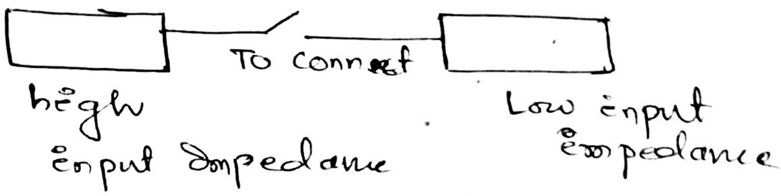
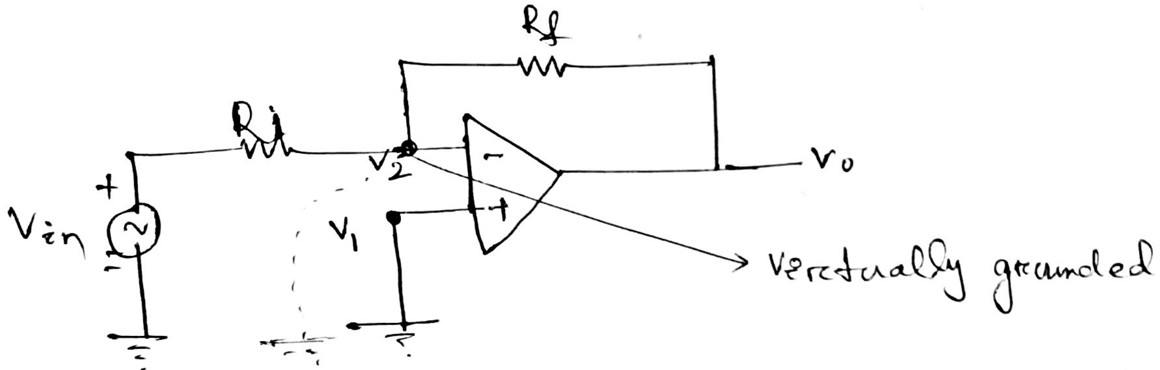
We can used Buffer



→ Since Buffer has high input impedance and low output impedance

Buffer.

2 Concept of Virtual ground



→ A point in any circuit is said to be grounded if the potential at that point is equal to the ground Potential. 0-volt.

$$V_o = A_{OL}(V_1 - V_2)$$

$$(V_1 - V_2) = \frac{V_o}{A_{OL}}$$

for ideal op-Amp

$$A_{OL} = \infty$$

$$V_1 - V_2 = \frac{V_o}{\infty} = 0$$

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

∵ Since $V_1 = 0$ (directly ground)

$\Rightarrow$ $V_2 = 0$ (Virtually ground.)

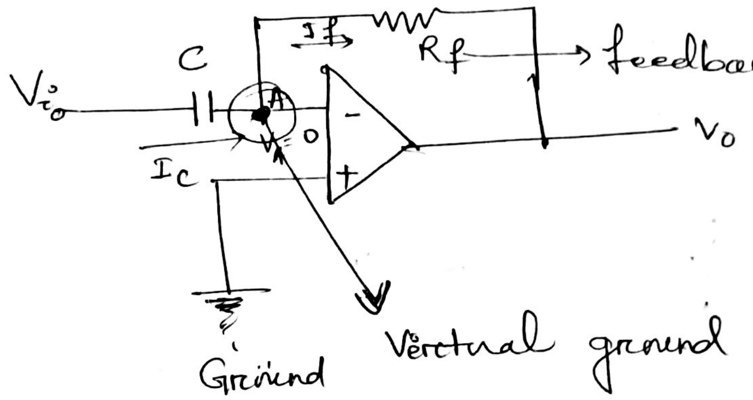
OP-AMP - As a differentiator :—

or,

OP-Amp as a differential amplifier :—

→ A circuit that perform mathematical differentiation of input signal is called differentiator.

→ The output of a differentiator is proportional to the rate of change of its input signal.



Now applying KCL at node A

$$I_c = I_F$$

{ I_c = current flowing through the capacitor.

$$\Rightarrow C \cdot \frac{dV_c}{dt} = \frac{\cancel{V_A}^{0} - V_o}{R_f}$$

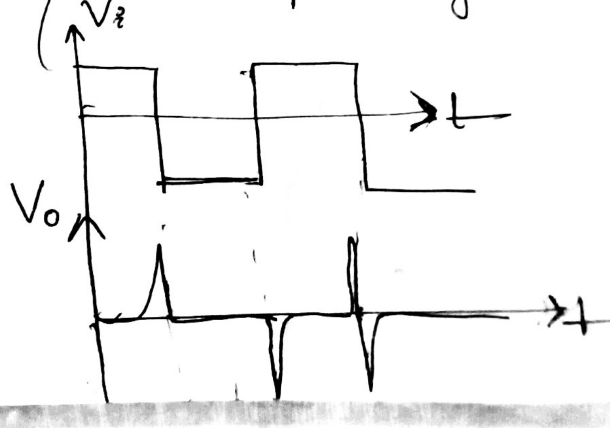
$$\boxed{V_c = V_i}$$

$$\Rightarrow C \cdot \frac{d(V_i)}{dt} = \frac{-V_o}{R_f}$$

V_o = output signal.

$$\Rightarrow \frac{d(V_i)}{dt} = -\frac{V_o}{R_f C}$$

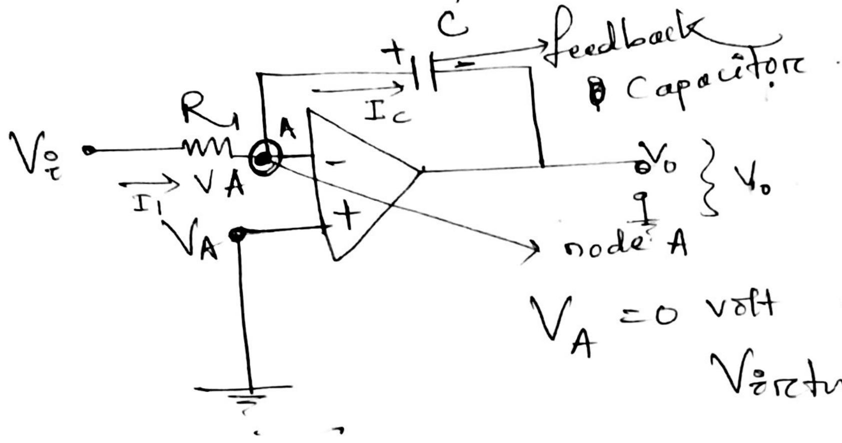
$$\Rightarrow \boxed{V_o = -R_f C \cdot \frac{dV_i}{dt}}$$



OP-AMP – As integrator :

→ A circuit that performs integration of input signals is called an integrator.

→ The output of an integrator is proportional to the Area of the input waveform over a period of time



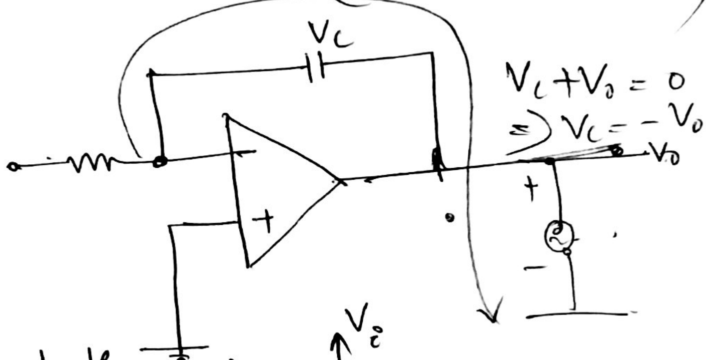
$V_A = 0$ volt due to Virtual ground concept

Applying KCL at node (A)

$I_1 = I_c$

$$\frac{V_i - \cancel{V_A}^{\,0}}{R_1} = C \cdot \frac{dV_c}{dt} \qquad \left(\because I_c = C\frac{dV}{dt} \right)$$

$$\Rightarrow \frac{V_i}{R_1} = C \cdot \frac{dV_c}{dt}$$



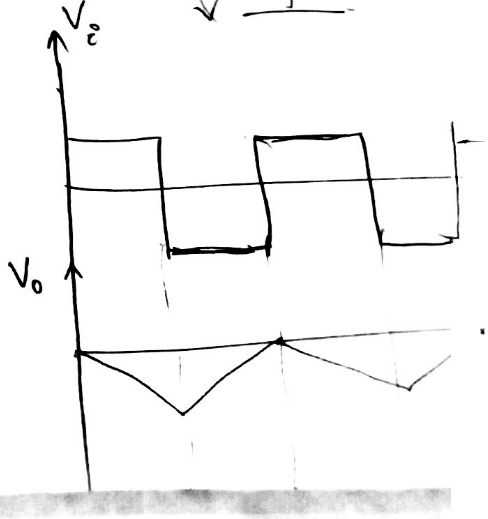
$$\Rightarrow \frac{V_i}{R_1} = \frac{C \cdot d(-V_o)}{dt}$$

Now integrating both side

$$\Rightarrow \int_0^t \frac{V_i}{R_1} \cdot dt = -C \int_0^t \frac{dV_o}{dt}\, dt$$

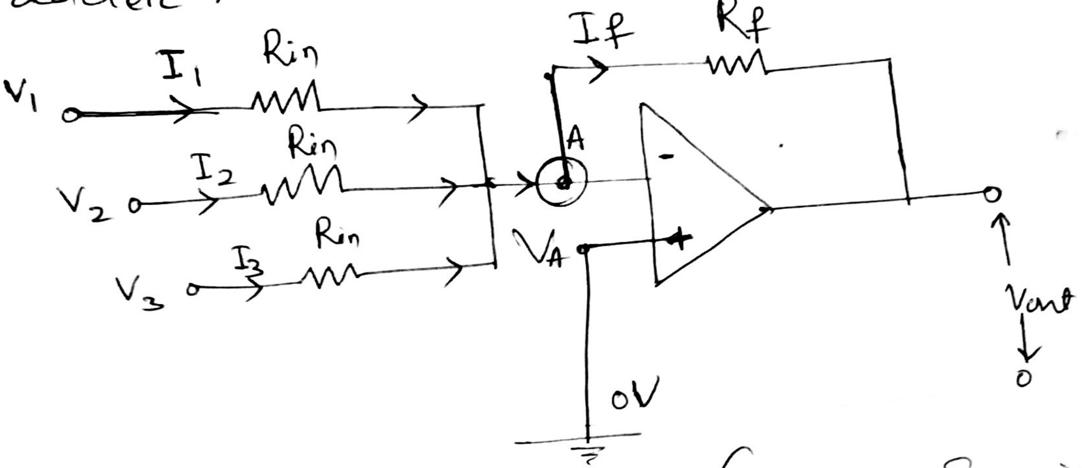
$$\Rightarrow \frac{1}{R_1} \int_0^t V_i\, dt = -C \cdot V_o$$

$$\Rightarrow V_o = -\frac{1}{RC} \int_0^t V_i\, dt$$



OP-AMP as Summing Amplifier:-

A Summing amplifier is an operational amplifier circuit which combines ~~the~~ two or, more i/p voltages into a single output voltages. it is also called voltage adder.



(inverting Summing Amplifier)

At Node A

$$I_F = I_1 + I_2 + I_3 \Rightarrow -\left[\frac{V_1}{Rin} + \frac{V_2}{Rin} + \frac{V_3}{Rin}\right]$$

As we know that from inverting amplifier

$$\boxed{V_0 = -\left(\frac{R_f}{Rin}\right)V_{in}}$$

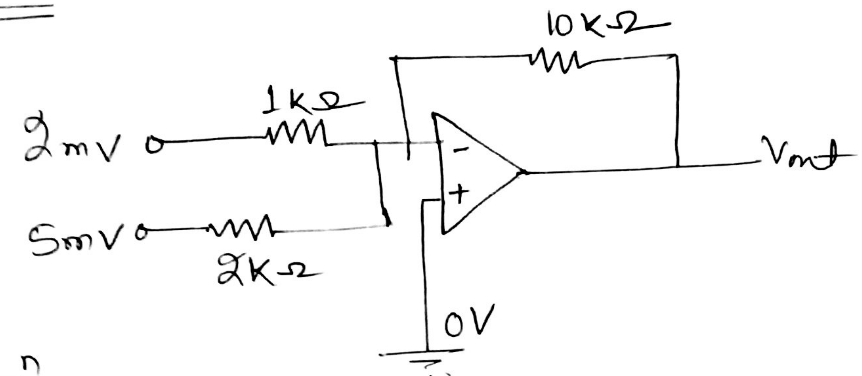
$$\Rightarrow V_0 = -\left[\frac{R_f}{Rin}V_1 + \frac{R_f}{Rin}V_2 + \frac{R_f}{Rin}V_3\right]$$

$$\Rightarrow V_{out} = -\frac{R_f}{R_i}\left[(V_1 + V_2 + V_3)\right]$$

$$\Rightarrow V_{out} = -\frac{R_f}{R_i}\left[V_1 + V_2 + V_3 \cdots\cdots\right]$$ for multiple number of input signal.

Problem on Summing amplifier

Ex-1



Sol^n

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

$$\Rightarrow V_{out} = -\left[\frac{10\,k\Omega}{1\,k\Omega} \times 2\,mV + \frac{10\,k\Omega}{2\,k\Omega} \times 5\,mV\right]$$

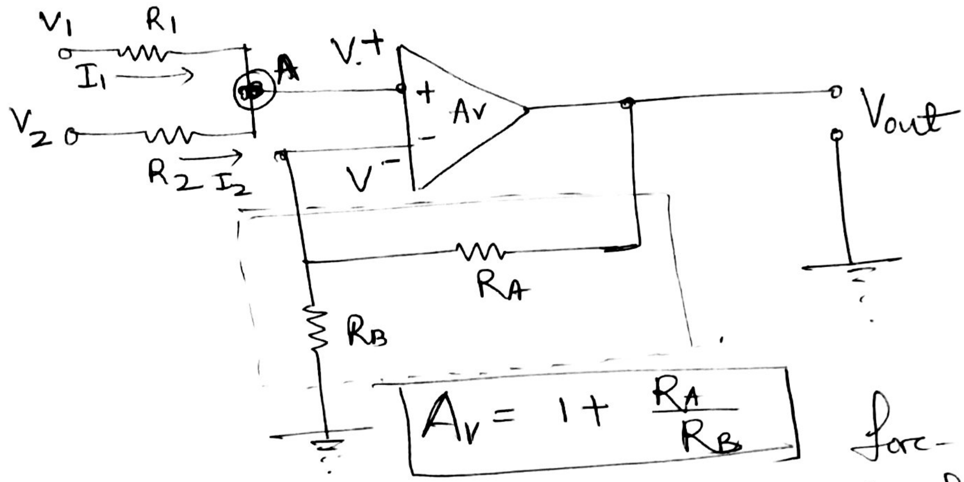
$$\Rightarrow V_{out} = -\left[20\,mV + 25\,mV\right]$$

$$\Rightarrow \boxed{V_{out} = -45\,mV}$$

– Sign ~~ca~~ indicates it is a inverting amplifier.

Imp L.Q

Non-inverting Summing Amplifier :—



$$\boxed{A_V = 1 + \frac{R_A}{R_B}}$$ for Non-inverting Amplifier gain

A_V = voltage gain.

at Node (A) applying KCL

$$I_{R_1} + I_{R_2} = 0$$

$$\frac{V_1 - V^+}{R_1} + \frac{V_2 - V^+}{R_2} = 0$$

$$\Rightarrow \frac{V_1}{R_1} - \frac{V^+}{R_1} + \frac{V_2}{R_2} - \frac{V^+}{R_2} = 0,$$

Let $R_1 = R_2 = R$

$$\Rightarrow \frac{V_1 + V_2}{R} - \frac{2V^+}{R} = 0 \Rightarrow \frac{V_1 + V_2}{\cancel{R}} = \frac{2V^+}{\cancel{R}}$$

$$\Rightarrow \boxed{V^+ = \frac{V_1 + V_2}{2}}$$

$$A_V = \frac{V_{out}}{V_{in}} = \frac{V_{out}}{V^+} = \left(1 + \frac{R_A}{R_B}\right)$$

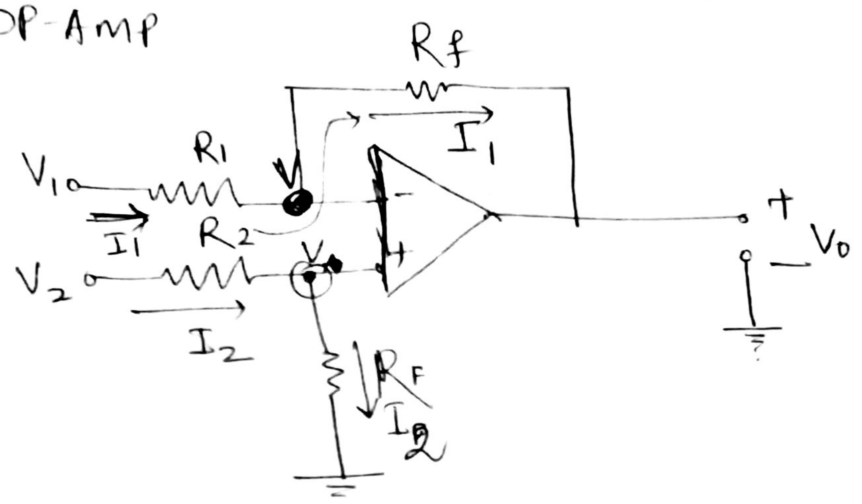
$$\Rightarrow \cancel{A_V = \frac{V_{out}}{}}\ V_{out} = \left(1 + \frac{R_A}{R_B}\right) \times V^+$$

Let $R_A = R_B = R$

$$\Rightarrow V_{out} = \cancel{2} \times \frac{V_1 + V_2}{\cancel{2}} = V_1 + V_2.$$

OP-AMP as Subtractor

The Subtraction of two input voltages is done by the OP-AMP



Let us consider a non-inverting amplifier.

$$\Rightarrow I_2 = \frac{V_2 - V}{R_2} = \frac{V - 0}{R_f}$$

$$\Rightarrow I_2 = \frac{V_2}{R_2} - \frac{V}{R_2} = \frac{V}{R_f}$$

$$\Rightarrow \frac{V_2}{R_2} = \frac{V}{R_f} + \frac{V}{R_2} \Rightarrow \frac{V_2}{\cancel{R_2}} = V\left[\frac{R_2 + R_f}{\cancel{R_2} R_f}\right]$$

$$\Rightarrow \boxed{V = V_2\left[\frac{R_f}{R_2 + R_f}\right]} \quad \text{——— (A)}$$

Similarly

$$I_1 = \frac{V_1 - V}{R_1} = \frac{V - V_o}{R_f}$$

$$= \frac{V_1}{R_1} - \frac{V}{R_1} = \frac{V}{R_f} - \frac{V_o}{R_f}$$

$$\Rightarrow \frac{V_o}{R_f} = \frac{V}{R_f} + \frac{V}{R_1} - \frac{V_1}{R_1}$$

$$\Rightarrow \frac{V_o}{R_f} = V\left[\frac{R_f + R_1}{R_f R_1}\right] - \frac{V_1}{R_1}$$

$\Rightarrow$ Now putting 'V' from equation (1) we get

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

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

if $R_1 = R_2$

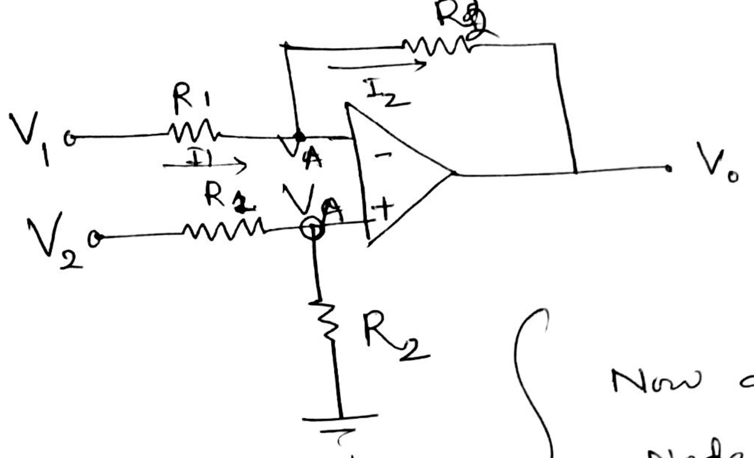
$$V_o = \frac{R_f}{R_1}\left[V_2 - V_1\right]$$

if $R_f = R_1 = R_2 = R$

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

Differential amplifier (when both i/p's are given)

A circuit that amplifies the difference between the two input signals.



Now applying KCL at Node- A

$$I_1 = I_2$$

$$\frac{V_1 - V_A}{R_1} = \frac{V_A - V_0}{R_2}$$

By voltage division

$$V_A = \frac{R_2 \times V_2}{R_1 + R_2} \quad \text{--- (1)}$$

$$\Rightarrow \frac{V_1}{R_1} - \frac{V_A}{R_1} = \frac{V_A}{R_2} - \frac{V_0}{R_2}$$

$$\Rightarrow \frac{V_1}{R_1} + \frac{V_o}{R_2} = \frac{V_A}{R_1} + \frac{V_A}{R_2}$$

$$\Rightarrow \frac{V_o}{R_2} = \frac{V_A}{R_2} + \frac{V_A}{R_1} - \frac{V_1}{R_1}$$

$$\frac{V_o}{R_2} = V_A\left(\frac{1}{R_1} + \frac{1}{R_2}\right) - \frac{V_1}{R_1}$$

$$\Rightarrow V_o = V_A\left(1 + \frac{R_2}{R_1}\right) - \frac{R_2}{R_1} V_1 \quad \text{--- (2)}$$

Now putting V_A from above equation (1) in (2)

$$\Rightarrow V_o = \frac{R_2 \times V_2}{R_1 + R_2}\left(\frac{R_1 + R_2}{R_1}\right) - \left(\frac{R_2}{R_1}\right) V_1$$

$$\Rightarrow V_0 = \frac{R_2}{R_1} V_2 - \frac{R_2}{R_1} V_1$$

$$\Rightarrow \cancel{\boxed{V_0 = \frac{R_2}{R_1}(V_2 - V_1)}}$$

$$\Rightarrow \boxed{V_0 = \frac{R_2}{R_1}(V_2 - V_1)}$$