EE16A Lab: Touchscreen 3a
Announcements

- Midterm 2 on Friday 11/2
- Schedule:
  - This week: Touch 3a
  - Next week: Buffer (Touch 1, 2, 3a)
  - The week after: Touch 3b
    - Touch 3b can be completed in APS buffer week (more details later)
- This lab is pretty theoretical!
Last Week

- Resistive touchscreen
  - Use voltages as signals
  - Two voltage dividers perpendicular to each other
- Why are resistive touchscreens obsolete?
  - Single touch only
  - Moving parts and complicated structure
Capacitive Touchscreens
This Week: Capacitive Touchscreen

● Today: capacitive touchscreens
  ○ Exploits capacitive properties of finger/body
  ○ Touching the screen changes the capacitance
● A lot better!
  ○ No moving parts
  ○ Multi-touch is possible
  ○ More sensitive
● How to measure capacitance?
Capacitance and the touchpad

What is a capacitor and how does it work?

[Diagram showing the structure of a capacitor with conductive plates and dielectric material.]
Touching Changes Capacitance

- Screen = unknown capacitance
- Screen + finger = different capacitance

Let’s try to figure out a way to detect this change in capacitance!
How to Detect Changing Capacitance?

- Not so easy to directly measure
- Instead, we try to measure something that a change in capacitance would create
  - Current can be hard to measure directly
  - Changes in voltage are easy to see
What do we know about capacitors?

\[ I = C \frac{dV}{dt} \]

- Note that if current is constant, voltage is just linear with time
  - integrate to get an expression
- Having a linear voltage signal is easy for us to read!
Finding the exact relationship $V(t)$ For a Constant Current

\[ I = C \frac{dV}{dt} \]

\[ \frac{dV}{dt} = \frac{I}{C} \]

\[ \int_{0}^{t} dV = \int_{0}^{t} \frac{I}{C} dt \]

\[ V(t) - V(0) = \frac{I}{C} t \]

\[ V(t) = \frac{I}{C} t + V(0) \]

- Voltage increases with time!
- Note: we’re assuming $I(0) = 0$
- What’s the slope of this line?
Finding the exact $V(t)$

Looks good right?  

$$V(t) = \frac{I}{C} t + V(0)$$
Issues with this model

- How high can $V(t)$ get? Too high.
  - In theory: infinity. In practicality: maybe not quite infinity, but still bad
- We’re going to need to discharge it to make its usage practical
  - Periodically apply a negative current
    \[ V(t) = \frac{I}{C} t + V(0) \rightarrow V(t) = -\frac{I}{C} t + V(0) \]
- Two different slopes!
- What shape/waveform/pattern/function over time does this give us now?
Applying negative current: The Square Wave

- A wave that only has two values: high and low
- We will use this to charge and discharge the capacitor
- High: Positive 10mA
- Low: Negative 10mA
- Note: We have 0mA in the beginning to set the initial condition
New waveform

Note: $V(0) = 0$ in this plot
Adding some touch ups

- We know how to measure voltage
- Reminder: we want to detect touch by seeing a change in voltage
- We need to quantify what it means for us to touch the screen
How does our finger affect the system?

- How does that change affect our voltage?
  \[ V(t) = \frac{L}{C} t - V_0 \]

- How does the change in our system affect the waveform?
Detecting touch

How do we detect this?
- Want to compare something about these two waveforms. What?
Comparators

- Idea: compare the peaks to some reference voltage
  - Higher peak: no touch
  - Lower peak: touch
Measuring Change in Voltage: Comparator

- Compares input voltage at positive terminal to a reference voltage at negative terminal (think “>” symbol)

If $V_{IN} > V_{REF}$ then $V_{OUT} = +V_{CC}$
If $V_{IN} < V_{REF}$ then $V_{OUT} = -V_{CC}$
Connecting to future lectures and lab

- Ideal current sources like this do not exist
- We need a different circuit topology that can help us generate the square wave current source
- Need a bit more knowledge on OpAmps and design principles for circuits
- More on this during Touchscreen 3B
Notes

- Materials: 2 copper strips, glass slide, tape, multimeter + probes
- Only need a bit tape and enough solder for two connections
- Remember to remove the backing of the copper strips [they are adhesive]
- Make sure the copper strips span the entire length of the glass slide