UNIT-V

SINUSOIDAL OSCILLATORS.

Introduction:-

The oscillators are electronic circuits makes a respective electronic signal generally the sine wave and the square wave. The oscillator converts the direct current from the power supply to an alternating current. The oscillator works on the principle of the oscillation and it is a mechanical or electronic device. The periodic variation between the two things is based on the changes in the energy. The oscillations are used in the watches, radios, metal detectors and in many other devices.

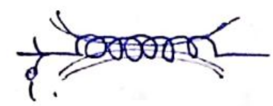
Tank circuit:

A circuit that produces electrical oscillations of a desired frequency is known as an oscillatory circuit or tank circuit.

A capacitor 'c' stores the energy in electric field

$$V_E = \frac{q^2}{2C}.$$

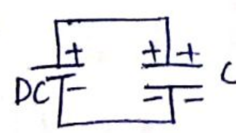
An inductor 'L' stores the energy in magnetic field



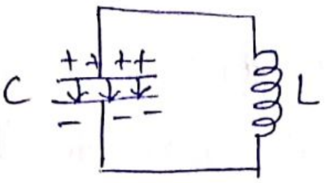
$$V_B = \frac{1}{2} L C^2.$$

A simple oscillatory circuit which contains a capacitor 'c' and an inductor L connected in parallel. The frequency of oscillations produced by this oscillatory circuit is determined by the value of C and L.

→ The circuit arrangment to charge the capacitor of an oscillatory circuit as shown in figure. A DC battery is used to charge the capacitor and then disconnect the DC power supply.

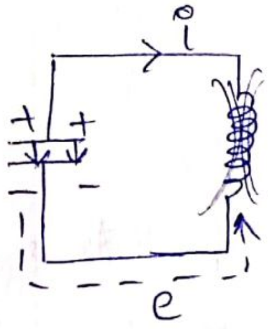


→ Now connect the fully charged capacitor to an inductor in parallel

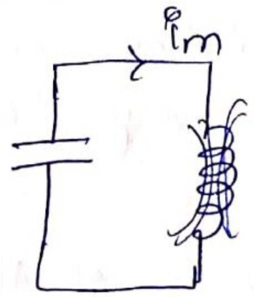


At $t=0$
the capacitor is fully charged in 'q_m'
and the current in the circuit $i=0$.

when the capacitor slowly discharges towards inductor and reduces to the positive potential then the charge of the capacitor reduces slowly and the electric field charge reduces towards magnetic field ie the inductor changes the current

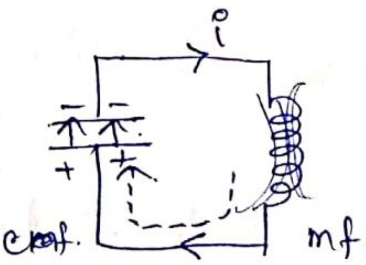


when $t = \frac{1}{4}T$



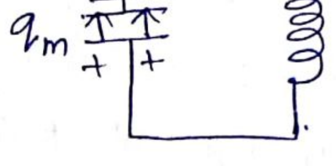
The charge in the capacitor becomes neutral and the charge in the inductor becomes maximum "i_m"

Now the inductor discharges the charge towards the capacitor and C charges the energy into electric field.

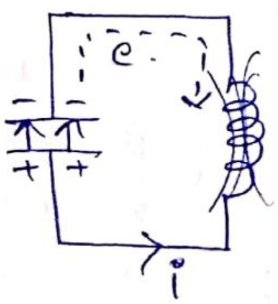


when $t = \frac{1}{2}T$

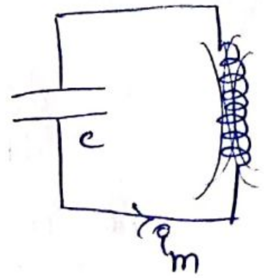
The magnetic field energy ie 'L' charge completely discharges and 'C' charges fully 'q_m' and $i_m = 0$.



After $t = \frac{1}{2}T$, the C slowly discharges towards L is opposite direction to the previous direction. Now q_m slowly decrease and 'i' slowly increases opposite direction.

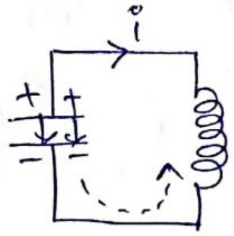


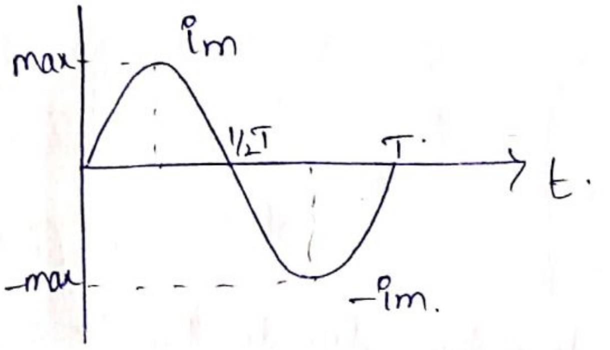
At $t = 3/4\,T$, the 'c' completely discharges $q_m = 0$, and the L completely charges 'i_m'

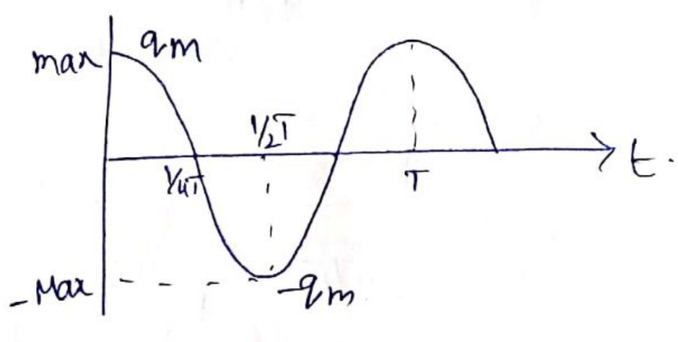


after $t = 3/4\,T$ again the 'L' slowly discharges and c slowly increases. magnetic field decreases and electric field increases.

At $t = T$ the L completely discharges $i = 0$ but c completely charges q_m is maximum.





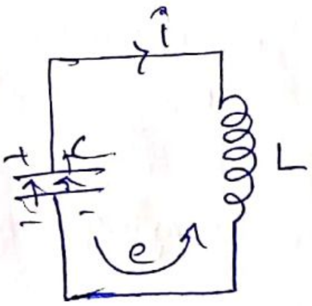


Let consider V_c across the capacitor

$$V_c = q/c.$$

V_L across the inductor

$$V = L\frac{di}{dt}.$$



Now apply KVL to the tank circuit

$$V_C - V_L = 0$$

$$\frac{q}{C} - L\frac{di}{dt} = 0.$$

But in the circuit i is in opposite direction, where electric field change ↓ then current ↑ $\quad i = -\frac{dq}{dt}$.

Now substitute the 'i' in above equation

$$\frac{q}{C} - L \cdot \frac{d\left(-\frac{dq}{dt}\right)}{dt} = 0.$$

$$L \cdot \frac{d^2q}{dt^2} + \frac{q}{C} = 0.$$

Now divide the above equation with L, then

$$\frac{d^2q}{dt^2} + \frac{1}{LC}\cdot q = 0.$$

Now compare the above equation with simple Harmonic motion eqn.

$$\frac{d^2x}{dt^2} + \omega_0^2 x = 0.$$

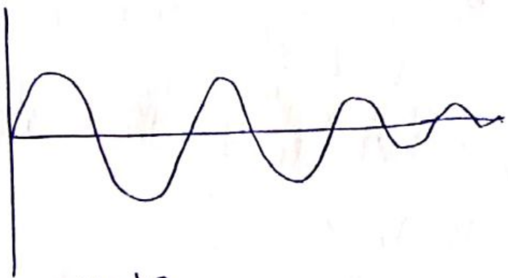
$$\frac{d^2x}{dt^2} = \frac{d^2q}{dt^2} \quad ; \quad \frac{1}{LC}\cdot q \Rightarrow \omega_0^2 x.$$

$\omega_0^2 = \frac{1}{LC}$ represents

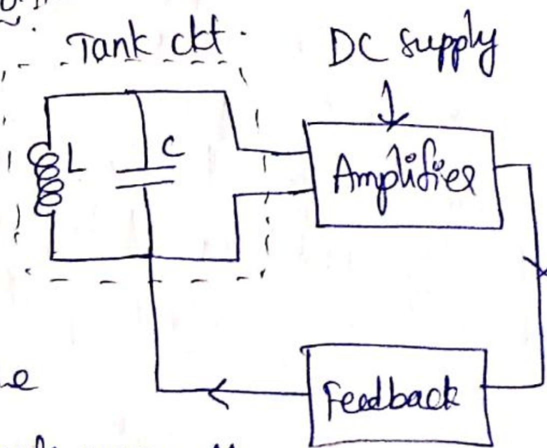
$$\omega_0 = \frac{1}{\sqrt{LC}}$$

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

The tank circuit cannot run for long time due to the losses. where the continuous change of electric field to magnetic field which causes radiation, and the losses of electromagnetic waves reduces the change levels in L & C due to this losses we go to the damping condition.



Block diagram of transistor oscillator:-



Tank circuit:-

The tank circuit consists of an inductor 'L' connected in parallel with capacitor 'C'. It is known as frequency determining network. The frequency of oscillations in the ckt depends upon the values of inductance & capacitance.

Transistor Amplifier:-

The function of the amplifier is to amplify the oscillations produced by LC circuit. The amplifier receives DC power from battery and converted it into ac. power for supplying to the tank circuit. The oscillations produced in tank circuit are applied to the i/p of the transistor. The transistor increases the o/p of these oscillations.

Feedback circuit:-

The function of feedback circuit is to transfer a part of the output energy to the LC circuit in proper phase. when the feedback is positive, the overall gain of the amplifier is

$$A_f = \frac{A}{1 - A\beta}$$

$A\beta$ = loop gain = 1 then $A_f = \infty$.

Thus the gain becomes infinity ie the output without any i/p, is called as oscillator.

$\therefore A\beta = 1$ It is called Barkhausen criterion ~~of~~ oscillations.

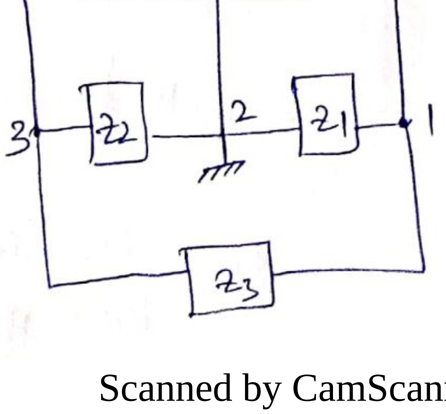
where $|A\beta|$ is the magnitude of the loop gain, a function of frequency and 'θ' phaseshift is also a function of frequency.

$\theta = \pm 360^\circ \rightarrow$ Barkhausen ~~cri~~ criterion

General form of an L-C oscillator:-

Any active device can be used as amplifier.

Z_1, Z_2 & Z_3 are the reactive elements.



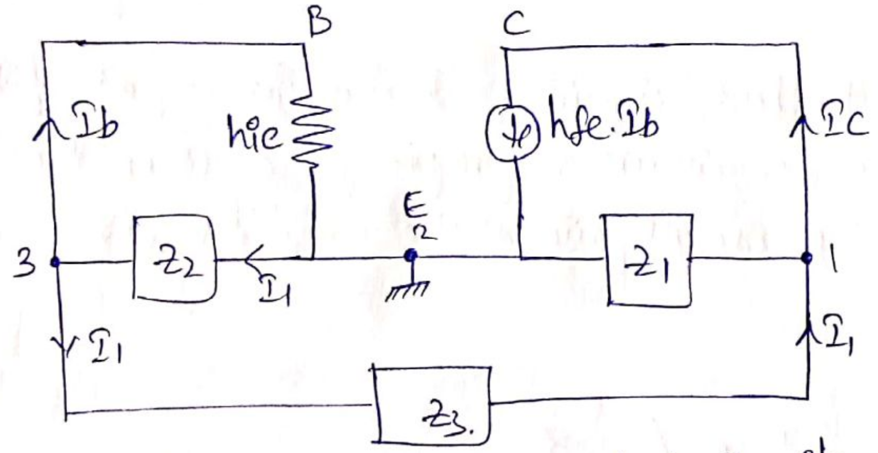
These circuit constituting the feedback tank circuit which determines the frequency of oscillations.

Z_1 & Z_2 works as an ac voltage divider for the o/p voltage and feedback signal.

Z_1 which links the o/p of amplifier with tank circuit.

Z_2 is used for feedback.

Z_1, Z_2 & Z_3 makes the tank circuit.



For the analysis of equivalent circuit, consider the following two assumptions.

→ h_{re} of transistor is negligibly small & the feedback source $h_{re} \cdot V_{out}$ is negligible.

→ h_{oe} of the transistor is very small ie o/p resistance $1/h_{oe}$ is very large.

The load impedance ~~prob~~ provided by the tank circuit to amplifier o/p is Z_L is given as

$$Z_L = Z_1 \parallel [Z_3 + (Z_2 \parallel h_{ie})]$$

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

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

From the approximate analysis of CE amplifier, the voltage gain is given as

$$A = \frac{-h_{fe} \cdot Z_L}{h_{ie}}.$$

The o/p voltage between the terminals 1 & 2 is

$$V_{out} = [Z_3 + (Z_2 \| h_{ie})] I_1$$

$$V_{out} = \left[\frac{h_{ie}(Z_2+Z_3) + Z_2 Z_3}{Z_2 + h_{ie}}\right] I_1$$

The feedback voltage between the terminals 2 & 3 is.

$$V_f = (Z_2 \| h_{ie}) I_1 = \left[\frac{Z_2 h_{ie}}{Z_2 + h_{ie}}\right] I_1$$

Now $\beta = \frac{V_f}{V_o}$ is

$$\beta = \frac{V_f}{V_o} = \frac{[Z_2 \| h_{ie}]}{Z_3 + (Z_2 \| h_{ie})} = \frac{Z_2 h_{ie}}{h_{ie}(Z_2+Z_3) + Z_2 Z_3}$$

As we have to get the Barkhausen criterion of oscillation is

$$A\beta = 1$$

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

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

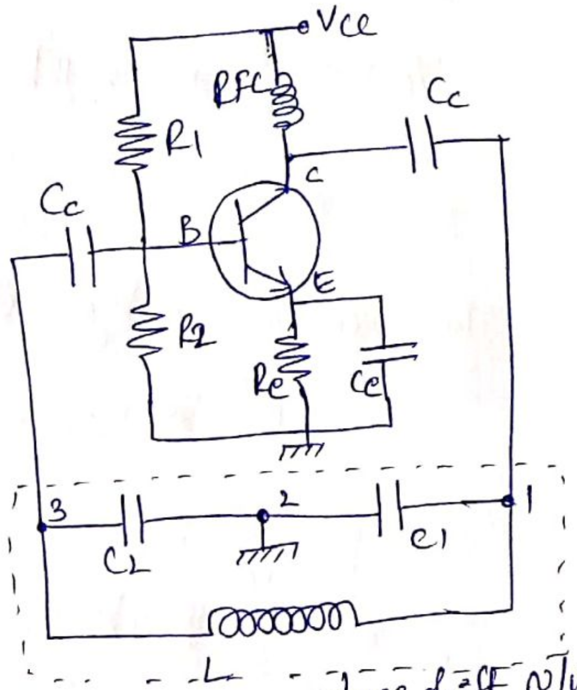
$$\frac{h_{fe} Z_2}{\cancel{h_{ie}(Z_2+Z_3) + Z_2 Z_3}} \times \frac{Z_1 \left(\cancel{h_{ie}(Z_2+Z_3) + Z_2 Z_3}\right)}{h_{ie}(Z_1+Z_2+Z_3) + Z_1 Z_2 + Z_2 Z_3} = -1$$

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

$$h_{ie}(z_1+z_2+z_3)+z_1z_2+z_2z_3=-h_{fe}\cdot z_2z_1$$

$$\boxed{h_{ie}(z_1+z_2+z_3)+z_1z_2(1+h_{fe})+z_2z_3=0.}$$

The above equation is known as general equation of oscillations for LC network



COLPITT'S OSCILLATOR:-

The colpitt's oscillator circuit can able to generate upto 100MHz frequency oscillations.

In the circuit, the two series capacitors C_1 & C_2 from the potential divider are used for providing the +ve feedback voltage where the voltage is developed across the C_2 which provides the regenerative feedback required for the sustained oscillations.

parallel combination of R_E with C_E & R_1 & R_2 provides the stabilized self bias conditions for the CE amplifier.

The collector supply voltage Vcc is applied to the collector through a radio frequency choke (RFC) which permits an easy flow of direct current but at the same time it offers very high impedance to the high frequency currents.

The Cc in the o/p circuit does not permit the DC currents to go to the tank circuit and Cc in the i/p circuit blocks dc but provides path to ac.

The CE amplifier transistor itself provides a phase shift of 180° and the other phase shift of 180° is provided by the capacitive feedback. Total 360° phase shift is produced, which is essential condition for developing oscillations.

Frequency of oscillation:-

The general equation of the LC network is given as

$$h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2(1+h_{fe})+Z_2Z_3=0.$$

Here the colpitts oscillator provides as

$$Z_1 = X_{C_1} = \frac{1}{j\omega C_1} = \frac{-j}{\omega C_1}$$

$$Z_2 = X_{C_2} = \frac{1}{j\omega C_2} = \frac{-j}{\omega C_2}$$

$$Z_3 = j\omega L.$$

Now by substituting in the general equation, we get

$$h_{ie}\left[\frac{-j}{\omega C_1}+\frac{-j}{\omega C_2}+j\omega L\right]+(1+h_{fe})\left[\frac{-j}{\omega C_1}\cdot\frac{-j}{\omega C_2}\right]+\frac{-j}{\cancel{\omega} C_2}\cdot j\cancel{\omega}L=0.$$

$$-j\,h_{ie}\left[\frac{1}{\omega C_1}+\frac{1}{\omega C_2}-\omega L\right]-\frac{1+h_{fe}}{\omega^2 C_1C_2}+\frac{L}{C_2}=0.$$

To get the resonance frequency, equate imaginary part to zero

$$j\,h_{ie}\left[\frac{1}{j\omega C_1}+\frac{1}{\omega C_2}+\omega L\right]+\left[\frac{1+h_{fe}}{\omega^2 C_1C_2}-\frac{L}{C_2}\right]=0.$$

$$h_{ie}\left[\frac{1}{\omega C_1}+\frac{1}{\omega C_2}-\omega L\right]=0.$$

$h_{ie}\neq 0$, then $\frac{1}{\omega C_1}+\frac{1}{\omega C_2}-\omega L=0.$

$$\frac{1}{\omega}\left[\frac{1}{C_1}+\frac{1}{C_2}\right]-\omega L=0.$$

$$\frac{1}{\omega}\left(\frac{1}{C_{eq}}\right) = \omega L$$

$$\omega^2 = \frac{1}{L C_{eq}}.$$

$$\boxed{f = \frac{1}{2\pi\sqrt{L C_{eq}}}}$$ resonance frequency

when $C_{eq} = C_1$ in series with C_2

To get the condition for oscillation, equate real part to '0', then we can get

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

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

$$1+h_{fe} = \frac{\omega^2 L C_1 \cancel{C_2}}{\cancel{C_2}}$$

we know that $\omega^2 = \frac{C_1+C_2}{C_1 C_2 L}$ substitute in the above equation

we get

$$1+h_{fe} = \frac{C_1+C_2}{\cancel{C_1} C_2 \cancel{L}} . \cancel{L}\cancel{C_1}$$

$$\cancel{1}+h_{fe} = \frac{C_1}{C_2} + \frac{\cancel{C_2}}{\cancel{C_2}}$$

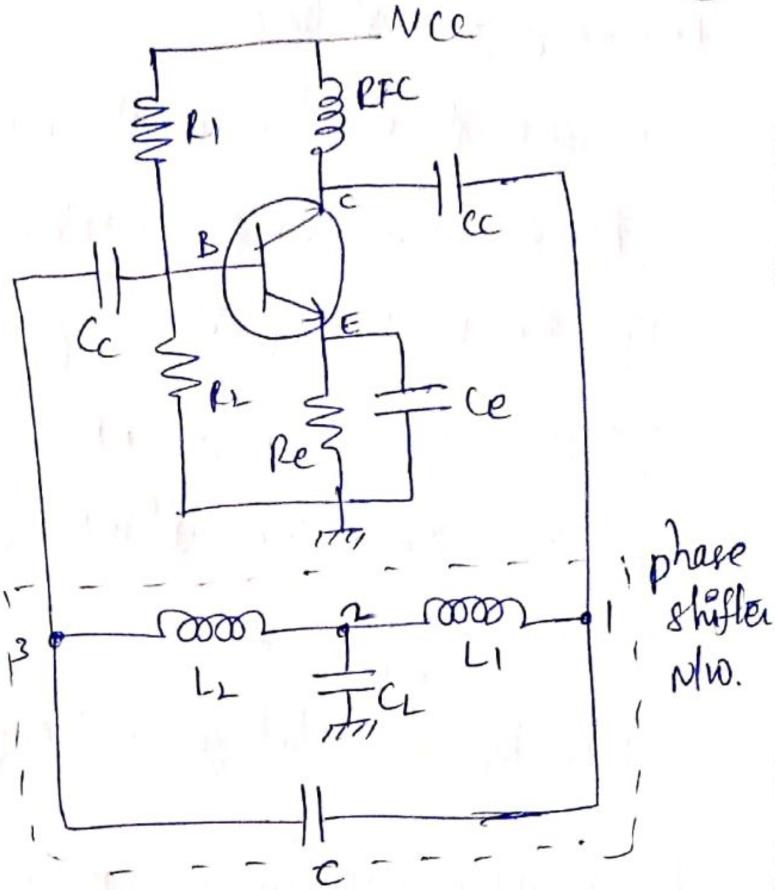
$$\boxed{h_{fe} = \frac{C_1}{C_2}}$$ condition for oscillations

Applications:
- wide range of frequencies are involved.
- It is intended to withstand high & low ~~frequen~~ temperatures.
- It is used for Development of mobile and radio communication

Advantages: good wave purity, stability & fine performance at high freq.

Disadvantage: poor isolation & hard to design.

Hartley oscillator:-



Hartley oscillator circuit can be able to generate upto 10KHz to 100MHz frequency of oscillations.

The o/p of the amplifier is applied across inductor L_1 and the voltage across inductor L_2 forms the feedback voltage.

The coil L_1 is inductively coupled to coil L_2 the combination functions as an auto frequencies.

Because of direct connection, the function of L_1 & L_2 cannot be directly grounded. Instead we can use another capacitor C_L.

considering the fact that there exists mutual inductance between coils L_1 & L_2 because the coils are wound on the same core, their net effective inductance is increased by mutual inductance M. so in this case effective inductance is given by the equation

$$L = L_1 + L_2 + 2M$$

when DC supply is given then I_C current starts raising and beings with charging the capacitor. once the capacitor is fully charged, its starts discharged through L_1 and L_2 and again starts charging.

Frequency of oscillations:

The general equation of the L-C network.

$$h_{ie}(Z_1+Z_2+Z_3) + Z_1Z_2(1+h_{fe}) + Z_2Z_3 = 0.$$

Here the Hartley oscillator provides as

$$Z_1 = X_{L_1} = j\omega L_1 + j\omega M.$$

$$Z_2 = X_{L_2} = j\omega L_2 + j\omega M$$

$$Z_3 = \frac{-j}{\omega C} = X_C.$$

Now by substituting in the general equation we get

$$h_{ie}\left[j\omega L_1 + j\omega M + j\omega L_2 + j\omega M - \frac{j}{\omega C}\right] + \left[(j\omega L_1 + j\omega M)(j\omega L_2 + j\omega M)\right]$$

$$\left[1+h_{fe}\right] + \left[(j\omega L_2 + j\omega M)(-j/\omega C)\right] = 0.$$

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

Now by equating all the imaginary part in the above equation to zero we get.

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

$\omega \neq 0$ $h_{ie} \neq 0$, then

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

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

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

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

Now by equating all the real parts in the equation to zero we get.

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

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

$$\omega \neq 0. \quad L_2+M \neq 0.$$

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

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

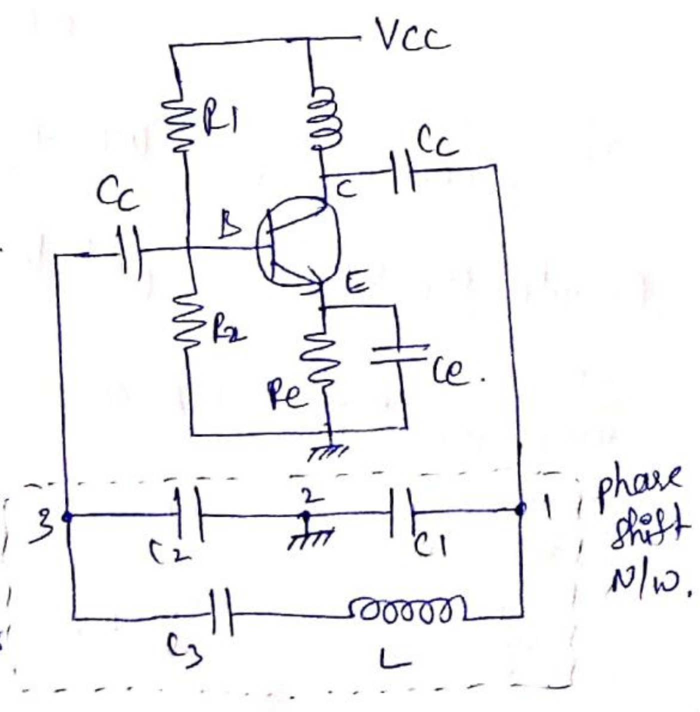
$$1+h_{fe} = \frac{L_1+L_2+2M}{L_1+M}$$

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

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

CLAPP OSCILLATOR:-

The single inductor found in the colpitts oscillator is replaced by a series LC combination. Addition of capacitor C_3 in series with L improves the frequency stability & eliminates the effect of transistor parameters



on the operation of the circuit.

The operation of the circuit is the same as that of colpitts oscillator. As the circulating tank current flows through C_1, C_2 and C_3 in series.

The equivalent of the capacitors is 'C' is

$$C = \frac{1}{1/C_1 + 1/C_2 + 1/C_3} = \frac{C_1 C_2 C_3}{C_1C_2 + C_2C_3 + C_1C_3}$$

The impedances for the oscillator

$$Z_1 = X_{C_1} = \frac{1}{j\omega C_1} = \frac{-j}{\omega C_1}$$

$$Z_2 = X_{C_2} = \frac{1}{j\omega C_2} = \frac{-j}{\omega C_2}$$

$$Z_3 = X_L + X_{C_3} = j\omega L - \frac{j}{\omega C_3}.$$

Apply in general equation of oscillator

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

$$h_{ie}\left[\frac{-j}{\omega C_1} - \frac{j}{\omega C_2} - \frac{j}{\omega C_3} + j\omega L\right] + \left[\frac{-j}{\omega C_1} \cdot \frac{-j}{\omega C_2}\right](1+h_{fe})$$
$$+ \frac{-j}{\omega C_2} \cdot \left(j\omega L - \frac{j}{\omega C_3}\right) = 0.$$

$$-j h_{ie}\left[\frac{1}{\omega C_1} + \frac{1}{\omega C_2} + \frac{1}{\omega C_3} - \omega L\right] + \left(\frac{-1}{\omega^2 C_1 C_2}\right)(1+h_{fe}) + \left[\frac{L}{C_2} - \frac{1}{\omega^2 C_2 C_3}\right] = 0.$$

Equate the imaginary part to zero to get the resonance frequency.

$$\frac{1}{\omega C_1} + \frac{1}{\omega C_2} + \frac{1}{\omega C_3} - \omega L = 0.$$

$$\frac{1}{\omega C_1} + \frac{1}{\omega C_2} + \frac{1}{\omega C_3} = \omega L.$$

$$\frac{1}{\omega}\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right] = \omega L$$

$$\omega^2 = \frac{1}{L}\left[\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}\right].$$

$$\omega = \frac{1}{\sqrt{LC_{eq}}}.$$

$$\boxed{f_C = \frac{1}{2\pi\sqrt{L\,C_{eq}}}}.$$

Now equate the real part to zero to get the condition of oscillations

$$\left(\frac{-1}{\omega^2 C_1 C_2}\right)(1+h_{fe}) + \frac{L}{C_2} - \frac{1}{\omega^2 C_2 C_3} = 0.$$

$$(1+h_{fe})\frac{1}{\omega^2 C_1 C_2} = \frac{L}{C_2} - \frac{1}{\omega^2 C_2 C_3}.$$

$$(1+h_{fe}) = \frac{L(\omega^2 C_1 \cancel{C_2})}{\cancel{C_2}} - \frac{\omega^2 C_1 \cancel{C_2}}{\omega^2 \cancel{C_2} C_3}$$

$$1+h_{fe} = L\omega^2 C_1 - \frac{C_1}{C_3} \Rightarrow \frac{\omega^2 L C_1 C_3 - C_1}{C_3}.$$

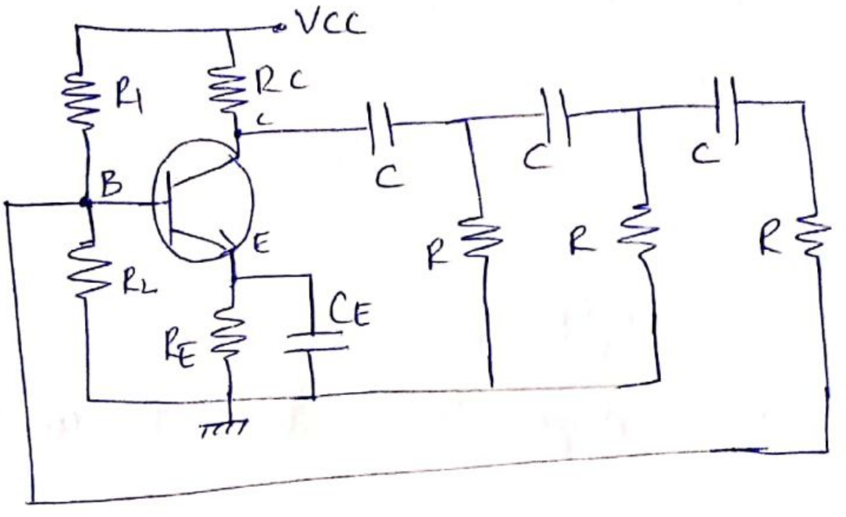
$$\cancel{1}+h_{fe} = LC_1\frac{1}{L}\left[\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}\right] - \frac{C_1}{C_3}.$$

$$\cancel{1}+h_{fe} = \cancel{1}+\frac{C_1}{C_2}+\frac{\cancel{C_1}}{\cancel{C_3}} - \frac{\cancel{C_1}}{\cancel{C_3}}$$

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

RC phase shift oscillator:-

The circuit is arranged by using NPN transistor in CE configuration and in voltage divider biasing method. The resistors R_1 and R_2 provides the dc emitter base bias. R_E and C_E provides temperature stability and prevent AC signal degeneration and collector resistor R_C controls the collector voltage. The oscillator o/p voltage is capacitively coupled to the load by capacitor "c".



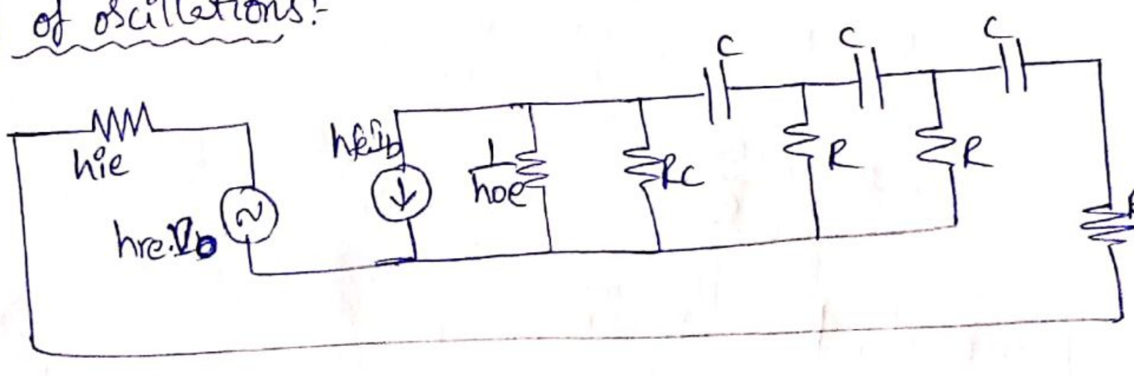
operation:-

The output of the amplifier is supplied to an RC feedback network. The RC network produces a phase shift of 180° between output and input signals (or) voltages.

∵ CE amplifier produces a phase reversal of the i/p signal.

Total phase shift becomes 360° (or) 0° which is essential for regeneration.

Frequency of oscillations:-



→ hre of the transistor is usually negligibly small and.

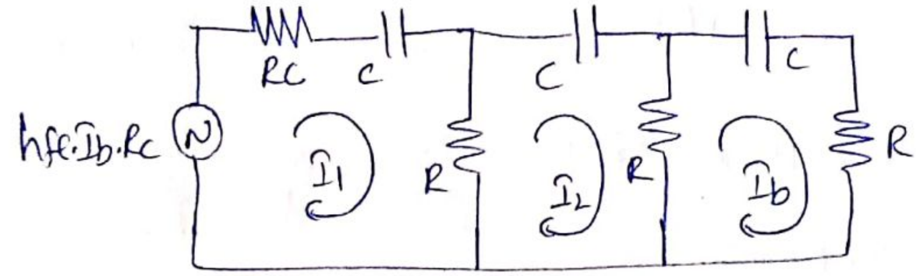
∴ hre. Vo is omitted from the circuit.

→ hoe of the transistor is very small ie 1/hoe is much larger than Rc.

Thus effect of the 1/hoe can be negligible.

→ In practical, R_C can be taken equal to R.

→ The current source is replaced by voltage source using thevenin's theorem equivalent circuit as shown below.



By applying KVL for the three loops we get

loop1 $\left(R+R_C+\frac{1}{j\omega C}\right)I_1 - RI_2 + h_{fe}\cdot I_b\cdot R_C = 0.$

loop2 $-RI_1 + \left(2R+\frac{1}{j\omega C}\right)I_2 - RI_b = 0$

loop3 $0 - RI_2 + \left(2R+\frac{1}{j\omega C}\right)I_b = 0.$

As the currents I_1, I_2 & I_b are non-vanishing parameters, so the determination of the coefficients of I_1, I_2 & I_b must be zero.

$$\begin{bmatrix} R+R_C-jX_C & -R & h_{fe}\cdot R_C \\ -R & 2R-jX_C & -R \\ 0 & -R & 2R-jX_C \end{bmatrix} = 0.$$

$$\Rightarrow (R+R_C-jX_C)\left[(2R-jX_C)(2R-jX_C)-R^2\right] + R\left[(-R)(2R-jX_C)\right]$$
$$+ h_{fe}\cdot R_C\left[R^2\right] = 0$$

$$\Rightarrow (R+R_C-jX_C)(4R^2 - X_C^2 - R^2 - 4RjX_C) - 2R^3 + R^2jX_C + h_{fe}\cdot R_C R^2 = 0$$

$$\Rightarrow \underline{4R^3} - \underline{RX_C^2} - \underline{R^3} - \underline{4R^2jX_C} + \underline{4R^2R_C} - \underline{R_CX_C^2} - \underline{R_CR^2} - \underline{4RR_CjX_C} - \underline{4R^2jX_C} + \underline{jX_C^3}$$
$$\underline{+jX_CR^2} - \underline{4RX_C^2} - \underline{2R^3} + \underline{R^2jX_C} + \underline{h_{fe}\cdot R_C\cdot R^2} = 0$$

$$R^3 + R_C R^2(3+h_{fe}) - 5R X_C^2 - R_C X_C^2 + 6j R^2 X_C + j X_C^3 - 4RR_C j X_C = 0.$$

Now consider only the imaginary part.

$$j\left[-6R^2 X_C + X_C^3 - 4RR_C X_C\right] = 0.$$

$$X_C\left[-6R^2 - 4RR_C + X_C^2\right] = 0.$$

$$-6R^2 - 4RR_C + X_C^2 = 0.$$

$$X_C^2 = 4RR_C + R^2 6$$

$$\frac{1}{(\omega C)^2} = R\left[4R_C + 6R\right].$$

$$\frac{1}{\omega C} = R\sqrt{6 + 4\frac{R_C}{R}}$$

$$\boxed{f_C = \frac{1}{2\pi RC\sqrt{6 + 4\frac{R_C}{R}}}}$$

if we consider $R = R_C$, then

$$\boxed{f_C = \frac{1}{2\pi RC\sqrt{10}}}$$

Now consider the real part, then.

$$R^3 + R_C R^2(3+h_{fe}) - \cancel{X_C^2}\left[5R + R_C\right] = 0.$$

Now substitute $X_C^2 = 6R^2 + 4RR_C$, then

$$R^3 + R_C R^2(3+h_{fe}) - (6R^2 + 4RR_C)(5R + R_C) = 0.$$

$$R^3 + R^2 R_C(3+h_{fe}) - 30R^3 - 6R^2 R_C + 20R^2 R_C + 4RR_C^2 = 0.$$

$$-29R^3 + R^2 R_C(-23 + h_{fe}) - 4RR_C^2 = 0.$$

$$R^2\left[-29R + R_C(-23+h_{fe}) - \frac{4R_C^2}{R}\right]=0.$$

$R^2 \neq 0$, then

$$-29R + R_C(-23+h_{fe}) - \frac{4R_C^2}{R} = 0.$$

$$R_C\left[-\frac{29R}{R_C} - 23 + h_{fe} - \frac{4R_C}{R}\right]=0.$$

$R_C \neq 0$, then

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

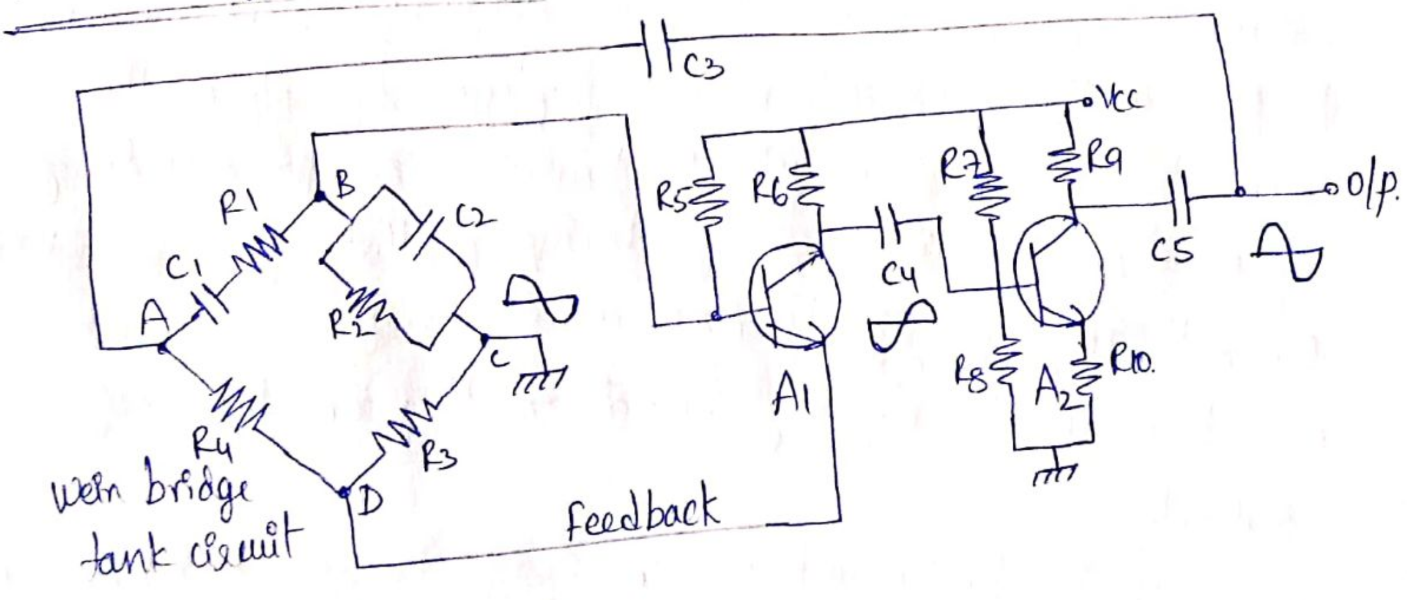
If $R_C = R$, then

$$h_{fe} = 56$$

For oscillations, the minimum value of h_{fe} is 56

$$\boxed{h_{fe} \geq 56}$$

Wein Bridge oscillator:- (100 - 1 MHz)



It is one of the popular oscillator used in audio and sub audio frequency ranges of 100 Hz to 1 MHz.

20 to 20Hz operating frequency is preferrable as its design is simple and compact in size. ~~and~~
It has more stability of frequency output.
It's output is free from distortion and its frequency can be varied easily.
The basic design of wein bridge consists of 2 transistors where each one produces a phase shift of 180° and totally we get 360° & 0°.

Operation: RC bridge circuit is a lead-lag network.
$R_1 - C_1$ lead network ; $R_2 - C_2$ lag network
The phase shift occurs the network lags with increasing frequency and leads with decreasing frequency. By adding wein bridge feedback network the oscillator becomes sensitive to a signal of only one particular frequency.
This particular frequency is that at which wein bridge is balanced and for which the phase shift is '0°'. If the wein bridge feedback network is not employed and o/p of the transistor Q_2 is feedback to transistor Q_1 for providing regeneration required for producing oscillation. The transistor Q_1 will amplify signals over a wide range of frequency and this direct coupling would result poor frequency stability.
In the bridge network R_1 is in series with C_1, R_3 & R_4. R_2 is in parallel with C_2 for the 4 arms for the circuit.

Analysis:

The bridge has to balance only when

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

$$R_4\left[\frac{R_2}{1+j\omega C_2R_2}\right] = R_3\left[R_1 + \frac{1}{j\omega C_1}\right].$$

$$R_4R_2 = R_3\left[R_1 - \frac{j}{\omega C_1}\right]\left[1+j\omega C_2R_2\right].$$

$$R_4R_2 = \left[R_3R_1 - j\frac{R_3}{\omega C_1}\right]\left[1+j\omega C_2R_2\right]$$

$$R_4R_2 = R_3R_1 + j\omega R_1R_2R_3C_2 - j\frac{R_3}{\omega C_1} + R_2R_3\frac{C_2}{C_1}$$

$$R_4R_2 - R_3R_1 - R_2R_3\frac{C_2}{C_1} = j\omega R_1R_2R_3C_2 - j\frac{R_3}{\omega C_1}$$

Equate imaginary part to zero, then

$$\omega C_2R_1R_2R_3 = \frac{R_3}{\omega C_1}$$

$$\omega^2 = \frac{1}{C_1C_2R_1R_2}$$

$$\boxed{f = \frac{1}{2\pi\sqrt{C_1C_2R_1R_2}}}$$

if $R_1 = R_2 = R$

$C_1 = C_2 = C$ then

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

Equate real part to zero, then we get condition for oscillation

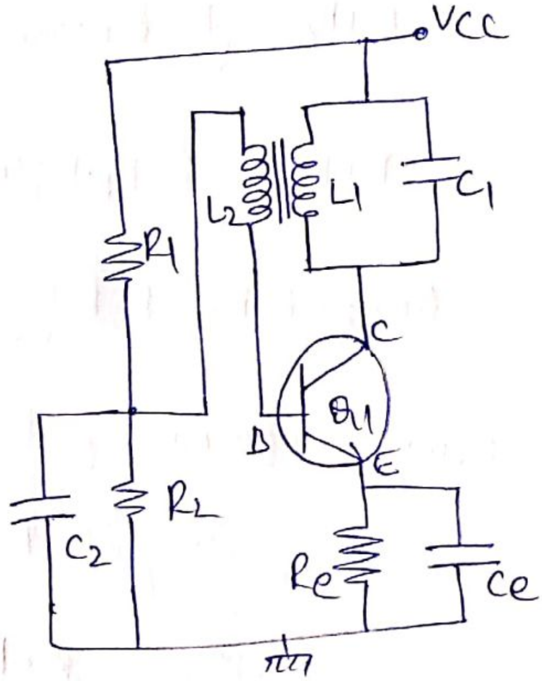
$$R_2R_4 - R_3R_1 - \frac{C_2}{C_1} R_2R_3 = 0.$$

$$R_2R_4 - R_3R_1 = \frac{C_2}{C_1} R_2R_3.$$

$$\frac{\cancel{R_2}R_4}{\cancel{R_2}R_3} - \frac{R_3R_1}{R_2R_3} = \frac{C_2}{C_1}$$

$$\boxed{\frac{R_4}{R_3} - \frac{R_1}{R_2} = \frac{C_2}{C_1}}$$

Tuned collector Oscillator:-



The tuned circuit is connected to the collector. The tuned circuit constituted by the L_1 and C_1 by setting the values of L_1 & C_1. oscillations of any desired freq can be obtained.

The resistors R_1, R_2 & R_e are used to dc biasing of the transistor. Capacitors C_2 & C_e are by pass capacitors to block the dc and mainly C_2 provides low reactance path to oscillations.

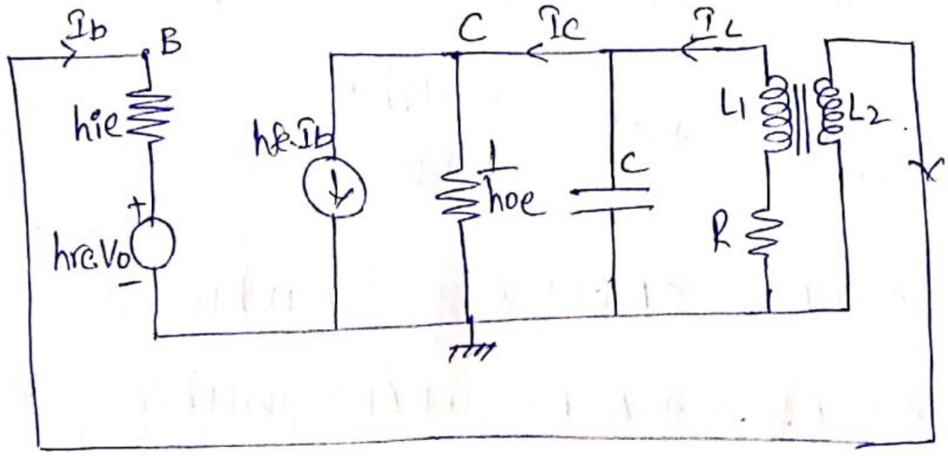
operation:- when the supply is ON, I_c starts increasing and charging the capacitor C_1 and C_1 discharges through inductor L_1 and setting up oscillation of frequency which works as a tank circuit.

The oscillations which are setup in the oscillator circuit will induce emf in the inductor L_2 magnetically linked with L_1. The frequency of emf induced in the coil L_2 is the same as that of oscillations in the oscillator circuit but the magnitude will depend upon the coupling and turn ratio between L_2 and L_1.

A phase difference of 180° is created in the emf's of L_1 & L_2 through transformer action and the further phase shift of 180° is obtained between base voltage & o/p voltage due to the properties of the transistor.

Analysis:-

For the analysis of tuned collector oscillator, the exact model of the transistor equivalent circuit is considered.



The LC tuned circuit acts as a load network, so.

$$Z_L = \frac{R + j\omega L}{1 + \omega^2 LC + j\omega RC}.$$

For exact model analysis the amplifier gain is given as

$$A = \frac{-h_{fe} \cdot Z_L}{h_{ie} + Z_L \cdot \Delta L}. \qquad \Delta L = h_{ie}h_{oe} - h_{re}h_{fe}.$$

$$\beta = \frac{\text{voltage induced in the secondary}}{\text{voltage across the primary coil.}}$$

$$= \frac{-jwMI_L}{(R+jwL)I_L} = \frac{-jwM}{R+jwL}.$$

–ve sign indicates the phase ~~diffe~~ shift of 180^0 between coils L_1 & L_2.

For Barkhausen criterion for sustained oscillations

$$|A\beta| = 1$$

$$\frac{1}{|A|} = |\beta|$$

$$\frac{h_{ie} + Z_L \cdot \Delta h}{h_{fe} \cdot Z_L} = \frac{jwM}{R+jwL}$$

Now substitute Z_L in the above equation, then

$$h_{ie}\left[\frac{1-w^2LC+jwRC}{R+jwL}\right] + \Delta h = \frac{jwMh_{fe}}{R+jwL}.$$

$$h_{ie}(1-w^2LC+jwRC) + \Delta L(R+jwL) = jwMh_{fe}.$$

$$h_{ie} - w^2LCh_{ie} + jwRCh_{ie} + \Delta LR + jwL\Delta L = jwMh_{fe}.$$

$$h_{ie} - w^2LCh_{ie} + \Delta L \cdot R = jwMh_{fe} - jwL \cdot \Delta L + jwRC \cdot h_{ie}.$$

To obtain the resonant frequency, equate real part equal to zero.

$$h_{ie} - w^2LCh_{ie} + \Delta L \cdot R = 0.$$

$$w^2LCh_{ie} = R \cdot \Delta L + h_{ie}.$$

$$w^2 = \frac{R \cdot \Delta L + h_{ie}}{LCh_{ie}}$$

$$\omega = \sqrt{\frac{hie}{LChie} + \frac{\Delta L \cdot R}{LC.hie}}$$

$$\omega = \frac{1}{\sqrt{LC}}\left(\sqrt{1+\frac{\Delta L \cdot R}{hie}}\right)$$

$$f = \frac{1}{2\pi\sqrt{LC}}\left(\sqrt{1+\frac{R.\Delta L}{hie}}\right)$$

But ΔL & R of the coil is very small, and hie is large

so we can neglect $\sqrt{1+\frac{R.\Delta L}{hie}} = 1$

Then

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

Now equate ~~to~~ imaginary part to zero to get the condition of oscillation.

$$\omega M hfe - \omega L.\Delta L - RC\omega hie = 0.$$

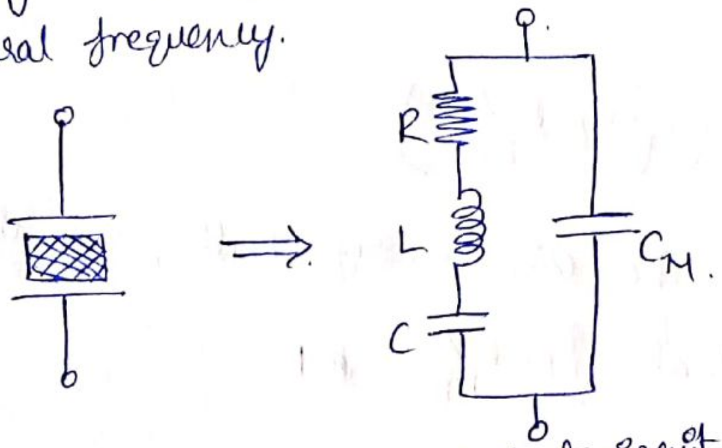
$$M hfe = L.\Delta L + RChie.$$

$$\boxed{M = \frac{Rc.hie + L.\Delta L}{hfe}}$$

Crystal Oscillator:-

In crystal oscillator, the usual electrical resonant circuit is replaced by a mechanically vibrating crystal. The crystal has a high degree of stability. A quartz crystal exhibits a property of piezoelectric effect. when a mechanical pressure is applied across the faces of the crystal. Due to this pressure, a

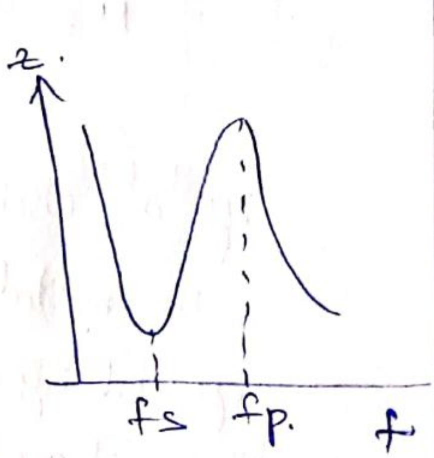
voltage is developed across the crystal.
When a voltage is applied across the crystal surfaces, the crystal is distorted by an amount proportional to the applied voltage. An alternating voltage applied to a crystal causes it to vibrate at its natural frequency.



Symbol Equivalent circuit.

The crystal is suitably cut and then mounted between two metal plates as shown in above figure. Although the crystal has electromechanical resonance but the crystal action can be represented by electrical circuit as shown in above figure.
The crystal actually behaves as a series R-L-C circuit in parallel with C_M where $C_M \Rightarrow$ capacitance of Mounting electrodes.
The crystal has two resonant frequencies due to the presence of C_M.

series resonance frequency f_s
parallel " " f_p.



The impedance in series resonance frequency is low and it is high in parallel resonance frequency.
In order to use the crystal properly it must be connected in a circuit so that its low impedance in series resonance operating mode is selected.

The resonant frequencies f_s & f_p are given by.

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

$$f_p = \frac{1}{2\pi}\sqrt{\frac{1+C/C_M}{LC}}$$

C/C_M ratio is very small. $f_p > f_s$ but the two frequencies are very close to each other.

Frequency stability of oscillator:-

The ability of the oscillator to maintain the required frequency constant over a long time interval as possible.

But in transistor oscillator, the frequency of oscillations doesnot remain stable during a long time because of the circuit features on which the oscillator frequency depends do not remain constant in time. The stability is affected due to the following features.

→ change in operating point:-

The operating point of the active device is adjusted on the linear portion of its characteristics. This point is shifted due to temperature variations and stability is affected.

→ Due to power supply:-

If the quality of power supply is poor, then the variations in supply voltage will cause of variations in V_{CC}. This variation results the frequency of oscillation is affected.

→ Variation in Temperature:-

In circuit various frequency determining components such as resistors, inductors and capacitors are used. All these parameters are temperature dependent.

→ change in output load:-

when a load is connected, the effective resistance of the tank circuit is changed. As a result the Q factor of LC tuned circuit is changed. This results a change in output frequency of oscillator

→ change in interelement capacitances:-

The interelement capacitance undergo change due to various reasons as temperature, voltage etc. This problem can be solved by using swapping capacitors across offending inter element capacitor.