Unit 2

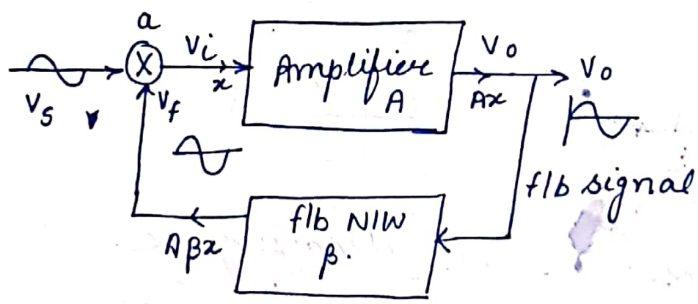
Sinusoidal Oscillators.

· **Introduction** (AP) :- An oscillator is a waveform generator that generates waveform of constant amplitude which oscillates at constant desired freq..

→ desired freq. can be obtained by varying ckt parameters.
→ If o/p signal is sinusoidal in nature then sinusoidal osc.
→ able to generate the waveform of very high freq. to Low freq. is limited by size of component.
→ Ind. & cap. become bulky at lower freq.
→ oscillators uses +ve f/b.
→ osc. does not require any i/p signal.

2. **Basic theory of oscillator** (AP) :- It uses positive f/b. as we know that

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

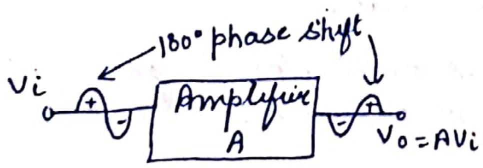


Now considering various value of β and A = 20 and Now calculate A_f.

A	β	A_f
20	0.005	22.22
20	0.04	100
20	0.045	200
20	0.05	∞

This result shows that the gain with f/b ↑ as the amount of positive f/b ↑. Signal x is applied to i/p whose gain is A, so o/p is xA. O/P is passed through f/b N/W whose gain is β. O/P is connected to pt. a and source is removed. Now new i/p is $A\beta x$ and o/p is available without any source. Source is required only once to start process. ~~It must~~ To start oscillations It must be noted that $\beta < 1$; otherwise $A_f = -ve$. it produces sinusoidal osc. $A\beta > 1$ but the ckt adjust itself to get $A\beta = 1$.

3. **Barkhausen criterion** (AP) : As Basic Amplifier is inverting, it produces a phase shift of 180° b/w i/p & o/p. But the f/b must be positive and V_o is in phase with V_i. Thus f/b N/W must introduce a phase shift of 180°. This ensures +ve f/b.



$$\therefore V_o = AV_i$$
$$V_f = \beta V_o$$
$$V_f = A\beta V_i$$

for oscillator, we ~~must~~ want that f/b should drive the amp^{r} and V_f must act as a V_i. hence from above eq^n

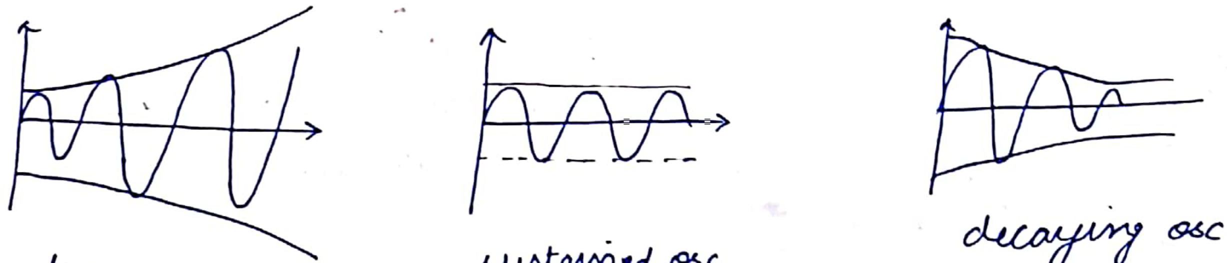
$$|A\beta| = 1$$

And phase of V_f is same as V_i, so f/b N/W should introduce 180° phase shift in addition to 180° phase shift introduce by inv. amp.
So Total phase shift = 360°.
These two condition are known as Barkhausen Criterion.

The B.H. criterion states that:
(i) The total phase shift 0 ~~to~~ 360°
(ii) $|A\beta| = 1$.

Satisfying these condition, the ckt. work as an oscillator.
In reality no i/p signal is needed to start oscillation. Only $A\beta$ is made greater than 1 to start oscillations. and then ckt. start itself to get $A\beta = 1$.

(i) $|A\beta| > 1$ (ii) $|A\beta| = 1$ (iii)



growing type of osc. sustained osc. decaying osc.

starting voltage → Every resistance have some free e^-. Under normal room temp. these free e^- move randomly in various dir. Such movement of free e^- ~~is called~~ generate a vtg. called noise vtg. Such noise vtg. present across the resistance are amplified. Hence to amplify such small noise vtg. and to start oscillation $|A\beta| > 1$.

4. Classification of oscillators: (AP)
(i) based on output waveform / Nature of waveform:
→ sinusoidal oscillator :- generate sine wave.
→ Relaxation oscillator / non sinusoidal oscillator :- generate triangular, square, sawtooth waveform.
(ii) based on ckt. component :-
→ RC oscillator
→ LC oscillator
→ crystal oscillator.

(iii) based on Range of frequency :

→ AF : 20 Hz to 200KHz. (low freq.)

→ RF : 20 KHz to 30MHz.

→ HF : 1·5 MHz to 30 MHz

→ VHF : 30 MHz to 300 MHz

→ UHF : 300 MHz to 3GHz.

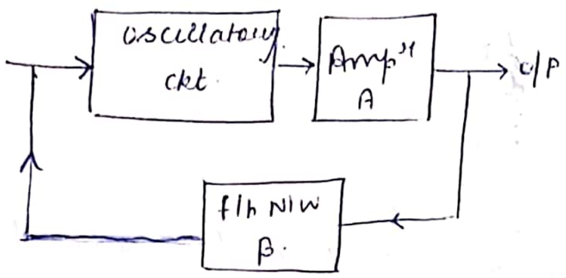
→ Microwave : > 3GHz.

(iv) Whether f/b is used or not?

→ f/b oscillators : f/b is used.

→ Negative resistance oscillators : in which f/b is not used to generate oscillation.

5. elements of transistor oscillator : (RT)



An oscillator contain following 3 elements :

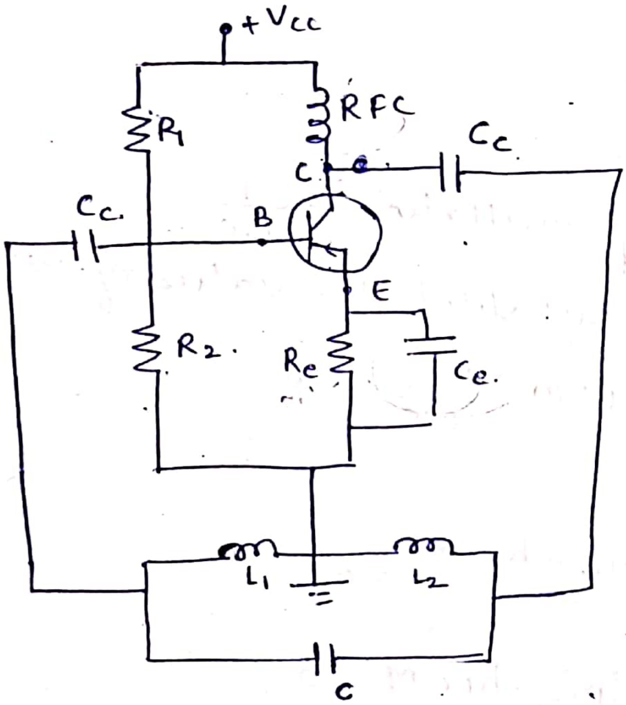
(i) Oscillatory circuit : these ckt contain parallel combination of L & C. freq. of operation is given as :

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

(ii) Internal Ampr (A): amplifies the signal

(iii) feedback N/W : Oscillator uses +ve f/b N/W.

(ii) Transistorised Hartley oscillator : vtg divider bias is provided by R_1 & R_2. C_e is bypass capacitor & C_c is coupling capacitor. Tuned ckt. is formed by L_1, L_2, C. Mutual coupling b/w inductor is M and it is positive in nature. V_{cc} is applied to collector through RFC which permit an easy flow to DC but at same time it offers very high ~~freq~~ imp to high freq. current. O/P of Tx is coupled back to the Tx i/p through tank ckt. Tx produces phase shift of 180°. another ~~f/b~~ ~~is~~ phase shift of 180° is provided by inductive f/b. Thus total phase shift of 360° is obtained.



Working :- As supply is switched on, c is ~~the~~ charged through Vcc. This capacitor discharge through L_1, L_2. oscillation across L_1 are applied to i/p of Tx and appear in amplified form in o/p ckt. This amplified o/p vtg. is applied to tuned ckt. to feed the losses in tank ckt. O/p is collected across L_2.

Mathematical Analysis :- (AP)

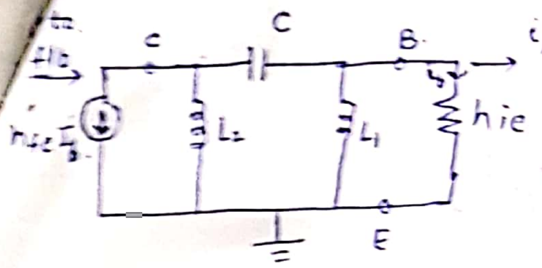


fig: equivalent ckt.

Now convert current source to vtg. source.

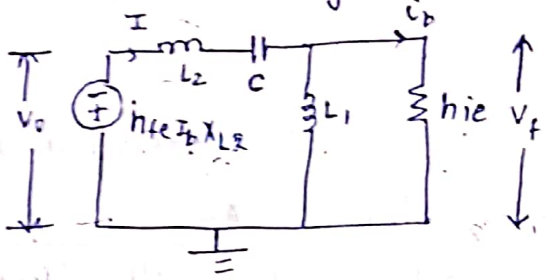


fig: simplified ckt.

$$V_o = h_{fe} I_b X_{L_2} = h_{fe} I_b j\omega L_2 \quad \text{--- (i)}$$

$$I = \frac{-V_o}{(X_{L_2}+X_C)+(X_{L_1} \| hie)}$$

where $X_{L2}+X_C = j\omega L_2 + \dfrac{1}{j\omega C}$

$$X_{L_1} \| hie = \frac{j\omega L_1 hie}{j\omega L_1 + hie}$$

$$I = \frac{-h_{fe} I_b j\omega L_2}{\left(j\omega L_2 + \frac{1}{j\omega C}\right) + \left(\frac{j\omega L_1 hie}{j\omega L_1 + hie}\right)} \qquad \text{[from eq (i)]}$$

Replace $j\omega$ by s.

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

$$= \frac{-s h_{fe} I_b L_2}{\left(\frac{1+s^2L_2C}{sC}\right) + \left(\frac{sL_1 hie}{sL_1+hie}\right)}$$

$$= \frac{-s h_{fe} I_b L_2 (sC)(sL_1+hie)}{(1+s^2L_2C)(sL_1+hie) + (sC)(sL_1 hie)}$$

$$= \frac{-s^2 C h_{fe} I_b L_2 (sL_1+hie)}{sL_1 + hie + s^3L_1L_2C + s^2L_2C\,hie + s^2CL_1\,hie}$$

$$= \frac{-s^2 h_{fe} I_b L_2 C (sL_1+hie)}{s^3L_1L_2C + s^2(L_2C\,hie + CL_1\,hie) + sL_1 + hie}$$

according to current division rule:

$$I_b = \frac{I\,X_{L_1}}{X_{L_1}+hie} \Rightarrow I_b = \frac{j\omega L_1 \cdot I}{j\omega L_1 + hie}$$

$$I_B = I \times \left[\frac{S L_1}{S L_1 + h_{ie}}\right]$$

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

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

$$1 = \frac{-s^3 h_{fe} L_1 L_2 C}{s^3 L_1 L_2 C + s^2 C h_{ie}(L_1+L_2) + sL_1 + h_{ie}}$$

$s = jw,\ s^2 = -w^2,\ s^3 = -jw^3$

$$1 = \frac{jw^3 h_{fe} L_1 L_2 C}{-jw^3 L_1 L_2 C - w^2 C h_{ie}(L_1+L_2) + jwL_1 + h_{ie}}$$

$$1 = \frac{jw^3 h_{fe} L_1 L_2 C}{[h_{ie} - w^2 C h_{ie}(L_1+L_2)] + jwL_1(1 - w^2 L_2 C)}$$

Rationalising the RHS of above eq^n

$$1 = \frac{jw^3 h_{fe} L_1 L_2 C\,[\{h_{ie} - w^2 C h_{ie}(L_1+L_2)\} - jwL_1(1-w^2L_2C)]}{[h_{ie} - w^2 C h_{ie}(L_1+L_2)]^2 + w^2 L_1^2 (1 - w^2 L_2 C)^2}$$

~~To satisfy this eqn, imaginary part must be zero.~~

$$1 = \frac{w^4 h_{fe} L_1^2 L_2 C(1 - w^2 L_2 C) + jw^3 h_{fe} L_1 L_2 C\,[h_{ie} - w^2 C h_{ie}(L_1 + L_2)]}{[h_{ie} - w^2 C h_{ie}(L_1+L_2)]^2 + w^2 L_1^2 (1 - w^2 L_2 C)^2}$$

To satisfy this eq^n, imaginary part must be zero

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

$$h_{ie} = w^2 C h_{ie}(L_1+L_2)$$

$$1 = w^2 C(L_1+L_2)$$

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

replace (L_1+L_2) by L_{eq}.

$$w^2 = \frac{1}{C L_{eq}}$$

$$w = \frac{1}{\sqrt{C L_{eq}}}$$

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

The above eq^n gives the freq. of oscillation and value of h_{fe} can be calculated, by equating the magnitude of both sides.

(5)

$$1 = \frac{w^4 h_{fe} L_1^2 L_2 C (1 - w^2 L_2 C)}{[h_{ie} - w^2 C h_{ie} (L_1 + L_2)]^2 + w^2 L_1^2 (1 - w^2 L_2 C)^2} \quad \text{at } w = \frac{1}{\sqrt{C(L_1+L_2)}}$$

$$1 = \frac{w^4 h_{fe} L_1^2 L_2 C (1 - w^2 L_2 C)}{\left[h_{ie} - \frac{C h_{ie}(L_1+L_2)}{C(L_1+L_2)}\right]^2 + \left\{ w^2 L_1^2 (1 - w^2 L_2 C)^2\right.}$$

$$1 = \frac{w^4 h_{fe} L_1^2 L_2 C (1 - w^2 L_2 C)}{w^2 L_1^2 (1 - w^2 L_2 C)^2}$$

$$1 = \frac{w^2 h_{fe} L_2 C}{(1 - w^2 L_2 C)}$$

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

$$1 = \frac{h_{fe} C L_2}{C L_1}$$

$$1 = \frac{h_{fe} L_2}{L_1}$$

$\boxed{h_{fe} = \frac{L_1}{L_2}}$ This is the value of h_{fe}, required to satisfy the oscillating condition.

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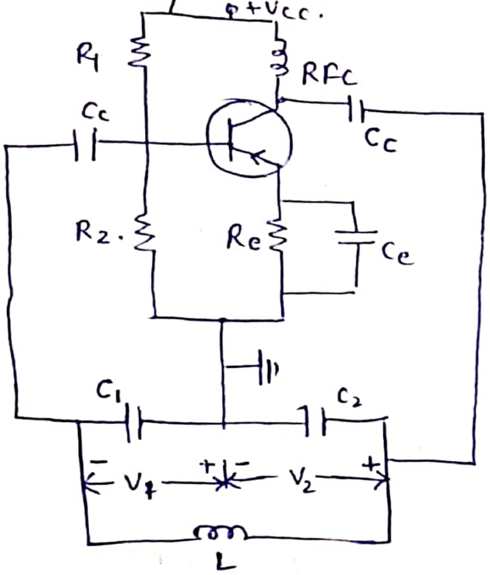
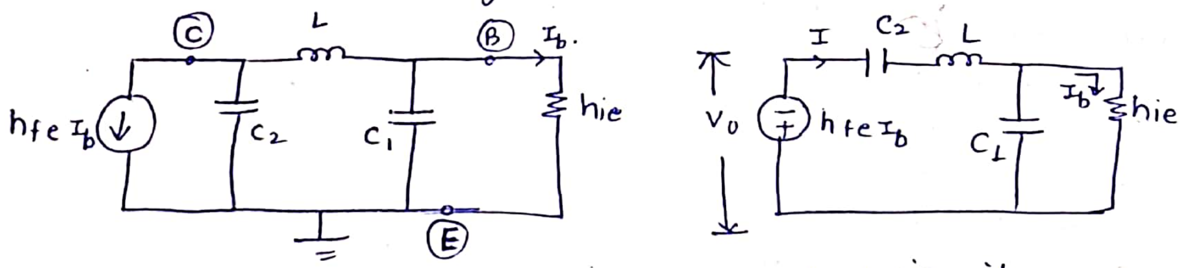
(RT) (AP)

8. Colpitts oscillator: When supply vtg is on, C_1 & C_2 charges through V_{cc}, then they discharge through inductor L. charging & discharging develop oscillation in tank ckt. whose freq. is decided by L_1, L_2, C. from fig it is clear that V_1 & V_2 are shifted by 180°. vtg V_1 act as a input for Tx, which further amplifies it and shifted by 180°. Net phase shift is 360°.



Mathematical Analysis :



fig, equivalent circuit

$$V_o = h_{fe} I_b X_{C2} = h_{fe} I_b \frac{1}{jwC_2}$$

$$I = \frac{-V_o}{(X_{C2}+X_L)+(X_{C1} \| h_{ie})}$$

where,
$$X_{C2}+X_L = \frac{1}{jwC_2} + jwL$$

$$X_{C1} \| h_{ie} = \frac{\frac{h_{ie}}{jwC_1}}{h_{ie} + 1/jwC_1}$$

$$I = \frac{\dfrac{-h_{fe} I_b}{jWC_2}}{\left[\dfrac{1}{jWC_2} + jWL\right] + \left[\dfrac{\dfrac{hie}{jWC_1}}{hie + \dfrac{1}{jWC_1}}\right]}$$

replace jw by s.

$$I = \frac{\dfrac{-h_{fe} I_b}{SC_2}}{\left[\dfrac{1}{SC_2} + SL\right] + \left[\dfrac{\dfrac{hie}{SC_1}}{hie + \dfrac{1}{SC_1}}\right]} \Rightarrow I = \frac{\dfrac{-h_{fe} I_b}{SC_2}}{\left(\dfrac{1+S^2LC_2}{SC_2}\right) + \left[\dfrac{hie}{hieSC_1 + 1}\right]}$$

$$I = \frac{-h_{fe} I_b (SC_2)(hie\,SC_1 + 1)}{(SC_2)\left[(1+S^2LC_2)(1+hie\,SC_1) + (hie)(SC_2)\right]}$$

$$I = \frac{-h_{fe} I_b (1 + SC_1 hie)}{\left[1 + hie\,SC_1 + S^2LC_2 + hie\,S^3LC_1C_2 + hie\,SC_2\right]}$$

$$I = \frac{-h_{fe} I_b (1 + SC_1 hie)}{S^3LC_1C_2 hie + S^2LC_2 + Shie(C_1 + C_2) + 1}$$

according to current division rule:

$$I_b = I \times \frac{X_{C_1}}{(X_{C_1} + hie)} \Rightarrow I_b = \frac{\dfrac{I}{jWC_1}}{hie + \dfrac{1}{jWC_1}}$$

$$I_b = \frac{I}{1 + Shie C_1}$$

$$I_b = \frac{-h_{fe} I_b}{S^3LC_1C_2 hie + S^2LC_2 + Shie(C_1 + C_2) + 1}$$

$$1 = \frac{-h_{fe}}{S^3LC_1C_2 hie + S^2LC_2 + Shie(C_1 + C_2) + 1}$$

replace $s = jw$, $s^2 = -w^2$, $s^3 = -jw^3$

$$1 = \frac{-h_{fe}}{-jw^3LC_1C_2 hie - W^2LC_2 + jwhie(C_1 + C_2) + 1}$$

$$1 = \frac{-h_{fe}}{(1 - w^2LC_2) + jwhie\left[C_1 + C_2 - w^2LC_1C_2\right]} \quad \text{— (i)}$$

To satisfy the eq^n imaginary part must be zero.

$$w\,hie\,[C_1 + C_2 - w^2 L C_1 C_2] = 0$$

$$w^2 = \frac{C_1 + C_2}{L C_1 C_2} \qquad C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

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

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

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

substitute the value of w in eqn (i)

$$1 = \frac{-h_{fe}}{\left[1 - \frac{(C_1 + C_2) L C_2}{L C_1 C_2}\right] + j w\, h_{ie} \left[C_1 + C_2 - \frac{L C_1 C_2}{L C_1 C_2}(C_1 + C_2)\right]}$$

$$1 = \frac{-h_{fe}}{\left(\frac{C_1 - C_1 - C_2}{C_1}\right) + 0}$$

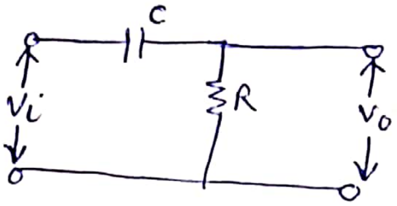
$$1 = \frac{-h_{fe}}{-C_2/C_1}$$

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

9. RC phase shift oscillator : (RT) (AP)

We have studied L-C oscillators, which generate high freq. oscillation. (7)
These can not be used for generating low freq. oscillation.
As we know $f \propto \frac{1}{\sqrt{L}}$ therefore generating low freq. signal requires high value of L, means it requires bulky inductor, which is expensive and ckt. miniaturization will not be possible. for generating audio freq. signals RC phase shift & wein bridge osc. are used.

principle of operation :



$$\frac{V_o}{V_i} = \frac{R}{R + \frac{1}{jWC}} \Rightarrow \frac{V_o}{V_i} = \frac{jWCR}{1 + jWCR}$$

$$\frac{V_o}{V_i} = \frac{WCR \angle 90^\circ}{\sqrt{1+W^2C^2R^2} \angle \tan^{-1} WCR}$$

$$\frac{V_o}{V_i} = \frac{WCR}{\sqrt{1+W^2C^2R^2}} \angle 90^\circ - \tan^{-1} WCR.$$

from above expression it is clear that vtg across R leads i/p vtg. by an angle $\phi = 90 - \tan^{-1} WCR$.
But practically R & C are so selected that ϕ is nearly equal to 60°.
Total phase shift required is 180°. To obtain these three section of RC required.
o/p of Tx is connected at i/p end while o/p of phase shift N/W is connected at i/p of Tx.
Tx provide phase shift of 180° & phase shift N/W provide 180°.
~~It is clear from eqn that~~

advantages :
→ provide good freq. stability.
→ ckt can be used for producing oscillation of low freq.
→ ckt does not require inductor or xformer.

Disadvantages :
→ can be used at high freq.
→ f/b is small, not easy to start oscillation
→ o/p of osc is comparatively small.

(1) Transistorised phase shift oscillator : practical transistorised RC phase shift oscillator consist of CE single stage amplifier and phase shifting N/W consist of three identical RC section.

Mathematical Analysis :

h_{ie} = i/P imp of amp stage

R_3 & h_{ie} is in series

$$R = R_3 + h_{ie}.$$

if R_1 & R_2 are considered then

$$R_i' = R_1 \| R_2 \| h_{ie}$$

value of R_3 must be

$$R_i' + R_3 = R$$

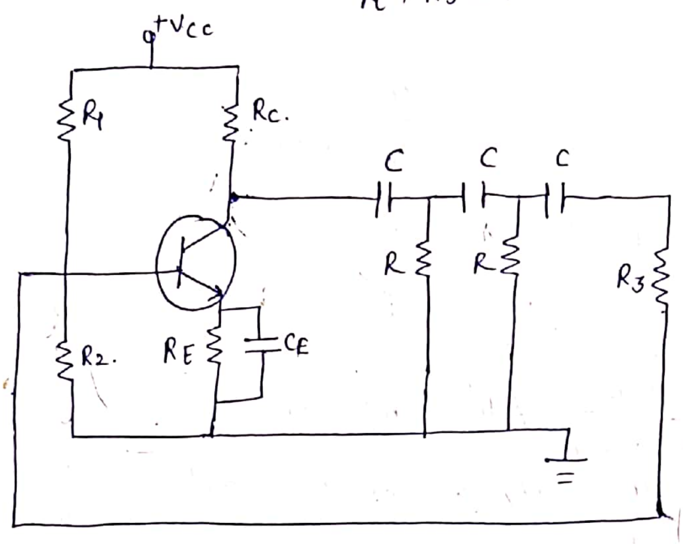


fig.: Phase shift osc. using Tx.

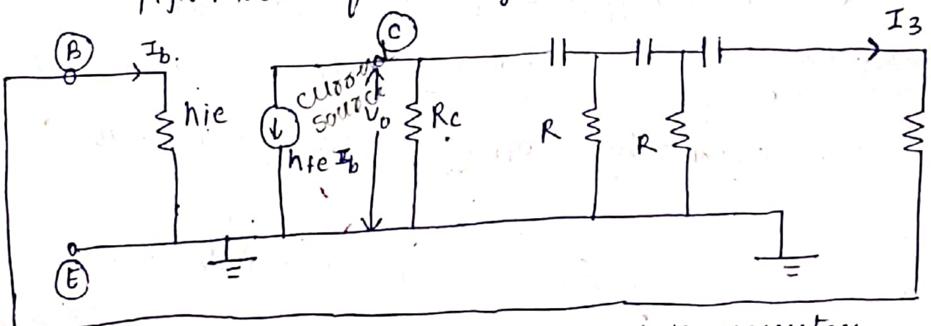


fig: equivalent ckt. using h parameter.

~~i/p~~

i/P of f/b = o/P of Amp = $h_{fe} I_b$

i/P of Amp ~~I_b~~ = i_b

o/P of f/b = i_3

$$\beta = \frac{i_3}{h_{fe} I_b}$$

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

$$A\beta = \frac{i_3}{i_b}$$

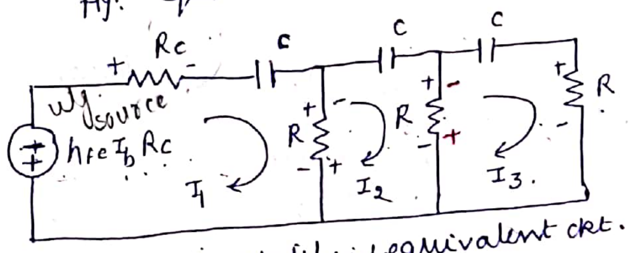


fig: Modified equivalent ckt.

Assume the Ratio of Rc to R be K.

$$K = \frac{R_c}{R}.$$

for loop 1 :

$$-I_1 R_c - \frac{I_1}{j\omega C} - I_1 R + I_2 R - h_{fe} I_b R_c = 0$$

Replace Rc by KR and $j\omega = s$.

$$I_1\left[\frac{1}{sC} + (1+K)R\right] - I_2 R = -h_{fe} I_b K R.$$

~~$I_1\left[R + \frac{1}{j\omega C}\right]$~~

for loop 2:

$$-\frac{1}{jwC} I_2 - I_2 R - I_2 R + I_1 R + I_3 R = 0$$

$$-I_1 R + I_2 \left[2R + \frac{1}{SC}\right] - I_3 R = 0$$

for loop 3:

$$-\frac{I_3}{jwC} - I_3 R - I_3 R + I_2 R = 0$$

$$-I_2 R + I_3 \left[2R + \frac{1}{SC}\right] = 0$$

Using Cramer's Rule to solve for I_3:

$$D = \begin{vmatrix} (K+1)R + \frac{1}{SC} & -R & 0 \\ -R & 2R + \frac{1}{SC} & -R \\ 0 & -R & 2R + \frac{1}{SC} \end{vmatrix}$$

$$D = \left[(K+1)R + \frac{1}{SC}\right]\left[\left(2R + \frac{1}{SC}\right)^2 - R^2\right] + R\left[(-R)\left(2R + \frac{1}{SC}\right)\right]$$

$$D = \left[(K+1)R + \frac{1}{SC}\right]\left(2R + \frac{1}{SC}\right)^2 - R^2\left[(K+1)R + \frac{1}{SC}\right] - R^2\left(2R + \frac{1}{SC}\right)$$

$$D = \frac{[SCR(K+1) + 1][2RSC + 1]^2}{S^3C^3} - \frac{R^2[2RSC + 1]}{SC} - \frac{R^2[(K+1)SCR + 1]}{SC}$$

~~first term can be written as :~~

$$D = \frac{[KSCR + SCR + 1][4R^2S^2C^2 + 1 + 4RSC]}{S^3C^3} - \frac{R^2[2RSC + 1 + 1 + KSCR + SCR]}{SC}$$

$$D = \frac{4KS^3R^3C^3 + KSCR + 4KS^2C^2R^2 + 4S^3R^3C^3 + SCR + 4R^2S^2C^2 + 4R^2S^2C^2 + 1 + 4RCRS}{S^3C^3} - \frac{R^2[2RSC + 2 + KSCR + SCR]}{SC}$$

$$D = \frac{4KS^3R^3C^3 + 4S^3R^3C^3 + 4KS^2R^2C^2 + 8R^2S^2C^2 + (5+K)SCR + 1 - 3S^3C^3R^3 - 2R^2S^2C^2 - KS^3C^3R^3}{S^3C^3}$$

$$D = \frac{3KS^3R^3C^3 + 4KS^2R^2C^2 + S^3R^3C^3 + (5+K)SCR + 6R^2S^2C^2 + 1}{S^3C^3}$$

$$D = \frac{S^3R^3C^3[3K+1] + S^2R^2C^2[4K+6] + SRC[5+K] + 1}{S^3C^3}$$

$$D_3 = \begin{vmatrix} (K+1)R+\frac{1}{sC} & -R & -h_{fe} I_b K R \\ -R & 2R+\frac{1}{sC} & 0 \\ 0 & -R & 0 \end{vmatrix}$$

$$D_3 = -R^2(h_{fe} I_b K R)$$

$$= -KR^3 h_{fe} I_b$$

$$I_3 = \frac{D_3}{D}$$

$$I_3 = \frac{-KR^3 h_{fe} \cancel{I_b} s^3 C^3}{s^3R^3C^3(3K+1) + s^2C^2R^2(4K+6) + sCR(5+K) + 1}$$

I_b = i/p current to amp.

I_c = i/p current to f/b ckt. ; $I_c = h_{fe} I_b$.

I_3 = o/p current of f/b ckt. ;

$$\beta = \frac{\text{o/p of f/b ckt.}}{\text{I/p of f/b ckt.}} = \frac{I_3}{h_{fe} I_b}.$$

$$A = \frac{\text{o/p of Amp ckt.}}{\text{i/p of Amp ckt.}} = \frac{h_{fe} I_b}{I_b} = h_{fe}$$

$$A\beta = \frac{I_3}{h_{fe} I_b} \times h_{fe} \Rightarrow A\beta = \frac{I_3}{I_b}.$$

$$A\beta = \frac{-KR^3 h_{fe} s^3 C^3}{s^3R^3C^3(3K+1) + s^2C^2R^2(4K+6) + sCR(5+K) + 1}$$

Replace $s = jw$, $s^2 = -w^2$, $s^3 = -jw^3$

$$A\beta = \frac{jw^3 K R^3 C^3 h_{fe}}{-jw^3R^3C^3(3K+1) - w^2C^2R^2(4K+6) + jwCR(5+K) + 1}$$

$$A\beta = \frac{jw^3 KR^3C^3 h_{fe}}{[1 - 4Kw^2R^2C^2 - 6w^2R^2C^2] - jw[3Kw^2R^3C^3 + w^2R^3C^3 - 5CR - KCR}$$

dividing Num & Den. by $(-jw^3R^3C^3)$

$$A\beta = \frac{-Kh_{fe}}{\left\{\frac{1 - 4Kw^2R^2C^2 - 6w^2R^2C^2}{-jw^3R^3C^3}\right\} - jw\left[\frac{3Kw^2R^3C^3 + w^2R^3C^3 - 5CR - KCR}{-jw^3R^3C^3}\right.}$$

Replace $-1/j = j$.

$$A\beta = \frac{-Kh_{fe}}{j\left\{\frac{1}{w^3R^3C^3} - \frac{4K}{wRC} - \frac{6}{wRC}\right\} + \left\{3K + 1 - \frac{5}{w^2R^2C^2} - \frac{K}{w^2R^2C^2}\right\}}$$

Repla

As per

$-Kh$

Replace $\frac{1}{WRC} = \alpha$

$$A\beta = \frac{-Khfe}{\{3K+1-5\alpha^2-K\alpha^2\} + j\{\alpha^3 - 4K\alpha - 6\alpha\}} \quad \text{— (i)}$$

~~As per Barkhausen criterion $\angle A\beta = 0^\circ$. Now the angle of Num term $-Khfe$ is 0°. Hence to have angle of the num term as 0°, imaginary part of Num must be 0°~~

To have phase shift of 180°, imaginary part must be zero.

$$\alpha^3 - 4K\alpha - 6\alpha = 0$$

$$\alpha(\alpha^2 - 4K - 6) = 0$$

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

$$\tan^{-1}\left(\frac{0}{\cdot}\right) = \tan^{-1}(0)$$

$$180 = \tan^{-1}(0)$$

$$\frac{1}{WRC} = \sqrt{4K+6}$$

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

$$\boxed{f = \frac{1}{2\pi RC\sqrt{4K+6}}}$$

This is the freq. at which $\angle A\beta = 360^\circ$ and $|A\beta| = 1$

substitute $\alpha = \sqrt{4K+6}$ in eq^n (i)

$$A\beta = \frac{-Khfe}{\{3K+1-5(4K+6)-K(4K+6)\} + j\{(4K+6)^{3/2} - 4K\sqrt{4K+6} - 6\sqrt{4K+6}\}}$$

$$A\beta = \frac{-Khfe}{\{3K+1-20K-30-4K^2-6K\} + j\sqrt{4K+6}\{4K+6-4K-6\}}$$

$$A\beta = \frac{-Khfe}{-3K-29-20K-4K^2}$$

$$A\beta = \frac{-Khfe}{-4K^2-23K-29}$$

$$\frac{-Khfe\,[(3K+1-5\alpha^2-K\alpha^2] + jKhfe(\alpha^3-4K\alpha-6\alpha)}{(3K+1)-5\alpha^2-K\alpha^2)^2 + (\alpha^3-4K\alpha-6\alpha)}$$

$$\frac{-Khfe}{(3K+1)-5\alpha^2-K\alpha^2)}$$

$$3K+1-5(4K+6)-K(4K+6)$$

$$3K+1-20K-30-4K^2-6K$$

$$-4K^2-33K-29$$

Now. $|A\beta| = 1$

$$\left|\frac{-Khfe}{-4K^2-23K-29}\right| = 1$$

$$Khfe = 4K^2 + 23K + 29$$

$$hfe = 4K + 23 + \frac{29}{K} \quad \text{— (ii)}$$

Minimum value of hfe:

To get min value; $\frac{dhfe}{dK} = 0$

$$\frac{d}{dk}\left[4k+23+\frac{29}{k}\right]=0$$

$$\cancel{4}\ \ 4-\frac{29}{k^2}=0$$

$$k^2=\frac{29}{4}$$

$k = 2.6925$ for min. h_{fe}.

substitute these value in eqn (ii)

$$(h_{fe})_{min} = 44.54$$

Thus for the ckt to oscillate, we must select the Tx whose $(h_{fe})_{min}$ should be greater than 44.54.

10. Wein bridge oscillator : (AP)

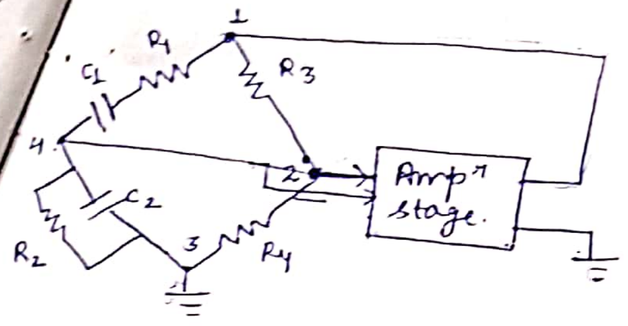


Fig 1 : Basic ckt.

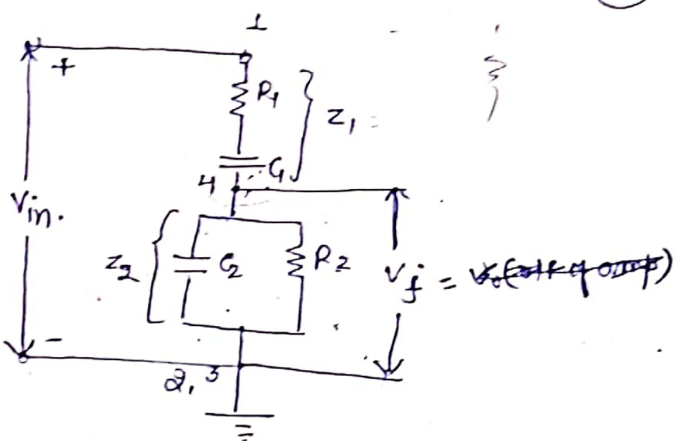


Fig 2 : f/b Network.

Generally in oscillator amplifier introduces 180° phase shift and f/b introduces 180°, to obtain 360° around a loop. This is required condition of any oscillator. But wein bridge uses non inverting amp and hence doesn't provide any phase shift during ampr stage. As total phase shift required is 0° or 360°, in wein bridge no phase shift is necessary through f/b. Thus total phase shift is 0°.

o/p of Amp → 1 & 3 → i/p of f/b N/W
i/p of Amp → 2 & 4 → o/p of f/b N/W

two arms R_1 & C_1 → series } freq. sensitive arms. because component
R_2 & C_2 → parallel } of these arms decide the freq. of osc.

It is most popular osc. and used for audio freq. range (20 to 20 KHz)

advantages :-
→ ckt. provide good freq. stability
→ very good sine wave o/p.
→ overall gain being a product of gain of 2 stages is very high.
→ freq. of osc. can be varied in the range of 10 MHz as compared to RC phase shift osc.

disadvantages :
→ osc. can not be used at high freq.
→ 2 stage Tx amp is used hence large no. of component required.

Limitation of LC or RC oscillators :-
→ The major problem with these osc. is that freq. does not remain strictly constant. This is because value of R & C changes with temp. To overcome this problem crystal osc. are used which have excellent freq. stability.

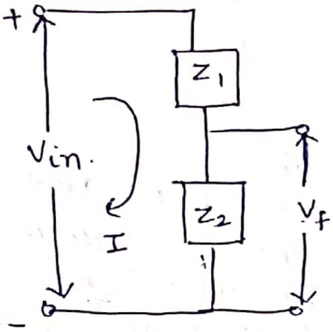
Mathematical Analysis :-
from fig. 2.

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

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

Replace $s = j\omega$

$$Z_1 = \frac{1 + sR_1C_1}{sC_1}, \quad Z_2 = \frac{R_2}{1 + sR_2C_2}$$



$$I = \frac{V_{in}}{Z_1 + Z_2}$$

$$V_f = I Z_2$$

$$V_f = \frac{V_{in} Z_2}{Z_1 + Z_2}$$

$$\beta = \frac{V_f}{V_{in}} = \frac{Z_2}{Z_1 + Z_2}$$

substitute the value of Z_1 & Z_2:

$$\beta = \frac{\frac{R_2}{1 + sR_2C_2}}{\frac{1 + sR_1C_1}{sC_1} + \frac{R_2}{1 + sR_2C_2}} \Rightarrow \beta = \frac{sR_2C_1}{R_2 sC_1 + (1 + sR_1C_1)(1 + sR_2C_2)}$$

$$\beta = \frac{sC_1R_2}{sR_2C_1 + 1 + sR_2C_2 + sR_1C_1 + s^2R_1C_1R_2C_2}$$

$$\beta = \frac{sC_1R_2}{1 + s(R_2C_1 + R_2C_2 + R_1C_1) + s^2(R_1R_2C_1C_2)}$$

Replace $s = j\omega$, $s^2 = -\omega^2$.

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

Rationalising the expression:

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

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

To have Zero phase shift of f/b N/W, its imaginary part must be Zero.

$$\omega C_1R_2(1 - \omega^2R_1R_2C_1C_2) = 0$$

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

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

Above eqn gives the freq. of osc. and it shows that the component of freq. sensitive arm are the deciding factors. (12)

$\therefore$ if $R_1 = R_2 = R$; $C_1 = C_2 = C$.

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

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

At $R_1 = R_2 = R$ & $C_1 = C_2 = C$, the gain of f/b N/W becomes.

$$\beta = \frac{w^2RC(3RC) + jwRC(1 - w^2R^2C^2)}{(1 - w^2R^2C^2) + w^2(3RC)^2}$$

put $w = \frac{1}{RC}$

$$\beta = \frac{\frac{3R^2C^2}{R^2C^2} + j\frac{RC}{RC}\left(1 - \frac{R^2C^2}{R^2C^2}\right)}{\left(1 - \frac{R^2C^2}{R^2C^2}\right) + \frac{9R^2C^2}{R^2C^2}}$$

$$\beta = \frac{3}{9} = \frac{1}{3}$$

positive sign of β shows that phase shift of f/b N/w ~~of~~ is $0°$.

Now to satisfy the Barkhausen criterion for the sustained oscillation.

$$|A\beta| \geq 1$$

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

$$|A| \geq 3$$

This is required gain of ampr stage.

11. Crystal oscillator :- (HP)(RT)(AP)

→ The crystals are either naturally ~~occur~~ occurring or synthetically manufactured, exhibit the piezoelectric effect. eg. quartz, tourmaline, Rochelle salt,.

→ piezo electric effect :- It means under the influence of the mechanical pressure, the vtg. get generated across the opposite faces of the crystal.

→ If the mechanical force is applied in such a way to force the crystal to vibrate, the a.c. vtg get generated across it. conversaly if the crystal is subjected to a.c. vtg.. it vibrates causing mechanical distortion in the crystal

→ every crystal has its own resonant freq. according to its shape.

→ ~~When~~ Application of force rearrange the charges, therefore one surface is +ve charged and other is -ve charged. It produces electrical potential.

→ for use in ckt, crystal is suitably cut and mounted b/w two Metal plate. The device is equivalent to capacitor with quartz as a dielectric

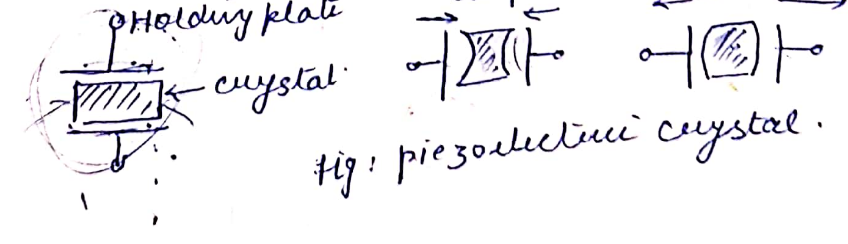


fig: piezoelectric crystal.

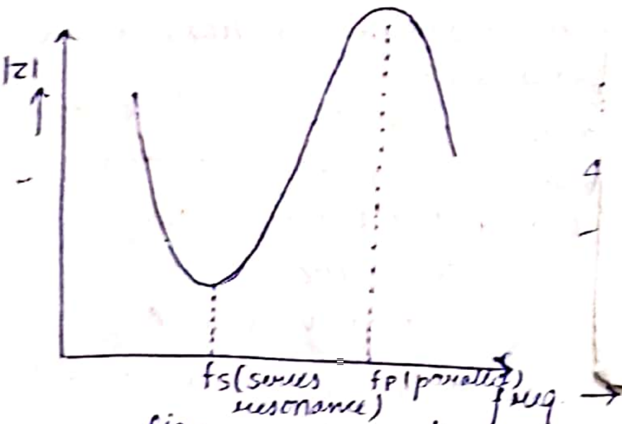


fig: freq. characteristics.

(*) pierce crystal oscillator: colpitts oscillator can be modified by using crystal to behave as an L. The ckt is called pierce crystal osc. two c are required in tank ckt. pierce crystal osc.'s working is same as colpitts oscillator. The oscillator ckt can be modified by using internal cap. of Tx used. separate C_1 & C_2 are not required in such ckt.

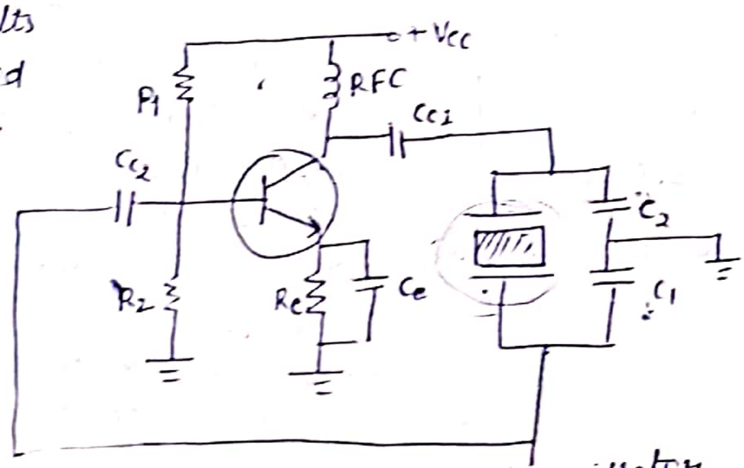


fig: pierce crystal oscillator

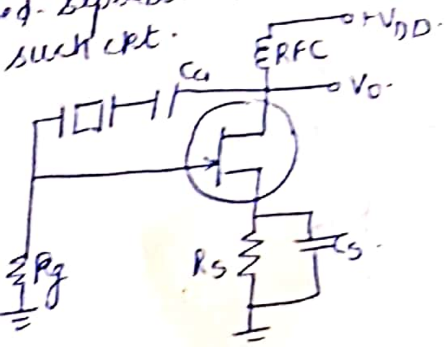


fig: using FET.

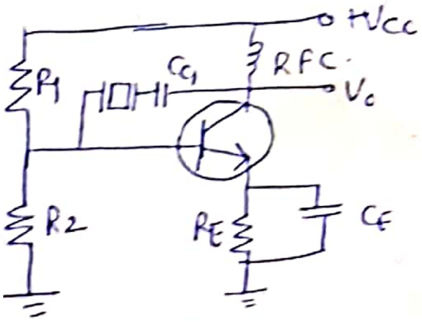


fig: using Tx.

(*) Miller crystal oscillator :- Hartley osc. can be modified to get Miller crystal osc. In Hartley osc. two ind. and one cap is required. One L is replace by a crystal. and one L & C is used.

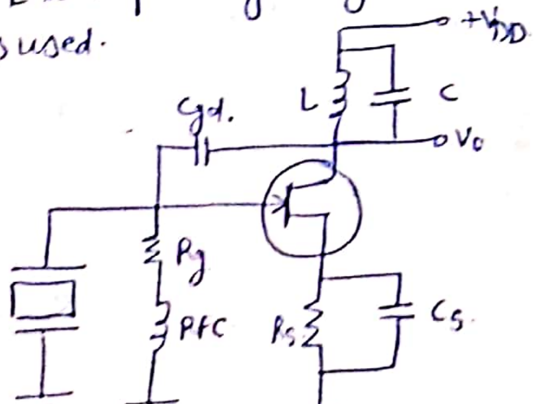


fig: using FET.

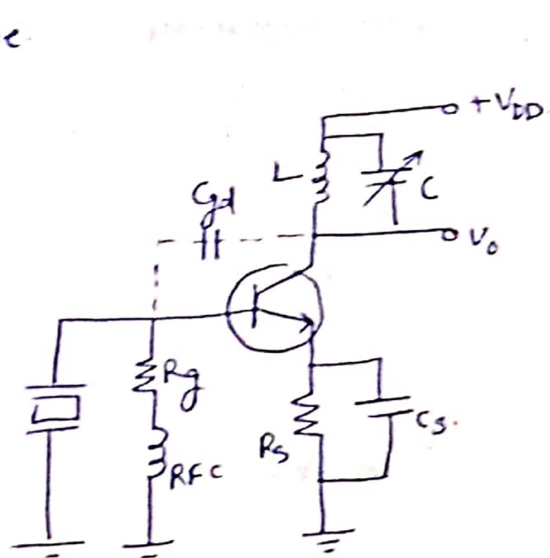


fig: crystal osc

→ crystal oscillator are preferred when greater freq. stability is required. used in watches, Tx, Rx.

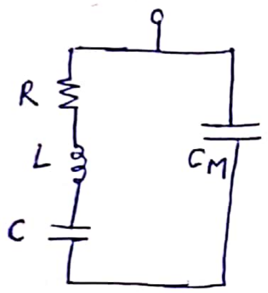
→ ~~main substance is quartz~~

→ Rochelle salts have greatest piezoelectric activity. for given a.c. vtg, they vibrate more than quartz & tourmaline. but it is mechanically weakest and break very easily.

→ Tourmaline shows least piezoelectric effect but mechanically strongest. very expensive and rarely used.

→ Quartz is compromise b/w them. inexpensive & easily available.

(*) electrical equivalent ckt:- when crystal is not vibrating, it is equivalent to mechanical ~~waiting~~ mounting of crystal. such a cap. exist due to two metal plate seperated by dielec. slab, called mounting capacitances denoted as C_M.



→ when it is vibrating, there are internal frictional looses which is denoted by R.

→ Mass of crystal is indication of inertia is represented by L.

→ In vibrating condition, it is having some stiffness which is represented by C.

(*) Series resonance freq :- (when $X_L = X_C$)

$$X_L = X_C$$

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

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

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

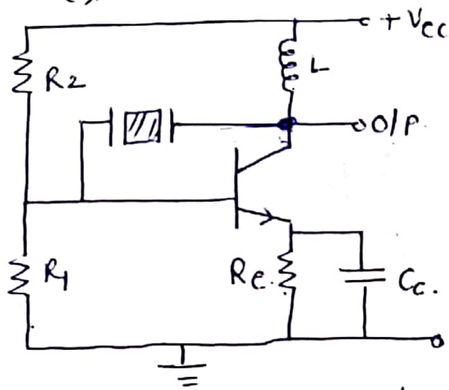


Fig: series resonant mode.

(*) parallel resonant freq :-

$$W_P L - \frac{1}{W_P C} = \frac{1}{W_P C_M}$$

$$W_P L = \frac{1}{W_P C_M} + \frac{1}{W_P C}$$

$$W_P^2 = \frac{1}{LC_M} + \frac{1}{LC}$$

$$W_P^2 = \frac{1}{L}\left[\frac{C C_M}{C + C_M}\right]$$

$$f_P = \frac{1}{2\pi}\sqrt{\frac{C C_M}{L(C + C_M)}}$$

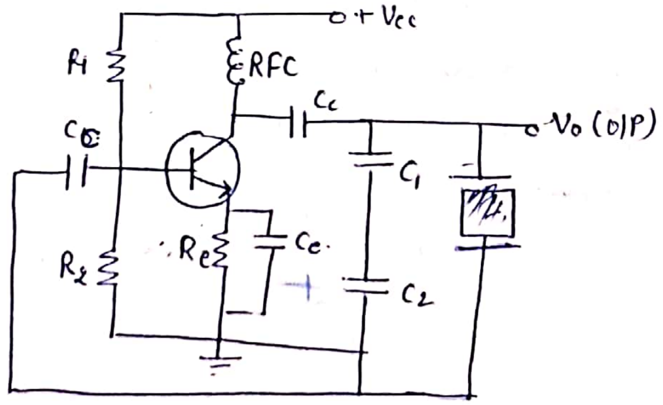


Fig. parallel resonant Mode.