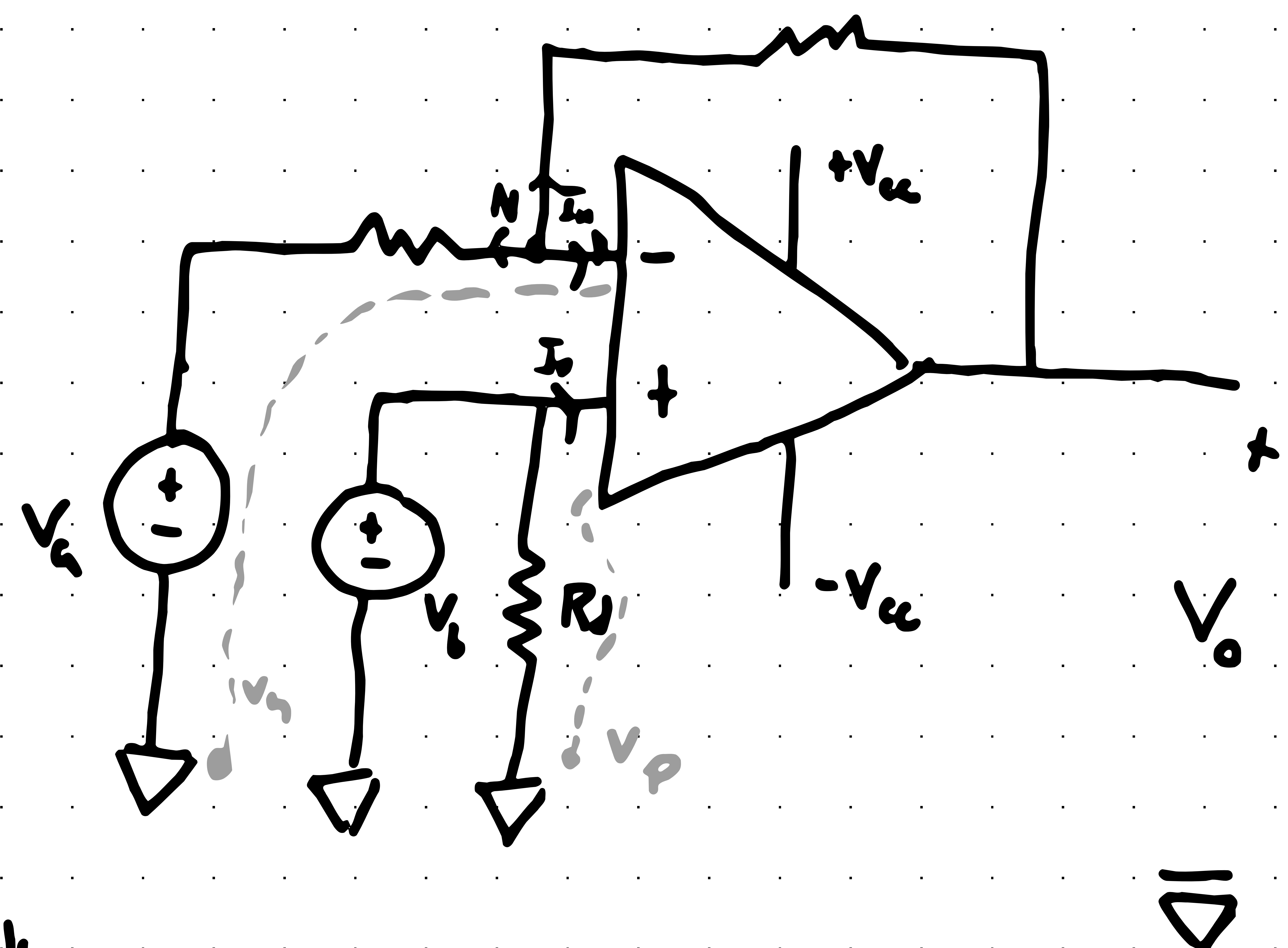
Lecture 14 ECED 2□□□

Difference Amplifier

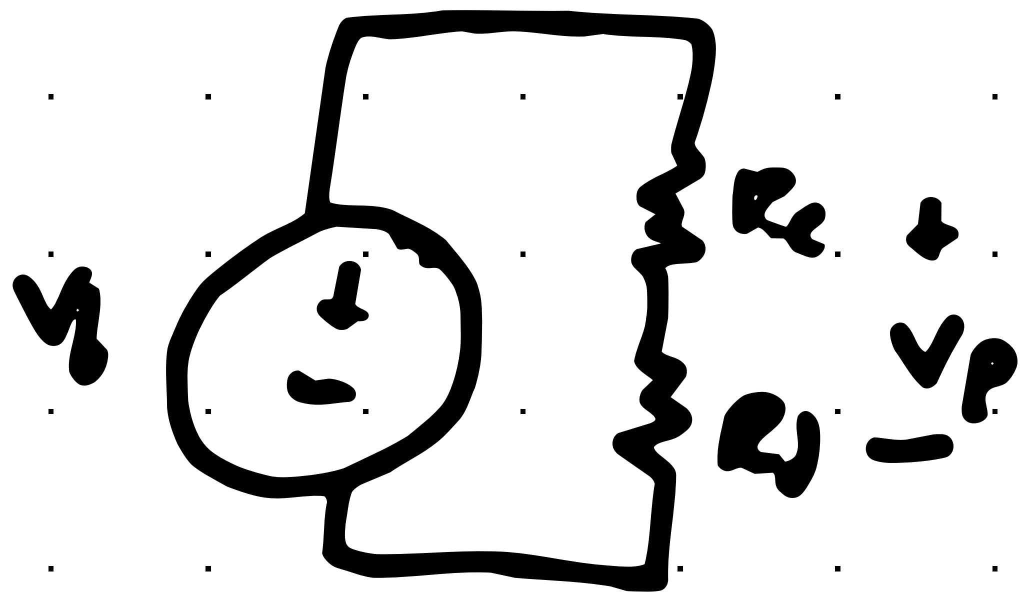


Feeding Inverting and Non-Inverting Input with two voltage supplies, will give you the difference.

$I_p = I_n = 0$ $V_p = V_n$

Using voltage divider identity

$$V_p = \frac{R_d}{R_c + R_d} V_b$$



$\sum I = 0$

Node (n)

$$\frac{\overset{V_p}{V_n} - V_a}{R_a} + \frac{\overset{V_p}{V_n} - V_o}{R_b} + \overset{0}{i_n} = 0$$

$$\frac{\frac{R_d}{R_c+R_d} V_b - V_a}{R_a} + \frac{\frac{R_d}{R_c+R_d} V_b - V_o}{R_b} = 0$$

So,

$$\boxed{V_o = \frac{R_d(R_a + R_b)}{R_a(R_c + R_d)} V_b - \frac{R_b}{R_a} V_a}$$

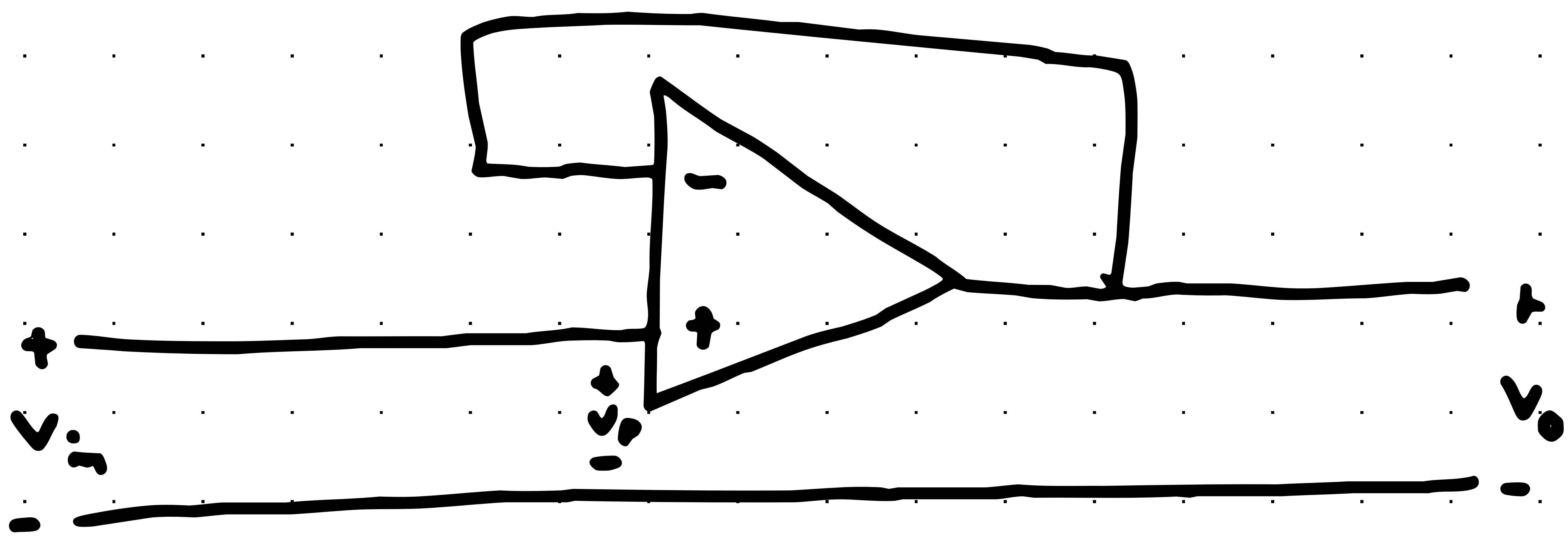
If

$$\frac{R_a}{R_b} = \frac{R_c}{R_d} \Longrightarrow \boxed{V_o = \frac{R_b}{R_a}(V_b - V_a)}$$

Difference Amplifier

Some different OP-Amp Configurations

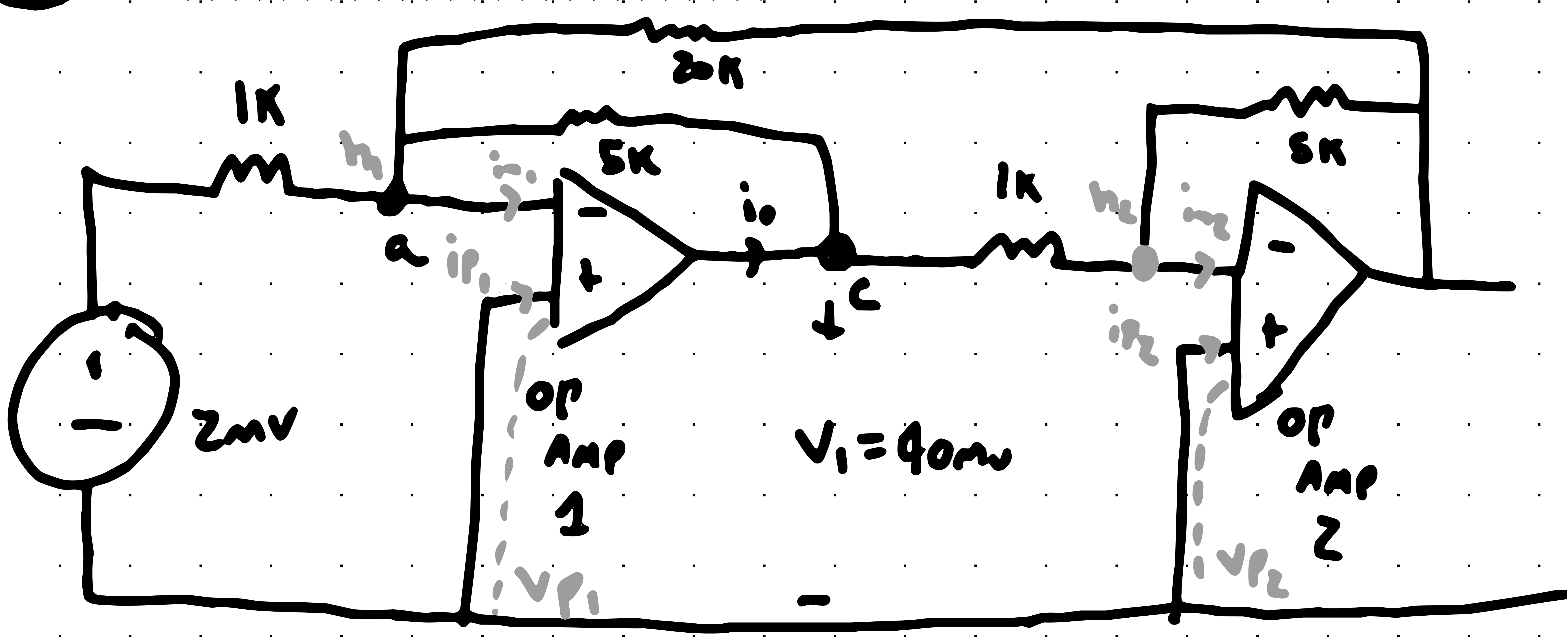
1 Buffer (voltage follower) amplifier



$V_p = V_n$ $\qquad$ $i_p = i_n$

Since $V_{in} = V_p$ and $V_o = V_n$ then $\boxed{V_o = V_{in}}$

② ~~Cascade Amplifier~~



Calculate V_o and i_o and the overall gain

Solution

OP AMP ①

$i_{n_1} = i_{p_1} = 0$, $V_p = V_{n_1}$

Since $V_{p_1} = 0$, $V_{n_1} = 0$

OP AMP ②

$i_{n_2} = i_{p_2} = 0$,

$V_{p_2} = V_{n_2}$

Since $V_{p_2} = 0$, $V_{n_2} = 0$

$\sum I = 0$

Node N_1

$$\frac{\overset{0}{V_{n1}} - 2\times10^{-3}}{1000} + \frac{\overset{0}{V_n} - 40\times10^{-3}}{5000} + \frac{V_{n1} - V_0}{20000} + \overset{0}{i_n} = 0$$

Mili

$$\frac{-2\times10^{-3}}{10^3} + \frac{40\times10^{-3}}{5\times10^3} - \frac{V_o}{20\times10^3} = 0$$

$$V_0 = -0.2V$$

$\sum I = 0$ $\quad i_0 = \dfrac{V_1 - V_{n_1}}{5\times10^3} + \dfrac{V_1 - V_{n_2}}{1000}$

Node C

$i_0 = 48\,\mu A$

If V_1 were unknown....

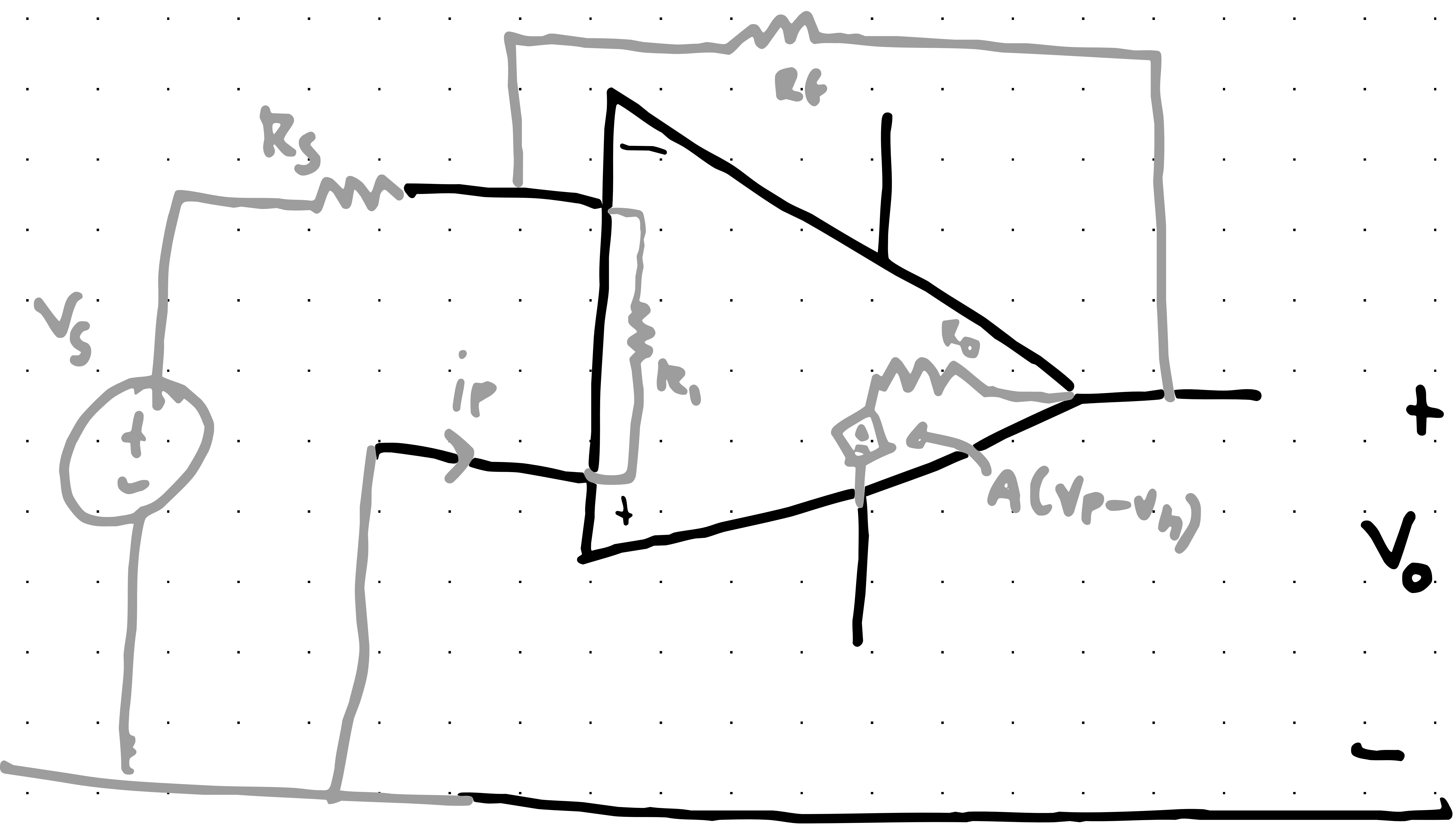
$\sum I = 0$ $\quad \dfrac{\overset{0}{V_{n_2}} - V_0}{5000} + \dfrac{\overset{0}{V_{n_2}} - \overset{0}{V_{n_1}}}{20000} + i_{n_2} + \dfrac{\overset{0}{V_{n_2}} - V_1}{1000} = 0$

Node 2

$\text{Gain} = \dfrac{V_0}{V_{in}} = \dfrac{-0.2}{2\times10^{-3}} = -100\,V$

Practical OP-Amp (will not be on the midterm)

Non-Inverting Practical op-amp circuit



Typical Values for MA741 OP-Amp

$R_i = 2M\Omega$ $A = 10^5$ $R_o = 75\Omega$

$$\sum_{\text{Node A}} I = 0 \qquad \frac{V_n - V_s}{R_s} + \frac{V_n - V_p}{R_i} + \frac{V_n - V_o}{R_f} = 0$$

$$\sum_{\text{Node B}} I = 0 \qquad \frac{V_o - V_n}{R_f} + \frac{V_o - A(V_p - V_n)}{R_o} = 0$$