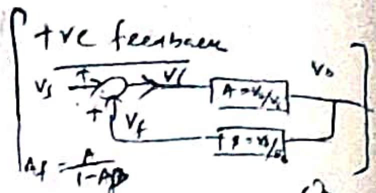
Oscillator



→ Which produces oscillation.

→ An electronic oscillator may be defined in any one of the following ways.

(i) It is a ckt. which converts d.c energy into a.c energy at very high frequency.

(ii) It is a ckt. which generates a.c o/p signal without requiring any externally applied i/p signal.

(iii) It is an unstable amplifier.

→ This definition excludes electromechanical alternator generating 50 HZ (low freq) a.c power or other devices which converts mechanical or heat energy into electrical energy.

Types :-

(i) Sinusoidal – which produces the o/p that are 'sine' waveform.

(ii) Non-Sinusoidal – which produces square, triangular, pulse, sawtooth etc. types waveform.

Basic principle of Sinusoidal Oscillator :-

Consider a feedback circuit shown in fig (1). When switch at the amplifier i/p is open, no oscillation occurs. Consider that we have

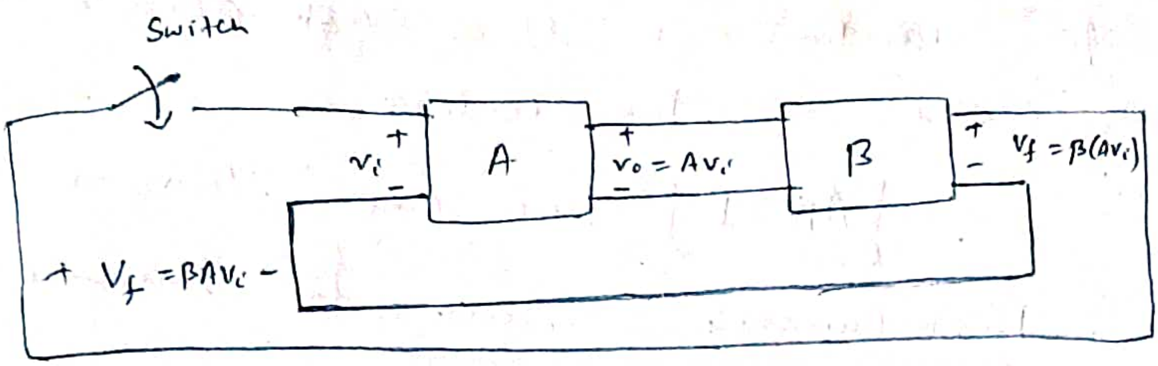


fig 1: feedback ckt used as an oscillator

a fictious voltage (noise) at the amplifier input V_i. This results in an O/P voltage $V_o = AV_i$ after the amplifier stage and in a voltage $V_f = \beta(AV_i)$ after the feedback stage.

→ Thus, we have a feedback voltage $V_f = \beta A V_i$, where $A\beta$ is referred to as the loop gain. If the circuits of the base amplifier & feedback n/w provide βA of a correct magnitude and phase, 'V_f' can be made equal to V_i

→ $$\cancel{V_f} = A\beta \cancel{V_i}$$

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

→ Then, when the switch is closed and the fictious voltage V_i is removed, the ckt will continue operating since the feedback voltage is sufficient to drive the amplifier and feedback circuits, resulting in a proper I/P voltage to sustain the loop operation.

→ The o/p waveform will still exist after the switch is closed if the condition

$\boxed{A\beta = 1}$, is met. This is known as Barkhausen's criterion for sustained oscillation.

Barkhausen's criterion :-

From the basic feedback eqn,

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

If $A\beta = -1$, i.e. $|A\beta| = 1$, $\angle A\beta = 180°$

or loop gain magnitude is 1 and phase angle 180°, the denominator is zero, gain with feedback becomes ∞.

Thus an infinitesimal (noise voltage) can provide a measurable o/p voltage and the ckt act as a oscillator even without the i/p signal.

So Barkhausen's criteria for sustained oscillation, is

1) Loop gain magnitude = 1, $|A\beta| = 1$ or $A\beta = -1$
& Phase = 180°

2) Total phase shift around the closed loop should be 0° or multiple of 360°.

In practice, $A\beta$ is made greater than 1, and the system is started oscillating by amplifying noise voltage, which is always present. Saturation factors in the practical ckt provide an "average" value of $A\beta$ of 1. The resulting waveforms are never exactly sinusoidal. However, the closer the value βA is to exactly 1, the more sinusoidal is the waveform.

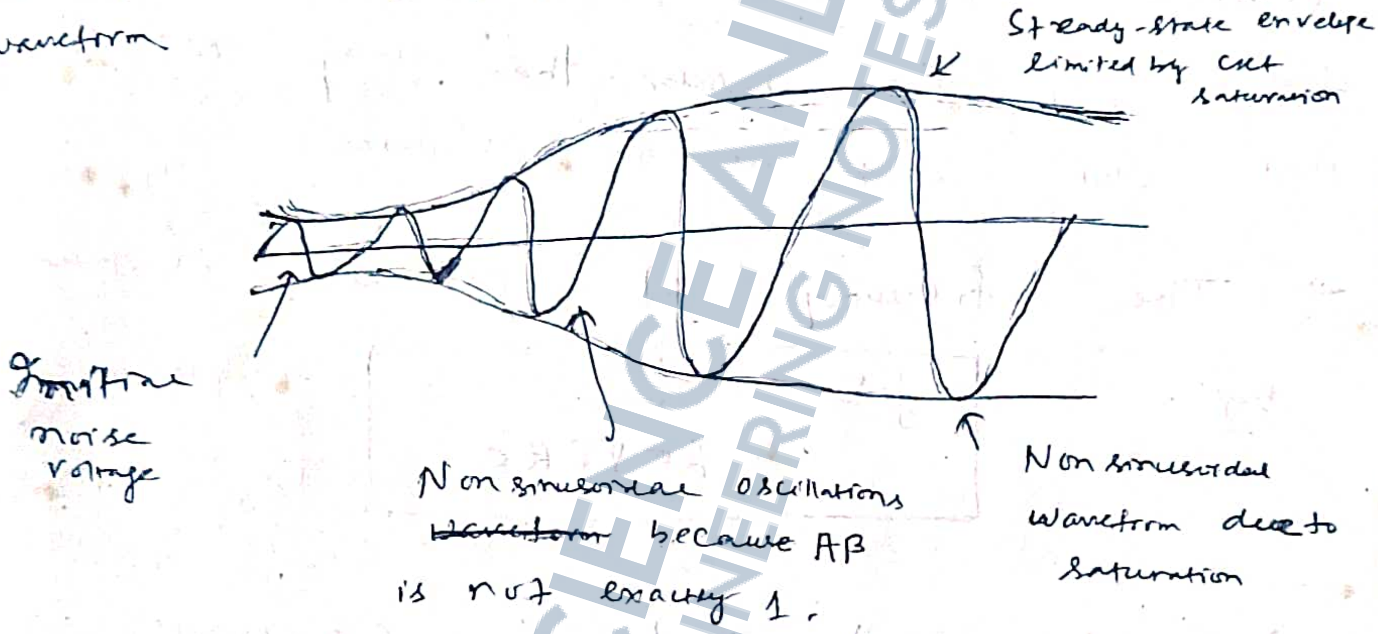


fig:- Build up of steady-state oscillations.

Different type of sinusoidal oscillator ckts.

1) RC Phase shift oscillator:- (a) Using OPAMP

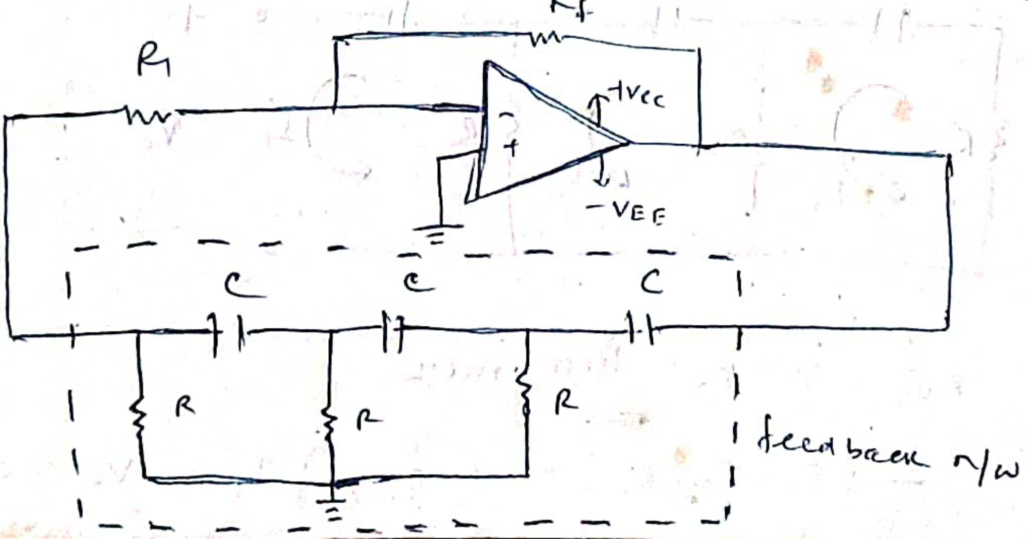


fig:- RC Phase shift Oscillator using OPAMP.

→ Here the OPAmp produces 180° phase shift [inverting amplifier] and another 180° phase shift is provided by RC ckt connected in cascade. Each RC ckt provides 60° phase shift.

→ If the OPAmp provides gain (set by resistors R_f and R_1) of greater than 29 and loop gain greater than unity results and ckt acts as an oscillator.

→ The frequency of oscillation is given by

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

$$\begin{bmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} d_1 \\ d_2 \\ d_3 \end{bmatrix}$$

→ $A\beta \geq 1$

$$\begin{bmatrix} a_1x + b_1y + c_1z = d_1 \\ a_2x + b_2y + c_2z = d_2 \\ a_3x + b_3y + c_3z = d_3 \end{bmatrix}$$

$A \geq 29$

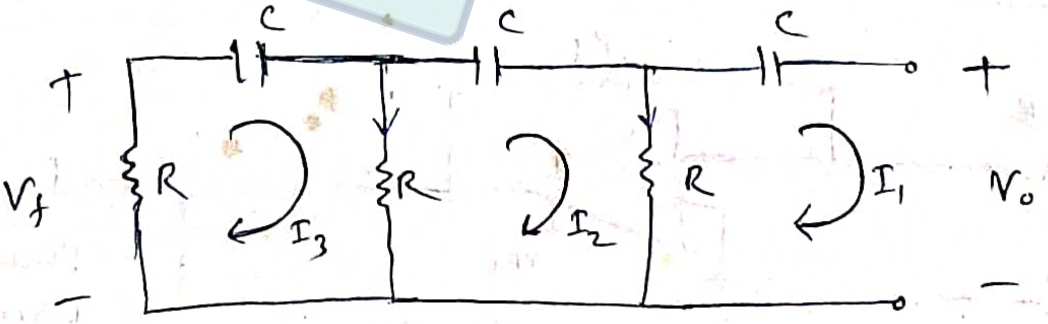
$\beta = \frac{1}{29}$

$$\Delta = \begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix} \qquad \Delta_1 = \begin{vmatrix} d_1 & b_1 & c_1 \\ d_2 & b_2 & c_2 \\ d_3 & b_3 & c_3 \end{vmatrix}$$

$x = \frac{\Delta_1}{\Delta}, \; y = \frac{\Delta_2}{\Delta}$

$z = \frac{\Delta_3}{\Delta}$

Proof:- Consider the feedback n/w



Applying KVL in the first mesh

$$-(I_1 - I_2)R - \left(\frac{1}{j\omega C}\right)I_1 - V_o = 0$$

$$\Rightarrow \; -\left(R+\frac{1}{j\omega C}\right) I_1 + I_2 R + 0 \cdot I_3 = V_0 \quad \text{--- (1)}$$

2nd mesh

$$-(I_2 - I_1)R - (I_2 - I_3)R - \frac{1}{j\omega C} \cdot I_2 = 0$$

$$\Rightarrow (I_2 - I_1)R + (I_2 - I_3)R + \frac{1}{j\omega C} I_2 = 0$$

$$\Rightarrow -R \cdot I_1 + \left(2R + \frac{1}{j\omega C}\right) I_2 - R \cdot I_3 = 0 \quad \text{--- (2)}$$

3rd mesh

$$-(I_3 - I_2)R - I_3 R - \left(\frac{1}{j\omega C}\right) \cdot I_3 = 0$$

$$\Rightarrow (I_3 - I_2)R + I_3 R + \frac{1}{j\omega C} \cdot I_3 = 0$$

$$\Rightarrow 0 \cdot I_1 - I_2 R + \left(2R + \frac{1}{j\omega C}\right) I_3 = 0 \quad \text{--- (3)}$$

$$\begin{bmatrix} -\left(R+\frac{1}{j\omega C}\right) & R & 0 \\ -R & 2R+\frac{1}{j\omega C} & -R \\ 0 & -R & 2R+\frac{1}{j\omega C} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} V_0 \\ 0 \\ 0 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} -\left(R+\frac{1}{j\omega C}\right) & R & 0 \\ -R & 2R+\frac{1}{j\omega C} & -R \\ 0 & -R & 2R+\frac{1}{j\omega C} \end{vmatrix}$$

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

$$\Delta_3 = \left[\text{Replacing } 3^{rd} \text{ column of } \Delta \text{ by } \begin{matrix} V_0 \\ 0 \\ 0 \end{matrix} \right]$$

$$\Delta_3 = \begin{bmatrix} -\left(R + \frac{1}{j\omega c}\right) & R & V_0 \\ -R & \left(2R + \frac{1}{j\omega c}\right) & 0 \\ 0 & -R & 0 \end{bmatrix}$$

$$\Delta_3 = -R\left(1 + \frac{1}{j\omega c}\right) \cdot 0 \quad -R \cdot 0 \quad + V_0 \left[R^2\right]$$

$$\boxed{\Delta_3 = V_0 R^2} \quad \text{——— (1)}$$

$$\Delta = -\left(R + \frac{1}{j\omega c}\right)\left[\left(2R + \frac{1}{j\omega c}\right)^2 - R^2\right] - R\left[-R\left(2R + \frac{1}{j\omega c}\right)\right]$$

$$= -\left(R + \frac{1}{j\omega c}\right)\left(2R + \frac{1}{j\omega c}\right)^2 + R^2\left(R + \frac{1}{j\omega c}\right) + R^2\left(2R + \frac{1}{j\omega c}\right)$$

$$= \left(2R + \frac{1}{j\omega c}\right)\left[-\left(R + \frac{1}{j\omega c}\right)\left(2R + \frac{1}{j\omega c}\right) + R^2\right] + R^3 + \frac{R^2}{j\omega c}$$

$$= \left(2R + \frac{1}{j\omega c}\right)\left[-\left(2R^2 + \frac{R}{j\omega c} + \frac{2R}{j\omega c} - \frac{1}{\omega^2 c^2}\right) + R^2\right] + R^3 + \frac{R^2}{j\omega c}$$

$$\Delta = \left(2R + \frac{1}{j\omega C}\right)\left[-R^2 - \frac{3R}{j\omega C} + \frac{1}{\omega^2 C^2}\right] + R^3 + \frac{R^2}{j\omega C}$$

$$= -2R^3 - \frac{6R^2}{j\omega C} + \frac{2R}{\omega^2 C^2} - \cancel{\frac{R^2}{j\omega C}} + \frac{3R}{\omega^2 C^2} + \frac{1}{j\omega^3 C^3} + R^3 + \cancel{\frac{R^2}{j\omega C}}$$

$$\Delta = \frac{-6R^2}{j\omega C} + \frac{5R}{\omega^2 C^2} + \frac{1}{j\omega^3 C^3} - R^3 \quad \text{——} \ (2)$$

$$I_3 = \frac{\Delta_3}{\Delta} \qquad \text{[from eqn (1) \& (2)]}$$

$$I_3 = \frac{V_o R^2}{\frac{-6R^2}{j\omega C} + \frac{5R}{\omega^2 C^2} + \frac{1}{j\omega^3 C^3} - R^3}$$

$$\Rightarrow I_3 R = \frac{V_o R^3}{-\frac{6R^2}{j\omega C} + \frac{5R}{\omega^2 C^2} + \frac{1}{j\omega^3 C^3} - R^3}$$

$$\Rightarrow -V_f = \frac{V_o R^3}{-\left[\frac{6R^2}{j\omega C} - \frac{5R}{\omega^2 C^2} - \frac{1}{j\omega^3 C^3} + R^3\right]}$$

$$\Rightarrow \beta \cancel{V_o} = \frac{\cancel{V_o} R^3}{\frac{6R^2}{j\omega C} - \frac{5R}{\omega^2 C^2} - \frac{1}{j\omega^3 C^3} + R^3}$$

$$\Rightarrow \beta\left[\frac{6R^2}{j\omega C} - \frac{1}{j\omega^3 C^3} - \frac{5R}{\omega^2 C^2} + R^3\right] = R^3 + j.0$$

$\Rightarrow$ Equating Real & Imaginary Parts,

$$\beta\left[R^3 - \frac{5R}{\omega^2 C^2}\right] = R^3, \qquad \beta\left[\frac{6R^2}{j\omega C} - \frac{1}{j\omega^3 C^3}\right] = 0$$

From the imaginary part,

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

$$\Rightarrow \frac{6R^2}{\cancel{j\omega C}} = \frac{1}{\cancel{j}\,\omega^{\cancel{3}} C^{\cancel{3}}} \quad \omega^2 C^2$$

$$\Rightarrow \omega^2 C^2 = \frac{1}{6R^2} \quad \text{--- (3)}$$

$$\Rightarrow \omega C = \frac{1}{\sqrt{6}\,R}$$

$$\Rightarrow 2\pi f C = \frac{1}{\sqrt{6}\,R}$$

$$\Rightarrow \boxed{f = \frac{1}{2\pi RC\sqrt{6}}} \quad \text{--- (4)}$$

From the Real part,

$$\beta\left[R^3 - \frac{5R}{\omega^2 C^2}\right] = R^3$$

$$\Rightarrow \beta\left[R^3 - 5R \times 6R^2\right] = R^3 \qquad \left[\text{from eqn (3)}, \ \frac{1}{\omega^2 C^2} = 6R^2\right]$$

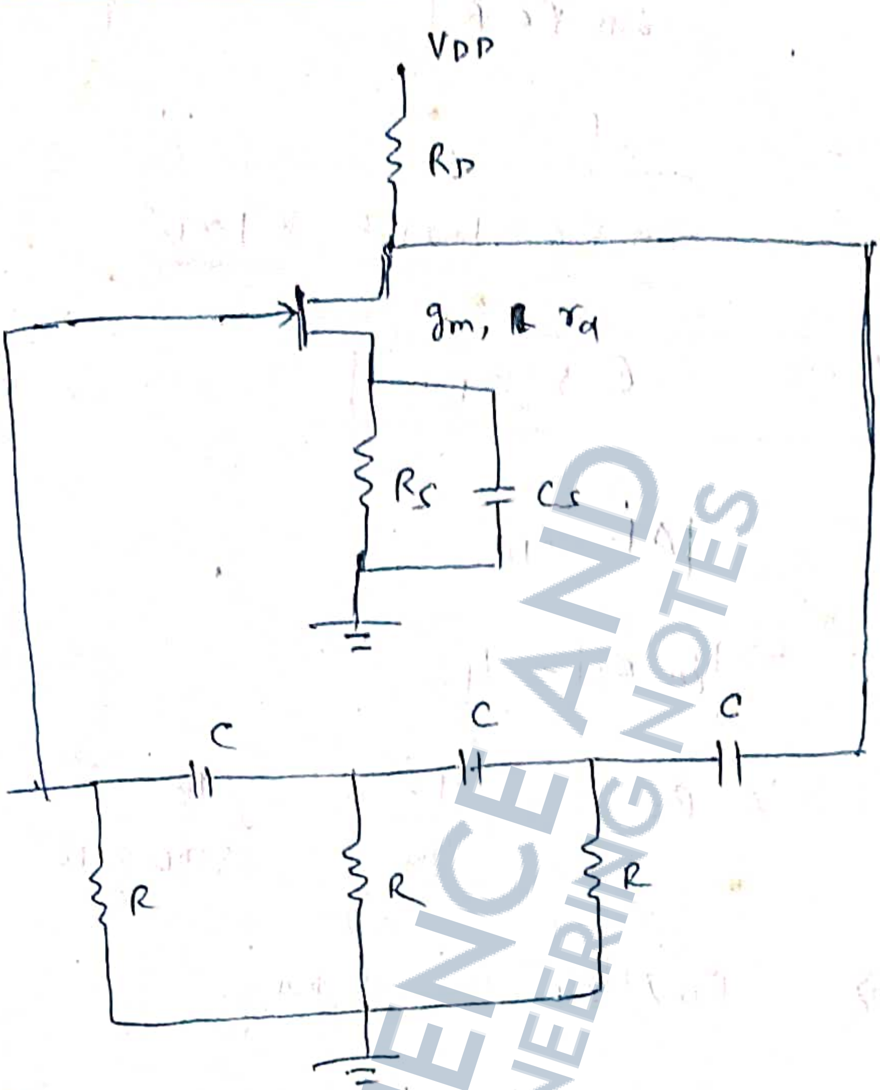
$$\Rightarrow \beta\left[\cancel{R^3} - 30 \times \cancel{R^3}\right] = \cancel{R^3}$$

$$\Rightarrow \beta\left[1 - 30\right] = 1$$

$$\Rightarrow \beta(-29) = 1$$

$$\Rightarrow \boxed{\beta = \frac{-1}{29}}$$

(b) RC Phase Shift Oscillator using FET



For Problems:-

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

$$|A| = g_m R_L$$

where $R_L = \dfrac{R_D r_d}{R_D + r_d}$ i.e. $R_D \,//\, r_d$

Prob. - Design a phase-shift oscillator, $g_m = 5000\,\mu S$, $r_d = 40k\Omega$, $R = 10k\Omega$. Select the value of $\boxed{C}$ for oscillator operation at 1 KHz, and $\boxed{R_D}$, for $A > 29$ to ensure oscillator action. [Given $A = 40$]

Ans :-

$$C = \frac{1}{2\pi\sqrt{6}\,Rf} \qquad \left[\because f = \frac{1}{2\pi\sqrt{6}\,RC}\right]$$

$$= \frac{1}{2\pi\sqrt{6} \times 10\times10^{3} \times 1\times10^{3}}$$

$$\boxed{C = 6.5\ nF}$$

Given $|A| = 40$

$$\Rightarrow |g_m R_L| = 40$$

$$\Rightarrow R_L = \frac{40}{g_m} = \frac{40}{5000\times10^{-6}} = 8\ k\Omega.$$

$$\Rightarrow R_D \parallel r_d = 8\ k\Omega.$$

$$\Rightarrow \frac{R_D \times r_d}{R_D + r_d} = 8\ k\Omega$$

$$\Rightarrow \frac{R_D \times 40K}{R_D + 40K} = 8K$$

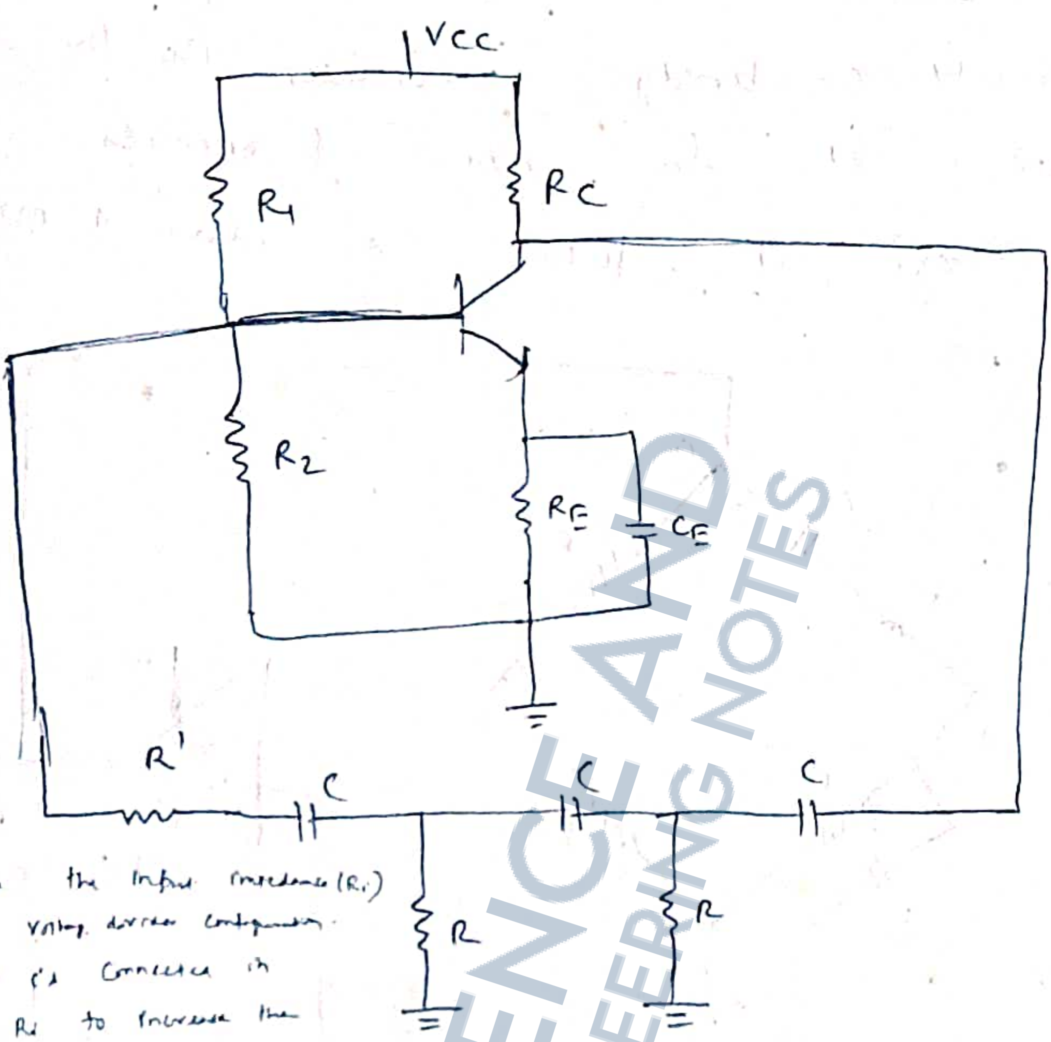
$$\Rightarrow R_D \times 40K = 8K \times R_D + 320K^2$$

$$\Rightarrow 32\cancel{K}\ R_D = 320\ \cancel{K^2}\ K$$

$$\Rightarrow R_D = \frac{320K}{32} = 10K$$

$$\therefore \boxed{R_D = 10\ k\Omega}$$

(C) Transistor Phase-shift Oscillator



Note:- Since the input impedance (R_i) of transistor voltage divider configuration is low, R' is connected in series with R_i to increase the i/p impedance of the amplifier.

In case of OPAmp & FET, i/p impedance is already high

$$f = \frac{1}{2\pi RC} \times \frac{1}{\sqrt{6+4(R_C/R)}}$$

2009 : BPUT Calculate the operating freq of BJT Phase shift oscillator for $R = 6k\Omega$, $C = 1500\ pF$ and $R_C = 18k\Omega$.

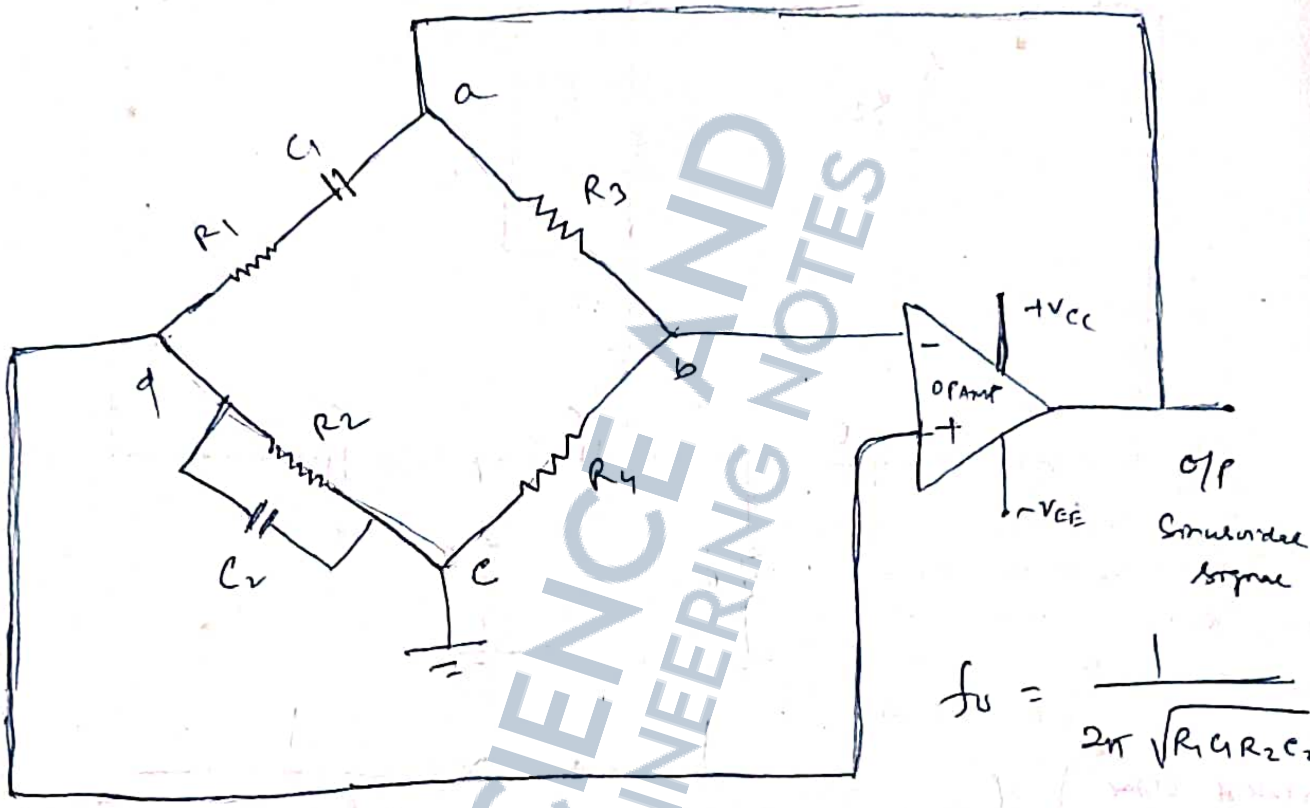
Ans :- $$f = \frac{1}{2\pi RC} \times \frac{1}{\sqrt{6+4.\left(\frac{R_C}{R}\right)}}$$

$$f = \frac{1}{2\pi \times 6\times10^{3} \times 1500\times10^{-12}} \times \frac{1}{\sqrt{6+4\times\left(\frac{18}{6}\right)}}$$

$$\boxed{f = 4.168\ KHz}$$

2) Wien Bridge Oscillator :-

The wien-bridge oscillator is the standard oscillator ckt for all frequencies in the range of 10 HZ to about 1 MHZ.



$$f_0 = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$

→ Fig shows the Wien bridge oscillator using OPAMP & RC bridge ckt.

→ Resistor R_1 & R_2 and capacitor C_1 & C_2 form the freq. adjustment elements and resistor R_3 & R_4 form part of the feedback path.

→ The OPAMP o/p is connected as the bridge input at point a.

→ The bridge ckt o/p at points b & d

i's the i/p to the OPAMP.

Neglecting loading effects of OP-AMP i/p & o/p impedance, the analysis of bridge ckt results in

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

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{R_1 C_1 R_2 C_2}}}$$

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

$$\boxed{f_0 = \frac{1}{2\pi RC} \qquad \frac{R_3}{R_4} = 2}$$

Proof:- For proper operation, the bridge should be balanced and the condⁿ is

$$\frac{R_4}{R_3} = \frac{R_2 \parallel X_{C_2}}{R_1 + X_{C_1}} = \frac{R_2 \parallel \frac{1}{j\omega C_2}}{R_1 + \frac{1}{j\omega C_1}} \quad \text{--- (1)}$$

$$R_2 \parallel \frac{1}{j\omega C_2} = \frac{R_2 \times \frac{1}{j\omega C_2}}{R_2 + \frac{1}{j\omega C_2}} = \frac{R_2}{1 + R_2 j\omega C_2} \quad \text{--- (2)}$$

$$R_1 + \frac{1}{j\omega C_1} = \frac{R_1 j\omega C_1 + 1}{j\omega C_1} \quad \text{--- (3)}$$

Using eq^n ② & ③ in eq^n ①, we have

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

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

$$\Rightarrow R_4 (1+R_2 j\omega C_2)(1+R_1 j\omega C_1) = R_2 R_3 j\omega C_1$$

$$\Rightarrow R_4 \left[1 + R_1 j\omega C_1 + R_2 j\omega C_2 - R_1 R_2 \omega^2 C_1 C_2\right] = R_2 R_3 j\omega C_1$$

$$\Rightarrow \left[R_4 - R_1 R_2 R_4 \omega^2 C_1 C_2\right] + j\left[R_1 R_4 \omega C_1 + R_2 R_4 \omega C_2\right] = 0 + j\omega C_1 R_2 R_3.$$

Equating Real & Imaginary parts,

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

$$\Rightarrow \omega^2 R_1 R_2 \cancel{R_4} C_1 C_2 = \cancel{R_4}$$

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

$$\Rightarrow \omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

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

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

$$R_1 R_4 \omega C_1 + R_2 R_4 \omega C_2 = \omega C_1 R_2 R_3$$

If $R_1 = R_2$, $C_1 = C_2$

$$\cancel{R_1} R_4 \cancel{\omega C_1} + \cancel{R_1} R_4 \cancel{\omega C_1} = \cancel{\omega C_1} \cancel{R_1} R_3$$

$$\Rightarrow R_4 + R_4 = R_3$$

$$\Rightarrow R_3 = 2R_4$$

$$\Rightarrow \boxed{\frac{R_3}{R_4} = 2}$$

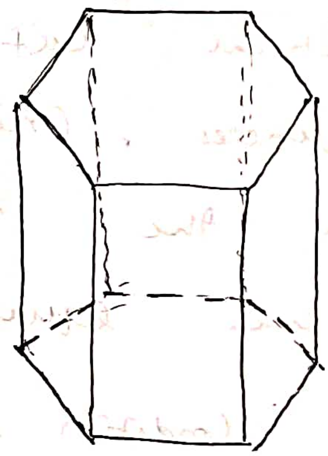
Crystal Oscillator :-

→ For an exceptionally high degree of frequency stability use of crystal oscillator is essential.

→ The method of cutting determines the crystal's natural frequency & its temperature coefficient.

→ Quartz crystals are generally used in crystal oscillators because of their great mechanical strength and simplicity of manufacture. The natural shape of quartz is hexagonal.

[Refer google for 3D pictures of crystal]



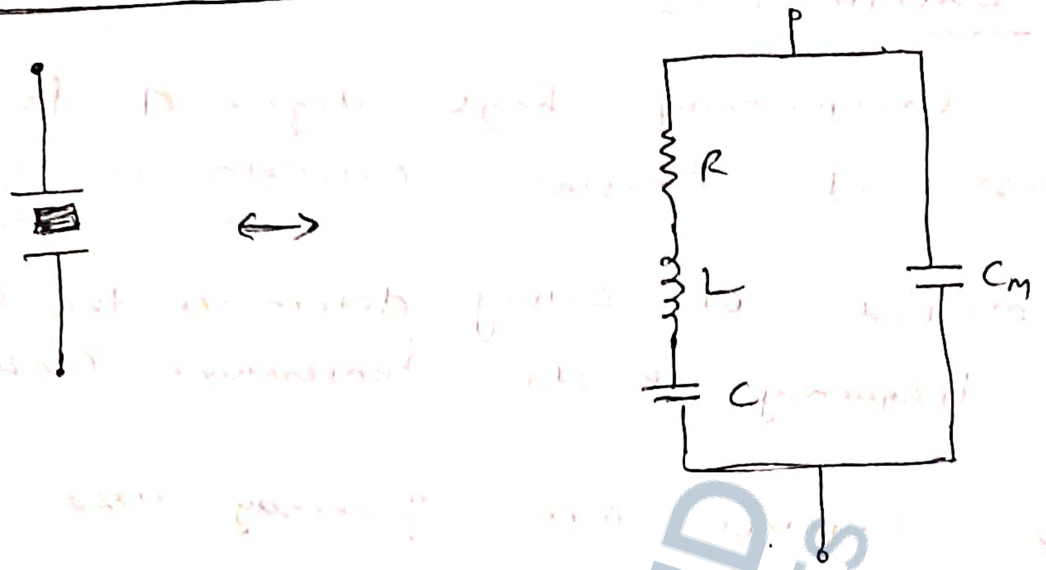
imp

Piezoelectric effect :-

A quartz crystal exhibits the property that when mechanical stress is applied across one set of its faces, a difference of potential develops across the opposite faces. [This property of a crystal is called piezoelectric effect.

→ Similarly, when a potential difference is applied across its 2 opposite faces, it causes the crystal to either expand or contract. If an alternating voltage is applied, the crystal wafer is set into vibration, the frequency of vibration is equal to the resonant frequency of the crystal.

Equivalent Electrical Ckt



$C_M \rightarrow$ Capacitance due to mechanical mounting of the crystal.

→ The crystal represented by the equivalent electrical ckt can have 2 resonant frequencies. One resonance condition occurs when the reactances of the series RLC leg are equal [i.e $X_L = X_C$]. For this condition, the series-resonant impedance is very low [equal to R].

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$X_L = X_C$

$Z = R$

$Z \rightarrow$ Impedance

$R \rightarrow$ Resistance

$X_L - X_C$ = Reactance

$$X_L = X_C$$

$$\Rightarrow |jWL| = \left|\frac{1}{jWC}\right|$$

$$\Rightarrow WL = \frac{1}{WC}$$

$$\Rightarrow W^2 = \frac{1}{LC}$$

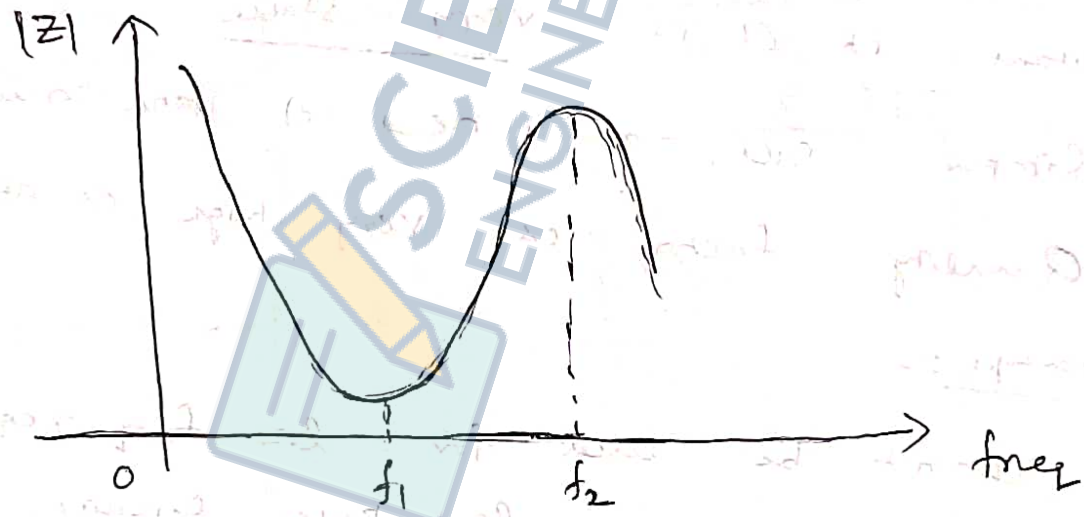
$$\Rightarrow W = \frac{1}{\sqrt{LC}}$$

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

$$\Rightarrow \quad \boxed{f_1 = \frac{1}{2\pi\sqrt{LC}}}$$

The other resonant cond^n occures at a higher frequency when the reactance of the series resonant leg equal to the reactance of the capacitor C_M. This is a parallel resonance or anti resonance cond^n of the crystal. At this frequency, the crystal offers very high impedance to the external circuit.

The impedance versus frequency of the crystal is shown below.



$f_1 \rightarrow$ Series resonance freq.

$f_2 \rightarrow$ Parallel resonance freq.

fig 2 – Crystal impedance versus freq.

To find parallel resonance freq (f_2)

At this cond^n, $|X_L| - |X_C| = |X_M|$

$$\Rightarrow \quad 2\pi f L - \frac{1}{2\pi f C} = \frac{1}{2\pi f C_M}$$

$\left(\because X_L = \omega L = 2\pi f L \right.$, $X_C = \frac{1}{\omega C} = \left. \frac{1}{2\pi f C} \right)$

$$\Rightarrow \quad 2\pi f L = \frac{1}{2\pi f}\left[\frac{1}{C} + \frac{1}{C_M}\right]$$

$$\Rightarrow \quad 4\pi^2 f^2 L = \frac{C + C_M}{C C_M}$$

$$\Rightarrow \quad f^2 = \frac{1}{4\pi^2 L} \cdot \frac{1}{C_T}$$

where $C_T = \frac{C C_M}{C + C_M}$

$$\Rightarrow \quad \boxed{f_2 = \frac{1}{2\pi\sqrt{L C_T}}}$$

Advantages :-

→ O/P frequency is very high and more important is it is very stable

→ Simple ckt, no need of tank circuit.

→ Quality factor is very high is about 2000.

Disadvantages :-

→ It can't be used for low freq required place

→ It is used in low power circuits.

Use :-

→ Used wherever greater stability is required, such as communication transmitter & receivers.

→ In digital clock.

Note:- The Crystal (quartz) ~~Produce~~ has a greater stability in holding constant at whatever freq the crystal is originally cut to operate.

Series - Resonant Circuits

To excite a crystal for operation in the series - resonant mode, it may be connected as a series element in a feedback path. At the series - resonant freq of the crystal, its impedance is smallest and the amount of (+ve) feedback is largest. A typical transistor circuit is shown below.

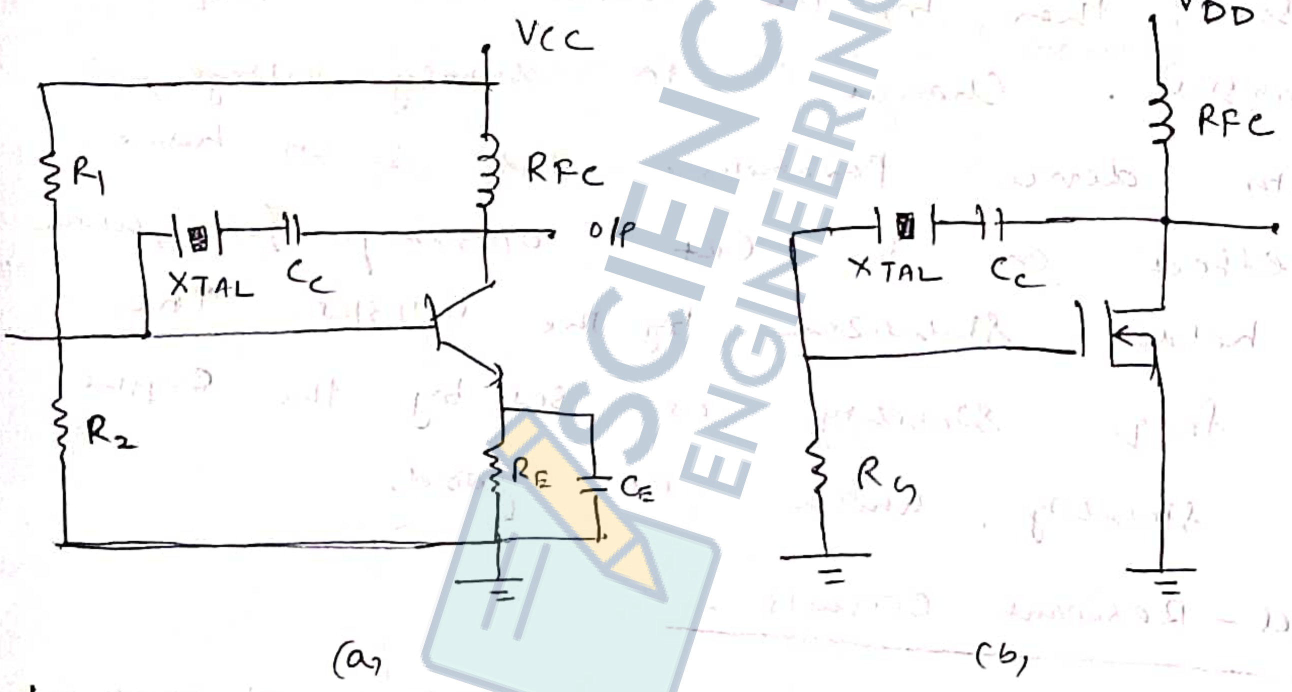


fig:- Crystal - Controlled oscillator using a crystal (XTAL) in series - feedback path (a) BJT ckt (b) FET ckt.

→ Resistor R_1, R_2 & R_E provide voltage - divider stabilized d.c bias ckt.

→ Capacitor C_E provides ac bypass of the emitter resistor and RFC (Radio Freq Coil)

Core provides for dc bias while decoupling any ac signal on the power lines from affecting the o/p signal.

The voltage feedback from the collector to base is max^m when the crystal impedance is min^m (in series-resonant mode). The coupling capacitor C_c has negligible impedance at the circuit operating freq but blocks any d.c between collector and base.

The resulting circuit freq of oscillation is set, then, by the series-resonant freq of the crystal. Changes in supply voltage, transistor device parameters and so on have no effect on the ckt operating freq, which is held stabilized by the crystal. The ckt freq stability is set by the crystal freq stability, which is good.

Parallel - Resonant circuits :-

Since the parallel-resonant impedance of crystal is a max^m value, it is connected in shunt. At the parallel-resonant operating freq, a crystal appears as an inductive reactance of largest value. Max^m voltage is developed across the crystal at its parallel-resonant freq. The voltage is coupled to the emitter by a capacitor voltage divider - capacitors C_1 & C_2.

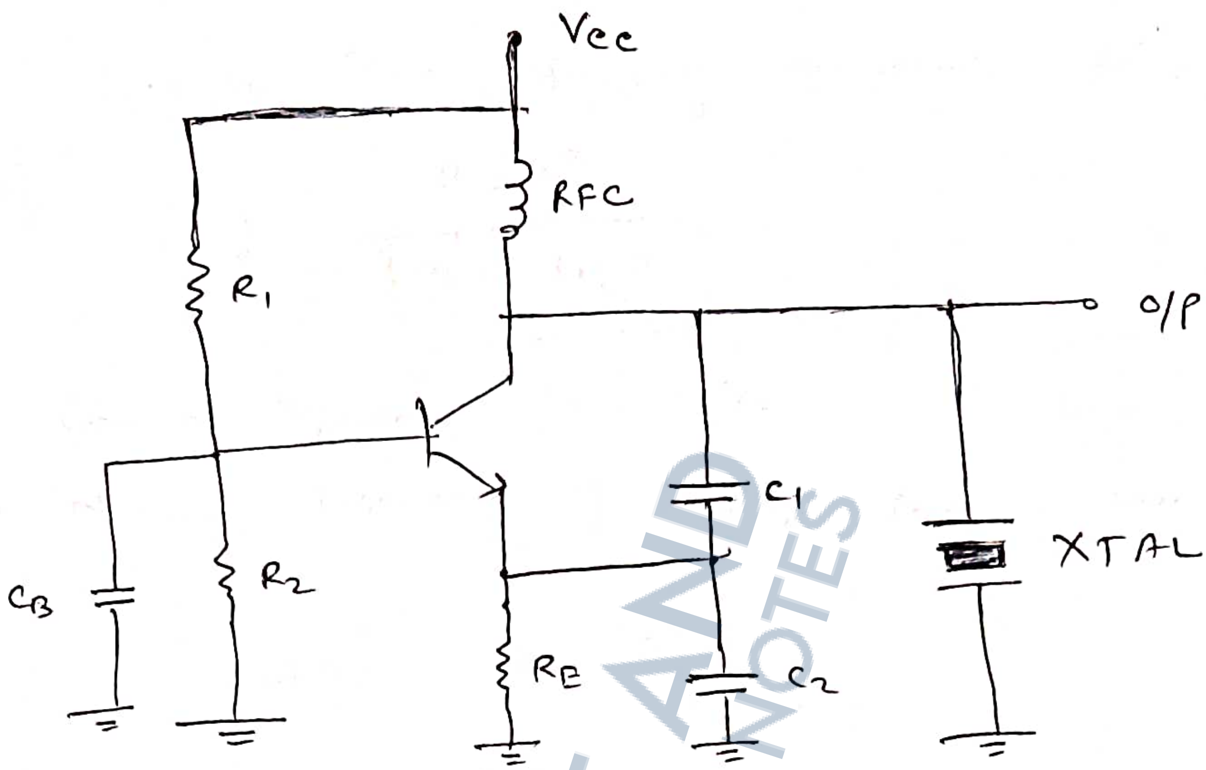
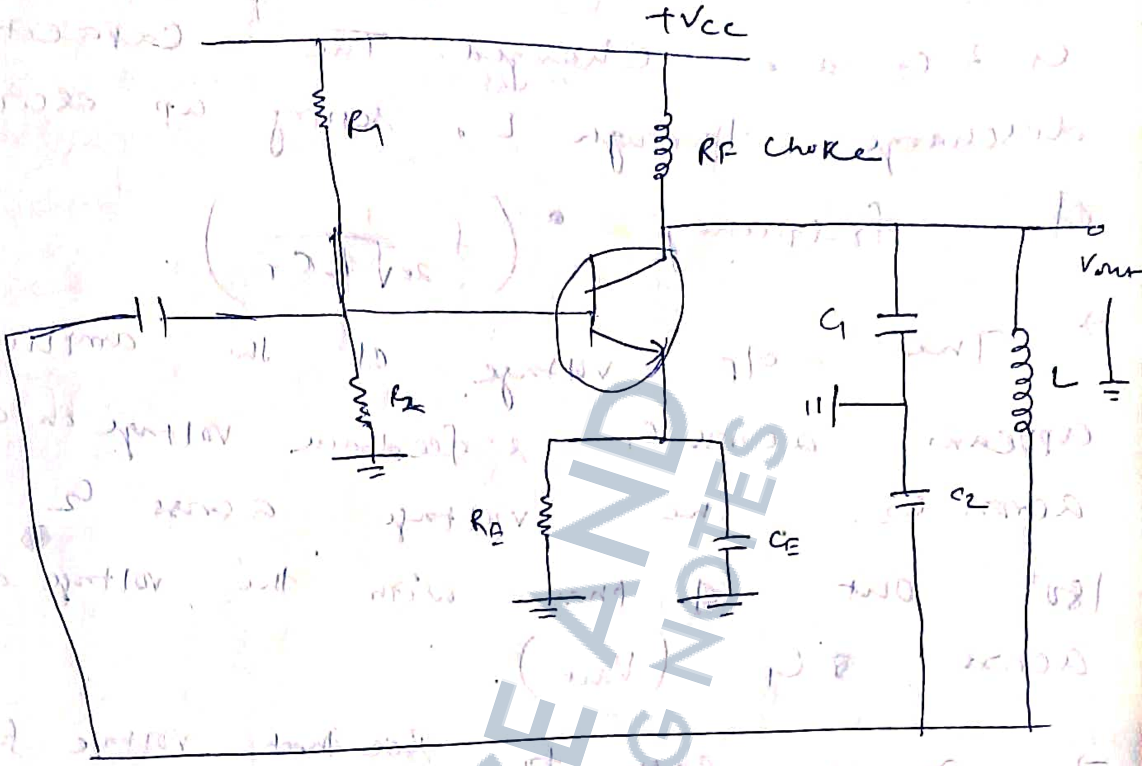


fig:- Crystal - controlled oscillator operating in parallel - resonant mode.

3) Colpitt's Oscillator :-



→ Figure shows a Colpitt's ~~Osc~~ Oscillator. It uses 2 capacitors C1 & C2 placed across a common inductor L and the center of the 2 capacitors is tapped. The tank ckt is made up of C1, C2 & L. The frequency of oscillation is determined by the values of C1, C2 & L and is given by

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

Where $C_T = \frac{C_1 C_2}{C_1 + C_2}$ | C_T = Total Capacitance

Note that $C_1 - C_2 - L$ is also the feedback ckt that produces a phase shift of 180°.

①

Ckt Operation:-

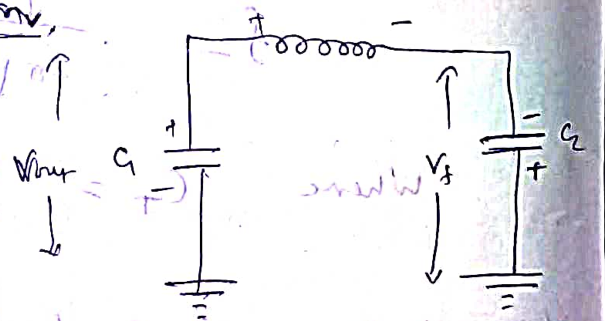
→ When the ckt is turned on, the capacitors C_1 & C_2 are charged. The capacitor discharge through L, setting up oscillations of frequency $\left(f = \frac{1}{2\pi\sqrt{LC_T}}\right)$.

→ The o/p voltage of the amplifier appears across C_1 & feedback voltage is developed across C_2. The voltage across C_2 is 180° out of phase with the voltage developed across C_1 (V_{out}).

→ It is easy to see that voltage feedback (voltage across C_2) to the transistor provides +ve feedback. A phase shift of 180° is produced by the transistor and further phase shift of 180° is produced by C_1-C_2 voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillations.

The feedback fraction m_v

The amount of feedback voltage in colpitts oscillator depend upon the feedback fraction m_v of the ckt.



$$m_v = \frac{V_f}{V_{out}} = \frac{X_{C_2}}{X_{C_1}} = \frac{C_1}{C_2}$$

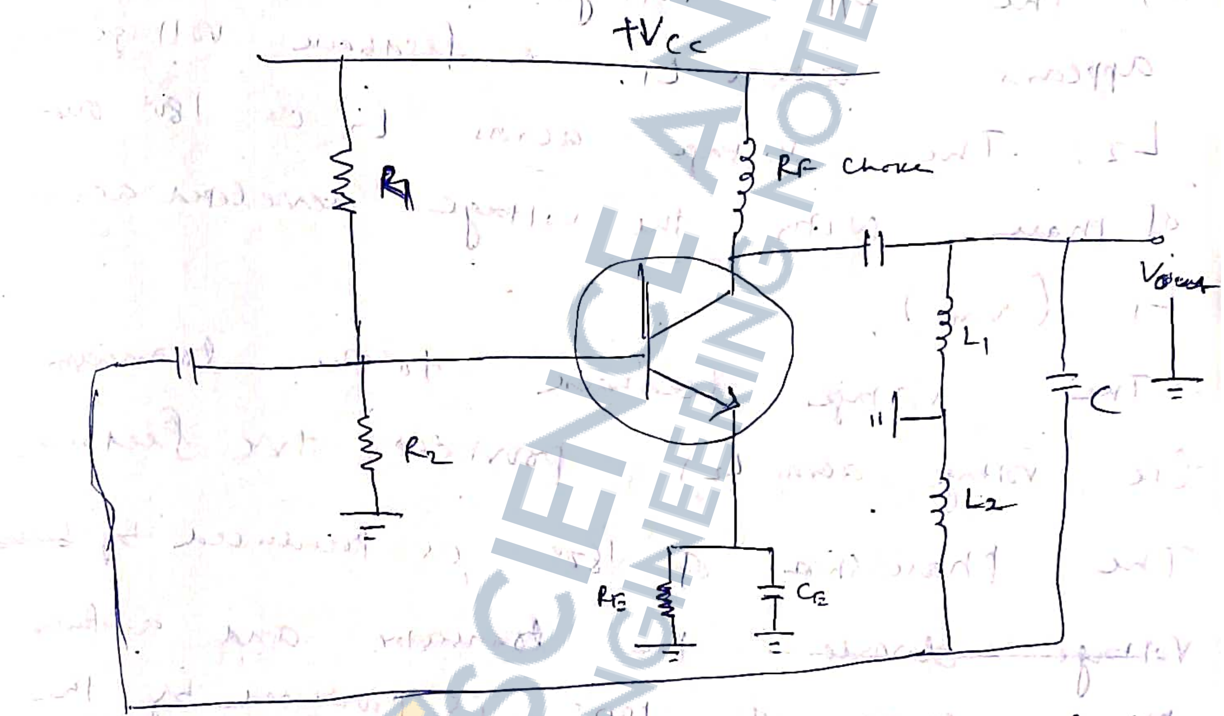
$X_{C_2} = \frac{1}{2\pi f C_2}$

$X_{C_1} = \frac{1}{2\pi f C_1}$

$$\therefore \boxed{m_v = \frac{C_1}{C_2}}$$

Hartley Oscillator (LC Oscillator)

The Hartley Oscillator is similar to Colpitt's Oscillator with minor modifications. Instead of using tapped capacitors, two inductors L_1 & L_2 are placed across a common capacitor C & the center of the inductors is tapped.



→ The Tank ckt is made up of L_1, L_2 & C. The frequency of oscillation is determined by the values of L_1, L_2 & C is given by

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

L_T = Total inductance

where

$$L_T = L_1 + L_2 + 2M$$

M = Mutual inductance betn L_1 & L_2

Note that $L_1 - L_2 - C$ is also the feedback n/w that produces a phase shift of 180°.

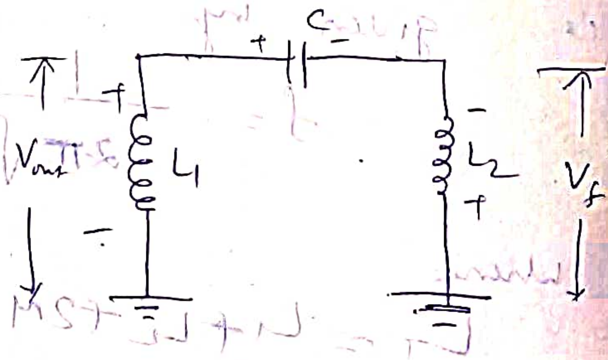
Ckt operation :-

→ When the ckt is turned on, the capacitor is charged. When this capacitor is fully charged, it discharges through coils L_1 & L_2 setting up oscillations of frequency $\left(f = \frac{1}{2\pi\sqrt{C L_T}} \right)$.

→ The o/p voltage of the amplifier appears across L_1 & feedback voltage across L_2. The voltage across L_2 is $180°$ out of phase with the voltage developed across L_1 (V_{out}).

→ The voltage feedback to the transistor (i.e voltage across L_2) provides +ve feedback. The phase shift of $180°$ is produced by ~~the voltage divider~~ the transistor and a further phase shift of $180°$ is produced by the L_1-L_2 voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillations.

Feedback fraction:-



Here the feedback voltage is across L_2 & o/p voltage is across L_1.

feedback fraction $m_v = \frac{V_f}{V_{out}} = \frac{X_{L_2}}{X_{L_1}} = \frac{L_2}{L_1}$