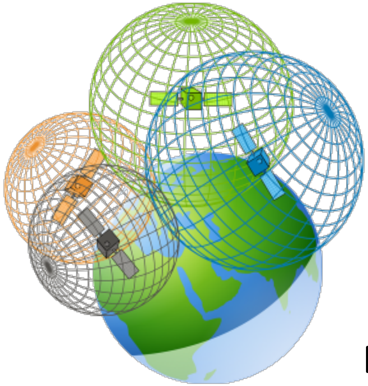
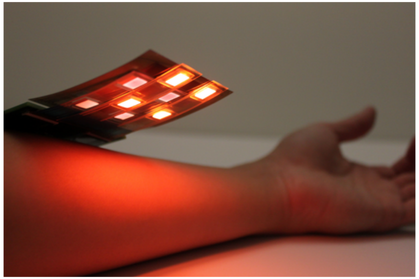




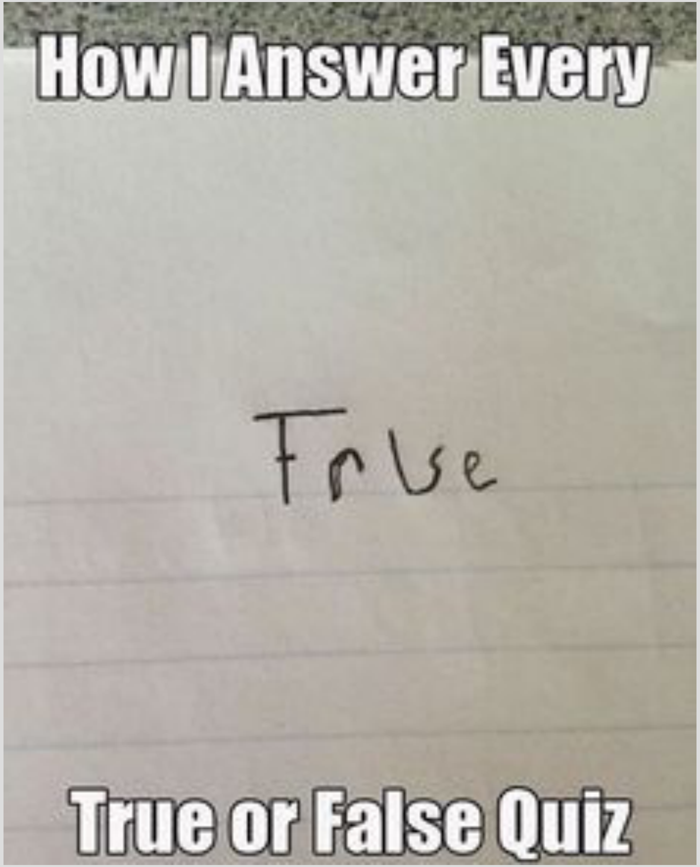
Welcome to EECS 16A!

Designing Information Devices and Systems I

Ana Claudia Arias and Miki Lustig

Fall 2021

Module 2
Lecture 5
Superposition and Equivalence
(Note 15)


How I Answer Every
True or False Quiz

Last lecture: 2D resistive Touchscreen circuit model

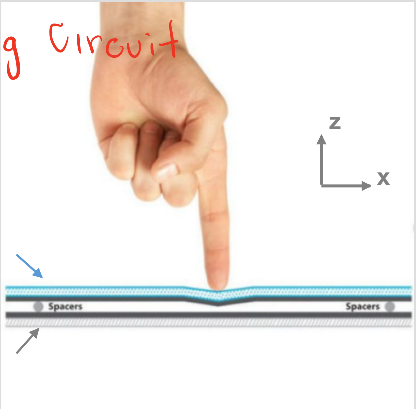
Voltage Divider

Interesting Circuit

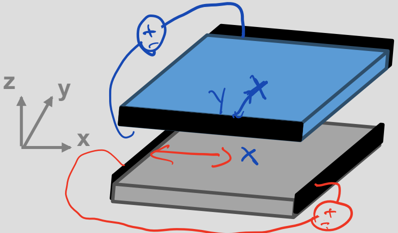
$\underline{V} = R \cdot \cancel{I}^{\to 0}$

O.C.

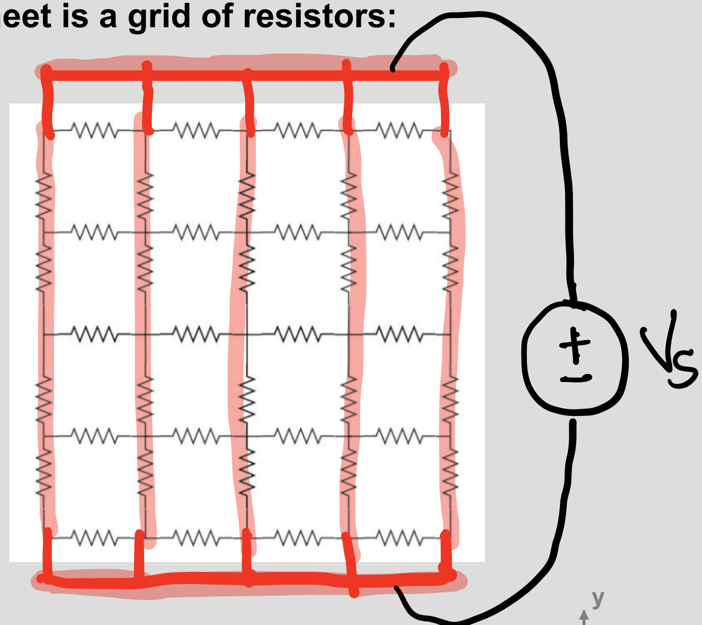
resistive sheet

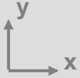


resistive sheet

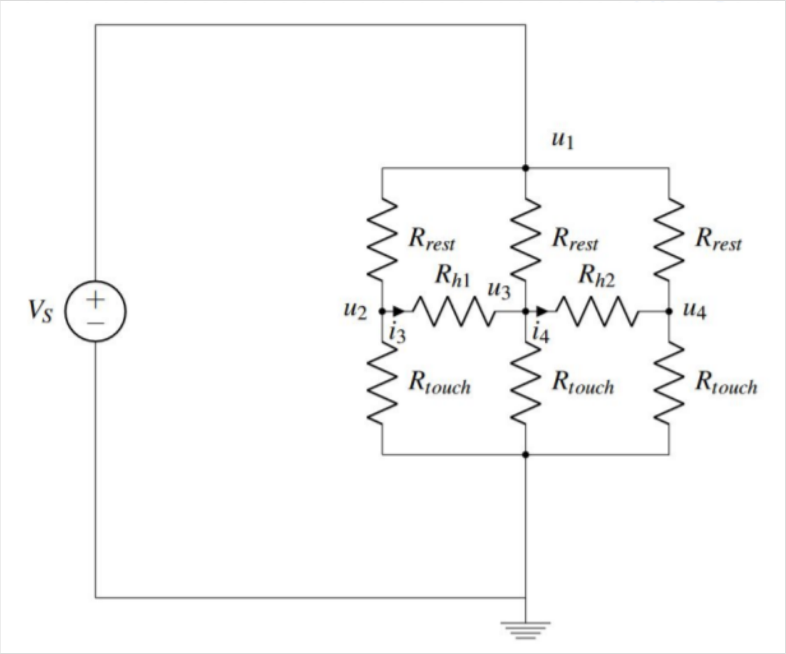


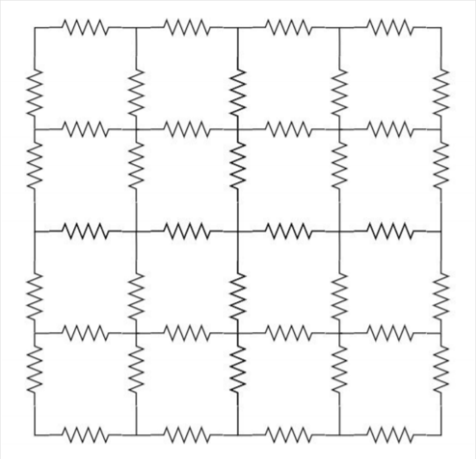
Our circuit model for each resistive sheet is a grid of resistors:



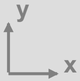


Connecting voltage source to top sheet gives *y-touch* position

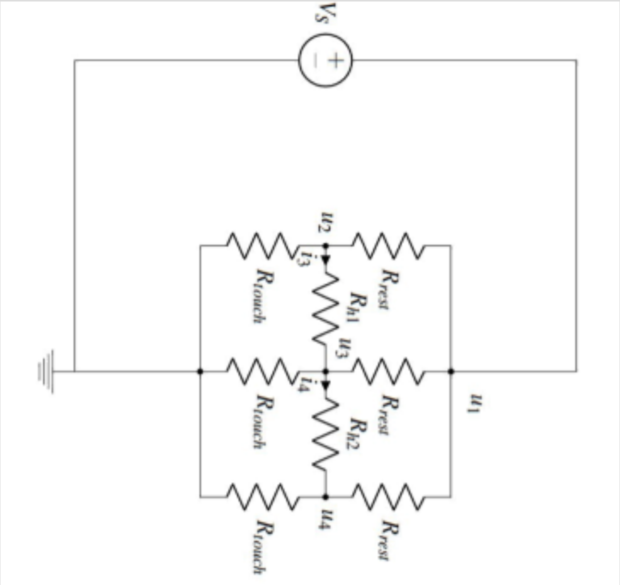


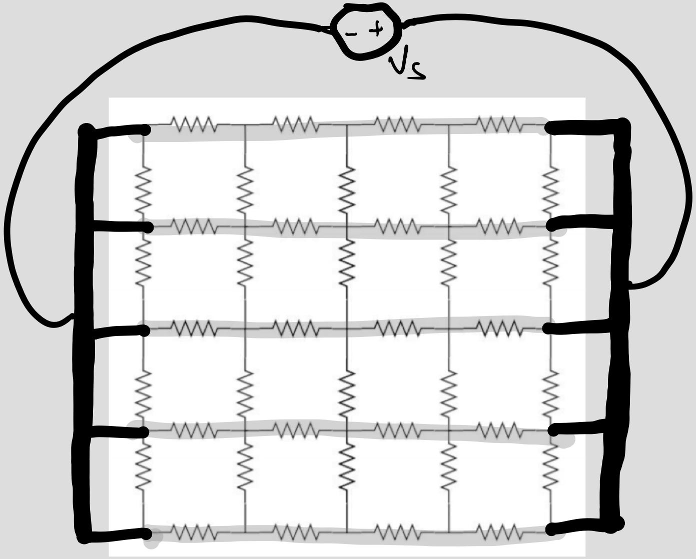


$$U_{mid} = \frac{L_{touch}}{L_V} \cdot V_S$$

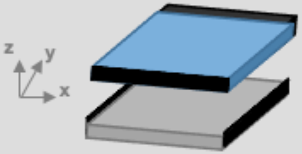


Connecting voltage source to bottom sheet gives *x-touch* position



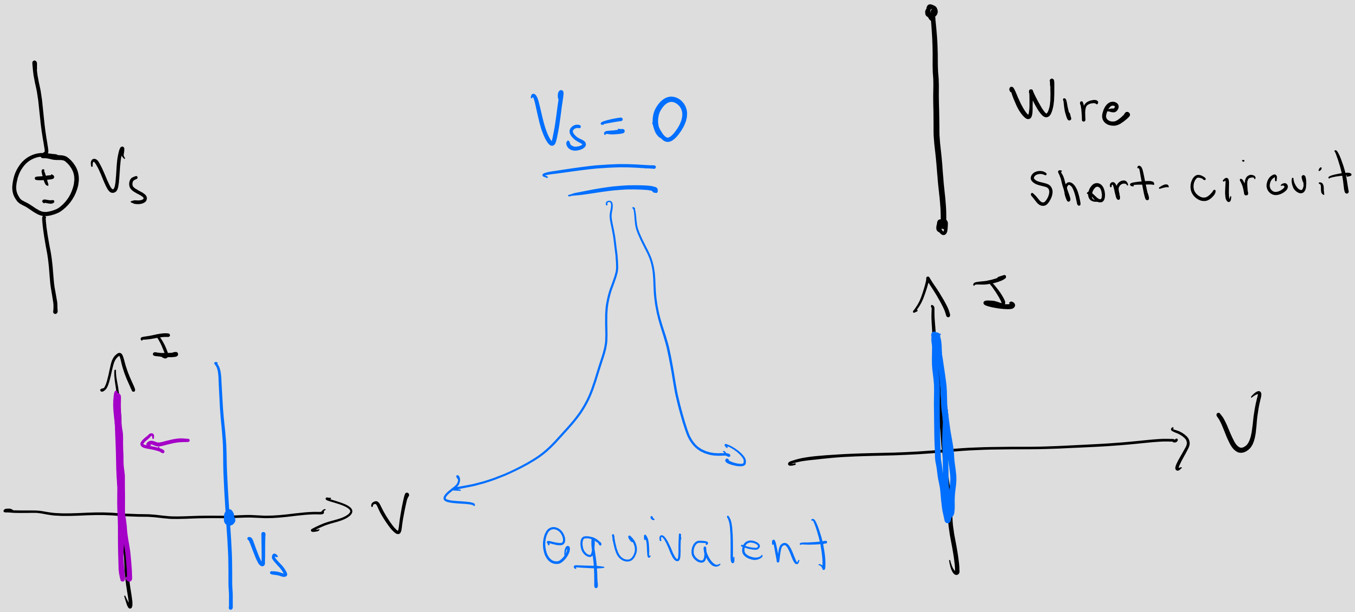


$$V_{mid} = \frac{L_{touch}}{L_H} \cdot V_s$$



Equivalence

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



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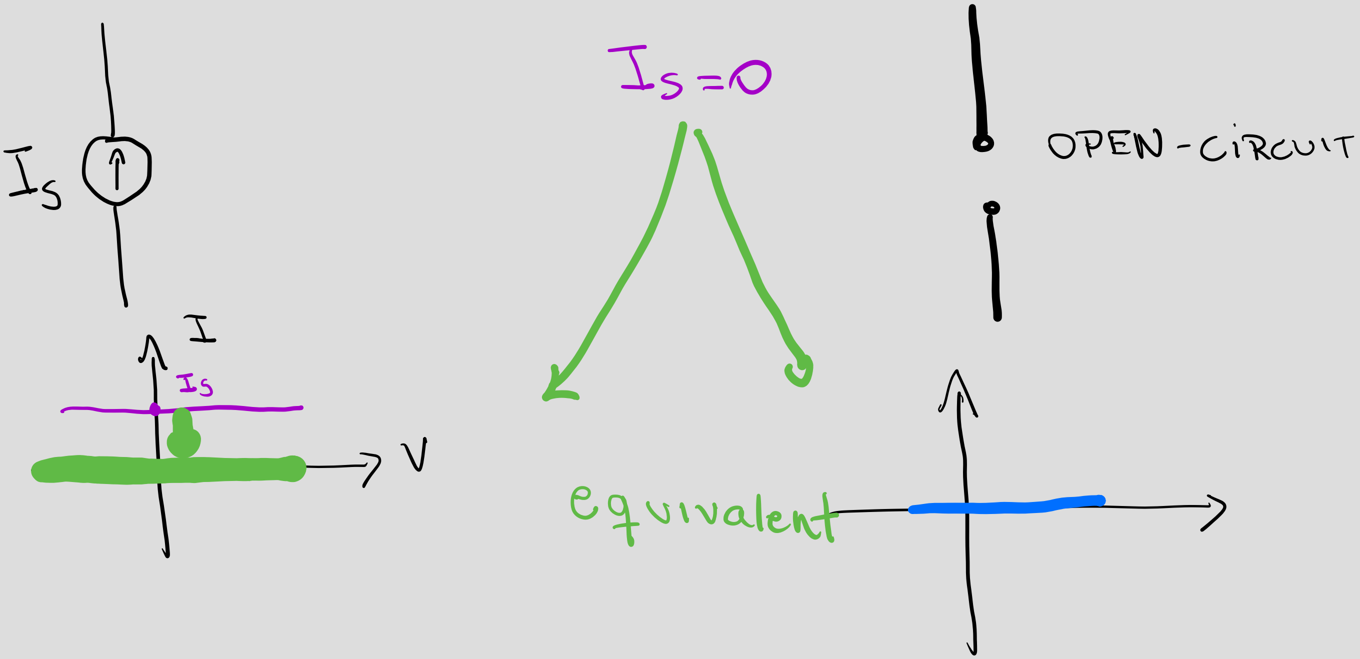

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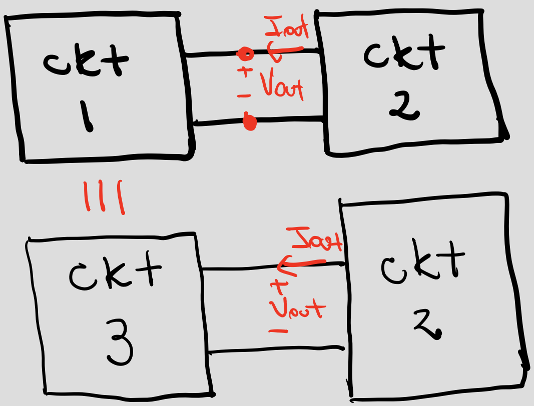
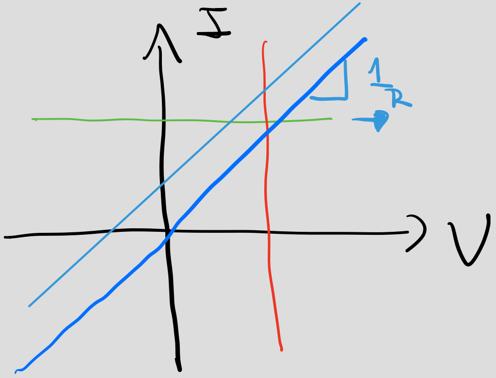
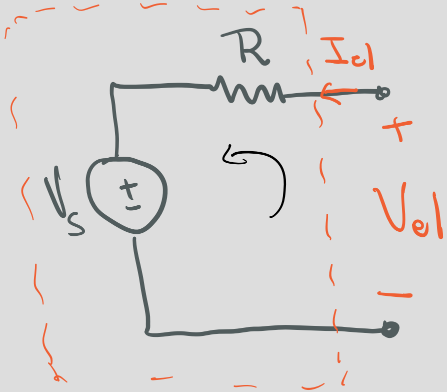
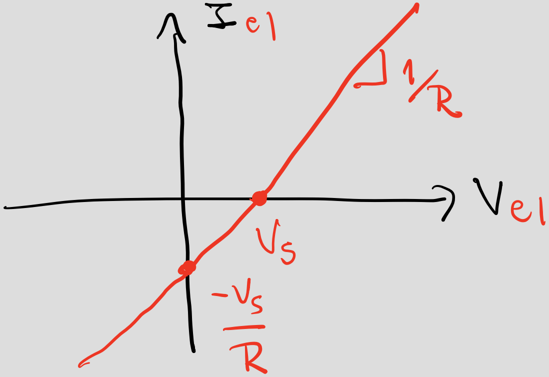




As long as the IV relantion is the same, circuits are equivalent!

Equivalence - Example





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

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

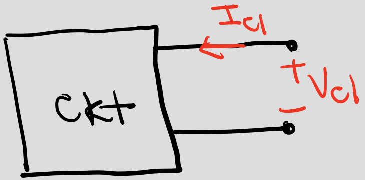
$$I_{el} = \frac{1}{R} V_{el} - \frac{V_s}{R}$$

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

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

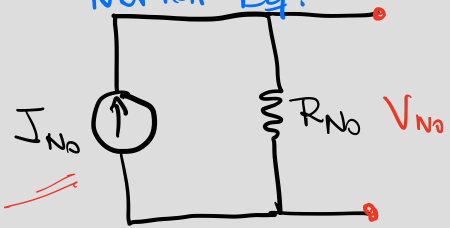
Two circuits are equivalent if they have the same I-V relationship.

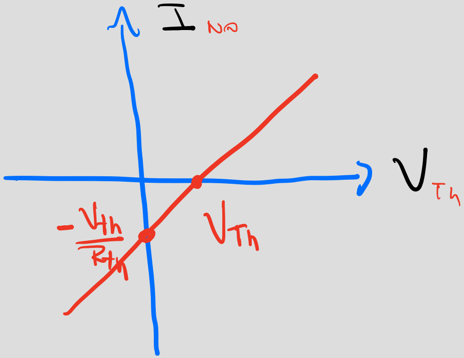
Thevenin and Norton Equivalent



Thevenin Eq.

Norton Eq.





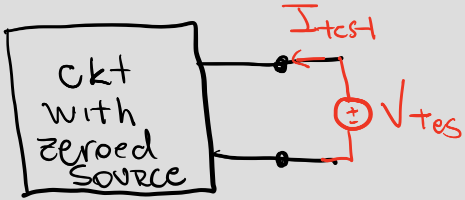
1) Find V_{Th} : Connect open-circuit

— $I = 0$

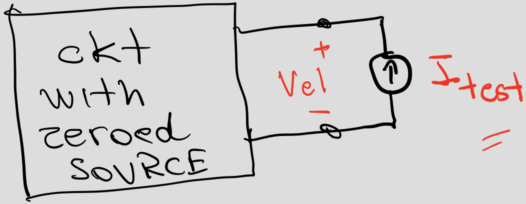
2) Find R_{Th} : Find slope

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

- Solve circuits for the currents and node potentials
- Set up a matrix problem of the form A $\vec{x} = \vec{b}$

  where

  $\vec{x}$ consists of the unknown currents and potentials

  $\vec{b}$ contains the independent current and voltage sources

  A describes the relationship between them.

Find $\vec{x} = \begin{bmatrix} I_1 \\ \vdots \\ I_m \\ V_1 \\ \vdots \\ V_k \end{bmatrix}$

$\vec{b} = \begin{bmatrix} I_{s_1} \\ I_{s_{12}} \\ \vdots \\ V_{s_1} \\ \vdots \\ V_{s_{m+k-1}} \end{bmatrix}$

$A\vec{x} = \vec{b}$ $\qquad$ $\underbrace{\vec{x} = A^{-1}\vec{b}}_{\text{solution}}$

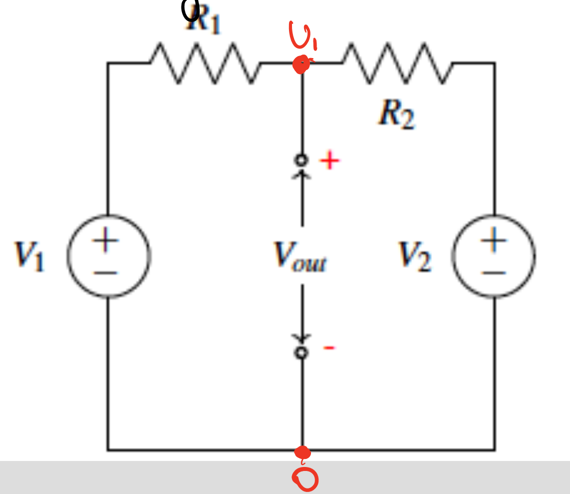
linear combination of sources

$$\begin{cases} I_i = \alpha_1 I_{s_1} + \dots + \alpha_1 I_{s_1} + \dots \alpha_{m+k} V_{s_{m+k-1}} \\ V_j = \beta_1 I_s + \dots + \dots \beta_{m+k} V_{s_{m+k-1}} \end{cases}$$

$I_i = \underbrace{I_{i_1}}_{\alpha I_{s_i}} + \dots \underbrace{I_{i_1}}_{\cancel{\alpha_1} I_{s_1}} + \dots$ $\to 0$

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

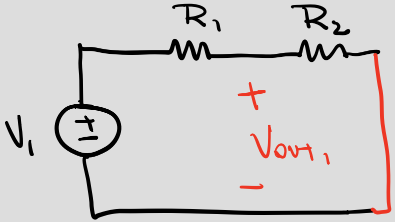
Voltage Summe



$U_1 - 0 = V_{out}$

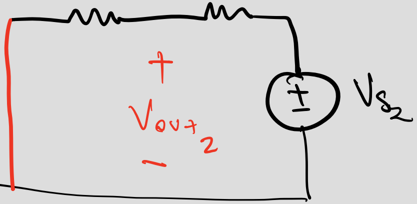
$U_1 = V_{out}$

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}



$$V_{out_2} = \frac{R_1}{R_1+R_2} \cdot V_{S_2}$$

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

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

$$U_1 = \frac{R_2}{R_1+R_2} \cdot V_{S_1} + \frac{R_1}{R_1+R_2} \cdot V_{S_2}$$

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

Superposition

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.