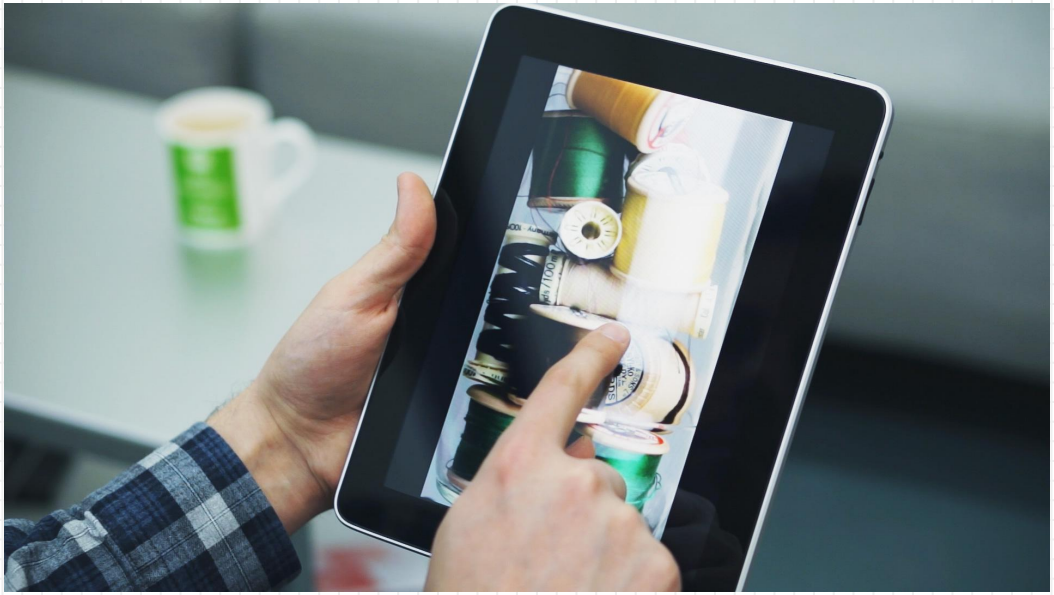
EECS16A Lab: Touchscreen 3

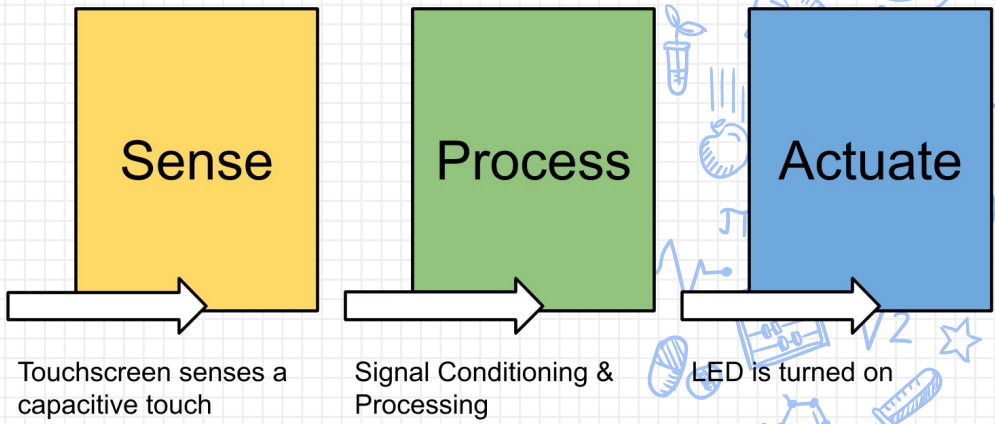
Capacitive Touchscreens



Electronic Systems

Most systems perform 3 tasks:

- ✘ Sense (Physical to Electrical)
- ✘ Process (Signal Conditioning)
- ✘ Actuate (Electrical to Physical)

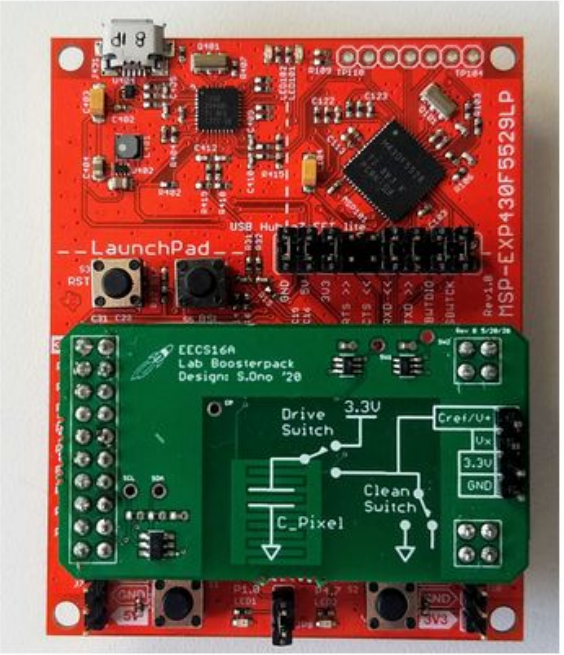


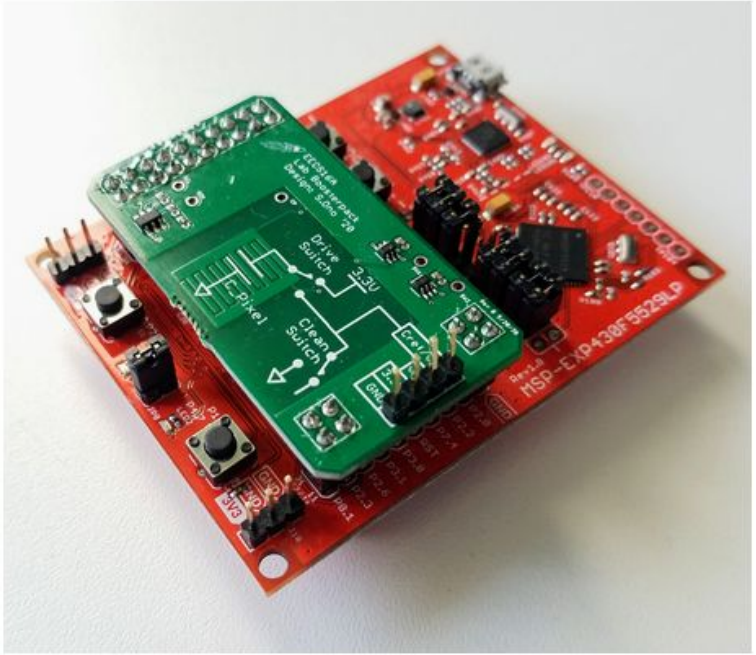
Goals: Touch 3

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

New Tools

Introducing: EECS16A Lab Boosterpack





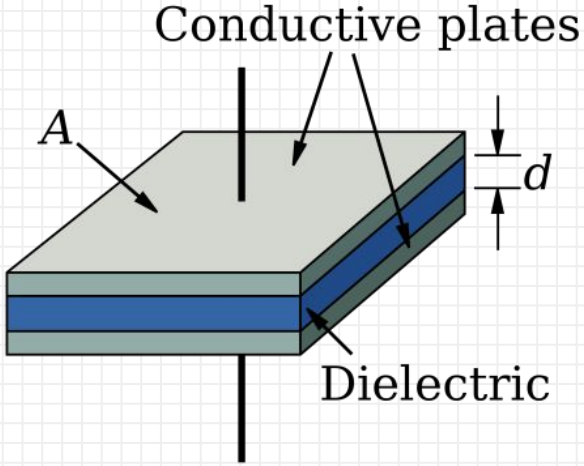
Capacitive Touchscreen

- ✘ 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

What is a capacitor and how does it work?



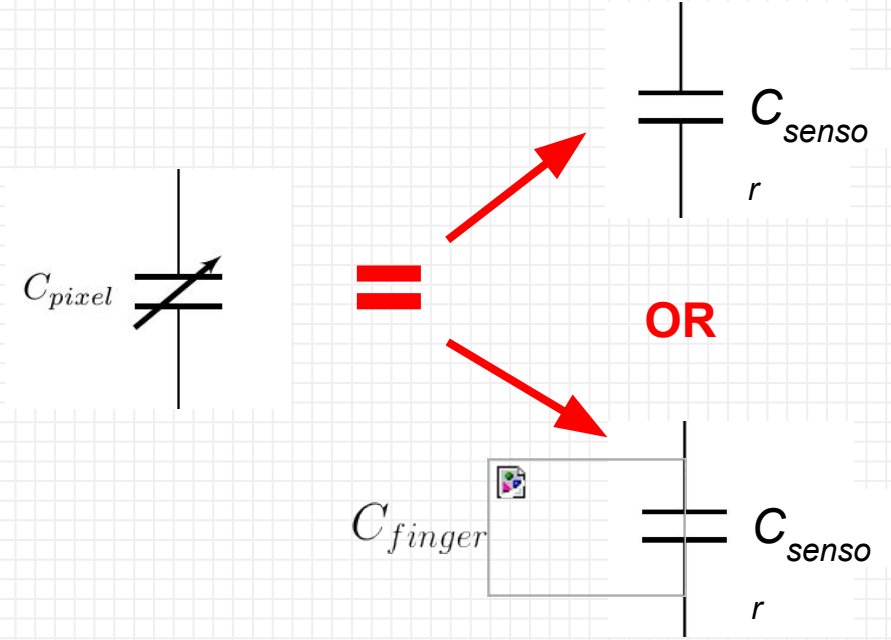
Capacitive Touch Sensor

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

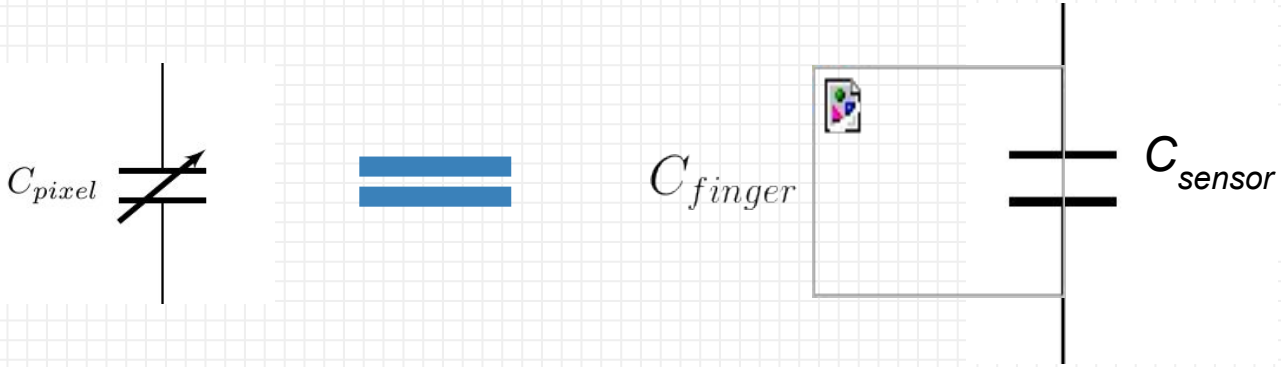
- ✘ Model finger as another capacitor in parallel with our capacitive touch sensor
- ✘ How does the capacitance of what we're charging change?

Poll Time!

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

(A) Increase

(B) Decrease

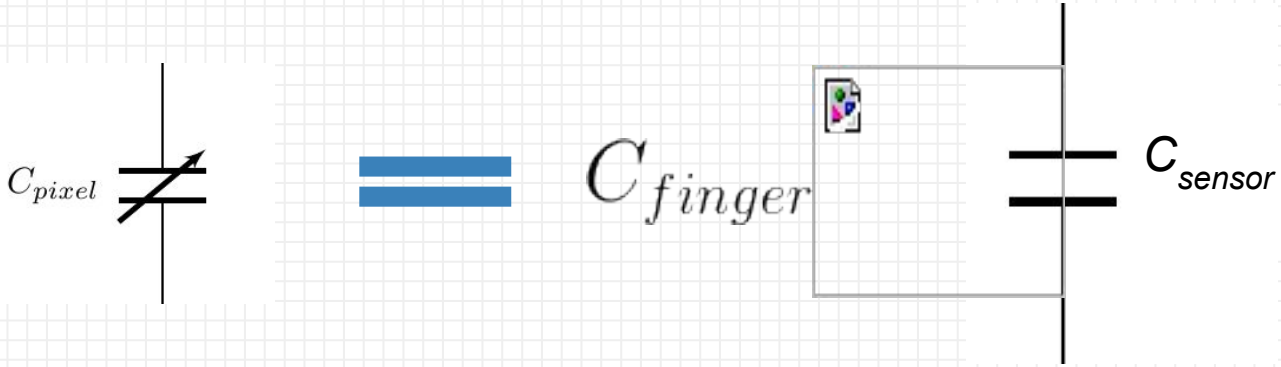


Poll Time! (Continued...)

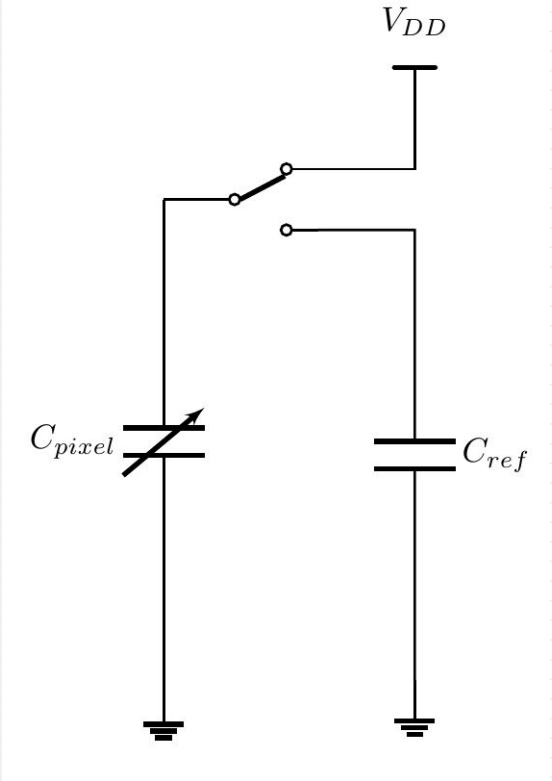
When you touch the screen, what will happen to C_pixel?

(A) Increase

(B) Decrease

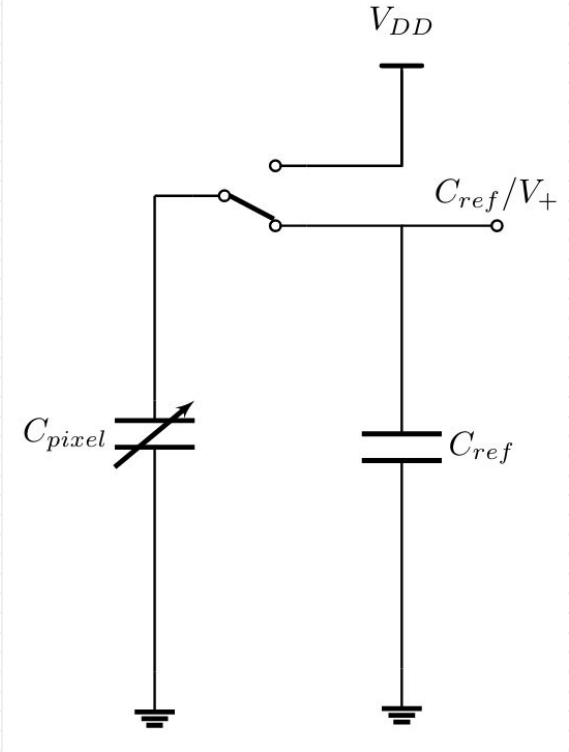


Measuring Capacitance



Start by charging our capacitor touch sensor

Measuring Capacitance



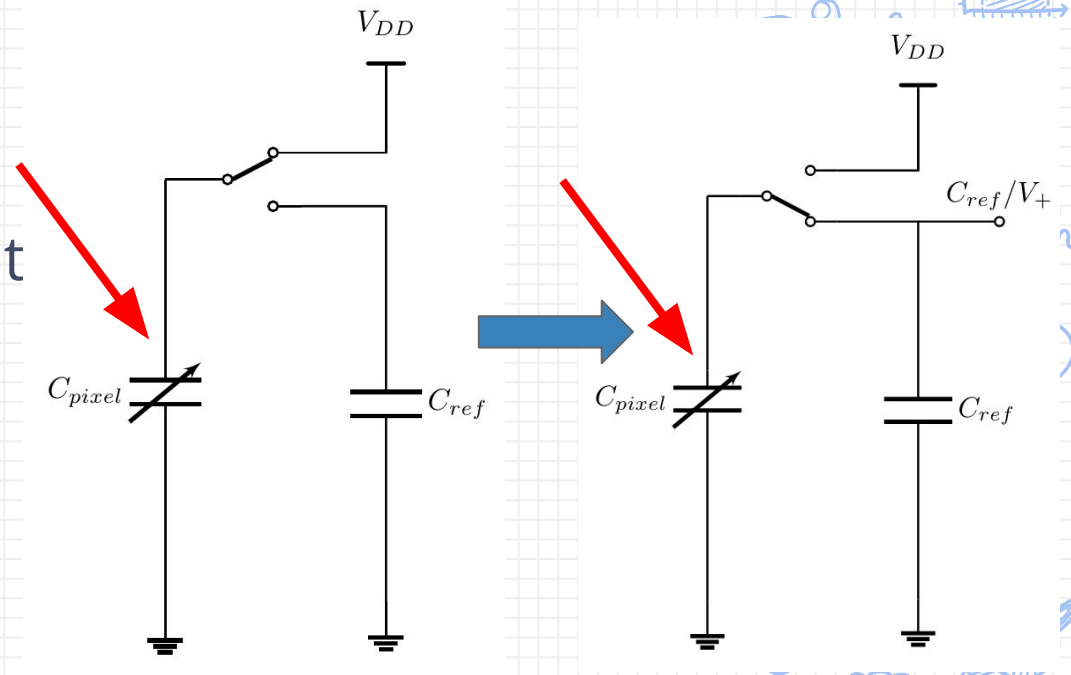
Charge-sharing invariant: $Q = CV$

- ✘ 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

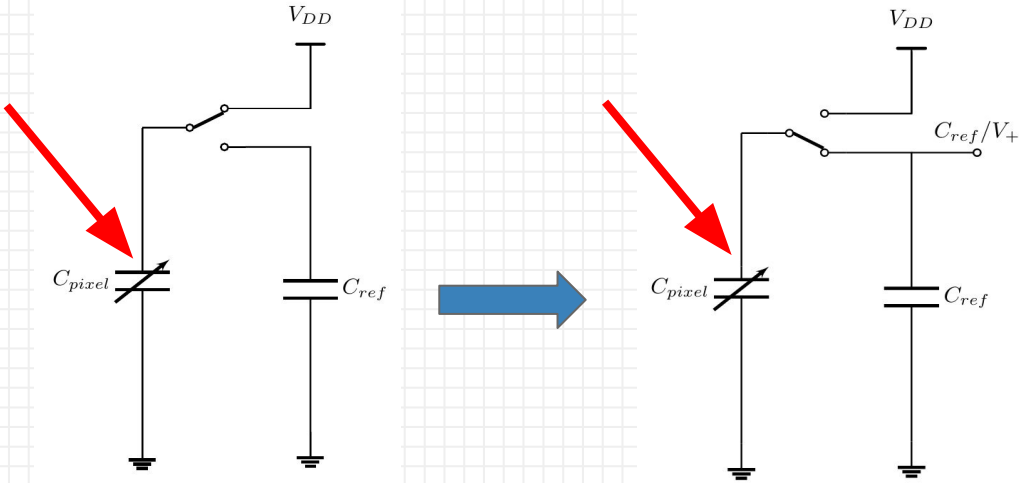


$$Q = CV$$

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 = C_ref/V+

$$Q = (C_{ref}/V+)(C_{pixel}) + (C_{ref}/V+)(C_{ref})$$

Charge is conserved:

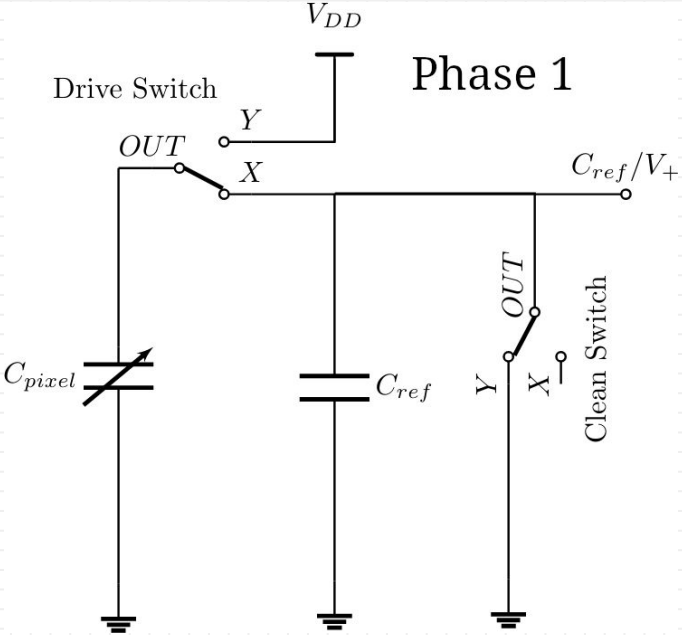
$$C_{pixel} * V_{DD} = (C_{pixel} + C_{ref}) * (C_{ref}/V+)$$

$$(C_{ref}/V+) = \frac{C_{pixel} * V_{DD}}{(C_{pixel} + C_{ref})}$$

$$(C_{ref}/V+) < V_{DD}$$

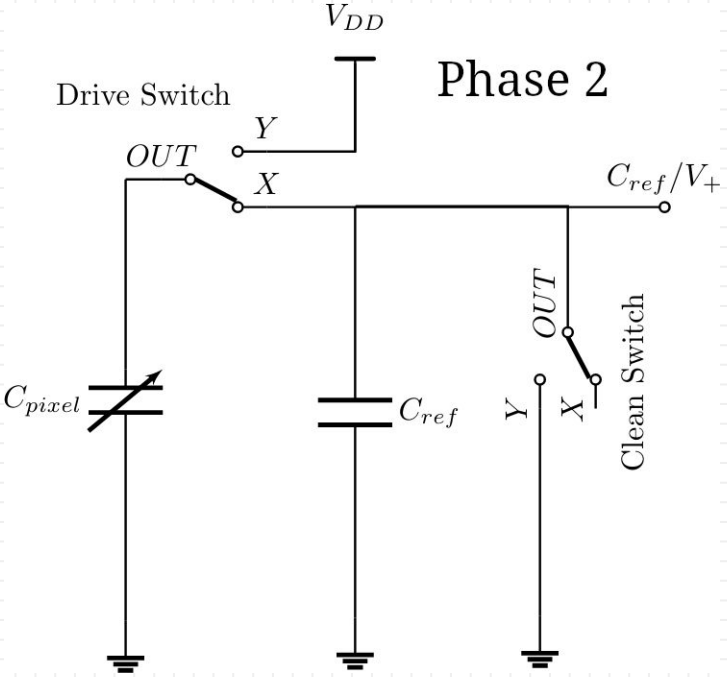
Measuring Capacitance: Full Cycle

1. Connect capacitors to ground to discharge fully



Measuring Capacitance: Full Cycle

2. Disconnect clean switch from ground to enable charge storing

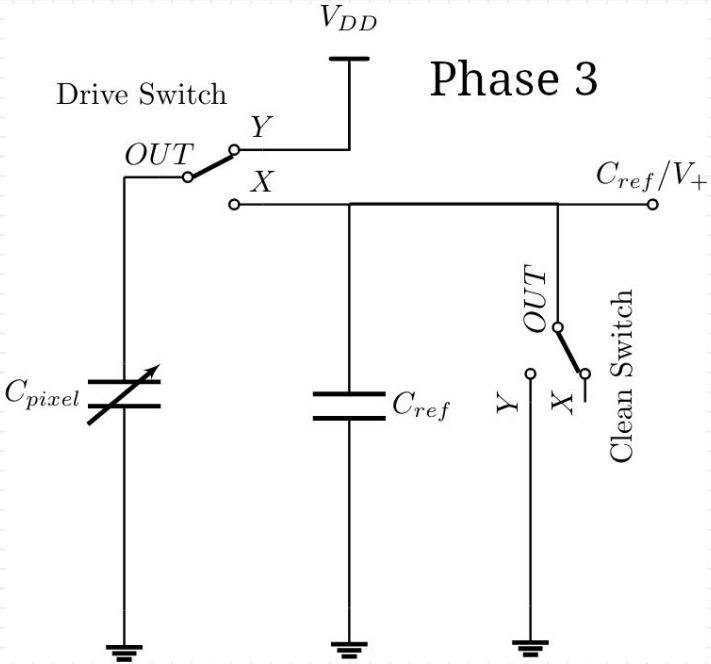


Measuring Capacitance: Full Cycle

3. Charge touchscreen (+ finger?)

Applying this equation: Q = CV

$$Q_{Phase3} = C_{pixel} * V_{DD}$$



Measuring Capacitance: Full Cycle

4. Share charge between **C_pixel** and C_ref

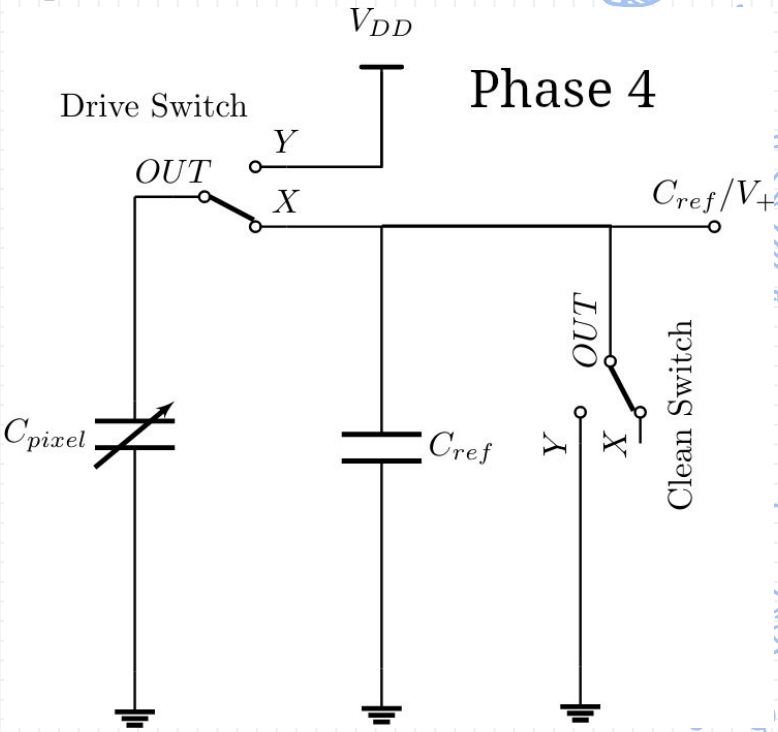
Charge is conserved between phases

$$Q_{Phase3} = Q_{Phase4} = C_{pixel} * V_{DD}$$

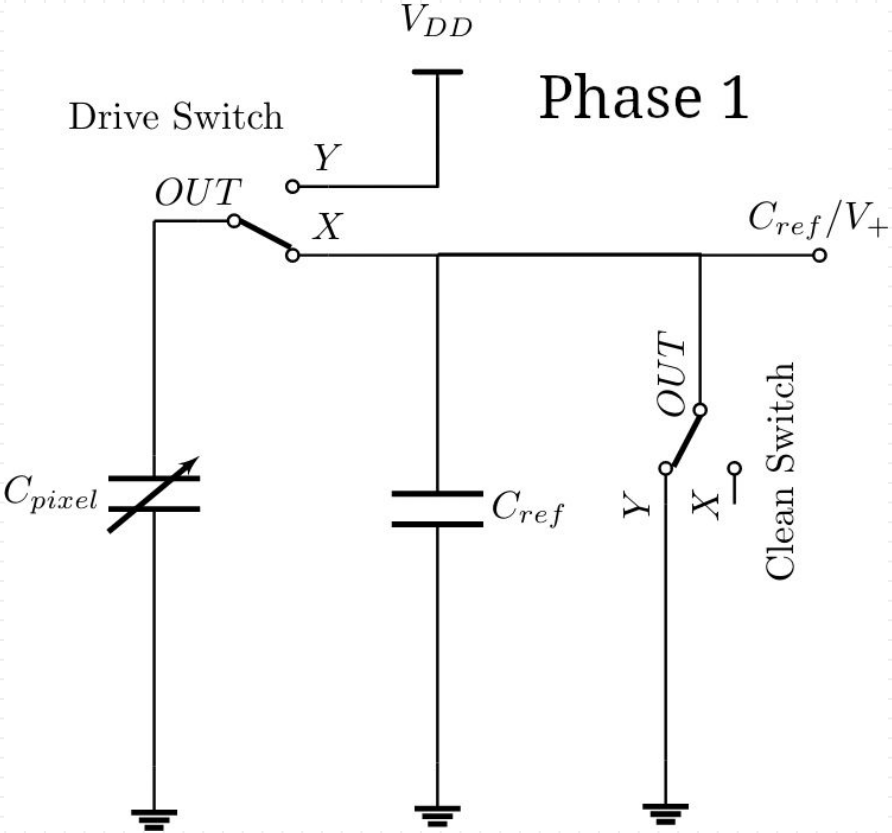
$$Q_{Phase4} = (C_{ref}/V+) * (C_{pixel} + C_{ref})$$

$$(C_{ref}/V+) * (C_{pixel} + C_{ref}) = C_{pixel} * V_{DD}$$

$$(C_{ref}/V+) = \frac{C_{pixel} * V_{DD}}{(C_{pixel} + C_{ref})}$$



Measuring Capacitance: Full Cycle

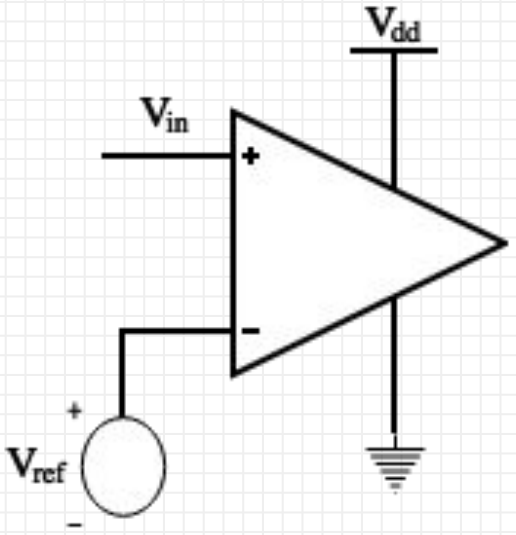


Process Comparator

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

<u>Essentially does:</u>

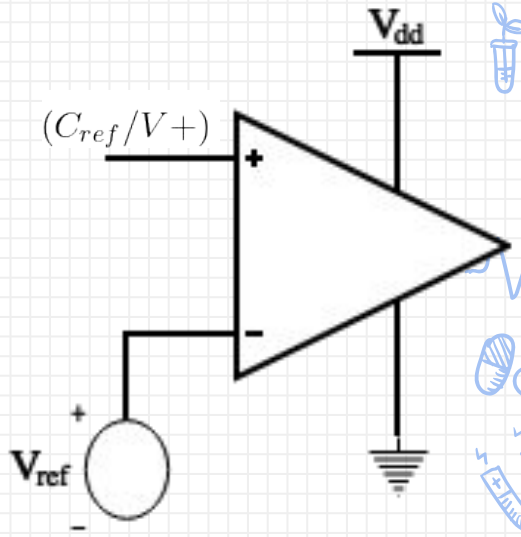
```
if V_in > V_ref:
    return V_dd
else:
    return GND = 0V
```



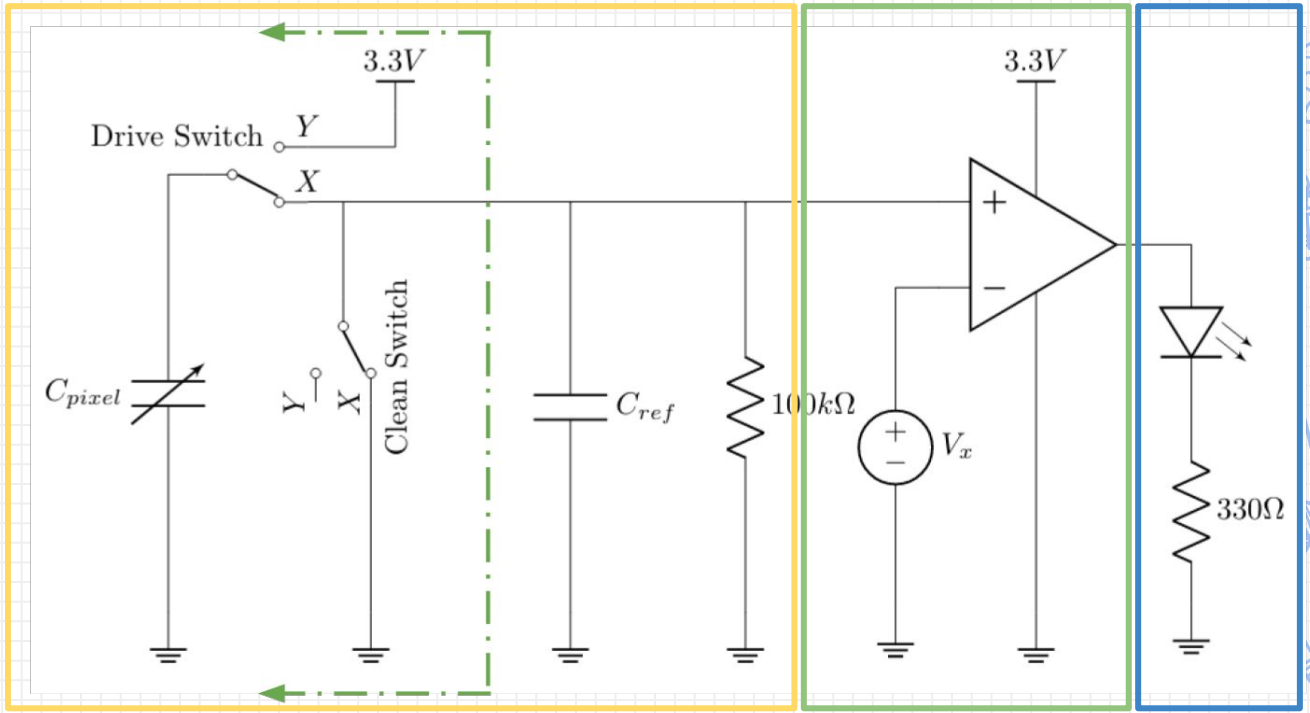
Process Comparator

Voltage we are measuring: $(C_{ref}/V+) = \frac{C_{pixel} * V_{DD}}{(C_{pixel} + C_{ref})}$

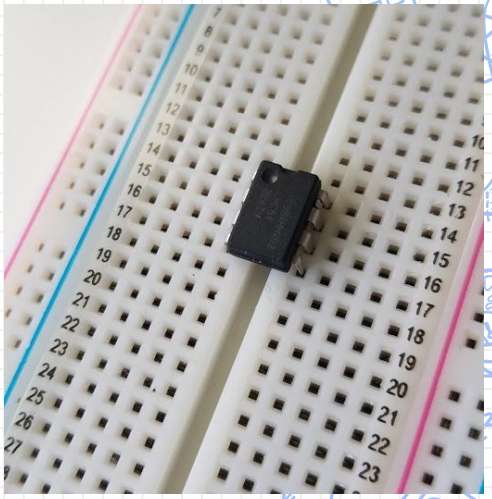
- In touch and no-touch cases, the voltage at Cref/V+ will be different
- Want to use the process comparator to distinguish between touch and no-touch voltages
- Desired comparator output:
  - **Touch**: V_DD
  - **No-touch**: 0V



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**