Lecture 2 - Module 2

Touchscreen intro - modeling with circuit elements

Today:
- Complete circuit analysis
- Voltage divider example
- Touchscreen construction
  * Modeling
  * Analysis + Modeling to design a touchscreen

Note 12 (reading)

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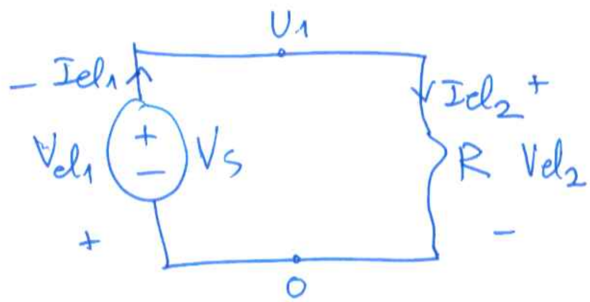
(12) **step 5:** summarize the unknowns

$$A\vec{x} = \vec{b} \qquad \vec{x} = \begin{bmatrix} I_{el_1} \\ \vdots \\ I_{el_K} \\ U_1 \\ \vdots \\ U_{N-1} \end{bmatrix}$$

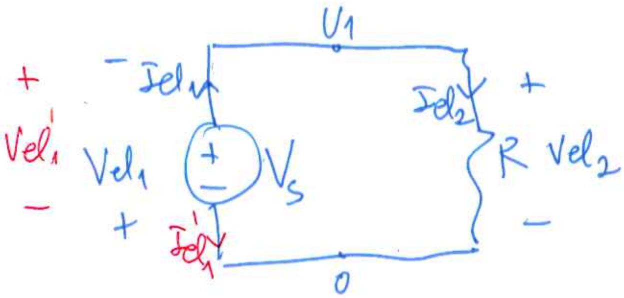
step 6: Use KCL to fill in as many rows of A as possible (lin. indep) #Nodes − 1



$$I_{el_1} = I_{el_2} \Rightarrow I_{el_1} - I_{el_2} = 0 \quad (1)$$

$$\begin{bmatrix} 1 & -1 & 0 \\ & & \\ & & \end{bmatrix} \begin{bmatrix} I_{el_1} \\ I_{el_2} \\ U_1 \end{bmatrix} = \begin{bmatrix} 0 \\ \\ \end{bmatrix}$$

step 7: Use I−V relationships for <u>each</u> element to fill the rest of the A matrix.



Voltage source: $V_{el_1}' = V_s$

$V_{el_1} = -V_s$

voltage def: $V_{el_1} = 0 - U_1 = -U_1$

subs.: $-V_s = -U_1 \Rightarrow \boxed{U_1 = V_s}$ (2)

Resistor: $V_{el_2} = I_{el_2} \cdot R$

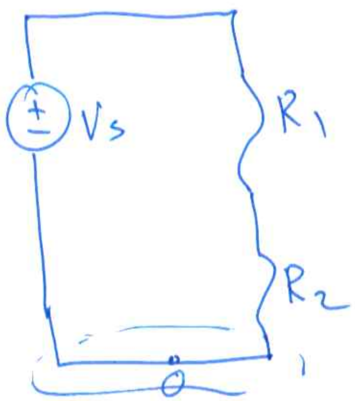
voltage def: $V_{el_2} = U_1 - 0 = U_1$

$\Rightarrow U_1 = I_{el_2} \cdot R$

$\boxed{R \cdot I_{el_2} - U_1 = 0}$ (3)

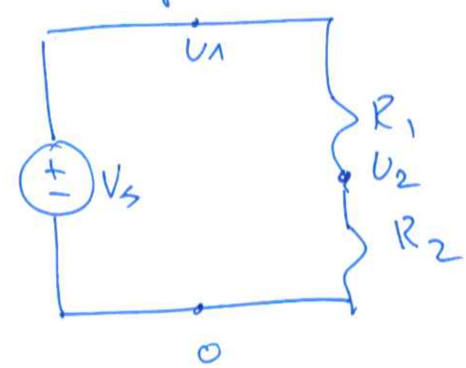
$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 0 & 1 \\ 0 & R & -1 \end{bmatrix} \begin{bmatrix} I_{el_1} \\ I_{el_2} \\ U_1 \end{bmatrix} = \begin{bmatrix} 0 \\ V_s \\ 0 \end{bmatrix} \Rightarrow \boxed{\begin{aligned} U_1 &= V_s \\ I_{el_1} &= \frac{V_s}{R} \\ I_{el_2} &= \frac{V_s}{R} \end{aligned}}$$

Voltage divider example:

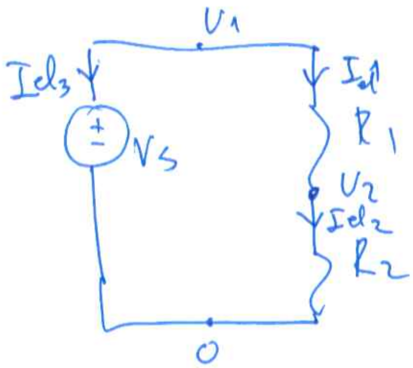


step 1 → label ref node

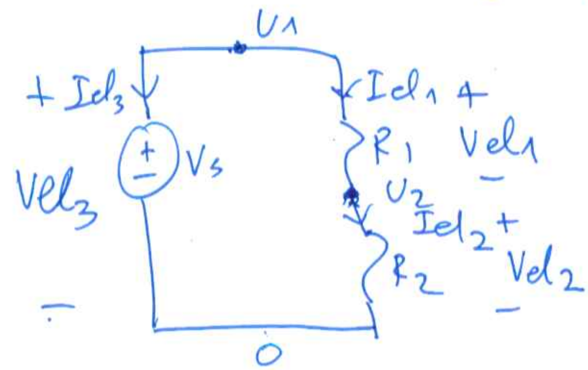
step 2: (label the potentials)



step 3: label the currents arbitrarily



step 4: "tricky" label the element voltages (passive sign conv).



step 5: identify unknowns:

$$\vec{x} = \begin{bmatrix} Iel_1 \\ Iel_2 \\ Iel_3 \\ U_1 \\ U_2 \end{bmatrix}$$

step 6: KCL

(1) $Iel_1 + Iel_3 = 0$

(2) $Iel_1 - Iel_2 = 0$

step 7: I-V & voltage defs for elements:

	~~Vel1~~ Voltage-defs	element I-V	
el 1:	$Vel_1 = U_1 - U_2$	$Vel_1 = R_1 \cdot Iel_1$	$\Rightarrow U_1 - U_2 = R_1 Iel_1$ (3)
	$Vel_2 = U_2 - 0 = U_2$	$Vel_2 = R_2 \cdot Iel_2$	$\Rightarrow U_2 = R_2 Iel_2$ (4)
	$Vel_3 = U_1 - 0 = U_1$	$Vel_3 = V_s$	$\Rightarrow U_1 = V_s$ (5)

(3) $R_1 Iel_1 - U_1 + U_2 = 0$

(4) $R_2 Iel_2 - U_2 = 0$

(5) $U_1 = V_s$

(24)

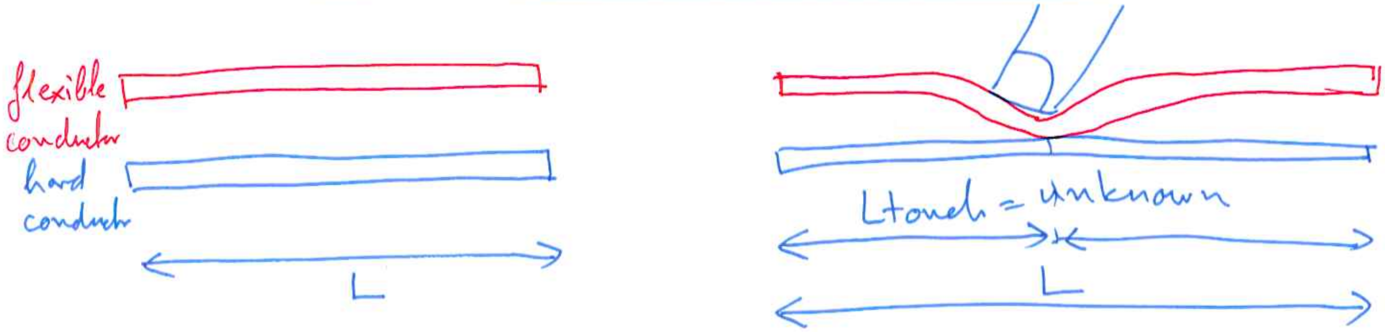
$$\begin{bmatrix} 1 & 0 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 \\ R_1 & 0 & 0 & -1 & 1 \\ 0 & R_2 & 0 & 0 & -1 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} I_{el_1} \\ I_{el_2} \\ I_{el_3} \\ U_1 \\ U_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ V_s \end{bmatrix}$$

$$I_{el1} = \frac{V_s}{R_1 + R_2}, \quad I_{el_2} = \frac{V_s}{R_1 + R_2}, \quad I_{el_3} = -\frac{V_s}{R_1 + R_2}$$

$$U_1 = V_s, \quad \boxed{U_2 = \frac{R_2}{R_1 + R_2} \cdot V_s}$$

voltage divider

Resistive touchscreen



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

Need to convert electrical quantity.

16A Physics

* Charge – can be either positive or negative
  basic element of electrical flow (e.g. electron)
  Unit: Coulomb [C]

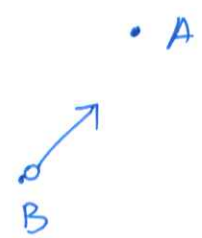
* Current – Net amount of charge that passes through some cross-section area over some period of time:

$$[A] \rightarrow I = \frac{dQ}{dt} \quad \begin{matrix} \leftarrow [C] \\ \leftarrow [s] \end{matrix}$$

Always do unit checks

* Voltage: Represents the energy to move a positive unit of charge from one point to another:

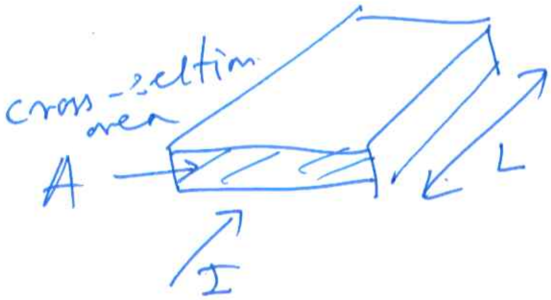
V_{AB}



$$[V] = \frac{[J]}{[C]} \leftarrow \text{energy unit}$$

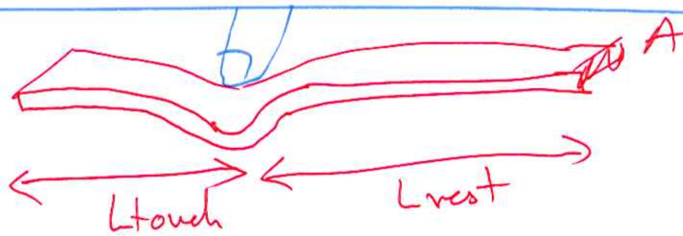
(16) * Resistance – real pieces of metal always require a certain amount of energy to allow charge to flow through

$$V_{el} = I_{el} R \qquad [V] = [A] \cdot [\Omega]$$



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

Physical:



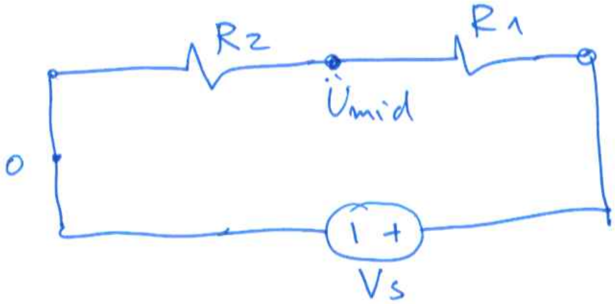
Model:

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

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

⇓

Design task: Build a circuit using this model to measure $\frac{L_{touch}}{L}$ as an electric quantity.



Subs.

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

$$= \frac{\rho \cdot \frac{L_{touch}}{A}}{\rho \cdot \frac{L_{rest}}{A} + \rho \cdot \frac{L_{touch}}{A}} \cdot V_s$$

$$U_{mid} = \frac{L_{touch}}{\underbrace{L_{rest} + L_{touch}}_{L}} \cdot V_s$$

$$\boxed{U_{mid} = \frac{L_{touch}}{L} \cdot V_s}$$

(7)

A more realistic model: