EECS 16A Fall 2022 — Designing Information Devices and Systems I

Discussion 10A

1. Capacitive Touchscreen

Consider the 2-dimensional capacitive touchscreen in Figure 1. Node F (green) represents the contact area of the finger with the top insulator. The finger contact area has horizontal width w_2 and depth (into the page) d_1. The 'top' metal at node E_1 (red) has width w_1 and depth d_1. The 'bottom' metal at node E_2 (grey) has width w and depth d_2, where w is much larger than w_1 and w_2. The vertical distance between the top metal (red) and bottom plate (grey) is t_1, and the vertical distance between the finger (green) and the bottom plate (grey) is t_2.

Table 1: Touchscreen Dimension Values

d_1	d_2	w_1	w_2	t_1	t_2
10 mm	1 mm	1 mm	2 mm	2 mm	4 mm

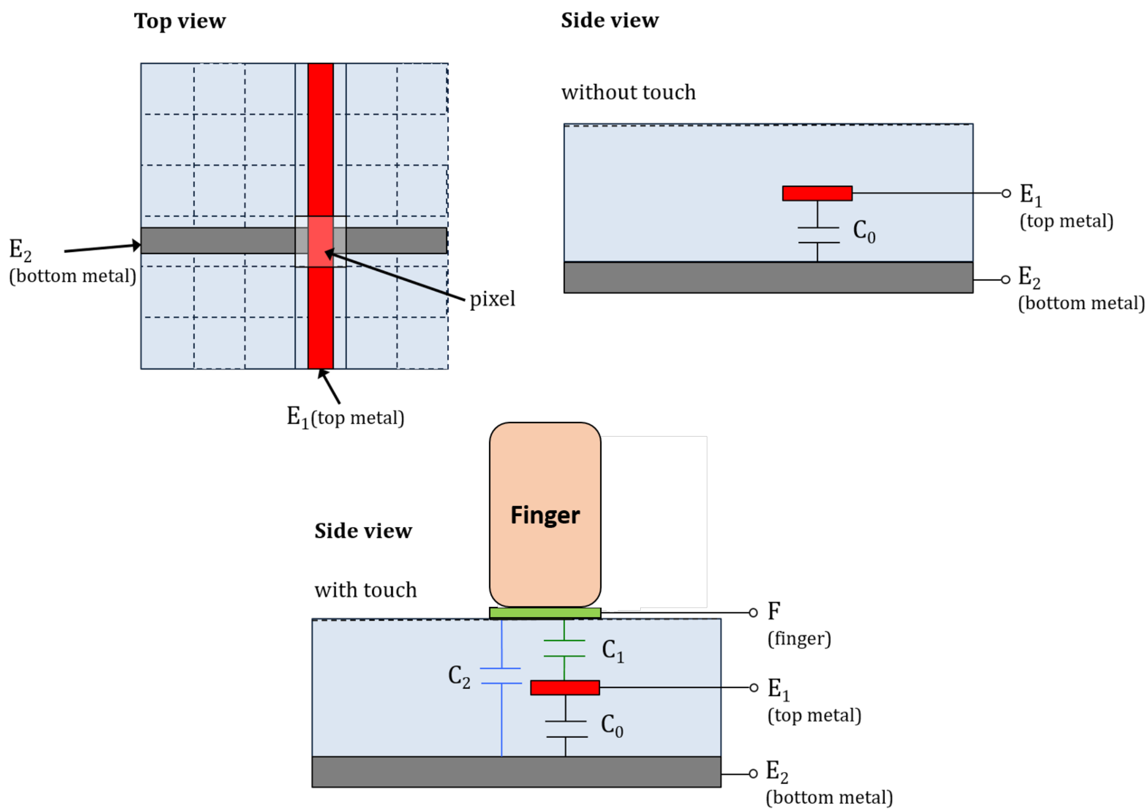


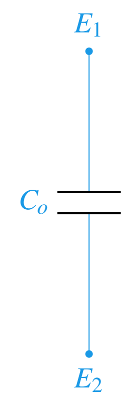
Figure 1: Model of capacitive touchscreen.

(a) Draw the equivalent circuit of the touchscreen that contains the nodes F, E_1, and E_2 when: (i) there is no finger present; and (ii) when there is a finger present. Express the capacitance values in terms of C_0, C_1, and C_2.

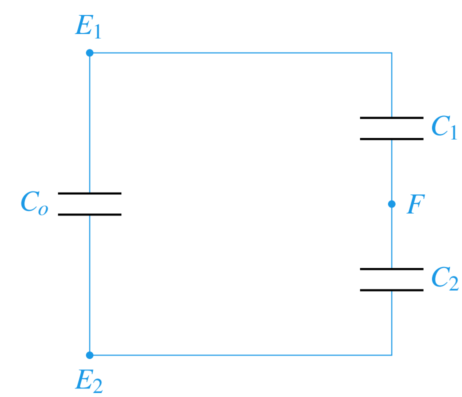
Hint: Note that node F represents the finger. When there is no touch node, F would be non-existent.

Answer:

i. Equivalent circuit with no finger present



ii. Equivalent circuit with a finger present



(b) What are the values of C_0, C_1, and C_2? Assume the insulating material has a permittivity of $\varepsilon = 4.43 \cdot 10^{-11}\,\mathrm{F/m}$ and the thickness of the metal layers is small compared to t_1 (so you can ignore the thickness of the metal layers). Also assume that the right edge of the top metal (red area) in the diagram is aligned with the right edge of the finger (green area) in the diagram.

Answer:

$$C_0 = \varepsilon \frac{d_2 w_1}{t_1} = 2.215 \cdot 10^{-14}\,\mathrm{F} = 22.15\,\mathrm{fF}$$

$$C_1 = \varepsilon \frac{d_1 w_1}{t_2 - t_1} = 2.215 \cdot 10^{-13}\,\mathrm{F} = 221.5\,\mathrm{fF}$$

$$C_2 = \varepsilon \frac{d_2 (w_2 - w_1)}{t_2} = 1.108 \cdot 10^{-14}\,\mathrm{F} = 11.08\,\mathrm{fF}$$

(c) What is the effective capacitance between the two metal plates (nodes E_1 and E_2) when a finger is present?

Answer:

The effective capacitance C_e between the two plates is $C_0 = 2.215 \cdot 10^{-14}\,\text{F}$ when there is no finger. When there is a finger, C_0 is in parallel with the series combination of C_1 and C_2, giving an additional capacitance $C_1 || C_2 = 1.055 \cdot 10^{-14}\,\text{F}$.

Therefore, the total effective capacitance (with finger) is $C_e = C_0 + C_1 || C_2 = 3.270 \cdot 10^{-14}\,\text{F}$.

(d) What are the advantages of a capacitive touchscreen over a resistive touchscreen?

Hint: Can we do multi-finger detections using a capacitive touchscreen? What about resistive touchscreens?

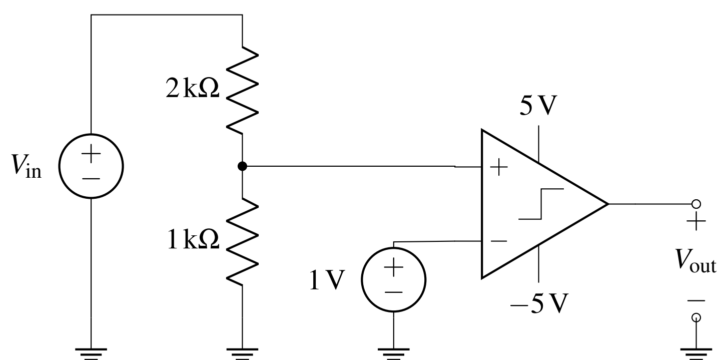
Answer:

Capacitive touchscreens can implement multi-touch gestures, while resistive screen can only locate a single touch position. In addition, capacitive touchscreens are also highly responsive, as they do not require any pressure to register a touch. Even the slightest touch will activate the screen.

2. Comparators

For each of the circuits shown below, plot V_{out} for V_{in} ranging from $-10\,\text{V}$ to $10\,\text{V}$ for part (a) and from $0\,\text{V}$ to $5\,\text{V}$ for part (b).

(a)

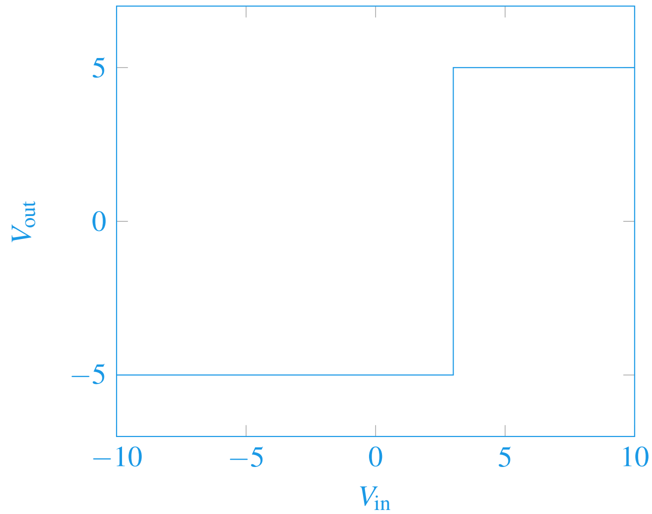


Answer:

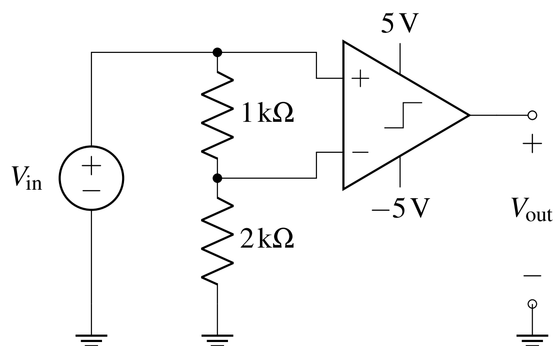
$$V_+ = \frac{1\,\text{k}\Omega}{2\,\text{k}\Omega + 1\,\text{k}\Omega} V_{\text{in}} = \frac{1}{3} V_{\text{in}}$$

$$V_- = 1\,\text{V}$$

The comparator will output +5 V when the voltage divider's output $V_+ > 1\,\text{V}$ and thus when $V_{\text{in}} > 3\,\text{V}$. Otherwise, it will output -5 V.



(b) **Practice**



Answer:

When the positive terminal's voltage, V_+, is greater than the negative terminal's voltage, V_-, the output voltage would be at the positive supply rail, V_{DD}. Likewise, if the negative terminal's voltage, V_-, has a higher voltage then the value at the negative supply rail, the output voltage would be V_{SS}. Since V_- is just the output of a voltage divider with the source $V_{\text{in}} = V_+$, it will always have lower absolute value and same polarity as the positive terminal. Thus, the comparator's output will depend only on the sign of the source V_{in}.

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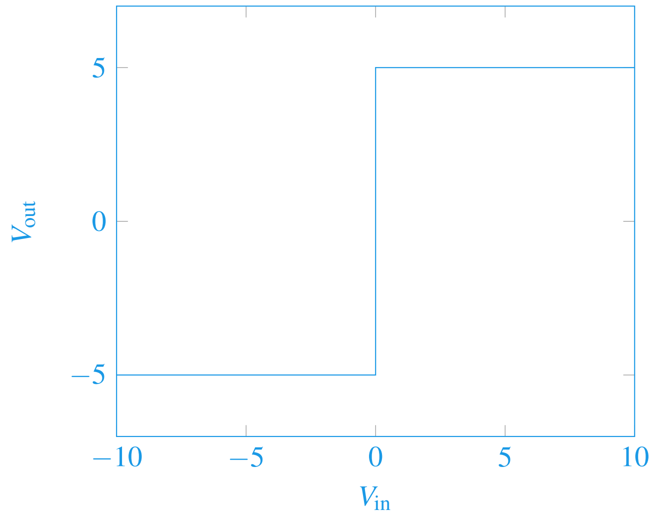
5
0
−5
−10
−5
0
5
10
V_{out}
V_{in}