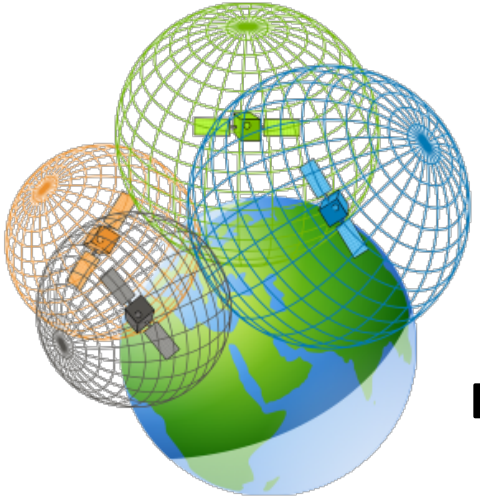


We  CS 16A!

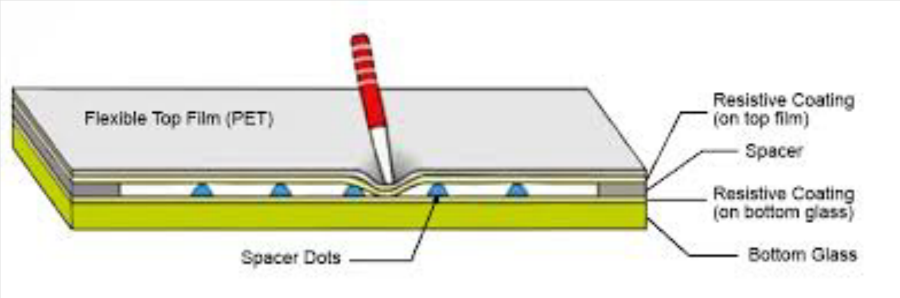
Designing Information Devices and Systems I

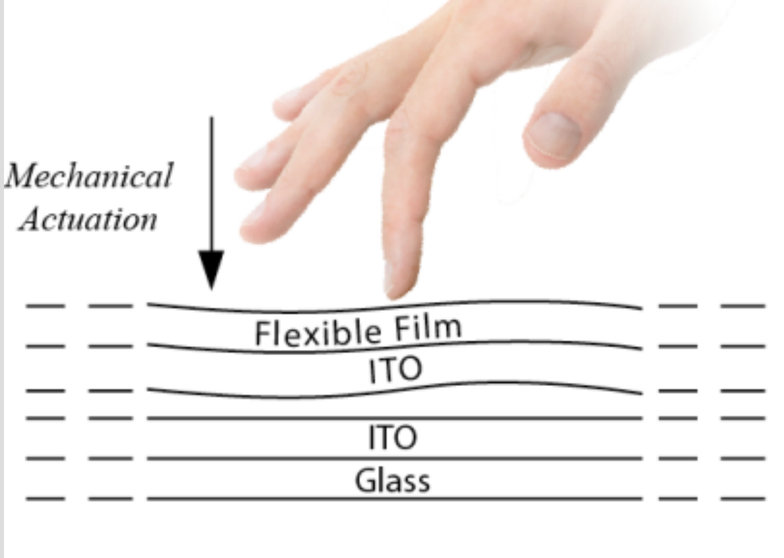
Ana Claudia Arias and Miki Lustig

Fall 2022

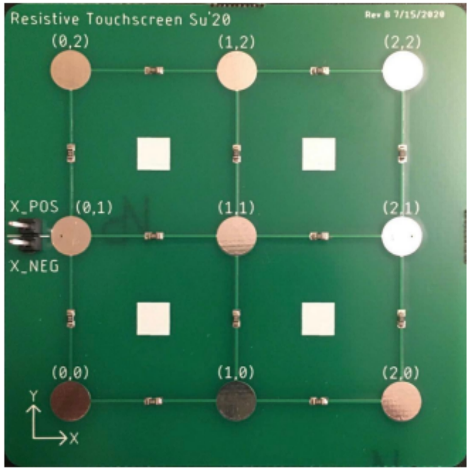
Module 2
Lecture 4
2D Touchscreen
(Note 14)

Resistive Touch Screen

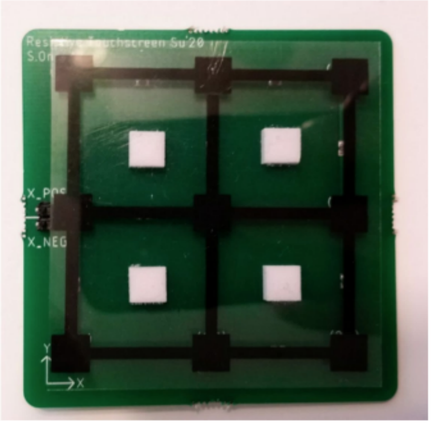




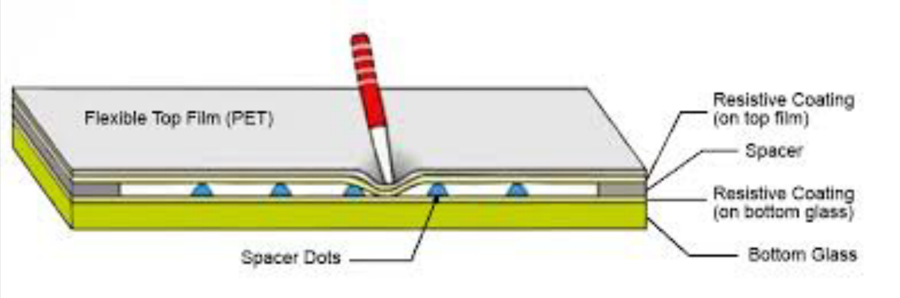
Bottom Layer: Resistive Layer

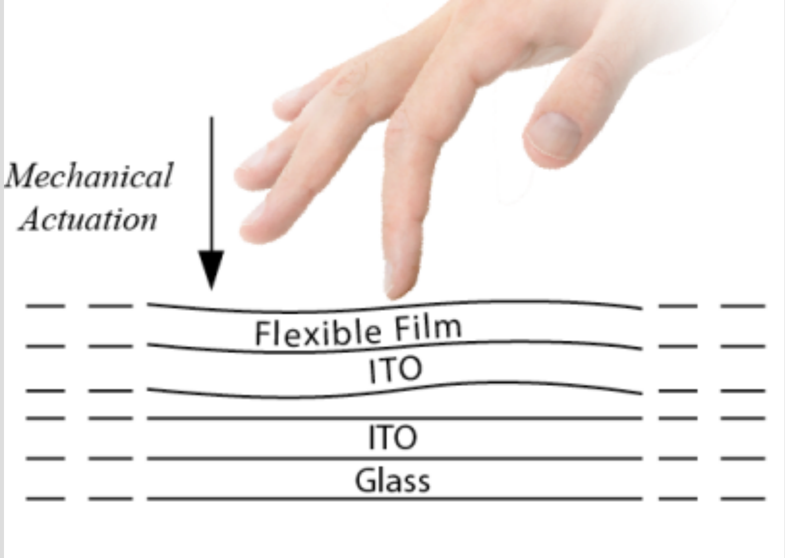


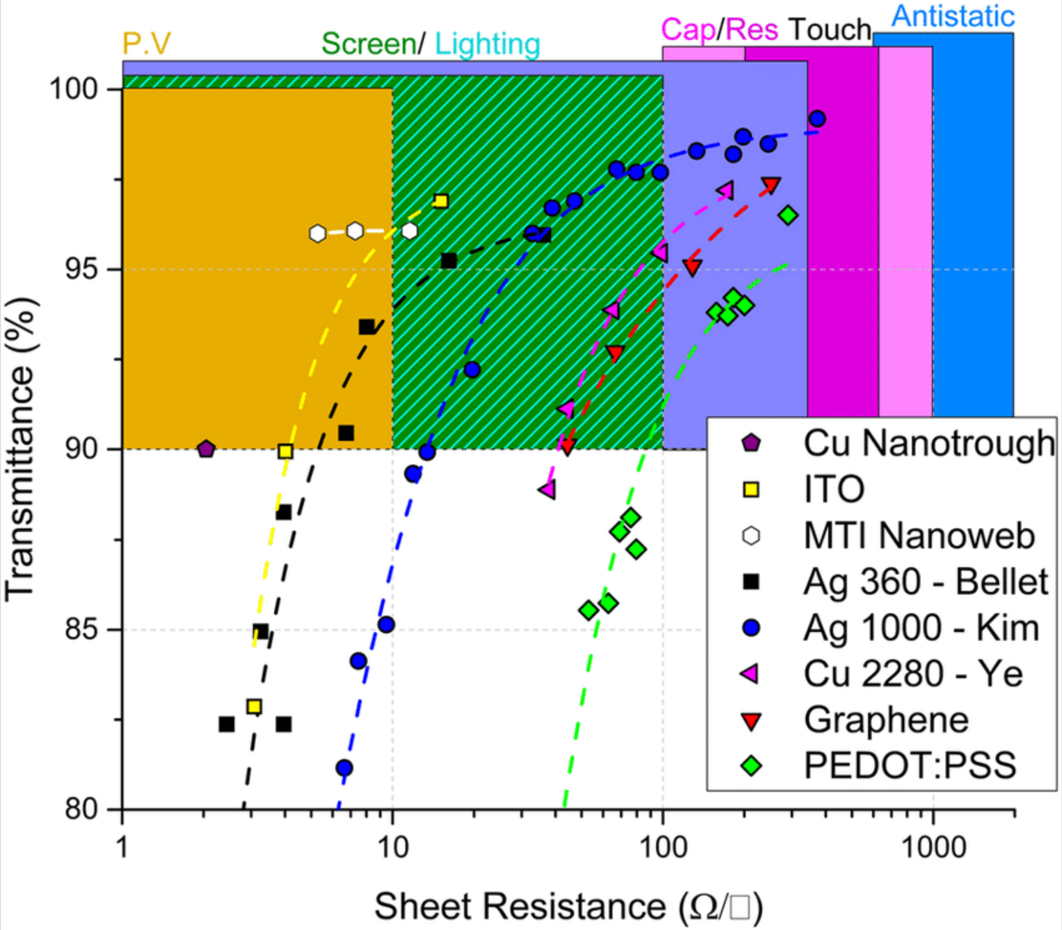
Top Layer: Flexible Resistive Layer



Resistive Touch Screen



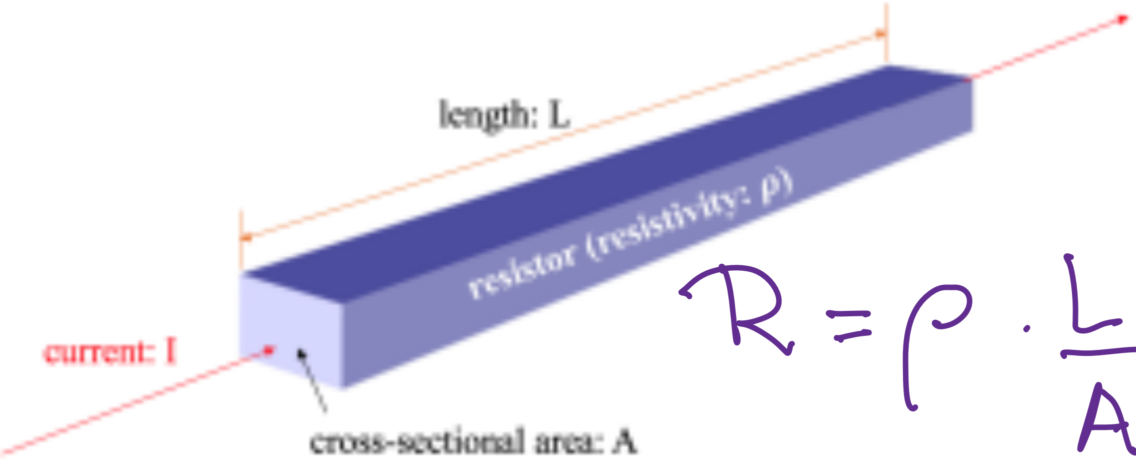




https://doi.org/10.1038/s41598-019-47777-2

Resistance, Resistivity, Conductivity – Properties of Materials

Material	Electrical characteristics	
	Electrical Resistivity (Ω x cm)	Electrical Conductivity (Ω^{-1} x cm^{-1})
Cu	0.034×10^{-5}	29×10^{5}
Fe	32.54×10^{-5}	0.031×10^{5}
Ag	0.36×10^{-5}	2.8×10^{5}
Al	0.03×10^{-5}	33.3×10^{5}
Ni	0.046×10^{-5}	21.7×10^{5}
Cu-Fe	33.37×10^{-5}	0.030×10^{5}
Cu-Ag	2.71×10^{-5}	0.37×10^{5}
Al-Ni	0.564×10^{-5}	1.77×10^{5}



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

Note 12

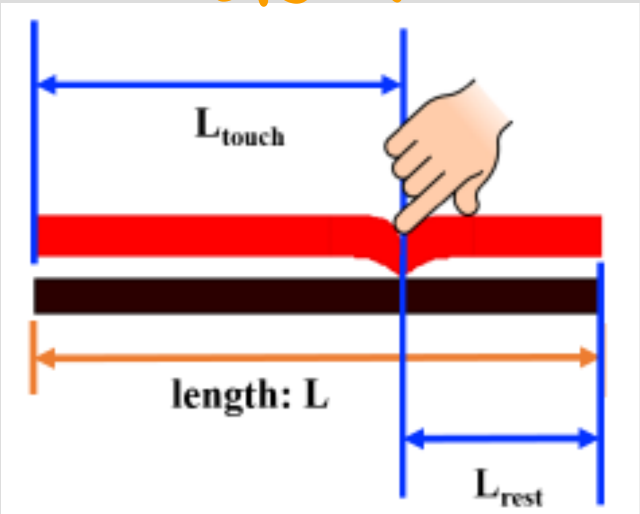
- Longer the wire → the more E is lost
- Wide wires → lower resistance
- Wire properties depend on materials choice.

ρ = resistivity (property of materials)

$\frac{L}{A}$: geometric parameters (property of the wire)

Resistive Touch Screen

Problem: to find the location of touch.



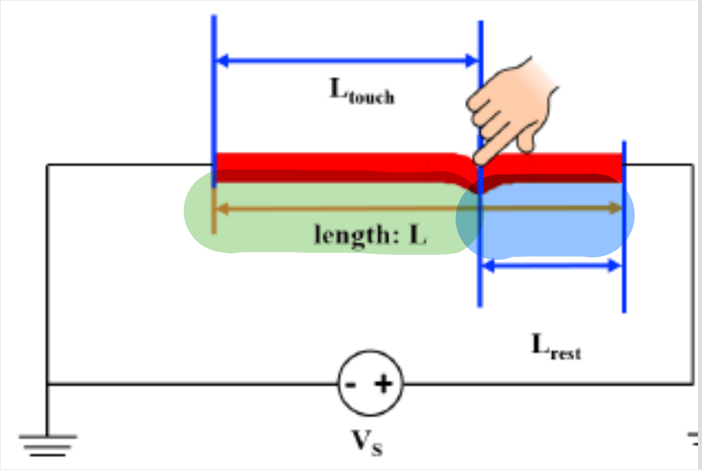
Go from mechanical to electrical quantity.

Want to measure $\frac{L_{touch}}{L}$

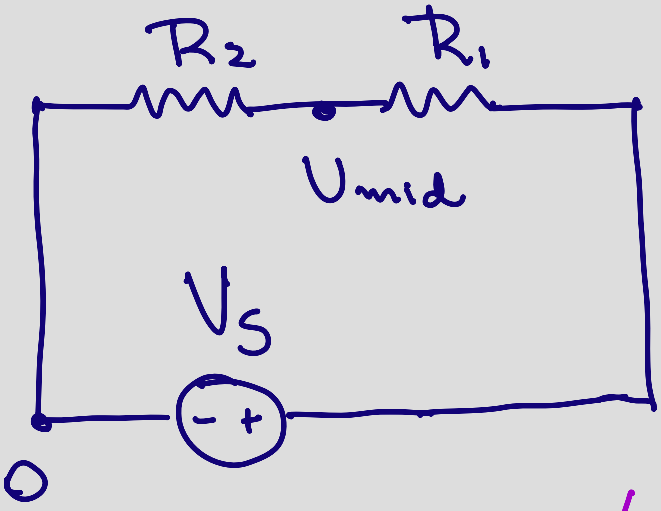
L_{touch} is unknown

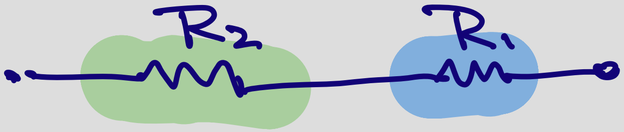
Resistive Touch Screen – First model

$U_{mid} = ?$



$\Rightarrow$





$$U_{mid} = \frac{R_2}{R_2 + R_1} \cdot V_S$$

(Voltage Divider)*

$$R_1 = \rho \cdot \frac{L_{rest}}{A}$$

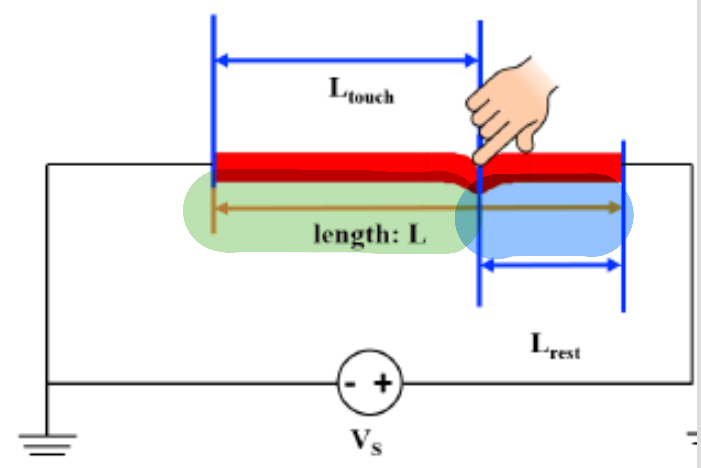
$$R_2 = \rho \cdot \frac{L_{touch}}{A}$$

$$U_{mid} = \frac{\rho \cdot L_{touch}/A}{\rho \cdot \frac{L_{touch}}{A} + \rho \frac{L_{rest}}{A}} \cdot V_S$$

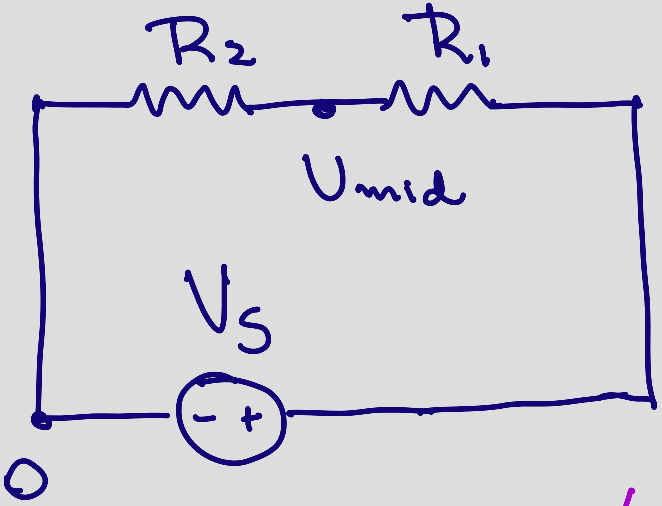
$$U_{mid} = \frac{L_{touch}}{L_{touch} + L_{rest}} \cdot V_S = \frac{L_{touch}}{L} \cdot V_S$$

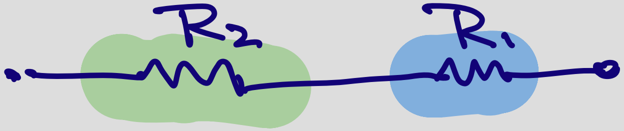
Resistive Touch Screen – First model

$U_{mid} = ?$



$\Rightarrow$





$$U_{mid} = \frac{R_2}{R_2 + R_1} \cdot V_S \quad (\text{Voltage Divider})^*$$

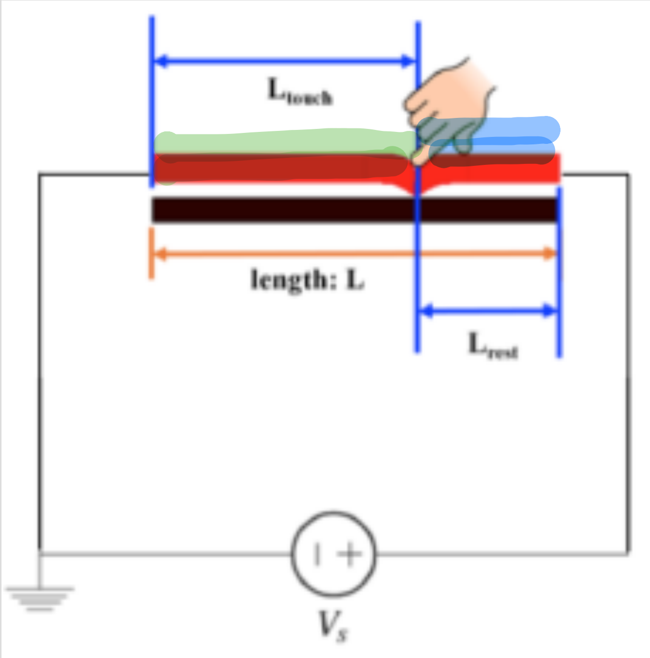
$$R_1 = \rho \cdot \frac{L_{rest}}{A}$$

$$R_2 = \rho \cdot \frac{L_{touch}}{A}$$

$$U_{mid} = \frac{\rho \cdot L_{touch}/A}{\rho \cdot \frac{L_{touch}}{A} + \rho \frac{L_{rest}}{A}} \cdot V_S$$

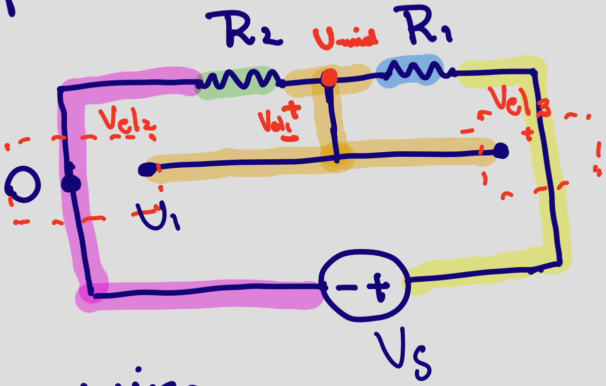
$$U_{mid} = \frac{L_{touch}}{L_{touch} + L_{res}} \cdot V_S = \frac{L_{touch}}{L} \cdot V_S$$

Resistive Touch Screen – More realistic model



⇒ Model 1

- Add ideal wire to represent bottom plate



el_1 : wire

el_2 : open-circuit (V_{el_2})

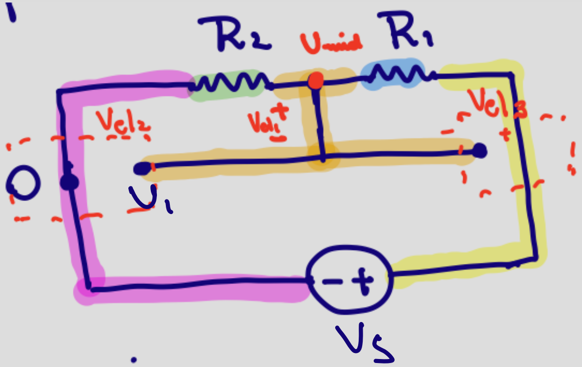
el_3 : open-circuit (V_{el_3})

Model 0

$$U_{mid} = \frac{R_2}{R_1 + R_2} \cdot V_s$$

Voltage Divider

Resistive Touch Screen – More realistic model



el1 : wire
el2 : open-circuit (Vel2)
el3 : open-circuit (Vel3)

Voltage Definition

El2 ∴ $V_{el_2} = U_1 - 0$

El1 ∴ $V_{el_1} = U_{mid} - U_1$

KVL

$U_{mid} - 0 = V_{el_2} + V_{el_1}$

$U_{mid} = V_{el_2} + V_{el_1}$ ($V_{el_1} \to 0$)

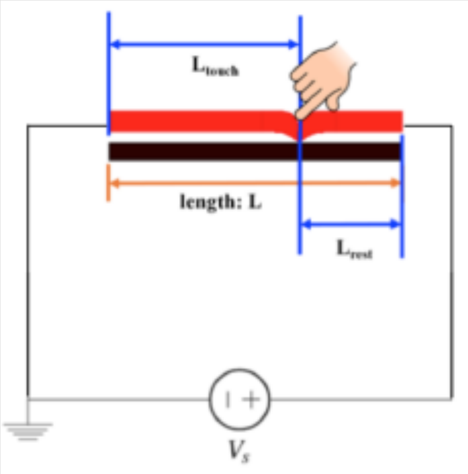
$U_{mid} = V_{el_1} + U_1$ ($V_{el_1} \to 0$)

el1 is a wire ∴ $V_{el_1} = 0$

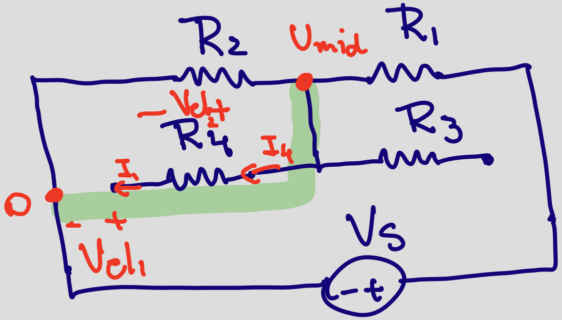
$U_{mid} = U_1$

↳ By measuring V_{el_2} we get U_{mid} for any touch

Resistive Touch Screen – More realistic and better model



Model 2 - imperfect conductor (resistor)
(top and botton plates)



KCL for el_2

$$I_1 = I_4$$

$$I_1 = 0 \therefore I_4 = 0$$

In this model we added:

el_1 : open-circuit

el_2 : resistor (R_4)

$$V_{el_2} = R_4 \cdot I_4 \text{ (Ohm's Law)}$$

KVL

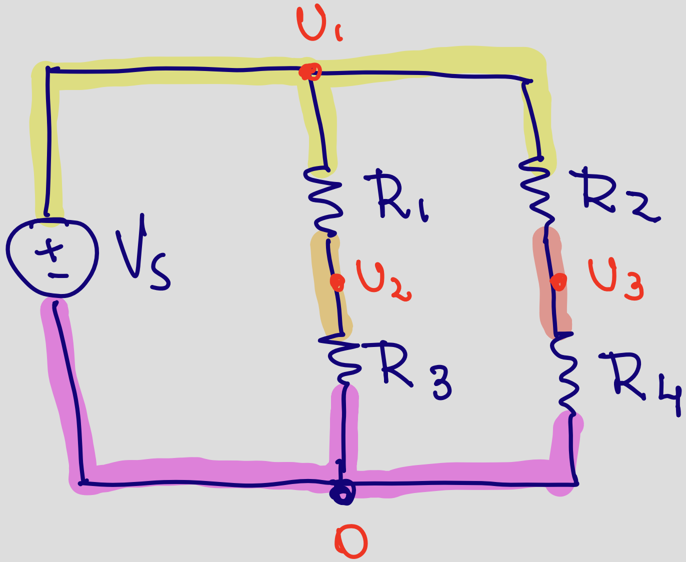
$$V_{el_1} + V_{el_2} = U_{mid} - 0$$

$$V_{el_1} + R_4 \cdot \cancel{I_4}^{\,0} = U_{mid}$$

$$U_{mid} = V_{el_1}$$

* By measuring V_{el_1} we get U_{mid} for any L_{touch};
inde endently of materials used in botton lane!

An interesting circuit



- What are U_2 and U_3?

$$U_2 = \frac{R_3}{R_1 + R_3} \cdot V_s$$

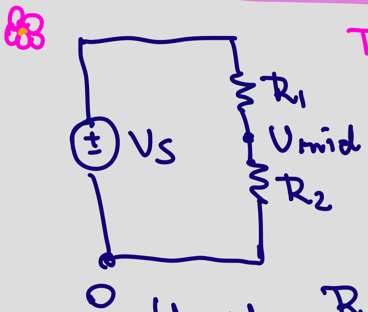
$$U_3 = \frac{R_4}{R_2 + R_4} \cdot V_s$$

$$U_2 - 0 = \frac{R_3}{R_1 + R_3} \cdot (U_1 - 0) \to V_s$$

$$U_3 - 0 = \frac{R_4}{R_2 + R_4} \cdot (U_1 - 0) \to V_s$$

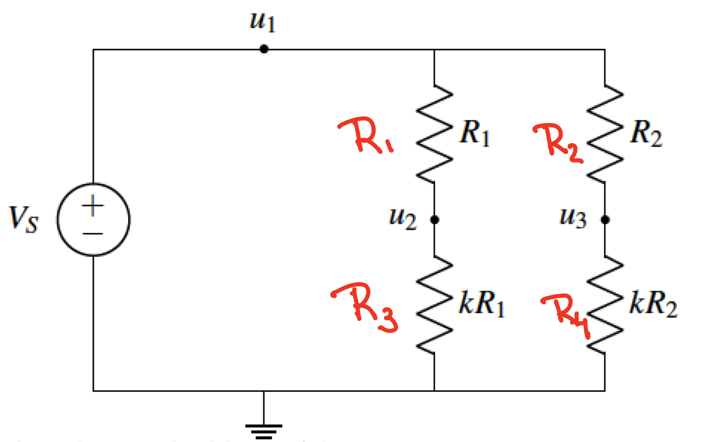
$$U_1 - 0 = V_s$$

Tool box



$$U_{mid} = \frac{R_2}{R_1 + R_2} \cdot V_s$$

An interesting circuit



As shown in Note 14

Power supply keeps U in wires equal to Vs regardless of how many branches we have!

$$U_2 = \frac{R_3}{R_1 + R_3} \cdot V_S$$

$$U_3 = \frac{R_4}{R_2 + R_4} \cdot V_S$$

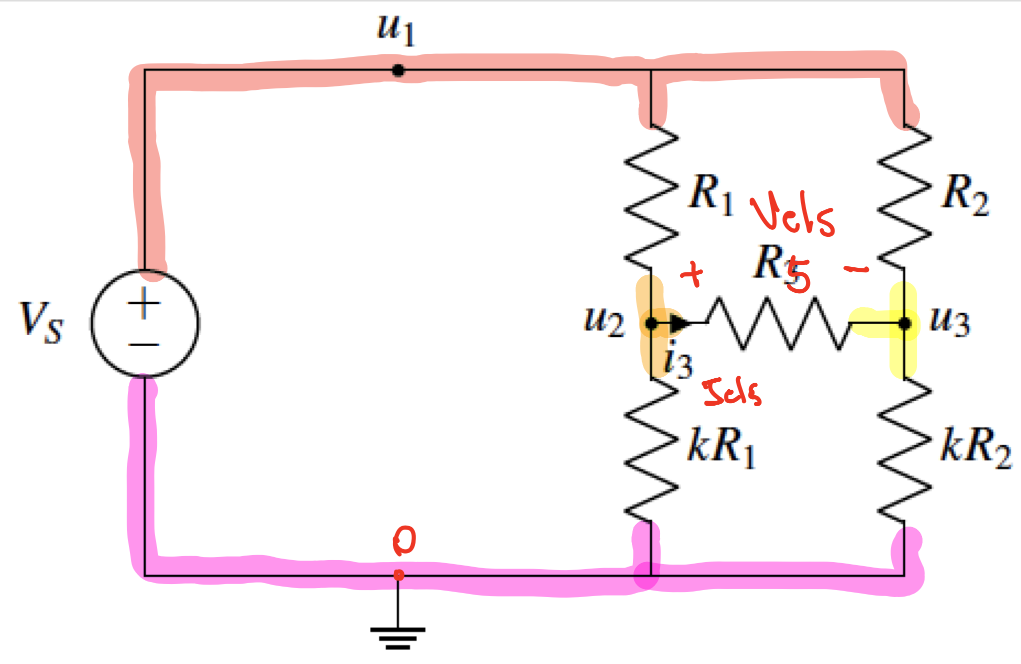
$$U_2 = \frac{kR_1}{R_1 + kR_1} \cdot V_S \quad \therefore \quad U_2 = \frac{k}{1+k} V_S$$

$$U_3 = \frac{kR_2}{R_2 + kR_2} \cdot V_S \quad \therefore \quad U_3 = \frac{k}{1+k} V_S$$

$$\boxed{U_2 = U_3}$$ *

wow!

Let's add on more resistor



$Elem_5$ = resistor (R_5)

$V_{el5} = U_2 - U_3$ (Voltage Def.)

Bold Assumption

$V_{el5} = 0$

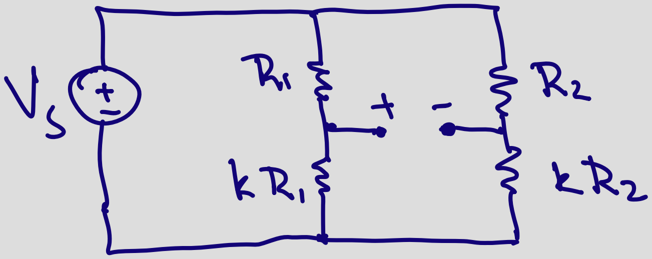
if $V_{el5} = 0 \Rightarrow J_{el5} = \frac{V_{el5}}{R_5} = 0$

if $J_{el5} = 0$

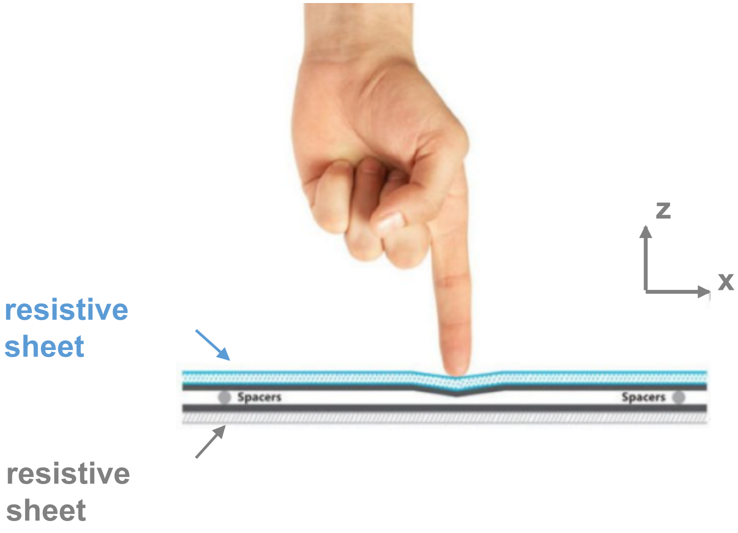
The circuit is the same as the one we already analysed without R_5.

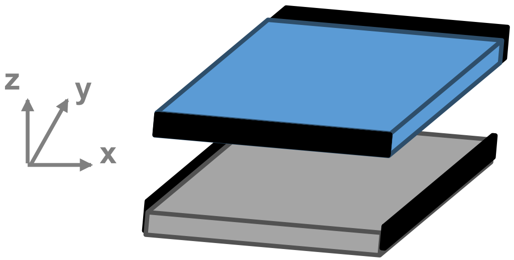
We showed: $U_2 = U_3$

$V_{el5} = U_2 - U_3 = 0$

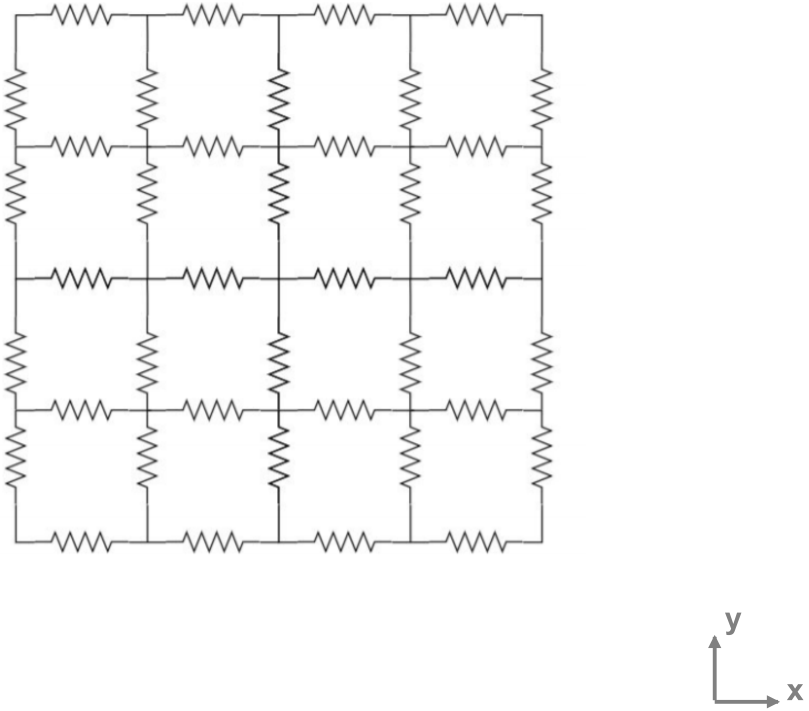


2D resistive Touchscreen circuit model

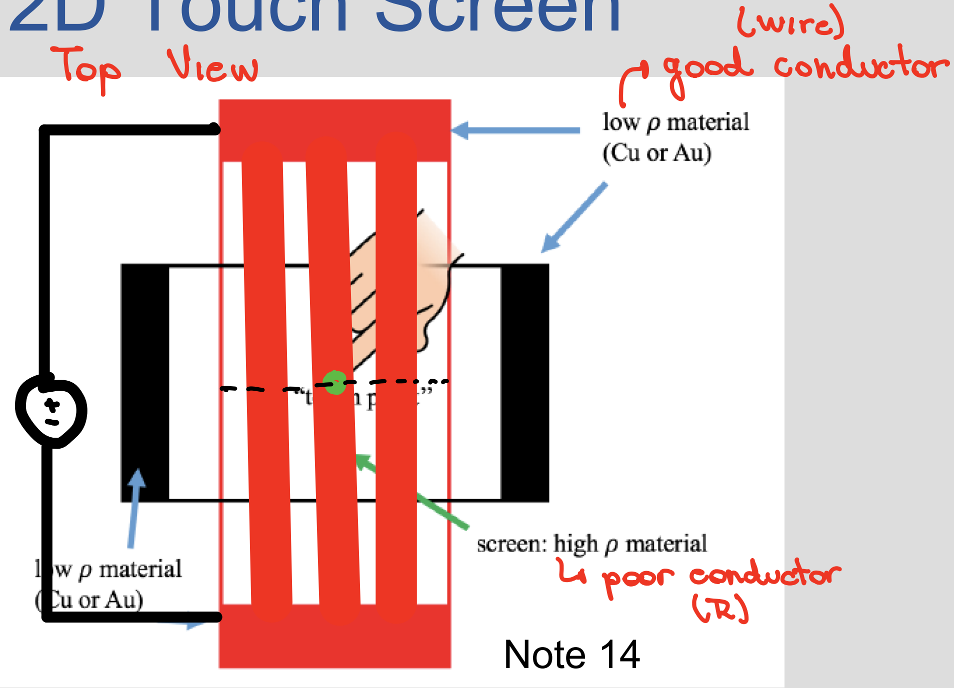


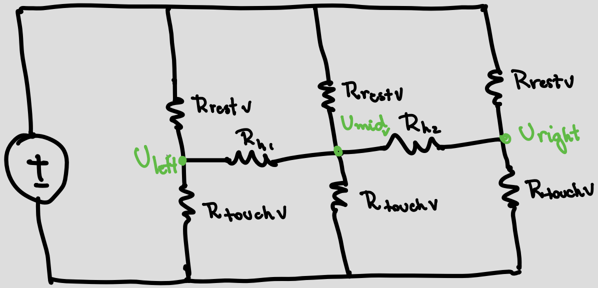


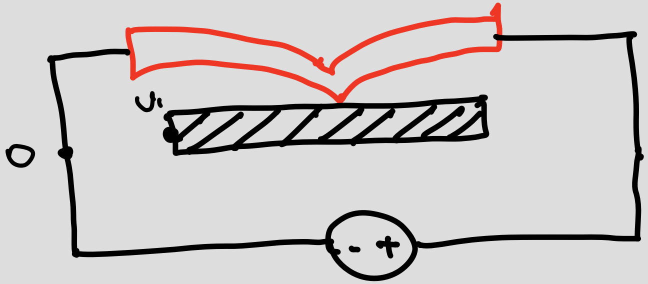
Our circuit model for each resistive sheet is a grid of resistors:



2D Touch Screen







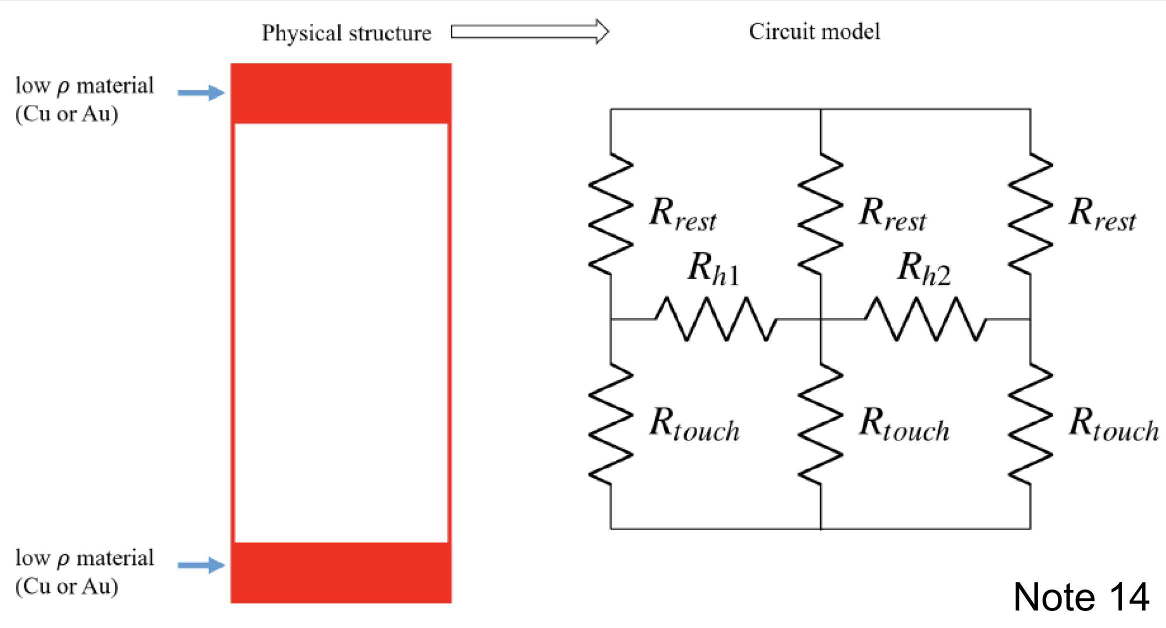
This is our interesting circuit

$$U_{mid,v} = U_{left} = U_{right}$$

$$U_{mid,v} = \frac{R_{touch}}{R_{rest} + R_{touch}} \cdot V_s$$

$$U_{mid,v} = \frac{\rho \frac{L_{touch}}{A}}{\rho \frac{L_{rest,v}}{A} + \rho \frac{L_{touch}}{A}} \cdot V_s$$

Top Plate Model

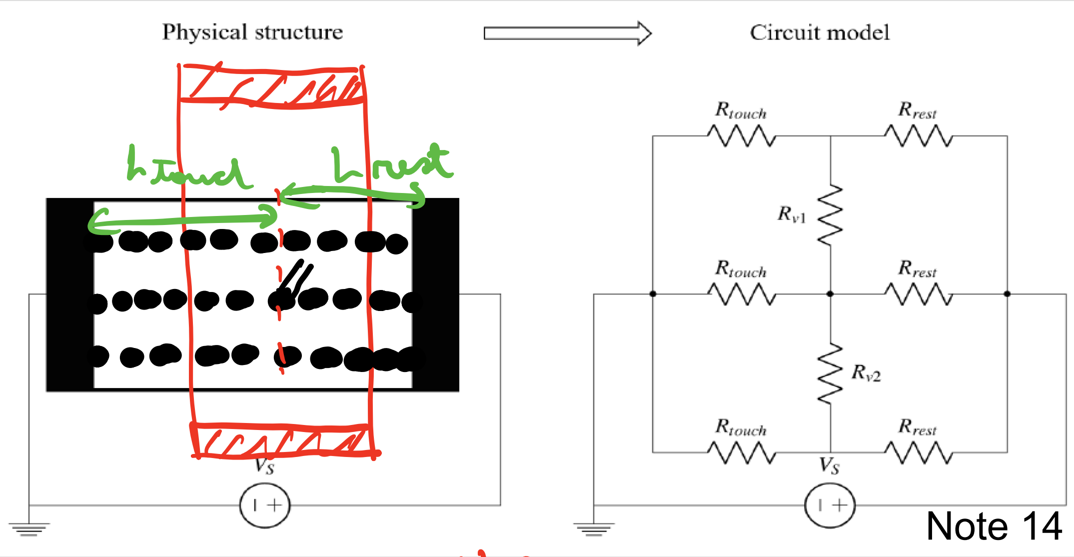


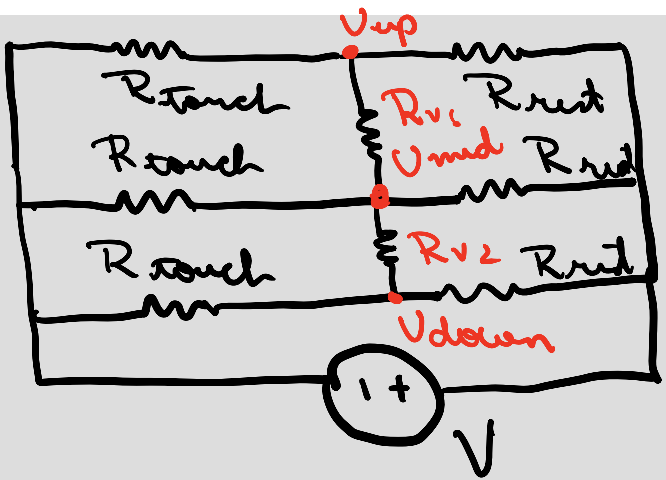
$$V_{midv} = \frac{R_{touch}}{R_{rest} + R_{touch}} \cdot V_s$$

* This gives us the vertical position in the screen.

What is the next step in the model?

Bottom Plate Model





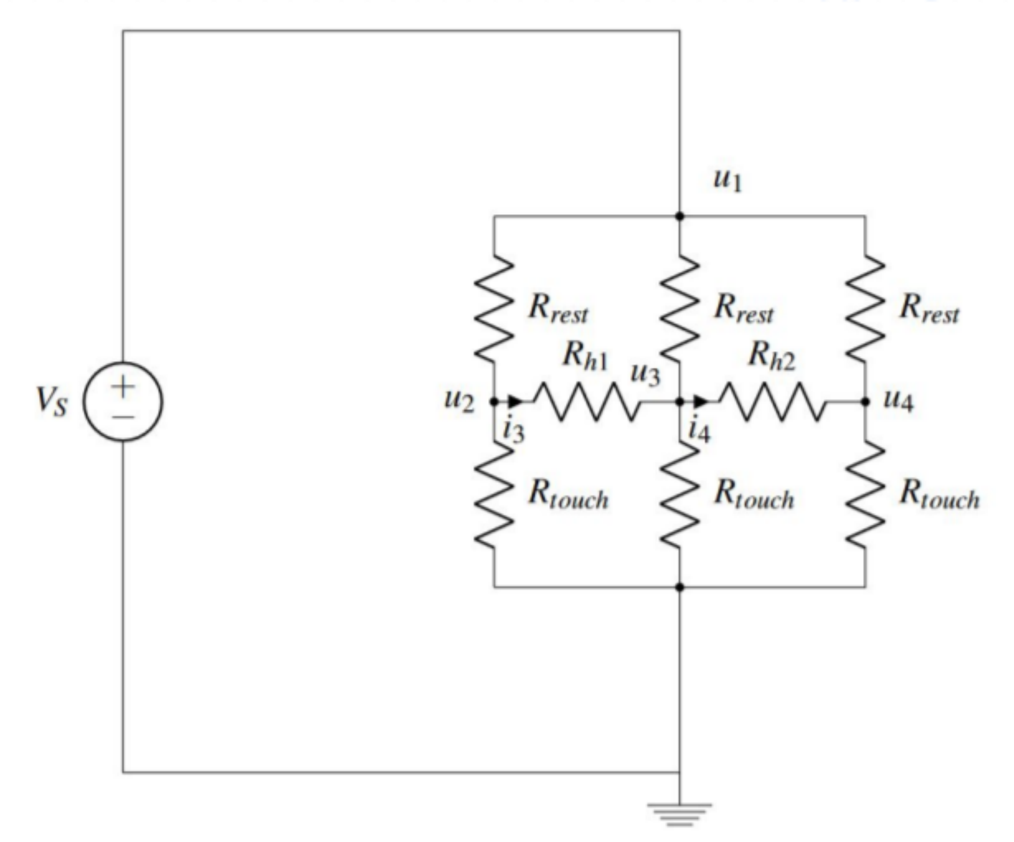
$$U_{up} = U_{mid} = U_{down}$$

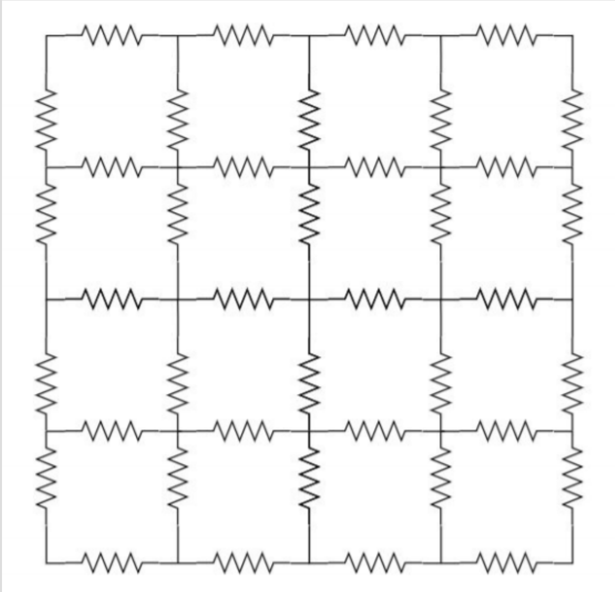
$$U_{mid,H} = \frac{R_{touch,H}}{R_{rest,H} + R_{touch}} \cdot V_s$$

$$U_{mid} = \frac{h_{touch,H}}{h_h} \cdot V_s$$

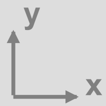
Horizontal information

Connecting voltage source to top sheet gives *y-touch* position

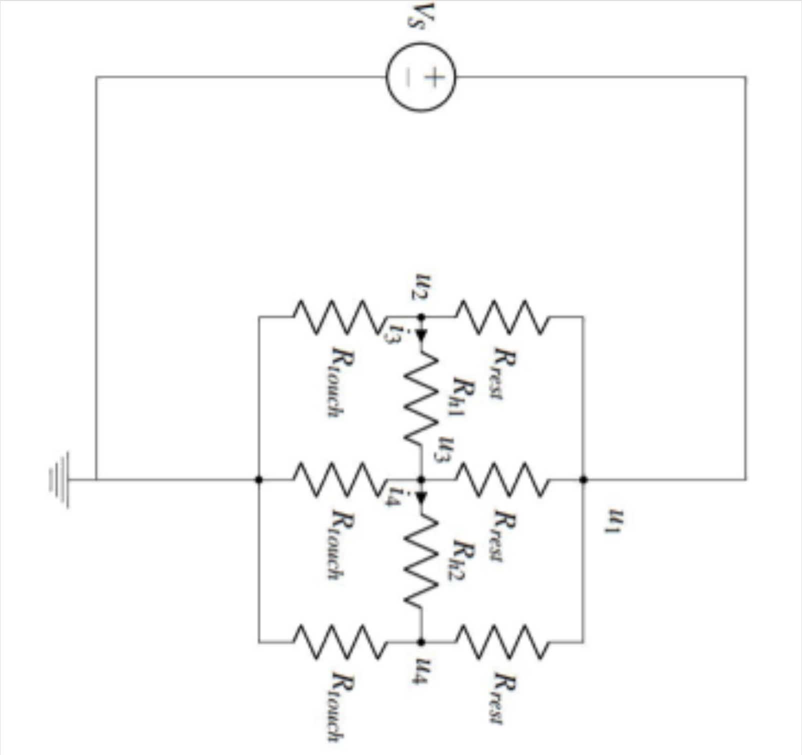


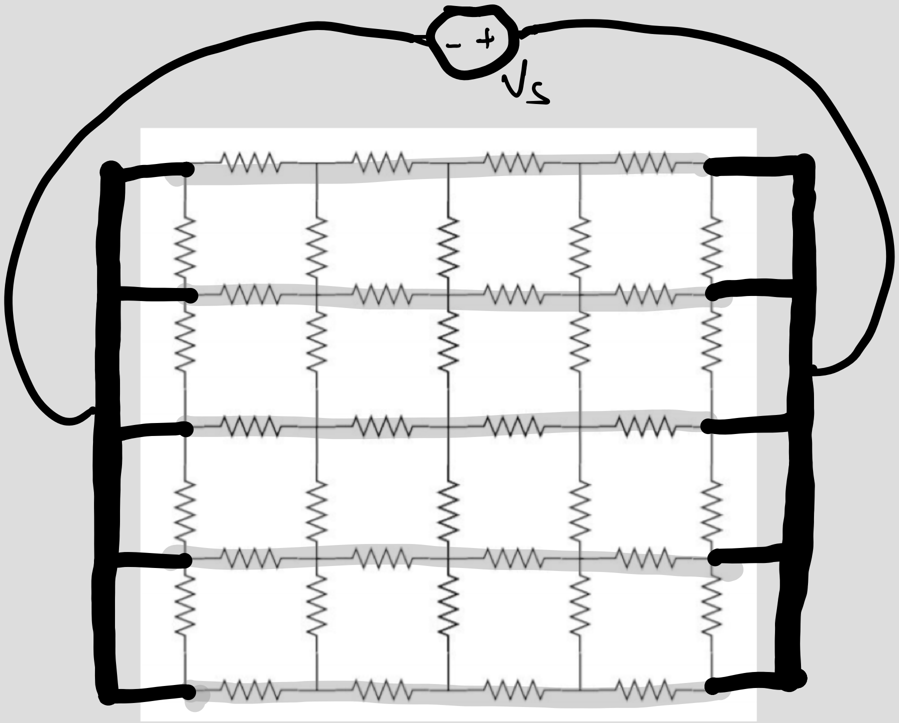


$$U_{mid} = \frac{h_{touch}}{h_v} \cdot V_s$$



Connecting voltage source to bottom sheet gives *x-touch* position





$$V_{mid} = \frac{L_{touch}}{L_H} \cdot V_S$$