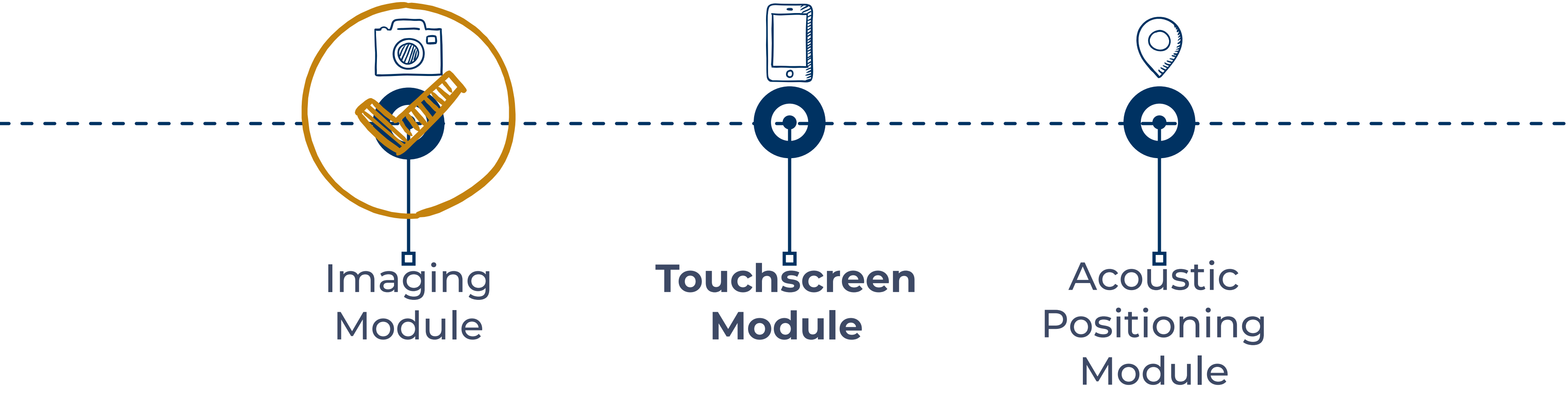
EECS 16A Touchscreen 3A

TA, ASE, ASE, ASE

Semester Outline



Lab Test??!!

If you didn't catch the Ed post, we will **NOT** be having a lab test this semester (April Fools!)

Last Time

- Resistive touchscreen
  - Use voltages as signals to determine touch
  - Multiple voltage dividers perpendicular to each other
  - Used voltage dividers with equivalent series resistances to find voltage values at different points
  - Did this in 2 orientations to detect touch points in 2D!

- Why are resistive touchscreens obsolete?
  - Single touch only
  - Moving parts and complicated structure
  - Need physical ‘contact’ between layers

This Week: Capacitive Touchscreens

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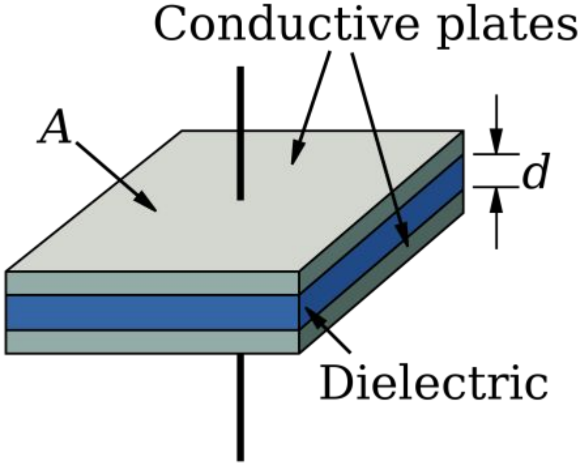
- Today: capacitive touchscreens
  - Exploits capacitive properties of finger/body
  - Touching the screen changes the capacitance
  - Build your own touchscreen using capacitors and a glass screen
  - Use Op-Amps (new circuit element!) to discretize touch

This Week: Capacitive Touchscreen

- Much better than resistive!
  - No moving parts
  - **Multi-touch is possible**
  - **More sensitive**
- How to measure (change in) capacitance?

Capacitance and the touchpad

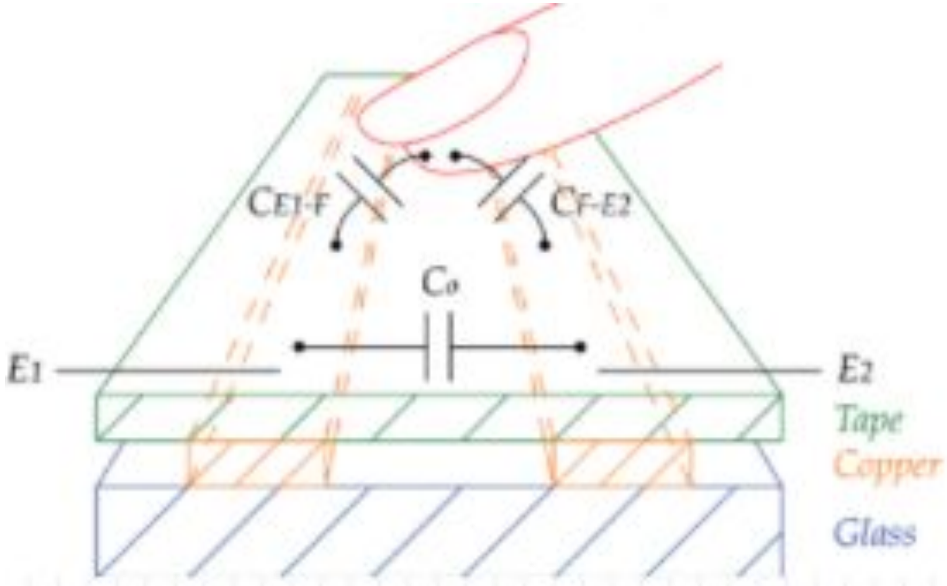
$$C = \frac{\epsilon_0 A}{d}$$



Capacitive Touchscreen Setup

Metal/Conductive Plate = Copper Tape

Dielectric = Scotch Tape

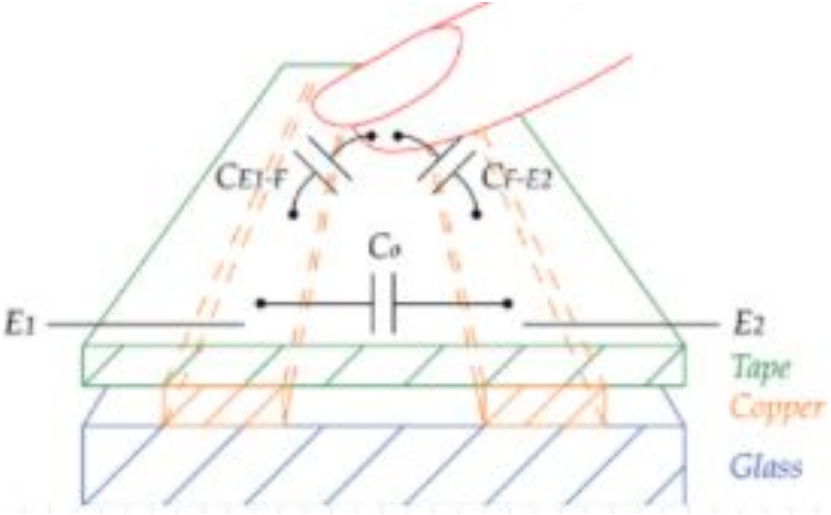


Touching Changes Capacitance

- Screen = some capacitance
- Screen + finger = different capacitance

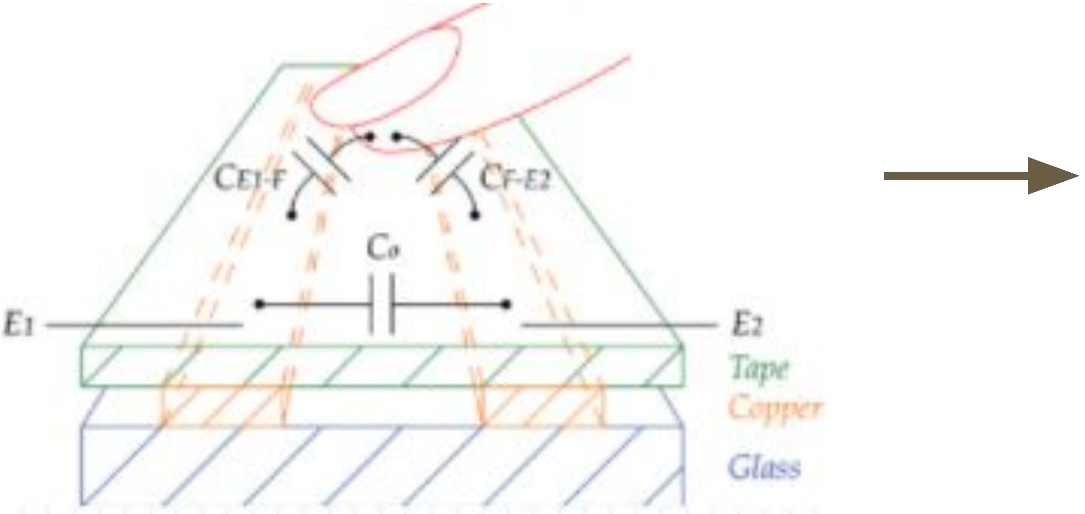
How do we detect this change in capacitance?

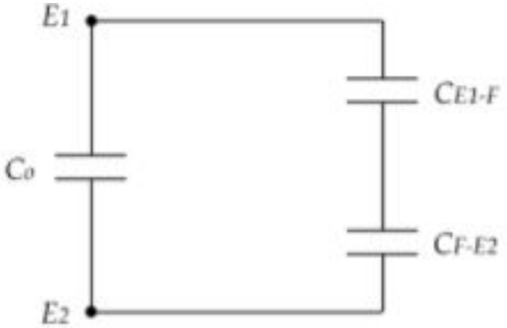
NOTE: This layout is slightly different compared to the one in the notes. This is easier to realize in the lab but the math is the same.



Effect of Touch on System

- Touch introduces two new capacitors to the system



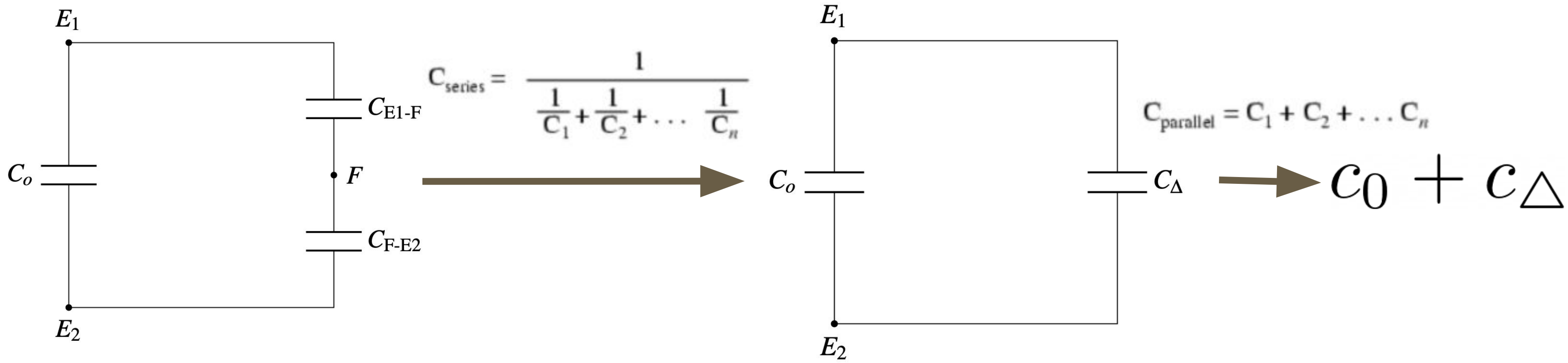


$$C_{series} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \ldots \frac{1}{C_n}}$$

$$C_{parallel} = C_1 + C_2 + \ldots C_n$$

Effect of Touch on System

- How does a touch affect the total capacitance?



When a finger is present (touch) $c_\triangle$ > 0

When a finger is not present (no touch) $c_\triangle$ = 0 (since CE1-F and CE2-F will not exist)

Capacitors and Current

- 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!
- Relation between voltage, current and capacitance of a capacitor gives by:

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

Refer to Note 17 and/or the Pre-Lab Reading for Touch 3A for the derivation

Finding V(t)

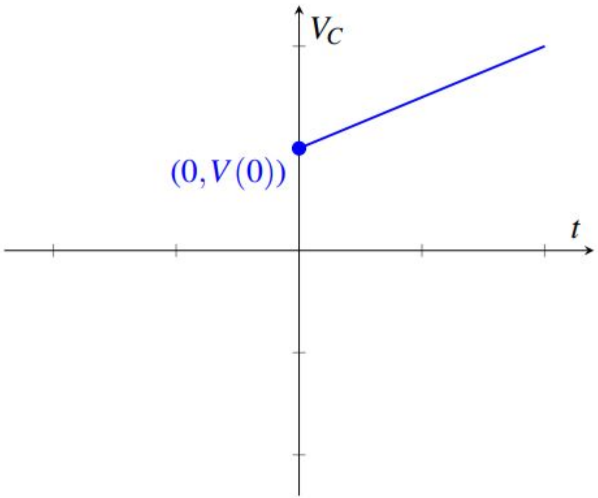
$$I = C\frac{dV}{dt}$$

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

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

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

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



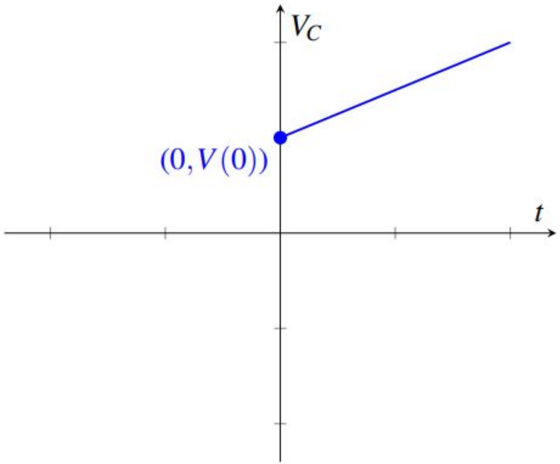
- Voltage increases with time!
- Note: we're assuming constant I
- **What's the slope of this line?**
  - y = mx + c

Effect of Touch on System

- Touch introduces capacitance, so C increases
- How does touch affect our voltage waveform?

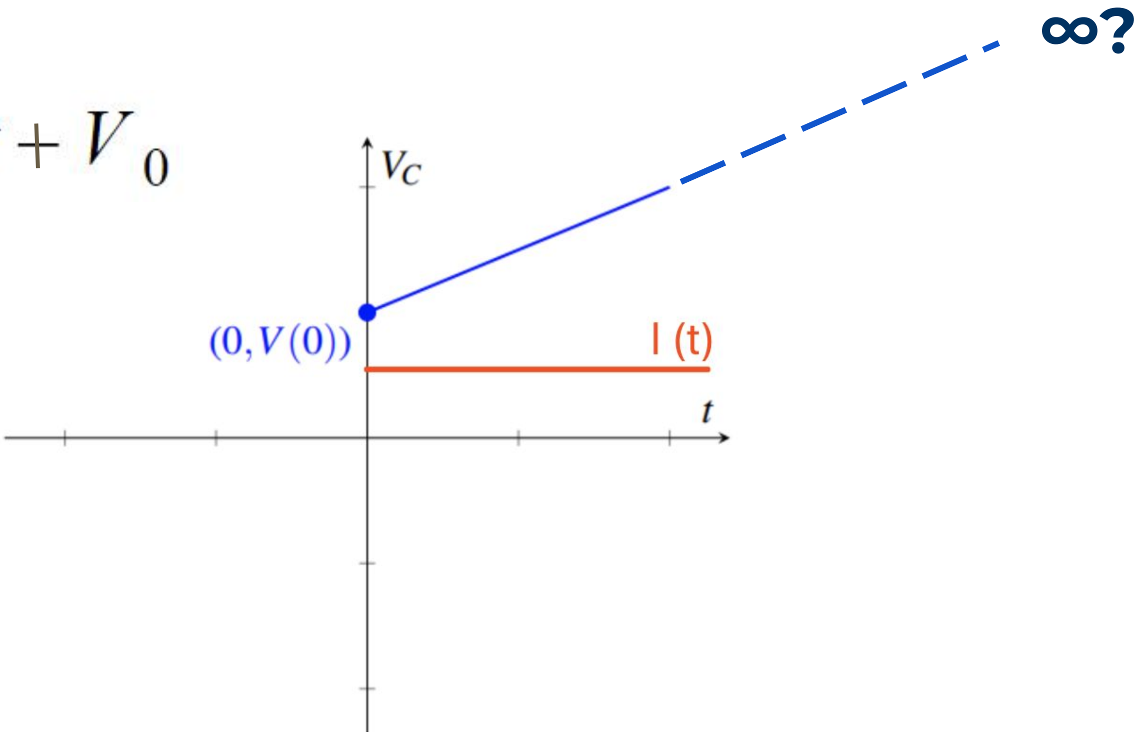
$$V(t) = \frac{I}{C}t + V_0$$

- **What happens to the slope?**
  - HINT: Touch = Increase in Capacitance



Issues with the Model

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



Issues with the Model

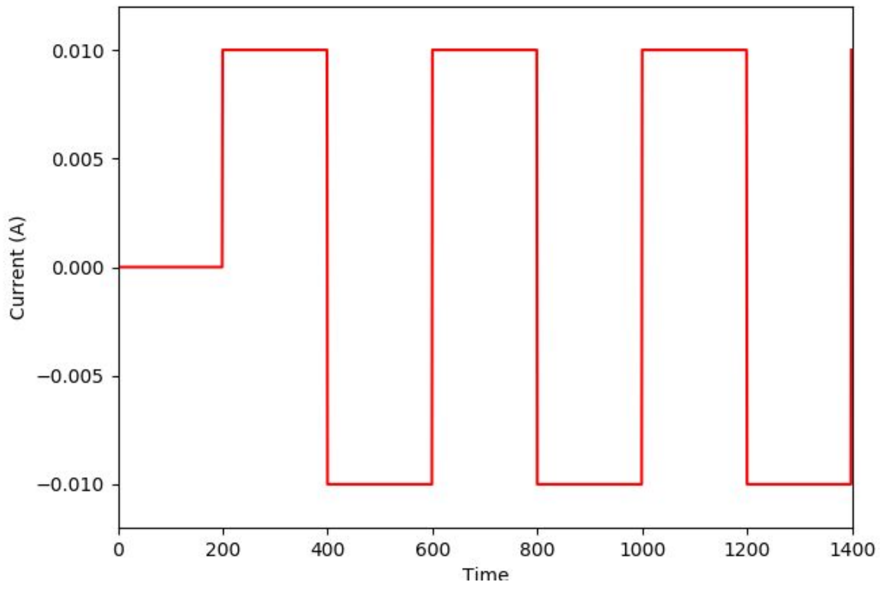
- How high can V(t) get?
  - In theory: infinity. In practice: not quite, but still too high.
- We need to discharge it to make its usage practical
  - Periodically apply negative current

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

- Two different slopes!
- **What's the shape of the applied current?**

Square Wave Current Source

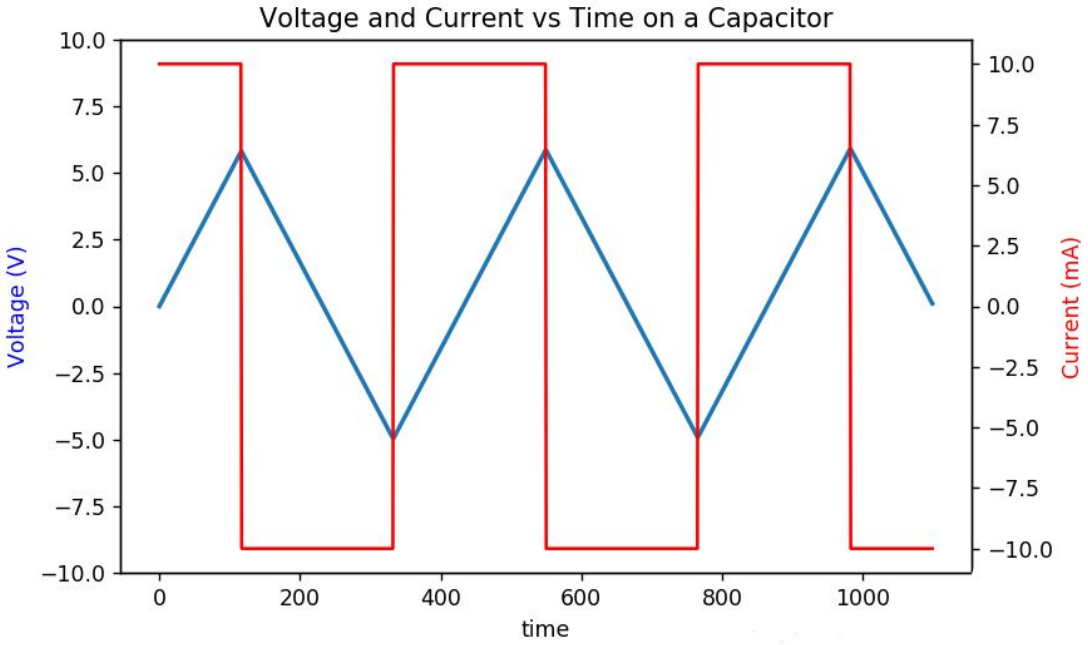
- Square waves only have two values: high and low (on and off)
- Use this to charge + discharge the capacitor
- High: +10mA
- Low: -10mA
- Note: We have 0mA in the beginning to set initial condition



Triangle Wave Voltage Reading

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

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

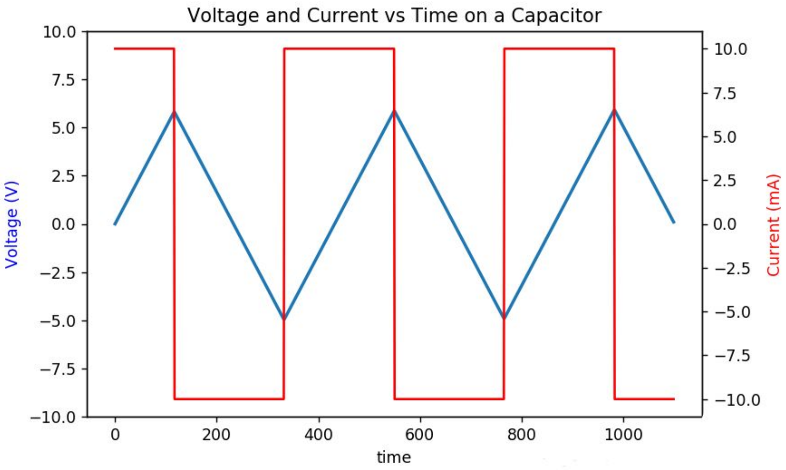


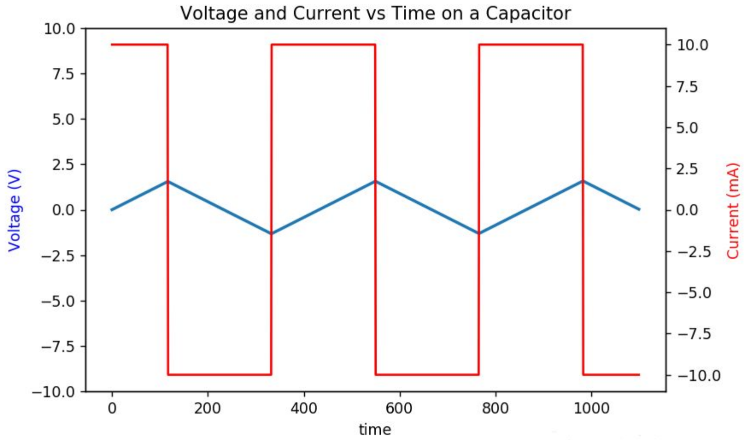
Note: V(0) = 0 in this plot

Measuring Capacitance Changes

- Capacitance isn't easy to directly measure, but we've mapped our capacitance into our voltage waveform
    - Current can be difficult to measure directly
    - Changes in voltage are easy to see
    - A touch induces a change in capacitance which will change our voltage waveform

Detecting Touch

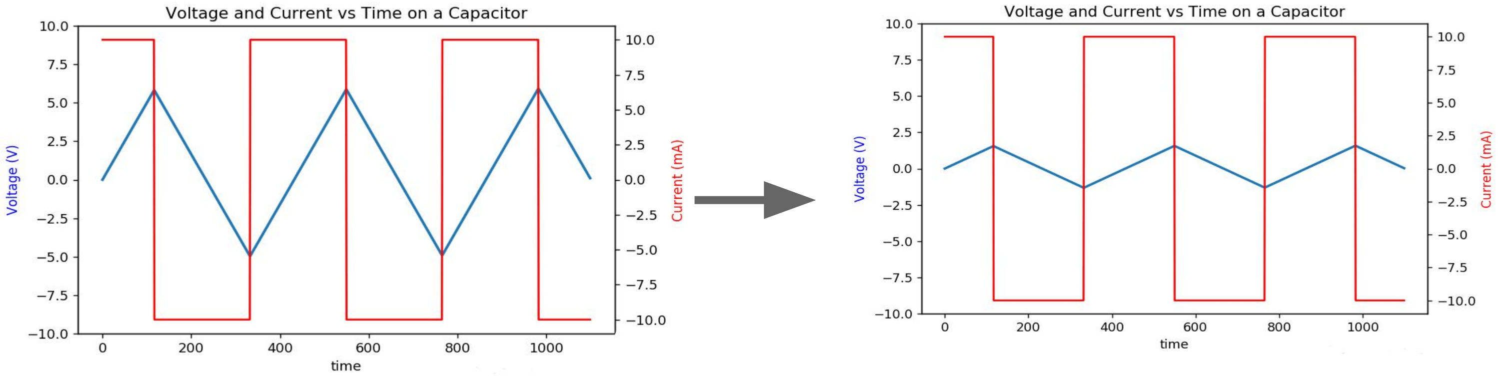




- How do we detect this?
    - **What do we need to compare between these two waveforms?**

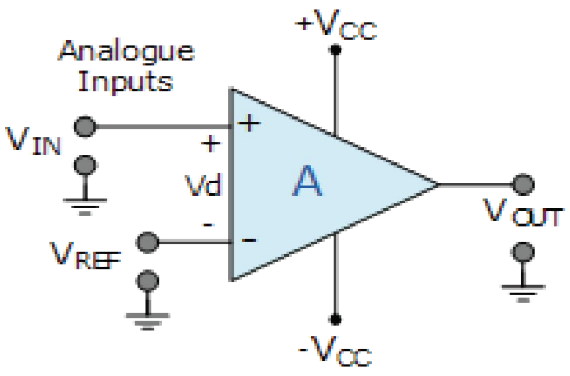
Difference in Peak Voltages

- To determine changes in capacitance, we can compare the peaks to some reference voltage
  - Higher peak: no touch
  - Lower peak: touch

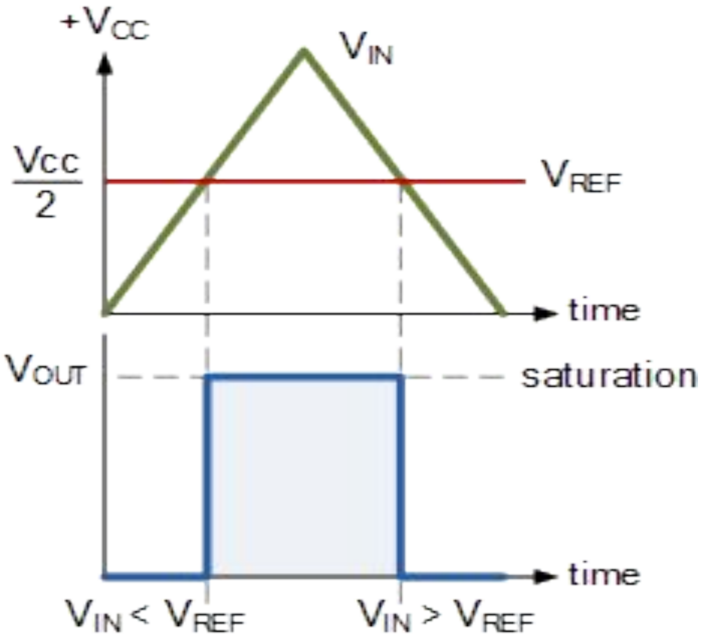


Comparators

- Compares input voltage at positive terminal to a reference voltage at negative terminal



If $V_{IN} > V_{REF}$ then $V_{OUT} = +V_{CC}$
If $V_{IN} < V_{REF}$ then $V_{OUT} = -V_{CC}$



Completing Actuation

- Use comparator to visualize difference
- We use an LED to visualize actuation
- Two outputs:
    - Touch: -5V
    - No touch: square wave
- LED will turn on if the voltage across it is high enough!

Lab Pointers

- Materials: 2 copper strips, glass slide, tape, solder
- Be sparing on tape and solder usage
- Remember to remove the backing of copper strips (they're adhesive)
- Make sure the copper strips span the length of the glass slide and a bit more

https://tinyurl.com/touch3a-sp23

http://tinyurl.com/training-sp23