} \left[Z_1 h_{ie} / \cancel{Z_1 + h_{ie}} \right]}{\cancel{-I_1} \left[\frac{Z_1 h_{ie} + Z_1 Z_3 + Z_3 h_{ie}}{\cancel{Z_1 + h_{ie}}} \right]}$$

$$= \frac{Z_1 h_{ie}}{Z_1 h_{ie} + Z_1 Z_3 + Z_3 h_{ie}}.$$

$\therefore \; A\beta = 1.$

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

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

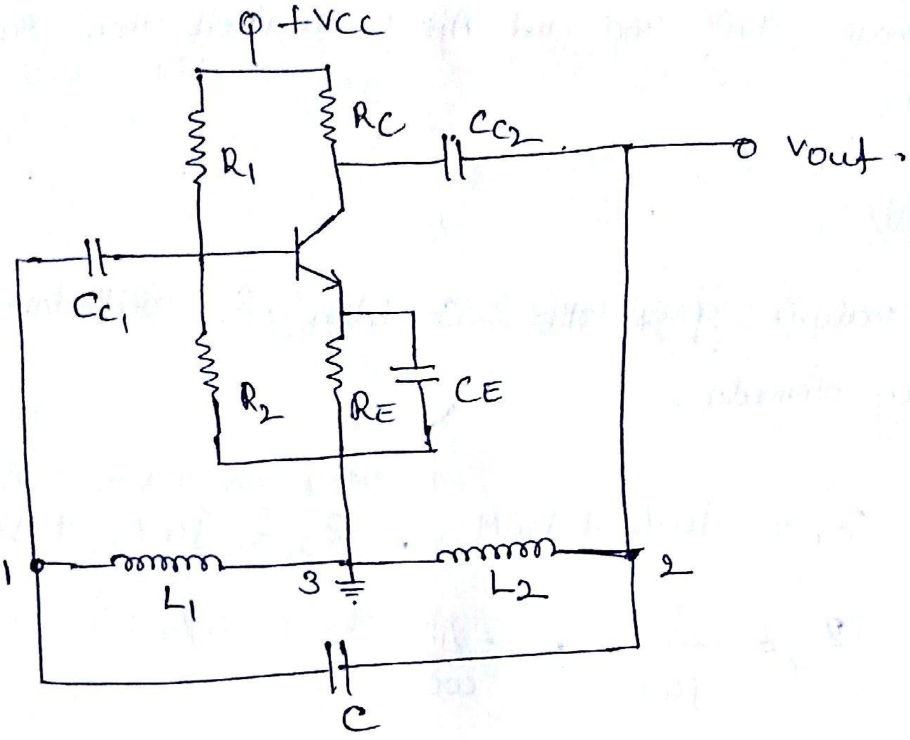
$$h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3 = -h_{fe} Z_1 Z_2$$

$$\therefore \; h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3 + h_{fe} Z_1 Z_2 = 0$$

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

This is the general expression for LC oscillator.

* Hartley oscillator



→ The Hartley oscillator consists of a CE amplifier circuit and feedback tank circuit consisting L_1, L_2 and C, determines frequency.

→ The Resistors R_1, R_2 and Re provide the necessary dc bias to the transistor. CE is bypass capacitor and C_{C1} & C_{C2} are coupling capacitors.

* operation :-

→ when the supply voltage +VCC is ON, the transient current is produced in the tank circuit and damped oscillations are set up in the ckt.

→ As terminal '3' is earthed, it is at zero potential. If terminal 1 is at +ve and terminal 2 is negative. Thus the phase difference b/w the terminals 1 and 2 is always 180°. In the CE mode, the transistor provides the phase difference 180° b/w input and o/p. The total phase shift is 360°.

→ If the feedback is adjusted so that the loop gain $A\beta = 1$ the circuit acts as an oscillator.

→ If the phase shift 360° and $A\beta = 1$ satisfied then sustained oscillations produced.

→ <u>Analysis</u>:-

This analysis gives the condition for oscillation and oscillating frequency formula.

Let $Z_1 = j\omega L_1 + j\omega M$, $Z_2 = j\omega L_2 + j\omega M$

$$Z_3 = \frac{1}{j\omega C} = \frac{-j}{\omega C}$$

→ The condition for LC oscillator for oscillations

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

→ $Z_1 + Z_2 + Z_3 = j\omega(L_1 + L_2 + 2M) - \frac{j}{\omega C}$

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

→ $Z_1 Z_3 = (j\omega L_1 + j\omega M) \times \frac{1}{j\omega C} = \frac{j\omega(L_1 + M)}{j\omega C}$

$$= \frac{L_1 + M}{C}$$

$$Z_1 Z_2 = (j\omega L_1 + j\omega M)(j\omega L_2 + j\omega M)$$

$$= j\omega(L_1 + M)\, j\omega(L_2 + M)$$

$$= j^2 \omega^2 (L_1 + M)(L_2 + M)$$

$$= -\omega^2 (L_1 + M)(L_2 + M).$$

then eq (1) becomes

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

$$j\omega h_{ie}\left(L_1+L_2+2M-\frac{1}{\omega^2 C}\right)-\omega^2(L_1+M)\left[(L_2+M)(1+h_{fe})-\frac{1}{\omega^2 C}\right]= \quad \text{— eq (2)}$$

$\Rightarrow$ making imaginary part $=0$.

$$\omega h_{ie}\left[L_1+L_2+2M-\frac{1}{\omega^2 C}\right]=0$$

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

$$L_1+L_2+2M=\frac{1}{\omega^2 C} \quad \text{— eq (3)}$$

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

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

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

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

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

$$\therefore f=\frac{1}{2\pi\sqrt{L_{eq}C}}$$ where $L_{eq}=L_1+L_2+2M$.

→ Condition for oscillation.

Make real part $=0$.

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

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

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

from eq (3)

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

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

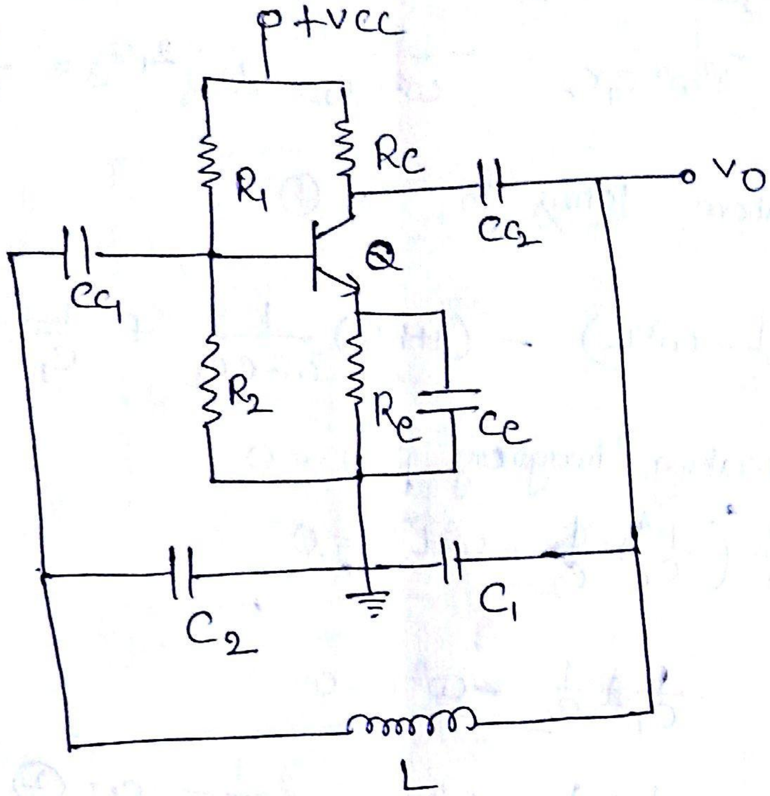
$$1+h_{fe} = \frac{L_1+L_2+2M}{L_2+M} = \frac{(L_1+M)+(L_2+M)}{(L_2+M)}$$

$$\cancel{1}+h_{fe} = \cancel{1} + \left(\frac{L_1+M}{L_2+M}\right)$$

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

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

Colpitt's oscillator:



→ The colpitts oscillator is also same as Hartley oscillator. But the tank circuit has two capacitancy and one inductance 'L'.

→ In this oscillator also 180° phase shift provided by CE Amplifier and remaining phase shift 180° provided by feedback n/w.

→ when the circuit is turned ON C_1 and C_2 are charged and after some time capacitors discharged through the inductor 'L'. Setting up the frequency of oscillations.

Analysis:-

The frequency of oscillation is in general form

$$h_{ie}(Z_1+Z_2+Z_3)+(1+h_{fe})Z_1Z_2+Z_1Z_3=0 \quad \text{—eq (1)}$$

where, in colpitts oscillator

$$Z_1=\frac{1}{j\omega C_1}, \quad Z_2=\frac{1}{j\omega C_2}, \quad Z_3=j\omega L.$$

$\rightarrow z_1+z_2+z_3 = \frac{1}{j\omega}\left(\frac{1}{C_1}+\frac{1}{C_2}-\omega^2 L\right)$

$\rightarrow \quad z_1 z_2 = \frac{1}{j^2\omega^2 C_1 C_2} = -\frac{1}{\omega^2 C_1 C_2}$, $z_1 z_3 = \frac{L}{C_1}$.

put the above terms in eq ①.

$$\frac{hie}{j\omega}\left(\frac{1}{C_1}+\frac{1}{C_2}-\omega^2 L\right) - (1+hfe)\frac{1}{\omega^2 C_1 C_2} + \frac{L}{C_1} = 0.$$

making imaginary part = 0.

$$-\frac{hie}{\omega}\left(\frac{1}{C_1}+\frac{\cancel{C}}{C_2}-\omega^2 L\right) = 0$$

$$\frac{1}{C_1}+\frac{1}{C_2} - \omega^2 L = 0$$

$$\frac{1}{C_1}+\frac{1}{C_2} = \omega^2 L \quad \text{—— eq ②}$$

$$\omega^2 = \frac{1}{L}\cdot\frac{C_1+C_2}{C_1 C_2}$$

$$\omega^2 = \frac{1}{L\,\frac{C_1 C_2}{C_1+C_2}}$$

$$\omega = \frac{1}{\sqrt{L\,\frac{C_1 C_2}{C_1+C_2}}}$$

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

$$\boxed{f = \frac{1}{2\pi\sqrt{L C_{eq}}}} \qquad C_{eq} = \frac{C_1 C_2}{C_1+C_2}$$

$\rightarrow$ making real part = 0.

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

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

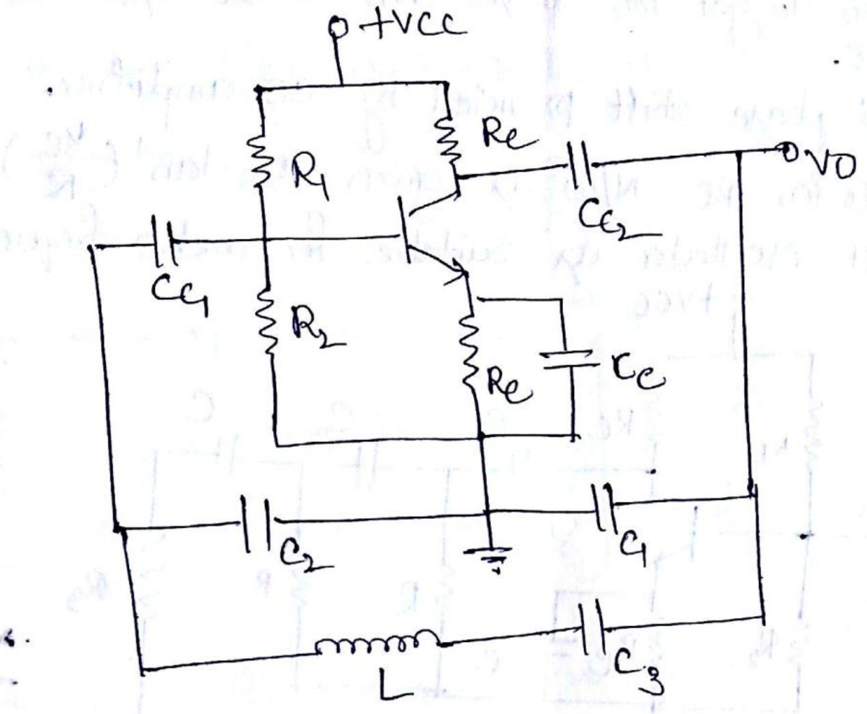
$$L\omega^2 C_2 = 1+hfe$$

$$\omega^2 L = \frac{C_1+C_2}{C_1 C_2}$$

$$\cancel{C_2}\left(\frac{C_1+C_2}{C_1 \cancel{C_2}}\right) = 1+hfe$$

$$1+hfe = 1+\frac{C_2}{C_1} \Rightarrow \boxed{hfe = \frac{C_2}{C_1}}$$

* clapp oscillator:- (6)



→ In the clapp oscillator C_1, C_2 and L series with C_3 are consider as feedback tank circuit.

→ The Additional C_3 improves the frequency stability of the oscillator.

→ The frequency of oscillation is

$$f_o = \frac{1}{2\pi\sqrt{LC_{eq}}}$$

where $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

or $C_{eq} = \frac{C_1 C_2 C_3}{C_1C_2 + C_2C_3 + C_1C_3}$.

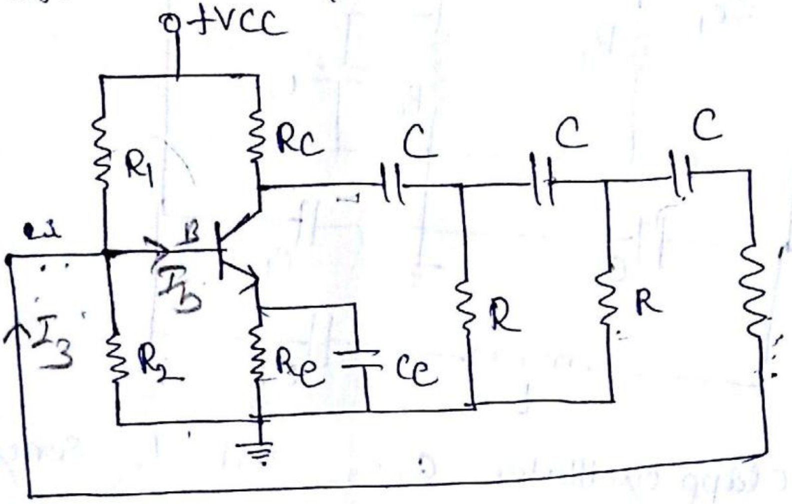
* RC phase shift oscillator :-

→ In the RC phase shift oscillator each RC-network provides phase shift of 60°. So to get 180° phase shift 3-RC-n/w are combined in this oscillator.

→ Additional 180° phase shift provided by CE amplifier.

→ The phase angle for RC-N/w is given $\Theta = \tan^{-1}\left(\frac{X_C}{R}\right) \Rightarrow \Theta = 60°$

→ RC-phase shift oscillator is suitable for audio frequencies.

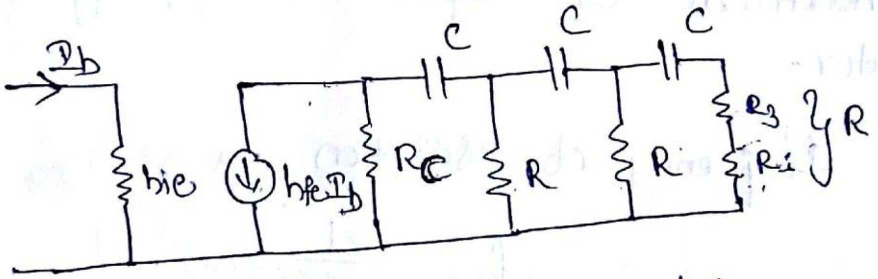


→ $R_3 + R_i = R$

→ $R_3 = R - R_i$

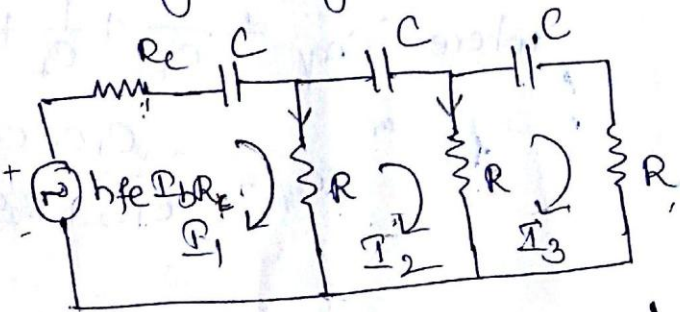
The approximate hybrid-equivalent circuit is given by.

⇒



→ Remodified by using thevenin's model.

⇒



where

$A = \frac{-h_{fe}I_b}{I_b}$

$\beta = \frac{I_3}{-h_{fe}I_b}$

$A\beta = -\cancel{h_{fe}} \times \frac{I_3}{-\cancel{h_{fe}}I_b}$

$A\beta = \frac{I_3}{I_b} = 1.$

Let $X_C = \frac{1}{\omega C} \Rightarrow Z_C = -jX_C$ (or) $\frac{-j}{\omega C}$

→ The mesh equations are. to find out I_3 value.

$$I_1(R_C+R-jX_C)-I_2R=-h_{fe}I_bR_C \quad \text{---} ①$$

$$-I_1R+I_2(2R-jX_C)-RI_3=0 \quad \text{---} ②$$

$$-I_2R+I_3(2R-jX_C)=0 \quad \text{---} ③.$$

→

$$\begin{bmatrix} R+R_C-jX_C & -R & 0 \\ -R & 2R-jX & -R \\ 0 & -R & 2R-jX \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}=\begin{bmatrix} -h_{fe}I_bR_C \\ 0 \\ 0 \end{bmatrix}$$

⇒ find $I_3=\dfrac{\Delta_3}{\Delta}$ (cramers rule).

$$\Delta_3=\begin{bmatrix} R+R_C-jX & -R & -h_{fe}I_bR_C \\ -R & 2R-jX & 0 \\ 0 & -R & 0 \end{bmatrix} = -h_{fe}I_bR_C\cdot R^2$$

$R+R_1-j X(0)$.

$$\Rightarrow \Delta=R^3\begin{bmatrix} 1+\frac{R_C}{R}-\frac{jX_C}{R} & -1 & 0 \\ -1 & 2-\frac{jX_C}{R} & -1 \\ 0 & -1 & 2-\frac{jX_C}{R} \end{bmatrix}$$

let $K=\dfrac{R_C}{R}$, $\alpha=\dfrac{X_C}{R}$.

$$=R^3\begin{bmatrix} 1+K-j\alpha & -1 & 0 \\ -1 & 2-j\alpha & -1 \\ 0 & -1 & 2-j\alpha \end{bmatrix}$$

$$=R^3\left[(1+K-j\alpha)\left[(2-j\alpha)^2-1\right]+1\left[j\alpha-2\right]\right]$$

$$=R3\ (1+K-j\alpha)(4-\alpha^2+4j\alpha-1)+j(\alpha-2)]$$

$$=R3\left[3-\alpha^2+4j\alpha+3k-\alpha^2k+4jk\alpha-3j\alpha+j\alpha^3+4\alpha^2+j\alpha-2\right]$$

$$\Delta = R^3\left[\left((1+3K) - (5+K)\alpha^2\right) - j\left[(6+4K)\alpha - \alpha^3\right]\right]$$

$$I_3 = \frac{\Delta_3}{\Delta} = \frac{-h_{fe} I_b R_C R^2}{R^3\left[(1+3K) - (5+K)\alpha^2 - j\left((6+4K)\alpha - \alpha^3\right)\right]}$$

$$I_3 = \frac{-h_{fe} I_b \frac{R_C}{R}}{\left[(1+3K) - (5+K)\alpha^2\right] - j\left[(6+4K)\alpha - \alpha^3\right]}$$

$$\frac{I_3}{I_b} = \frac{-h_{fe}K}{\left[(1+3K) - (5+K)\alpha^2\right] - j\left[(6+4K)\alpha - \alpha^3\right]} = 1$$

$$\Rightarrow \left[(1+3K) - (5+K)\alpha^2\right] - j\left[(6+4K)\alpha - \alpha^3\right] = -h_{fe}K.$$

make imaginary part $= 0$

$$(6+4K)\alpha - \alpha^3 = 0.$$

$$(6+4K)\cancel{\alpha} = \alpha^{\cancel{3}2}$$

$$\alpha^2 = 6+4K$$

$$\left(\frac{X_C}{R}\right)^2 = 6+4K. \Rightarrow \left(\frac{1}{\omega C R}\right)^2 = 6+4K. \Rightarrow \frac{1}{\omega C R} = \sqrt{6+4K}$$

$$\omega = \frac{1}{RC\sqrt{6+4K}}.$$

frequency of oscillation. $\boxed{\therefore f = \frac{1}{2\pi RC\sqrt{6+4K}}}$

put ~~imaginary~~ real part $= 0$: $\alpha^2 = 6+4K$ in eq (1)

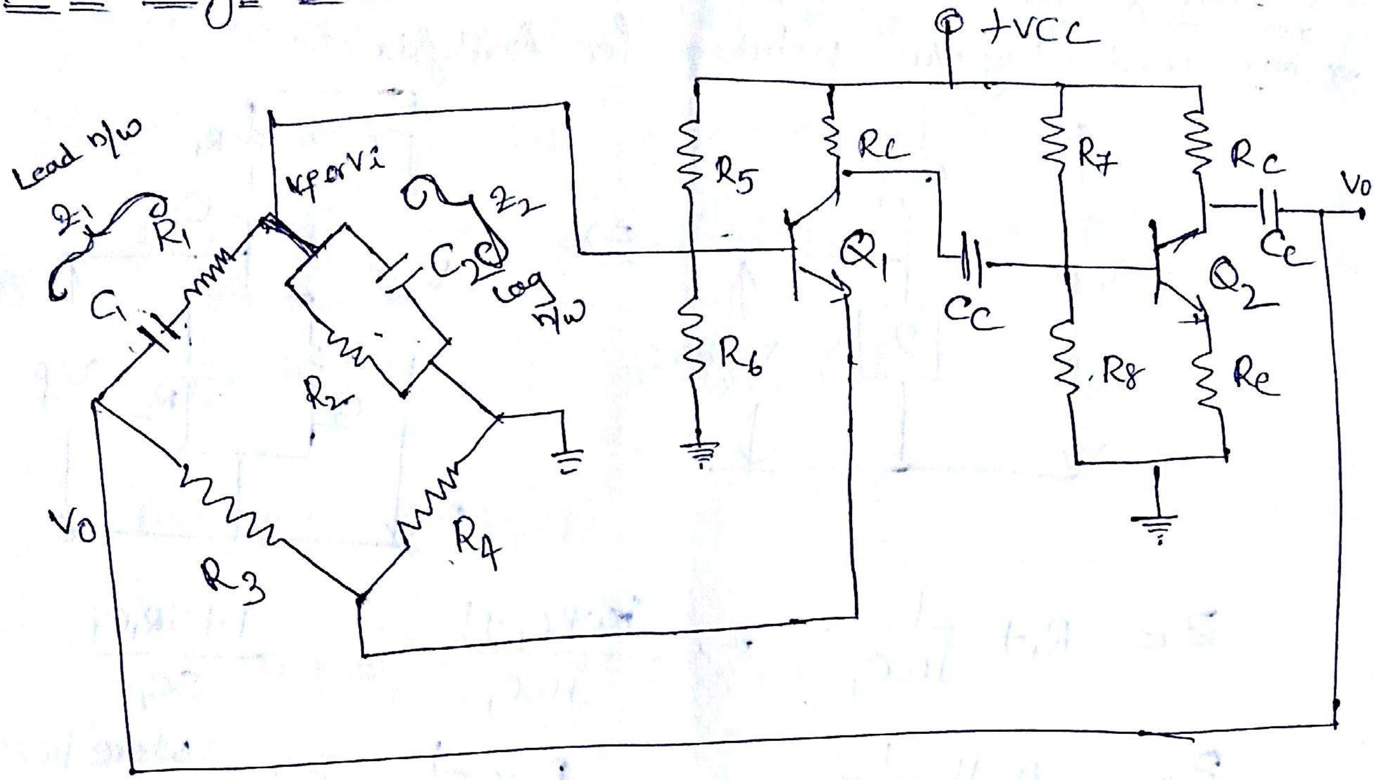
$$1+3K - \alpha^2(5+K) = -h_{fe}K$$

$$1+3K - (6+4K)(5+K) = -h_{fe}K$$

$$+h_{fe} = \frac{4K^2 + 23K + 29}{K}$$

$\boxed{\therefore h_{fe} = \frac{29}{K} + 23 + 4K.}$ Condition for oscillation.

* Wien Bridge oscillator :-



→ The wien bridge oscillator consists of a two stage RC-coupled amplifier and a balanced bridge. where two stage Amplifier produce phase shift of 360°. Then there is no need to provide extra phase shift by feedback network.

→ The feedback bridge consists of Lead-Lag circuit which provides positive feedback and connected to i/p of the Ist stage Amplifier.

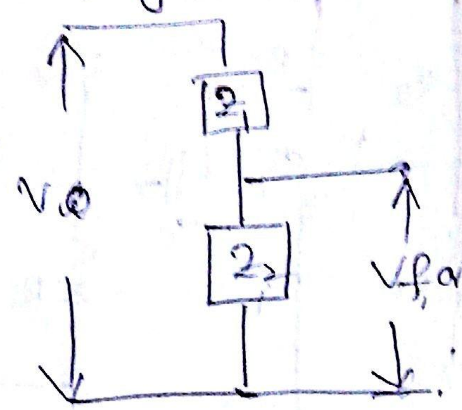
→ In this Lead-Lag network series combination of $R_1 + C_1$ is Lead network and parallel combination of $R_2 + C_2$ is Lag network.

→ The R_3 and R_4 in bridge is voltage divider which gives -ve feedback and connected to emitter of the amplifier.

→ These oscillators used for commercial audio signal generators.

Conditions for oscillations:-

→ only Lead-lag n/w is taken for Analysis



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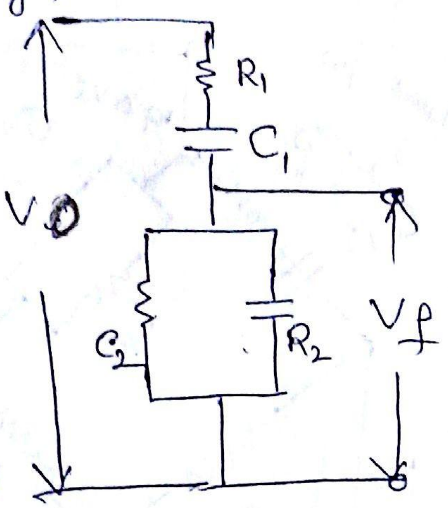


$$Z_1 = R_1 + \frac{1}{j\omega C_1} = \frac{j\omega R_1C_1 + 1}{j\omega C_1} = \frac{1+SR_1C_1}{SC_1}$$

where $j\omega = S$

$$Z_2 = R_2 \parallel \frac{1}{j\omega C_2} \Rightarrow \frac{R_2 \times \frac{1}{j\omega C_2}}{R_2 + \frac{1}{j\omega C_2}}$$

$$= \frac{R_2}{j\omega R_2C_2 + 1} = \frac{R_2}{1+SR_2C_2}.$$

$$\Rightarrow \boxed{\beta = \frac{V_f}{V_0}} \; ?$$

from the above ckt.

$$\Rightarrow V_f = \frac{Z_2}{Z_1+Z_2} \cdot V_0$$

$$\therefore \beta = \frac{V_f}{V_0} = \frac{Z_2}{Z_1+Z_2}$$

$$\Rightarrow \beta = \frac{\frac{R_2}{1+SR_2C_2}}{\frac{1+SR_1C_1}{(SC_1)} + \frac{R_2}{(1+SR_2C_2)}} = \frac{R_2(SC_1)}{1+S^2R_1C_1R_2C_2 + SR_1C_1 + SR_2C_2 + R_2SC_1}$$

$$= \frac{j\omega R_2C_1}{1+(j\omega)^2R_1C_1R_2C_2 + j\omega R_1C_1 + j\omega R_2C_2 + j\omega R_2C_1}$$

$$\beta = \frac{j\omega R_2C_1}{(1-\omega^2R_1R_2C_1C_2)+j\omega(R_1C_1+R_2C_2+C_1R_2)}$$

Rationalising the above expression

$$\beta = \frac{j\omega R_2C_1\left[(1-\omega^2R_1R_2C_1C_2)-j\omega(R_1C_1+R_2C_2+C_1R_2)\right]}{(1-\omega^2R_1R_2C_1C_2)^2+\omega^2(R_1C_1+R_2C_2+C_1R_2)}$$

$A=1$
$A\beta=1.$

Imaginary part $=0$

$$\omega R_2C_1(1-\omega^2R_1R_2C_1C_2)=0$$

$$\omega^2R_1R_2C_1C_2=1$$

$$\Rightarrow \omega^2=\frac{1}{R_1R_2C_1C_2}$$

$$(2\pi f)^2=\frac{1}{R_1R_2C_1C_2}$$

$$\boxed{\therefore\ f=\frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}}$$

If $R_1=R_2=R,\ C_1=C_2=C$

$$\boxed{f=\frac{1}{2\pi RC}} \Rightarrow \omega=\frac{1}{RC}$$

$$\Rightarrow \beta=\frac{\frac{1}{(RC)^2}3(RC)^2+0}{0+\frac{1}{(RC)^2}[3(RC)]^2}=\frac{3}{9}=\frac{1}{3}.$$

$A\beta=1 \Rightarrow \boxed{A=3}$

closed Amplitude 3.

* Crystal oscillators :-

→ Crystal oscillator is basically a tuned oscillator. It uses a 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 preferred Ex:- communication transmitters, digital clocks etc.

↳ A quartz crystal exhibits a very important property known as piezoelectric effect.

when an A.C voltage is applied across the crystal it vibrates at the frequency of the applied voltage.

(or) when a crystal is subjected to mechanical stress it produces an AC voltage. This phenominan is called piezo electric effect.

→ The other substances that exhibit piezoelectric effect besides Quartz are Rochelle salt and tourmaline.

Rochelle salt → greatest piezo electric activity — but mechanically weak. they break easily. → microphones, headset, + loudspeakers

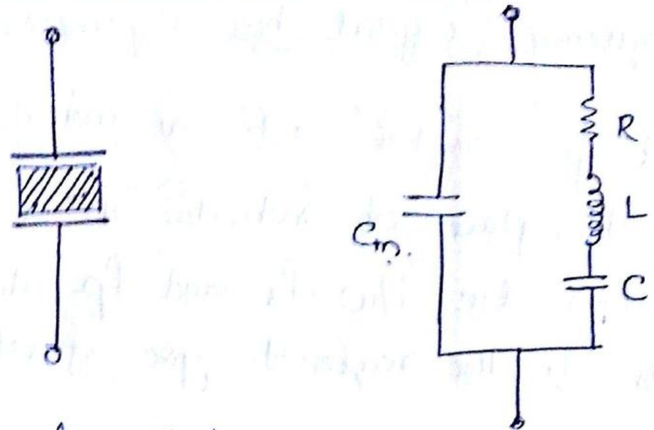
Tourmaline → Least piezo electric activity — most expensive. ↳ Rarley used for high frequencies

↳ Quartz is a compromise b/w Rochelle salt and tourmaline.

↳ It is inexpensive and readily available in nature.

↳ It is used mainly for rf oscillators.

⇒ For use in electronic oscillators, the crystal material is suitably cut and then mounted b/w two metal plates as shown in figure. The electrical equivalent circuit of the crystal also shown in figure.



→ The frequency of crystal is depends on the cut and how the crystal is mounted.

→ The outstanding feature of crystals as compared with discrete LC tank circuits is high Quality factor Q. due to this high freq. stability achived.

→ The crystal has two different frequencies

1) The Inductance L resonates with series capacitance 'C' and produces series resonant frequency 'f_s'.

$$X_L = X_C$$

$$\omega L = \frac{1}{\omega C} \Rightarrow \omega^2 = \frac{1}{LC}$$

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

↳ Above frequency f_s, the series branch LCR has inductive Reactance only. This inductance resonates with ∥ capacitance Cm. called parallel resonant frequency 'f_p'.

$$X_{Cm} = X_{sL} - X_{p}$$

$$\frac{1}{\omega_p C_m} = \omega_p L - \frac{1}{\omega_p C} \Rightarrow \frac{1}{\omega_p C_m} + \frac{1}{\omega_p C} = \omega_p L$$

$$\frac{C + C_m}{\omega_p C C_m} = \omega_p L$$

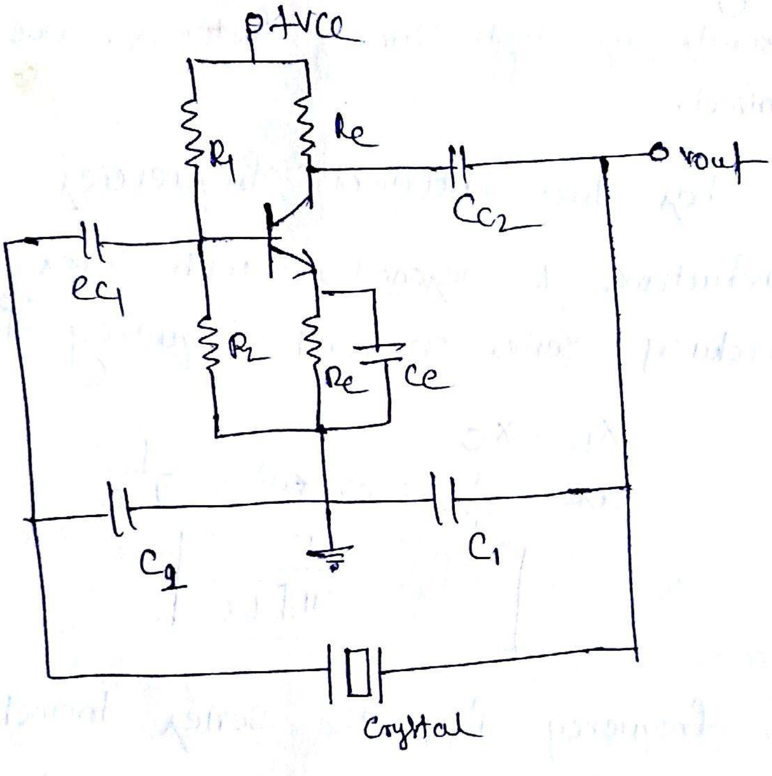
$$\Rightarrow \omega_p^2 = \frac{1}{L \frac{C C_m}{C + C_m}}$$

$$\Rightarrow \boxed{f_p = \frac{1}{2\pi\sqrt{L C_{eq}}}} \quad C_{eq} = \frac{C C_m}{C + C_m}.$$

→ Above this f_p frequency crystal has capacitive reactance only.

→ only b/w f_s and f_p crystal acts as inductor. If the crystal is used in the place of inductor in an oscillator ckt, the frequency of oscillation lie b/w f_s and f_p - differ by very small amount → This is the reason to give great frequency stability

→ The following circuit represents the colpitts crystal oscillator



* 1. In the Hartley oscillator $L_2 = 0.4mH$ and $C = 0.004\,\mu F$. If the frequency of the oscillator is 120kHz. Find the value of L_1, Neglect mutual inductance.

$$f_o = \frac{1}{2\pi\sqrt{L_{eq} C}}$$

$$L_{eq} = L_1 + L_2$$

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

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

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

$$= \frac{1}{4\times\pi^2 (120\times10^3)^2 \times (0.004\times10^{-6})} - 0.4\times10^{-3}$$

$$= 0.04mH.$$

* 2. In a transistorized Hartley oscillator, the two inductances are 2mH and 20µH while the frequency is to be changed from 950 KHz to 2050 kHz. Calculate the range over which the capacitor is to be varied.

Sol:- If $L_1 = 2mH$, $L_2 = 20\mu H$, $f_1 = 950kHz$, $f_2 = 2050kHz$.

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

If $f_o = 950KHz \Rightarrow C = 13.89pF$

If $f_o = 2050kHz \Rightarrow C = 2.98pF$

range of capacitance is from 2.98pF to 13.89pF

* In a Hartley oscillator, the value of the Capacitor in the tuned circuit is 500 pF and the two sections of coil have inductancy 38 µH and 12 µH. Find the frequency of oscillations and the feedback factor β.

Sol:- $f_0 = 1MHz$ $\Rightarrow f_0 = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$.

$\beta = \frac{L_1}{L_2} = 3.166$