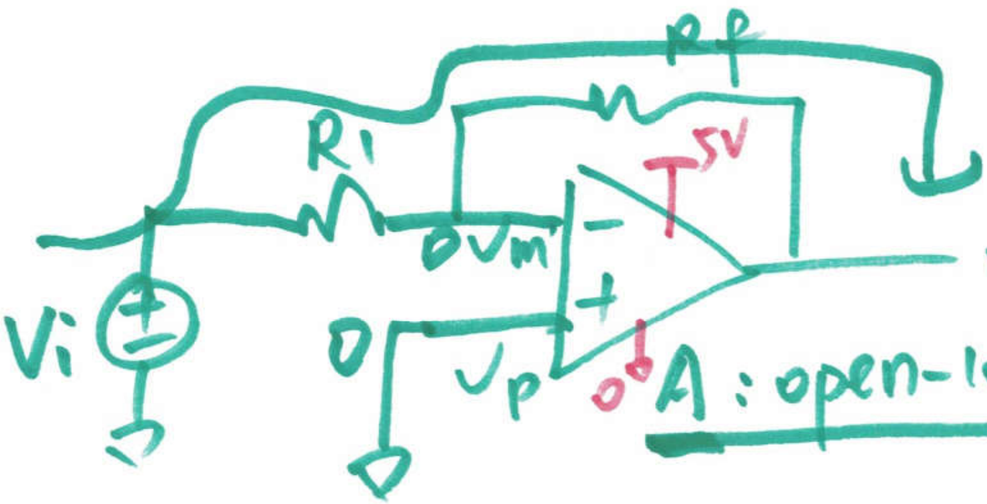
Lec 22

Op Amp IV



$V_{out} = (V_p - V_m)A$

A : open-loop gain

① Infinite open-loop gain A, then $V_p = V_m$.

② Finite open-loop gain A.

∞A : $$\frac{V_i - 0}{R_1} = \frac{0 - V_0}{R_f} \Rightarrow \boxed{\frac{V_0}{V_i} = -\frac{R_f}{R_1}}$$

$$\boxed{V_p = V_m = 0}$$

①

$$\begin{cases} \dfrac{V_i - V_m}{R_1} = \dfrac{V_m - V_0}{R_f} \\ V_0 = (V_p - V_m)\cdot A \\ V_p = 0 \end{cases} \Rightarrow V_0 = -V_m \cdot A$$

$$\Rightarrow V_m = -\frac{V_0}{A}$$

V_0 , V_i

$$\frac{V_i + \frac{V_0}{A}}{R_1} = \frac{-\frac{V_0}{A} - V_0}{R_f}$$

$$\frac{R_f}{\infty} \approx 0$$

$$V_i R_f + \frac{V_0}{A} \cdot R_f = -\frac{V_0}{A} \cdot R_1 - V_0 R_1$$

$$A = \infty$$

$$\boxed{R_f = 100 R_1}$$

$$V_i \cdot R_f = -\frac{V_0}{A} \cdot R_f - \frac{V_0}{A} \cdot R_1 - V_0 R_1$$

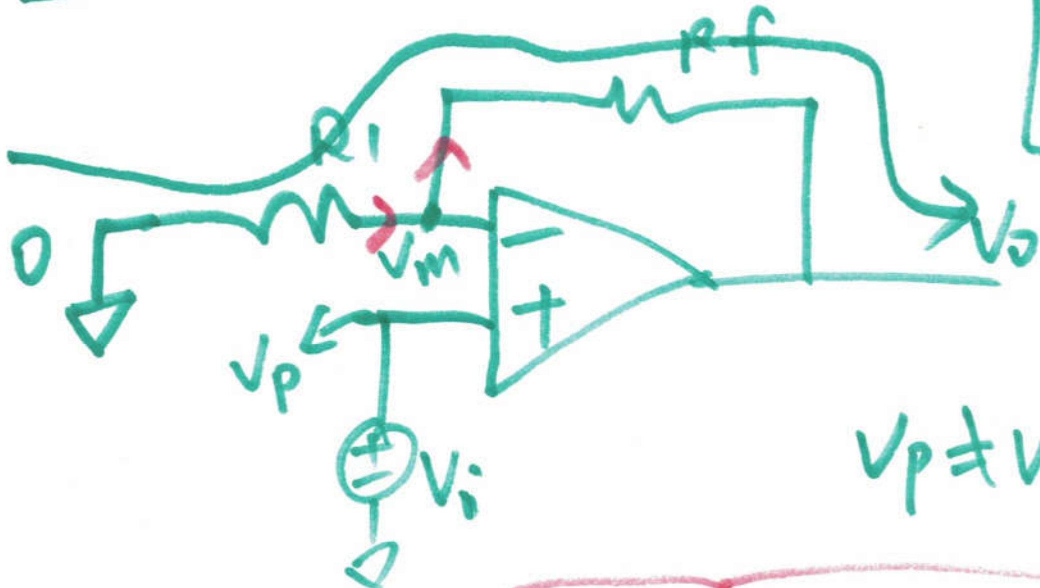
$$= -\left(\frac{R_f}{A} + \frac{R_1}{A} + R_1\right) V_0$$

②

$$\boxed{\frac{V_0}{V_i} = -\frac{R_f}{\frac{R_f}{A} + \frac{R_1}{A} + R_1}} \approx -\frac{R_f}{R_1} (A \to \infty)$$

Non-inverting Topology

Finite gain



$V_p \neq V_m$

$$\begin{cases} \dfrac{0 - V_m}{R_1} = \dfrac{V_m - V_o}{R_f} \\ (V_p - V_m) \cdot A = V_o \\ V_p = V_i \end{cases}$$

$\Rightarrow (V_i - V_m) \cdot A = V_o$

$\Rightarrow \boxed{V_m = V_i - \dfrac{V_o}{A}}$

③

$$\frac{0 - V_i + \frac{V_o}{A}}{R_1} = \frac{V_i - \frac{V_o}{A} - V_o}{R_f}$$

$$-V_i \cdot R_f + \frac{V_o}{A} \cdot R_f = V_i R_1 - \frac{V_o}{A} \cdot R_1 - V_o R_1$$

$$+ V_i\left(R_f + \cancel{V_i} \cdot R_1\right) = \left(+\frac{R_f}{A} + \frac{R_1}{A} + R_1\right) \cdot V_o$$

$$\boxed{\frac{V_o}{V_i} = \frac{R_f + R_1}{\frac{R_f}{A} + \frac{R_1}{A} + R_1}}$$

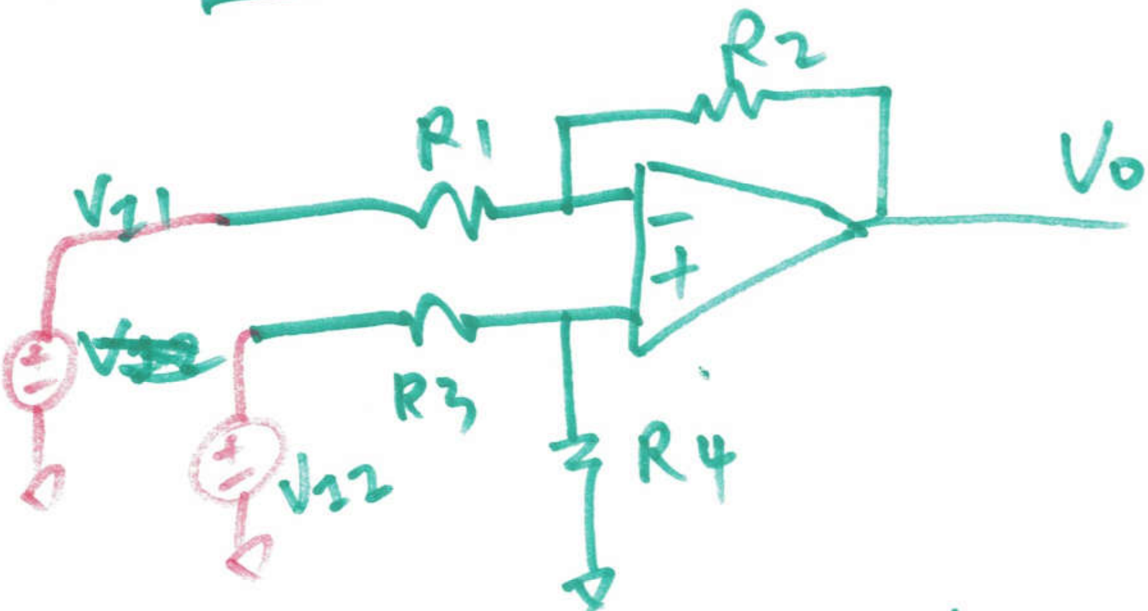
if $A = \infty$

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

$$= \boxed{1 + \frac{R_f}{R_1}}$$

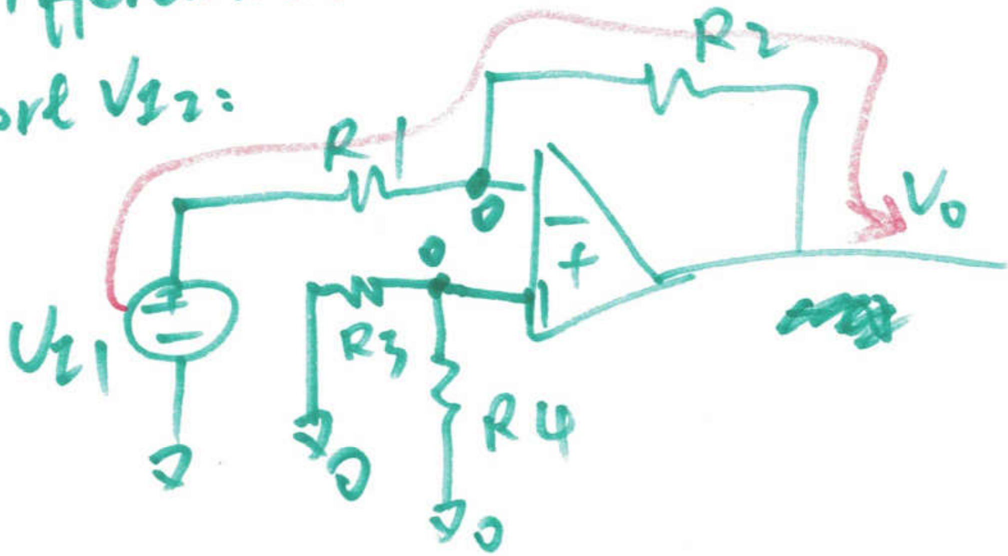
Difference Amplifier

Infinite Gain



① Differential Gain Ad

Short Vi2:



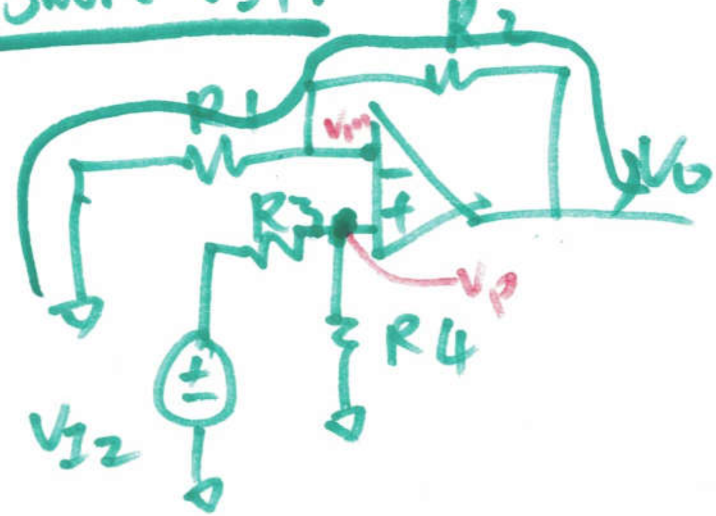
$$-\frac{R_f}{R_1}$$

$$\frac{V_{I1} - 0}{R_1} = \frac{0 - V_o}{R_2}$$

$$\frac{R_2}{R_1} = \frac{-V_o}{V_{I1}}$$

$$\frac{V_o}{V_{I1}} = -\frac{R_2}{R_1}$$

Short V_{I1}:



$$V_p = V_{I2} \cdot \frac{R_4}{R_3 + R_4}$$

$$\frac{0 - V_m}{R_1} = \frac{\cancel{0}\, V_m - V_o}{R_2}$$

$$V_m = V_p$$

$$0 - V_{I2}\cdot\frac{R_4}{R_4+R_3} = \frac{V_{I2}\cdot\frac{R_4}{R_3+R_4} - V_o}{R_2}$$

$$\frac{R_2}{R_1} = \frac{V_o - V_{I2}\cdot\frac{R_4}{R_3+R_4}}{V_{I2}\cdot\frac{R_4}{R_3+R_4}}$$

$$= \frac{V_o}{V_{I2}\cdot\frac{R_4}{R_3+R_4}} - 1$$

$$\frac{V_o}{V_{I2}} = \left(1+\frac{R_2}{R_1}\right)\cdot\frac{R_4}{R_3+R_4}$$

Given/choose $\boxed{\begin{matrix} R_1 = R_3 \\ R_2 = R_4 \end{matrix}}$ $\quad \frac{V_o}{V_{I2}} = \frac{\cancel{R_1+R_2}}{R_1}\cdot\frac{R_2}{\cancel{R_1+R_2}}$

$$\frac{V_0}{V_{I_2}} = \frac{R_2}{R_1}$$

Finally (super-position):

$$V_0 = V_{I_2} \cdot \frac{R_2}{R_1} + \left(-V_{I_1} \cdot \frac{R_2}{R_1}\right)$$

$$= \left(V_{I_2} - V_{I_1}\right) \cdot \frac{R_2}{R_1}$$

$$\therefore V_d = \frac{V_0}{V_{I_2} - V_{I_1}} = \frac{R_2}{R_1} = \frac{R_4}{R_3}.$$