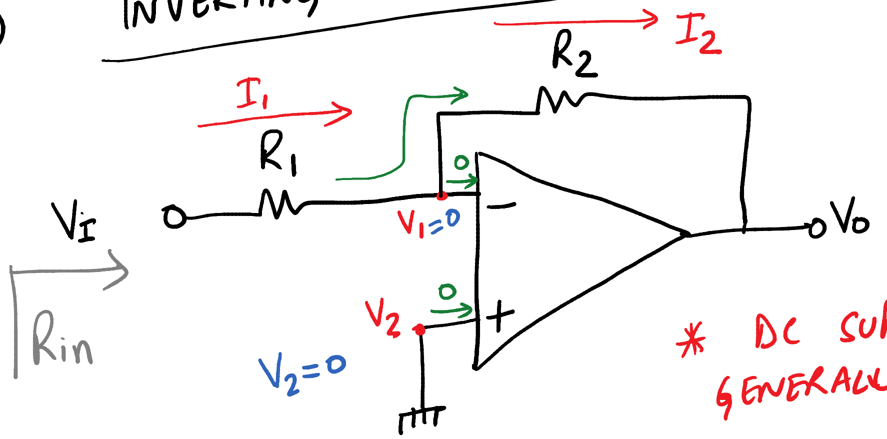
LECTURE - 40

* OP-AMPS → OPEN LOOP GAIN IS HIGH (∞)

* TYPICAL USE → EMPLOY NEGATIVE FEEDBACK, FROM OUTPUT TO INPUT USING EXTERNAL CIRCUIT, TO CONTROL GAIN

* NOTE → DERIVATIONS ARE IMPORTANT

① INVERTING AMPLIFIER



* DC SUPPLY VOLTAGES GENERALLY ARE NOT SHOWN

* OPEN LOOP GAIN Ad (A) ↑↑

* CLOSED LOOP GAIN

$$\boxed{A_V = \frac{V_o}{V_I}}$$

* IDEAL CONDITIONS

$$A_d \to \infty$$

$$\boxed{R_{in} \to \infty\ \Omega}$$

$$R_o \to 0\ \Omega$$

* IDEAL CONDITIONS $A_d\ \underline{\underline{\infty}}$ AND $V_2 = 0$

* IDEAL CONDITIONS

$A_d\ \infty$ AND $V_2 = 0$

$V_1 = 0\,V$ ["VIRTUAL GROUND"]

[NOT GROUNDED]

$$I_1 = \frac{V_I - V_1}{R_1} = \frac{V_I}{R_1}$$

$$I_2 = \frac{V_1 - V_o}{R_2} = -\frac{V_o}{R_2}$$

CURRENT INTO OP-AMP $= 0$ [$\because$ R_{IN} IS $\infty\,\Omega$]

$$\therefore\ I_1 = I_2$$

$$\frac{V_I}{R_1} = -\frac{V_o}{R_2}$$

IDEAL!

$$\boxed{A_V = \frac{V_o}{V_I} = -\frac{R_2}{R_1}}$$

PHASE REVERSAL

* GAIN IS A FUNCTION OF EXTERNAL CIRCUIT!

$$R_{in} = \frac{V_I}{I_1} = R_1$$

[$\because$ OF VIRTUAL GROUND THEORY]

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Ex

$$A_v = \overset{\downarrow}{-}5$$

$v_s = 0.1 \sin(\omega t)$

MAX. SUPPLY CURRENT OF 5μA

$$I_1 = \frac{V_I}{R_1} = \frac{v_s}{R_1}$$

$$R_1 = \frac{V_{s,M}}{I_1} = \frac{0.1}{5\mu} = \underline{\underline{20K\Omega}}$$

$$A_v = -\frac{R_2}{R_1} = -5$$

$$R_2 = \underline{\underline{100K\Omega}}$$

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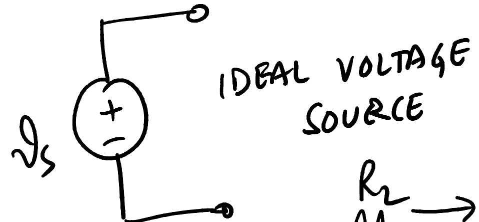
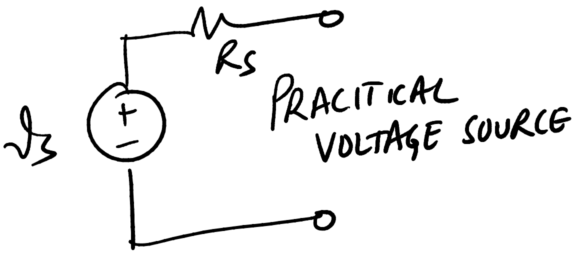
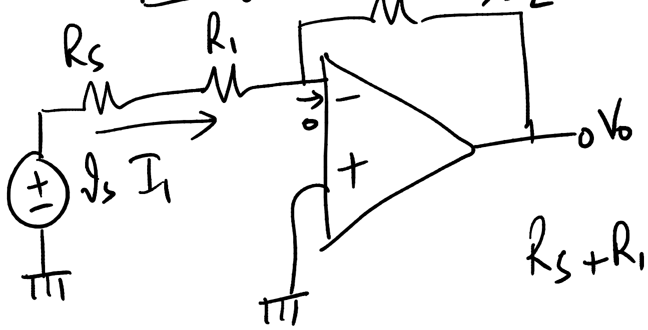
* IF SOURCE HAS A FINITE R_s OF $\underline{\underline{1K\Omega}}$







$$I_1 = \frac{V_I}{R_s + R_1}$$

$$R_s + R_1 = \frac{V_I}{I_1} = \frac{0.1}{5\mu} = 20K\Omega$$

$$R_1 = \underline{19K\Omega}$$

$$R_2 = 5(19K + 1K) = \underline{\underline{100K\Omega}}$$

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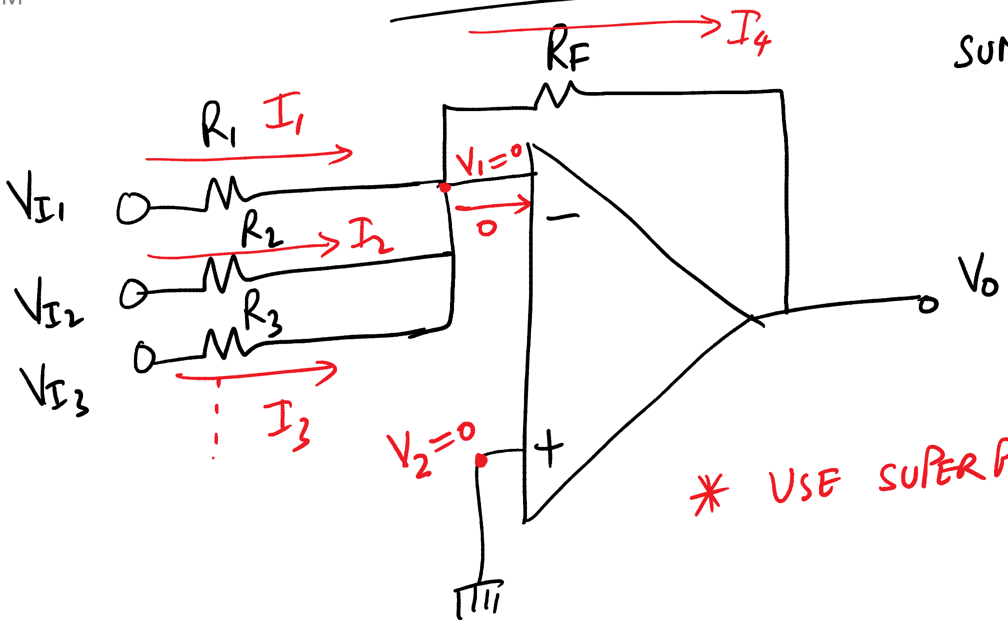
SUMMING AMPLIFIER

SUMS THREE INPUT VOLTAGES



* USE SUPERPOSITION

① SET $V_{I_2} = V_{I_3} = 0$

$$\therefore I_1 = \frac{V_{I_1}}{R_1} \qquad I_2 = I_3 = 0 \quad \because V_1 = 0$$

VIRTUAL GROUND AND INPUTS ARE 0

$I_4 = I_1$

$$\therefore V_{o_1} = -\frac{R_F}{R_1} V_{I_1}$$

$|||^{lwy}$

$$V_{o_2} = \frac{-R_F}{R_2} V_{I_2}$$

$$V_{o_3} = -\frac{R_F}{R_3} V_{I_3}$$

$$\therefore V_o = V_{o_1} + V_{o_2} + V_{o_3}$$

$$= -\frac{R_F}{R_1} V_{I_1} - \frac{R_F}{R_2} V_{I_2} - \frac{R_F}{R_3} V_{I_3}$$

IF $R_1 = R_2 = R_3 = R$

$$V_O = \underbrace{\boxed{-\frac{R_F}{R}}}_{\text{SINGLE GAIN FACTOR!}} \underbrace{\left[V_{I_1} + V_{I_2} + V_{I_3}\right]}_{\text{SUM}}$$

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Ex

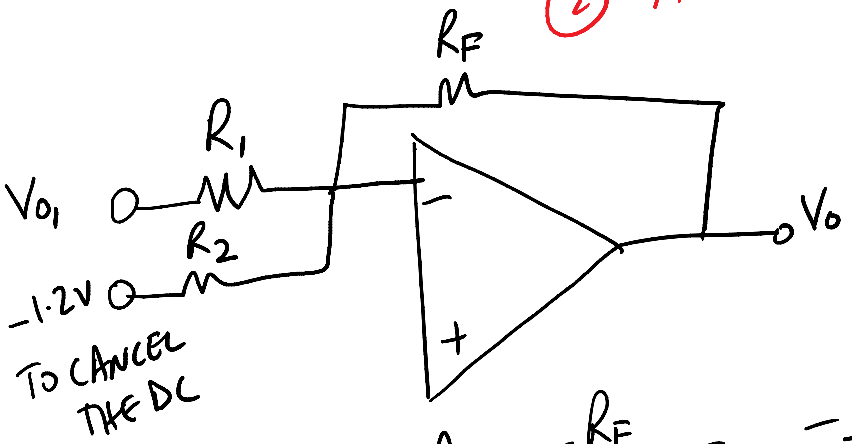
DESIGN.

OUTPUT OF AN AMPLIFIER $= V_{o1} = \overset{DC}{\downarrow}1.2 - \overset{AC}{\downarrow}0.5\sin(\omega t)$

DESIRED O/P ⇒ $V_o = +\underset{\overset{\uparrow}{AC}}{2}\sin(\omega t)$

→ ① REMOVE DC

② AMPLIFY AC



TO CANCEL THE DC

$$A_V = -\frac{R_F}{R_1} = -\frac{V_o}{V_1} = \frac{-2}{0.5} = -4$$

$$\therefore \boxed{R_F = 4R_1}$$

CHOOSE $R_1 = R_2 = 30\,k\Omega$

$\underline{\underline{R_F = 120\,k\Omega}}$

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INVERTING AMPLIFIER

CLOSED LOOP GAIN

$$\boxed{A_v = -\frac{R_2}{R_1}}$$

[ASSUMING IDEAL CONDITIONS]

$\boxed{A_d \to \infty}$

$R_{IN} \to \infty \Omega$

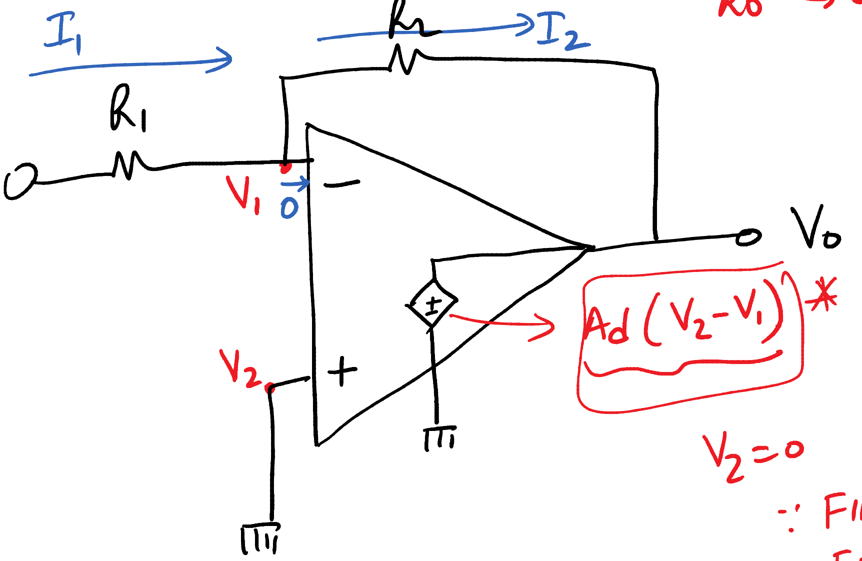
$R_o \to 0 \Omega$

EFFECT OF FINITE GAIN

$\underline{A_d \text{ FINITE}}$

$\underline{R_{IN} \to \infty \Omega}$

$R_o \to 0 \Omega$



$V_2 = 0 \quad V_1 \neq 0$

∵ FINITE GAIN
FINITE VALUE OF
$V_1 > 0$

$$I_1 = \frac{V_I - V_1}{R_1}$$

$$I_2 = \frac{V_1 - V_o}{R_2}$$

$$\boxed{V_o = A_d(V_2 - V_1)} \to \text{ALWAYS VALID!}$$

$V_2 = 0 \, V$

$$V_o = -A_d V_1 \Rightarrow \boxed{V_1 = -\frac{V_o}{A_d}} \cdots ①$$

$$I_1 = I_2 \quad \because \quad R_{IN} \to \infty$$

$$\frac{V_I - V_1}{R_1} = \frac{V_1 - V_o}{R_2}$$

$$\frac{V_I + \frac{V_o}{A_d}}{R_1} = \frac{-\frac{V_o}{A_d} - V_o}{R_2}$$

$$\frac{V_I}{R_1} + \frac{V_o}{A_d R_1} = -\frac{V_o}{R_2}\left[\frac{1}{A_d} + 1\right]$$

$$\frac{V_I}{R_1} = -V_o\left[\frac{1}{A_d}\left(\frac{1}{R_1} + \frac{1}{R_2}\right) + \frac{1}{R_2}\right]$$

$$\boxed{\frac{V_o}{V_I} = A_v = -\frac{1}{R_1}\,\frac{1}{\left[\underbrace{\frac{1}{A_d}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}_{0} + \frac{1}{R_2}\right]}}$$

$$\lim_{A_d \to \infty} \Rightarrow \boxed{\frac{V_o}{V_I} = \frac{-R_2}{R_1}}$$

A_d → (A) → OPEN LOOP GAIN [FOUND IN DATA SHEETS]

A_v → CLOSED LOOP GAIN [BASED ON EXTERNAL CIRCUIT]

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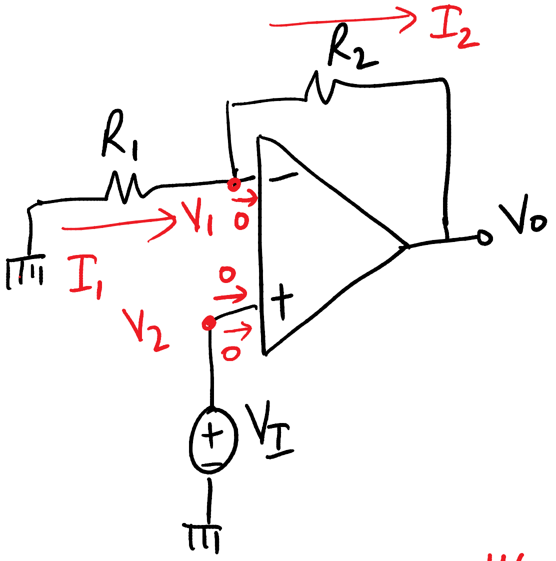
NON-INVERTING AMPLIFIER

IDEAL CASE



* A CHANGE IN V_2 WILL CAUSE A CHANGE IN V_o. BUT DUE TO FEEDBACK, CHANGE IN V_o WILL CAUSE V_1 TO FOLLOW V_2 ∴ $\boxed{V_1 = V_2}$

(VIRTUAL SHORT), NO CURRENT IS FLOWING INTO THE TERMINALS

$$V_1 - V_2 = 0$$

$$\underline{V_1} = V_2 = \underline{V_I}$$

$$I_1 = -\frac{V_1}{R_1} = -\frac{V_I}{R_1}$$

$$I_2 = \frac{V_1 - V_o}{R_2} = \frac{V_I - V_o}{R_2}$$

$$I_1 = I_2$$

$V_I - V_o$

$I_1 = I_2$

$$-\frac{V_I}{R_1} = \frac{V_I - V_O}{R_2}$$

$$\boxed{A_V = \frac{V_O}{V_I} = 1 + \frac{R_2}{R_1}}$$

- * OUTPUT IS IN PHASE WITH INPUT
- * GAIN > 1
- * $R_{IN} = \frac{V_I}{I_{IN}} = \frac{V_I}{0} = \infty$

  IDEAL $R_{IN} = \infty$