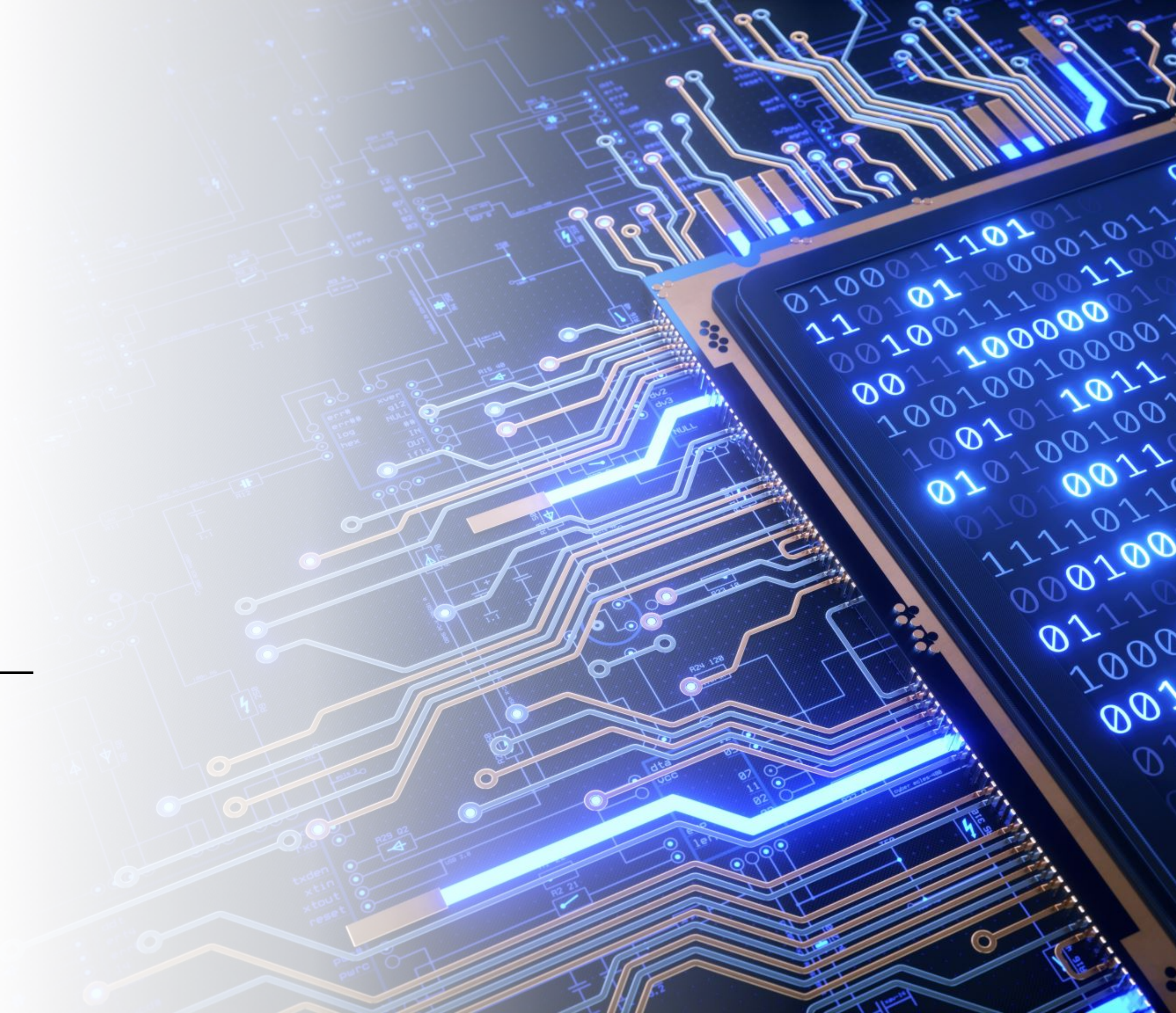
Basic Electronics Review



Review/Intro to Basic Electronic Principles and Terminology

Motivation

- We will be using the Arduino to explore microcontroller development and interfacing
- Understanding interfacing requires a very basic understanding of electronic principles
- Not everyone in class has the same background in electronic circuit theory

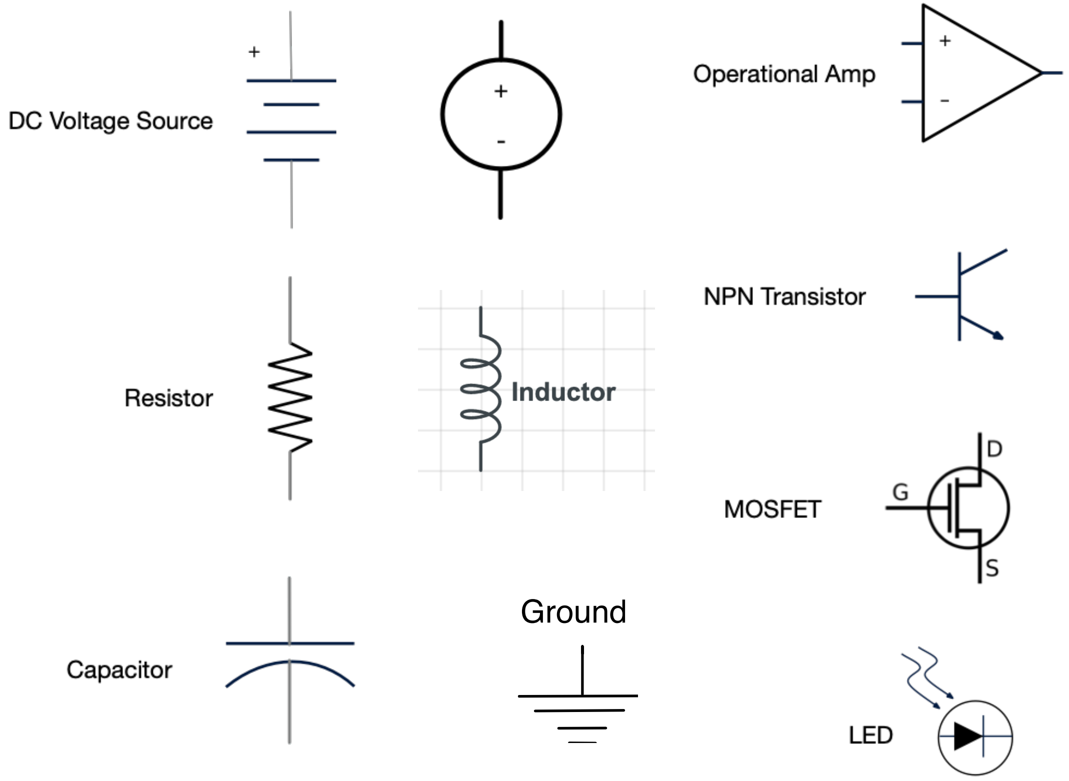
Voltage, Current, and Resistance

- At the most basic level, we need to understand the relationship between voltage, current, and resistance (impedance)
- Mathematically, the relation is given by Ohm's Law

$$V = IR$$

or more generally $\boldsymbol{V} = \boldsymbol{I} \cdot \boldsymbol{Z}$

Electronic Component Symbols

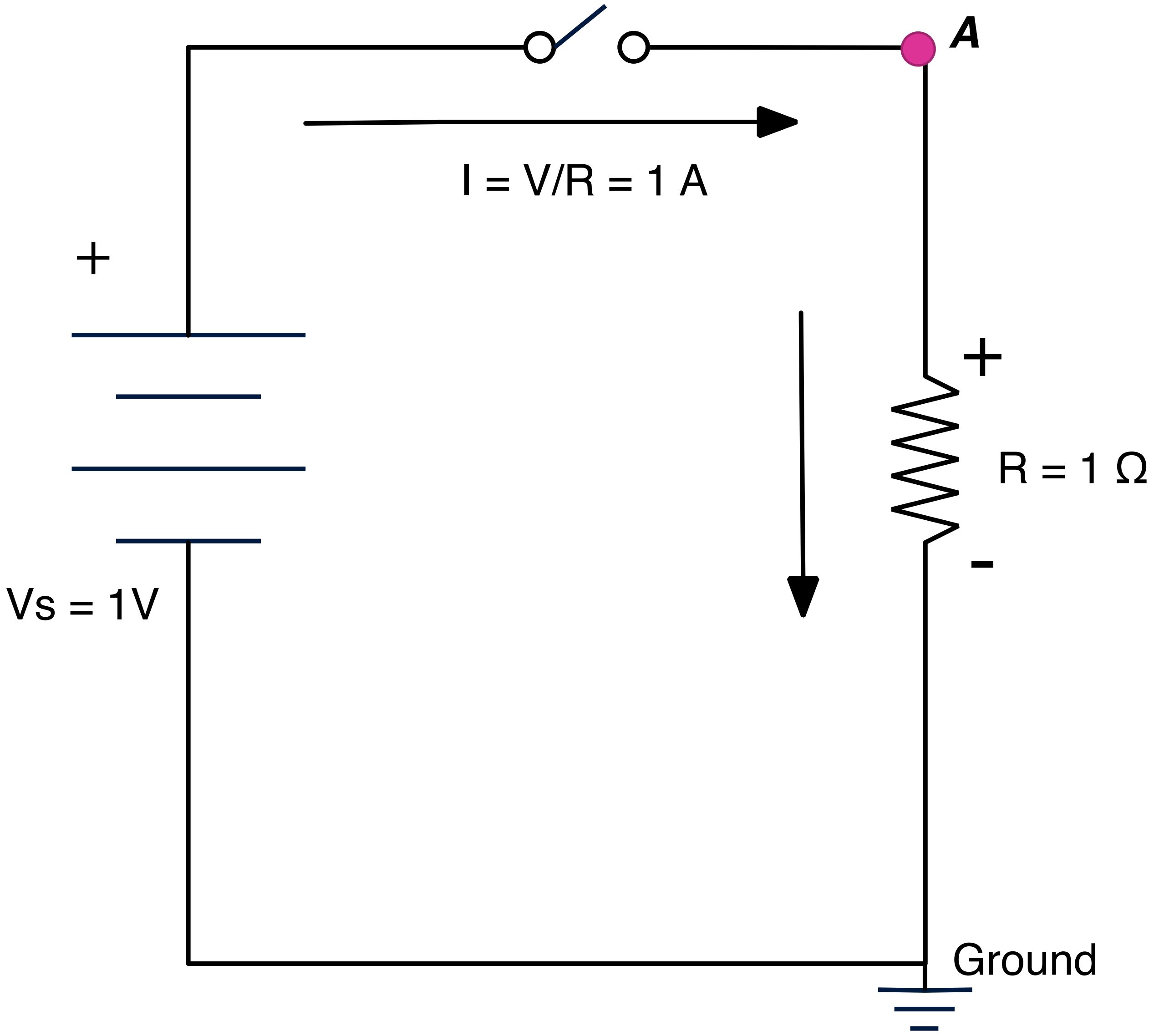


A Basic Resistive Direct Current Circuit

- The arrows indicate the flow of current when the switch is closed.

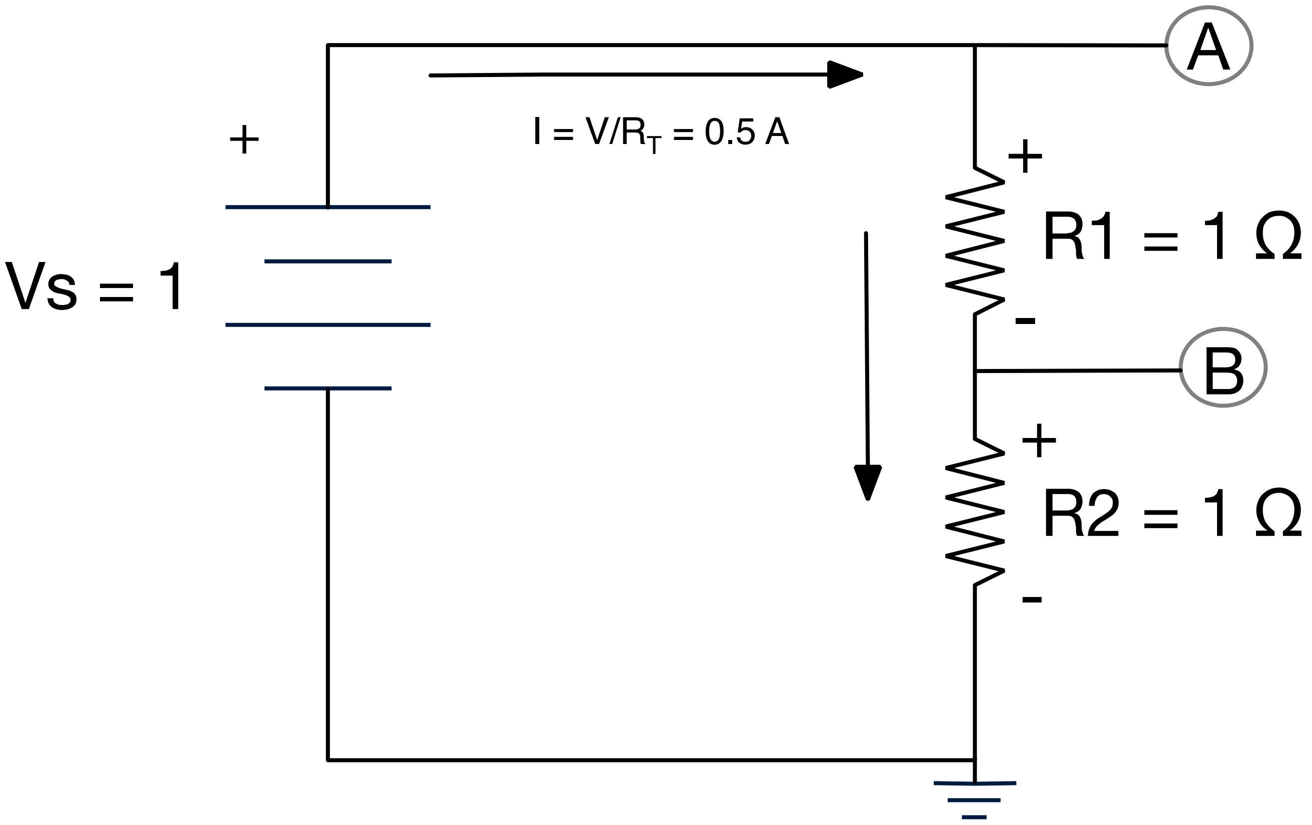
- Are they pointing in the correct direction?

- What is the voltage measured from point A to ground?



A Basic Voltage Divider

- The arrows indicate the flow of current when the switch is closed.
- Voltage is said to *drop* across a resistor
- What is the voltage measured from point A to ground?
- What is the voltage from point B to ground?
- What is the voltage from point A to B?



These resistors are in *series.* Resistors in series are simply added together.

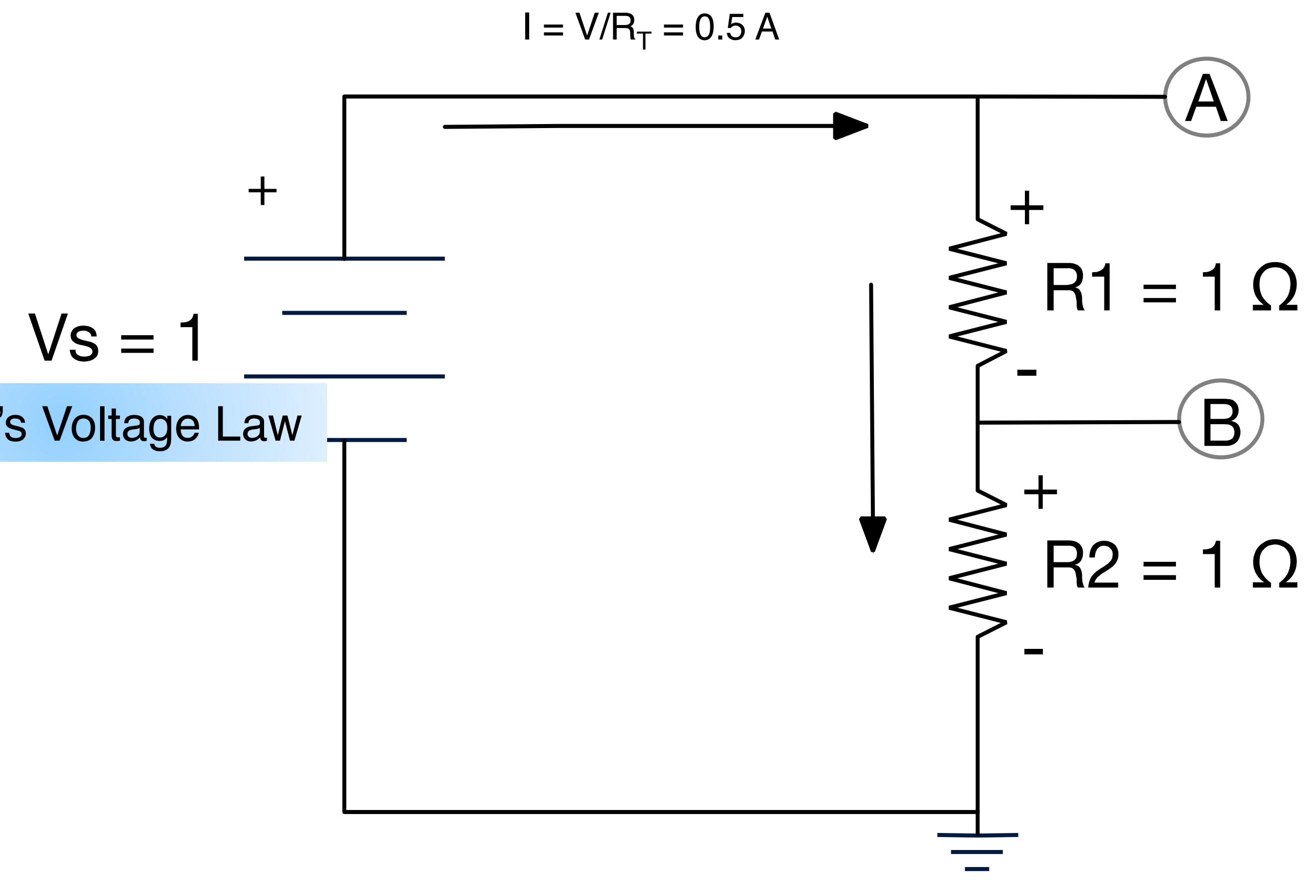
The Voltage Divider Rule

$$I = \frac{V_s}{R_1 + R_2}$$

$$V_s = IR_1 + IR_2$$

Kirchhoff's Voltage Law

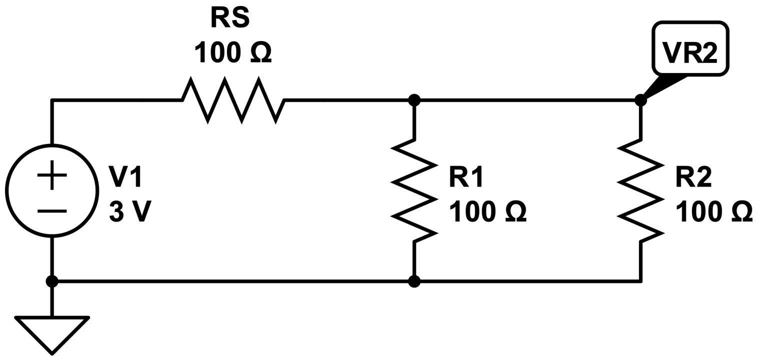
$$\boxed{V_{R_1} = V_s \frac{R_1}{R_1 + R_2}}$$



Resistors in Parallel

- Formula for resistors in parallel

$$R_t = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}}$$



$$R_t = \frac{1}{\frac{1}{100} + \frac{1}{100}} + 100 = 150\Omega$$

- *Conductances (G)* add in parallel circuits

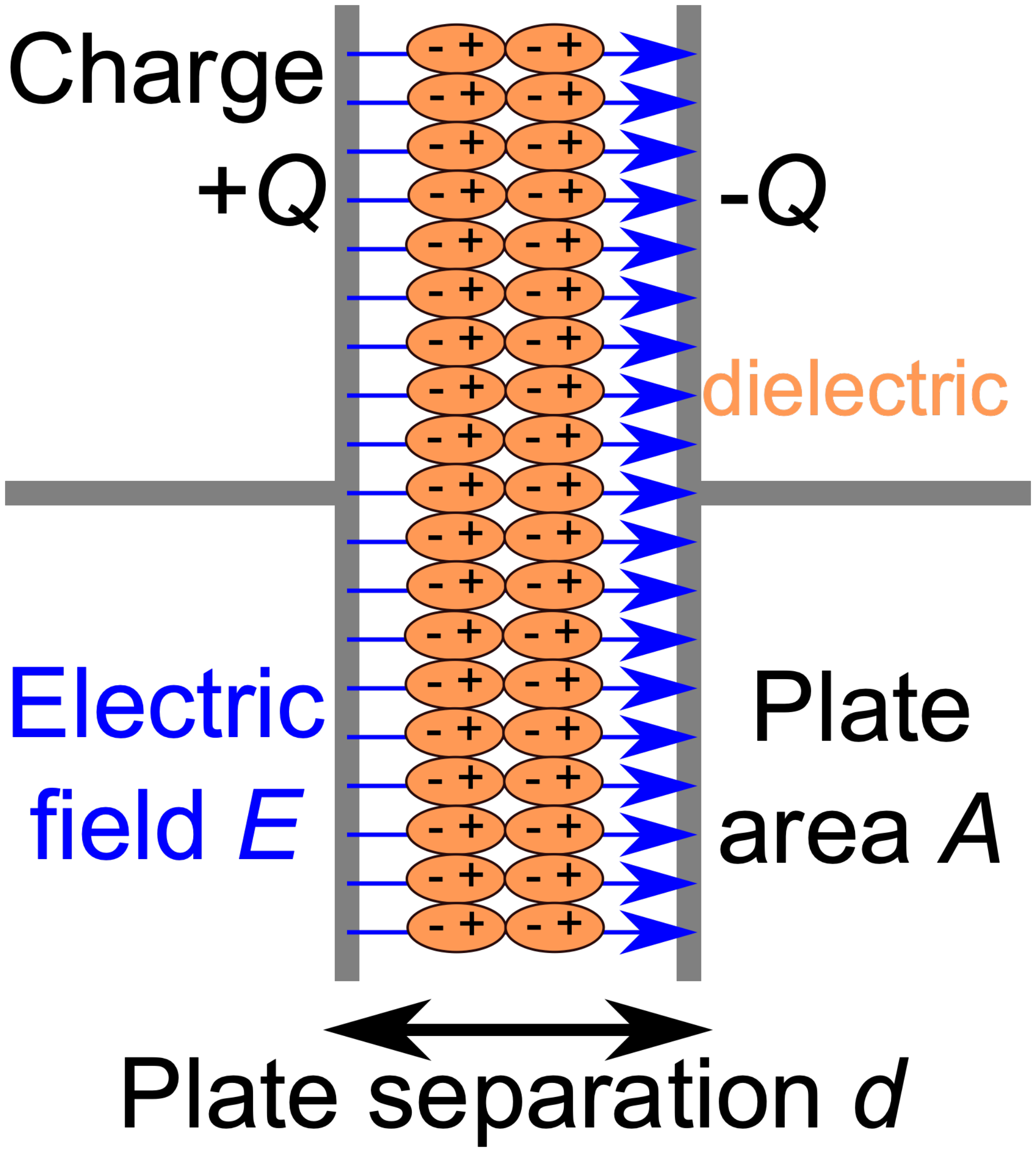
$$G \equiv 1/R$$

$$G_t = \sum_n G_n \Rightarrow R_t = 1/G_t$$

Special Case for 2 Resistors $R_t = \frac{R_1 R_2}{R_1 + R_2}$

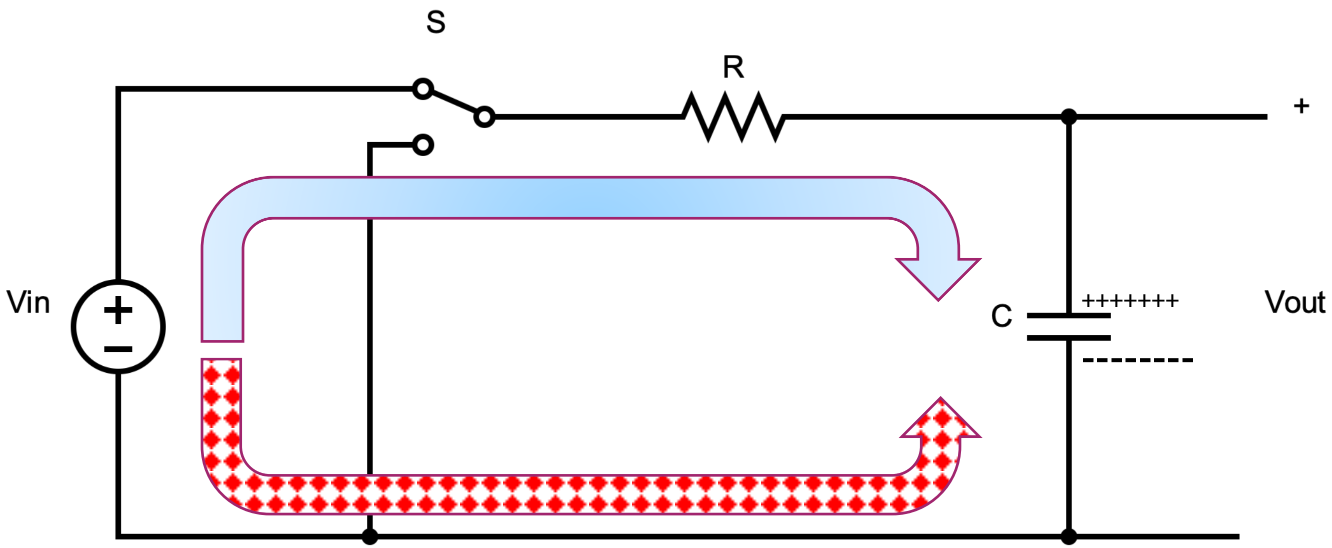
Capacitance

- A capacitor holds electric charge, even after being disconnected from a circuit
- Used in DC circuits to filter out ripple and to provide timed voltage changes
  - Caps resist changes in voltage
- Used in AC circuits to provide frequency-dependent impedance



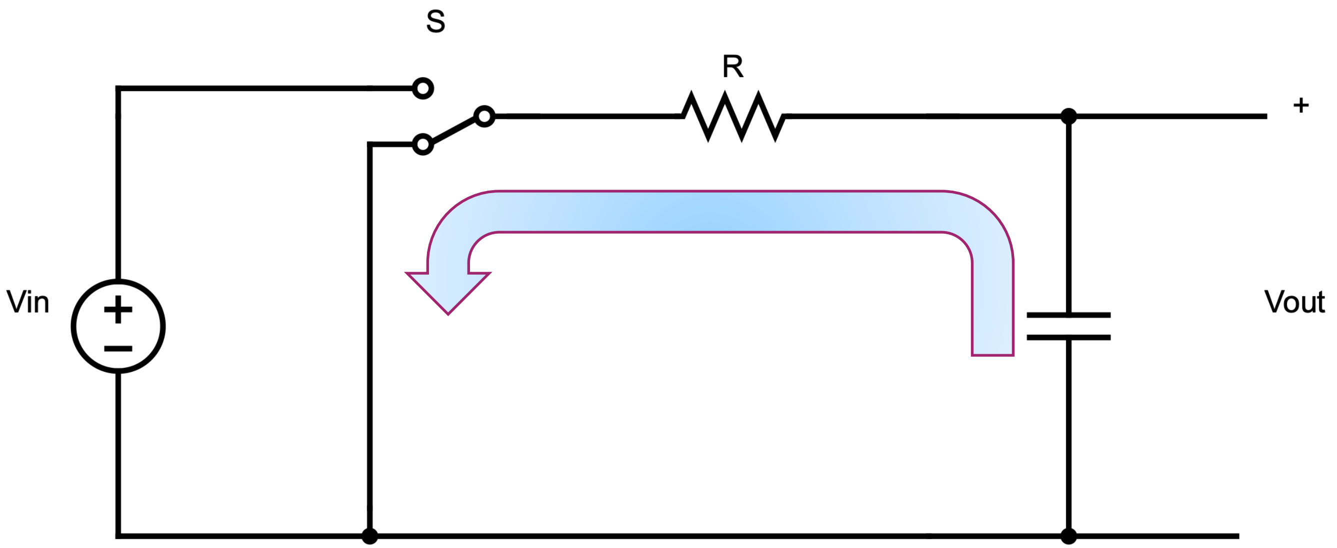
Capacitors in DC Circuits

- Charging Cycle (Step response)
    - Switch is flipped to position shown
    - Current is at maximum, Vout is equal to 0
        - The cap acts essentially as a short circuit
    - Over time, capacitor charges
    - Current reduces to 0
    - Vout goes to Vin
    - Vr goes to 0
- How long this takes depends on the product C and R
    - C*R gives seconds!

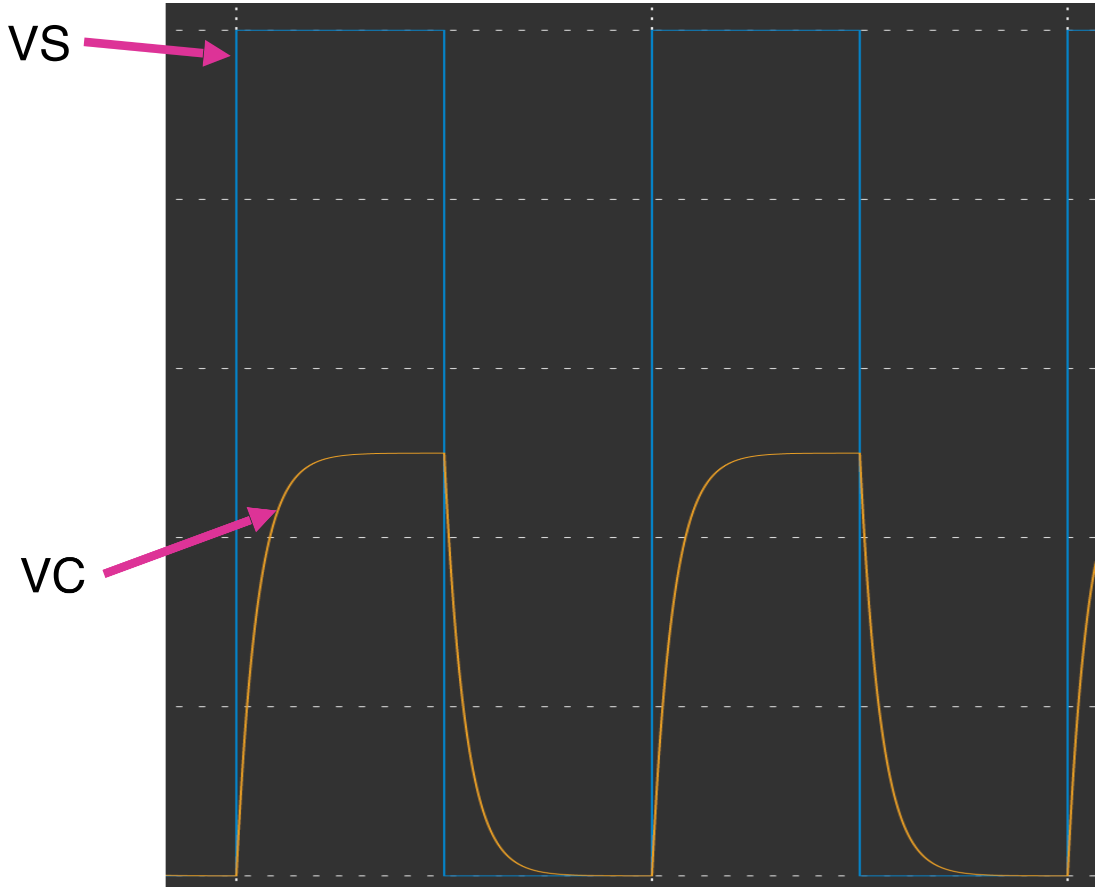


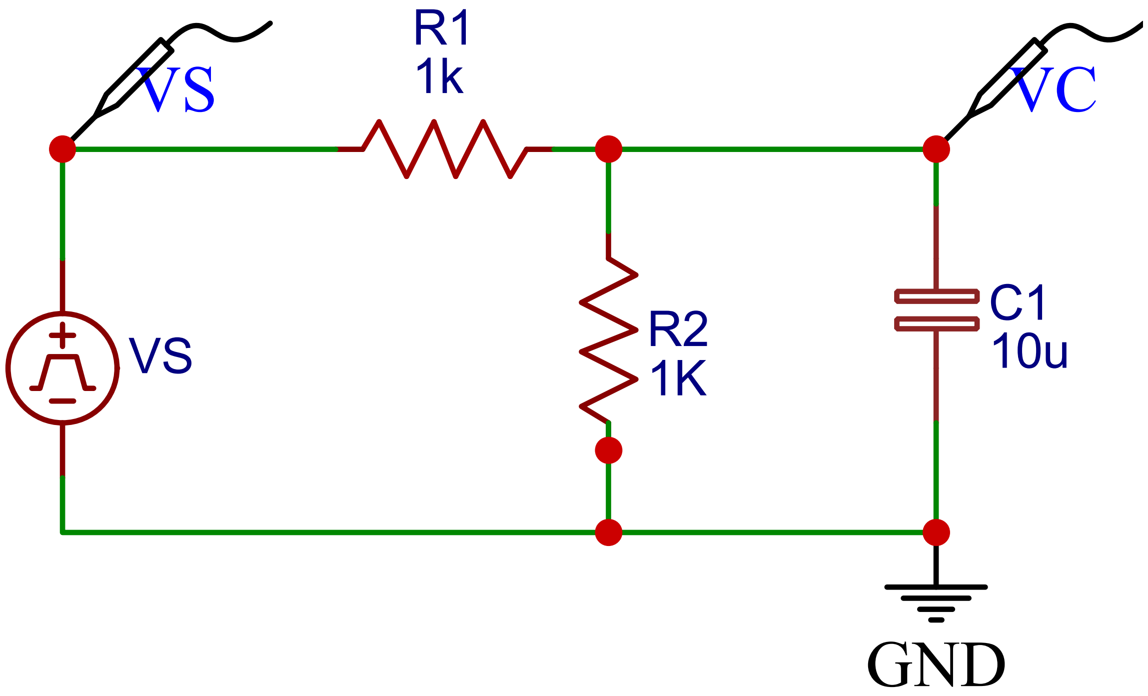
Capacitors in DC Circuits (2)

- Discharge Cycle
  - Switch is flipped as shown
  - Cap acts as a voltage source!
  - Over time, capacitor *dis*charges
  - Current reduces to 0
  - Vout goes to 0
- How long this takes depends on the product C and R
  - C*R gives seconds!



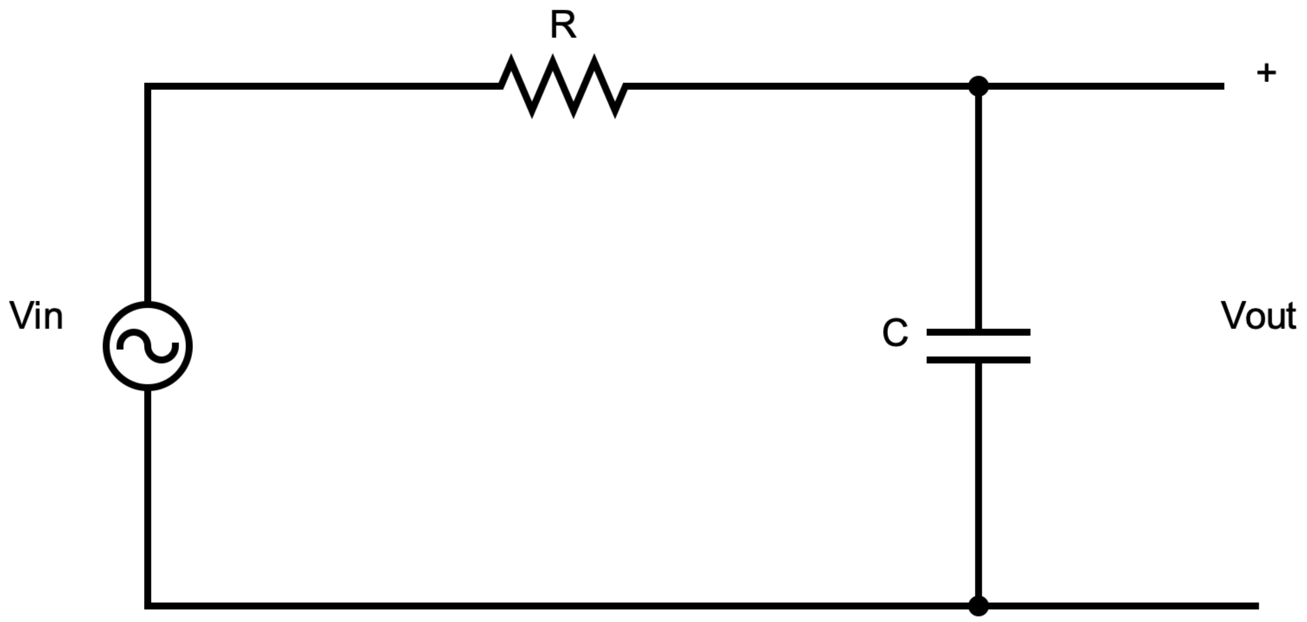
RC Response to Pulse Train





Capacitors in AC Circuits

- Capacitor in AC acts as impedance, measured in Ohms
- Impedance of a capacitor is a function of the frequency of the source
- Impedance is a *complex number*
- For a series circuit, the total impedance is just the sum of the individual impedances
- *Impedance* has a phase component, while pure resistance does not

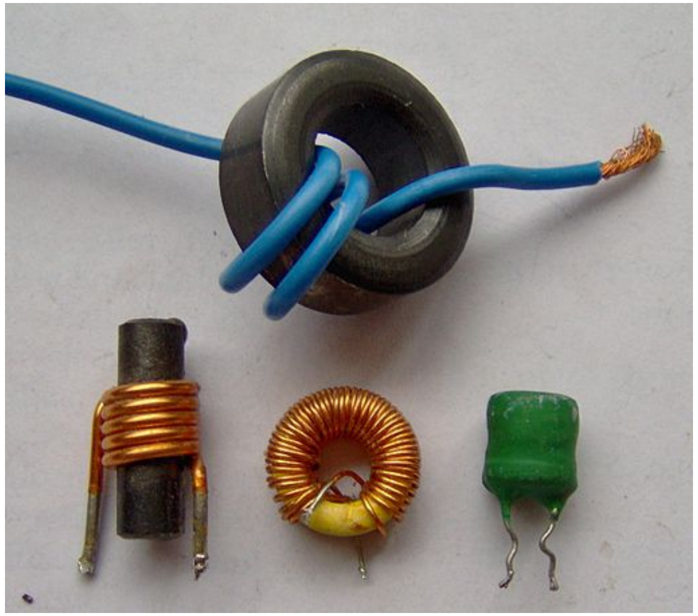


In essence, the higher the frequency, the lower the impedance
Note: the voltage in the capacitor lags the current

This RC circuit is an example of a *low-pass filter.*

A Brief Word About Inductors

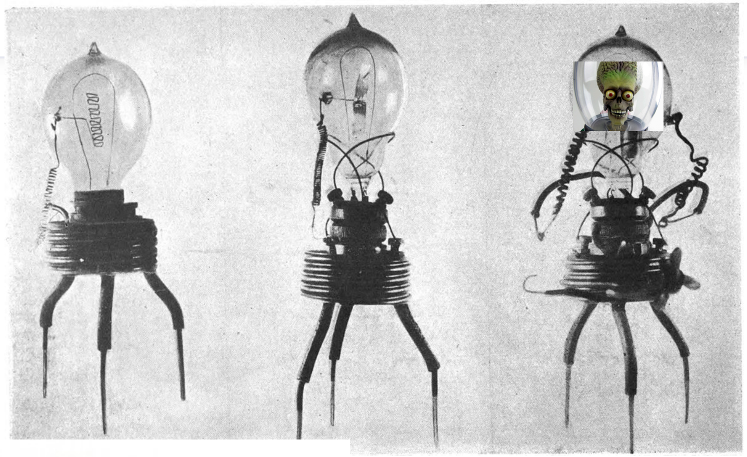
- Inductance responds to changes in current
- Current creates a magnetic field in the inductor
- The field collapses when the current is reduced, pushing current into the system
- Acts as a short-circuit to DC

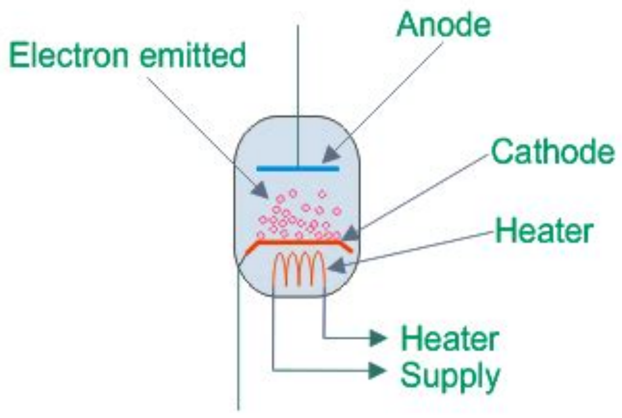


Source: https://en.wikipedia.org/wiki/Inductor

Diodes

- Electronic component that limits current to flowing in one direction
- Early diodes were constructed using vacuum tubes
- Now use semiconductor materials (P-N junctions, etc.)

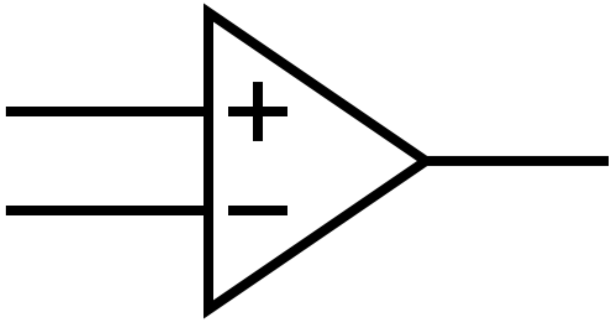




Diodes

- A diode allows current to flow only in one direction
- Can be modeled as having a constant voltage drop
  - Simplified analysis: substitute the diode with a battery (power source) equal to the forward bias voltage drop

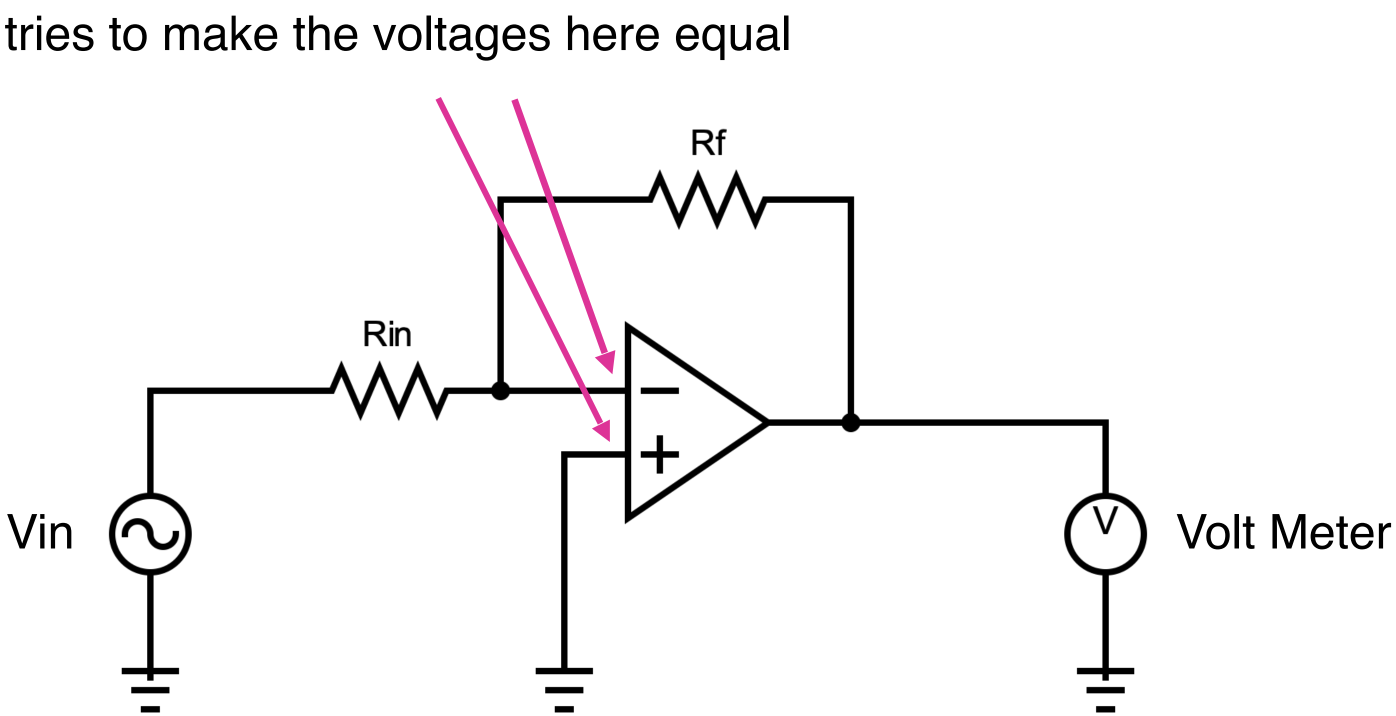
Operational Amplifiers aka Op Amps



- Like the diode, the op-amp is an *active* component
  - Requires power to operate
  - Can *add* power (voltage, current) to a circuit
  - Passive components can only reduce (consume) power
- Op-amps have two inputs and one output
- We will see them in when we discuss ADCs and DACs

Op-Amps as Amplifiers

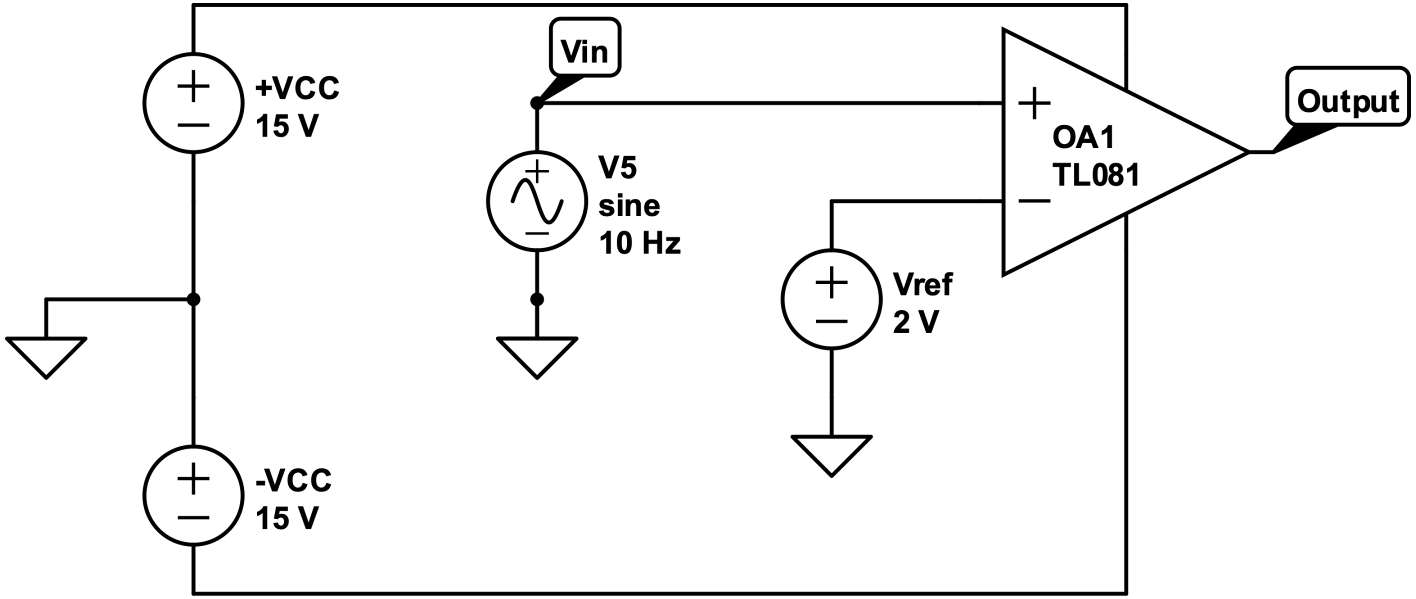
- This configuration is called an inverting amplifier
- The op-amp tries to force its inputs to be at equal voltages
- Amplification is determined by the ratio of the resistors in this configuration



$$V_{out} \approx -V_{in} \frac{R_f}{R_i}$$

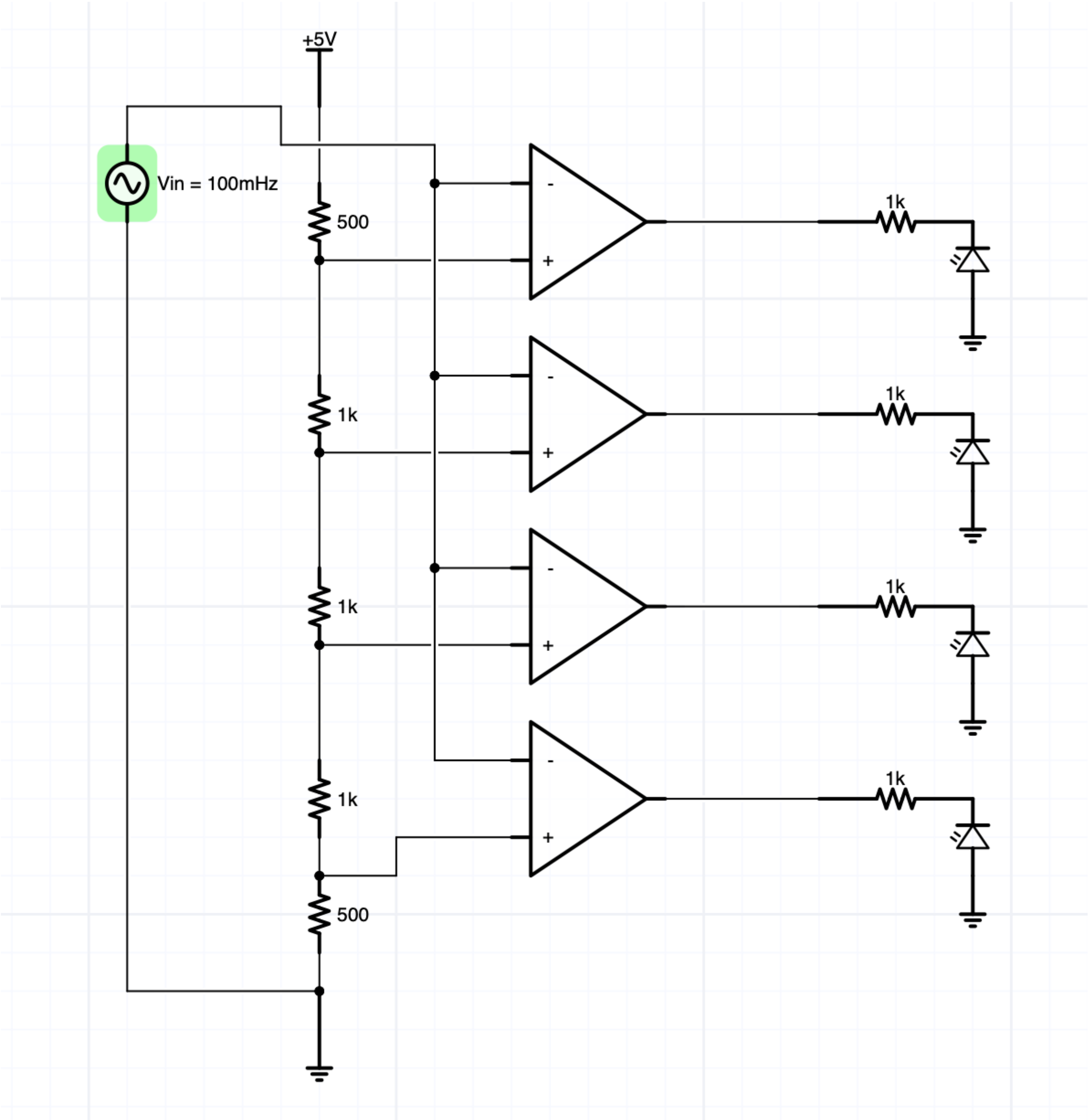
Op-Amps as Comparators

- Comparators provide a way of comparing (duh) two voltages
- Op-amps can be used as comparators by removing feedback circuits, as shown
- In this simple version, the output “goes to the rails”, meaning that the output is +-Vcc
- For use in digital circuits, outputs should be clamped to 0 and 5 volts



Voltage Dividers and Comparators in a Flash ADC

- ADC (analog to digital converter) takes an analog voltage and converts it to a binary signal
- In a flash ADC, a voltage divider feeds into
- *iCircuit Demo*



Reading / Videos

- Review the following sections on TutorialsPoint basic electronics section:
  - Resistors
  - Capacitors
  - Diodes