OpAmps

- Review
- Gain Stages
- NVA w/ OpAmps
- Current Source
- Examples
Review of OpAmps

Ideal OpAmp

Don't worry for analysis now, just when building circuits in the lab (or in real life).

- Negative Feedback Assumption
- Ideal OpAmp
  - $I^+ = 0, I^- = 0$
  - $V^+ = V^-$ (when OpAmp in negative feedback)

Golden Rules
  - $A_v$ (open-loop gain) $\to \infty$, $v_{out} = A_v (V^+ - V^-)$

Aside:

Negative Feedback

Positive Feedback

$v_{out} = A_v (V^+ - V^-)$
Non-Inverting Amplifier

\[ V_{out} = \left(1 + \frac{R_2}{R_1}\right)V_{in} \]

By choosing \( R_1 \), \( R_2 \) values, we can multiply an input voltage by \( A > 1 \)

\[ R_2 = \frac{3k}{R_1} = \frac{1k}{\Rightarrow A = 4} \]

Note: See Module 2, Lecture 9 for derivation.
Inverting Amplifier

\[ I_1 = \frac{V_{in} - 0}{R_1} = \frac{0 - V_{out}}{R_2} \]

\[ \frac{V_{in}}{R_1} = -\frac{V_{out}}{R_2} \Rightarrow V_{out} = -\frac{R_2}{R_1} \cdot V_{in} \]

Solution Method #1

\[ A = [0 \ldots -\infty] \]

\[ [0, 0.5, 1, \ldots, 1000] \]

Solution Method #2

\[ \frac{V_{out} - V_{in}}{R_1} = I_1 \]

\[ V_{in} = I_1 R_1 \Rightarrow I_1 = \frac{V_{in}}{R_1} \]

\[ V_{out} = -I_1 R_2 \Rightarrow I_1 = -\frac{V_{out}}{R_2} \]

\[ -\frac{V_{out}}{R_2} = \frac{V_{in}}{R_1} \Rightarrow V_{out} = -\frac{R_2}{R_1} \cdot V_{in} \]
Solution
Method #3
(NVA w/OPA)

\[ \text{KCL:} \]
\[ \frac{V^- - V_{\text{in}}}{R_1} + \frac{V^- - V_{\text{out}}}{R_2} = 0 \]

\[ \sum I'_s \text{ leaving} = \sum I'_s \text{ entering} \]

\[ V^- = V^+ (= 0) \]

\[ -\frac{V_{\text{in}}}{R_1} + -\frac{V_{\text{out}}}{R_2} = 0 \]

\[ V_{\text{out}} = -\frac{V_{\text{in}}}{R_1} \]

\[ V_{\text{out}} = -\frac{R_2}{R_1} V_{\text{in}} \]
**NVA w/ OPamps**

**Goal:** Find all voltages (and currents) in a circuit that contains op amps.

**Procedure:**

1. Verify **negative feedback**
2. Verify **ideal opamp**

Add the following rules to NVA:

- Write KCL at both inputs ($V^+, V^-$) (unless the voltage is set by a source)
- Do **not** write an eqn for the output node of opamp ($V_{out}$)
- Add $V^+ = V^-$ to eqns to solve circuit.

**Apply NVA Example**

![Circuit Diagram]

\[ V_{out} = f(V_A, V_B, R_1, R_2) \]
Aside: Why do we need a buffer?
Current Source

\[ I_R = \frac{V_S}{R} \]

\[ R_{\text{LOAD}} \neq R \]

**Why is \( V^- = 0 \)?**
Because \( V^+ = 0 \) and Golden Rule
\( V^- = V^+ \)

\[ I_S = \frac{V_S - 0}{R} = \frac{V_S}{R} \]

**Why does \( I_L = I_S \)?**
@ Node \( V^- \): \( \phi \)
\[ I_S = I_L + \sum \text{I/O} \]
Golden Rule
\[ \therefore I_S = I_L \]

\[ I_L = ? \]
\[ I^+ = ? \]
\[ V^+ = V^- \]
**Touch Sensor**

\[
\text{Graph of: } V_{\text{touch}}(t) = \frac{Q}{C_{\text{touch}}} = \frac{I_s}{C_{\text{touch}}} \cdot t
\]

**In Lab**

\[
V_{\text{out}} \text{ (w/ finger)} \quad V_{\text{out}} \text{ (w/o finger)} \quad V_{\text{ref}} \text{ (threshold for touch detection)}
\]

*C\text{touch} changes when you touch screen.*