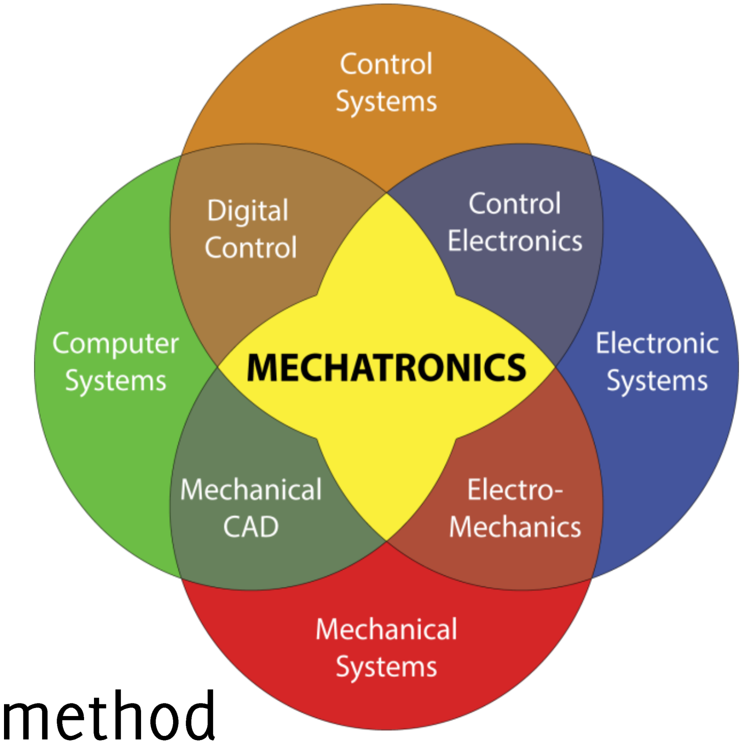
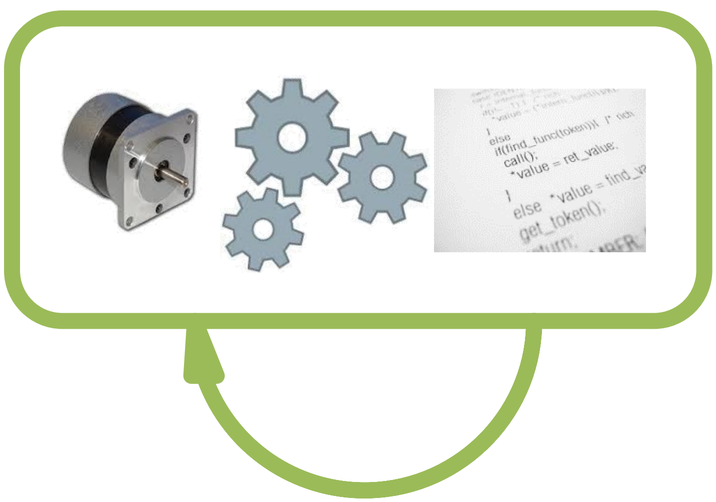
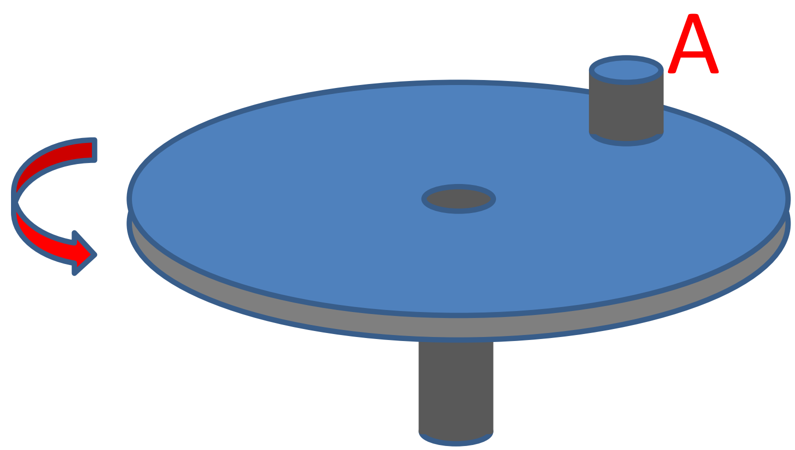
UNIT 1:
FROM LAST TIME…



Mechatronic Design

- What is Mechatronics?
- Shelton's Design Rules
- Traditional vs. Integrated design method
- Design trade-offs





UNIT 2:
ELECTRONIC SYSTEMS

AT THE END OF THIS SECTION, STUDENTS SHOULD BE ABLE TO:

- Explain the importance of electronic systems in mechatronics
- Identify basic electronic components
- Analyze simple electronic circuits
- Incorporate basic electronic systems into a mechatronic device

WHY DO ELECTRONIC SYSTEMS MATTER?

- Electrons are very fast!
  - Signals travel through twisted-pair copper wires at 0.4 to 0.7 times the speed of light
- Filter, amplify and switch signals quickly and efficiently
- Interface sensors and actuators with microcontrollers
- Accommodate high-speed signal processing
- Reasonably-priced tools are widely available

TOPICS

- Part A: Passive Electronics
- Part B: Active Electronics (Diodes)
- Part C: Active Electronics (Transistors)
- Part D: Analog Interfacing

UNIT 2:
ELECTRONIC SYSTEMS

PART A:
PASSIVE ELECTRONICS

ELECTRONIC COMPONENTS CLASSIFIED AS EITHER "PASSIVE" OR "ACTIVE"

- Passive
  - Does not require an external energy source
  - Stores or dissipates energy
  - Fundamental properties not altered by input
  - Resistors, capacitors, inductors, etc.
- Active
  - Requires an external energy source
  - Fundamental properties vary with input
  - Usually fabricated from semi-conductor materials
  - Diodes, transistors, integrated circuits, etc.

- Others define "active" and "passive" differently…

RESISTORS

Image: http://store.curiousinventor.com/guides/Surface_Mount_Soldering/Resistor/

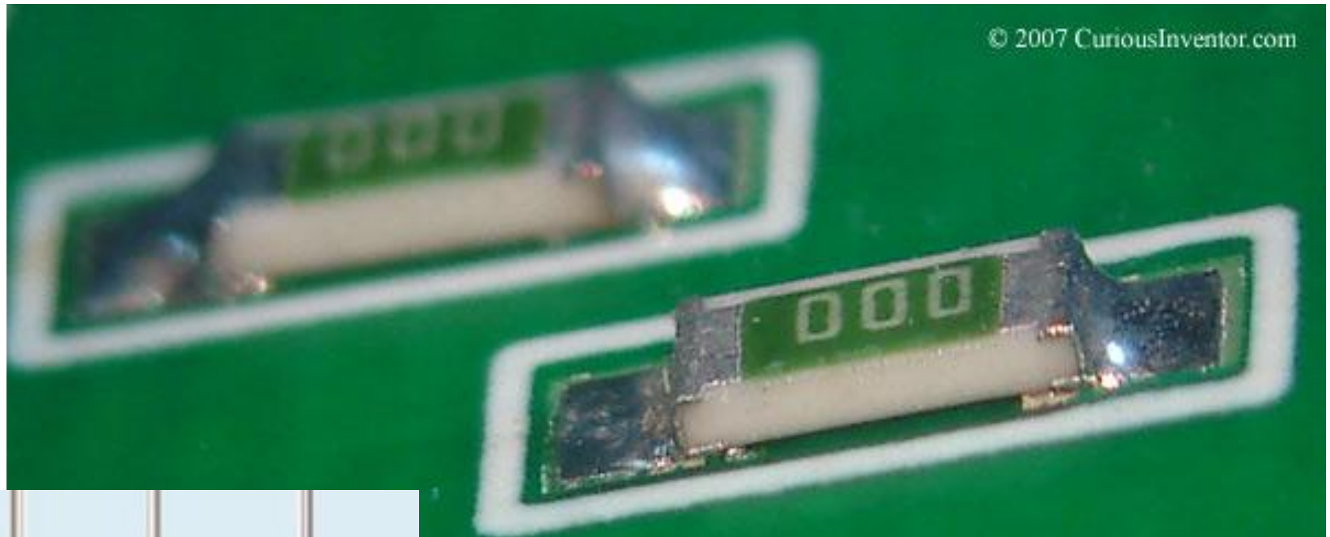


Image: http://www.circuitstoday.com/working-of-resistors

RESISTORS DISSIPATE ENERGY AS HEAT

Standard power ratings for carbon composition resistors:

- **1/8 W** (~3.0 mm long x 1.8 mm dia.)
- **1/4 W** (~6.3 mm long x 2.2 mm dia.)
- **1/2 W** (~9.2 mm long x 3.2 mm dia.)
- **1 W** (~11 mm long x 5 mm dia.)
- **2 W** (~14 mm long x 6 mm dia.)

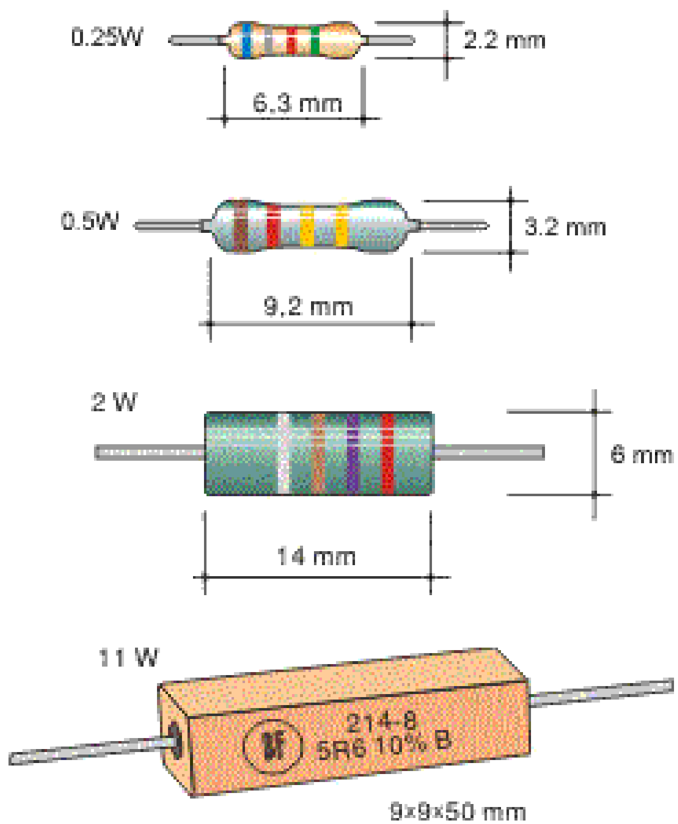
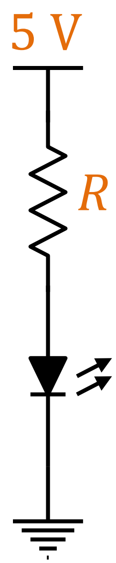
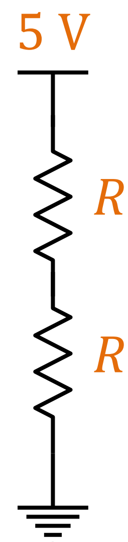


Image: http://www.mikroe.com/old/books/keu/01.htm

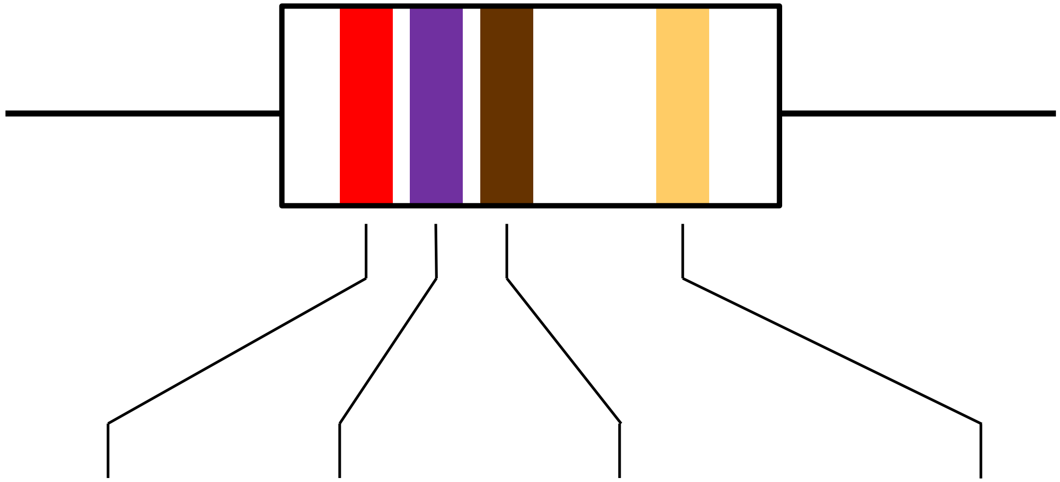
WHY DO WE NEED RESISTORS?





1. Limit current flow (mostly)
2. Divide voltages (sometimes)

RESISTOR VALUES ARE NORMALLY INDICATED BY COLOR BANDS



1st Digit	2nd Digit	Multiplier	Tolerance	
0	0	1	± 10%	Silver
1	1	10	± 5%	Gold
2	2	100	± 2%	
3	3	1K	± 1%	
4	4	10K	± 0.5%	
5	5	100K	± 0.1%	
6	6	1M	± 0.25%	
7	7	10M		
8	8			
9	9			

CAPACITORS STORE ENERGY AS AN ELECTRIC FIELD

Image: http://green.autoblog.com/2007/07/04/new-capacitor-research-could-increase-capacities-by-seven-times/

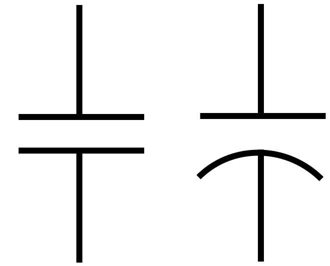
Capacitance normally given in μF or pF

A FARAD IS A LARGE UNIT OF CAPACITANCE!

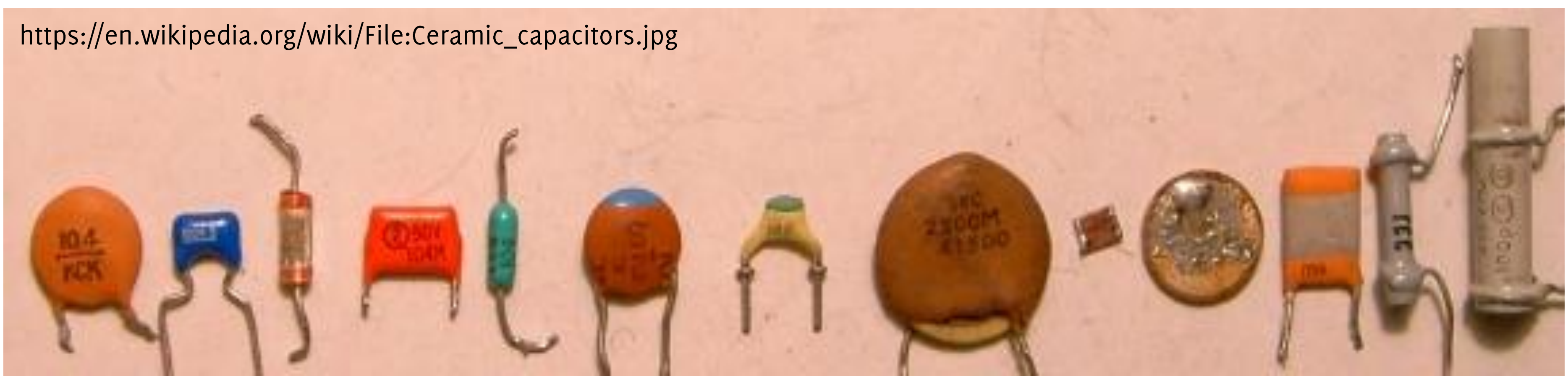
Which is why component capacitance is normally given in μF or pF:

$$
\begin{aligned}
1\ \text{F} &= 10^{3}\ \text{mF} \\
&= 10^{6}\ \mu\text{F} \\
&= 10^{9}\ \text{nF} \\
&= 10^{12}\ \text{pF}
\end{aligned}
$$

NON-POLARIZED CAPACITORS

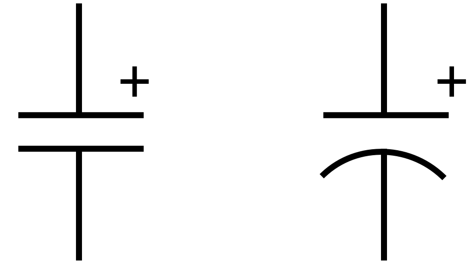


- Ceramic (1 pF – 10 μF) and Film (10 pF – 100 μF)
- Low leakage current; long life
- Can be temperature sensitive
- Useful at high frequencies



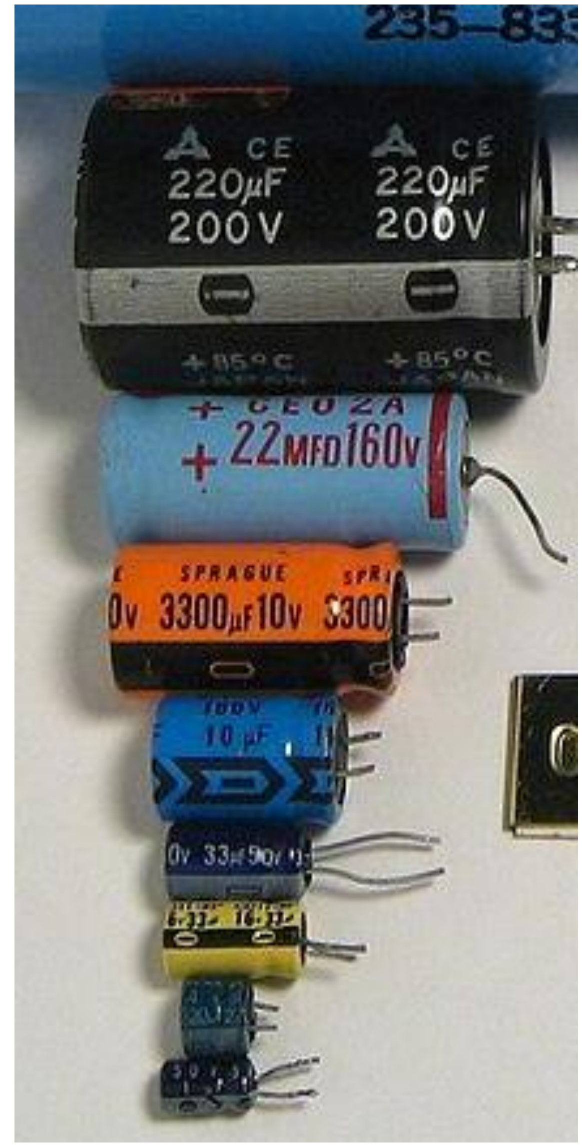
https://en.wikipedia.org/wiki/File:Ceramic_capacitors.jpg

POLARIZED CAPACITORS



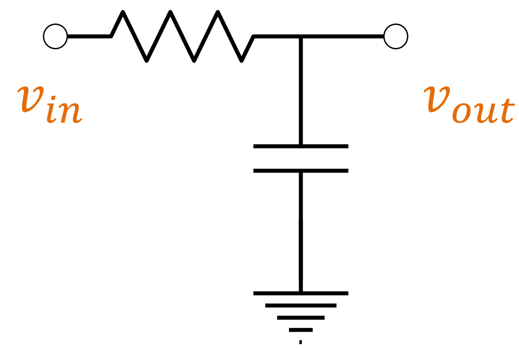
- Aluminum and Tantalum Electrolytic
- Typically 1 μF – 0.1 F
- No AC without DC bias (may burst)!
- High leakage current; short life

Large capacitors can hold a significant charge for a long time. Treat them with respect!

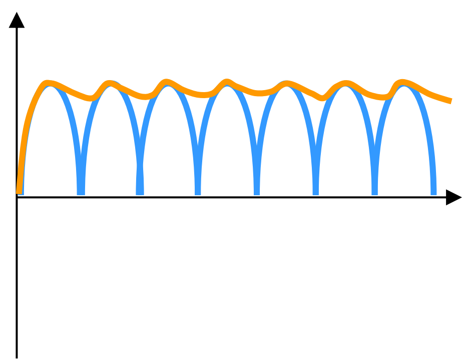


https://en.wikipedia.org/wiki/File:Electrolytic_capacitors.jpg

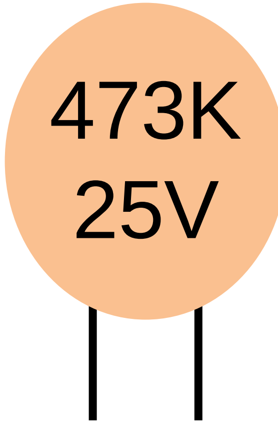
WHY DO WE NEED CAPACITORS?



1. Energy storage
2. Signal coupling/decoupling
3. Noise filters
4. Tuned circuits
5. Power conditioning



CAPACITORS



Letter Code	Tolerance
F	1%
G	2%
H	3%
J	5%
K	10%
M	20%
Z	+80%, -20%

Capacitance values for smaller capacitors are usually given in picofarads (pF). If there are just two numbers, read that value in pF.

If there are three numbers, use the first two to establish a value in pF, then multiply by 10^X, where X is the third number. However, if the third digit is 8, divide by 100, and if the third digit is 9, divide by 10.

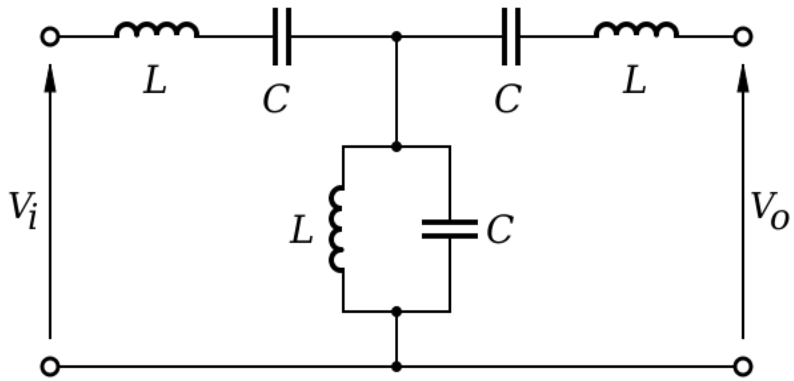
A letter code normally indicates capacitor tolerance, as in the provided table.

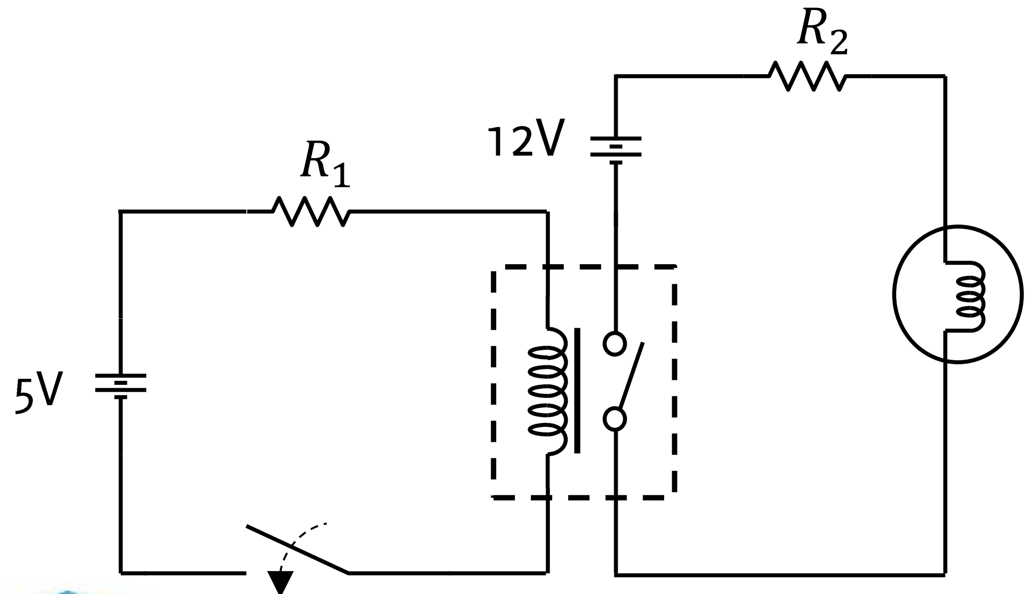
INDUCTORS STORE ENERGY AS A MAGNETIC FIELD

Image: http://www.eeweb.com/blog/andrew_carter/the-basics-of-inductor

Inductance normally given in mH

WHY DO WE NEED INDUCTORS?

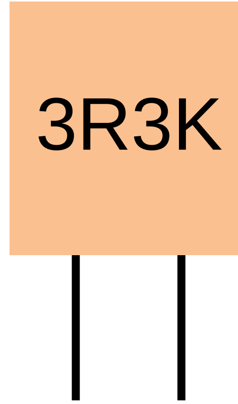




SPST

1. Analog filters
2. Actuators (motors, electromagnets, mechanical switches, etc.)
3. “Choke" off input ripple

INDUCTORS



Letter Code	Tolerance
F	1%
G	2%
H	3%
J	5%
K	10%
M	20%
Z	+80%, -20%

Inductance values for smaller inductors are usually given in microHenries (μH). If there are just two numbers, read that value in μH.

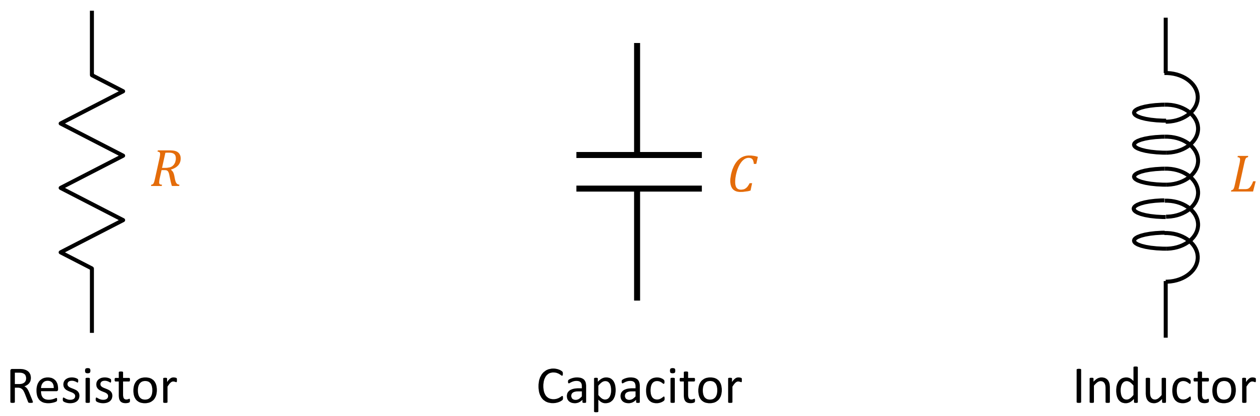
If there are three numbers, use the first two to establish a value in μH, then multiply by 10^X, where X is the third number. However, if the third digit is 8, divide by 100, and if the third digit is 9, divide by 10.

If an "R" appears in the code, it acts as a decimal point, and there is no multiplier.

A letter code normally indicates inductor tolerance, as in the provided table.

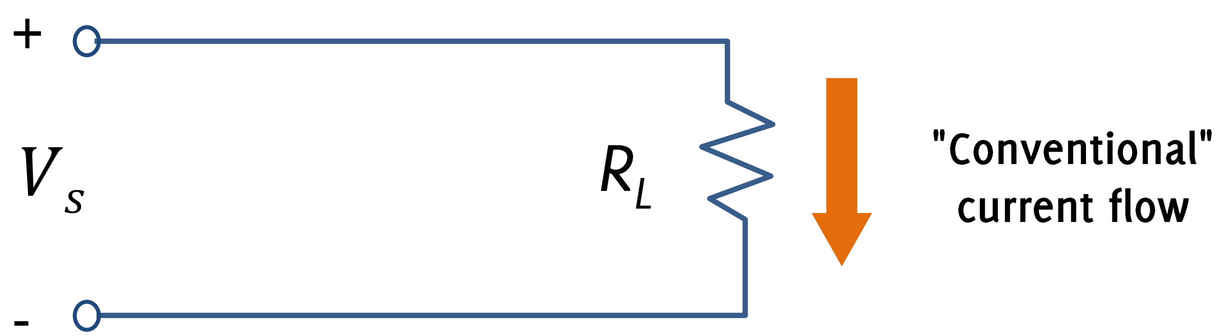
ANALYZING PASSIVE ELECTRONIC CIRCUITS

Simple equations allow us to determine rate at which energy is being stored or dissipated



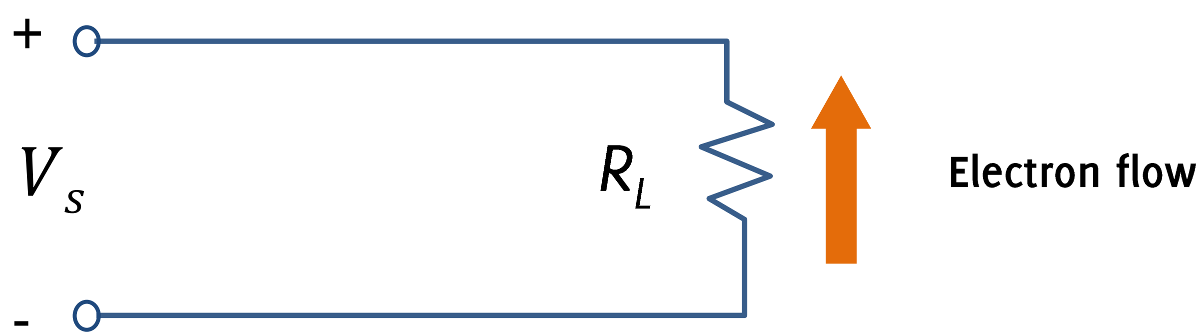
ELECTRON FLOW

Benjamin Franklin (1750) visualized electricity as an invisible fluid that flowed from areas of excess charge (positive) to areas with a deficiency of charge (negative). Thus, a large number of theoretical developments were based on what we now call "conventional" flow.



ELECTRON FLOW

Unfortunately, Franklin guessed incorrectly! Electrons flow from a negative charge to a positive charge. For most circuit analysis, this is immaterial. However, to understand semiconductor theory in later lessons, we need to recognize the true direction of electron flow.



BASIC RULES (REVIEW)

Resistors

- $V = IR$

Capacitors

- $I = C\frac{dV}{dt}$

Inductors

- $V = L\frac{dI}{dt}$

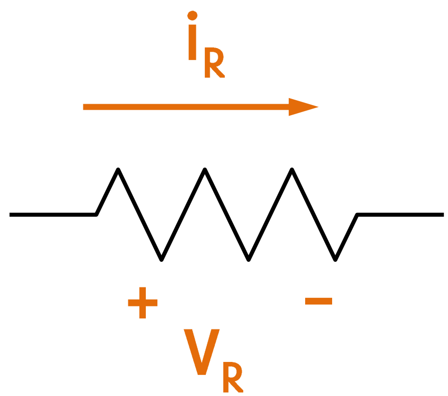
Kirchhoff's Laws

- $\sum_{k=1}^{n} I_k = 0$ at any node
- $\sum_{k=1}^{n} V_k = 0$ around any closed circuit

RESISTORS

Ohm's Law

$$V = IR$$



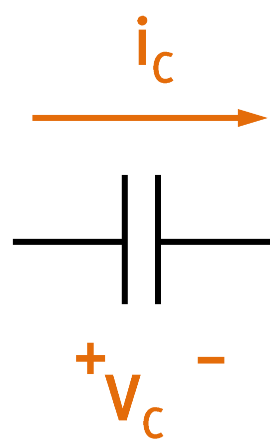
CAPACITORS

Charge–Voltage Relationship:

$$Q = CV$$

Current–Voltage Relationship:

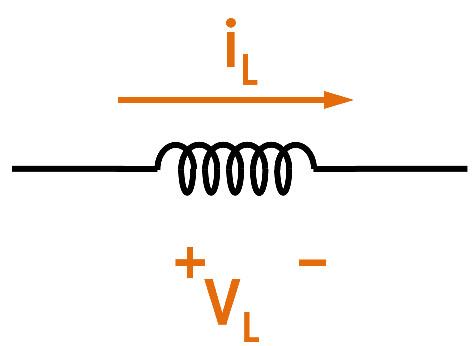
$$I = C\frac{dV}{dt}$$



INDUCTORS

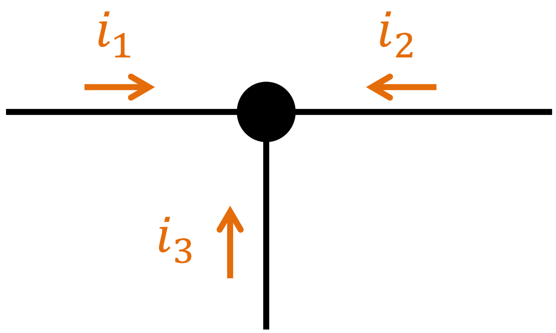
Current–Voltage Relationship:

$$V = L\frac{dI}{dt}$$



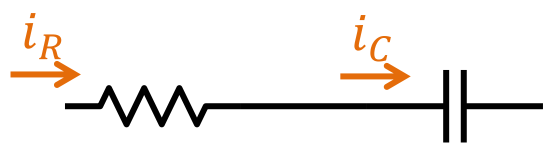
KIRCHHOFF'S CURRENT LAW (KCL)

- $\sum_{k=1}^{n} I_k = 0$ at any node



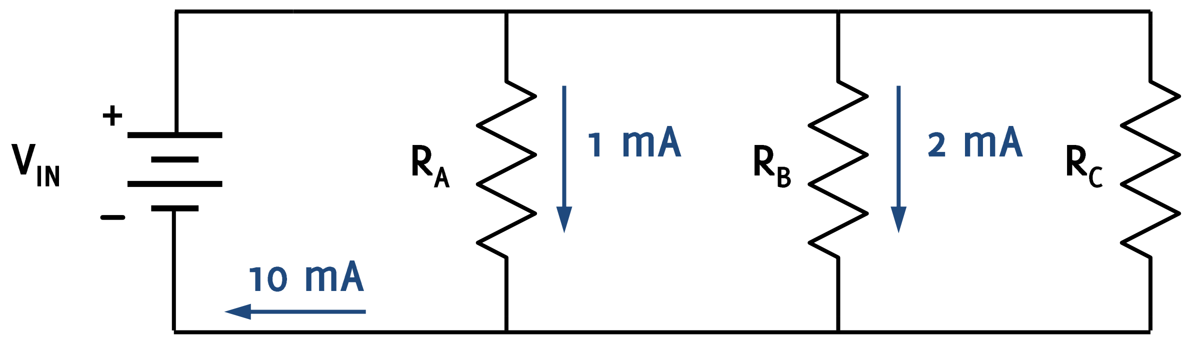
$$i_1 + i_2 + i_3 = 0$$

- Elements in series experience the same current



$$i_R = i_C$$

QUICK CHECK

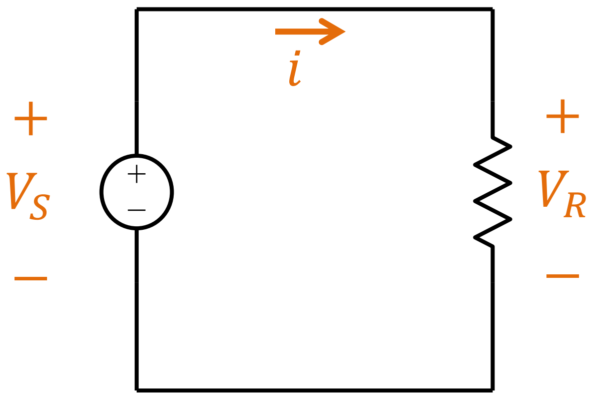


What is the current through R_C?

BASIC RULES (REVIEW)

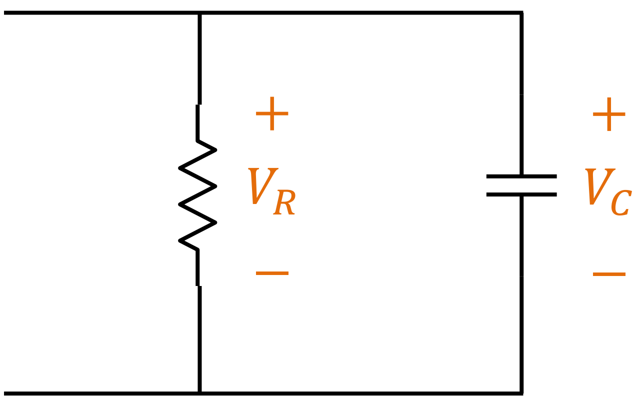
Kirchhoff's Voltage Law

- $\sum_{k=1}^{n} V_k = 0$ around any closed circuit



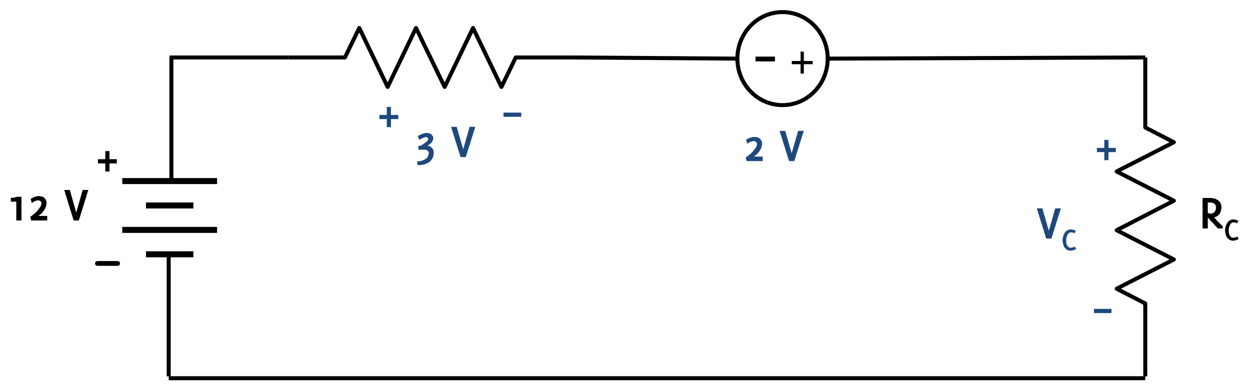
$$-V_S + V_R = 0$$

- Elements in parallel circuit experience the same voltage drop



$$V_R = V_C$$

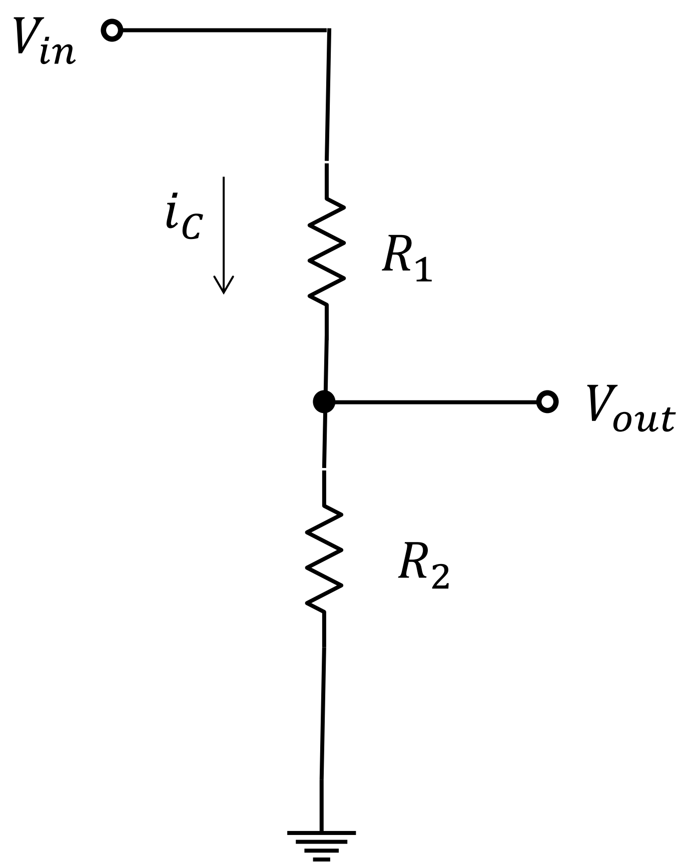
QUICK CHECK



What is the voltage across R_c?

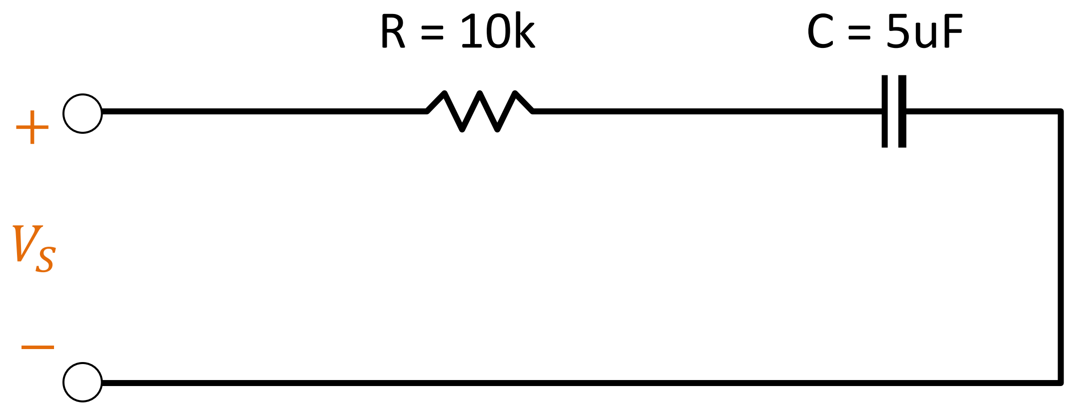
CIRCUIT ANALYSIS

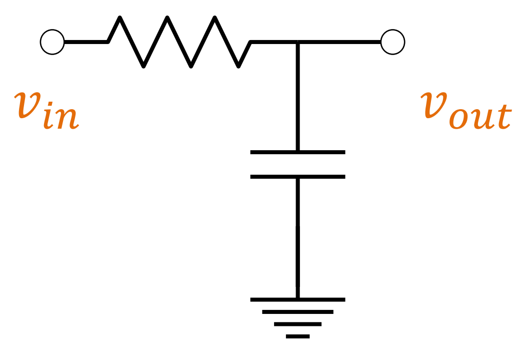
A voltage divider partitions voltage in a linear manner across the divider elements



$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

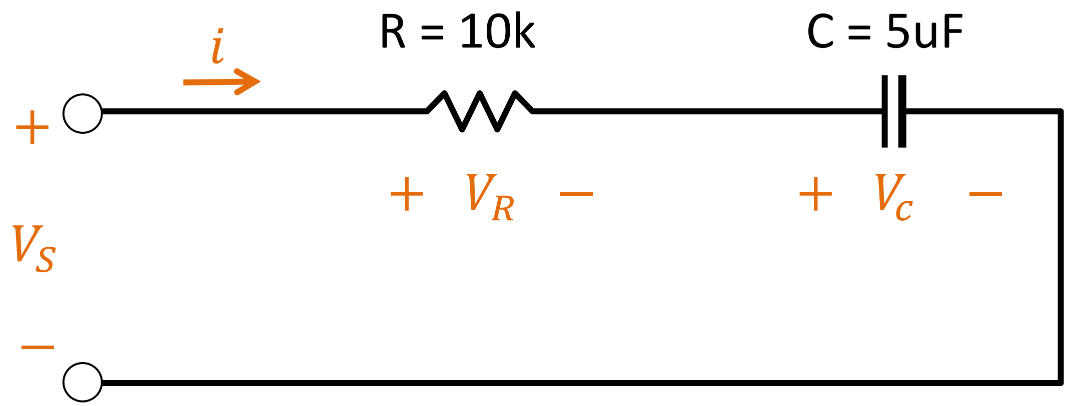
DETERMINE THE RELATIONSHIP BETWEEN INPUT AND OUTPUT SIGNALS





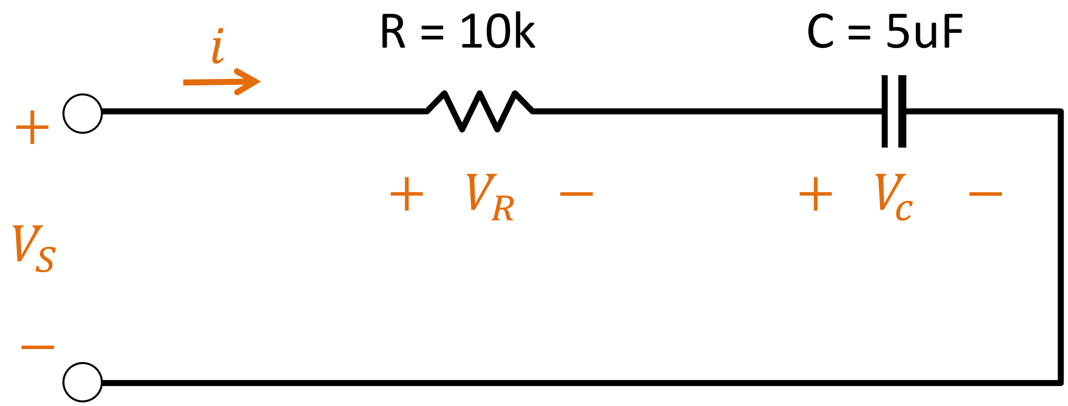
- Input: V_s
- Output: V_C

STEP 1: APPLY KVL TO THE LOOP FORMED BY V_S, V_R, AND V_C



$$-V_S + V_R + V_C = 0 \qquad \Rightarrow \quad V_R = V_S - V_C$$

STEP 2: APPLY OHM'S LAW AND KCL



$$\frac{V_s - V_c}{R} = i_r = i_c = C\frac{dV_c}{dt}$$

STEP 3: SUBSTITUTE AND SIMPLIFY

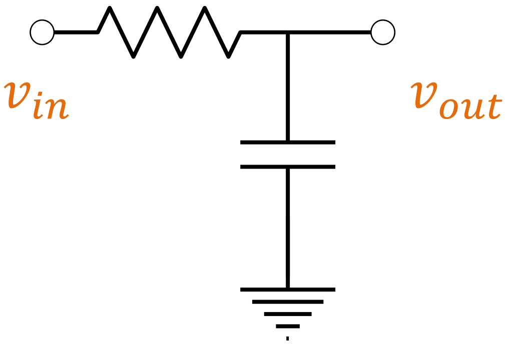
$$\frac{V_s - V_c}{R} = C\frac{dV_c}{dt}$$

$$V_s = RC\frac{dV_c}{dt} + V_c$$

$$(RC)\dot{V}_C + V_C = V_s$$

$$\tau\dot{x} + x = Ky$$

STEP 4: INTERPRET MEANING



For canonical form $\tau\dot{x} + x = Ky$:

- Cutoff Frequency:

$$\omega_{co} = \frac{1}{\tau} = \frac{1}{RC}$$

- Magnitude Gain:

$$|G(j\omega)| = \frac{K}{\sqrt{1+(\omega\tau)^2}} = \frac{1}{\sqrt{1+(\omega RC)^2}}$$

- Phase Shift:

$$\angle G(j\omega) = -\tan^{-1}(\omega\tau) = -\tan^{-1}(\omega RC)$$

ACTION ITEMS

1. Submit student questionnaire (or drop course) by 5 pm on Friday, 16 January
2. Purchase Arduino Uno (R3) and USB cable
3. First lab either 1/20 or 1/21