CSE251: Electronic Devices and Circuits

Lecture 5:

Op-amp Voltage Transfer Characteristics

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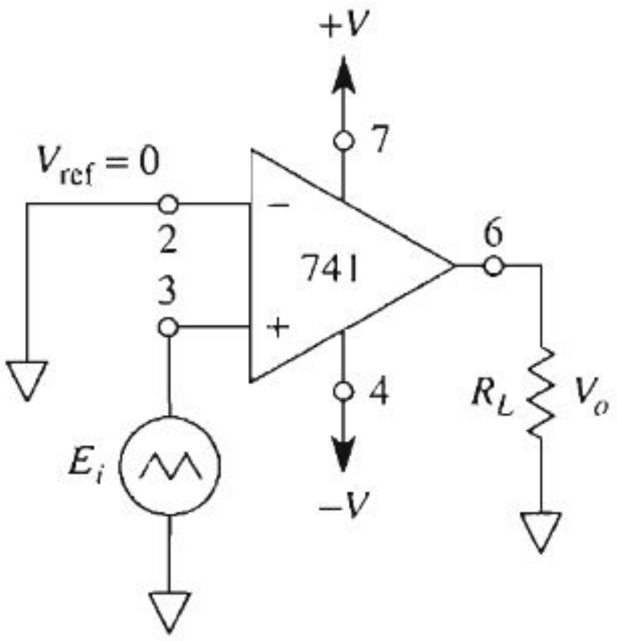
Basic Op-Amp Configurations

- **Open-loop Configurations**
  1. Comparator / Voltage Level Detectors

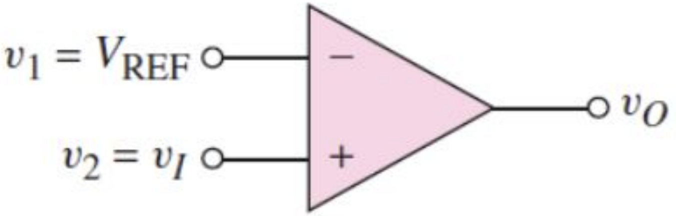


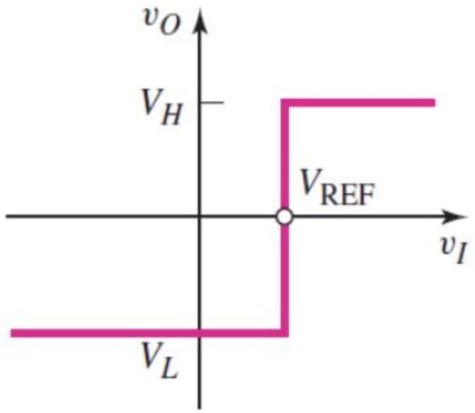
- **Closed Loop Configurations**
  1. Voltage Follower
  2. Inverting Amplifier
  3. Inverting Summer
  4. Non-Inverting Amplifier
  5. Weighted Subtractor
  6. Integrator
  7. Differentiator
  8. Exponential Converter
  9. Logarithmic Converter
  10. Multiplier
  11. Divider

Open Loop (Comparator) – VTC (NON-INVERTING)

NON-INVERTING Level Crossing Detector / Comparator

$$\boldsymbol{V_d = v_I - V_{\mathrm{REF}}} \; \{$$





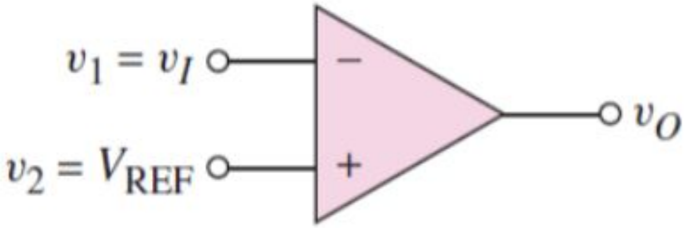
$$\boldsymbol{V_d = v_I - V_{\mathrm{REF}} > 0 \quad \Rightarrow \quad v_O = V_H}$$

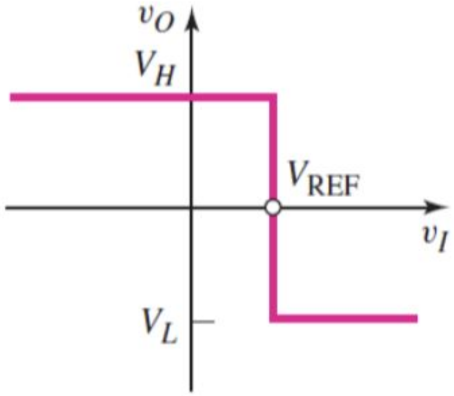
$$\boldsymbol{v_I > V_{\mathrm{REF}} \quad \Rightarrow \quad v_O = V_H}$$

Open Loop (Comparator) – VTC (INVERTING)

INVERTING Level Crossing Detector / Comparator

$$V_d = V_{\mathrm{REF}} - v_I \quad \{$$

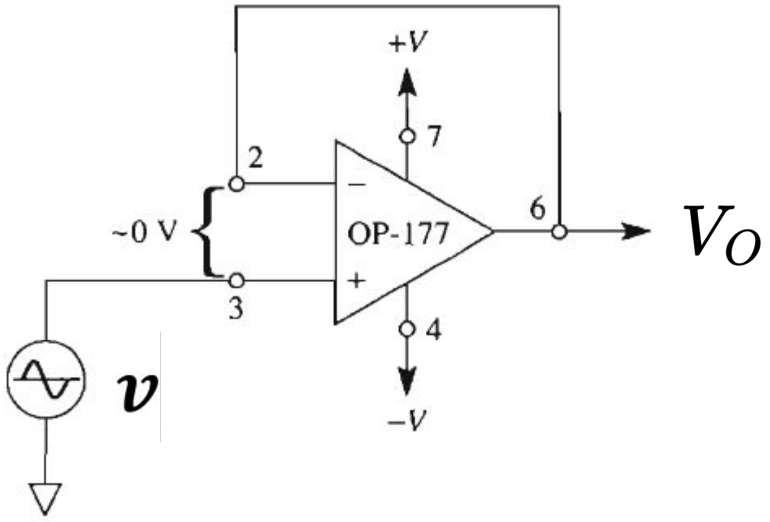


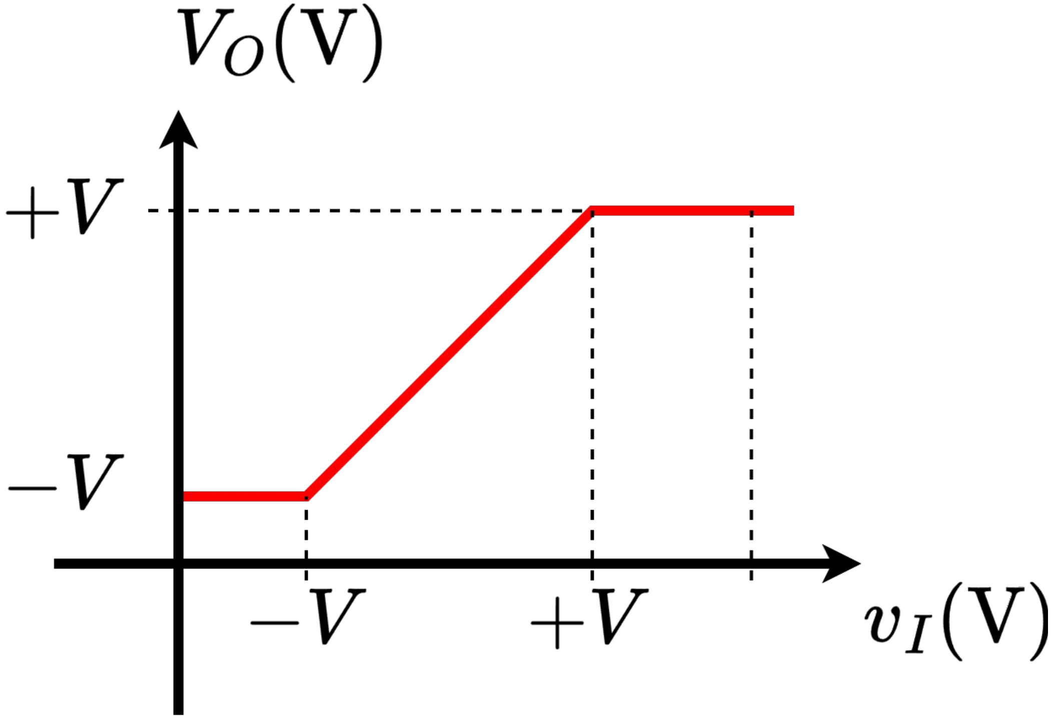


$$V_d = V_{\mathrm{REF}} - v_I > 0 \quad \Rightarrow \quad v_O = V_H$$

$$v_I < V_{\mathrm{REF}} \quad \Rightarrow \quad v_O = V_H$$

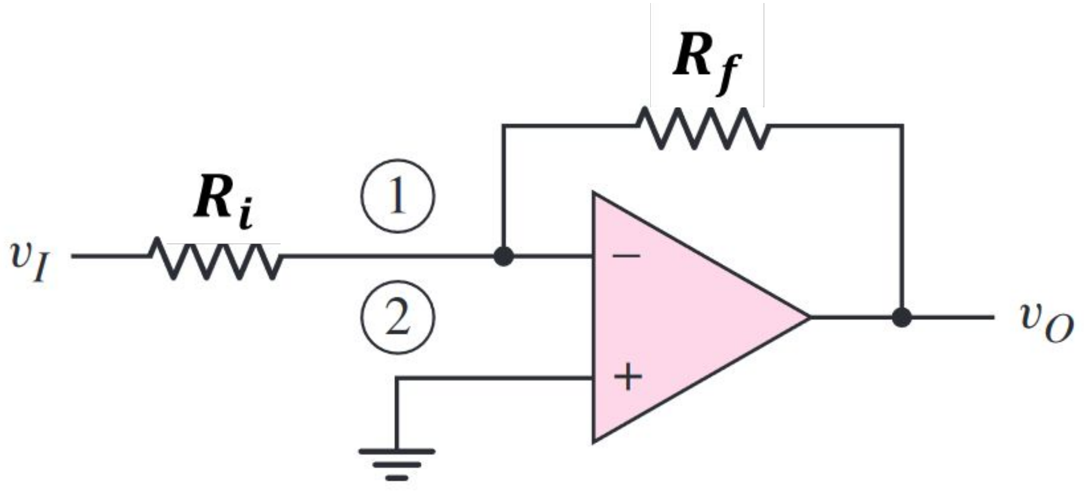
Voltage Follower – VTC

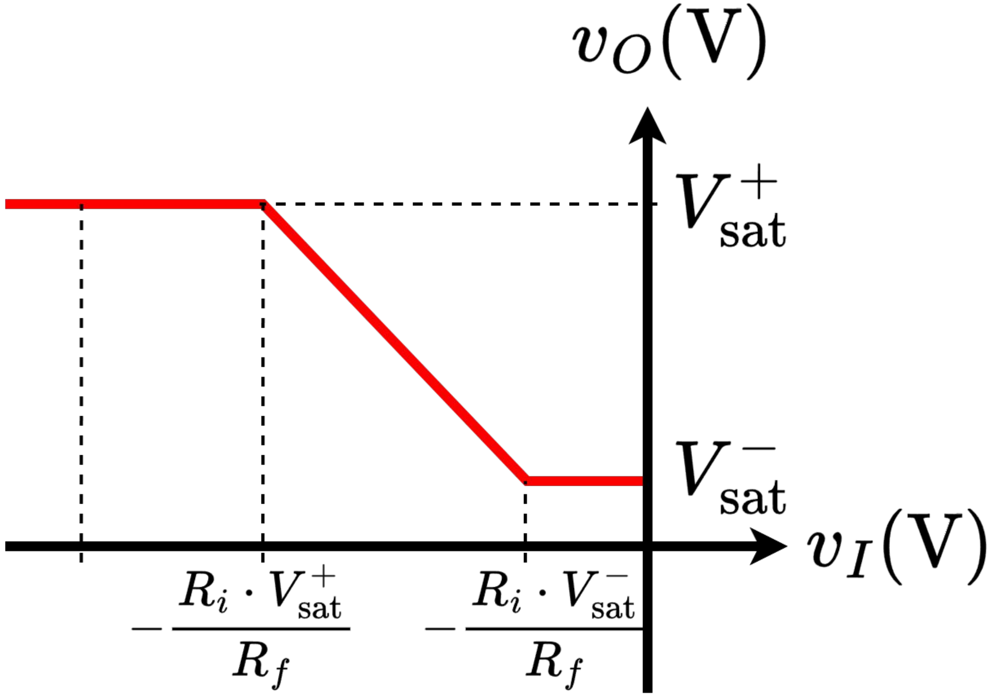




$$V_O = \begin{cases} +V, & \text{if } v_I \geq +V \\ v_I, & \text{if } -V \leq v_I \leq +V \\ -V, & \text{if } v_I \leq -V \end{cases}$$

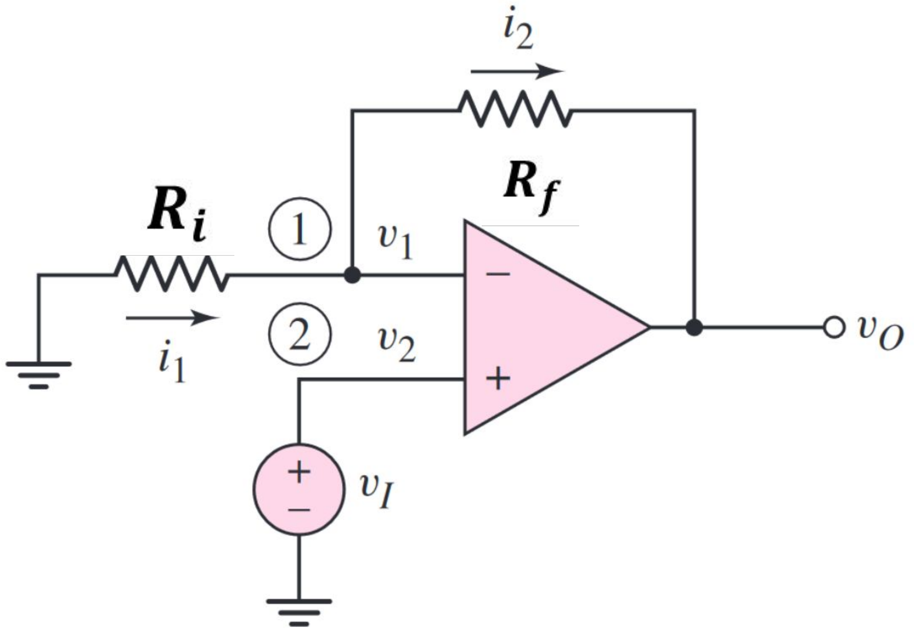
Inverting Amplifier – VTC

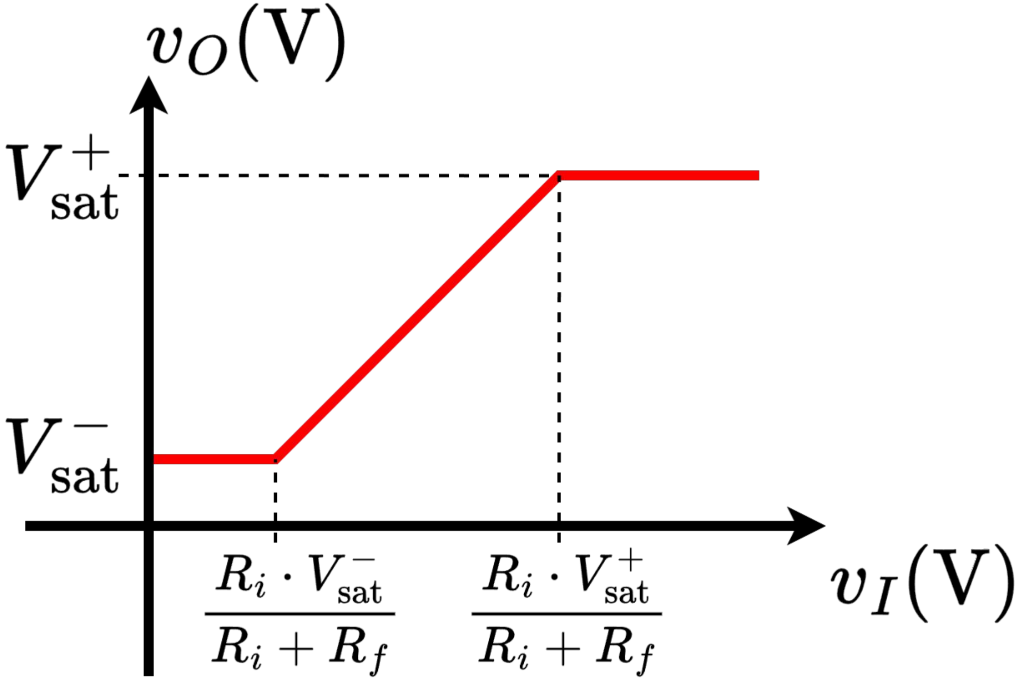




$$v_O = \begin{cases} V_{\mathrm{sat}}^{+}, & \text{if } v_O \geq V_{\mathrm{sat}}^{+} \\ -v_I \cdot \frac{R_f}{R_i}, & \text{if } V_{\mathrm{sat}}^{-} \leq v_O \leq V_{\mathrm{sat}}^{+} \\ V_{\mathrm{sat}}^{-}, & \text{if } v_O \leq V_{\mathrm{sat}}^{-} \end{cases}$$

Non-Inverting Amplifier – VTC

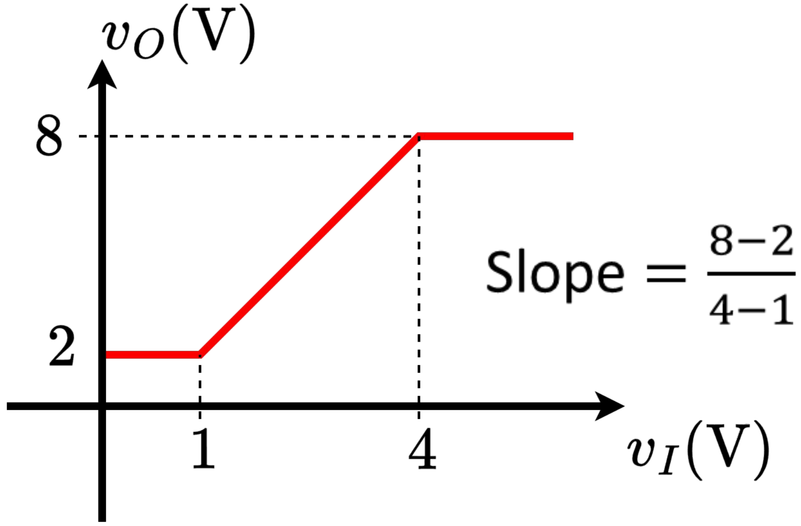




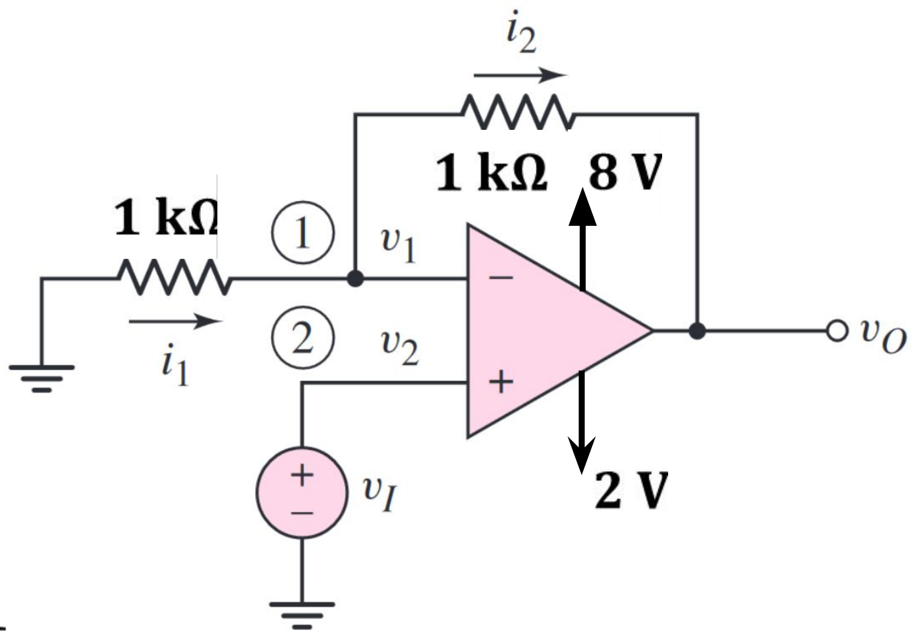
$$v_O = \begin{cases} V_{\mathrm{sat}}^{+}, & \text{if } v_O \geq V_{\mathrm{sat}}^{+} \\ v_I \cdot (1 + \frac{R_f}{R_i}), & \text{if } V_{\mathrm{sat}}^{-} \leq v_O \leq V_{\mathrm{sat}}^{+} \\ V_{\mathrm{sat}}^{-}, & \text{if } v_O \leq V_{\mathrm{sat}}^{-} \end{cases}$$

Non-Inverting Amplifier – VTC

Draw an Op-Amp Circuit with the following VTC



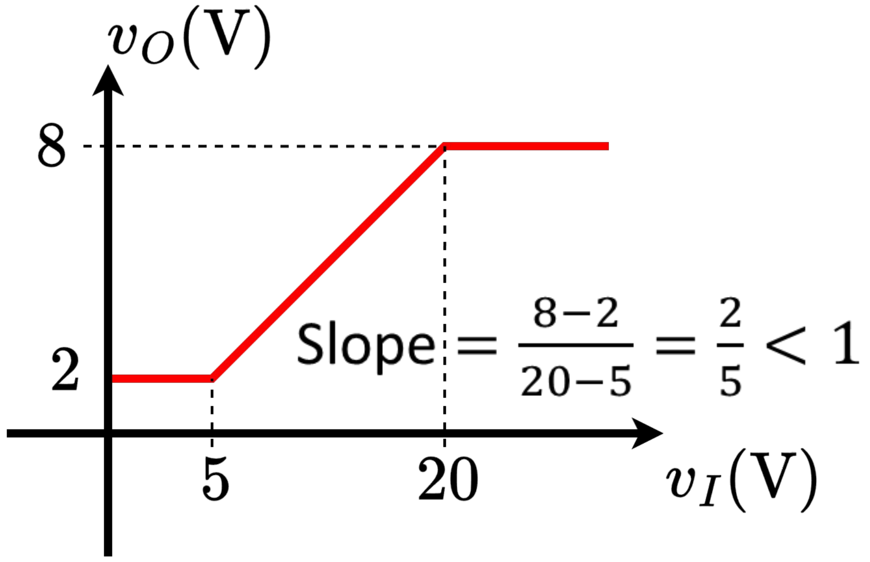
$$\text{Slope} = \frac{8-2}{4-1} = 2 = \left(1 + \frac{R_f}{R_i}\right)$$

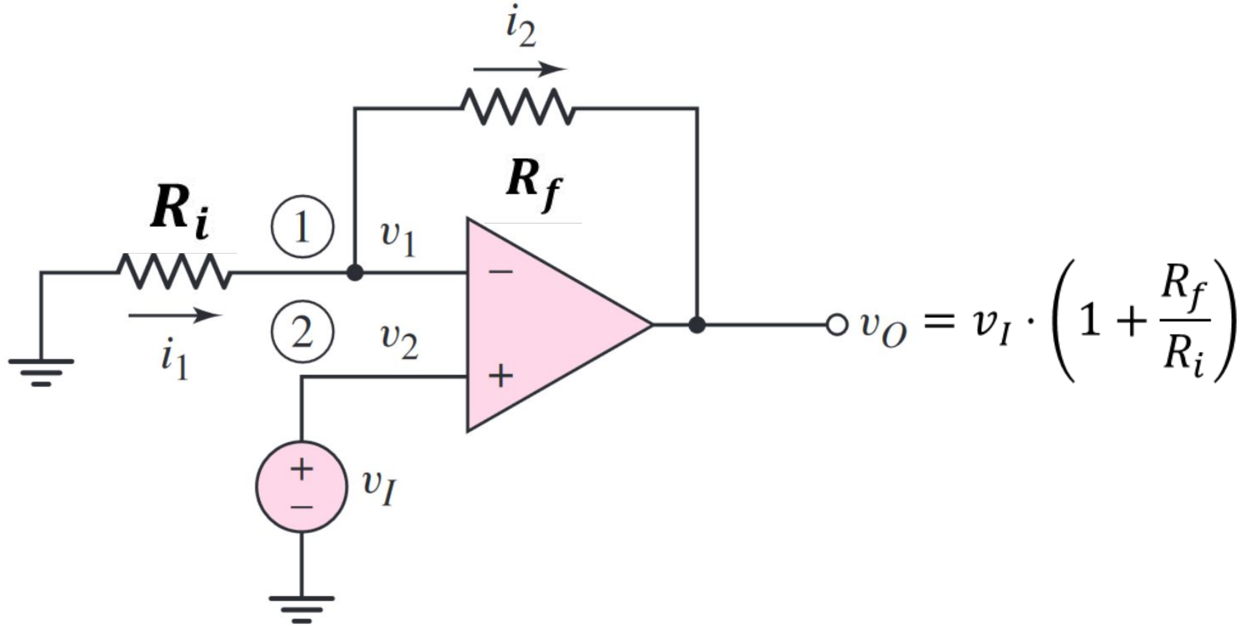


$$\left(1 + \frac{R_f}{R_i}\right) = 2 \qquad \Rightarrow \frac{R_f}{R_i} = 1$$

Non-Inverting Amplifier – VTC

Draw an Op-Amp Circuit with the following VTC. (What if the slope is less than **1?**)

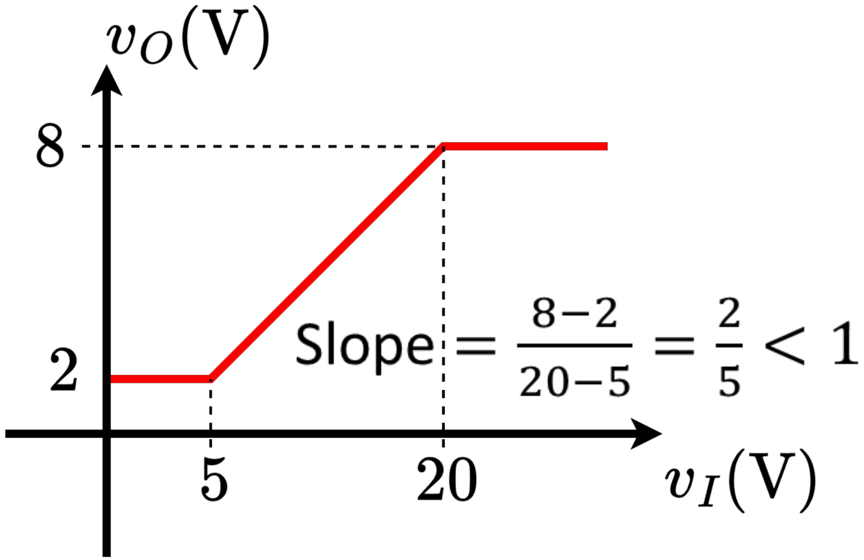


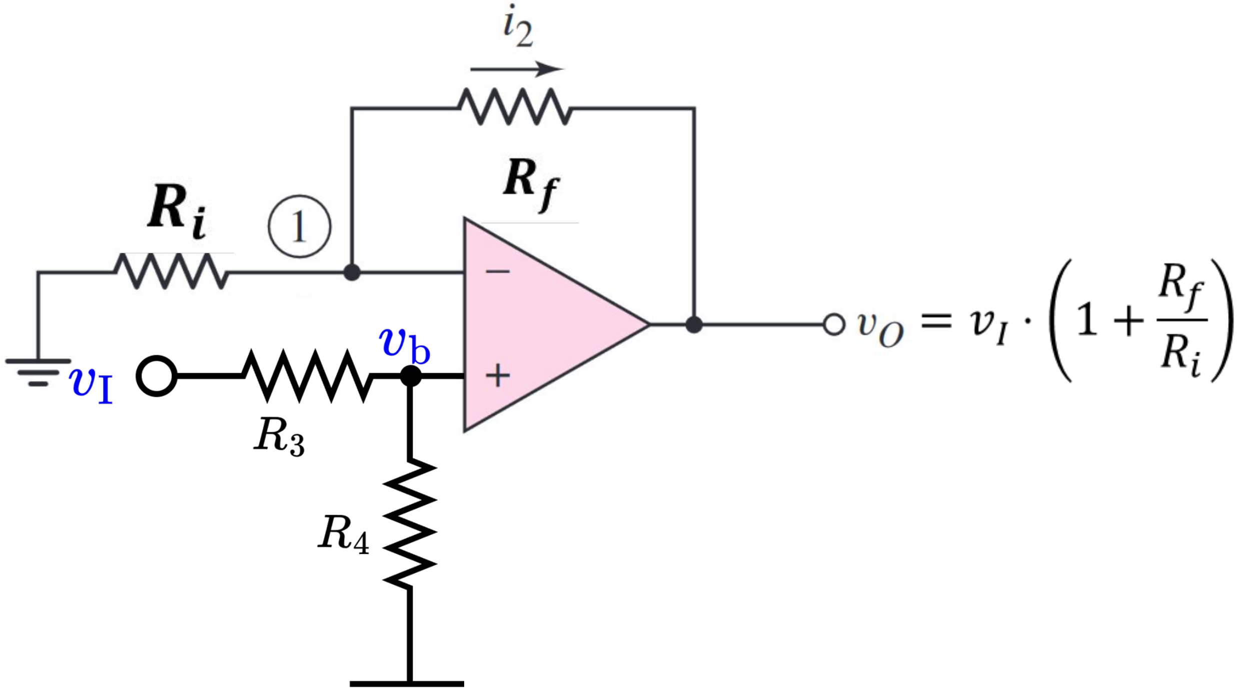


A non-inverting amplifier closed loop gain $\left(1 + \frac{R_f}{R_i}\right) > 1$. So, it is not possible to use this configuration for less than unity gain.

Non-Inverting Amplifier – VTC

Draw an Op-Amp Circuit with the following VTC. (What if the slope is less than **1?**)

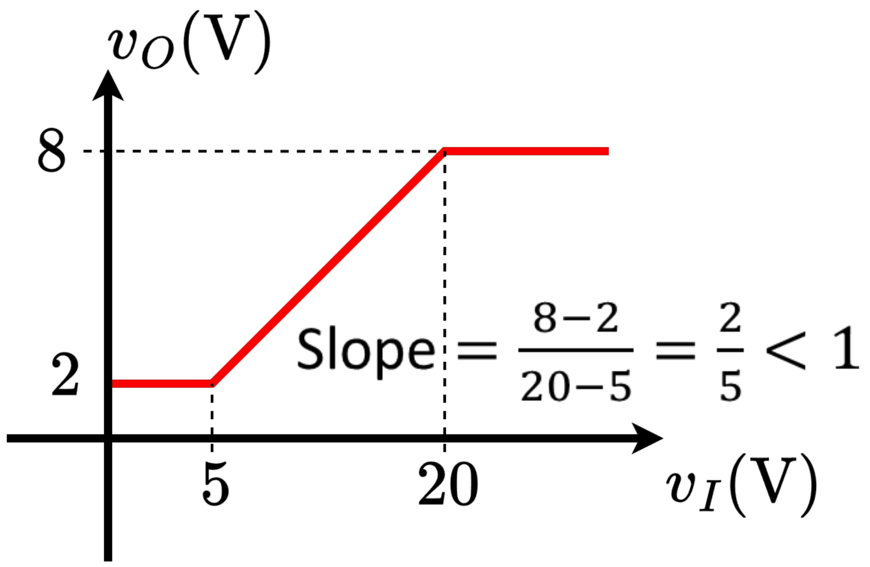


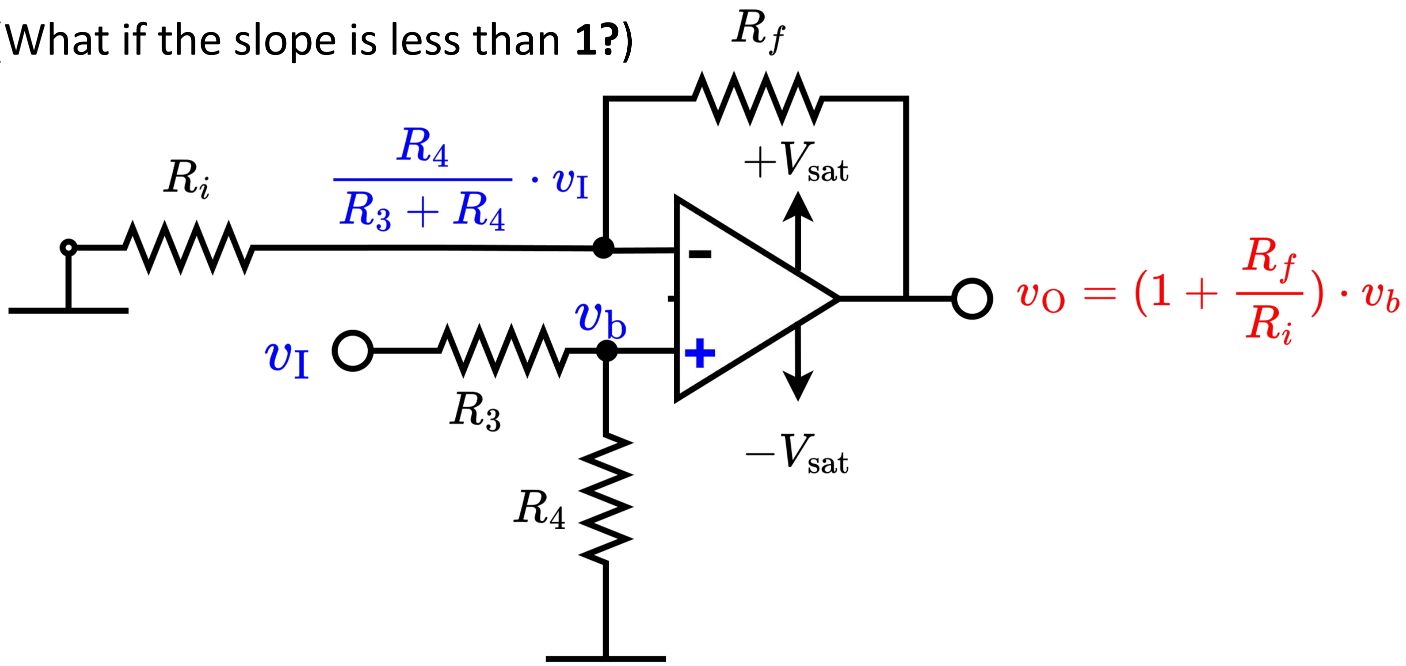


If Slope < 1, then, an additional voltage divider network should be added to the non-inverting terminal.

Non-Inverting Amplifier – VTC

Draw an Op-Amp Circuit with the following VTC. (What if the slope is less than **1?**)

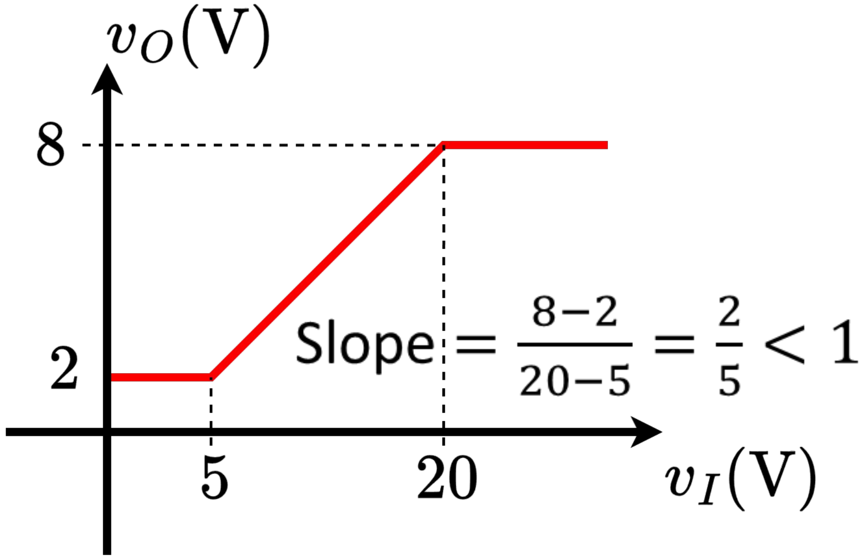




Voltage at the non-inverting terminal is converted from v_I to $v_I \cdot \left(\frac{R_4}{R_3+R_4}\right)$. So, the overall gain becomes: $\left(1 + \frac{R_f}{R_i}\right)\left(\frac{R_4}{R_3+R_4}\right)$ which can be less than **1.**

Non-Inverting Amplifier – VTC

Draw an Op-Amp Circuit with the following VTC. (What if the slope is less than **1?**)



So, $\left(1+\frac{R_f}{R_i}\right)\left(\frac{R_4}{R_3+R_4}\right) = \frac{2}{5}$ can be true if:

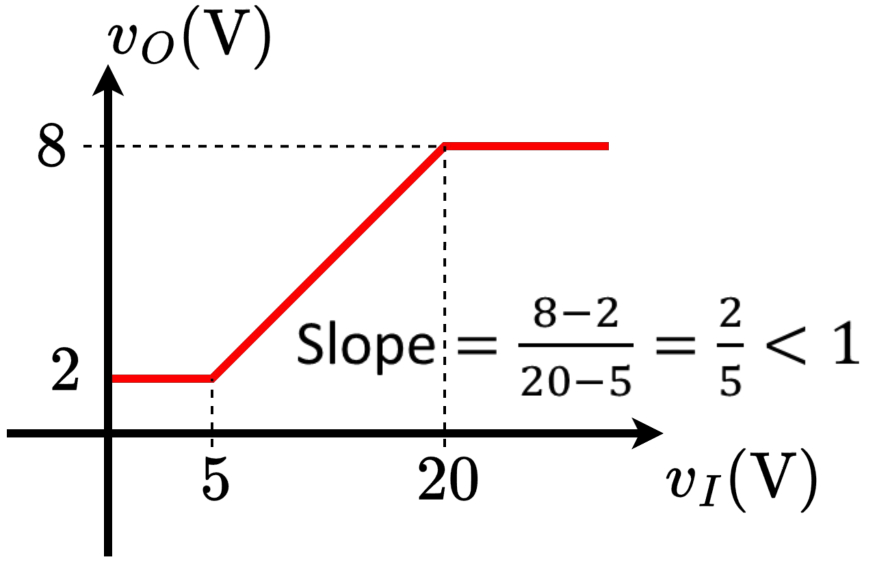
$$\left(1+\frac{R_f}{R_i}\right) = 2$$

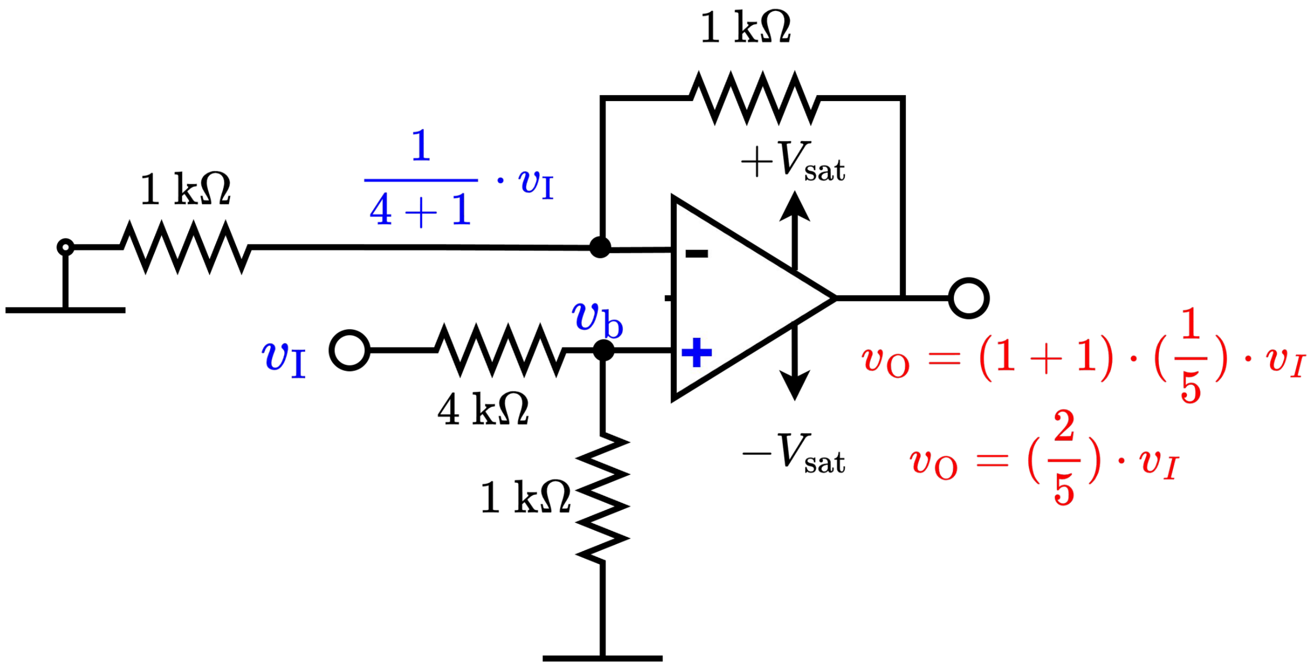
and

$$\left(\frac{R_4}{R_3+R_4}\right) = \frac{1}{5}$$

Non-Inverting Amplifier – VTC

Draw an Op-Amp Circuit with the following VTC. (What if the slope is less than **1?**)





$$\left(1 + \frac{R_f}{R_i}\right) = 2$$

and

$$\left(\frac{R_4}{R_3+R_4}\right) = \frac{1}{5}$$