Operational Amplifiers

E80 Lecture
Matthew Spencer
2016-02-02
Submitting Your Work on Time

• Many snafus when submitting work at the last minute

• E.g.: Wrong naming convention for submitted files

• Think about administrative/IT stuff during prelab. How will I submit?
Clarifying What is OK Outside of Lab

• “Dry fits” which are dissembled by the time you enter lab

• No Measurements. No working with “actual” data.

• Don’t do the lab outside the lab

• If you need a rule of thumb, any hardware you are allowed to take with you is fair game. Anything permanently in lab is not.
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An Idea of Equivalent Importance

What We Want to Know

• What the heck is an operational amplifier (op-amp)?

• How should I think about using it?

• What are it’s many applications?

• If time: What are it’s limitations?
An Op-Amp is Used to Solve Analog Problems

Physical Item  Circuit Symbol  Circuit Model
The Big Input Resistance Isolates Circuits

\[ V_{out} = A*(V+ - V-) \]

Op-amp magic:
R_in and A are both _very_ big
An Example Where Input Isolation Helps

R_sensor could be 100M-Ohm!
Input Isolation Lets V+ Remain Large

R_in \approx \infty

What’s V+?  
What’s I_{Rin}?

V_{out} = A(V+ - V-)

Does this circuit work?  
What is the output?
Negative Feedback Lets Us Use the Huge Gain

Description of negative feedback on board.

This is a “Unity Gain Buffer” Super good!

$$V_{out} = A(V_+ - V_-)$$
The Two Cardinal Rules of Op Amp Analysis

• $I_{in} = 0$

• In negative feedback, $V_{out}$ is forced so $V_+ = V_-$

• Invoke these two rules to analyze any op-amp circuit

• The rabbit hole goes significantly deeper
Let’s Analyze a New Configuration

Called an inverting amplifier configuration
Now You Guys Try
Summing and Offset Amplifiers
Impedance and Op-Amps

• E59 big reveal: L and C can be treated as imaginary R for sine waves
• Can put L and C into our existing op-amp model, which uses resistors.
Example: Integrator

https://en.wikipedia.org/wiki/Operational_amplifier_applications
You Try

https://en.wikipedia.org/wiki/Operational_amplifier_applications
High Pass and Low Pass Filters

https://en.wikipedia.org/wiki/Low-pass_filter
https://en.wikipedia.org/wiki/High-pass_filter
Sallen-Key Filter Topologies

\[
\frac{v_{\text{out}}}{v_{\text{in}}} = \frac{Z_3 Z_4}{Z_1 Z_2 + Z_3 (Z_1 + Z_2) + Z_3 Z_4}
\]

https://en.wikipedia.org/wiki/Sallen%E2%80%93Key_topology
Don’t Forget About Power

• So far, we’ve skipped V+ and V- connections. They are for power.
• V+ and V- Set maximum and minimum in/out voltage. Voltage rails.
• Use decoupling capacitors. Read all of the instructions!
Single Supply vs. Dual Supply + GND

Dual Supply + GND
Symmetric + and − V, GND halfway between

Single Supply
Only GND and +V. Can’t generate negative voltage

Instrumentation Amplifiers