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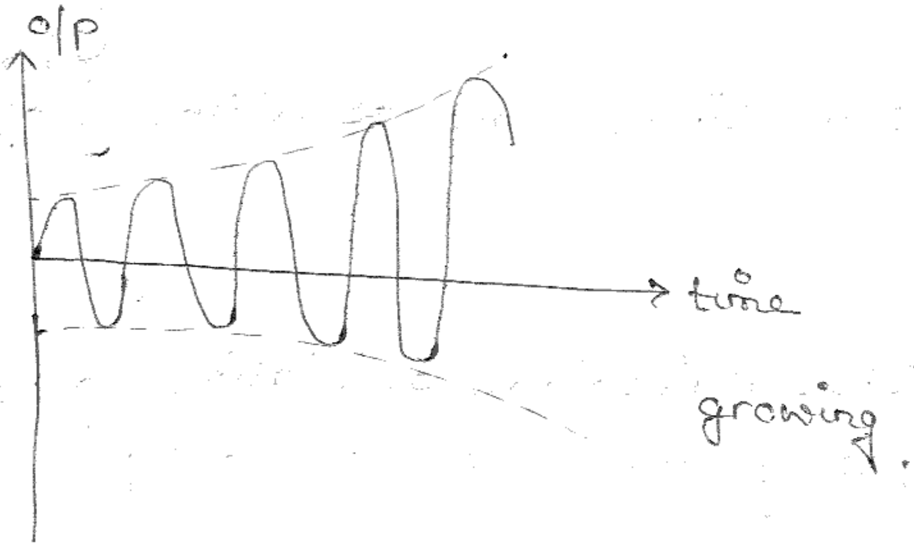
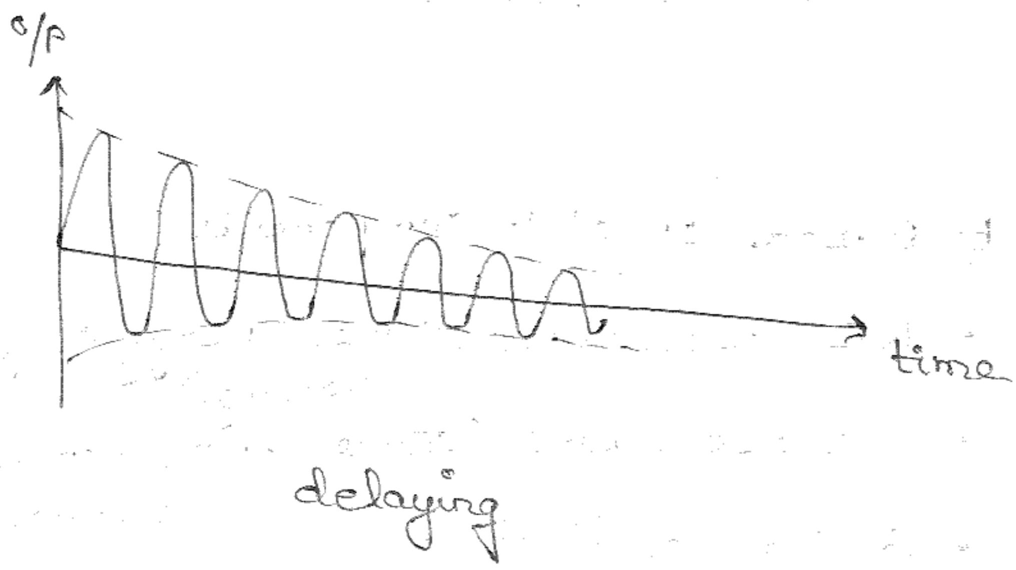
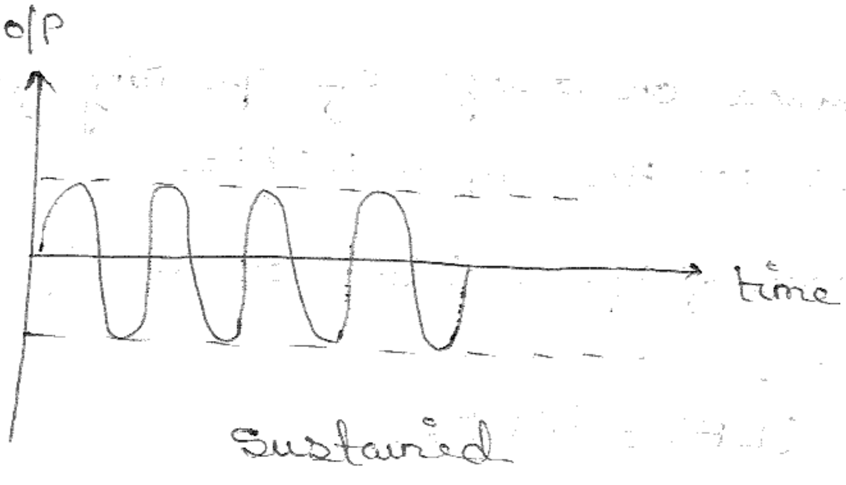
★ Oscillators







→ Classification of oscillators

- Sinusoidal oscillators
- Non-sinusoidal oscillators

} based on o/p wave

→ The sinusoidal oscillators generates purely sine wave at the o/p.

→ Non-sinusoidal oscillators generates saw-tooth, triangular.

b) Based on ckt components

- RC oscillators (stores energy in form of voltage)
- LC oscillators (stores energy in form of current)
- Crystal oscillators

c) Based on range of operating freq.

- (20-100)Hz upto 20KHz

audio freq. oscillor or low freq. osci.
(LF) oscillator

• (200 to 300) Hz to GHz

High freq or Radio freq (RF) oscillator

d) Based on feedback

• Non-feedback oscillator -
which uses -ve resistance region of characteristic of device(UJT relaxtion osci).

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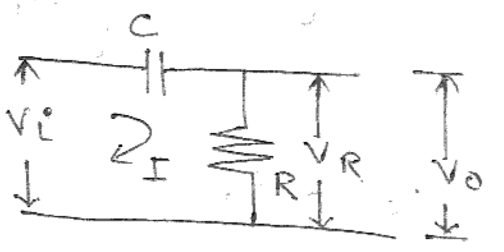
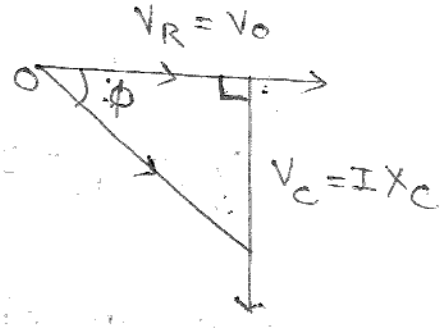
• <u>RC phase shift oscillator</u>



ckt



phasor diagram

~~Basically the ckt consist of~~
capacitor C and R is connected in series and

$$X_C = \frac{1}{2\pi f_C} \Omega$$

Total impedance $= R - jX_C$

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

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

$$\text{current } I = \frac{V_i \angle 0^\circ}{|Z| \angle -\phi^\circ} \cancel{= \frac{V_i \angle \phi_i}{\;}}$$

where,

$$|Z| = \sqrt{R^2 + (X_c)^2}$$

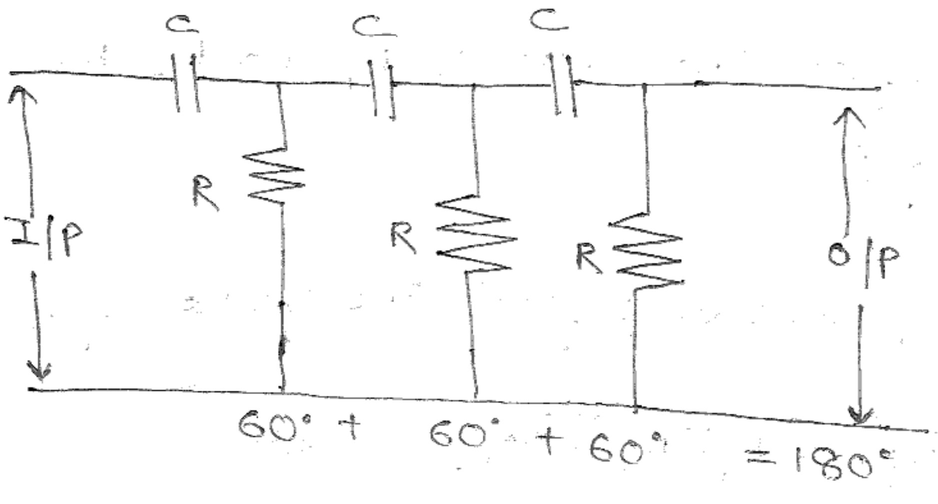
$$\phi = \tan^{-1}\left(\frac{X_c}{R}\right)$$

I = leads input voltage V_i by angle ϕ

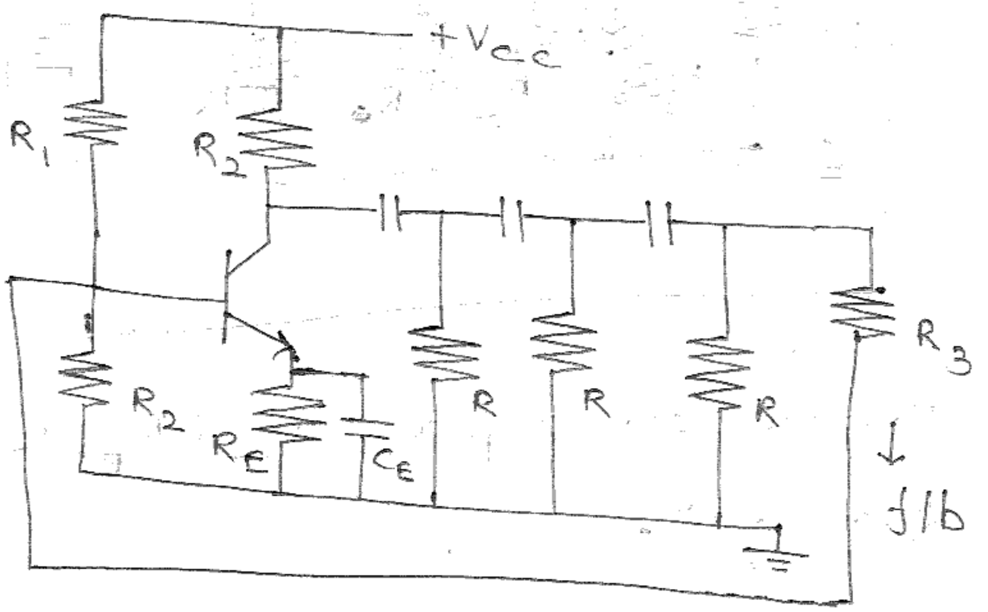
$$V_o = V_R = IR \quad ; \quad V_c = I X_c$$

V_R is in phase with I i.e. current while drop V_c lags current I by 90° (I_c leads V_c by 90°).

By using proper values of R and C the $\angle \phi$ is adjusted in practice equal to 60°



- **Transistorised RC phase shift oscillator**



The o/p of a f/b n/w gets loaded due to the low i/p impedance (hie) of a transistor.

$$R = h_{ie} + R_3 \quad \text{——} \quad (1)$$

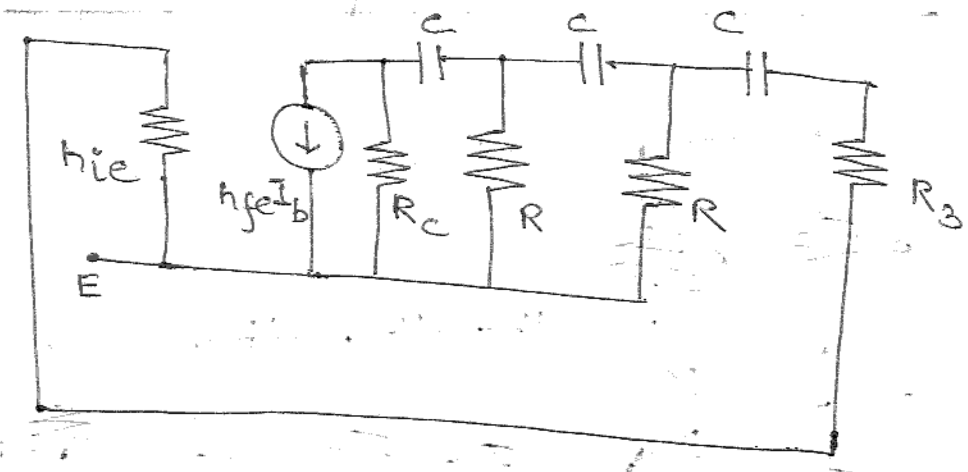
Neglect the value of R_1 and R_2 we get eq (1)

If we not neglect the value of R_1 & R_2

$$R_i' = R_1 \| R_2 \| h_{ie} \quad \text{— (1a)}$$

$$R_i' + R_3 = R \quad \text{— (1b)}$$

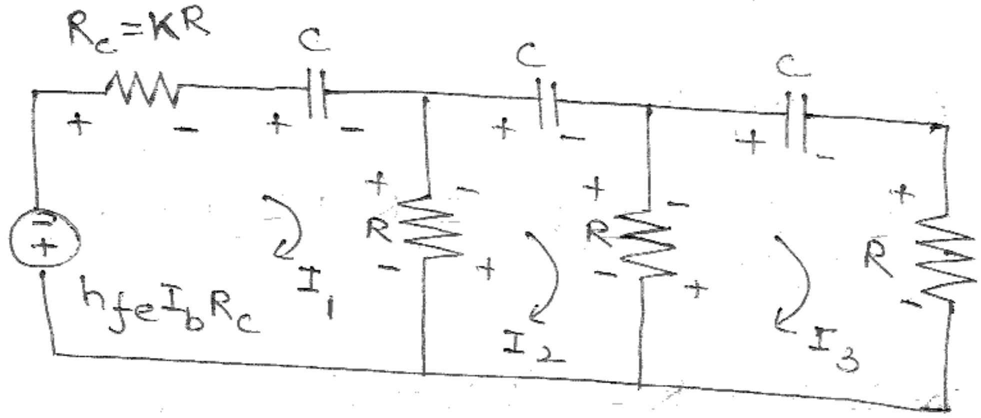
Derivation of freq of oscillation



Now we can replace $h_{ie} + R_e$ as R from eq (1).

Similarlly we can replace the current Source $h_{fe} I_b$ by its equivalent voltage Source

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



by applying KVL to loop 1

$$-I_1 R_c - I_1 \frac{1}{j\omega} - I_1 R - h_{fe} I_b R_c = 0$$
$$+ I_2 R$$

Replace R_c by KR and $j\omega$ by s

$$-I_1 KR - I_1 \frac{1}{S} - I_1 R - h_{fe} I_b KR = 0$$
$$+ I_2 R$$

$$I_1 \left[(K+1)R + \frac{1}{SC}\right] - I_2 R = -h_{fe} I_b KR \quad \text{— (2)}$$

for loop 2

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

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

$$-I_2\left(\frac{1}{SC} + R + R\right) + I_1 R + I_3 R = 0$$

$$I_1 R + I_2 \left[\frac{1}{SC} + 2R\right] - I_3 R = 0 \quad \text{— (3)}$$

For loop 3

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

$$-I_2 R + I_3\left[2R + \frac{1}{sC}\right] = 0 \quad \text{—} (4)$$

using cramers rule we can solve for I_3

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

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

$$+ R\left\{(R)\left(2R + \frac{1}{sC}\right) - 0\right\}$$

$$D = (K+1)R + \frac{1}{sC} \left\{\frac{1}{s^2C^2} + 2 \times 2R \times \frac{1}{sC} + 4R^2 - R^2\right\}$$

$$+ R\left\{2R^2 + \frac{R}{sC}\right\}$$

$$= KR + R + \frac{1}{sC} \left\{\frac{1}{s^2C^2} + \frac{4R}{sC} + 3R^2\right\}$$

$$+ 2R^3 + \frac{R^2}{SC}$$

$$D = \frac{KR}{S^2C^2} + \frac{4KR^2}{SC} + \frac{3R^2}{1} + \frac{R}{S^2C^2} + \frac{4R^2}{SC}$$

$$+ 3R^3 + \frac{1}{S^3C^3} + \frac{4R}{S^2C^2} + \frac{3R^2}{SC} + 2R^3 + \frac{R^2}{SC}$$

$$D = \frac{R}{S^2C^2}\left[K + 1 + 4\right] + \frac{R^2}{SC}\left[4K + 4 + 4\right]$$

$$+ \frac{1}{S^3C^3} + 3R^2 + 5R^3$$

$$= \frac{R}{S^2C^2}[K+5] + \frac{R^2}{SC}[4K+8] + \frac{1}{S^3C^3}$$

$$+ 3R^2 + 5R^3$$

$$= \frac{RK + 5R}{S^2C^2} + \frac{4KR^2 + 8R^2}{SC} + \frac{1}{S^3C^3} + 3R^2$$

$$+ 5R^3$$

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

$-R^2\}$

$$\mathcal{D}_3 = \begin{bmatrix} (K+1)R+\frac{1}{SC} & -R & -h_{fe}I_bKR \\ R & \frac{1}{SC}+2R & 0 \\ 0 & -R & 0 \end{bmatrix}$$

$$\mathcal{D}_3 = (K+1)R+\frac{1}{SC}\{0\} + R\{0\}$$

$$-h_{fe}I_bKR\{-R^2-0\}$$

$$= -h_{fe}I_bKR^3 \quad \text{—— } 6$$

$$\mathcal{D}_2 = \begin{bmatrix} (K+1)R+\frac{1}{SC} & -h_{fe}I_bKR & 0 \\ R & 0 & -R \\ 0 & 0 & 2R+\frac{1}{SC} \end{bmatrix}$$

$$= (K+1)R+\frac{1}{SC}\times 0 - \{-h_{fe}I_bKR\}\left\{R\left(2R+\frac{1}{SC}\right) - 0\right\}$$

$$= h_{fe}I_bKR\left\{2R^2+\frac{R}{SC}\right\}$$

$$= 2h_{fe}I_bKR^3 + \frac{h_{fe}I_bKR^2}{SC}$$

$$D_2 = \frac{2h_{fe}I_bKR^3SC + h_{fe}I_bKR^2}{SC}$$

$$D_2 = \frac{h_{fe}I_bKR^2\left[2SCR+1\right]}{SC}$$

$$D_1 = \begin{bmatrix} -h_{fe}I_bKR & -R & 0 \\ 0 & \frac{1}{SC}+2R & -R \\ 0 & -R & 2R+\frac{1}{SC} \end{bmatrix}$$

$$= -h_{fe}I_bKR\left\{\left(\frac{1}{SC}+2R\right)^2 - R^2\right\}$$

$$+R\left\{0-0\right\}$$

$$= -h_{fe}I_bKR\left\{\frac{1}{SC^2+4RSC+4R^2} - R^2\right\}$$

$$= -h_{fe}I_bKR\left\{\frac{1-R^2\left\{SC^2+4RSC+4R^2\right\}}{SC^2+4RSC+4R^2}\right\}$$

$$= -h_{fe}I_bKR\left\{\frac{1-SC^2R^2-4R^3SC-4R^4}{SC^2+4RSC+4R^2}\right\}$$

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$$I_3 = \frac{-KR^3 h_{fe} I_b S^3 C^3}{S^3C^3R^3[3K+1] + S^2C^2R^2[4K+6] + SCR[5K+1]+1} \longrightarrow (7)$$

Here,

I_3 = o/p current of f/b ckt

I_b = I/P current of amp

$I_c = h_{fe} \cdot I_b$ = I/P current of f/b ckt

$$\beta = \frac{\text{o/p f/b ckt}}{\text{I/P f/b ckt}}$$

$$A = \frac{\text{o/p of amp ckt}}{\text{I/P of amp ckt}}$$

$$A\beta = \frac{I_3}{\cancel{h_{fe}} I_b} \times \frac{\cancel{h_{fe}}}{1} = \frac{I_3}{I_b} \quad — (8)$$

using eqn (8)

$$A\beta = \frac{-KR^3 h_{fe} S^3 C^3}{S^3C^3R^3[3K+1] + S^2C^2R^2[4K+6] + SCR[5K+1]+1} \quad — (9)$$

Subt $s = j\omega$ and $s^2 = -\omega^2$; $s^3 = -j\omega^3$

in eq (9)

$$A\beta = \frac{-KR^3 h_{fe} (-j\omega^3) c^3}{(-j\omega^3) c^3 R^3 [3K+1] + (-\omega^2) c^2 R^2 [4K+6] + (j\omega) CR [5K+1] + 1}$$

$$A\beta = \frac{KR^3 h_{fe}\, j\omega^3 c^3}{-j\omega^3 c^3 R^3 (3K+1) - \omega^2 c^2 R^2 (4K+6) + j\omega CR(5K+1) + 1}$$

Separate real and imaginary part

$$A\beta = \frac{-j\omega^3 R^3 c^3 h_{fe} K}{[1 - 4K\omega^2 c^2 R^2 - 6\omega^2 c^2 R^2] - j\omega [3K\omega^2 R^2 c^3 + \omega^2 R^3 c^3 - 5RC - KRC]}$$

Dividing num and deno. by $-j\omega^3 c^3 R^3$

$$A\beta = \frac{K h_{fe}}{\left[\frac{1 - 4K\omega^2 c^2 R^2 - 6\omega^2 c^2 R^2}{-j\omega^3 R^3 C^3}\right] - \left[\frac{j\omega [3K\omega^2 R^2 c^3 + \omega^2 R^3 c^3 - 5RC}{-j\omega^3 R^3 c^3}\right]}$$

Replacing $-\frac{1}{j} = j$ in above equation

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

Replacing $\frac{1}{\omega RC} = \alpha$ for so simplification

$$A\beta = \frac{Kh_{fe}}{[3K+1-5\alpha^2 - K\alpha^2] + j[\alpha^3 - 4K\alpha - 6\alpha]} \quad \text{—— (10)}$$

As per barkhausen criterion $\angle A\beta = 0^\circ$

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

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

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

$$\alpha = \sqrt{4K+6}$$

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

$$\omega = \frac{1}{2\pi f} \; ; \; f = \frac{1}{2\pi\sqrt{4K+6}} \quad \text{—— (11)}$$

Here,
f = freq. of oscillation at which $\angle A\beta = 0^\circ$

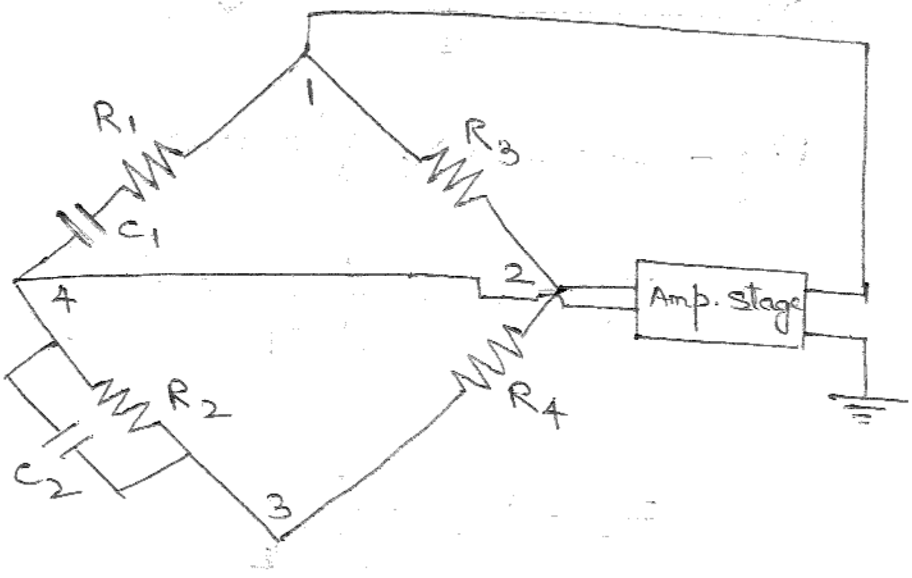
and

$$|A\beta| = 1$$

Wein Bridge Oscillator

→ Generally in an oscillator amplifier stage introduces 180° phase shift and f/b introduces additional 180° to obtain phase shift of 360°.

→ The wein bridge oscillator uses a non-inverting amp and hence does not provide any phase shift during the amplifier stage.



I lead by V 90°

I lag by V

The output of amplifier is applied b/w the terminal 1 and 3 which is the i/p to the feedback network. While the i/p is supplied from diagonal terminal 2 and 4 which the o/p from feedback.

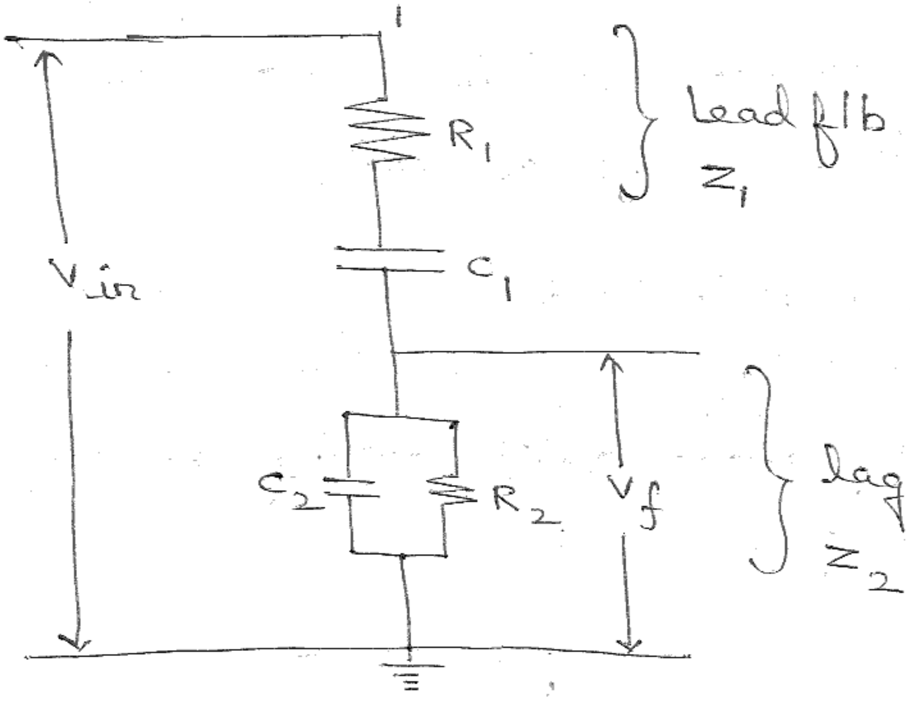


Fig - Lead-Lag f/b ckt

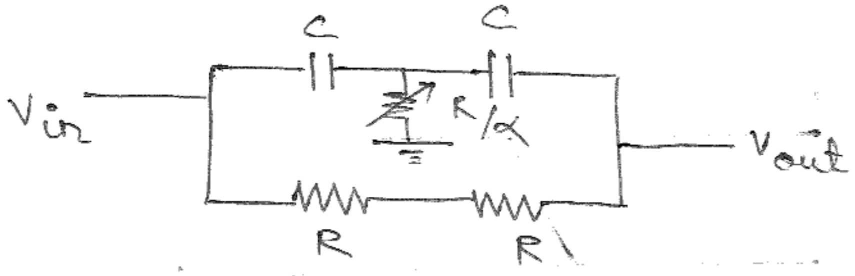
$$Z_1 = R_1 + \frac{1}{jwC_1} = \frac{1 + Rjwc_1}{jwc_1}$$

$$Z_2 = R_2 \parallel \frac{1}{jwC_2}$$

$$= \frac{R_2 / \cancel{jwC_2}}{\frac{R_2 jwC_2 + 1}{\cancel{jwC_2}}} = \frac{R_2}{1 + jwR_2C_2} \quad \text{—(i)}$$

Twin T-oscillator

- RC n/w or RC oscillator
- -90° to 90°



$$f = f_r$$

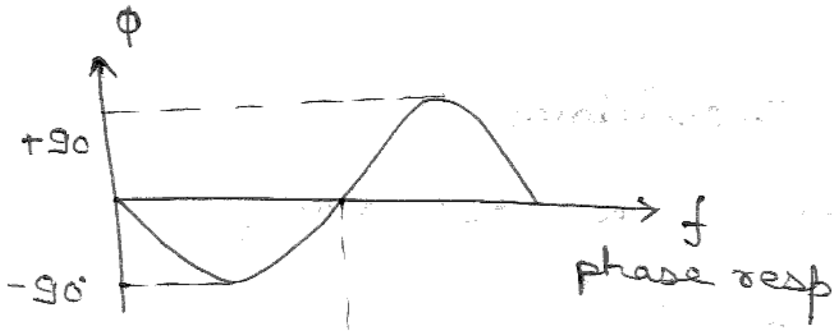
- The twin T oscillator is bascically lead-lag circuit whose phase angle varies b/w $+90^\circ$ to -90°.

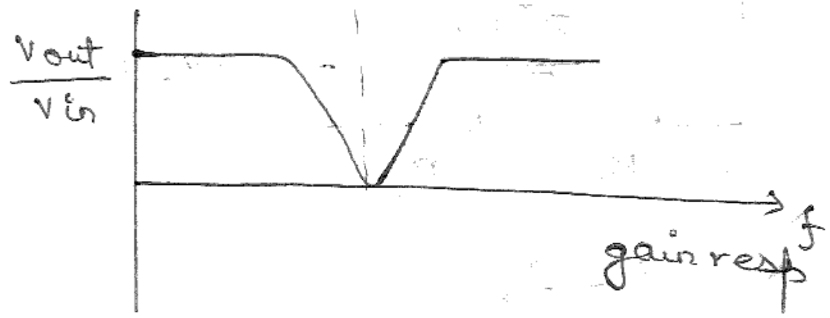
- At $f = f_r$, its phase angle is 0° and it does not introduce any phase shift

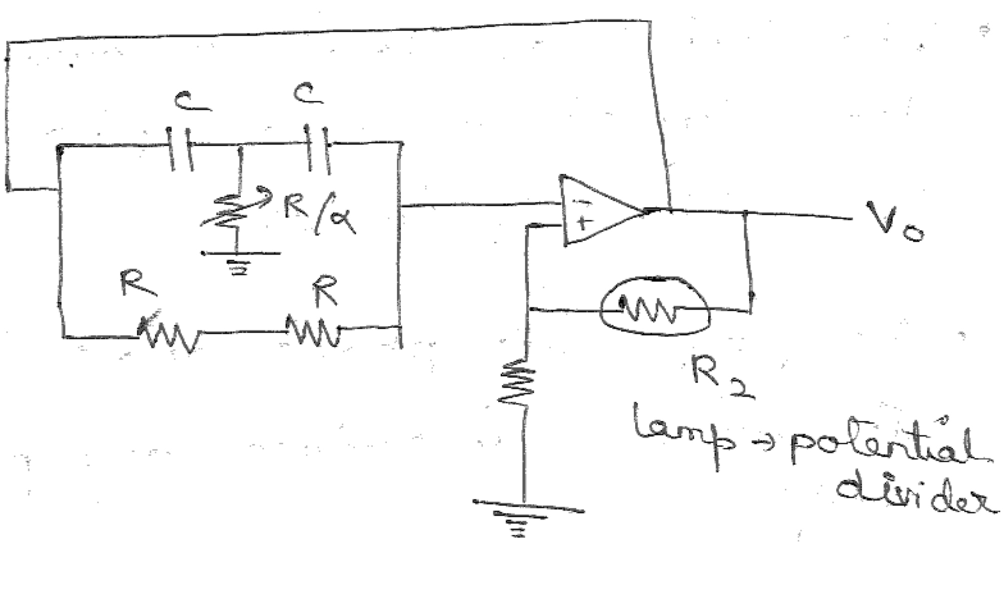
- Equation for its resonating freq. as same as that of wein bridge ckt.

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

- Twin-T filter is a combination of low pass and high pass filter







- The -ve f/b to the inverting i/p is given through Twin-T filter
- R_2 of the potential divider is lamp.
- -ve f/b is given through Twin T-filter.

- When power is given to the circuit lamp resistance R_2 will be low and +ve feedback of the circuit will be max. (Act as a osc).

- The oscillation growing on R_2 will be increased and +ve feedback will decrease.

- Oscillation freq. near the Notch freq $\frac{R}{2}$ of the twin T filter is kept variable.

- Only at fr, the -ve f/b is negligible and +ve f/b through R_1 and R_2 allows the circuit to oscillate.

- The oscillator is rarely used compared to RC. and wein bridge because it operates only at one frequency.

LC oscillator

Two types

- Hartley osc.
- Collpitts osc.

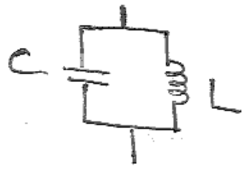
→ 'L' and 'c' as components

→ It is also called tank circuit

→ It is 20 KHz to few GHz

→ RF oscillator ckt (radio freq).

- LC tank circuit



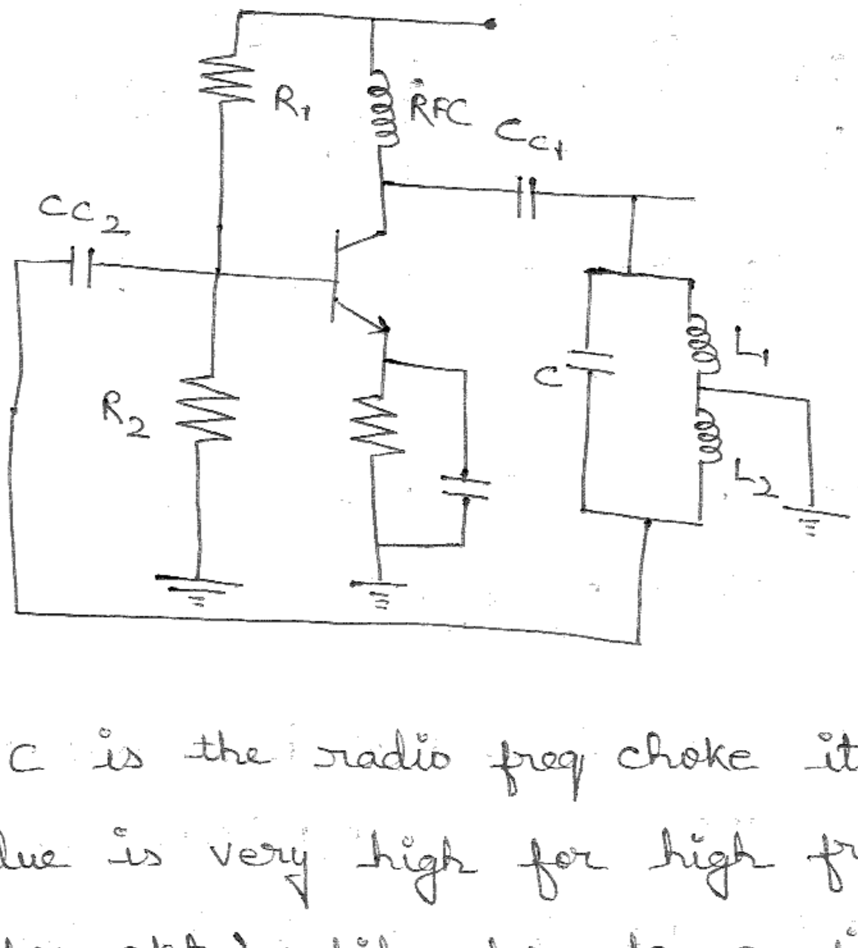
LC tank circuit used along with transistor amplifier can be used to obtain oscillators called LC oscillators. Due to the suppy of energy which is lost oscillation get maintain hence called sustained oscillation or undamped oscillation.

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

Based on reactances X_1, X_2 and X_3

	X_1	X_2	X_3
Hartley osci	L	L	C
colpitt osci	C	C	L

→ Hartley oscillator :



- RFC is the radio freq choke its reactance value is very high for high frequence (open ckt) while for dc condition tends to zero reactance.

- Due to RFC the isolation between AC and DC operation is achieved.

- LC n/w gives the phase shift of 180°

CE amp provides addition 180°.

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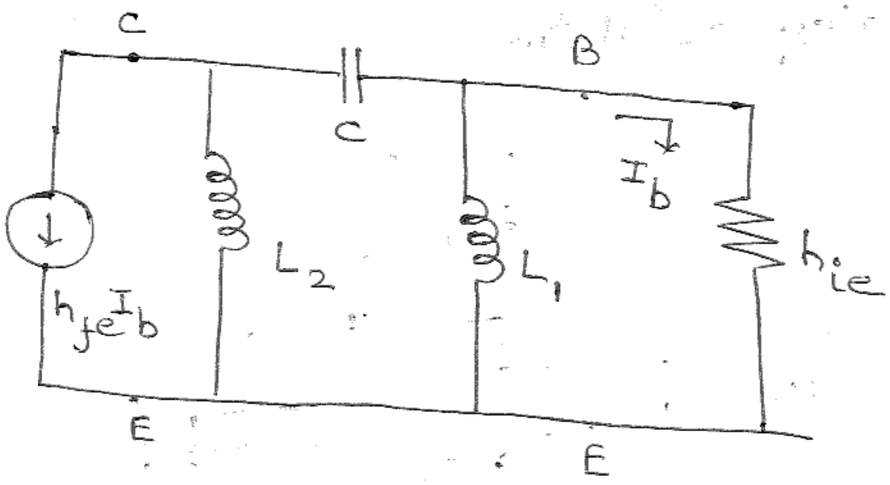
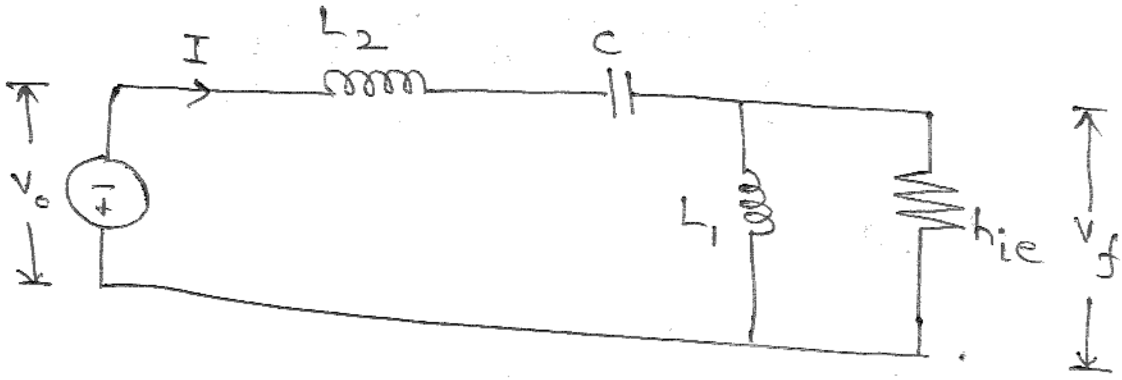
★ Derivation for Freq of osc of Hartley Osc



- The o/p current which is the collector current is $h_{fe} I_b$.

- Capacitor C is b/w base and collector and inductor L_1 is b/w base and emitter. while the inductor L_2 is b/w collector to emitter.

eqvalent ckt of the above figure



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

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

$$I = \frac{-V_o}{[X_{L_2} + X_C] + [X_L \parallel h_{ie}]} \quad \text{— (2)}$$

$$X_{L_2} + X_C = j\omega L_2 + \frac{1}{j\omega C}$$

$$X_{L_1} \parallel h_{ie} = j\omega L_1 \parallel h_{ie}$$

$$= \frac{j\omega L_1 h_{ie}}{j\omega L_1 + h_{ie}}$$

Subt in eq (2) we get

$$I = \frac{-V_0}{\dfrac{j^2\omega^2 L_2 C + 1}{j\omega C} + \dfrac{j\omega L_1 h_{ie}}{j\omega L_1 + h_{ie}}}$$

Replace $j\omega$ by 'S'

$$I = \frac{-V_0}{\dfrac{S^2 L_2 C + 1}{SC} + \dfrac{SL_1 h_{ie}}{SL_1 + h_{ie}}}$$

$$I = \frac{-h_{fe} I_b S L_2}{\dfrac{(S^2 L_2 C+1)(SL_1 + h_{ie}) + (SL_1 h_{ie} Sc)}{SC(SL_1 + h_{ie})}}$$

$$I = \frac{-(h_{fe} I_b S L_2)(S^2 C L_1 + SC h_{ie})}{(S^2 L_2 C + 1)(SL_1 + h_{ie}) + S^2 L_1 C h_{ie}}$$

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

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

A/c to current division in parallel ckt

$$I_b = ?$$

$$I_b = I \times \frac{X_{L_1}}{X_{L_1} + h_{ie}}$$

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

$$I_b = I \times \frac{SL_1}{SL_1 + h_{ie}} \quad \text{——} (4)$$

Subt (3) in (4)

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

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

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

—— (5)

Sub $s = j\omega$, $s^2 = -\omega^2$, $s^3 = -j\omega^3$ in eq (5)

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

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

Rationalising the RHS of above eq (6)

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

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

To satisfy this eq the imaginary part of RHS = 0

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

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

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

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

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

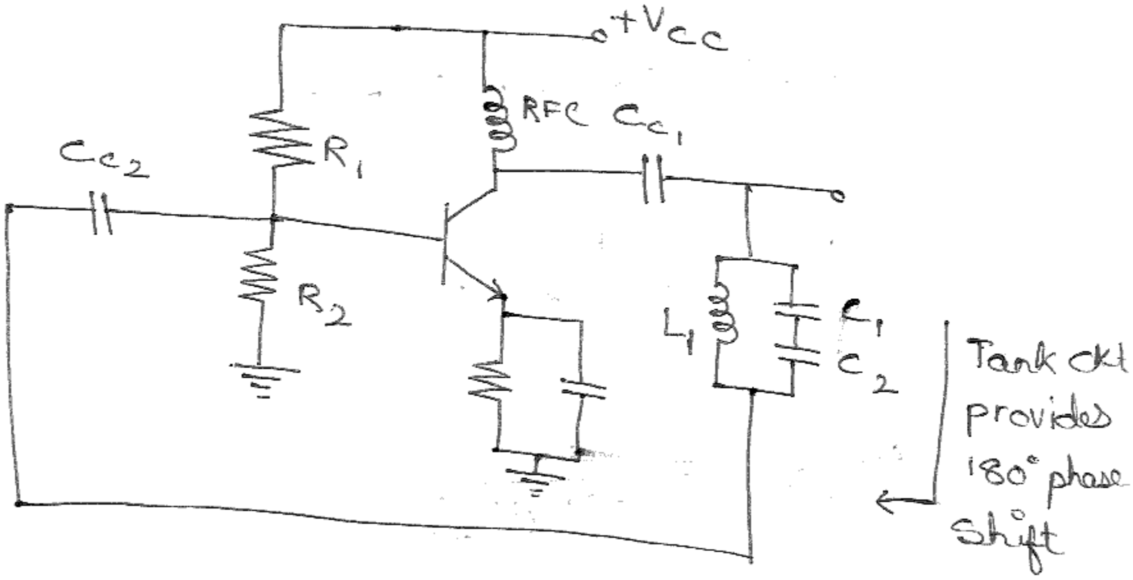
$$f^2 = \frac{1}{4\pi^2 C(L_1 + L_2)}$$

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

22.07.11

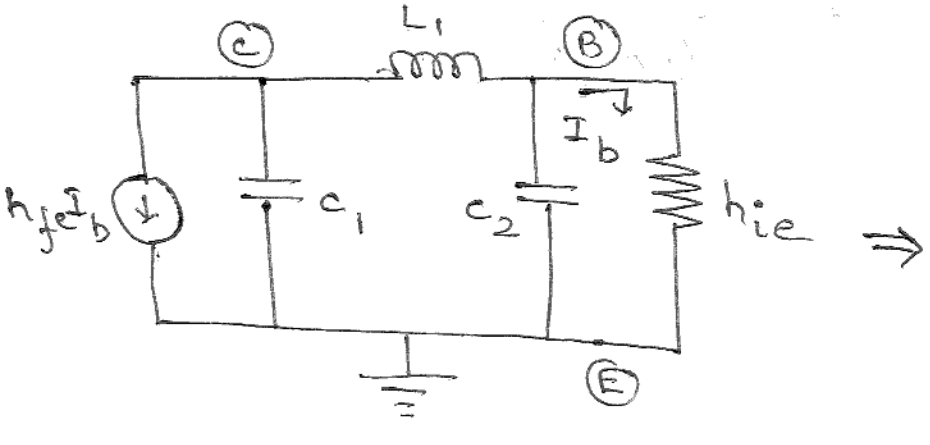
★ Colpits Oscillator

LC oscillators which uses two capacitive reactances and one ~~in the~~ inductive reactance in the feedback (tank ckt).

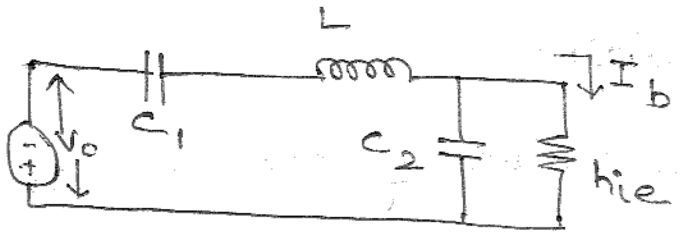


→ Derivation of freq oscillation :

The basic ckt is same as the transistorised hartley osc. except tank circuit.



⇒



$$V_o = h_{fe} I_b X_{C_2} = h_{fe} I_b \times \frac{1}{jWC_2} \quad \text{— ①}$$

$$I = \frac{-V_o}{[X_{C_2} + X_{C_1}] + [X_{C_1} \| h_{ie}]} \quad \text{— ②}$$

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

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

where

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

★ Crystal oscillator

- Crystals are naturally occured or synthetically manufactured exhibiting the piezo electric effect.

- Under the influence of mechanically pressure the voltage gets generated across the opposi face of crystal.

- Crystal oscillator gets generate AC voltage which is used in watches, communication transmitters and receivers.

- Piezo electric materials are quartz, rochele salt, fourmaline.

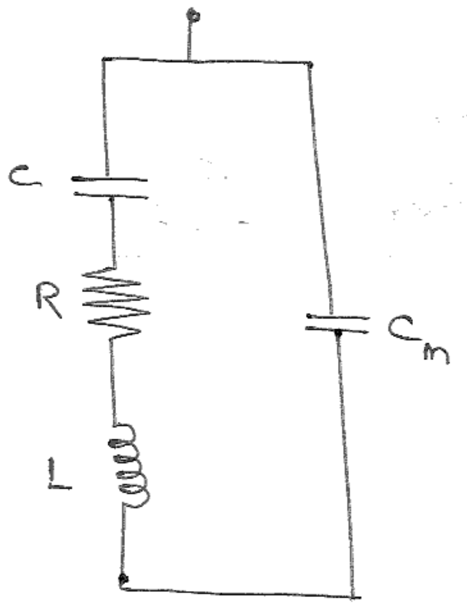


Fig. AC eq ckt of crystal

- The crystal material (Rochele salt) which is mostly used in microphones associated with tape recorder, head set, loud speaks.
- Quartz is inexpensive and easily available in nature.

- When the crystal is not vibrating it is equivalent to a capacitance due to the mechanical mounting of crystal.
- When it is vibrating there are internal frictional losses which are denoted by R while mass of crystal which is the indication of inertia force (inductor).