MODULE 3: Basic Circuits – Resistance and Capacitance

SUMMER CHALLENGE

Electrical Engineering: Smart Lighting

Prachi Shukla

PhD Candidate

Boston University

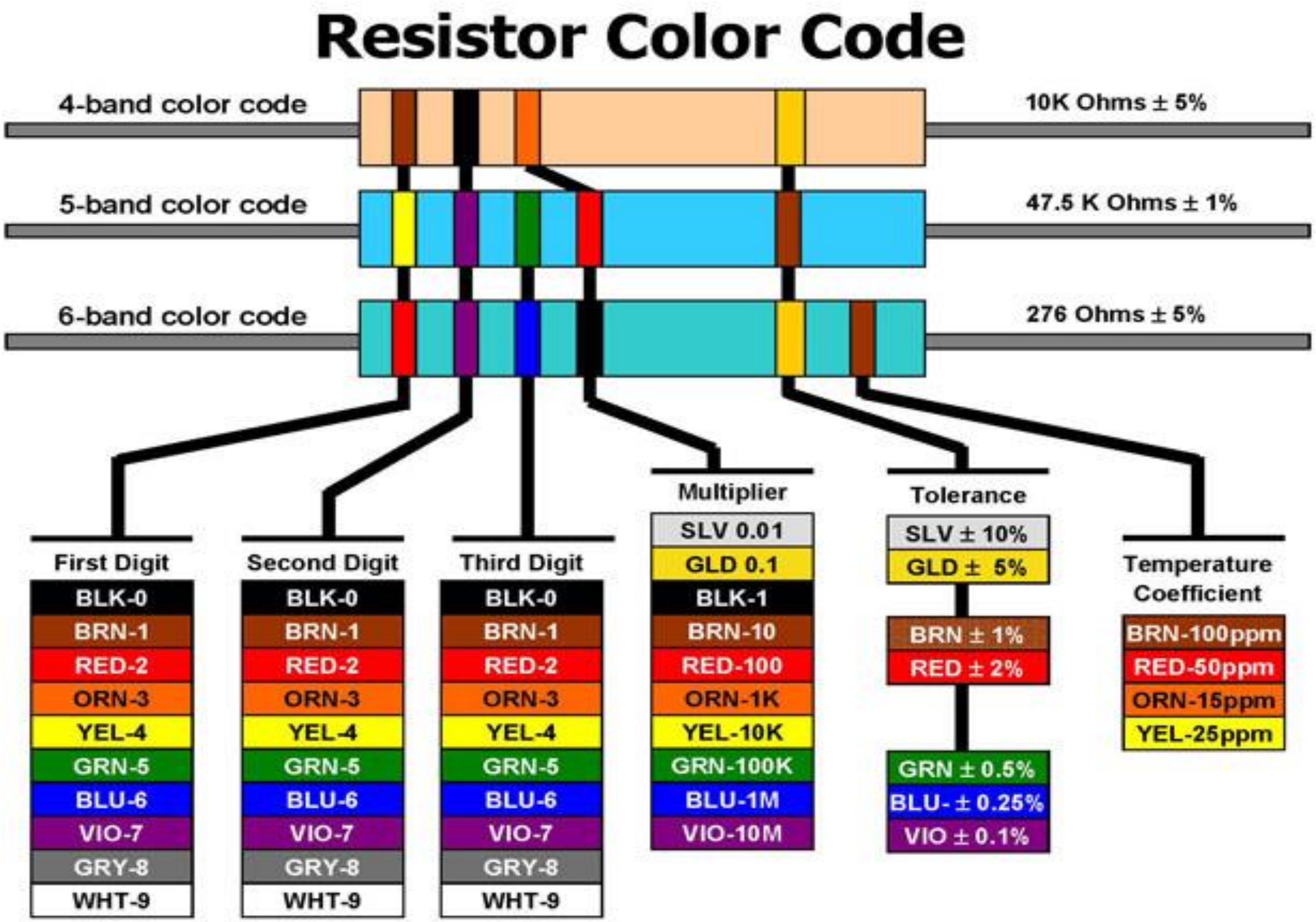
prachis@bu.edu

BOSTON UNIVERSITY

Overview

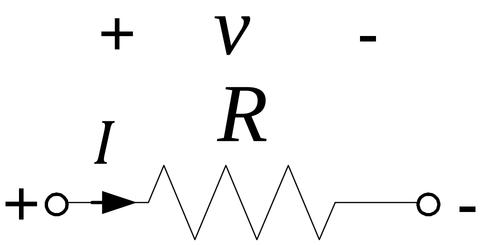
- Recap
  - Resistance and Resistors
  - Ohms Law
  - Breadboards
- Capacitance
- Experiments
  - Resistive Circuit
  - Voltage Divider
  - RC Circuit

Resistors


Resistor Color Code
4-band color code
10K Ohms ± 5%
5-band color code
47.5 K Ohms ± 1%
6-band color code
276 Ohms ± 5%
First Digit
BLK-0
BRN-1
RED-2
ORN-3
YEL-4
GRN-5
BLU-6
VIO-7
GRY-8
WHT-9
Second Digit
BLK-0
BRN-1
RED-2
ORN-3
YEL-4
GRN-5
BLU-6
VIO-7
GRY-8
WHT-9
Third Digit
BLK-0
BRN-1
RED-2
ORN-3
YEL-4
GRN-5
BLU-6
VIO-7
GRY-8
WHT-9
Multiplier
SLV 0.01
GLD 0.1
BLK-1
BRN-10
RED-100
ORN-1K
YEL-10K
GRN-100K
BLU-1M
VIO-10M
Tolerance
SLV ± 10%
GLD ± 5%
BRN ± 1%
RED ± 2%
GRN ± 0.5%
BLU- ± 0.25%
VIO ± 0.1%
Temperature Coefficient
BRN-100ppm
RED-50ppm
ORN-15ppm
YEL-25ppm

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!

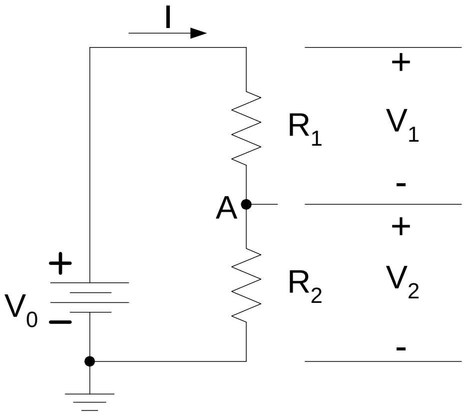


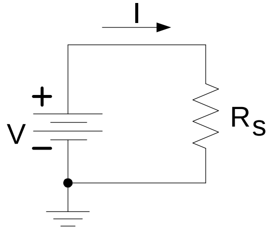
$$V = IR \Rightarrow I = \frac{V}{R} \Rightarrow R = \frac{V}{I}$$

$$V = IR$$

Series vs Parallel

- Series Resistance



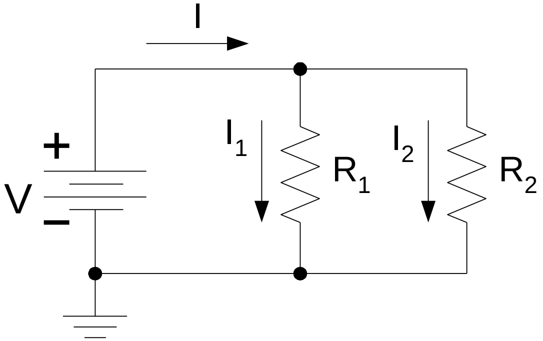


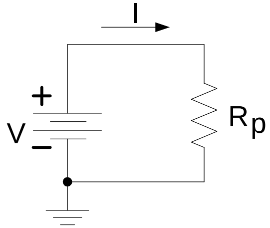
$$V_0 = V_1 + V_2 = IR_1 + IR_2$$
$$= I\left(R_1 + R_2\right)$$
$$= IR_s$$

$$R_s = R_1 + R_2$$

- Parallel Resistance

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





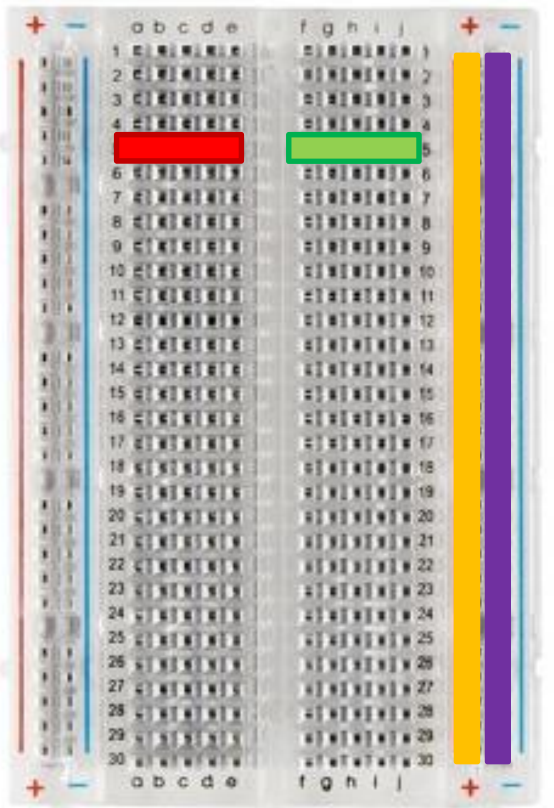
$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

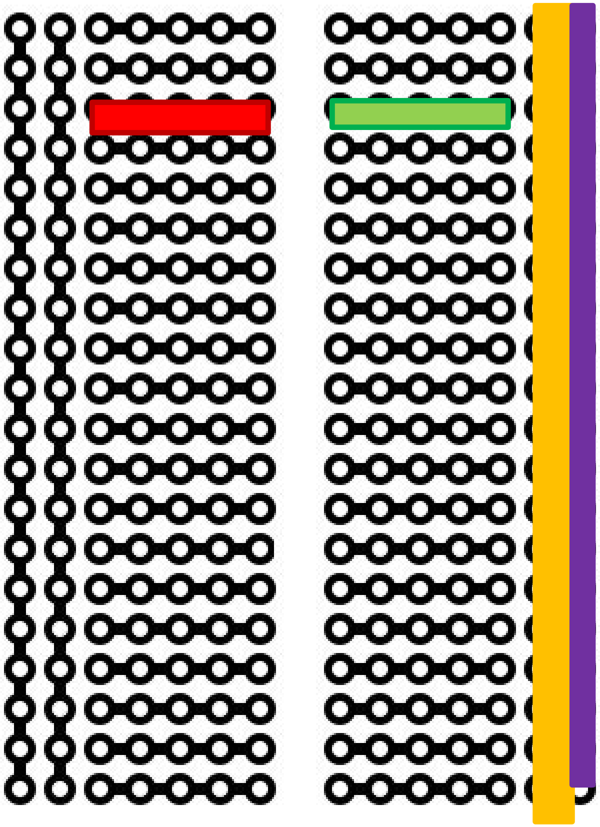
$$R_p = \frac{R_1 R_2}{R_1 + R_2}$$

Breadboard

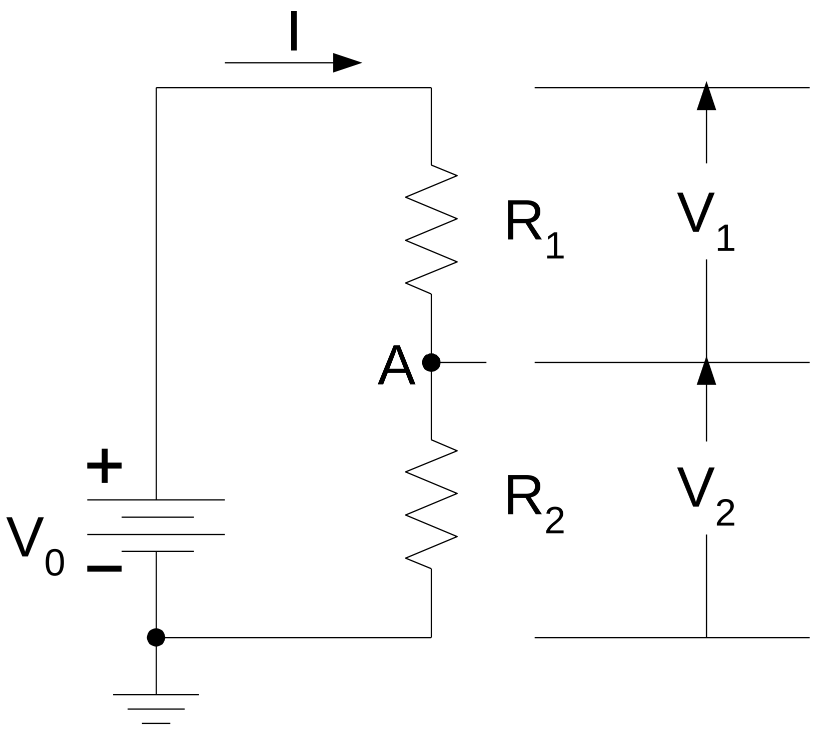
Why do we use breadboards?

Temporary sircuits, prototyping, no soldering





Voltage Divider Circuit



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

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

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

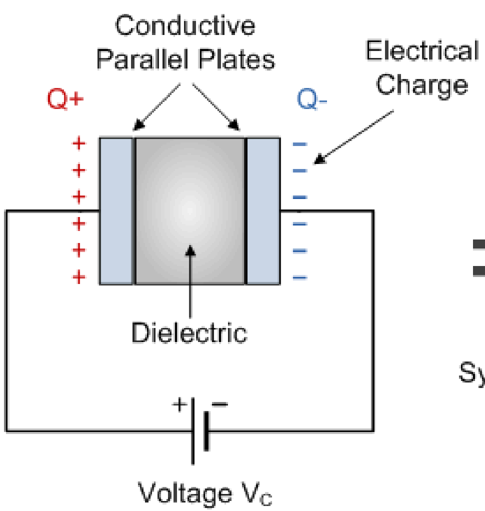
$$V_2 = \frac{R_2}{(R_1 + R_2)} V_0$$

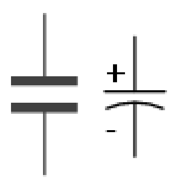
Experiment I

- Voltage Divider
- Resistive Circuits

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 $[F]$





Symbol

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

i = Instantaneous Current

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

Capacitors are *sometimes* polarized

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

ε = dielectic constant

A = Area of plate overlap

d = distance between plates

NOTE: Directly connecting a capacitor to a voltage supply isn't practical

Capacitors

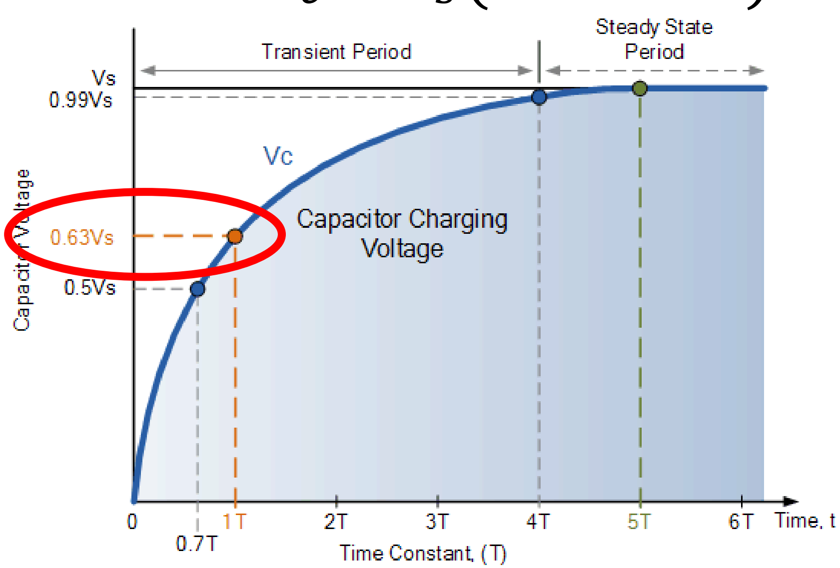
- The charge on a capacitor cannot change instantaneously
- The charge on the plates of the capacitor is given as Q = C*V
- The current flowing into a capacitor after a long time interval (i.e., steady-state) is zero
  - Charge contained in the capacitor instead of flowing through the circuit

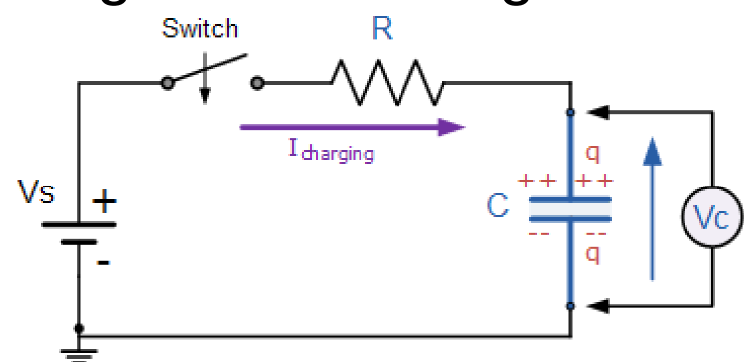
RC Circuits

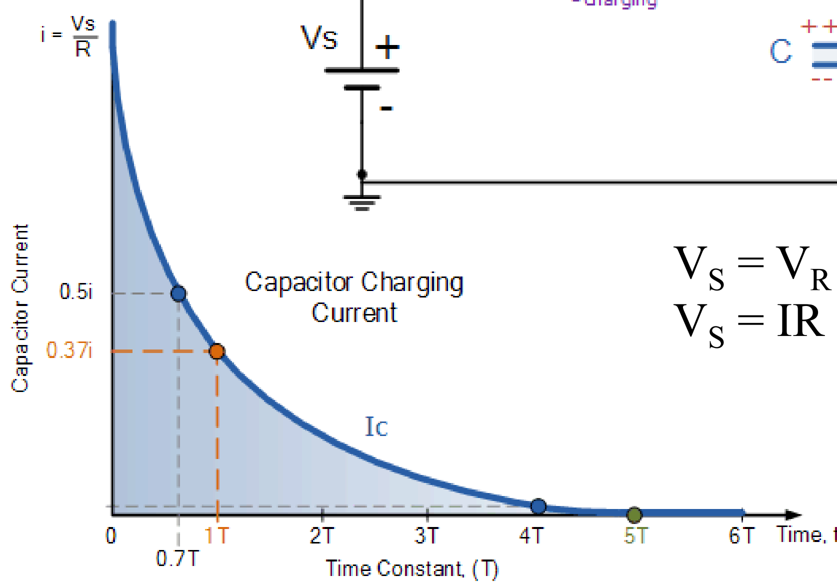
- RC circuits consist of a resistor and capacitor in series
- A capacitor stores energy and a resistor placed in series with it control the rate at which it charges or discharges.

$$\tau \equiv RC$$

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





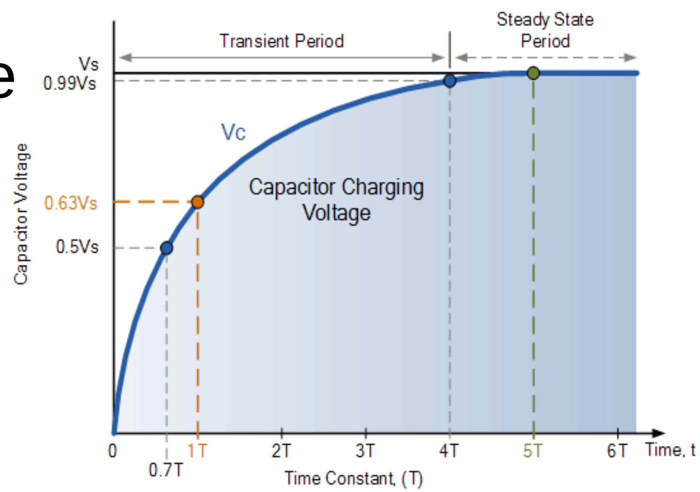


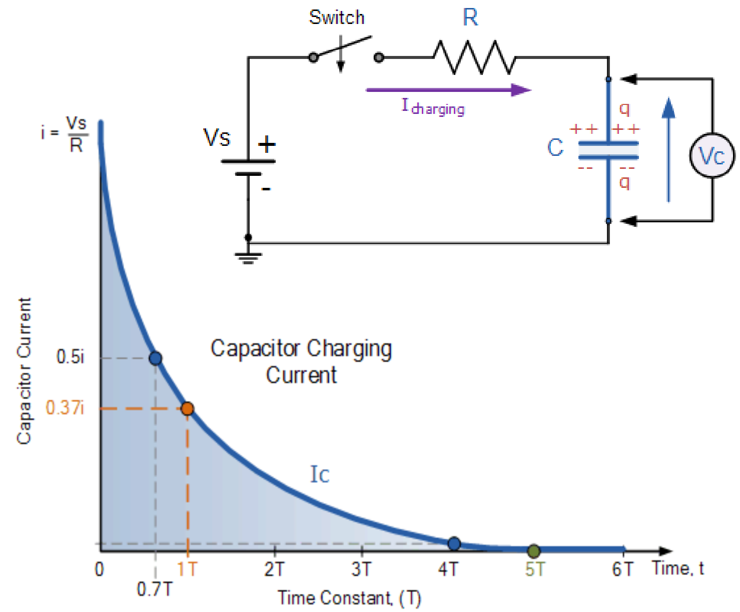
$$V_S = V_R + V_C$$

$$V_S = IR + Q/C$$

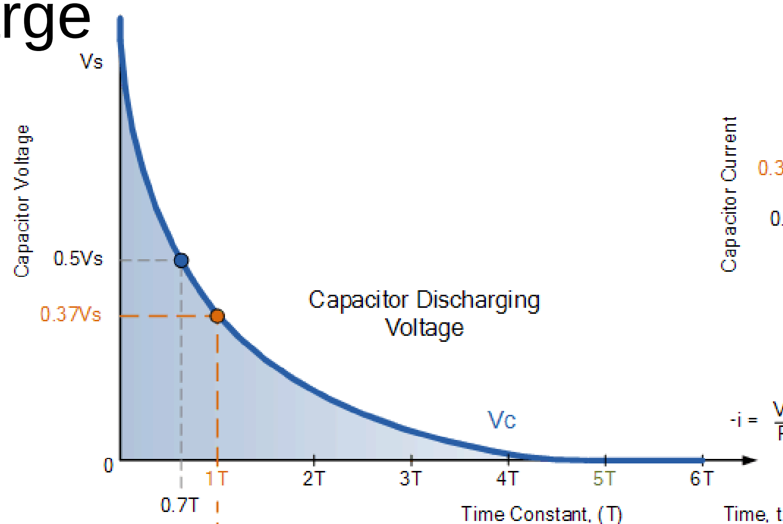
RC Circuits

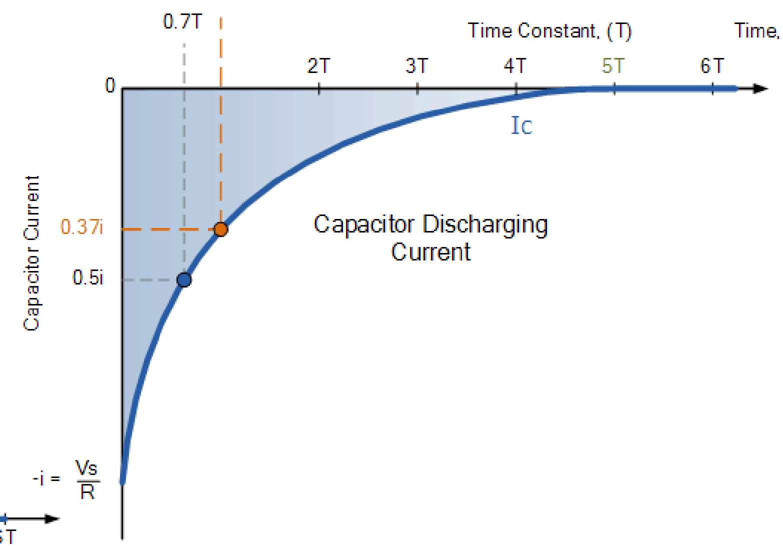
- Charge





- Discharge





Experiment II

- Resistor – Capacitor (RC) Circuits

Recap

- What did you 

today?