EECS 16A Touchscreen 3

Insert your names here

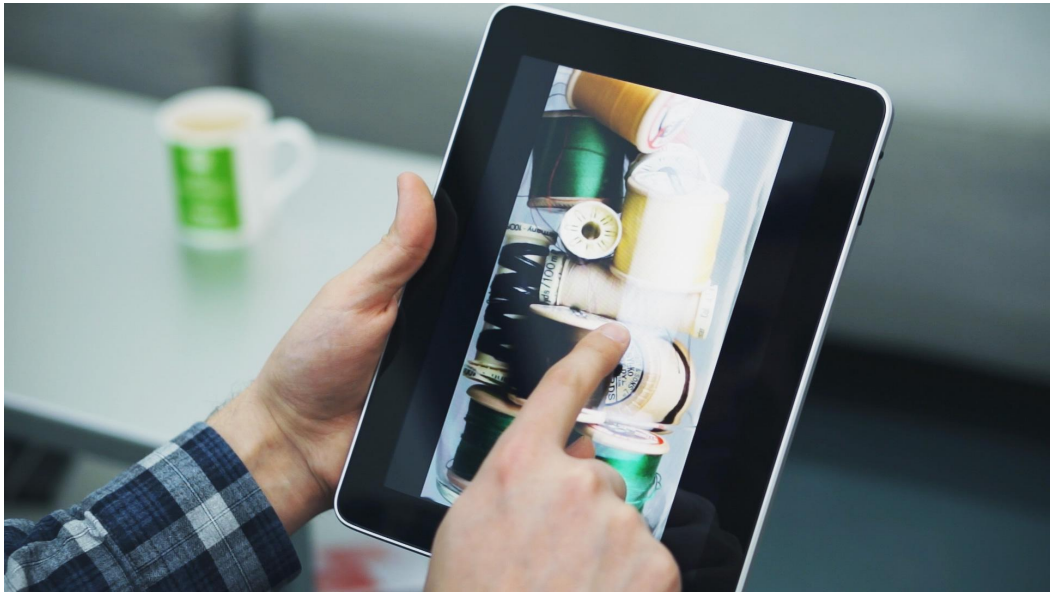
Announcements

- Buffer labs will be **11/8-11/12**
  - 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

Announcements

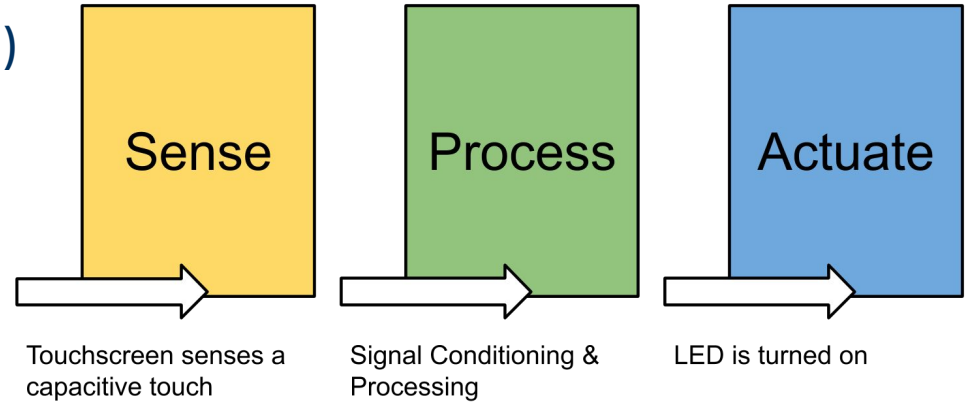
- Optional Touch Labs!
  - In-Person (11/8, 11/9): Integrator + Soldering + Op Amp configurations
  - Might add another section on 11/12 if there's significant interest and students can't make the other times
- Fill out the sign-up form (linked at the end of the lab notebook) if you plan to attend an optional lab section
- See upcoming Piazza post for more details on Touch Buffer and the Optional Touch Lab

Capacitive Touchscreens



Electronic Systems

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

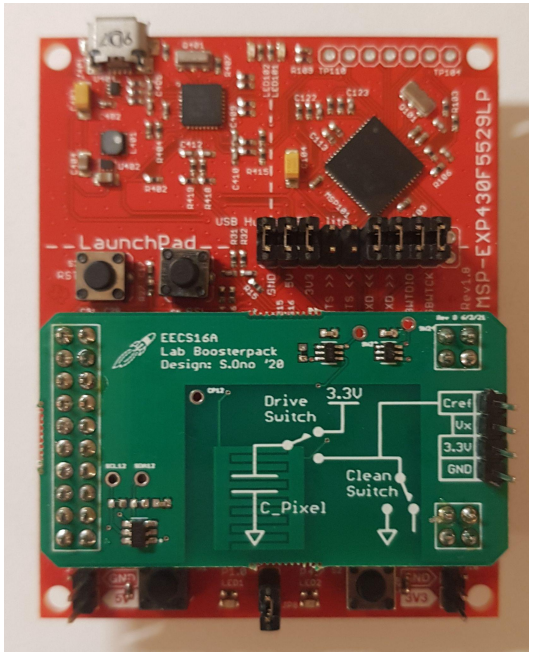


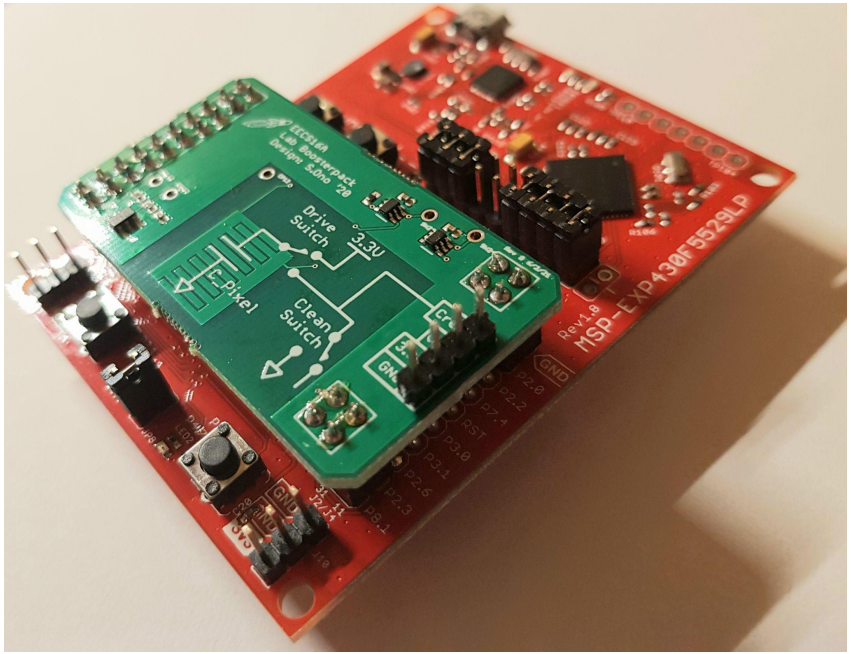
Goals: Touch 3

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

New Tools

Introducing: EECS16A Lab Boosterpack



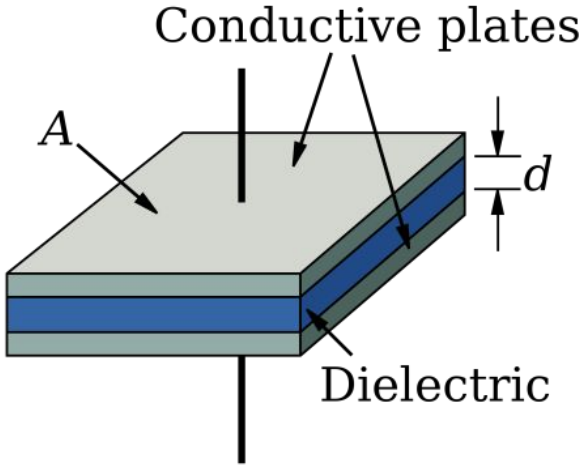


Capacitive Touchscreen

- 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



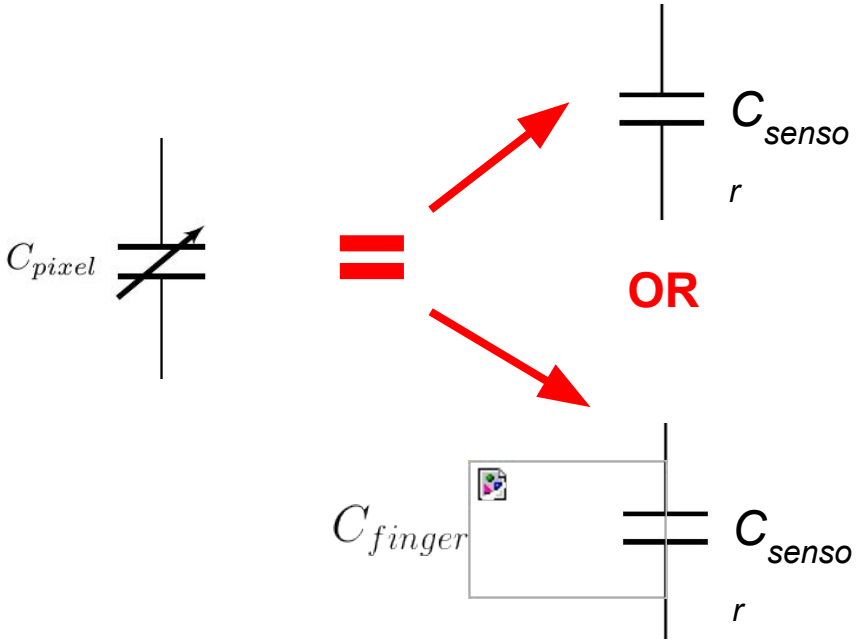
Capacitive Touch Sensor

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

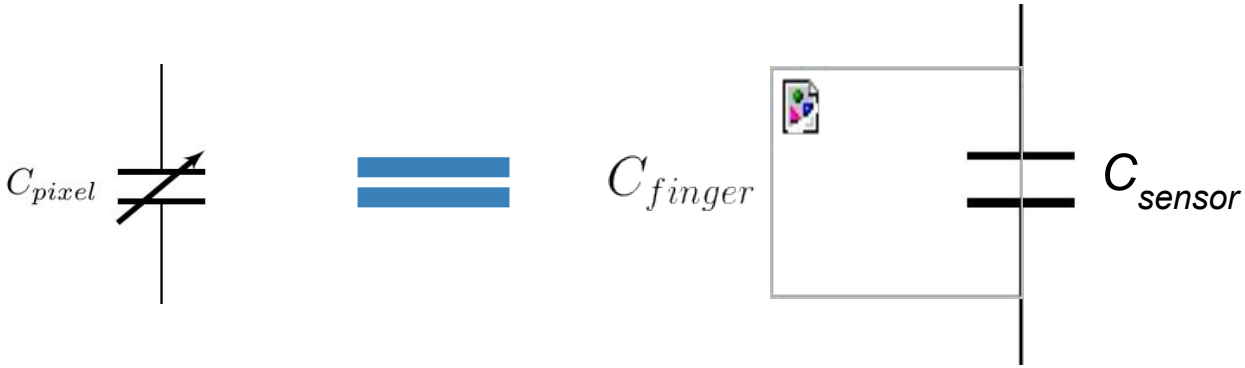
- Model finger as another capacitor in parallel with our capacitive touch sensor
- How does the capacitance of what we're charging change?

Poll Time!

When you touch the screen, what will happen to C_pixel?

(A) Increase

(B) Decrease

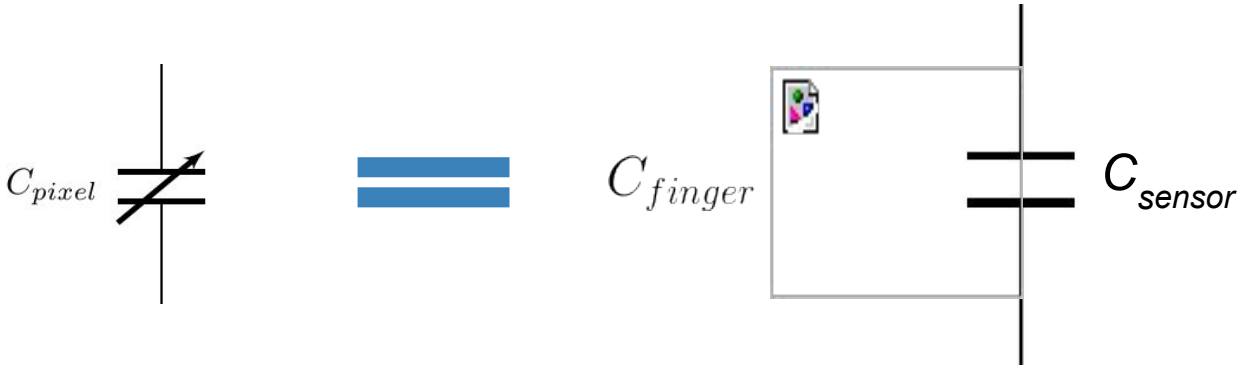


Poll Time! (Continued…)

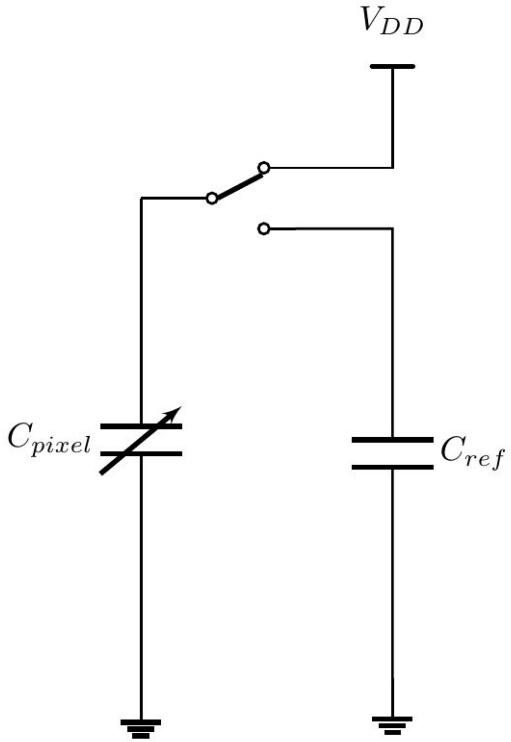
When you touch the screen, what will happen to C_pixel?

(A) Increase

(B) Decrease

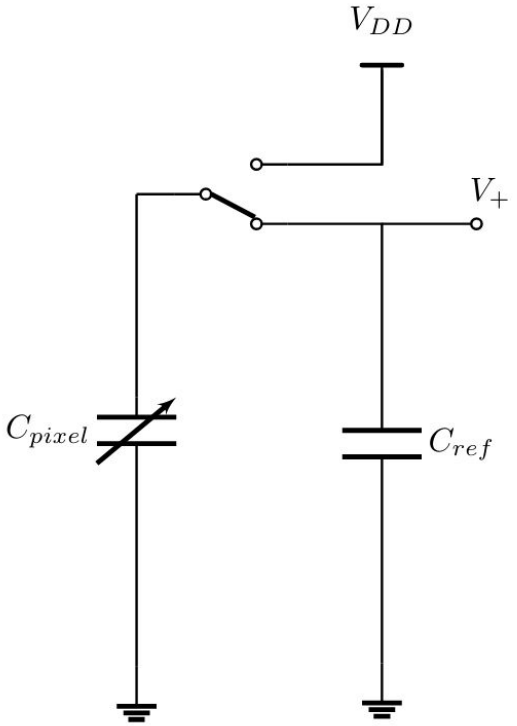


Measuring Capacitance



Start by charging our touch sensor capacitor

Measuring Capacitance



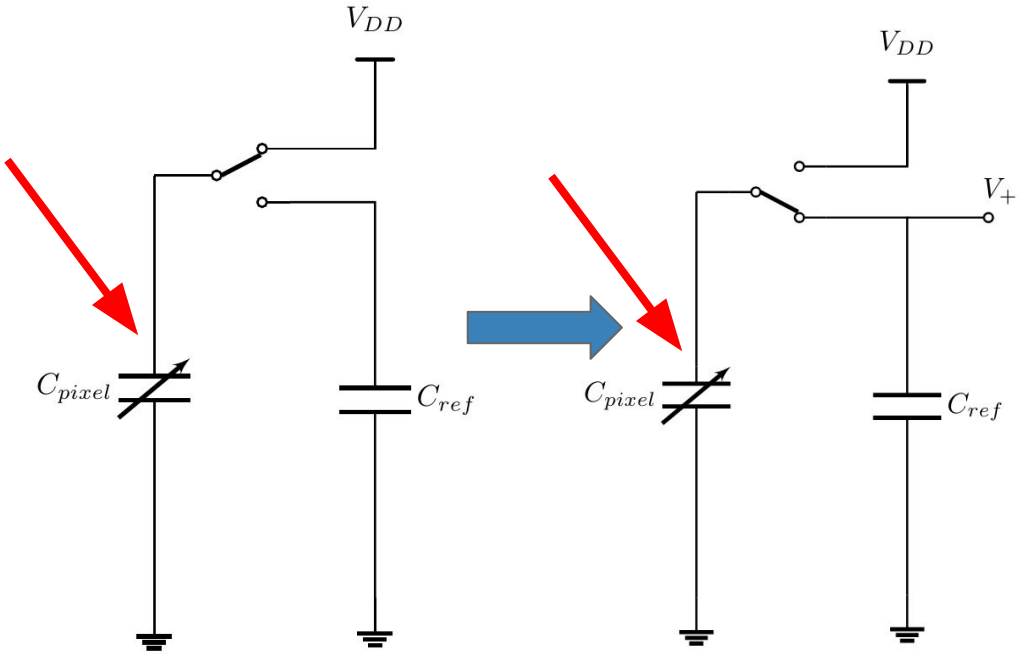
Charge-sharing invariant: $Q = CV$

- Q remains constant
- What happens to capacitors in parallel?

Poll Time!

When the charge is shared across C_pixel and C_ref, what will happen to the voltage at the positive plate of C_pixel?

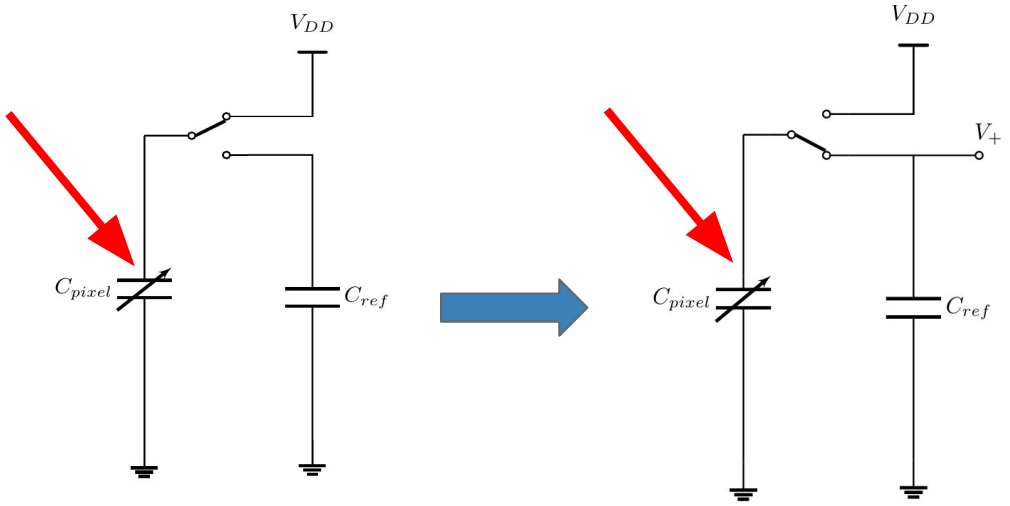
(A) Increase
(B) Decrease



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



Voltage = V_DD

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

Voltage = V_+

$$Q = (V_+)(C_{pixel}) + (V_+)(C_{ref})$$

Charge is conserved:

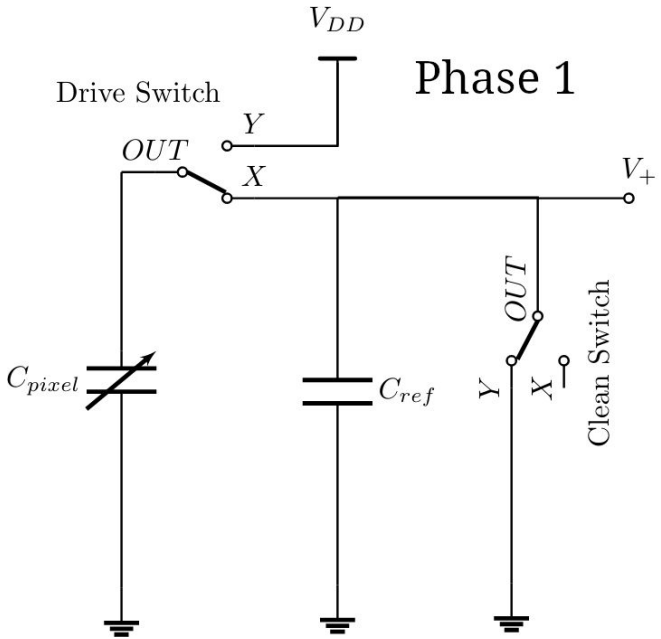
$$C_{pixel} \times V_{DD} = (C_{pixel} + C_{ref}) \times (V_+)$$

$$V_+ = \frac{C_{pixel} \times V_{DD}}{C_{pixel} + C_{ref}}$$

$$V_+ < V_{DD}$$

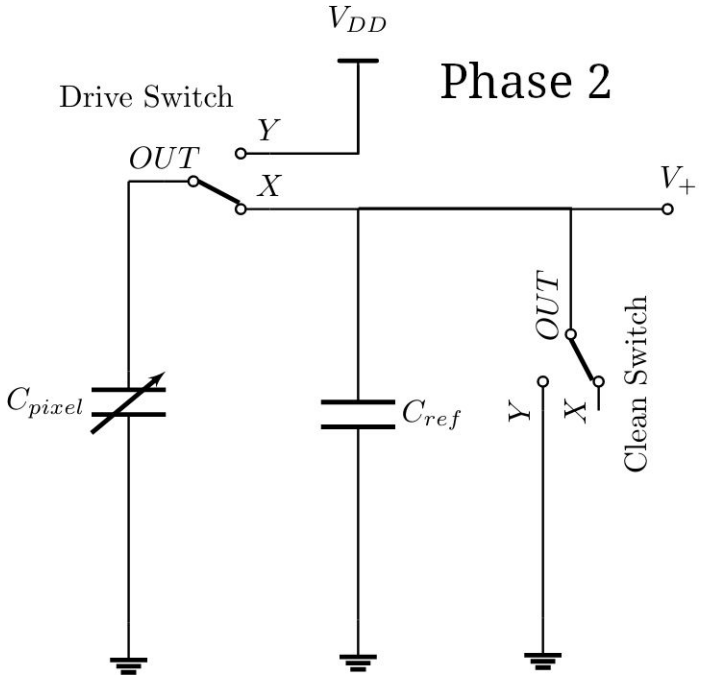
Measuring Capacitance: Full Cycle

1. Connect capacitors to ground to discharge fully



Measuring Capacitance: Full Cycle

2. Disconnect clean switch from ground to enable charge storing

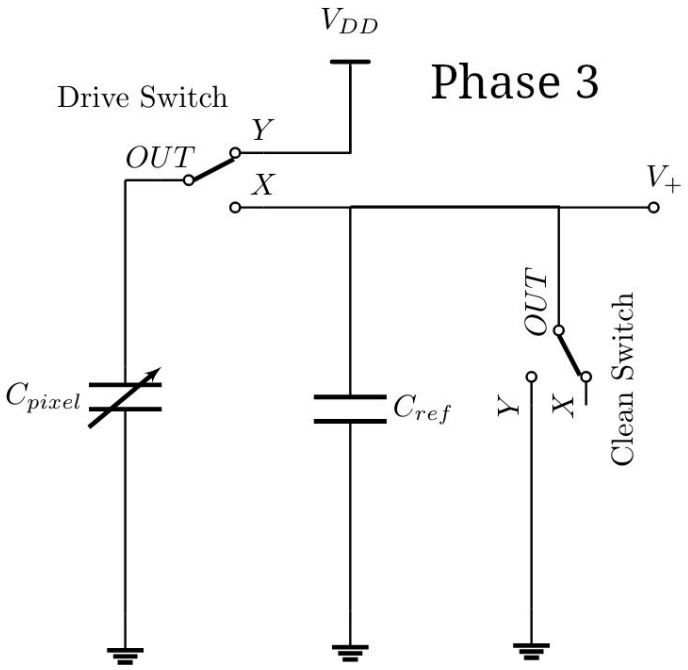


Measuring Capacitance: Full Cycle

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_pixel** and C_ref

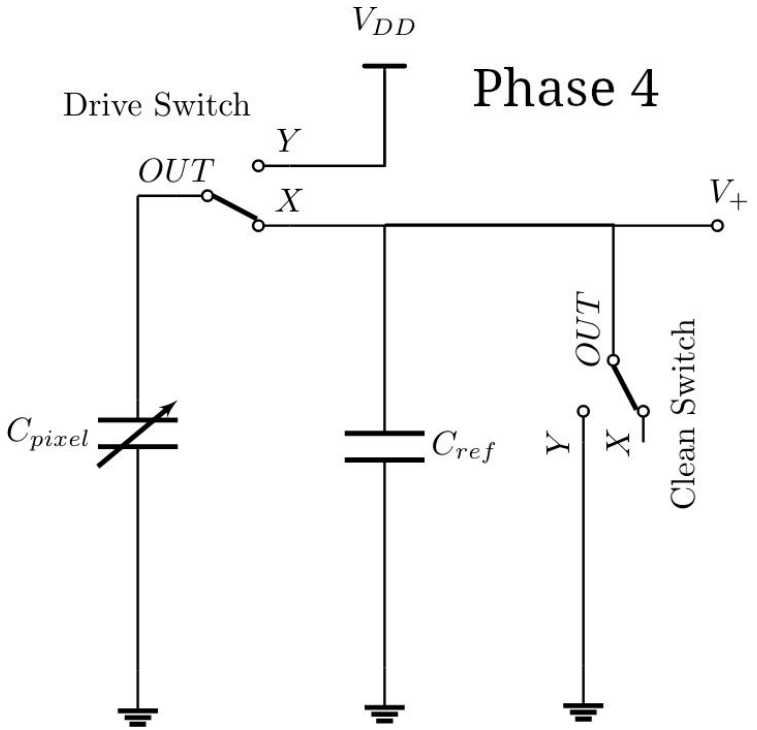
Charge is conserved between phases

$$Q_{Phase3} = Q_{Phase4} = C_{pixel} \times V_{DD}$$

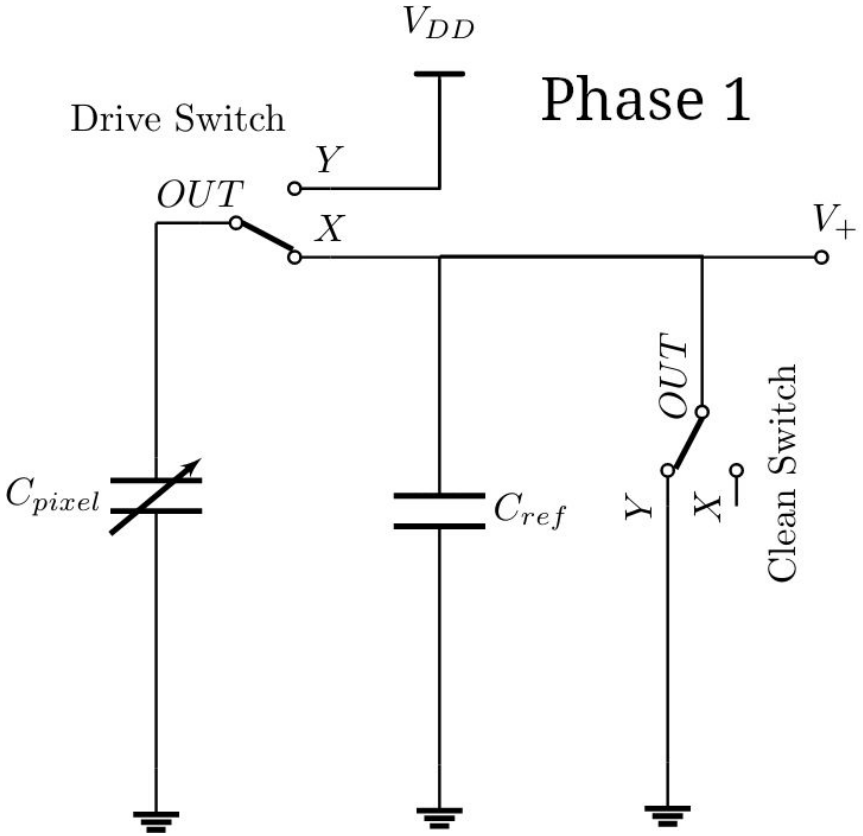
$$Q_{Phase4} = (V_+) \times (C_{pixel} + C_{ref})$$

$$(V_+) \times (C_{pixel} + C_{ref}) = C_{pixel} \times V_{DD}$$

$$\boxed{V_+ = \frac{C_{pixel} \times V_{DD}}{C_{pixel} + C_{ref}}}$$



Measuring Capacitance: Full Cycle



Process Comparator

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

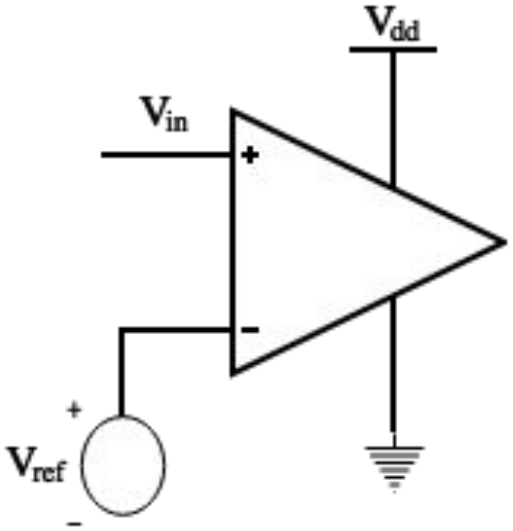
<u>Essentially does:</u>

if V_in > V_ref:

    return V_dd

else:

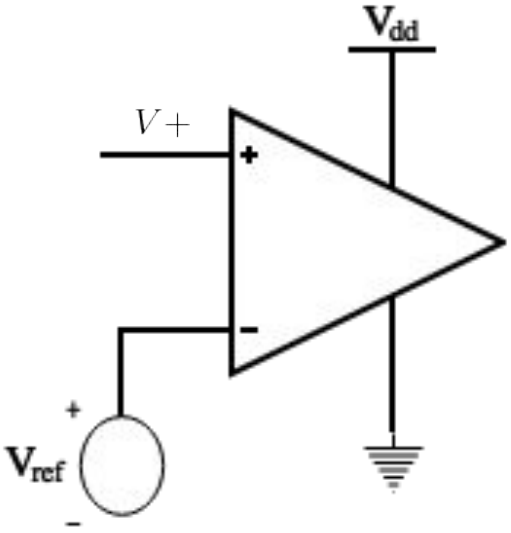
    return GND = 0V



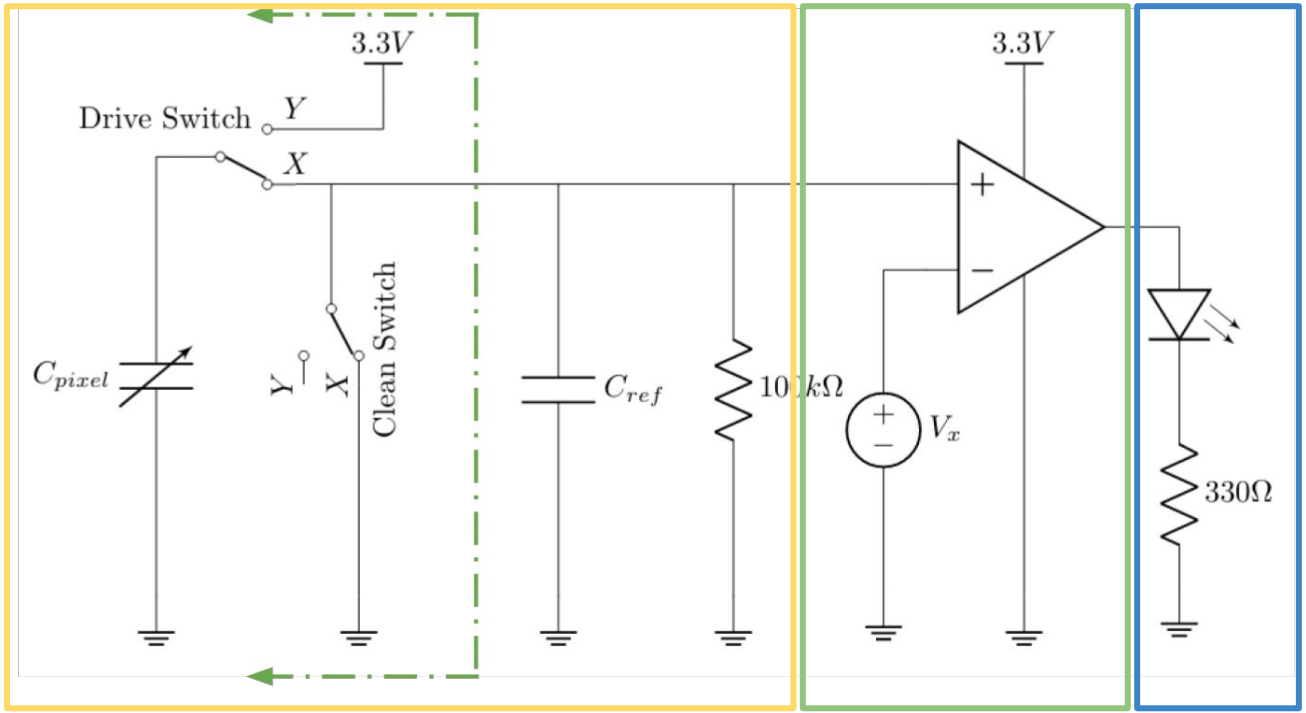
Process Comparator

Voltage we are measuring: $V_+ = \frac{C_{pixel} \times V_{DD}}{C_{pixel} + C_{ref}}$

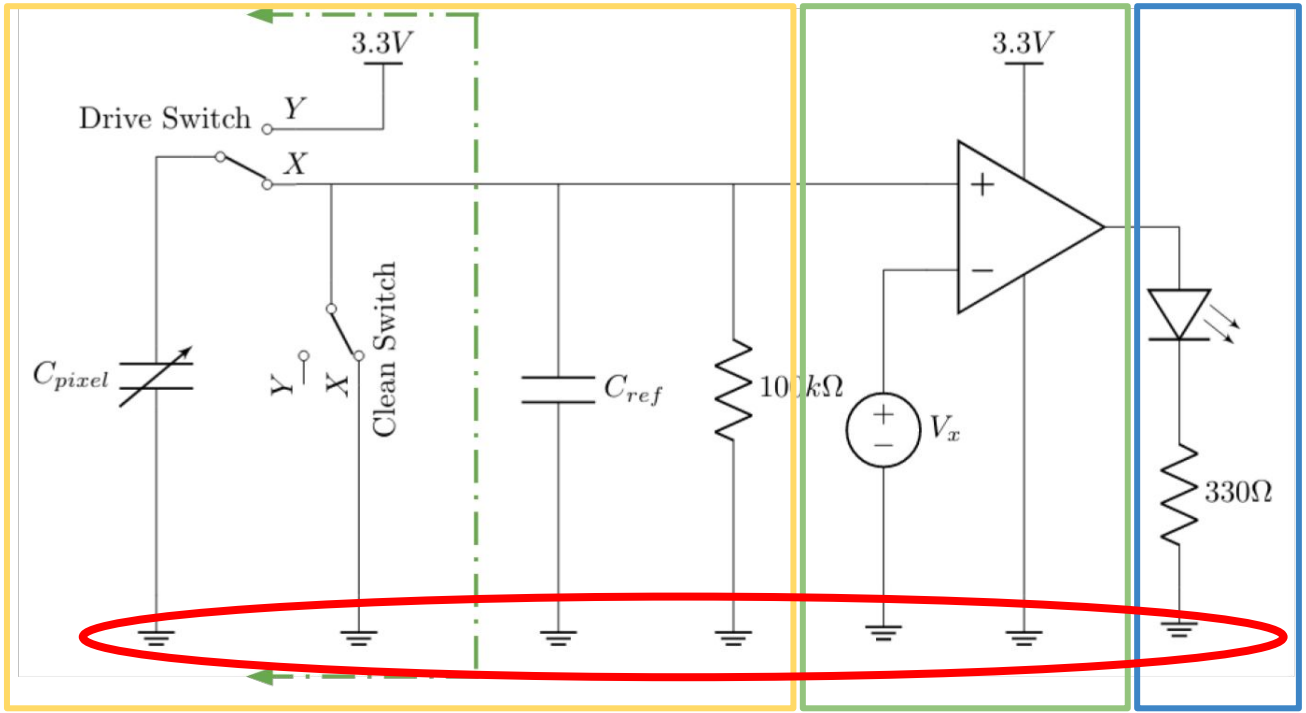
- In touch and no-touch cases, the voltage at V+ will be different
- Want to use the process comparator to distinguish between touch and no-touch voltages
- Desired comparator output:
  - Touch: V_DD
  - No-touch: 0V



Full Circuit - Sense Process Actuate

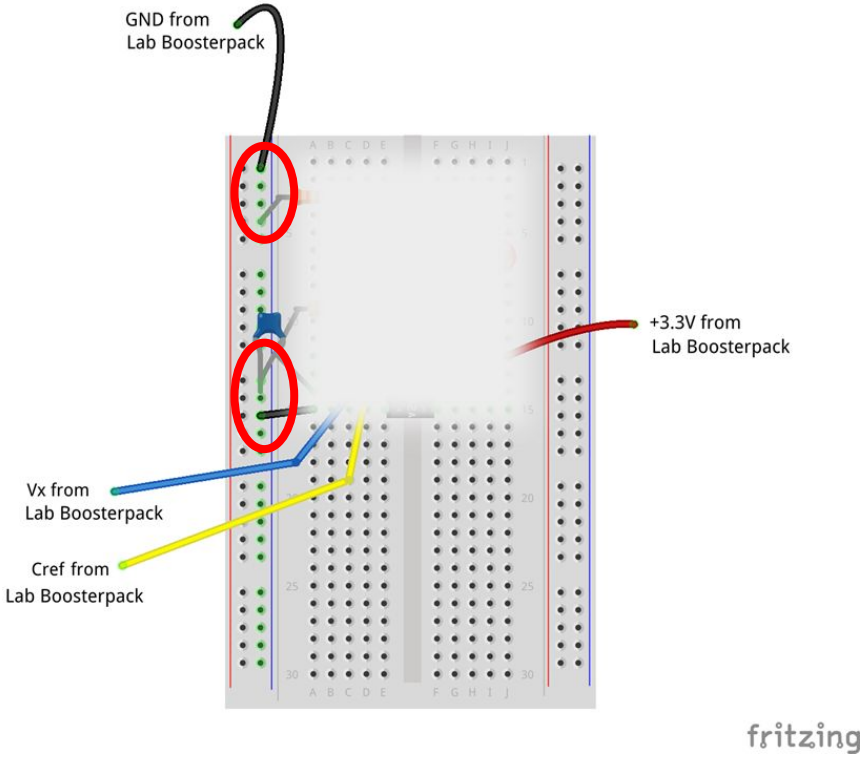


Full Circuit - Sense Process Actuate



Note: these are all the same node! They are all connected to the breadboard ground rail.

Full Circuit - Sense Process Actuate



Note: All ground connections are the same node!

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**