* Application of OP-Amp :-

OP-Amp

Open Loop

→ OP Amp is used without Feed back.

⇒ OP-Amp will Act as voltage comparator.

Closed Loop

→ OP-Amp is used with Feed back.

- -ve Feed back
  Ex:- Amplifiers, Filters.
- +ve feed back
  Schmitt Trigger

* Open Loop OPAmp Configurations:-

⇒ Open Loop:- No connection (direct or indirect) exits between input and output.

→ under open loop, OP-Amp acts as high gain Amplifier.

→ There are 3 open loop configurations.

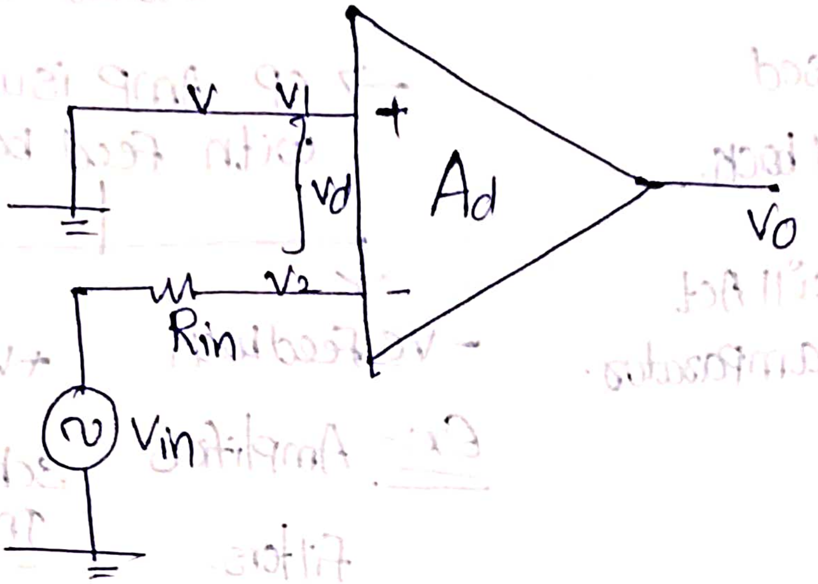
→ Inverting Amplifier

→ Non Inverting Amplifier

→ Differential Amplifier.

* Inverting amplifier:-

⟹ Input is applied to Inverting terminal and non inverting terminal is grounded.



⟹ $V1 = 0$, $V2 = Vin$

⟹ The O/P & I/P relation of Inverting Amp

$$Vo = Ad\ vd = Ad\ (V1 - V_2)$$

$$= Ad\ (0 - Vin)$$

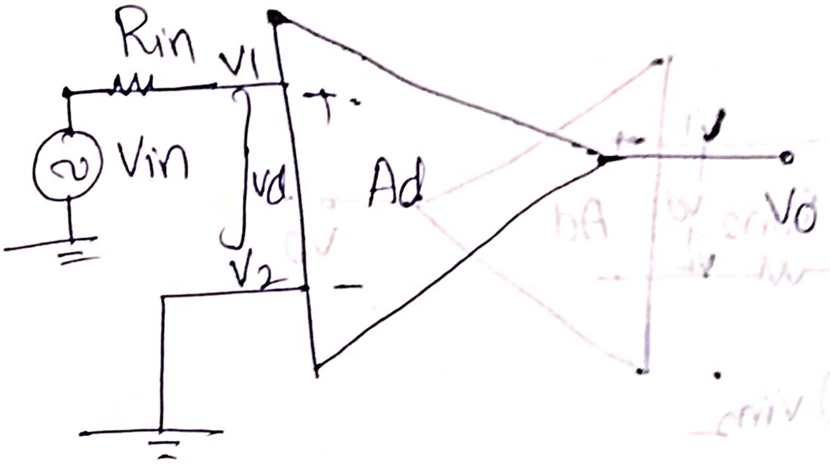
$$\boxed{Vo = -Ad\ Vin}$$

- sign indicates 180° Phase shift between input and output.

⟹ Here we are giving +ve voltage input and we will get -ve voltage as output & vice-versa.

* Non- Inverting Amplifier:-

⇒ Input is applied to Non- Inverting terminal and inverting terminal is grounded.



⇒ Here $V_1 = V_{in}$, $V_2 = 0$.

⇒ The O/P and I/P relation of non-Inverting Amplifier.

$$V_O = A_d \cdot V_d = A_d [V_1 - V_2].$$

$$V_1 = V_{in}, \quad V_2 = 0$$

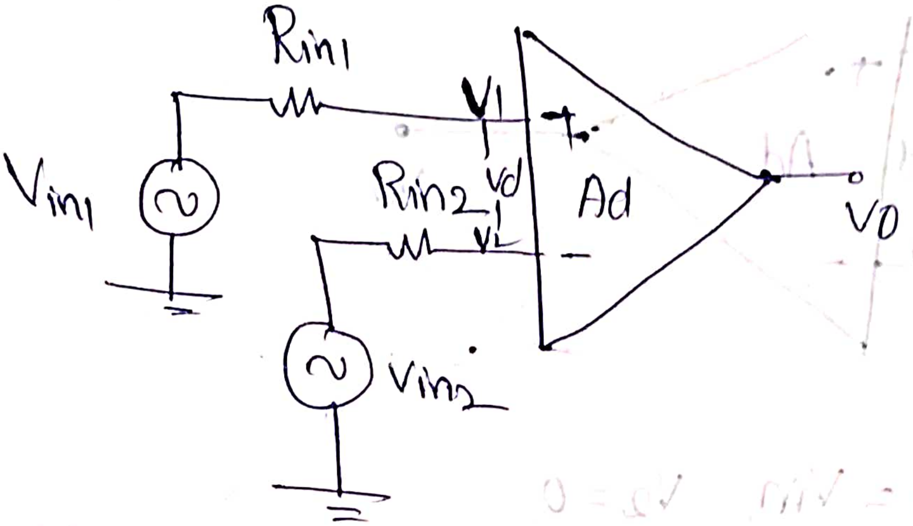
$$\therefore V_O = A_d [V_{in}]$$

$$\boxed{V_O = A_d V_{in}}$$

⇒ No Phase shift between input and output.

* Differential Amplifier:-

* Input is Applied to both the terminals
* Amplifies the difference of two input signals.



⟹ Here $V_1 = V_{in1}$, $V_2 = V_{in2}$

⟹ The O/P & I/P relation of the diff Amp

$$V_o = A_d \cdot V_d = A_d (V_1 - V_2)$$

$$\boxed{V_o = A_d (V_{in1} - V_{in2})}$$

⟹ Output Polarity depends on difference input Polarity.

⟹ For Open Loop Configurations, mostly the output is $\pm V_{sat}$.

* Limitations

⟹ only the smaller signals having Low freq may be Amplified.

⇒ open Loop voltage gain varies with temperature and power supply.

⇒ Bandwidth for open Loop OP-Amp is negligibly small.

⇒ not suitable for linear Applications.

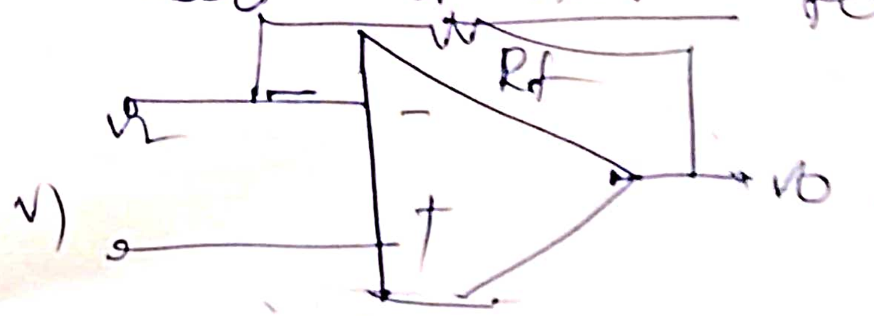
* Closed Loop OP-Amplifier:-

Feedback:- A portion of the output signal is fedback to the input is called feed back.

⇒ Amplifiers using feed back are called closed Loop Amplifiers.

⇒ The gain of the OP-Amp can be controlled, if feed back is introduced in the circuit.

⇒ This is the diagram of closed Loop Amp



feedback Resistor.

Here from o/p to i/p side we are giving one Resistive feedback ఇక్కడ.

Feedbacks

Positive feedback. —ve feedback

⟹ If the i/p signal and feedback are in phase (0°) the feedback is called Positive feed back.

⟹ If the i/p signal & feedback signal are in out of phase (180°), the feedback is called Negative feedback.

* Most of the Linear Circuits use OP-Amp in a closed loop mode with —ve feedback with R_f

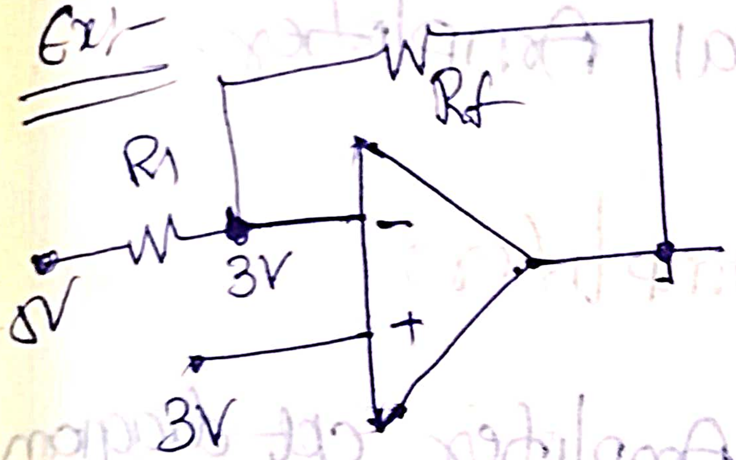
Advantages of negative feedback:-

1. It Reduces the gain and makes it controllable.
2. It reduces the possibility of distortion.
3. It increases the bandwidth i.e freq range.
4. It increases the i/p resistance of OP-AMP
5. It decreases the O/P resistance of OP-AMP.
6. It reduces the effect of temperature power supply on the gain of the circuit

* Virtual Ground Concept :-

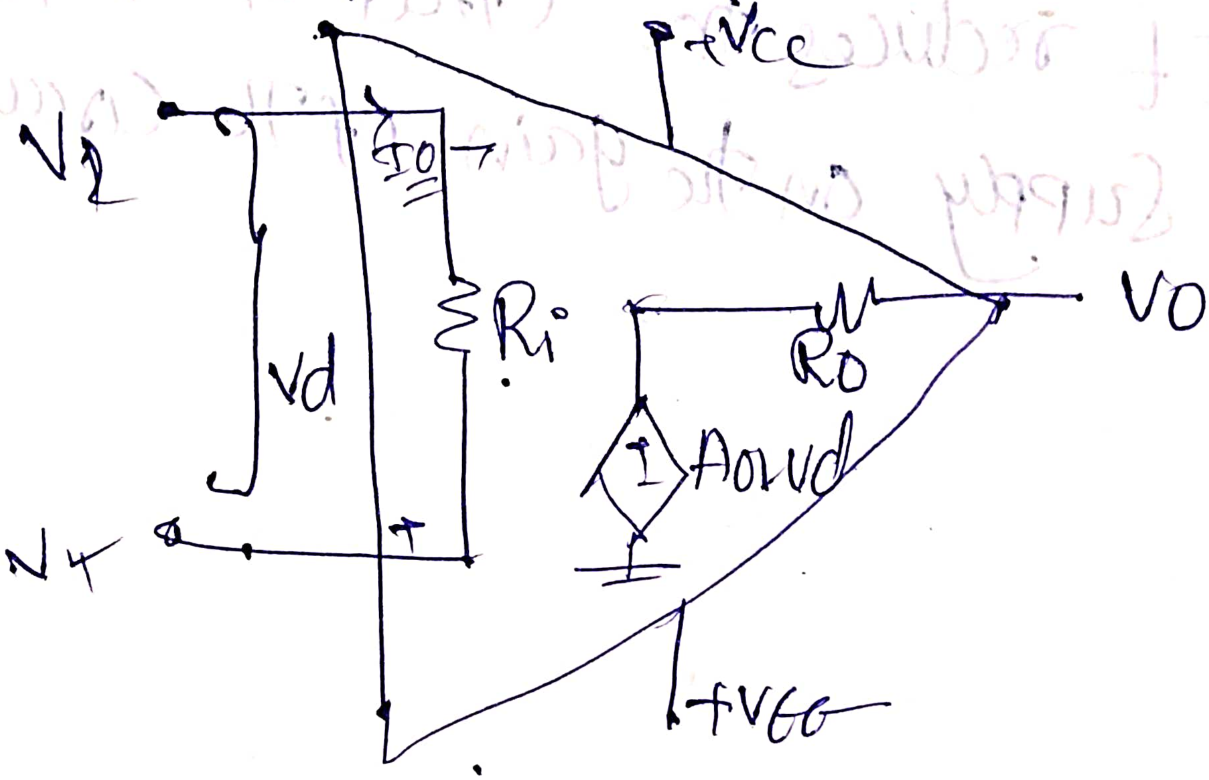
* In OP-Amps the term Virtual ground means that the voltage at the particular node is almost equl to ground voltage (or)

Ex:-



* In the above circuit V_i is connected ground, so $V_1 = 0$, Thus V_2 also will be at ground Potential.

⟹ Consider the equivalent ckt of OP-Amp



$V_o = \underline{\underline{A_{OL}}} \cdot \underline{\underline{V_d}}$

$V_1 - V_2 = 0$

$\boxed{V_1 = V_2}$

① $\underline{\underline{R_i = \infty}}$, $\underline{\underline{A_{OL} = \infty}}$

$V_1 = V_2$

$V_d = \dfrac{V_o}{\infty} = 0$

NOTE :-

* following Assumptions are used in analysis of -ve feed back OP-Amp Circuit.

1. Inverting & non-inverting terminals are virtually shorted.
2. Input currents of OP-Amp are neglizible.

* Closed Loop OP-Amp Configurations:-

* In general OP-Amp is used in closed Loop Configuration to increase the Linear range of operation.

* ⟹ Closed Loop OP-Amp Can be Configured into 3 types.

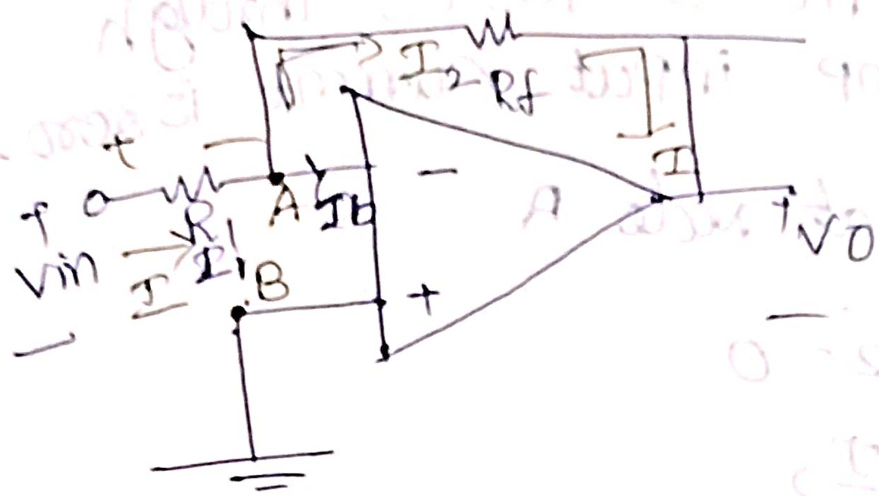
1. Inverting Amplifier — Id
2. Non-Inverting Amp
3. Differential Amplifier.

* Ideal Inverting Amplifier:

Ideal Inverting Amplifier ckt diagram As Shown in fig.

⟹ Ideal means There is no Loss. In This ideal OP-Amp gain = ∞, $R_i = \infty$

Out Put Res = 0.



* An Amplifier which Provides a Phase shift of 180° between input and out put is called inverting Amplifier.

* **Derivation of closed Loop gain:-**

∴ According to VG

$$V_A = V_B = 0$$

At the i/P side side

$$I_1 = \frac{V_{in} - V_A}{R_1}$$

$$I_1 = \frac{V_{in}}{R_1} \quad \text{--- (1)}$$

From the out side

$$I_2 = \frac{V_A - V_0}{R_f} = \frac{-V_0}{R_f} \quad \text{--- (2)}$$

* Entire current I passes through R_f as OP-Amp input current is zero

now apply KCL at node A

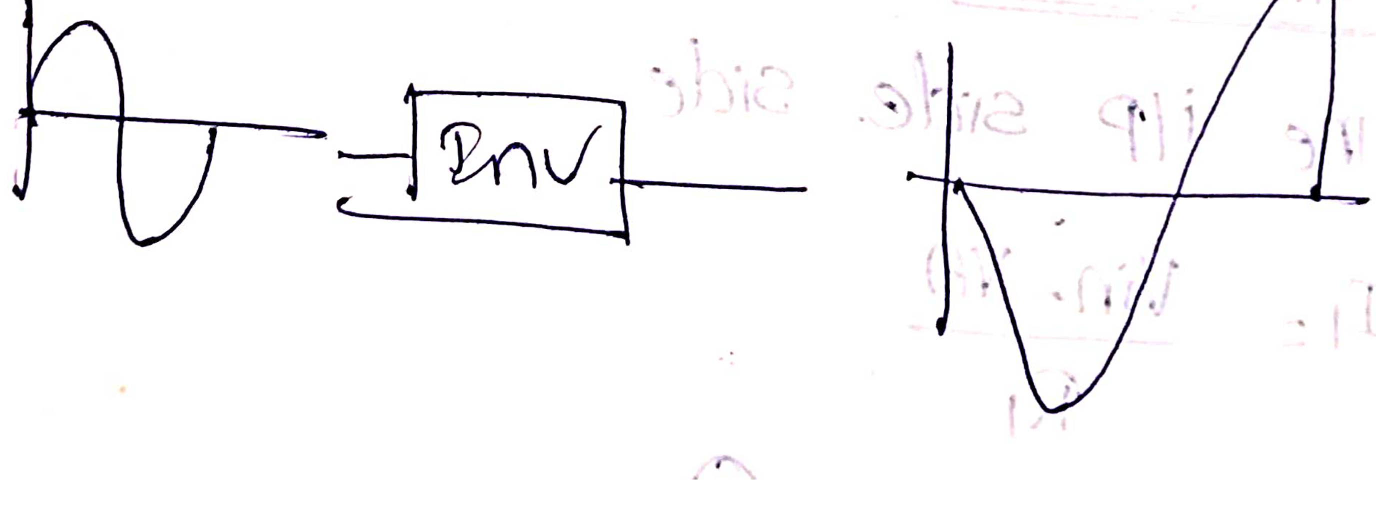
$$\therefore I_1 - I_2 = 0$$

$$I_1 = I_2$$

$$\frac{V_{in}}{R_i} = \frac{-V_O}{R_F}$$

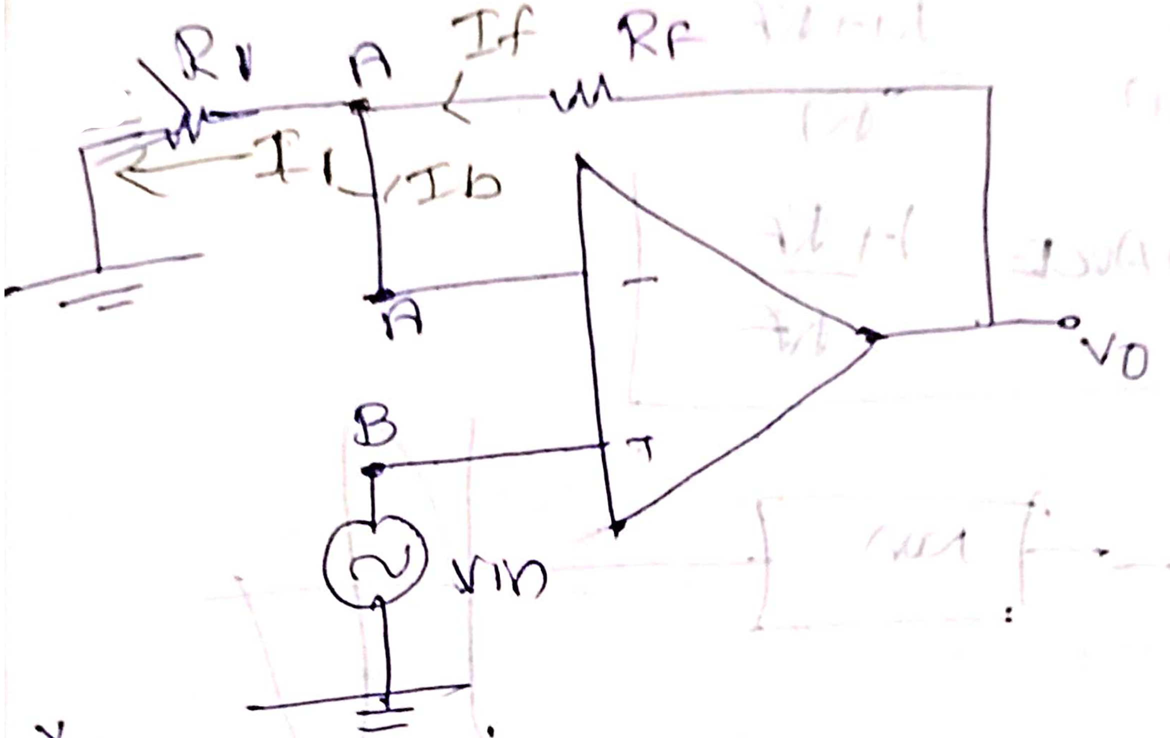
$$\therefore \frac{V_O}{V_{in}} = \frac{-R_F}{R_1}$$

$$\therefore \boxed{A_{VF} = -\frac{R_F}{R_1}}$$



* Ideal Non-Inverting Amplifier:-

An Amplifier which Amplifies the input with out producing any phase shift between input and out put is called non-Inverting Amp



*

$\therefore V_A = V_B = V_{in}$

$\therefore I_1 = \frac{V_A}{R_1} = \frac{V_{in}}{R_1}$ — (1)

$\Rightarrow I_f = \frac{V_0 - V_{in}}{R_f} = \frac{V_0 - V_{in}}{R_f}$ — (2)

now Apply KCL at A

$I_f - I_1 - I_b = 0$

$\therefore I_1 = I_f$

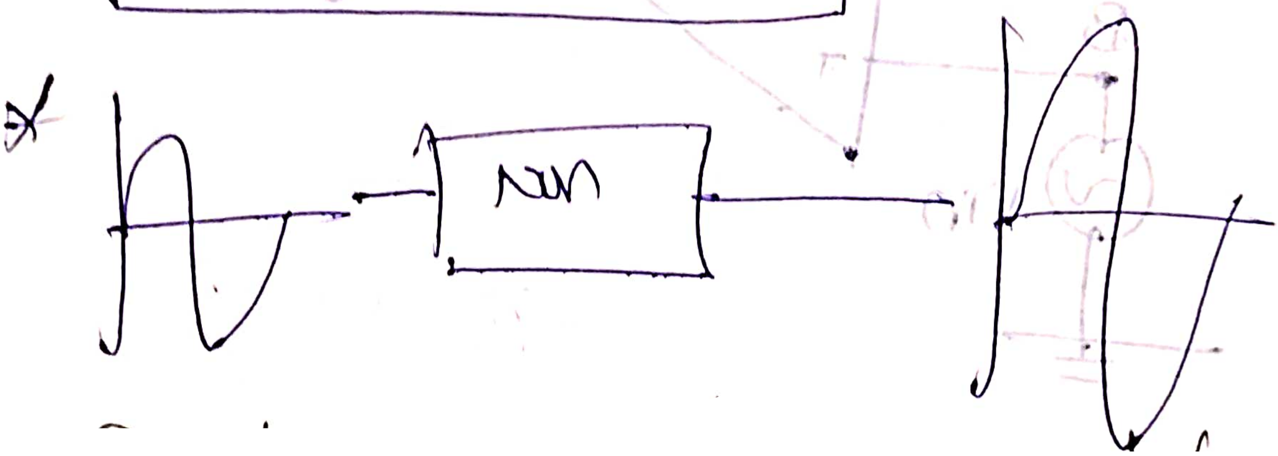
Equating ee (1) (2)

$$\frac{Vin}{R1} = \frac{Vo - Vin}{Rf}$$

$$Vin\left(\frac{R1+Rf}{R1\cancel{Rf}}\right) = \frac{Vo}{\cancel{Rf}}$$

$$\therefore \frac{Vo}{Vin} = \frac{R1+Rf}{R1}$$

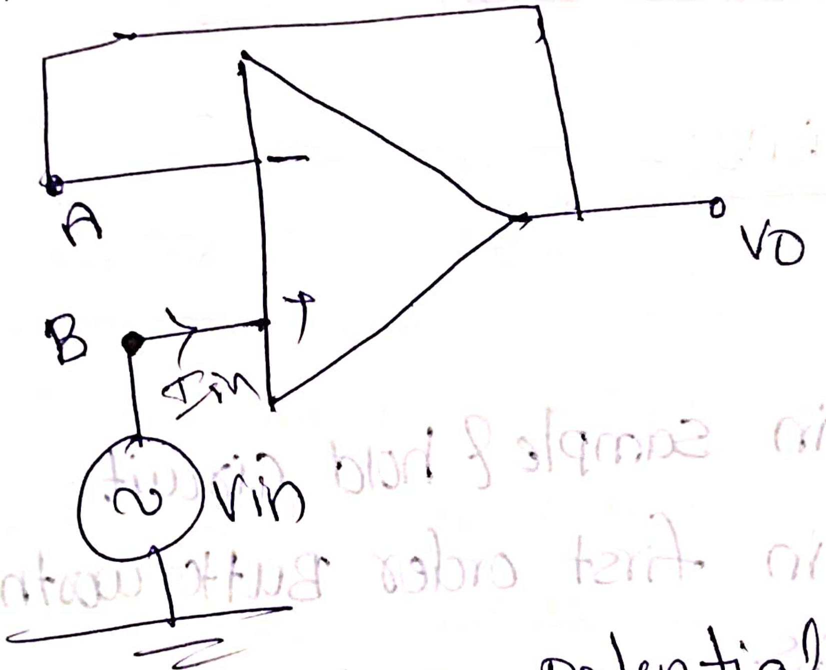
$$\boxed{Avf \text{ or } AvcL = 1 + \frac{Rf}{Rf}}$$



* OP-Amp as voltage follower :-

A circuit in which the output voltage follows the input voltage is called voltage follower circuit.

⇒ The voltage follower circuit using OP-Amp is shown in fig



The Node at B potential $V_B = V_{in}$.

∴ According VG $V_A = V_B = V_{in}$

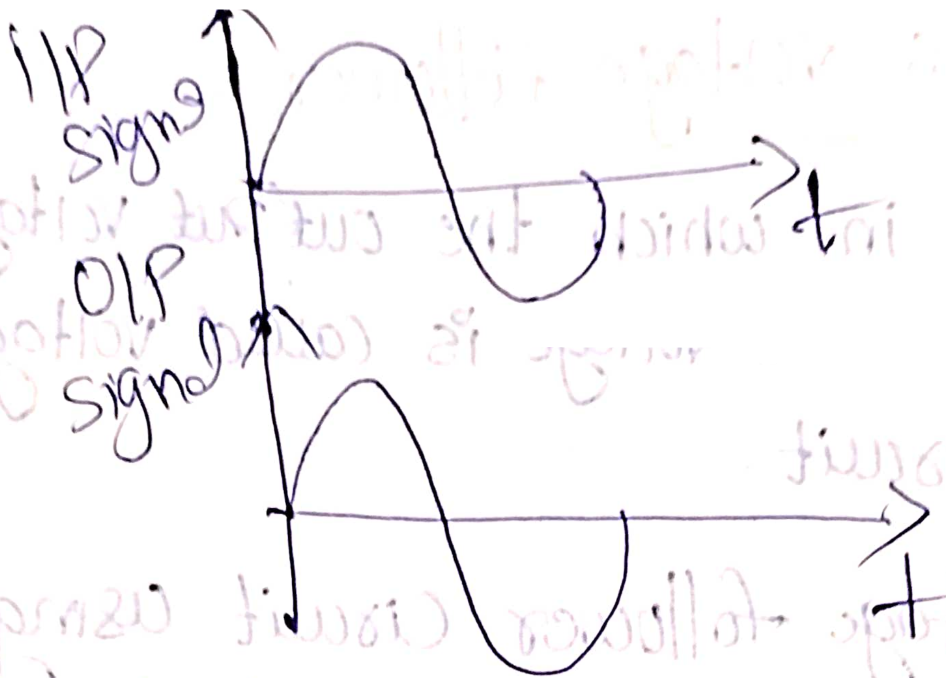
∴ $\boxed{V_O = V_{in}}$

* I/P Resistance

$$\frac{V_{in}}{I_{in}} = \frac{V_{in}}{0} = \infty$$

Gain

$$\boxed{\frac{V_O}{V_{in}} = 1}$$



⇒ Voltage Buffer

* Applications:—

① use in sample & hold circuit.

② use in first order Butterworth filters.

④ use in Instrumentation Amplifier.

* Basic Applications of OP Amp:-

* OP-Amp was designed to do some mathematical operations, such as

→ Addition or summing
→ subtraction or differentiation
→ multiplication
→ Integration, Differentiation
→ Comparision etc.

* Summer or Adder Circuit:-

⇒ As the input impedance of an OP-Amp is extremly large, more than one input signal can be applied to the inverting Amplifier.

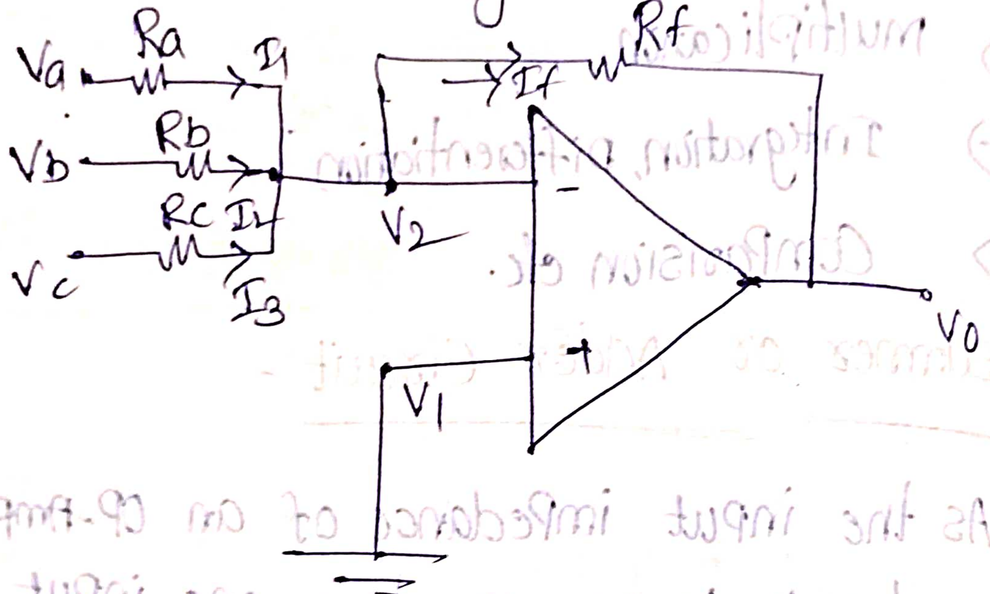
⇒ Such Circuit gives the Addition of the applied signals at the output. Hence it is called Summer or Adder circuit.

⇒ Depending upon the sign of the output the summer circuits are classified as inverting summer and non-inverting summer.

* Inverting summer:-

⇒ In this Circuit, all the input signal to be added are applied to the inverting input terminal of the OP-Amp.

⇒ The Circuit with two input signals is shown in figure



Apply KCL at Node V_2

$$I_1 + I_2 + I_3 - I_f = 0$$

$$I_1 + I_2 + I_3 = I_f$$

$$\frac{V_a - V_2}{R_a} + \frac{V_b - V_2}{R_b} + \frac{V_c - V_2}{R_c} = \frac{V_2 - V_0}{R_f}$$

We know that According V_4

$$V_1 = V_2 = 0$$

$$\frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c} = \frac{-V_0}{R_f}$$

∴ The output voltage

$$\boxed{V_O = -\left[\frac{R_f}{R_1} V_a + \frac{R_f}{R_2} V_b + \frac{R_f}{R_3} V_c\right]}$$

⇒ If This Circuit shown $R_a = R_b = R_c = R$

$$\boxed{V_O = -\frac{R_f}{R}\left[V_a + V_b + V_c\right]}$$

⇒ when $R_f = R$ then the output voltage is equi to negative sum of all inputs

$$\boxed{V_O = -(V_a + V_b + V_c)}$$

✗ Based on the values of R_f and R in the Circuit, may be Acts as scaling amplifier or Average Amplifier.

Case 1
$$\frac{R_f}{R_a} \neq \frac{R_f}{R_b} \neq \frac{R_f}{R_c}$$

$$V_O = -\left(\frac{R_f}{R_a} V_a + \frac{R_f}{R_b} V_b + \frac{R_f}{R_c} V_c\right]$$

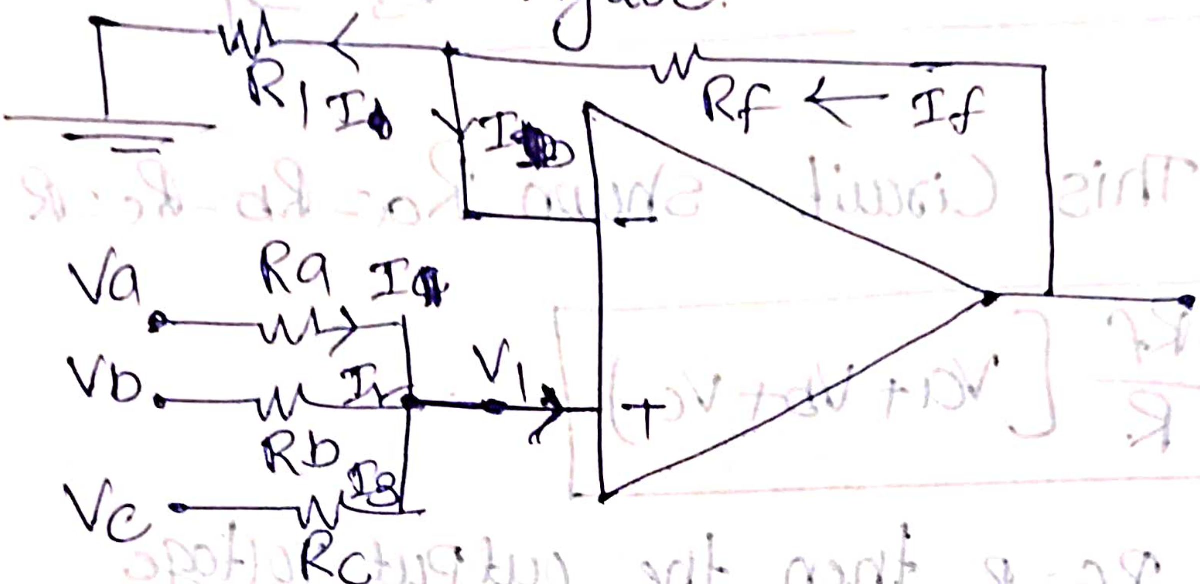
→ scaling Amp

Case 2
$R_a = R_b = R_c = R$ & $R_f / R = 1/n$ where n is the num of i/P then $R_f / R = 1/3$

$$V_O = -\frac{(V_a + V_b + V_c)}{3}$$ (Average Amplifier)

Non Inverting Adder:-

Non Inverting Adder Circuit As shown in Figure.



⇒ Now we want to calculate output voltage V_o.

⇒ Apply KCL at Node V_1

$$I_1 + I_2 + I_3 = 0$$

$$\frac{V_a - V_1}{R_a} + \frac{V_b - V_1}{R_b} + \frac{V_c - V_1}{R_c} = 0$$

$$\frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c} = V_1\left[\frac{1}{R_a} + \frac{1}{R_b} + \frac{1}{R_c}\right]$$

$$V_1 = \frac{\frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c}}{\frac{1}{R_a} + \frac{1}{R_b} + \frac{1}{R_c}} \quad \text{--- (1)}$$

⇒ we know that the output equation for non-Inverting Amplifier

$$V_0 = \left(1 + \frac{R_f}{R_1}\right) \cdot V_1 \quad \text{--- (2)}$$

∴ sub eq (1) in eq (2)

$$V_0 = \left(1 + \frac{R_f}{R_1}\right) \left[\frac{\frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c}}{\frac{1}{R_a} + \frac{1}{R_b} + \frac{1}{R_c}}\right]$$

let As take $R_1 = R_a = R_b = R_c = R = \frac{R_f}{2}$

$$V_0 = \left[1 + \frac{2\cancel{R}}{\cancel{R}}\right] \left[\frac{\frac{V_a + V_b + V_c}{R}}{\frac{1}{R} + \frac{1}{R} + \frac{1}{R}}\right]$$

$$= 3 \frac{\frac{V_a + V_b + V_c}{\cancel{R}}}{\cancel{3}/\cancel{R}}$$

∴ The output voltage

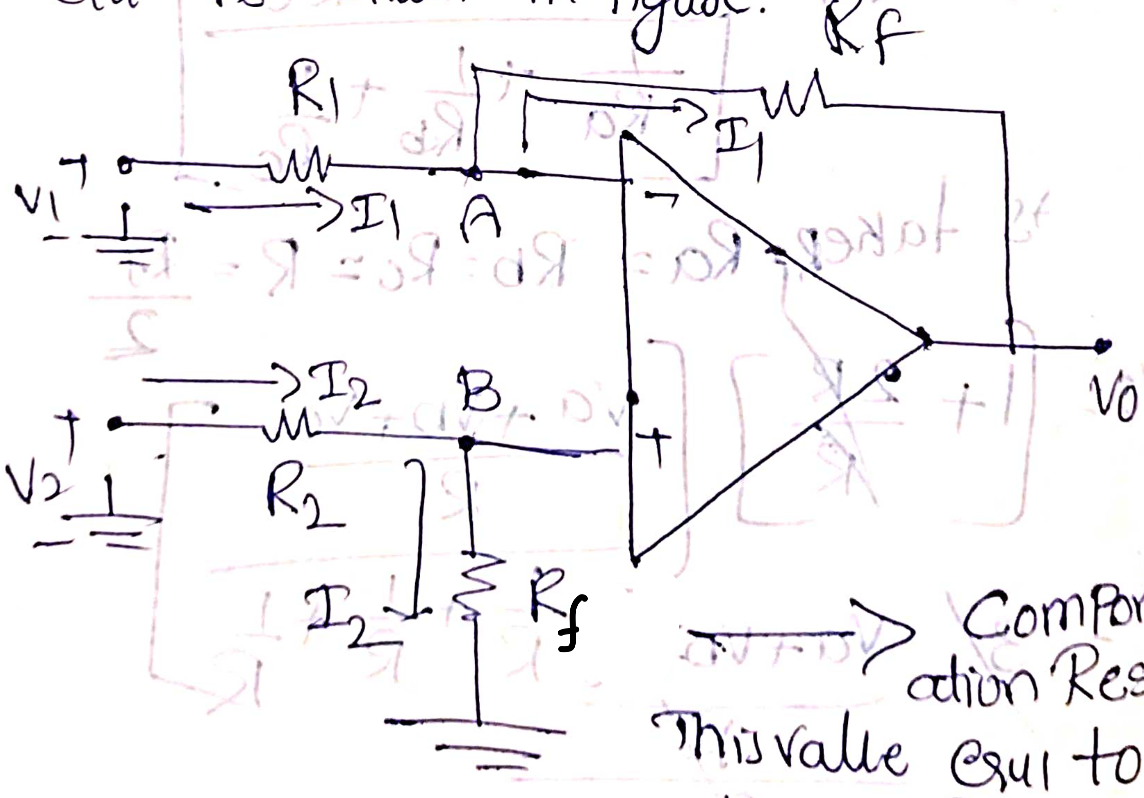
$$\boxed{V_0 = (V_a + V_b + V_c)}$$

∴ The output voltage is sum of input voltages.

* Subtractor (or) Difference Amplifier:-

⟹ Similar to the summer circuit, the subtraction of two input voltages is possible with help of OP-Amp circuit, called subtractor (or) difference amplifier circuit.

⟹ The circuit diagram of subtractor ckt as shown in figure.



⟶ Compensation Resistor

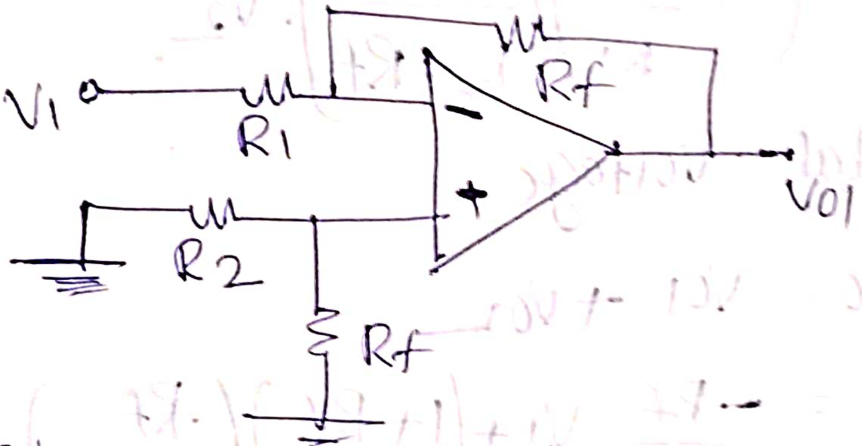
This value equal to feedback Resistance

* calculation of V_0

* As we are having two inputs superposition theorem can be used to find the output voltage

⇒ V_{01} – output voltage when V_1 acting $(V_2=0)$
V_{02} – output voltage when V_2 acting $(V_1=0)$

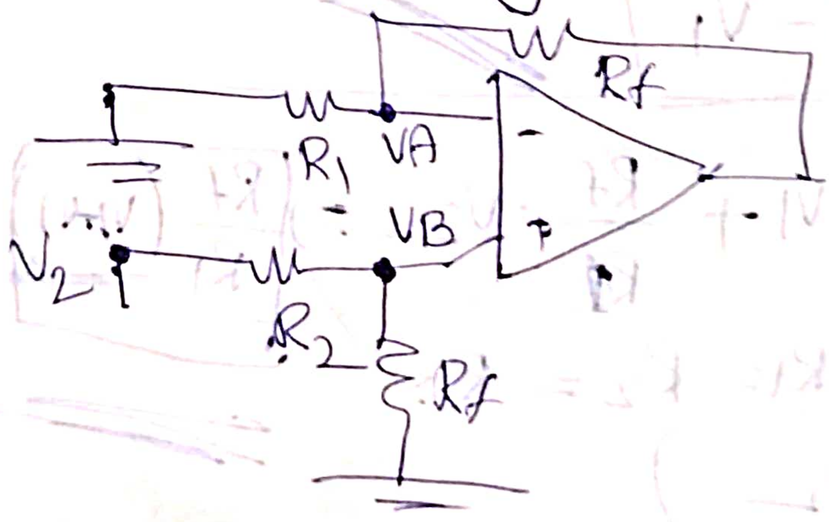
Case 1 V_1 Acting & $V_2=0$



This circuit can acting as Inverting Amplifier

$$\therefore V_{01} = -\frac{R_f}{R_1} \cdot V_1 \quad \text{—— } (1)$$

Case 2 V_2 Acting & $V_1=0$



$$\left(1+\frac{R_f}{R_1}\right) \cdot V_2$$

Apply voltage divider Rule

$$V_B = \left(\frac{R_f}{R_2+R_f}\right) \cdot V_2$$

$\therefore$ The out put voltage

$$V_{02} = \left(1+\frac{R_f}{R_1}\right) \cdot V_B$$

$$V_{02} = \left(1+\frac{R_f}{R_1}\right)\left(\frac{R_f}{R_2+R_f}\right) \cdot V_2$$

$\therefore$ The total voltage

$$V_0 = V_{01} + V_{02}$$

$$= -\frac{R_f}{R_1} \cdot V_1 + \left(1+\frac{R_f}{R_1}\right)\left(\frac{R_f}{R_2+R_f}\right) V_2$$

1st Assume $R_1 = R_2 = R$

$$V_0 = -\frac{\cancel{R}}{\cancel{R}} \cdot V_1 + \left(1+\frac{\cancel{R}}{\cancel{R}}\right)\left(\frac{\cancel{R}}{\cancel{R+R}}\right) \cdot V_2$$

$$\therefore \boxed{V_0 = V_2 - V_1}$$

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

Let Assi $R_f = R_1 = R_2 = R$

$$\therefore \boxed{V_0 = -V_1 + V_2}$$

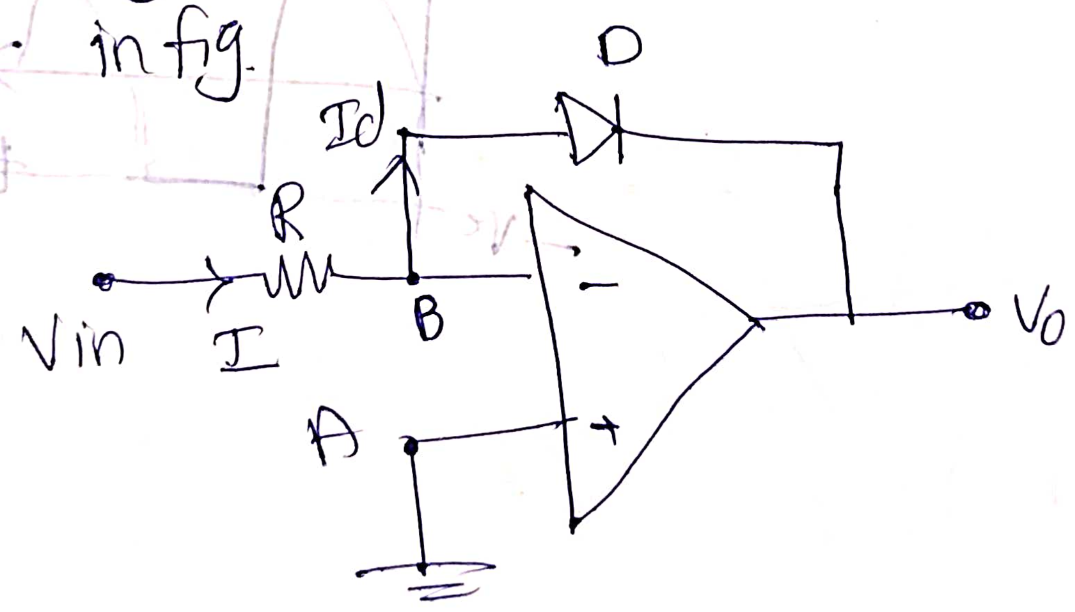
$\therefore \boxed{V_0 = (V_2 - V_1)}$

$\Rightarrow$ out put Voltage is equl to the subtraction of two input signals.

* Logarithmic Amplifier:-

→ The fundamental log amplifier is formed by placing a diode or a transistor in the negative feedback path of the OP-Amp.

⇒ The circuit diagram of basic log amplifier using diode is shown in fig.



⇒ The diode 'D' is used in the negative feedback path

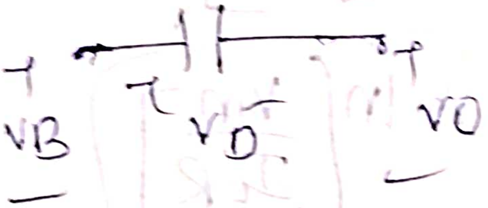
∴ The node A is grounded the node 'B' is at virtual ground $V_B = 0$

$$\therefore I = \frac{V_{in} - V_B}{R} = \frac{V_{in}}{R} \quad \text{— (1)}$$

⇒ As the OP-Amp input current is zero.

$\therefore I = I_f$ = Diode current

⇒ Now I_f is the current through diode and voltage across diode is $V_B - V_0$ ie $-V_0$



$$-V_B + V_D + V_O = 0$$

$$V_D = V_B - V_O = -V_O \; [\because V_B = 0]$$

$$\therefore \boxed{V_D = -V_O}$$

we know that diode current

$$I_f = I_0\left[e^{V_D/\eta V_T} - 1\right] \quad \text{— (2)}$$

$$I_f = I_0 e^{\frac{V_D}{\eta V_T}} - \cancel{I_0} \quad \text{—}$$

$$I_f = I_0 e^{\frac{V_D}{\eta V_T}} \quad \text{— (2)}$$

∴ equating (1) (2)

$$\frac{V_{in}}{R} = I_0 e^{\frac{V_D}{\eta V_T}}$$

$$\frac{V_{in}}{I_0 \cdot R} = e^{\frac{V_D}{\eta V_T}}$$

$$\therefore \frac{V_D}{\eta V_T} = \ln\left[\frac{V_{in}}{I_0 \cdot R}\right]$$

$$V_D = \eta V_T \ln\left[\frac{V_{in}}{I_0 R}\right]$$

$$\therefore \boxed{V_O = -\eta V_T \ln\left[\frac{V_{in}}{I_0 R}\right]}$$

$$V_O = -\cancel{\eta} V_T \ln\left[\frac{V_{in}}{I_0 R}\right]$$

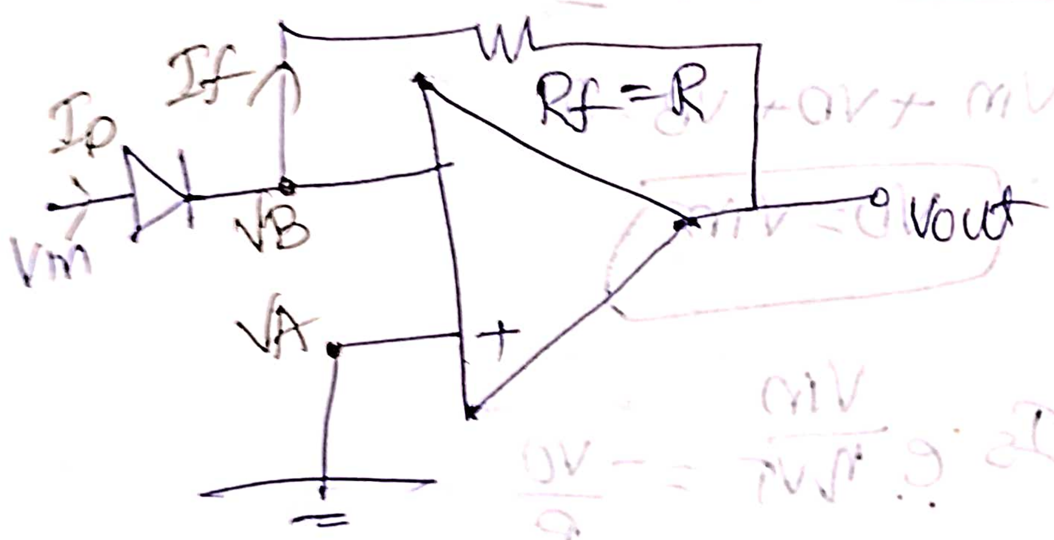
⟹ output voltage is a function of logarithm of the input voltage Vin.

Anti-log Amplifier:-

Anti-log Amplifier is an inverting Amplifier in which the input Resistor is replaced by a diode.

∴ The output is proportional to anti-log of input voltage.

The ckt diagram of anti-log Amplifier as shown in fig



Apply KCL at Node B

$$I_D = I_f$$

$$I_s\left[e^{\frac{V_D = V_f}{\eta V_T}} - 1\right] =$$

I_s = saturation current of diode.

V_f = forward voltage of diode.

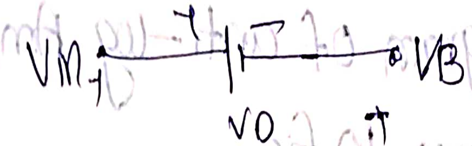
V_T = Thermal voltage.

η = ideality factor value between 1 & 2

$$e^{\frac{V_f}{\eta V_T}} >> 1$$

$$\therefore I_D = I_S e^{\frac{V_D}{\eta V_T}} = \frac{V_B - V_O}{R}$$

$$\therefore I_S e^{\frac{V_d}{\eta V_T}} = \frac{-V_O}{R}$$



$$-V_{in} + V_O + V_B = 0$$

$$\therefore \boxed{V_O = V_{in}}$$

$$I_S \, e^{\frac{V_{in}}{\eta V_T}} = -\frac{V_O}{R}$$

Taking log on both

$$\log V_d = -I_O \cdot R \frac{V_{in}}{\eta V_T} \log e \quad (\log e = 1)$$

$$V_O = -I_O \cdot R \text{ Antilog } \frac{V_{in}}{\eta V_T}$$

Considering η, V_T, R and I_O constant

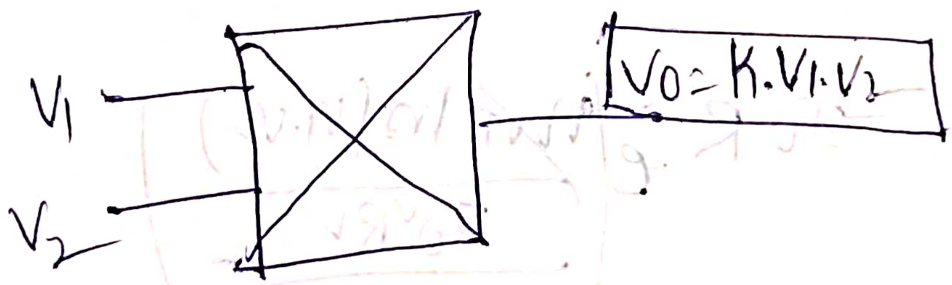
$\therefore V_O \propto$ Antilog V_{in}

* multiplier:-

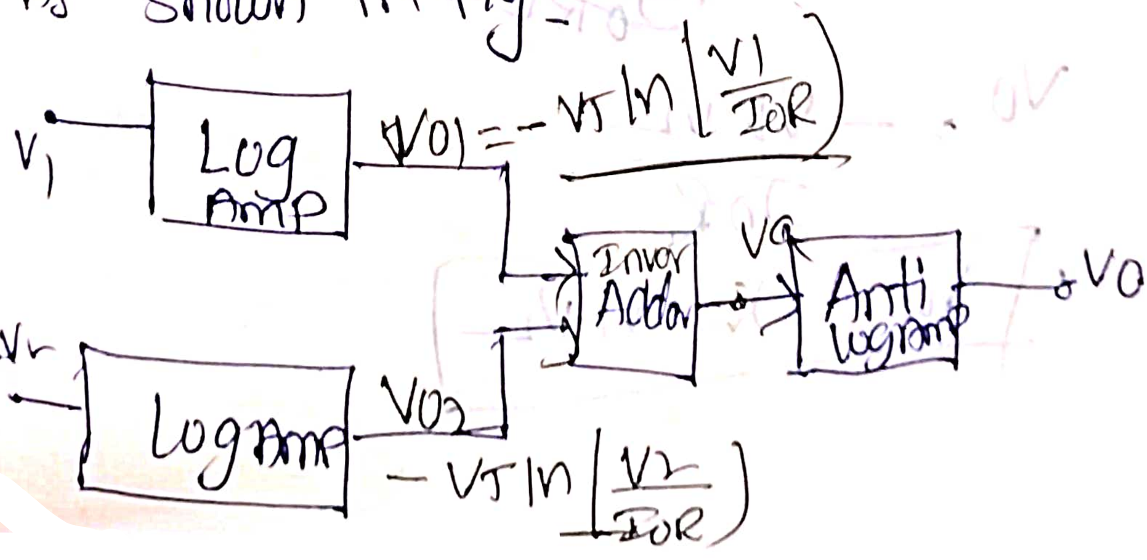
* In analog - signal processing the need often arises for a circuit that takes two analog input and produces an output proportional to their product. Such circuits are termed analog multipliers

=) Analog multiplier is a circuit in which the output voltage is proportional to multiplication of input voltages.

∴ The symbol Repre of multiplier As shown in fig.



The block diagram of multiplier ckt As shown in fig.



$\therefore$ The out put voltage of Inv

$$V_a = -\left[\eta V_T \ln\left[\frac{V_1}{I_0 R}\right] - \eta V_T \ln\left[\frac{V_2}{I_0 R}\right]\right]$$

$$\therefore V_a = +(-(\eta V_T))\left[\ln\left(\frac{V_1}{I_0 R}\right) + \ln\left(\frac{V_2}{I_0 R}\right)\right]$$

$$V_a = \eta V_T \ln\left[\frac{V_1 \cdot V_2}{I_0 R^2}\right]$$

$\therefore$ The o/p of anti log Amp.

$$\therefore V_0 = -I_0 R\, e^{\left(\frac{V_{in}}{\eta V_T}\right)}$$

$$V_0 = -I_0 \cdot R\, e^{\left(\frac{\cancel{\eta V_T} \ln\left(\frac{V_1 \cdot V_2}{I_0^2 R^2}\right)}{\cancel{\eta V_T}}\right)}$$

$$V_0 = -\cancel{I_0 R} \cdot \frac{V_1 \cdot V_2}{\cancel{I_0^2 R^2}}$$

$$V_0 = -\frac{V_1 \cdot V_2}{I_0 R}$$

$$\boxed{V_0 = A \times V_1 \cdot V_2}$$

* Open Loop - OP-Amps:-

* Comparator:-

A comparator is an electronic circuit which compares the two inputs that are applied to it and produces an output. The output value of the comparator indicates which of the inputs is greater or lesser.

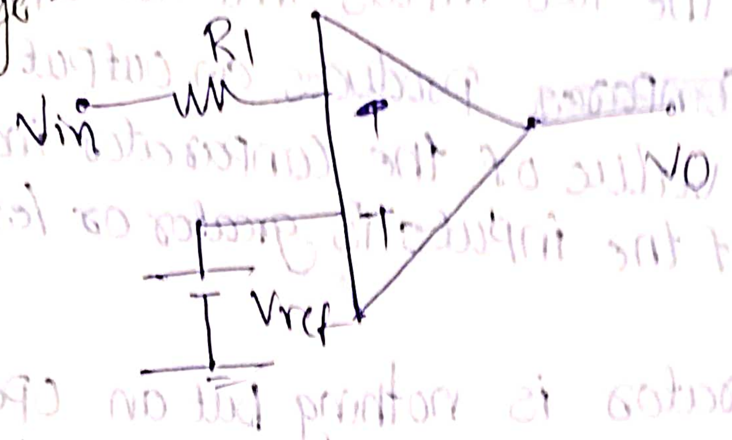
* Comparator is nothing but an open loop OP-Amp with two inputs and one output.

* It compares a signal voltage applied to one input to OP-Amp with known voltage applied to other input. The output of comparator is either positive saturation or negative saturation depending on which input is larger.

* It has following types.
  1. Inverting comparator
  2. Non-Inverting comparator.

* Inverting Comparator with +ve Reference Voltage

It is



* Operation:-

→ When Vin is less than Vref, the voltage at non inverting terminal is greater than voltage at inverting terminal. This makes the differential voltage Vid positive and hence output will be in Positive Saturation (+Vsat).

→ When Vin is greater than Vref, the voltage at inverting terminal is greater than voltage at non-Inverting terminal. This makes the differential voltage vid negative and hence output will be in negative Saturation (-Vsat).

case1 Vin > Vref

case1 Vin < Vref

$\boxed{V_0 = +V_{sat}}$

we prove that

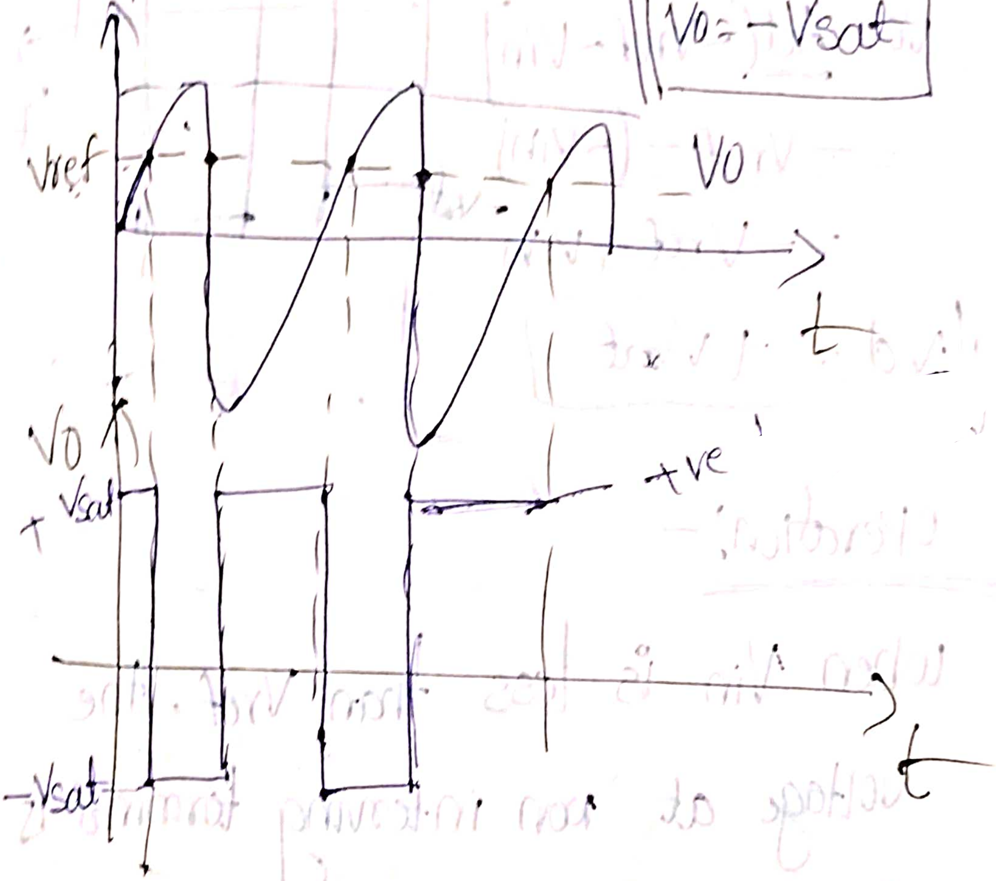
$V_0 = A_d(V_d)$

$\because V_d = V_{ref} - V_{in}$

$V_0 = A_d(V_{ref} - V_{in})$

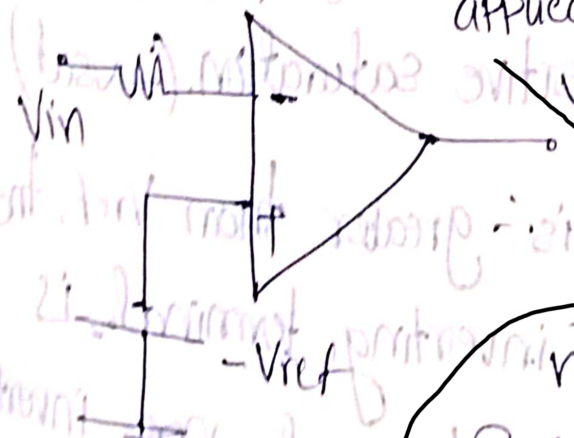
$V_0 = \infty(V_{ref} - V_{in})$

$\boxed{V_0 = -V_{sat}}$



11) Inverting comparator with -ve Reference Voltage

* It is the comparator in which input is applied to inverting terminal and Reference voltage is applied to non-Inverting terminal



$V_0 = A_d(-V_{ref} - V_{in})$

* Reference voltage applied is -ve.

(i) Vin > Vref

Vo = -Vsat

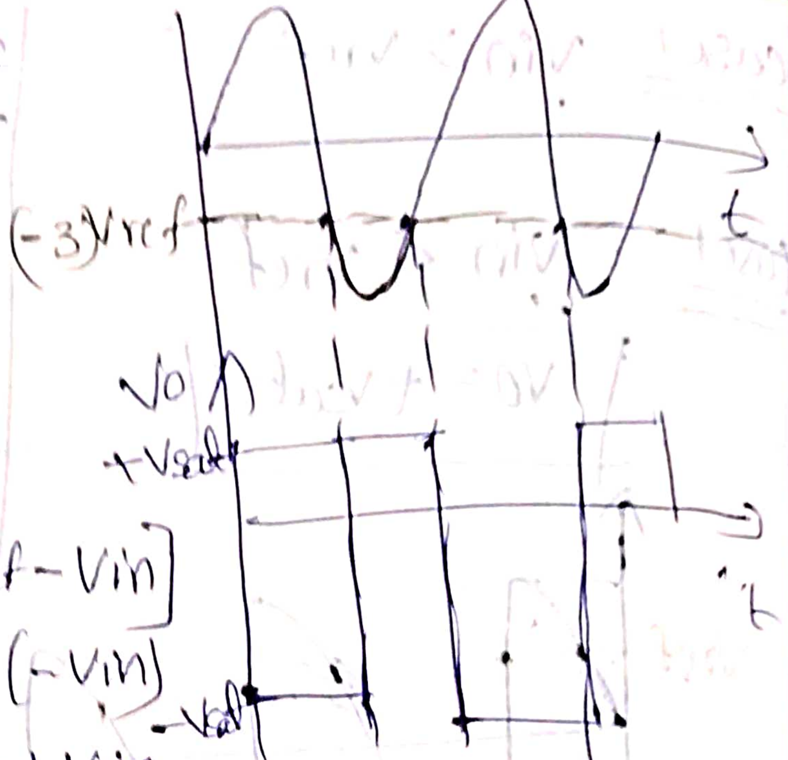
(ii) Vin < Vref

Vo = Ad(-Vref - Vin)

= -Vref - (-Vin)

= -Vref + Vin

$\boxed{Vd = +Vsat}$



* Operation:-

When Vin is less than Vref, the voltage at non inverting terminal is greater than voltage at inverting terminal. This makes the differential voltage Vd Positive and hence output will be in Positive saturation. (+Vsat)

⇒ When Vin is greater than Vref, the voltage at inverting terminal is greater than voltage at non-inverting terminal.

This makes the differential voltage V_{id} negative and hence output will be in negative saturation. ($-V_{sat}$).

* SCHMITT TRIGGER :- (Regenerative ...)

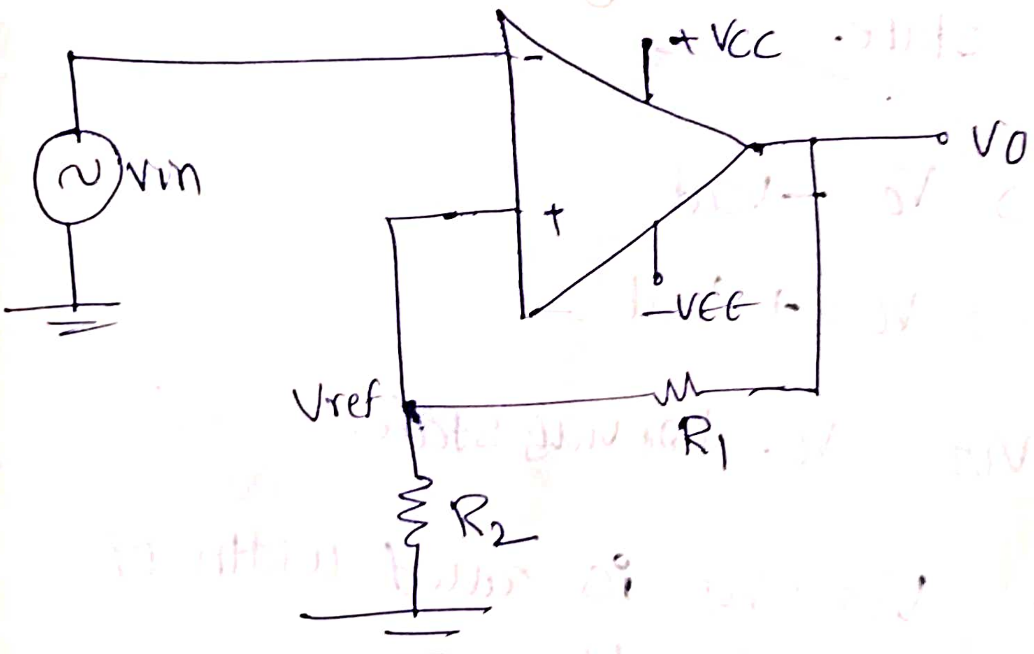
- The class of comparators which use the positive (Regenerative) feedback is known as the schmitt trigger or regenerative comparator.

⟹ It can be classified into 2 types.

1. Inverting schmitt trigger
2. Non-Inverting schmitt trigger.

* Inverting schmitt trigger :-

⟹ The ckt diagram of Inverting schmitt trigger As shown in the fig.



Here R_1 & R_2 forms the voltage divider N/WKS. which is used to generate the reference the voltage.

⟹ we know that $V_{in} > V_{ref}$ $V_o = -V_{sat}$

$V_{in} < V_{ref} \rightarrow V_o = +V_{sat}$

• Ref. voltage controlled by the R_1 & R_2 Resistors.

$$+V_{ref} = \frac{V_0}{R_1+R_2} \cdot R_2 = \frac{+V_{sat}}{R_1+R_2} \cdot R_2$$ — Positive saturation

$$-V_{ref} = \frac{V_0}{R_1+R_2} \cdot R_2 = \frac{-V_{sat}}{R_1+R_2} \cdot R_2$$ — Negative saturation voltage.

⇒ $+V_{ref}$ is for Positive saturation when $V_0 = +V_{sat}$ and is called upper threshold voltage (V_{UT}) [$+V_{sat}$ to $-V_{sat}$]

⇒ $-V_{ref}$ is negative saturation when $V_0 = -V_{sat}$ and is called lower Threshold voltage (V_{LT}) [$-V_{sat}$ to $+V_{sat}$)

* Based on these Two voltages our out will be change its state.

After i/p & o/p waveform:

* $V_{in} > V_{UT} \Rightarrow V_0 = -V_{sat}$

$V_{in} < V_{LT} \Rightarrow V_0 = +V_{sat}$

• $V_{LT} < V_{in} < V_{UT} \Rightarrow V_0 =$ Previous state

* The diff b/w V_{UT} & V_{LT} is called width of hysteresis. Denoted as H.

* Hysteresis is also called dead band or dead zone.

$H = \dfrac{2 V_{sat} R_2}{R_1 + R_2}$

② $V_{id} = V_{ref} - V_{in}$

$V_{id} = +V_{LT} - V_{in}$

$V_{id} = -3 - (-4)$

$= +ve = +V_{sat}$

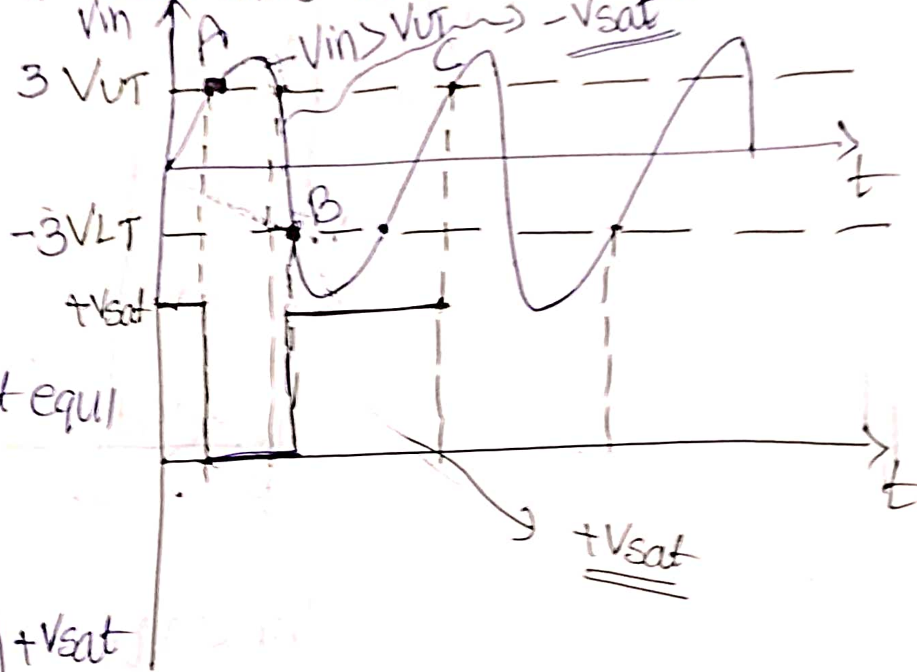
* Working:-

① $V_{id} = [V_{ref} - V_{in}]$

$V_{id} = +ve \rightarrow V_O = +V_{sat}$

$V_{id} = -ve \rightarrow V_O = -V_{sat}$

The input and O/P wave forms of schmitt trigger As shown in fig.



* Procedure:-

1) Assume output equl to $+V_{sat}$.

2) ∴ $V_{UT} = \left(\dfrac{R_2}{R_1+R_2}\right) + V_{sat}$

① $V_{in} > V_{ref}$. V_{id} is $-ve$ so $V_O = -V_{sat}$

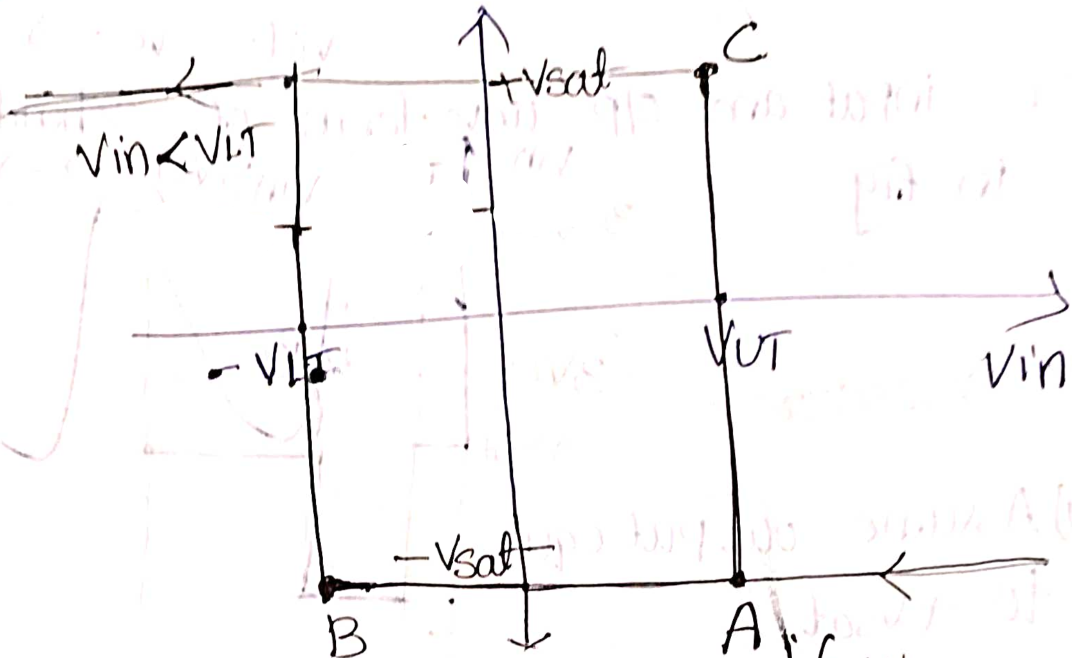
③ Therefore Reference voltage changes to V_{LT}

④ As long As $V_{in} > V_{ref}$ The V_o continues to be Equl to $-V_{sat}$

⑤ As soon As $V_{in} < V_{ref}$ i.e V_{LT}. The out O/P Voltage will switch $+V_{sat}$

* Transfer characteristics! - (The graph b/w i/p voltage and out put voltage)

* Due to feedback the comparator is said to exhibit "hysteresis"



$\Rightarrow$ The interval $V_{LT} < V_{in} < V_{UT}$ is called deadzone or dead band. This dead band condition is defind as hysteresis

$$\therefore \quad H = V_{UT} - V_{LT} = \frac{+V_{sat} R_2}{R_1 + R_2} - \frac{-V_{sat} R_2}{R_1 + R_2}$$

$$\boxed{= \frac{2 V_{sat} R_2}{R_1 + R_2}}$$