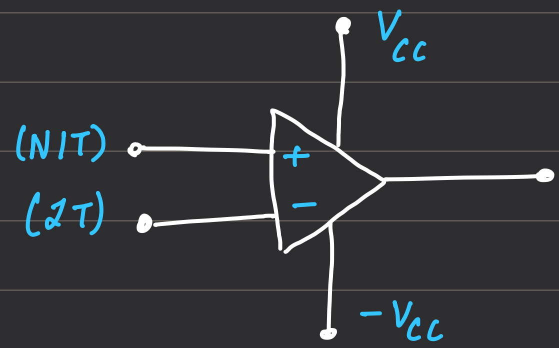
Operational Amplifier



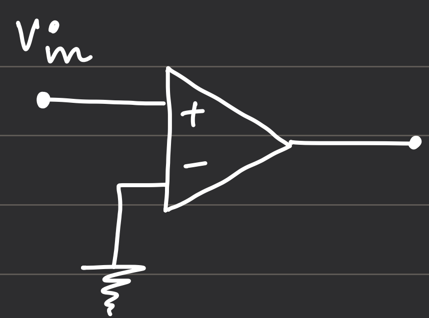
$V_o = A_{OL}(V_{id})$

Open loop Gain

$$\boxed{V_{id} = V_{NIT} - V_{IT}}$$

Differential i/p voltage

Example ①



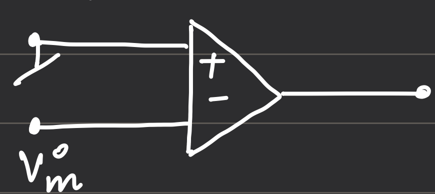
$V_o = A_{OL} V_{id} = A_{OL}(V_a - V_b)$

$V_o = A_{OL}(V_{in} - 0)$

$= A_{OL} V_{in}$

★ O/P has a 0° phase shift

Example ②



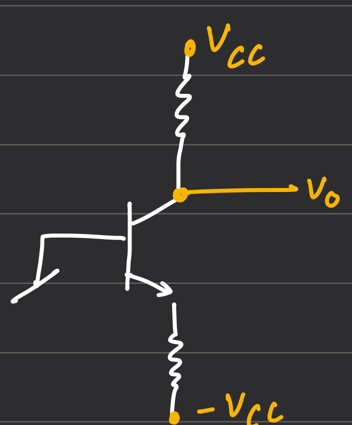
$V_o = A_{OL}(V_{id}) = A_{OL}[V_a - V_b]$

$V_o = A_{OL}[0 - V_{in}]$

$= -A_{OL} V_{in}$

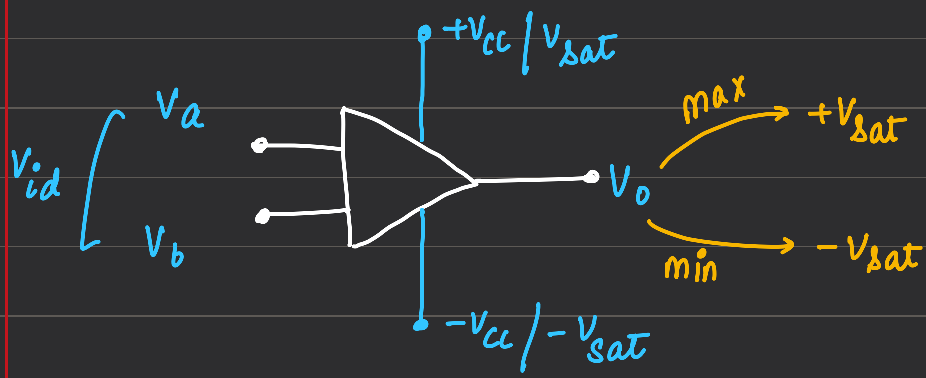
★ o/p has a 180° phase shift

Example ③



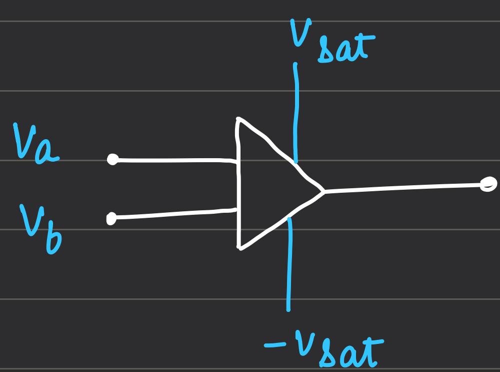
$\Rightarrow V_{cc} \le V_o \le V_{cc}$

Similarly



$$\boxed{-V_{sat} \leq V_o \leq V_{sat}}$$

Example (4)



$V_o = A_{OL} V_{id}$

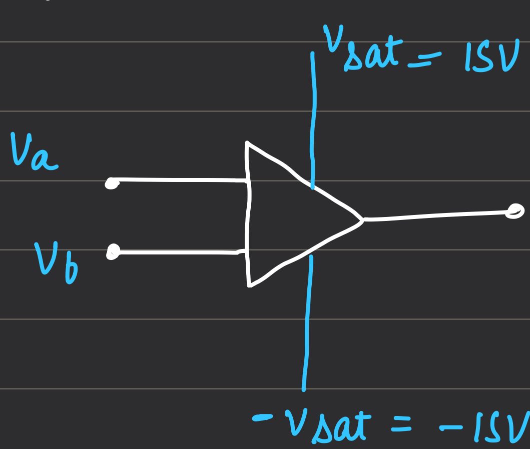
$V_{id} = \dfrac{V_o}{A_{OL}}$ $\xrightarrow{MAX}$ $+V_{sat} / A_{OL}$

$\phantom{V_{id} = \dfrac{V_o}{A_{OL}}}$ $\xrightarrow{MIN}$ $-V_{sat} / A_{OL}$

★ If V_{id} goes out of limit then the o/p gets saturated

Example (5)

$A_{OL} = 10^4$



$V_o = A_{OL} V_{id}$

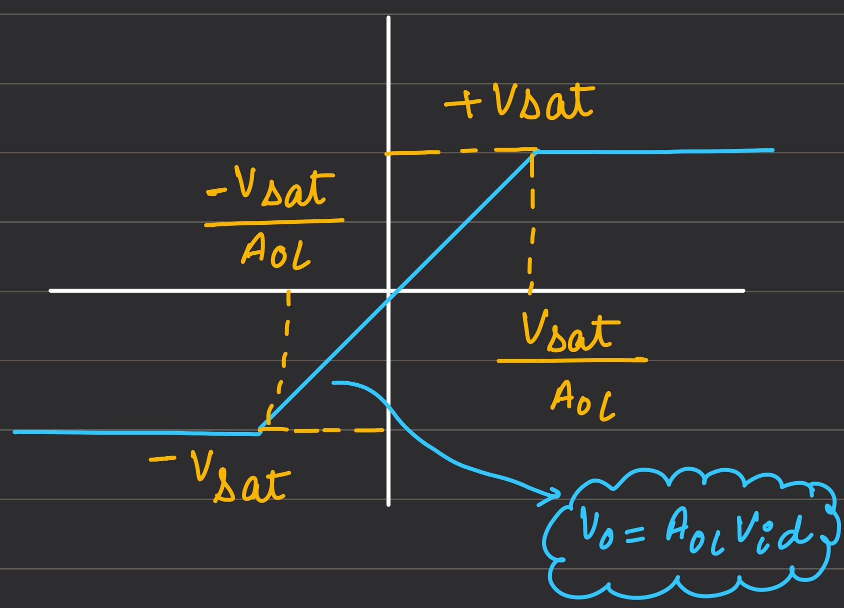
$V_o(max) \longrightarrow 15V$

$V_o(min) \longrightarrow -15V$

★ Always check for limits since if limits are exceeded the o/p values may be clipped.

$$\frac{-V_{sat}}{A_{OL}} \le V_{id} \le \frac{V_{sat}}{A_{OL}}$$ ★★

Transfer Char.



$y = mx$

$\Rightarrow$ slope : $A_{OL} = \tan\theta$

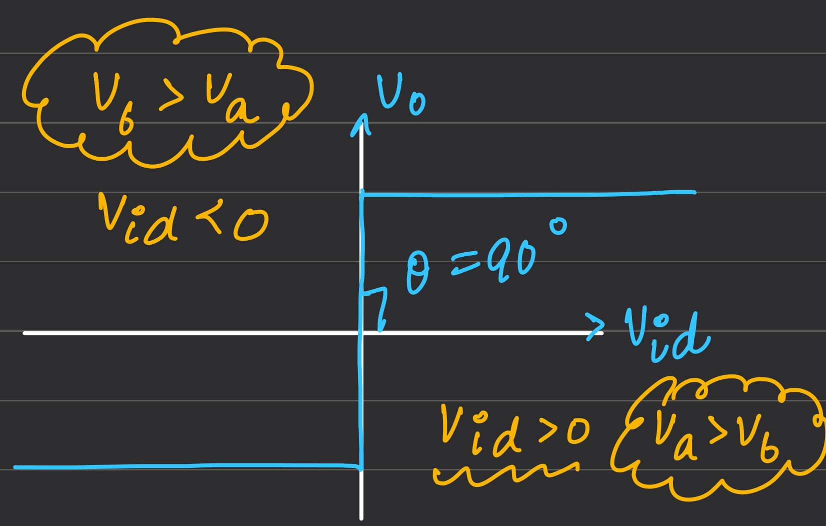
since A_{OL} is $>>>$

$\therefore \theta \approx 90^\circ \Rightarrow$ Approaches 90°

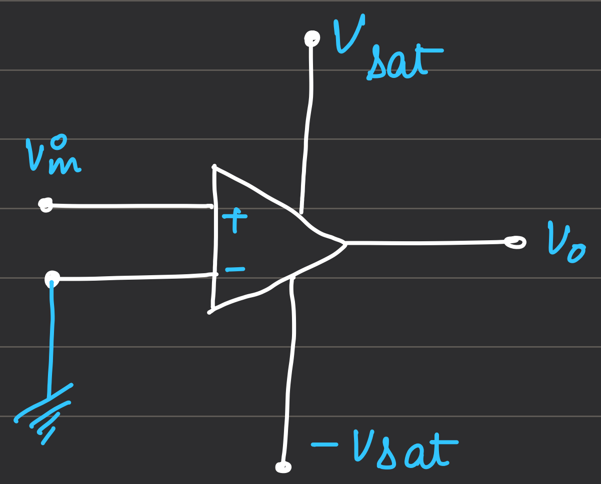
Thus in case of ideal op-amp:-

$A_{OL} \longrightarrow \infty$

$\theta = \tan^{-1}(\infty) = 90^\circ$



Example ⑥



$A_{OL} = \infty$

$V_o = A_{OL} V_{id}$

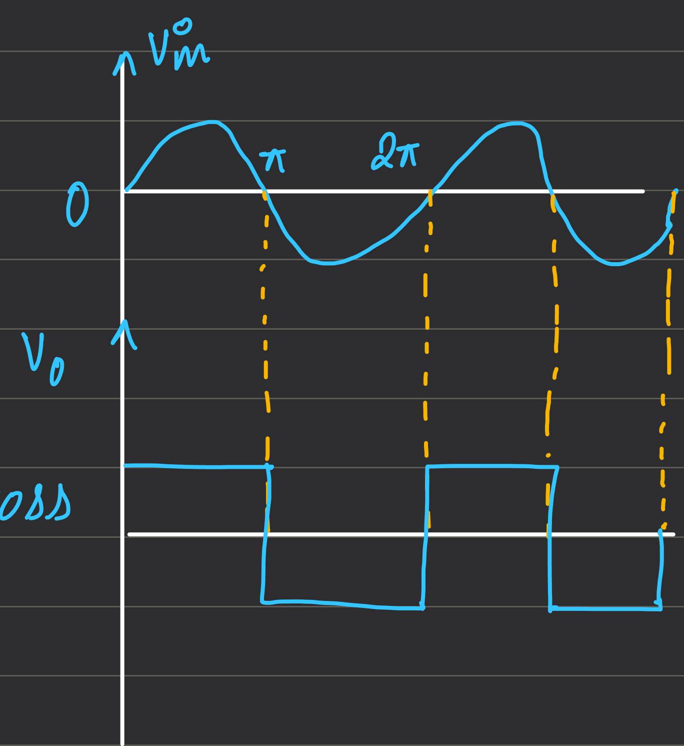
$V_{id} = \dfrac{V_o}{A_{OL}}$ → $\dfrac{+V_{sat}}{A_{OL}} = \dfrac{+(\ )}{\infty} = +0$

→ $\dfrac{-V_{sat}}{A_{OL}} = \dfrac{-(\ )}{\infty} = -0$

$V_{id} > 0 \Rightarrow V_o = +V_{sat}$

$V_{id} < 0 \Rightarrow V_o = -V_{sat}$

$V_{id} = V_{in} - 0 = V_{in}$



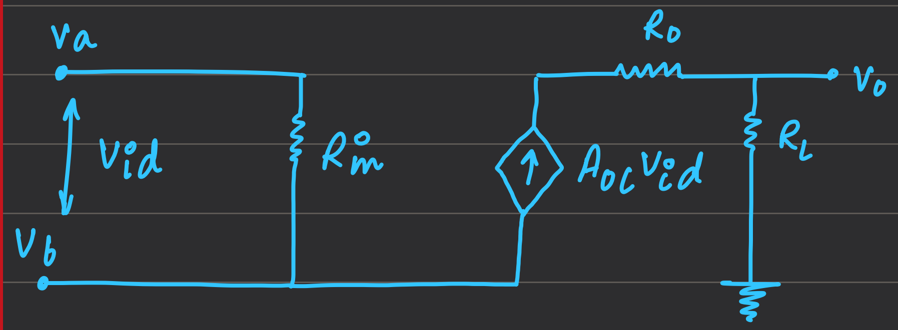
* This circuit is called 0-cross detector
* It is also a comparator

Char. of Ideal Op-Amp

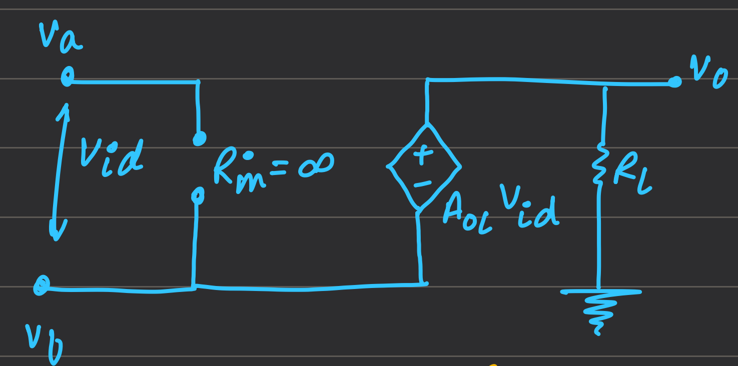
① ∞ I/P impedance
② 0 O/P impedance
③ ∞ open loop gain
④ ∞ Bandwidth
⑤ ∞ CMRR

Feedback → +ve (increases gain)
→ -ve (↓ gain)

Eq. Circuit of Ideal Op-Amp

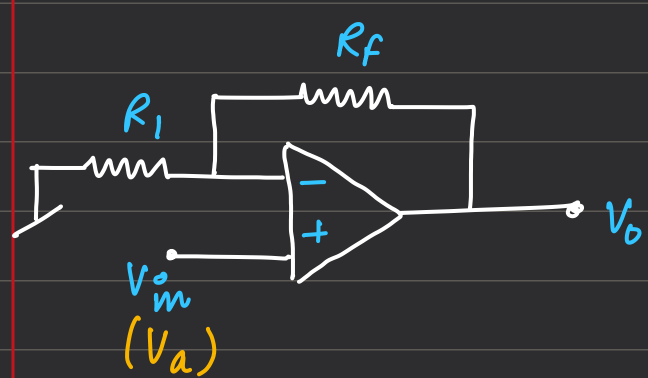


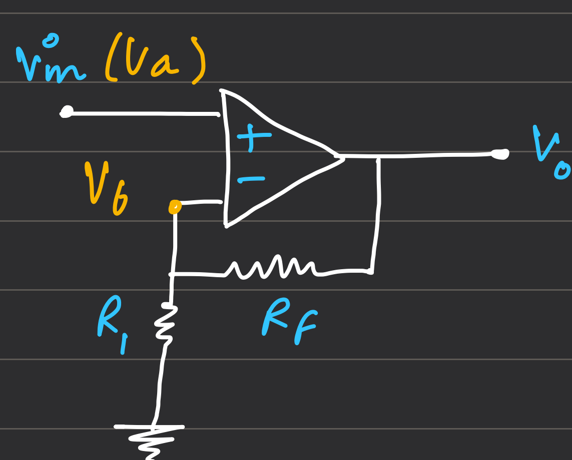
* Practical Op-Amp



* Ideal Op-Amp

Negative Feedback





$V_o = A_{OL} V_{id}$

$= A_{OL}(V_a - V_b)$

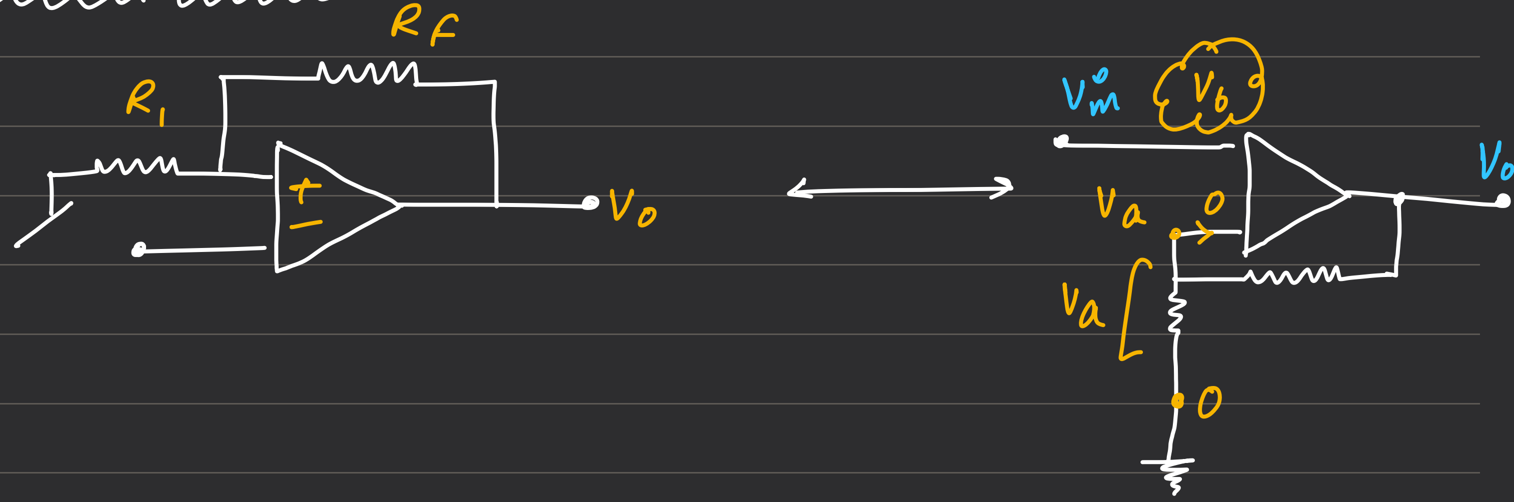
$= A_{OL}(V_{in} - V_b)$

$V_b = \dfrac{V_o R_1}{R_L + R_2}$

$V_o \uparrow \longrightarrow V_b \uparrow \longrightarrow V_o \downarrow$ hence $-ve$ feedback

$V_o \downarrow \longrightarrow V_b \downarrow \longrightarrow V_o \uparrow$ hence $-ve$ feedback

Positive feedback



$$V_o = A_{OL} V_{id}$$
$$= A_{OL}(V_a - V_b)$$
$$= A_{OL}(V_a - V_{in})$$

$$V_a = V_o\left(\frac{R_1}{R_1 + R_F}\right)$$

$V_o \uparrow \longrightarrow V_a \uparrow \longrightarrow V_o \uparrow$

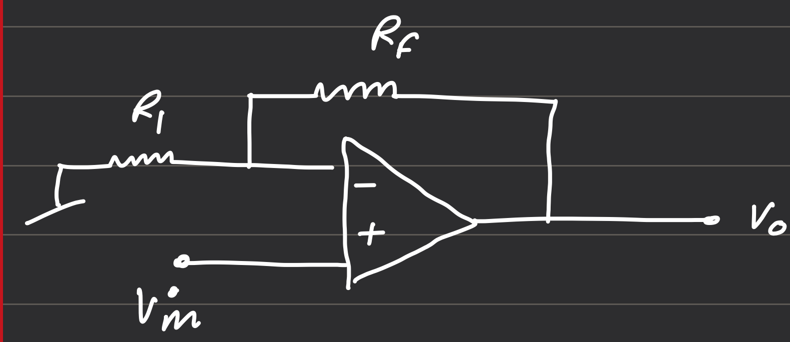
LOOP $\longrightarrow \infty$

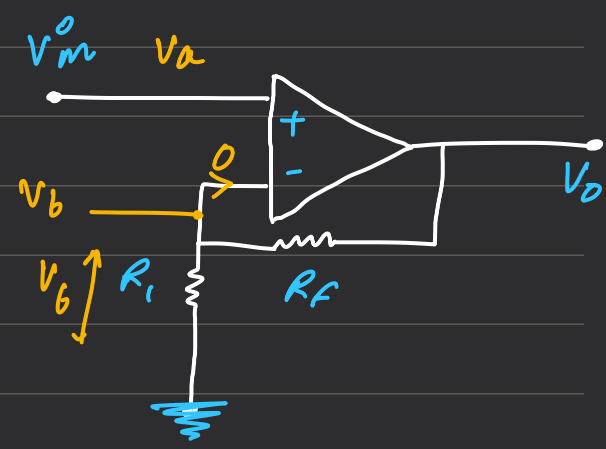
$V_o \downarrow \longrightarrow V_a \downarrow \longrightarrow V_a \downarrow$

LOOP $\longrightarrow \infty$

$\longrightarrow$ $+ve$ feedback

=> **NON-Inverting Amp.**





we need to find V_o/V_{in} $(A_{CL}) = ?$

$$V_b = \frac{V_o R_1}{R_1 + R_f}$$

$$V_o = A_{OL}(V_{id})$$
$$= A_{OL}(V_a - V_b)$$
$$= A_{OL}(V_{in} - V_b)$$

$$V_b = V_a - \frac{V_o}{A_{OL}}$$

$$\frac{V_o R_1}{R_1 + R_f} = V_{in} - \frac{V_o}{A_{OL}}$$

$$\frac{R_1}{R_1 + R_f} = \frac{V_{in}}{V_o} - \frac{1}{A_{OL}}$$

$$\frac{V_{in}}{V_o} = \frac{R_1}{R_1 + R_f} + \frac{1}{A_{OL}}$$

$$= \frac{R_1 A_{OL} + R_1 + R_f}{A_{OL}(R_1 + R_f)}$$

$$\frac{V_o}{V_{in}} = \frac{A_{OL}(R_1 + R_f)}{R_1 A_{OL} + R_1 + R_f}$$

$$= \frac{A_{OL} R_1 \left[1 + R_f/R_1\right]}{R_1 A_{OL}\left[1 + \frac{1}{A_{OL}}\left(1 + \frac{R_f}{R_1}\right)\right]}$$

**

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

If $A_{OL} \to \infty$

$$\boxed{\frac{V_o}{V_{in}} = 1 + \frac{R_f}{R_1}} \longrightarrow \text{Ideal OP-AMP}$$

Approx. Method

If $A_{OL} \to \infty$

$$V_b = V_a - \frac{V_o}{A_{OL}}$$

$$\Rightarrow V_b = V_a - 0$$

$$\Rightarrow V_b = V_a \longrightarrow \text{Case of Virtual Short}$$