UNIT-3

OSCILLATORS

→ Oscillator is a circuit which generates AC output waveform without any AC input waveform.

→ It generates AC-output waveform by making use of dc supply.

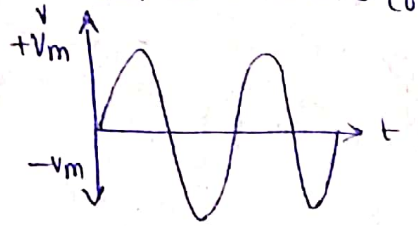
Classification of Oscillators: 1b)

→ There are different classifications.

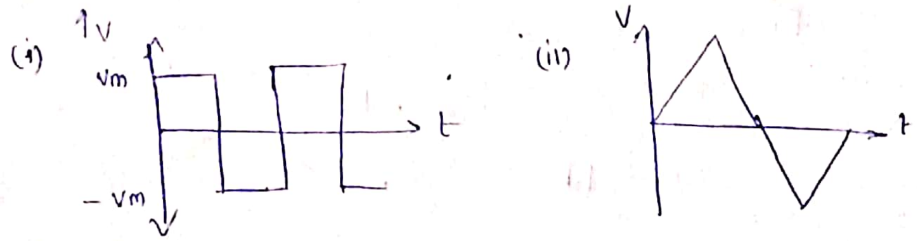
1) Based on output waveform generated:

ⓐ Sinusoidal Oscillators (or) Harmonic Oscillators.

o/p



ⓑ Relaxation Oscillators (or) Non-sinusoidal Oscillators



2) Based on fundamental - Mechanism used:

ⓐ Feedback Oscillator (+ve feedback).

ⓑ Negative Resistance Oscillator eg(UJT, Tunnel diode)

③ Based on frequencies generated: Giga 10^9

ⓐ Audio frequency oscillator (20Hz - 20KHz)

ⓑ Radio frequency Oscillator (20KHz - 30MHz).

ⓒ Very high frequency oscillator (30MHz - 300MHz).

ⓓ Ultra high frequency oscillator (300MHz - 3GHz)

ⓔ Microwave frequency Oscillator (>3GHz).

type of ckt used in
(4) Sinewave oscillators

(a) LC tuned Oscillators (>1MHz) frequency produced

(b) RC oscillators (<1MHz) phase shift

1# Condition for sustained oscillations:

$A_f = \frac{A}{1-A\beta}$ (+ve fb)

If, $A\beta = 1 \Rightarrow \boxed{A_f = \infty}$

→ Infinite gain means we can expect some output without any input.

→ Oscillators work on circuit trasients and noise.

→ $A\beta = 1 \Rightarrow |A\beta| = 1$

$A\beta = 1\angle 0^\circ$ & $\angle A\beta = 0^\circ/360^\circ$.

⇓ Polar form

"$A\beta$" Is loop gain.

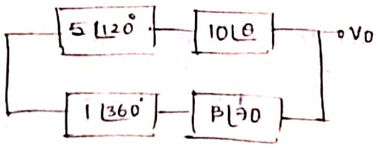
Conditions (Barkhausen criterion):-

1) $|A\beta| = 1$ ⇒ Gain around loop must be equal to 1

2) $\angle A\beta = 0^\circ$ or 360° ⇒ phase angle around loop must be 0° or 360°.

→ The oscillator circuit is set into oscillations by a random variation caused in the base current due to noise component or a small variation in the dc power supply.

Q) Calculate θ and β for sustained Oscillations.



→ Condition for sustained oscillations,

1. $|A\beta| = 1$
2. $\angle A\beta = 0^\circ$

1. → Gain around loop (loop gain) must be 1,

⇒ $5 \times 10 \times \beta \times 1 = 1$

⇒ $\beta = \frac{1}{50}$

2. → phase angle around loop must be $0^\circ/360^\circ$

⇒ $120^\circ + \theta + 360^\circ + 70^\circ = 0/360$

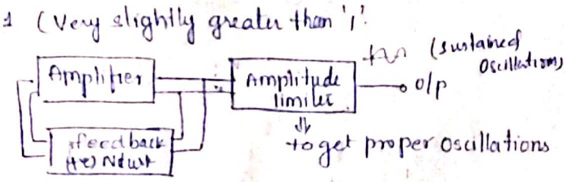
⇒ $\theta + 550^\circ = 0/360^\circ$

⇒ $\theta + 190^\circ = 0/360^\circ$

⇒ $\theta = -190^\circ/170^\circ$

practical Considerations for sustained Oscillations:

↳ $|A\beta| > 1$ (Very slightly greater than '1'.



→ Two sin

Two Simple steps to solve any Oscillator:

Step-1: Recognize the 'β' network and find 'β'.

$$\beta = \frac{V_f}{V_0} = (\beta_{real} + j\beta_{imaginary}).$$

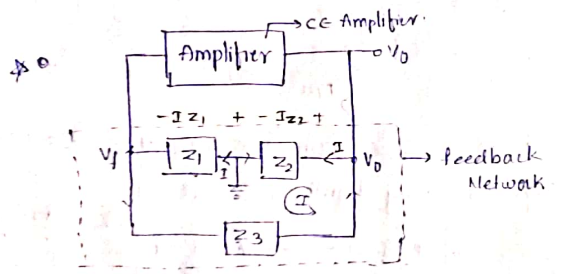
Step-2: Find Amplifier gain 'A'.

$$A = \frac{V_0}{V_f}$$

and $|A\beta| = 1$. ie, $A = \frac{V_0}{V_f}[\beta_{real} + j\beta_{imaginary}] = 1$

Seperate real and imaginary terms findout the condition for sustained oscillations.

General Configuration for LC-Oscillator:-



$$\Rightarrow \beta = \frac{V_f}{V_0} = \frac{-IZ_1}{+IZ_2} = -\frac{Z_1}{Z_2}$$

$\hookrightarrow \beta = -\frac{Z_1}{Z_2}$ [-ve sign indicates 180° phase shift]

→ Amplifier should also provide 180° since β network is providing 180° phase shift for sustained Oscillation

∴ The amplifier should be CE-Amplifier.

→ In LC Oscillators we have,
ⓐ Heartly Oscillator ⓑ Colpitts Oscillator.

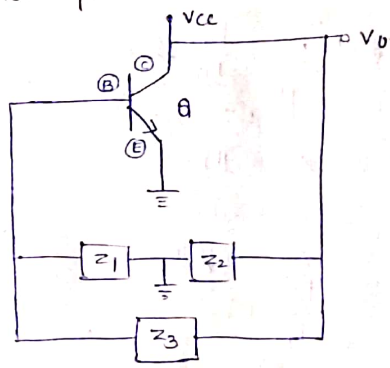
ⓐ Heartly Oscillatore

⇒ If $Z_1 = j\omega L_1$, $Z_2 = j\omega L_2$ and $Z_3 = \frac{1}{j\omega C}$, then it is Heartly Oscillator.

ⓑ Colpitts Oscillator:

→ If $Z_1 = \frac{1}{j\omega C_1}$, $Z_2 = \frac{1}{j\omega C_2}$ and $Z_3 = j\omega L$ then it is colpitts Oscillator.

General Configuration of an LC Oscillator with transistor equivalent circuit:-



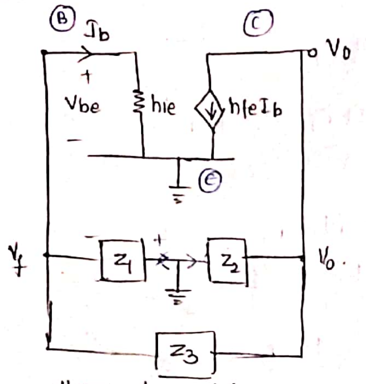
⇒ Any of the active devices such as vaccume tubes, FETS, Transistors may be used in Amplifier section.

→ Z_1, Z_2, Z_3 are reactive elements constituting the feedback tank circuit which determines fosc.

→ Z_1, Z_2 serves as an ac voltage divider for o/p voltage & f/b signal. Voltage across Z_1 is f/b signal.

(LC) $f_{osc} = \frac{1}{2\pi\sqrt{LC}}$.

→ Ac equivalent circuit:



H-parameter model

Condition for sustained Oscillators:

→ Voltage gain without f/b: $\boxed{A = -\frac{h_{fe}}{h_{ie}}(Z_L)}$

$Z_L = Z_2 \,||\, (Z'+Z_3)$

where, $Z' = Z_1 \,||\, h_{ie}$

$= \frac{Z_1 h_{ie}}{Z_1+h_{ie}}$

$\Rightarrow Z'+Z_3 = \frac{Z_1 h_{ie}}{Z_1+h_{ie}} + Z_3$

$\Rightarrow Z'+Z_3 = \frac{Z_1 h_{ie} + Z_1 Z_3 + h_{ie} Z_3}{Z_1+h_{ie}}$

$\Rightarrow Z'+Z_3 = \frac{(Z_1+Z_3)h_{ie} + Z_1 Z_3}{Z_1+h_{ie}}$

$\Rightarrow \frac{1}{Z_L} = \frac{1}{Z_2} + \frac{1}{Z'+Z_3}$

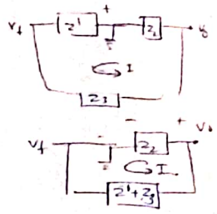
$\Rightarrow \frac{1}{Z_L} = \frac{1}{Z_2} + \frac{Z_1+h_{ie}}{(Z_1+Z_3)h_{ie}+Z_1Z_3}$

$\Rightarrow \frac{1}{Z_L} = \frac{h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2+Z_1Z_3}{Z_2[(Z_1+Z_3)h_{ie}+Z_1Z_3]}$

$\Rightarrow Z_L = \frac{Z_2[(Z_1+Z_3)h_{ie}+Z_1Z_3]}{h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2+Z_1Z_3}$

$\beta = \frac{V_f}{V_o} \Rightarrow V_f = -IZ'$ $\quad (Z' = Z_1 \,||\, h_{ie})$.

$V_f = \frac{-I Z_1 h_{ie}}{Z_1+h_{ie}}$



$V_o = -I(Z'+Z_3)$

$= -I\left[\frac{Z_1 h_{ie}}{Z_1+h_{ie}} + Z_3\right]$

$= -I\left[\frac{h_{ie}(Z_1+Z_3)+Z_1Z_3}{Z_1+h_{ie}}\right]$.

→ $\boxed{\beta = \frac{V_f}{V_o} = \frac{Z_1 h_{ie}}{h_{ie}(Z_1+Z_3)+Z_1Z_3}}$

$\Rightarrow A\beta = 1$ [∵ for sustained oscillation]

$-\frac{h_{fe}}{\cancel{h_{ie}}} \frac{Z_2[(Z_1+Z_3)\cancel{h_{ie}}+Z_1Z_3]}{h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2+Z_1Z_3} \times \frac{Z_1\cancel{h_{ie}}}{h_{ie}\cancel{(Z_1+Z_3)+Z_1Z_3}} = 1$

$\Rightarrow \frac{-h_{fe} Z_1 Z_2}{h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2+Z_1Z_3} = 1$

$\Rightarrow -h_{fe}Z_1Z_2 = h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2+Z_1Z_3$

$\Rightarrow \boxed{h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2[1+h_{fe}]+Z_1Z_3 = 0}$

Condition for sustained Oscillations.

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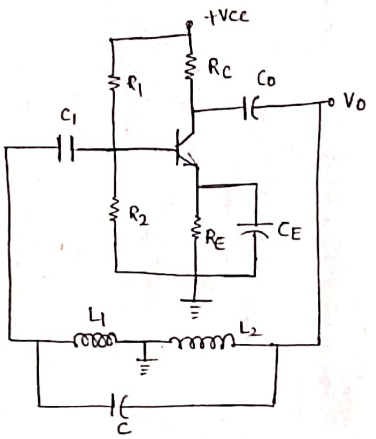
15/2/2020

Heartly Oscillators:

For heartly Oscillator, $Z_1 = j\omega L_1 + j\omega M = j\omega(M + L_1)$ — Mutual Inductance

$Z_2 = j\omega L_2$

$Z_3 = \frac{1}{j\omega C}$



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

from ①

$\rightarrow h_{ie}\left[j\omega(L_1 + L_2 + 2M) + \frac{1}{j\omega C}\right] + j^2\omega^2\left[L_1L_2 + M(L_1+L_2) + M^2\right]$

$(1+h_{fe}) + j\omega(L_1 + M) \times \frac{1}{j\omega C} = 0$

$\Rightarrow j\omega h_{ie}\left[(L_1 + L_2 + 2M) - \frac{1}{\omega^2 C}\right] - \omega^2\left[L_1L_2 + M(L_1+L_2) + M^2\right]$

$(1+h_{fe}) + \left(\frac{L_1 + M}{C}\right) = 0$

→ equating part on bothsides,

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

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

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

$\boxed{f = \frac{1}{2\pi\sqrt{L_{eq} C}}}$ → frequency of oscillations

where, $L_{eqv} = L_1 + L_2 + 2M$.

Similarly equating real parts on both sides,

$-\omega^2\left[L_1L_2 + M(L_1 + L_2) + M^2\right](1 + h_{fe}) + \frac{L_1 + M}{C} = 0$

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

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

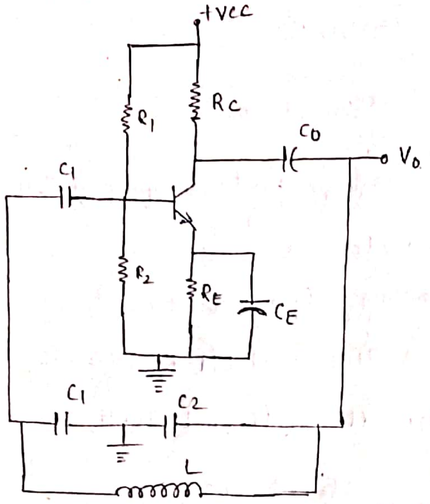
$1 + h_{fe} = \frac{L_1 + L_2 + 2M}{L_2 + M}$

$\boxed{h_{fe} = \frac{L_1 + M}{L_2 + M}}$ ⇒ condition for sustainable Oscillations in Heartly Oscillator.

usually, $h_{fe} \geq \frac{L_1 + M}{L_2 + M}$.

ie, $(L_1 \geq L_2)$ then only we will get Oscillations.

Colpitts Oscillator:



→ $z_1 = \frac{1}{j\omega C_1}$, $z_2 = \frac{1}{j\omega C_2}$, $z_3 = j\omega L$

→ $h_{ie}(z_1+z_2+z_3) + z_1 z_2 (1+h_{fe}) + z_1 z_3 = 0$ —(1)

Sub z_1, z_2, z_3 in (1),

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

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

by taking imag part

$$-\frac{h_{ie}}{\omega}\left(\frac{C_1 * C_2}{C_1+C_2}\right) + h_{ie}\,\omega L = 0.$$

→ $\frac{h_{ie}(C_1 * C_2)}{\omega(C_1+C_2)} = h_{ie}\,\omega L$

→ $\frac{C_1 * C_2}{(C_1+C_2)L} = \omega^2$

→ $\omega = \frac{1}{\sqrt{L\left(\frac{C_1 * C_2}{C_1+C_2}\right)}}$

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

where, $C_{eqv} \Rightarrow \cancel{\frac{C_1+C_2}{C_1C_2}}\ \frac{C_1C_2}{C_1+C_2}$.

equating realpart,

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

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

→ $L\omega^2 C_2 = 1+h_{fe}$

→ $L\left[\frac{1}{L\left(\frac{C_1+C_2}{C_1C_2}\right)}\right] C_2 = 1+h_{fe}$

→ $\frac{C_1+C_2}{C_1} = 1+h_{fe}$

→ $h_{fe} = \frac{C_1+C_2}{C_1} - 1$

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

$h_{fe} \geq \frac{C_2}{C_1}$

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Q# In a transistorized Hearty Oscillator two Inductance are 2mH and 20 µH., while the frequency is to be changed from 950kHz to 2050 kHz. Calculate range over which the capacitor is to be varied.

→ Given, $L_1 = 2mH$, $L_2 = 20\mu H$.

$$L_{eq} = L_1 + L_2 = 2\times10^{-3} + 2\times10^{-6}$$
$$= 2.02\,mH$$

$$f_{osc} = \frac{1}{2\pi\sqrt{L_{eqv}C}}$$

⇒ Given $f_1 = 950\,kHz \longrightarrow C_1$.

5966000 $\frac{1}{\sqrt{\ }}$

$$f_1 = \frac{1}{2\pi\sqrt{L_{eqv}C_1}}$$

$$950\times10^3 = \frac{1}{2\pi\sqrt{2.02\times10^{-3}\,C_1}}$$

$$C_1 = 13.89\,pF$$

→ $f_2 = 2050\,kHz \longrightarrow C_2$

$$f_2 = \frac{1}{2\pi\sqrt{L_{eq}C_2}}$$

$$2050\times10^3 = \frac{1}{2\pi\sqrt{2.02\times10^{-3}\times C_2}}$$

$$C_2 = 2.98\,PF$$

→ Range of 'C' from 2.98 PF – 13.89 PF

Q) Design Colpitts Oscillator for 1MHz frequency.

→ Colpitts Oscillator.

$$f_{osc} = \frac{1}{2\pi\sqrt{L\,C_{equ}}} = 1\times10^6\,Hz$$

Let $L = 10\mu H$

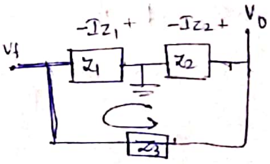
$$1\times10^6 = \frac{1}{2\pi\sqrt{10\times10^{-6}\times C_{eqv}}}$$

$C_{eqv} = 2.53\,nF$.

∴ $C_{eqv} = 2.53\,nF$.

Let $C_1 = 5nF$ & $C_2 = 5nF$.

Q) In a Hearty Oscillator the value of capacitor in a tuned circuit is 500pF and two sections of coil have Inductances 38µH and 12µH. Find frequency of Oscillations and Feedback factor (β) ?



$$f_{osc} = \frac{1}{2\pi\sqrt{L_{eqv}C}}$$

→ $L_{eq} = (38+12)\,\mu H$
$= 50\,\mu H$

$$f_{osc} = \frac{1}{2\pi\sqrt{L_{eqv}C}}$$

$$= \frac{1}{2\pi\sqrt{50\times10^{-6}\times500\,pF}} = 1006584.2\,Hz$$

$\simeq 1MHz$

$$\to \beta = \frac{V_f}{V_0} = \frac{-I_{Z_1}}{I_{Z_2}} = \frac{-Z_1}{Z_2}$$

$\rightarrow \beta = \frac{-L_1}{L_2}$

$= \frac{-38}{12}$ ($\because L_1 > L_2$)

$\rightarrow \beta = -3.16$

$= 3.16 \angle 180^\circ$

Q) A Colpits Oscillator, the values of inductors & Capacitors in a tank ckt are $L = 40mH$, $C_1 = 100PF$, $C_2 = 500PF$. Find

(a) frequency of oscillations (f_{osc})

(b) If o/p voltage is 10V. Calculate feedback voltage V_f?

(c) Calculate minimum gain if frequency is changed by changing 'L' alone.

(d) Value of C_1 for a gain of 10. ($h_{fe} = 10$) and also find new frequency (f_{new})?

Sol: $L = 40mH$, $C_1 = 100PF$, $C_2 = 500PF$.

$$f_{osc} = \frac{1}{2\pi\sqrt{LC_{eqv}}} = \frac{1}{2\pi\sqrt{40\times10^{-3}\times C_{eqv}}}$$

$$C = \frac{C_1C_2}{C_1+C_2} = \frac{100\times10^{-12}\times500\times10^{-12}}{(100+500)\times10^{-12}} = 83.3\,pF$$

$$f_{osc} = \frac{1}{2\pi\sqrt{40\times10^{-3}\times83.3\times10^{-12}}}$$

$= \underline{87.1\,KHz}$

(b) $V_0 = 10V$, $V_f = ?$

$$\beta = \frac{V_f}{V_0} = \frac{-Z_1}{Z_2} = \frac{-C_2}{C_1}$$

$$\Rightarrow \frac{V_f}{10} = \left|\frac{500}{100}\right|$$

$\rightarrow V_f = 50V$

(c) $(h_{fe})_{min} = \frac{C_2}{C_1} = \frac{500}{100} = 5$

(d) $h_{fe} = 10 = \frac{C_2}{C_1}$

$\Rightarrow 10 = \frac{500\,pF}{C_1}$

$C_1 = 50pF$.

$C_{eq} = \frac{C_1C_2}{C_1+C_2} = 45.45\,pF$

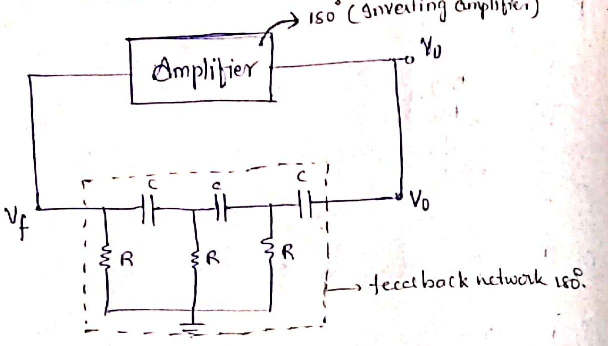
$C_1 = 50pF$ & $C_2 = 500PF$

$$(f_{osc})_{new} = \frac{1}{2\pi\sqrt{LC_{eqv}}} = 118.038\,KHz$$

→ All the oscillators using tuned LC circuits operate well at high frequency.
- At low frequencies as the inductors and capacitors are bulky RC found suitable.

RC phase shift Oscillator: (Audio frequency Oscillator)

(2a)



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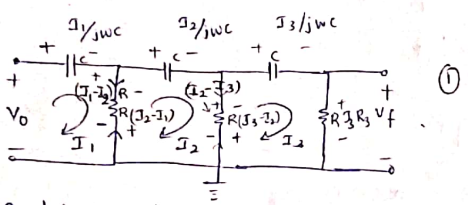


⇒ Applying mesh analysis,

KVL (1) ⇒ $+V_0 - \frac{I_1}{j\omega C} - R(I_1 - I_2) = 0$

$$\Rightarrow I_1\left[R + \frac{1}{j\omega C}\right] - RI_2 = V_0 \quad \text{—(1)}.$$

KVL (2)

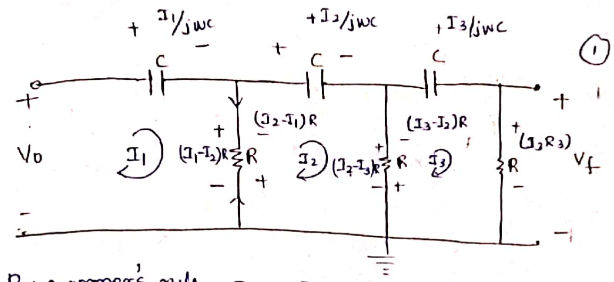
$$\Rightarrow -(I_2 - I_1)R - \frac{I_2}{j\omega C} - (I_2 - I_3)R = 0$$

$$-I_1R_1 + I_2\left[2R + \frac{1}{j\omega C}\right] - RI_3 = 0 \quad \text{—(2)}$$

KVL (3)

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

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



→ By Crammer's rule, $I_3 = \frac{D_3}{\Delta}$

$$= \frac{\begin{vmatrix} R + \frac{1}{j\omega C} & -R & V_0 \\ -R & 2R + \frac{1}{j\omega C} & 0 \\ 0 & -R & 0 \end{vmatrix}}{\begin{vmatrix} R + \frac{1}{j\omega C} & -R & 0 \\ -R & 2R + \frac{1}{j\omega C} & -R \\ 0 & -R & 2R + \frac{1}{j\omega C} \end{vmatrix}}$$

$a_1x_1 + b_1y + c_1z = p$
$a_2x + b_2y + c_2z = q$
$a_3x + b_3y + c_3z = r$ (3)

$\frac{D_3}{\Delta}$

$$\frac{\begin{vmatrix} a_1 & b_1 & p \\ a_2 & b_2 & q \\ a_3 & b_3 & r \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}}$$

$$\Rightarrow I_3 = \frac{0 - (-R)(0) + V_0(R^2 - 0)}{\left(R + \frac{1}{j\omega C}\right)\left[\left(2R + \frac{1}{j\omega C}\right)^2 - R^2\right] - (-R)\left[(-R)\left(2R + \frac{1}{j\omega C}\right) - 0\right] + 0}$$

$$I_3 = \frac{V_0 R^2}{\left(R + \frac{1}{j\omega C}\right)\left(4R^2 - \frac{1}{\omega^2 C^2} + \frac{4R}{j\omega C} - R^2\right) - 2R^3 - \frac{R^2}{j\omega C}}$$

$$= \frac{V_0 R^2}{3R^3 - \frac{R}{\omega^2 C^2} + \frac{4R^2}{j\omega C} + \frac{3R^2}{j\omega C} - \frac{1}{j\omega^3 C^3} - \frac{4R}{\omega^2 C^2} - 2R^3 - \frac{R^2}{j\omega C}}$$

$$= \frac{V_0 R^2}{R^3 - \frac{5R}{\omega^2 C^2} + \frac{6R^2}{j\omega C} - \frac{1}{j\omega^3 C^3}}$$

$$\Rightarrow I_3 = \frac{V_0 R^2}{R^3\left[1 - \frac{5}{w^2C^2R^2} + \frac{6}{jwRC} - \frac{1}{jw^3R^3C^3}\right]}.$$

$$\beta = \frac{V_f}{V_0} = \frac{I_3 R}{V_0}$$

$$= \frac{1}{\left(1 - \frac{5}{w^2C^2R^2}\right) - j\left[\frac{6}{wRC} - \frac{1}{w^3C^3R^3}\right]}.$$

$$\longrightarrow \beta = \frac{1}{\left(1 - \frac{5}{w^2C^2R^2}\right) + j\left[\frac{1}{w^3C^3R^3} - \frac{6}{wRC}\right]}.$$

Let, $\alpha = \frac{1}{wRC}$

$$\Rightarrow \beta = \frac{1}{(1-5\alpha^2) + j(\alpha^3 - 6\alpha)}.$$

$-\frac{h_{fe}}{h_{ie}} \cdot R_L \approx A_v$ for CE

$|A\beta| = 1$ → Complex; always real

equating imaginary part to zero:

$$\Rightarrow \alpha^3 - 6\alpha = 0$$

$$\alpha^2 = 6$$

$$\alpha = \sqrt{6}$$

$$\Rightarrow \frac{1}{wRC} = \sqrt{6}$$

$$\Rightarrow w = \frac{1}{\sqrt{6}RC}$$

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

f_{osc} (freq of Oscillations for RC-phaseshift Oscillator).

$\because \alpha = \sqrt{6}$

$$\Rightarrow \beta = \frac{1}{(1 - 5(\sqrt{6})^2) + j(0)}$$

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

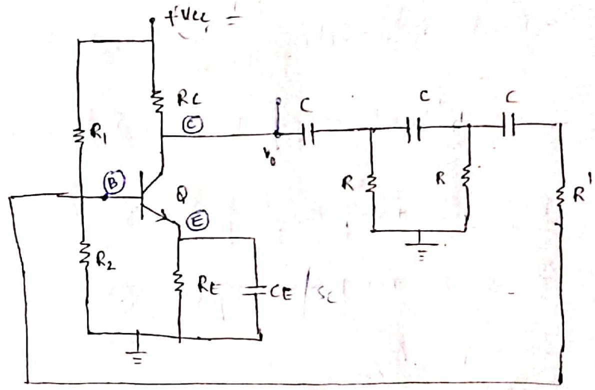
$$\Rightarrow \beta = -\frac{1}{29} \angle 180^\circ$$

$\Rightarrow \because A\beta = 1$

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

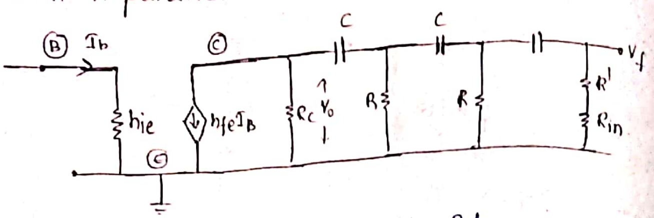
$$\Rightarrow A = 29\angle 180^\circ$$

RC phase shift Oscillator using BJT (CE):

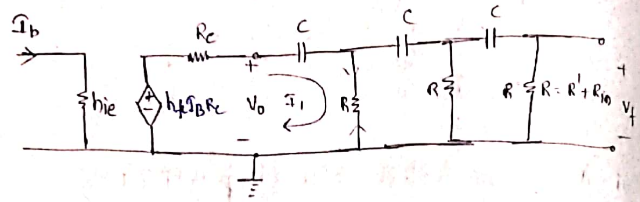


where $R' = R - R_{in}$.

→ Draw Ac-equivalent Circuit and Replace transistor with h-parameter model.



⇓ voltage division Rule.



→ ① ⇒ $h_{fe}R_CI_b - I_1R_C - \frac{I_1}{j\omega C} - (I_1 - I_2)R = 0$

$\Rightarrow I_1\left[R_C + R + \frac{1}{j\omega C}\right] - I_2R = h_{fe}R_CI_b$ — ①.

② ⇒ $-I_1R_1 + I_2\left[2R + \frac{1}{j\omega C}\right] - I_3R = 0$ — ②.

③ ⇒ $-I_2R + I_3\left[2R + \frac{1}{j\omega C}\right] = 0$ — ③

$I_3 = \Delta_3/\Delta.$

⇒ $f_{osc} = \frac{1}{2\pi RC\sqrt{6 + 4(R_C/R)}}$

$f_{osc} = \frac{1}{2\pi RC\sqrt{6+4K}}$ where $K = \frac{R_C}{R}$

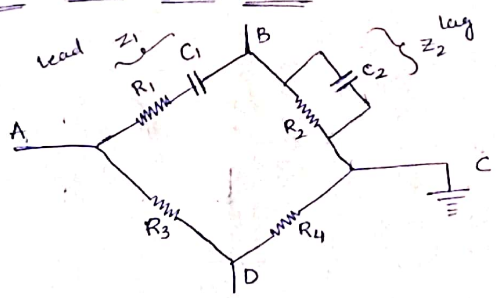
doubt → $h_{fe}R_C = -29 - 23K - 4K^2$ → Condition for sustained Oscillations.

— $h_{fe}R_C = \frac{h_{fe}I_bR_C}{I_b} = \frac{V_0}{I_b} = A$

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

→ $\boxed{h_{fe}R_C = A = -29 - 23K - 4K^2}$

WEIN-BRIDGE OSCILLATOR : (Lead-lag network)



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

$Z_2 = R_2 \,||\, \frac{1}{j\omega C_2}$

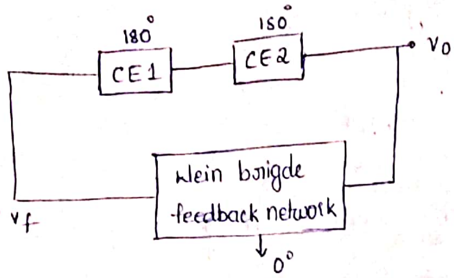
⇒ Bridge is Balanced if,

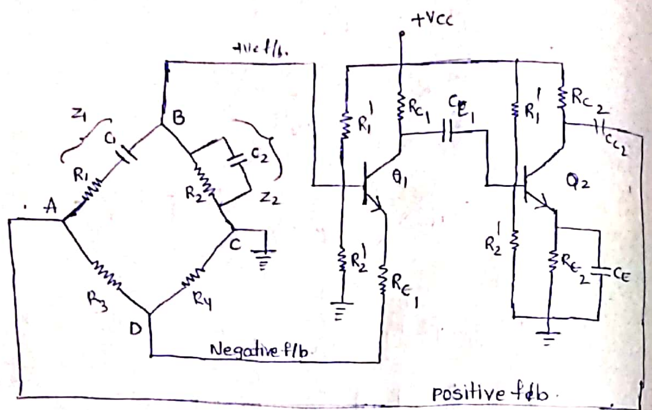
$$\frac{R_3}{R_4} = \frac{Z_1}{Z_2} = \frac{R_1 + \frac{1}{j\omega C_1}}{R_2 \,||\, \frac{1}{j\omega C_2}}.$$

→ $f_{osc} = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$.

If $R_1 = R_2 = R$ and $C_1 = C_2 = C$.

→ $f_{osc} = \frac{1}{2\pi RC}$.





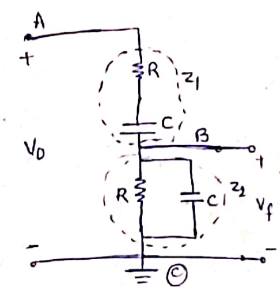
→ Klein bridge oscillators is used for both negative and positive feedback.

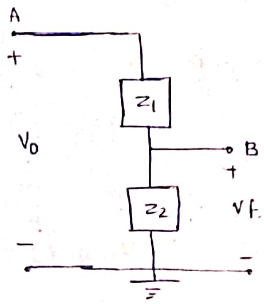
→ V_f is measured between point B and C.

→ Vo is measured between point A and C.

\# Feedback network consists of a lead lag network (R_1-C_1 and R_2-C_2) and a voltage divider (R_3-R_4). The lead-lag network provides a positive feedback to the input of first stage and the voltage divider provides a negative feedback to the emmitter of Q_1.

Let us consider, $R_1 = R_2 = R$; $C_2 = C_1 = C$.





$$\Rightarrow V_f = \frac{V_o Z_2}{Z_1 + Z_2}$$

$$\rightarrow \frac{V_f}{V_o} = \beta = \frac{Z_2}{Z_1 + Z_2}.$$

$$\Rightarrow Z_1 = R + \frac{1}{j\omega C}.$$

$$Z_2 = R \,||\, \frac{1}{j\omega C}$$

$$= \frac{R\left(\frac{1}{j\omega C}\right)}{R + \frac{1}{j\omega C}}$$

$$\Rightarrow \frac{\frac{R/j\omega C}{R + 1/j\omega C}}{R + \frac{1}{j\omega C} + \frac{R/j\omega C}{R + 1/j\omega C}}.$$

$$\Rightarrow \frac{\frac{R}{j\omega RC + 1}}{R + \frac{1}{j\omega C} + \frac{R}{j\omega RC + 1}}$$

$$\Rightarrow \frac{\dfrac{R}{jwRC+1}}{\dfrac{jwRC(jwRC+1)+jwRC+1+Rjwc}{jwc(jwRC+1)}}$$

$$\Rightarrow \frac{jwRC}{-w^2R^2C^2+3jwRC+1} \Big/ jwRC$$

$$\beta = \frac{1}{jwRC+3+\dfrac{1}{jwRC}}$$

$$\beta = \frac{1}{3+j\left(wRC-\dfrac{1}{wRC}\right)}$$

→ To calculate frequency of oscillations make imaginary part of 'β' equal to zero.

$$\rightarrow wRC - \frac{1}{wRC} = 0$$

$$w = 1/RC$$

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

$$\Rightarrow \beta = \frac{1}{3+j(0)} \Rightarrow \beta = 1/3 \angle 0°$$

$$\rightarrow A\beta = 1 \Rightarrow A = 1/\beta = 3\angle 0°$$

Condition for sustained Oscillations:

$$\beta = \frac{Z_2}{Z_1+Z_2} = \frac{1}{3}$$

→ If the bridge is balanced,

$$\frac{R_3}{R_4} = \frac{Z_1}{Z_2}$$

$$\Rightarrow \frac{R_3}{R_4}+1 = \frac{Z_1}{Z_2}+1$$

$$\Rightarrow \frac{R_3+R_4}{R_4} = \frac{Z_1+Z_2}{Z_2} = 3$$

$$\Rightarrow R_3+R_4 = 3R_4$$

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

Q) Differentiate RC-phase shift Oscillator & wein Bridge Oscillator.

RC-phase shift	Wein bridge
1. Consists of 3 identical RC-sections connected in cascade.	1. Uses Wein bridge as feedback network.
2. Feedback network produces 180° phase shift at frequency of oscillations.	2. Feedback network produces 0°/360° phaseshift at frequency of oscillations.
3. Amplifier must produce 180° phase shift at freq. of oscillation	3. Amplifier must produce 0°/360° phaseshift at freq. of oscillations
4. $f_{osc} = \dfrac{1}{2\pi\sqrt{6}RC}$	4. $f_{osc} = \dfrac{1}{2\pi RC}$
5. $\beta = -1/29$	5. $\beta = 1/3$
6. $\lvert A\rvert \geq 29$ for sustained oscillations.	6. ~~$\lvert A\rvert \geq 3$~~ $A \geq 3$ for sustained oscillations.

7. Inverting amplifier is used.

8. Only (+ve) ~~negative~~ positive feedback is used.

9. Relative less stable.

10. Cheaper than Wein bridge

7. Non-Inverting amplifier is used.

8. Both positive & Negative feedback are used.

9. More stable because of negative feedback.

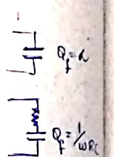
10. Costlier than R.C. phase shift oscillator.

Frequency stability of an Oscillator:

→ Frequency stability of an Oscillator is a measure of its ability to maintain as nearly a fixed frequency as possible over as long a time interval as possible.

* Frequency Sensitivity of an oscillator w.r.t temp$_n$.

$$S_T^{\omega} = \frac{\left[\frac{\Delta\omega}{\omega_0}\right]}{\left[\frac{\Delta T}{T_0}\right]}$$



where, ω_0 = Operating frequency / desired frequency.
T_0 = Operating temperature.

* Frequency stability is given by,

$S_\omega = \frac{d\phi}{d\omega}$: change in phase introduced for small change in nominal frequency.

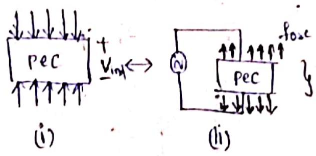
If $\frac{d\phi}{d\omega}$ is more ⇒ frequency stability is more.

If Q-factor is ↑ $\frac{d\phi}{d\omega}$ ↑ stability ↑.

To improve frequency stability, i.e., to obtain high degree of frequency stability.

Crystal Oscillator (uses Piezo electric crystal) ↳ is an active transducer

D



} → Piezo electric property.

(i) When dynamic pressure is applied then voltage is produced.

(ii) When voltage is applied the crystal vibrates

→ Some of piezo electric materials:

1. Quartz
2. Rochelle Salt } Naturally available
3. Barium Titanate ($BaTiO_3$) } Artificial made
4. Tourmaline.

→ Vibrating frequency of the crystal is inversely proportional to the thickness of the crystal.

$$f_{osc} = \frac{P}{2l}\sqrt{\frac{Y}{\rho}}$$

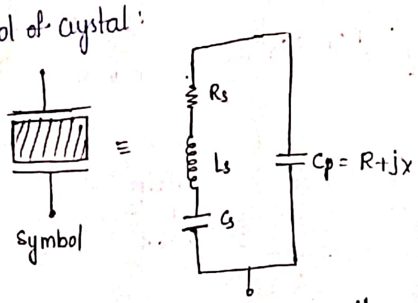
where, P = 1, 2, 3 ......
l = thickness of the crystal.
ρ = density of the crystal.
Y = Youngs modulus = $\frac{\text{stress}}{\text{strain}}$.

→ Cutting of crystal:

↑ Y - mechanical axis (Y-cut)
→ X - electrical axis (X-cut)

→ Method of manufacturing crystal and thickness decides the vibrating frequency. (Txthoof reff)

Circuit symbol of crystal:



Equivalent circuit.

→ Assume $R_s = 0$;

$$\Rightarrow jX = \left[j\omega C_s + \frac{1}{j\omega C_s} \right] \| \left[\frac{1}{j\omega C_p} \right]$$

$$\Rightarrow jX = \frac{1}{j\omega C_p} \left[\frac{\omega^2 - \omega_s^2}{\omega^2 - \omega_p^2} \right].$$

$\omega_s = 2\pi f_s$
$\omega_p = 2\pi f_p$

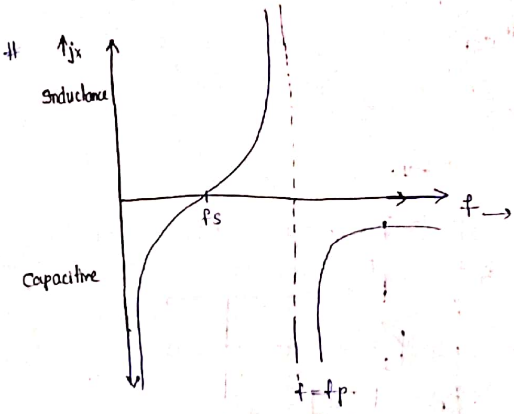
where, $f_s = \frac{1}{2\pi\sqrt{L_s C_s}}$ and

$f_p = \frac{1}{2\pi\sqrt{L_s C_{eq}}}$ and $C_{eqv} = \frac{C_s C_p}{C_s + C_p}$.

→ f_s . Series Resonant frequency.
f_p parallel

→ If $C_p >> C_s \Rightarrow C_{eqv} = C_s$ and $f_s = f_p$.

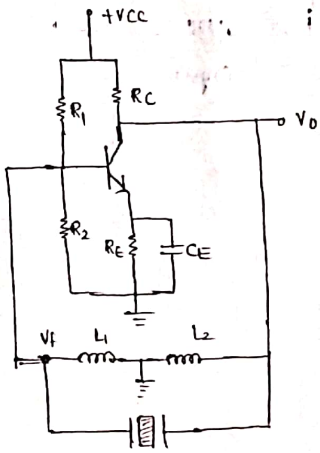
#



$Z_L = j\omega L$
$Z_C = \frac{1}{j\omega C} = \frac{-j}{\omega C}$

Heartly Crystal Oscillator –

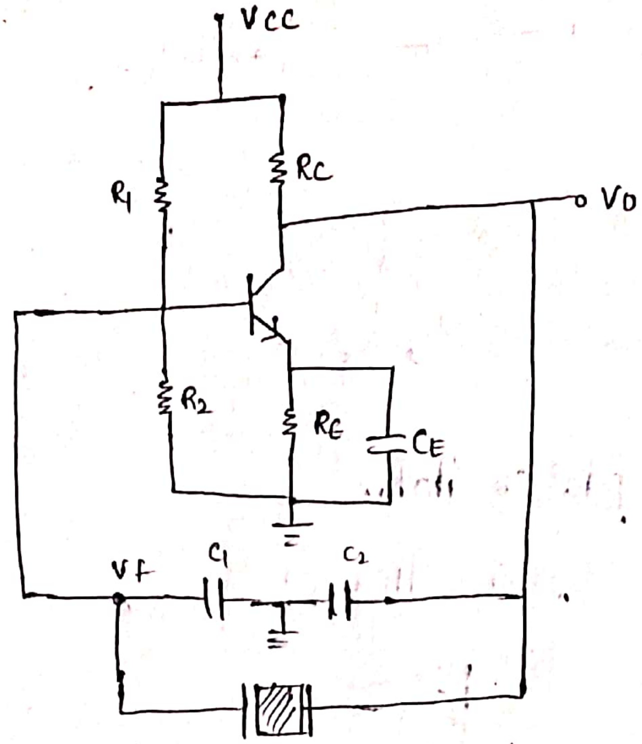
– Replace capacitor with crystal,



crystal.

* Colpits Oscillator:

→ Replace Inductor with crystal.



Crystal.