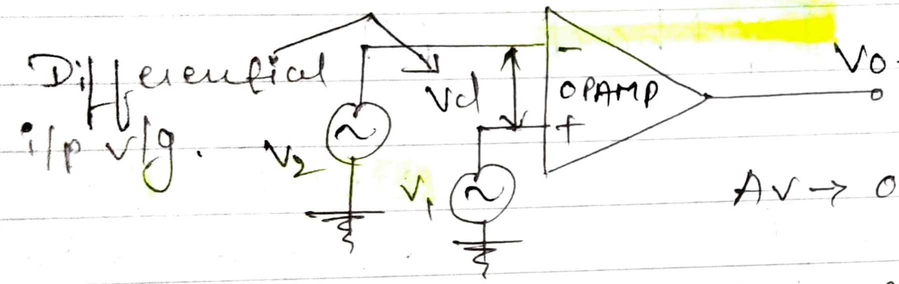
→ OPAMP works in
- Open loop Configuration (without feedback)
- Closed loop Configuration. (with feedback)

→ Open loop Configuration

➤ It means there is no feedback present from output to the i/p. ie. no part of output is connected to the i/p.



$V_0 = Av.Vd$

$Av \rightarrow$ open loop gain.

OPAMP in Open loop Configuration.

→ V_1 is applied to non-inverting terminal & V_2 is applied to inverting terminal.

→ Vd is the differential i/p to the OPAMP $= V_1 - V_2$.

→ Av is the open loop gain & it is very high.
o/p v/g is given by, $V_0 = Av.Vd = Av(V_1 - V_2)$.
$= \pm Vsat$.

because maximum value of $V_0 = \pm Vsat$.

→ Depending upon polarity of i/p ie. 'Vd', o/p will change from +Vsat or −Vsat.

→ As the value of 'Av' is very high, very small value of Vd will drive OPAMP in to +Vsat or −Vsat so 'Vo' is not propotional to ~~o/p~~ 'Vd' ∴ open loop configuration is not used for linear appⁿ.

[ie. → that is, Appⁿ → Application]

→ Features of Open loop Config.

No feedback, High R_i, Low R_o, Very high 'AV', large Bandwidth, Can't used as linear ampr.

→ Closed loop Configuration of OPAMP.

In this feedback is given to the i/p from its output. i.e. Some part of o/p is given to the i/p.

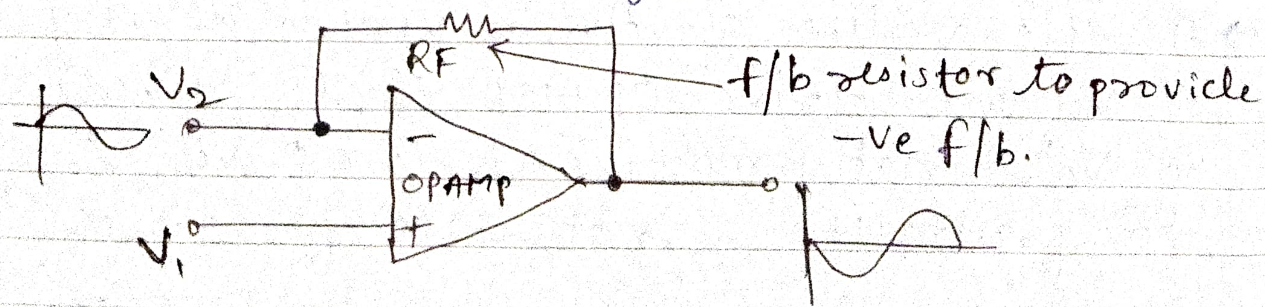
Feed back (f/b)

- Positive f/b i.e. regenerative f/b.
- Negative f/b i.e. Degenerative f/b.

• +ve f/b → When i/p original s/g & f/b s/g are in phase with each other, then it is called '+ve f/b'. Eg. in appn such as Oscillator, Schmitt trigger.

• -ve f/b → When feedback s/g & original s/g are 180° out of phase then it is called as '-ve f/b'.

→ In OPAMP as an ampr feedback Resistor 'R_F' is connected between o/p & inverting i/p to introduce -ve feedback.
As o/p & i/p are 180° out of phase it is -ve f/b.



[s/g → Signal, f/b → feedback, ampr → amplifier]

Chintan Jethva

→ Advantages of -ve f/b.

(Why -ve f/b is used?)

- → Ri is more & Ro is less.
- → It Reduces distortion.
- → It increases Bandwidth
- → It reduces & stabilizes gain
- → Reduces effect of variations in temperature & supply voltage on the o/p of OPAMP.

As gain ∞, small i/p required, Also distortion of noise ∴ to reduce gain -ve f/b required.

→ Comparison of Open loop & Closed loop Config.

	Open loop Config.	Closed loop Config.
Type of f/b.	No feedback	+ve or -ve f/b.
v/g gain	Very high	low
Ri	Very high	Depends on ckt
Ro	Low	Very low
Bandwidth	High	Very high
Drawback	Waveform Distor^n	Low gain.
App^n.	Comparator	Linear amp^r, osc^r etc

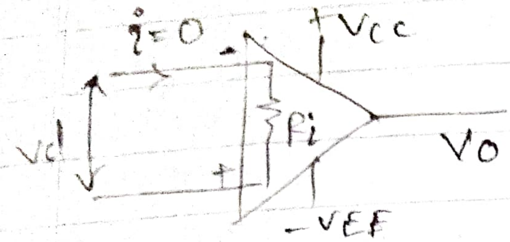
→ Virtual Short & Virtual Ground Concept.

It means the potential difference bet^n two i/p terminal of OPAMP is zero. i.e. both the i/p have the same potential.

→ Virtual Short

Ideally i/p Resistance of OPAMP is '∞'. So c/n folowing from one terminal to other will be zero ∴ v/g drop across 'Ri' will be zero & both i/p ~~will~~ will be at same potential means vitually shorted.

[Distor^n → Distortion, Osc^r → Oscillator, amp^r → amplifier]



$V_o = A_V \cdot V_d$ & $V_d = V_o / A_V$.

But ideally $V_d = 0$ ie. $V_1 - V_2 = 0$

$\therefore V_1 = V_2$.

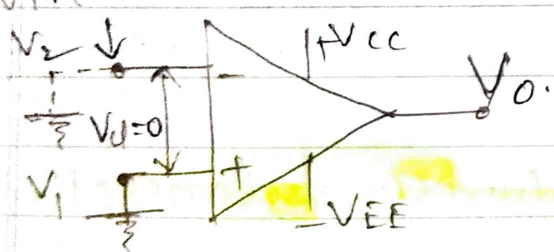
> **Virtual Ground**

> If non-inverting terminal is connected to ground then because of the 'Virtual short' concept as ~~we know~~ above ie. $V_1 = V_2$, the inverting terminal will also be at ground potential.

> Thus actually inverting terminal is not connected to ground but the potential is zero $\therefore$ it is said to be Virtual ground.

It can be also possible if inverting terminal is grounded.

Virtual Ground



$V_d = V_1 - V_2 = 0$ ... Virtual short.

& here $V_1 = 0$

$\therefore V_2 = 0$ ... as $V_1 = V_2$

→ **OPAMP.**

Open loop Config.
- → Inverting ampr
- → Non Inverting ampr
- → Differential ampr

Closed loop Config.
- → Inverting ampr
- → Non Inv. ampr
- → Differential ampr.

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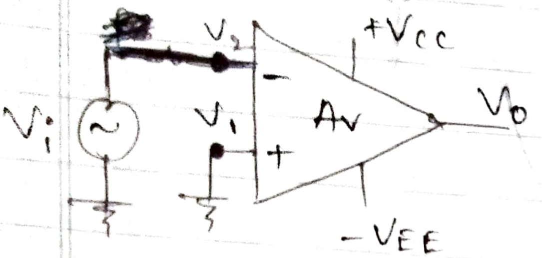
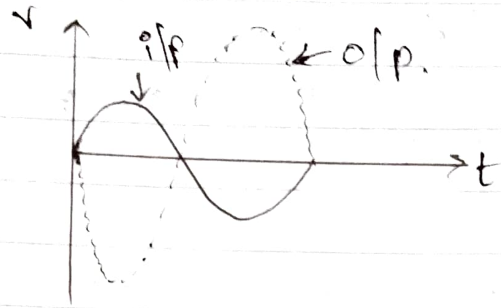
Open loop amplifier.

i) Inverting ampr → I/p is applied to Inv. terminal & other terminal is connected to gnd.



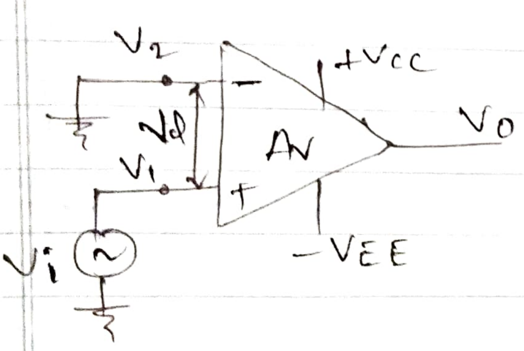


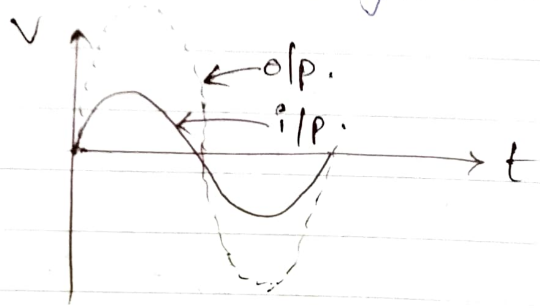
$V_o = Av \cdot Vd = Av(V_1 - V_2)$ but $V_2 = V_i$ & $V_1 = 0$.

$\therefore V_o = Av(-V_i)$ i.e. $V_o = -Av \cdot V_i$

The -ve sign indicates that o/p is 180° out of phase. ie. o/p is inverted ∴ known as inverting ampr.

ii) Non Inverting ampr → I/p is applied to Non inv. & Inv. terminal is connected to ground.



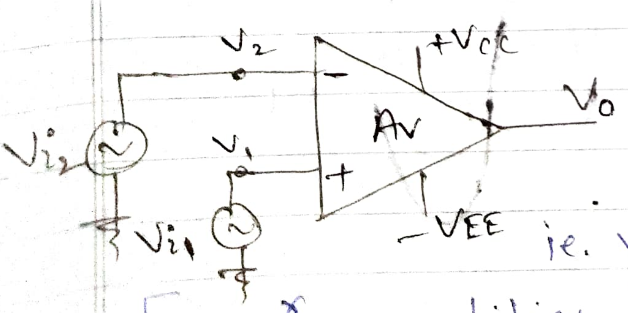


Here $V_o = Av \cdot Vd = Av(V_1 - V_2)$ ... but $V_1 = V_i$ & $V_2 = 0$.

$\therefore V_o = Av(V_i) = AV_i$.

Thus there is no phase shift between i/p & o/p. ∴ known as non-inverting amplifier.

(iii) Differential ampr → I/p if applied to both terminal



$V_o = Av \cdot Vd = Av(V_1 - V_2)$

but $V_1 = V_{i_1}$ & $V_2 = V_{i_2}$

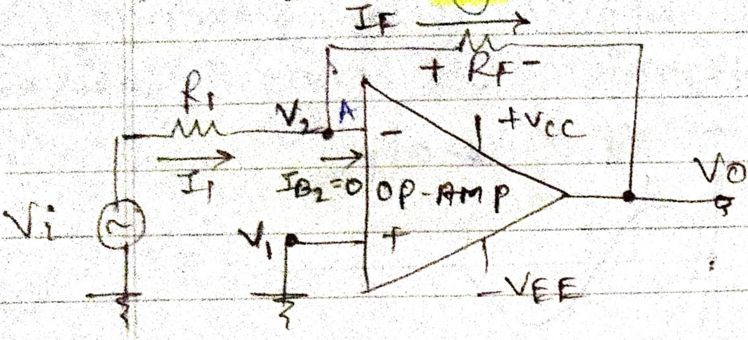
$\therefore V_o = Av(V_{i_1} - V_{i_2})$

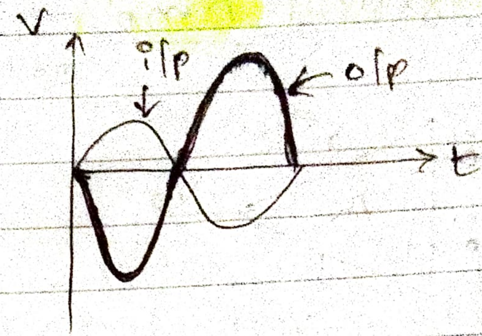
ie. Vo is depends on both i/p.

[ampr → amplifier]

→ Closed loop amplifiers.

i) Inverting ampr → I/P applied to Inv. terminal.





Applying KCL at point 'A',

$I_1 = I_{B_2} + I_F \rightarrow ①$

But $I_{B_2} = 0$ --- Since $R_i = \infty$ ie. c/n flowing to OPAMP is zero.

$\therefore I_1 = I_F \rightarrow ②$

By ohm's law $I = V/R$

$\therefore I_1 = \frac{V_i - V_2}{R_1}$ & $I_F = \frac{V_2 - V_0}{R_F}$

$\therefore \frac{V_i - V_2}{R_1} = \frac{V_2 - V_0}{R_F}$

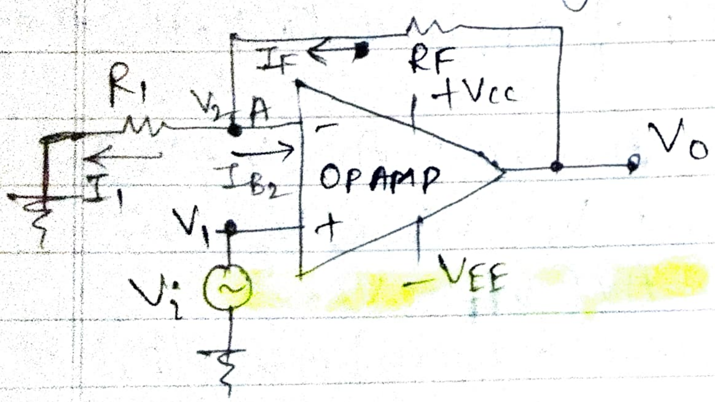
But $V_2 = 0$ --- virtual ground concept.

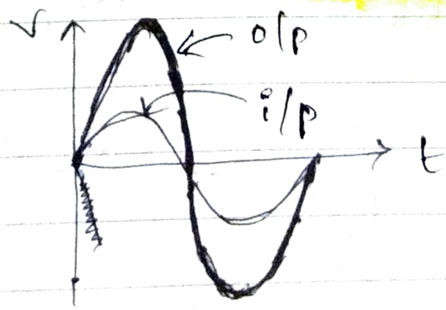
$\therefore V_i / R_1 = -V_0 / R_F$

$\therefore \boxed{V_0 = \left(-\frac{R_F}{R_1}\right) V_i}$

shows 180° phase shift

(ii) Non Inverting ampr → I/P is applied to Non Inv.





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Applying KCL at point A;

$$I_1 + I_{B_2} = I_F \rightarrow (1)$$

But $I_{B_2} = 0$ ---- Since $R_i = \infty$.

$$\therefore I_1 = I_F \rightarrow (2)$$

$$I_1 = \frac{V_2 - 0}{R_1} \quad \& \quad I_F = \frac{V_0 - V_2}{R_f}$$

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

But $V_2 = V_i$ ---- Since virtually short

$\therefore V_1 = V_2$ & $V_1 = V_i$

$$\therefore \frac{V_i}{R_1} = \frac{V_0 - V_i}{R_F}$$

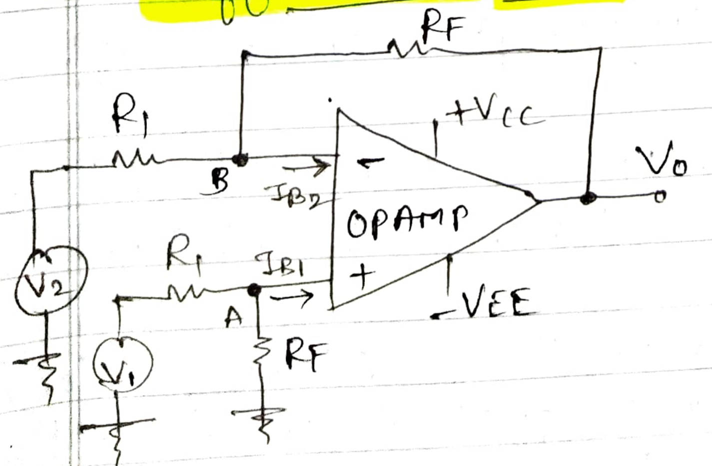
$$\therefore R_f \cdot V_i = R_1 \cdot V_0 - R_1 \cdot V_i$$

$$\therefore V_0 = \frac{R_1 V_i + R_f \cdot V_i}{R_1}$$

$$\therefore V_0 = V_i \left(\frac{R_1 + R_f}{R_1} \right)$$

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

(iii) **Differential Amp^r** → I/P is applied to both the i/ps.



Case 1 When $V_1 = 0$ i.e. grounded.

$\therefore$ Inverting amp^r is formed.

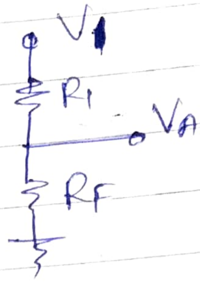
$$\therefore V_{O_2} = \left(-\frac{R_f}{R_1}\right) \cdot V_2 \rightarrow (1)$$

Case 2 When $V_2 = 0$ ie. grounded.

$\therefore$ Non-inverting ampr is formed.

$$\therefore V_{o_1} = \left(1 + \frac{R_f}{R_1}\right) \cdot V_A \rightarrow (2)$$

By voltage divider rule,



$$V_A = \frac{R_f}{R_1 + R_f} \cdot V_1$$

$\therefore$ equation (2) becomes,

$$V_{o_1} = \left(1 + \frac{R_f}{R_1}\right) \cdot \left(\frac{R_f}{R_1 + R_f}\right) \cdot V_1$$

$$= \left(\frac{\cancel{R_1 + R_f}}{R_1}\right)\left(\frac{R_f}{\cancel{R_1 + R_f}}\right) V_1$$

$$V_{o_1} = \left(\frac{R_f}{R_1}\right) V_1 \rightarrow (3)$$

Now adding both the o/p. ie. $V_o = V_{o_1} + V_{o_2}$

$$\therefore V_o = V_{o_1} + V_{o_2} = \frac{R_f}{R_1} V_1 - \frac{R_f}{R_1} \cdot V_2$$

$$\therefore \boxed{V_o = V_{o_1} + V_{o_2} = \frac{R_f}{R_1}\left(V_1 - V_2\right)}$$

★ Comparison

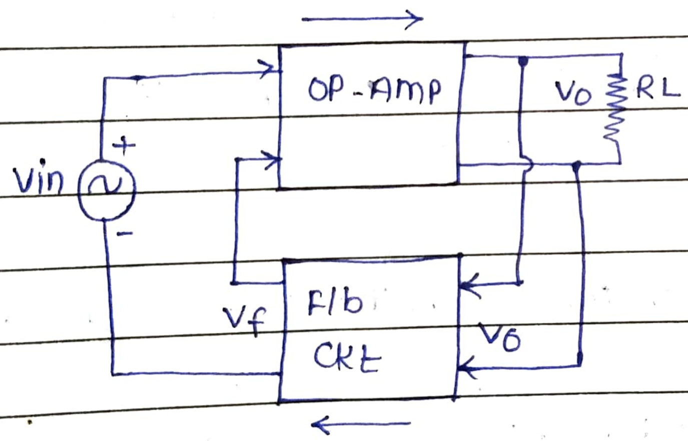
	Inverting Ampr	Non-Inv. Ampr
• v/g gain.	$A_{VF} = -R_f/R_1$	$A_{VF} = 1 + R_f/R_1$
• Phase Relation betn i/p & o/p.	180' out of phase.	In phase.
• Value of gain.	Can be more than, Less than or equal to unity	Alway greater than or equal to unity.

[betn → between]

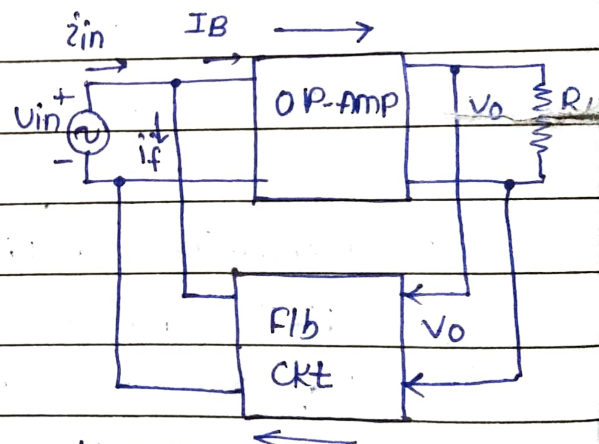
→ **OP-AMP with F/b :- closed loop configuration:**

- An op-amp that uses f/b is called a feedback ampr.
- Also referred as a closed loop ampr. because the f/b forms a closed loop betn the I/P & the O/P.
- It consists of two parts; an op-amp & a f/b ckt.
- There are 4 ways to connect these two parts as
  - voltage - series f/b
  - voltage - shunt f/b
  - current - series f/b
  - current - shunt f/b.

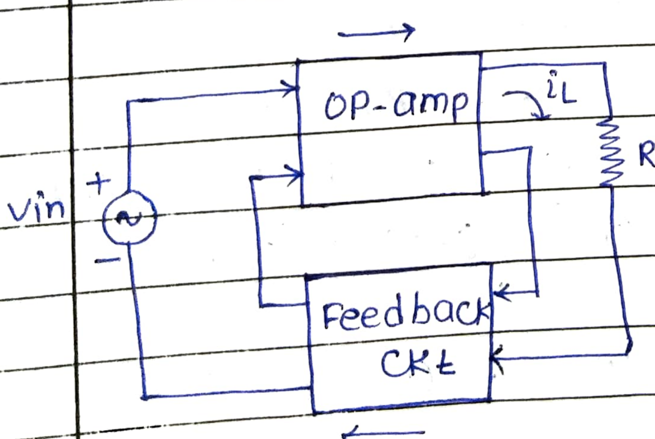
Imp



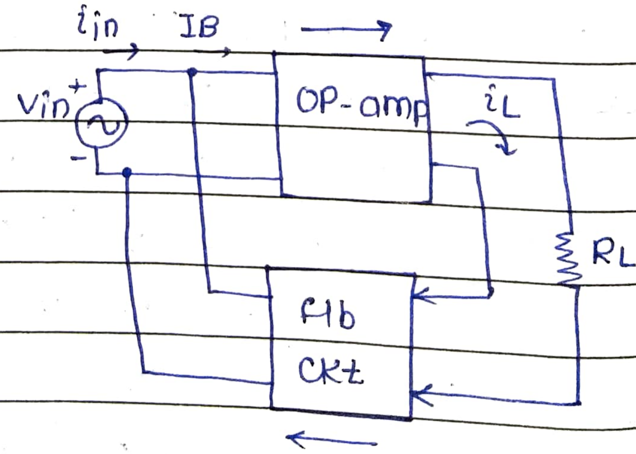
a) voltage - series f/b.



b) Voltage - shunt f/b.



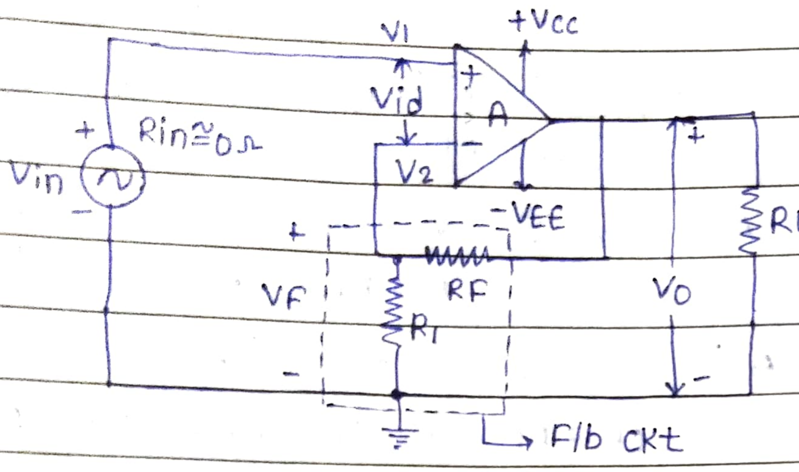
c) current - series F/b



d) Current - shunt

→ Arrow indicates the signal flow direction.

A) voltage series f/b amp^r (non-inverting amp^r with f/b) :→



- non-inv amp^r with f/b because it uses f/b & the I/P is applied at the non-inv terminal. of op-amp.
- open-loop vtg. gain (gain without f/b) $A = v_o / v_{id}$
- closed-loop vtg. gain (gain with f/b) $\boxed{A_F = v_o / v_{in}}$
- gain of the f/b ckt. $B = v_f / v_o$.

→ Negative f/b :

- Apply KVL to the I/P loop $(v_{in} - V_{id} - V_f = 0)$

$\therefore \quad v_{id} = v_{in} - V_f$

where v_{in} = I/P voltage

v_f = feedback vtg.

V_{id} = difference I/P vtg.

- The f/b vtg. always opposes the I/P voltage (or is out of phase by 180° w.r.t the I/P voltage). Hence the f/b is said to be negative.

- closed loop vtg. gain :-

we know that. $A_{f0} = v_o / v_{id}$.

$A_F = \dfrac{v_o}{v_{in}}$ & $v_o = A(v_1 - v_2)$

from fig. we see that.

$v_1 = v_{in}$

$v_2 = v_f = \dfrac{R_1 \cdot v_o}{R_1 + R_F}$ since $R_i >> R_1$.

$$\star\ V_o + \frac{A R_1 V_o}{R_1+R_F} = \frac{A(R_1+R_F)V_{in}}{R_1+R_F} \Rightarrow V_o\left[1+\frac{AR_1}{R_1+R_F}\right] = \frac{A(R_1+R_F)V_{in}}{R_1+R_F}$$

Question No.

$$V_o\frac{(R_1+R_F+AR_1)}{R_1+R_F} = \frac{A(R_1+R_F)V_{in}}{R_1+R_F} \qquad \frac{V_o}{V_{in}} = \frac{A(R_1+R_F)V_{in}}{R_1+R_F+AR_1}$$

START WRITING HERE
(Begin answer for each question on a new page)

$$\therefore\ v_o = A_v\left(v_{in} - \frac{R_1 v_o}{R_1+R_F}\right) = A\left[\frac{(R_1+R_F)V_{in}}{R_1+R_F} - \frac{R_1 V_o}{R_1+R_F}\right]$$

$\star$

$$\text{i.e.}\quad v_o = \frac{A_v(R_1+R_F)\cdot v_{in}}{R_1+R_F+A_vR_1}$$

Thus,
$$A_F = \frac{V_o}{V_{in}} = \frac{A_v(R_1+R_F)}{R_1+R_F+A_vR_1} \quad \text{---- (1)}$$

Generally A_v is very large (2×10^5).

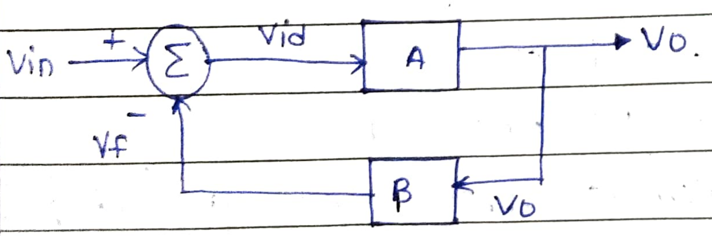
$$\therefore\ A R_1 >> (R_1+R_F) \ \& \ (R_1+R_F+A_vR_1) \cong AR_1$$

Thus,
$$A_{F_v} = \frac{v_o}{v_{in}} = 1+\frac{R_F}{R_1} \quad \text{--- (2)}$$

- External component values should be less than 1 MΩ so that they do not adversely affect the internal circuitry of the op-amp.

- Gain of F/b ckt $(B) = \frac{v_F}{v_o} = \frac{R_1}{R_1+R_F}$

- For given R_1 & R_F the values of A_F & B are fixed.



: Block dia. representation of noninverting ampr with feed back :

- The closed loop gain A_F can be expressed as in terms of open loop gain A & F/b ckt gain B as.

$$A_{F_v} = \frac{A_v\left(\frac{R_1+R_F}{R_1+R_F}\right)}{\frac{R_1+R_F}{R_1+R_F}+\frac{A_vR_1}{R_1+R_F}} \quad (\text{from eq}^n\ (1))$$

$$\therefore\ A_{F_v} = \frac{A_v}{1+AB}$$

where. A_F = closed-loop vtg. gain

A_v = Open-loop vtg. gain

B = gain of the f/b ckt.

A_vB = loop gain.

⇒ Difference I/P vtg. is ideally zero (i.e $v_{id} \simeq 0$).

we know that, $A_v = \frac{v_o}{v_{id}}$

i.e $v_{id} = \frac{v_o}{A_v}$ → ①

As A is very large, $v_{id} \cong 0$

that means $v_1 \cong v_2$ → ②

from fig. of the non-inv f/b ampr.

$v_1 = v_{in}$ & $v_2 = v_f$ → ④

$v_f = \frac{R_1 v_o}{R_1 + R_F}$ → ③

∴ $v_{in} = \frac{R_1 v_o}{R_1 + R_F}$

i.e $\boxed{A_F = \frac{v_o}{v_{in}} = 1 + \frac{R_F}{R_1}}$ – vtg. gain of non-inv ampr with f/b.

⇒ I/P resi. with f/b (R_{iF}):-

$R_{iF} = \frac{v_{in}}{i_{in}} = \frac{v_{in}}{v_{id}/R_i}$

But $v_{id} = \frac{v_o}{A_v}$ & $v_o = \frac{A_v}{1+A_vB} \cdot v_{in}$ (As $\frac{V_o}{V_{in}} = A_{vf} = \frac{A_v}{1+A_vB}$

∴ $R_{iF} = R_i \cdot \frac{v_{in}}{v_o/A_v}$

$= A_v R_i \cdot \frac{v_{in}}{A_v v_{in}/(1+A_vB)}$

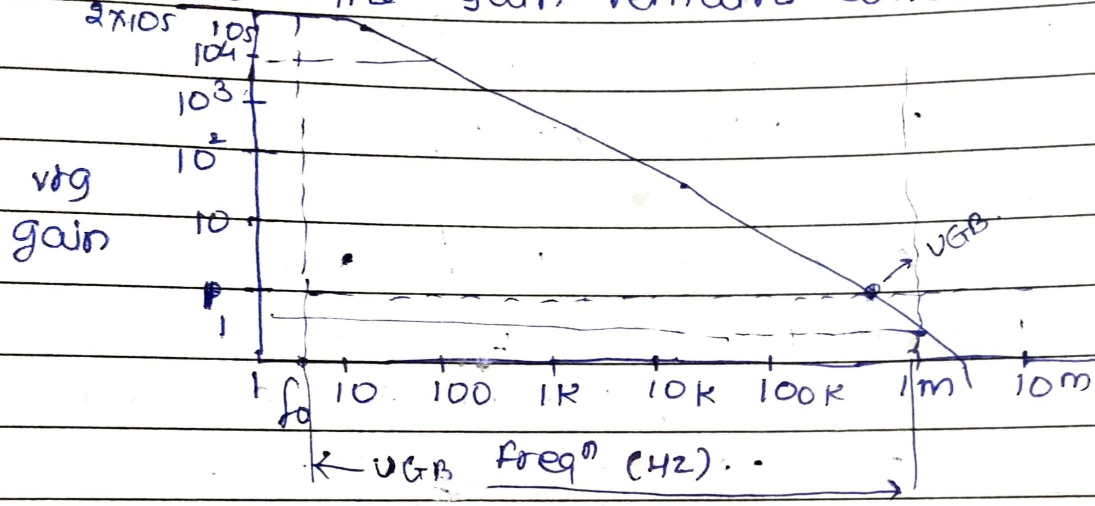
$\boxed{R_{iF} = R_i(1+A_vB)}$ R_i – I/P resi without f/b.

⇒ O/P resistance with F/b (ROF):-

$$ROF = \frac{Ro}{1+AB}$$

⇒ B/W with F/b:-

– B/W of an ampr is the band (range) of freqncy for which the gain remains constant.



– Break freqn :- freqn at which the gain A is 3dB down from its value at 0 Hz & denoted by fo.

– unity gain B/W :- The freqn at which the gain equals 1 is known as the unity gain B/W. UGB

$$UGB = (A_v)\cdot(fo) \quad \text{---} (1)$$

where A = Open-loop vtg. gain

fo = break freqn of an op-amp.

$$UGB = A_{vF}\cdot f_F \quad \text{---} (2)$$

where AF = closed-loop vtg. gain

f_F = bandwidth with F/b.

∴ from eqn (1) & (2)

$$A_v\cdot fo = A_{vF}\cdot f_F$$

$$f_F = \frac{A_v\, fo}{A_{vF}} \quad \text{----} (3)$$

However for the non-inverting ampr with F/b

$$A_{vF} = \frac{A_v}{1+A_vB}$$

(Begin answer for each question on a new page)

∴ substituting value of AF in eqⁿ ③ we get.

$$f_F = \frac{(A) \cdot f_O}{A / (1+AB)}$$

or $f_F = f_O\,(1+AB)$.

⇒ Total O/P offset vltg with f/b:

$$V_{OOT} = \frac{\pm V_{sat}}{1+AB}.$$

⇒ Adv. of -ve f/b:

- high I/P resistance.
- very low O/P resi
- stable vtg gain
- large B/W &
- very little O/P offset vtg.

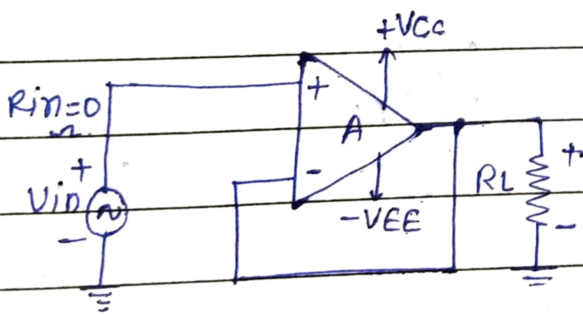
→ It can be used to

- reduce significantly the effect of noise
- variations in supply vltgs &
- changes in temp. on the O/P vtg

v. Imp

⇒ Vtg. follower:

Application:- used to remove the loading on the 1st n/w when placed betⁿ two n/ws.



- non-inv ampʳ with unit gain is called as vtg. follower.
- B = AF = 1

EX: The 741C op-amp has following parameters is connected as a non-inv. ampʳ. with $R_1 = 1K\Omega$ & $R_F = 10K\Omega$.

$A = 2 \times 10^5 = 200{,}000$, supply vtgs = ±15V

$R_i = 2M\Omega$, O/P vtg swing = ±13V

$R_O = 75\Omega$, compute value of A_F, R_{iF}, R_{OF}, f_F & V_{OOT}.

$f_O \cong 5MHz$

$$B = \frac{R1}{R1+RF} = \frac{1K}{1K+10K} = \frac{1}{11}$$

$$\left[\beta = \frac{Vf}{VO} = \frac{\left(\frac{R1}{R1+RF}\right)\cdot VO}{VO}\right.$$

$$\boxed{\beta = \frac{R1}{R1+RF}}$$

$$1+AB = 1 + \frac{200{,}000}{11} = 18{,}182.8$$

$$AF = \frac{200{,}000}{18{,}182.8} = 10.99$$

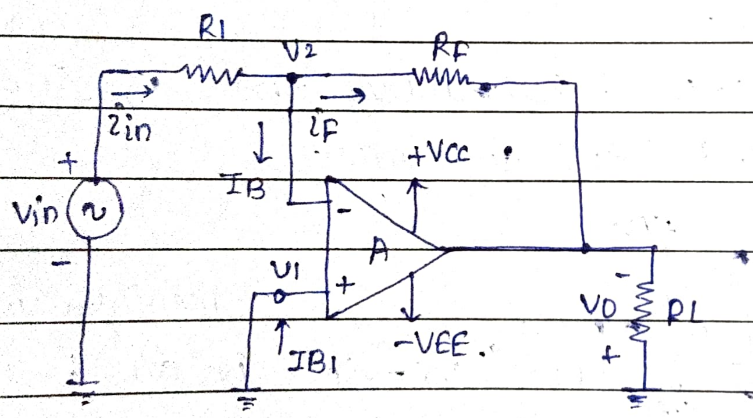
$$RiF = 2M\Omega\,(18{,}182.8) = 36.4\,G\Omega$$

$$ROF = \frac{75\Omega}{18{,}182.8} = 4.12\,m\Omega$$

$$f_F = (5\,Hz)\cdot(18{,}182.8) = 90.9\,KHz.$$

$$VOOT = \frac{\pm 13V}{18{,}182.8} = \pm 0.715\,mV.$$

* ⇒ Voltage shunt f/b ampr: (Inv ampr with f/b):-



→ closed loop vtg. gain :-

From above fig.

$$i_{in} = i_F + I_B \qquad \text{—} (1)$$

∵ Ri is very large, the I/P bias current IB is negligibly small.

$$\therefore i_{in} \cong i_F \qquad \text{—} (2)$$

i.e $$\frac{v_{in} - v_2}{R1} = \frac{v_2 - v_0}{RF} \qquad \text{—} (3)$$

As, $A = v_0/v_{id}$, $v_{id} = v_0/A$ i.e. $v_1 - v_2 = \frac{v_0}{A}$

since $v_1 = 0V$, $v_2 = -\frac{v_0}{A}$

∴ from eqn ③, we get.

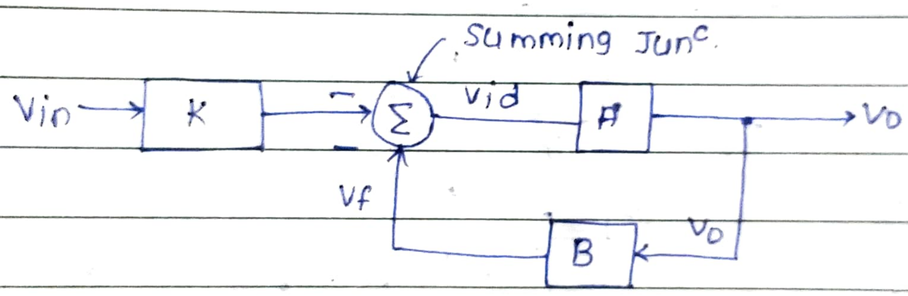
$$\frac{v_{in} + v_0/A}{R_1} = \frac{-(v_0/A) - v_0}{R_F}$$

$$\therefore A_F = \frac{v_0}{v_{in}} = -\frac{AR_F}{R_1 + R_F + AR_1 \approx AR_1} \quad — ④$$

→ − sign indicates that the I/P & O/P signals are out of phase by 180° (or of opposite polarities). Hence called inv ampr.

As A is very large (2×10^5), eqn ④ can be written as,

$$A_F = \frac{v_0}{v_{in}} = \frac{-R_F}{R_1}$$



: Block dia. of inv. ampr. with F/b using a vtg. summing Junn: -

⇒ Virtual ground :-

- see the fig. of ~~non~~-inv ampr, non-inv terminal is grounded. & the I/P signal is applied to the inv. terminal via Resi. R_1.
- As discussed earlier, since A is very large the eqn becomes

$$v_{id} = \frac{v_0}{A}, \quad v_{id} \simeq 0 \quad (\because A >>).$$

$$\therefore v_1 \simeq v_2$$

- Thus as v_1 (non-inv) is gnded. v_2 is also at same potential i.e $v_2 = 0$
- Therefore the inverting terminal (v_2) is said to be at virtual ground.

→ <u>B/W with F/b</u> :-

$$f_F = \frac{UGB\,(1+AB)}{A} = \frac{UGB\,(K)}{AF}$$

where, $K = \frac{RF}{R1+RF}$ $\quad AF = \frac{AK}{1+AB}.$

→ <u>Total O/P offset vtg</u> : <u>VOOT</u> :-

$$VOOT = \frac{\pm Vsat}{1+AB}.$$

} same for both inv. & non inv F/b amprs.

where $\pm Vsat$ = saturation voltages

A = open-loop vtg. gain

B = gain of F/b ckt. $= \frac{R1}{R1+RF}$

Sol^n a) We know that. $A_D = 1 + \frac{R_F}{R_1}$.

$\therefore A_D = 1 + 6.8K / 680\Omega = 11$

I/P resi.

$$R_{iFy} = (2M\Omega) \cdot \left[1 + \frac{(2)(10^5) \cdot (6.8K\Omega)}{6.8K\Omega + 680\Omega} \right] = 364\ G\Omega$$

$$R_{iFx} = (2M\Omega) \left[1 + \frac{(2)(10^5) \cdot (680)\Omega}{6.8K\Omega + 680\Omega} \right] = 36.4\ G\Omega$$

b) O/P vtg. can be calculated by,

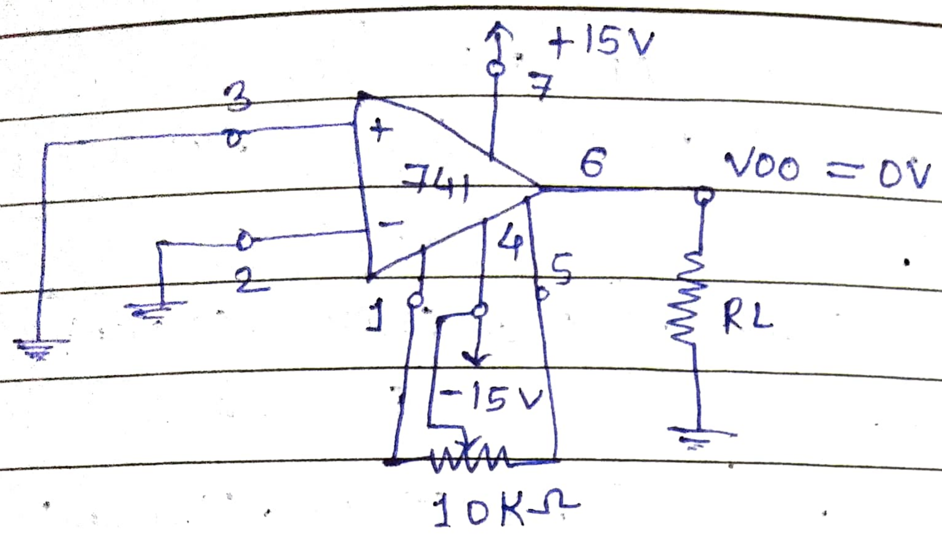
$$v_0 = \left(1 + \frac{R_F}{R_1}\right) \cdot V_{xy} = (11) \cdot (-1.5 + 2) = 5.5\ V_{pp}$$ sine wave at 1 KHz.

⇒ Practical Op-Amp :-

- It has some DC O/P vtg. called output offset voltage, even though both inverting & noninverting I/P terminals are grounded.
- We will see the properties of practical op-amp that produce the output offset voltage.
- Causes of O/P offset voltage:
  1) By mismatching bet^n two I/P terminals

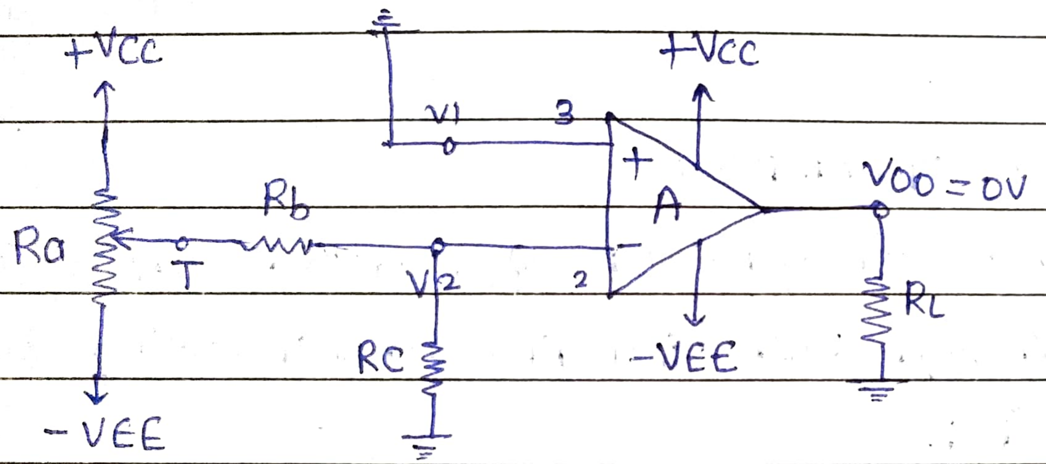
⇒ To reduce V_{OO} to 0, we need to have a ckt. at the I/P terminals of the op-amp that will give us the flexibility of obtaining V_{IO} of proper amplitude & polarity. This ckt. is called as an I/P offset voltage-compensating n/w.

- Before applying external I/P vtg. by using this ckt we make the $V_{OOT} = 0$. The op-amp is then said to be nulled or balanced.
- For 741C these offset null pins have been provided so no external offset voltage-compensating n/w is not required.



→ By changing the position of the wiper, we can adjust the v

⇒ Offset vtg. compensating n/w :-



→ vtg a/c RC = V_2 = I/P vtg a/c inv terminal:

- above ckt can be used as a non-inverting ampr since the compensating n/w is connected to the I/P terminal the op-amp.
- Pot. Ra is connected betn +Vcc & −VEE.

& Voltage a/c RC = V_2

- By adjusting wiper on Ra, V_2 can be made equal to V_1 i.e V_{io} can be made 0.

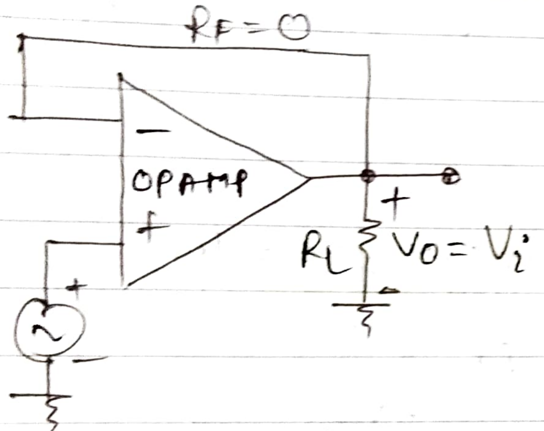
Chintan Jethva

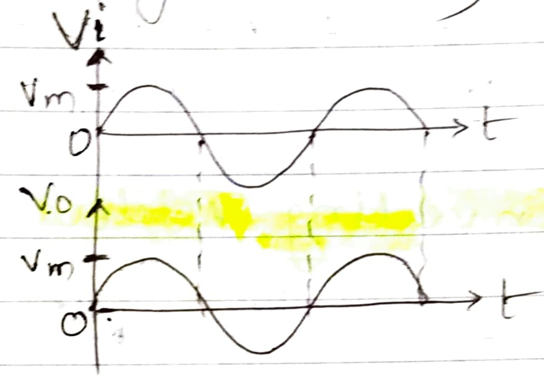
Find v/g gain of Inv. & non Inv. amp if $R_F = 100k\Omega$, $R_1 = 1k\Omega$, $V_i = 10mV$, $V_{cc} = \pm 12$.

Sol^n Inverting mode, $V_o = -\frac{R_f}{R_1} \cdot V_i = \frac{-100}{1} \times 10 \times 10^{-3} = -1V.$

Non Inverting mode, $V_o = \left(1 + \frac{R_f}{R_1}\right) \cdot V_i = \left(1 + \frac{100}{1}\right) \times 10 \times 10^{-3} = 1.01V$

→ **Voltage Follower (Unity gain Buffer)**





> When $R_1 = \infty$ & $R_F = 0$ then non-inverting amp^r becomes voltage follower or unity gain amp^r.

It is configured such as to obtain gain = 1.

> It is obtained by short ckting R_F i.e. $R_F = 0$ & open ckting R_1 i.e. $R_1 = \infty$. Thus all o/p is fed back to i/p of OPAMP.

$$V_o = A_{VF} \cdot V_i \rightarrow (1)$$

& for non-inverting amp^r $A_{VF} = 1 + \frac{R_f}{R_1}$ ..but $R_F = 0$ & $R_1 = \infty$

$\therefore A_{VF} = 1$ & from equation (1) it is clear that o/p v/g is equal to & in phase with the i/p v/g.

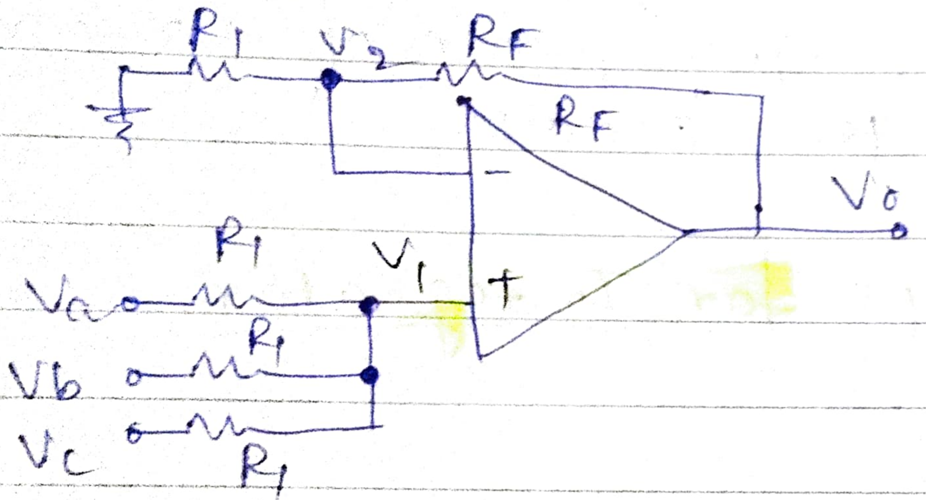
→ **Application**

→ As a Buffer amplifier to avoid loading of source

→ For impedance matching.

→ For non-inverting ~~amp~~ summing ampʳ having i/p $V_a, V_b, V_c = 1v, 2v, 3v$ & If $R_F = 10k\Omega$, $R_1 = 5k\Omega$ what is o/p v/g. Draw ckt also.

Solⁿ



i) If $V_b = V_c = 0$.

$$\therefore V_1' = \frac{R_1 \| R_1}{R_1 + (R_1 \| R_1)} \times V_a = \frac{R_1/2}{R_1 + R_1/2} \cdot V_a = \frac{V_a}{3} //$$

IIIy, If $V_a = V_c = 0$, $V_1'' = \frac{V_b}{3} //$

& If $V_a = V_b = 0$, $V_1''' = \frac{V_c}{3} //$

$$A_{VF} = 1 + \frac{R_F}{R_1} = 1 + \frac{10}{5} = 3$$

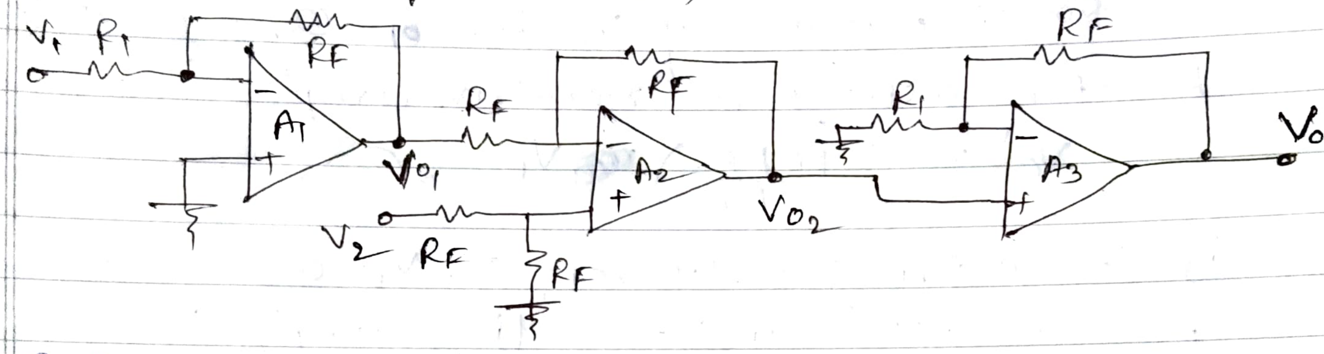
Chintan Jethva

$V_o = A_{VF} \times V_1$ & $V_1 = V_1' + V_1'' + V_1''' = \frac{1}{3}(V_a + V_b + V_c)$

$V_o = \cancel{3} \frac{1}{\cancel{3}} (V_a + V_b + V_c)$

$\therefore V_o = V_a + V_b + V_c = 6V.$

→ Give o/p of circuit, $R_1 = 1K\Omega$, $R_F = 10K\Omega$.



Sol^n: i) $V_{o_1} = -\frac{R_F}{R_1} \times V_1 = -10V_1$

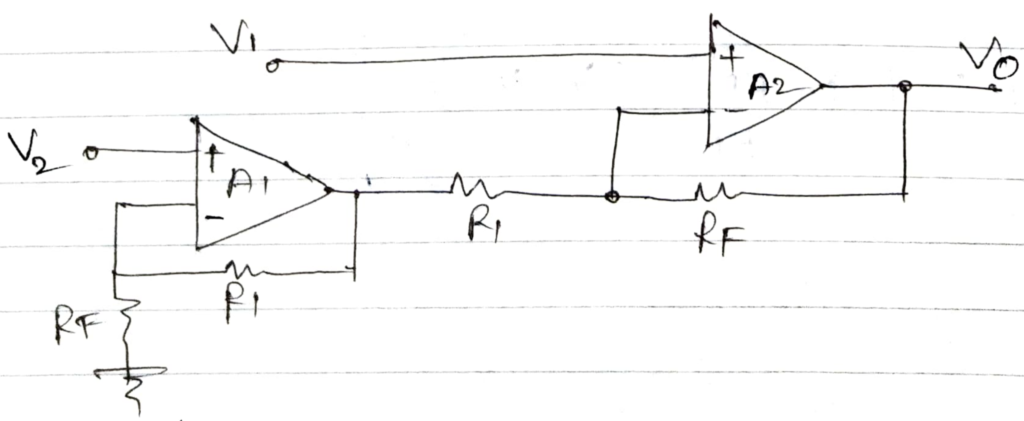
ii) $V_{o_2} = V_2 - V_{o_1} = V_2 - (-10V_1)$

$V_{o_2} = V_2 + 10V_1$

iii) $V_o = \left[1 + \frac{R_F}{R_1}\right] V_{o_2} = \left[1 + \frac{10}{1}\right](V_2 + 10V_1)$

$\therefore \boxed{V_o = 11(V_2 + 10V_1)}$

→ Give expression of o/p v/g.



Solⁿ → Consider o/p of A_1 as V_{o1}, which is acting as non-inv. ampⁿ,

$$V_{o1} = \left(1 + \frac{R_1}{R_F}\right) V_2 \longrightarrow (1).$$

→ Now for A_2 two cases,

i) Considering only V_1 i.e. $V_{o1} = 0$, i.e. grounded.
As it is acting as non-inv. ampⁿ,

$$V_o' = \left(1 + \frac{R_F}{R_1}\right) V_1 \longrightarrow (2).$$

ii) Considering only V_{o1}, i.e. $V_1 = 0$ is grounded.
As it is acting as inverting ampⁿ,

$$V_o'' = \left(-\frac{R_F}{R_1}\right) \cdot V_{o1} \longrightarrow (3)$$

→ Now $V_o = V_o' + V_o''$

$$V_o = \left(1 + \frac{R_F}{R_1}\right) V_1 - \frac{R_F}{R_1} V_{o1}$$

& put value of V_{o1} from eqⁿ (1).

$$\therefore V_o = \left(1 + \frac{R_F}{R_1}\right) V_1 - \left[\frac{R_F}{R_1}\left(1 + \frac{R_1}{R_F}\right) V_2\right]$$

$$= \left(1 + \frac{R_F}{R_1}\right) V_1 - \left[\left(\frac{R_F + R_1}{R_1}\right) V_2\right]$$

$$\boxed{V_o = \left(1 + \frac{R_F}{R_1}\right)(V_1 - V_2)}$$