MODULE 3: Basic Circuits

BU SUMMER CHALLENGE

Electrical Engineering: Smart Lighting Project

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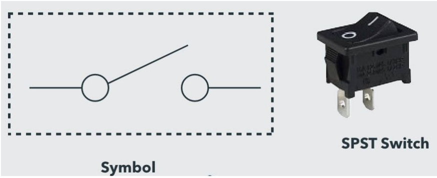
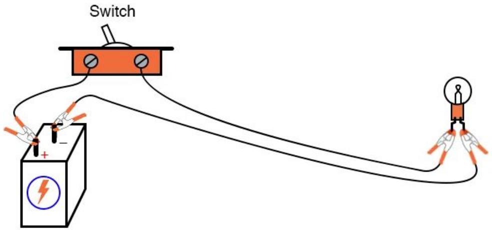
Overview

- Circuits Review
- Resistance and Resistors
- Ohm's Law
- Breadboards
- Capacitance
- Experiments
    - Resistive Circuit
    - Voltage Divider
    - RC Circuit

Recap - What is a Circuit?

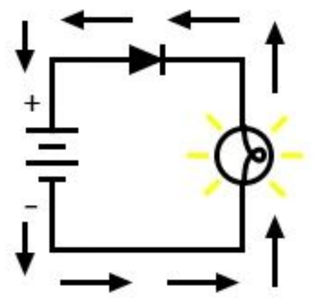
- In a circuit, how are the start and end related?
  - They're the same!
- What happens if there isn't a continuous path?
  - Open Circuit – No flow of charge (or electrons)
- What happens when a conduit connects two points?
  - Charge (and electrons) can flow between the points
  - Short Circuit – Directly connecting two points of different voltage
- Switch
  - Device that can open or close a circuit





Resistance

- As charge flows from high to low V, energy is released
  - Where does it go??
- As electrons flow, they encounter resistance
  - Generate heat as a result of this opposition
  - Resistance is a function of material, length, and cross-sectional area
  - Resistance is measured in Ohms [Ω]
- Wires have resistance, but it is minimal and a direct connection between different voltage levels is a short
  - The filament in an incandescent light introduces resistance
    - The heat energy causes the filament to “glow” white-hot and produce light



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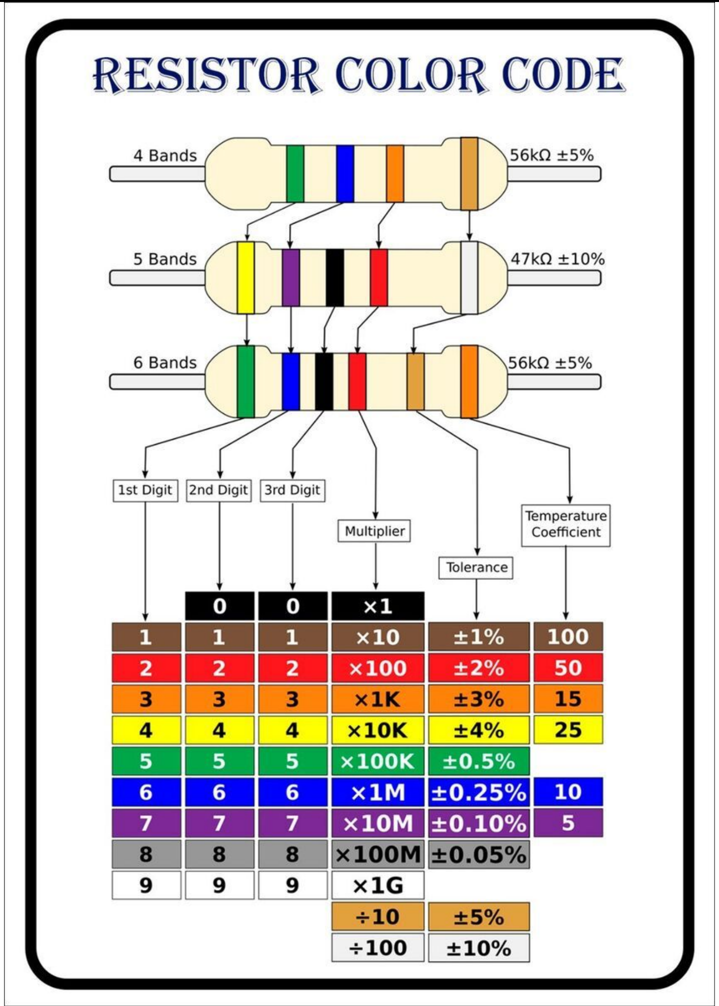
Resistors


RESISTOR COLOR CODE
4 Bands
56kΩ ±5%
5 Bands
47kΩ ±10%
6 Bands
56kΩ ±5%
1st Digit
2nd Digit
3rd Digit
Multiplier
Tolerance
Temperature Coefficient
0 0 ×1
1 1 1 ×10 ±1% 100
2 2 2 ×100 ±2% 50
3 3 3 ×1K ±3% 15
4 4 4 ×10K ±4% 25
5 5 5 ×100K ±0.5%
6 6 6 ×1M ±0.25% 10
7 7 7 ×10M ±0.10% 5
8 8 8 ×100M ±0.05%
9 9 9 ×1G
÷10 ±5%
÷100 ±10%

Ohm's Law

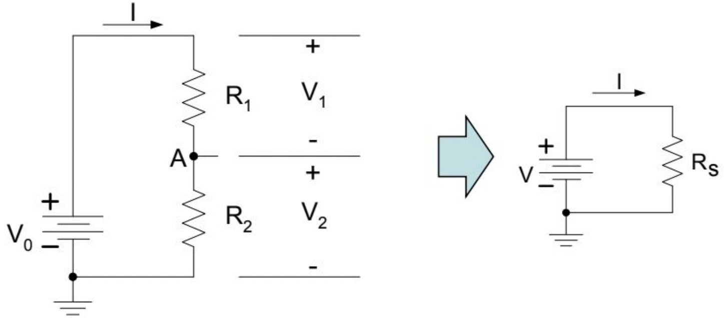
$$V = IR$$

What happens in the case of an open circuit (i.e., $R \approx \infty$)?

What happens in the case of a short circuit (i.e., $R \approx 0$)?

Series vs Parallel

- Series Resistance

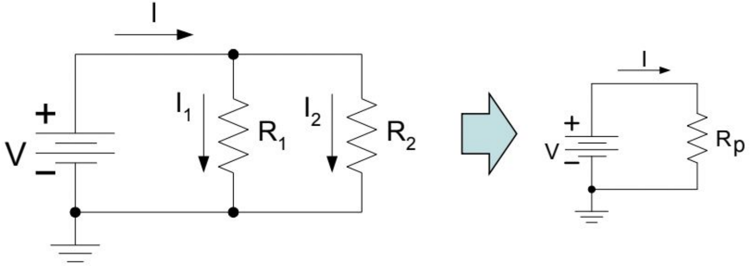


$$V_0 = V_1 + V_2 = IR_1 + IR_2$$
$$= I\left(R_1 + R_2\right)$$
$$= IR_s$$

$$\boxed{R_s = R_1 + R_2}$$

- Parallel Resistance

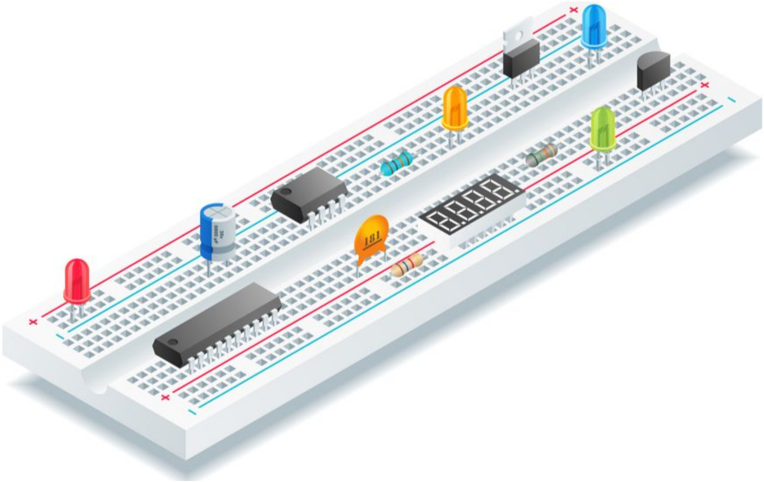
$$I = I_1 + I_2 = \frac{V}{R_1} + \frac{V}{R_2} = V\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{V}{R_p}$$

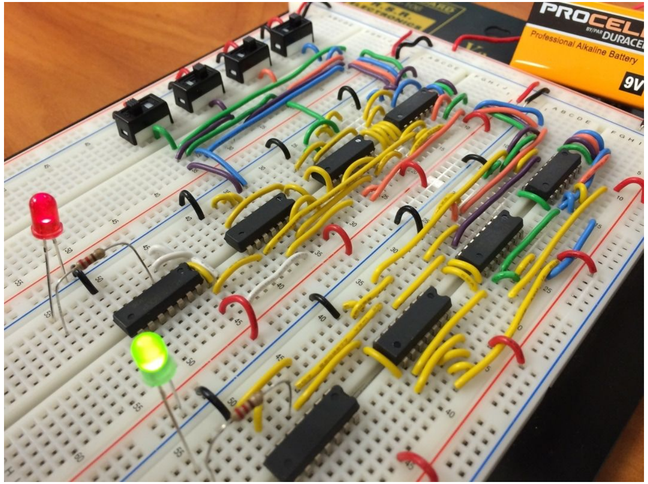


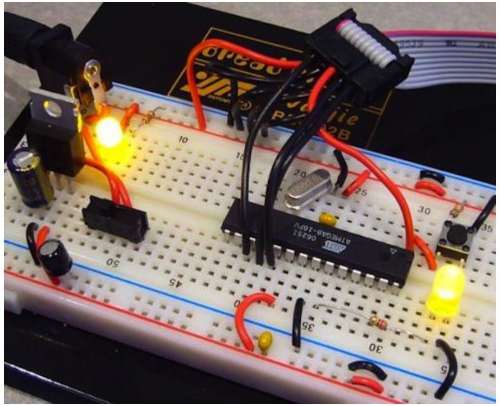
$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow \boxed{R_p = \frac{R_1 R_2}{R_1 + R_2}}$$

Breadboards

- Why do we use breadboards?
  - Temporary Circuits
  - Prototyping
  - No Soldering







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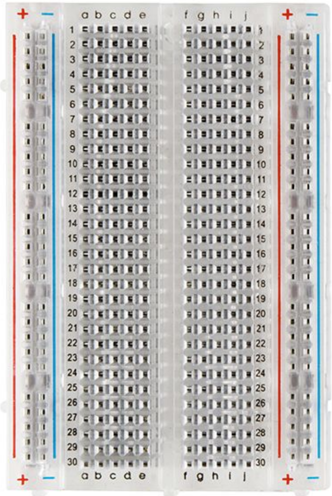
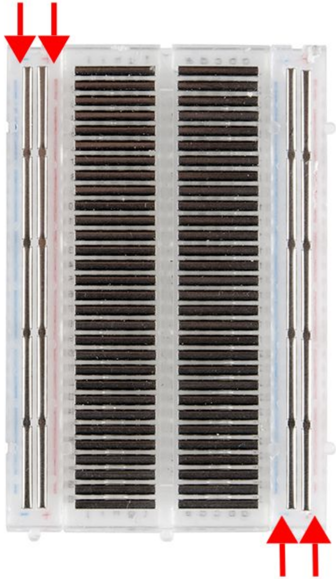
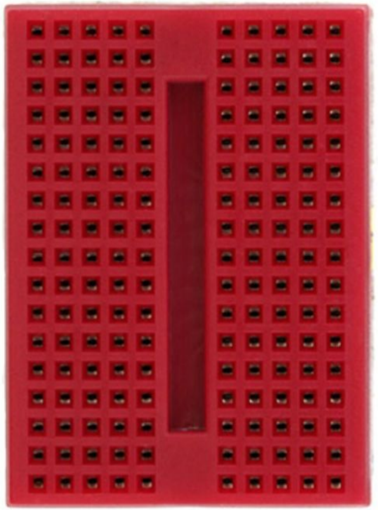
Anatomy of a Breadboard

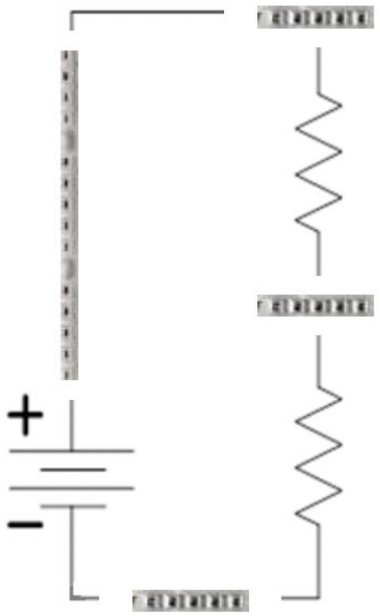


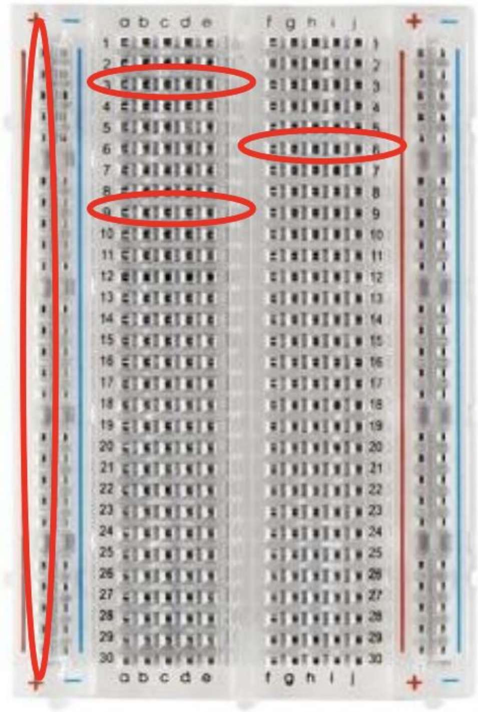




Schematics and Breadboards

Connect nodes of a schematic to a connected row of the breadboard





Schematics and Breadboards

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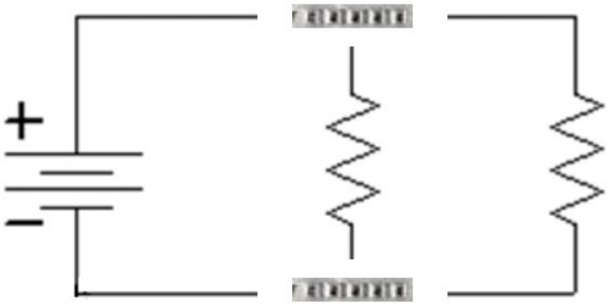
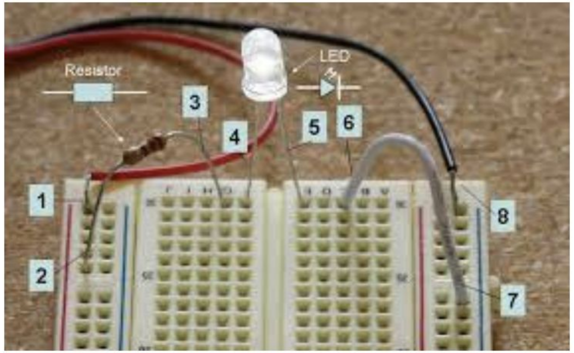
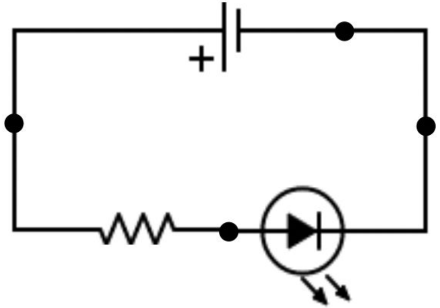
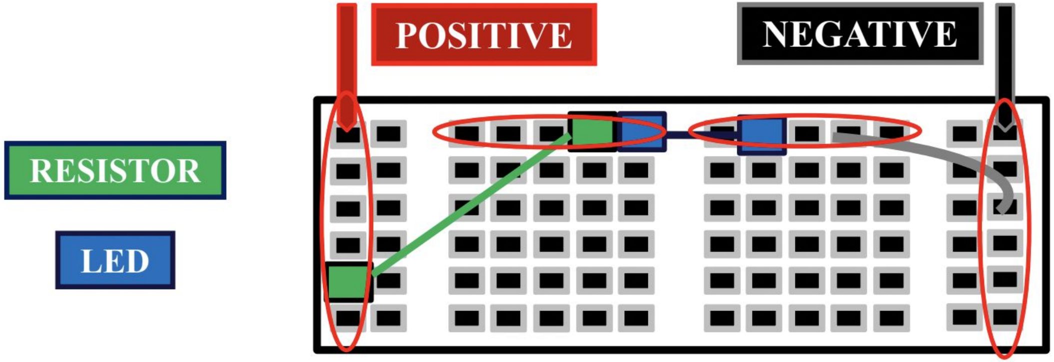
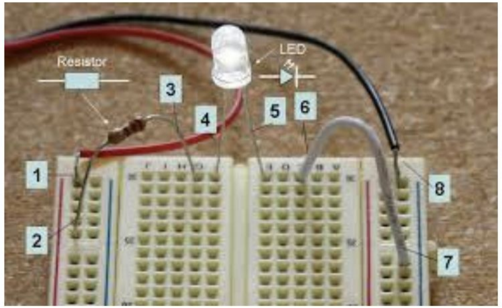



Resistor
LED
1
2
3
4
5
6
7
8

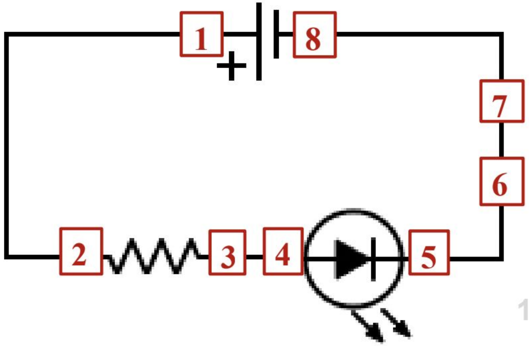

+


RESISTOR
LED
POSITIVE
NEGATIVE



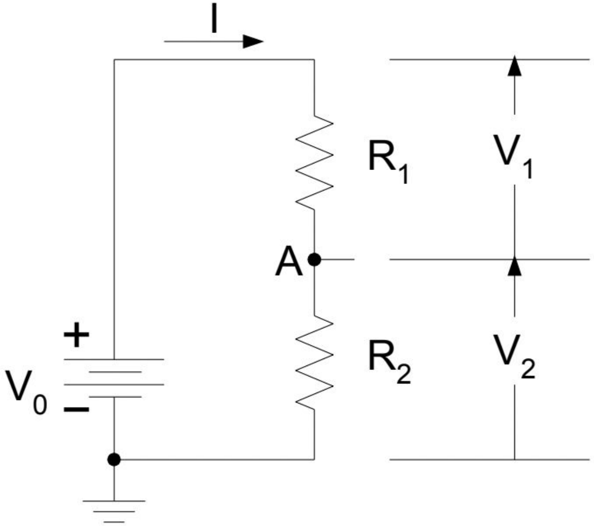
SHORT EXERCISE

1. Copy the schematic.
2. Label where each of the numbers are.



13

Voltage Divider Circuit



$$I = \frac{V_0}{R_s} = \frac{V_0}{R_1 + R_2}$$

$$V_2 = IR_2 = \frac{V_0}{(R_1 + R_2)} R_2$$

$$\text{Also } V_1 = \frac{R_1}{(R_1 + R_2)} V_0$$

$$V_2 = \frac{R_2}{(R_1 + R_2)} V_0$$

Experiment I

- Go to **“Lab Module 3: Basic Circuits”** in your experiment manual
- Voltage Divider
- Resistive Circuits

★ Reflect on what you learned so far!

- References:
  - http://www.physicsclassroom.com/
  - http://www.allaboutcircuits.com/

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  - Breadboards
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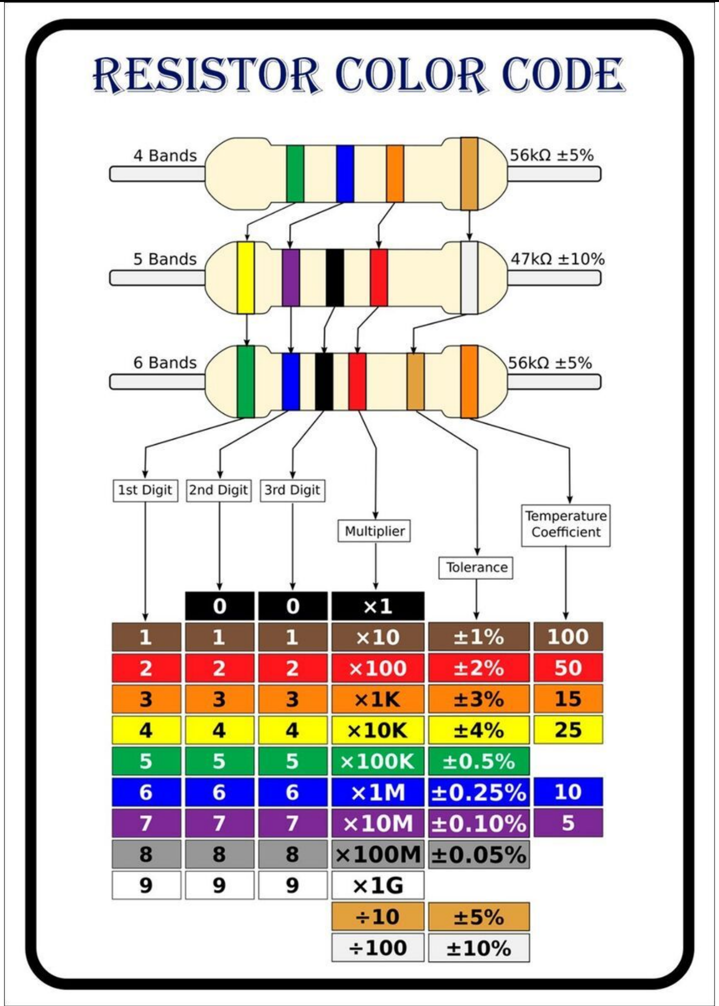
  - RC Circuit

Resistors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×1
1
1
1
×10
±1%
100
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2
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×100
±2%
50
3
3
3
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±3%
15
4
4
4
×10K
±4%
25
5
5
5
×100K
±0.5%
6
6
6
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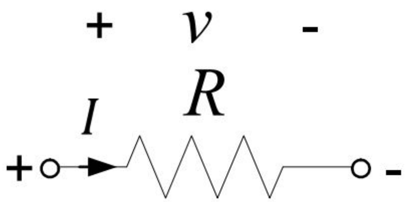
±0.25%
10
7
7
7
×10M
±0.10%
5
8
8
8
×100M
±0.05%
9
9
9
×1G
÷10
±5%
÷100
±10%

Ohm’s Law

- Ohm's Law: Voltage across a resistor is directly proportional to the current flowing through it.
- The proportionality constant is the resistance!



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

$$V = IR$$

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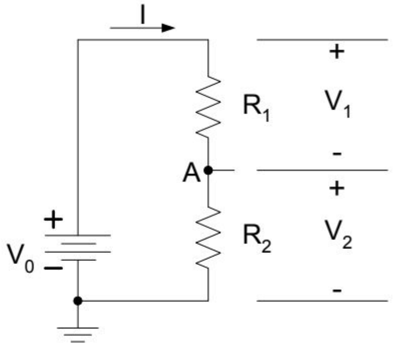
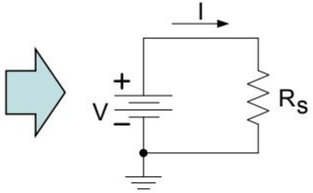
Series vs Parallel

- Series Resistance





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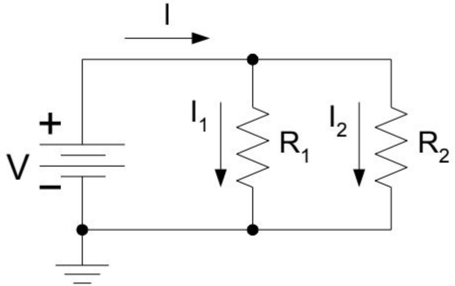

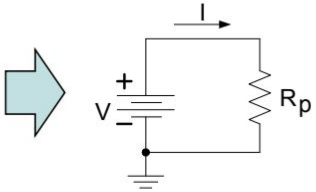

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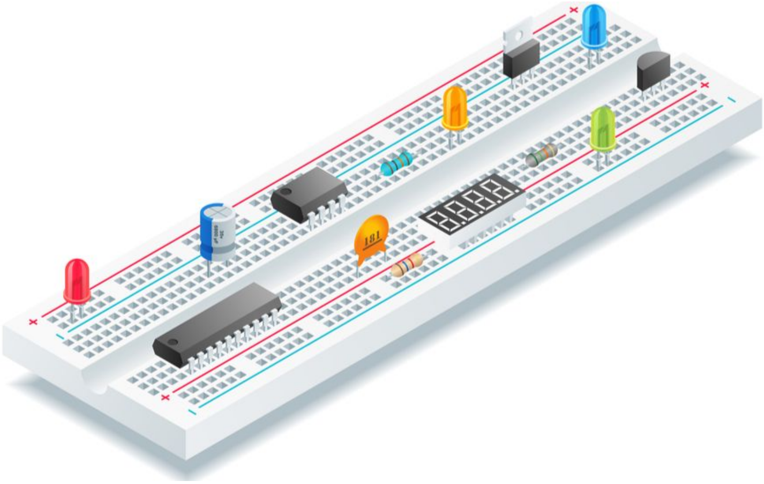

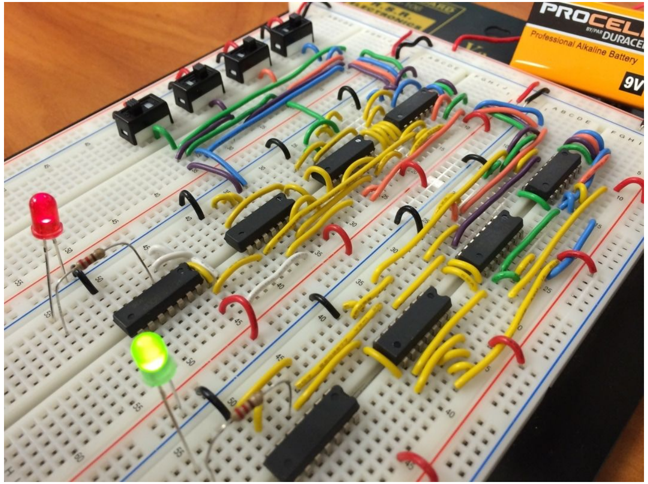

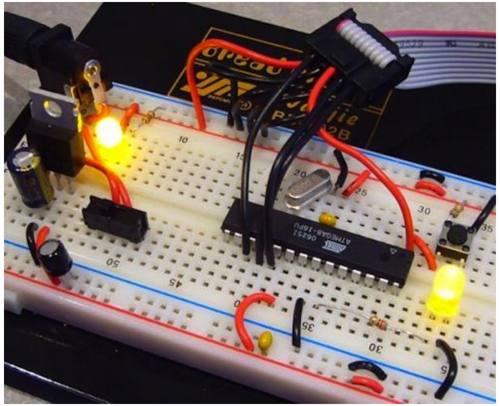

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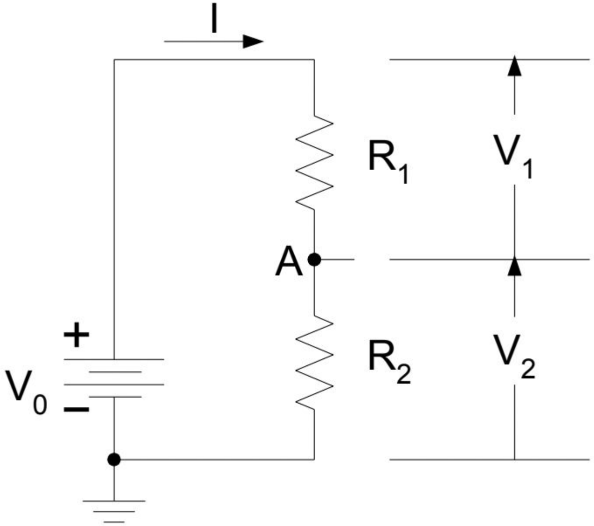
Voltage Divider Circuit



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Also $V_1 = \frac{R_1}{(R_1 + R_2)} V_0$

$$V_2 = \frac{R_2}{(R_1 + R_2)} V_0$$

Capacitors

- A capacitor has capacity to store energy in the form of electrical charge producing a voltage across plates
- Storage of energy is time dependent
  - This was NOT the case in purely resistive circuits.
- Capacitance is measured in Farads [F]

$$i = C\frac{\mathrm{d}V}{\mathrm{d}t}$$

i = Instantaneous Current

$\frac{\mathrm{d}V}{\mathrm{d}t}$ = Instantaneous rate of voltage change

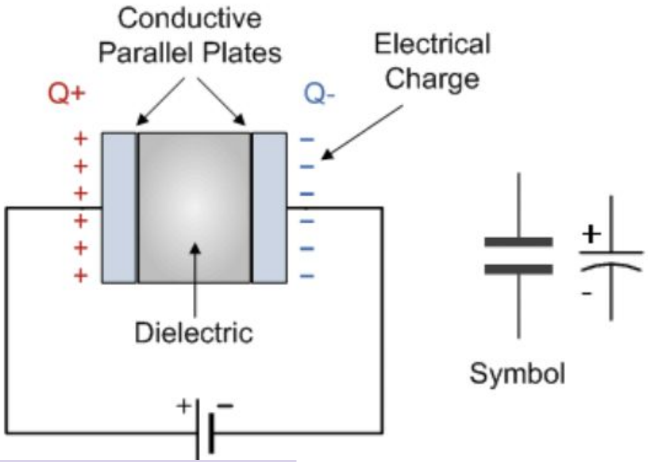
$$C = \frac{\varepsilon A}{d}$$

ε = dielectic constant

A = Area of plate overlap

d = distance between plates

Capacitors are sometimes polarized.



NOTE: Directly connecting a capacitor to a voltage supply is not practical.

Capacitors

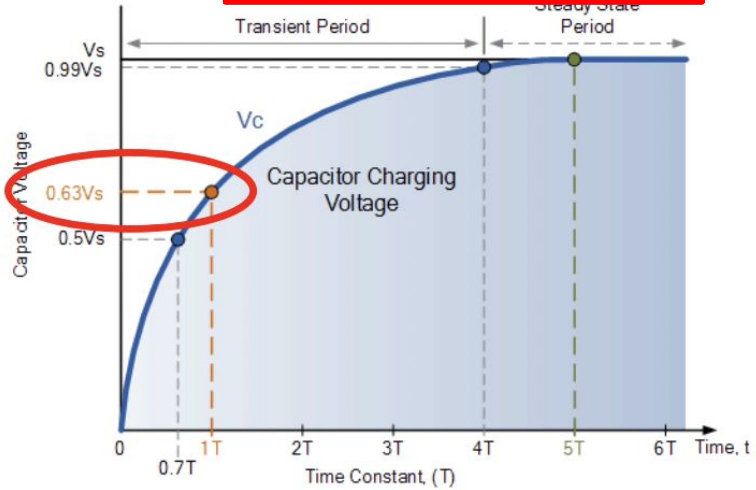
- The charge on a capacitor cannot change instantaneously
- The charge on the plates of the capacitor is given as $Q = CV$
- The current flowing into a capacitor after a long time interval (i.e., steady-state) is zero
  - Charge contained in the capacitor instead of flowing through the circuit

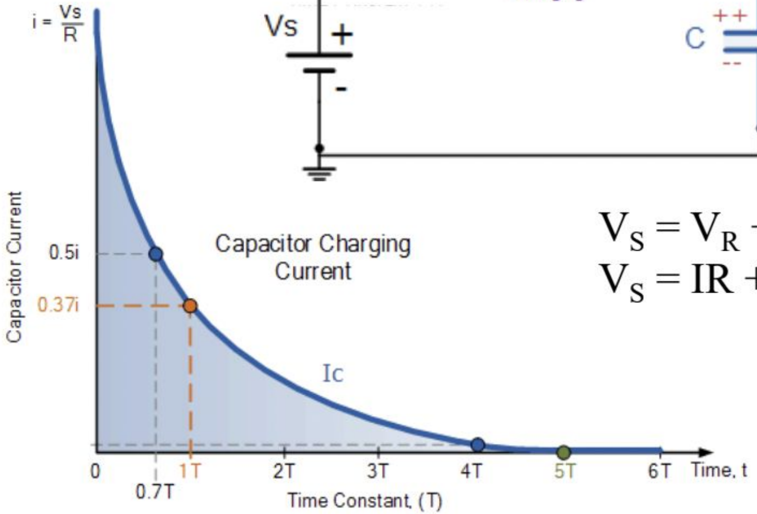
RC Circuits

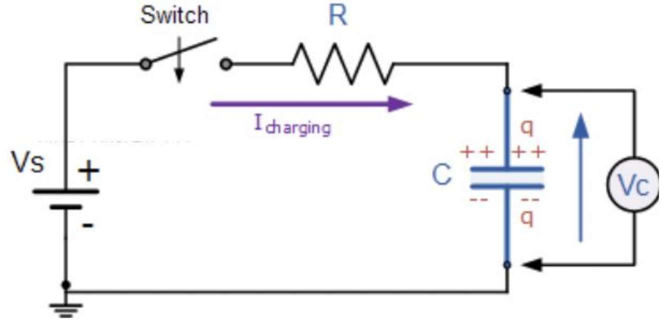
- RC circuits consist of a resistor and capacitor in series
- A capacitor stores energy and a resistor placed in series with it controls the rate at which it charges or discharges.

$$\tau \equiv RC$$

$$V_c = V_s\left(1 - e^{-t/\tau}\right)$$





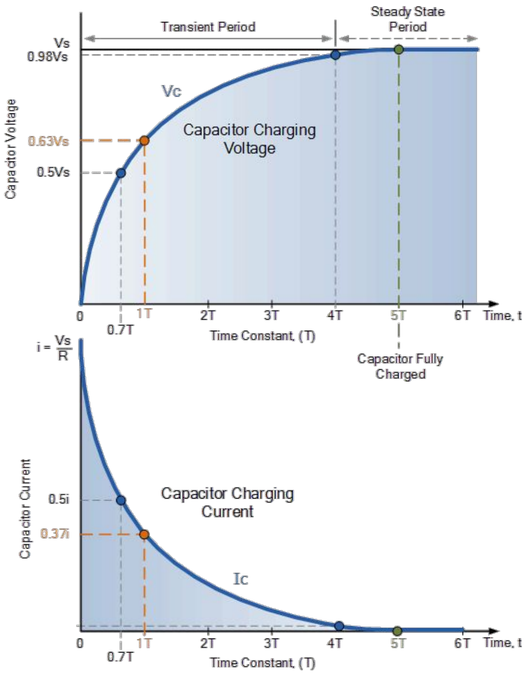


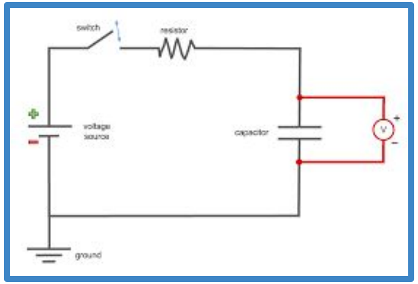
$$V_S = V_R + V_C$$

$$V_S = IR + Q/C$$

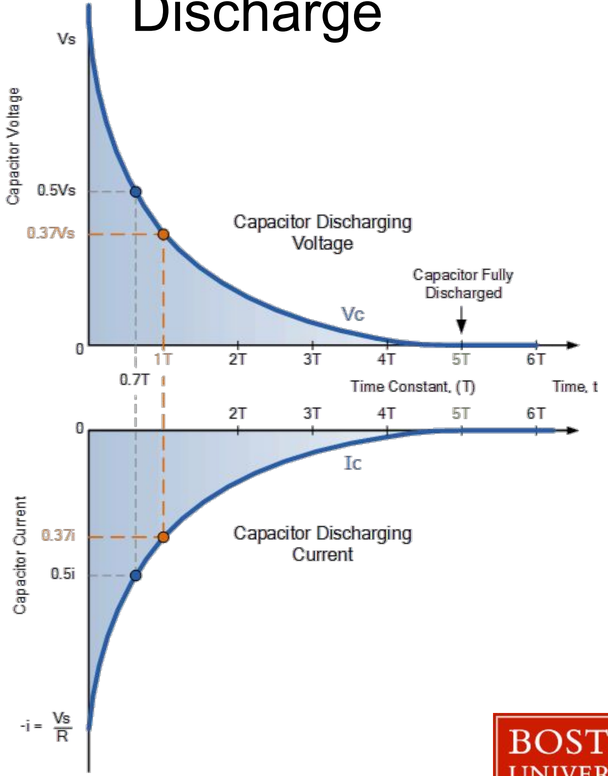
RC Circuits

Charge





Discharge



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Experiment II

Resistor – Capacitor (RC) Circuits

Think – Pair – Share