EE16A Lab: Touchscreen 3a

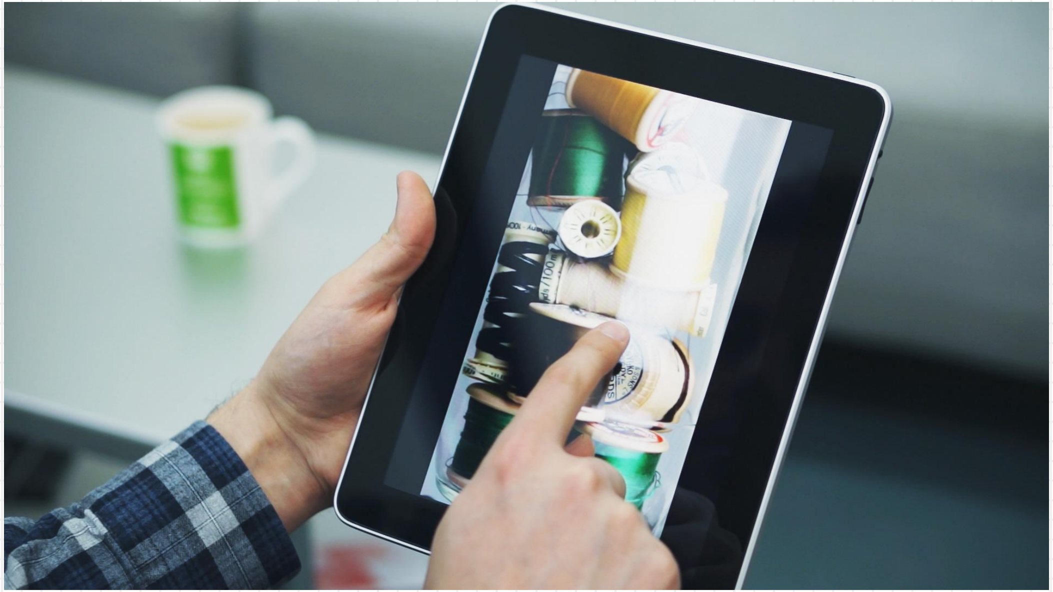
Announcements

- 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

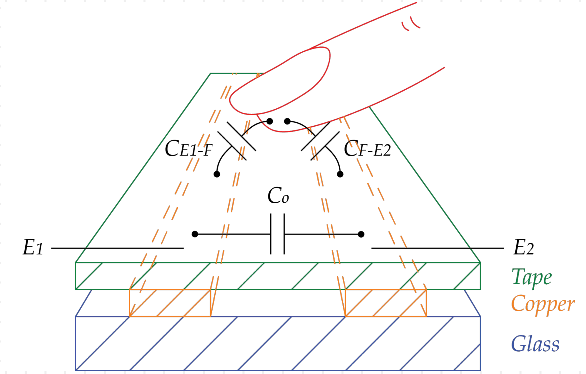


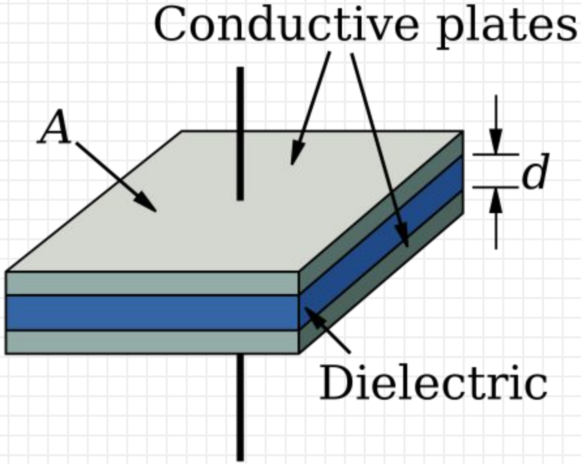
This Week: Capacitive Touchscreen

- 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?





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

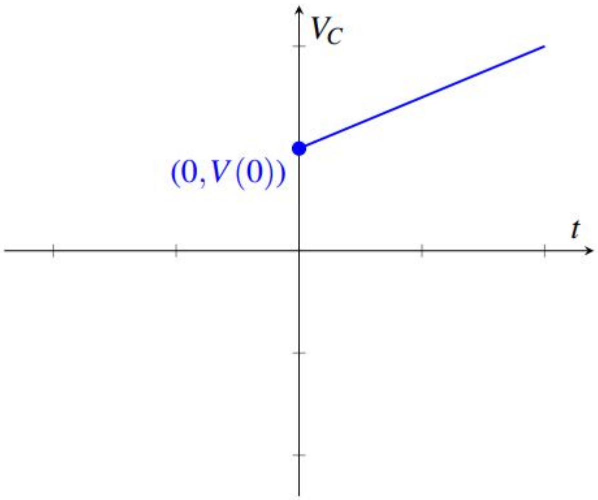
$$I = C\frac{dV}{dt}$$

$$\frac{dV}{dt} = \frac{I}{C}$$

$$\int_0^t dV = \int_0^t \frac{I}{C}\,dt$$

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

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

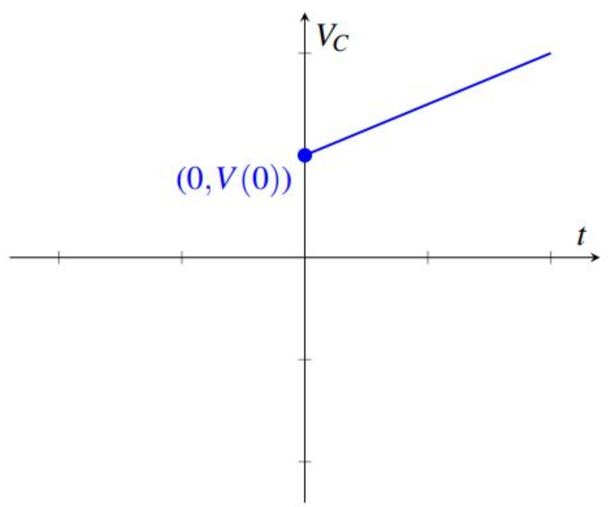


- Voltage increases with time!
- Note: we're assuming I(0) = 0
- **What's the slope of this line?**

Finding the exact V(t)

Looks good right?

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



Issues with this model

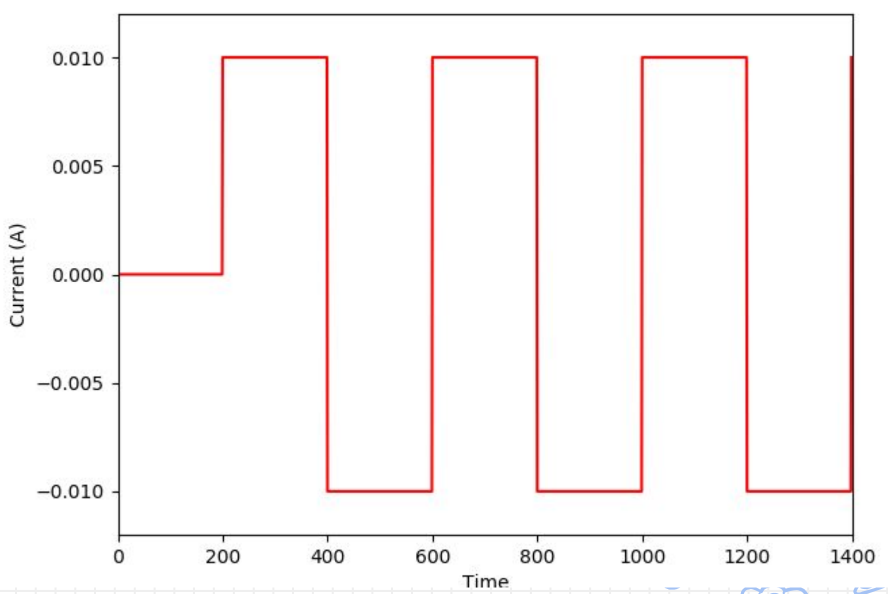
- How high can V(t) get? Too high.
  - In theory: infinity. In practicality: maybe not quite infinity, but still bad
- We're going to need to discharge it to make its usage practical
  - Periodically apply a negative current

$$V(t) = \frac{I}{C}t + V(0) \quad \rightarrow \quad V(t) = -\frac{I}{C}t + V(0)$$

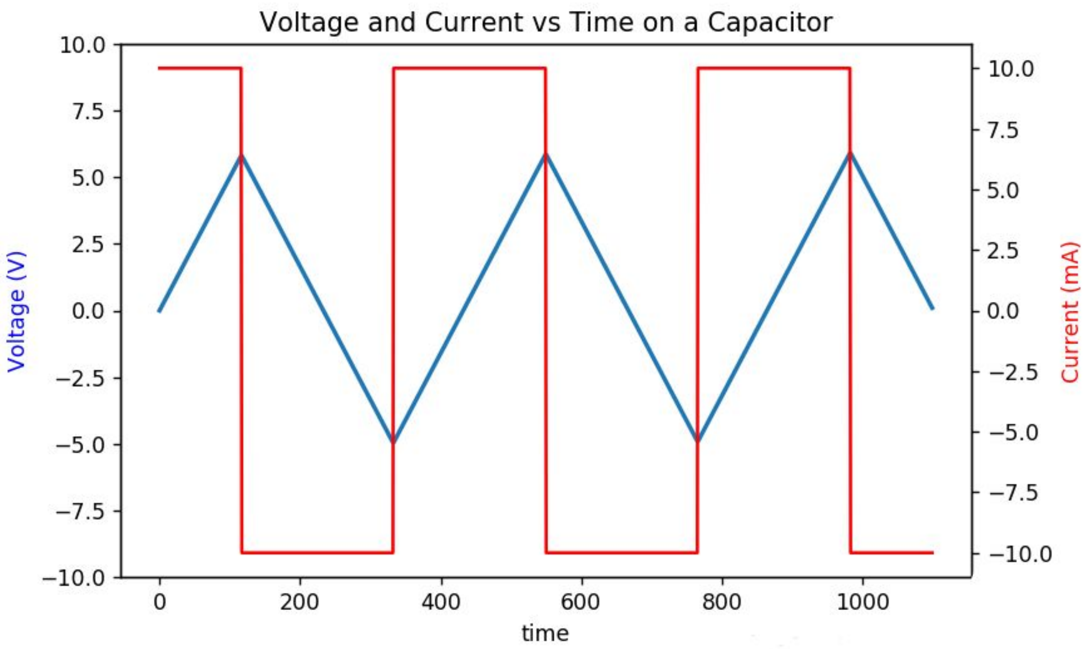
- Two different slopes!
- **What shape/waveform/pattern/function over time does this give us now?**

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

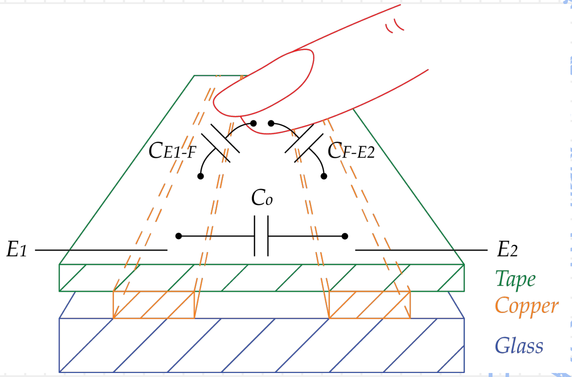
- We know how to measure voltage
- Reminder: we want to detect touch by seeing a change in voltage
- We need to quantify what it means for us to touch the screen

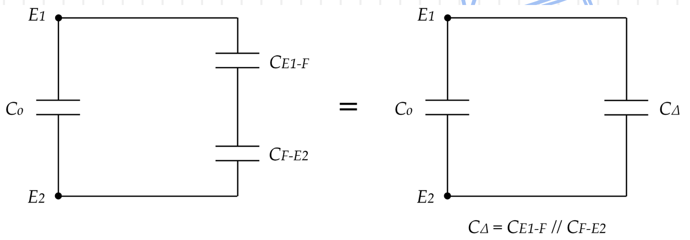
How does our finger affect the system?

- How does that change affect our voltage?

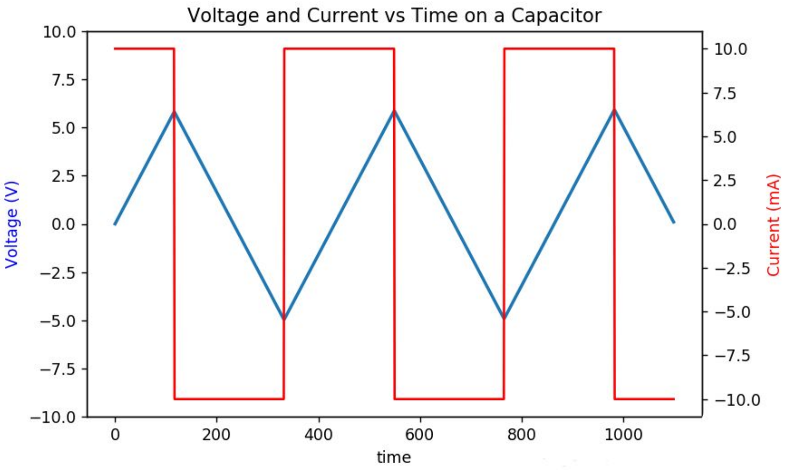
$$V(t) = \frac{I}{C}t - V_0$$

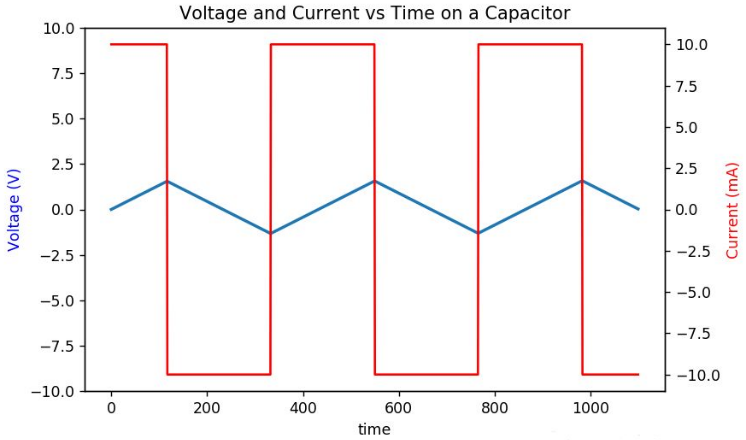
- How does the change in our system affect the waveform?





Detecting touch

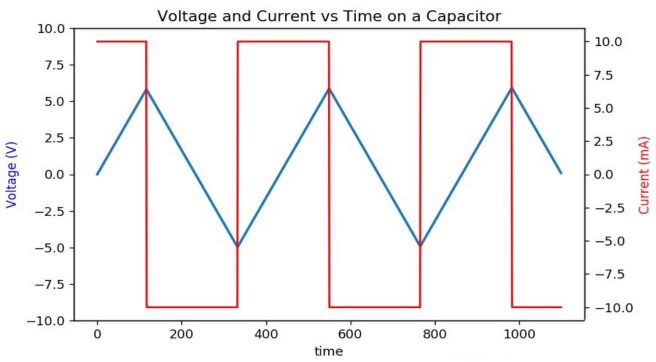


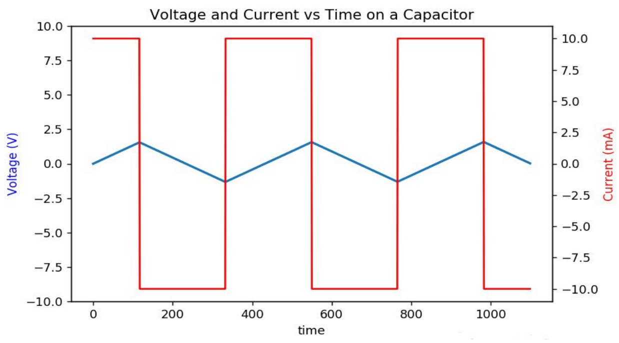


- How do we detect this?
    - Want to compare something about these two waveforms. **What**?

Comparators

- Idea: compare the peaks to some reference voltage
  - Higher peak: no touch
  - Lower peak: touch

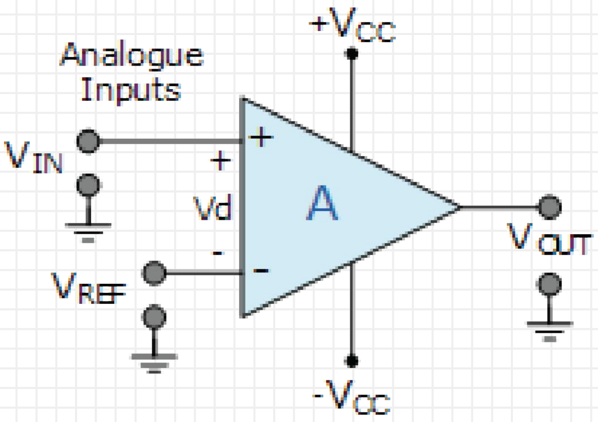


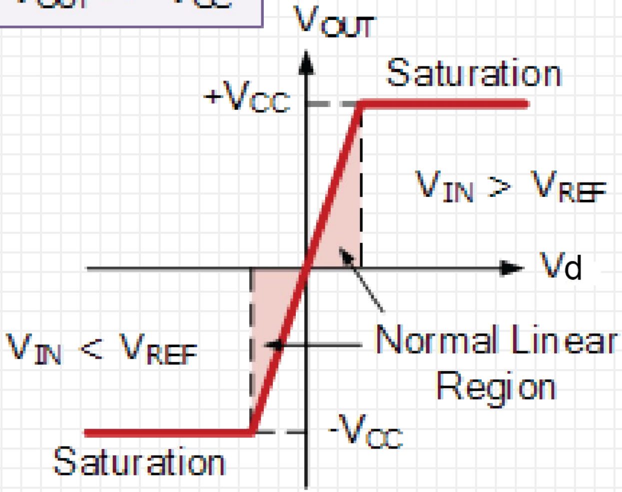


Measuring Change in Voltage: Comparator

- 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**