EECS16A DIS6B

OH: W 10AM-12PM PST

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$\boxed{1}$ How was the MT?

$\boxed{2}$ First Circuits discussion!

Learning Objectives

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

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

Today's tracklist

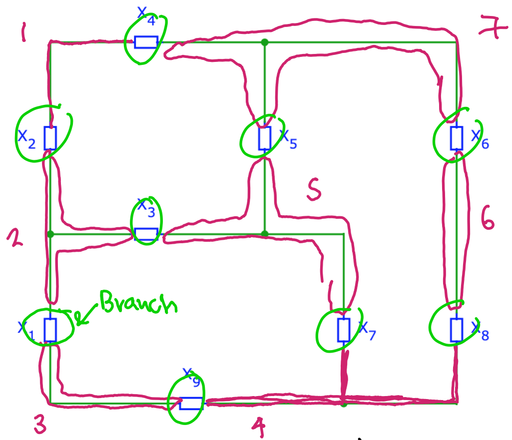
1. Wings of liberty - Himmel
2. Human Bloom - Capillary
   ↳ Suggested by Yoni Elsips
3. Lianne La Havas
   Unstoppable

Suggest more tracks @ bit.ly/16ajukebox

EECS 16A Designing Information Devices and Systems I
Fall 2020 Discussion 6B

1. Nodes and Branches

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



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

Branches: connections between nodes examples
→ circuit elements ( )

→ Element currents / Branch currents - currents through a branch/element $I = 1A$

ways we label I I I

→ Element voltages / Branch voltage - Voltage over/across/on a branch/element

\+ V − ← labeling of a branch voltage

Q: Does +/- direction matter?

A: In a way, we'll see

→ Node voltage - voltage on a node

u_1 u_2

There is a really important relationship between node voltages & element/branch voltages

2. Voltage Divider

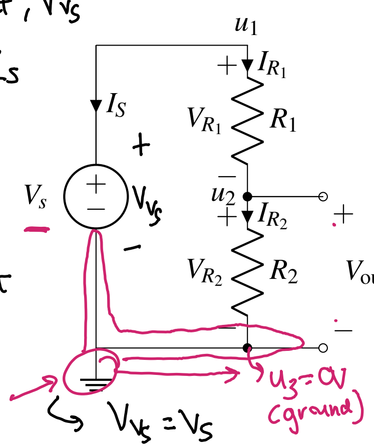
For the circuit below, your goal will be to find the voltage V_{out} in terms of the resistances R_1, R_2, and V_s, using NVA (Node Voltage Analysis). The labeling steps (steps 1-4) have already been done for you.

Element voltages: $V_{R_1}, V_{R_2}, V_{out}, V_{V_S}$

Element currents: I_{R_1}, I_{R_2}, I_S

Node voltages: u_1, u_2

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



Every element has an associated → element voltage & element current

Q: What is the relationship between node voltage & element voltage

A: element voltage = node voltage on plus end − node voltage on minus end

u_1 + V − u_2 $V = u_1 - u_2$

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.

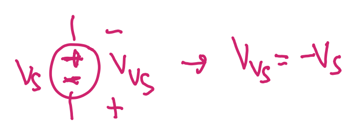
(voltage polarity − plus/minus labeling)

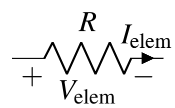
- **Step 2:** Label all nodes with voltage set by voltage sources.
- **Step 3:** Label remaining nodes.
- **Step 4:** Label element voltages and currents, following **Passive Sign Convention** (discussed below).

Passive sign convention

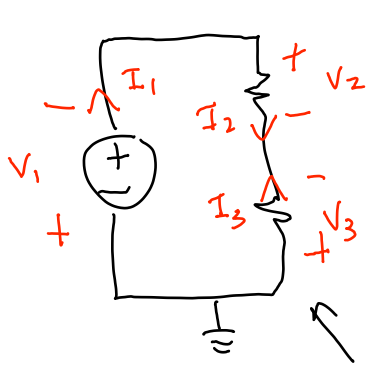
The **passive sign convention** dictates that positive current should *enter* the positive terminal and *exit* the negative terminal of an element. Below is an example for a resistor:

↳ end/side of element



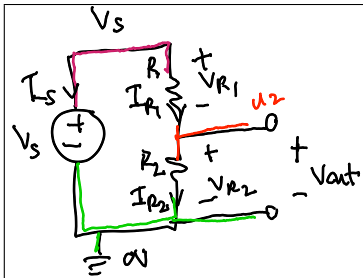


As long as this convention is followed consistently, it does not matter which direction you arbitrarily assigned each element current to; the voltage referencing will work out to determine the correct final sign. When we discuss *power* later in the module, you will see why we call this convention "passive."



If my ground is in the same place ⇒ my node voltages will be the same

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 eqn (written @ a node)

$$\sum i_{in \, (\text{to node})} = \sum i_{out \, (\text{of node})}$$

$$\rightarrow I_{R_1} = I_{R_2} \text{ @ } u_2$$

Ohm's law (I-R relationship
element voltage & element current relationship for a resistor)

$$V = RI$$

$$R_1: \boxed{I_{R_1} = \frac{V_{R_1}}{R_1}}$$

$$R_2: \boxed{I_{R_2} = \frac{V_{R_2}}{R_2}}$$

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

$$R_1: I_{R_1} = \frac{\boxed{V_{R_1}}}{R_1} = \frac{V_s - u_2}{R_1}$$

$$R_2: I_{R_2} = \frac{\boxed{V_{R_2}}}{R_2} = \frac{u_2 - 0V}{R_2} = \frac{u_2}{R_2}$$

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

Step 8: Substitute expressions found in step 7 into the KCL equations from step 5.

$I_{R_1} = I_{R_2}$

$I_{R_1} = \boxed{\frac{V_S - u_2}{R_1}}$

$I_{R_2} = \boxed{\frac{u_2}{R_2}}$

$$\frac{V_S - u_2}{R_1} = \frac{u_2}{R_2} \checkmark$$

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, $V_{out} = u_2 - 0 = u_2$.

1 eq'n

1 unk. (u_2)

skipping algebra

$$\boxed{u_2 = \frac{R_2}{R_1 + R_2} V_S}$$

Q: ~~W~~ Can we choose $\pm$ - labelings separately for each element?

Yes! The labeling on R_1 doesn't affect labeling on R_2

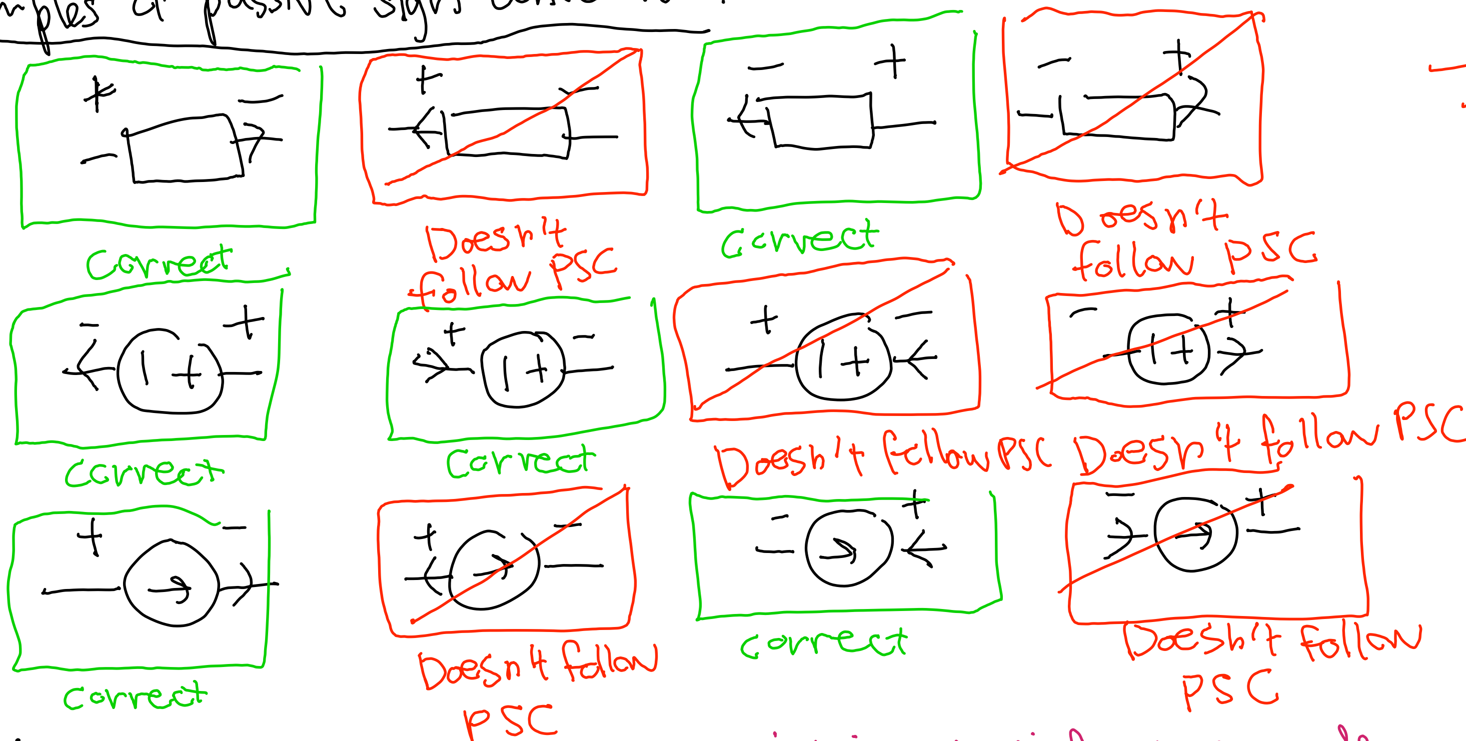
Q: What direction is the current moving in, in the real physical system:

A: Assume $V_s > 0$

Extra notes:

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)

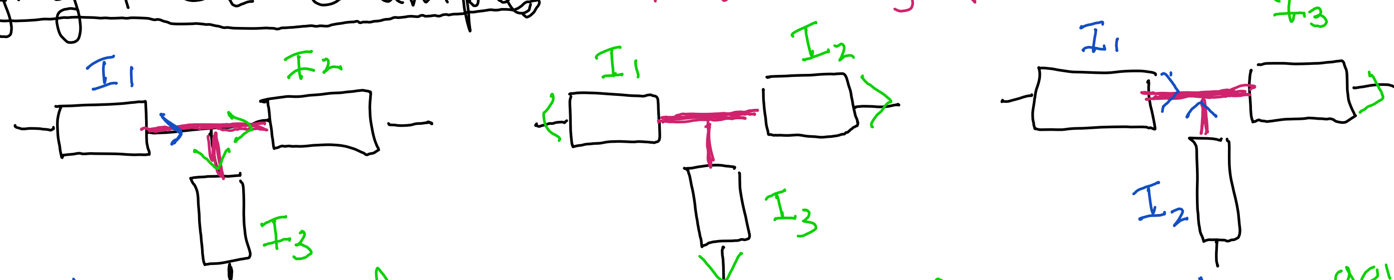
Examples of passive sign convention



The ones that fail have a mismatch between > (current direction) & + − (voltage polarity)

Applying KCL examples

KCL is being applied at • node



going into • going out of •
$I_1 = I_2 + I_3$

going into • going out of •
$0 = I_1 + I_2 + I_3$

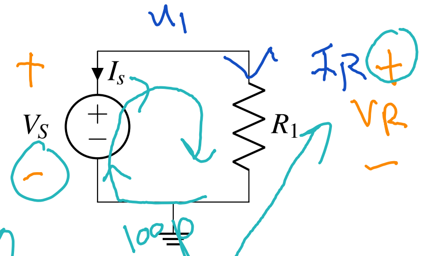
going into • going out of •
$I_1 + I_2 = I_3$

KCL equation depends on how currents are oriented

3. Practice: A Simple Circuit

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

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



Writing KVL
- Start at some node (ground in this case)
- Go through an element signing each element voltage with the first sign you hit.

KCL @ top node:

$I_S + I_R = 0$

$\boxed{I_S = -I_R}$

KVL around loop:

$-V_S + V_R = 0$

$\boxed{V_R = V_S}$

Ohm's law:

$V_R = R I_R \Rightarrow \boxed{I_R = \frac{V_R}{R}}$

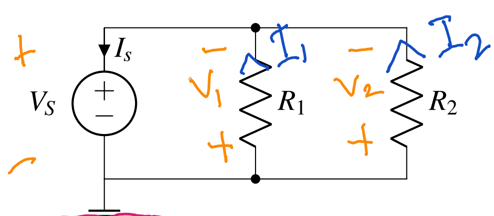
$I_S = -\frac{V_S}{R} = -\frac{5V}{1k\Omega} = -1mA$

(kilo = 1000, milli = $\frac{1}{1000}$)

$\frac{V}{\Omega} = A$

Negative means current in system goes in opposite direction to what was labeled. A positive 1mA goes up.

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



KVL loop 1

$-V_S - V_1 = 0$

$\boxed{V_1 = -V_S}$

KVL loop 2

$-V_S - V_2 = 0$

$\boxed{V_2 = -V_S}$

KCL @ top node

$\boxed{I_S = I_1 + I_2}$

Ohm's law

$\boxed{\frac{V_1}{R_1} = I_1, \frac{V_2}{R_2} = I_2}$

$I_S = -\frac{V_S}{R_1} - \frac{V_S}{R_2}$

$I_S = -\left(\frac{1}{R_1} + \frac{1}{R_2}\right) V_S$

$I_S = -\left(\frac{1}{2k\Omega} + \frac{1}{2k\Omega}\right) 1V$

$I_S = -1mA$