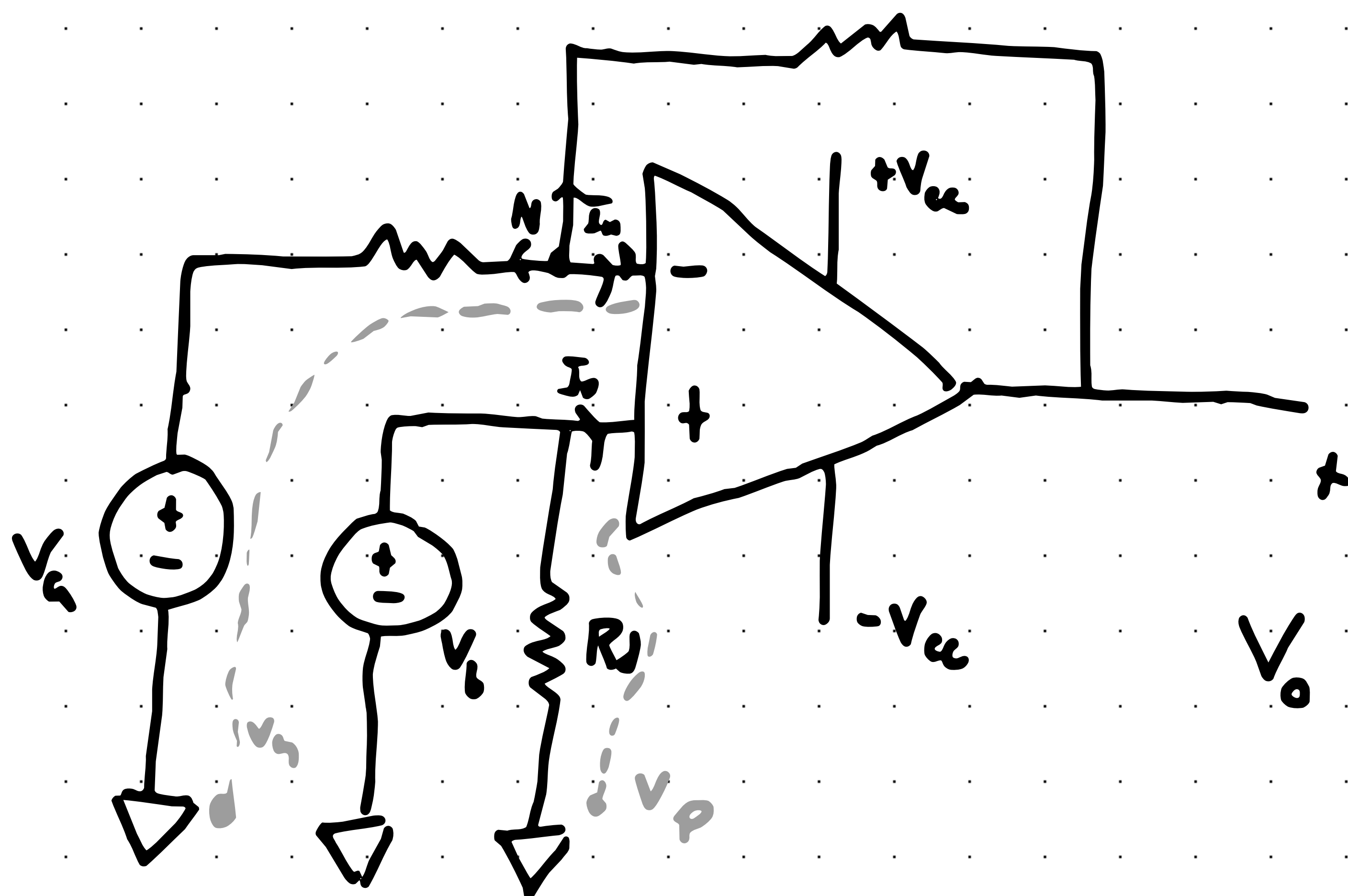


# Difference Amplifier



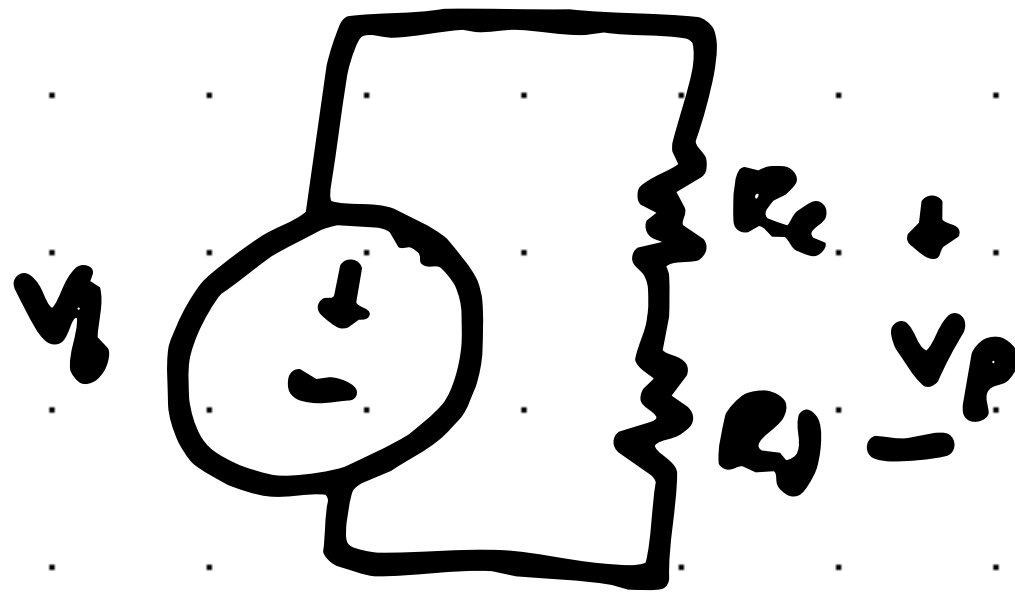
Feely Inverting and Non-Inverting Input with two voltage supplies, will give you the difference.

$$I_p = I_n = 0$$

$$V_p = V_n$$

Using voltage divider identity

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



$$\sum I = 0$$

Note (h)

$$\frac{V_b - V_a}{R_a} + \frac{V_b - V_o}{R_b} + i_{in} = 0$$

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

So,

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

If

$$\frac{R_a}{R_b} = \frac{R_c}{R_d} \Rightarrow$$

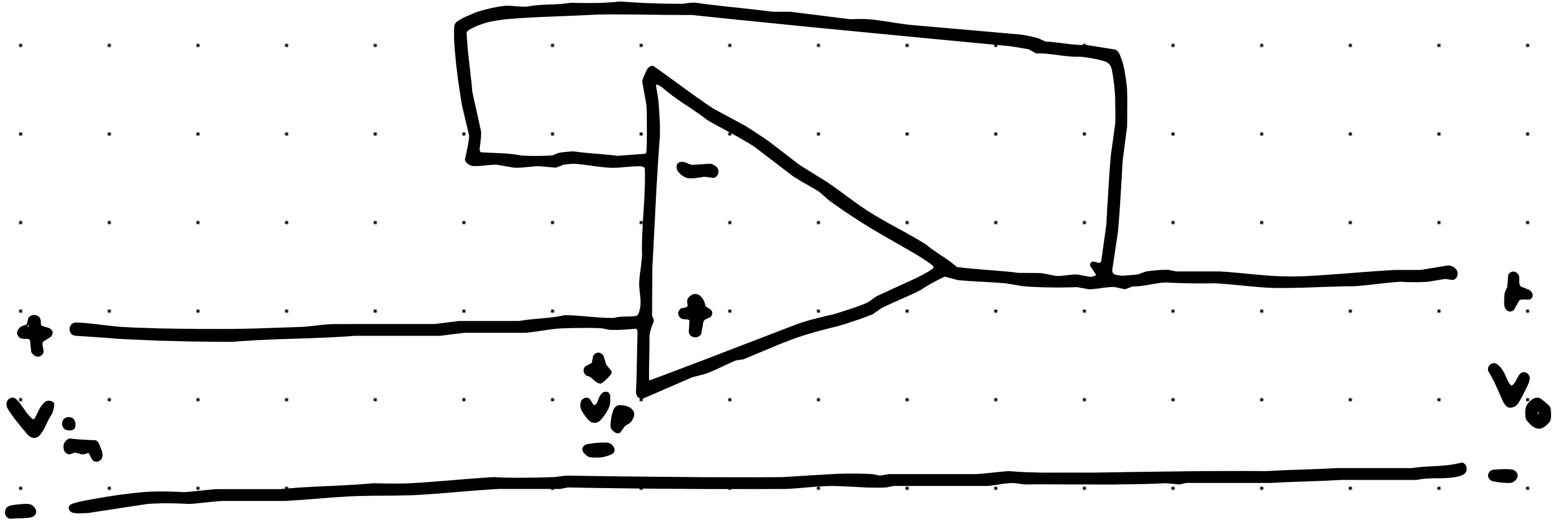
$$V_o = \frac{R_b}{R_a} (V_b - V_a)$$

Differential Amplifier

# Some different OP-Amp Configurations

①

~~Buffer (Voltage follower) amplifier~~



$$V_p = V_{in}$$

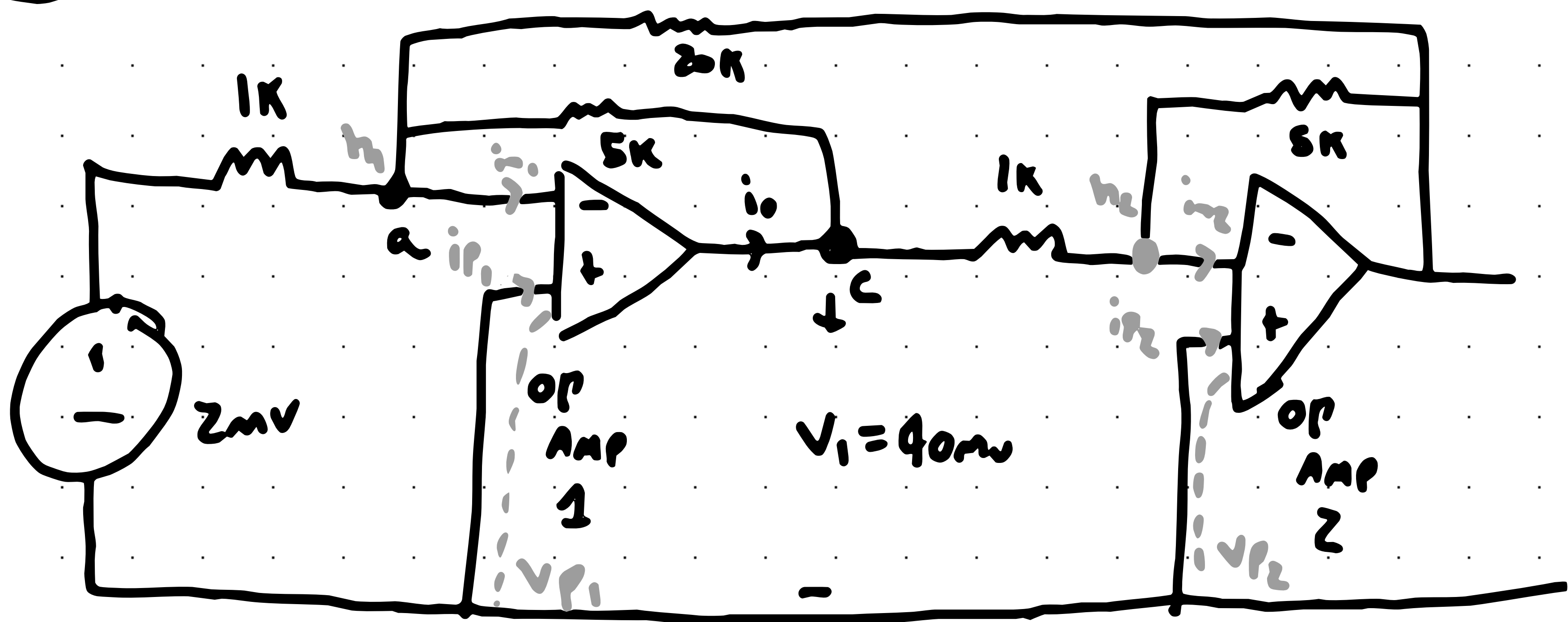
$$i_p = i_n$$

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

$$V_o = V_{in}$$

2

# Cascade Amplifier



Calculate  $V_0$  and  $i_0$  and the overall gain

Solution

OP AMP ①

$i_{n1} = i_{p1} = 0$ ,  $V_p = V_n$ ,  
Since  $V_{p1} = 0$ ,  $V_{n1} = 0$

$$\sum I = 0 \quad \text{Node } N_1$$

$$\frac{V_{n1} - 2 \times 10^{-3}}{1000} + \frac{V_{n1} - 40 \times 10^{-3}}{5000} + \frac{V_{n1} - V_0}{20000} + i_{n1} = 0$$

$$\frac{-2 \times 10^{-3}}{10^3} + \frac{40 \times 10^{-3}}{5 \times 10^3} - \frac{V_0}{20 \times 10^3} = 0$$

$$V_0 = -0.2V$$

OP AMP ②

$i_{n2} = i_{p2} = 0$ ,

$V_{p2} = V_{n2}$

Since  $V_{p2} = 0$ ,  $V_{n2} = 0$

$$\sum I = 0 \quad \text{Node (1)} \quad i_o = \frac{V_1 - V_{n1}}{5 \times 10^3} + \frac{V_1 - V_{n2}}{1000}$$

$$i_o = 48 \mu A$$

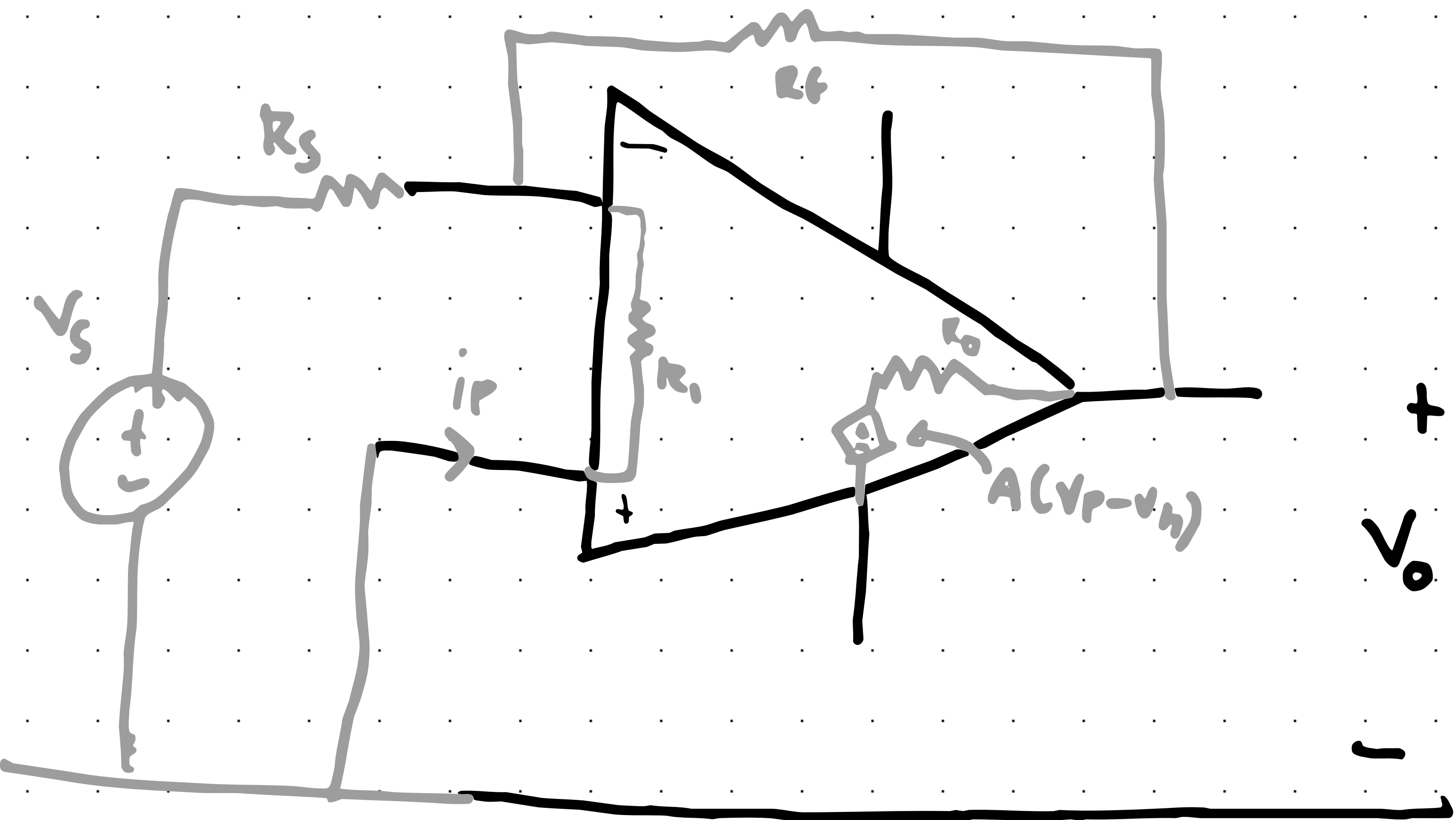
If  $V_1$  were unknown...

$$\sum I = 0 \quad \text{Node (2)} \quad \frac{V_{n2} - V_o}{5000} + \frac{V_{n2} - V_{n1}}{20000} + i_{n2} \frac{V_{n2} - V_1}{1000} = 0$$

$$\text{Gain} = \frac{V_o}{V_{in}} = \frac{-0.2}{2 \times 10^{-3}} = \underline{\underline{-100 V}}$$

# Practical OP-Amp (will not be on the million)

## Non-Inverting Practical OP-AMP circuit



Typical values for MA741 OP-AMP

$$R_i = 2\text{M}\Omega \quad A = 10^5 \quad R_o = 75\Omega$$

$$\left. \begin{aligned} \sum_{\text{Node A}} I &= 0 & \frac{V_n - V_s}{R_s} + \frac{V_n - V_p}{R_i} + \frac{V_n - V_o}{R_f} &= 0 \\ \sum_{\text{Node B}} I &= 0 & \frac{V_o - V_n}{R_f} + \frac{V_o - A(V_p - V_n)}{R_o} &= 0 \end{aligned} \right\}$$

