UNIT-IV

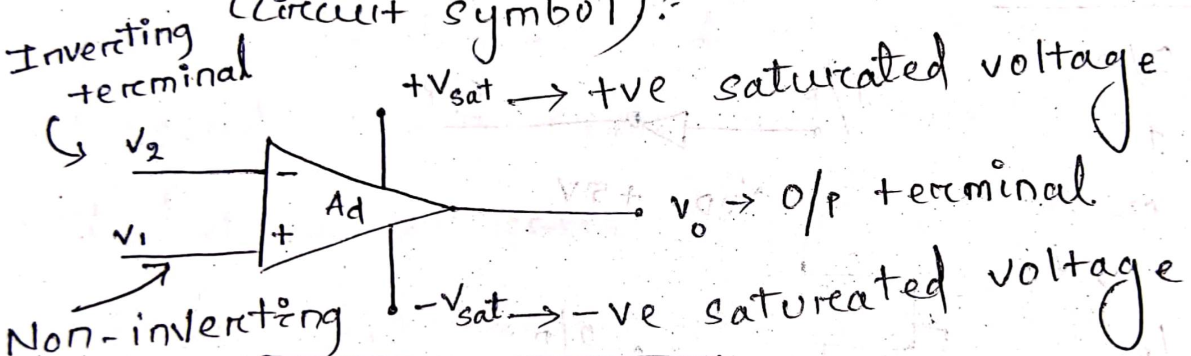
Op-Amp - Operational Amplifier :-

→ Op-Amp is a high gain differential amplifier with very high i/p impedance & very low o/p impedance and used for mathematical operations like addition, substraction, multiplication, differentiation, integration, exponential oper^n, log oper^n etc.

11/11/19

Schematic diagram of op-amp :-

(Circuit symbol):-

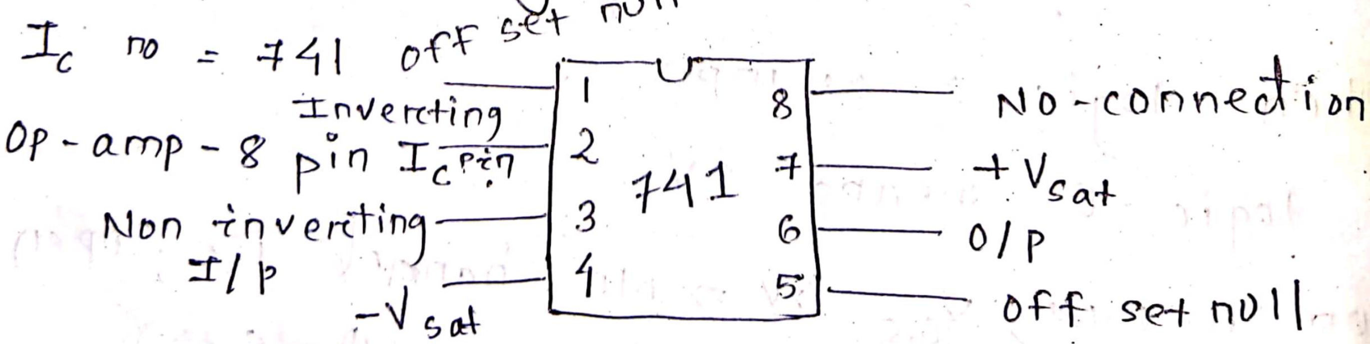


$$\boxed{V_0 = A_d (V_1 - V_2)}$$

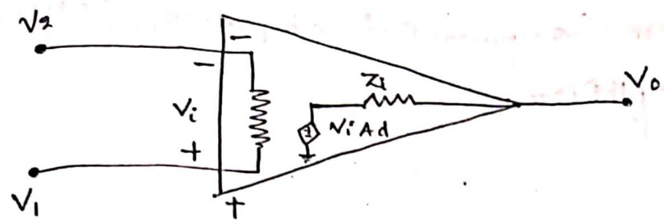
PIN / Ic configuration of OP-amp :-

I_c no = 741

Op-amp - 8 pin Ic



Internal st^{re} of op-Amp :-



characteristics of ideal op-Amp :-

→ I/P impedance is very high ; $Z_i = \infty$

→ O/P impedance is very small , $Z_i = 0$.

→ voltage gain = very high ;

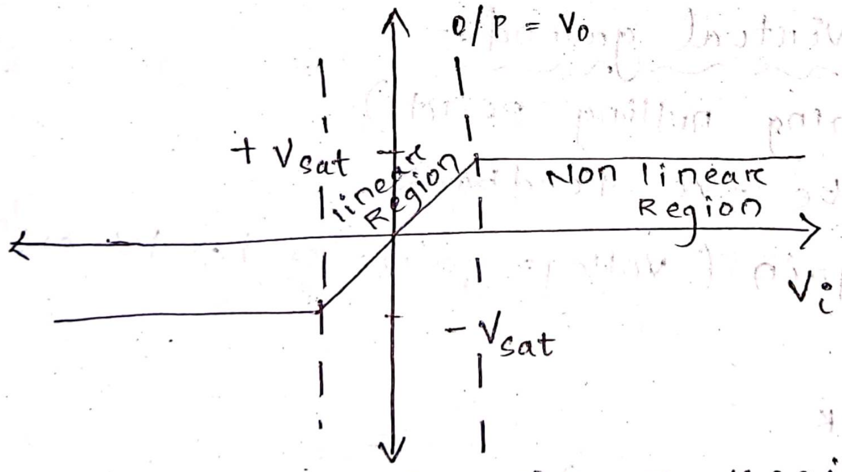
$$A_d = \infty$$

→ there is no offset voltage.

→ very high CMRR ; CMRR = ∞
(common mode rejection ratio)

→ very slow slew rate , slew rate = 0 .

Transfer characteristics :-



App. of op-Amp in linear region :-

→ Inverting amplifier

→ Non-inverting amplifier

→ Summing amplifier (Adder)

→ Subtracter

→ Buffer (voltage "follower")
→ Log amplifier
→ Antilog amplifier (Exponential amplifier) } Optional
→ Differential amplifier.
→ Differentiate
→ Integrator

Virtual Ground :-

13/11/2019

→ Earth surface is equipotential surface, so, the potential diff. betn 2 points on the earth's surface is always 0.

→ Ground is also equipotential surface in which each point is having 0 V potential.
So P.V betn two points on ground is 0V.

→ Current into the ground is maxm. (I_{max})

→ In case of virtual ground, P.V is 0 and current into the virtual ground is 0A.

Condn for virtual ground :-

(Establishing nulling point)

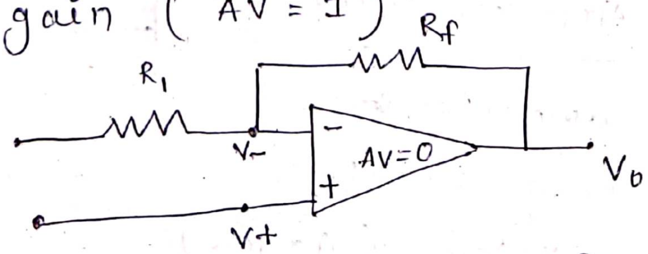
→ There must be −ve feedback.

→ Very high gain (voltage gain = ∞) ⇒ $A_V = \infty$.

or

→ +ve feedback

→ Unit gain ($A_V = 1$)



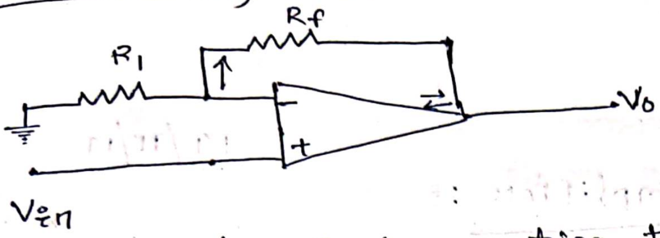
In case of OP-AMP, with −ve feedback and high gain, that exist virtual ground, betn inverting & non-verting terminal.

→ In the above fig, $V_+ = V_-$ where,

$V_+ \rightarrow$ Potential at non-inverting terminal.

$V_- \rightarrow$ Potential at inverting terminal.

<u>Non-inverting amplifier :-</u>



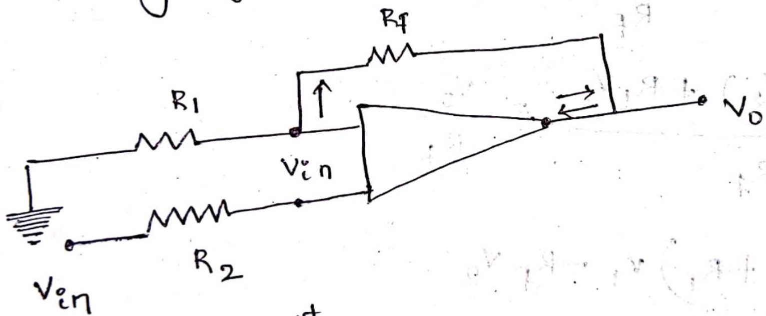
Applying nodal eq^n at Inverting terminal :-

$$\frac{V_{in} - 0}{R_1} + \frac{V_{in} - V_0}{R_f} + 0$$

$$\boxed{V_0 = \left(1 + \frac{R_f}{R_1}\right) V_{in}}$$

$$\frac{V_0}{V_{in}} = \text{Voltage gain} = \left(1 + \frac{R_f}{R_1}\right)$$

Q:-

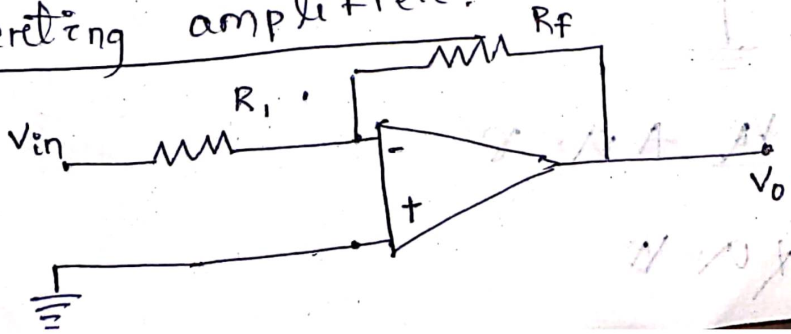


Calculate the output.

$$\frac{V_{in} - 0}{R_1} + \cancel{\frac{V_{in} - 0}{R_2}} + \frac{V_{in} - V_0}{R_f} + 0 = 0$$

$$V_0 = \left(1 + \frac{R_f}{R_1}\right) V_{in}$$

<u>Inverting amplifier :-</u>



$$\cancel{\frac{0-V_{in}}{R_1} + \frac{V_{in}-V_{in}}{R_f} + 0 = 0}$$

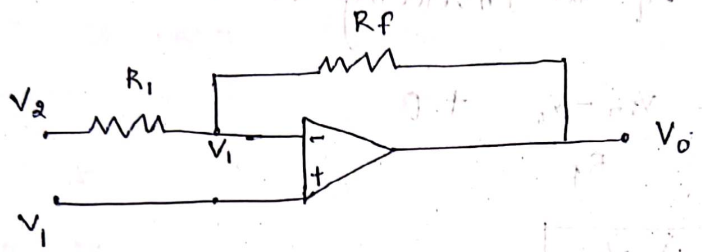
$$\cancel{V_o = \left(1 + \frac{R_1}{R_f}\right) V_{in}}$$

$$\frac{0 - V_{in}}{R_1} + \frac{0 - V_i}{R_f} = 0$$

$$V_o = -\frac{R_f}{R_1}$$

14/11/19

Differential Amplifier :-



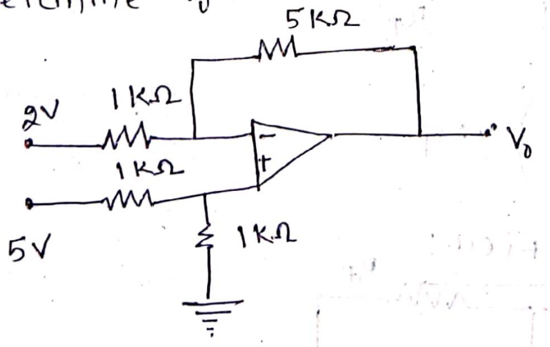
Applying nodal at inverting terminal

$$\frac{V_1 - V_2}{R_1} + \frac{V_1 - V_0}{R_f} + 0 = 0$$

$$\Rightarrow \frac{R_f(V_1 - V_2) + R_1 V_1}{R_1 R_f} = \frac{V_0}{R_f}$$

$$\Rightarrow V_o = \frac{(R_f + R_1)V_1 - R_f V_2}{R_1}$$

Q:- Determine V_0 for the following circuit.



$$\cancel{\frac{5-2}{1} + \frac{5-V_0}{5} + 0 = 0}$$

$$\cancel{\Rightarrow 3 + \left(1 - \frac{V_0}{5}\right) + 0 = 0}$$

~~$\Rightarrow V_5 \neq \frac{V_0}{5}$~~

~~$\Rightarrow V_0 = 12.5$~~

$$V_+ = \frac{5 \times 1K\Omega}{1K + 1K\Omega} = \frac{5}{2} V = 2.5 V$$

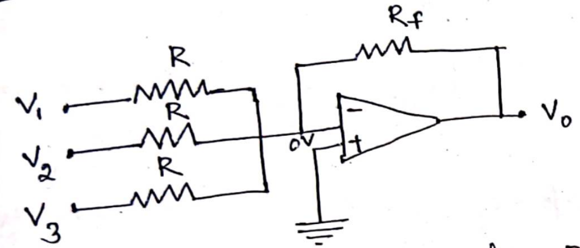
$$V_- = \frac{5}{2} V = 2.5 V$$

Applying nodal at inverting terminal,

$$\frac{2.5 - 2}{1K\Omega} + \frac{2.5 - V_0}{5K\Omega} + 0 = 0$$

$$\Rightarrow \boxed{V_0 = 5V}$$

Summing Amplifier :- (Adder)



Apply nodal at inverting terminal,

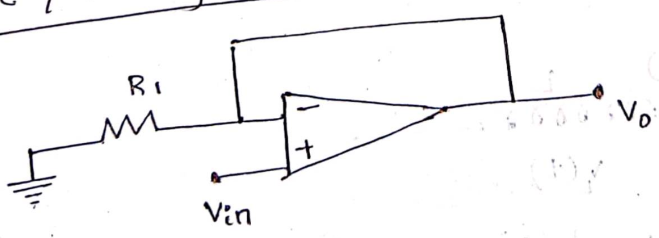
~~$\frac{V_1 - V_2}{R} + \frac{V_1 - V_0}{}$~~

$$\frac{0 - V_0}{R_f} + \frac{0 - V_1}{R} + \frac{0 - V_2}{R} + \frac{0 - V_3}{R} + 0 = 0$$

$$\Rightarrow \frac{0 - V_0}{R_f} + \left(\frac{-1}{R}\right)(V_1 + V_2 + V_3) = 0$$

$$\Rightarrow \boxed{V_0 = \frac{-R_f}{R}(V_1 + V_2 + V_3)}$$

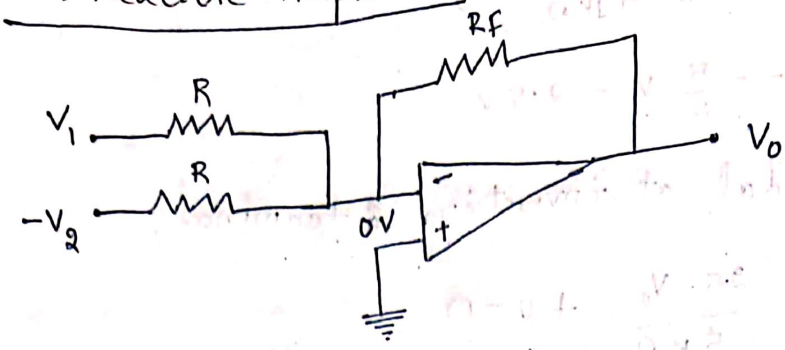
Buffer / voltage follower:-



$V_0 = V_{in}$

gain $= A_V = 1$

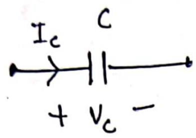
Subtractor Amplifier :-



$$\frac{0-V_0}{R_f} + \frac{0-V_1}{R} + \frac{0+V_2}{R} = 0$$

$$\boxed{V_0 = -\frac{R_f}{R_1}(V_1 - V_2)}$$

Note-1



$$\boxed{I_c = C\frac{dV}{dt}}$$

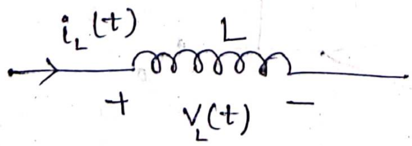
$$\Rightarrow C\frac{dV}{dt} = i_c$$

$$\Rightarrow \frac{dV_c}{dt} = \frac{1}{C}\,t_c$$

$$\Rightarrow \int dV_c = \frac{1}{C}\int i_c\,dt$$

$$\Rightarrow \boxed{V_c(t) = \frac{1}{C}\int_{-\infty}^{t} i_c(t)\,dt}$$

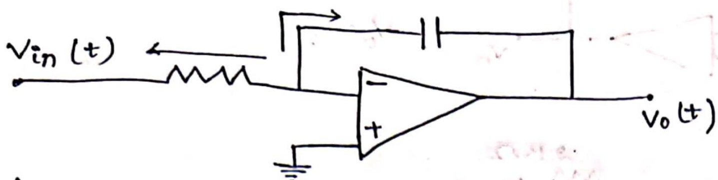
Note-2 Inductor (L)



$$V_L(t) = L\frac{di(t)}{dt}$$

$$\boxed{i_L(t) = \frac{1}{L}\int_{-\infty}^{t} V_L(t)\,dt}$$

Integrator :-



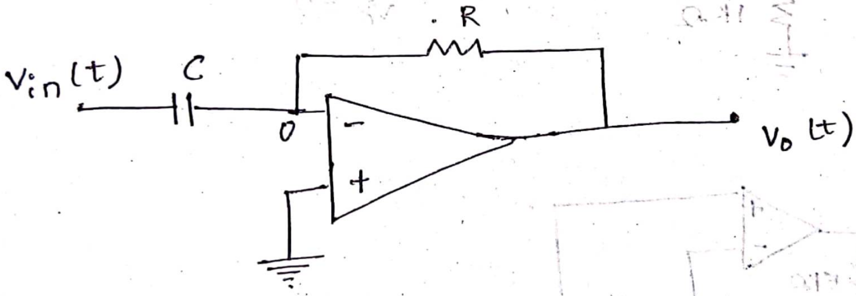
Applying nodal at inverting terminal,

$$\frac{0 - V_{in}(t)}{R} + C \frac{d}{dt}(0 - V_o(t)) + 0 = 0$$

$$\Rightarrow -C \frac{d V_o(t)}{dt} = \frac{V_{in}(t)}{R}$$

$$\Rightarrow \frac{d V_o(t)}{dt} = \frac{-1}{RC} V_{in}(t)$$

$$\Rightarrow \boxed{V_o(t) = -\frac{1}{RC} \int_{-\infty}^{t} V_{in}(t)\, dt}$$

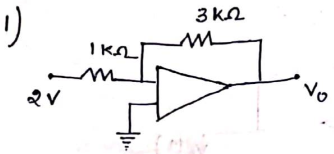


$$C \frac{d}{dt}(0 - V_{in}(t)) + \frac{0 - V_o(t)}{R} + 0 = 0$$

$$\Rightarrow \boxed{V_o(t) = -RC \frac{d}{dt} V_{in}(t)}$$

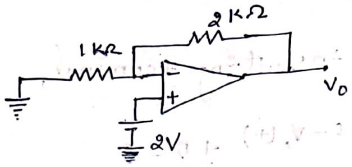
18/11/19

Q:-1)



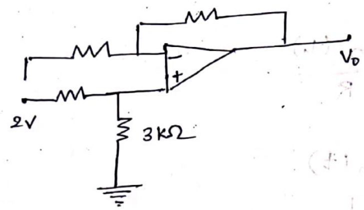
$V_o = ?$

Q:- 2)

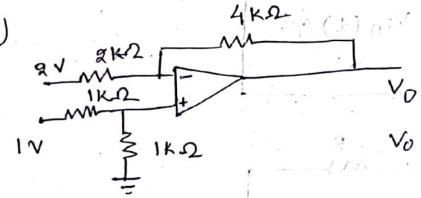


$V_o = ?$

Q:- 3)

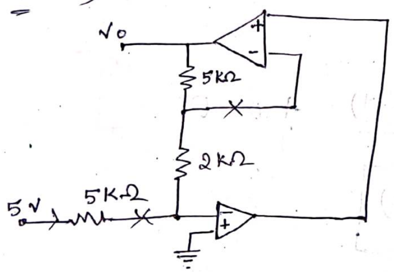


Q:- 4)

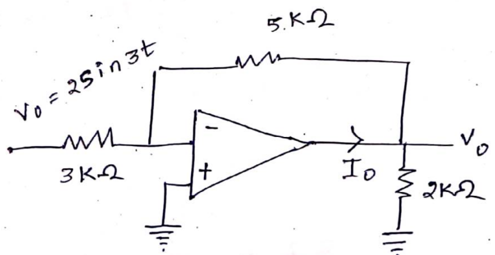


$V_o = ?$

Q:- 5)



Q:- 6)



$V_o = ?$ $I_o = ?$

1) Applying nodal at inverting terminal,

$$\frac{0-V_0}{R_f} + \frac{0-V_1}{R} + 0 = 0$$

$$\Rightarrow V_0 = \frac{-R_f}{R_1}(V_1 - V_2)$$

$$\Rightarrow V_0 = \frac{-3}{1}(2-0)$$

$$\Rightarrow \boxed{V_0 = -6\ V}$$

4) Applying nodal at inverting terminal,

$$\cancel{V_+ = \frac{4\times 2}{2+1} = \frac{8}{3} = 2.6}$$

$3 | 80 | 2.6$

$V_- = \frac{1}{2}\ V = 0.5\ V$

$$\frac{0.5-2}{2} + \frac{0.5-V_0}{4} = 0 \Rightarrow \frac{-3+0.5-V_0}{4} = 0$$

$$\Rightarrow -2.5 - V_0 = 0 \Rightarrow \boxed{V_0 = -2.5\ V}$$

2) $$\frac{2-0}{1K} + \frac{2-V_0}{2K} + 0 = 0$$

$$\Rightarrow V_0 = \left(1+\frac{2}{1}\right)\times 2 = 3\times 2 = 6\ V$$

$$\Rightarrow \boxed{V_0 = 6\ V}$$

3) $$V_+ = \frac{2\times 3K}{3K+3K} = 1\ V$$

$$\frac{1-0}{6K} + \frac{1-V_0}{6K} + 0 = 0$$

$$\Rightarrow \boxed{V_0 = 2V}$$

5) Here ; $$\frac{0-5}{5K} + \frac{0-V_0}{7K} + 0 = 0$$

$$\Rightarrow \frac{-35-5V_0}{35} = 0 \Rightarrow -35-5V_0 = 0 \Rightarrow 5V_0 = -35$$

$$\Rightarrow \boxed{V_0 = -7V}$$

6) $\frac{0 - V_{in}}{3K} + \frac{0 - V_0}{5K} + 0 = 0$

$\Rightarrow V_0 = \frac{-5}{3} V_{in}$

$= \frac{-10}{3} \sin 3t \ V$

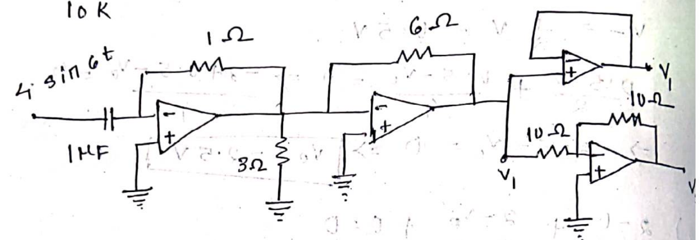
Applying KVL ;

$-I_0 + \frac{V_0 - 0}{5K} + \frac{V_0 - 0}{2K} = 0$

$\Rightarrow \frac{V_0}{5K} + \frac{V_0}{2K} = I_0$

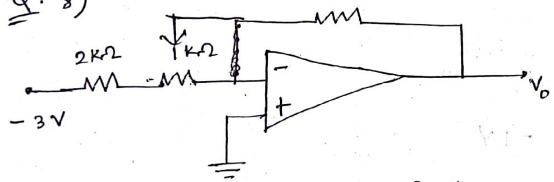
$\Rightarrow I_0 = \frac{7V_0}{10K} = \frac{-7}{3} \sin 3t \ mA .$

Q:- 7)



Find relationship betn V_1 & V_2.

Q:- 8)



Find the range of V_0.

Ans :-

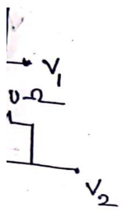
7) $\frac{0 - V_2}{10} + \frac{0 - V_1}{10} = 0$

$\Rightarrow \frac{-V_2}{10} = \frac{V_1}{10}$

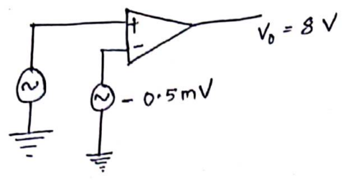
$\Rightarrow \boxed{V_1 = -V_2}$ or $\boxed{V_2 = -V_1}$

8) $V_0 = \frac{-1}{\cancel{3}} \times \cancel{-3} = 1V$

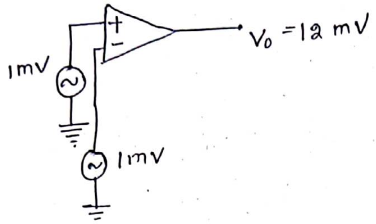
$V_0 = \frac{-1}{2} \times -3 = \frac{3}{2} = 1.5\,V$



Q:- For an experimental set up, which op-Amp as shown below:-



CMRR = ?



$$CMRR = \frac{A_d}{A_c}$$

$$A_d = \frac{V_{id}}{V_{id}} = \frac{8V}{V_1 - V_2} = \frac{8\,V}{0.5 + 0.5mV} = 8000.$$

$$A_c = \frac{V_{oc}}{\left(\frac{V_1 + V_2}{2}\right)} = \frac{12\,mV}{1\,mV} = 12$$

$$CMRR = \frac{8000}{12} \rightarrow \text{Absolute state}$$

$$CMRR|_{dB} = 20\log_{10}\left(\frac{8000}{12}\right) dB.$$

Q:- Determine the o/p voltage of Op-Amp for the i/p voltage $V_{11} = 200\,\mu V$, $V_{12} = 140\,\mu V$. The amplifier has the differential gain $A_d = 6000$ and CMRR is 200.

$V_{11} = 200\,\mu V$

$V_{12} = 140\,\mu V$

$CMRR = 200$

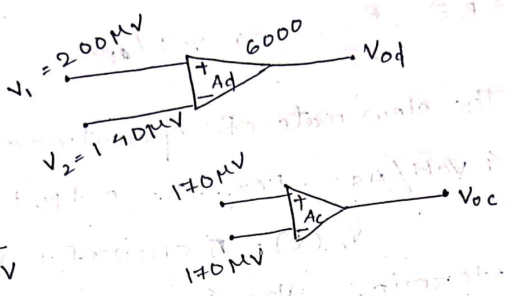
$A_d = 6000$

$V_{id} = V_{i1} - V_{i2} = 200 - 140 = 60 \mu A$

$V_{ic} = \dfrac{V_{i1} + V_{i2}}{2} = 170 \mu V.$

$CMRR = \dfrac{A_d}{A_c}$

$\Rightarrow \cancel{200} = \dfrac{\overset{30}{\cancel{6000}}}{A_c}$



$\Rightarrow \boxed{A_c = 30}$

$A_d = \dfrac{V_{od}}{V_{id}} = \dfrac{V_{od}}{60 \mu V}$

$\Rightarrow V_{od} = 6000 \times 60 \mu V$

$= 360 mV.$

$A_c = \dfrac{V_{oc}}{V_{ic}} = \dfrac{V_{oc}}{170 \mu V}$

$\Rightarrow V_{oc} = 30 \times 170 \mu V = 5100 = 5.1 mV$

$V_D = V_{od} + V_{oc}$

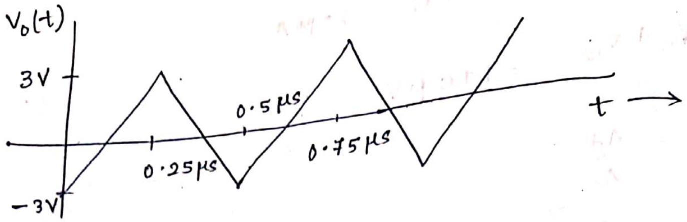
$= 360 + 5.1 = 365.1 \ mV.$

Slew Rate:-

This is the characteristics of Op-Amp and defined as max^m rate of change of o/p for any applied input.

Mathematically, $SR \triangleq \left.\dfrac{dV_B}{dt}\right|_{max.} \left(Volt/\mu s \right)$

Q:- Determine the slew rate ;



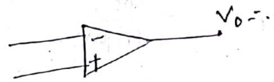
$$SR \triangleq \frac{6}{0.25} = 24 \text{ Volt}/\mu s.$$

Q:- The slew rate of operational amplifier is 24 Volt/μs. For the output ~~$V_o = A_M \sin 2\pi F_m t$~~

$$V_o(t) = 5 \sin 2\pi f_o t \text{ V.}$$

Determine the frequency of O/P signal of Op-Amp.

$$SR \triangleq = 24 \text{ Volt}/\mu s.$$



$$Sl = \left.\frac{dV_B}{dt}\right|_{max}$$

$$= 10\pi f_o \cos 2\pi f_o t \Big|_{max}$$

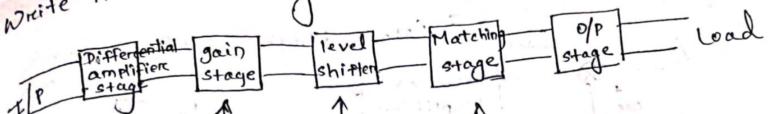
$$24 \text{ V}/\mu s = 10\pi f_o$$

$$f_o = \frac{24}{10\pi} \times 10^6 \text{ Hz} = \frac{24}{\pi} \text{ MHz}$$

Significance of slew rate:-

→ It is used to calculate the frequency of O/P signal and also used to calculate the max^m swing in O/P signal.

Write the block diagram of Op-Amp :-



$V_0 = A_d(V_1 - V_2)$

gain

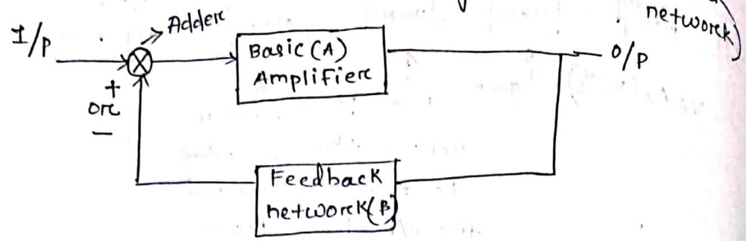
Used to remove the dc part at the o/p of gain stage.

Used to transfer the max^m power of level shifter to the o/p stage

25/11/19

Feedback Amplifier :-

(Block diagram of feedback network)



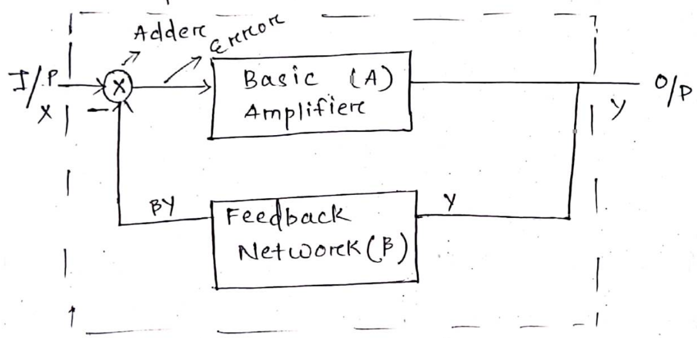
→ Feedback network is used to ~~feedback circuit~~ control the O/P of the system by adding or substracting some part of O/P in the I/P

Types of feedback :-

(1) Negative Feedback :-

→ It is also known as degenerative circuit.

Ex :- All amplifiers.



$$\boxed{error = x - \beta Y}$$

$$\boxed{Y = A \cdot error}$$

$\Rightarrow Y = A(x - \beta Y)$

$\Rightarrow Y = Ax - A\beta Y$

$\Rightarrow Y + A\beta Y = AX$

$\Rightarrow Y(1 + A\beta) = AX \Rightarrow \boxed{\frac{Y}{X} = \frac{A}{1 + A\beta}}$ = Gain of −ve feedback ~~network~~ amplifier

Concept of –ve feedback:-

→ All the o/p should be reached at the i/p of the feedback (β) network, if the o/p is voltage the connection ~~of~~ β betn i/p & β network and o/p ~~connection~~ must be in shunt / parallel.

→ If the o/p is current, then the connection betn i/p of β network and o/p must be in series.

→ Input & output of β network are connected in ~~a~~ such a mannere that, both will have significance.

→ If the i/p is current, i/p & o/p of an β network must be connected in parallel.

→ If the i/p is voltage i/p & o/p of β network must be in series.

27/11/1

−Ve feedback connection types OR (types of −Ve feedback amplifiers) :- (Topology)

→ There are 4 types of feedback amplifier

(i) Voltage amplier

(ii) Current amplier

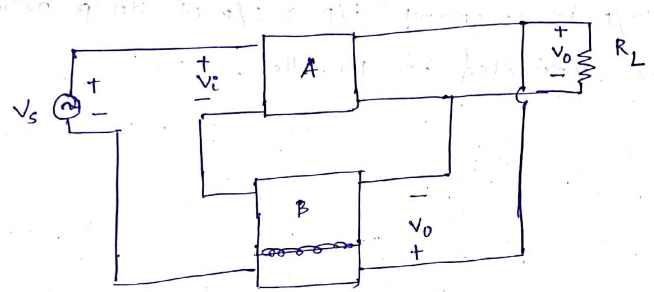
(iii) Trans impedance

(iv) Trans conductance.

Voltage Amplier :-

OR voltage-series or series-shunt.

→



$V_f = BV_o$

Gain with feedback = $A_f \triangleq \frac{V_o}{V_s}$

$A_f = \frac{V_o}{V_s}$

Applying KVL at I/P,

$V_s - V_i - V_f = 0$

$\Rightarrow V_s = V_i + V_f$

$$\boxed{A = \frac{V_o}{V_i}}$$

$$A_f = \frac{V_o}{V_s}$$

$$= \frac{V_o}{V_i + V_f} = \frac{\frac{V_o}{V_i}}{\frac{V_i + V_f}{V_i}}$$

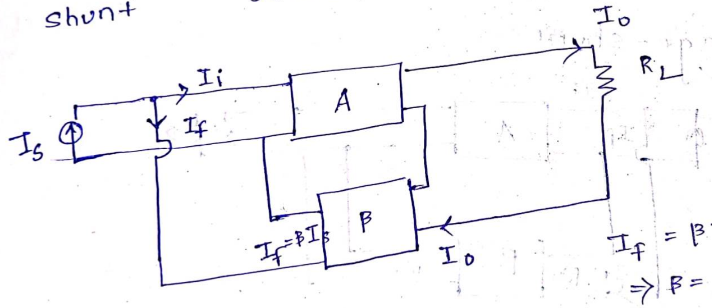
$$= \frac{A}{1 + \frac{V_f}{V_i}} = \frac{A}{1 + \frac{V_f}{V_o} \times \frac{V_o}{V_i}}$$

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

Current Amplifier :-

OR shunt-series OR current shunt

I/P	O/P
I	I
shunt	series



$I_f = \beta I_s$

$\Rightarrow \beta = \frac{I_f}{I_s}$

$$A_f = \frac{I_o}{I_s}$$

Applying KCL at input

$$I_s = I_i + I_f$$

$$A_f = \frac{I_o}{I_i + I_f}$$

$$A = \frac{I_o}{I_i}$$

$$A_f = \frac{\frac{I_o}{I_i}}{\frac{I_i + I_f}{I_i}}$$

$$= \frac{A}{1 + \frac{I_f}{I_i}}$$

$$= \frac{A}{1 + \frac{I_f}{I_o} \times \frac{I_o}{I_i}} = \frac{A}{1 + \beta A}$$

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

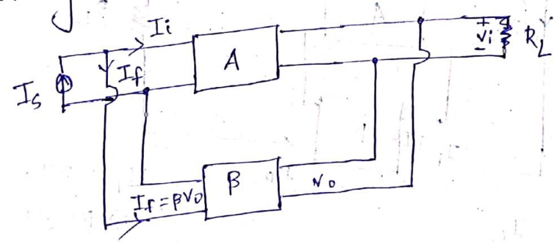
Trans-impedance :-

$\frac{I/P}{I}$ $\frac{O/P}{V}$

shunt shunt

Name :- shunt-shunt

Voltage-shunt



$I_f = \beta V_o \Rightarrow \beta = \frac{I_f}{V_o}$

Here, $A_f = \frac{V_o}{I_s}$

Applying KCL at I/P

$I_s = I_i + I_f$

$A_f = \frac{V_o}{I_i + I_f}$

$$= \frac{\frac{V_o}{I_i}}{\frac{I_i + I_f}{I_i}}$$

$$= \frac{A}{1 + \frac{I_f}{I_i}}$$

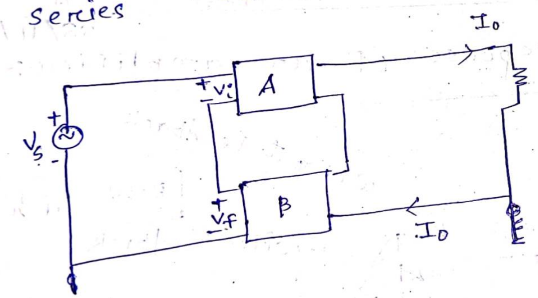
$$= \frac{A}{1 + \frac{I_f}{V_o} \cdot \frac{V_o}{I_i}}$$

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

Trans - conductance :-

(series - series or Current series)

$\frac{I/P}{V}$ series $\qquad \frac{O/P}{I}$ series



$$A_f = \frac{I_o}{V_s}$$

Applying KVL at I/P. ;

$$V_s = V_i + V_f$$

$$A_f = \frac{\frac{I_o}{V_i}}{\frac{V_s}{V_i}} = \frac{\frac{I_o}{V_i}}{\frac{V_i + V_f}{V_i}}$$

$$\Rightarrow A_f = \frac{A}{1+\frac{V_f}{V_i}}$$

$$= \frac{A}{1+\frac{V_f}{I_o}\cdot\frac{I_o}{V_i}}$$

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

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

I/P imp.

★. Voltage Amplifier $\rightarrow A_{V_f} = \frac{A_V}{1+A_V\beta}$ $\uparrow Z_{if} = Z_i(1+A\beta)$

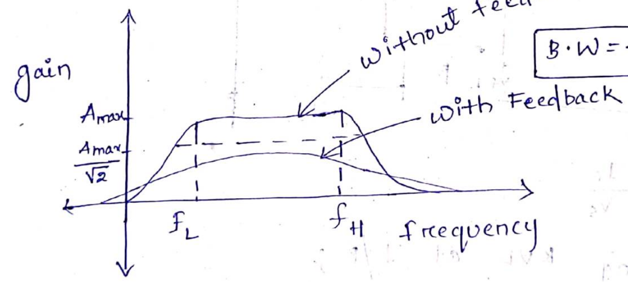
★. Current Amplifier $\rightarrow A_{I_f} = \frac{A_I}{1+A_I\beta}$ $\downarrow Z_{if} = \frac{Z_i}{1+A\beta}$

★. Trans ~~Amplifiers~~ impedance $\rightarrow A_{Z_f} = \frac{A_Z}{1+A_Z\beta}$ $\downarrow Z_{if} = \frac{Z_i}{1+A\beta}$

★. Trans conductance $\rightarrow A_{gf} = \frac{A_g}{1+A_g\beta}$ $\uparrow Z_{if} = Z_i(1+A\beta)$

28/11/19

Frequency response of an amplifier:—



$\boxed{B\cdot W = f_H - f_L}$

★ Note :-

$\boxed{\text{Gain}\downarrow \times B\cdot W\uparrow = \text{Constant}}$

$$B\cdot W|_f = (1+A\beta)\, B\cdot W$$

The B.W of amplifier will increase the

amplifier with -ve feedback by factor of $(1+A\beta)$ term.

Distortion (Noise) :- ↓

$$\boxed{D_f = \frac{D}{1+A\beta}}$$

Advantages :- Negative feedback produces the stable output by reducing the gain.

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

$A_f \rightarrow$ Gain with feedback

$A \rightarrow$ Gain without feedback (openloop gain)

$\beta \rightarrow$ Feedback factor

$A\beta \rightarrow$ Closed loop gain.

O/P imp.

$\downarrow Z_{of} = \frac{Z_o}{1+A\beta}$

$\uparrow Z_{of} = Z_o(1+A\beta)$

$\downarrow Z_{of} = \frac{Z_o}{1+A\beta}$

$\uparrow Z_{of} = Z_o(1+A\beta)$

→ Negative feedback enhances the i/p impedance of voltage amplifier.

→ -ve feedback reduces the o/p impedance of voltage amplifier. $Z_{if} = Z_i(1+A\beta)$

$$Z_{of} = \frac{Z_o}{1+A\beta}$$

→ -ve feedback enhances the $B.W|_f = (1+A\beta)\, B.W$

→ -ve feedback reduces the noise (distortion).

$$D_f = \frac{D}{1+A\beta}$$

Q:- When -ve voltage feedback is applied to an amplifier with gain $(A) = 1000$. Overall gain false to $A_f = 6$. Calculate the feedback factor (β) ?

Ans :- $A = 1000$

$A_f = 6$

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

$\Rightarrow 6 = \frac{1000}{1+1000\beta}$

$\Rightarrow 6 + 6000\beta = 1000$

$\Rightarrow 6000\beta = 1000 - 6$

$\Rightarrow \beta = \frac{1000-6}{6000} = \frac{994}{6000} = 0.16$

Q:- The gain & distortion of an amplifier are 150 & 5% respectively without feedback. If the stage has 10% of its o/p voltage apply as -ve feedback, Find the distortion of amplifier with -ve feedback.

Ans :- $A = 150$

$D = 5\%$

$\beta = 10\% = \frac{1}{10}$

$$D_f = \frac{D}{1+A\beta} = \frac{5\%}{1+15\cancel{0}\times\frac{1}{1\cancel{0}}} = \frac{5\%}{16} = 0.003.$$

Q: Determine the voltage gain, i/p & o/p impedance with feedback for a voltage series feedback having $A = -100$, $R_i = 10 k\Omega$, $R_o = 20 k\Omega$. (a) $\beta = -0.1$

(b) $\beta = -0.5$

(a) $A_f = \frac{A}{1+A\beta} = \frac{-100}{1+(-100)(-0.1)} = \frac{-100}{101} = -0.9$

$Z_{if} = Z_i(1 + A\beta) =$

$Z_{of} = \frac{Z_o}{1+A\beta} =$

Q:- If an amplifier with gain $A = -1000$, with $\beta = -0.1$ has a gain change of 20% due to temperature. Calculate the change in gain of calculate feedback.

Ans:- $A = -1000$ $\quad$ $1000 \times \frac{1}{10}$

$\beta = -0.1$

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

$$\frac{dA_f}{dA} = \frac{(1+A\beta)1 - A(\beta)}{(1+A\beta)^2} = \frac{1}{(1+A\beta)^2}$$

$$dA_f = \frac{dA}{(1+A\beta)^2} = \frac{20\%}{1+(-1000)(-0.1)} = \frac{20\%}{1+100}$$

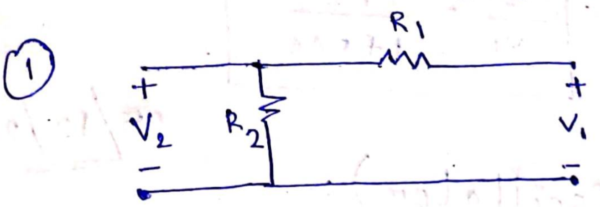
$$= \frac{\frac{20}{100}}{101} = \frac{1}{505} = 0.0019.$$

Wednesday.

02/12/19

—0—

(1)



$\frac{V_2}{V_1} = ?$

$\frac{R_2}{R_1+R_2}$

In series, voltage division occurs.

$$V_2 = \frac{V_1 R_2}{R_1 + R_2}$$

$$\Rightarrow \frac{V_2}{V_1} = \frac{R_2}{R_1 + R_2}.$$

★. Impedance offered by capacitor, $\frac{1}{j}\frac{1}{\Omega C} = \frac{1}{2\pi f C}$
inductor, $= j\omega L$ = ohm
resistor, = R.

↓

Unit = ohm

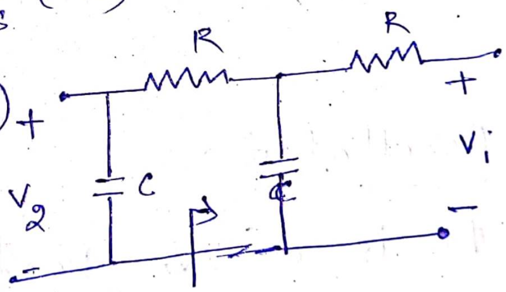
L = 1 Henry.

$i, j = \sqrt{-1}$

★. $Z_C = \frac{1}{j\omega C} = \frac{-1}{\omega C} = \frac{1}{CS}\ (\Omega)$

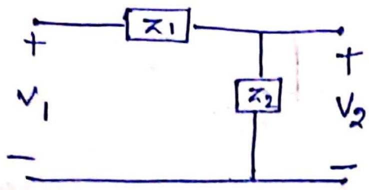
★. $Z_L = j\omega L = LS\ (\Omega)$

★. $\boxed{Z = R + jX}$



★. $S = \cancel{\sigma}^{0} + j\omega$

★. NOTE :-



$$\boxed{V_2 = \frac{V_1 \times Z_2}{Z_1 + Z_2}}$$

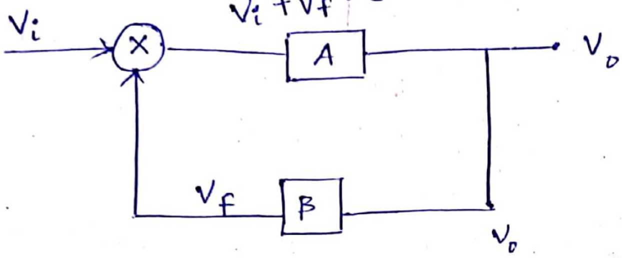
Z = Impedance

$$\Rightarrow V_2 = \frac{V_1 \times \frac{1}{CS}}{R + \frac{1}{CS}} = \frac{V_1}{RCS + 1}$$

$$\boxed{\frac{V_2}{V_1} = \frac{1}{1 + RCS}}$$

05/12/2019

Positive Feedback (Oscillator) :-



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

e → error.

$$\frac{V_o}{e} = A$$

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

$$\Rightarrow V_o = eA = (V_i + V_f)A$$

$$= V_i A + \beta V_o A$$

$V_o = \sin \omega_o t$.

$$V_o(1 - A\beta) = V_i A$$

$$\boxed{A_f = \frac{V_o}{V_i} = \frac{A}{1 - A\beta}}$$

Oscillator :-

It is a +ve feedback circuit in which there is no external input is applied and its generate and produces a sino-sodial signal (single frequency component).

Sustain Oscillator :-

When the O/P signal is a sinosodial with one frequency and the peak amplitudes are fixed that signal is known as sustain oscillated signal.

Condition for sustain oscillation :-

(Bark hansen's critarion of principle)

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

$$1 - A\beta = 0$$

$$A\beta = 1 = 1 + j0 = 1 \angle 0^\circ \text{ or } 360^\circ$$

$$|A\beta| = 1 \quad , \quad \angle AB = 360^\circ$$

$$i = j = \sqrt{-1}$$

$$|z| = \sqrt{x^2 + y^2} \quad \theta = \tan^{-1}\left|\frac{y}{x}\right|$$

$$z = x + iy$$

$$= |z| e^{j\theta}$$

$$= |z| \angle \theta$$

$\beta \rightarrow$ May be real or may be complex.

$$z = 1 + j1$$

$$= \sqrt{2} \angle 45^\circ$$

gain = Real number

i.e A = real.

$$z = j = 0 + j1$$

$$= 1 \angle 90^\circ$$

$$z = 1 + j0$$

$$= 1 \angle 0^\circ \text{ or } 360^\circ$$

$\beta \rightarrow$ Feedback factor / Gain of β network.

$A \rightarrow$ Gain of basic amplifier / Gain without feedback

$A\beta \rightarrow$ Loop gain.

Principles :-

1. Magnetude of loop gain = 1

$|A\beta| = 1$ (magnitude condⁿ)

2. Phase of Loop gain = 360°.

$\angle A\beta = 360^\circ$. (Phase condⁿ)

3. $\beta = \beta_r + j\beta_i$

For sustain oscillator,

$A\beta = 1$

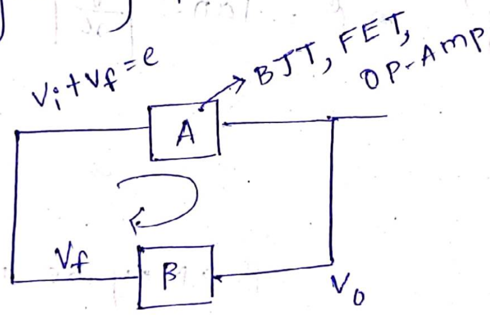
$A(\beta_r + \cancel{j\beta_i}^{\,0}) = 1$

$Im(\beta) = \beta_i = 0$ (It must be 0).

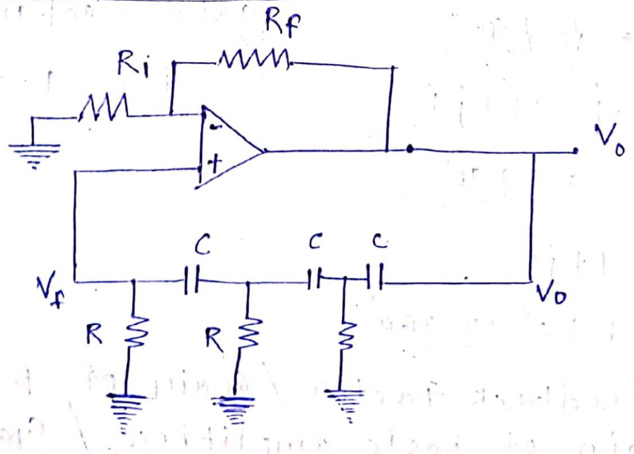
Procedure to calculate frequency of Oscillat. (ω_0, F_0)

→ calculate β.

→ Put imaginary part of β to calculate F_0.



RC phase shift oscillator:-



Note :-

$$Z_c = \frac{1}{j\omega c} = \frac{1}{sc}$$

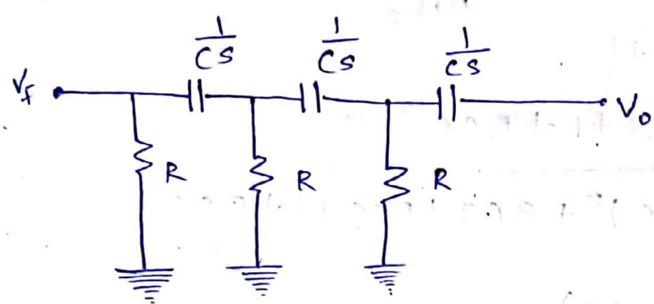
$$Z_L = j\omega L = SL$$

$$Z_R = R$$

Q.1 ← 1 mark compulsory.

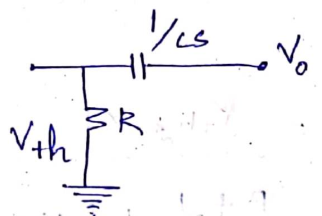
2, 3, 4, 5, 6 } 2 mark

7, 8, 9, 10, 11 } Lq.



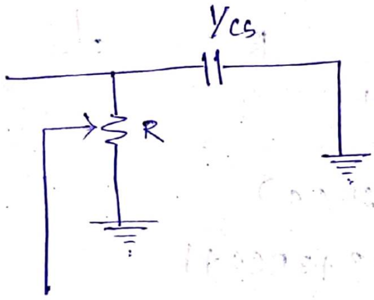
Derivation of frequency of oscillator:-

$$V_{th_1} = \frac{V_0 \times R}{R + \frac{1}{CS}}$$



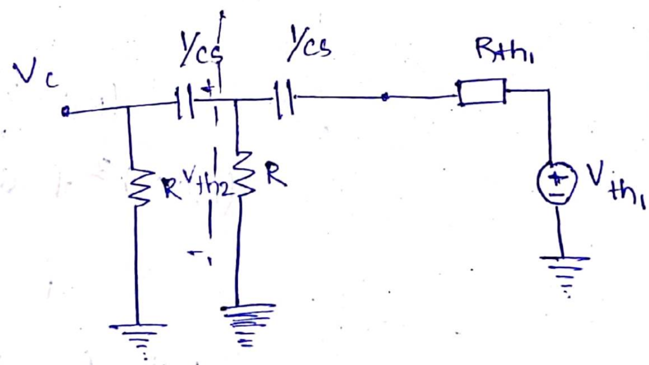
$$= \frac{V_o RCS}{RCS + 1}$$

R_{th_1}



R_{th_1}

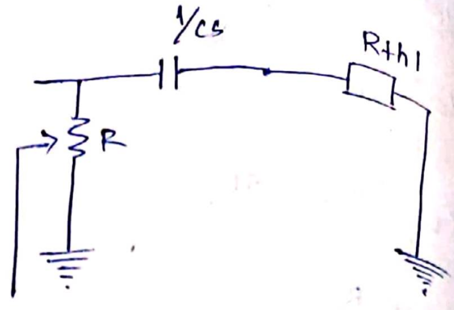
$$R_{th_1} = \frac{R \times \frac{1}{CS}}{R + \frac{1}{CS}}$$



$$V_{th_2} = \frac{V_{th_1} R}{\frac{1}{CS} + \frac{R}{RCS+1} + R}$$

$$= \frac{\frac{V_0 RCS}{\cancel{1+RCS}} \cdot R}{\frac{1+RCS + RCS + (RCS)^2 + RCS}{CS(\cancel{1+RCS})}}$$

$$= \frac{V_0 (RCs)^2}{(RCs)^2 + 3RCs + 1}$$



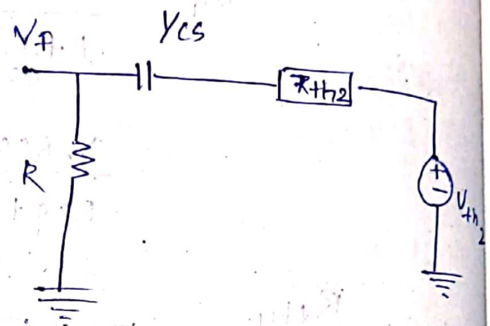
Rth2

$$R_{th2} = \frac{R\left(\frac{1}{Cs} + \frac{R}{RCs+1}\right)}{R + \frac{1}{Cs} + \frac{R}{RCs+1}}$$

$$R_{th2} = \frac{R(RCs + 1 + RCs)}{(RCs)^2 + RCs + RCs + 1 + RCs}$$

$$= \frac{R(1 + 2RCs)}{(RCs)^2 + 3RCs + 1}$$

$$V_f = \frac{V_{th_2} \times R}{R + \frac{1}{Cs} + R_{th_2}}$$



$$= \frac{\dfrac{V_0 (RCs)^2}{(RCs)^2 + 3RCs + 1} R}{R + \frac{1}{Cs} + \dfrac{R(1+2RCs)}{(RCs)^2 + 3RCs + 1}}$$

$$\boxed{\begin{array}{l} s = j\omega \\ s^2 = -\omega^2 \\ s^3 = -j\omega^3 \end{array}}$$

$$\beta = \frac{V_f}{V_0} = \frac{(RCs)^3}{(RCs)^3 + 3(RCs)^2 + RCs + (RCs)^2 + 3RCs + 1 + RCs + 2(RCs)^2}$$

$$= \frac{(RCs)^2}{(RCs)^3 + 6(RCs)^2 + 5RCs + 1}$$

$$= \frac{1}{1 + \frac{6}{RCs} + \frac{5}{(RCs)^2} + \frac{1}{(RCs)^3}}$$

$$= \frac{1}{1 - \frac{j6}{RC\omega} - \frac{5}{R^2C^2\omega^2} + j\frac{1}{R^3C^3\omega^3}}$$

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$$\Rightarrow \beta = \frac{1}{1 - \frac{5}{R^2c^2\omega^2} - j\left(\frac{6}{RC\omega} - \frac{1}{R^3c^3\omega^3}\right)}$$

For sustain oscillation,

$$\frac{6}{RC\omega} - \frac{1}{R^3c^3\omega^3} = 0$$

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

$$\Rightarrow 6R^2c^2\omega^2 = 1$$

$$\Rightarrow \omega^2 = \frac{1}{6R^2c^2}$$

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

$$\Rightarrow F_0 = \frac{1}{2\pi\sqrt{6}\,RC}$$

$A\beta_{R} = 1$

$$\Rightarrow A \frac{1}{1 - \frac{5}{R^2c^2\omega^2}} = 1$$

$$\Rightarrow A = 1 - \frac{5}{R^2c^2\omega^2}$$

$$\Rightarrow A = 1 - \frac{5}{\cancel{R^2}\cancel{c^2} \times \frac{1}{6\cancel{R^2}\cancel{c^2}}} = 1 - 30 = -29$$

$$\Rightarrow A = -29$$

60