

EE16A Circuits Review 12/8/16

Credited to Ori Hoxha

Resistors



Useful formulas

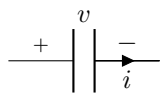
- Ohm's Law:

$$R = \frac{V}{I}$$

- Resistivity:

$$R = \rho \frac{l}{A}$$

Capacitors



Useful formulas

- Charge:

$$C = \frac{Q}{V}$$

- Current:

$$i = C \frac{dV}{dt}$$

Equivalence

Resistors

$$R_{series} = \sum_i R_i$$

$$R_{parallel} = \left(\sum_i \frac{1}{R_i} \right)^{-1}$$

Capacitors

$$C_{series} = \left(\sum_i \frac{1}{C_i} \right)^{-1}$$

$$C_{parallel} = \sum_i C_i$$

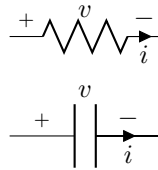
Analysis

There are some key things to always remember:

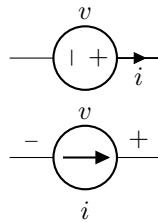
- **Voltages across parallel branches are the same**
- **Current in a loop is the same**
- **Passive Sign Convention:**

Disclaimer: passive sign convention is a convention, and some people might prefer the complete opposite of what I put here, but as long as you are consistent then your analysis should be correct.

Passive Components have a voltage drop across them with currents flowing from the positive terminal to the negative terminal. Passive Components include resistors, capacitors, and in 16B, inductors.



Active Components have a voltage increase across them with currents flowing from the negative terminal to the positive terminal. Active Components include voltage sources and current sources.

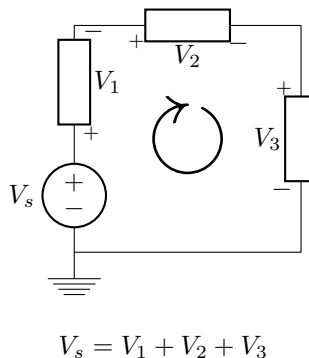


Note 1: It's best to define the direction of current as the direction of the current source. Remember that you can arbitrarily set the direction of current for analysis as long as you are consistent with your sign convention.

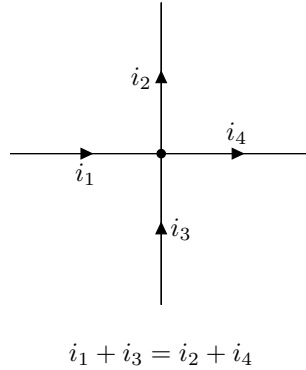
Note 2: Yes, a current source can have voltage across it, and current flows through a voltage source. All that is required of these sources is that they provide the set current and voltage, respectively

Kirchoff's Voltage and Current Laws (KVL, KCL)

- **KVL:** the increase in voltages in a loop has to equal the decrease in voltages in a loop



- **KCL:** all the current entering a node has to equal the current exiting a node



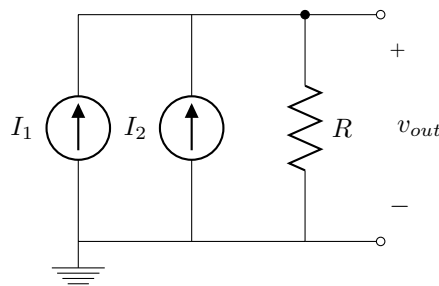
Superposition

Nearly all the circuits you'll encounter in EE16A/B are what we call "linear." Because these circuits are linear, we can calculate voltages and currents across passive components by considering only one active component at a time while the other active components are "turned off" and then adding up their contributions. This property is called superposition.

Key things to remember:

- **Turning off voltage sources means you SHORT it;** this is the same as adding a replacing it with a resistor $R = 0$ so that there is no voltage contribution from it while you analyze the other active components.
- **Turning off current sources means you OPEN it;** this is the same as adding a replacing it with a resistor $R = \infty$ so that there is no current contribution from it while you analyze the other active components.

Here's an example:



What is the voltage and current across R ?

Due to I_1 :

$$v_{out1} = I_1 R$$

$$i_{out1} = I_1$$

Due to I_2 :

$$v_{out2} = I_2 R$$

$$i_{out2} = I_2$$

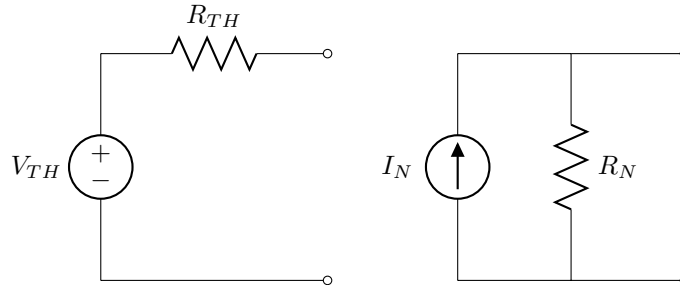
By superposition:

$$v_{out} = (I_1 + I_2) R$$

$$i_{out} = I_1 + I_2$$

Thevenin/Norton

We can treat any portion of a circuit with an active component as a black box that has some source voltage and series source resistance (Thevenin voltage and resistance) or some source current and parallel source resistance (Norton current and resistance).

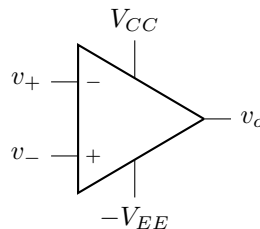


It turns out that $V_{TH} = V_{OC}$ and $I_N = I_{SC}$, where OC means open circuit and SC means short circuit. Key things to remember when finding open circuit voltage and short circuit current of a circuit that you're probing:

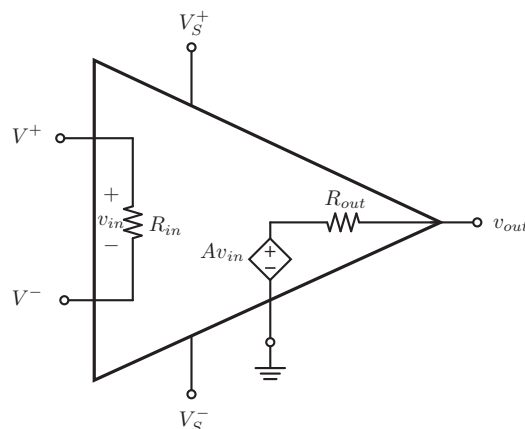
- **For V_{oc} :** find the voltage across the component(s) you're probing using regular analysis techniques.
- **For I_{sc} :** **SHORT** your probes! Then consider that short to be part of the circuit, then find the current going through that short.
- **For R_{TH} :** Use Ohm's Law, $R_{TH} = \frac{V_{oc}}{I_{sc}}$

Operational Amplifiers

Amplifier Diagram:



At an abstract level this is also what an opamp looks like:

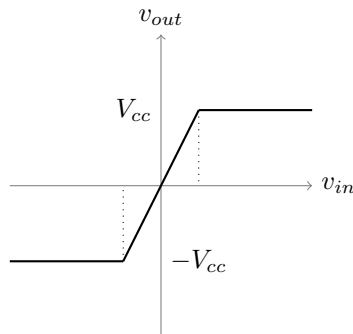


So ideally, the gain is $A = \infty$, input resistance $R_i = \infty \Omega$, output resistance $R_o = 0 \Omega$. A high input resistance is so we can put in the full input voltage v_i . Zero output resistance is so we get the full output voltage v_o . Having a high voltage gain A is the main characteristic of an op amp. If the output voltage is represented as:

$$v_{out} = A(v_{in})$$

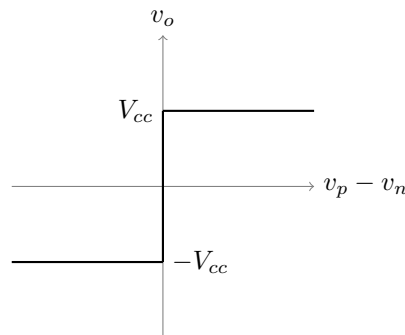
$$v_{in} = v^+ - v^-$$

This produces a linear response. But will the line go on forever? No. The limiting factor here will be the power supplies. The region that has a $v_{out} = V_{CC}$ is the positive saturation region and the region that has a $v_{out} = -V_{EE}$ is the negative saturation region.



Op Amps as comparators

If A is really high, then the slope of the linear response is also really high. Let $A = \infty$. The graph looks like this:



So if $v_p > v_n$, $v_o = V_{cc}$ and if $v_p < v_n$, $v_o = -V_{cc}$. This means we can use op amps to compare the input voltage to a reference (usually ground).

OpAmps in Negative Feedback

Negative feedback is defined to be when the output of the opamp is fed back to the negative input in such a way that an increase in the input will create a decrease in the output and vice versa.

$$i_+ = i_- = 0$$

*** This rule only applies in negative feedback ***

$$v_+ = v_-$$