Oscillators :-

- capable of generating a variety of O/P w/fs.
- Basically funⁿ of an oscillator is to generate alternating current or voltage w/fs.
- an oscillator is a ckt that generates a repetitive w/f of fixed amplitude & freqⁿ without any external I/P signal.

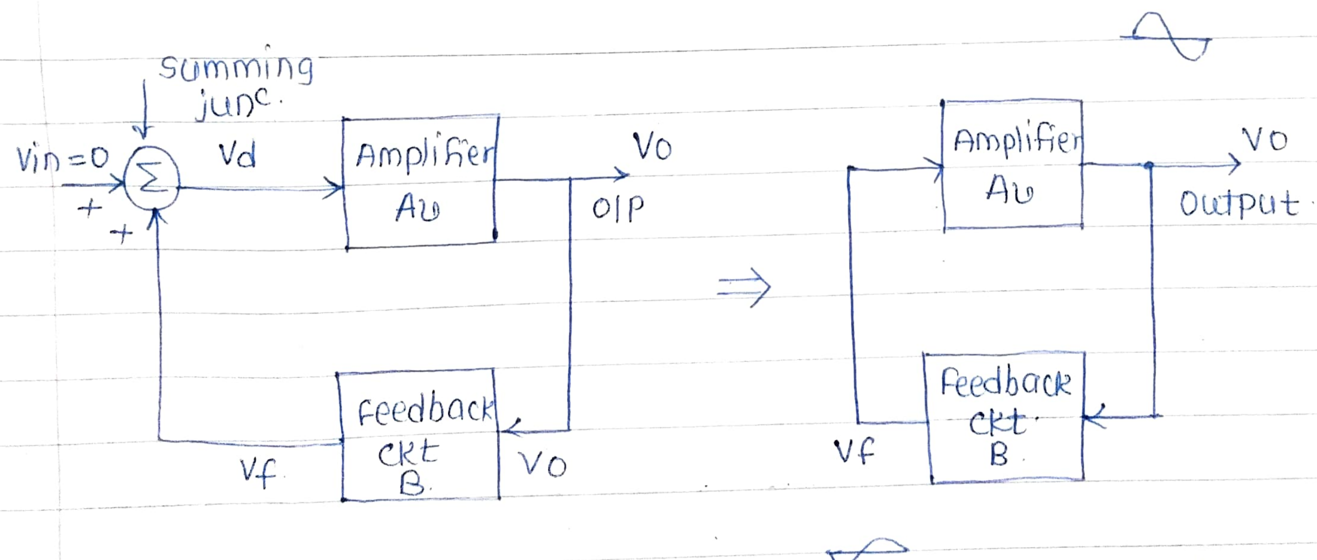
Applications :

- In radio, T.V, computers & commⁿ.

Oscillator Principles :-

- It is a type of f/b ampʳ in which part of the O/P is fed back to the I/P via a feedback ckt. If the signal fed back is of proper magnitude & phase, the ckt produces alternating currents or voltages.

Oscillator Block diagram :-



→ Here vin = 0 & the f/b is +ve, because most oscillators use +ve f/b. Finally, the closed-loop gain of the ampʳ. is denoted by Av, rather than Af.

From block diagram,

$$v_d = v_f + v_{in}$$

$$v_o = A_v \cdot v_d$$

$$v_f = B \cdot v_o$$

Using these relationships, the following eqⁿ is obtained.

$$\frac{v_o}{v_{in}} = \frac{A_v}{1 - A_v \cdot B}$$

However, $v_{in} = 0$ & $v_o \neq 0$ implies that,

$$A_v \cdot B = 1$$

Expressed in polar form,

$$A_v \cdot B = 1 \angle 0^\circ \text{ or } 360^\circ \quad \text{--- (1)}$$

Eqⁿ (1) gives the two requirements for oscillation:

1) magnitude of the loop gain $A_v B$ must be at least 1 &
2) total phase shift of the loop gain $A_v B$ must be equal to 0° or 360°.

- The type of o/p generated by oscillator depends on the components in the ckt & hence may be sinusoidal, square or triangular.
- freqⁿ of oscillation is determined by the components in the fb ckt.

⇒ Oscillator Types :-

	Types of components used.	Freqⁿ of oscillation	Type of o/p generated.
1.	RC oscillator	Audio freqⁿ (AF)	Sinusoidal
2.	LC oscillator	Radio freqⁿ (RF)	Square wave
3.	Crystal oscillator		Triangular wave
			Sawtooth wave, etc.

⇒ Freqⁿ stability :-

- Ability of the oscillator ckt to oscillate at one exact freqⁿ is called freqⁿ stability.
- no. of factors may cause changes in oscillator freqⁿ.
- Primary factors are temp. changes & changes in the DC power supply.

- Temp & power supply changes cause variations in the op-amp's gain, in junction capacitances & resistances of the transistors in an op-amp & in external ckt. components.

- Another imp. factor that determines freq^n stability is the figure of merit Q of the ckt.

- higher the Q, the greater the stability.

Hence crystal oscillators are far more stable than RC or LC, especially at higher frequencies.

- LC CKTS & crystals are generally used for the generation of high freq^n signals, while RC components are most suitable for audio freq^n applications.

- We will see audio-freq^n RC oscillators only.

1. phase shift oscillator.
2. wein bridge oscillator
3. Quadrature oscillator :

Wein Bridge Oscillator :-

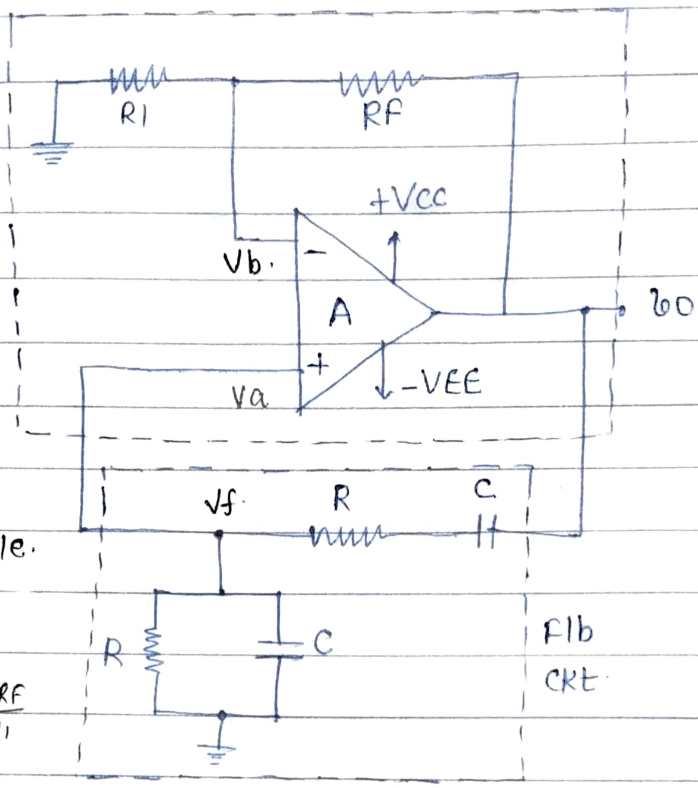
- It is simple & stable. Hence one of the most commonly used audio freq^n oscillators is the wein bridge.
- Fig. shows wein Bridge oscillator in which the wein bridge ckt is connected bet^n the amp^r. I/P terminals & the O/P terminals.
- The bridge has a series RC n/w in one arm & ||el RC n/w in the adjoining arm.
- In the remaining two arms of the bridge resistors R1 & RF are connected.
- The phase angle criterion for oscillation is that the total phase shift around the ckt must be 0°. This condition occurs only when the bridge is balanced, i.e at resonance. The freq^n of oscillation fo is exactly the resonant freq^n of the balanced wein bridge & is given by,

$$f_o = \frac{1}{2\pi RC} = \frac{0.159}{RC}$$

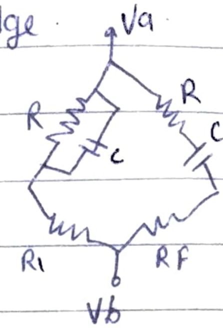
Assuming that the resistors are equal in value & the capacitors are equal in value in the reactive leg of the wein bridge. At this freqⁿ the gain required for sustained oscillations is given by,

$$A_v = \frac{1}{B} = 3$$

Amplifier.



- simple & stable
- Bridge.



when Va = Vb, phase shift = 0

$$\Downarrow$$

$$f_o = \frac{1}{2\pi RC} = \frac{0.159}{RC}$$

$$A_v = \frac{1}{\beta} = 3.$$

Vf - using vtg divider rule.

$$\Downarrow$$

$$\beta = \frac{V_f}{V_o}.$$

$$A_v = \frac{V_o}{V_f} = 1 + \frac{R_F}{R_1}$$

$A_v \cdot \beta = 1.$

$$\Downarrow$$

$R_F = 2R_1$ i.e

or

$A_v = 3 = \frac{1}{\beta}.$

(530)

wein bridge ckt → ||el + series RC n/w

$$1 + \frac{R_F}{R_1} = 3. \qquad \therefore \frac{R_F}{R_1} = 2$$

or $R_F = 2R_1$

Que: Design the wein bridge oscillator for $f_o = 965$ Hz.

solⁿ:- Let $C = 0.047\ \mu F$.

$$\therefore R = \frac{0.159}{(0.047) \times 10^{-6} \times 965}$$

$$R = \frac{0.159}{45.355 \times 10^{-6}} = 0.0035057 \times 10^{6}$$

$$R = 3.5\ K\Omega$$

Now, let $R_1 = 12\ K\Omega$,

$$\therefore R_F = (2) \cdot (12\ K\Omega) = 24\ K\Omega$$

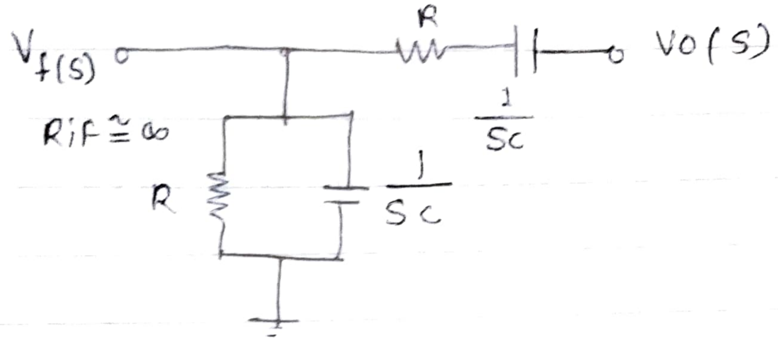
use R_F = 50 K pot.

Derivation of wein-bridge oscillator.

Prove that $f_0 = \frac{1}{2\pi RC}$ ---(1)

$R_F = 2R_1$ ---(2).

First consider the f/b ckt of wein bridge oscillator.
The s-domain representation is,



A/c to vtg divider rule,

$$V_f(s) = \frac{Z_P(s) \cdot V_o(s)}{Z_P(s) + Z_S(s)} \quad \text{---(3)}$$

where $Z_P(s) = R \parallel \frac{1}{SC} = \frac{R}{RSC+1}$

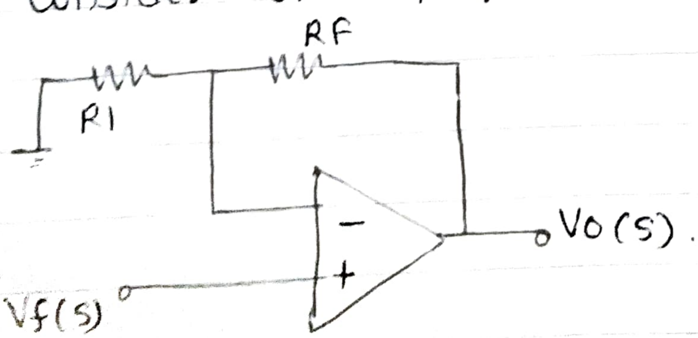
$$Z_S(s) = R + \frac{1}{SC} = \frac{RSC+1}{SC}.$$

∴ substitute $Z_P(s)$ & $Z_S(s)$ in eqⁿ (3)

∴ $$V_f(s) = \frac{(RCS) \cdot V_o(s)}{(RCS+1)^2 + RCS}$$

or $$\beta = \frac{V_f(s)}{V_o(s)} = \frac{RCS}{R^2C^2S^2 + 3RCS + 1} \quad \text{---(4)}$$

Let us consider op-amp part of wein bridge osc.



The vtg gain of op-amp is,

$$A_v = \frac{V_o(s)}{V_f(s)} = 1 + \frac{R_F}{R_1} \quad \cdots (4)$$

Finally requirement for oscillator is.

$$A_v \cdot \beta = 1.$$

$\therefore$ using eq^n (3) & (4)

$$\left(1 + \frac{R_F}{R_1}\right) \cdot \frac{RCs}{R^2C^2s^2 + 3RCs + 1} = 1.$$

substitute $s = j\omega$ & equate real & img part.

$$\left(1 + \frac{R_F}{R_1}\right) jRC\omega = -R^2C^2\omega^2 + j3RC\omega + 1$$

Real part,

$$-R^2C^2\omega^2 + 1 = 0.$$

$$\therefore \quad R^2C^2\omega^2 = 1.$$

$$\therefore \quad \omega^2 = \frac{1}{R^2C^2} \qquad \text{i.e} \quad \omega = \frac{1}{RC}.$$

$$\text{or} \quad \boxed{f_o = \frac{1}{2\pi RC}}$$

Img. part,

$$\left(1 + \frac{R_F}{R_1}\right) RC\omega = 3RC\omega.$$

$$\therefore \quad 1 + \frac{R_F}{R_1} = 3.$$

$$\boxed{\text{i.e} \quad R_F = 2R_1}$$

Phase shift Oscillator :-

It consists of an op-amp as the amplifying stage & three RC cascaded n/ws as the f/b ckt.

f/b ckt provides feedback vtg. from the o/p back to the i/p of the amplifier.

op-amp is used in the inverting mode, therefore, any signal that appears at the inverting terminal is shifted by 180° at the o/p. An additional 180° phase shift required for the oscillation is provided by the cascaded RC n/ws. Thus the total phase shift around the loop is 360° (or 0°).

- At the some specific freqn when the phase shift of the cascaded RC n/ws is exactly 180° & the gain of the ampr is sufficiently large, the ckt will oscillate at that freqn.
- This freqn is called the freqn of oscillation, f_o, & is given by

$$f_o = \frac{1}{2\pi\sqrt{6}RC} = \frac{0.065}{RC}$$

- At this freqn, the gain A_v must be at least 29.

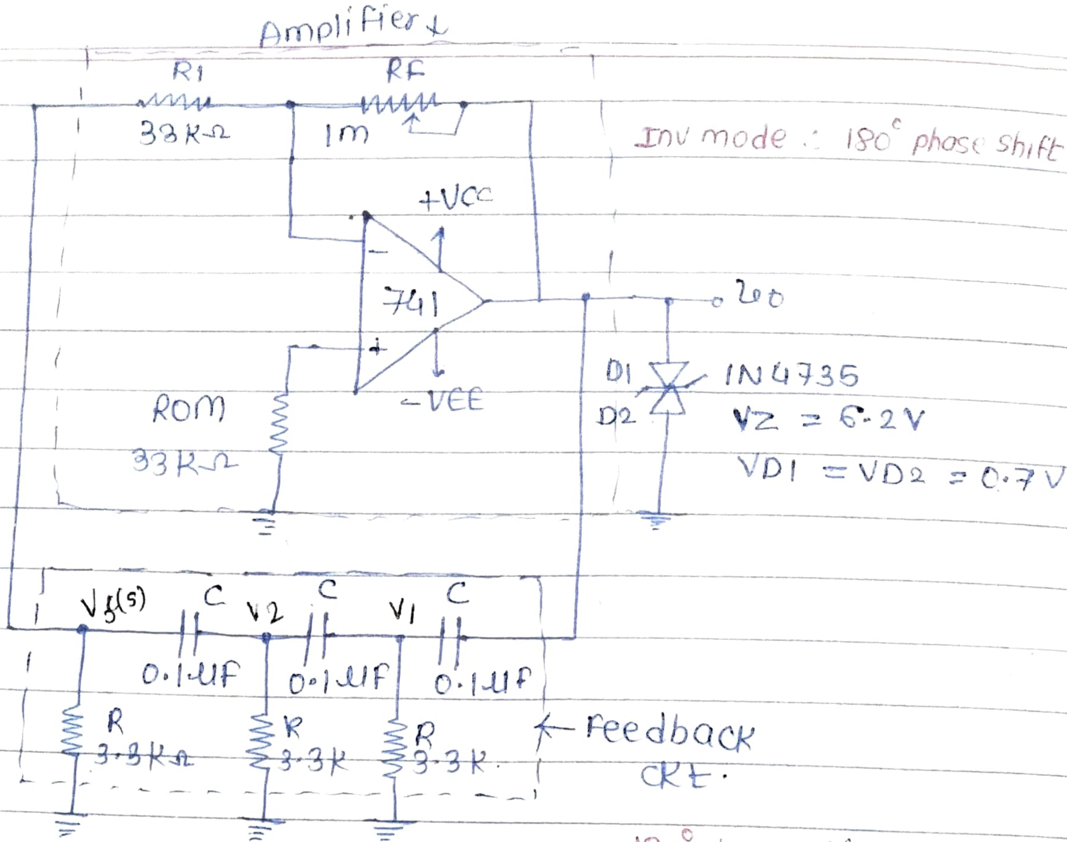
i.e $$\left|\frac{R_F}{R_1}\right| = 29$$

or $$R_F = 29 \cdot R_1$$

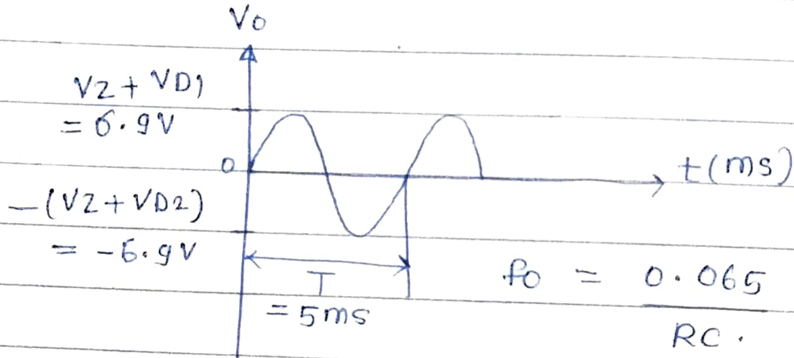
- This ckt will produce a sine wave of freqn f_o if the gain is 29 & the total phase shift around the ckt is exactly 360°.
- For a desired freqn of oscillation, choose a capacitor C & then calculate the value of R from eqn.

$$f_o = \frac{1}{2\pi\sqrt{6} \cdot RC} = \frac{0.065}{RC}$$

- The desired o/p amplitude, however can be obtained with back to back zeners connected at the o/p terminal.



180° phase shift



$$f_o = \frac{0.065}{RC}$$

: phase shift oscillator & it's O/P w/f :

Que: Design the phase shift oscillator with $f_o = 200Hz$.

Sol^n: Let $C = 0.1\mu F$

Then, $R = \dfrac{0.065}{(200)(10^{-7})} = 3.25K\Omega$

(use $R = 3.3K\Omega$)

To prevent the loading of the ampr because of RC n/ws, it is necessary that $R_1 \geq 10R$.

$\therefore$ let $R_1 = 10R = 33K\Omega$.

Then,

$R_F = 29 (33 K\Omega) = 957 K\Omega$.

(use $R_F = 1 M\Omega$ pot).

when choosing an op-amp, 741 can be used at lower freq^ns (< 1 KHz); however, at higher freq^ns, an op-amp such as the LM 318 or LF 351 is recommended because of its increased slew rate.

(1) $\frac{V_f}{V_o} =$

Apply KCL at V_1, V_2,

$V_f(s) =$

$V_2(s)$

$\frac{V_f}{V_o} = \beta$

$A_v = -\frac{R_F}{R_1}$

$A_v \cdot \beta = 1$

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

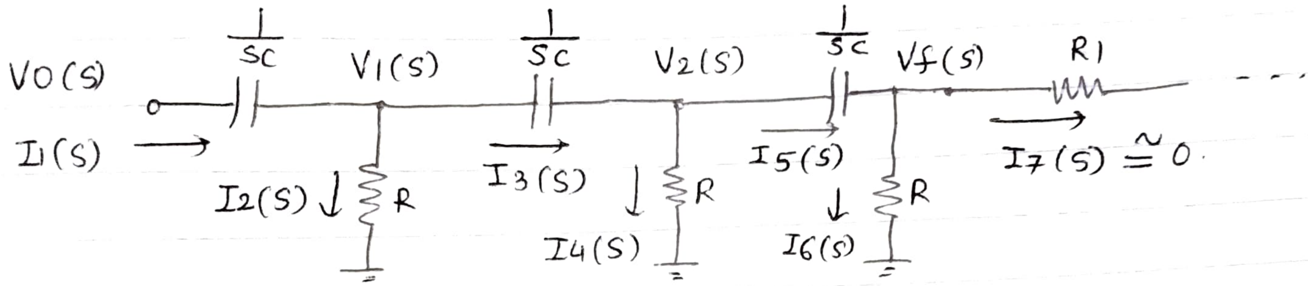
$\frac{R_F}{R_1} = 29$

Derivation of phase shift oscillator,

To show : $f_o = \dfrac{1}{2\pi\sqrt{6}RC}$

$$\left|\frac{R_F}{R_1}\right| = 29.$$

First consider f/b ckt consisting of RC combⁿ of phase shift osc.
S-domain representation of f/b ckt is,



Apply KCL at node $V_1(S)$

$$I_2(S) + I_3(S) = I_1(S).$$

i.e $$\frac{V_o(S) - V_1(S)}{1/SC} = \frac{V_1(S)}{R} + \frac{V_1(S) - V_2(S)}{1/SC}.$$

solving for $V_1(S)$, we get.

$$V_1(S) = \frac{V_o(S) + V_2(S)\cdot RCS}{2RCS+1} \quad \text{--- (1)}$$

writing KCL at node $V_2(S)$,

$$I_3(S) = I_4(S) + I_5(S)$$

i.e $$\frac{V_1(S) - V_2(S)}{1/SC} = \frac{V_2(S)}{R} + \frac{V_2(S) - V_f(S)}{1/SC}$$

solving for $V_1(S)$,

$$V_1(S) = \frac{(2RCS+1)V_2(S)}{RCS} - V_f(S) \quad \text{--- (2)}$$

If $R_1 >> R$ in ckt, then $I_7(S) = 0$

i.e $I_5(S) = I_6(S)$.

∴ using vtg divider rule,

$$V_f(S) = \frac{R}{R + (1/SC)} \cdot V_2(S)$$

or $V_2(S) = \dfrac{(RCS+1)\cdot V_f(S)}{RCS}$

substitute value of $V_2(S)$ in eqⁿ 1,

$$\therefore V_1(S) = \frac{RCS\cdot V_o(S)}{2RCS+1} + \frac{(RCS+1)\cdot V_f(S)}{2RCS+1} \quad \text{--- (3)}$$

substitute value of $V_2(S)$ in eqⁿ 2

$$\therefore \cancel{V_1(S)} = \frac{\cancel{(RCS)\cdot V_o(S)}}{2\cancel{RCS+1}} + \frac{\cancel{(RCS+1)\cdot V_f(S)}}{\cancel{2RCS+1}}$$

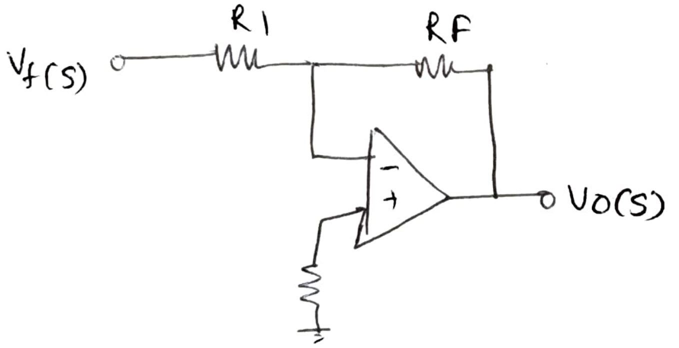
$$V_1(S) = \frac{(2RCS+1)(RCS+1)\cdot V_f(S)}{(RCS)\cdot(RCS)} - V_f(S) \quad \text{--- (4)}$$

equate eqⁿ 3 & 4

$$\frac{V_f(S)}{V_o(S)} = \frac{R^3C^3S^3}{(R^3C^3S^3+6R^2C^2S^2+5RCS+1)} = \beta \quad \text{--- (5)}$$

Consider op-amp part of phase shift osc.

Vtg. gain of op-amp is



$$A_v = \frac{V_o(S)}{V_f(S)}$$

$$A_v = -\frac{R_F}{R_1} \quad \text{--- (6)}$$

for an oscillator,

$$A_v\cdot\beta = 1. \quad \frac{-R_F}{R_1}\cdot\frac{R^3C^3S^3}{R^3C^3S^3+6R^2C^2S^2+5RCS+1} = 1.$$

$\therefore$ using above eqⁿ 5 & 6, & substitute $j\omega = S$.

$$-\frac{R_F}{R_1}(-jR^3C^3\omega^3) = (-jR^3C^3\omega^3) - (6R^2C^2\omega^2) + j5RC\omega + 1$$

compare real & img. parts.

$$-6R^2C^2\omega^2 + 1 = 0$$

or $6R^2C^2\omega^2 = 1$ i.e. $\omega^2 = \frac{1}{6R^2C^2}$

$$\therefore \omega = \frac{1}{\sqrt{6}RC}$$

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

img. part,

$$\left(-\frac{RF}{R1}\right)\left(-jR^3C^3\omega^3\right) = \left(-jR^3C^3\omega^3\right) - \left(6R^2C^2\omega^2\right) + \left(j5RC\omega\right) + 1$$

$$-\frac{RF}{R1}\left(-jR^3C^3\omega^3\right) = -jR^3C^3\omega^3 + j5RC\omega$$

$$\therefore \frac{-RF}{R1} = 1 - \frac{5}{R^2C^2\omega^2}$$

substituting value of ω^2.

$$\therefore \frac{-RF}{R1} = 1 - \frac{5}{R^2C^2 \cdot 1/6R^2C^2}$$

$$= 1 - \frac{5 \times 6R^2C^2}{R^2C^2} = 1 - 30 = 29.$$

$$\therefore \frac{-RF}{R1} = -29.$$

$$\boxed{\therefore \frac{RF}{R1} = 29}$$