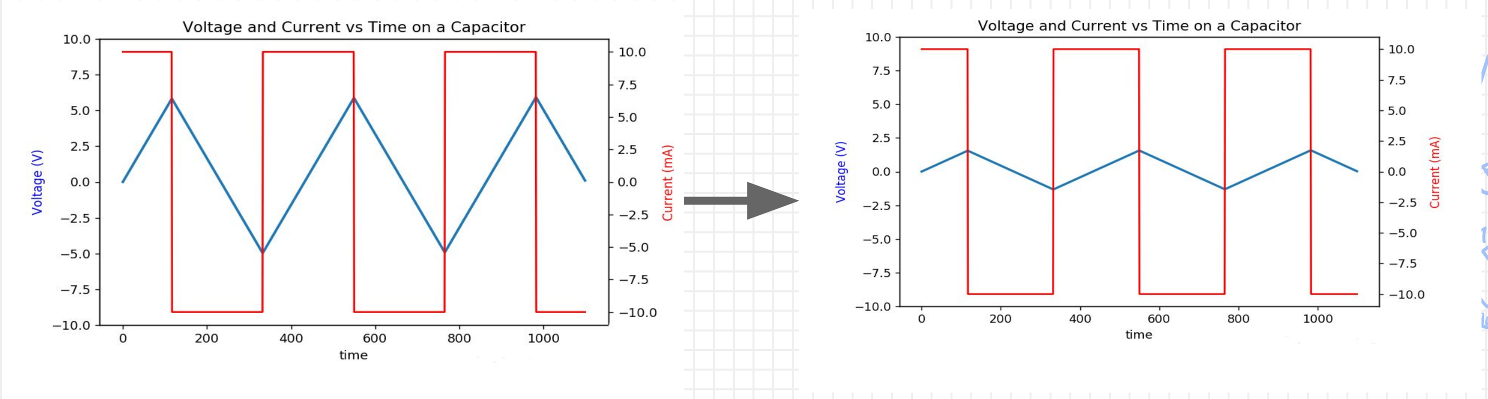
EE16A Lab: Touchscreen 3b

Announcements

- Wrapping up circuits with Touch 3B
  - If you can’t finish today, make it up in APS Buffer Week
- Can use your own computer for this lab

Last Week: Touch 3A

- Simulated a touch-sensing circuit
  - Current source onto cap gave $V(t) = \frac{I}{C}t + V_0$
  - Periodically charging and discharging gives a triangular shaped waveform
- **What changed between touch and no touch?**
  - Can tell apart this change with a comparator!



Last Week: Touch 3A

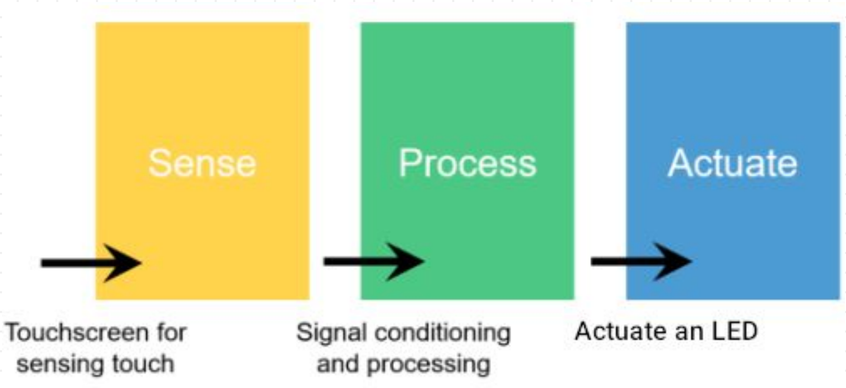
- Problem: we don’t have ideal square current sources
  - Need another way to implement last lab’s waveforms (the triangle wave output)
  - How do we go about creating a similar system that still fits our model?

This week: Touch 3B

- Explore an alternative to ideal current sources
    - Use our new (and proven) op amp skills
- Build a complete system that will detect touch and actuation

Electronic Systems: A review

- Sensing is only a part of a complete system. Most systems perform 3 tasks:
    - Sense (Physical to Electrical)
    - Process (Signal Conditioning)
    - Actuate (Electrical to Physical)



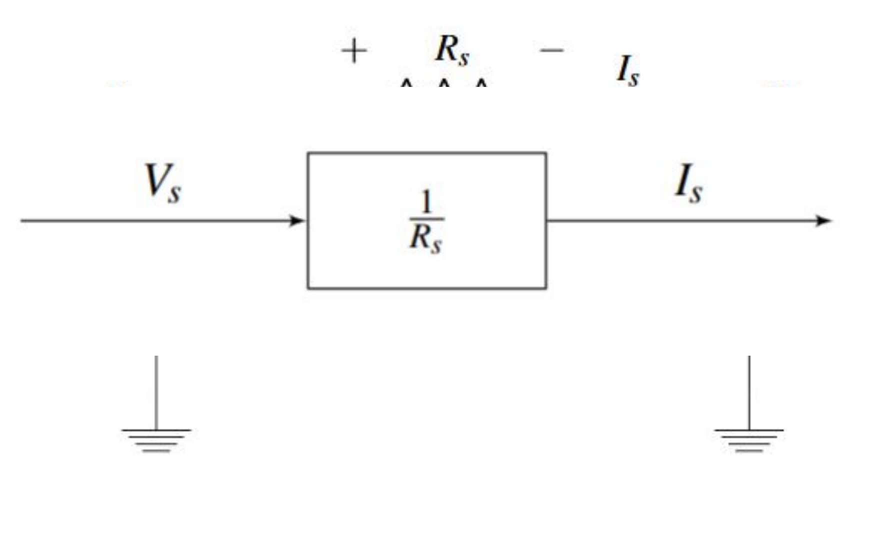
Building a current source (Note 20)

- Need a circuit that outputs a constant current regardless of voltage across
- What we have:
  - Voltage sources
  - $V = IR$ relationship for resistors
  - Note 20's guidance

First Attempt at a Current Source

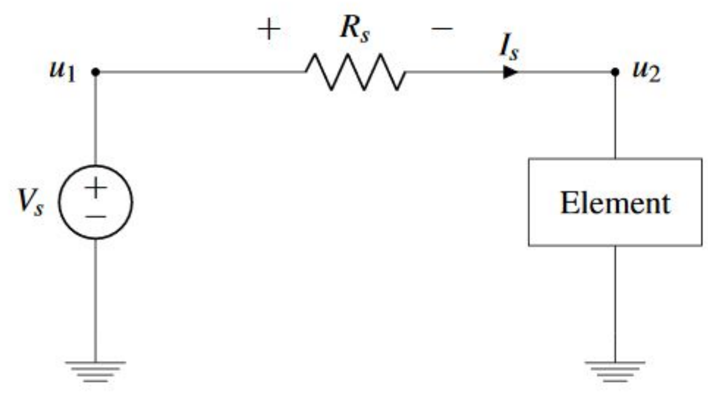
- If we have a voltage source and a resistor then we can create a "current source"

- The current is just (Vs-0)/Rs *since the other side is 0V*



First Attempt Evaluation

- Ok, now let's attach our load
- Assume that the element is a resistor of value RL
- **Does this work?**

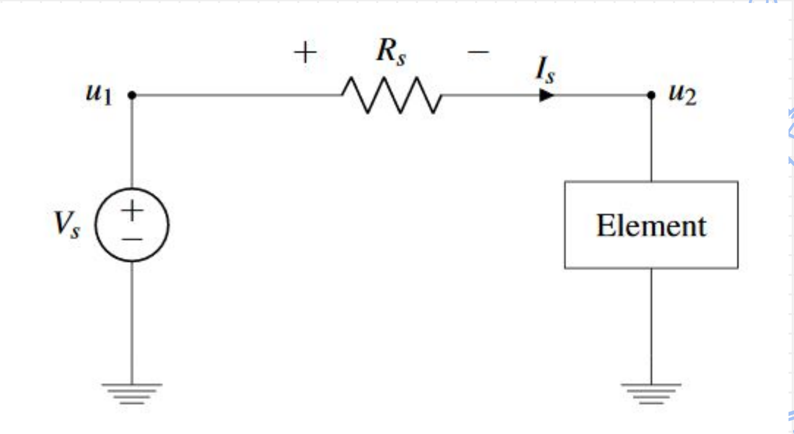


NOPE, it changes the current

$$I_s = \frac{V_s}{R_S + R_L}$$

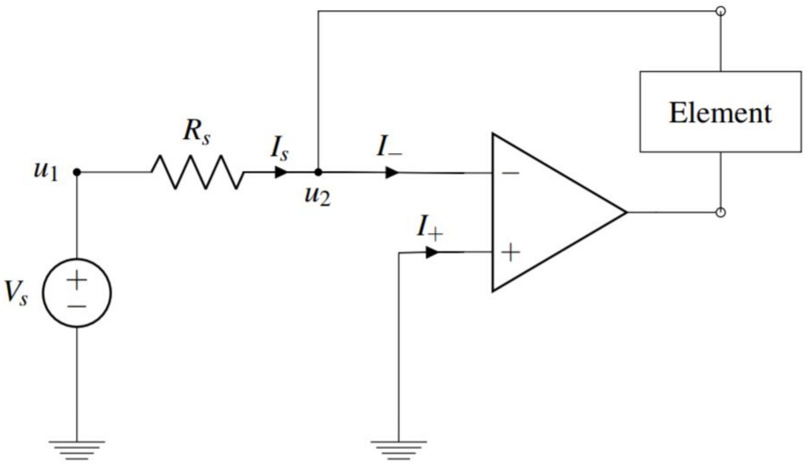
Let’s Try Again

- The issue here is that we had $I_s = \dfrac{V_s - 0}{R_S}$
- But a load made it so Rs isn’t connected to 0 on the other side
- We need to set the u2 node to 0 for this to work
- **Do you know anything that can force nodes to 0V?**



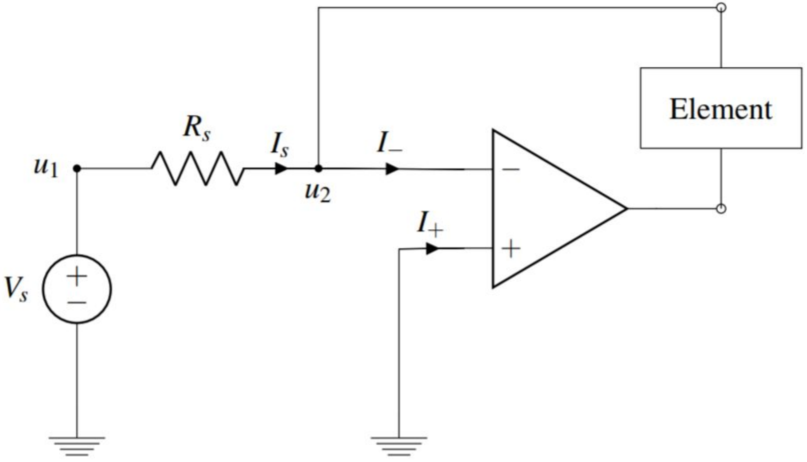
Note 20: An “almost” current source

- We can use an op amp!
  - GR #1: No current going in to op amp
  - GR #2: U+ = U-, so let’s make one of them 0V
    - **What must be true for this to hold?**



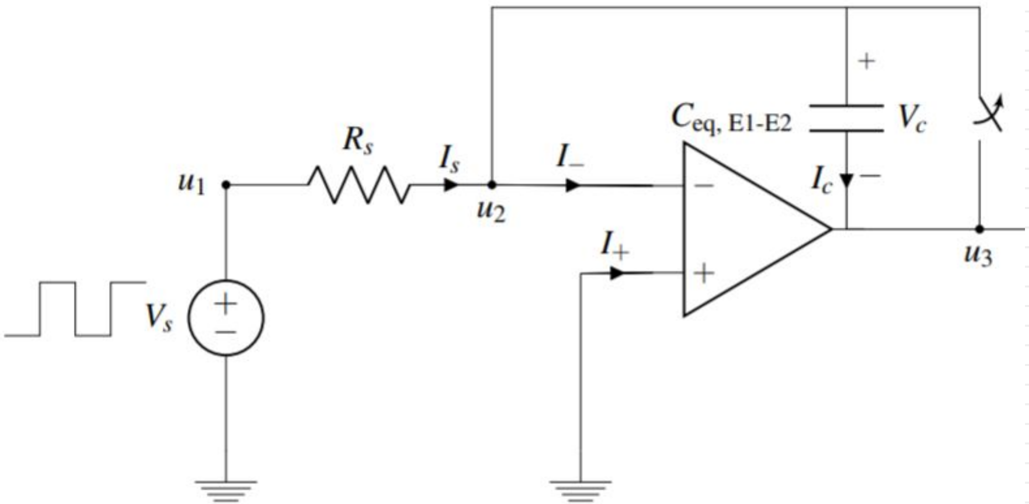
Note 20: An “almost” current source

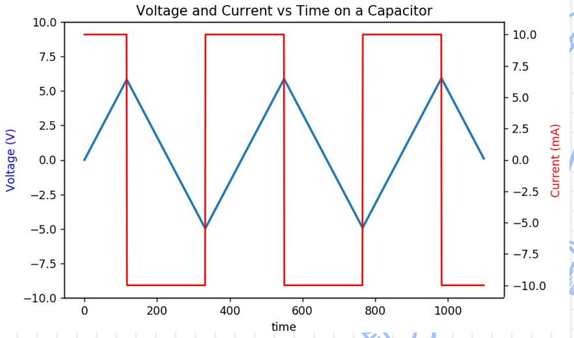
- Since we are in negative feedback, $u_2 = 0V$
  - $I_s = \frac{V_s - 0}{R_S}$
- All current will go to the element, since $I_- = 0$



Sensing a Completion

- Hook up our capacitive touch screen
- We get a constant current through the capacitor
- **What's the output of this circuit?**





Note 20: An “almost” current source

- Constant current is cool, but we want periodic current to discharge the cap.
- What if we periodically switch voltage?

$$I_S = \frac{V_s}{R} \longrightarrow I_S = \frac{-V_s}{R}$$

An Alternate Viewpoint

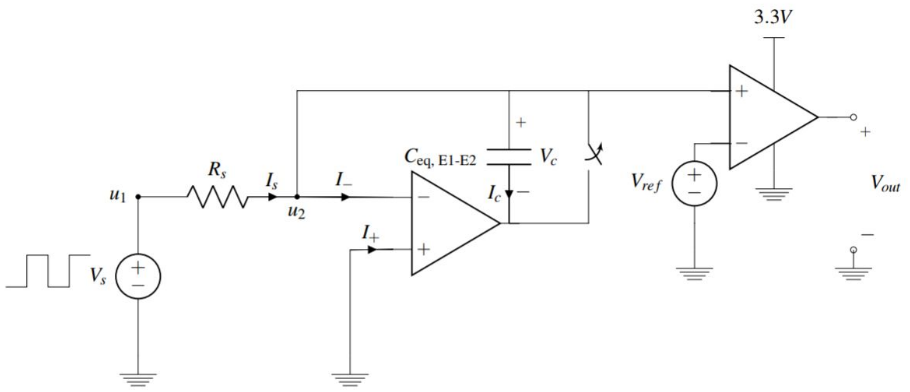
- Note that the output of this circuit is $V_{out} = -\frac{1}{R_s C}\int_0^t V_s dt$
- It's also an integral, just like last week. You can think of our new circuit as an "almost current source" or just trading current for voltage.
- We're now integrating a constant voltage instead of a current, but the net result is the same as last week
- *We traded one type of input for another!*
- *Variable voltage sources do exist, so this is good! What are they like though?*

What’s our new input?

- Function generator
- Can create different waves
- Treat it as a non-constant voltage source
- Now we can make the current source of our dreams!

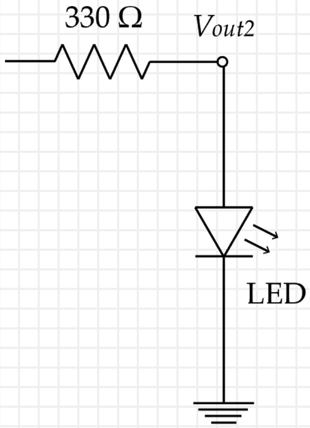
Processing the rest of our system

- Our circuit behaves just like we saw last week, great!
- Plus, no need to change how we do the processing: just feed the signal into a comparator

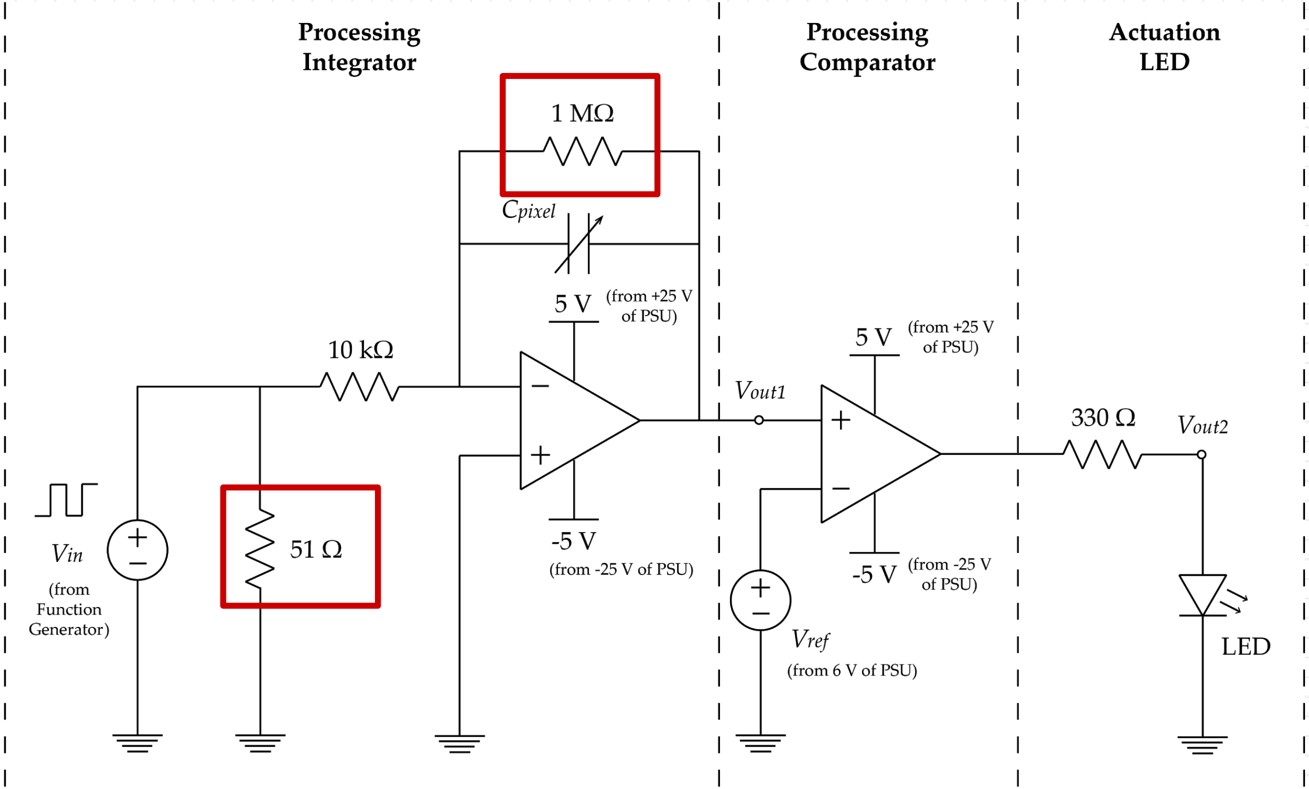


Completing Actuation

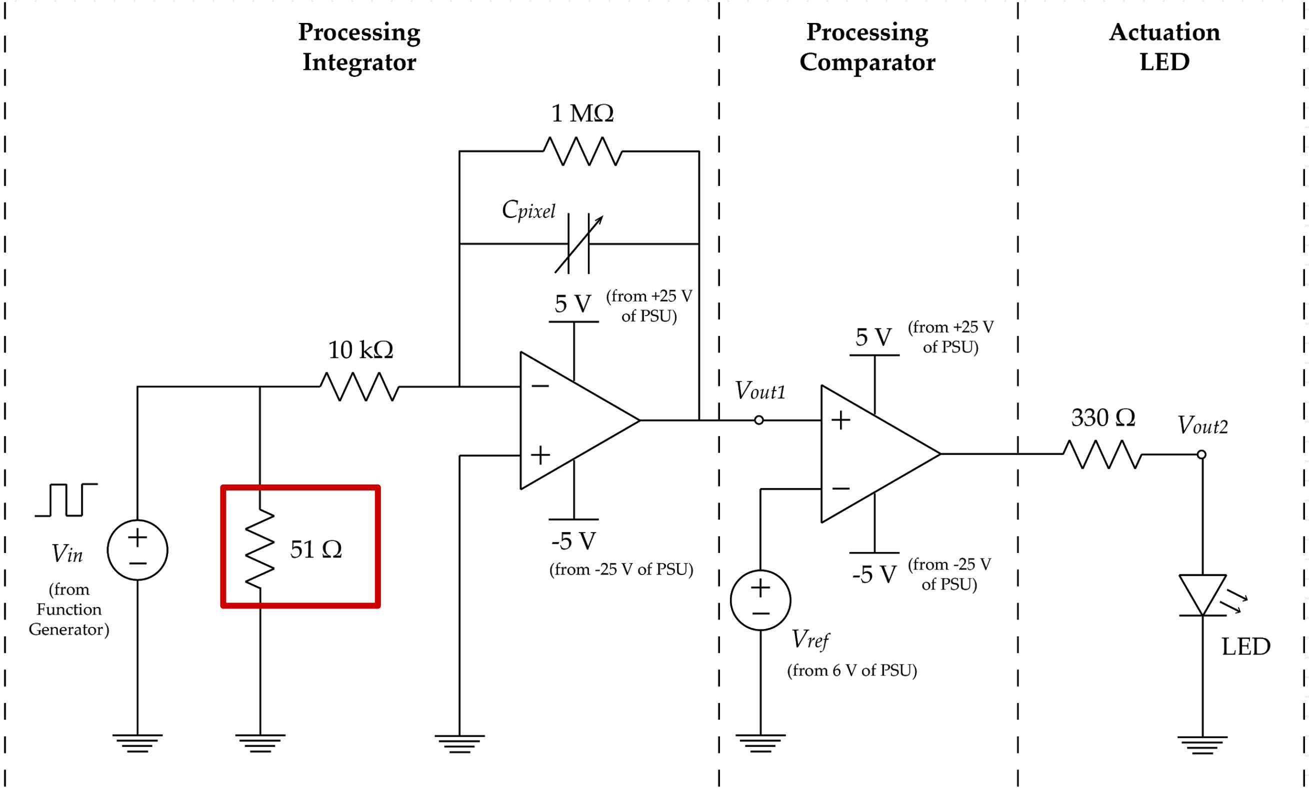
- We can really be actuating anything we want, but to visually tell if we're touching we can use an LED
- Two outputs (from last week):
  - Touching: -5V
  - No touching: a square wave
- LED will light up when the square appears!
  - But it repeats so fast it looks like it's constantly lit!



Our real world circuit

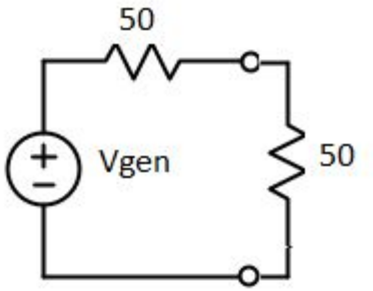


Our real world circuit



Aside: Voltage Dividers

- The function generator has a 50 Ohm source resistance
- Our function generator assumes a 50 Ohm load is attached (don't ask why).
  - **What's the voltage you get across this load?** (hint: it's easier than you think)



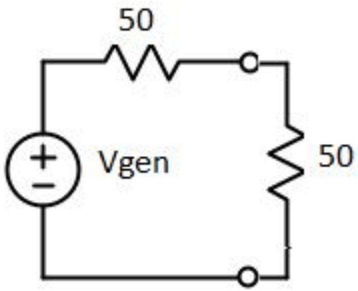
If you also attach a 50 Ohm load, then the load only gets ½ of Vin applied to it

Aside: Voltage Dividers

- The function generator will automatically double its output so that the voltage across the load is

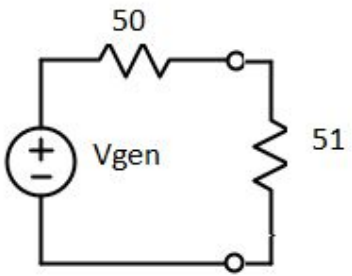
  ½ * 2 = 1*Vout

  As you would expect

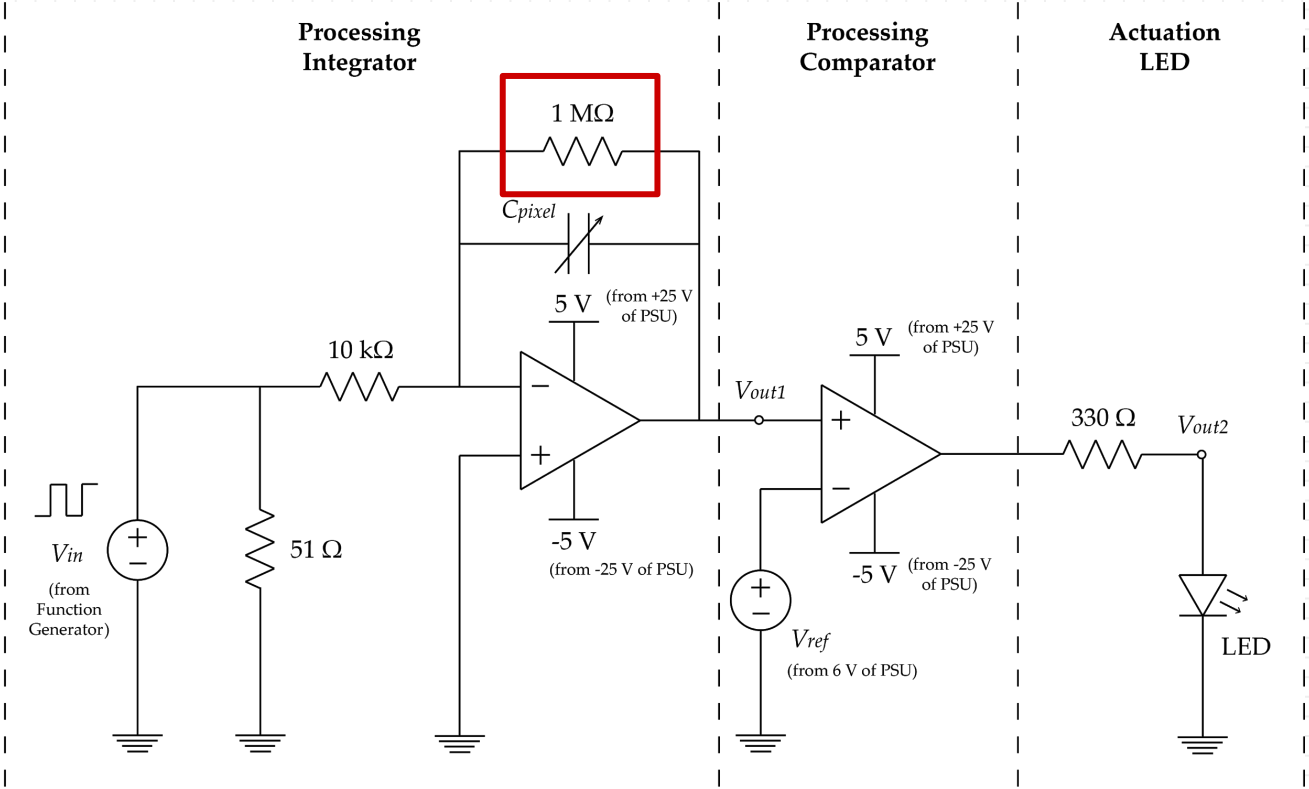


How does it help?

- Compute the thevenin resistance of our circuit from the input port
  - It’s about 51 Ohms
- Our circuit looks like a 51 ohm load with respect to the input, so the function generator is happy!
- (Note 50 Ohm resistors basically don’t exist so we use 51 because it’s the next closest value)



Our real world circuit



Another difference:

- It’s a little out of scope
- It ensures that the circuit is always in negative feedback
    - Since it’s 1 million Ohms it draws almost 0 current, and thus doesn’t really affect our analysis
- If it was not there, the Capacitor acts as an open during constant voltage, so there is no feedback

Taking the Limit

- Okay, cool the LED turns on/off.
- But [insert friendly lab TA name here], didn’t you say capacitive touchscreen is way better than resistive? Why do we only have one touch point instead of nine?

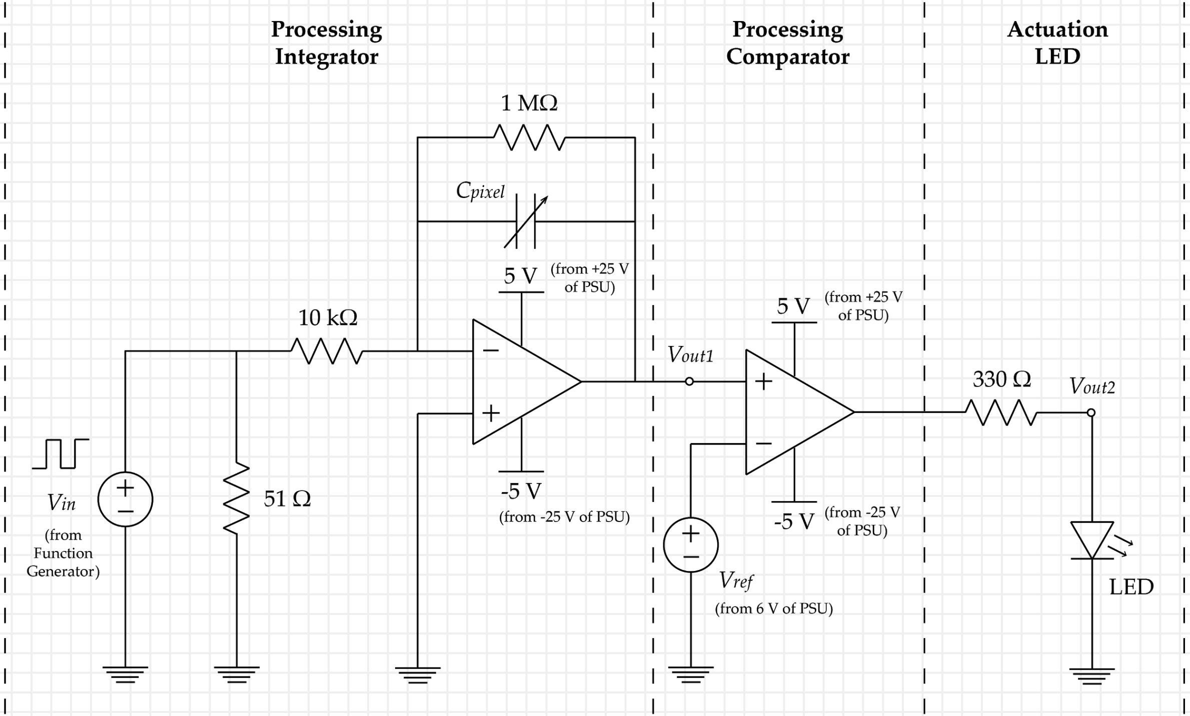
Taking the Limit

- Note that this isn't dependent on voltage dividers at all, only on if you are locally touching the capacitor
- **How to add more touch points?**
  - Duplicate the entire circuit and put them next to each other. Each one is a pixel
- They're independent, so the more you add the more points you can sense

Taking the Limit

- Make the caps really small, put them in the size of a screen
- Thousands of these sensing circuits can be made incredibly small
    - (less than 4mm x 4mm)
- Put a thousand of these and you can recognize 1000 different touch points
- No moving parts, much better (and more accurate) than the resistive touchscreen

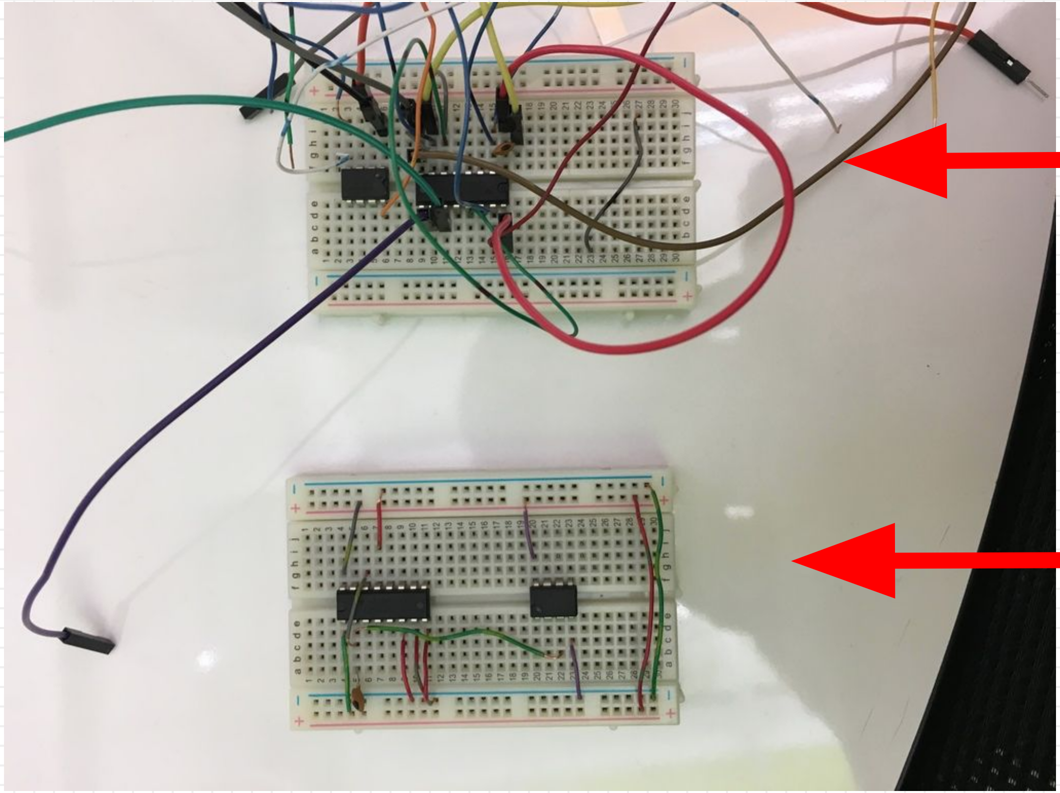
And that’s it!


Processing
Integrator
Processing
Comparator
Actuation
LED
1 MΩ
Cpixel
5 V
(from +25 V
of PSU)
10 kΩ
Vout1
5 V
(from +25 V
of PSU)
330 Ω
Vout2
Vin
(from
Function
Generator)
51 Ω
-5 V
(from -25 V of PSU)
-5 V
(from -25 V
of PSU)
Vref
(from 6 V of PSU)
LED

A Quick note

- Planar wiring **required**
- We can and will refuse to help you fix your circuit if it’s too messy
    - Use the copper wires at the TA desk and the wire strippers at your stations
    - Cut wires and resistors to be as short as you can and have them still work.

Why do u gotta be so strict tho :(



1.5 Hour to debug;
Falls apart easily

5 seconds to debug;
Practically 2D;
Lasts a lifetime

Keep your circuits neat!

- **Cut wires to correct lengths.**
- Place op amp across the middle of your breadboard.
- If circuit is not neat, will not debug until it is.