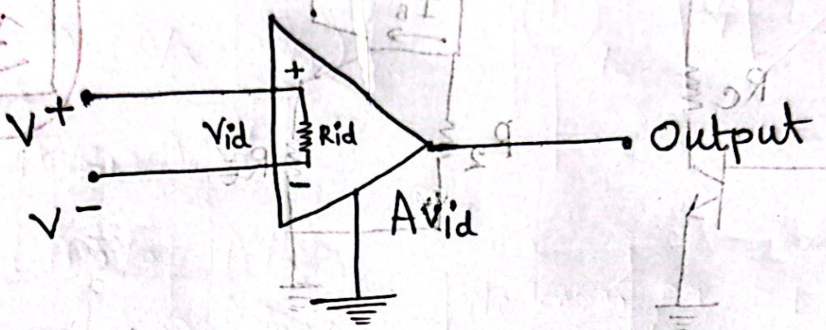
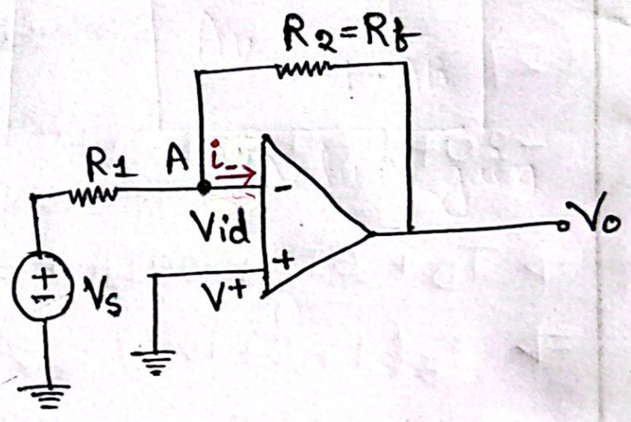
Operational Amplifier



V^+ = Non inverting input
V^- = Inverting input
A = Open circuit Voltage gain.

$$A_v = \frac{\text{Output}}{\text{Input}}$$

Inverting Amplifier:



Voltage gain, $A_v = \frac{V_o}{V_i}$

$\therefore V_{id} = V^+ - V^-$

$\therefore R_{id} = \infty$, $i_- = 0$

Apply KCL at node A,

$i_s = i_2 + i_-$

$\Rightarrow i_s = i_2 + 0$

$\therefore i_s = i_2$

Applying KVL, $-V_S + i_S R_1 + i_2 R_2 + V_o = 0$

$$\Rightarrow -V_S + i_S R_1 + i_S R_2 + V_o = 0$$

$$\Rightarrow \cancel{-V_S} + \left(\frac{\cancel{V_S}}{\cancel{R_1}} \times \cancel{R_1}\right) + \left(\frac{V_S}{R_1} \times R_2\right) + V_o = 0$$

$$\Rightarrow \frac{V_S R_2}{R_1} + V_o = 0$$

$$\Rightarrow V_o = -\frac{V_S R_2}{R_1}$$

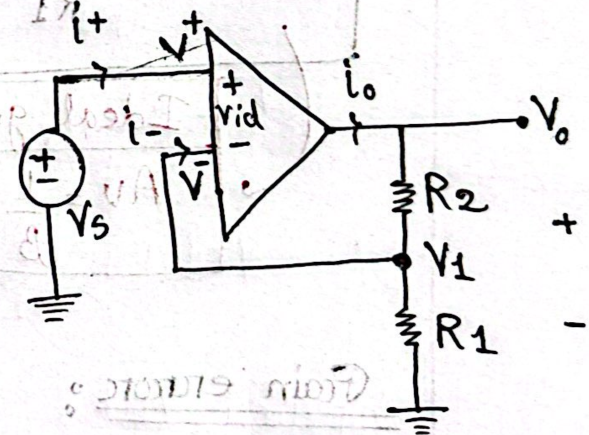
$$\Rightarrow \frac{V_o}{V_S} = -\frac{R_2}{R_1} \qquad \left[A_v = \frac{V_o}{V_S}\right]$$

$$\therefore A_v = -\frac{R_2}{R_1}$$ (Voltage gain for inverting amplifier)

$R_1 > R_2$ = gain small

$R_2 > R_1$ = gain বড় হবে

Non-Inverting Amplifier:



$V_{id} = V^+ - V^- = V_S - V_1$

$i_- = 0$, $V_{id} = 0$,

$\therefore V_{id} = V_S - V_1$

$\therefore 0 = V_S - V_1$

$\therefore V_S = V_1$

Using VDR, $V_S = \frac{V_o R_1}{R_1 + R_2}$

$$\Rightarrow \frac{V_S}{V_o} = \frac{R_1}{R_1 + R_2} = 1 + \frac{R_1}{R_2} = A_v.$$

$$\therefore V_0 = AV_{id} = A(V^+ - V^-)$$

$$\Rightarrow V_0 = A(V_S - V_1)$$

$$\Rightarrow V_0 = A(V_S - \beta V_0)$$

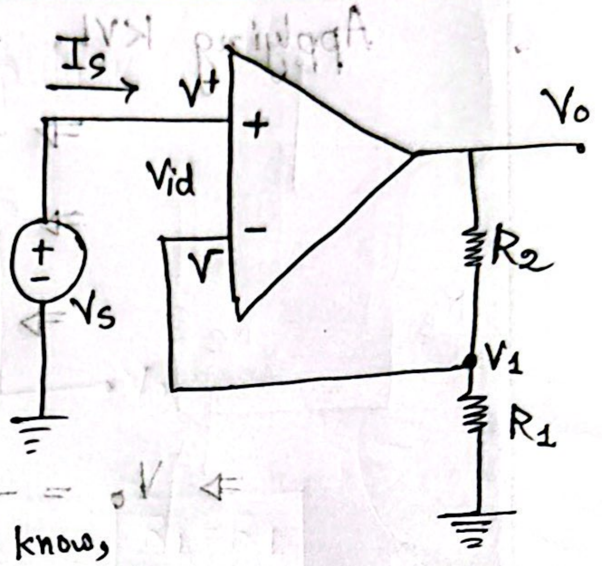
$$\Rightarrow V_0 = AV_S - A\beta V_0$$

$$\Rightarrow V_0 + A\beta V_0 = AV_S$$

$$\Rightarrow V_0(1 + A\beta) = AV_S$$

$$\Rightarrow \frac{V_0}{V_S} = \frac{A}{1 + A\beta}$$

$$\therefore A_v = \frac{A}{1 + AB}$$



We know,

$$\therefore A_v = \frac{V_0}{V_S}$$

$$\therefore V_1 = \frac{V_0 R_1}{R_1 + R_2} = \frac{R_1}{R_1 + R_2} \times V_0$$

$$\therefore V_1 = \beta V_0$$

$$\boxed{A_v = 1 + \frac{R_2}{R_1} = \frac{R_1 + R_2}{R_1} = \frac{1}{\beta}}$$

$$\boxed{A_v = \frac{A}{1 + AB}}$$

Actual gain

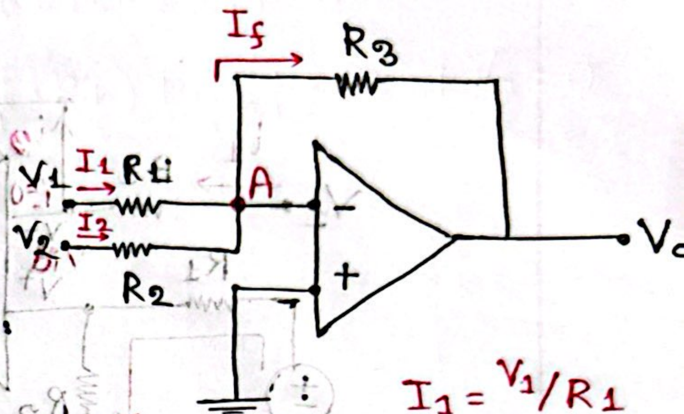
Ideal gain
$A_v = \frac{1}{\beta}$

Gain error: Ideal gain − Actual gain

$$GE = \frac{1}{\beta(1 + A\beta)}$$

Summing Amplifier / Adder Amplifier

Applying KCL at node A,



$I_1 = V_1/R_1$

$I_2 = V_2/R_2$

$$I_1 + I_2 = I_3$$

output to input

$$\Rightarrow \frac{V_1}{R_1} + \frac{V_2}{R_2} = -\frac{V_0}{R_3} \quad \text{---} \; (1)$$

if $\boxed{V_1 = V_2 = V_S}$, from eqn (1),

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} = -\frac{V_0}{R_3};$$

$$\Rightarrow V_S\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = -\frac{V_0}{R_3}$$

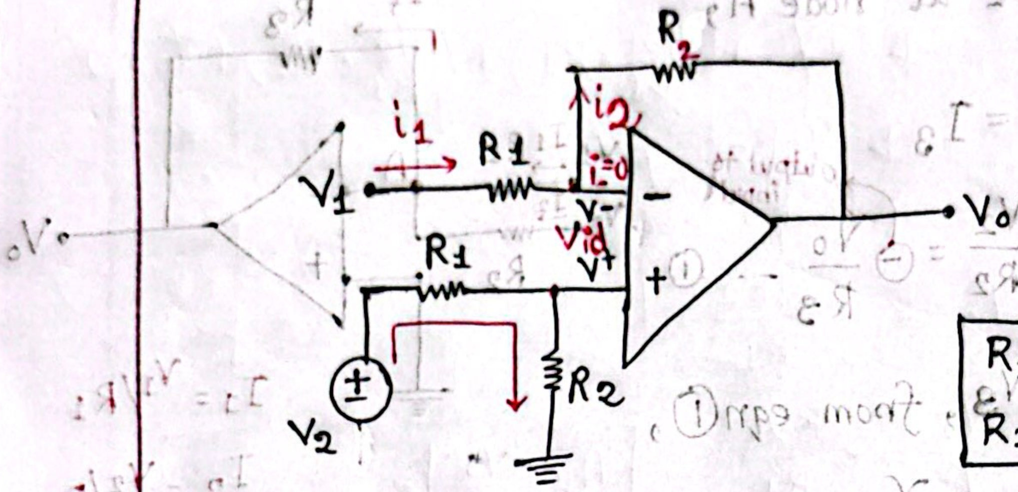
$$\Rightarrow R_3\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = -\frac{V_0}{V_S}$$

$$\Rightarrow A_v = -R_3\left(\frac{R_1 R_2}{R_1 + R_2}\right)$$

Note

* Summing amp. হচ্ছে এমন একটি inverting amp. যার input এ একাধিক value গ্রহণ করে, output এ ১টা মান দেখায়। এর output valu Input value গুলোর যোগফলের সমানুপাতিক, কিন্তু বিপরীত চিহ্নযুক্ত।

Difference Amplifier /Subtractor



$$\boxed{\begin{aligned} R_1 &= R_1 \\ R_2 &= R_2 \end{aligned}}$$

$$i_1 = \frac{V_1 - V^-}{R_1}$$

$$V_o = V^- - i_2 R_2$$

$$= V^- - i_1 R_2$$

$$= V^- - \left(\frac{V_1 - V^-}{R_1} \times R_2\right)$$

$$= V^- - \frac{R_2}{R_1}\left(V_1 - V^-\right)$$

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

$$\therefore V_o = V^-\left(1 + \frac{R_2}{R_1}\right) - \frac{R_2}{R_1} V_1 \quad \text{-----} \quad (I)$$

Applying VDR, $V^+ = \dfrac{V_2 R_2}{R_1 + R_2}$

$$V^- = V^+ = \frac{V_2 R_2}{R_1 + R_2} \quad \text{----} \quad (II)$$

from eqn (ii), $V^+ = \frac{V_2 R_2}{R_1+R_2}$

from eqn (i),

$$\Rightarrow \left(1+\frac{R_2}{R_1}\right)V^- - V_1\frac{R_2}{R_1} = \frac{V_2R_2}{R_1+R_2}$$

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

if $R_1 = R_2$

$$\underbrace{V_0 = -(V_1 - V_2) = V_2 - V_1}_{\text{unit gain amplifier}}$$