1 Node Voltage Analysis (Branch Current) Recipe

1.1 Ingredients

- Voltage Definitions
- KCL
- KVL maybe
- Passive Sign Convention

1.2 Directions

1. **Label your nodes.** Conventionally, everything will be relative to ground.
    - Note: some great choices for ground are: negative terminal of a voltage source, a node with lots of elements connected to it, somewhere near the "bottom" of the circuit
    - Note: ground is just a label for a node. Just like you'd label u_1, you'd label ground.
2. **Mark your current flow directions.** Use passive sign convention.
    - Note: either choose direction arbitrarily or choose the element's polarity arbitrarily, but do not choose both arbitrarily.
    - Note: choosing current direction arbitrarily will mean your calculated current will wither be negative or positive, telling you which way it is flowing in respect to the current direction you drew for it.
    - Note: negative current means negative voltage, vice versa

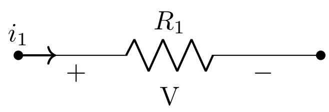


Figure 1: Passive Sign Convention

    - **Voltage sources.** It is common that we use the polarity on the battery itself to determine current direction. (It simplifies things) This means we do not arbitrarily choose. It also means, our element current is often negative. If you did the opposite, your calculated value of the voltage source would theoretically be negative.

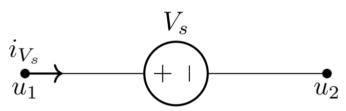


Figure 2: V_s = u_1 - u_2

    - **Voltage definitions.** Often times, for every element you add nodes via the element's polarity signs that we've assigned.

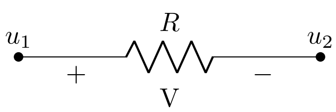


Figure 3: V = u_1 - u_2

3. **Simplifications.** Look for voltage dividers, resistors in series/parallel. Current dividers (opposites).

4. **Write your KCL equations.** As a reminder, *what goes in must come out.*
   - If you are trying to solve for current, consider using KVL. You'll arrive faster.
   - If there are more nodes than mesh loops, consider using KVL. You have less equations to deal with.
5. **Rewrite your KCL equations in terms of *Ohm's Law* and *Voltage Definitions.***
6. **At this point, stop and check if you have more knowns than unknowns.** If so, solve.

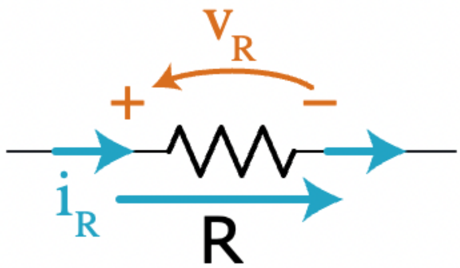
1.3 Shortcut Toolkit

- $R_1 + R_2$
- $\frac{R_1 R_2}{R_1 + R_2}$
- $V_{diff} = \frac{R_{lower}}{R_{lower} + R_{upper}} V_s$
- $I_{target} = \frac{R_{opp}}{R_{opp} + R_{target}} I_s$
- I is constant for resistors in series
- V is constant for elements in parallel.
- Thevenin/Norton for reevaluating IV
- $C_1 + C_2$ for parallel
- $\frac{C_1 C_2}{C_1 + C_2}$

1.4 Sign Convention

1.4.1 Passive Sign Convention for Passive Components

Note: This applies only to passive components. Resistors, inductors, capacitors. Current direction always goes into the positive end and out the negative end. We either choose current direction arbitrarily or the signs arbitrarily.



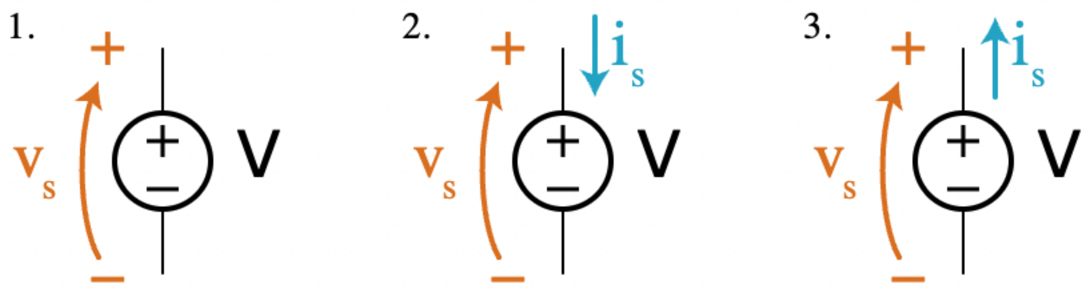
1.4.2 Voltage Source/Battery

In most cases, the current flows out of the positive terminal of a voltage source. If you apply the passive sign convention to the voltage source, in most cases the current ends up with a negative sign. This current arrow direction may feel "wrong," or you may find it annoying, but it is not technically an error. It just means the current has a - minus sign, which isn't a big deal. Note: everything in this section that applies to voltage sources, will apply to batteries.

There are a few ways of handling voltage sources:

- No current label. Usually you don't need to label current through a voltage source. The surrounding circuit context determines the direction of the current

- If you are doing power calculations, you probably want the correct sign for power: + plus sign for power dissipation and - minus sign for generation. Use the same convention we defined for passive components: Current points into the positive voltage terminal of a voltage source
- If it is important (or comforting) for the sign of current in a voltage source to have a positive sign, then use a convention where the current arrow points out of the positive voltage terminal



You can also orient the + plus and - minus signs the opposite way. It can be unconventional but not wrong.

1.4.3 Current Source

The actual voltage across the current source will emerge from the analysis of the surrounding circuit. Current is often labeled in the same direction with our current source. Labeling the other way works, but gets incredibly confusing and highly uncommon. Hypothetically, you'd treat I_s as a constant scalar and current as a one-dimensional vector.

2 Mesh Current Analysis (Loop Analysis)

Sometimes there are fewer essential meshes than actual nodes, which lessens our calculations.

1. Identify the essential meshes, (the open windows of the circuit). They cannot contain sub-meshes.
2. Assign a current variable to each mesh, using a consistent direction (clockwise or counterclockwise).
3. Write KVL equations around each mesh.
4. Solve your system of equations for mesh currents.

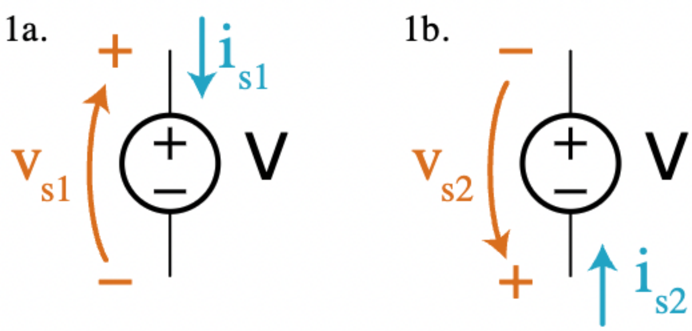


Figure 4: Both are correct, 1a is more common/less confusing