(l1)

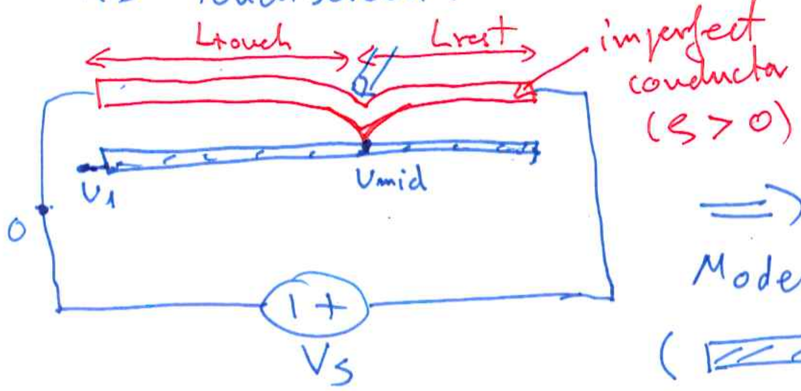
Lecture 3 - Module 2

Today:

- Revisit 1D Touchscreen
- Measuring voltage & current
- Power
- An interesting circuit

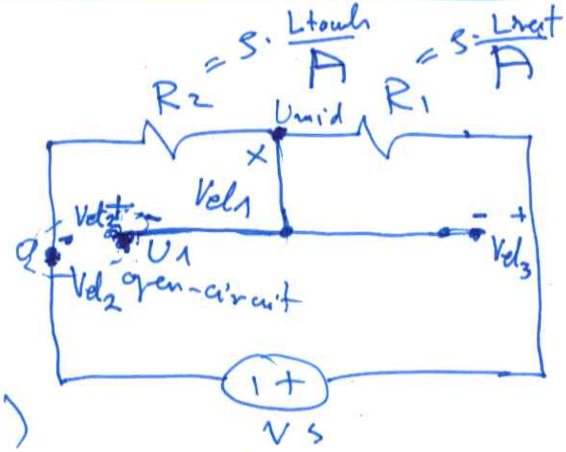
Note 13 and part of Note 14

1D Touchscreen:



$\Longrightarrow$ Model 1

ideal wire



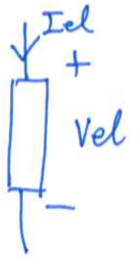
Model 0: (last lecture) $u_{mid} = \frac{R_2}{R_1+R_2} V_s$

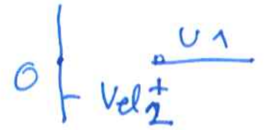
Model 1: added (with respect to Model 0)

el 1 : wire

el 2 : open-circuit (Vel_2)

el 3 : open-circuit (Vel_3)

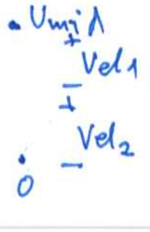




el2: $V_1 - 0 = Vel_2$ (definition of elem. voltage)

el1: $u_{mid} - u_1 = Vel_1$ (definition of elem. voltage)

KVL: $u_{mid} - 0 = Vel_2 + Vel_1$



$\underline{V_1 = Vel_2}$

$U_{mid} - \cancel{U_1} + \cancel{U_1} - 0 = Vel_1 + Vel_2$

$U_{mid} - U_1 = Vel_1$

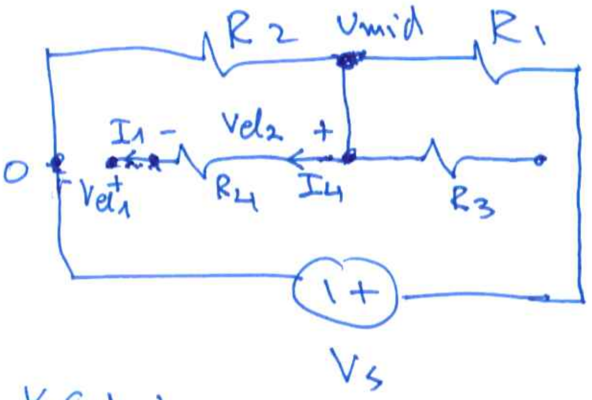
$U_{mid} = Vel_1 + Vel_2$

def of the element voltage : $Vel_1 = 0$

$$\underline{\underline{U_{mid}}} = Vel_2 + 0 = Vel_2 = \underline{\underline{U_1}}$$

what I wanted : by measuring Vel_2 we get U_{mid} for any Ltouch.

Model 2: imperfect  conductor (resistor)



el1: open-circuit

el2: resistor

$Vel_2 = R_4 \cdot I_4$

(Ohm's Law)

KCL: $I_1 = I_4$

el1 def: $I_1 = 0$

$\Downarrow$

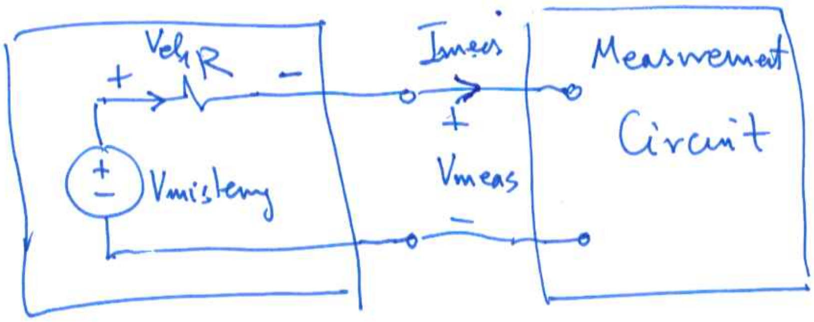
$I_4 = 0$

KVL: $U_{mid} - 0 = Vel_1 + Vel_2$

$U_{mid} = Vel_1 + R_4 \cdot \cancelto{0}{I_4}$

$$\boxed{U_{mid} = Vel_1}$$

Measure Umid at Vel1 regardless of the backplane conductor material and value of Ltouch.



Goal : $V_{meas} = V_{mistery}$

$$V_{el1} = I_{meas} \cdot R$$

KVL: $\underline{V_{mistery}} = V_{meas} + V_{el1} = \underline{V_{meas}} + \overset{0}{\cancel{I_{meas}}} \cdot R$

$$V_{mistery} = V_{meas} \Big|_{I_{meas} = 0}$$

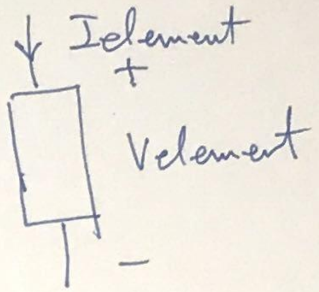
Measurement should not change the energy of the circuit (cause energy dissipation)

Defined a voltage between points A and B as: $V_{AB} = \frac{dE}{dq}$ dE energy required to to move dq from B to A.

Power (rate of energy change):

$$P = \frac{dE}{dt} = \underbrace{\frac{dE}{dq}}_{V} \cdot \underbrace{\frac{dq}{dt}}_{I} = V \cdot I$$

passive - sign convention :



$$P_{element} = V_{element} \cdot I_{element}$$

$$= \Big| \underbrace{R \cdot I_{element}}_{V} \cdot I_{element} = R \cdot I_{element}^2 \geqslant 0$$

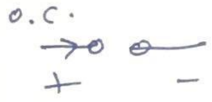
if element

is R

$(V_{element} = R \cdot I_{element})$

$$\frac{V_{element}}{R} = I_{element}$$

$$= V_{element} \cdot \frac{V_{element}}{R} = \frac{V_{element}^2}{R} \geqslant 0$$



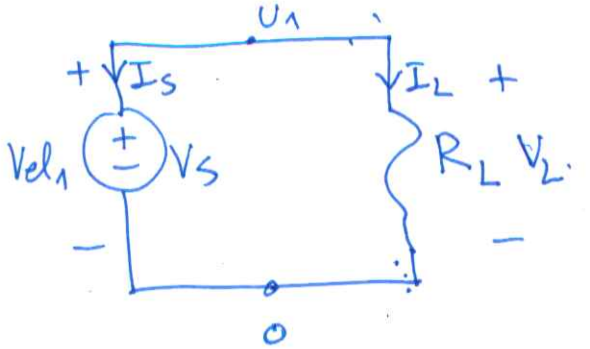
$$P_{element} = V_{element} \cdot \overset{0}{\cancel{I_{element}}} = 0$$

$$P_{element} = \overset{0}{\cancel{V_{element}}} \cdot I_{element} = 0$$

Units: Power [W]   [W] = [V] · [A]

l5

Example:



$I_L = -I_S \Leftarrow I_L + I_S = 0$ (KCL)

$V_1 - 0 = V_L = Vel_1$ (KVL)

$Vel_1 = V_S$ (elem.-def)

$P_L = I_L \cdot V_L$ (def)

$P_S = I_S \cdot Vel_1$ (def)

$= I_S \cdot V_S \leq 0$

$P_L = (-I_S) \cdot V_L$

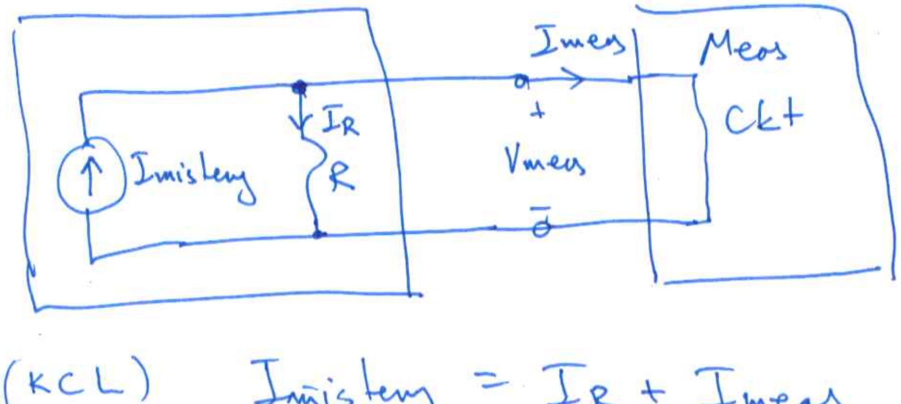
$= (-I_S) \cdot Vel_1$

$= (-I_S) \cdot V_S$

$$\boxed{P_L + P_S = 0}$$

$$\boxed{P_L = -P_S}$$

Conservation of energy (power) $P_L \geq 0$ (since R_L is a resistor)



Task:

Measure $I_{mistery}$

(KCL) $I_{mistery} = I_R + I_{meas}$

$= I_{meas} \Big|$ if $\underbrace{I_R = 0}$

$V_{meas} = I_R \cdot R$

$I_R = \frac{V_{meas}}{R}$

$V_{meas} = 0$

(by def)

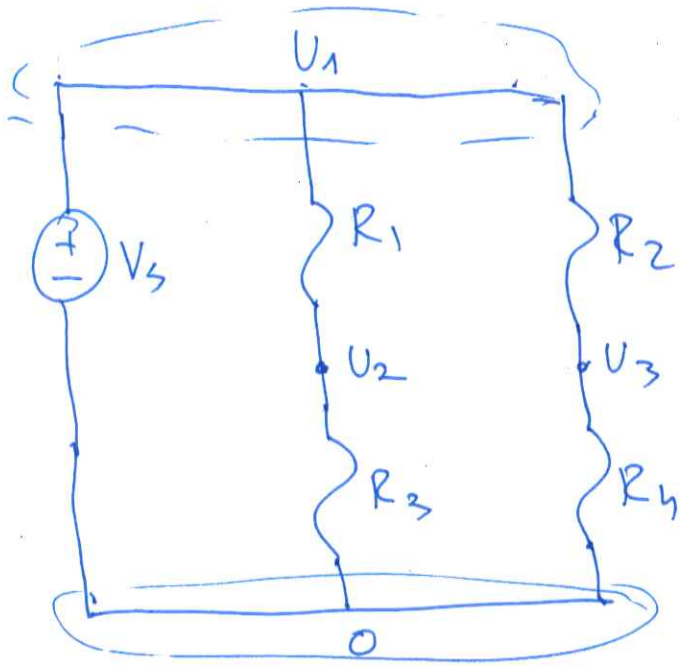
$P_{meas} = \cancel{V_{meas}}^{0} \cdot I_{meas}$

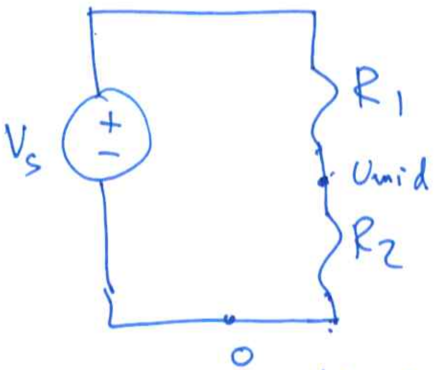
$= 0$

looks like a wire if Meas ckt

l6

An interesting circuit:





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

voltage divider

What are U_2 & U_3?

$$U_2 = \frac{R_3}{R_1+R_3} V_s \qquad U_3 = \frac{R_4}{R_2+R_4} V_s$$

$$V_s = U_1 - 0$$

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

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