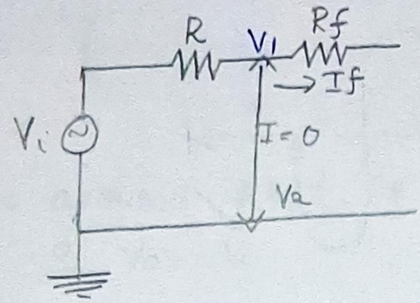
MODULE-2

APPLICATIONS OF OP-AMP

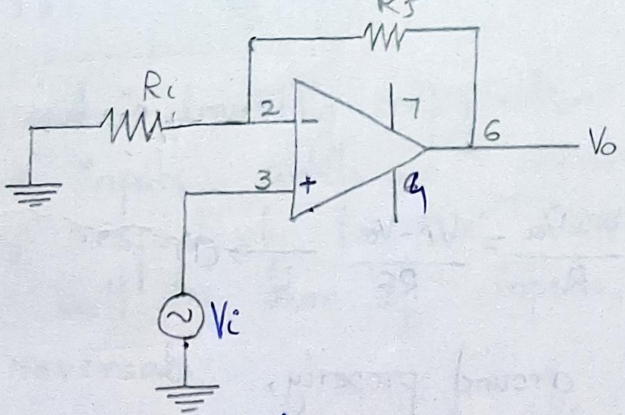
VIRTUAL GROUND PROPERTY

This means the differential input voltage between inverting and non-inverting terminals essentially zero.



From the figure there is a virtual shot between 2 input terminals, but no current flows from input terminals to this ground. The 2 input terminal of OP-AMP are always at same potential w.r.t ground.

NON-INVERTING AMPLIFIER (SCALE CHANGER)



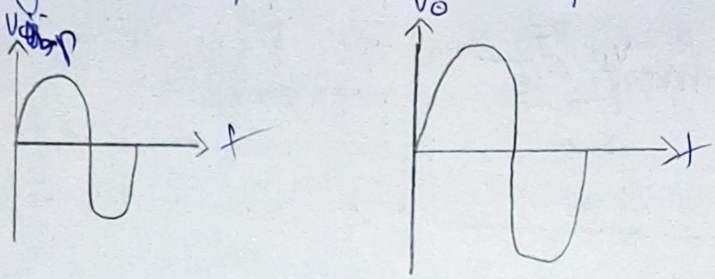
Voltage divider rule

$$V_i = V_o \times \frac{R_i}{R_i + R_f}$$

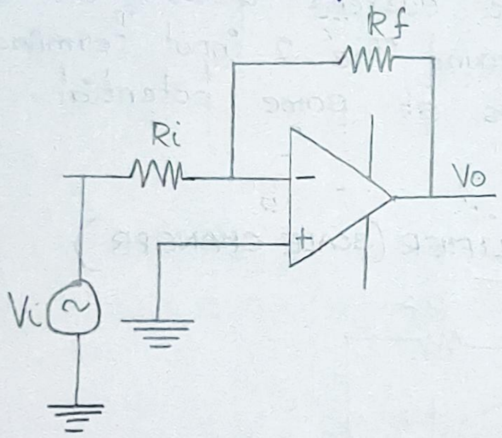
$$\frac{V_o}{V_i} = \frac{R_f + R_i}{R_i}$$

$$A_v = 1 + \frac{R_F}{R_i}$$, gain of non-inverting amplifier.

In non-inverting amplifier the input is applied to the non-inverting input terminal and we will get the o/p which is in phase with input.



INVERTING AMPLIFIER / SIGN CHANGER



V_i

From figure $\frac{V_i - V_a}{R_i} = \frac{V_A - V_o}{R_F} \longrightarrow (1)$

Due to virtual ground property,

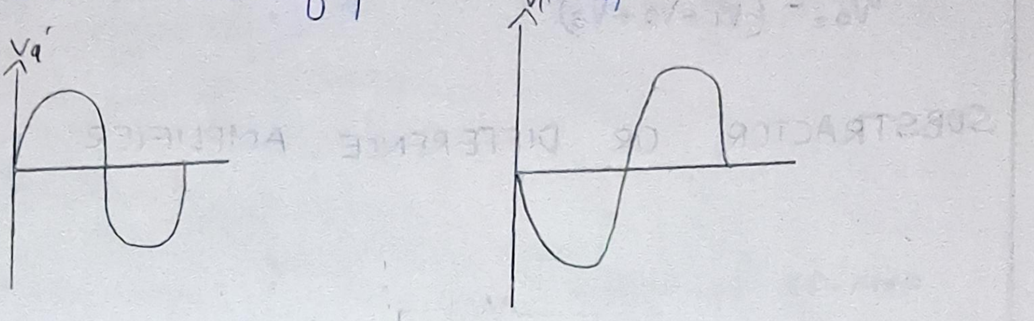
$V_i = 0$

Eqn (1) becomes

$$\frac{V_i}{R_i} = \frac{-V_o}{R_F}$$

$\frac{V_o}{V_i} = \frac{-R_f}{R_i} = A_V$, gain of inverting amplifier.

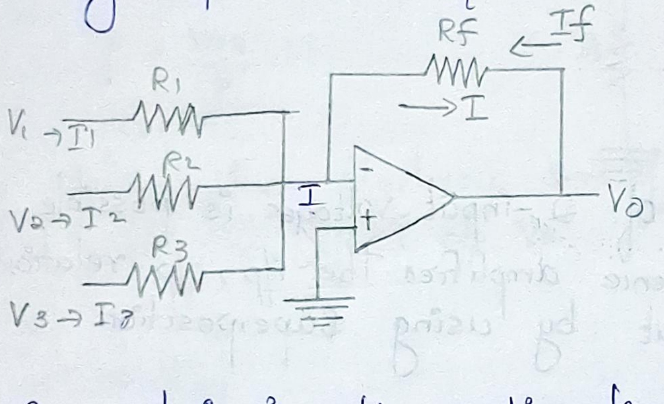
In the inverting amplifier, the input is given to inverting terminal and so the o/p generated will be in out-of phase with i/p.



Let us assume $R_f = R_i$,

So $V_o = -V_i$

Summing Amplifier or Adder Circuit



It is used in inverting configuration where V_1, V_2, V_3 are the inputs which are connected through R_1, R_2, R_3 respectively to the inverting terminal. The o/p will be sum of inputs, with the phase reversal.

From figure $I = I_1 + I_2 + I_3$

Since $I = -I_f$

$-I_f = I_1 + I_2 + I_3$

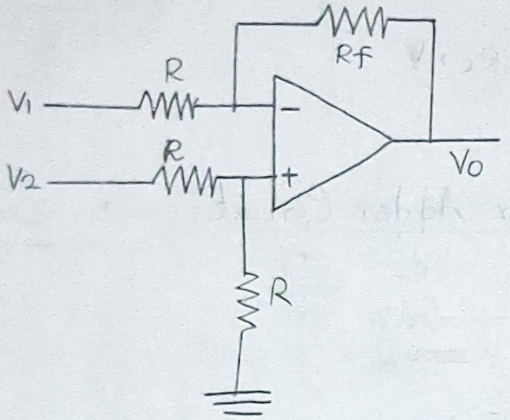
$$\frac{-V_o}{R_f} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$$

If $R_1 = R_2 = R_2 = R_f = R$

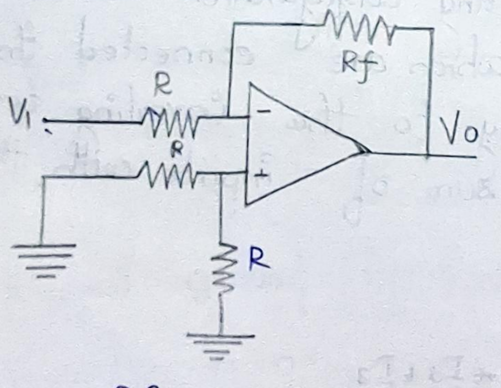
$$-V_o = V_1 + V_2 + V_3$$

$$V_o = -(V_1 + V_2 + V_3)$$

SUBSTRACTOR OR DIFFERENCE AMPLIFIER



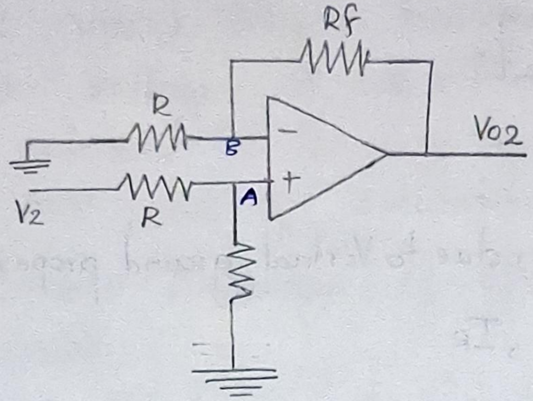
The substraction of 2-input voltages is possible with using difference amplifier. The i/p, o/p relation can be found out by using superposition theorem.



$$V_{o1} = -\frac{R_f}{R_i} \times V_1$$

If $R_f = R$

$V_{O1} = -V_1$



$$V_A = V_2 + \frac{\cancel{R}}{2\cancel{R}}$$

$$V_B = V_A = \frac{V_2}{2} \rightarrow (1)$$

V_A will couple to the -ve terminal of OP-AMP

so $V_B = V_A$

$$V_B = V_{O2} \times \frac{R}{2R} = \frac{V_{O2}}{2} \rightarrow (2)$$

Equate eqn (1) and eqn (2)

$$\frac{V_2}{\cancel{2}} = \frac{V_{O2}}{\cancel{2}}$$

$$V_2 = V_{O2}$$

By taking the algebraic sum of V_{O1} and V_{O2} we can have the final o/p V_O

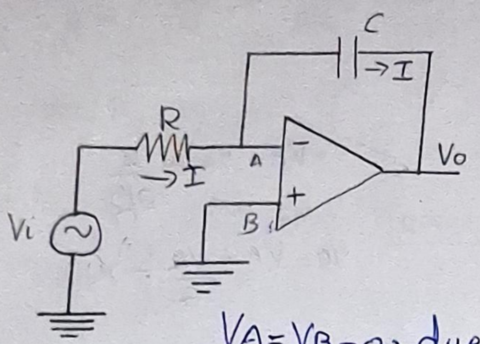
$$V_O = V_{O1} + V_{O2}$$

$$= -V_1 + V_2$$

$$\underline{V_O = V_2 - V_1}$$

INTEGRATOR

Integrator is a circuit whose o/p voltage is the integral of i/p voltage. An integrator without OP-AMP or transistor, is called passive Integrator.
While an integrator with OP-AMP active integrator



$V_A = V_B = 0$, due to Virtual ground property

Current through resistor, I_R

$$I_R = \frac{(V_i - V_A)}{R} = \frac{V_i}{R} \rightarrow (1)$$

Current through capacitor

$$I_C = C \cdot \frac{dv}{dt} = C\frac{d(V_A - V_o)}{dt}$$

$$\cancel{I_C = C\frac{V_o}{dt}}$$

$$I_C = -C\frac{dV_o}{dt} \longrightarrow (2)$$

Since current through resistor ~~is~~ = Current through capacitor

$$I_R = I_C$$

$$= \frac{V_i}{R} = -C\frac{dV_o}{dt}$$

Integrate both sides,

$$= \frac{1}{R}\int V_i - C\int \frac{\cancel{d}V_o}{\cancel{dt}}$$

$$= \frac{1}{R}\int V_i = -CV_o$$

So $V_o = \frac{-1}{RC}\int V_i dt$

LIMITATIONS OF IDEAL INTEGRATOR

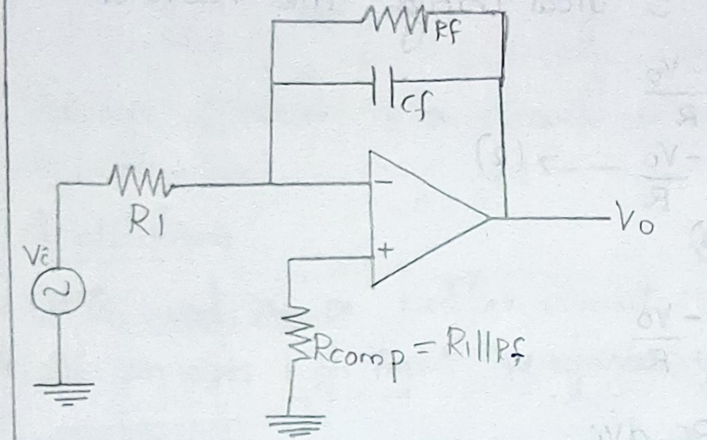
The OP-AMP has input offset voltage and input bias current. These two parameters produce an error voltage at output. This may cause OP-AMP to saturate. It is very difficult to pull the OP-AMP out of saturation.

Another limitation of ideal OP-AMP integrator is its low bandwidth.

Infinite gain at low frequencies. At DC c acts as a open circuit

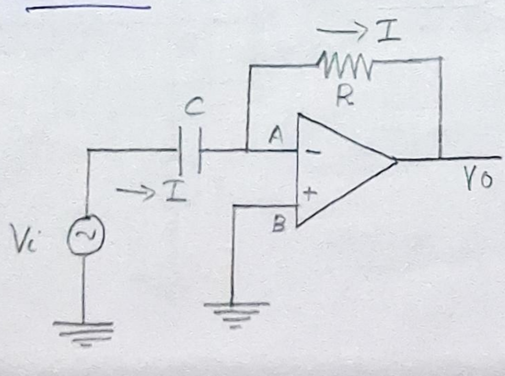
Noise

PRACTICAL INTEGRATOR



Here the resistance Rcomp or Compensation resistor is used to overcome errors due to offset voltage and bias current and Rf reduces the voltage gain at low frequency and there by preventing the OP-AMP from saturation.

DIFFERENTIATOR



In this circuit the o/p is proportional to differential of input voltage. Here the terminal B is connected to ground ~~and~~ so the potential at B is will be coupled to terminal A

$\therefore V_A = V_B = 0$

Now the current through the capacitor,

$$I = C\frac{d}{dt}\left[V_i - V_A\right] \quad (V_A = 0)$$

$$I = C\frac{dV_i}{dt} \longrightarrow (1)$$

The same current flow through the resistor

$$I = \frac{V_A - V_o}{R}$$

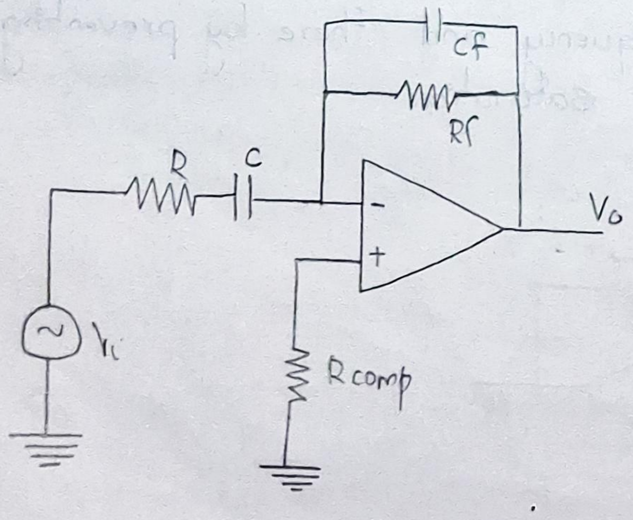
$$I = \frac{-V_o}{R} \longrightarrow (2)$$

Equate ~~Now~~ eqn(1) and eqn(2)

$$\frac{C\,dV_i}{dt} = \frac{-V_o}{R}$$

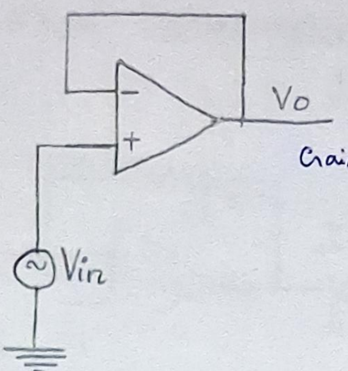
$$V_o = -RC\frac{dV_i}{dt}$$

PRACTICAL DIFFERENTIATOR.



Through this circuit we can acheive, bias compensation, noise reduction and gain stability

VOLTAGE FOLLOWER



Gain=1, $V_o = V_{in}$.

Voltage follower is a circuit whose gain is equal to 1 ie; $V_o = V_{in}$.

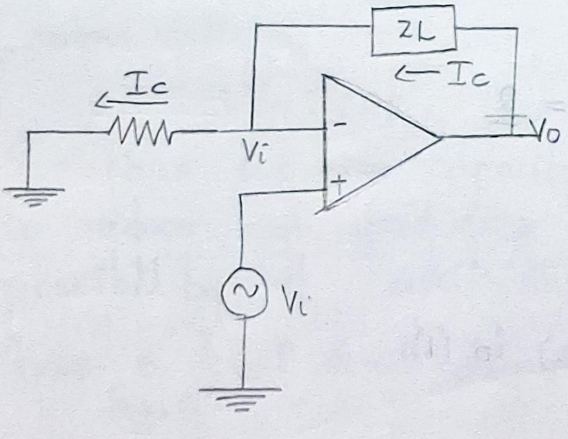
Applications

* It is used as a buffer circuit
* It provides high input impedance for the amplifier.

VOLTAGE TO CURRENT AND CURRENT TO VOLTAGE CONVERTERS

V TO I CONVERTER

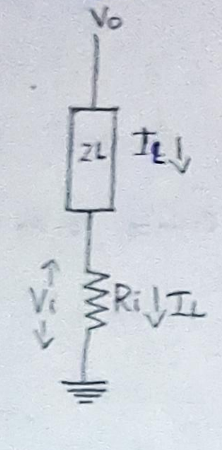
V to I converter with floated load



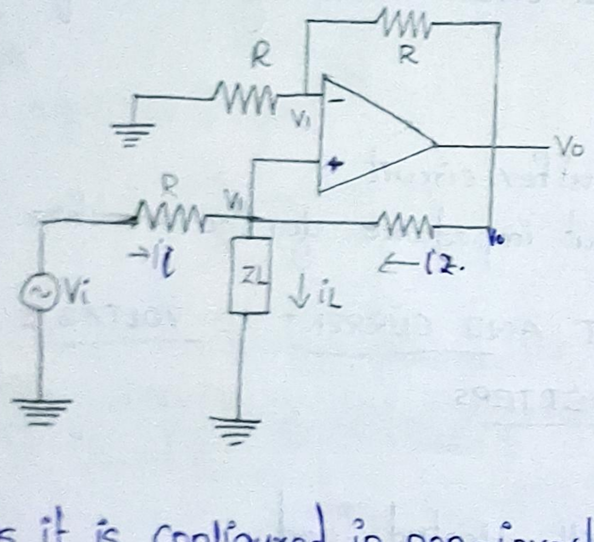
$$I_L = \frac{V_i}{R_i}$$

With floating load voltage to current converter the expression for load current, I

$$I_L = \frac{V_i}{R_i}$$



VTO I converter using grounded load.



$$i_L = i_1 + i_2.$$

$$i_L = \frac{V_i - V_1}{R} + \frac{V_o - V_1}{R}$$

$$i_L = \frac{V_i + V_o - 2V_i}{R} \rightarrow (1)$$

As it is configured in non-inverting type, the gain is equal to

$$\text{Gain} = 1 + \frac{R_f}{R_i} = 1 + \frac{R}{R} = 2$$

$$V_o = 2V_1 \rightarrow (2)$$

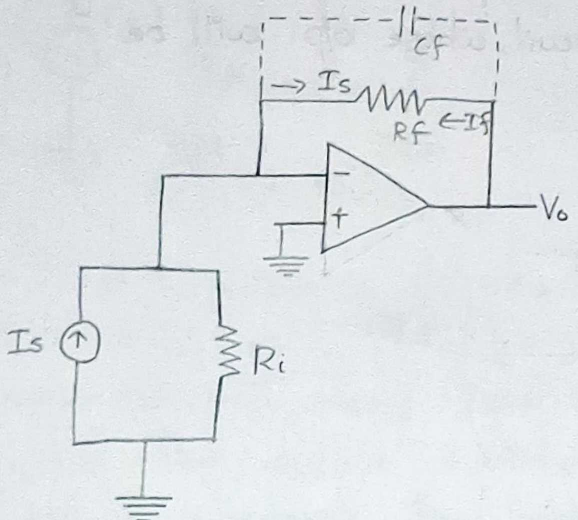
~~V1=2~~

Then Substitute eqn (2) in (1)

$$i_L = \frac{V_i + 2V_1 - 2V_1}{R}$$

$$\boxed{i_L = \frac{V_i}{R}}$$

CURRENT VOLTAGE CONVERTER



$I_f R_f$

$V_o = \cancel{I_f R_f}$

Photovoltaic cell, ~~or~~ photodiode etc gives an output current, which is directly proportional to incident energy or light. The current through the device can be converted into voltage by using current to voltage converter.

In figure, the entire source current Is flows through feedback resistance Rs and expression for output voltage,

$$V_f = I_f R_f$$

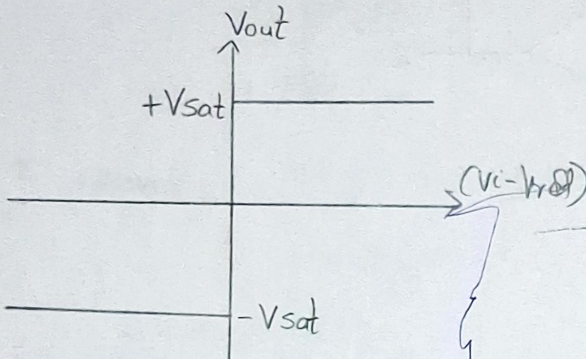
Sometimes we use capacitor Cf in the feedback to reduce high frequency noise and the possibility of oscillations.

Q) Explain in detail about logarithmic and antilog amplifiers. Fig, Eqn.

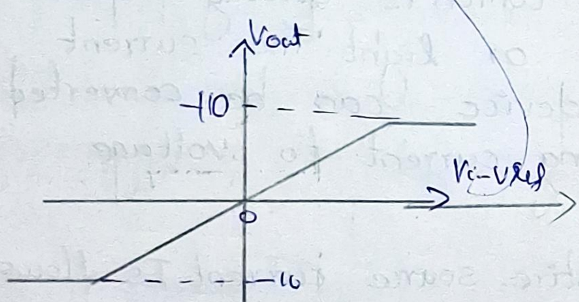
COMPARATORS

~~Comparator Circuit~~

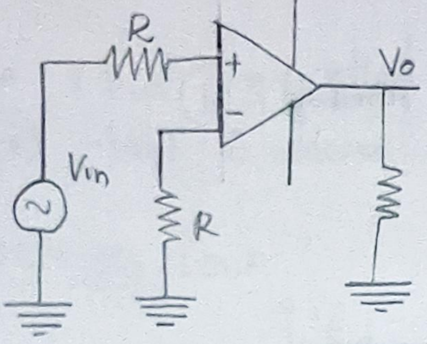
A comparator is a circuit which a signal voltage applied at one of the input with a non-reference voltage at the other input. It is basically an open-loop OP-AMP circuit, whose o/p will be ± ~~or~~ - Vsat.

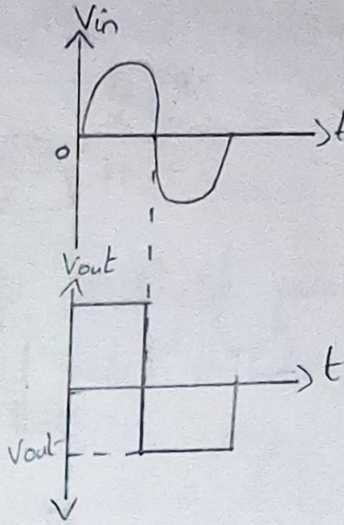


PRACTICAL CHARACTERISTICKS



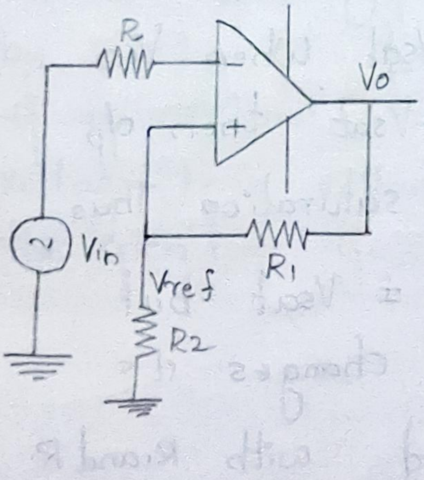
ZERO CROSSING DETECTOR

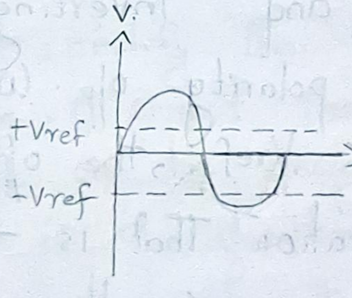




In a zero crossing detector, the reference voltage is set to zero. Figure shows a non-inverting zero crossing detector, where input is given to non-inverting terminal. The output switches between $+V_{sat}$ and $-V_{sat}$ whenever the input signal crosses the zero value. It is a sine wave to square wave convertor.

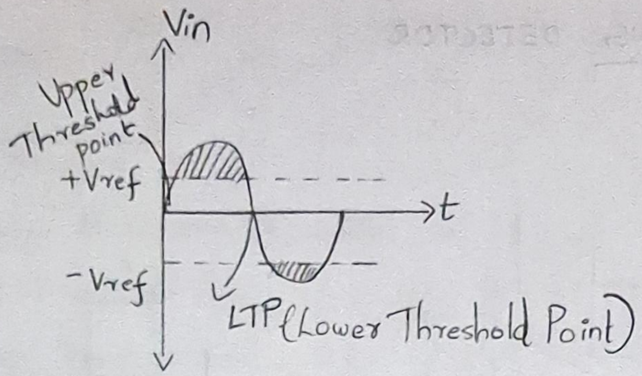
SCHMITT TRIGGER

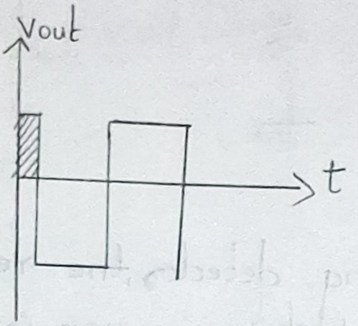




$$V_{ref} = +V_{sat} \times \frac{R_2}{R_1+R_2}$$

$$V_{ref} = -V_{sat} \times \frac{R_2}{R_1+R_2}$$





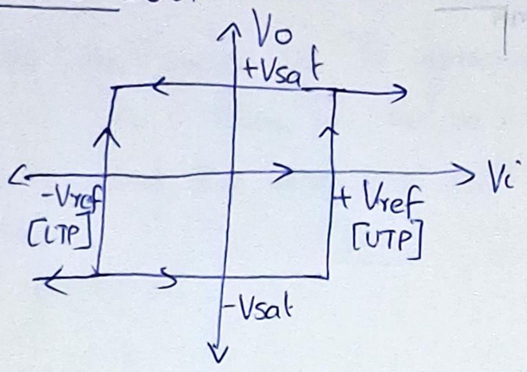
Schmitt Trigger is a sine to square wave converter which uses a -ve feedback. Here the i/p applied to the inverting terminal and inverting mode produced opposite polarity o/p. When Vin is slightly more +ve than Vref, the o/p gets drives into -ve saturation. That is -Vsat. When Vin becomes more -ve than -Vsat then o/p gets driven into +ve saturation. Thus o/p voltage is always ± Vsat but voltage at which it changes its state can be controlled with R_1 and R_2 which forms voltage divider

$$+V_{ref} = +V_{sat} \times \frac{R_2}{R_1+R_2}$$

$$-V_{ref} = -V_{sat} \times \frac{R_2}{R_1+R_2}$$

Here $+V_{ref}$ is called upper threshold point (UTP) $-V_{ref}$ is lower threshold point (LTP)

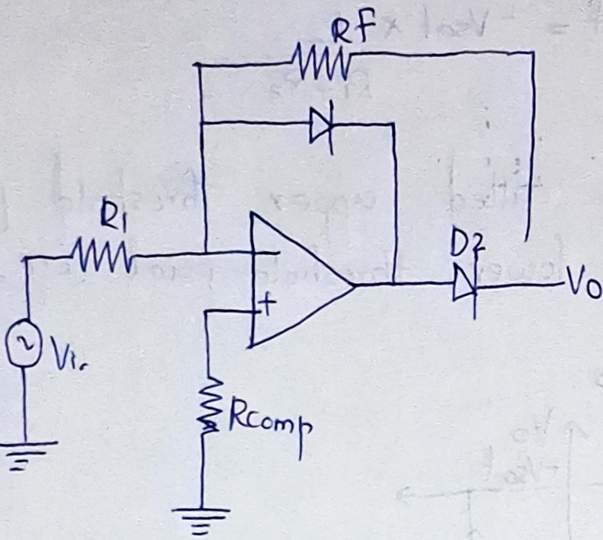
HYSTERISIS LOOP



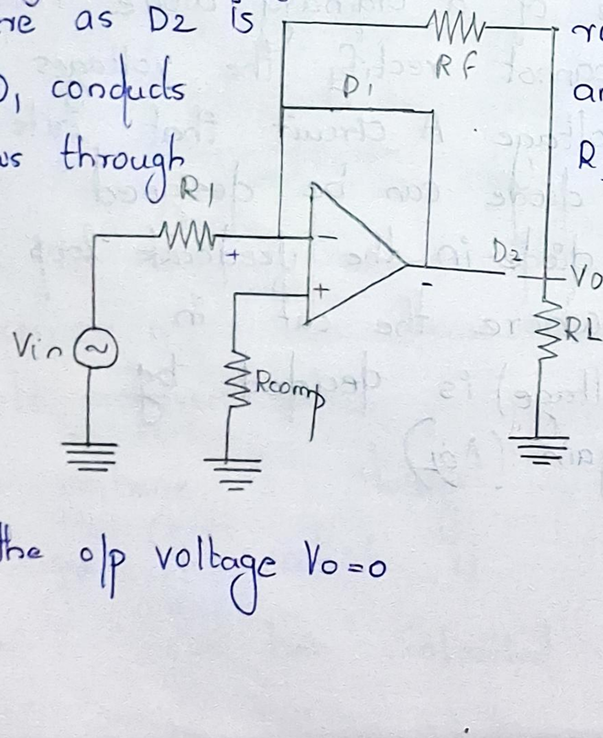
PRECISION RECTIFIER

The major function of a ordinary diode rectifier is that it cannot rectify the voltages below knee voltage. A circuit that acts as a ideal diode can be designed by placing a diode in the feedback loop of a OP-AMP where the cut in voltage (knee voltage) is decided by the open loop gain (A_{OL})

PRECISION HALFWAVE RECTIFIER

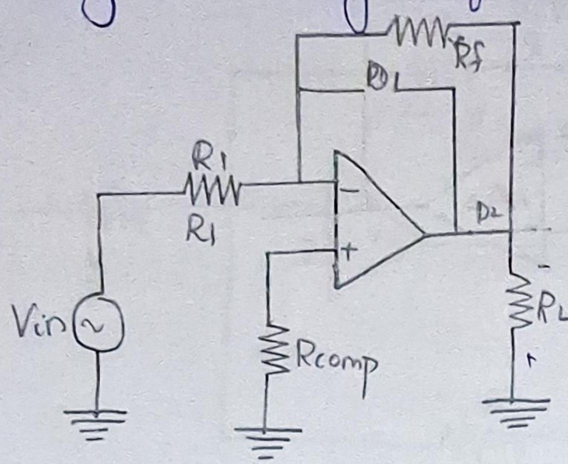


During +ve half cycle diode D_1 become forward biased where as D_2 is reverse biased.
∴ D_1 conducts and practically no current flows through $R_f = 0$

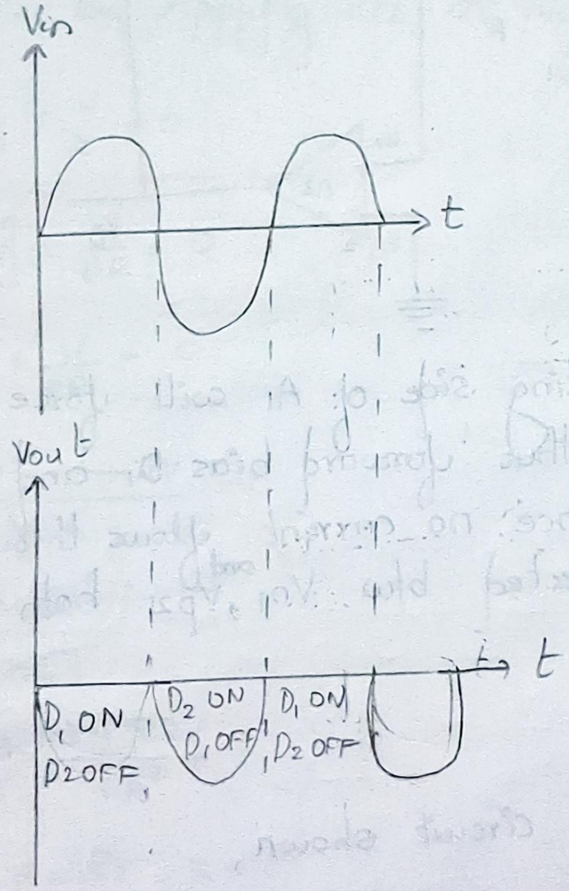


So the o/p voltage $V_o = 0$

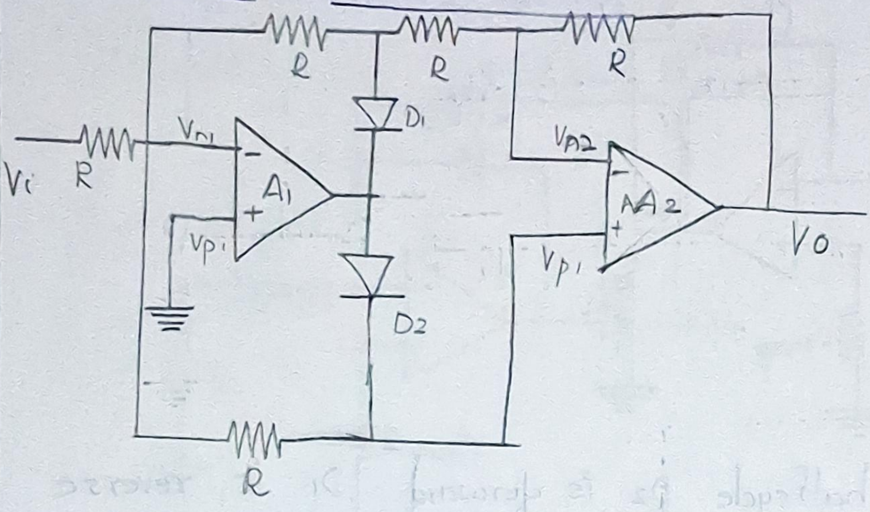
During -ve half cycle of input



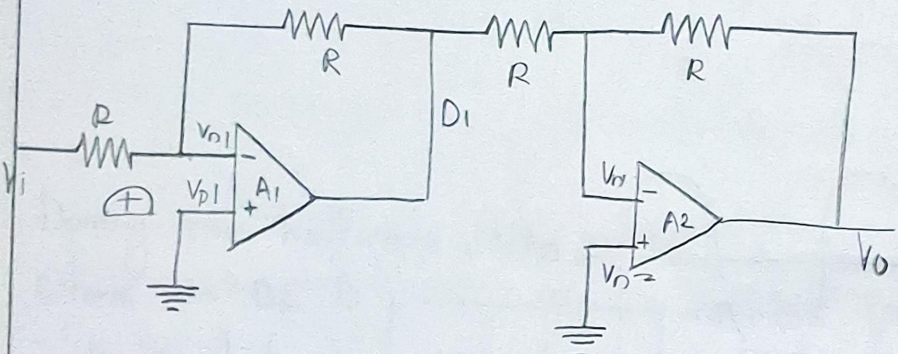
During -ve halfcycle D2 is forward D1 is reverse biased at this time, the entire current flows through RL and Rf and we will get an o/p voltage across RL.



PRECISION FULLWAVE RECTIFIER



During +ve halfcycle, Vin > 0



When Vin>0, the inverting side of A_1 will force the o/p to swing -ve, thus forward bias D_1 and reverse bias D_2. Since no current flows through resistance R connected b/w V_{n1} and V_{p2} both are at equipotential ie;

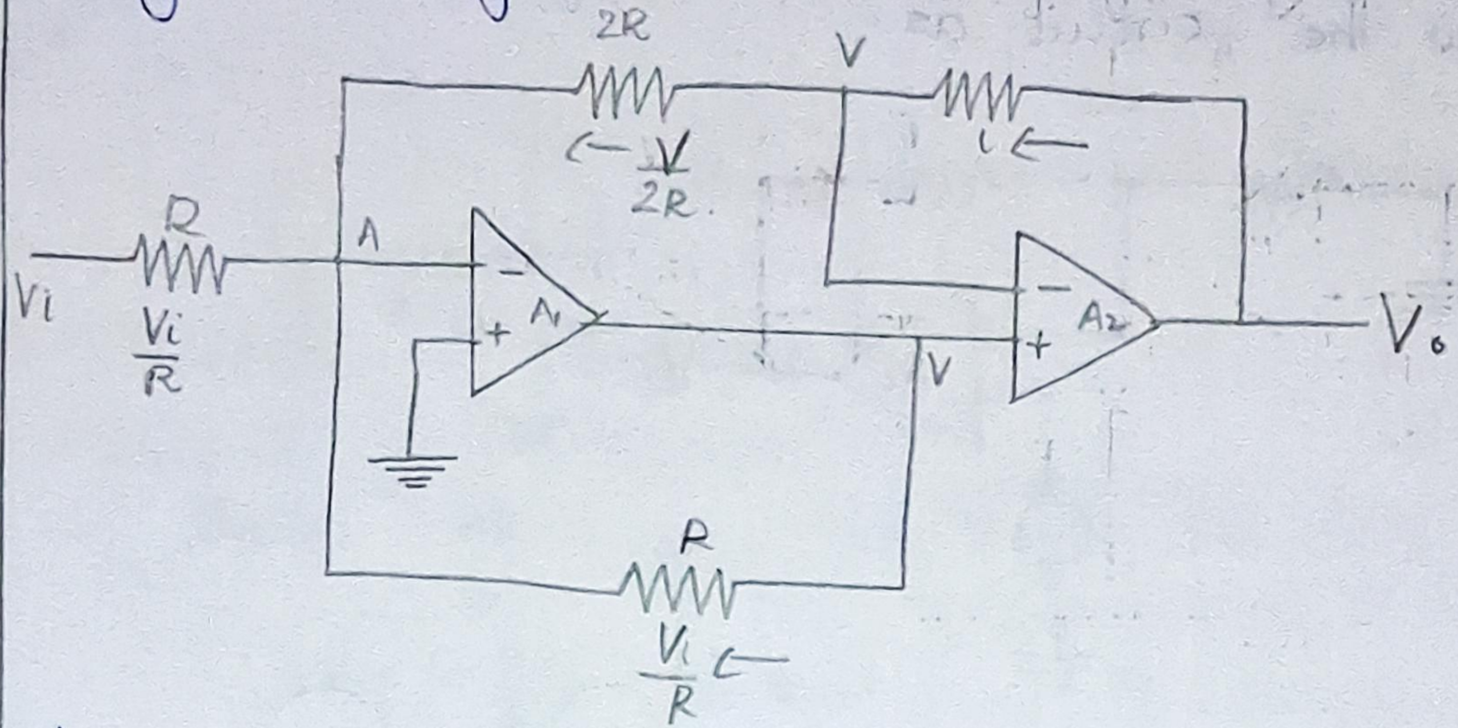
$$V_{n1} = V_{p2} = 0$$

From the equivalent circuit shown,

$$V_o = V_{in}\left(\frac{-R}{R}\right) \times \left(-R/R\right)$$

$$V_o = V_{in}$$

During -ve half cycle



$\frac{V_i}{R}$ During -ve half cycle the o/p of A_1 swings to +ve making D_1 reverse biased and D_2 forward biased. So By Applying KCL at Node A

$$\frac{V_i}{R} + \frac{V}{2R} + \frac{V}{R} = 0$$

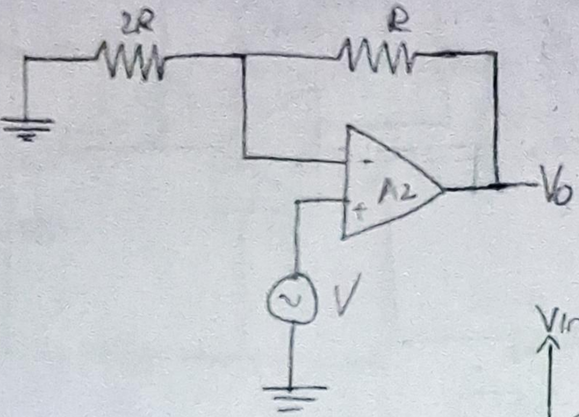
$\cancel{2}R$

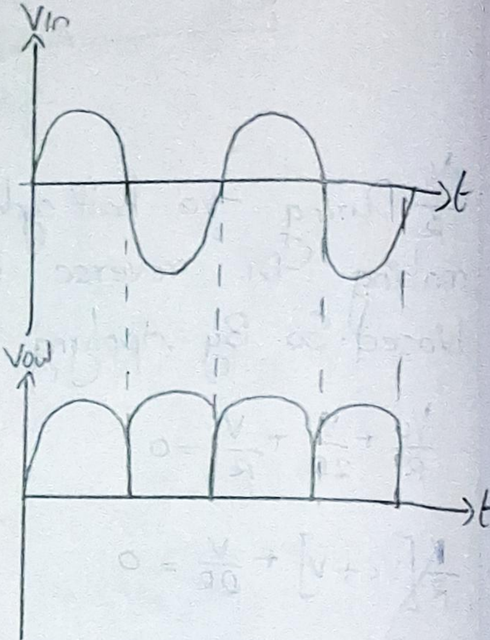
$$= \frac{Vi}{R} + \frac{RV + 2RV}{2R^2}$$

$$\frac{Vi}{R} + \frac{3\cancel{R}V}{3R^{\cancel{2}}} = 0$$

$$V = \frac{-2Vi}{3}$$

Inorder to get final o/p in terms of V we will redraw the circuit as.





$$V_o = V\left[1 + \frac{R}{2R}\right]$$

$$= V\left[\frac{2R+R}{2R}\right]$$

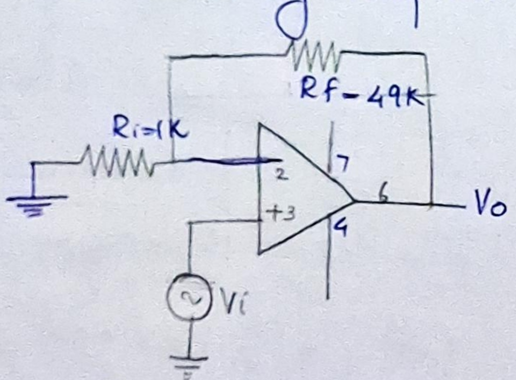
$$= V\left[\frac{3R}{2R}\right]$$

$$V_o = V \times 3/2$$

$$V_o = -\frac{2V_i}{3} \times \frac{3}{2}$$

$$\underline{\underline{V_o = -V_i}}$$

2. Design a non-inverting amplifier for a gain = 50



$R_i = 1K$

$$\text{Gain} = \frac{1 + RF}{Ri}$$

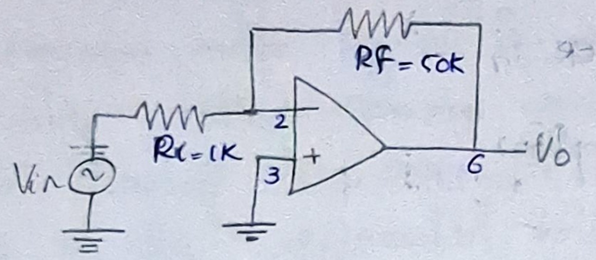
$$50 = \frac{1}{1} + \frac{RF}{Ri}$$

$$50 = \frac{Ri + RF}{Ri}$$

$50 = 1 + Rf$

$50 - 1 = RF$, $\underline{\underline{RF = 49K}}$

2. Design an inverting Amplifier for gain 50



$$\text{Gain} = \frac{-RF}{Ri}$$

$$50 = -\frac{RF}{\cancel{Ri}\,1} \qquad Rf = 50K$$