Inverting operation of an Op-Amp:

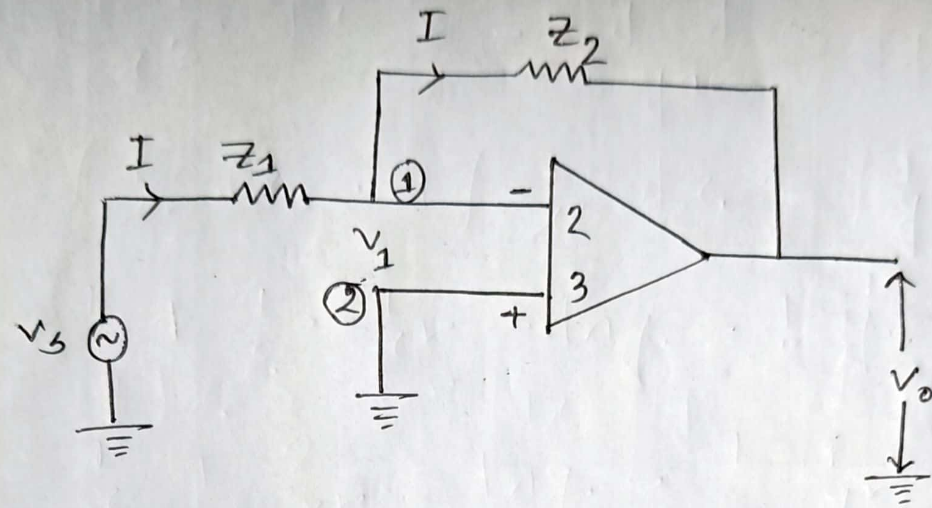


Fig-1: Inverting Op-Amp

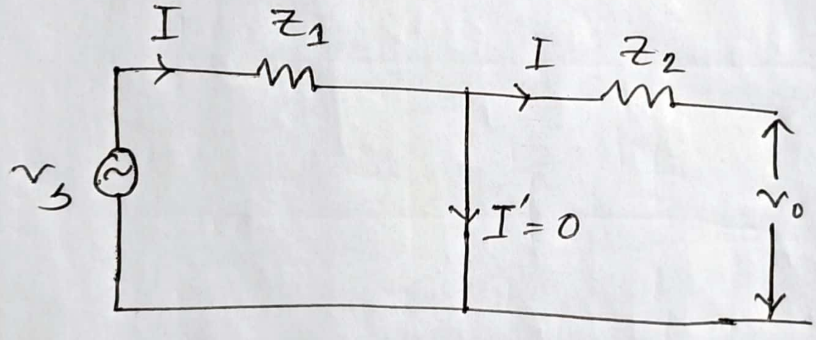


Fig-2: Equivalent circuit

In this mode of operation, the positive input terminal of the amplifier is grounded and the input signal is applied to the negative input terminal through impedance, Z_1. The feedback applied through the impedance Z_2, from the output to input terminal is negative.

voltage gain:

current I flowing through Z_1 will also flow through Z_2.

$$\therefore \frac{v_s - v_i}{Z_1} = \frac{v_i - v_o}{Z_2}$$

$$\Rightarrow \frac{v_s}{Z_1} - \frac{v_i}{Z_1} = \frac{v_i}{Z_2} - \frac{v_o}{Z_2}$$

$$\Rightarrow \frac{v_s}{Z_1} = v_i \left(\frac{1}{Z_1} + \frac{1}{Z_2}\right) - \frac{v_o}{Z_2}$$

$$\Rightarrow \frac{v_o}{Z_2} = -\frac{v_o}{A}\left(\frac{1}{Z_1} + \frac{1}{Z_2}\right) - \frac{v_s}{Z_1} \quad \left[\because A = -\frac{v_o}{v_i} \Rightarrow v_i = -\frac{v_o}{A}\right]$$

$$\Rightarrow v_o \left\{\frac{1}{Z_2} + \frac{1}{A}\left(\frac{1}{Z_1} + \frac{1}{Z_2}\right)\right\} = -\frac{v_s}{Z_1}$$

$$\Rightarrow v_o \left\{\frac{1}{Z_2} + \frac{1}{A} \cdot \frac{1}{Z_2}\left(1 + \frac{Z_2}{Z_1}\right)\right\} = -\frac{v_s}{Z_1}$$

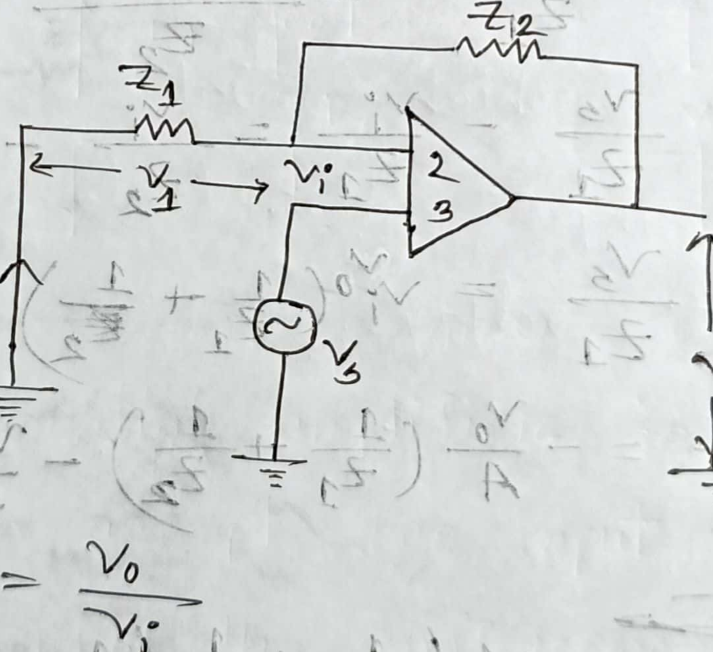
$$\Rightarrow v_o \frac{1}{Z_2} \left\{1 + \frac{1}{A}\left(1 + \frac{Z_2}{Z_1}\right)\right\} = -\frac{v_s}{Z_1}$$

$$\Rightarrow \frac{v_o}{v_s} = -\frac{Z_2}{Z_1} \frac{1}{\left\{1 + \frac{1}{A}\left(1+\frac{Z_2}{Z_1}\right)\right\}}$$

$$\Rightarrow \frac{v_o}{v_s} = -\frac{Z_2}{Z_1} \quad [\because A = \infty]$$

which is the gain of inverting OP-Amp.

Non-inverting amplifier:



Here, $A = \frac{v_o}{v_i}$

$$\Rightarrow A = \frac{v_o}{v_1 - v_s}$$

$$\Rightarrow v_1 - v_s = \frac{v_o}{A}$$

$$\Rightarrow v_1 - v_s = 0$$

or, $v_1 = v_s$

$$\therefore I = \frac{v_0}{Z_1 + Z_2}$$

Again,

$$v_1 = I Z_1$$

$$\Rightarrow v_1 = \frac{v_0}{Z_1 + Z_2} Z_1$$

$$\Rightarrow v_s = \frac{v_0 Z_1}{Z_1 + Z_2}$$

$$\Rightarrow \frac{v_0}{v_s} = \frac{Z_1 + Z_2}{Z_1}$$

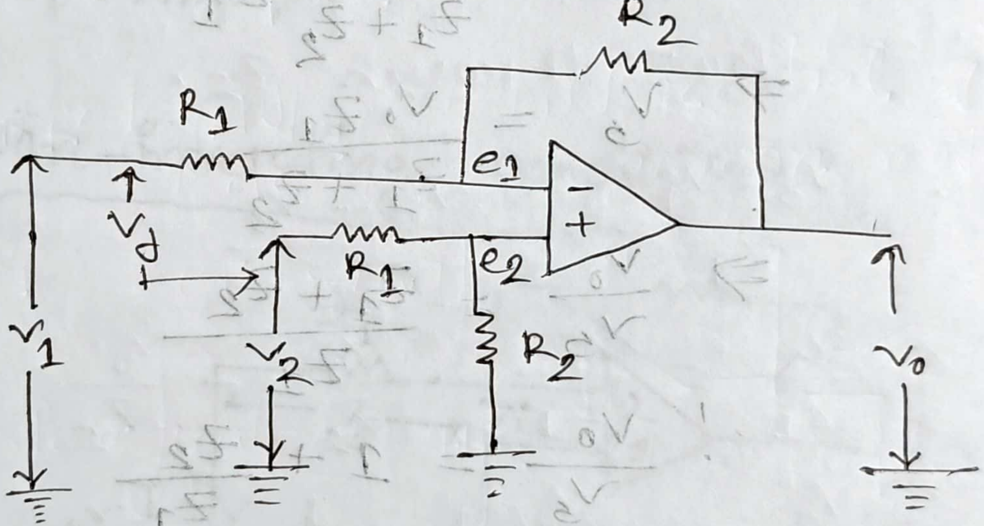
$$\therefore \frac{v_0}{v_s} = 1 + \frac{Z_2}{Z_1}$$

which is the gain of a non-inverting operational amplifier.

Operation:

In non-inverting OP-Amp output is equal to and in phase with the input voltage. The input voltage v_s is directly applied to the non-inverting terminal. So no phase inversion results at the output.

Differential Amplifier:



Definition: A differential amplifier is a circuit that can accept two input signals and amplify the difference between these two input signals.

This amplifier provides the gain for differential input and rejects the input voltage common to both

The voltage e_2, at the non-inverting terminal 2 is given by

$$e_2 = \frac{R_2}{R_1+R_2} v_2$$

Similarly by the principle of superposition, the voltage at the inverting input terminal 1 is,

$$e_1 = \frac{v_1}{R_1+R_2} R_2 + \frac{v_0}{R_1+R_2} R_1$$

Now, $e_1 = e_2$

$$\Rightarrow \frac{R_2}{R_1+R_2} v_2 = \frac{v_1}{R_1+R_2} R_2 + \frac{v_0}{R_1+R_2} R_1$$

$$\Rightarrow R_2 v_2 = v_1 R_2 + v_0 R_1$$

$$\Rightarrow v_1 R_2 + v_0 R_1 = R_2 v_2$$

$$\Rightarrow v_0 R_1 = R_2 (v_2 - v_1)$$

$$\therefore v_0 = \frac{R_2}{R_1} (v_2 - v_1)$$

☐ Common mode Rejection Ratio (CMRR)

It is the measure of a device's ability to reject the signal common to both the positive and negative device input.

$$CMRR = \frac{A_d}{A_c} = \frac{\text{Differential gain}}{\text{Common mode gain}}$$

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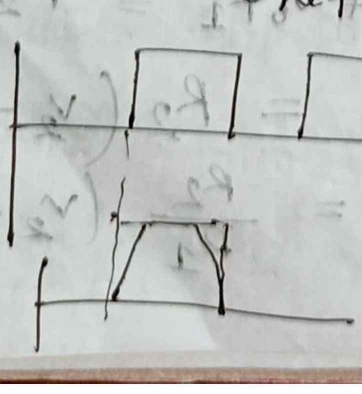
☐ Slew rate:

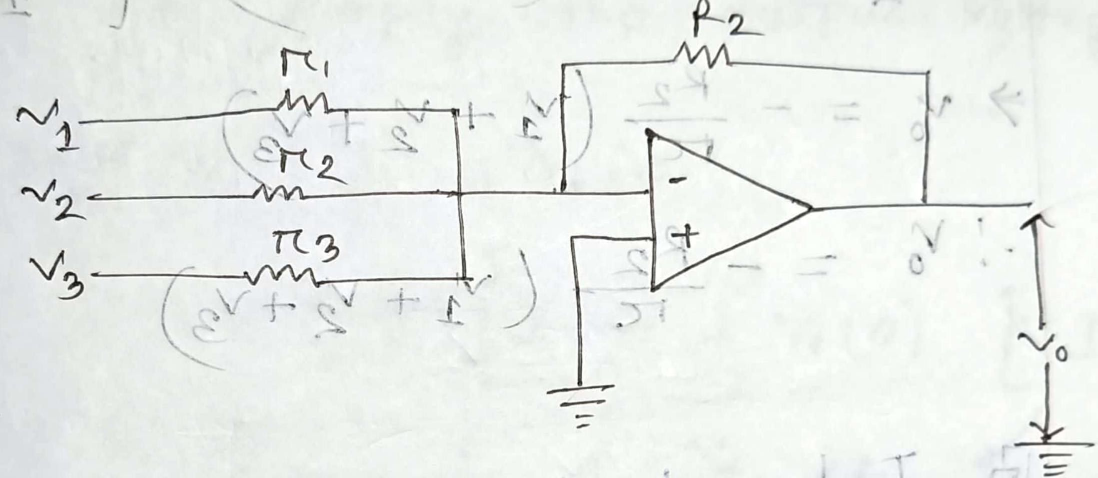
The slew rate is defined as the maximum rate of output voltage change per unit time.

$$\text{slew rate, } S = \left(\frac{dv_o}{dt}\right)_{max}$$

Unit: Volts / μs



Summing Amplifier :



It is the same as the inverting amplifier except that it has several input terminals. Virtual ground exists at the inverting terminal due to feedback and the input current to the ideal amplifier is zero. Thus the current equation for the node at the inverting terminal is

$$\frac{v_1}{r_1} + \frac{v_2}{r_2} + \frac{v_3}{r_3} + \cdots = -\frac{v_0}{R_2}$$

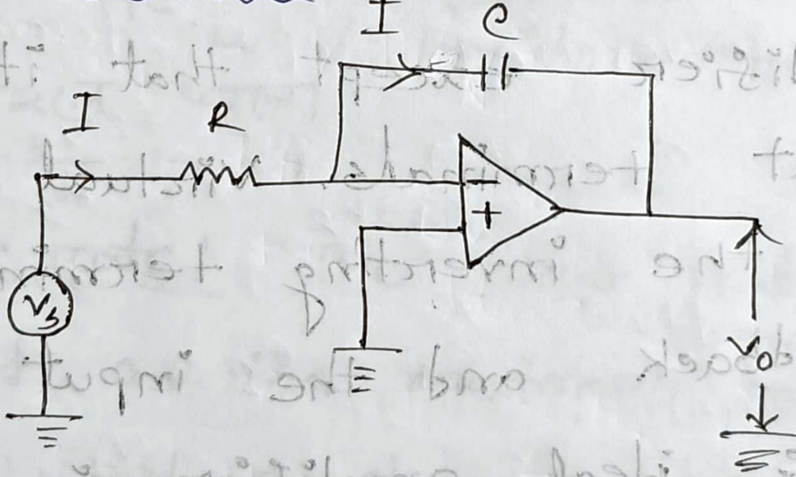
$$\Rightarrow \frac{v_1}{r_1} + \frac{v_2}{r_2} + \frac{v_3}{r_3} + \cdots + \frac{v_0}{R_2} = 0$$

$$\Rightarrow \frac{v_0}{R_2} = -\frac{1}{r}(v_1 + v_2 + v_3) \quad [\because r_1 = r_2 = r_3 = r]$$

$$\Rightarrow v_0 = -\frac{R_2}{r}(v_1 + v_2 + v_3)$$

$$\therefore v_0 = -\frac{R_2}{r}(v_1 + v_2 + v_3)$$

$\boxed{\text{I}}$ Integrator:



~~In~~ this inverting ~~amplifier feedback~~ ~~Resistor~~

~~In~~ Here feedback through the capacitor forces a virtual ground to exist at the inverting input terminal. It means voltage across c is simply the output voltage v_o.

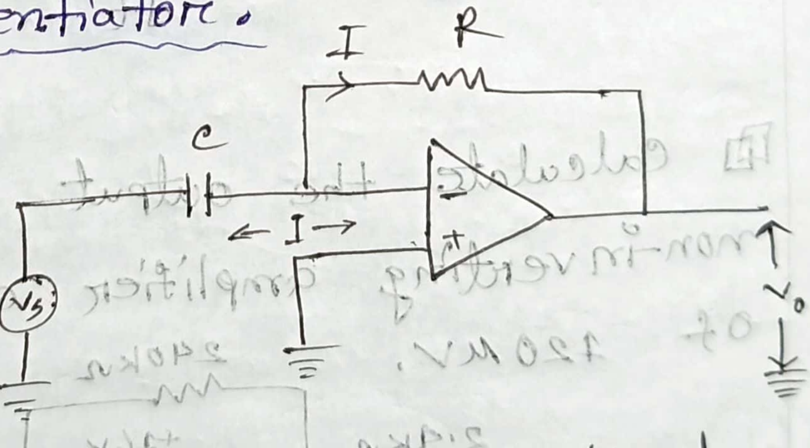
$$v_o(t) = -\frac{q}{C} + v_o(0)$$

$$= -\frac{1}{C}\int_0^t I\,dt + v_o(0) \quad \left[\because I = \frac{v_s}{R}\right]$$

$$\Rightarrow v_o(t) = -\frac{1}{C}\int_0^t \frac{v_s}{R}\,dt + v_o(0)$$

$$= -\frac{1}{RC}\int_0^t v_s\,dt + v_o(0)$$

$\boxed{F}$ Differentiator:



In inverting operational amplifier, we replace the input resistance by a capacitor to design a differentiator. Because of virtual ground at the inverting terminal, we have,

$$I = \frac{dq}{dt}$$

$$= \frac{d}{dt}(C v_s)$$

$$= C \frac{dv_s}{dt}$$

The output voltage,

$$v_0 = -IR$$

$$= -RC \frac{dv_s}{dt}$$