EECS 16A DIS 6B

OH: W 10 AM - 12 PM PST
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1. How was the MT?
2. First Circuits discussion!

Learning Objectives

1. Identify nodes and branches
2. Use NVA to analyze circuit behavior
   - Skill: labeling circuits
   - Skill: write element voltages in terms of node voltages
   - Skill: apply KCL to circuits
3. Goal: Setup and solve a system of equations with the unknowns being node voltages

3. If time: more KVL + KCL practice
   - How to identify loops for KVL equations

Today's tracklist
1. Wings of Liberty - Himmel
2. Human Bloom - Capillary
   - Suggested by Yoni Elsips
3. Lianne, La Havas - Unstoppable
   - Suggest more tracks @ bit.ly/16ajukebox
1. Nodes and Branches

In the circuit shown below, label and count all nodes and branches.

**Nodes**: continuous piece of wire (—, ——), take your pencil and draw without lifting your pencil

**Branches**: connections between nodes, examples

→ circuit elements (elivery of electric current through a branch/element, \( I = 1 \text{A} \))

→ Branch currents / Node voltages - voltage across/on a branch/element

→ Node voltage - voltage on a node

There is a really important relationship between node voltages and branch voltages.
2. Voltage Divider

For the circuit below, your goal will be to find the voltage $V_{out}$ in terms of the resistances $R_1$, $R_2$, and $V_s$, using NVA (Node Voltage Analysis). The labeling steps (steps 1-4) have already been done for you.

Element voltages: $V_{R1}, V_{R2}, V_{In}, V_{S}$
Element currents: $I_{R1}, I_{R2}, I_S$
Node voltages: $u_1, u_2$

NVA: The algorithm by which you find/solve for all node voltages in a circuit (unknowns)

Here is a reminder of the labeling steps followed to get the circuit diagram above:

- **Step 1**: Select a reference (ground) node. Any node can be chosen for this purpose. We will measure all of the voltages in the rest of the circuit relative to this point.
- **Step 2**: Label all nodes with voltage set by voltage sources.
- **Step 3**: Label remaining nodes.
- **Step 4**: Label element voltages and currents, following **Passive Sign Convention** (discussed below).

**Passive sign convention**

The **passive sign convention** dictates that positive current should enter the positive terminal and exit the negative terminal of an element. Below is an example for a resistor:

As long as this convention is followed consistently, it does not matter which direction you arbitrarily assigned each element current to; the voltage referencing will work out to determine the correct final sign. When we discuss power later in the module, you will see why we call this convention “passive.”
To achieve your goal of finding $V_{out}$, perform the rest of the NVA steps in the boxes below:

**Step 5:** Write KCL equations for all nodes with unknown voltages.

![KCL equation diagram]

**Step 6:** Find expressions for all element currents in terms of element voltages and characteristics.

- Ohm’s law ($I = \frac{V}{R}$)
- $V = RI$
- $R_1: I_{R_1} = \frac{V_{R_1}}{R_1}$
- $R_2: I_{R_2} = \frac{V_{R_2}}{R_2}$

**Step 7:** Substitute all element voltages with node voltages found in your step 6 equations.

- $R_1: I_{R_1} = \frac{V_{R_1}}{R_1} = \frac{V_5 - U_2}{R_1}$
- $R_2: I_{R_2} = \frac{V_{R_2}}{R_2} = \frac{U_2 - 0V}{R_2} = \frac{U_2}{R_2}$
Step 8: Substitute expressions found in step 7 into the KCL equations from step 5.

Step 9: Solve for the node voltage values. At this point the analysis procedure is effectively complete - all that’s left to do is solve the system of linear equations (by applying Gaussian Elimination, inverting A, etc.) to find the values for the u’s. Then we can go back to our Step 7 equations and calculate the I’s. Note that in our circuit, $V_{out} = u_2 - 0 = u_2$. 
Q: Can we choose - labelings separately for each element?
   Yes! The labeling on $R_1$ doesn't affect labeling on $R_2$.

Q: What direction is the current moving in, in the real physical system?

A: Assume $V_3 > 0$. 

![Diagram showing current direction]
Terms you might hear or read: "solve a circuit" - meaning: find all quantities (element voltages, element currents) in terms of component values (e.g., resistances, voltage sources, current sources).

Examples of passive sign convention:

- Correct: (+) going into, (-) going out of
  \[ I_1 = I_2 + I_3 \]

- Doesn't follow PSC: (+) going into, (-) going out of
  \[ I_1 = I_2 + I_3 \]

- Correct: (−) going into, (+) going out of
  \[ 0 = I_1 + I_2 + I_3 \]

- Doesn't follow PSC: (−) going into, (+) going out of
  \[ I_1 + I_2 = I_3 \]

KCL equation depends on how currents are oriented.

KCL is being applied at a node with currents: (\(I_1\), \(I_2\), \(I_3\)).
3. Practice: A Simple Circuit

Use KVL and/or KCL to solve the following circuits.

(a) For this problem assume $V_S = 1V$ and $R_1 = 1\,\text{k}\Omega$. Find the current, $I_s$ flowing through the voltage source.

\[
I_s = -\frac{V_s}{R} = -\frac{5\,\text{V}}{1\,\text{k}\Omega} = -5 \,\text{mA}
\]

(b) For this problem assume $V_S = 1V$, $R_1 = 2\,\text{k}\Omega$, and $R_2 = 2\,\text{k}\Omega$. Find the current, $I_s$ flowing through the voltage source.

\[
I_s = -\frac{V_s}{R} = -\frac{1\,\text{V}}{4\,\text{k}\Omega} = -0.25 \,\text{mA}
\]