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

True
Last lecture: 2D resistive Touchscreen circuit model

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

\[ V = R \cdot X \]

Voltage Divider
Interesting Circuit

O.C.
resistive sheet
resistive sheet

z
x
y
z
x
y
Connecting voltage source to top sheet gives $y$-touch position

\[ U_{\text{mid}} = \frac{h_{\text{touch}}}{lV} \cdot V_s \]
Connecting voltage source to bottom sheet gives \textit{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 I-V relation is the same, circuits are equivalent!
Equivalence - Example

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

\[ V_{el} = V_s + V_R \]
\[ V_{el} = V_s + I_{el} \cdot R \]
\[ I_{el} = \frac{1}{R} V_{el} - \frac{V_s}{R} \]

\[ I_{el} \cdot R = V_{el} - V_s \]
\[ I_{el} = \frac{V_{el}}{R} - \frac{V_s}{R} \]
Thevenin and Norton Equivalent

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.

\[
A \, \vec{x} = \vec{b} \quad \vec{x} = A^{-1} \, \vec{b}
\]

**Linear combination of sources**

\[
\begin{align*}
I_i &= \alpha_i \cdot I_{s_1} + \ldots + \alpha_i \cdot I_{s_i} + \ldots + \alpha_i \cdot V_{s_{m+k-1}} \\
U_j &= \beta_j \cdot I_{s_1} + \ldots + \beta_j \cdot V_{s_{m+k-1}}
\end{align*}
\]

**Solution**

\[
I_i = I_{i_1} + \ldots + I_{i_l} + \ldots + \alpha_i \cdot I_{s_1} + \ldots + \alpha_i \cdot I_{s_i}
\]
Circuit Analysis Method – What happens when we have multiple Voltage or Current sources?

1st 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 $V_{s_2}$

$$V_{out_2} = \frac{R_1}{R_1 + R_2} \cdot V_{s_2}$$
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 $V_{out,k}$s for all $k$. 