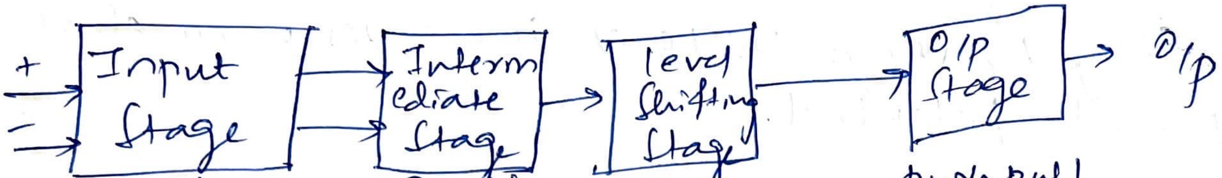
Block Diagram of OPAMP

4 - Stages



Dual i/p balanced O/p differentialy amplifier

Dual i/p unbalanced O/p differentialy Amplifier

Emitter follower

push pull Amplifier

Opamp gain ⇒ $A \Rightarrow 10^5 - 10^6$

1) **Input Stage:-**

* this Stage consist of two i/ps (Non inverting i/p & Inverting i/p) and dual O/ps.

5V, 3V, I_S, A=5 $\quad 5\times2 \Rightarrow 10 \quad \because 2V$ = difference of i/p

A → gain of opamp

Assume A=5

* this Stage provides most of the voltage gain of op-amp
* this Stage decides the value of i/p Resistance (R_i).

2) **Intermediate Stage:-** differential Amplifier.

* it consists of dual i/p & Single O/p.
* it is driven by the O/p of i/p Stage.
* i/p Stage alone can't provide high gain, so intermediate Stage provide the required additional voltage gain.

3) **level Shifting Stage:-**

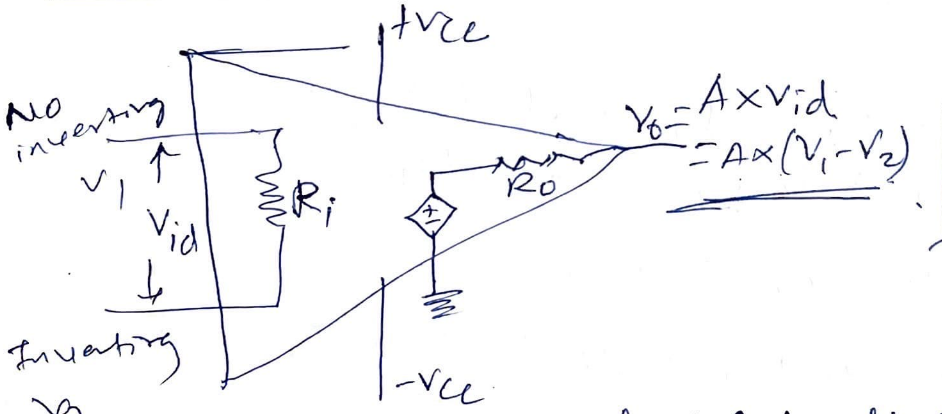
* level Shifting Stage is used after the intermediate Stage to Shift the DC level to zero volts w.r.t ground.
* O/p level of intermediate Stage is above as direct Coupling is used.

* As op-amp amplifies the DC signals also & in different cascading stages coupling capacitors are not used hence stage by stage DC level increases well above the ground potential.

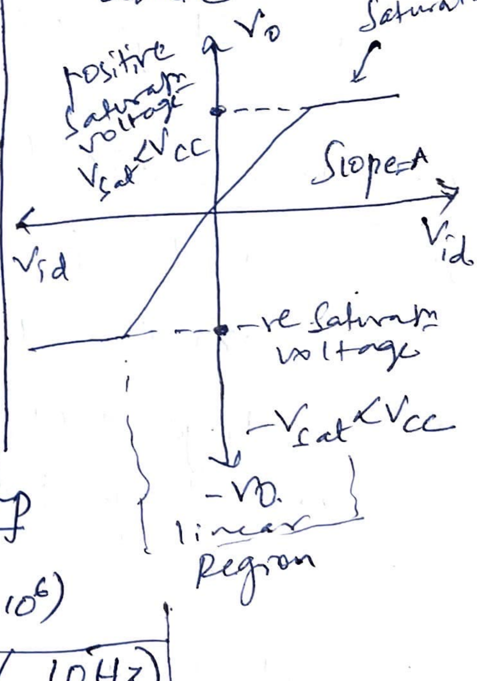
4) O/p Stage

* This stage increases the O/p voltages & raises the current carrying capability of op-amp.
* As push-pull complementary amplifiers meets all these requirements & hence used as an O/p stage.
* provide low O/p Resistance.

Equivalent Ckt of Op-amp



voltage transfer curve

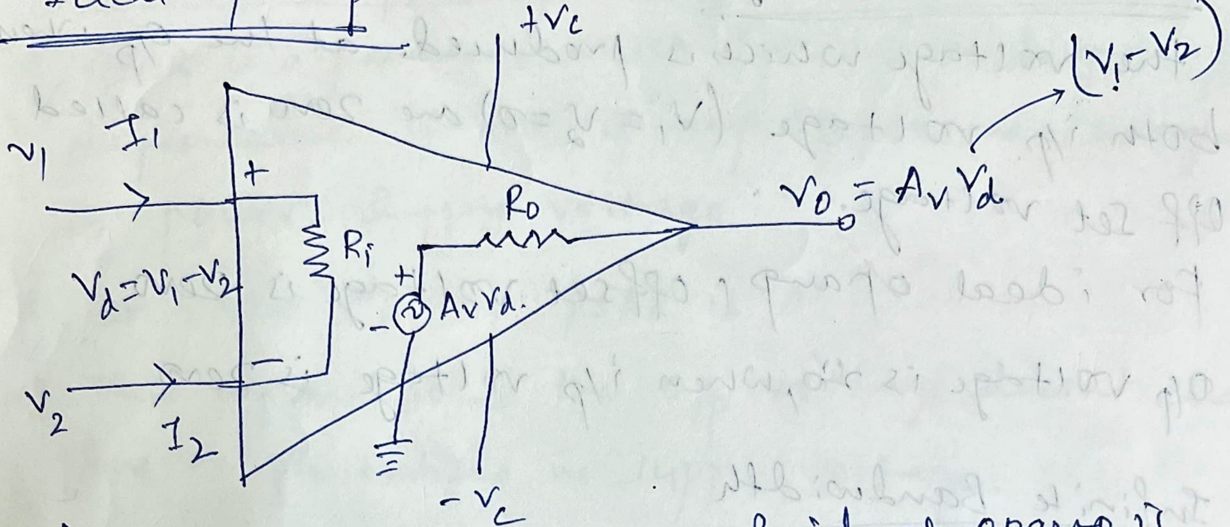


Comparision of an ideal & practical opamp

	Ideal	practical
Open loop gain	Infinite	very high ($10^5 - 10^6$)
Open loop bandwidth	Infinite	Dominant pole (10Hz)
CMRR	Infinite	High (> 60dB)
i/p Resistance	infinite	High (>1MΩ)
O/p Resistance	~~infinite~~ zero	low (< 100Ω)
i/p Bias current	zero	low (< 50nA)
offset voltages	zero	low (< 10mV)

offset currents	zero	low (< 50nA)
Slew Rate	Infinite	A few V/μs
Drift	zero	Low.

Ideal Op-amp



* the important characteristics of ideal opamp is.

1) <u>Infinite voltage gain</u> $(A_v = \infty)$ $A_{V(OL)} = \frac{V_{out}}{V_{in}}$

Open loop of ideal opamp is denoted by A_v. $= 20 \log \frac{V_{out}}{V_{in}}$

2) <u>Infinite input Resistance</u> $(R_i = \infty)$. $A_{V(CL)} = \frac{V_{out}}{V_{in}}$

* i/p Resistance is the total resistance measured between the 2 i/p terminals of op-amp.
* the i/p Resistance of ideal opamp is $(R_i = \infty)$
* Due to which the current flowing in each i/p terminal will be zero i.e <u>$I_1 = I_2 = 0$</u>

3) <u>Zero o/p Resistance</u> $(R_o = \infty)$

* the o/p resistance of op-amp is the resistance viewed from its o/p terminal.
* the o/p resistance of an ideal op-amp is "zero"

4) Zero offset voltage

* the voltage which is produced at the o/p when both i/p voltage ($V_1 = V_2 = 0$) are zero is called off set voltage.
* For ideal opamp, offset voltage is zero.
* O/p voltage is zero, when i/p voltage is zero

5) Infinite Bandwidth

* Bandwidth of an amplifier is the range of frequencies over which all the signal frequencies are amplified almost equally.
* the bandwidth of an Ideal op-amp is ∞ So it can amplify any freq. signal from 0 to ∞ HZ.

6) Infinite CMRR:

* the CMRR is the ability of op amp to reject common mode signal successfully

this arise due to noise present at the i/p terminal of opamp

$$CMRR = \frac{|A_v|}{|A_c|}$$

* For an ideal op-amp CMRR is ∞

7) Infinite slew Rate ($S = \infty$)

Slew Rate is defined as the max^m^ rate of ~~the~~ change of o/p voltage with time i.e

$$S = \left.\frac{dV_o}{dt}\right|_{max}$$

$\boxed{V_o = A_v V_d}$ for ideal so V_o

* For an ideal op-amp, slew Rate (S) is ∞

8) Zero power-supply rejection ratio (PSRR)

* PSRR is a parameter which specifies the degree of dependence of the op-amp o/p on the changes in power supply voltage.

* For ideal op-amp PSRR is '0'

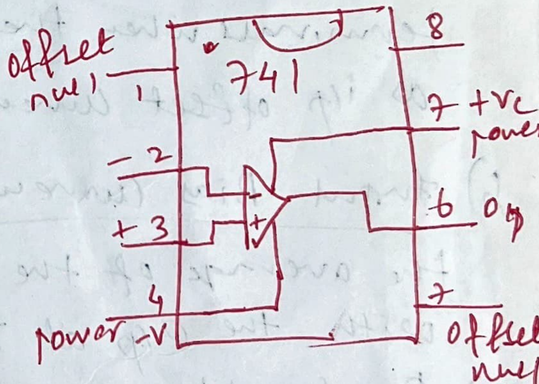
* This means that the o/p voltage doesn't change due to fluctuations in supply voltage.

Parameters of Op-amp

Resistor → opposes both AC & DC

impedance → opposes only the flow of AC

1) voltage gain
2) i/p impedance.
3) o/p "
4) i/p offset voltage
5) " " current
6) " Bias current
7) Bandwidth



1) voltage gain ⇒ gain = $\frac{\text{o/p voltage}}{\text{i/p voltage}}$ $V_{O(OL)} = \frac{V_{out}}{V_{IN}}$

$V_{O(CL)} = \frac{V_{out}}{V_{IN}}$

2) input impedance ⇒

At i/p, voltage drop is high, so i/p impedance is always High.

$R_{IN} = \frac{V_{IN}}{I_{IN}}$

3) Output impedance:-

the Resistance offered by the O/p of an op-amp is called as O/p impedance

$R_{out} = \frac{V_{out(oc)}}{I_{out(sc)}}$

* voltage drop at O/p must be '0' ⇒ V_{Rout}

* R_{out} must be as low as possible.

4) Input offset voltages:-

* when i/p is '0', O/p has to be zero, i.e in ideal condition, but in practical it is not zero, we need to apply dc voltage at the i/p terminal to force the O/p voltage to be zero:

$V_{out} = Z - Z = 0.$

5) input offset current :- $I_1 - I_2$ or $I_2 - I_1$

the difference between the currents into the two i/p terminals when the O/p is held at zero is called as i/p offset current

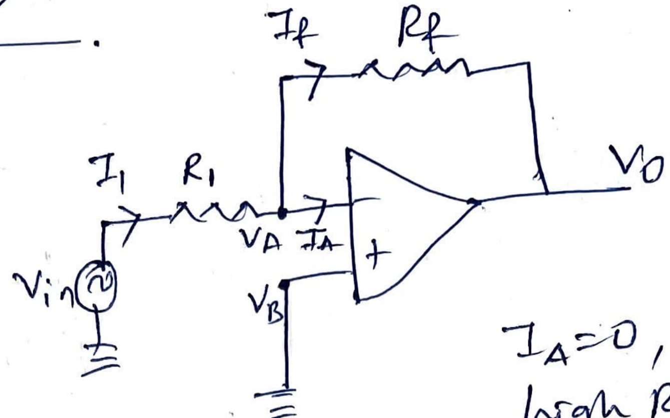
6) Input Bias current ⇒ $\frac{I_1 - I_2}{2}$

the average of the currents into the two i/p terminals with the O/p at zero volts is called IBC

7) Bandwidth

the rang of frequencies for which an op-amp can be used is called as 'Bandwith' of an opamp

Inverting Amplifier



$I_1 = I_f$

$$\frac{V_{in} - V_A}{R_1} = \frac{V_A - V_o}{R_f}$$

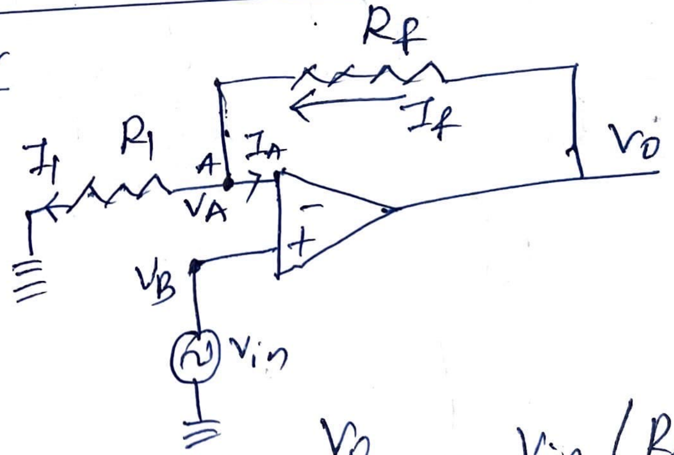
$$\frac{V_{in} - 0}{R_1} = \frac{0 - V_o}{R_f}$$

$$\frac{V_{in}}{R_1} = \frac{-V_o}{R_f} \Rightarrow \boxed{\frac{V_o}{V_{in}} = -\frac{R_f}{R_1}}$$

$I_A = 0$, due to high Resistance at R_i

$V_A = V_B = 0$ due to virtual ground.

Non Inverting Amplifier



Apply KCL at Node A.

$I_f = I_1 + I_A$

$I_A \to 0$ due to high i/p

$I_f = I_A$

$$\frac{V_o - V_A}{R_f} = \frac{V_A - 0}{R_1}$$

$V_A = \cancel{V_B}$ due to virtual ground

$V_B = V_{in}$

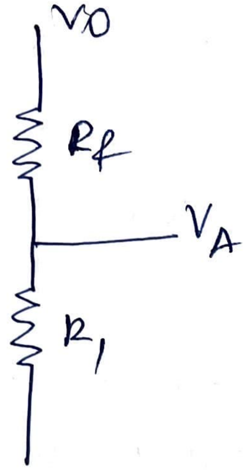
$$\frac{V_o - V_{in}}{R_f} = \frac{V_{in}}{R_1} \Rightarrow \frac{V_o}{R_f} - \frac{V_{in}}{R_f} = \frac{V_{in}}{R_1}$$

$$\frac{V_o}{R_f} = V_{in}\left(\frac{R_f + R_1}{R_1 R_f}\right) \qquad \frac{V_o}{R_f} = \frac{V_{in}}{R_1} + \frac{V_{in}}{R_f}$$

$$\frac{V_o}{\cancel{R_f}} = V_{in}\left(\frac{R_f + R_1}{R_1 \cancel{R_f}}\right)$$

$$\frac{V_o}{V_{in}} = \left(\frac{R_f + R_i}{R_1}\right)$$

$$\frac{V_o}{V_{in}} = \left(1 + \frac{R_f}{R_1}\right)$$



By voltage division Rule

$$V_A = \frac{R_1}{R_1 + R_f} \times V_O$$

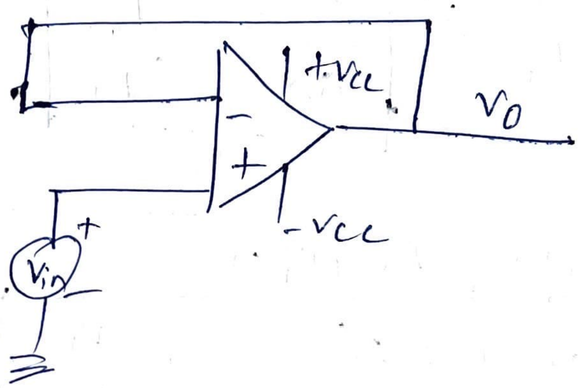
$V_A = V_{in}$ virtual ground

$$V_{in} = \frac{R_1}{R_1 + R_f} \times V_O$$

$$\frac{V_{in}}{V_O} = \frac{R_1}{R_1 + R_f} \Rightarrow \frac{V_{in}}{V_O} = \left(\frac{R_1}{R_f} + 1\right)$$

3) Op amp as voltage follower

$R_f = 0, \quad R_1 = \infty$



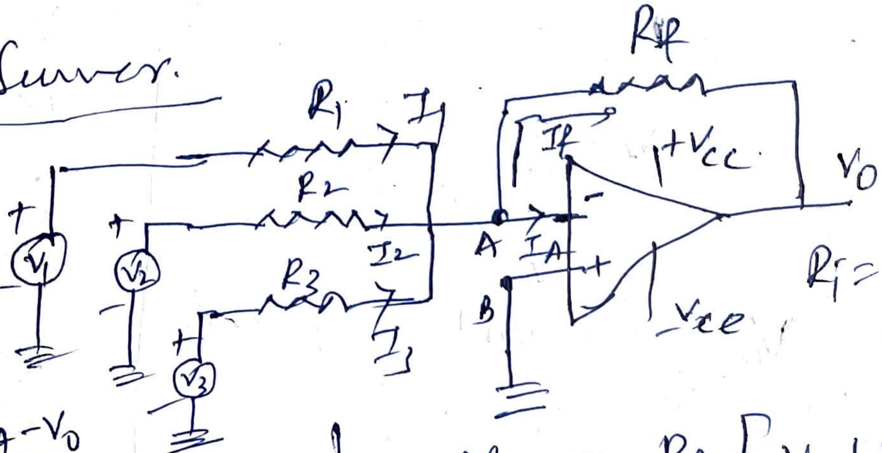
$$\frac{V_O}{V_{in}} = \left(1 + \frac{R_f}{R_f}\right)$$

$R_f = 0$

$A = \boxed{1}$

$$\boxed{V_O = V_{in}}$$

4) Op-amp as Summer.



Applying KVL to Node A

$R_i = \infty$ for ideal opamp

$$I_1 + I_2 + I_3 = I_f + I_A$$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = \frac{V_A - V_0}{R_f}$$

$R_1 = R_2 = R_3 = R_{in}$

$$\frac{1}{R_{in}}\left[V_1 + V_2 + V_3\right] = \left(0 - \frac{V_0}{R_f}\right)$$

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

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

if $(R_f = R_{in})$

$$V_0 = -\left[V_1 + V_2 + V_3\right]$$