Lecture Scribe 3/5: Quincy Huynh

Review from Last Lecture

(a) Multi-touch in a resistive touch screen:

Remember that for multi-touch resistive touch screens, we can only measure the distance between the two touch points. This means we can really only measure gestures (pinches or flicks to zoom in or out).

"Pinch to zoom" decreases voltage since this gesture increases the distance between the two touch points and therefore decreases the total resistance driven by the current source.

How do we detect twists since counter clockwise twists and clockwise twists produce the same voltage differences? We have to monitor the passive layers as well. Counter clockwise and clockwise twist voltage sampling shows that the waveform for one is flipped vertically with respect to the other (i.e if $\mathbf{V_{X+}}$ is at the peak of one, then the peak of the wave is $\mathbf{V_{X-}}$ of the other). Refer to the sampling of the passive layer on slide 49.

Operational Amplifiers

(a) Buffering:

We want a way to connect a voltmeter without loading the system and lowering the voltage readout (remember that a resistor in parallel lowers the voltage read between two points). What is loading the system? Loading the system means to draw current from it. Real voltmeters and ammeters will do this because they have an internal resistance in series and parallel, respectively.

We can do this with a **buffer:** buffers have high input resistance and don't draw current from the system because it takes energy from another supply. It reproduces the input voltage without actually affecting the system.
*Note: a buffer cannot produce its own energy, it *always* needs energy from some other power supply.

(b) Amplifier IC (Integrated Circuit):

amplifier IC: takes an input signal V_{in} and amplifies/scales/multiplies it by a fixed amount and outputs it as V_{out}.

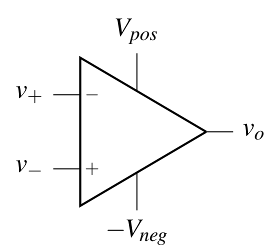
$$V_{\text{out}} = A_V \cdot V_{\text{in}}$$

A_V is the multiplier or "voltage gain"

So if we say that an amplifier has a "gain of 10", then the multiplier is 10.

Note*: Even though the purpose of making amplifiers was to reduce cost, a very nice consequence about amps is that they are abstracted. We really only need to care about what we put in and what we get out of it!

Amplifier Diagram:



(c) Op Amp (Operational Amplifier):

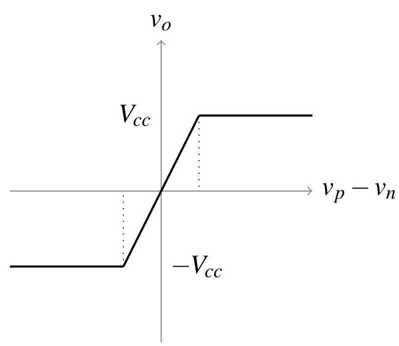
Components:

$$v^{+} \text{ positive (non-inverting) input} \tag{1}$$
$$v^{-} \text{ negative (inverting) input} \tag{2}$$
$$v_o \text{ output} \tag{3}$$
$$V_p, V_{neg} \text{ power supply} \tag{4}$$

Having a high voltage gain A is the main characteristic of an op amp. If the output voltage is represented as:

$$v_o = A(v_p - v_n)$$

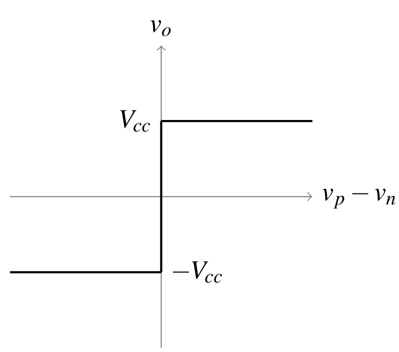
This produces a linear response. But will the line go on forever? No. The limiting factor here will be the power supply. The region that has a $v_o = V_{cc}$ is the positive saturation region and the region that has a $v_o = -V_{cc}$ is the negative saturation region.



So ideally, the gain is $A = \infty$, input resistance $R_i = \infty\,\Omega$, output resistance $R_o = 0\,\Omega$. A high input resistance is so we can put in the full input voltage $v_p - v_n$. Zero output resistance is so we get the full output voltage v_o. But why should the gain be high and why can the supply voltage be anything specified by the user?

Op Amps as comparators

If A is really high, then the slope of the linear response is also really high. Let $A = \infty$. The graph looks like this:



So if $v_p > v_n$, $v_o = V_{cc}$ and if $v_p < v_n$, $v_o = -V_{cc}$. This means we can use op amps to compare the input voltage to a reference (usually ground).

Introduction to Capacitors

(a) Capacitive Touch Screens

Capacitive touch screens don't have the hard pressure or complicated multitouch problems that resistive touch screens do.

Self-capacitance Touch Screens

Touch location is determined by changes in capacitance on the X and Y electrode arrays, measuring each row and column. But since they measure from the electrode to earth (ground), there are issues when it comes to multi-touch. This is called *ghosting*, which is when there is ambiguity with the rows and columns when there are two or more touches.

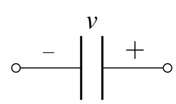
Mutual Capacitance Touch Screens

Enable multi-touch because one orientation is driven while the other is sensed, meaning we measure the effective capacitance between the rows and column as opposed to measuring it with respect to ground. Physics Note: the fringe field from a capacitor (electric field differences at the edges of the parallel plate capacitors) interact with nearby capacitors. Since we no longer assume that the plates are infinitely long, then electric field is not really constant between plates.

What do fingers do to the capacitors? Fingers themselves can be modeled as capacitors, and touching the screen would be like putting them in parallel with the capacitors in the touch screen, creating a node and splitting current.

(b) Capacitance and Capacitors

What are capacitors? Remember from the earlier lectures that capacitors are passive elements that store charge in an electric field in between the plates. The most common type is the parallel plate capacitor. They can be charged or discharged and ideally, charged capacitors don't lose their charge.



(c) Formulas for Capacitance:

$$\begin{aligned}
i &= C\frac{\mathrm{d}v}{\mathrm{d}t} \\
q &= Cv \\
v &= \frac{1}{C}\int_{t_o}^{t} i\,\mathrm{d}t + v(t_0) \\
C &= \frac{\varepsilon A}{d}
\end{aligned}$$

where A is the cross-sectional area of the plates and d is the distance between plates.

Using KCL and KVL, we can find the effective capacitance in parallel and series, respectively:

Parallel:

$$C_{eq} = \sum_{i}^{N} C_i$$

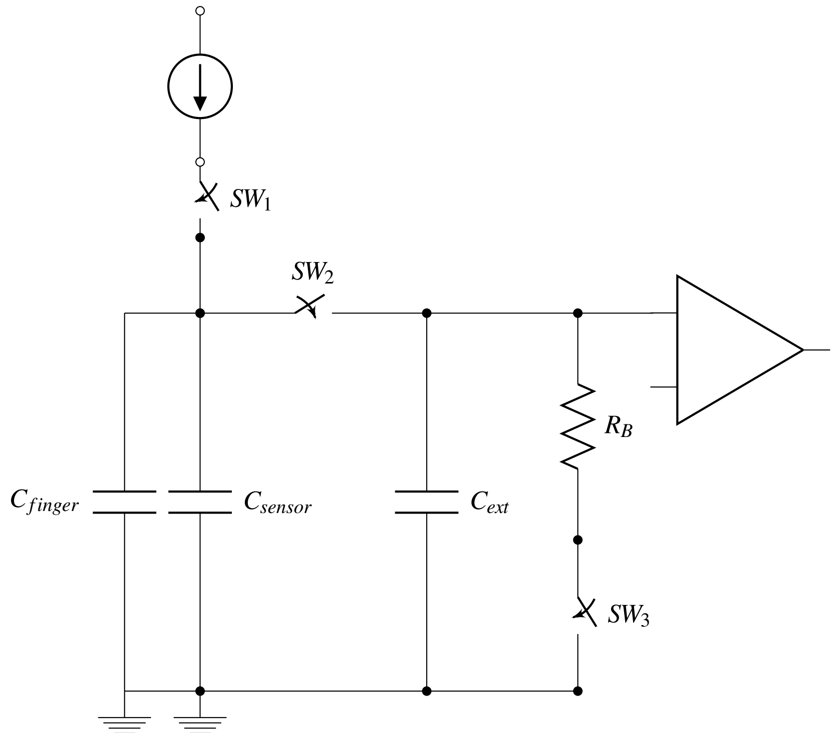
Series:

$$\frac{1}{C_{eq}} = \sum_{i}^{N} \frac{1}{C_i}$$

(c) Detecting Capacitance

If we use a constant current, then using the first formula we just have to measure the change in voltage to get the capacitance. So, we can design a capacitive touch screen reader using a current source, capacitors, resistors and an op amp. This is essentially what we'll be building in the touch screen lab.

Imagine a touch screen with this layout. If we touch it with our finger that acts as a capacitor, we are putting it in parallel with the C_{sensor}.



Our finger is a capacitor in parallel with C_{sensor}. This draws current away from C_{sensor}, so the change in voltage based off the first formula is lowered. This is fed to our op amp and compared to some reference voltage.