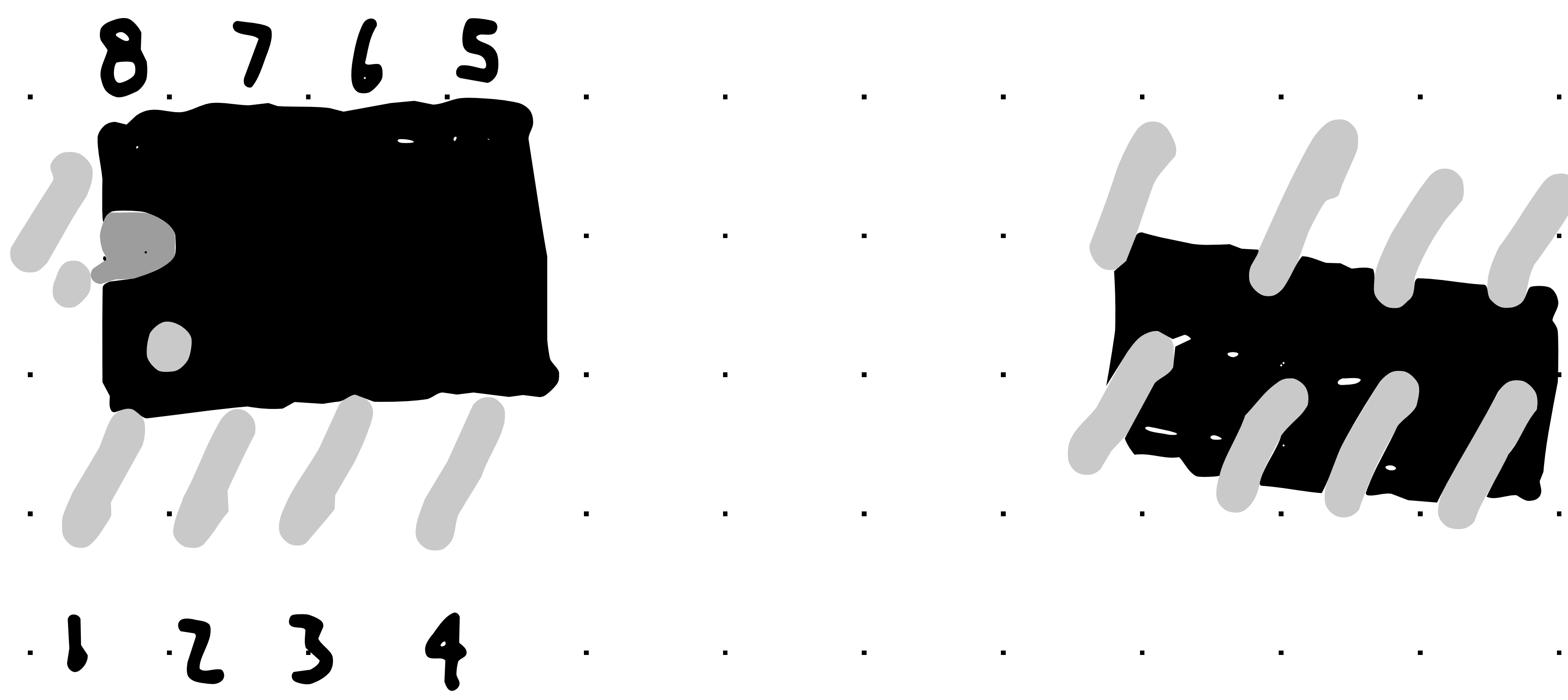
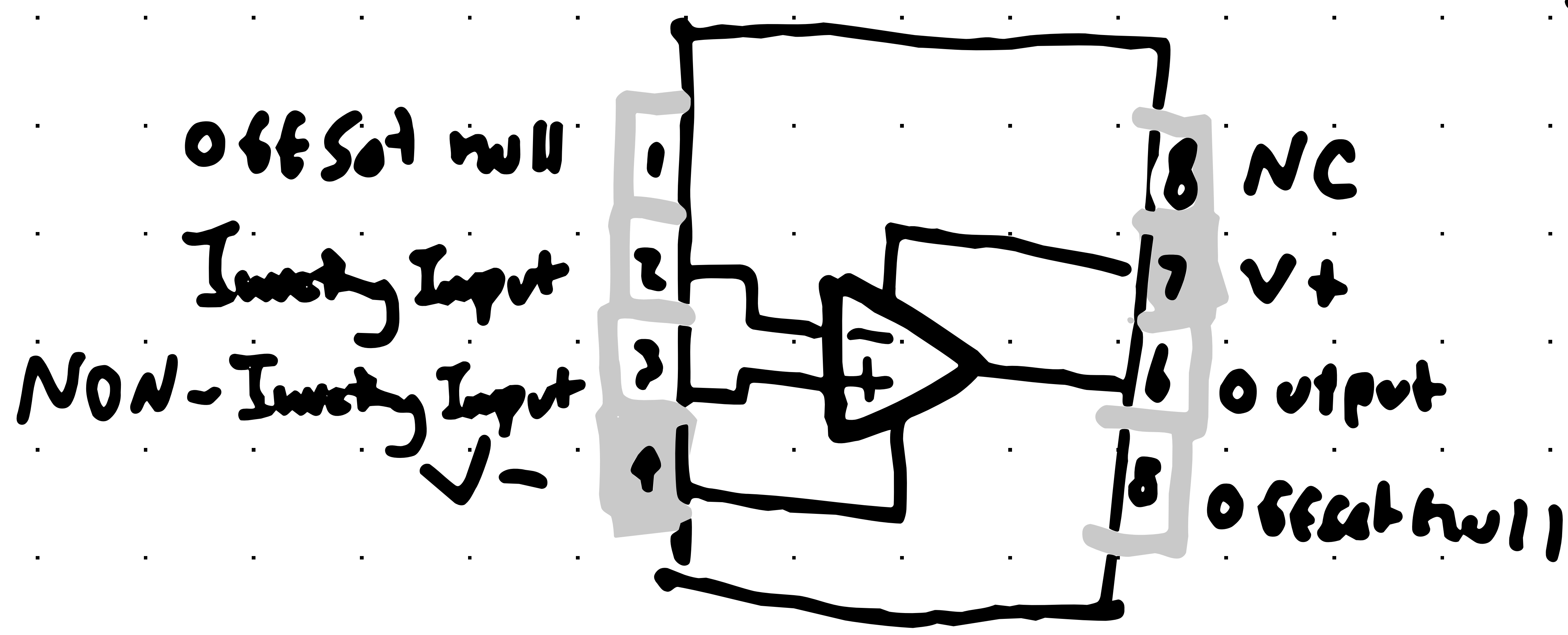
Lecture 12 ECED 2□□□

Operational Amplifiers (Op-Amps)

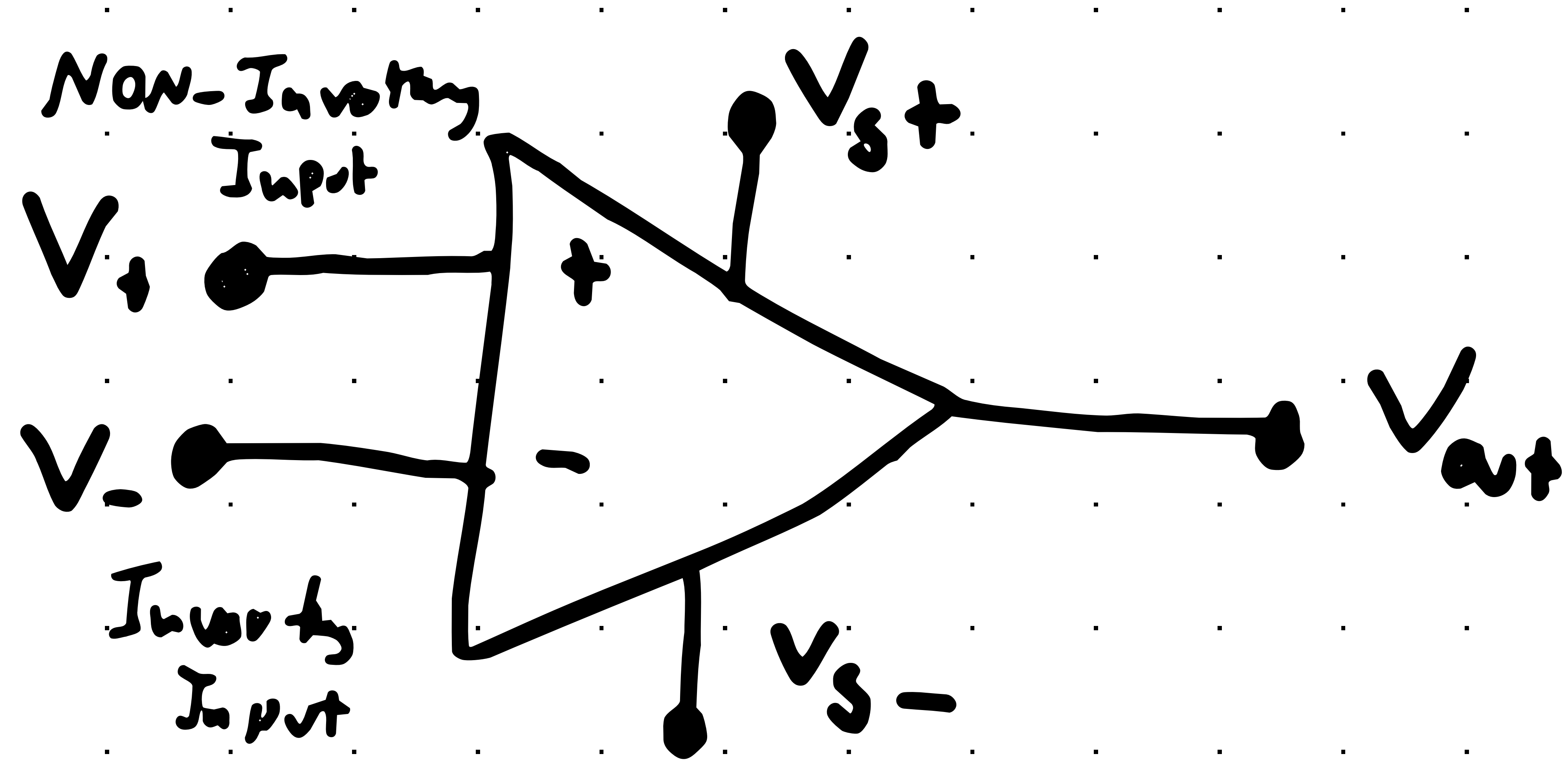


Type 741



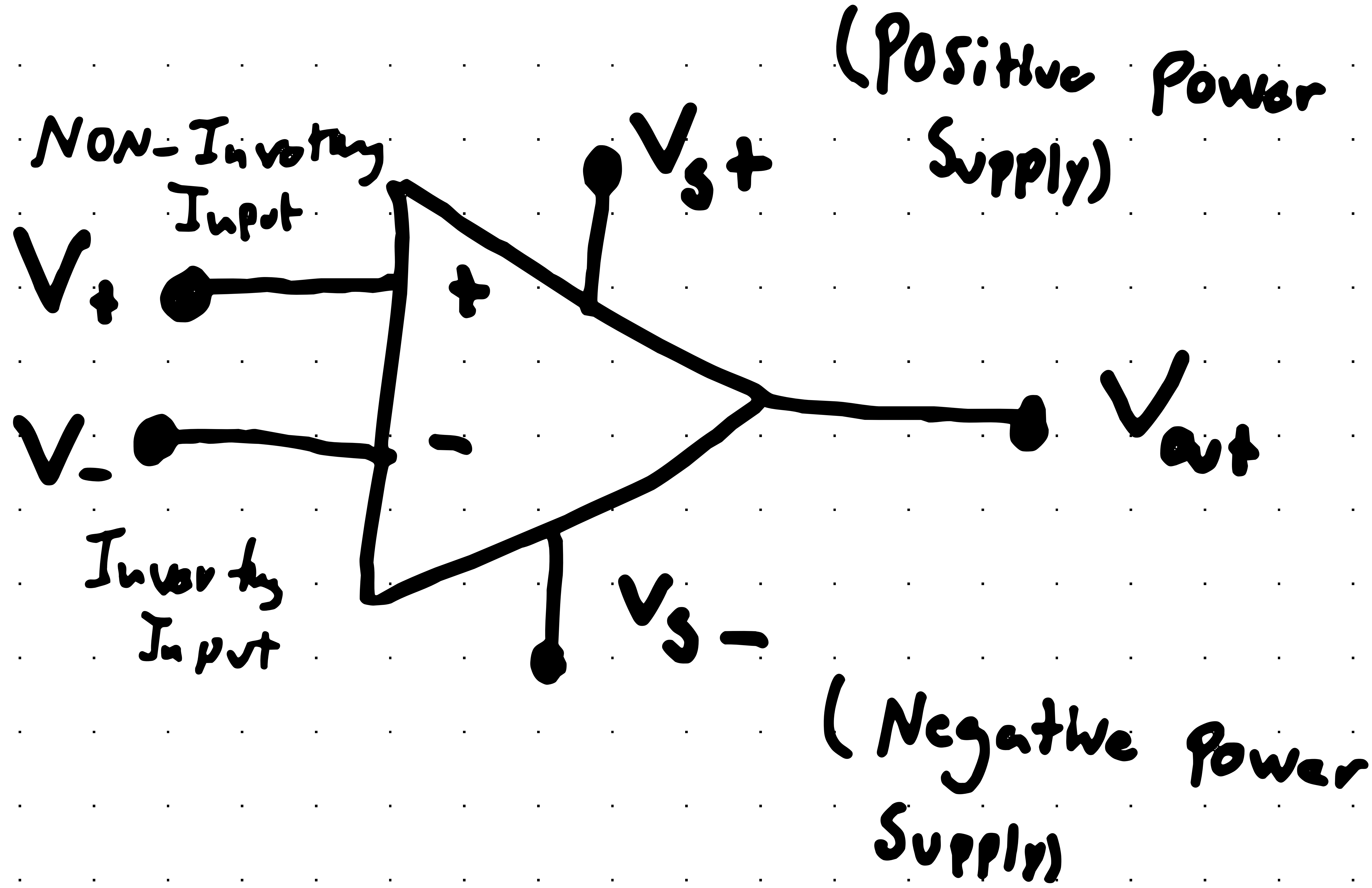
741 IC pinout
(Integrated Circuit)

- Purpose: Add, Subtract, divide, Multiply, adjust voltage

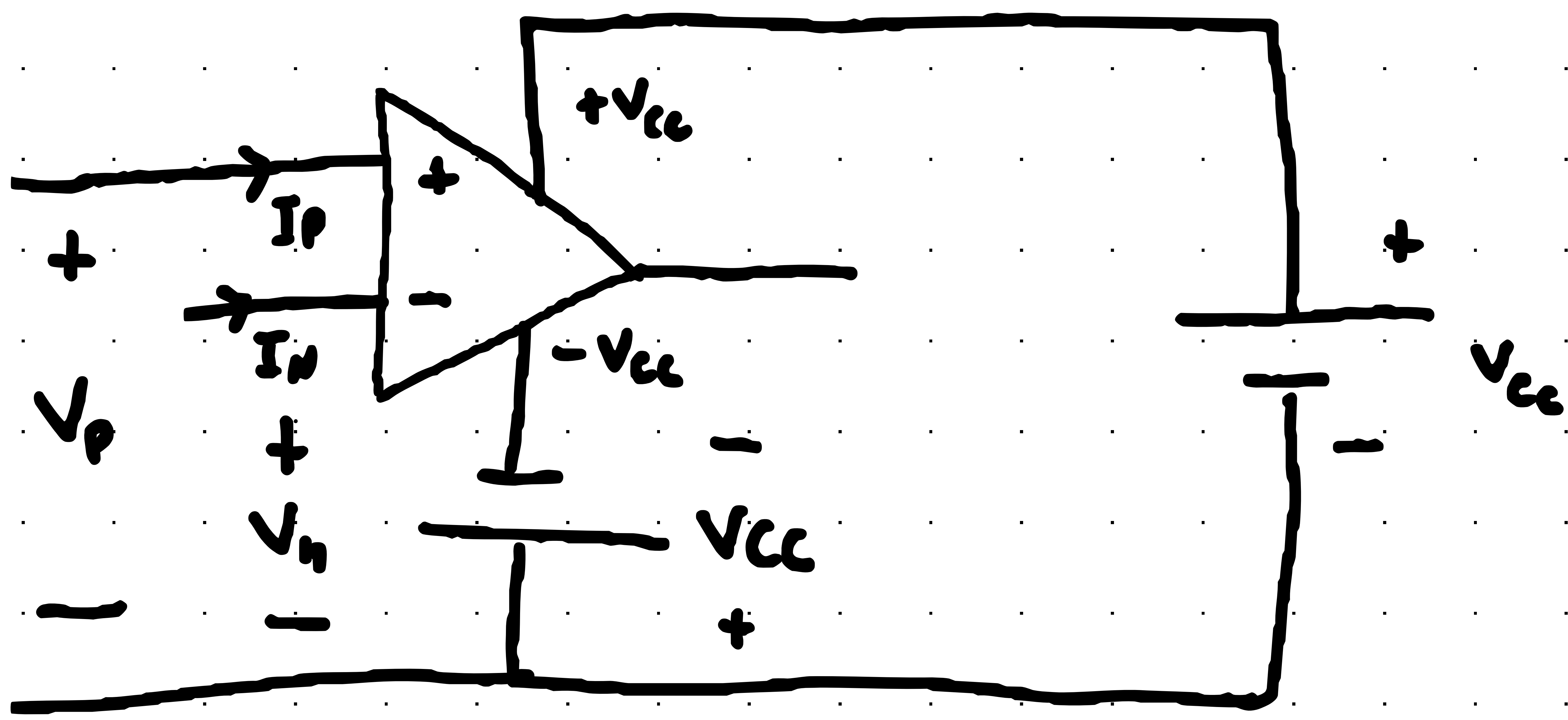


Non-Inverting Input: If I'd like to Amplify a voltage, without changing the polarity, use the Non-Inverting Input.

Inverting Input: If I'd like to Amplify a voltage, <u>AND</u> change the polarity, use the Inverting Input.



Terminal Voltages and Currents



V_p: Positive Voltage

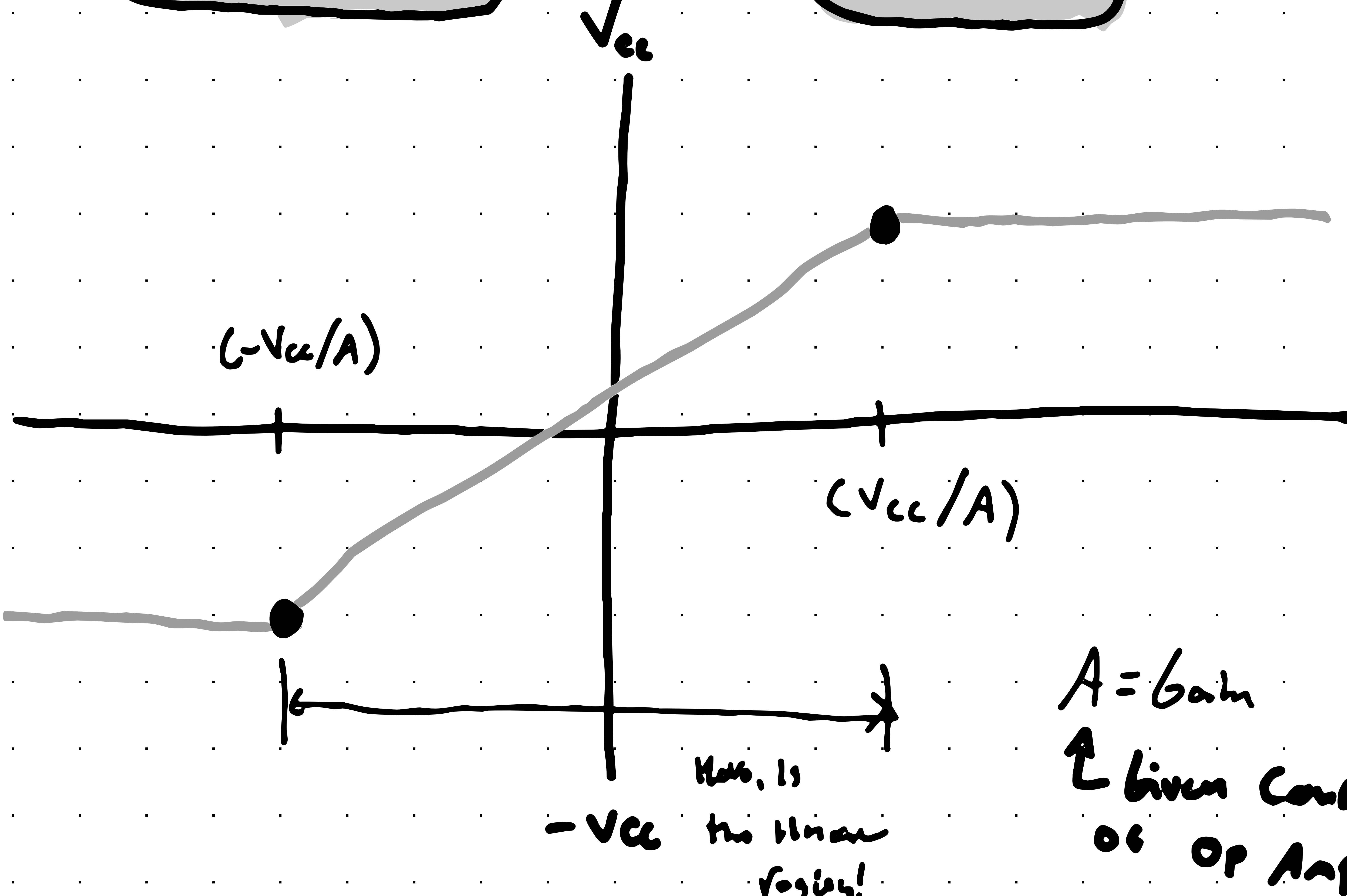
V_n: Negative Voltage

i_p: Positive Current

i_n: Negative Current

Ideal Op Amp

$\boxed{i_p = i_n = 0}$ and $\boxed{V_p = V_n}$



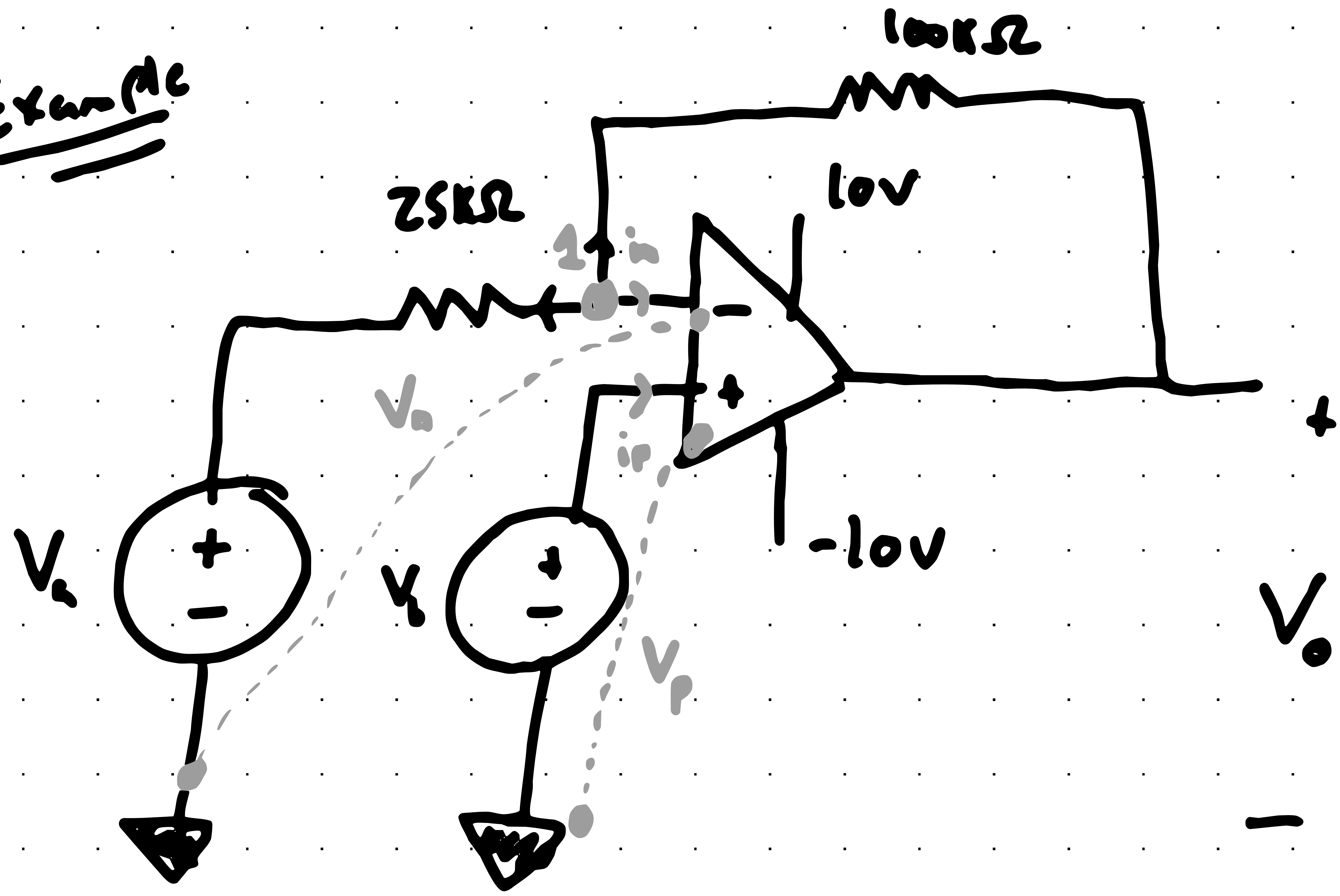
A = Gain
↳ Given constant of Op Amp

$$V_0 = \begin{cases} -V_{cc} \\ A(V_p - V_n) \\ +V_{cc} \end{cases}$$

$$-V_{cc} \leq \underbrace{A(V_p - V_n)}_{\text{Range of Op Amp effectiveness}} \leq V_{cc}$$

- If we are not in the range of the linear region, or above or below $-V_{cc}$ or V_{cc}, the V_0 just becomes $-V_{cc}$ or $+V_{cc}$

Example



a) Calculate V_o if $V_a = 1$ and $V_b = 0$

b) Repeat @ for $V_a = 1V$ and $V_b = 2V$

c) If $V_a = 1.5V$, Specify the range of V_b that avoids amplifier Saturation

Solution

$i_p = i_n = 0, \quad V_p = V_n$

$V_p = V_b \longrightarrow V_p = V_n = V_b$

$$\sum_{\text{Node 1}} I = 0 \qquad \frac{V_n - V_a}{25K} + \frac{V_n - V_o}{100K} + \cancelto{0}{I_N} = 0$$

Case a)

$V_a = 1, \; V_b = 0$ Calculate V_o

$V_p = V_n = V_b$

$$\frac{V_n - V_a}{25K} + \frac{V_n - V_o}{100K} \rightarrow \frac{0-1}{25{,}000} + \frac{0 - V_o}{100{,}000} = 0$$

$V_o = -4V$

$$\underbrace{-10 \leq -4 \leq 10}_{\text{In effective range!}}$$

$V_o = -4V$

Case b

$V_a = 1 \quad V_b = 2$

$$\frac{2-1}{25{,}000} + \frac{2 - V_o}{100{,}000} = 0$$

$V_o = 6V$

$-10V \leq 6V \leq 10V$

In effective region!

$V_o = 6V$

Case C

$V_a = 1.5V \quad V_b = ?$ Range?

If $V_o = -10V$ min

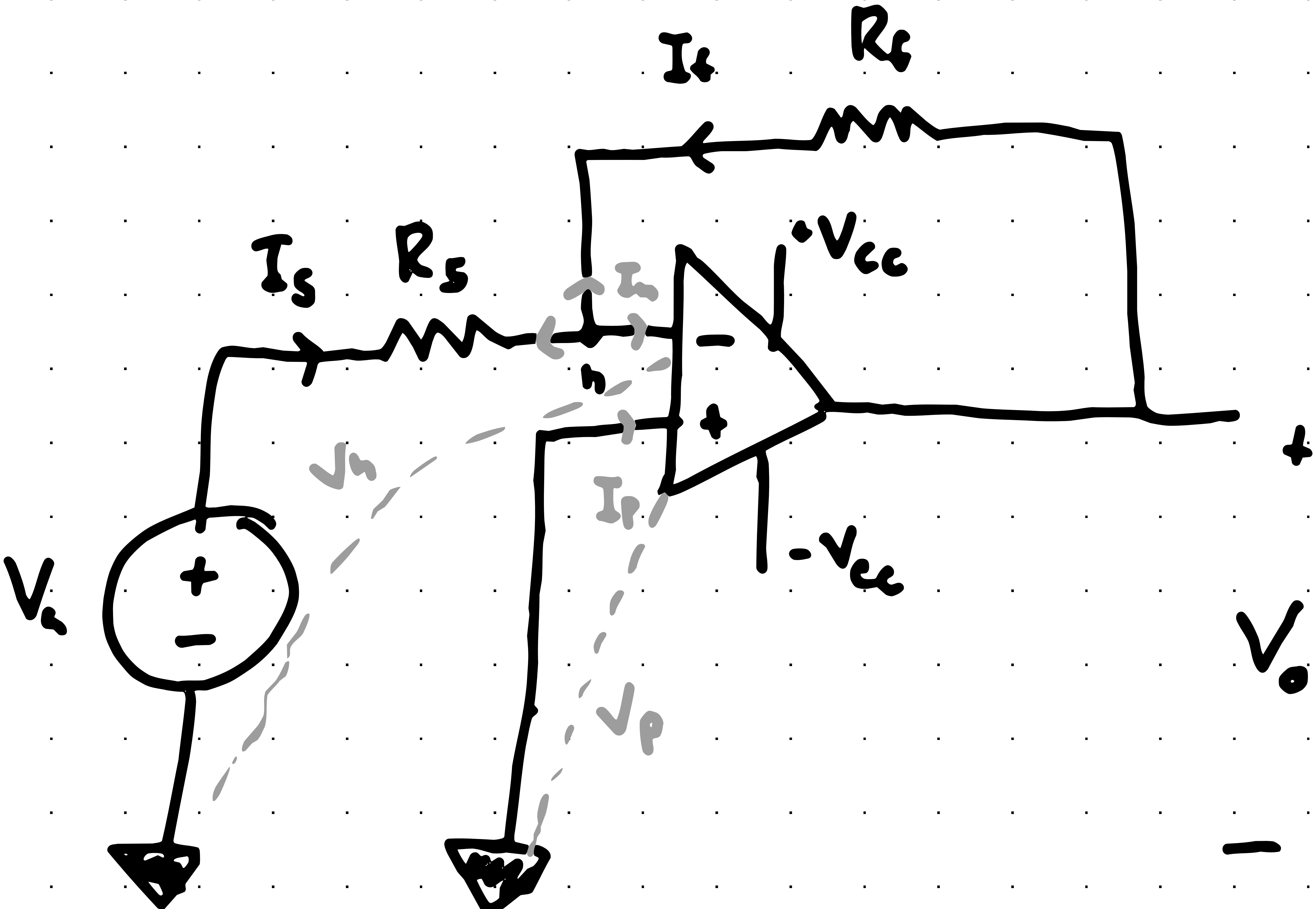
$$\frac{V_b - 1.5}{25{,}000} + \frac{V_b - (-10)}{100{,}000}$$

If $V_o = 10V$ max

$$\frac{V_b - 1.5}{25{,}000} + \frac{V_b - (10)}{100{,}000}$$

$$-0.8 \leq V_b \leq 3.2$$

Inverting Amplifier Circuit



$I_p = I_n = 0$, $v_p = v_p$

Since $v_p = 0$, then $v_n = 0$

$\sum I = 0$ Node (n) $\quad \frac{\cancel{v_n}^{\,0} - v_s}{R_s} + \frac{\cancel{v_n}^{\,0} - v_o}{R_f} + \cancel{i_n}^{\,0} = 0$

$$\frac{-v_s}{R_s} = \frac{v_o}{R_f}$$

Inverting Amplifier In/out Relation

$$\boxed{V_o = -\frac{R_f}{R_s} V_s}$$

Output   Input

Gain = $\frac{R_f}{R_s}$