

# TI-RSLK

Texas Instruments Robotics System Learning Kit



TEXAS INSTRUMENTS



# Module 2

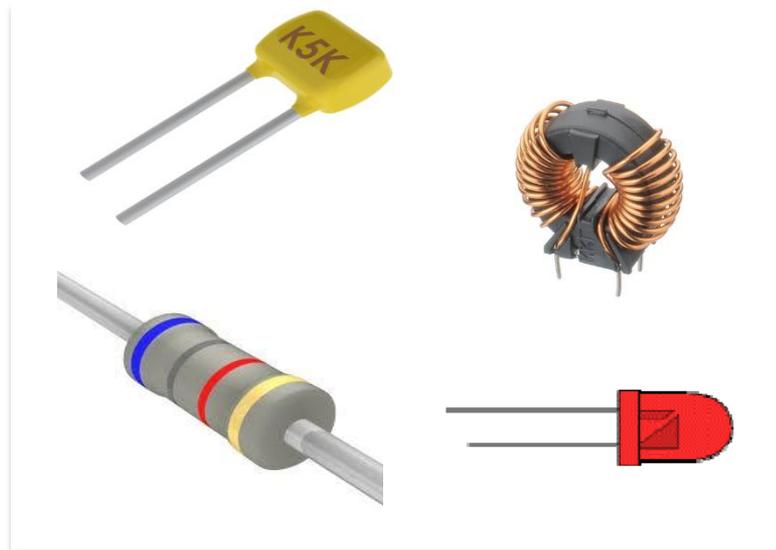
Lecture: Voltage, Current and Power



# Voltage, Current and Power

## You will learn in this module

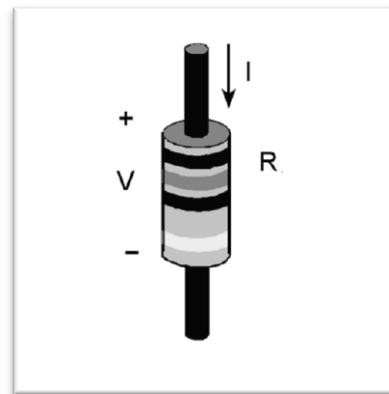
- Electrical Engineering Terms
  - Voltage,  $V$  (volts)
  - Current,  $I$  (amps)
  - Energy,  $E$  (joules)
  - Power,  $P$  (watts)
- Electrical Engineering Devices
  - Resistors
  - Capacitors
  - Inductors
  - LEDs
- Test Equipment
  - Voltmeter, ohmmeter, current meter
  - Oscilloscope





# Current

- Definition of Current
  - Current is caused by motion of electrons
  - Symbol is **I**, **measurement unit is Ampere or Amps**
  - 1 ampere (A) is  $6.241 \times 10^{18}$  electrons per second
  - Current of 1A = one coulomb of charge per second
- Properties
  - Directional, along a path or wire
  - Stimulates muscles and nerves
  - Drive motors of your robot
  - Follows Ohm's Law ( $V = IR$ )
- Measurements
  - Current inside a circuit can be measured with a meter
  - Voltage across a know resistor  $V = I \cdot R$

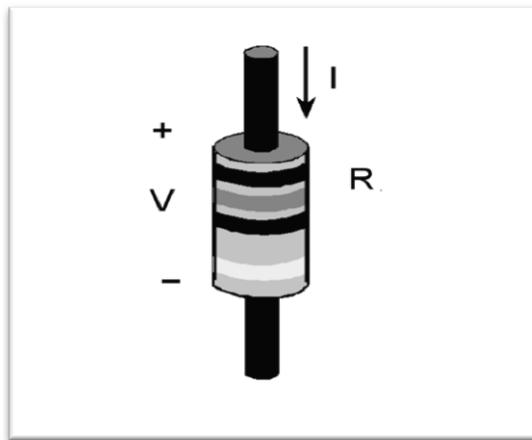


**MSP432 can source/sink  
up to 6 mA**



# Voltage

- Definition of voltage
  - Voltage is caused by potential difference between two points
  - Symbol is  $V$  and is measured in Volts
  - Electromotive force or potential to produce current
- Properties
  - Always measured as a difference
  - Signed, directional causes current to flow
  - Battery used to drive motors of your robot
  - Follows Ohm's Law
- Measurements
  - Voltmeter measures DC and AC voltage
  - Oscilloscope measures voltage changes as function of time (  $V$  v/s t )



**MSP432 can output 0V or 3.3V**



# Energy and Power

- Definition of energy
  - Amount of storage, for battery specification
  - Units of energy are joules( $J = \text{volts} * \text{amps} * \text{time}$ )
  - $E = 1J$  delivers 1V at 1A for 1 second
- Batteries
  - Constant voltage
  - Rated in amp-hour
- Power
  - Rate of change of energy
  - $P = V * I$
  - Units of power are watts= $J / \text{sec} = \text{volts} * \text{amps}$
  - Conversions: electrical, optical, mechanical, thermal, acoustic

**MSP432 requires 5mA at 3.3 V**

**AA alkaline battery has  
2 A-h at 1.5V**

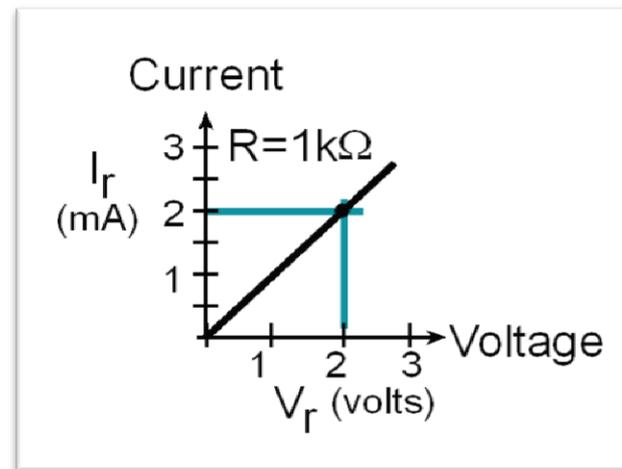
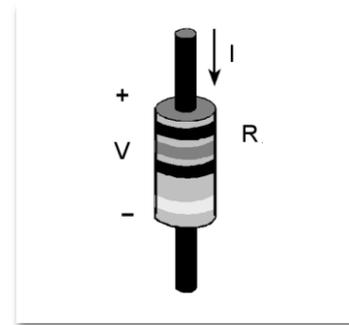
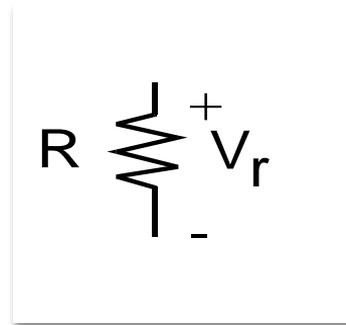
### **Power budget:**

Two AA alkaline batteries will power an MSP432 for 16 days,  
 $2000 \text{ mA-h} = 5\text{mA} * 400\text{h}$



# Resistor

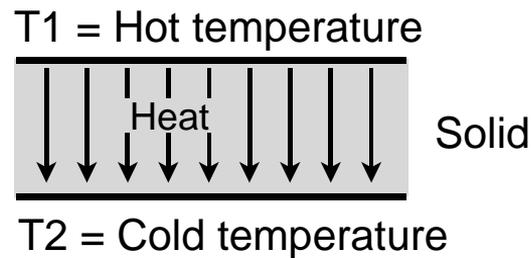
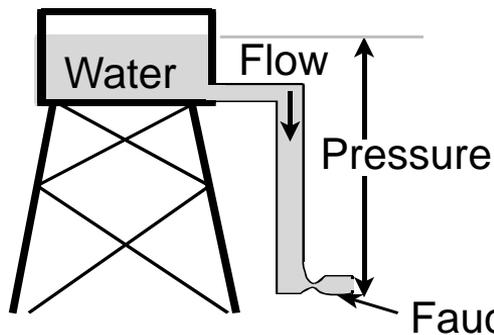
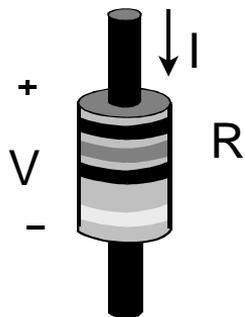
- Definition of resistor
  - Passive device with a linear V-I relationship
  - Resistance is measured in R, in Ohms ( $\Omega$ )
  - Follow's Ohm's Law
- Parameters
  - Tolerance, e.g., **5% ( $1000 \Omega \pm 5\%$ )**
  - Maximum power, wattage ( $\frac{1}{4}$  watt = 250 mW)
  - For a  $V = 2 \text{ V}$ ,  $I = 2 \text{ mA}$ ,  $P = 2 * 2 \text{ mA} = 4 \text{ mW}$
- Applications
  - Used to limit or control current
  - Used in circuits to effect gain, offset, frequency response





## Analogy

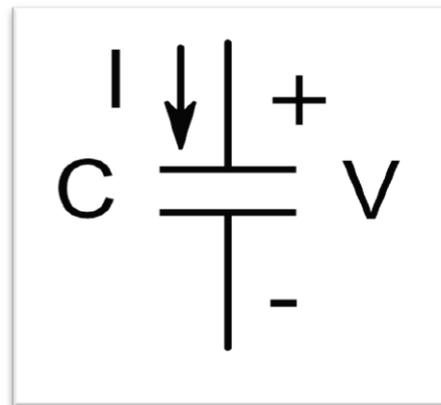
- Current = Voltage/Resistance
- Fluid Flow = Pressure/Resistance
- Heat Flow = Temperature/Resistance





# Capacitor

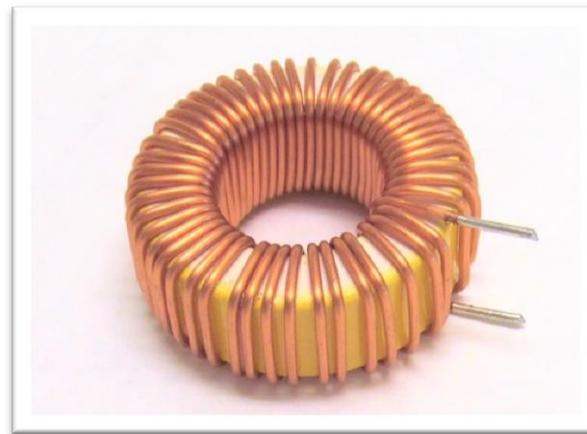
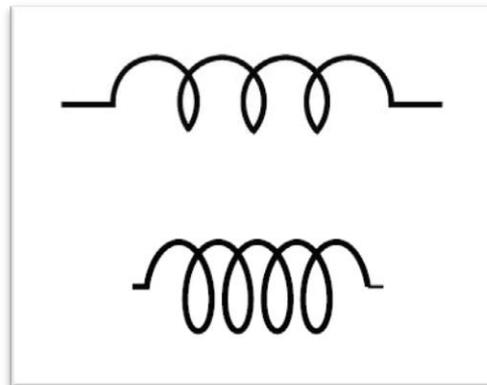
- Definition of capacitor
  - Passive device that can store charge
  - Complex impedance,  $Z = 1/(j2\pi fC)$
  - Open circuit at DC
  - Allows current at AC
  - Reactance,  $|V|/|I| \equiv X = 1/(2\pi fC)$
- Parameters
  - Capacitance,  $C$ , in farads (F)
  - Tolerance, e.g., 5%
  - Maximum voltage
  - Type, e.g., ceramic, tantalum
- Applications
  - Used as temporary storage of energy
  - Used in circuits to effect frequency response
  - Used to reduce noise in circuits





# Inductor

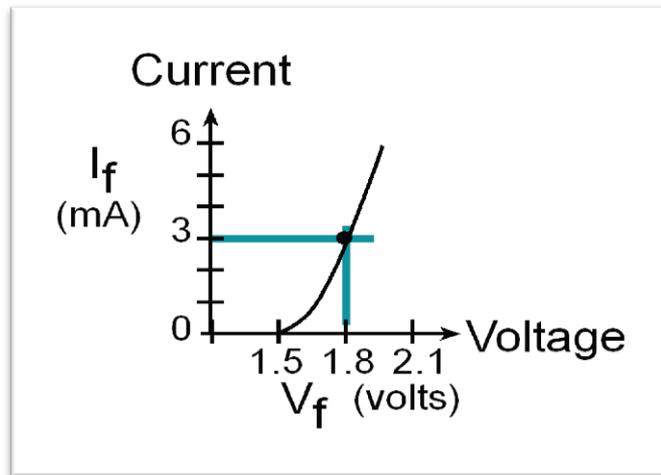
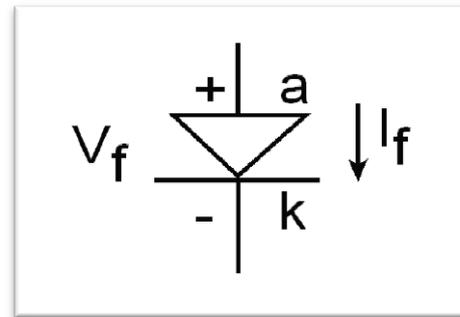
- Definition of inductor
  - Passive device build with coiled wire
  - Complex impedance  $V/I \equiv Z = j2\pi fL$
  - Closed circuit at DC
  - Resists current at AC
- Parameters
  - Inductance,  $L$ , in Henries (H)
- Applications
  - Used as to build DC motors





# Light Emitting Diode

- Definition of LED
  - Semiconducting device that can emit light
  - Electrical power => optical power
  - Conducts in one direction only
- Parameters
  - Voltage, current
  - Efficiency, brightness
  - Size
- Applications
  - Lights, displays, sensors
  - Isolation circuits, fiber optics



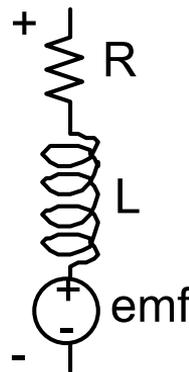


## DC motor

- Definition of DC Motor
  - Electromechanical device
  - Electrical power => mechanical power
  - Spins in both directions
- Parameters
  - Voltage, current
  - Efficiency, torque
  - Size, weight
- Applications
  - Robot actuator



### Electrical Model



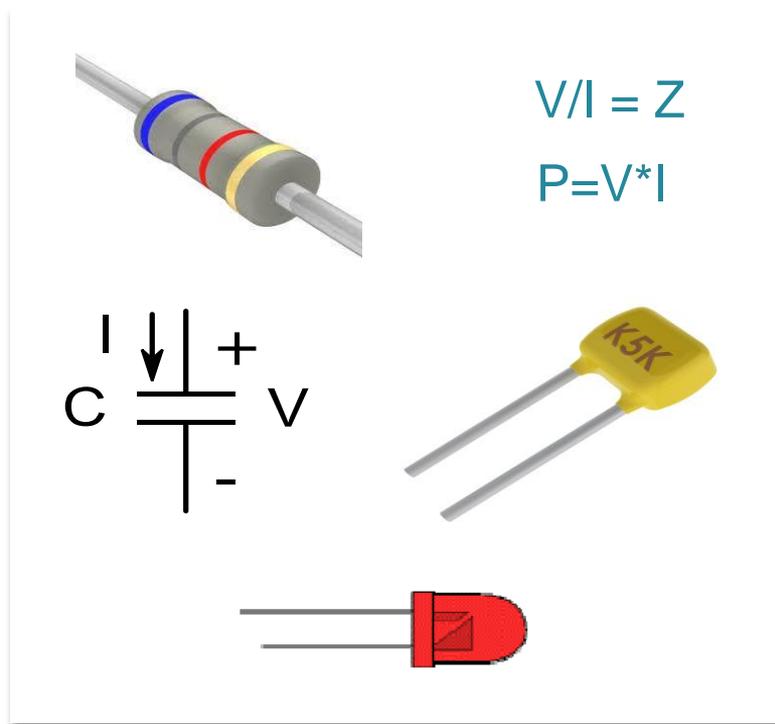
- Resistance,  $R$
- Inductance,  $L$
- emf,  $V$



# Voltage, Current, Power

## Summary

- Resistors
  - Voltage, current, power
  - Ohm's Law,  $V=I \cdot R$
- Capacitors
  - Voltage, current
  - Reactance,  $X = 1/(2\pi fC)$
  - Impedance,  $Z = 1/(j2\pi fC)$
- Inductors
  - Voltage, current
  - Impedance,  $Z = j2\pi fL$
- LEDs
  - Voltage, current, power
  - Unidirectional
  - Nonlinear





# Module 2

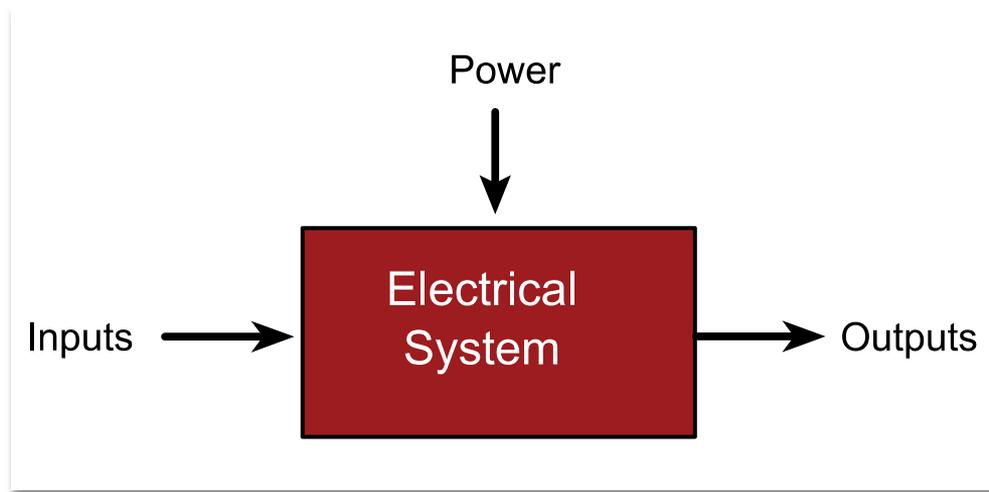
Lecture: Introduction to Circuits



# Introduction to Circuits

## You will learn in this module

- Electrical systems combine
  - Power
  - Inputs
  - Components
  - Connections
  - Outputs
- Simple DC circuit
  - Battery, switch, resistor, and LED
  - Voltmeter, current meter
- Simple AC circuit
  - Sine wave input, resistor, capacitor
  - Signal generator, oscilloscope
- Motor Drive Circuit
  - Microcontroller input, motor output
  - Logic analyzer



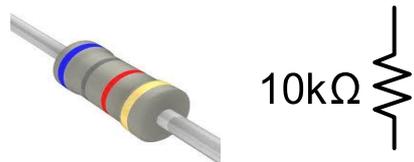
## An electrical circuit includes

- Power
- Electrical components
- Interconnection of the components
- Mechanisms for testing



# Electrical Components

## Resistor



## Switch



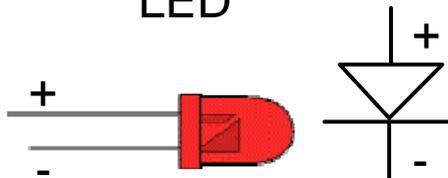
## Power/Ground



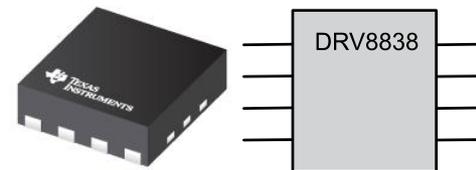
## Capacitor



## LED



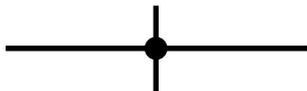
## Motor Driver



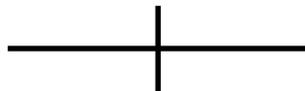


# Interconnection Rules

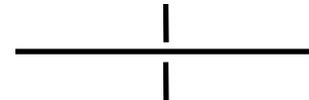
Connected



Not connected



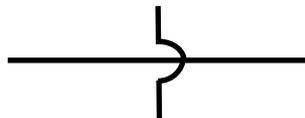
Not connected



Connected



Not connected



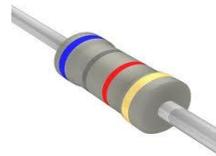
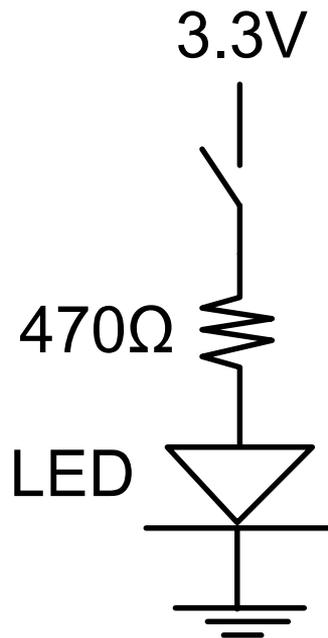
Bad style





## Switch-controlled LED

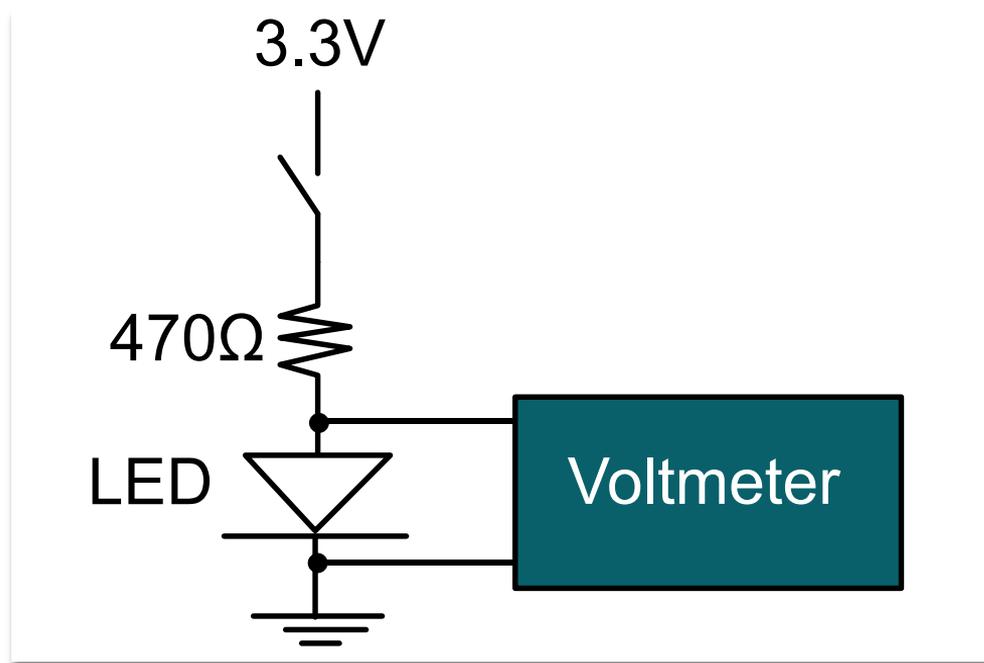
- Input
  - SPST switch
- Power
  - 3.3V supply
  - Ground
- Output
  - Light from LED





## Switch-controlled LED

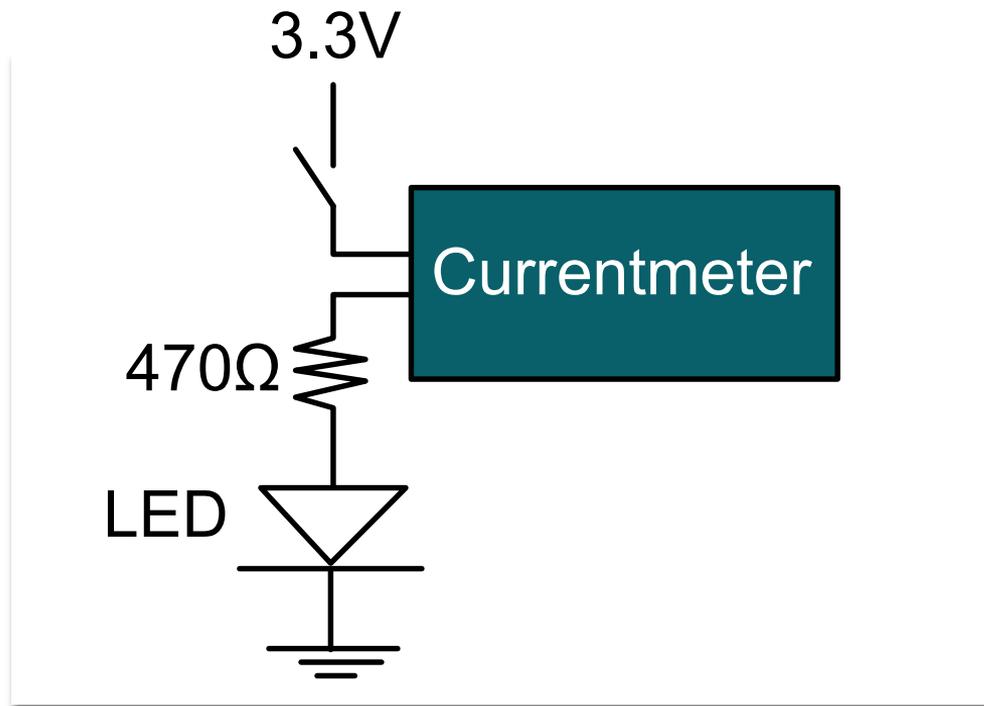
- Input
  - SPST switch
- Power
  - 3.3V supply
  - Ground
- Output
  - Light from LED
- **Testing**
  - **Voltmeter**





## Switch-controlled LED

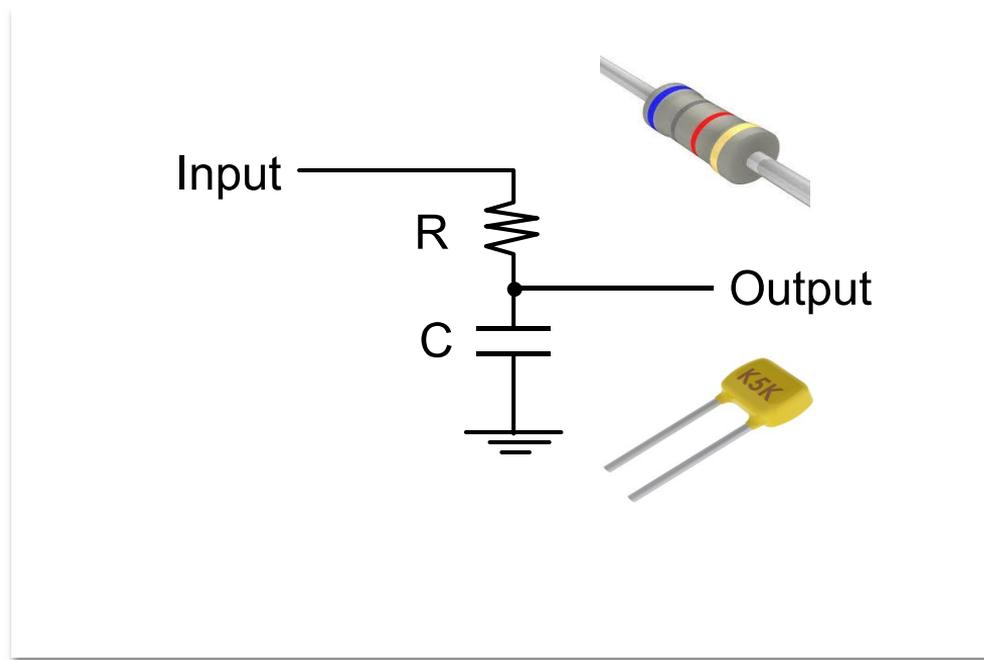
- Input
  - SPST switch
- Power
  - 3.3V supply
  - Ground
- Output
  - Light from LED
- **Testing**
  - Voltmeter
  - **Current meter**





## Analog Low Pass Filter

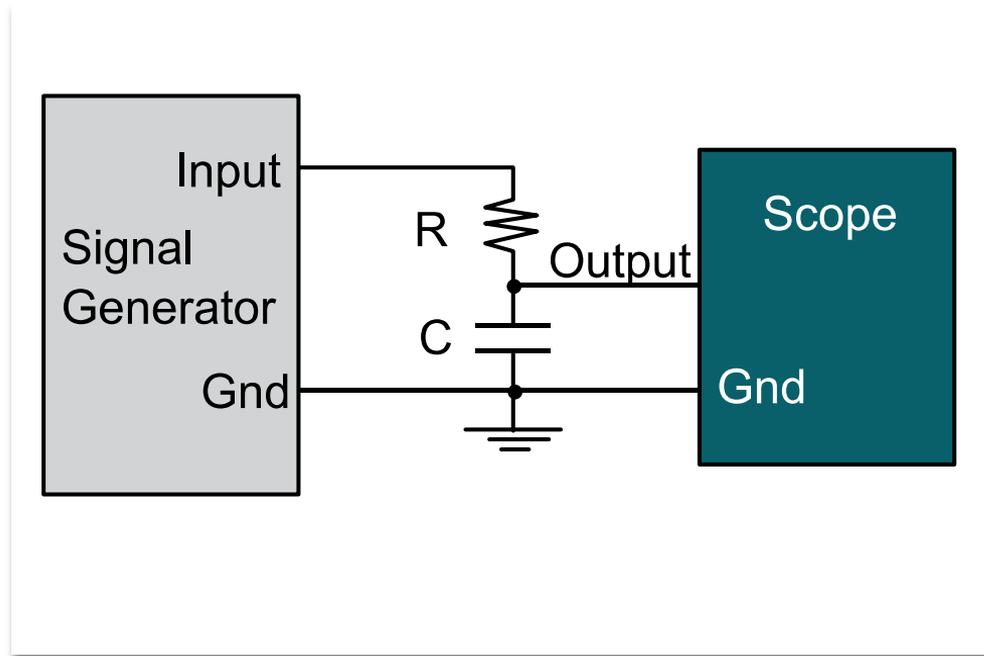
- Input
  - Signal from other circuit
- Power
  - Ground
- Output
  - Signal to other circuit





## Analog Low Pass Filter

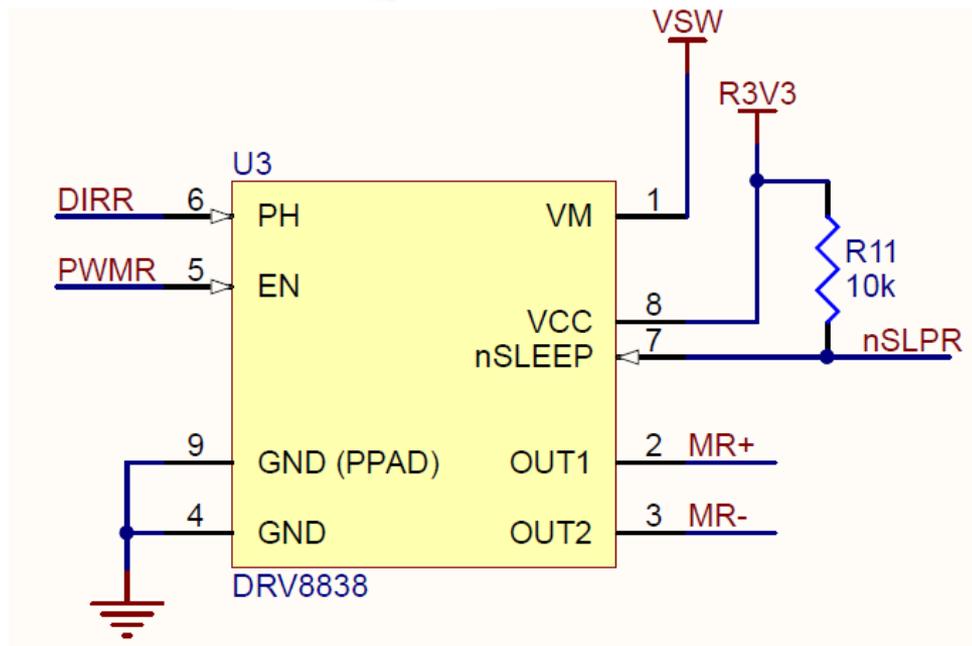
- Input
  - Signal from other circuit
- Power
  - Ground
- Output
  - Signal to other circuit
- **Testing**
  - **Signal Generator**
  - **Oscilloscope**





# Motor Driver

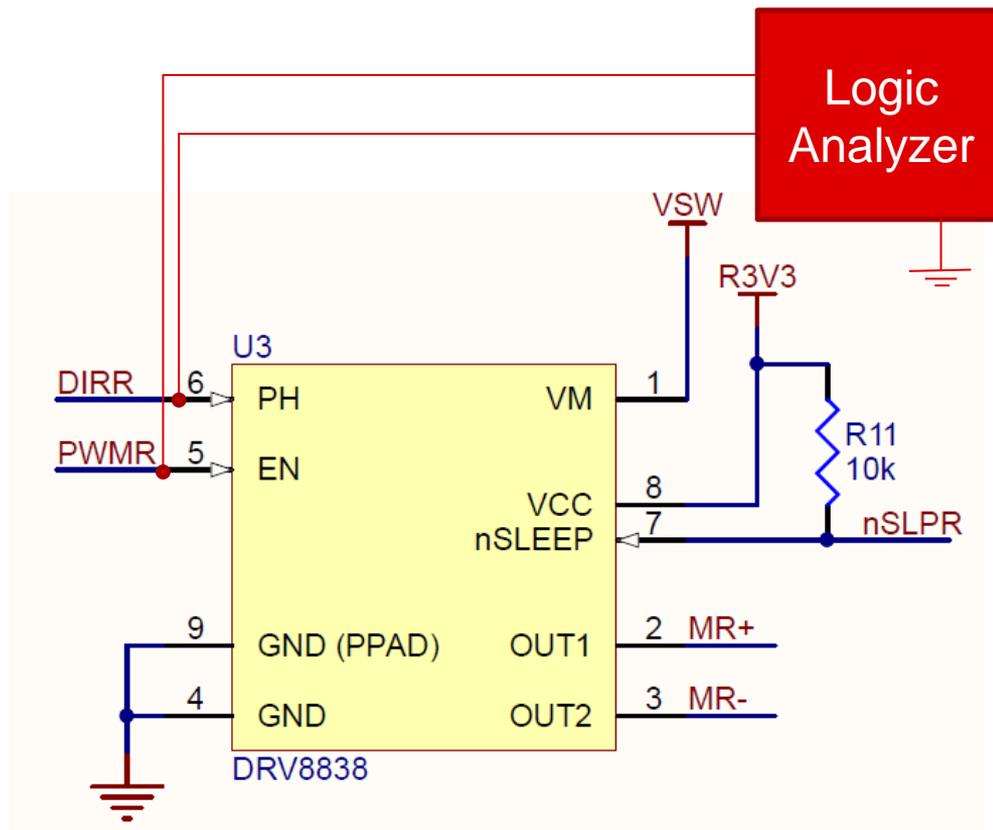
- Input
  - Signals from microcontroller
- Power
  - VSW = 7.2V
  - R3V3 = 3.3V
  - Ground
- Output
  - Signals to motors





# Motor Driver

- Input
  - Signals from microcontroller
- Power
  - VSW = 7.2V
  - R3V3 = 3.3V
  - Ground
- Output
  - Signals to motors

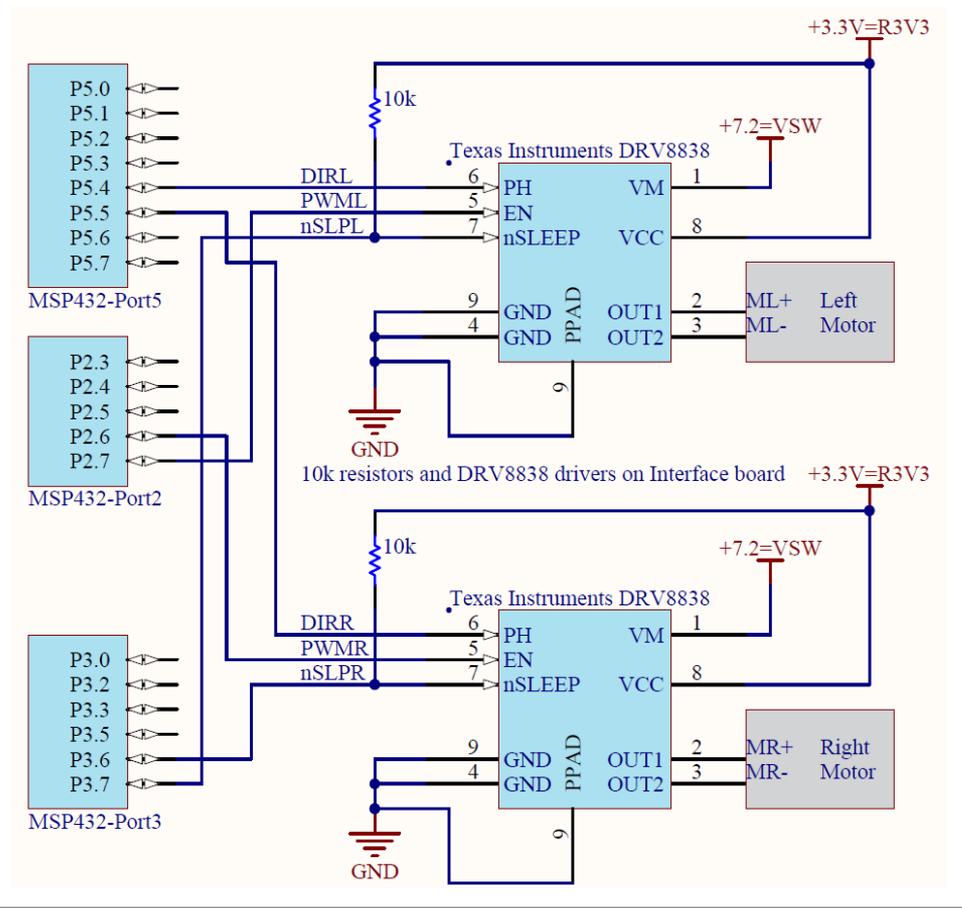




# Introduction to Circuits

## Summary

- Electrical Systems have
  - Inputs
  - Electrical Circuits
  - Outputs
  
- Electrical Circuits
  - Power Source
  - Components
  - Interconnections
  
- Mechanisms for Testing
  - Voltmeter
  - Current meter
  - Signal generator
  - Oscilloscope
  - Logic Analyzer



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