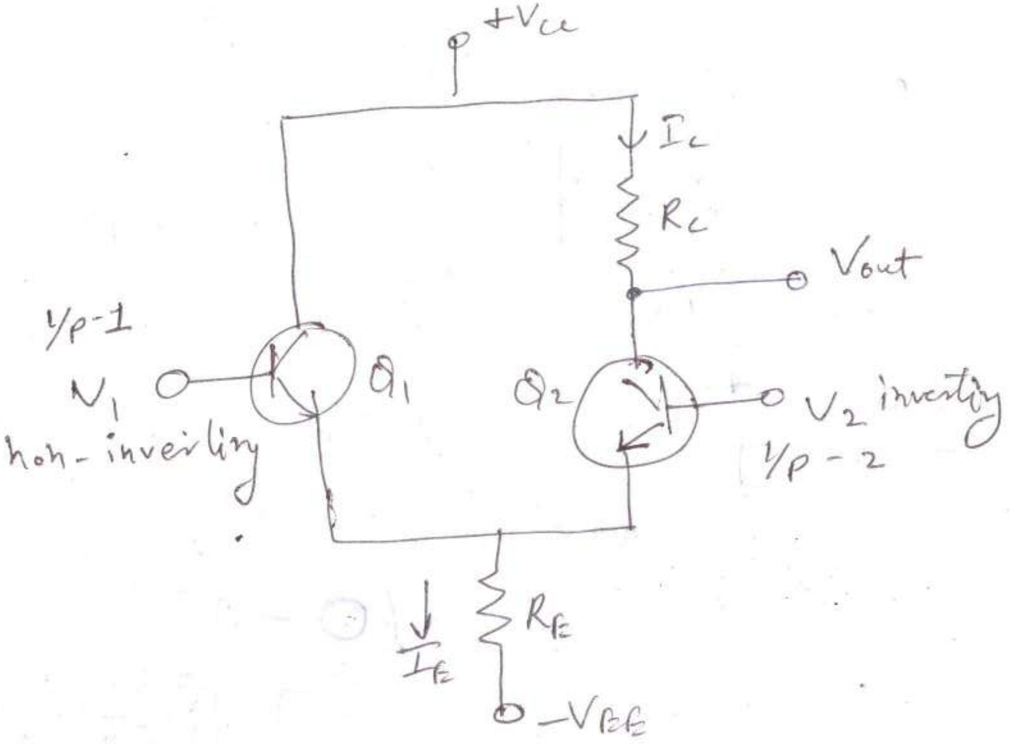
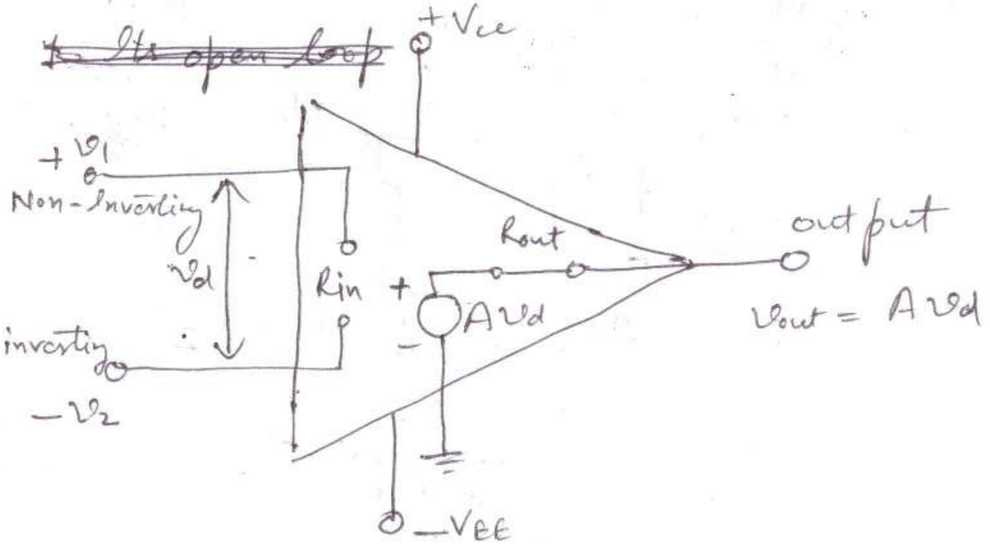
Basic Operational Amplifier Ckt



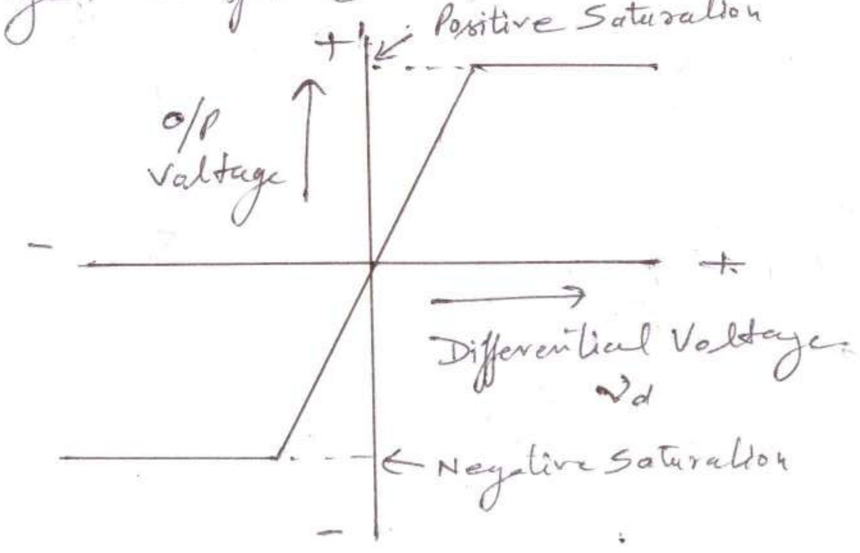
IDEAL OP-AMP

~~1. Its open loop~~

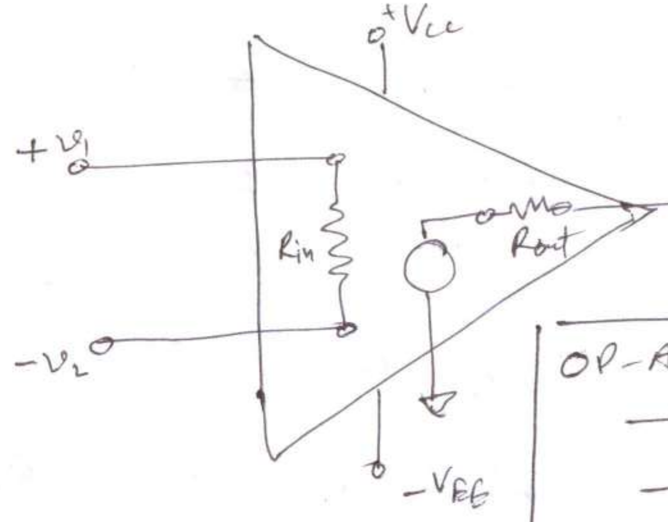


1. Its open loop gain A is infinite.
2. Its i/p resistance Rin is ~~zero~~ infinite.
3. Its out impedance Rout is zero.
4. Infinite frequency bandwidth.
5. Drift of characteristics with temperature is nil.
6. Common mode rejection Ratio (CMRR) is infinite
7. Slew rate is infinite.
8. offset voltage is zero.

Voltage Transfer Curve



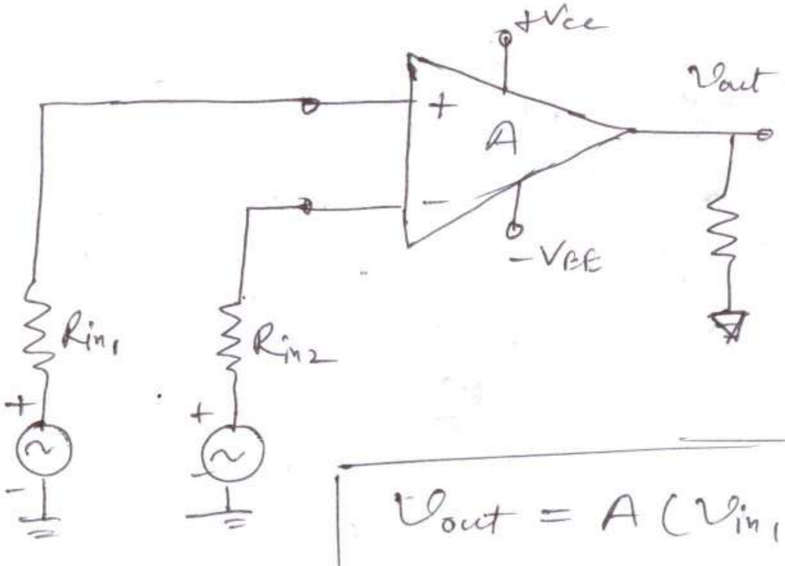
Practical OP-AMP



OP-AMP
→ OPEN LOOP
→ CLOSED LOOP

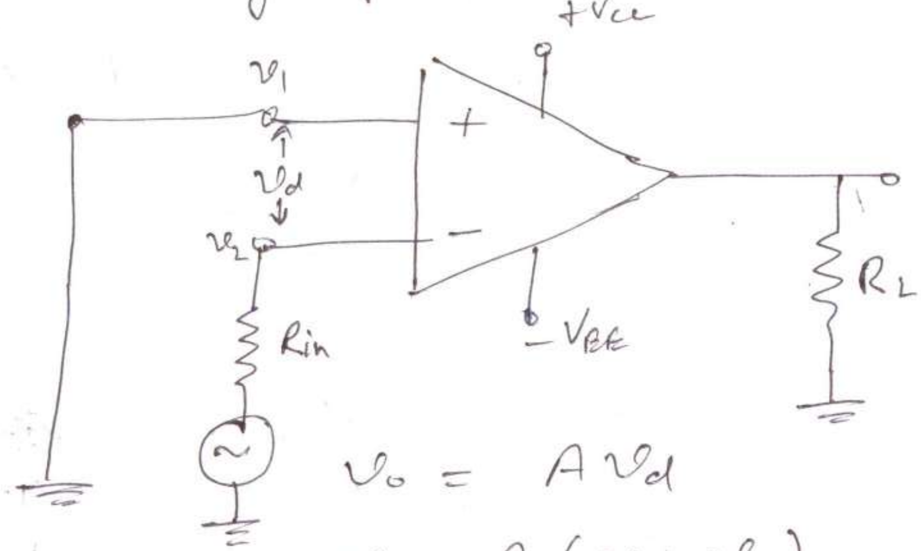
Open Loop OP-AMP Configurations

1. Differential Amp



$$\boxed{v_{out} = A(v_{in_1} - v_{in2})}$$

2. Inverting Amp



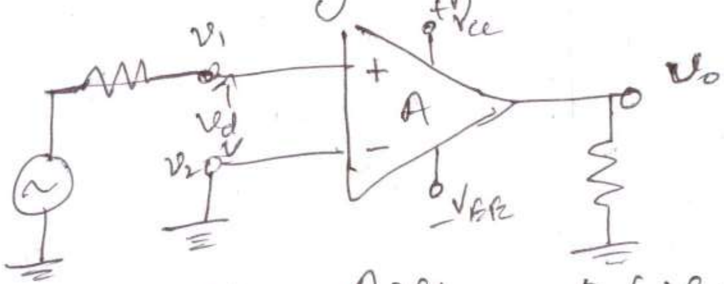
$$v_o = A v_d$$

$$v_o = A(v_1 - v_2)$$

$$= A(0 - v_2)$$

$$\boxed{v_o = -A v_2} \quad \boxed{v_o = -A v_{in}}$$

3. Non Inverting Amp



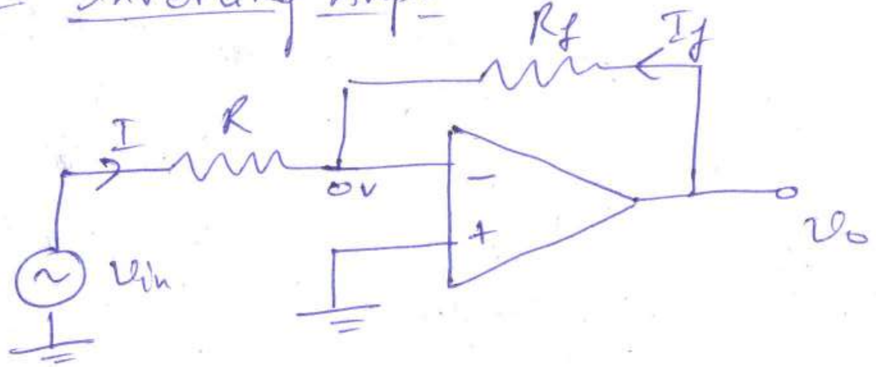
$$v_o = A v_d = A(v_1 - v_2)$$

$$v_o = A(v_1 - 0)$$

$$\boxed{v_o = A v_i} \quad \boxed{v_o = A v_{in}}$$

Closed loop op-amp Configurations

1. Inverting Amp.



From the figure.

$$I + I_f = 0$$

$$\frac{V_{in} - 0}{R} + \frac{V_o - 0}{R_f} = 0$$

$$\frac{V_{in}}{R} + \frac{V_o}{R_f} = 0$$

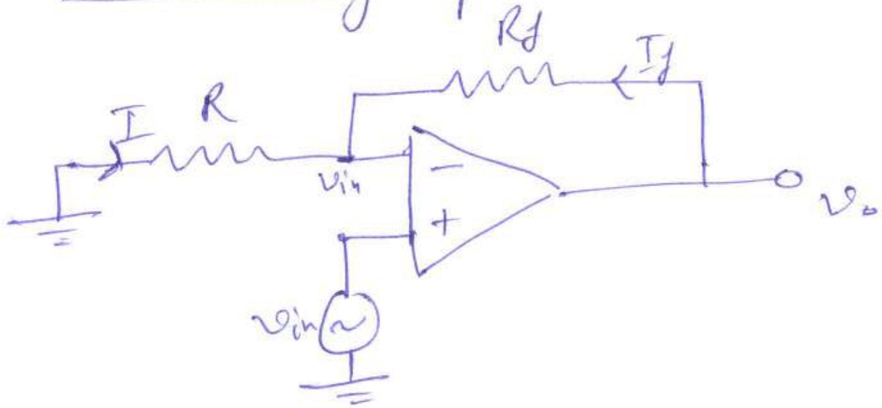
$$\frac{V_o}{R_f} = -\frac{V_{in}}{R}$$

$$V_o = -\frac{R_f}{R} V_{in}$$

$$\boxed{V_o = -A_f V_{in}}$$

where $A_f = \frac{R_f}{R}$

2. Non-Inverting Amp.



$$I + I_f = 0$$

$$\frac{0 - V_{in}}{R} + \frac{V_o - V_{in}}{R_f} = 0$$

$$-\frac{V_{in}}{R} + \frac{V_o}{R_f} - \frac{V_{in}}{R_f} = 0$$

$$\frac{V_o}{R_f} = \frac{V_{in}}{R_f} + \frac{V_{in}}{R}$$

$$V_o = V_{in}\left(\frac{R_f}{R_f} + \frac{R_f}{R}\right)$$

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

$$\boxed{V_o = A_f . V_{in}}$$

where $A_f = \left(1 + \frac{R_f}{R}\right)$

~~Ne~~

① Design a non-inverting amplifier ckt that is capable of providing a voltage gain of 10. Assume an ideal op-amp. (~~ideal op-amp;~~ resistance should not exceed 30 kΩ)

Solⁿ for non-inverting op-amp

$$A_f = 1 + \frac{R_f}{R}$$

$$10 = 1 + \frac{R_f}{R}$$

$$\frac{R_f}{R} = 10 - 1 = 9$$

$$R_f = 9R \quad \text{——} \quad ①$$

if we take R is as 3 kΩ

$$R_f = 9 \times 3 = 27 \text{ k}\Omega$$

$$\boxed{R_f = 27 \text{ k}\Omega}$$

which is less than 30 kΩ. ANS

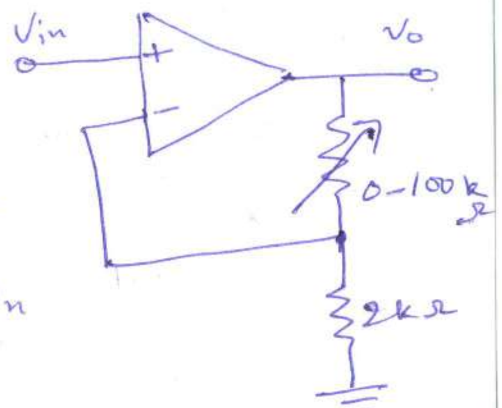
② In the given figure, the variable resistance varies from 0 to 100 kΩ. Find out the maximum and the minimum closed loop voltage gain.

Solⁿ

$R = 2\text{ k}\Omega$

$R_{f(min)} = 0 \text{ k}\Omega$

$R_{f(max)} = 100 \text{ k}\Omega$



Closed loop voltage gain

$$A_f = 1 + \frac{R_f}{R}$$

$$A_{f(max)} = 1 + \frac{100}{2} = 1 + 50 = 51 \quad \text{ANS}$$

$$A_{f(min)} = 1 + \frac{0}{2} = 1 \quad \text{ANS}$$

3. An Inverting amplifier has $R_f = 500\,k\Omega$ and $R_1 = 5\,k\Omega$. Determine the amplifier ckt voltage gain, input resistance and output resistance. Also Determine the output voltage and input current if the input voltage is ~~0 V~~ 0.1 V.
(Assume op-amp to be ideal one.)

Sol^n $R = 5\,k\Omega$; $R_f = 500\,k\Omega$

$V_{in} = 0.1V$

Voltage gain $A_f = -\frac{R_f}{R} = -\frac{500\,k\Omega}{5\,k\Omega} = -100$ ANS

i/p resistance $R_{in} = R = 5\,k\Omega$ ANS

o/p resistance $R_{out} = 0$ ANS

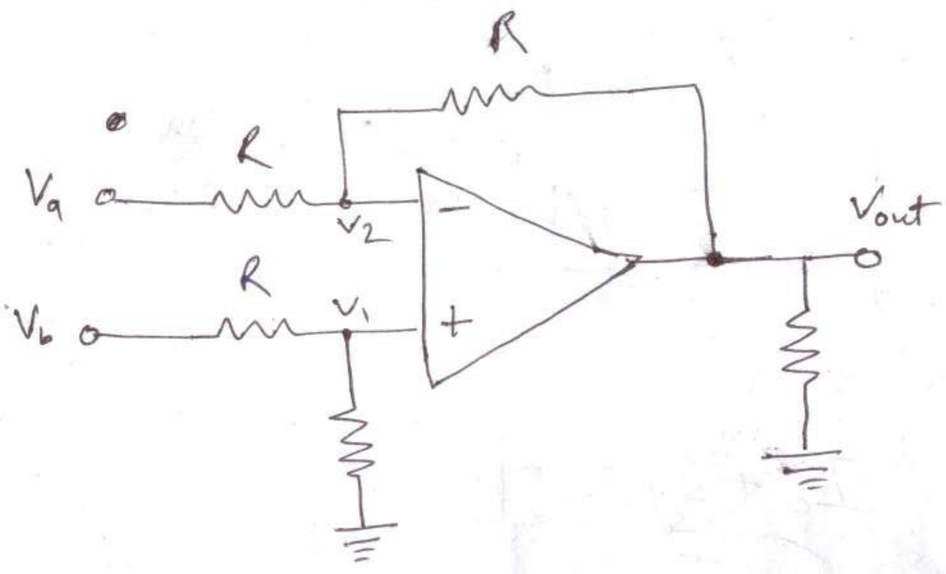
output voltage $v_o = A_f V_{in} = -100 \times 0.1$

$\boxed{v_o = 10\,V}$ ANS

input current $I_{in} = \frac{V_{in}}{R} = \frac{0.1}{5 \times 1000} =$

$\boxed{I_{in} = 0.02\,mA}$ ANS

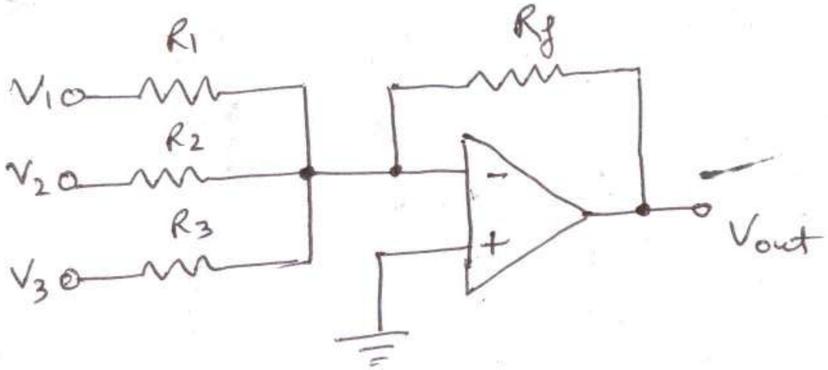
OP-Amp Subtractor



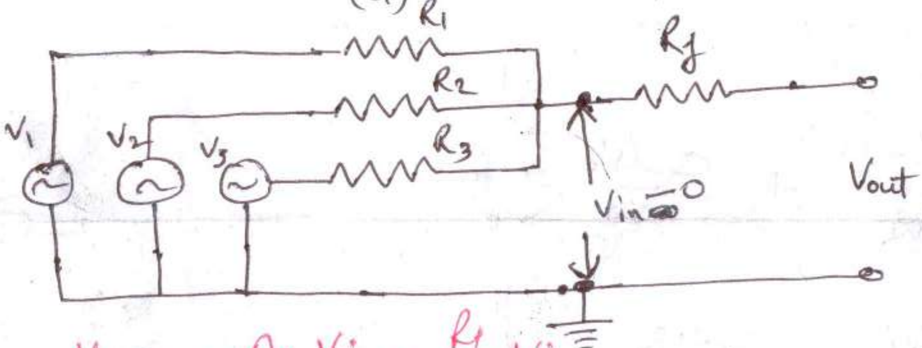
~~O/P~~ $V_{out} = \frac{-R}{R}(V_a - V_b)$

$$\boxed{V_{out} = V_a - V_b}$$

Adder or Summing Amp.



(a)



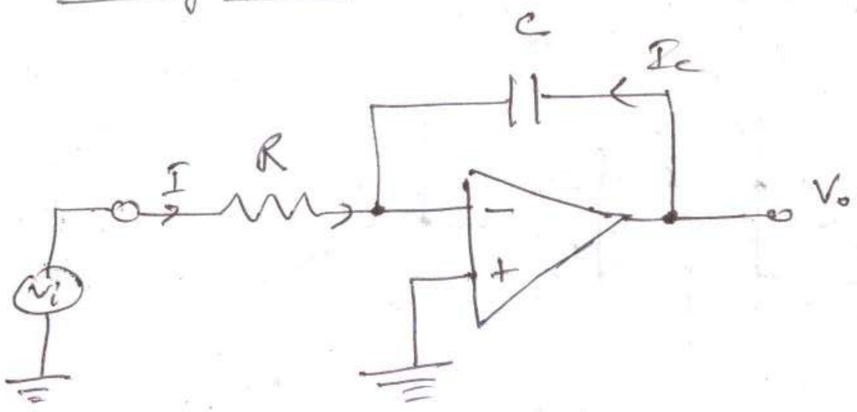
$V_o = -A_f V_i = \frac{R_f}{R} V_i$

$$V_{out} = -R_f\left[\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right]$$

if $R_1 = R_2 = R_3 = R_f$.

then $V_{out} = -(V_1 + V_2 + V_3)$

Integrator



$$I + I_c = 0$$

$$\frac{V_i - 0}{R} + \frac{C\,dV_o}{dt} = 0$$

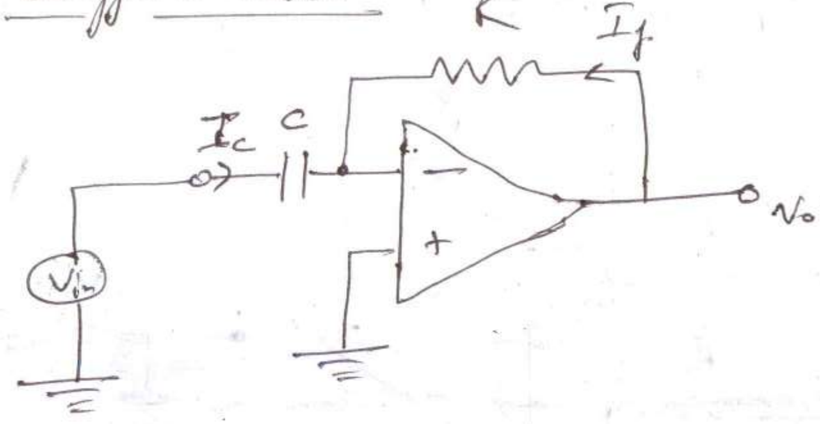
$$\frac{V_i}{R} + \frac{C\,dV_o}{dt} = 0$$

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

$$\frac{dV_o}{dt} = -\frac{V_i}{RC}$$

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

Differentiator



$$I_c + I_f = 0$$

$$\frac{C\,dV_i}{dt} + \frac{V_o}{R_f} = 0$$

$$\frac{V_o}{R_f} = -C\frac{dV_i}{dt}$$

$$\boxed{V_o = -R_f C\frac{dV_i}{dt}}$$

Comparator:

- A comparator compares a voltage signal applied to one input of the op-amp with a known voltage, called reference voltage applied at the other input.
- In its simplest form, the comparator consist of an op-amp ~~open loop~~ operated in open loop.
- In this configuration op-amp produces one of the two saturation voltages, namely, positive or negative at the output of opamp.

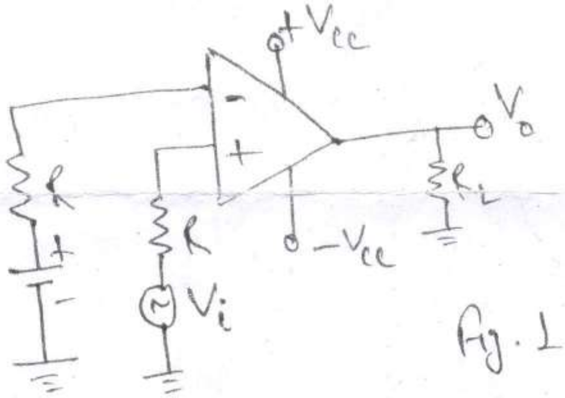
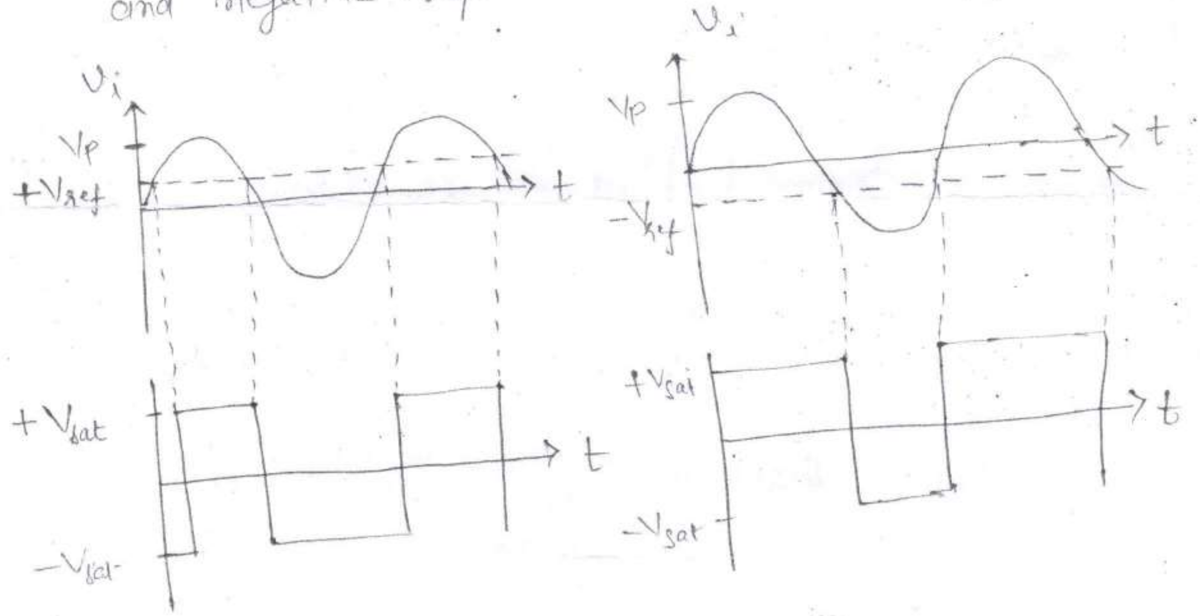


Fig. 1

- Fig 1 shows an op-amp configured for use as a non-inverting comparator.
- A fixed reference voltage V_{ref} is applied to (−) input and a time varying signal V_i is applied to (+) input.
- When the non-inverting input V_i is less than the reference voltage V_{ref}, the output voltage v_o is at $-V_{sat} \simeq -V_{EE}$.

- When v_i greater than V_{ref}, the output voltage v_o is at $+V_{sat} \approx +V_{cc}$
- Thus the output v_o changes from one saturation level to another depending on the voltage difference between v_i and V_{ref}
- Fig 2 (a) and (b) show the input and output waveform of the comparator when V_{ref} is postive and negative respective.

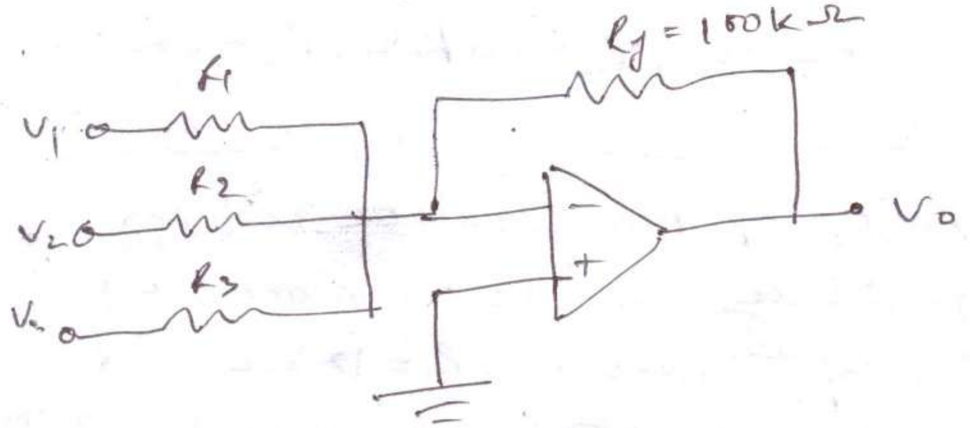


Exp Design an adder circuit using an op-amp to get o/p expression as

$$V_o = -(V_1 + 10V_2 + 100V_3) \quad \text{——} (1)$$

where V_1, V_2 and V_3 are the i/p

Given that $R_f = 100\,k\Omega$.



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

$$V_o = -\left[\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right] \quad \text{——} (2)$$

Comparing the above expression.

(i) $\frac{R_f}{R_1} = 1$, (ii) $\frac{R_f}{R_2} = 10$

(iii) $\frac{R_f}{R_3} = 100$

(i) $R_f = R_1 = 100\,k\Omega$

(ii) $\frac{R_f}{R_2} = 10 \Rightarrow R_2 = \frac{R_f}{10} = \frac{100}{10} = 10\,k\Omega$

(iii) $\frac{R_f}{R_3} = 100 \Rightarrow R_3 = \frac{R_f}{100} = \frac{100}{100} = 1\,k\Omega$

$R_1 = 100\,k\Omega$, $R_2 = 10\,k\Omega$, $R_3 = 1\,k\Omega$.

---x---x---

Exp An opamp has feedback resistor $R_f = 12\,k\Omega$ and the resistance on the input sides are $R_1 = 12\,k\Omega$, $R_2 = 2\,k\Omega$, $R_3 = 3\,k\Omega$. The corresponding i/p are $V_1 = +9V$, $V_2 = -3V$, $V_3 = -1V$. Non-inverting terminal is grounded. Calculate the o/p voltage.

~~Rg~~

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

$$= -12\left[\frac{9}{12} - \frac{3}{2} - \frac{1}{3}\right]$$

$$= -[9 \cancel{+} 18 - 4]$$

$$= 18 + 4 - 9 = 13\,V.$$

Exp Sketch the circuit of summer using op-amp to get

$$V_o = -V_1 + 2V_2 - 3V_3 \quad \cancel{(2)}$$

Sol

$$V_o = -\left[\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right] \quad (1)$$

~~Comparing (1) and (2)~~

$$V_o = -(V_1 - 2V_2 + 3V_3) \quad (1)$$

By comparing.

$$\frac{R_f}{R_1} = 1, \quad \frac{R_f}{R_2} = 2, \quad \frac{R_f}{R_3} = 3$$

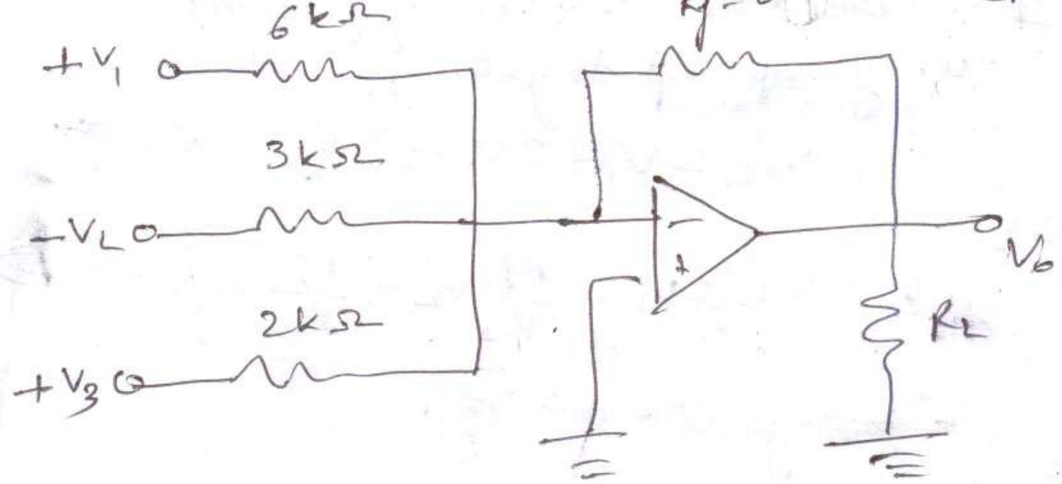
Taking $R_f = 6\,k\Omega$.

$$R_1 = R_f = 6\,k\Omega$$

$$R_2 = \frac{R_f}{2} = 3\,k\Omega$$

$$R_3 = \frac{R_f}{3} = 2\,k\Omega$$

(4)



~~Ex Realize a ckt to~~ .

Exp Realise a ckt to obtain

$V_o = -2V_1 + 3V_2 + 4V_3$

use minimum value of resistance as $10\ k\Omega$.

sol^n $V_o = -\left[\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right]$ — ①

Give $V_o = -\left[2V_1 - 3V_2 - 4V_3\right]$ — ②

By Comparing.

$\frac{R_f}{R_1} = 2 \quad , \quad \frac{R_f}{R_2} = 3 \quad , \quad \frac{R_f}{R_3} = 4$

~~$R_3 = \frac{R_f}{4} =$~~

$R_f = 4R_3 = 4 \times 10 = 40\ k\Omega$

$R_1 = \frac{40}{2} = 20\ k\Omega$

$R_2 = \frac{40}{3} = 13.33\ k\Omega$

$R_3 = \frac{40}{4} = 10\ k\Omega$.

2