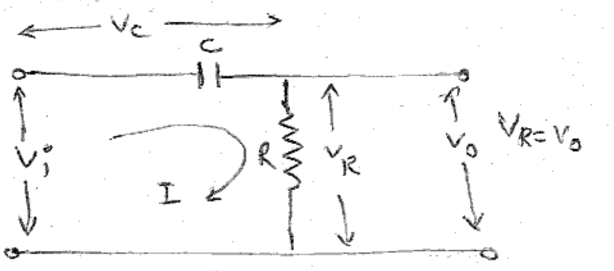
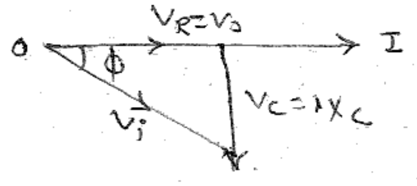
Q2 Draw the circuit diagram of RC phase shift Oscillator and explain its operation?

Sol^n RC phase shift Oscillator basically consists of an amplifier and feedback n/w consisting of resistors and Capacitors arranged in ladder fashion. Hence such an oscillator is also called ladder type RC phase shift oscillator.

To understand the operation of this oscillator let us study the RC circuit first which is used in the feed back n/w of this oscillator.



circuit



Phasor Diagram

The Capacitor C and resistance R are in series. Now X_c is the Capacitive reactance in Ohms given by:

$$X_c = \frac{1}{2\pi f c}\ \Omega$$

Total impedance of the circuit is

$$Z = R - jX_c = R - j\left(\frac{1}{2\pi f c}\right)\Omega$$

$$|Z| \angle -\phi^\circ \Omega$$

The r.m.s value of the i/p voltage applied is say V_i volts. Hence the current is given by.

$$I = \frac{V_i \angle 0^\circ}{Z} = \frac{V_i \angle 0^\circ}{|Z| \angle -\phi} = \frac{V_i}{Z} \angle +\phi \quad A$$

where

$$\boxed{\begin{aligned} |Z| &= \sqrt{R^2 + (X_c)^2} \\ \phi &= \tan^{-1}\left(\frac{X_c}{R}\right) \end{aligned}}$$

From expression of current it can bee seen that current I leads i/p voltage V_i by angle ϕ.

The o/p voltage V_o is the drop across resistance R given by,

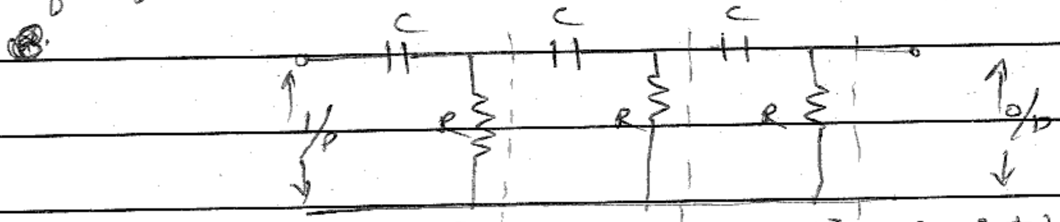
$$V_o = V_R = IR$$

The voltage across the capacitor is.

$$V_c = I X_c$$

RC Feedback N/w

In Oscillation feedback n/w must introduce a phase shift of 180° to obtain total phase shift around a loop as 360°. Thus If one RC Network produces phase shift of $\phi = 60°$ then to produce phase shift of 180°. Such three RC network must be connected in cascade. Hence in RC phase shift Oscillator, the feedback network consist of three RC sections. Each producing a phase shift of 60°, thus total phase shift due to feedback is 180° (3×60°)



60° + 60° + 60° = 180° total phase shift

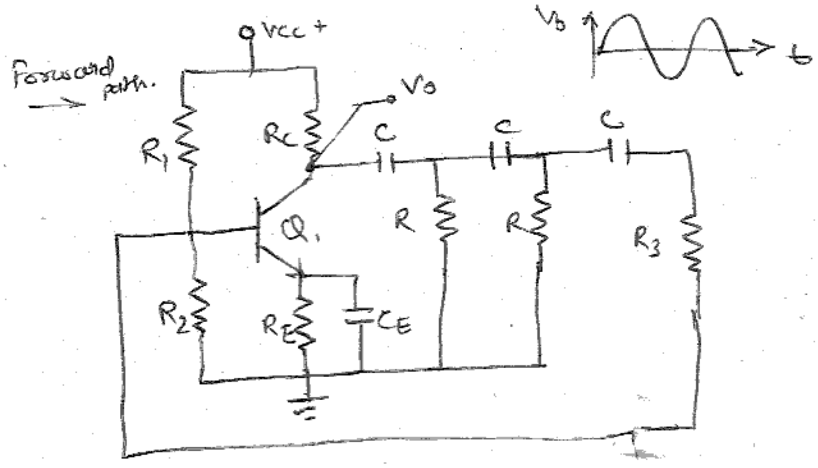
The network is also called the ladder Network. All the resistance values and all the capacitance value are same, so that for a particular freq. Each section of R & C produce phase shift of 60°

* Transistorised RC Phase shift Oscillator :-

Transistorised RC phase shift Oscillator, a transistor is used as an active element of the amplifier stage. RC phase shift which uses a common emitter single stage amplifier and a phase shifting N/w consisting of three identical RC Sections.

The output of the feedback n/w gets loaded due to low input impedance (hie) of a transistor. Hence an emitter follower input stage before the common emitter amplifier stage can be used, to avoid the problem of low input impedance. But if only single stage is to be used then the voltage shunt feedback, denoted by resistance R_3 in the fig. is used, connected in series with the amplifier input resistance.

A phase shifting n/w is a feed back n/w, so output of the amplifier is given as an input to the feedback network while the output of the feed back network is given as an input to the amplifier. Thus amplifier supplies its own input, through the feedback n/w.



Neglecting R_1 and R_2 as there are sufficiently large, we can write
hie = Input impedance of the amplifier stage.

Now the resistance R_3 and hie are in series and the value of R_3 is so selected such that the resultant of the two resistance is R which is the required value of the resistance in the last section of RC phase shifting n/w.

$$\boxed{h_{ie} + R_3 = R}$$

This ensure that all the three sections of the phase shifting n/w are identical.

$$\boxed{R_i' = R_1 \| R_2 \| R_3}$$

In such a case, the value of R_3 must be so selected that

$$\boxed{R_i' + R_3 = R}$$

Q3 Explain Clapp's Oscillator and derive the expression for freq of oscillation. Also explain how frequency stability can be improved Clapp's oscillator.

Soln

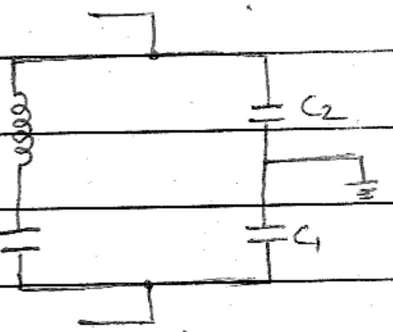


Fig Modified tank CKT

To acheive the frequency stability colpitts oscillator circuit is slightly modified in practice, called clapp Oscillator. The basic tank circuit with two capative reactances and one inductive reactance remains same. But the modification in the tank circuit is that one more capacitor C_3 is introduced in series with the inductance.

Now the Equivalent capacitance becomes

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

While the Oscillator frequency is given by the same expression

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

The freq are almost same, hence in practice the C_1, C_2 value are neglected and C_3 are assumed to be Ceq. Hence the freq is given by

$$\boxed{f = \frac{1}{2\pi\sqrt{LC_3}}}$$

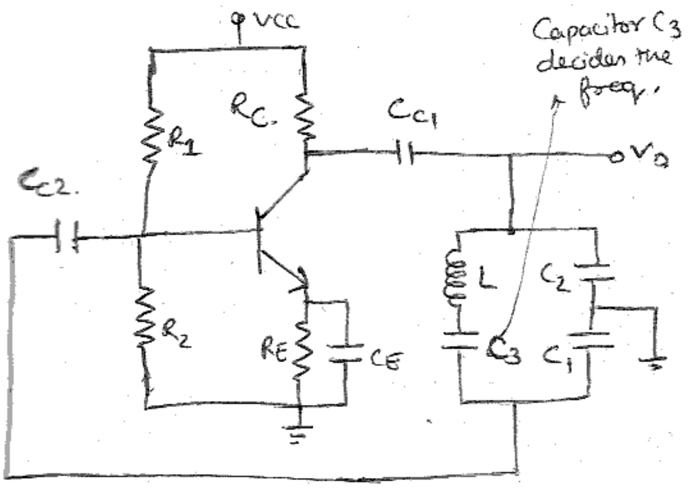


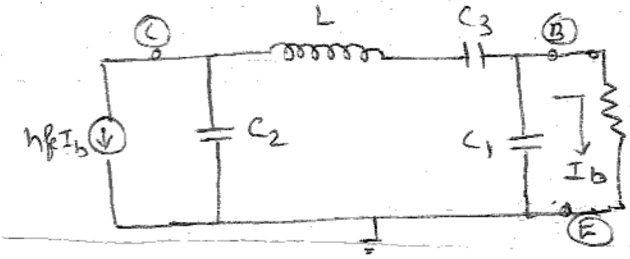
Fig Transistorized clapp Oscillator.

Now across C_3 there is no transistor parameter and hence the freq. of the Clapp Oscillator is stable and accurate. The transistor and stray capacitance have no effect on C_3 hence good frequency stability is achieved in Clapp oscillator, Hence practically clapp oscillator is preferred over Colpitts Oscillator. The transistorised Clapp Oscilator is shawn in fig.

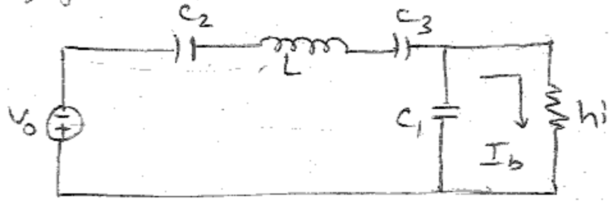
Another advantage of C_3 is that it can be kept variable. As frequency is dependent on C_3, the frequency can be varied in the desired range.

* Derivation of frequency of Oscillations!-

The Derivation is similar to the Colpitt Oscillator with C_3 series with L in the equivalent circuit of transistorised clapp Oscillator. The Equivalent Circuit shawn in the fig.



Converting current source to voltage source we get the Equivalent circuit as shawn in fig



$$V_o = h_{fe} I_b X_{C_2}$$

$$\boxed{V_o = h_{fe} I_b \cdot \frac{1}{j\omega C_2}}$$

$$\therefore I = \frac{-V_o}{[X_{C_2} + X_{C_3} + X_L] + [X_{C_1} \| h_{ie}]}$$

The negative sign as the direction of I is assumed opposite to that which voltage source will force the current I through the circuit.

$$X_{C_2} + X_{C_3} + X_L = \frac{1}{j\omega C_2} + \frac{1}{j\omega C_3} + j\omega L$$

$$X_{C_1} \,\|\, h_{ie} = \frac{1/j\omega C_1 \times h_{ie}}{1/j\omega C_1 + h_{ie}}$$

$$I = \frac{-h_{fe} I_b \cdot 1/j\omega C_2}{1/j\omega C_2 + 1/j\omega C_3 + j\omega L + \left[\dfrac{1/j\omega C_1\, h_{ie}}{1/j\omega C_1 + h_{ie}}\right]} \quad \text{--- (3)}$$

Replacing $j\omega$ by s.

$$I = \frac{-h_{fe} I_b \cdot 1/sC_2}{1/sC_2 + 1/sC_3 + sL + \left[\dfrac{h_{ie}/sC_1}{1/sC_1 + h_{ie}}\right]} \quad \text{--- (4)}$$

Multiply by sC_2 to denominator.

$$= \frac{-h_{fe} I_b}{1 + C_2/C_3 + s^2 L C_2 + \dfrac{sC_2 h_{ie}}{(1 + sC_1 h_{ie})}}$$

$$= \frac{-h_{fe} I_b \cdot C_3}{C_3 + C_2 + s^2 L C_2 C_3 + \dfrac{sC_2 C_3 h_{ie}}{(1 + sC_1 h_{ie})}}$$

$$= \frac{-h_{fe} I_b C_3 (1 + sC_1 h_{ie})}{C_3 + sC_1 C_3 h_{ie} + C_2 + sC_1 C_2 h_{ie} + s^2 L C_2 C_3 + s^3 L C_1 C_2 C_3 h_{ie} + s C_2 C_3 h_{ie}}$$

$$\therefore I = \frac{-h_{fe} I_b C_3 (1 + sC_1 \cdot hie)}{s^3 LC_1 \cdot C_2 C_3 \cdot hie + s^2 LC_2 C_3 + s\,hie\,[C_2C_3 + C_1C_2 + C_1C_3] + C_2 + C_3} \quad \text{--- (5)}$$

$$\therefore I_b = I \times \frac{X_{C_1}}{X_{C_1} + hie} = \frac{I \times 1/j\omega C_1}{1/j\omega C_1 + hie} = \frac{I \times 1/sC_1}{1/sC_1 + hie}$$

$$\therefore I_b = \frac{I}{(1 + sC_1 hie)} \quad \text{--- (6)}$$

Substituting I,

$$I_b = \frac{-h_{fe} I_b C_3 (1 + sC_1 hie)}{s^3 LC_1C_2C_3 \cdot hie + s^2 LC_2C_3 + s\,hie\,[C_2C_3 + C_1C_2 + C_1C_3] + C_2 + C_3} \times \frac{1}{(1+sC_1 hie)}$$

$$1 = \frac{-h_{fe} C_3}{s^3 LC_1C_2C_3 \cdot hie + s^2 LC_2C_3 + s\,hie\,[C_1C_2 + C_2C_3 + C_3C_1] + C_2 + C_3}$$

Substituting $s = j\omega$, $s^2 = j^2\omega^2 = -\omega^2$, $s^3 = -j\omega^3$

$$1 = \frac{-h_{fe} C_3}{-j\omega^3 LC_1C_2C_3\,hie - \omega^2 LC_2C_3 + j\omega\,hie\,[C_1C_2 + C_2C_3 + C_3C_1] + C_2 + C_3}$$

$$\therefore 1 = \frac{-h_{fe} C_3}{C_2 + C_3 - \omega^2 LC_2C_3 + j\omega\,hie\,\{[C_1C_2 + C_2C_3 + C_3C_1] - \omega^2 LC_1C_2C_3\}} \quad \text{--- (10)}$$

As there is no imaginary part in numerator to satisfy Barkhausen criterion, imaginary part in the denominator must be zero. But ω and hie are not zero hence.

$$\therefore C_1C_2 + C_2C_3 + C_3C_1 - \omega^2 LC_1C_2C_3 = 0$$

$$\omega^2 = \frac{C_1C_2 + C_2C_3 + C_3C_1}{LC_1C_2C_3} = \frac{C_1C_2C_3\,[C_1 + C_2 + C_3]}{LC_1C_2C_3}$$

$$\omega^2 = \frac{1/C_1 + 1/C_2 + 1/C_3}{L} = \frac{1/C_{eq}}{L}$$

$$\omega^2 = \frac{1}{LC_{eq}}$$

$$\omega = \frac{1}{\sqrt{L C_{eq}}}$$

$$\therefore f = \frac{1}{2\pi\sqrt{L C_{eq}}}$$

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

But as $C_3 << C_1$ and C_2, $C_{eq} = C_3$

$$\boxed{f = \frac{1}{2\pi\sqrt{L C_3}}}$$

Advantage:

1) The frequency is stable and accurate.
2) The good freq. stability
3) The stray capacitance have no effect on C_3 which decide the freq
4) Keeping C_3 variable, freq. can be varied in the desired range.

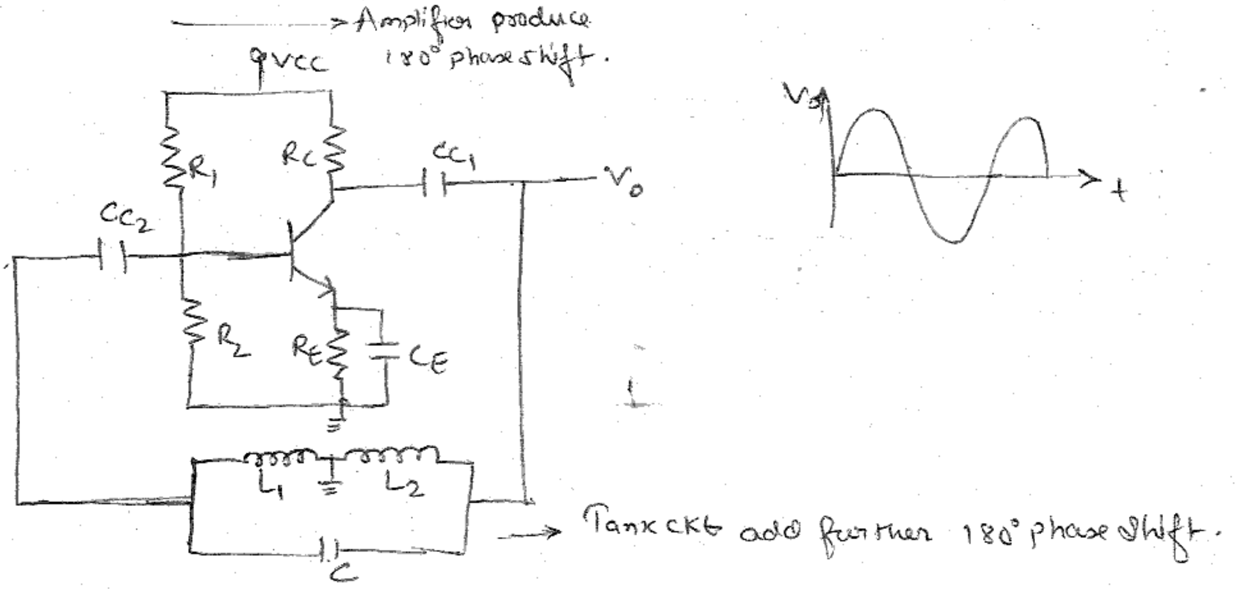
~~Black. Brown Red Orange Yellow Green Blue Violet Grey White~~

Q4 Explain Hartley Oscillator and derive the Eqn for Oscillation.

A LC Oscillator which uses two inductive reactances and one Capacitive reactance in its feed back network is called Hartley Oscillator.

Transistorised Hartley Oscillator:-

The amplifier stage uses an active device as a transistor in common emitter configuration. The practical circuit is shown in fig.



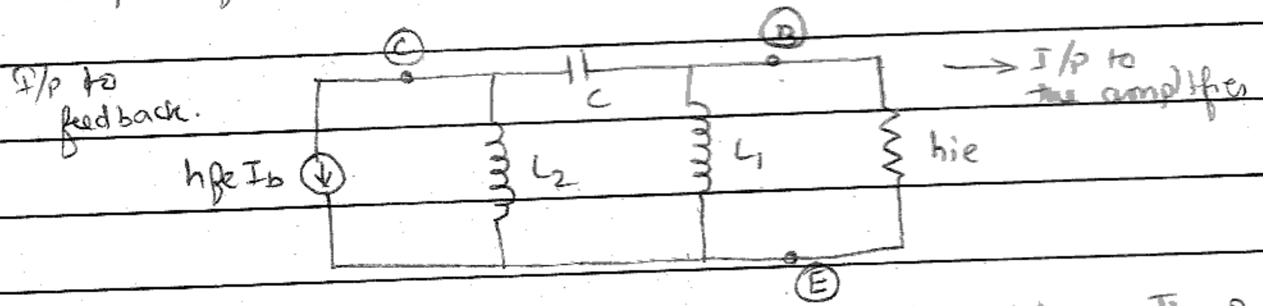
The resistance R_1 and R_2 are the biasing resistance. The RFC is the radio frequency choke. Its reactance value is very high for high frequencies, hence it can be treated as open circuit, while for dc conditions, the reactance is zero hence causes no problem for dc capacitors.

Hence due to RFC, the isolation b/w a.c and d.c operation is achieved. R_E is also a biasing circuit resistance and C_E is the emitter bypass Capacitor. C_{c1} and C_{c2} are the Coupling Capacitor.

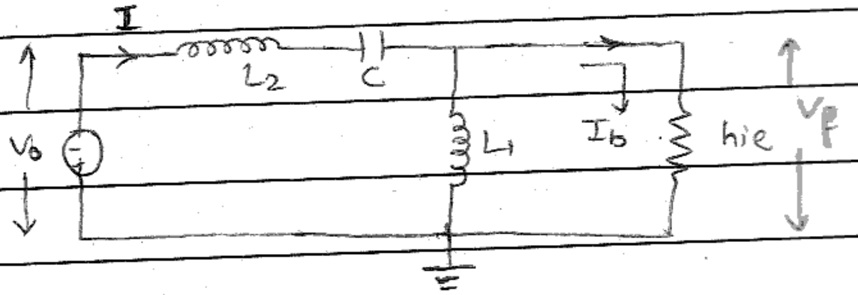
The Common emitter amplifier provides a phase shift of 180°. As emitter is grounded, the base and the collector voltages are out of phase by 180°. As the centre of L_1 and L_2 is grounded. When upper ends becomes +ve, the lower becomes -ve and vice versa. So the LC feed back n/w gives an additional phase shift of 180°, necessary to satisfy Oscillation Conditions.

* Derivation of frequency of Oscillations :-

The Output current which is the collector current is $h_{fe} I_b$ where I_b is the base current. Assuming coupling condensers are short, the capacitor C is between base and collector. The inductance L_1 is between base and emitter while the inductance L_2 is b/w collector and emitter. The Equivalent circuit of the feedback n/w is shown in the fig.



As hie is the input impedance of the transistor. The Output of the feedback is the current I_b which is the input current of the transistor. While I/p to the feedback n/w is the O/P of the transistor which is $I_c = h_{fe} I_b$, Converting current source into voltage source we get,



$$\boxed{V_o = h_{fe} I_b X_{L2} = h_{fe} I_b j\omega L_2} \quad \text{—(1)}$$

Now L_1 and hie are in parallel, so that total current I drawn from the supply is.

$$I = \frac{-V_0}{[X_{L2} + X_C] + [X_{L1} \parallel h_{ie}]} \quad \text{--- (2)}$$

Now, $X_{L2} + X_C = j\omega L_2 + 1/j\omega C$

and $X_{L1} \parallel h_{ie} = \frac{j\omega L_1 h_{ie}}{(j\omega L_1 + h_{ie})}$

Substituting in the Eqn (2) we get.

$$I = \frac{-h_{fe} I_b j\omega L_2}{\left[j\omega L_2 + \frac{1}{j\omega C}\right] + \left(\frac{j\omega L_1 h_{ie}}{(j\omega L_1 + h_{ie})}\right)} \quad \text{--- (3)}$$

Replace $j\omega$ by s.

$$I = \frac{-s h_{fe} I_b L_2}{\left[sL_2 + 1/sC\right] + \frac{sL_1 h_{ie}}{(sL_1 + h_{ie})}}$$

$$= \frac{-s h_{fe} I_b L_2}{\frac{[1 + s^2 L_2 C]}{sC} + \frac{sL_1 h_{ie}}{(sL_1 + h_{ie})}}$$

$$= \frac{-s h_{fe} I_b L_2 (sC)(sL_1 + h_{ie})}{[1 + s^2 L_2 C][sL_1 + h_{ie}] + (sC)(sL_1 h_{ie})}$$

$$= \frac{-s^2 h_{fe} I_b L_2 C (sL_1 + h_{ie})}{s^3 L_1 L_2 C + sL_1 + h_{ie} + s^2 L_2 C h_{ie} + s^2 L_1 C h_{ie}}$$

$$I = \frac{-s^2 h_{fe} I_b L_2 C (sL_1 + h_{ie})}{s^3 L_1 L_2 C + s^2 C h_{ie} (L_1 + L_2) + sL_1 + h_{ie}}$$

According to current division in parallel circuit.

$$I_b = I \times \frac{X_{L1}}{X_{L1} + h_{ie}}$$

$$= I \times \frac{j\omega L_1}{(j\omega L_1 + h_{ie})}$$

$$\boxed{I_b = I \times \left[\frac{sL_1}{(sL_1 + h_{ie})}\right]} \quad \text{--- (4)}$$

Substituting value of I from Eqn (3) in eqn (4).

$$I_b = \frac{-S^2 h_{fe} I_b L_2 C\,(SL_1 + h_{ie})}{[S^3(L_1 L_2 C) + S^2 C h_{ie}(L_1+L_2) + SL_1 + h_{ie}]} \times \frac{SL_1}{(SL_1 + h_{ie})}$$

$$I_b = \frac{-S^3 h_{fe} I_b C L_1 L_2}{S^3(L_1 L_2 C) + S^2 C h_{ie}(L_1+L_2) + SL_1 h_{ie}}$$

$$1 = \frac{-S^3 h_{fe} C L_1 L_2}{S^3(L_1 L_2 C) + S^2 C h_{ie}(L_1+L_2) + SL_1 + h_{ie}} \quad (5)$$

Substituting $s = j\omega$, $s^2 = -\omega^2$, $s^3 = -j\omega^3$ we get

$$1 = \frac{j\omega^3 h_{fe} C L_1 L_2}{-j\omega^3 L_1 L_2 C - \omega^2 C h_{ie}(L_1+L_2) + j\omega L_1 + h_{ie}}$$

$$= \frac{j\omega^3 h_{ie} C L_1 L_2}{[h_{ie} - \omega^2 C h_{ie}(L_1+L_2)] + j\omega L_1 (1 - \omega^2 L_2 C)} \quad (6)$$

Rationalising the R.H.S of the above Eqn.

$$\therefore \quad 1 = \frac{j\omega^3 h_{fe} C L_1 L_2 [h_{ie} - \omega^2 C h_{ie}(L_1+L_2) - j\omega L_1(1-\omega^2 L_2 C)]}{[h_{ie} - \omega^2 C h_{ie}(L_1+L_2)]^2 + \omega^2 L_1^2 (1-\omega^2 L_2 C)^2}$$

$$1 = \frac{\omega^4 h_{fe} L_1^2 L_2 C(1-\omega^2 L_2 C) + j\omega^3 h_{fe} L_1 L_2 C[h_{ie} - \omega^2 C h_{ie}(L_1+L_2)]}{[h_{ie} - \omega^2 C h_{ie}(L_1+L_2)]^2 + \omega^2 L_1^2 (1 - \omega^2 L_1^2 L_2 C)^2} \quad (7)$$

To satisfy this Eqn imaganary part of RHS must be zero

$$\therefore \omega^3 h_{fe} L_1 L_2 C\,[h_{ie} - \omega^2 h_{ie} C(L_1+L_2)] = 0$$

$$\therefore \omega^3 h_{fe} h_{ie} L_1 L_2 C\,[1 - \omega^2 C(L_1+L_2)] = 0$$

$$1 - \omega^2 C(L_1+L_2) = 0$$

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

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

$$\boxed{f = \frac{1}{2\pi\sqrt{C(L_1+L_2)}}} \qquad \text{—— (8)}$$

This is the frequency of the Oscillation.

At this freq. the restriction of the value of h_{fe} can be obtained by equating the magnitude of the both sides of the eqn (7)

$$1 = \frac{\omega^4 h_{fe} L_1^2 L_2 C(1-\omega^2 L_2 C)}{0 + \omega^2 L_1^2 (1-\omega^2 L_2 C)^2} \quad \text{at } \omega = \frac{1}{\sqrt{C(L_1+L_2)}}$$

$$1 = \frac{h_{fe} L_2}{(1-\omega^2 L_2 C)} \quad \text{at } \omega = \frac{1}{\sqrt{C(L_1+L_2)}}$$

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

$$\boxed{h_{fe} = \frac{L_1}{L_2}} \qquad \text{—— 9 (a)}$$

This is the value of h_{fe} reqd. to satisfy the oscillating condn.

For a mutual inductance of M.

$$\boxed{h_{fe} = \frac{L_1 + M}{L_2 + M}} \qquad \text{—— 9 (b)}$$

Now $L_1 + L_2$ is the Eqivalent inductance of two inducance L_1 and L_2 Connected in series denoted as

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

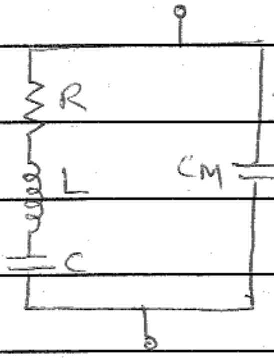
Hence the freq of oscillation is given by

$$\boxed{f = \frac{1}{2\pi\sqrt{C\,L_{eq}}}}$$

Q5 Explain the response frequency of crystal. And draw the pierce Crystal oscillator circuit and derive the Eqn for oscillation.

Soln

When the Crystal is not vibrating it is equivalent to a Capacitance due to the mechanical mounting of the crystal. Such a capacitance existing due to the two metal plates separated by a dielectric like crystal slab. is called mounting capacitance denoted as C_m or C'



When it is Vibrating, there are internal frictional losses which are denoted by a resistance R. while the mass of the crystal, which is indication L. In vibrating condition, it is having some Stiffness, which is represented by a Capacitor.

The mounting capacitance is a shunt capacitance. And hence the overall equivalent circuit of a crystal can be shown as in the fig.

RLC forms a resonating circuit. The expr. for the resonating freq fr is

$$\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}\sqrt{\frac{Q^2}{1+Q^2}}} \quad \text{——} (1)$$

where. Q = Quality factor. $Q = \frac{\omega L}{R}$

The Q factor of the crystal is very high, typically 20,000. Value of Q upto 10^6 also can be achieved. Hence $\sqrt{Q^2/1+Q^2}$ factor approaches to unity and we get the resonating freq as.

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

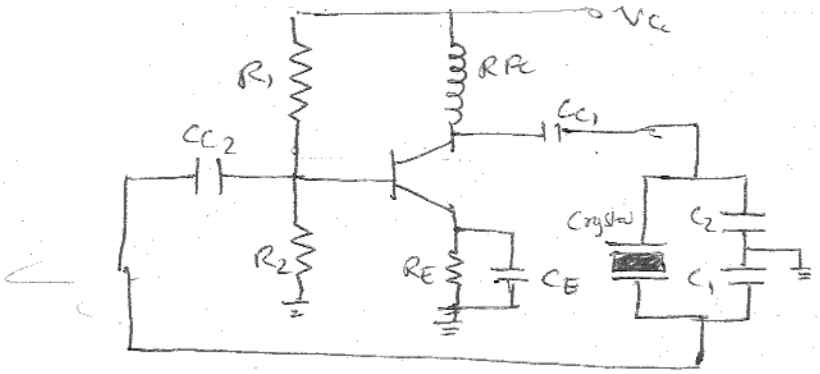
The crystal freq. is in fact inversely proportional to the thickness of the crystal.

$$\boxed{f \propto \frac{1}{t}}$$

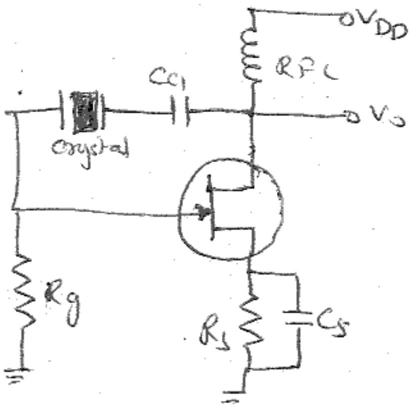
where t = thickness.

* Pierce Crystal Oscillator:

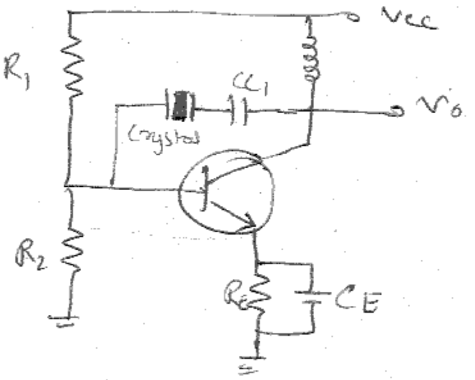
The colpitts oscillator can be modified by using the crystal to behave as an inductor. The circuit is called Pierce crystal oscillator. The crystal behaves as an inductor for a freq. slightly higher than the series resonance freq. f_s. The two capacitors C_1 C_2 reqd. in the tank ckt along with an inductor are used as they are used in colpitts oscillator ckt. As only inductor gets replaced by the crystal which behaves as an inductor, the basic working principle of Pierce crystal oscillator is same as that of colpitts oscillator.



The resistance R_1 R_2 R_E provides dc bias while the capacitor C_E is emitter bypass capacitor. RFC (Radio frequency choke) provides isolation b/w ac and d.c operation. Cc_1 and Cc_2 are coupling capacitors.



Using FET



Using Transistor.

The resulting circuit freq. is set by the series resonant freq. of the crystal. Change in the supply voltage, tempr. transistor parameters have no effect on the circuit operating condition and hence good freq. stability is obtained.

The Oscillator ckt can be modified by using the internal capacitance of the transistor used instead of C_1 and C_2. The separate capacitors C_1, C_2 are not required in such circuit.