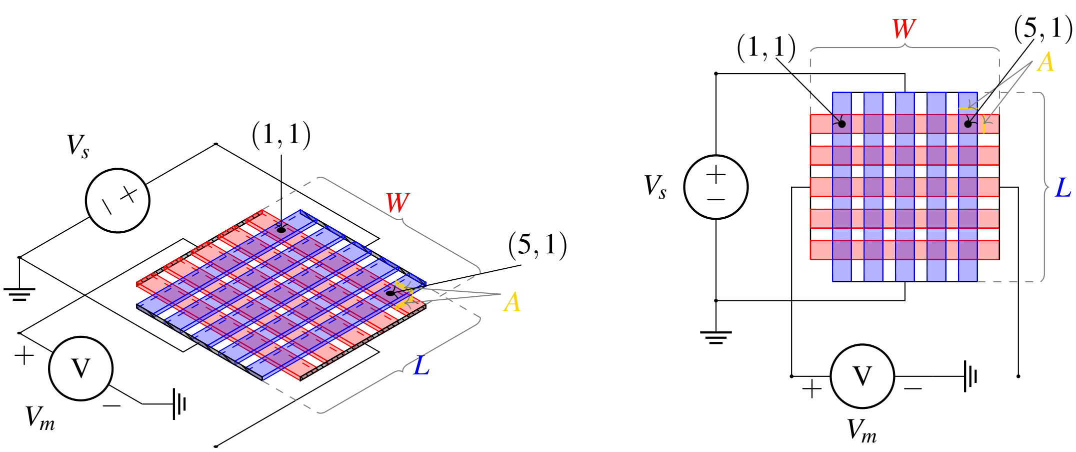
EECS 16A Designing Information Devices and Systems I
Spring 2023 Discussion 7B

1. Resist the Touch

Investigate the $N \times N$ resistive touchscreen with vertical length L and horizontal width W shown in Figure 1. The touchscreen is constructed in two layers: a flexible conductive top layer comprised of N vertically oriented strips with even spacing $\frac{W}{N+1}$; and a rigid conductive bottom layer comprised of horizontally oriented strips with even spacing $\frac{L}{N+1}$.

The vertical and horizontal strips form a grid of detectable touch points. The upper left touch point in Figure 1(b) is position $(1,1)$, and the upper right touch point is $(N,1)$. All strips in top and bottom layers have equal resistivity, ρ, and cross-sectional area, A.



(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, $N = 5$

(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 ρ, and the cross-sectional area A.

Answer:

The equation for resistance of a rectangular prism is $R = \dfrac{\rho l}{A}$, where ρ is the resistivity, l is the length, and A is the cross-sectional area.

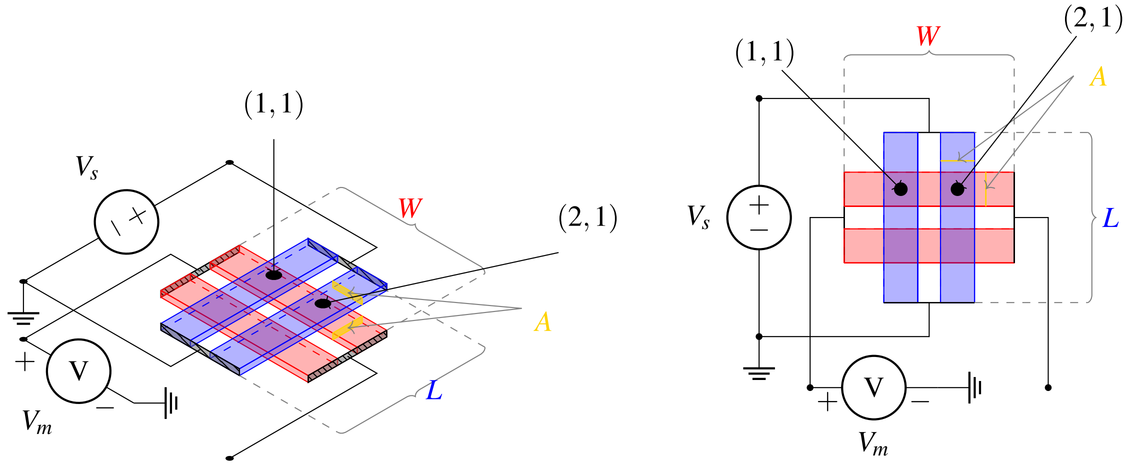
Therefore for the horizontal (red, bottom layer) resistive strips we have, $R_x = \dfrac{\rho W}{A}$.

For the vertical (blue, top layer) resistive strips, $R_y = \dfrac{\rho L}{A}$.

(b) Consider a 2×2 example for the touchscreen circuit, as shown in Figure 2.

Assume a voltage source V_s is connected from the top to bottom terminals of all the vertical (blue) strips, and a voltmeter V_m is connected from the left terminal of all horizontal (red) strips to the negative terminal of the voltage source.

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.



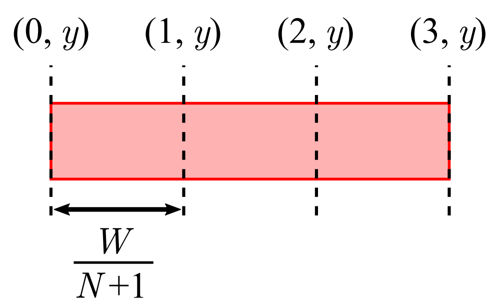
(a) 2×2 2-D Resistive Touch Screen Oblique View

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

Figure 2: 2×2 Resistive Touch Screen

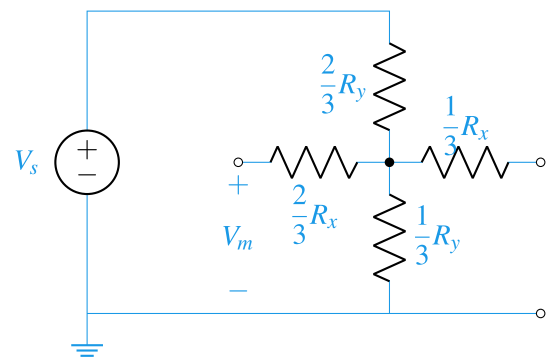
Answer:

All top layer strips and bottom layer strips are spaced apart equally, the upper left touch point is position $(1,1)$, and the lower right touch point is $(2,2)$. The spacing between the vertical (blue) strip centerlines in the top layer is $\frac{W}{N+1}$, and the spacing between the horizontal (red) strip centerlines in the bottom layer is $\frac{L}{N+1}$. Consequently, each strip can be effectively divided into $N+1$ equal length segments.

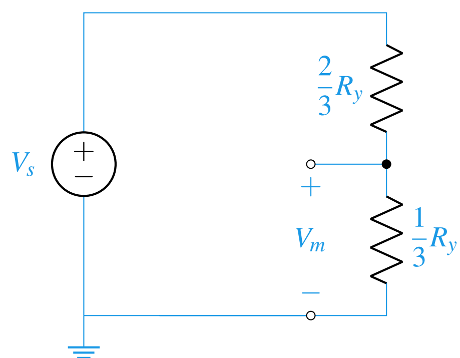


Since all of the resistive strips are equally spaced, the resistance above point $(2,2)$ on the top layer, vertical, blue strip becomes $\rho\frac{\frac{2L}{3}}{A} = \frac{2}{3}\rho\frac{L}{A} = \frac{2}{3}R_y$ and the resistance below point $(2,2)$ on this vertical strip becomes $\rho\frac{\frac{L}{3}}{A} = \frac{1}{3}\rho\frac{L}{A} = \frac{1}{3}R_y$.

A similar argument can be made for the horizontal (red, bottom layer) strip resistances R_x. However they do not affect the measured voltage, V_m, as they are terminated with equivalent open circuits, leading to no current flow and therefore no voltage drops.



Observing that the rightmost vertical (blue, top layer) resistive strip forms a voltage divider, and remembering that there is no voltage drop across the dangling R_x resistors we can write an equivalent circuit



and we can determine V_m using the voltage divider equation.

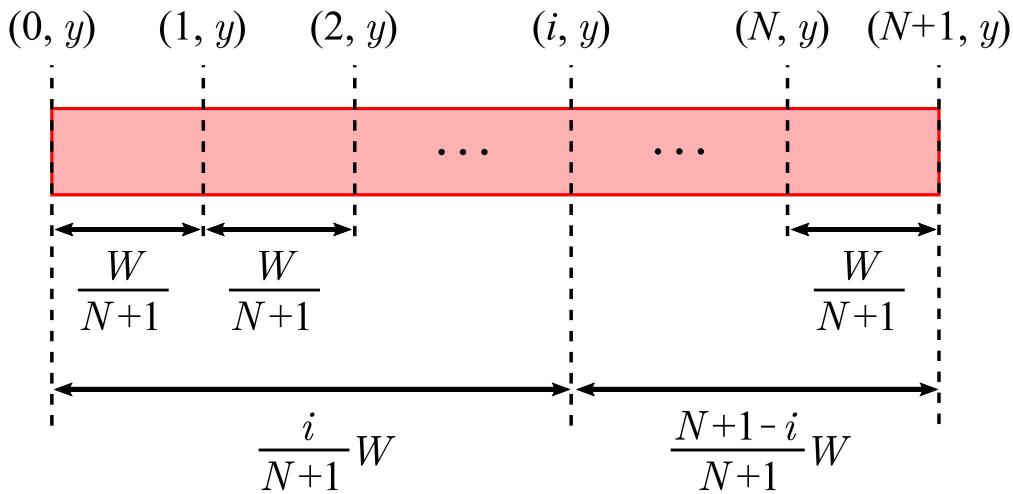
$$V_m = V_{(2,2)} = V_s \frac{\frac{1}{3}R_y}{\frac{1}{3}R_y + \frac{2}{3}R_y} = \frac{1}{3}V_s = 1\text{V}$$

Notice the measured voltage V_m does not depend on the actual strip resistances R_x and R_y.

(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 diagrams. Find an expression for V_m as a function of V_s, N, i, and j.

Answer:

Just like for the 2x2 resistive touchscreen in part (b), the spacing between the vertical (blue) strip centerlines in the top layer is $\frac{W}{N+1}$, and the spacing between the horizontal (red) strip centerlines in the bottom layer is $\frac{L}{N+1}$. Consequently, each strip can be effectively divided into $N+1$ equal length segments.



The voltage does not depend on the x coordinate, i, as the voltmeter is connected to the ends of the dangling horizontal stripe (red). Just like in part (b), we will only be able to detect changes in the y coordinate. If the touch point occurs at (i, j), the i-th vertical (blue) strip from the left will be split into lengths of $L_{top} = \frac{j}{N+1}L$ and $L_{bottom} = \frac{N+1-j}{N+1}L$ at the j-th touch point from the top. The voltmeter measures the voltage across the bottom half of the vertical (blue) resistance. We can also express the voltage divider directly as a ratio of the *lengths* of the resistances as

$$V_m = \frac{L_{bottom}}{L_{top} + L_{bottom}} V_s = \frac{L_{bottom}}{L} V_s = \frac{\frac{N+1-j}{N+1}L}{L} V_s = \frac{N+1-j}{N+1} V_s$$