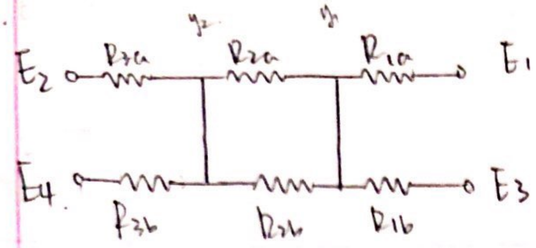
5. Multitouch Resistive Touchscreen

(a) $4k\Omega$

Since $W = 3cm = 0.03m, H = 12cm = 0.12m, T = 1mm = 1 \cdot 10^{-3}m = 0.001m$, so we can calculate the resistance between E_1 and E_2 as:

$$R = \rho \cdot \frac{L}{A} = \rho \cdot \frac{H}{W \cdot T} = 1\Omega m \cdot \frac{0.12m}{0.03m \cdot 0.001m} = 4000\Omega = 4\ k\Omega$$

(b).



Given that $R_{total} = \rho \frac{H}{W \cdot T} = 8\,k\Omega$, $y_1 = 3cm$ $y_2 = 7cm$ $H = 12cm$

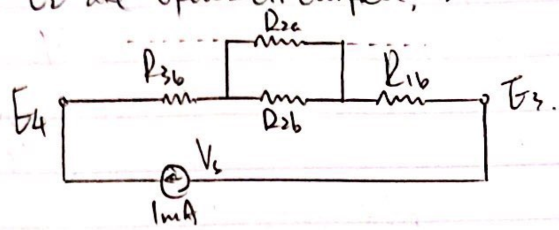
with $R_{total} = 8k\Omega$,

so $R_{1a} = R_{1b} = R_{total} \cdot \frac{y_1}{H} = 2k\Omega$.

$R_{2a} = R_{2b} = R_{total} \cdot \frac{y_2 - y_1}{H} = 2.667\ k\Omega$.

$R_{3a} = R_{3b} = R_{total} \cdot \frac{H - y_2}{H} = 3.333\ k\Omega$

(c). Using the given conditions, since E_1 and E_2 are open-circuited, so no current flow through resistors R_{3a} and R_{1a}, which means that the circuit diagram is equivalent to:



We can calculate using methods that the resistance between E_4 and E_3 is:

$$R_{eq} = R_{3b} + \frac{1}{1/R_{2a} + 1/R_{2b}} + R_{1b} = R_{total} \cdot \frac{H - y_2}{H} + \frac{1}{2} \cdot R_{total} \cdot \frac{y_2 - y_1}{H} + R_{total} \cdot \frac{y_1}{H}$$

with $y_1 = 3cm$, $y_2 = 7cm$, $H = 12cm$, so

$$= R_{total} \cdot \frac{H - y_2/2 + y_1/2}{H} = \frac{20}{3}\,k\Omega = 6.667\,k\Omega$$

Thus, $V_s = I_s \cdot R_{eq} = 1mA \cdot 6.667\,k\Omega = 6.667\,V$.

which means that $V_{E_4 - E_3} = V_s = \boxed{6.667V}$.

(d) Using what we've deduced in the steps of part (c), we have that.

$$R_{eq} = R_{total} \cdot \frac{H - y_2/2 + y_1/2}{H}.$$

$$\text{So, } V_{E_4 - E_3} = V_s = I_s \cdot R_{eq} = 1mA \cdot 8k\Omega \cdot \frac{H - y_2/2 + y_1/2}{H} = 8V \cdot \left(1 - \frac{y_2}{24} + \frac{y_1}{24}\right)$$

$$\text{So, } \boxed{V_{E_4 - E_3} = \left(8 - \frac{1}{3} y_2 + \frac{1}{3} y_1\right)\ V.}$$

(e). Using similar logic from part (c) and (d), so we can ① drive E_2, E_4 with a 1mA current source and measure $V_{E_4 - E_2} = I_s \cdot R_{eq_{2,4}}$ where

$$R_{eq_{2,4}} = R_{3a} + \frac{1}{1/R_{2a} + 1/R_{2b}} + R_{3b} = R_{total} \cdot \left(\frac{H - y_2}{H} + \frac{1}{2} \cdot \frac{y_2 - y_1}{H} + \frac{H - y_2}{H}\right).$$

$$= 8k\Omega \cdot \frac{2H - \frac{3}{2} y_2 - \frac{1}{2} y_1}{H}.$$

$$\text{So, } V_{E_4 - E_2} = 1mA \cdot 8k\Omega \cdot \left(2 - \frac{3}{24} y_2 - \frac{1}{24} y_1\right) = \left(16 - y_2 - \frac{1}{3} y_1\right)\ V.$$

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Similarly, $Req_{1,3} = R_{1a} + \frac{1}{1/R_{2a} + 1/R_{2b}} + R_{1b} = R_{total} \cdot \left(\frac{y_1}{H} + \frac{1}{2} \cdot \frac{y_2 - y_1}{H} + \frac{y_1}{H} \right)$

$= 8k\Omega \cdot \left(\frac{y_1 + \frac{1}{2}y_2 - \frac{1}{2}y_1 + y_1}{H} \right)$ where $H = 12$ (cm)

$= 8k\Omega \cdot \left(\frac{1}{8} y_1 + \frac{1}{24} y_2 \right)$

And, providing/driving E_1, E_3 with a 1mA current source gives:

$V_{E_1-E_3} = I_s \cdot Req_{1,3} = 1mA \cdot 8k\Omega \left(\frac{1}{8} y_1 + \frac{1}{24} y_2 \right)$

so $V_{E_1-E_3} = \left(y_1 + \frac{1}{3} y_2 \right)$ V

Thus, we have two (plus one) equations:

$$V_{E_4-E_2} = \left(16 - \frac{1}{3} y_1 - y_2 \right) \text{ V.}$$

$$V_{E_1-E_3} = \left(y_1 + \frac{1}{3} y_2 \right) \text{ V}$$

[formed). $V_{E_4-E_3} = \left(8 + \frac{1}{3} y_1 - \frac{1}{3} y_2 \right)$ V