EECS 16A Touchscreen 3

**Insert your names here**
Announcements

- Buffer labs will be **4/5-4/9**
  - You can make up **one** missed lab from the Touch Module, if needed (unless you have received approval to make-up multiple labs)
  - Fill out the sign-up form (linked at the end of the lab notebook) if you plan to attend a buffer section
- See upcoming Piazza post for more details on Touch Buffer
Capacitive Touchscreens
Electronic Systems

- Most systems perform 3 tasks:
  - Sense (Physical to Electrical)
  - Process (Signal Conditioning)
  - Actuate (Electrical to Physical)

- Touchscreen senses a capacitive touch
- Signal Conditioning & Processing
- LED is turned on
Goals: Touch 3

- Understand charge-sharing circuit for a capacitive touch sensor
- Understand comparators
- Build a functioning Touch Pixel
New Tools

Introducing: EECS16A Lab Boosterpack
Capacitive Touchscreen

- Exploits capacitive properties of finger/body
- Touching the screen changes the capacitance
- No moving parts
- Multi-touch is possible
- More sensitive

How to measure capacitance?
Capacitance and the touchpad
Capacitive Touch Sensor

Capacitive touch sensor consists of two parts:

- **C_pixel**: Screen + finger = unknown capacitance
- **C_ref**: In parallel with known capacitance

Let’s try to figure out a way to detect this increase in capacitance!
Measuring Capacitance

C_pixel is a variable value – may contain our finger or not

- Model finger as another capacitor in parallel with our capacitive touch sensor
- How does the capacitance of what we’re charging change?
Poll Time!

When you touch the screen, what will happen to $C_{\text{pixel}}$?

(A) Increase

(B) Decrease
Poll Time! (Continued…)

When you touch the screen, what will happen to $C_{\text{pixel}}$?

(A) Increase  
(B) Decrease
Measuring Capacitance

Start by charging our touch sensor capacitor
Measuring Capacitance

Charge-sharing invariant: \[ Q = CV \]

- Q remains constant
- What happens to capacitors in parallel?
Poll Time!

When the charge is shared across $C_{\text{pixel}}$ and $C_{\text{ref}}$, what will happen to the voltage at the positive plate of $C_{\text{pixel}}$?

(A) Increase
(B) Decrease
Poll Time! (cont.)

When the charge is shared across $C_{pixel}$ and $C_{ref}$, what will happen to the voltage at the positive plate of $C_{pixel}$?

(A) Increase
(B) Decrease

Charge is conserved:

$$C_{pixel} * V_{DD} = (C_{pixel} + C_{ref}) * \left(\frac{C_{ref}}{V_+}\right)$$

$$\left(\frac{C_{ref}}{V_+}\right) = \frac{C_{pixel} * V_{DD}}{C_{pixel} + C_{ref}}$$

$$\left(\frac{C_{ref}}{V_+}\right) < V_{DD}$$

Voltage = $V_{DD}$

$$Q = C_{pixel} * V_{DD}$$

Voltage = $C_{ref}/V_+$

$$Q = \left(\frac{C_{ref}}{V_+}\right)(C_{pixel}) + \left(\frac{C_{ref}}{V_+}\right)(C_{ref})$$
Measuring Capacitance: Full Cycle

1. Connect capacitors to ground to discharge fully
Measuring Capacitance: Full Cycle

2. Disconnect clean switch from ground to enable charge storing
Measuring Capacitance: Full Cycle

3. Charge touchscreen (+ finger?)

Applying this equation: \( Q = CV \)

\[ Q_{Phase3} = C_{pixel} \times V_{DD} \]
Measuring Capacitance: Full Cycle

4. Share charge between $C_{\text{pixel}}$ and $C_{\text{ref}}$

Charge is conserved between phases

\[ Q_{\text{Phase3}} = Q_{\text{Phase4}} = C_{\text{pixel}} \times V_{DD} \]

\[ Q_{\text{Phase4}} = (C_{\text{ref}}/V+) \times (C_{\text{pixel}} + C_{\text{ref}}) \]

\[ (C_{\text{ref}}/V+) \times (C_{\text{pixel}} + C_{\text{ref}}) = C_{\text{pixel}} \times V_{DD} \]

\[ (C_{\text{ref}}/V+) = \frac{C_{\text{pixel}} \times V_{DD}}{(C_{\text{pixel}} + C_{\text{ref}})} \]
Measuring Capacitance: Full Cycle

Phase 1

Drive Switch

$V_{DD}$

$C_{pixel}$

$C_{ref}$

$C_{ref}/V_+$

Clean Switch
Process Comparator

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

Essentially does:
if $V_{in} > V_{ref}$:
  return $V_{dd}$
else:
  return GND = 0V
Process Comparator

Voltage we are measuring: 

\[
\frac{(C_{\text{ref}}/V+)}{V+} = \frac{C_{\text{pixel}} \cdot V_{DD}}{(C_{\text{pixel}} + C_{\text{ref}})}
\]

- In touch and no-touch cases, the voltage at Cref/V+ will be different
- Want to use the process comparator to distinguish between touch and no-touch voltages
- Desired comparator output:
  - Touch: V_DD
  - No-touch: 0V
Full Circuit - Sense Process Actuate
Notes

- Unplug MSP before moving circuit components
- Op Amp goes across middle of breadboard
- Read op-amp pin diagram carefully
- Make sure your circuit is grounded and has a common ground
- Initial charge sharing diagrams are theoretical; don’t start building right away