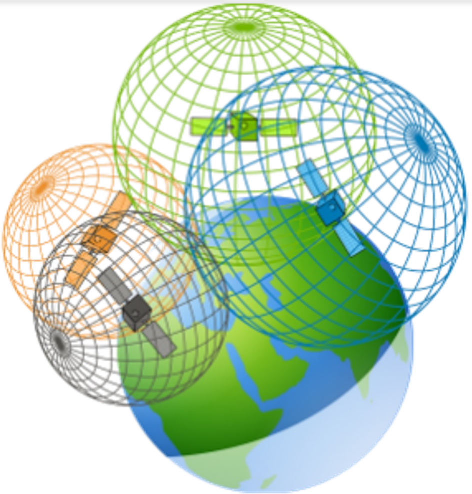


Welcome to EECS 16A!

Designing Information Devices and Systems I

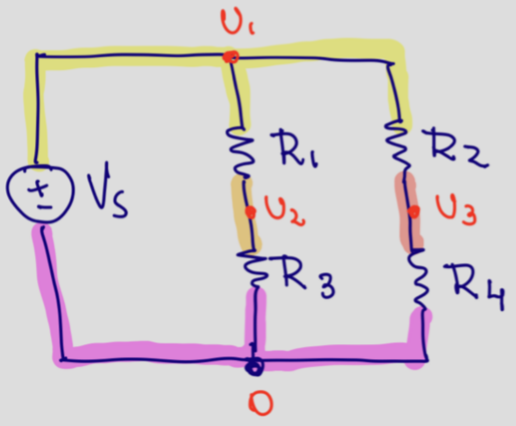
Ana Claudia Arias and Miki Lustig

Fall 2022

Module 2
Lecture 5
2D resistive touch screen
Superposition and Equivalence
(Note 13,14,15)

Last class:

An ~~interesting~~ surprising circuit



- What are U_2 and U_3?

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

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

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

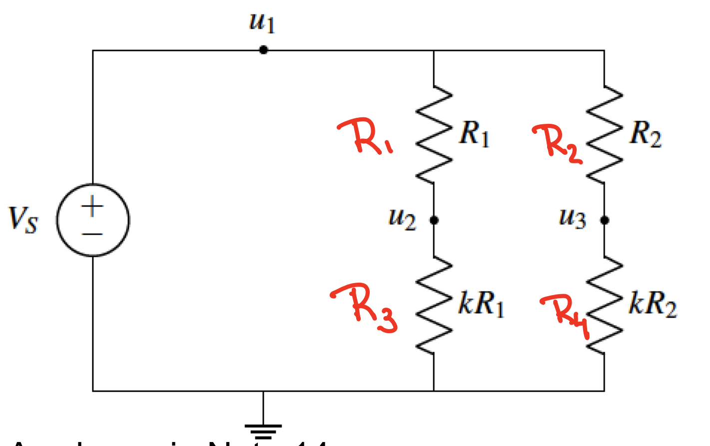
$$U_3 - 0 = \frac{R_4}{R_2+R_4} \cdot (U_1 - 0)$$

$$U_1 - 0 = V_s$$

Today:

- 2D model
- Equivalence

An interesting circuit



As shown in Note 14

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

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

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

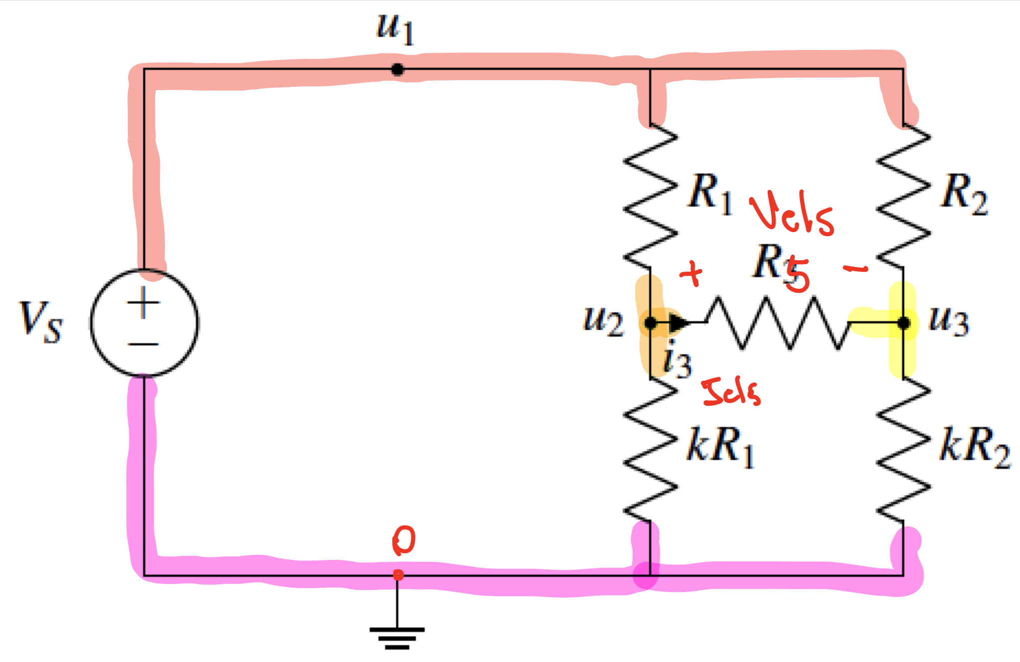
$$U_3 = \frac{k\cancel{R_2}}{\cancel{R_2} + k\cancel{R_2}} \cdot V_S \quad \therefore \quad U_3 = \frac{k}{1+k} V_S$$

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

wow!

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

Let's add on more resistor



$Elem_5$ = resistor (R_5)

$V_{el_5} = U_2 - U_3$ (Voltage Def.)

Bold Assumption

$V_{el_5} = 0$

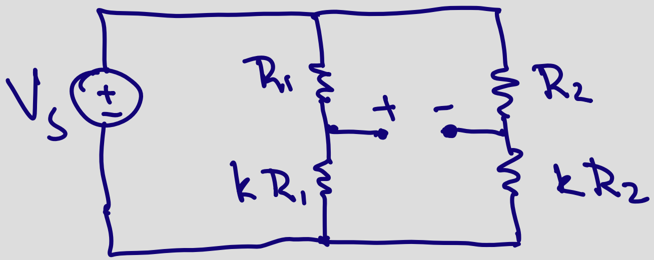
if $V_{el_5} = 0 \Rightarrow I_{el_5} = \frac{\cancel{V_{el_5}}\,0}{R_5} = 0$

if $I_{el_5} = 0$

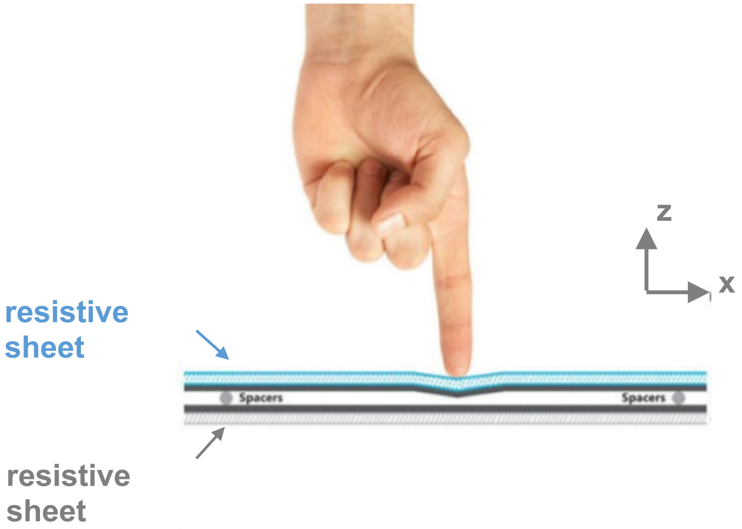
The circuit is the same as the one we already analysed without R_5.

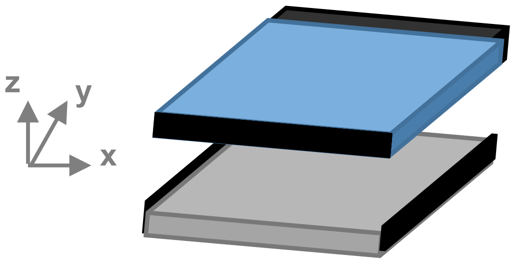
We showed : $U_2 = U_3$

$\boxed{V_{el_5} = U_2 - U_3 = 0}$

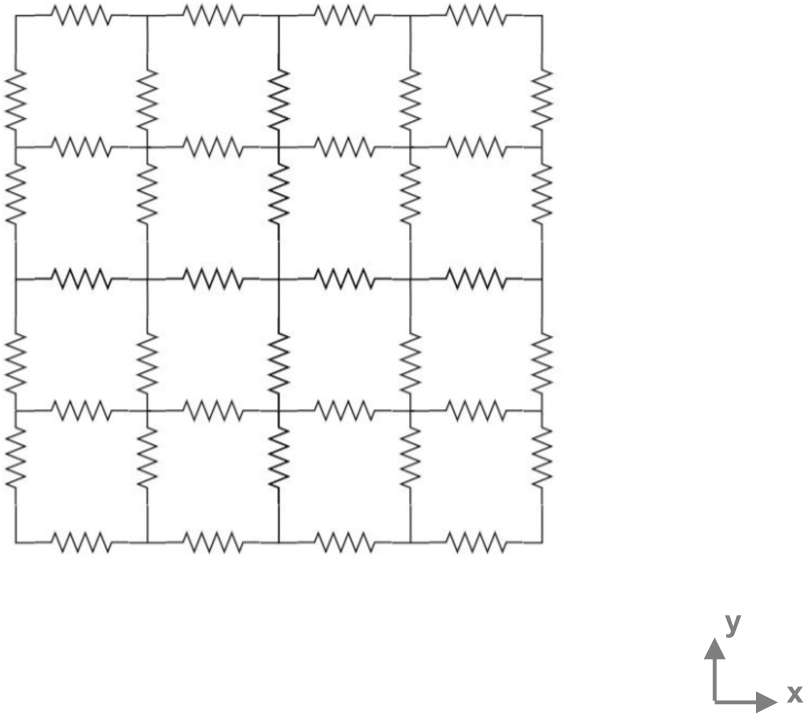


2D resistive Touchscreen circuit model

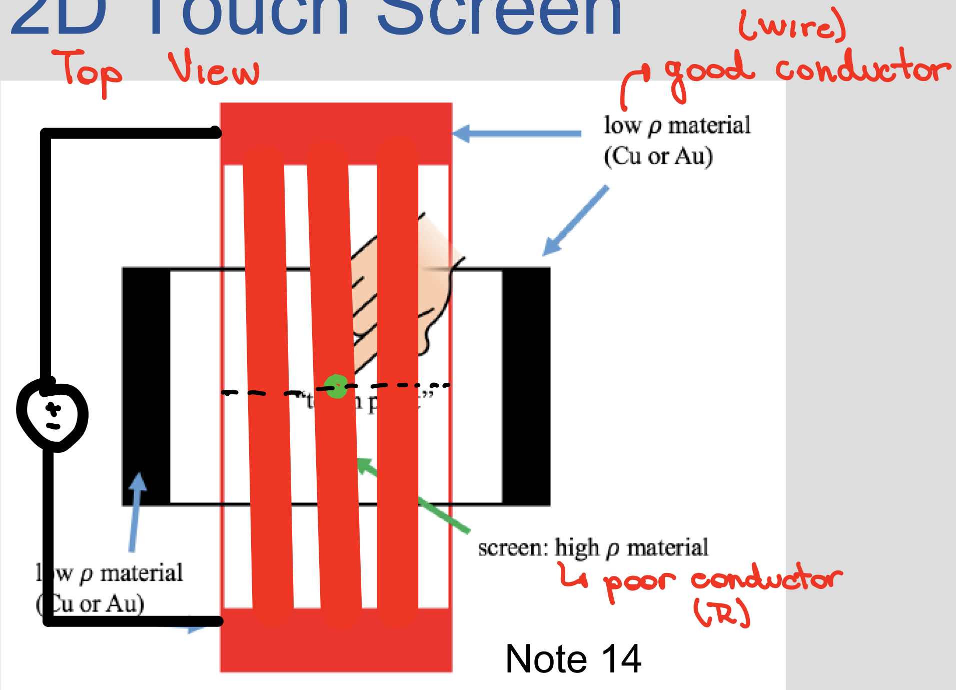


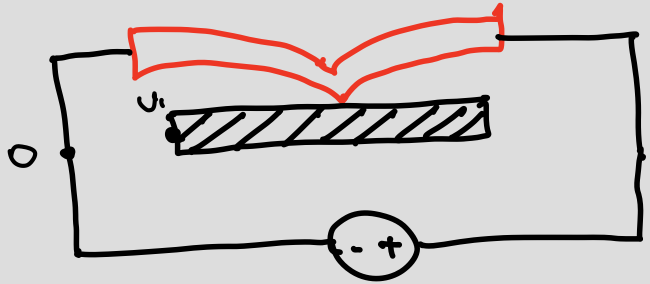


Our circuit model for each resistive sheet is a grid of resistors:



2D Touch Screen



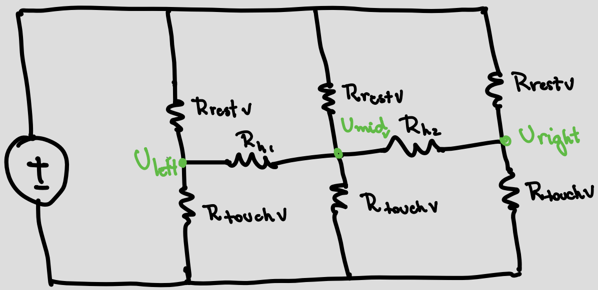


This is our interesting circuit

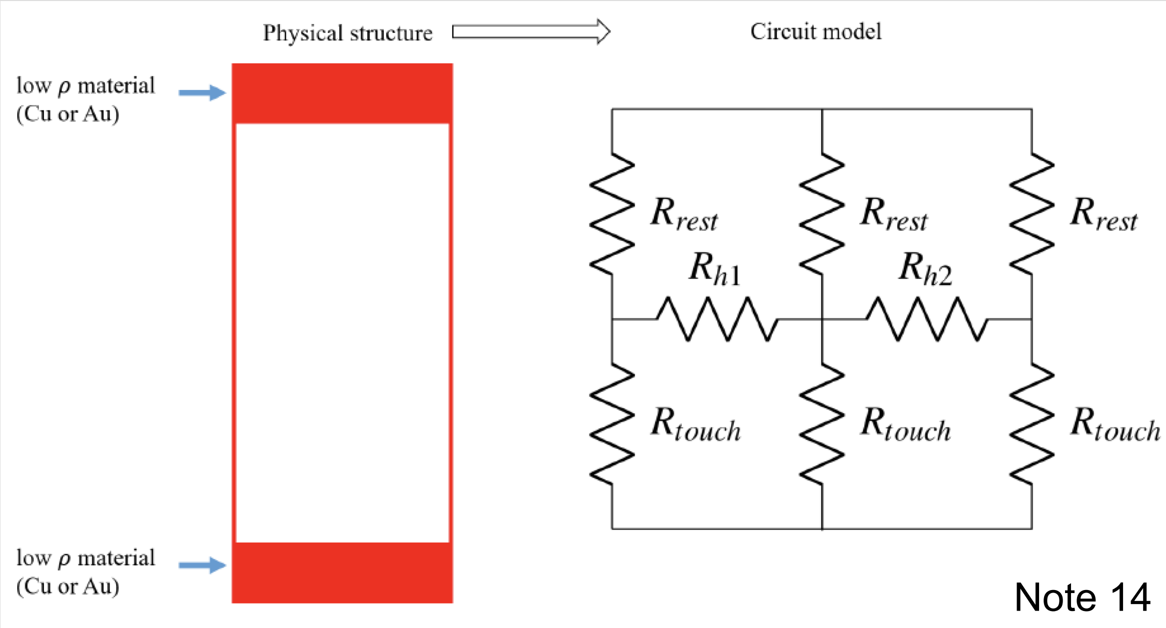
$$U_{mid\,v} = U_{left} = U_{right}$$

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

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



Top Plate Model

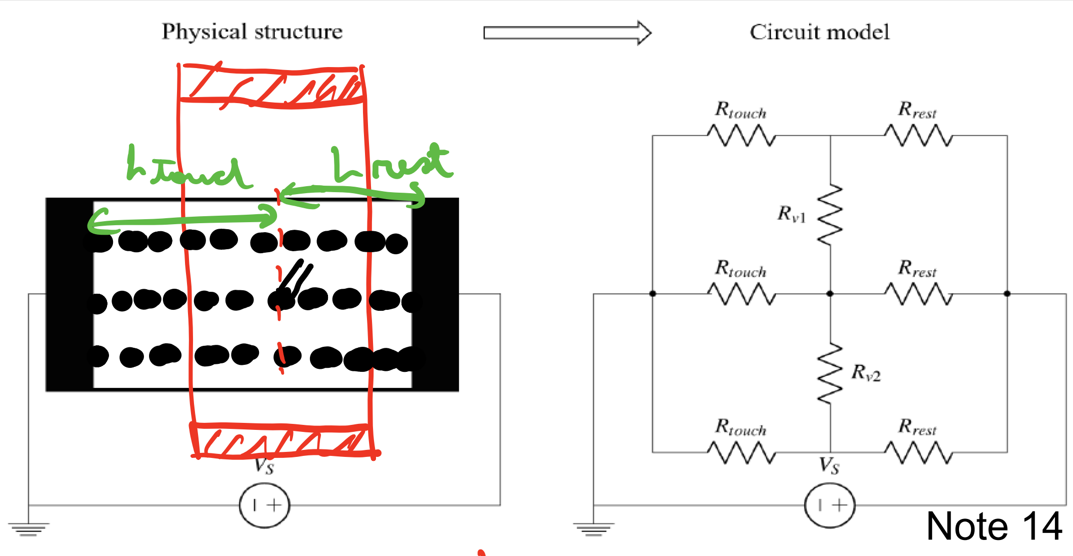


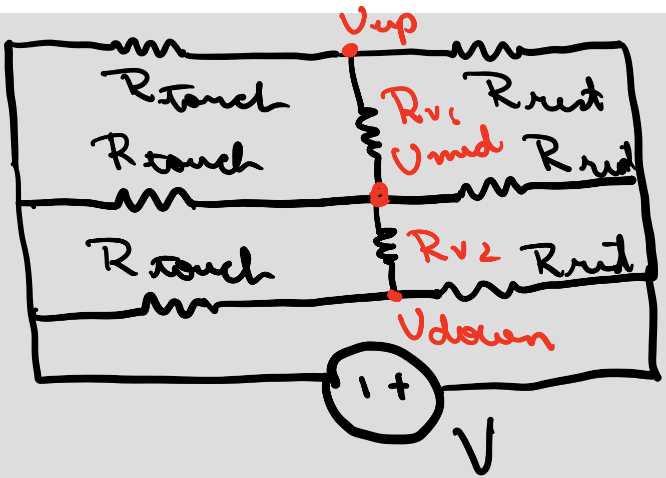
$$V_{mid,v} = \frac{R_{touch}}{R_{rest} + R_{touch}} \cdot V_s$$

* This gives us the vertical position in the screen.

What is the next step in the model?

Bottom Plate Model





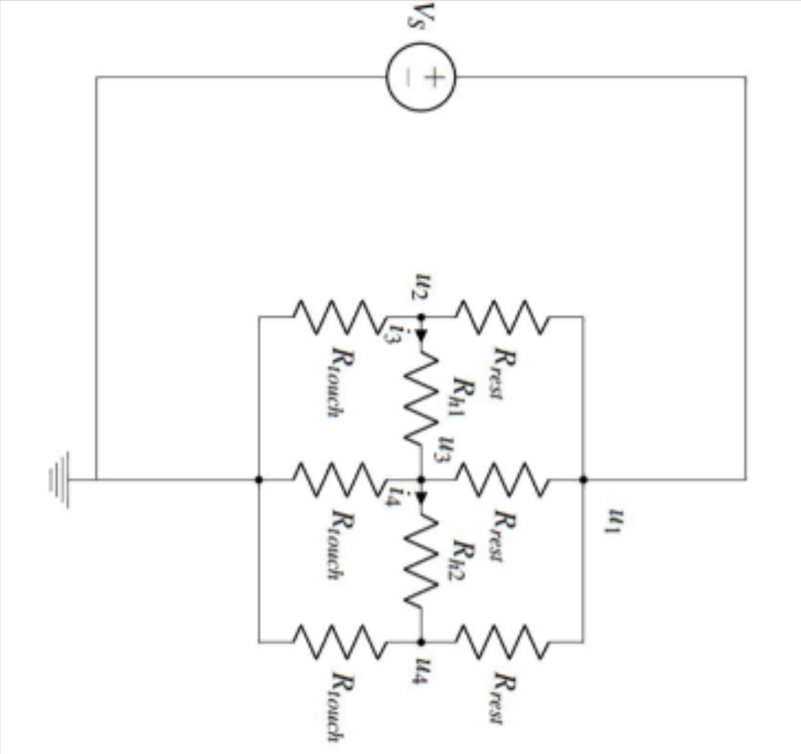
$$U_{up} = U_{mid} = U_{down}$$

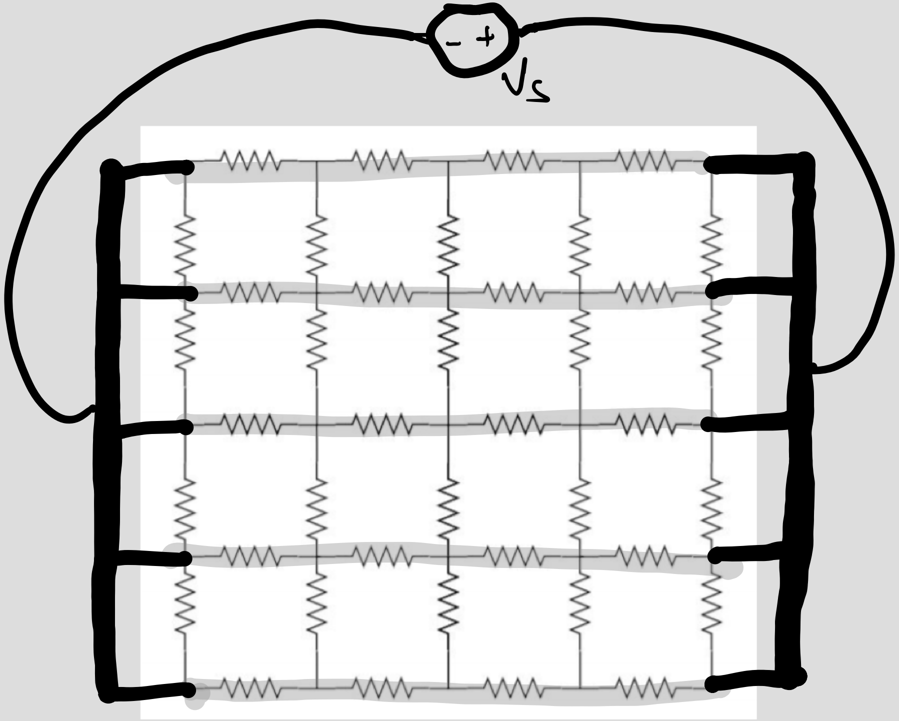
$$U_{mid,H} = \frac{R_{touch,H}}{R_{rest,H} + R_{touch}} \cdot V_s$$

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

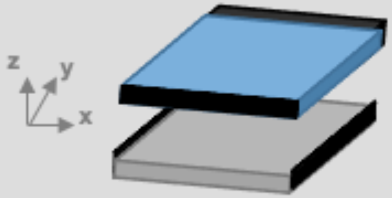
Horizontal information

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

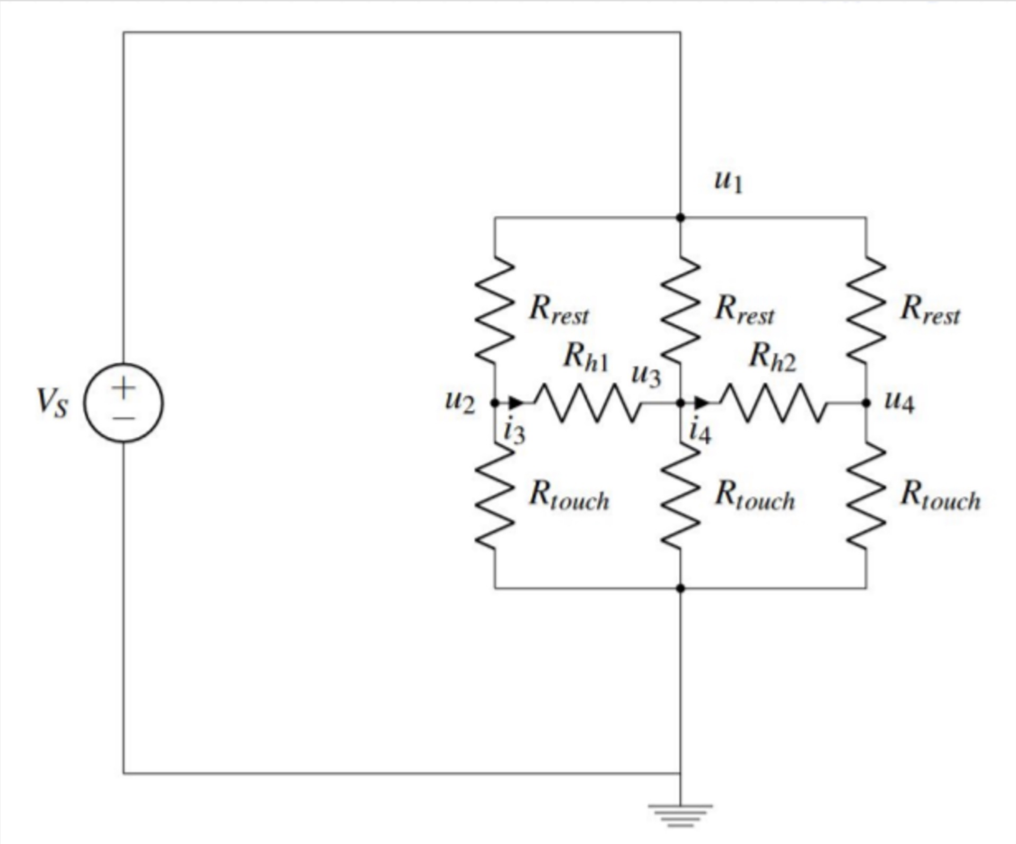


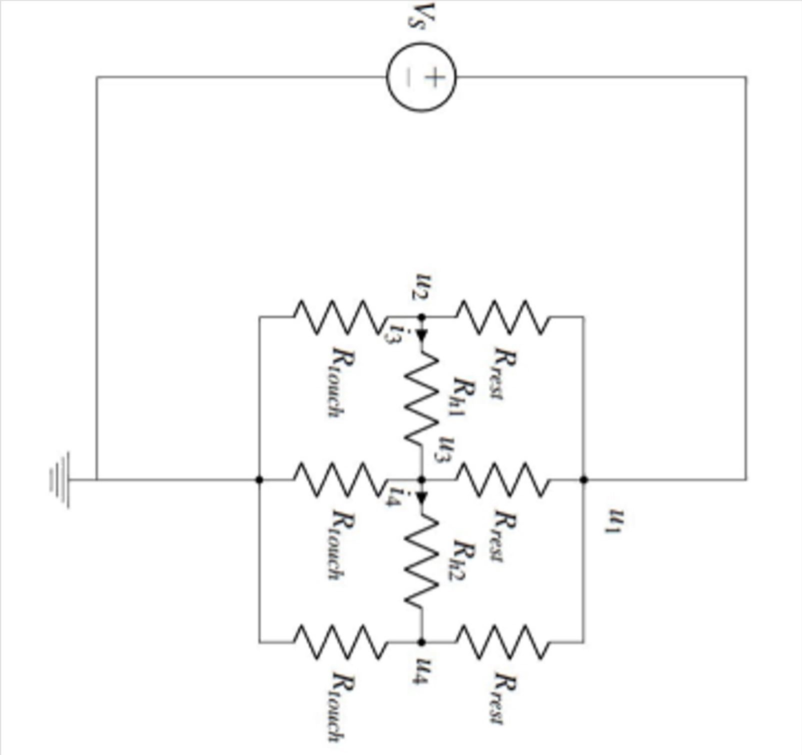


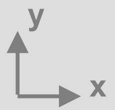
$$V_{mid} = \frac{L_{touch}}{L_H} \cdot V_S$$



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

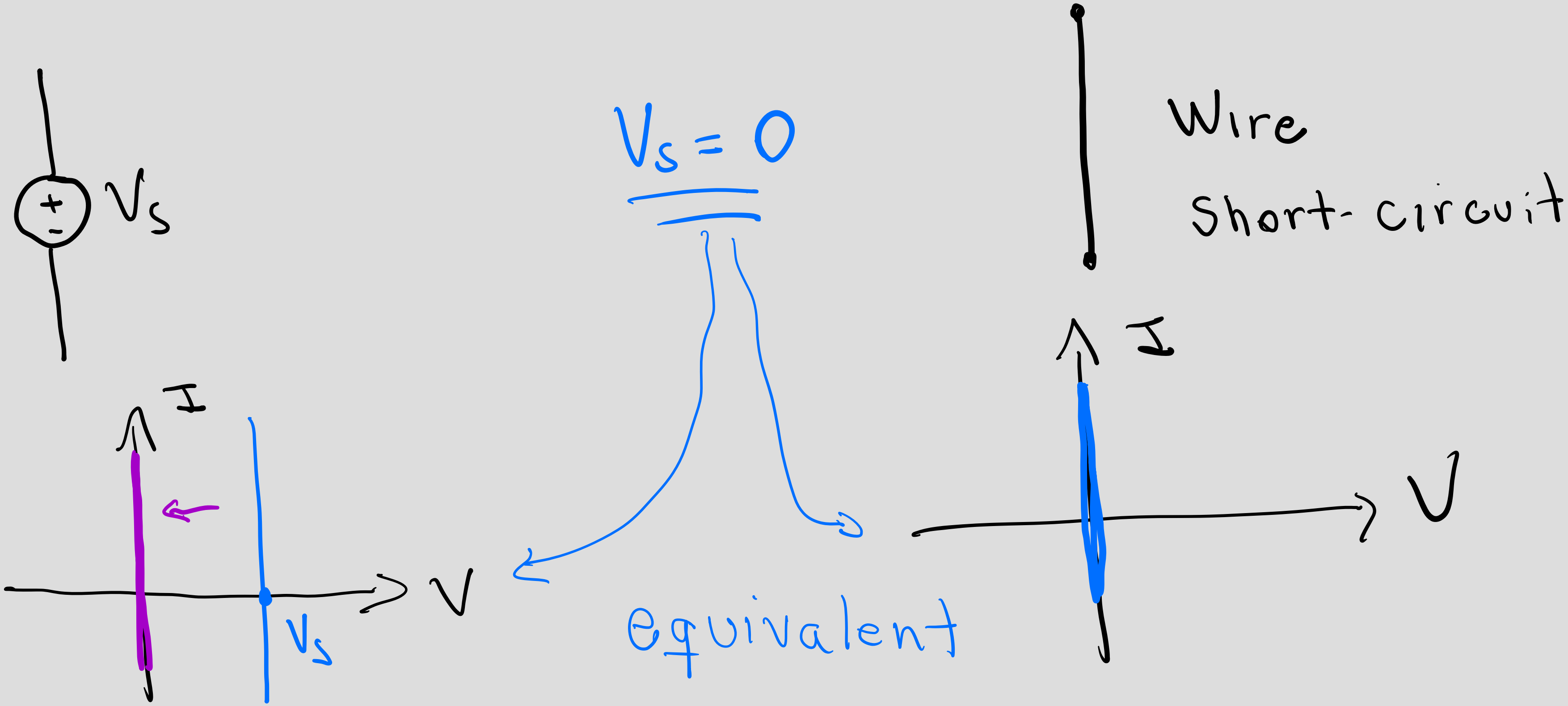






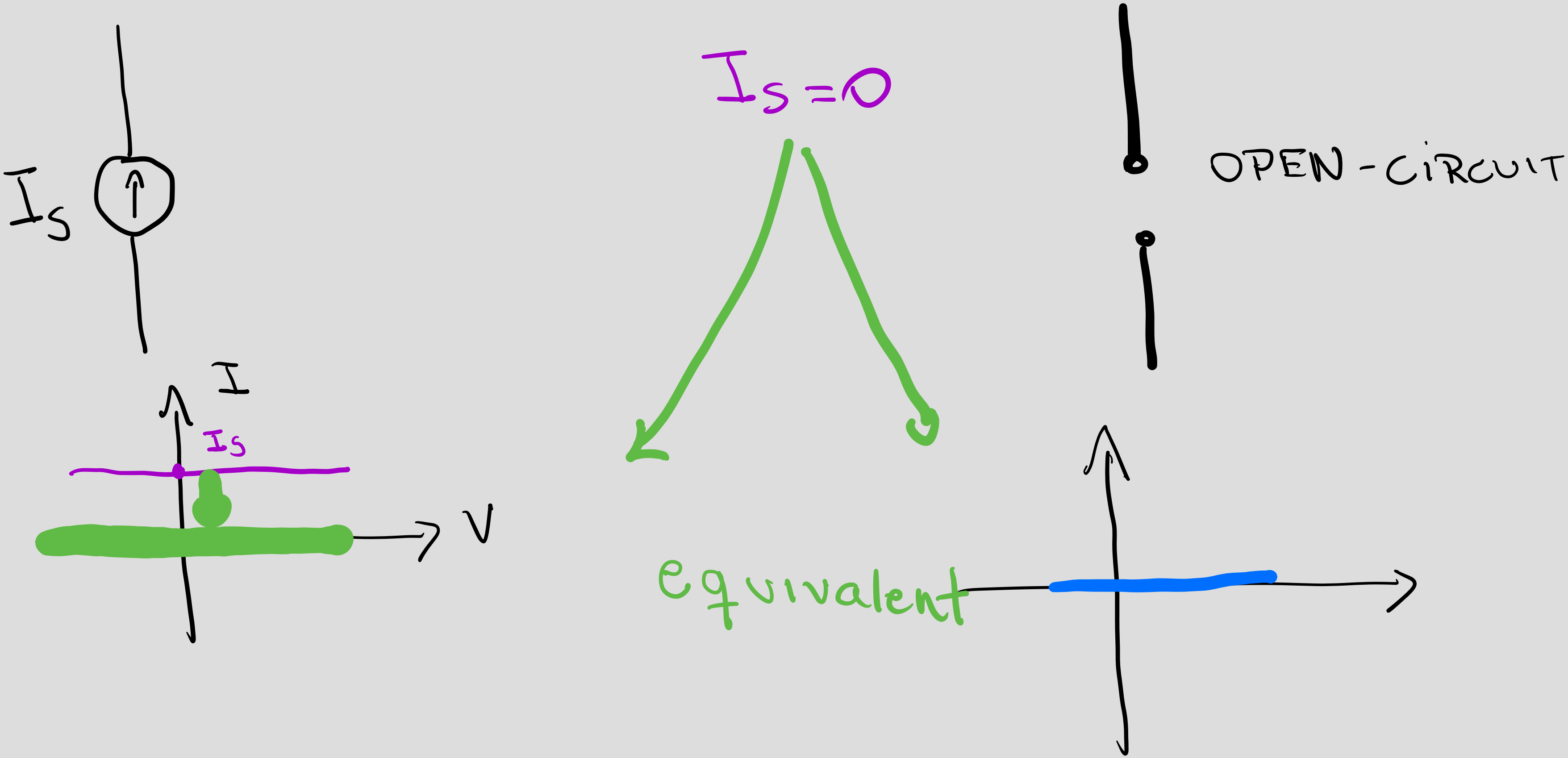
Equivalence

Two circuits are equivalent if they have the same I-V relationship.



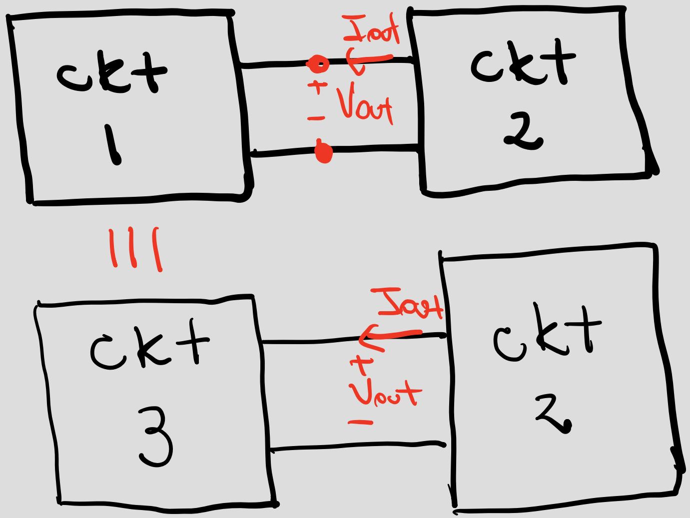
Equivalence

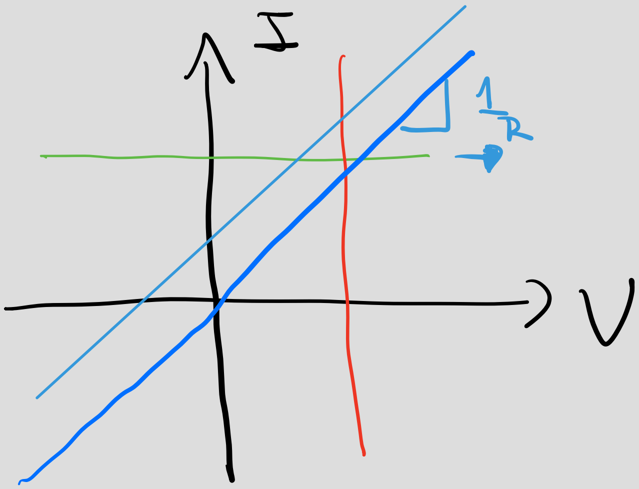
Two circuits are equivalent if they have the same I-V relationship.



Equivalence

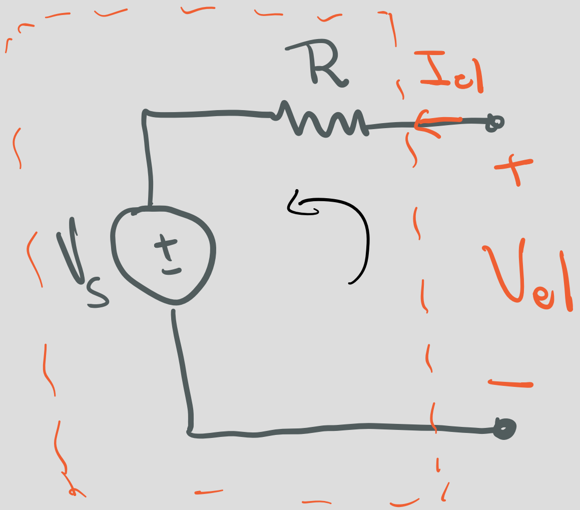
Two circuits are equivalent if they have the same I-V relationship.

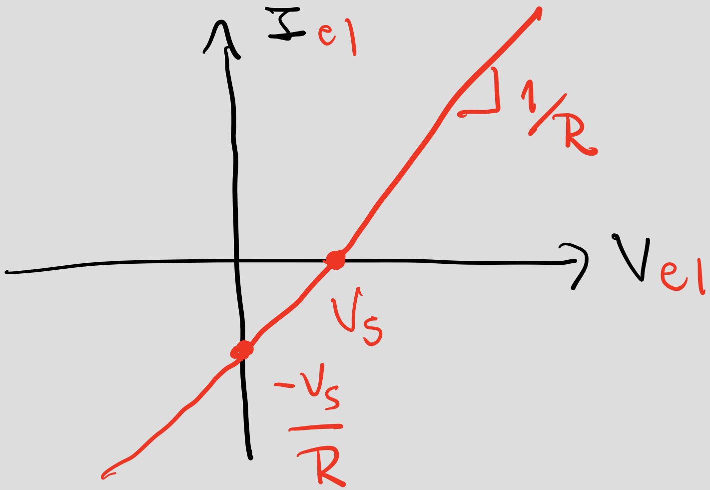




As long as the IV relantion is the same, circuits are equivalent!

Equivalence - Example





$$V_{el} = V_s + V_R$$

$$V_{el} = V_s + I_{el} \cdot R$$

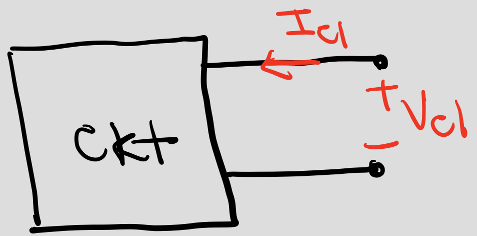
$$I_{el} = \frac{1}{R} V_{el} - \frac{V_s}{R}$$

$$I_{el} \cdot R = V_{el} - V_s$$

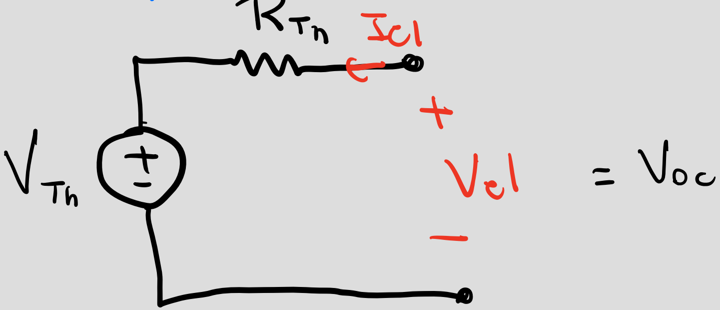
$$I_{el} = \frac{V_{el}}{R} - \frac{V_s}{R}$$

Two circuits are equivalent if they have the same I-V relationship.

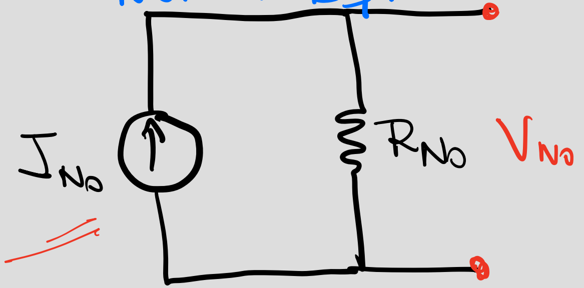
Thevenin and Norton Equivalent

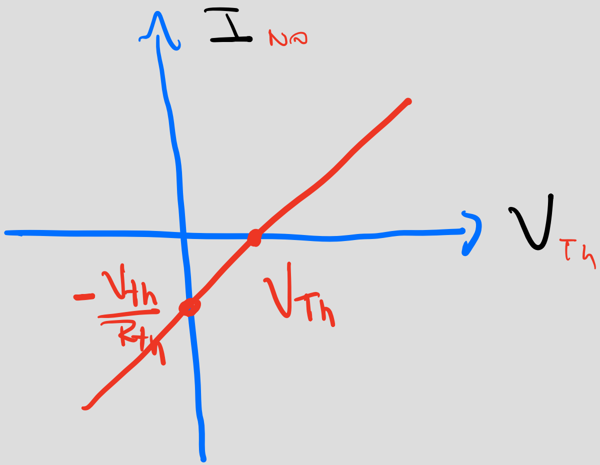


Thevenin Eq.



Norton Eq.





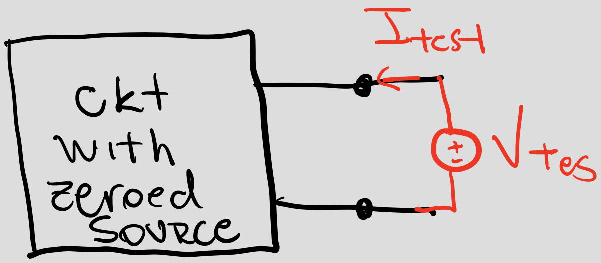
1) Find V_{Th} : Connect open-circuit

— $I = 0$

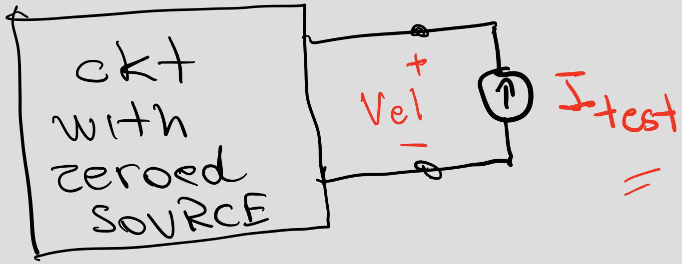
2) Find R_{Th} : Find slope

Zero-out independent source

Thevenin and Norton Equivalent



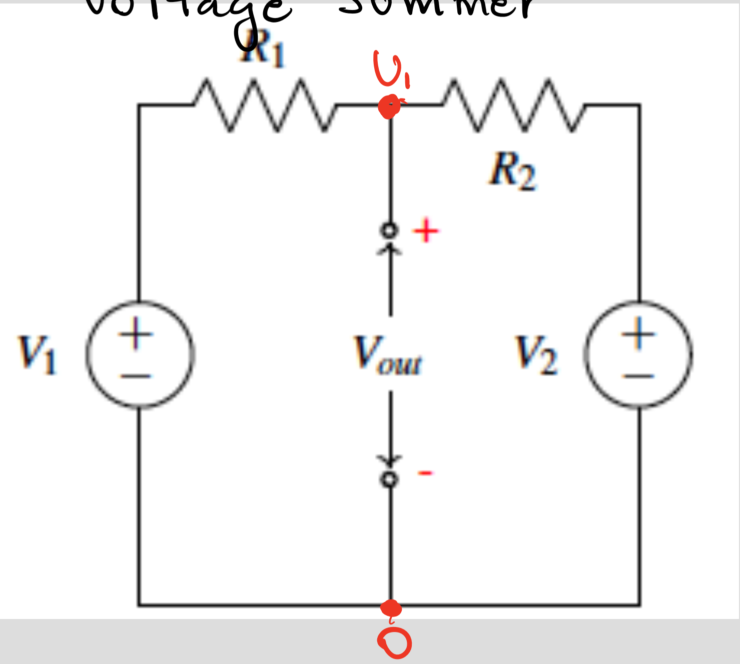
$$R_{Th} = \frac{V_{test}}{I_{test}}$$



$$R_{No} = \frac{V_{test}}{I_{test}}$$

Circuit Analysis Method – What happens when we have multiple Voltage or Current sources?

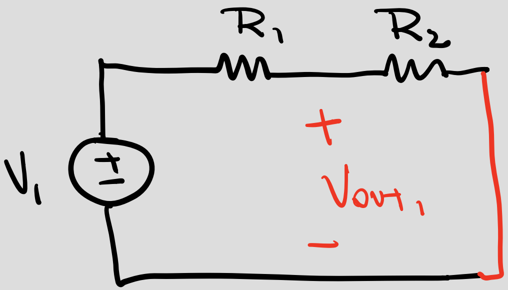
Voltage Summer



$U_1 - 0 = V_{out}$

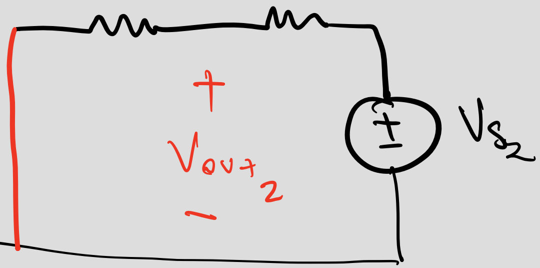
$U_1 = V_{out}$

1 step: Compute a response to V_{s_1} (Set $V_{s_2}=0$)



$$V_{out_1} = \frac{R_2}{R_1+R_2}\cdot V_{s_1}$$

2nd step: Compute a response to V_{s_2}



$$V_{out_2} = \frac{R_1}{R_1+R_2}\cdot V_{s_2}$$

$$V_{out} = V_{out_1} + V_{out_2}$$

$$U_1 = U_{11} + U_{12}$$

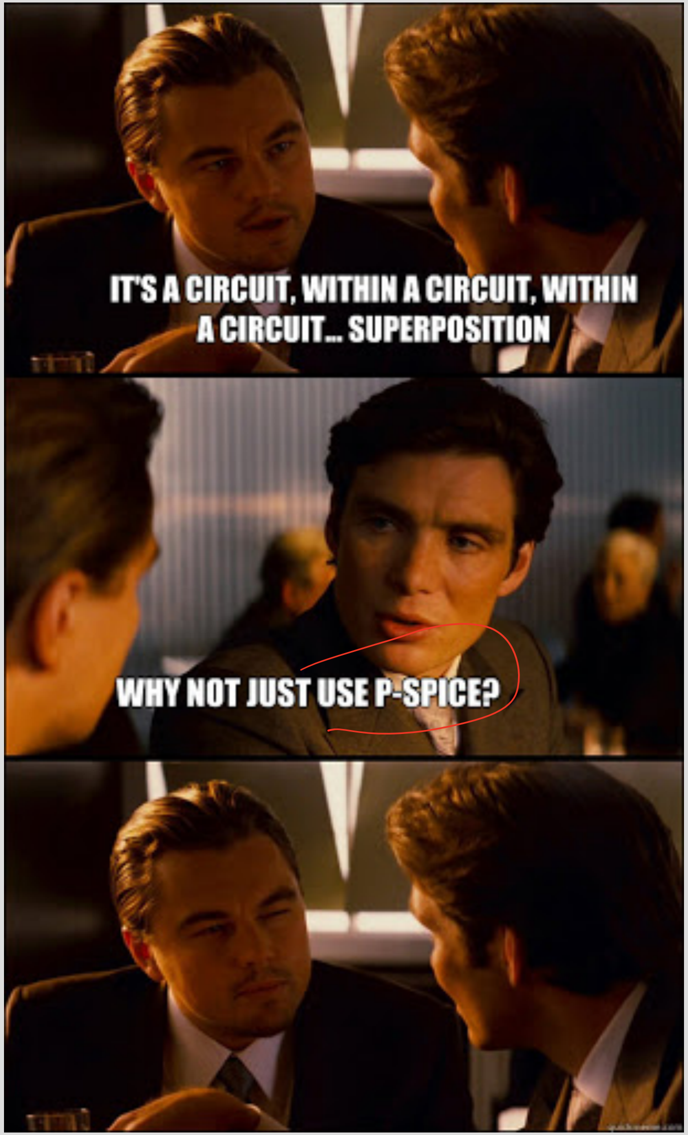
$$U_1 = \frac{R_2}{R_1+R_2}\cdot V_{s_1} + \frac{R_1}{R_1+R_2}\cdot V_{s_2}$$

Superposition

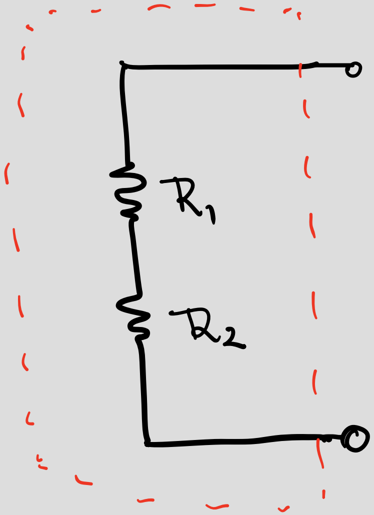
$\alpha < 1$ $\beta < 1$

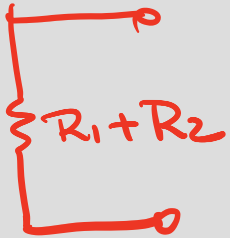
For each independent source k (either voltage source or current source)

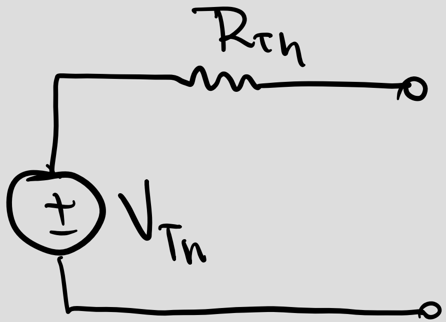
- Set all other independent sources to 0
- Voltage source: replace with a wire
- Current source: replace with an open circuit
- Compute the circuit voltages and currents due to this source k
- Compute V_{out} by summing the Vout;ks for all k.



Practice – Example 1



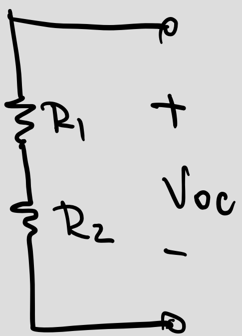




$$R_{Th} = \frac{V_{test}}{I_{test}} = (R_1+R_2)$$

In series means that the same I flows trough the elements.

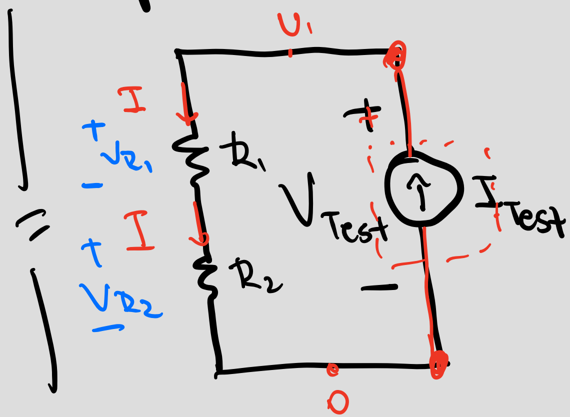
Step 1:



$V_{oc} = 0$

$V_{Th} = 0$

Step 2: No sources



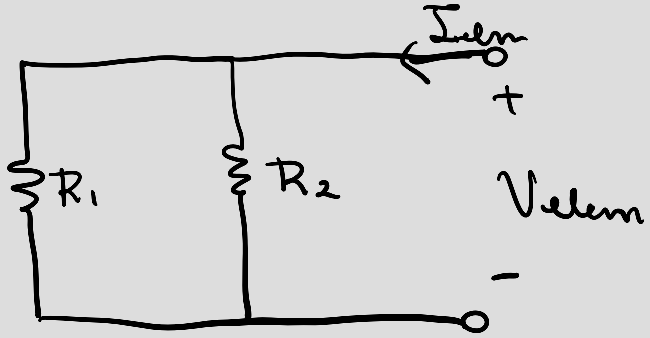
$$V_{Test} = V_{R1} + V_{R2}$$

$$V_{Test} = IR_1 + IR_2$$

$$= I_{test} R_1 + I_{Test} R_2$$

$$V_{Test} = (R_1+R_2) \cdot I_{Test}$$

Practice – Example 2

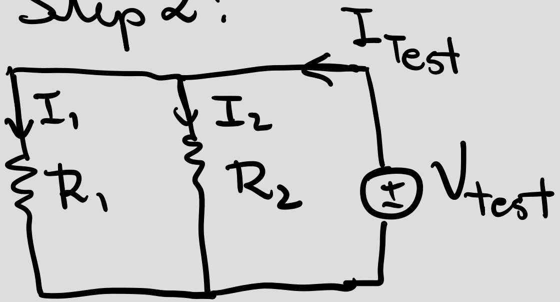


$\Longrightarrow$

Step 1

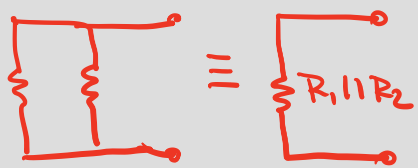
$V_{th} = 0$

Step 2:



$I_1 = \dfrac{V_{test}}{R_1}$

$I_2 = \dfrac{V_{test}}{R_2}$



Parallel operator

$$I_{test} = I_1 + I_2 = V_{test}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$R_{Th} = \frac{V_{test}}{R_{test}} = \frac{\cancel{V_{test}}}{\cancel{V_{test}}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{R_1 R_2}{R_1 + R_2} = \boxed{R_1 \parallel R_2}$$

Definition

Simple rule :

Series elements will have the exact same current through them due to KCL.

Parallel elements will have the exact same voltage across them due to KVL.