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Module 2, Lecture 3

EECS 16A
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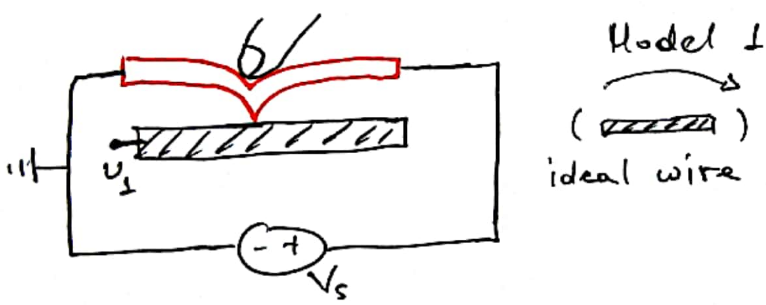
Last time:
* NVA on voltage divider
* Resistive Touchscreen Construction
* Resistive Touchscreen Analysis + Modeling

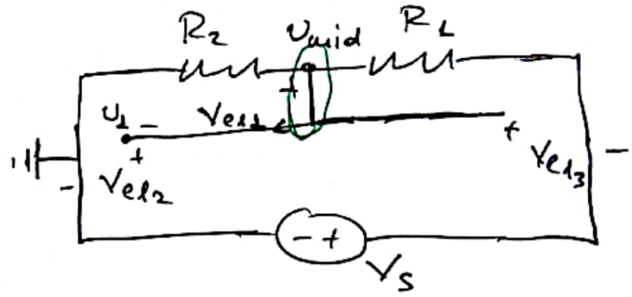
} Note 12

Today:
* Revisit 1D Touchscreen
* Measuring Voltage and Current
* Power
* An interesting circuit

} Note 13

1D - Resistive Touchscreen (Revisited)





Additions to Simple Volt. Div.

1. Wire (V_{el} 1)
2. Open-ckt (V_{el} 2)
3. Open-ckt (V_{el} 3)

$V_{el_2} = u_1 - 0$ (def. of element voltage)

$V_{el_1} = u_{mid} - u_1$ (— " —)

$V_{el_1} = 0$ (wire I-V curve)

$\Rightarrow \cancel{V_{el_1}}^{\,0} = u_{mid} - u_1$

$\Rightarrow u_{mid} = u_1$

$\Rightarrow \boxed{V_{el_2} = u_{mid}}$

What I want is to measure V_{el_2} all the time and get u_{mid} for any L_{touch}.

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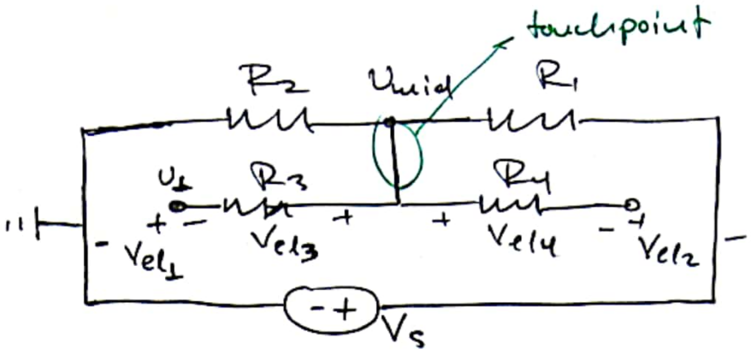
Model 2

( )

imperfect conductor

aka resistor



Addition to simple volt. div.

1. Open-ckt (V_{el_1})
2. Open-ckt (V_{el_2})
3. R_3 (V_{el_3})
4. R_4 (V_{el_4})

$V_{el_1} = v_1 - 0$ (element voltage def.)

$I_{el_1} = 0$ (open-ckt def of I-V)

"KCL" on v_1:

$I_{el_3} = I_{el_1} = 0$

$V_{el_3} = R \cdot I_{el_3} = 0$ (Ohm's law)

$V_{el_3} = u_{mid} - v_1$ (element voltage def.)

$\Rightarrow 0 = u_{mid} - v_1 \Rightarrow u_{mid} = v_1$

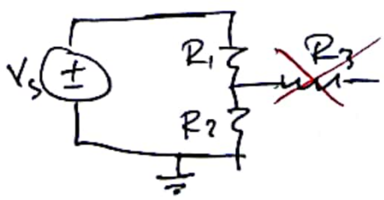
$$\boxed{V_{el_1} = v_1 - 0 = u_{mid}}$$ ✓

Again I want to measure V_{el_1} all the time and get u_{mid} for any L_{touch}.

Note: Resistors who are connected on one terminal to our ckt and on the other terminal to an open-circuit have no current flowing through them and no voltage drop across them.

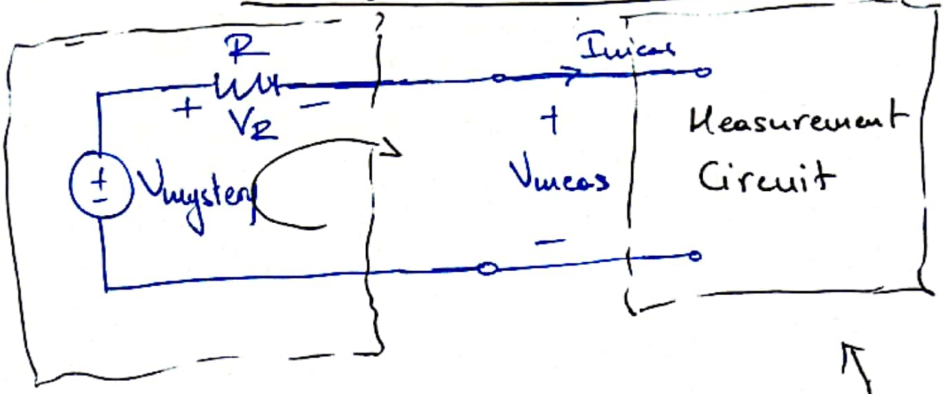
$\Rightarrow$ they don't affect our circuit!

e.g.



(p3)

Voltage Measurement



Goal:

Measure $V_{mystery}$

i.e. $V_{meas} = V_{mystery}$

Problem:

R is "in the way"

KVL: $V_{mystery} - V_R - V_{meas} = 0$

$\Rightarrow V_{mystery} = I_{meas} \cdot R + V_{meas}$

$\Rightarrow V_{mystery} = V_{meas} \Big|_{\text{if } I_{meas} = 0}$

measurement circuit needs to look like an open-circuit

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

Defined voltage between points A and B as:

$V_{AB} = \frac{dE}{dq}$ — dE is the energy spent to move dq from point A to point B.

Power (rate of change of energy)

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

Units: Power $\underbrace{[W]}$ → Watts $= [V] \cdot [A]$

$= [J] / [s]$

(p4)

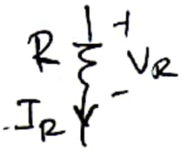
Power + Passive Sign Convention

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

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

with $\rho > 0$, $\frac{l}{A} > 0$

For a resistor:

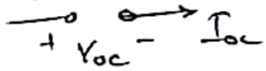


$$P_R = V_R \cdot I_R$$
$$= I_R \cdot R \cdot I_R = I_R^2 \cdot R \geq 0$$

$$P_R = V_R I_R$$
$$= V_R \cdot \frac{V_R}{R} = \frac{V_R^2}{R} \geq 0$$

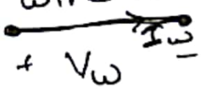
→ Resistors always dissipate power!

open-ckt



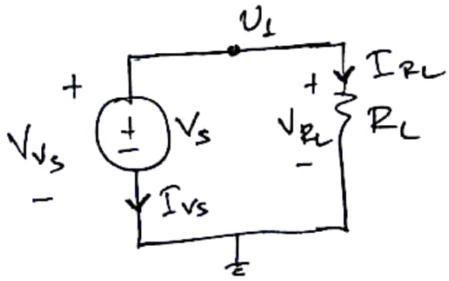
$$P_{oc} = V_{oc} \cdot \cancel{I_{oc}}^{\,0} = 0$$

wire (short-ckt)



$$P_w = \cancel{V_w}^{\,0} \cdot I_w = 0$$

Example #1



Resistor:

$$U_1 = V_s$$

$$I_{R_L} = \frac{V_{R_L}}{R_L} = \frac{U_1 - 0}{R_L} = \frac{V_s}{R_L}$$

$$P_{R_L} = I_{R_L} \cdot V_{R_L} = \frac{V_s^2}{R_L} \geq 0$$

Voltage Source:

KCL on U_1: $0 = I_{V_s} + I_{R_L}$

$$\Rightarrow I_{V_s} = -I_{R_L} = -\frac{V_s}{R_L}$$

$$V_{V_s} = V_s \; (= U_1 - 0)$$

$$P_{V_s} = V_{V_s} \cdot I_{V_s} = -\frac{V_s^2}{R_L} \leq 0$$

$$P_{V_s} = -P_{R_L}$$

$$\Rightarrow \boxed{P_{V_s} + P_{R_L} = 0}$$

$\Downarrow$

Energy (and power) are conserved!

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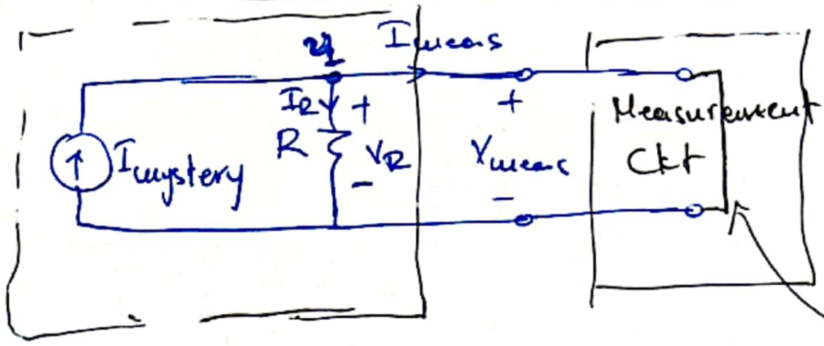
Current Measurement



Goal:

Measure $I_{mystery}$

i.e. $I_{meas} = I_{mystery}$

Problem:

R is "in the way"

needs to look like a wire

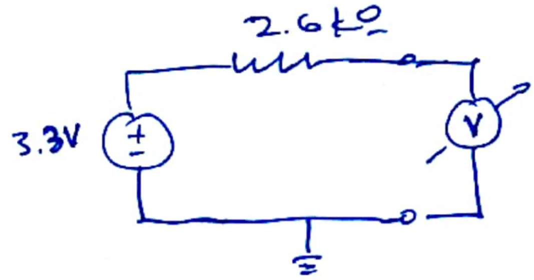
KCL on v_1: $I_{mystery} = I_R + I_{meas}$

$$\Rightarrow I_{mystery} = \frac{V_{meas}}{R} + I_{meas}$$

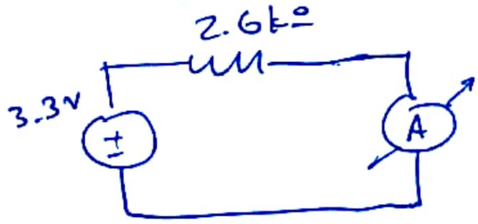
$$\Rightarrow I_{mystery} = I_{meas} \quad \Big| \text{ if } V_{meas} = 0$$

$P_{meas} = \cancel{V_{meas}}^{\,0} \cdot I_{meas} = 0$ ✓ (measurement ckt does not dissipate any power)

Demo ckt:



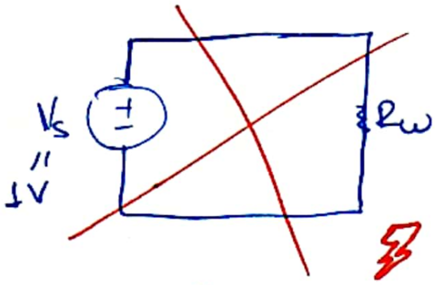
$V = 3.3V$



$$I = \frac{V}{R} = \frac{3.3\,V}{2.6\,k\Omega}$$

Scanned with CamScanner

Example #2



BOOM

Don't do this!

$R_\omega \longrightarrow 0$

Let's say $R_\omega = 10^{-3}\,\Omega$, $V_s = 1V$

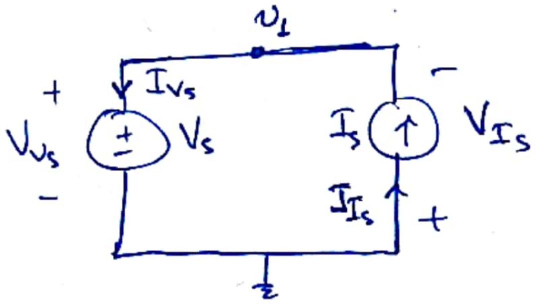
$P_\omega = I_\omega \cdot V_\omega$

$V_\omega = V_s$, $I_\omega = \dfrac{V_\omega}{R_\omega} = 1000\,A$!

Too BIG (Something will get fried)

$P_\omega = I_\omega V_\omega = 1kW$!

Example #3



Voltage Source:

$V_{V_s} = v_1 - 0 = V_s$

$I_{V_s} = I_{I_s} = I_s$ (KCL on v_1)

$P_{V_s} = V_{V_s} \cdot I_{V_s} = V_s \cdot I_s = 1W > 0$

dissipates

Current Source:

$V_{I_s} = 0 - v_1 = -V_s$

$I_{I_s} = I_s$

$P_{I_s} = V_{I_s} \cdot I_{I_s} = -1W < 0$

generates

Note: If more than one sources exist in the ckt you have to use nodal analysis (NVA) to determine whether they ~~both~~ ~~[illegible]~~ ~~[illegible]~~ generate or dissipate power.

At least one needs to generate the power dissipated by the rest.