EECS16A Touchscreen 3B

Sit with the same lab partner as in 3A!

TA, ASE, ASE, ASE
Announcements

- Congrats on finishing the circuits midterm!
- Wrapping up circuits with Touch 3B
- Can use your own computer for this lab
Last time: Touch 3A

- Simulated a touch-sensing circuit
  - Current source onto cap gave
  - Periodically charging and discharging gives a triangular shaped waveform
- **What changed between touch and no touch?**
  - Can see this change with a comparator!

\[ V(t) = \frac{I}{C} t + V_0 \]
Last time: Touch 3A

- Implemented a Comparator and actuated an LED
- 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 \((V_s-0)/R_s\) 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 $R_L$
- Does this work?

NOPE, it changes the current

$$I_S = \frac{V_S}{R_S + R_L}$$
The issue here is that we had \[ I_s = \frac{V_s - 0}{R_s} \]

But a load made it so Rs isn’t connected to 0 on the other side.

We need to set the u2 node voltage 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?

\[ I_S = \frac{V_s}{R} \quad \rightarrow \quad I_S = \frac{-V_s}{R} \]
An alternate viewpoint

- Note that the output of this circuit is
- It’s also an integral, just like last time.
  - New circuit is 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 time
- We traded one type of input for another!
- Variable voltage sources do exist, so this is good! What are they like though?

\[
V_{out} = -\frac{1}{R_s C} \int_0^t V_s dt
\]
What’s our new input?

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

- Our circuit behaves as intended
- We can feed the new signal into our comparator circuit from last time
Our real-world circuit

Processing Integrator

- 1 MΩ
- C_{\text{pixel}}
- 5 V (from +25 V of PSU)
- -5 V (from -25 V of PSU)

Processing Comparator

- 5 V (from +25 V of PSU)
- -5 V (from -25 V of PSU)

Actuation LED

- 330 Ω
- V_{\text{out1}}
- V_{\text{out2}}
- LED

V_{\text{in}}

- 51 Ω
- (from Function Generator)

V_{\text{ref}}

- (from 6 V of PSU)
Our real-world circuit

Processing Integrator

- \( V_{\text{in}} \)
- \( 10 \, \text{k}\Omega \)
- \( 51 \, \Omega \)
- \( C_{\text{pixel}} \)
- \( 1 \, \text{M}\Omega \)
- \( 5 \, \text{V} \) (from +25 V of PSU)
- \( -5 \, \text{V} \) (from -25 V of PSU)

Processing Comparator

- \( V_{\text{out1}} \)
- \( 330 \, \Omega \)
- \( 5 \, \text{V} \) (from +25 V of PSU)
- \( -5 \, \text{V} \) (from -25 V of PSU)

Actuation LED

- \( V_{\text{out2}} \)
- \( V_{\text{ref}} \) (from 6 V of PSU)
- LED
Note: Voltage dividers

- The function generator has a 50 Ohm source resistance
- Our function generator also assumes a 50 Ohm load is attached (just because).
  - What’s the voltage you get across this load?

If you attach a 50 Ohm load, then the load only gets ½ of Vin applied
Note: Voltage dividers

- The function generator will automatically double its output voltage ($V_{in}$) so that the voltage across the load ($V_{load}$) is what you would expect after it is halved.
What does the 51 ohm do?

- Compute the Thevenin resistance of our circuit from the input port
  - It’s about 51 Ohms
- Our circuit (from the input) looks like a 51 Ohm resistor
What does the 51 ohm do?

- 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

Processing Integrator

1 MΩ

C_{pixel}

5 V (from +25 V of PSU)

-5 V (from -25 V of PSU)

Processing Comparator

V_{out1}

5 V (from +25 V of PSU)

Actuation LED

330 Ω

V_{out2}

5 V (from -25 V of PSU)

-5 V (from -25 V of PSU)

V_{ref} (from 6 V of PSU)

LED

V_{in}

(from Function Generator)

10 kΩ

51 Ω
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
That’s it!
Quick note

- Planar wiring **required**
- We can and will refuse to help you fix your circuit if it’s too messy
  - Use the breadboarding 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 (should already be there).
- If circuit is not neat, will not debug until it is.
- Get Started!
And that’s it!

### Band Colors

<table>
<thead>
<tr>
<th>R</th>
<th>Band Colors</th>
</tr>
</thead>
<tbody>
<tr>
<td>51 Ω</td>
<td>Gr Br Bl G</td>
</tr>
<tr>
<td>10 kΩ</td>
<td>Br Bl O G</td>
</tr>
<tr>
<td>1 MΩ</td>
<td>Br Bl Gr G</td>
</tr>
<tr>
<td>330 Ω</td>
<td>O O Br G</td>
</tr>
</tbody>
</table>