



CSE251: Electronic Devices and Circuits

Lecture 5:
Op-amp Voltage Transfer Characteristics

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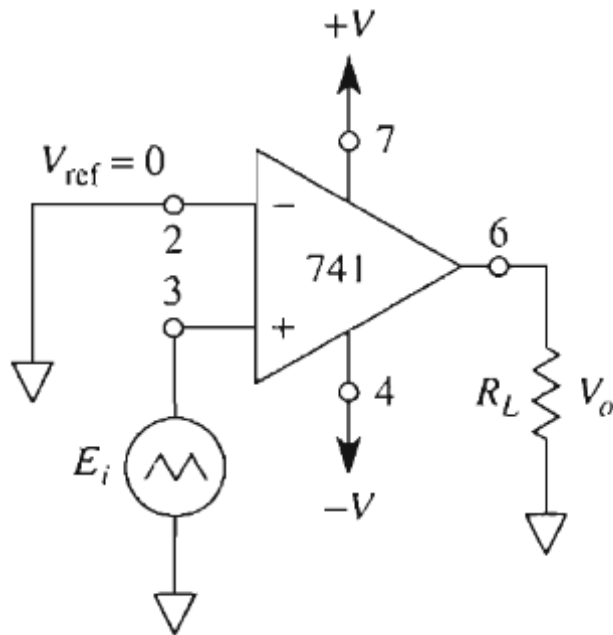
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Basic Op-Amp Configurations

- **Open-loop Configurations**

1. Comparator / Voltage Level Detectors

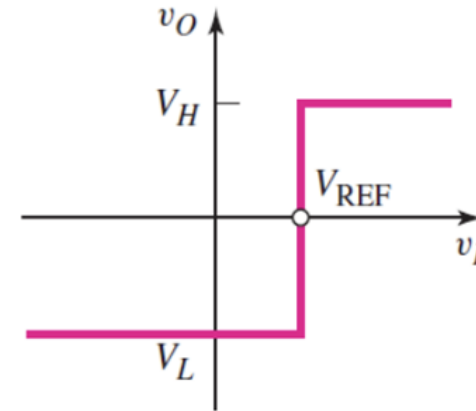
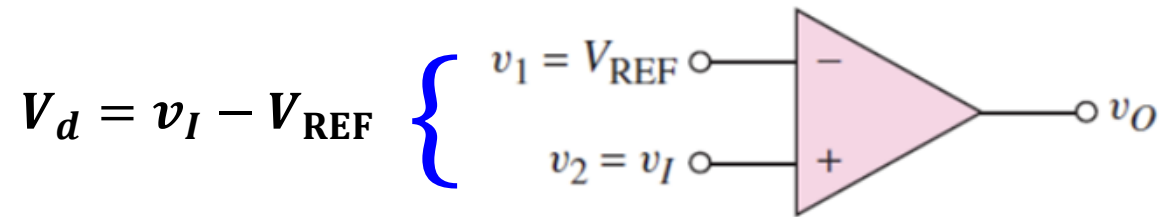


- **Closed Loop Configurations**

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

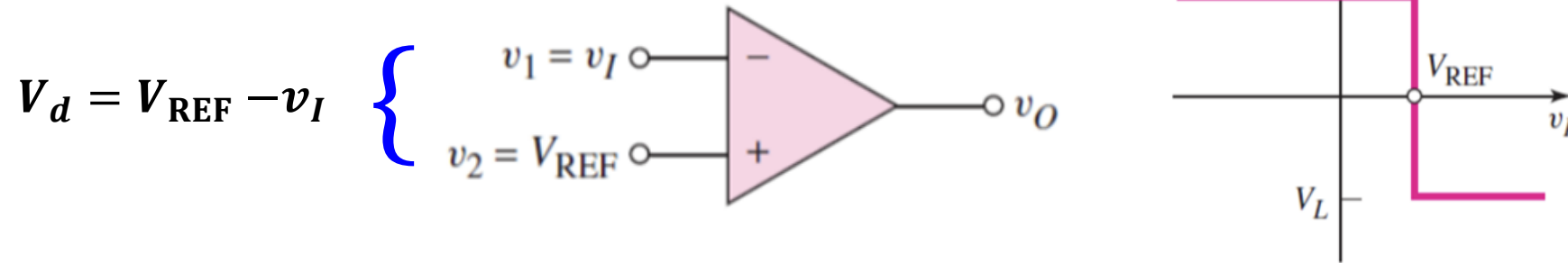


$$V_d = v_I - V_{\text{REF}} > 0 \quad \Rightarrow \quad v_O = V_H$$

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

Open Loop (Comparator) – VTC (**INVERTING**)

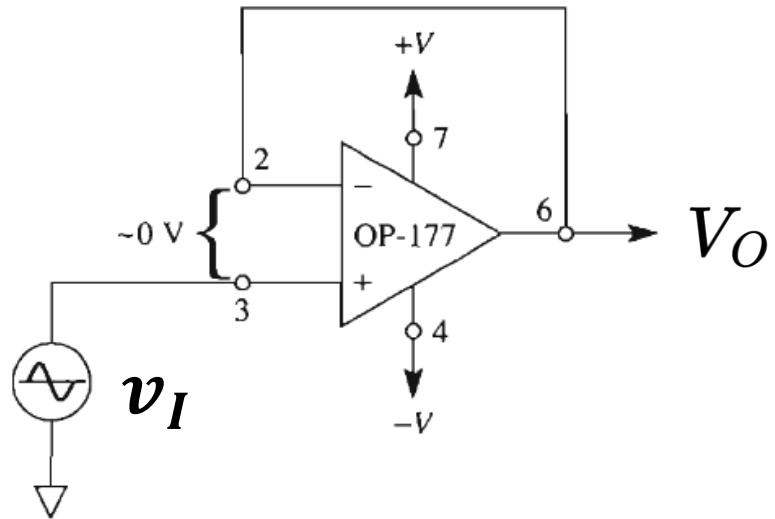
INVERTING Level Crossing Detector / Comparator



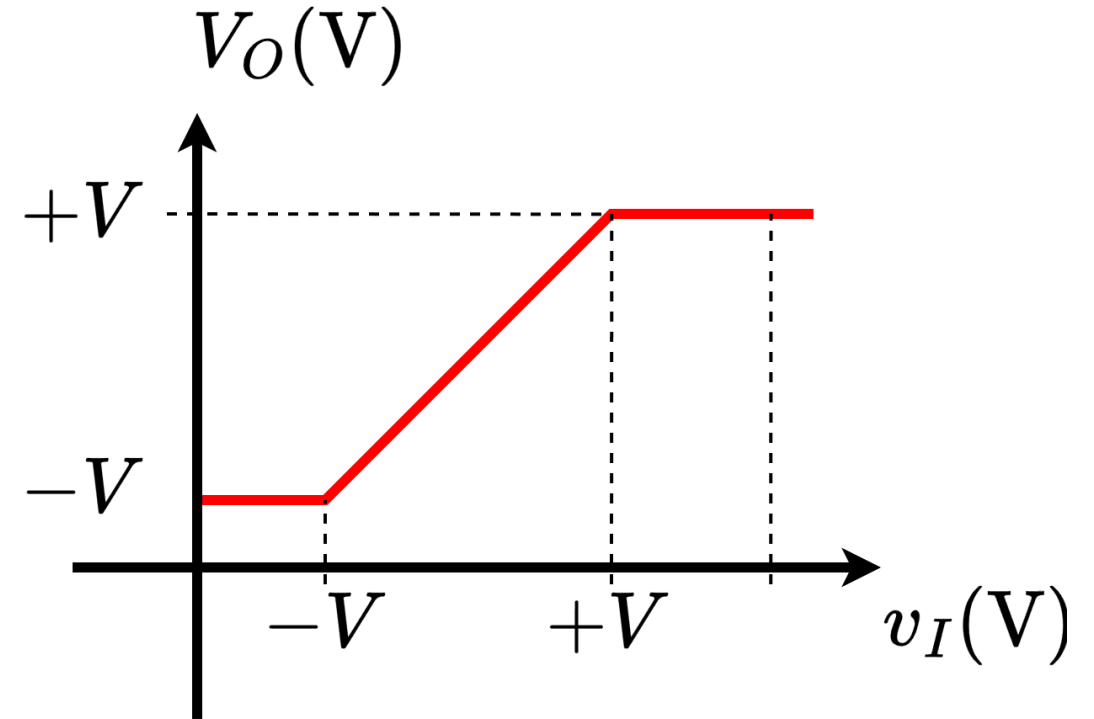
$$V_d = V_{\text{REF}} - v_I > 0 \quad \Rightarrow \quad v_O = V_H$$

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

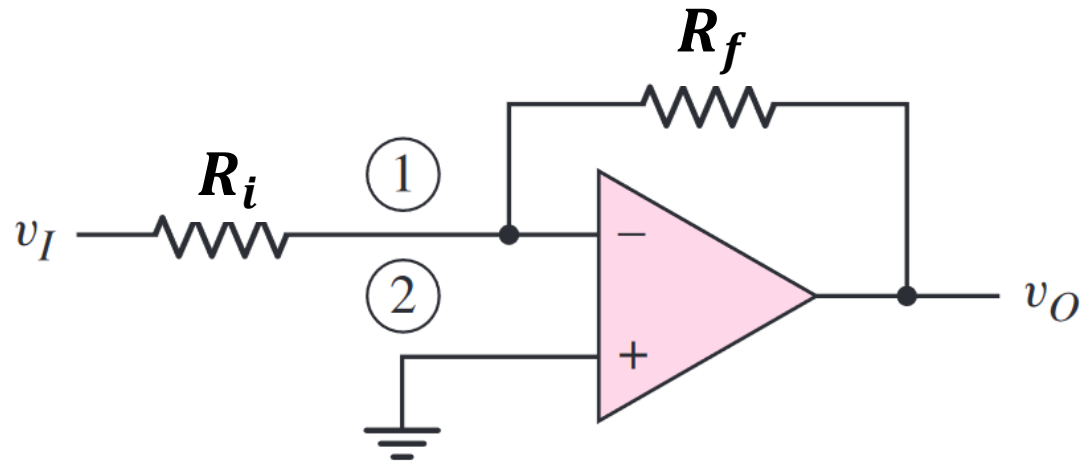
Voltage Follower – VTC



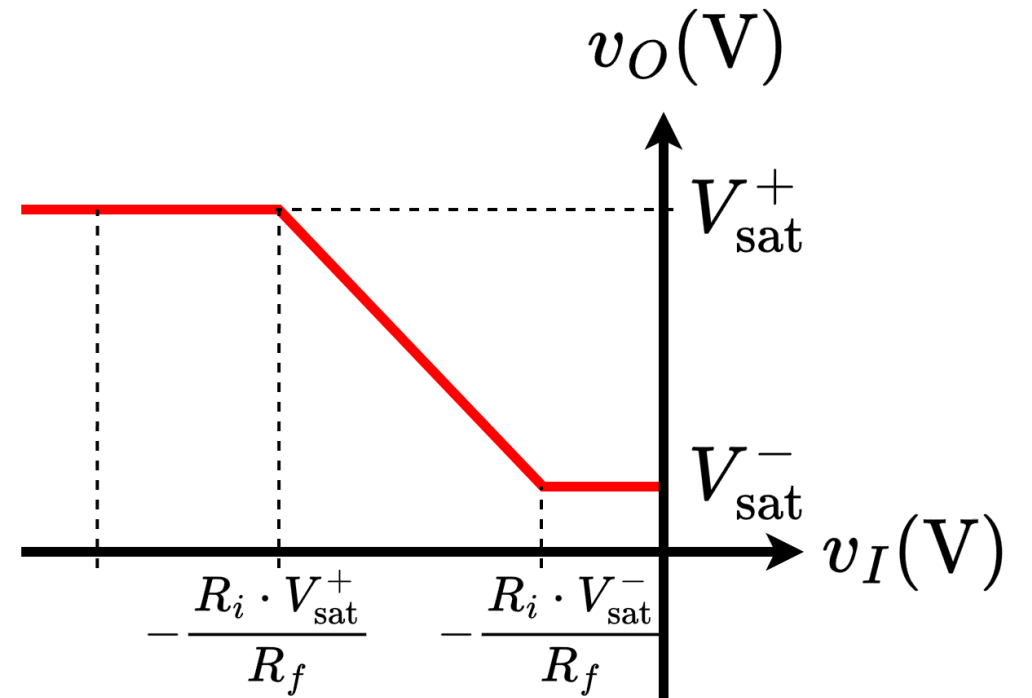
$$V_O = \begin{cases} +V, & \text{if } v_I \geq +V \\ v_I, & \text{if } -V \leq v_I \leq +V \\ -V, & \text{if } v_I \leq -V \end{cases}$$



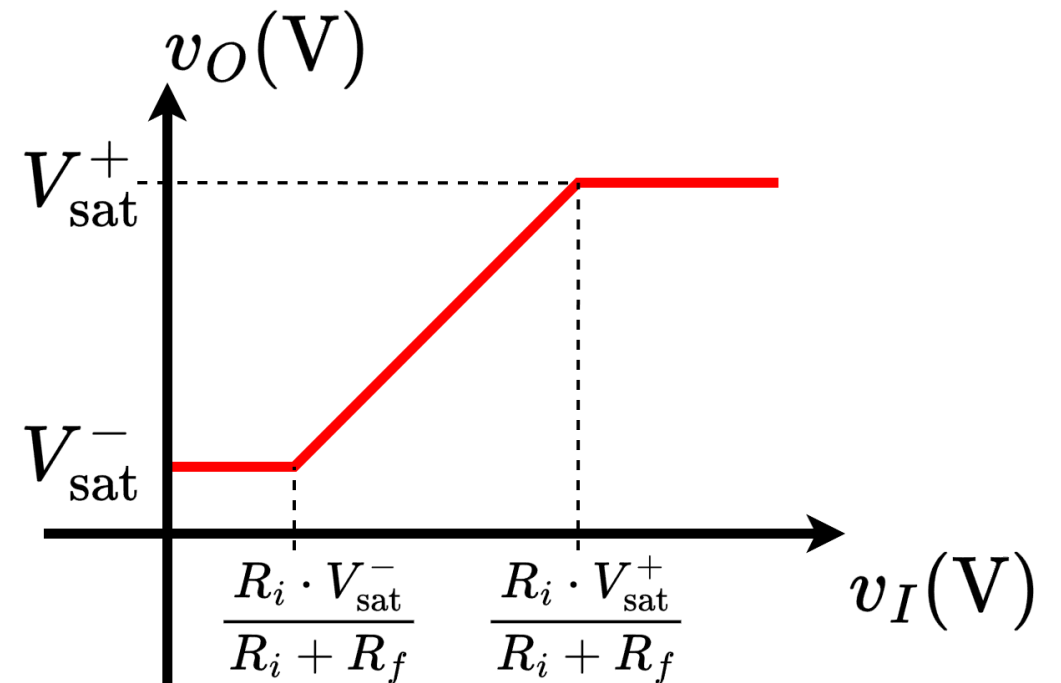
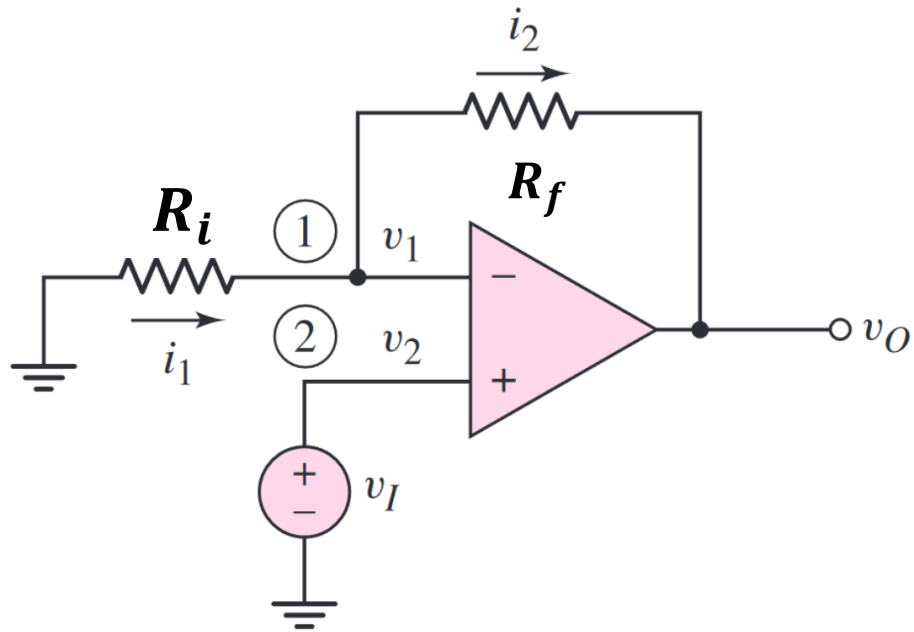
Inverting Amplifier – VTC



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

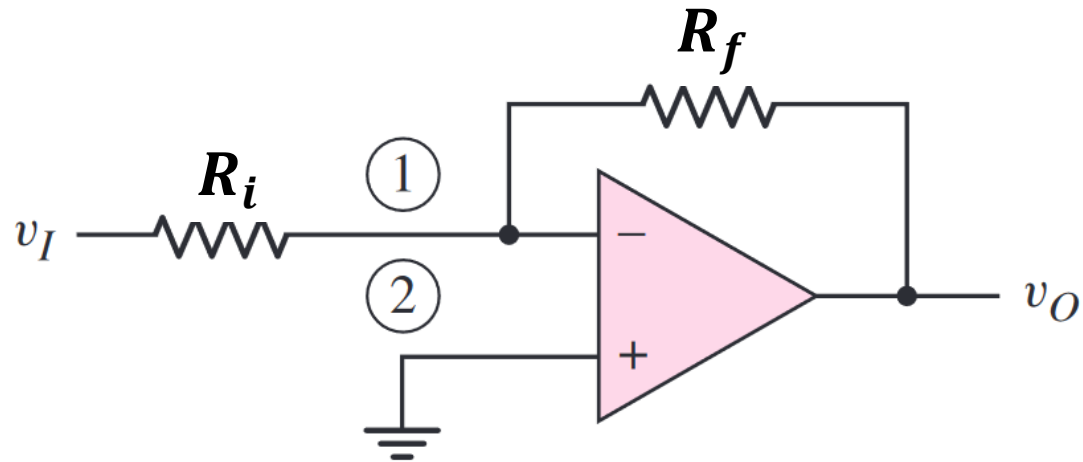


Non-Inverting Amplifier – VTC

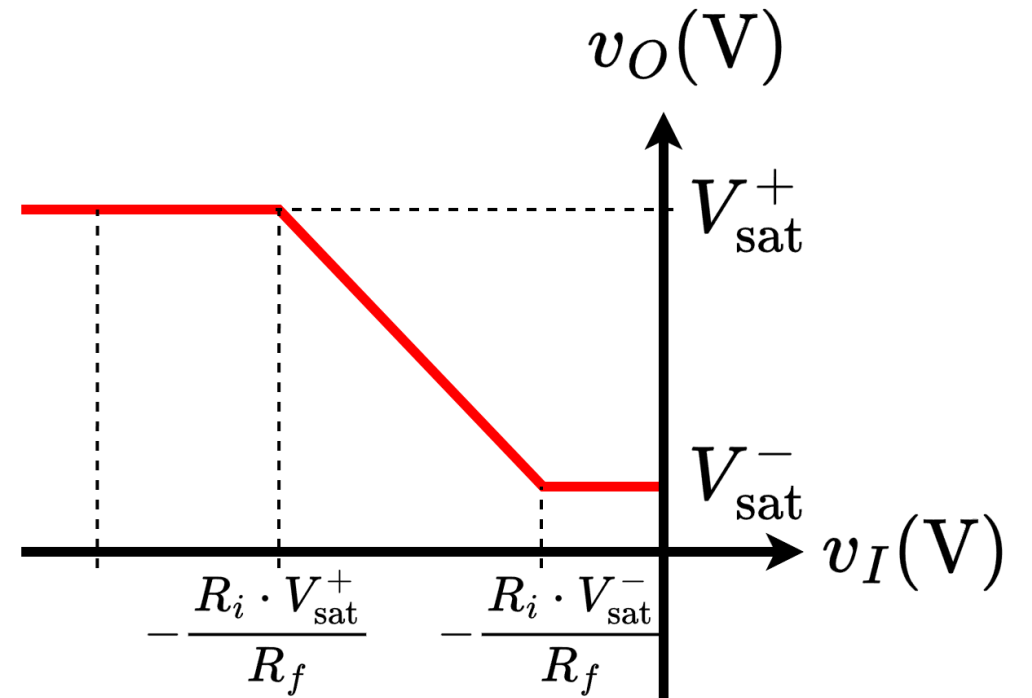


$$v_O = \begin{cases} V_{\text{sat}}^+, & \text{if } v_O \geq V_{\text{sat}}^+ \\ v_I \cdot \left(1 + \frac{R_f}{R_i}\right), & \text{if } V_{\text{sat}}^- \leq v_O \leq V_{\text{sat}}^+ \\ V_{\text{sat}}^-, & \text{if } v_O \leq V_{\text{sat}}^- \end{cases}$$

Inverting Amplifier – VTC

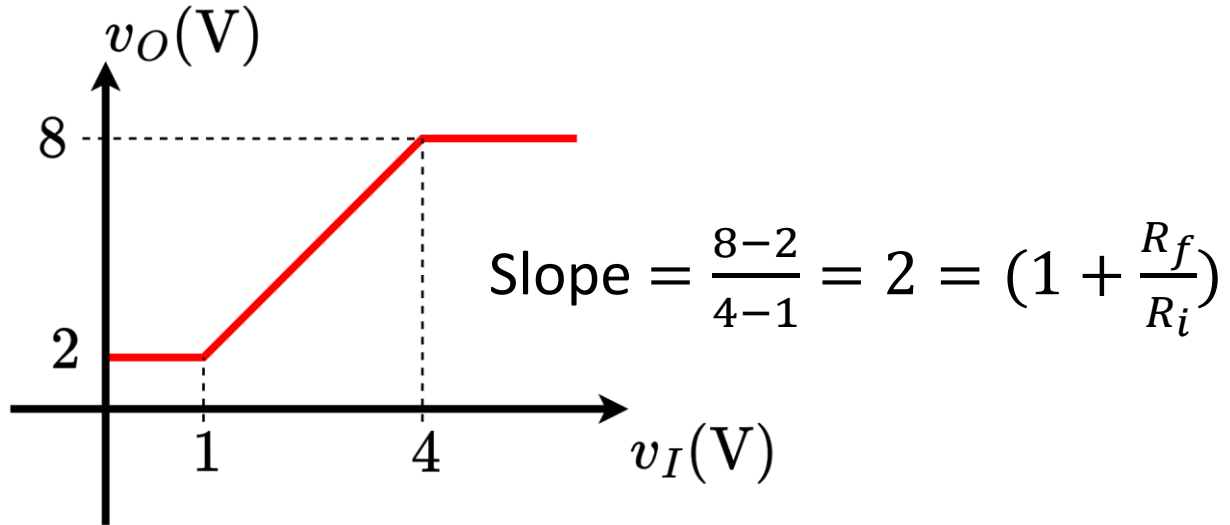


$$v_O = \begin{cases} V_{\text{sat}}^+, & \text{if } v_O \geq V_{\text{sat}}^+ \\ -v_I \cdot \frac{R_f}{R_i}, & \text{if } V_{\text{sat}}^- \leq v_O \leq V_{\text{sat}}^+ \\ V_{\text{sat}}^-, & \text{if } v_O \leq V_{\text{sat}}^- \end{cases}$$



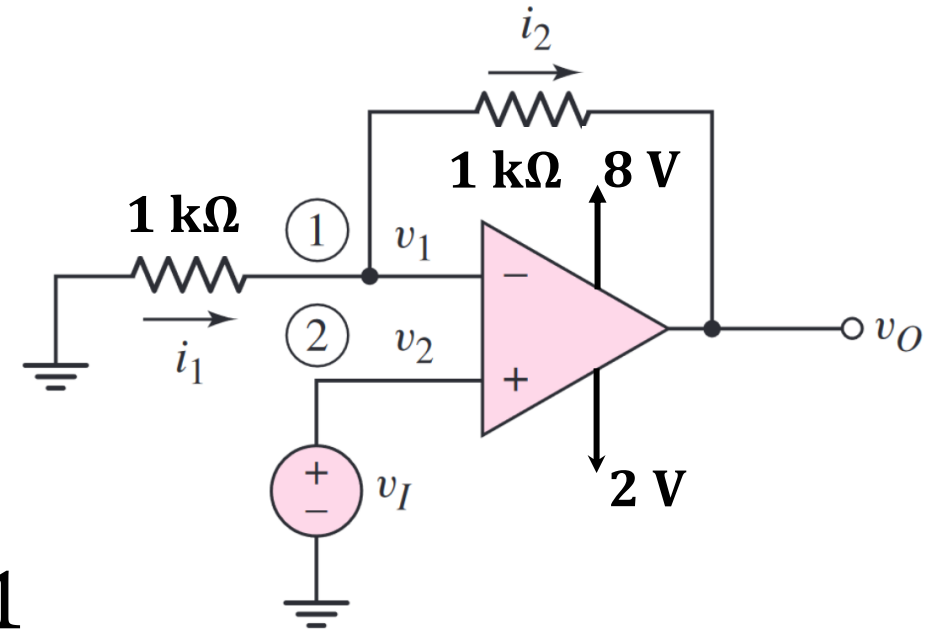
Non-Inverting Amplifier – VTC

Draw an Op-Amp Circuit with the following VTC



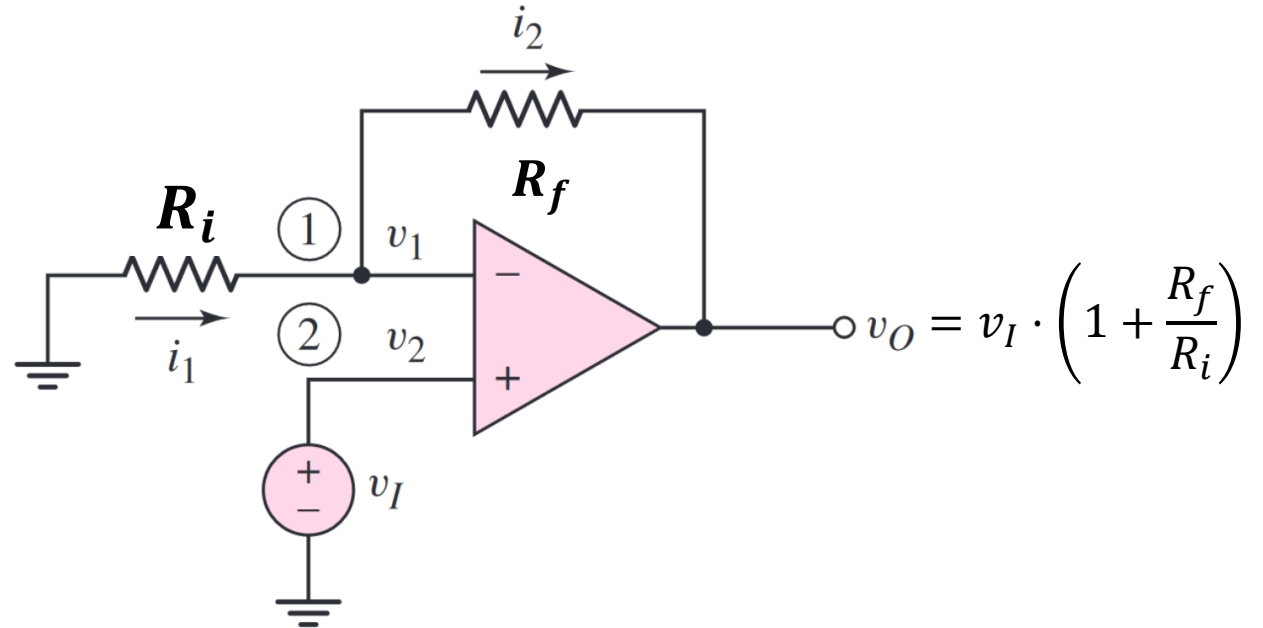
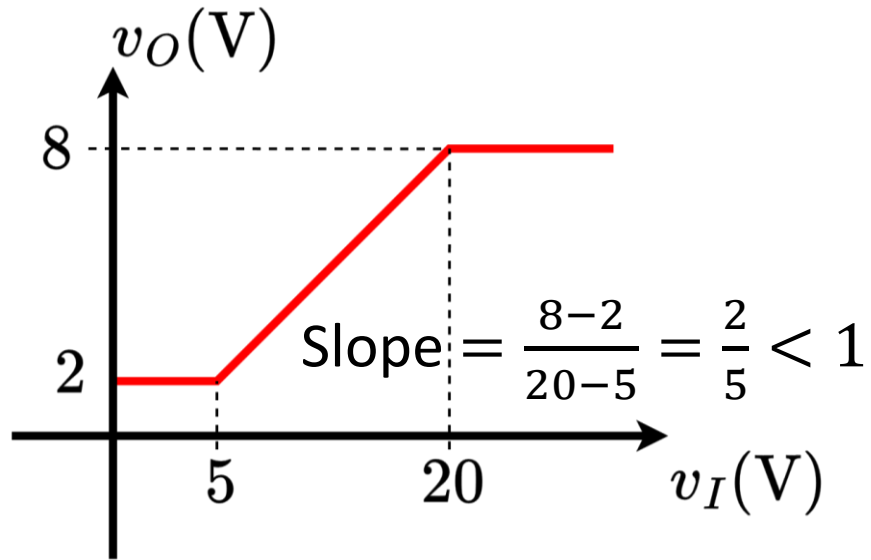
$$\left(1 + \frac{R_f}{R_i}\right) = 2$$

$$\Rightarrow \frac{R_f}{R_i} = 1$$



Non-Inverting Amplifier – VTC

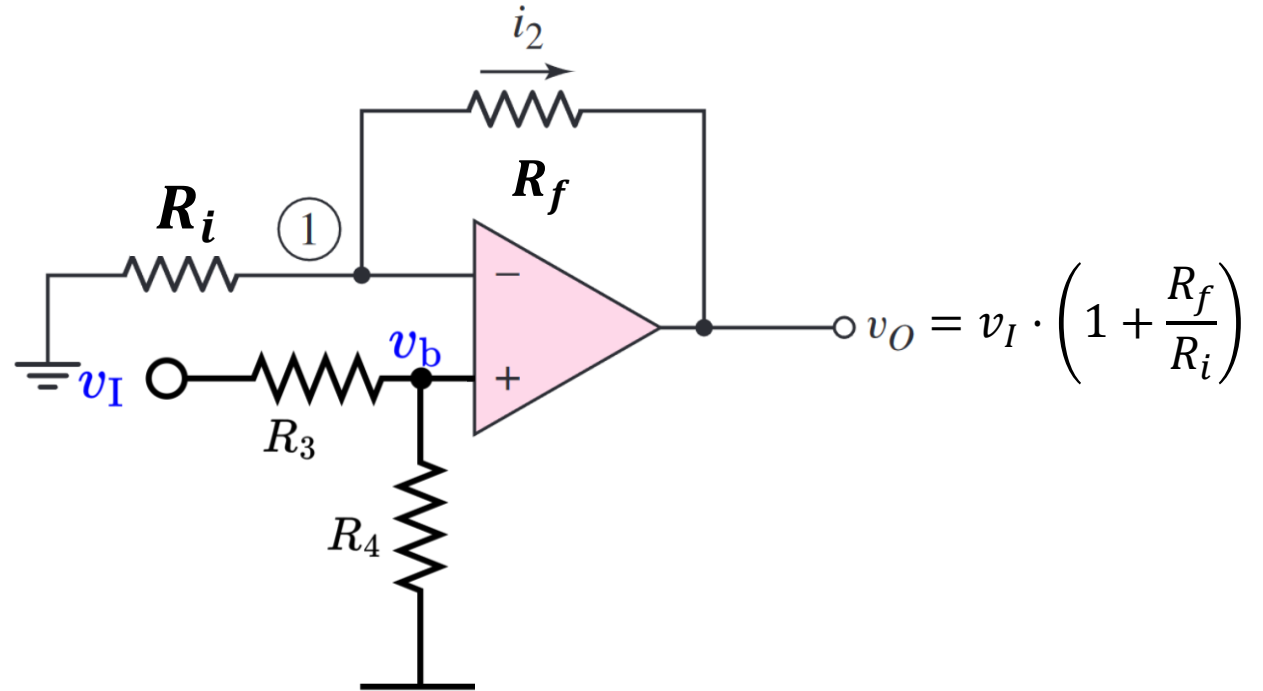
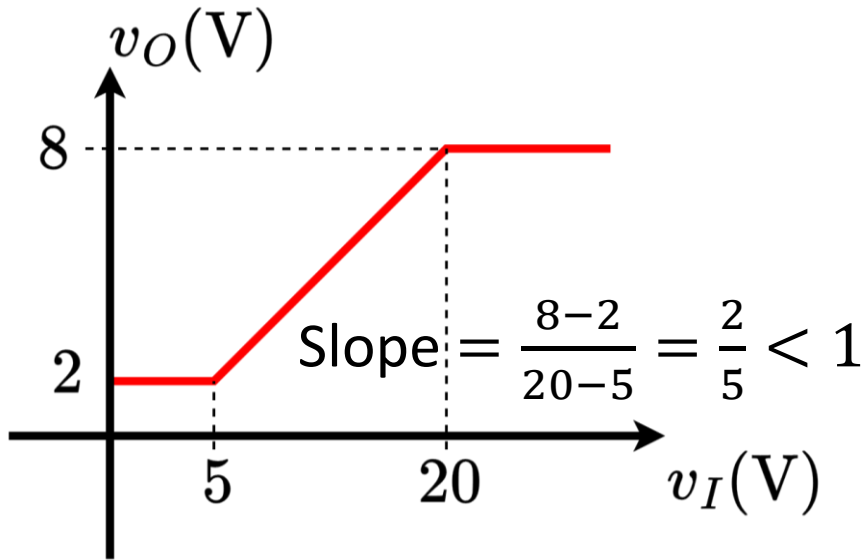
Draw an Op-Amp Circuit with the following VTC. (What if the slope is less than **1**?)



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

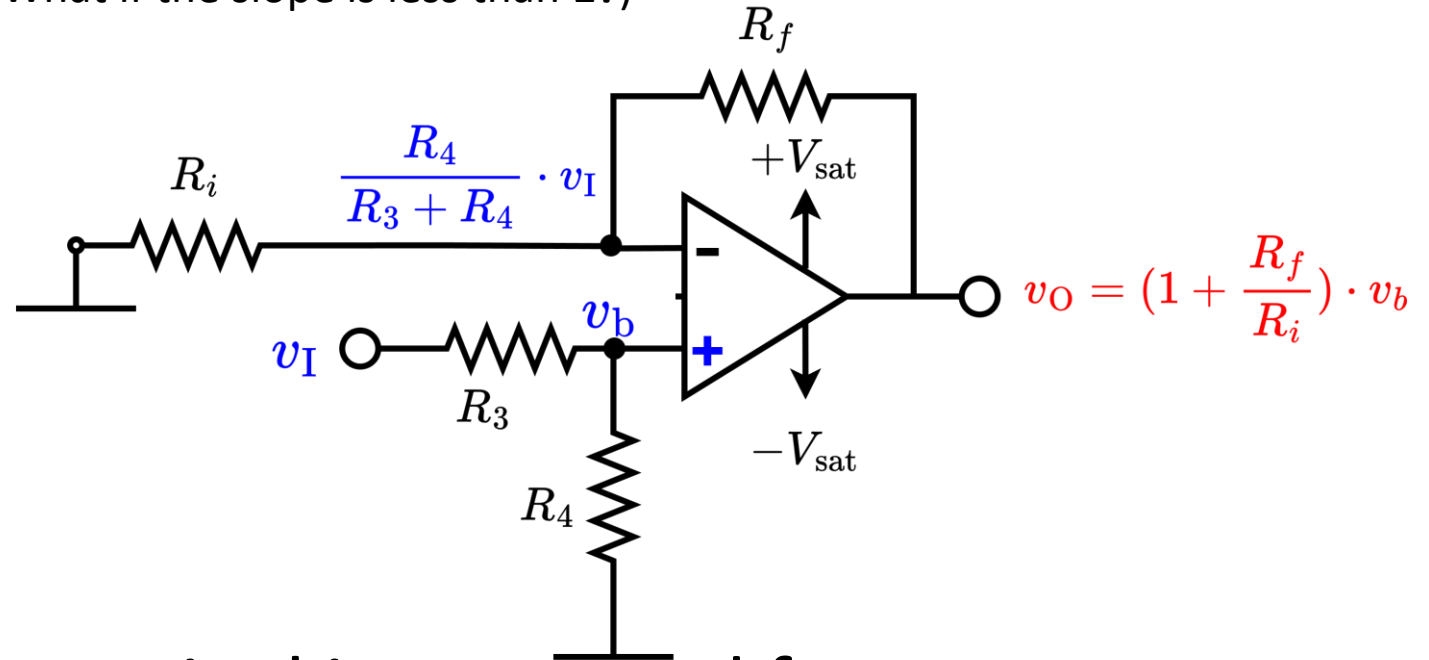
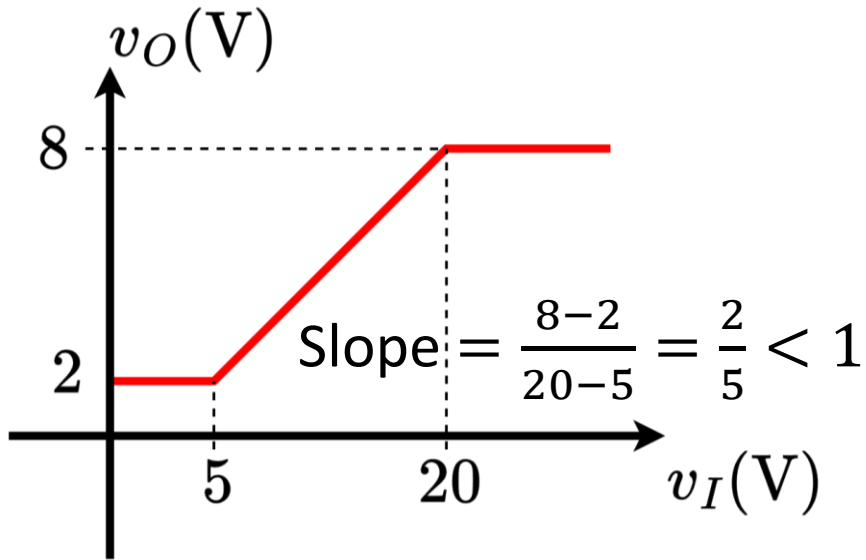
Draw an Op-Amp Circuit with the following VTC. (What if the slope is less than 1?)



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**?)

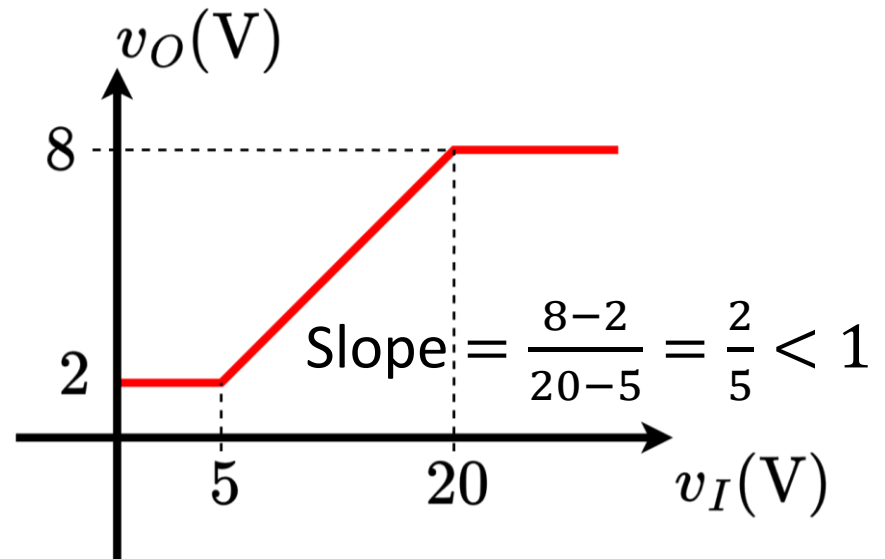


Voltage at the non-inverting terminal is converted from v_I to $v_I \cdot \left(\frac{R_4}{R_3 + R_4}\right)$. So, the overall gain becomes: $\left(1 + \frac{R_f}{R_i}\right) \left(\frac{R_4}{R_3 + R_4}\right)$ which can be less than **1**.

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:



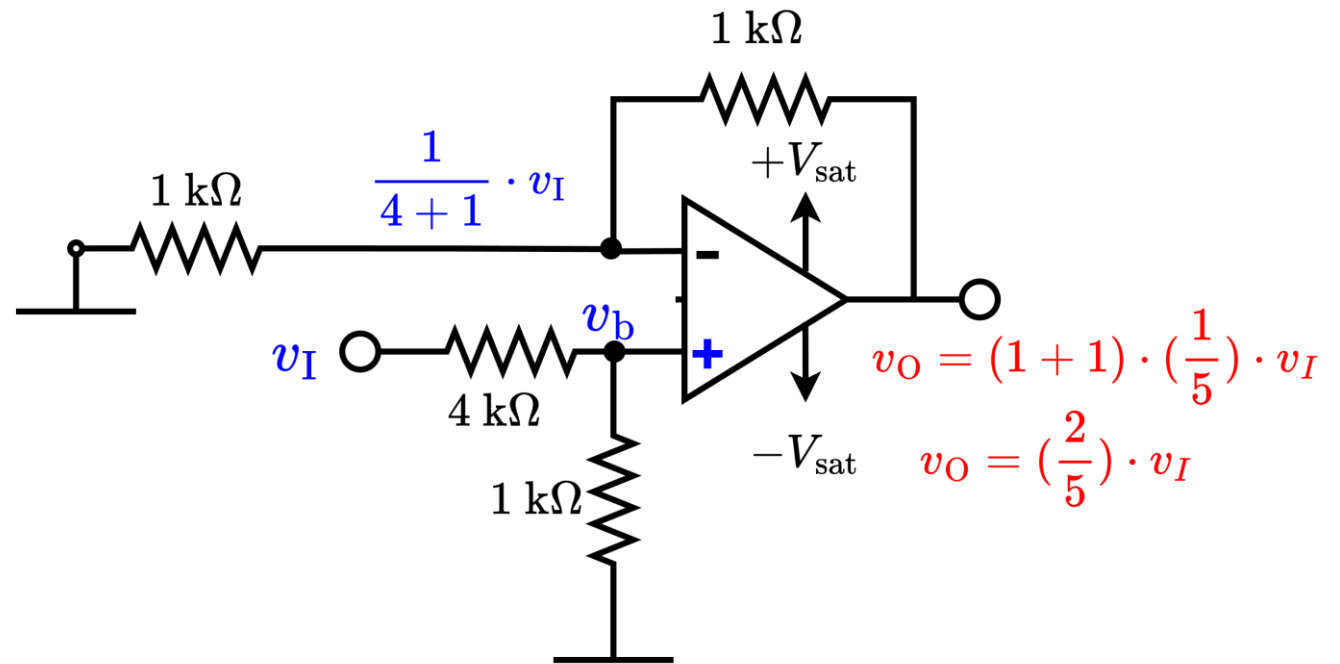
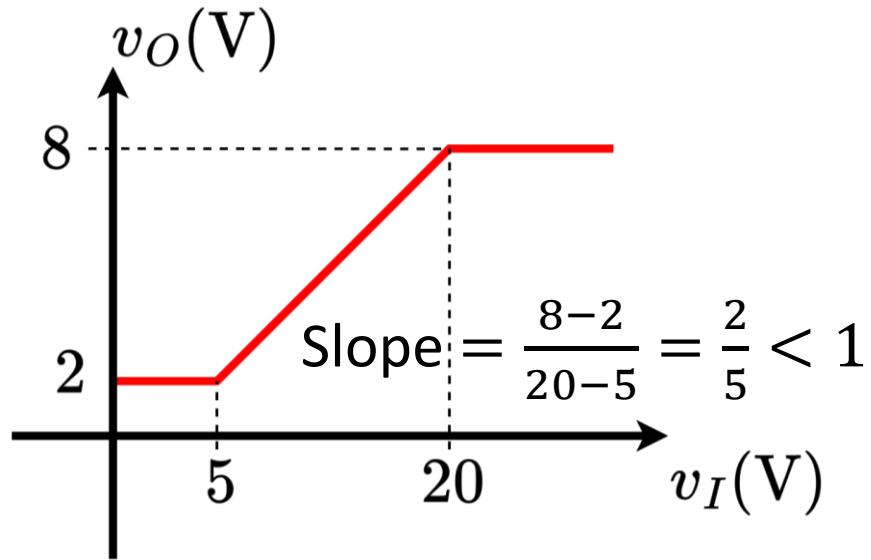
$$\left(1 + \frac{R_f}{R_i}\right) = 2$$

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

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