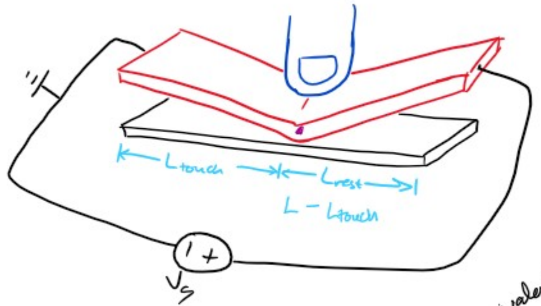
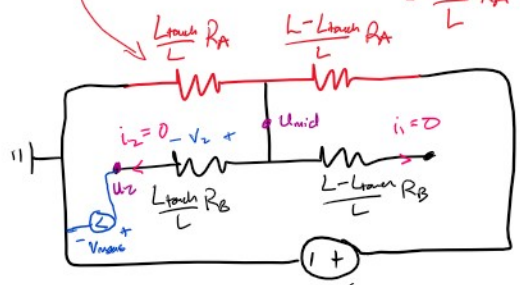
Dis 7B EECS16A

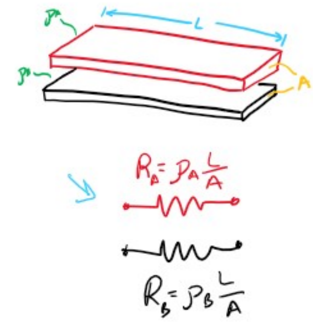
tinyurl.com/miyuki-feedback

# Resistive Touchscreen




$$\rho_A \frac{L_{touch}}{A} = \rho_A \frac{L_{touch}}{A}\frac{L}{L} = \frac{L_{touch}}{L}\rho_A \frac{L}{A} = \frac{L_{touch}}{L} R_A$$



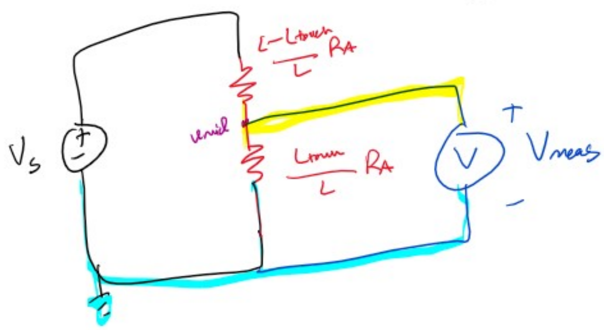




$$V_2 = u_{mid} - u_2 = \cancel{i_2}\left(\frac{L_{touch}}{L} R_B\right) = 0$$

$u_{mid} = u_2$

entire bottom plate has voltage $u_{mid}$

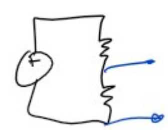
equivalent



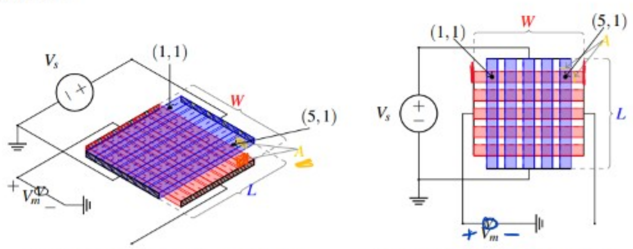

$u_2 = 0$

$$V_{meas} = u_{mid} - 0 = \frac{\frac{L_{touch}}{\cancel{L}} \cancel{R_A}}{\frac{L-L_{touch}}{\cancel{L}}\cancel{R_A} + \frac{L_{touch}}{\cancel{L}}\cancel{R_A}} V_s$$

$$= \frac{L_{touch}}{L} V_s \Rightarrow L_{touch} = \frac{V_{meas}}{V_s} L$$

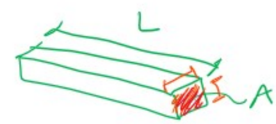


**1. Resist the Touch**




(a) 5×5 2-D Resistive Touch Screen Oblique View (b) 5×5 2-D Resistive Touch Screen Top View

Figure 1: $N \times N$ Resistive Touch Screen, $N = 5$




In this question we will be re-examining the 2-dimensional resistive touchscreen. This touchscreen, is slightly different to the one shown in lecture and more like the one we will be examining in lab.

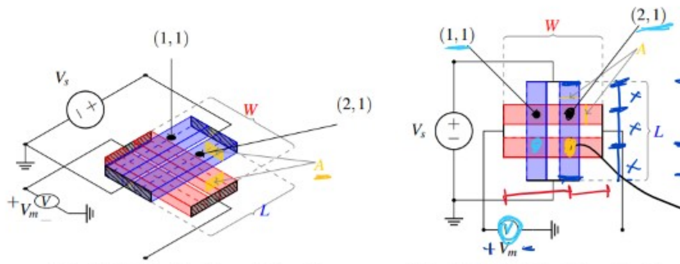
The touchscreen has length $L$ and width $W$ and is composed of a rigid bottom-layer and a flexible top-layer. Instead of a having a two continuous resistive sheets on the top and bottom layers, this is a simpler implementation with $N$ vertical strips of conductive material in the top layer and $N$ horizontal strips of conductive material in the bottom layer. The strips of a single layer are all connected by an ideal conducting plate on each side. All strips have resistivity, $\rho$, and cross-sectional area, $A$.

$$R = \rho \frac{L}{A}$$

Assume that all top layer resistive strips and bottom layer resistive strips are spaced apart equally, and that the upper left touch point in Figure 1(b) is position $(1,1)$, and the upper right touch point is $(N,1)$. The spacing between the strips in the top layer is $\frac{W}{N+1}$, and the spacing between the strips in the bottom layer is $\frac{L}{N+1}$.

(a) Find the resistance $R_y$ for a single vertical blue strip and $R_x$ for a single horizontal red strip, as a function of the screen dimensions $W$ and $L$, the strip resistivity $\rho$, and the cross-sectional area $A$.

$$R_x = \rho \frac{W}{A} \qquad R_y = \rho \frac{L}{A}$$



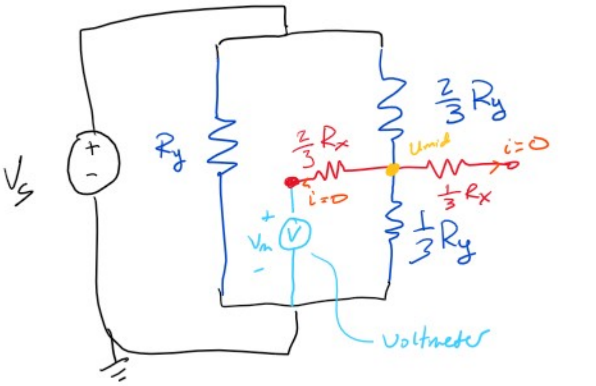

(a) 2×2 2-D Resistive Touch Screen Oblique View (b) 2×2 2-D Resistive Touch Screen Top View

Figure 2: $2 \times 2$ Resistive Touch Screen

$\frac{2}{3}L = L - L_{touch}$

$\frac{1}{3}L = L_{touch}$

$\rightarrow \frac{L - L_{touch}}{L} R_y = \frac{\frac{2}{3}L}{L} R_y = \frac{2}{3} R_y$



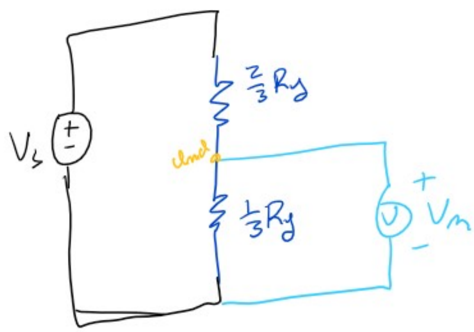

(b) Consider a $2 \times 2$ example for the touchscreen circuit, shown in Figure 2.

Assume that we connect a voltage source $V_s$, between the top and bottom terminals of the blue strips, and a voltmeter $V_m$ to one of the left or right terminals as depicted in the diagram.

If $V_s = 3\,\text{V}$, $R_x = 2000\,\Omega$, and $R_y = 2000\,\Omega$, draw the equivalent circuit for when the point $(2,2)$ is pressed and solve for the measured voltage, $V_m$, with respect to ground.

Reminder: all top layer resistive strips and bottom layer resistive strips are spaced apart equally, and that the upper left touch point is position $(1,1)$. The spacing between the strips in the top layer is $\frac{W}{N+1}$, and the spacing between the strips in the bottom layer is $\frac{L}{N+1}$.

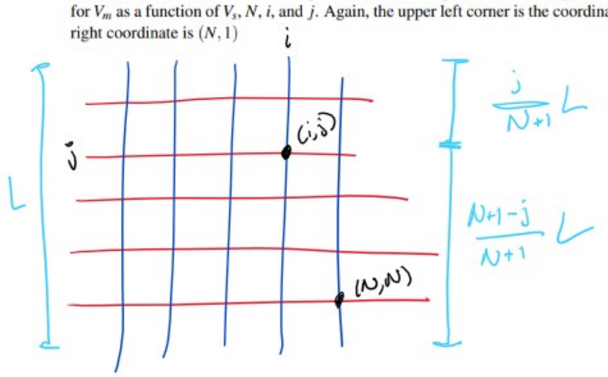
equivalent




$$V_m = u_{mid} - 0 = \frac{\frac{1}{3}\cancel{R_y}}{\frac{1}{3}\cancel{R_y} + \frac{2}{3}\cancel{R_y}} V_s = \boxed{\frac{1}{3} V_s}$$

* did we need to know the values of $R_x$ or $R_y$?
  no!
* can we determine $(x, y)$ location of touch?
  no! if I touch at $(1,2)$ $V_m = \frac{1}{3}V_s$
  → only measures $y$ location
* how can we find the $x$ location?
  → place voltage source over red bars
  measure blue bar voltage
  (i.e. rotate 90°)

(c) Suppose a touch occurs at coordinates $(i, j)$ for an arbitrary $N \times N$ touchscreen, and the voltage source and meter are connected as in the figures. A $5 \times 5$ example is shown in Figure 1(b). Find an expression for $V_m$ as a function of $V_s$, $N$, $i$, and $j$. Again, the upper left corner is the coordinate $(1,1)$ and the upper right coordinate is $(N,1)$



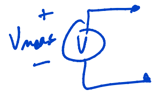

$$V_m = \frac{\frac{N+1-j}{N+1} R_y}{\frac{N+1-j}{N+1} R_y + \frac{j}{N+1} R_y} V_s = \boxed{\frac{N+1-j}{N+1} V_s}$$

(d) Optional / Fun: Experiment with the TinkerCad models below to validate the theoretical results you just derived.

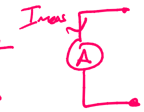
TinkerCad model of $2 \times 2$ equivalent circuit: https://www.tinkercad.com/things/0wIXz3MkD7B

TinkerCad model of $3 \times 2$ equivalent circuit: https://www.tinkercad.com/things/k5oolj2tUEN

Voltmeter: measures voltage across terminals

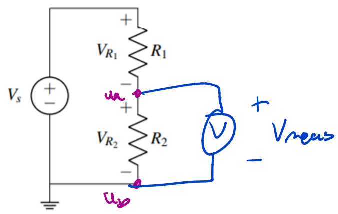



Ammeter: measures current through terminals

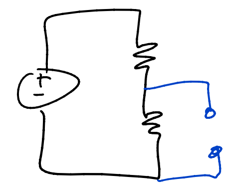



**2. Volt and Ammeter**

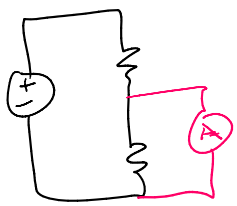
(a) For the voltage divider below, how would we connect a voltmeter to the circuit to measure the voltage $V_{R_2}$?

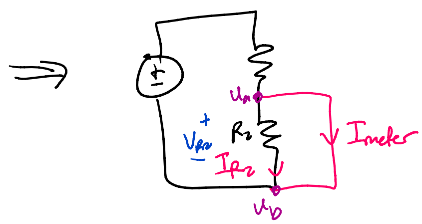



$V_{meas} = u_a - u_b = V_{R_2}$



(b) What would happen if we accidentally connected an ammeter in the same configuration instead? Assume our ammeter is ideal. wire



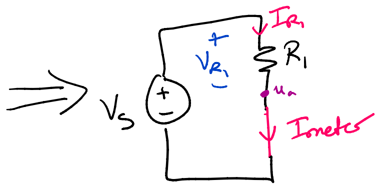




now $u_a$ and $u_b$ are the same node!

$u_a = u_b$

$V_{R_2} = u_a - u_b = 0$

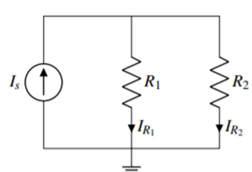
$I_{R_2} = \frac{V_{R_2}}{R_2} = \frac{0}{R_2} = 0$

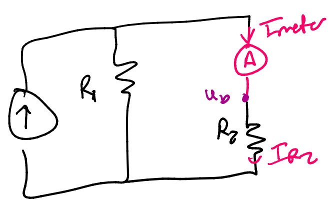



KCL @ $u_a$: $I_{R_1} = I_{meter}$

$I_{meter} = I_{R_1} = \frac{V_{R_1}}{R_1} = \frac{V_s}{R_1}$

(c) For the current divider below, how would we connect an ammeter to the circuit to measure the current $I_{R_2}$?

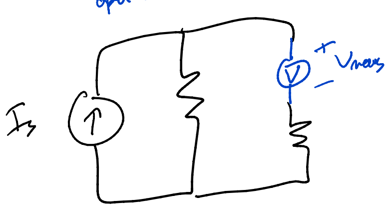


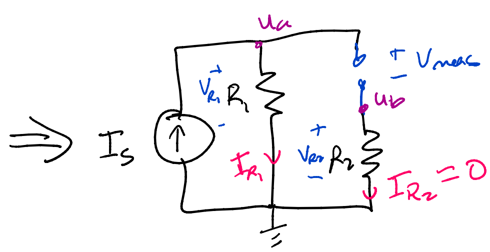




KCL @ $u_b$:

$I_{meter} = I_{R_2}$

(d) What would happen if we accidentally connected a voltmeter in that configuration instead? Assume the voltmeter is ideal. open circuit

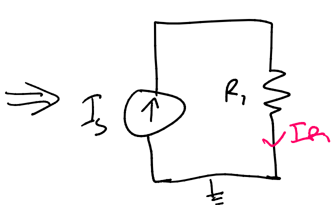



$u_b = 0$

$V_{R_2} = u_b - 0 = \cancel{I_{R_2}}^{0} R_2 = 0$

$u_b = 0$




$V_{meas} = u_a - u_b = V_{R_1} = I_{R_1} R_1 = I_s R_1$