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College of Engineering and Petroleum

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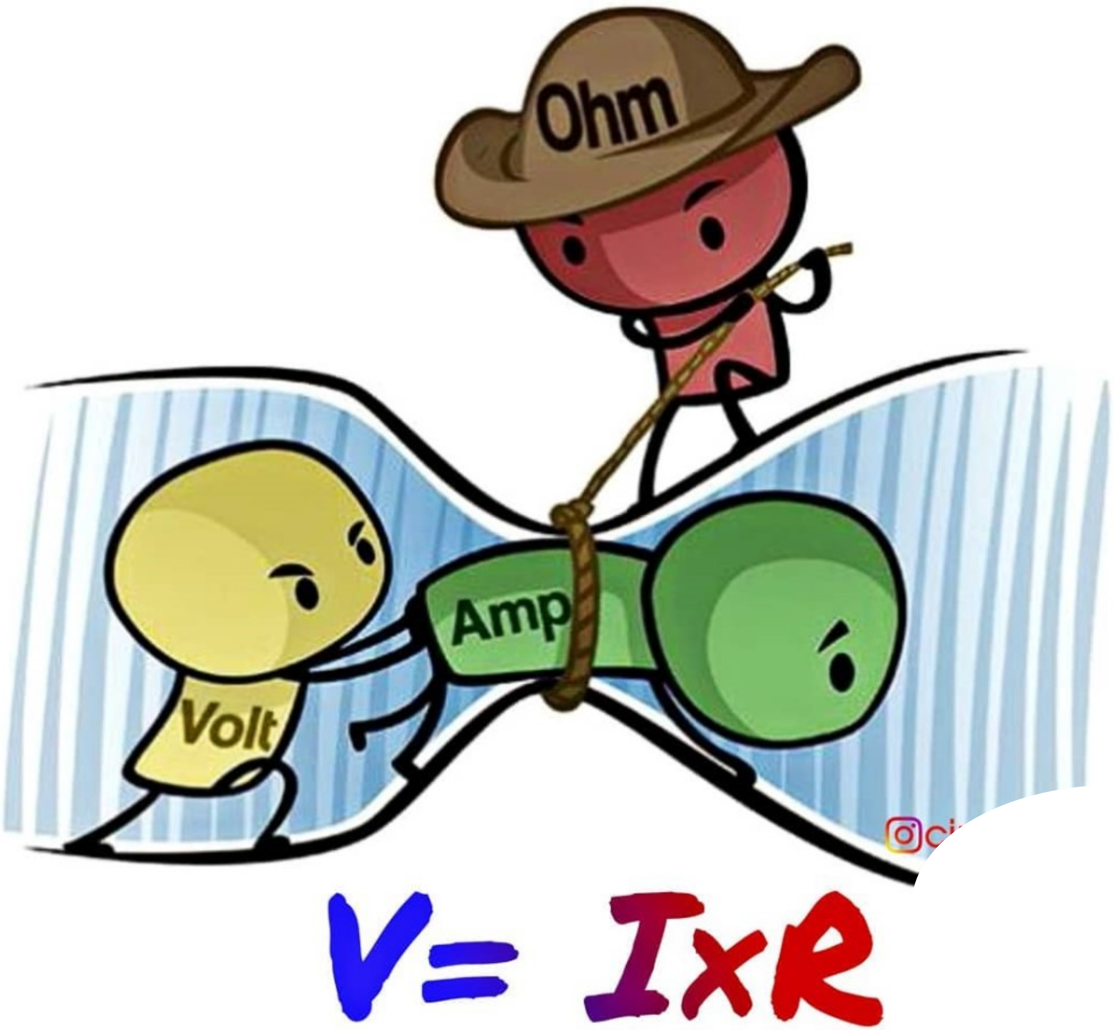
ME319 MECHATRONICS

Part II: The Cells – Electronic Circuits

Lecture 1: Passive Circuit Components

Spring 2021

Ali AlSaibie


Ohm
Amp
Volt
V= IxR

Lesson Objectives

- Understand basic electrical components and circuit analysis methods
- Understand concept of resistance, capacitance, inductance, and impedance

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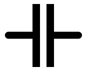
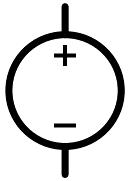
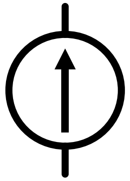
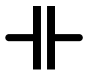
Basic Circuit Elements

Name	Reference Symbol	Circuit Symbol (IEC)
Resistor	R	
Capacitor	C	
Inductor	L	
Ideal Voltage Source	V	 5V
Ideal Current Source	I	 100mA

Constitutive Relationships

$V = IR$  $\frac{dV}{dt} = \frac{1}{C} I$  $\frac{dI}{dt} = \frac{1}{L} V$ 

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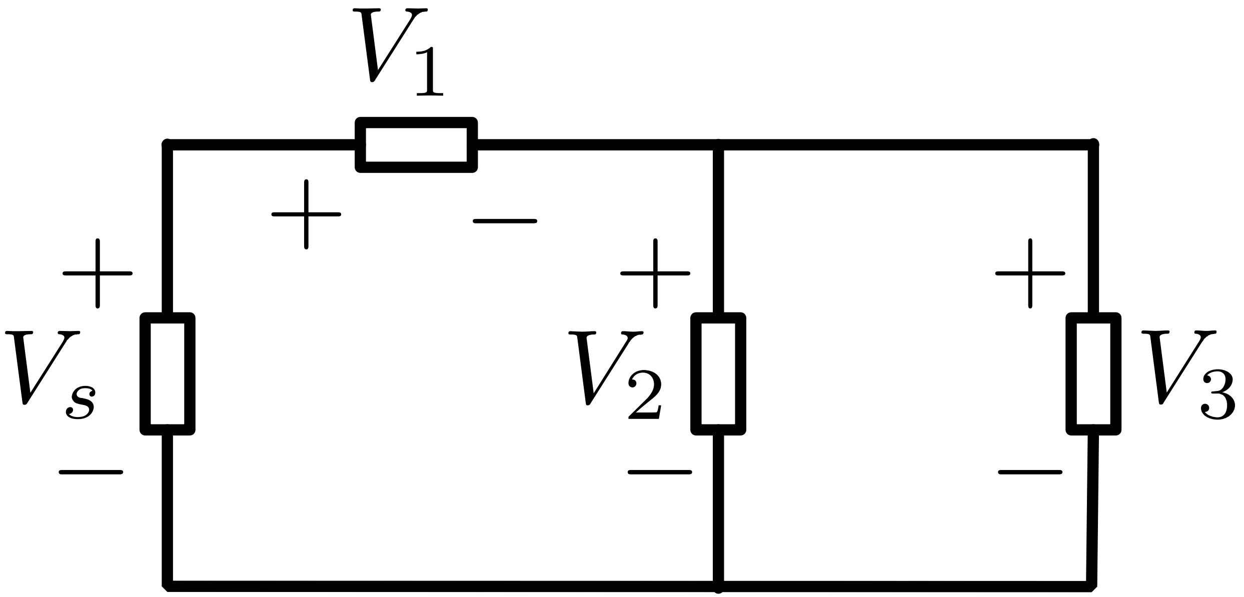
IEC (International) Symbols

Name	Reference Symbol	Circuit Symbol (IEC)	Circuit Symbol (ANSI)
Resistor	R		

- Sum of voltage drops and rises around any closed path in circuit is zero

$$\sum_{j=1}^{N} V_j = 0$$

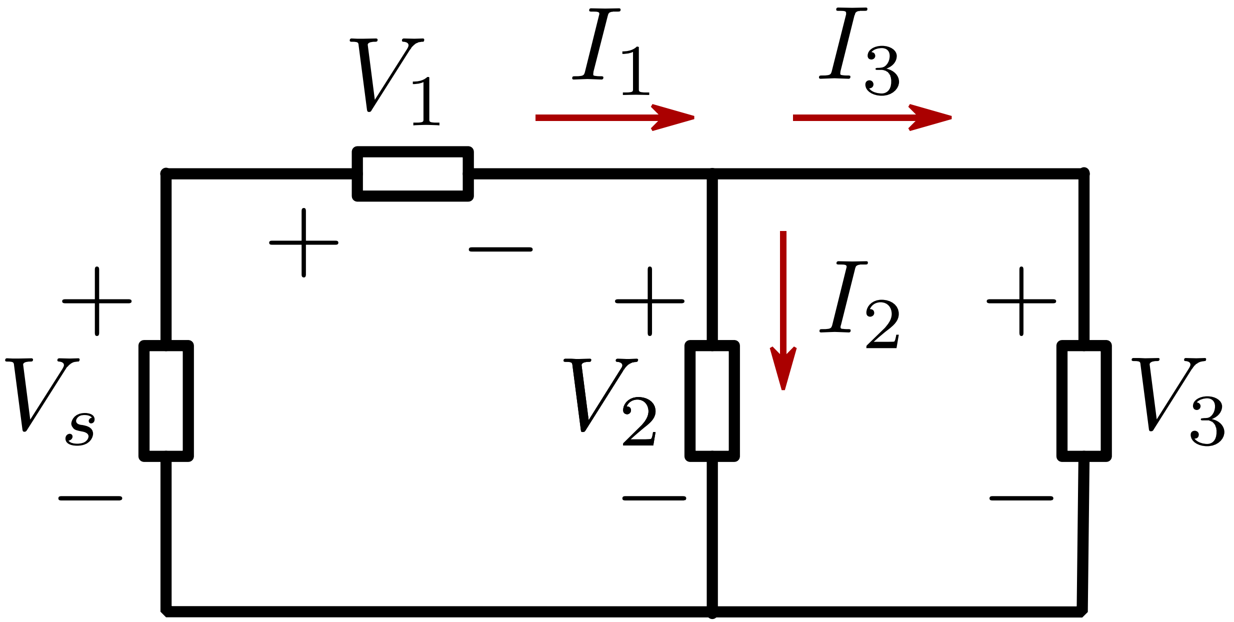


$$V_S - V_1 - V_2 = 0$$

$$V_S - V_1 - V_3 = 0$$

- Sum of current into a node is zero

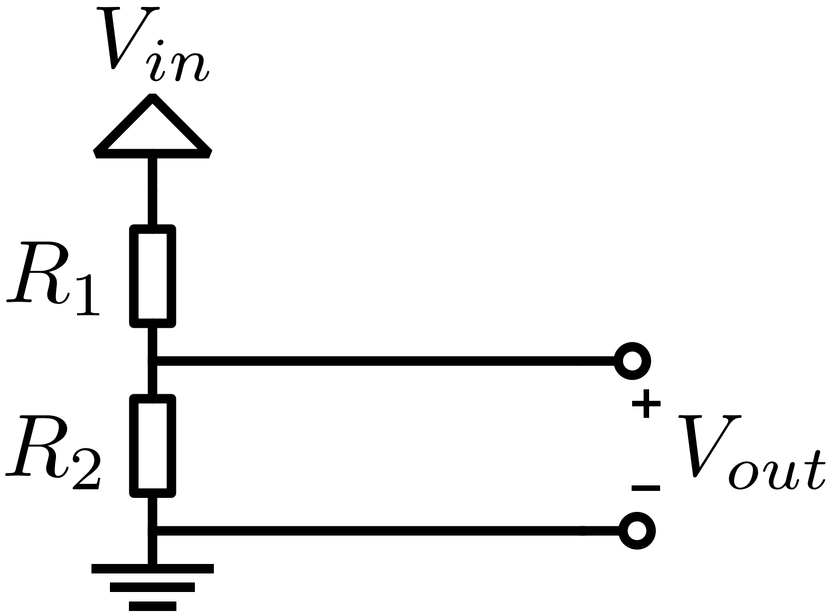
$$\sum_{j=1}^{N} I_j = 0$$



$$I_1 - I_2 - I_3 = 0$$

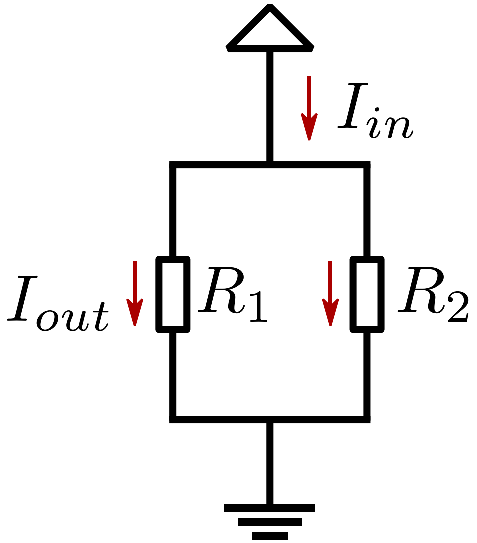
- By placing two resistors in series and taking voltage between resistors, we create a ***voltage divider*** *(Think restriction orifice)*
  - Extremely useful when stepping down input source voltage for a sensor, actuator, or processor

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



- By placing two resistors in parallel and taking current along one branch, we create a ***current divider***
- *Think parallel water pipes*

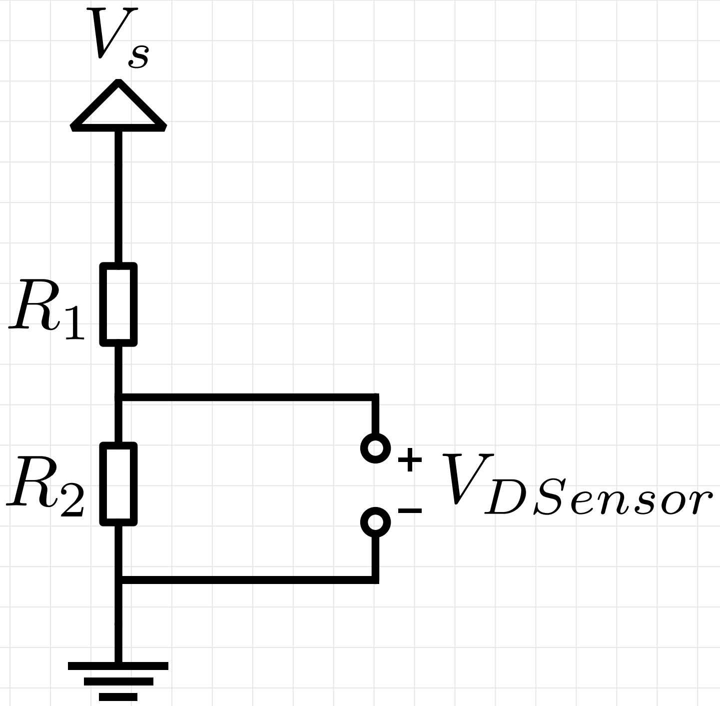
$$I_{out} = \frac{R_1}{R_1 + R_2} I_{in}$$



Example 1

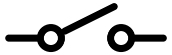
A certain sensor requires an input voltage of 5 VDC. You have a voltage source available which only provides 15 VDC. Design a voltage divider that will allow you to power the sensor from this power supply.

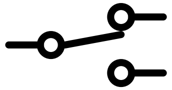
(Practically not efficient, use a dedicated voltage regulator)

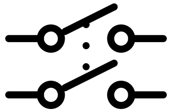


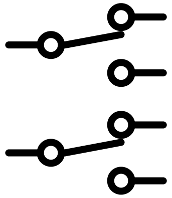
Switch Types

Toggle Switches

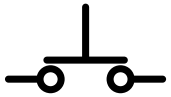
Single Pole Single Throw (SPST) 

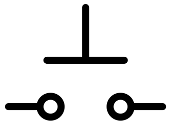
Single Pole Double Throw (SPDT) 

Double Pole Single Throw (DPST) 

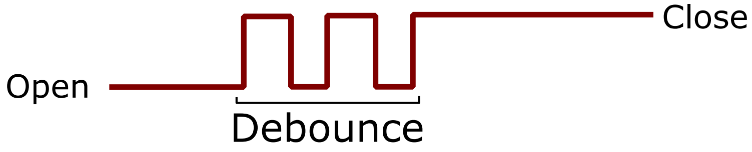
Double Pole Double Throw (DPDT) 

Push Buttons

 Normally Closed (NC)

 Normally Open (NO)

Switch Debouncing



Requires use of debouncing circuit or software logic

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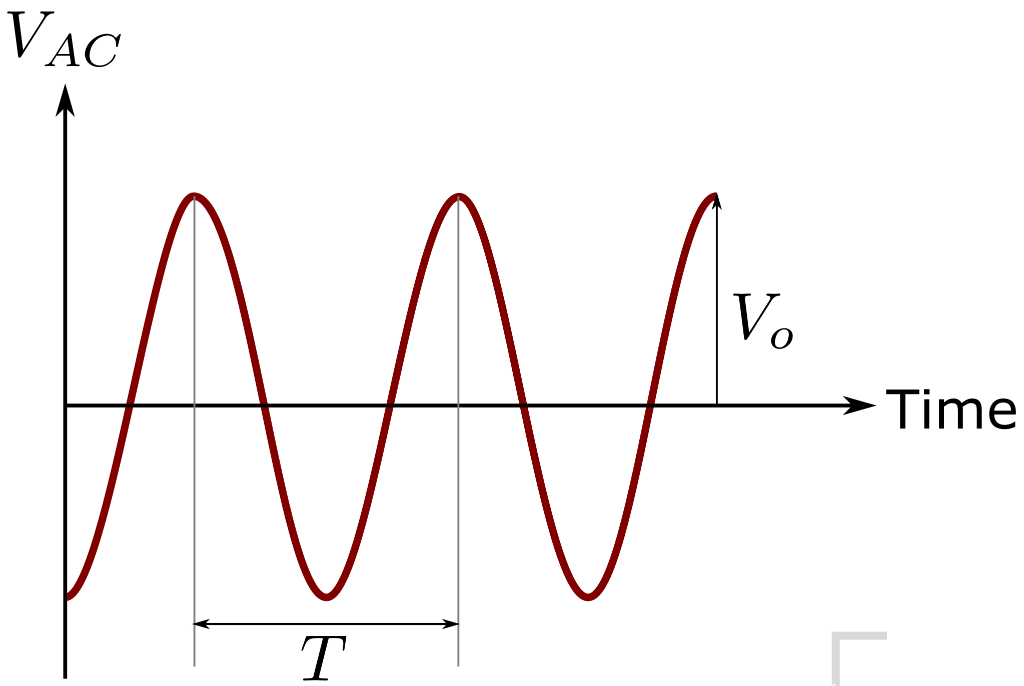
- AC (alternating current) signals have sinusoidally varying voltage

$$V_{AC} = V_o sin(\omega t + \phi)$$

- AC current from wall is 110 VAC, meaning the RMS voltage is 110 V.

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T V^2 dt} = 0.707V_o$$

$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^T I^2 dt} = 0.707I_o$$



- Power defined as voltage time current

$$P(t) = I(t)V(t) \quad \Rightarrow^{DC\,Voltage} \quad P = IV = I^2R$$

$$\Downarrow \; AC\,Voltage$$

$$P(t) = V_o I_o \sin(\omega t + \phi_V) \sin(\omega t + \phi_I)$$: Instantaneous Power

$$P(t) = V_{RMS} I_{RMS} \underbrace{\cos(\phi_V - \phi_I)}_{Power\,Factor}$$: Average Power

Power Factor: Measures how much of supplied power is converted into real or useful power

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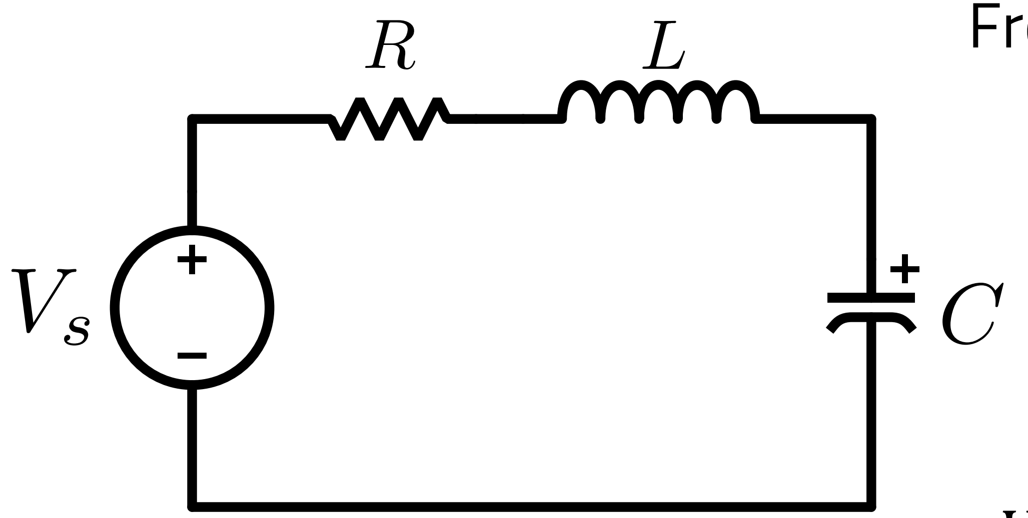
- Impedance (Z) is generalization of resistance

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

- Gives us a measure of "resistance" in circuit that includes more elements than just pure resistors



From Kirchhoff's Voltage Law:

$$V_s(s) = RI(s) + \frac{I(s)}{Cs} + LsI(s)$$

$$\Downarrow \mathcal{L}^{-1}$$

$$V_s(t) = Ri(t) + \frac{1}{C}\int i(t)dt + L\frac{di(t)}{dt}$$

- If voltage varies sinusoidally with frequency ω, can substitute $s = \omega j$ for the steady state response:

$$\frac{V_s(s)}{I(s)} = \underbrace{R}_{Resistor\ Impedance} + \underbrace{\frac{1}{C\omega j}}_{Capacitor\ Impedance} + \underbrace{L\omega j}_{Inductor\ Impedance}$$

- DC Voltage Source: Impedance of **RLC** Circuit is infinite: due to capacitor impedance and since $\omega = 0$
  - Impedance of **RL** Circuit is R
- AC Voltage Source: Impedance of **RLC** Circuit is infinite as $\omega \rightarrow \infty$
  - Impedance of **RC** Circuit approaches R as $\omega \rightarrow \infty$

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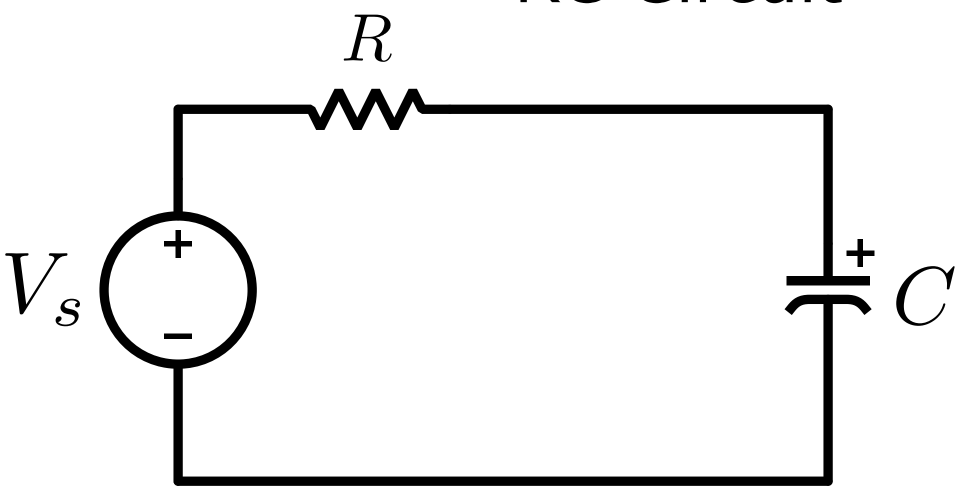
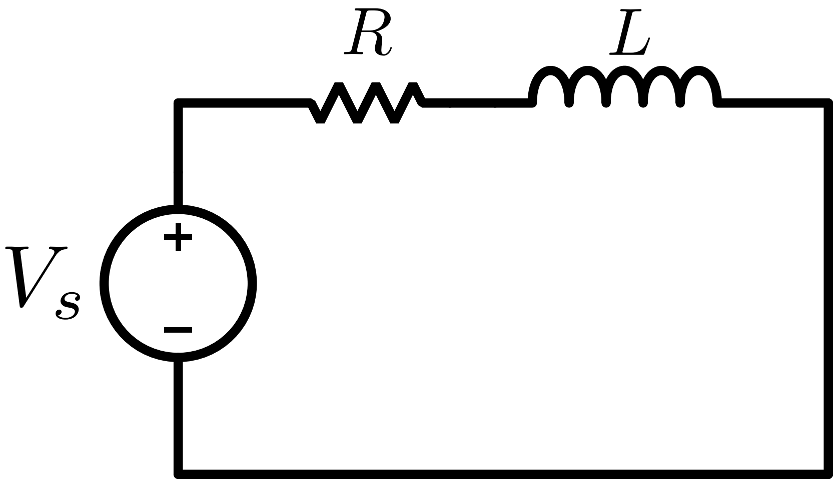
- Impedance is a complex quantity

$$Z = \underbrace{R}_{Resistance} + \underbrace{Xj}_{Reactance}$$

RC Circuit

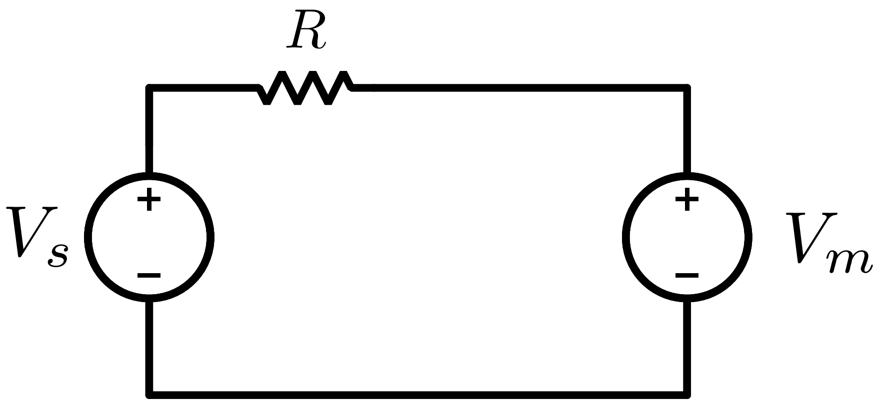


RL Circuit



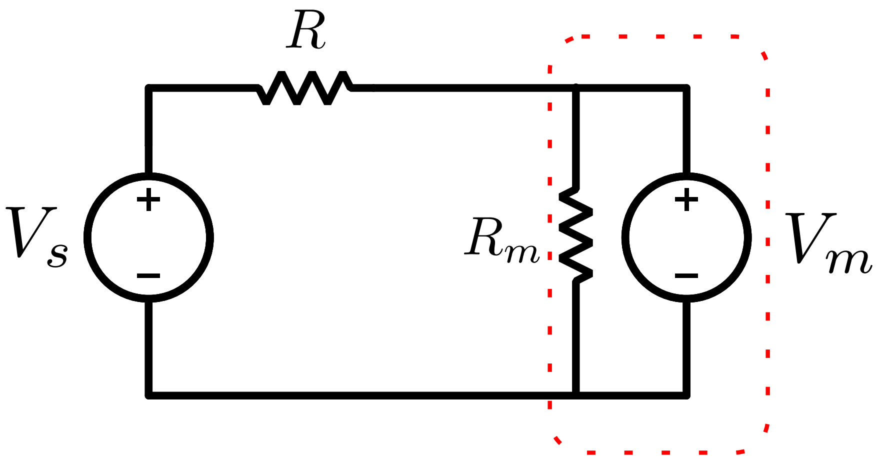
- Voltmeters have finite impedance

Ideal Voltmeter



$$V_s = V_m$$

Actual Voltmeter



$$V_m = \frac{R_m}{R+R_m} V_s$$

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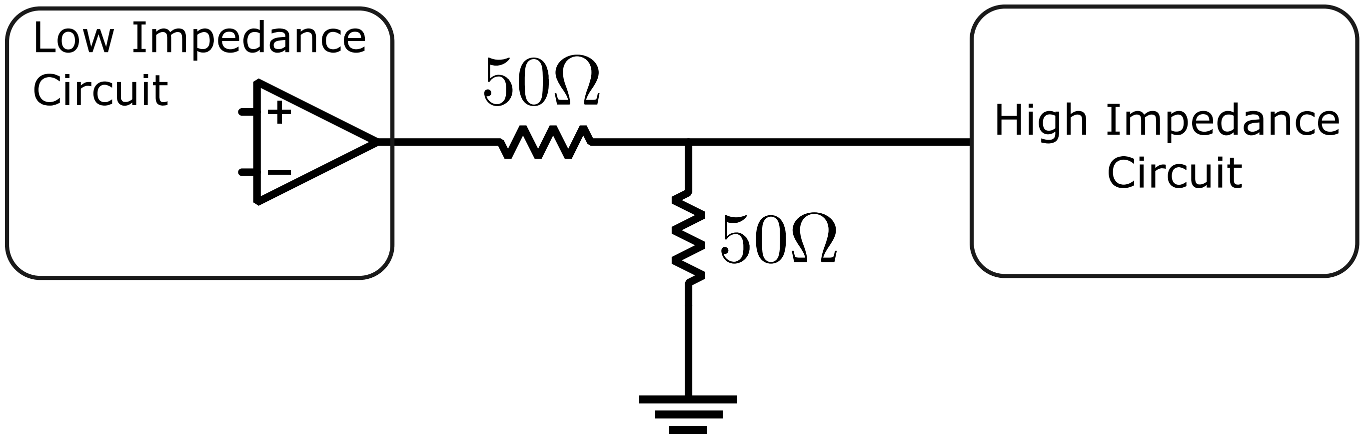
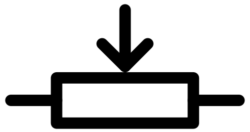
Impedance: Practical Considerations

- When connecting electrical devices together, important to make sure **impedances** are **matched**
- Otherwise **high-impedance** device can reflect back signal produced by low-impedance device
- Impedance matching can be accomplished by adding appropriate resistors to circuit



- Potentiometers and rheostats are variable **resistors**
- Potentiometers have **three** terminals
- Rheostats have **two**
- Useful for user interfaces, or to adjust resistor value to precise level needed in circuit design
- Resistors only come in discrete values

Potentiometer Symbol



Potentiometer

Rheostat

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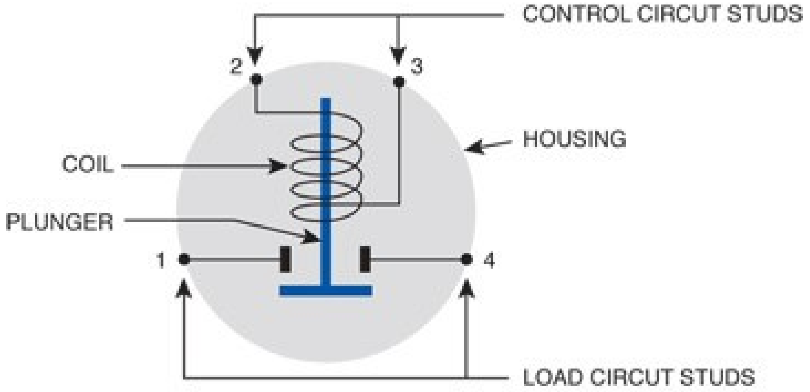
- Mechanical switches for switching high power devices (mechanical) using low power device (microcontroller)

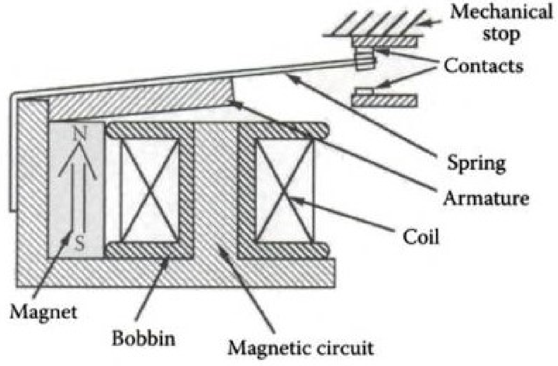
  - Usually travel less than 1 inch
  - Incorporate springs such that when coil is off, armature (plunger) is held to off position
  - Switching times usually ~10 ms

  - Latches in position when current applied due to combination of fixed magnet and spring
  - Current applied in either direction to coil in order to switch relay

Solenoid Switch

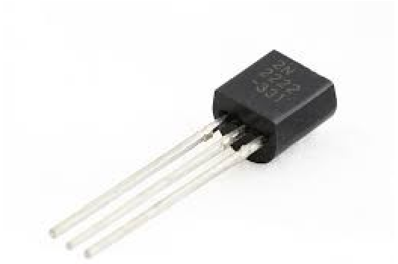


Electromechanical Latch Relay



Semiconductors

- Semiconductors are special materials that are between conductors and insulators
- They can be made to conduct current if sufficient voltage is present
- Most important semiconductor device is the transistor, which can be viewed as a solid-state switching device
- Logic gates
- Interface between processors and mechanical devices



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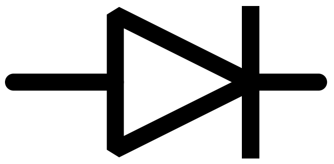
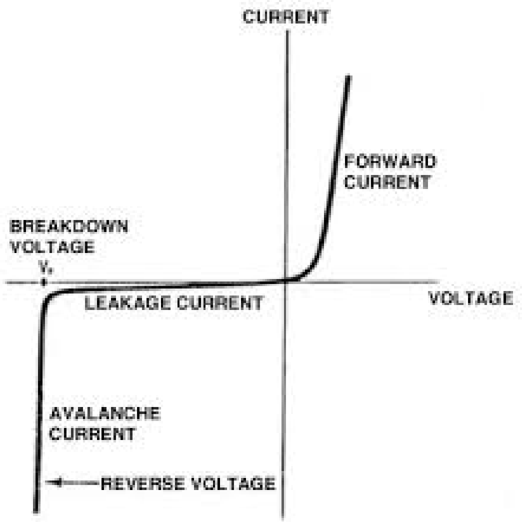
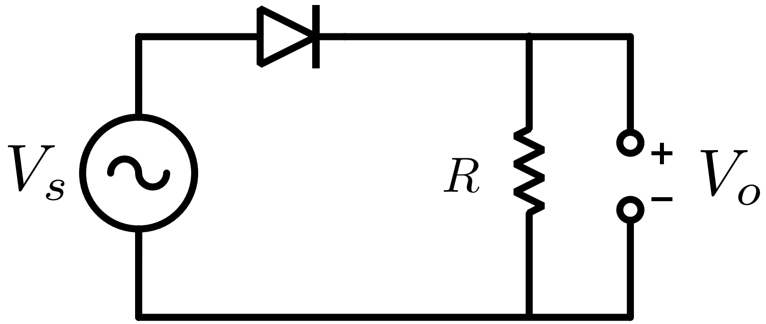
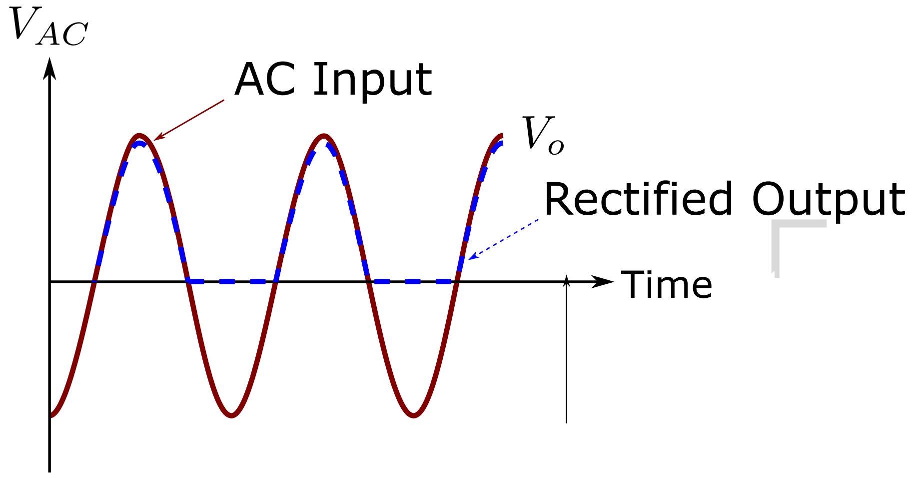
- Diodes are semiconductor devices that only allow current to flow one way
- Symbol:



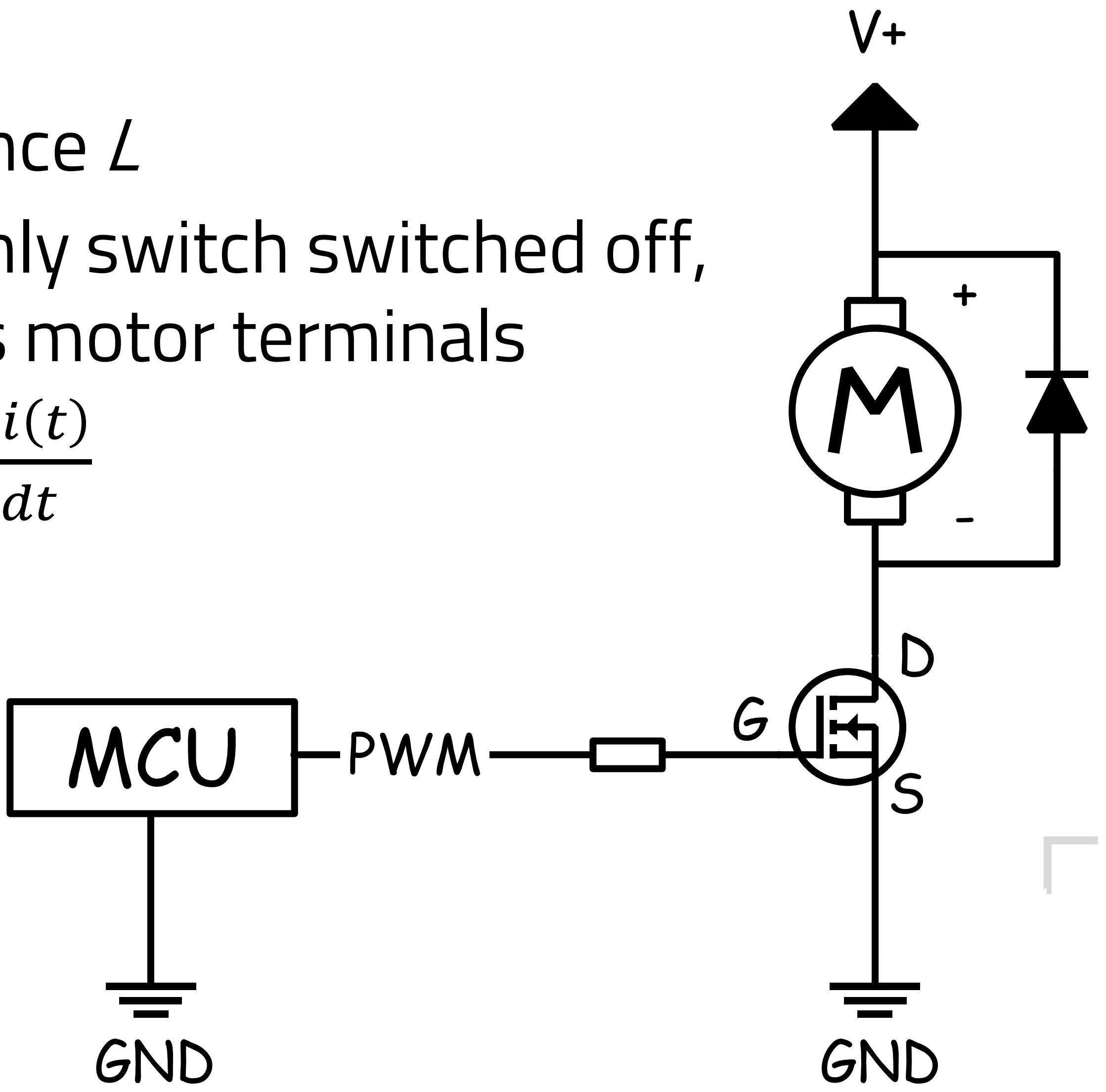


- *Think one-way valve*
- Example Use: Rectify AC voltage into DC voltage

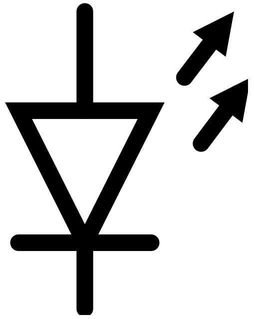




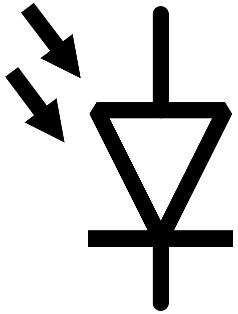
- Consider the following circuit for motor control using a switch
  - Motor has high inductance L
  - When the motor suddenly switch switched off, voltage develops across motor terminals according to: $V(t) = L\frac{di(t)}{dt}$



- **Light Emitting Diodes (LED)**
  - Emit light when "forward biased"
  - Have voltage drop of about 2V* when on
  - Colors determined either by semiconductor material or plastic housing over diode



- **Photodiodes**
  - Opposite of LED
  - Amount of current diode passes is proportional to amount of light it receives
  - Commonly used as light sensors (i.e., nightlight)



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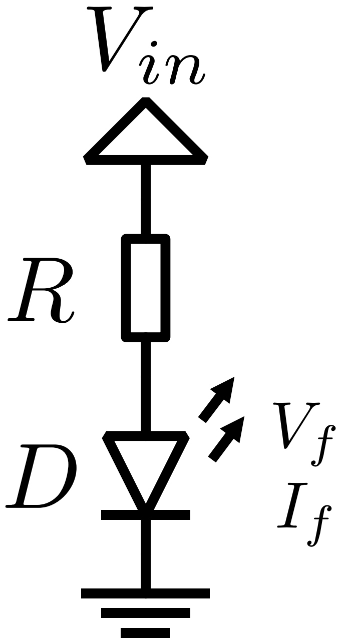
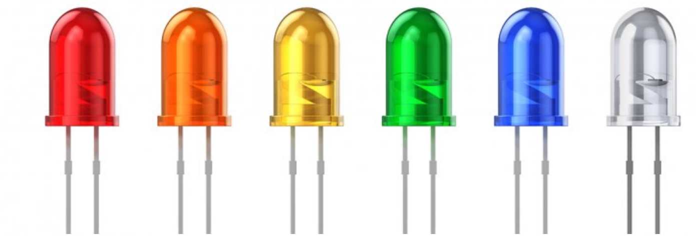
LED Forward Voltage and Forward Current

- The **Forward Voltage** of an LED, is the voltage required across the LED to cause current to flow and switch the LED On (Close the circuit)
  - Higher Forward Voltage will damage LED, lower Forward Voltage will not close the circuit
- The **Forward Current**, is the current passing through the LED. This must be limited not to damage the LED.
- Different LEDs (even same size/shape but different colors) have different **Forward Voltage** and **Forward Current Limit**
- To control voltage/current, add resistor:

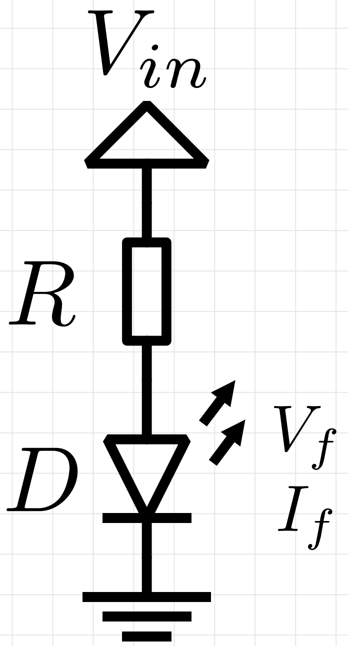


$$R = \frac{V_{in} - V_f}{I_f}$$



A blue SMD LED is to be placed on a board. If the supply (input) voltage is 5V. Compute the minimum resister value required to safely operate the LED.

Using the available LEDs from the provided list.



1206 smd LEDs 3.2x1.6x1.1MM		Forward voltage (V) IF=20mA		Dominant wavelength IF=20mA		Luminous Intensity (mcd) IF=20mA		Viewing angle
Part number	Emitting Color	TYP	MAX	MIN	MAX	TYP	MAX	(degree)
SS-1206R	Red	2.1	2.3	640	650	650	660	120
SS-1206Y	Yellow	2.2	2.8	590	600	550	560	120
SS-1206O	Orange	2.2	2.8	635	645	470	480	130
SS-1206B	Blue	3.2	3.4	465	475	650	660	120
SS-1206G	Plain Green	3.2	3.4	568	573	420	430	120
SS-1206JG	Jade-green	3.2	3.4	530	540	590	600	120
SS-1206W	White	3.2	3.4	X=0.285	Y=0.295	500	800	120
SS-1206P	Pink	3.2	3.4	----	---	300	400	120
SS-1206UV	UV(Purple)	3.2	3.4	380	400	120	160	120

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