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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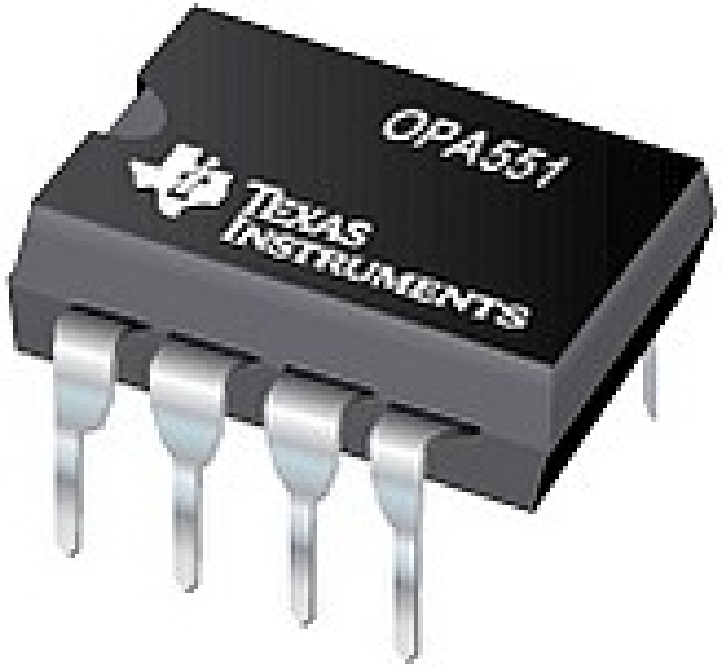
An Idea of Equivalent Importance

http://www.stanleysupplyservices.com/search.aspx?f=2%3AVise+Grip

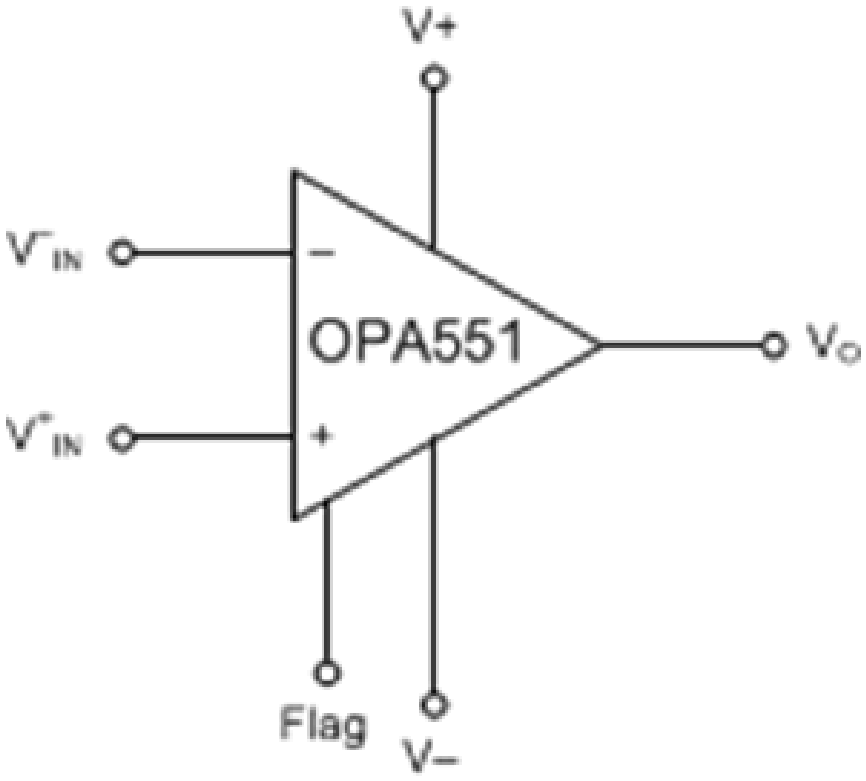
What We Want to Know

- 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?

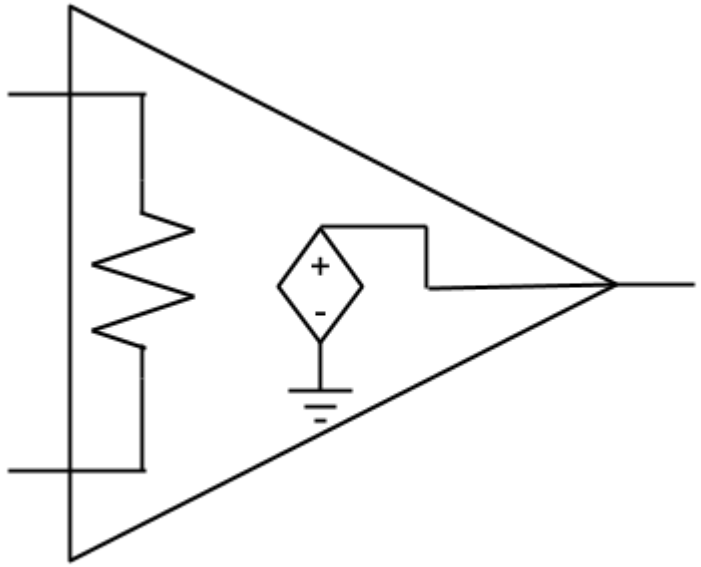
An Op-Amp is Used to Solve Analog Problems



Physical Item

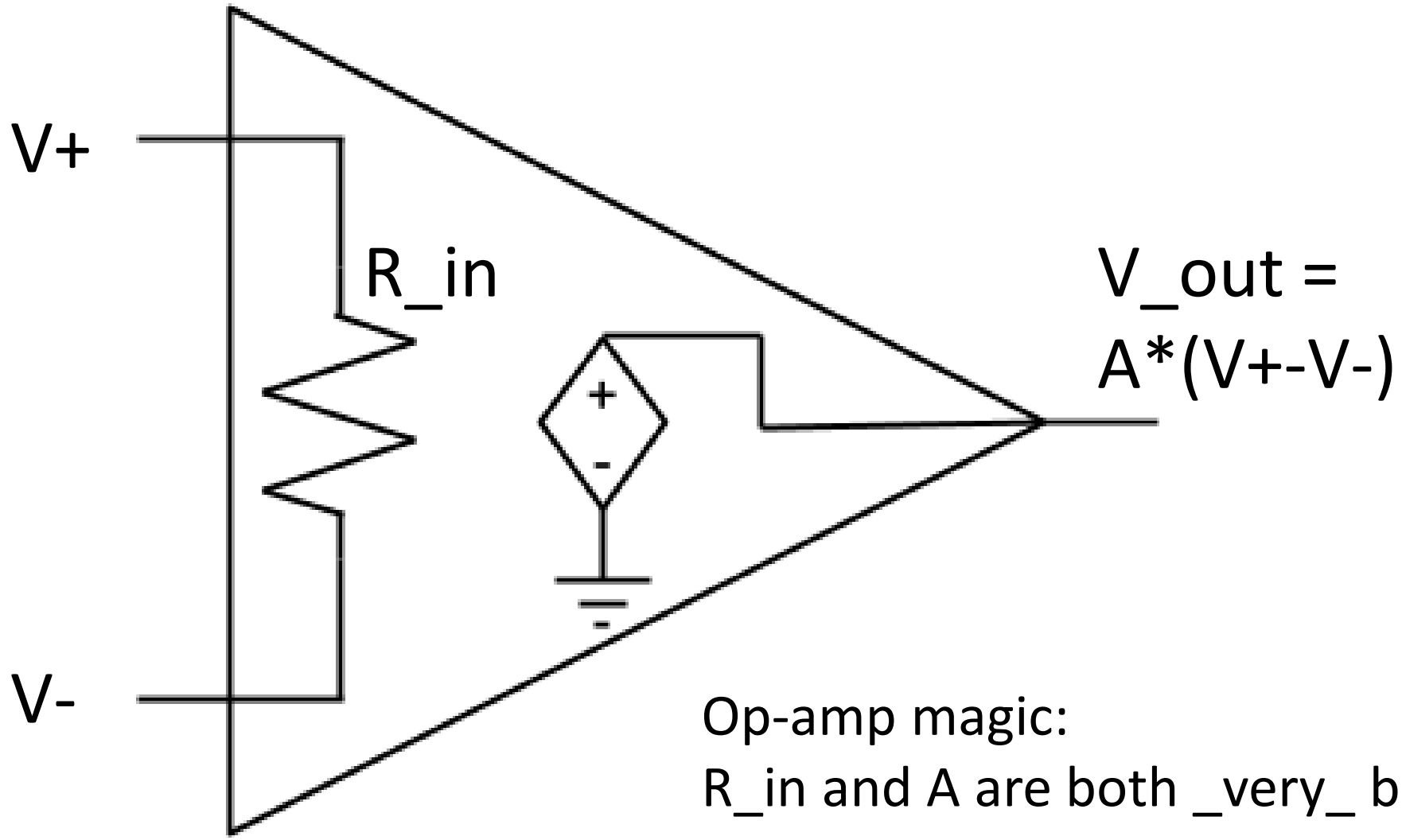


Circuit Symbol



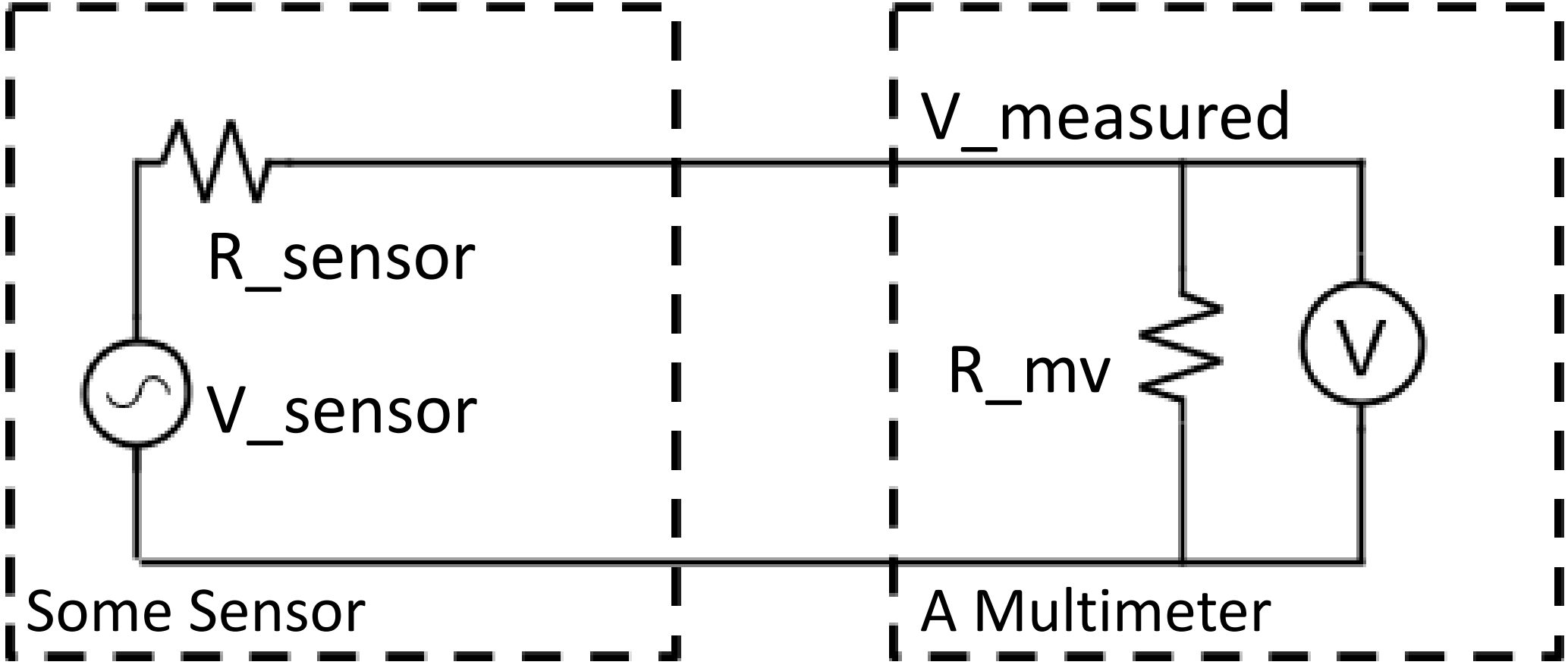
Circuit Model

The Big Input Resistance Isolates Circuits



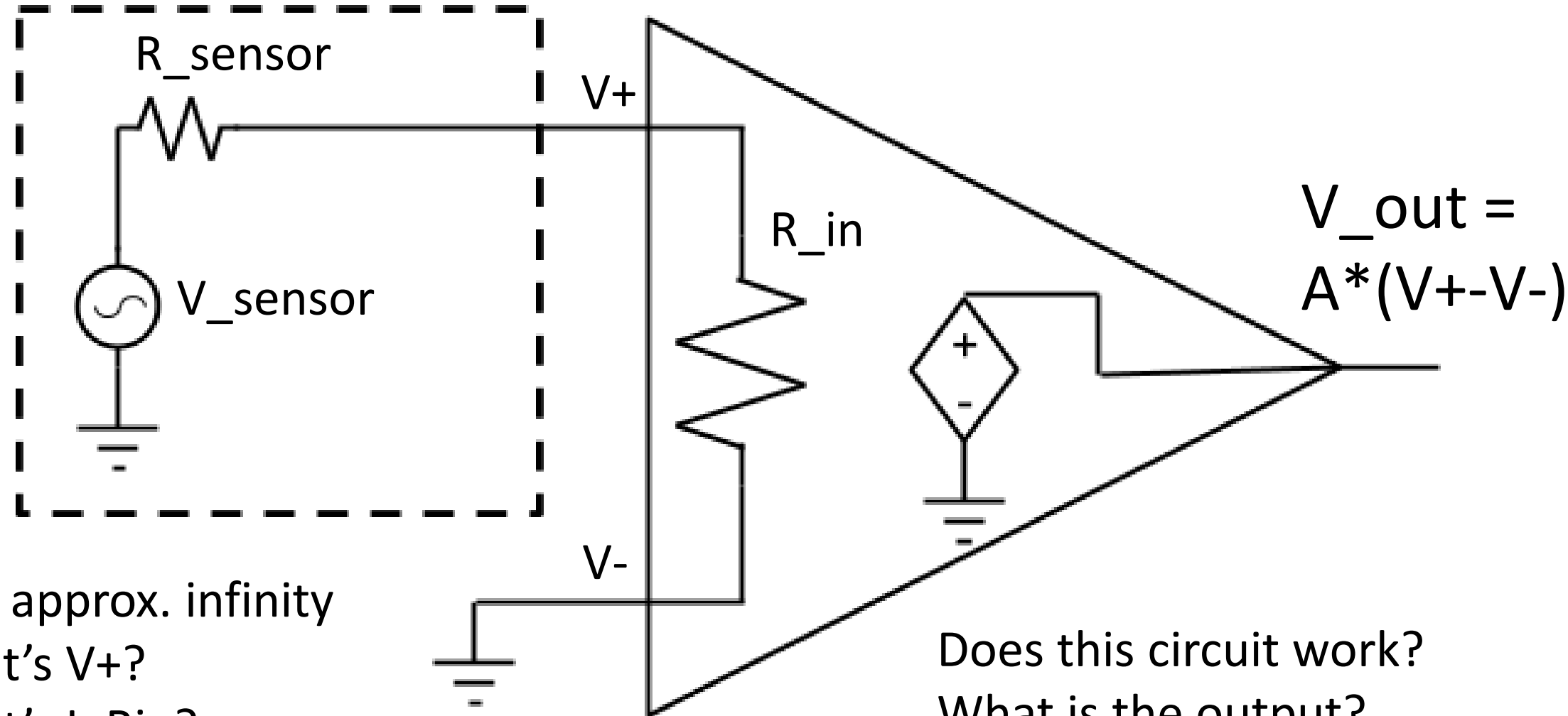
Op-amp magic:
R_in and A are both _very_ big

An Example Where Input Isolation Helps



R_sensor could be 100M-Ohm!

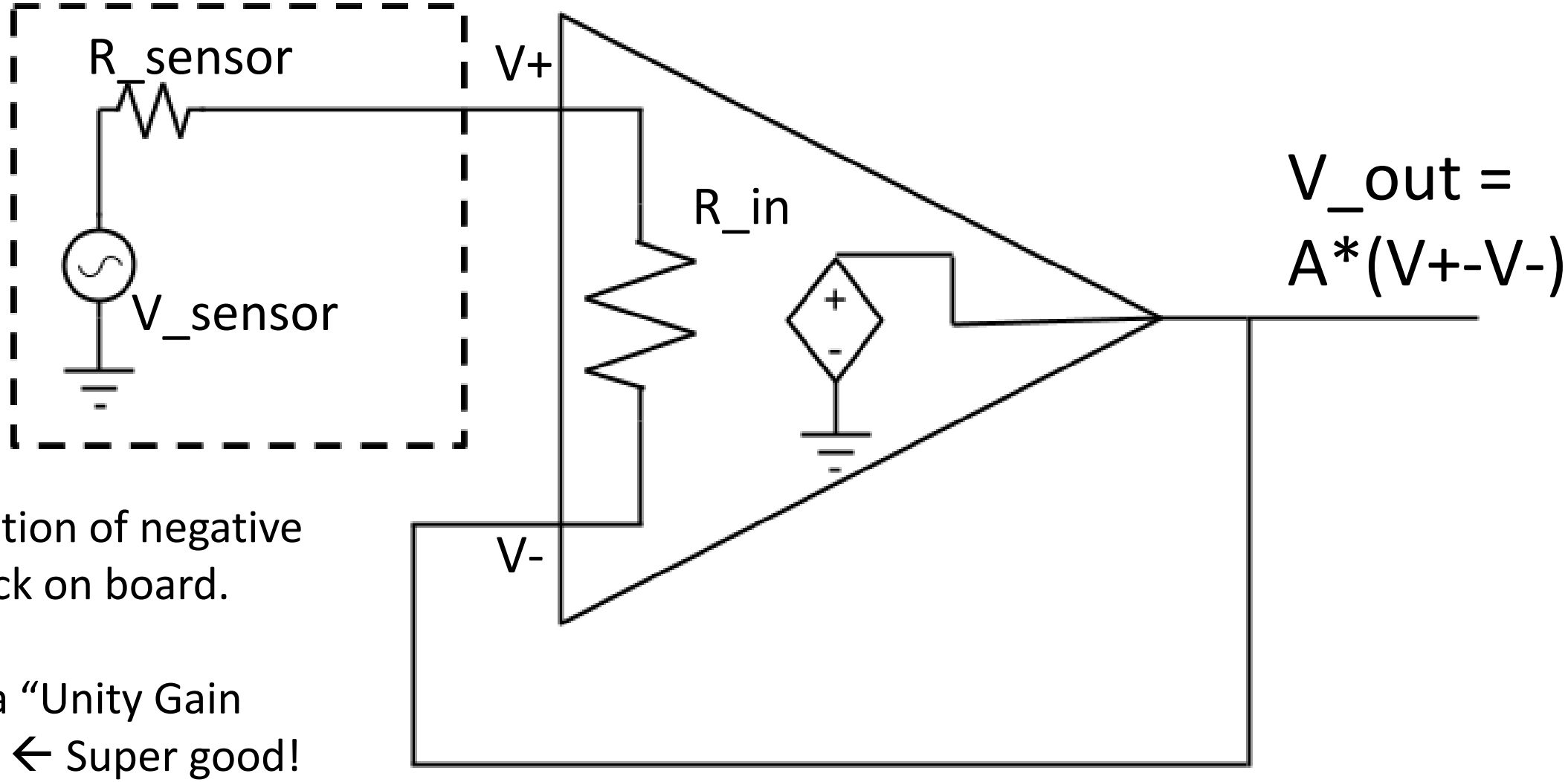
Input Isolation Lets V+ Remain Large



R_in approx. infinity
What's V+?
What's I_Rin?

Does this circuit work?
What is the output?

Negative Feedback Lets Us Use the Huge Gain



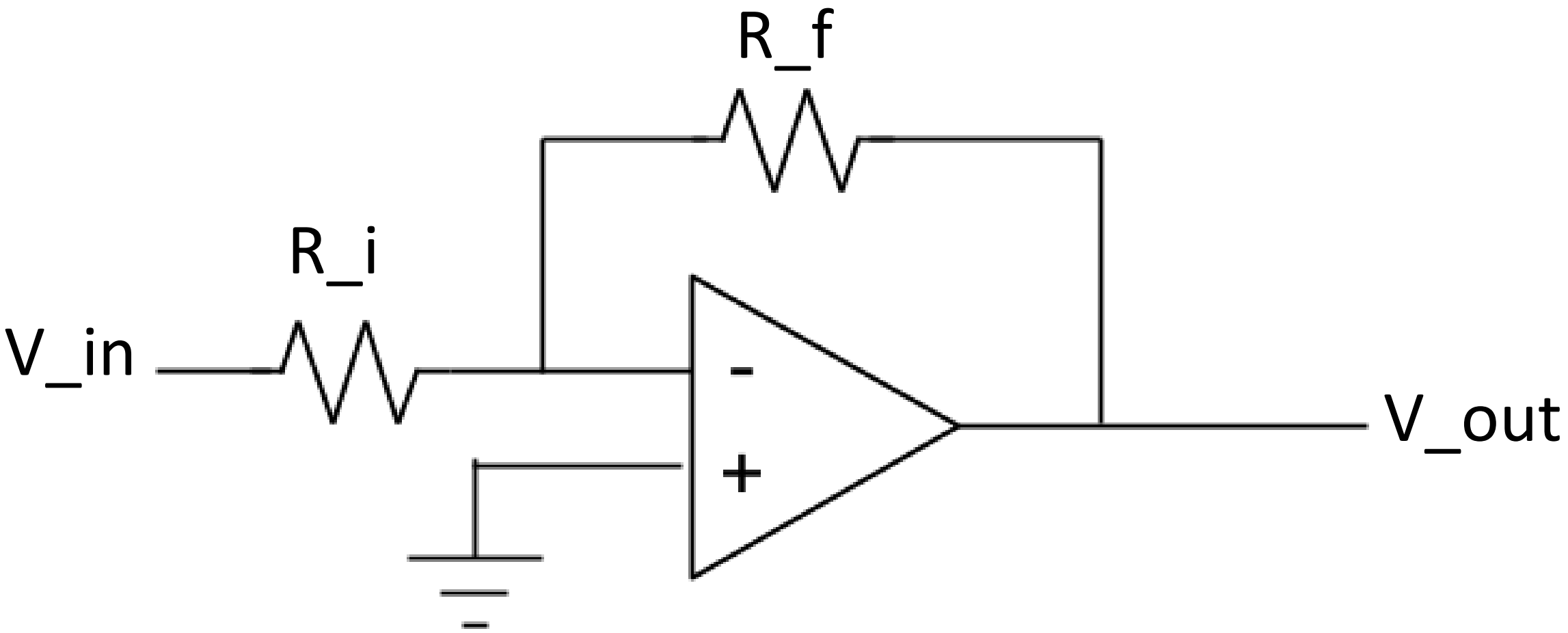
Description of negative feedback on board.

This is a “Unity Gain Buffer” ← Super good!

The Two Cardinal Rules of Op Amp Analysis

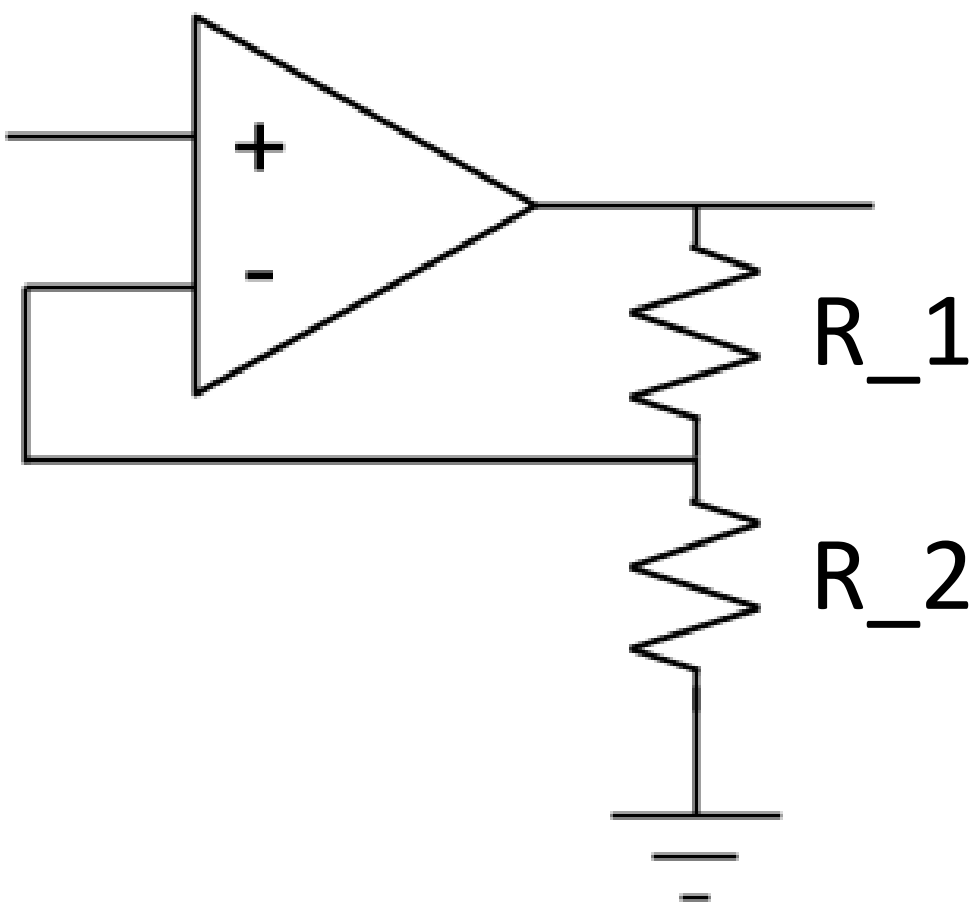
- **I_in = 0**
- In negative feedback, Vout is forced so **V+=V-**
- Invoke these two rules to analyze any op-amp circuit
- The rabbit hole goes significantly deeper

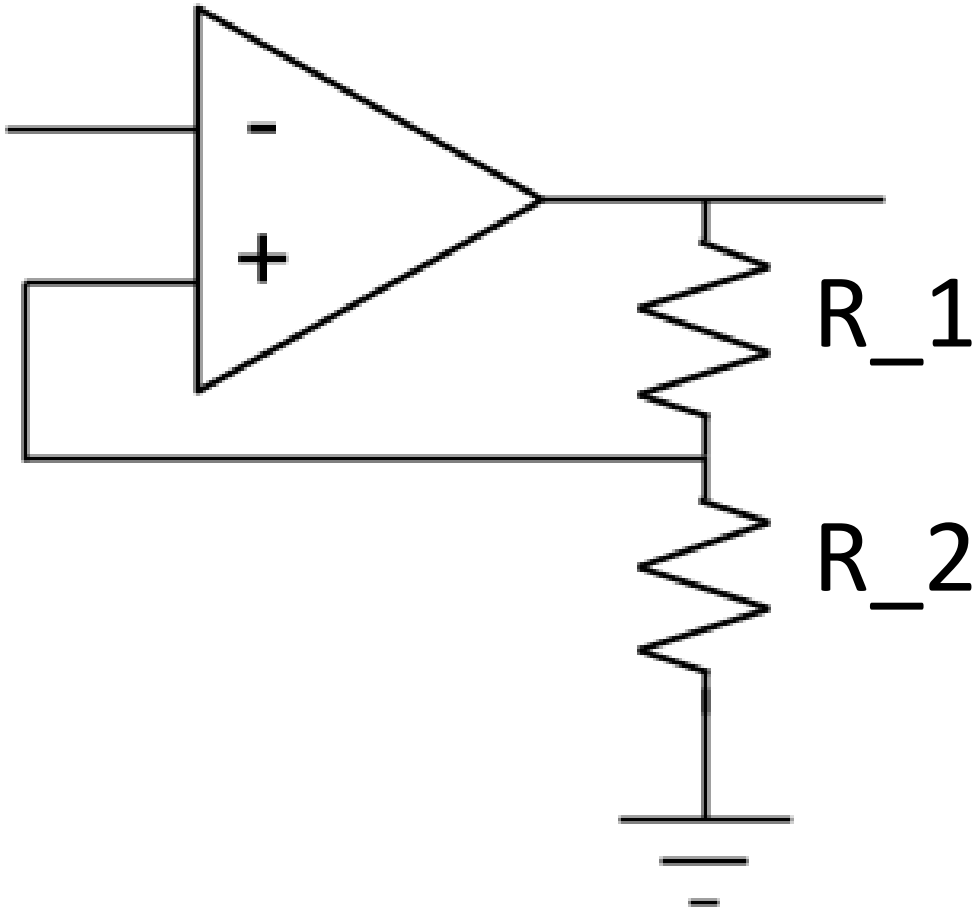
Let’s Analyze a New Configuration



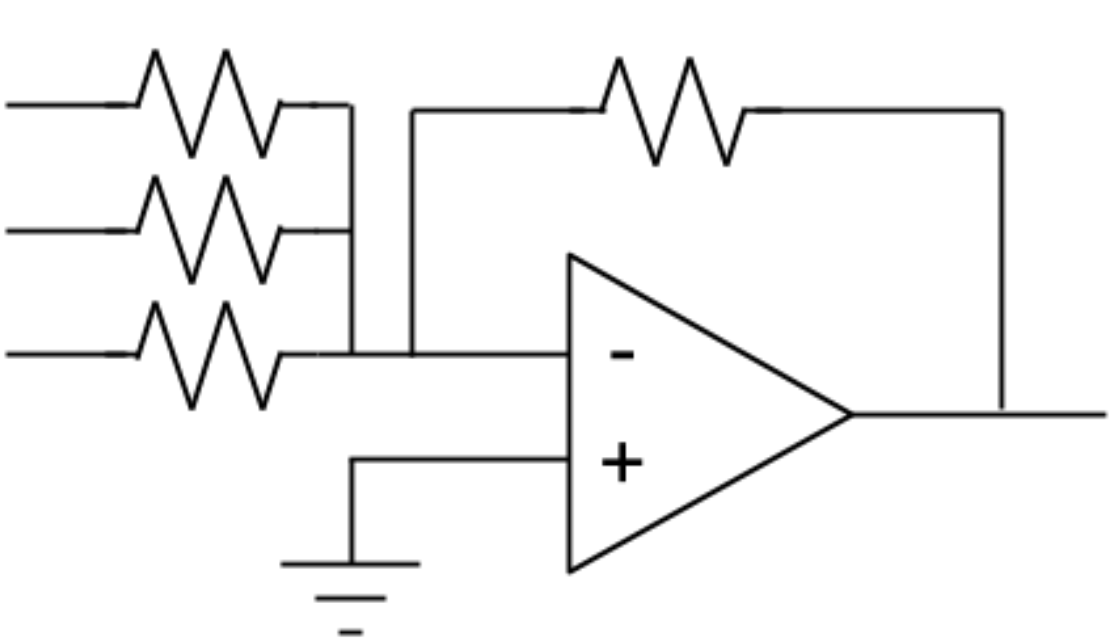
Called an inverting amplifier configuration

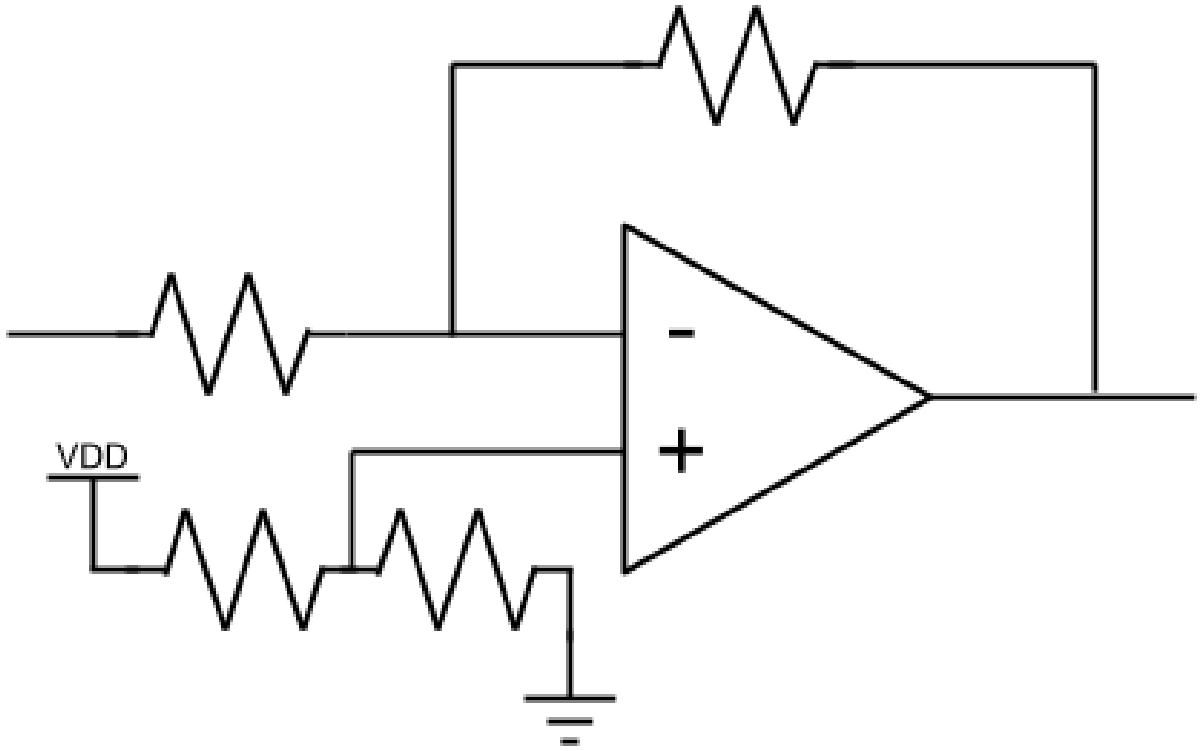
Now You Guys Try





Summing and Offset Amplifiers

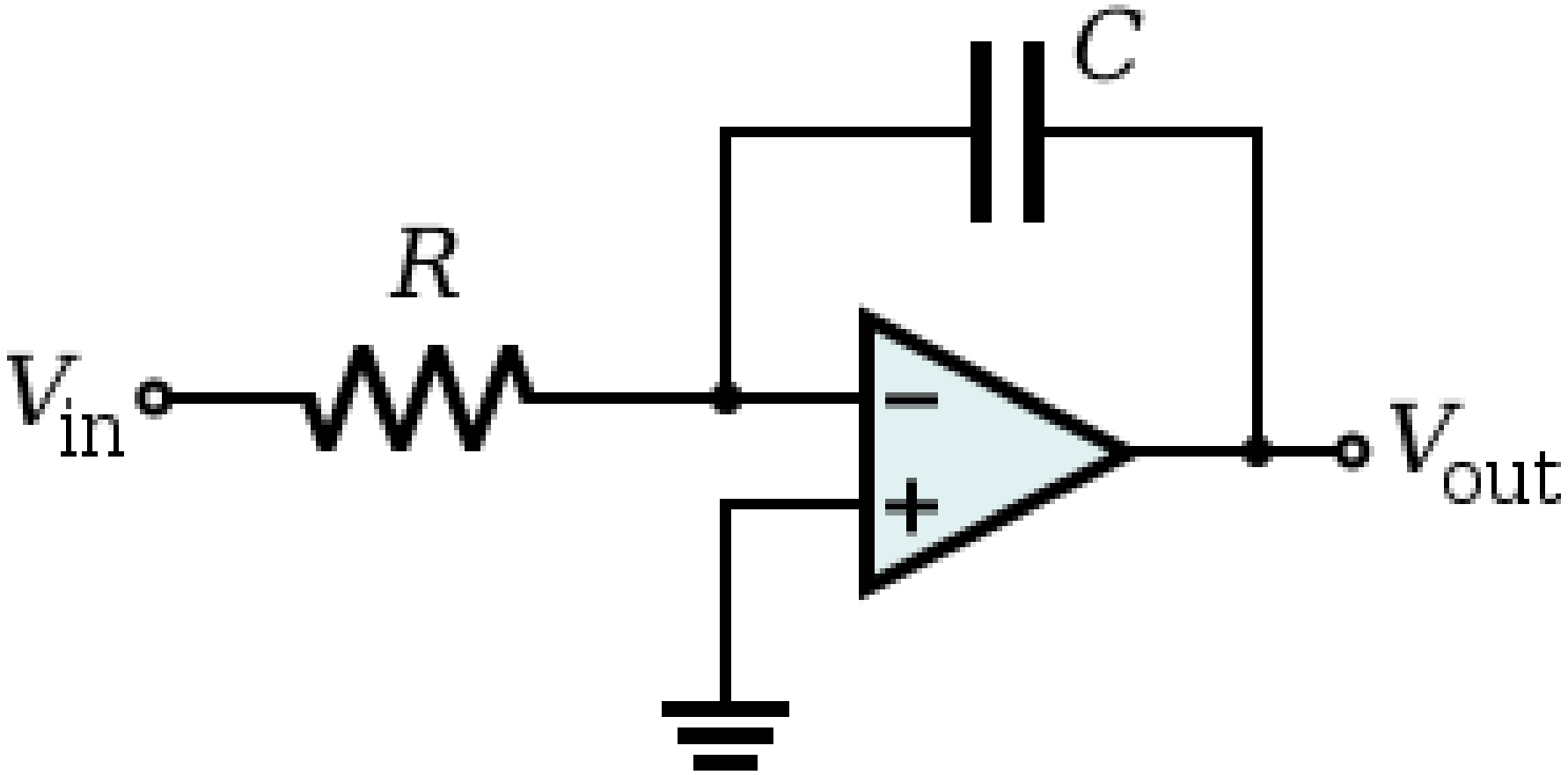




Impedance and Op-Amps

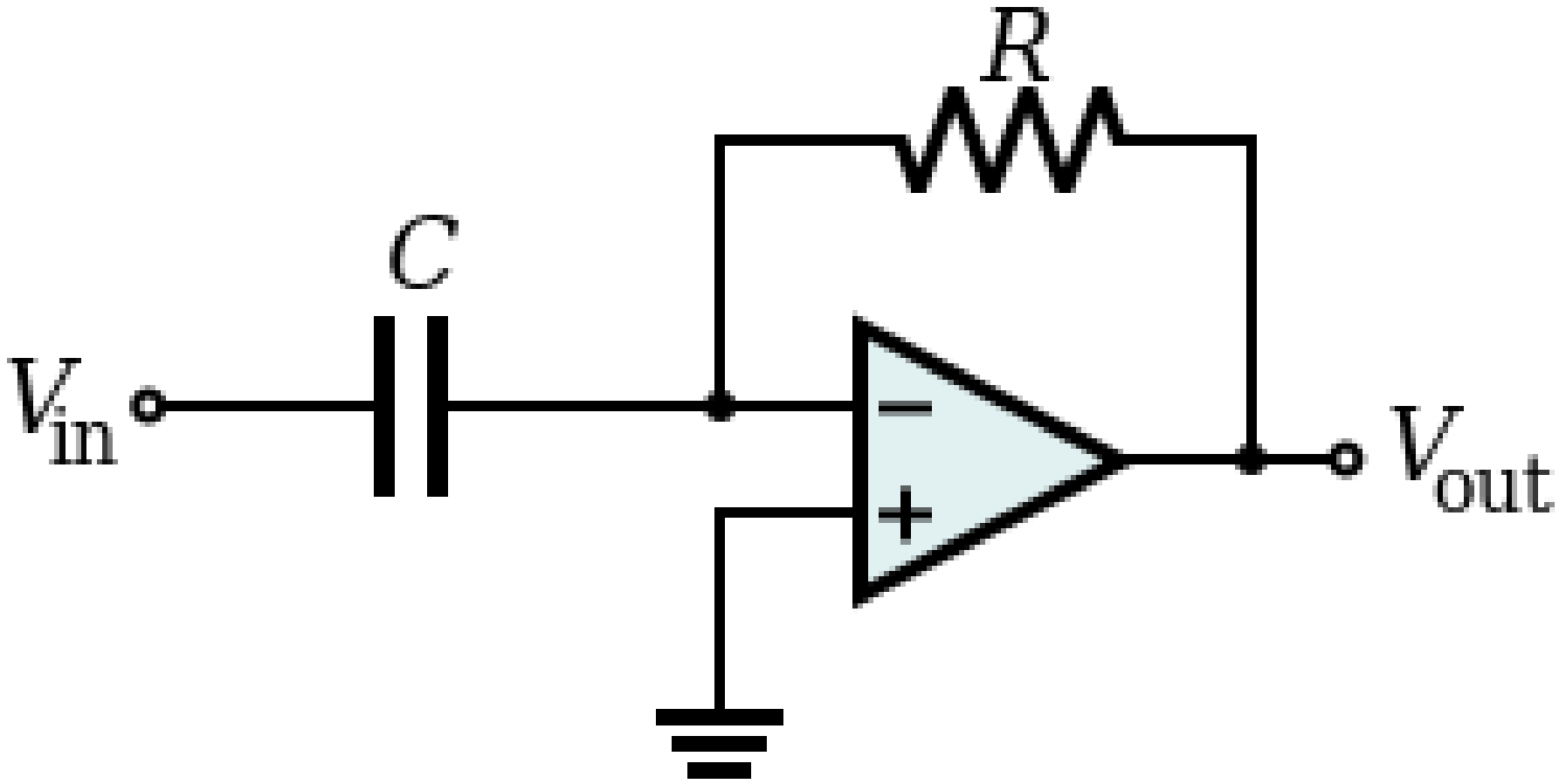
- E59 big reveal: L and C can be treated as imaginary R for sine waves
- Can put L and C into our existing op-amp model, which uses resistors.

Example: Integrator



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

You Try



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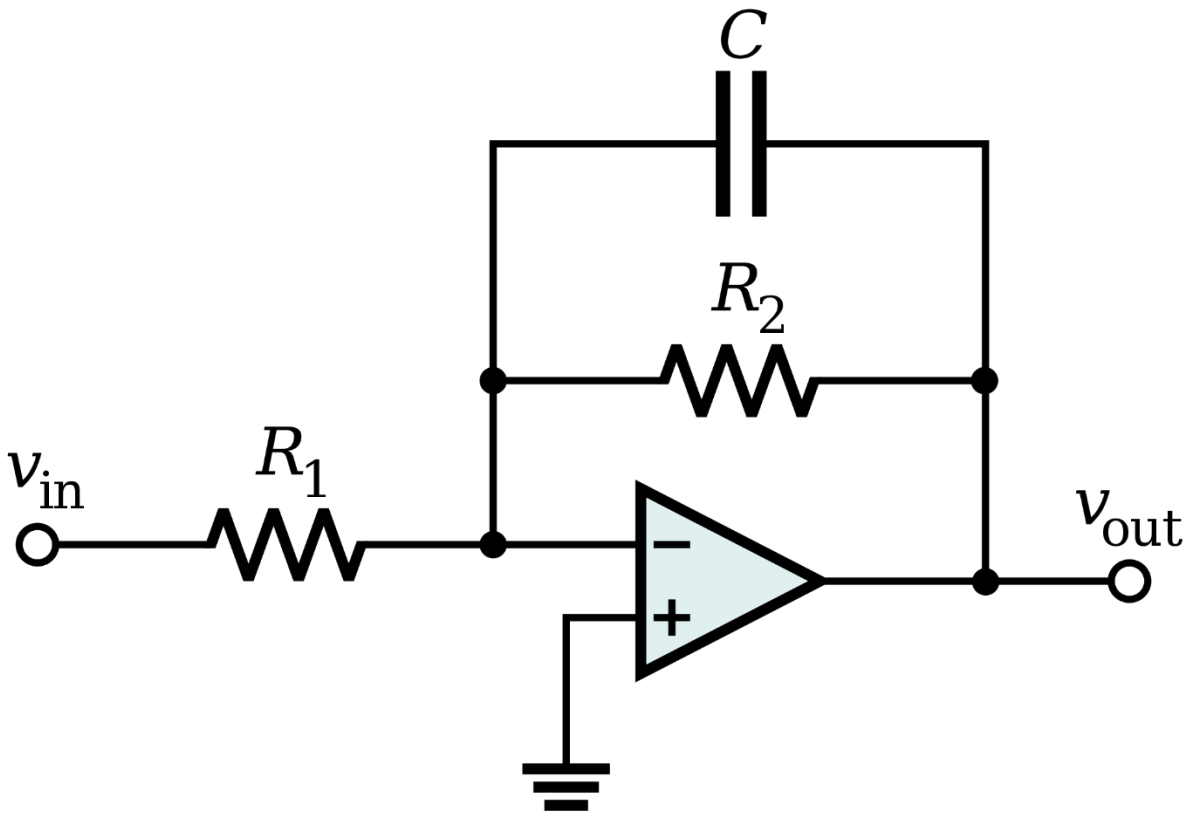
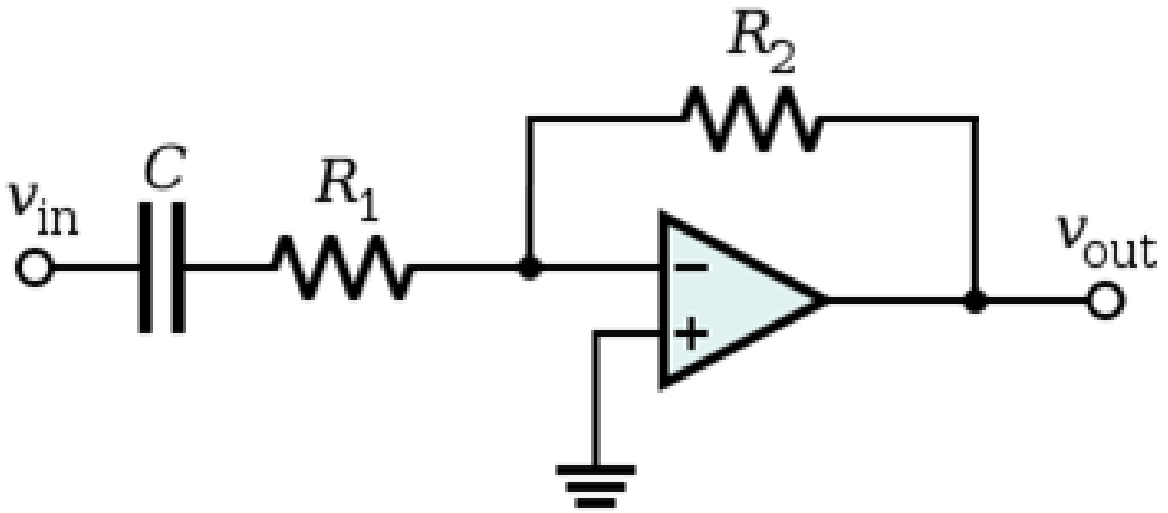
High Pass and Low Pass Filters

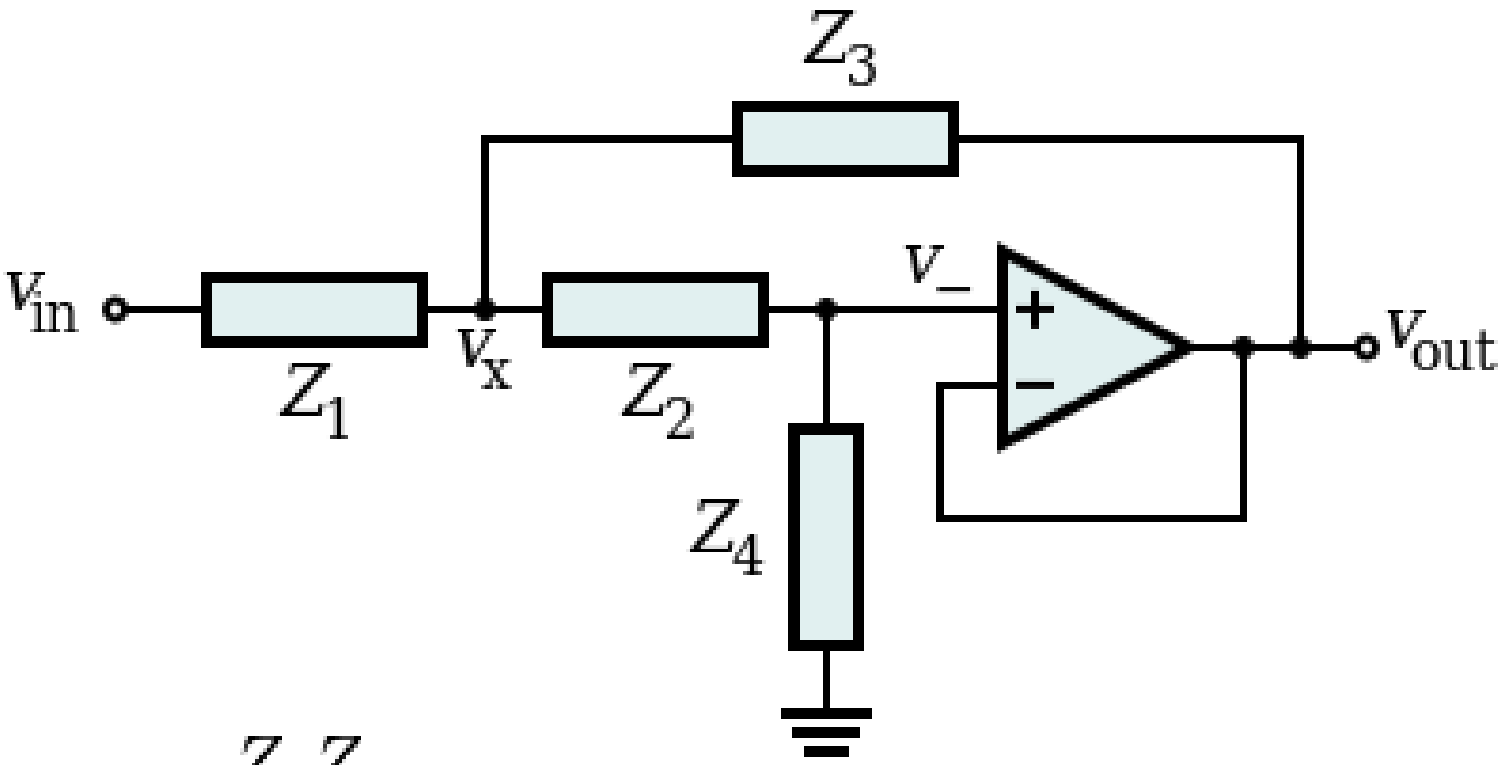




https://en.wikipedia.org/wiki/Low-pass_filter

https://en.wikipedia.org/wiki/High-pass_filter

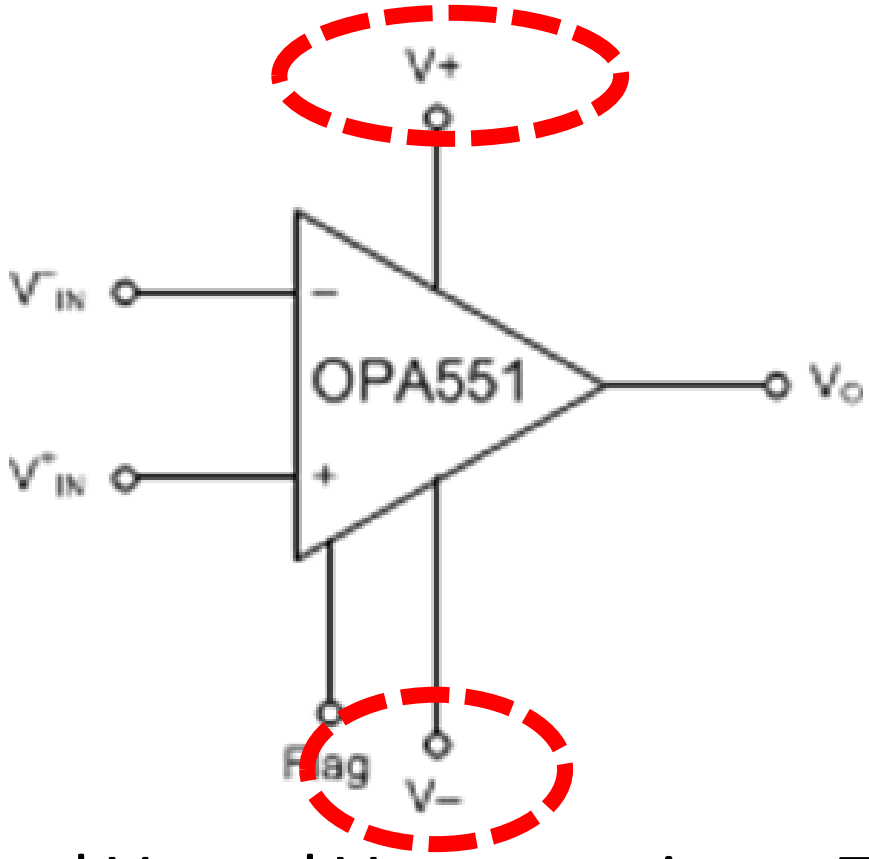
Sallen-Key Filter Topologies



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

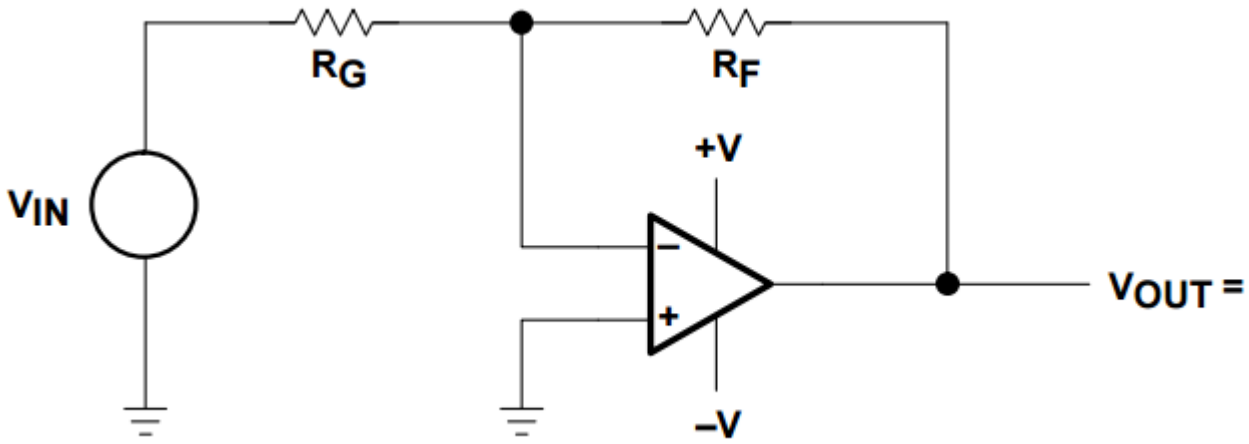
https://en.wikipedia.org/wiki/Sallen%E2%80%93Key_topology

Don’t Forget About Power



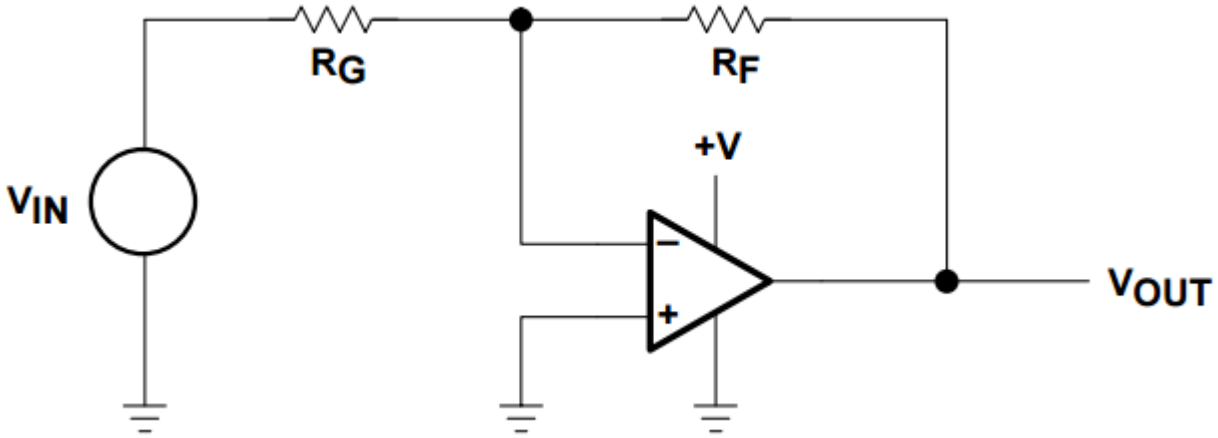
- So far, we’ve skipped V+ and V- connections. They are for power.
- V+ and V- Set maximum and minimum in/out voltage. Voltage rails.
- Use decoupling capacitors. Read all of the instructions!

Single Supply vs. Dual Supply + GND



Dual Supply + GND

Symmetric + and – V, GND halfway between

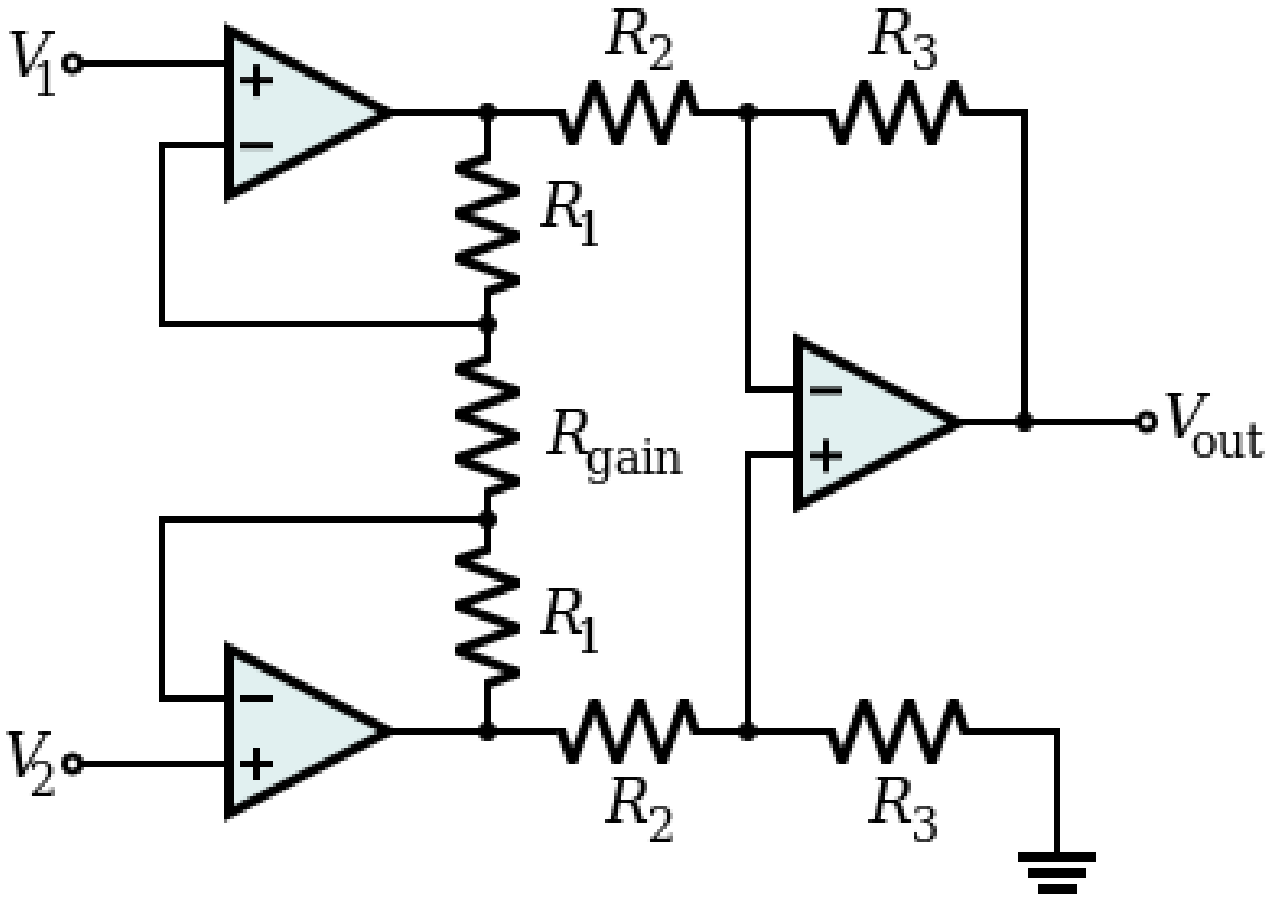


Single Supply

Only GND and +V. Can't generate negative voltage

http://www.ti.com/lit/an/sloa030a/sloa030a.pdf

Instrumentation Amplifiers



https://en.wikipedia.org/wiki/Instrumentation_amplifier#/media/File:Op-Amp_Instrumentation_Amplifier.svg