Announcements

• Visit the class website to see updated TA section assignments
  http://www-inst.eecs.berkeley.edu/~ee40

• Lab section 13 (Mondays 6-9PM) is cancelled

• Prof. King’s Office Hour tomorrow (Thu. 9/4) will be held from 8:30AM-9:30AM

• HW assignments will NOT be accepted in class. Turn in your assignments BEFORE class on Friday in 240 Cory.

Lecture #4

OUTLINE

• Circuit element \( I-V \) characteristics
• Construction of a circuit model
• Kirchhoff’s laws – a closer look

Reading

(Finish Chapter 2)
Current vs. Voltage (I-V) Characteristic

- Voltage sources, current sources, and resistors can be described by plotting the current \( i \) as a function of the voltage \( v \).

Later, we will see that the I-V characteristic of any circuit consisting only of sources and resistors is a straight line.

I-V Characteristic of Ideal Voltage Source

1. Plot the I-V characteristic for \( v_s > 0 \). For what values of \( i \) does the source absorb power? For what values of \( i \) does the source release power?
2. Repeat (1) for \( v_s < 0 \).
3. What is the I-V characteristic for an ideal wire?
**I-V Characteristic of Ideal Current Source**

1. Plot the \( I-V \) characteristic for \( i_s > 0 \). For what values of \( v \) does the source absorb power? For what values of \( v \) does the source release power?

2. Repeat (1) for \( i_s < 0 \).

3. What is the \( I-V \) characteristic for an open circuit?

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**I-V Characteristic of Ideal Resistor**

1. Plot the \( I-V \) characteristic for \( R = 1 \, \text{k}\Omega \). What is the slope?
“Lumped Element” Circuit Modeling

(Model = representation of a real system which simplifies analysis)

- In circuit analysis, important characteristics are grouped together in “lumps” (separate circuit elements) connected by perfect conductors (“wires”)
- An electrical system can be modeled by an electric circuit (combination of paths, each containing 1 or more circuit elements) if
  \[ \lambda = \frac{c}{f} >> \text{physical dimensions of system} \]
  Distance travelled by a particle travelling at the speed of light in one period

Example: \( f = 60 \text{ Hz} \)
  \[ \lambda = \frac{3 \times 10^8 \text{ m/s}}{60} = 5 \times 10^6 \text{ m} \]

Construction of a Circuit Model

- The electrical behavior of each physical component is of primary interest.

- We need to account for undesired as well as desired electrical effects.

- Simplifying assumptions should be made wherever reasonable.
**Terminology: Nodes and Branches**

**Node**: A point where two or more circuit elements are connected – entire wire

**Branch**: A path that connects two nodes

**Notation: Node and Branch Voltages**

- Use one node as the reference (the “common” or “ground” node) – label it with a symbol
- The voltage drop from node \( x \) to the reference node is called the node voltage \( v_x \).
- The voltage across a circuit element is defined as the difference between the node voltages at its terminals

Example:
Using Kirchhoff’s Current Law (KCL)

Consider a node connecting several branches:

- Use reference directions to determine whether currents are “entering” or “leaving” the node – with no concern about actual current directions.

Formulations of Kirchhoff’s Current Law

(Charge stored in node is zero.)

**Formulation 1:**
Sum of currents entering node = sum of currents leaving node

**Formulation 2:**
Algebraic sum of currents entering node = 0
  • Currents leaving are included with a minus sign.

**Formulation 3:**
Algebraic sum of currents leaving node = 0
  • Currents entering are included with a minus sign.
A Major Implication of KCL

• KCL tells us that all of the elements in a single branch carry the same current.
• We say these elements are connected in series.

\[ i_1 = i_2 \]

KCL Example

Currents entering the node:

Currents leaving the node:

3 formulations of KCL:
1.
2.
3.
Generalization of KCL

- The sum of currents entering/leaving a closed surface is zero. Circuit branches can be inside this surface, i.e. the surface can enclose more than one node!

This could be a big chunk of a circuit, e.g. a "black box"

Generalized KCL Examples

- [Diagram showing current directions and values]
- [Diagram showing current directions and values]
Using Kirchhoff’s Voltage Law (KVL)

Consider a branch which forms part of a loop:

- Use reference polarities to determine whether a voltage is dropped—without concern about actual voltage polarities.

Formulations of Kirchhoff’s Voltage Law

(Conservation of energy)

**Formulation 1:**
Sum of voltage drops around loop
\[ = \text{sum of voltage rises around loop} \]

**Formulation 2:**
Algebraic sum of voltage drops around loop = 0
- Voltage rises are included with a minus sign.

(Handy trick: Look at the first sign you encounter on each element when tracing the loop.)

**Formulation 3:**
Algebraic sum of voltage rises around loop = 0
- Voltage drops are included with a minus sign.
A Major Implication of KVL

- KVL tells us that any set of elements which are connected at both ends carry the same voltage.
- We say these elements are connected in parallel.

Applying KVL in the clockwise direction, starting at the top:
\[ v_b - v_a = 0 \Rightarrow v_b = v_a \]

KVL Example

Three closed paths:

Path 1:

Path 2:

Path 3:
An Underlying Assumption of KVL

• No time-varying magnetic flux through the loop
  Otherwise, there would be an induced voltage (Faraday’s Law)

• Note: Antennas are designed to “pick up” electromagnetic waves; “regular circuits” often do so undesirably.

Avoid these loops!

How do we deal with antennas (EECS 117A)?

Include a voltage source as the circuit representation of the induced voltage or “noise”.
(Use a lumped model rather than a distributed (wave) model.)

Summary

• An ideal voltage source maintains a prescribed voltage regardless of the current in the device.

• An ideal current source maintains a prescribed current regardless of the voltage across the device.

• A resistor constrains its voltage and current to be proportional to each other:
  \[ v = iR \] (Ohm’s law)

• Kirchhoff’s current law states that the algebraic sum of all currents at any node in a circuit equals zero.

• Kirchhoff’s voltage law states that the algebraic sum of all voltages around any closed path in a circuit equals zero.