LECTURE I

Introduction to Electrical Engineering and Embedded Systems

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SECTION I

What is an Embedded System?

Embedded Systems

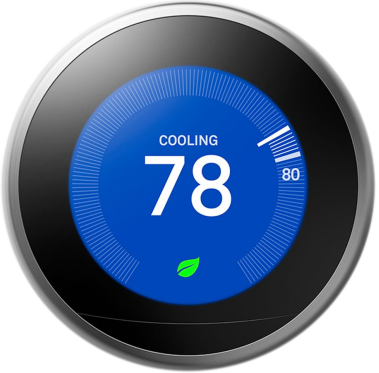
- An **embedded system** is a combination of hardware and software designed for a specific purpose
  - Ex) alarm clock, camera, or MP3 player


  - Contrasts from a **general-purpose system**, like a smartphone or laptop
    - These devices can act as an alarm, camera, and a media player *combined*
    - They typically have much more functionality than an embedded system

Embedded Systems

I/A

What are some more **examples** of embedded systems?



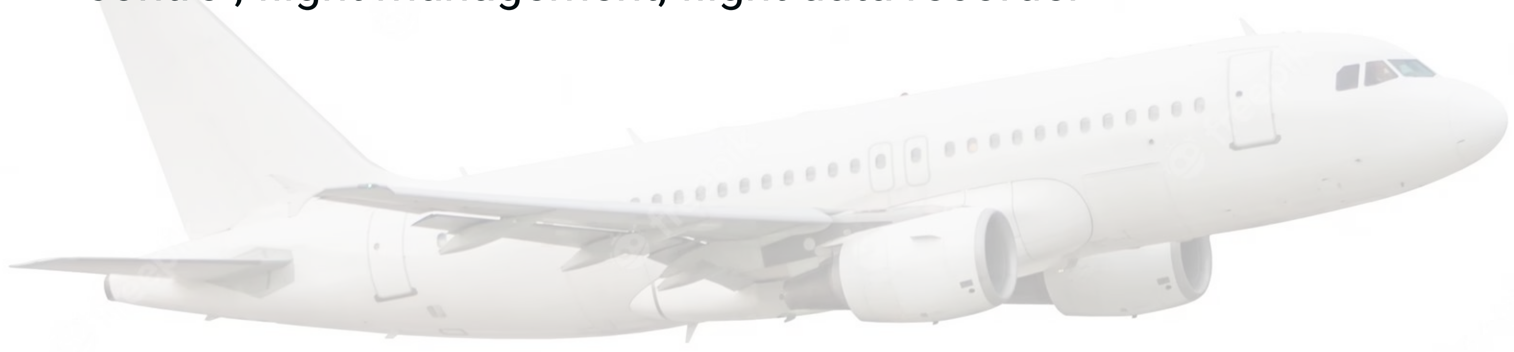
What are some more examples of embedded systems?

Nobody has responded yet.

Hang tight! Responses are coming in.

Embedded Systems

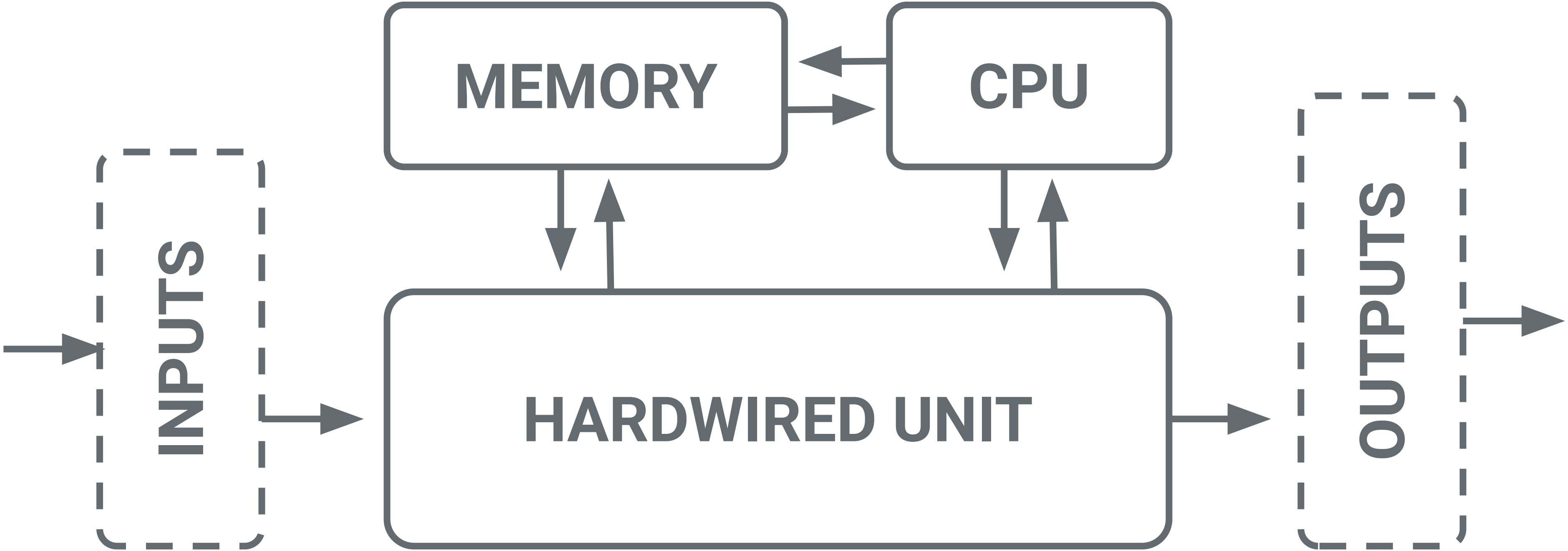
- Large-scale mechanical and electrical systems often consist of **multiple, smaller embedded systems**
  - Each embedded system has a function that supports the larger system
  - Ex) **Airplanes** - in-flight entertainment system, temperature control, speed control, flight management, flight data recorder



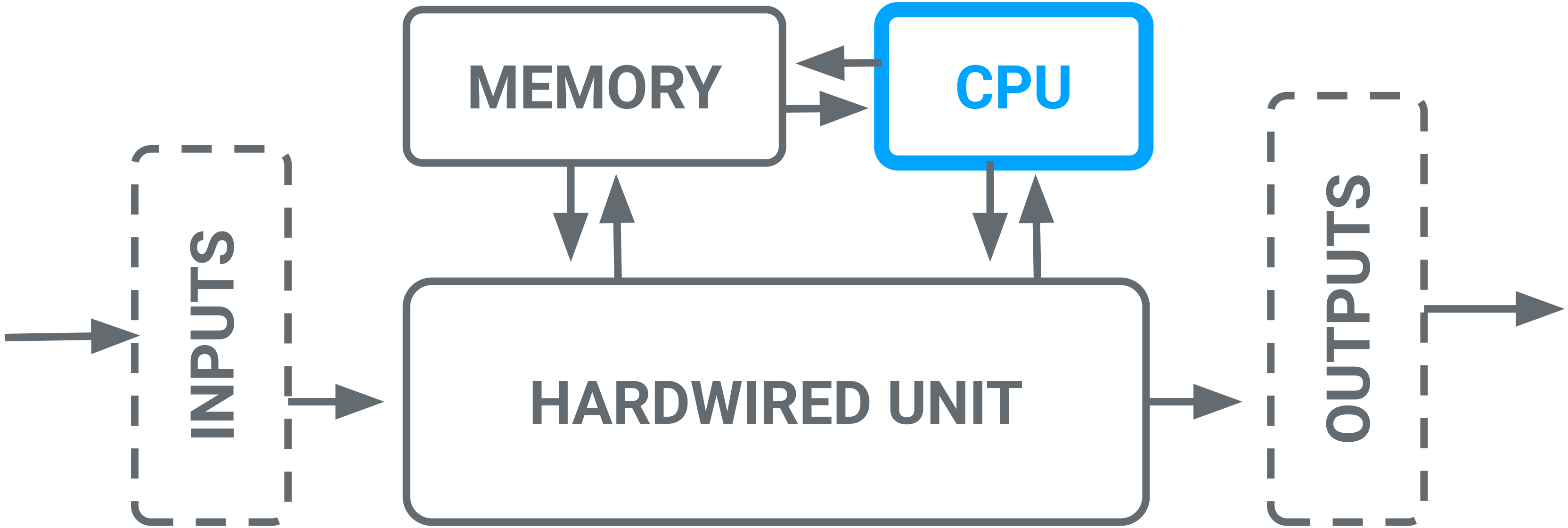
Embedded Systems

- Main components of an embedded system:
  - **Central Processing Unit (CPU)**
  - **Memory**
  - **Hardwired Unit**
  - **Inputs/Sensors**
  - **Outputs**

Embedded Systems

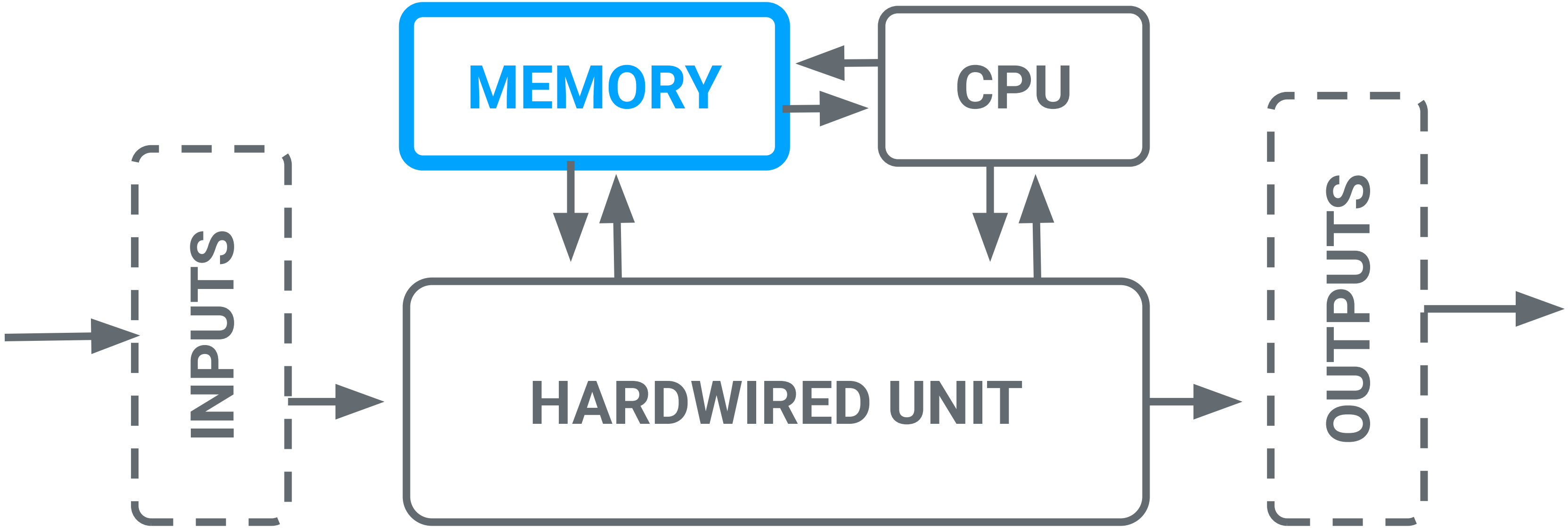


Embedded Systems



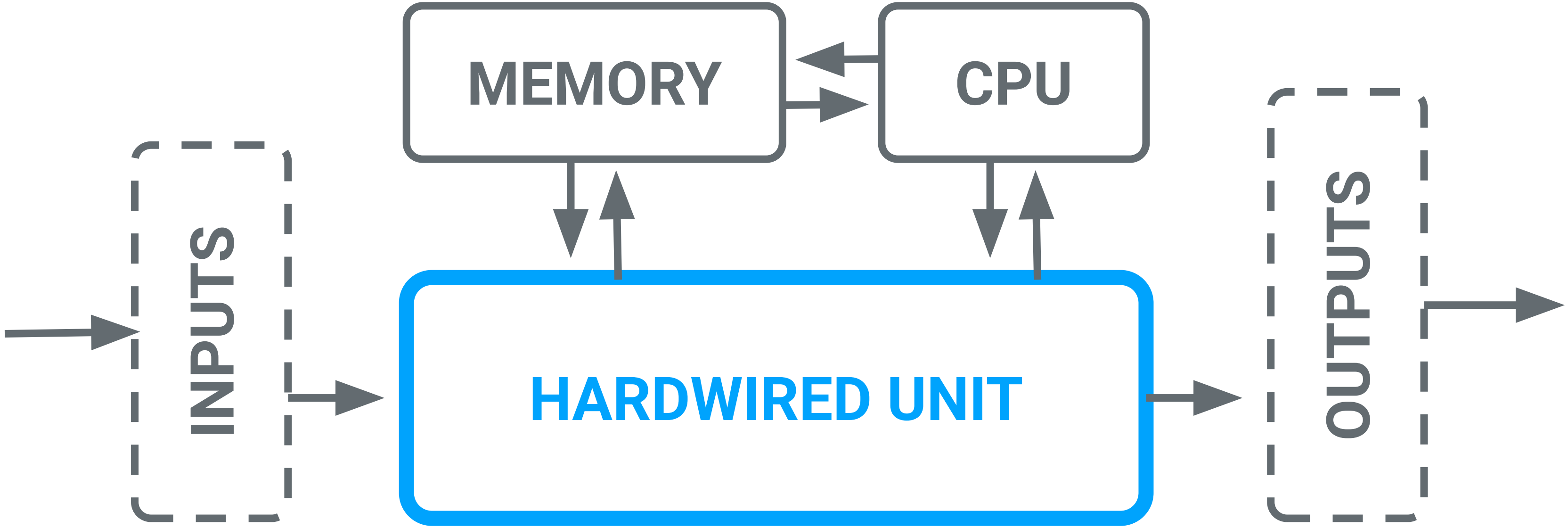
A CPU **executes instructions** provided by a memory unit. These instructions may be mathematical **computations**, memory **data transfer**, or signals to **input and output** ports.

Embedded Systems



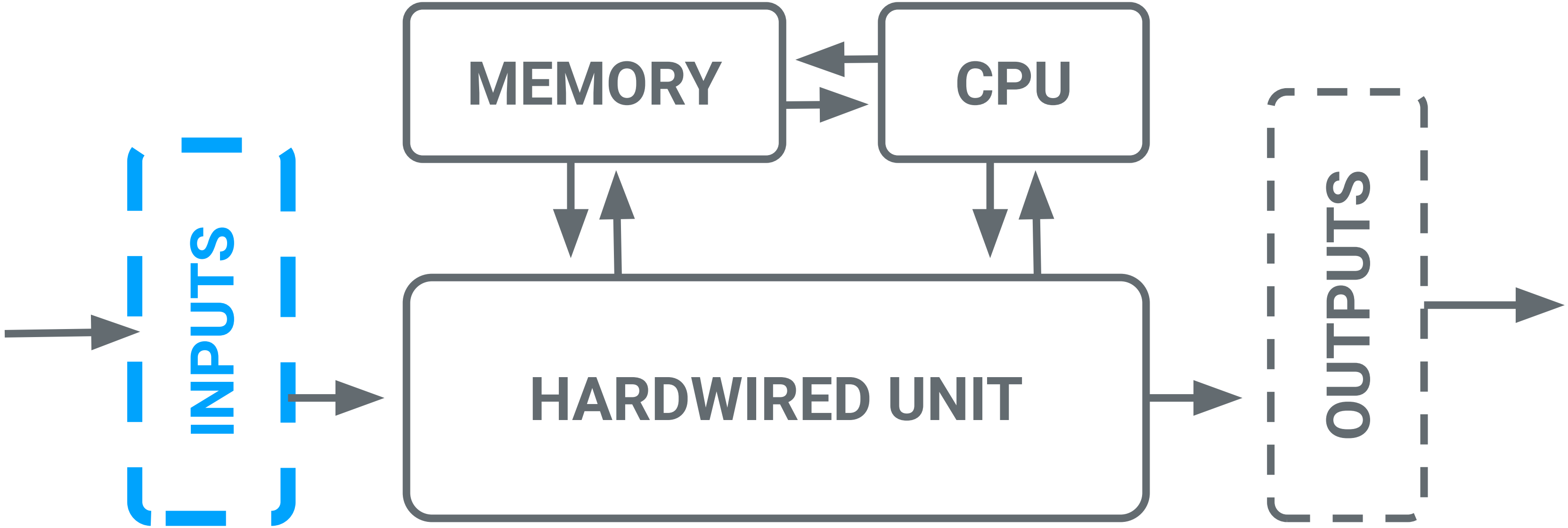
A **memory** **unit stores data and instructions.** There are multiple units of memory, some of which are for short-term storage **(RAM)** while others are long-term **(EEPROM/Flash).**

Embedded Systems



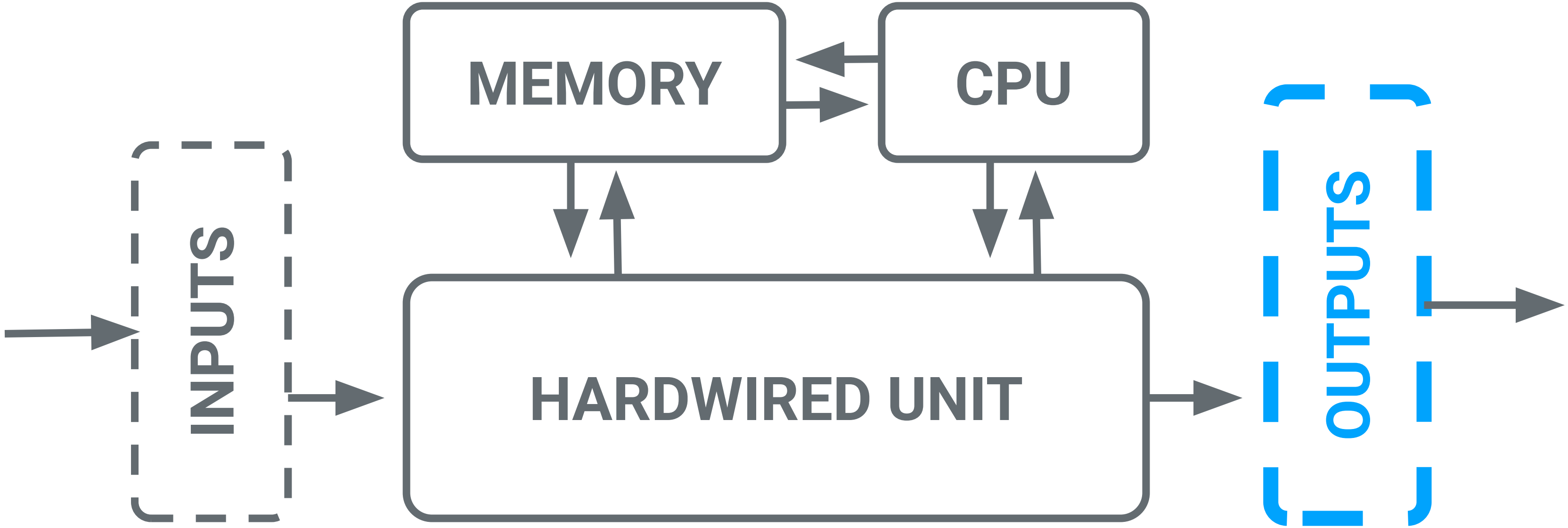
The hardwired unit contains *hardwired* electronics that control the system's input and output. The CPU sends signals to the hardwired unit to perform specific functions (i.e. activate an actuator at a certain port or reset an internal timer).

Embedded Systems



Inputs are sensors and other peripheral devices (a switch, thermometer, microphone, etc.) that send data to the hardwired unit. This data may be stored in memory or interpreted by the CPU.

Embedded Systems



Outputs are devices (actuators, light bulbs, displays, etc.) that are controlled by or receive data from the hardwired unit.

Embedded Systems

- In **Lecture IV**, we discuss the architecture of embedded systems in the context of Arduino
- For now, we will focus on the physics and circuits principles that embedded systems rely on…

Please submit questions about the lecture content.

Nobody has responded yet.

Hang tight! Responses are coming in.

SECTION II

The Science of Electric Circuits

Energy

- **Energy** is the ability to do work
  - In physics class, you learned about potential and kinetic energy
    - **Potential energy** represents the energy stored in an object that has the *potential* to become another form of energy (usually kinetic)
    - **Kinetic energy** is the energy associated with an object’s motion
      - Mechanical motion
      - Radiation/light emission
      - Electron flow
    - **Work** is the *change* in kinetic energy in a system; work creates motion

Energy

I/A

What are some of the **different types** of potential/kinetic energy?

What are some different types of potential/kinetic energy?

Nobody has responded yet.

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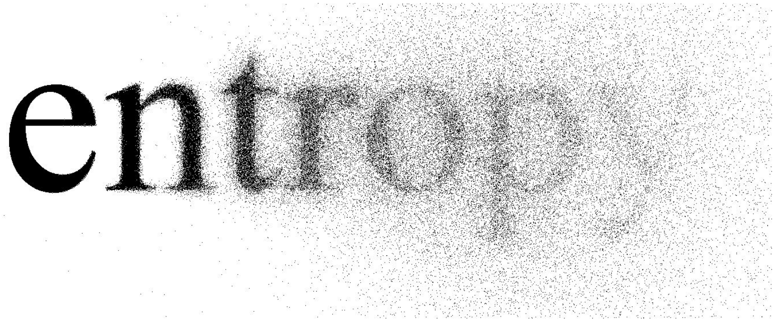
Entropy

- **Nature favors systems with higher entropy**, which increases stability
- In stable systems, **energy is more *randomly* distributed**
    - The **potential energy** of bodies in the system **is reduced and disbursed** as other forms of energy (like thermal energy)

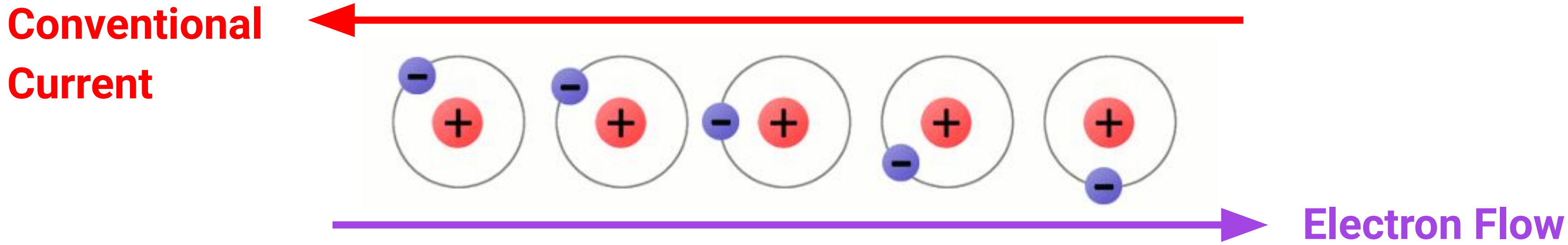


Electricity

- We focus on **electrical energy** - the energy associated with charged particles
  - Charged particles include (but are not limited to) protons and electrons, but we are concerned only with **electrons**
  - Still electrons are boring, but electrons in motion generate **electricity**

Current

- **Current** is the flow of charged particles, usually electrons
  - Current has a magnitude **Amperes** (**A**) and direction
  - **Conventional current** flows in the direction *opposite* to the electron flow



  - But what generates current?

ELECTRIC POTENTIAL

- **Electric potential** is the amount of work needed to move a charged particle between two points
    - Measured in **Volts, V**
- Charged particles move from points of higher electric potential to points of lower electric potential (remember entropy?)
    - … this means that electron flow - ***current*** - is **generated when there is a difference in electric potential** between two points

Voltage

- **Voltage** is the **electric potential difference**
  - Current can flow where **voltage** exists
  - Measured in **Volts, V**
- **Batteries** are a voltage source
  - Current will flow from the **positive (+)** terminal to the **negative (-)** terminal when connected
    - The **positive (+)** terminal has a *higher* potential than the **negative (-)**

Voltage

- **Measuring voltage requires a reference point** because it is the difference in volts between two points

called "**Ground**"/"**GND**"

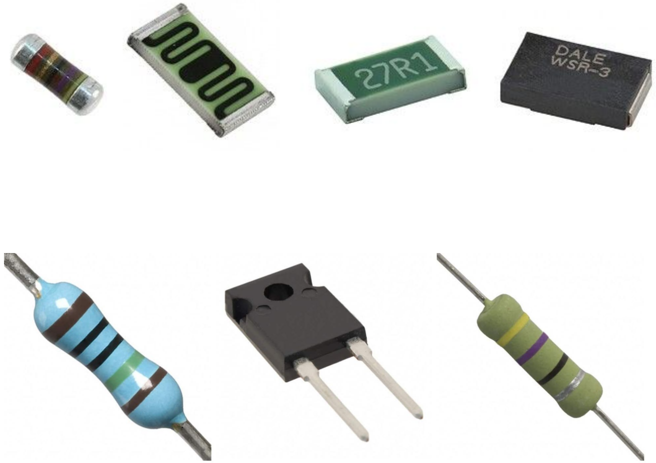
- Using the **negative (-)** terminal of the battery as a reference point…
  - The **positive (+)** terminal has a **voltage** of **+9V**
  - The **negative (-)** terminal has a **voltage** of **+0V**
    - **Why zero?** There is no potential difference at the same location as the reference point

Conductors

- Current cannot flow without a path for the electrons to move
- A **conductor** is a material in which electrons can move freely
  - If a **voltage** exists across a conductor, current will flow
- Common conductors include:
  - **Copper**
  - Gold
  - Silver
  - Aluminum

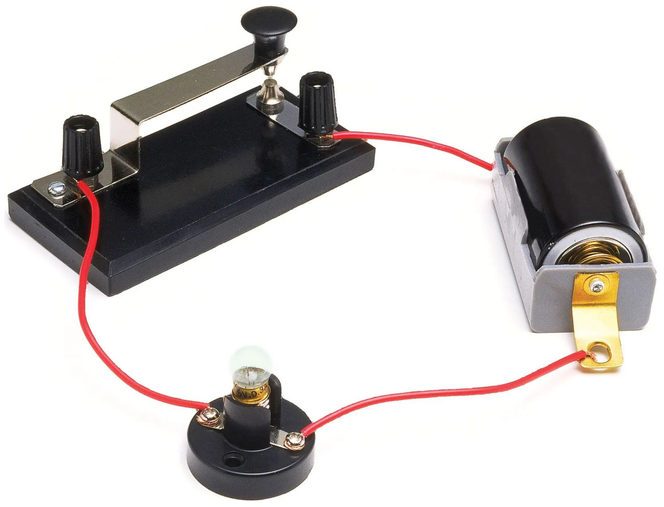
Resistors

- A **resistor** is a component that reduces the flow of current
- **Resistance, ohms (Ω)** is the ability to *resist* current



Circuits

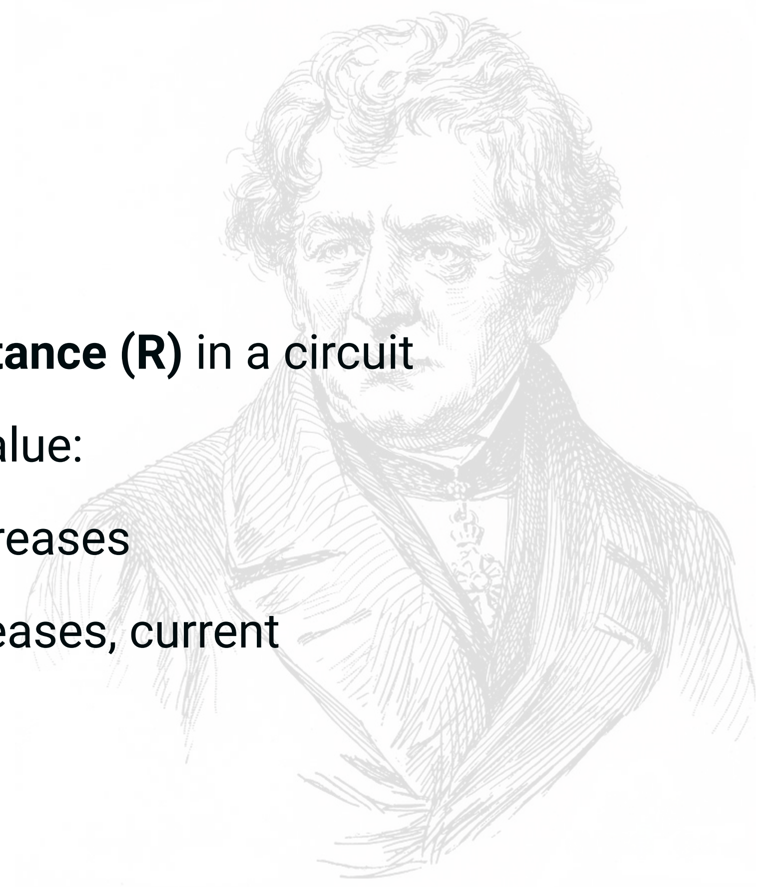
- A **circuit** is a **closed loop** path where electrons can flow
- An **open circuit contains a discontinuity** that disrupts the current flow
  - Ex) An open switch on a circuit prevents current from flowing
- A **closed circuit** has a **fully continuous** path for current to flow through



Ohm's Law

$$V = IR$$

- Relates the **voltage (V)**, **current (I)**, and **resistance (R)** in a circuit
- Suppose we hold the voltage at a constant value:
  - As the resistance increases, current decreases
  - In the opposite case, as resistance decreases, current increases



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SECTION III

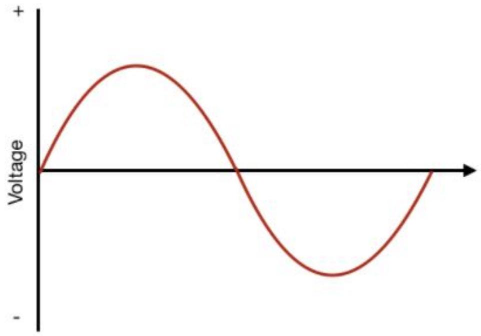
Building DC Circuits

AC/DC Circuits

- This course's projects focus on **direct current (DC)** circuits where the **voltage and direction of current is constant**
- Other circuits rely on **alternating current (AC)** where the **current's direction oscillates** back and forth

Direct Current

Alternating Current



Circuit Components

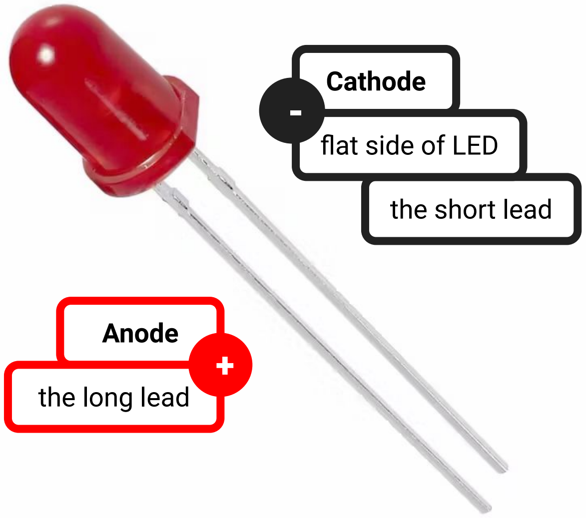
- All circuits require the following three components:
  - A **voltage source** to provide electrical energy and generate current
    - Ex) DC generators, batteries, solar cells
  - A **conductive path** for current to flow
    - Ex) wire, circuit board traces, occasionally air (lightning)
  - A **load** to expend the electrical energy
    - Ex) light bulbs, sound speakers, motors, occasionally you

Polarized Components

- A polarized component is one which can only be **connected** to the circuit **in one direction**
    - Ex) Batteries, LEDs, Electrolytic Capacitors
    - These components have a **positive (anode)** and **negative (cathode)** terminal
        - Remember that current flows from **positive** to **negative**
        - Terminals may be **distinguished by lead length**, **labels**, or **notches** on the component
        - Sketches of circuits will also indicate the components' polarities

LEDs

- The **Light Emitting Diode (LED)** is a component that emits light (big surprise)
  - As a **diode**, the LED is **polarized** and has a constant **forward voltage** between its anode and cathode terminals (in normal operating conditions)
  - Refer to the LED's **datasheet** to find its **operating conditions**
    - Recommended operating current
    - Forward Voltage

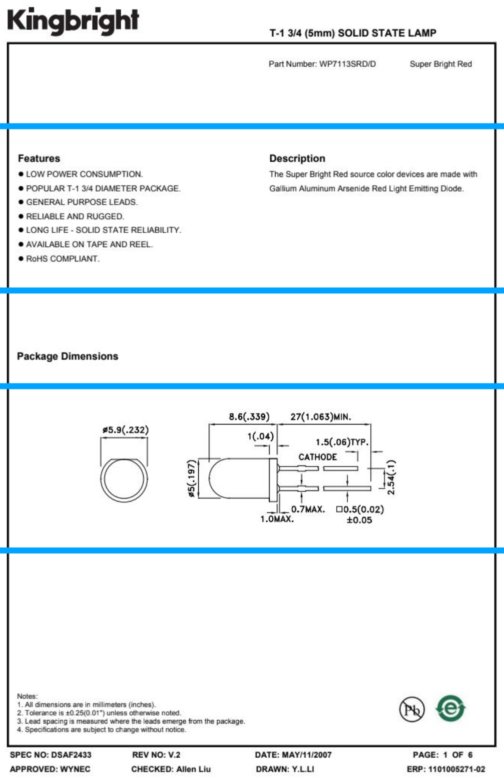


Datasheets

- The manufacturer of a component or device creates a **datasheet** to document its **characteristics** and **operating conditions**
- Common features of a datasheet:
  - **Summary**
  - Functional block diagram or schematic diagram
  - Pinout
  - **Recommended operating conditions**
  - Graphs
  - Truth Tables
  - Timing Diagrams

We will only focus on these two features today

Datasheets


Kingbright

T-1 3/4 (5mm) SOLID STATE LAMP

Part Number: WP7113SRD/D Super Bright Red

Features

- LOW POWER CONSUMPTION.
- POPULAR T-1 3/4 DIAMETER PACKAGE.
- GENERAL PURPOSE LEADS.
- RELIABLE AND RUGGED.
- LONG LIFE - SOLID STATE RELIABILITY.
- AVAILABLE ON TAPE AND REEL.
- RoHS COMPLIANT.

Description

The Super Bright Red source color devices are made with Gallium Aluminum Arsenide Red Light Emitting Diode.

Package Dimensions

Notes:
1. All dimensions are in millimeters (inches).
2. Tolerance is ±0.25(0.01") unless otherwise noted.
3. Lead spacing is measured where the leads emerge from the package.
4. Specifications are subject to change without notice.

SPEC NO: DSAF2433	REV NO: V.2	DATE: MAY/11/2007	PAGE: 1 OF 6
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Summary

- The first page of a datasheet is often a **summary** of the device
- It contains a **description** of the device and its **features**
- It may also include a **high level schematic** of the device and its **dimensions**

Datasheets

Kingbright

Selection Guide

Part No.	Dice	Lens Type	Iv (mcd) [2] @ 20mA		Viewing Angle [1]
			Min.	Typ.	2θ1/2
WP7113SRD/D	Super Bright Red (GaAlAs)	RED DIFFUSED	180	250	30°

Notes:
1. θ1/2 is the angle from optical centerline where the luminous intensity is 1/2 the optical centerline value.
2. Luminous intensity/ luminous Flux: +/-15%.

Electrical / Optical Characteristics at TA=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λpeak	Peak Wavelength	Super Bright Red	660		nm	IF=20mA
λD [1]	Dominant Wavelength	Super Bright Red	640		nm	IF=20mA
Δλ1/2	Spectral Line Half-width	Super Bright Red	20		nm	IF=20mA
C	Capacitance	Super Bright Red	45		pF	VF=0V;f=1MHz
VF [2]	Forward Voltage	Super Bright Red	1.85	2.5	V	IF=20mA
IR	Reverse Current	Super Bright Red		10	uA	VR = 5V

Notes:
1.Wavelength: +/-1nm.
2. Forward Voltage: +/-0.1V.

Absolute Maximum Ratings at TA=25°C

Parameter	Super Bright Red	Units
Power dissipation	75	mW
DC Forward Current	30	mA
Peak Forward Current [1]	155	mA
Reverse Voltage	5	V
Operating/Storage Temperature	-40°C To +85°C	
Lead Solder Temperature [2]	260°C For 3 Seconds	
Lead Solder Temperature [3]	260°C For 5 Seconds	

Notes:
1. 1/10 Duty Cycle, 0.1ms Pulse Width.
2. 2mm below package base.
3. 5mm below package base.

SPEC NO: DSAF2433 REV NO: V.2 DATE: MAY/11/2007 PAGE: 2 OF 6
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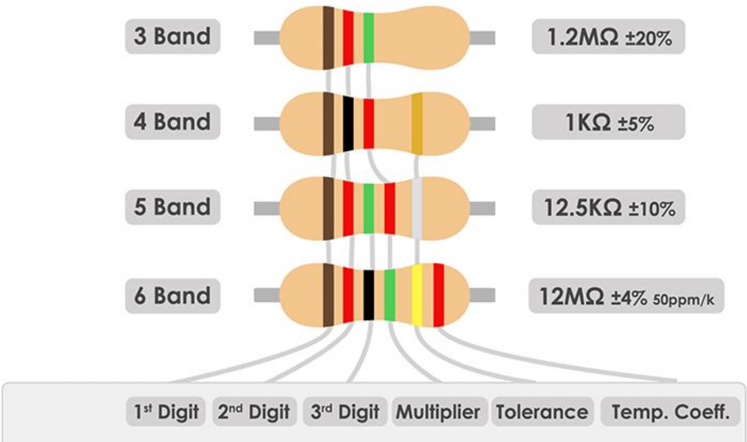
Recommended Operating Conditions

- This section of the datasheet usually contains a **suggested current and/or voltage** as input to the device
- **Absolute maximum ratings** are the limit for operating the device safely
  - Use reasonably lower values than ones listed as the maximums

Resistor Bands

- The **resistance** of many **axial resistors** (which have a lead at either end of the resistor) can be determined using their **colored bands**



	1st Digit	2nd Digit	3rd Digit	Multiplier	Tolerance	Temp. Coeff.
Black	0	0	0	x 10^{0}		250 (U)
Brown	1	1	1	x 10^{1}	±1%	100 (S)
Red	2	2	2	x 10^{2}	±2%	50 (R)
Orange	3	3	3	x 10^{3}	±3%	15 (P)
Yellow	4	4	4	x 10^{4}	±4%	25 (Q)
Green	5	5	5	x 10^{5}	±0.5%	20 (Z)
Blue	6	6	6	x 10^{6}	±0.25%	10 (Z)
Violet	7	7	7	x 10^{7}	±0.1%	5 (M)
Grey	8	8	8	x 10^{8}	±0.05%	1 (K)
White	9	9	9	x 10^{9}		
Gold	-	-	-	x 10^{-1}	±5%	
Silver	-	-	-	x 10^{-2}	±10%	

Please submit questions about the lecture content.

Nobody has responded yet.

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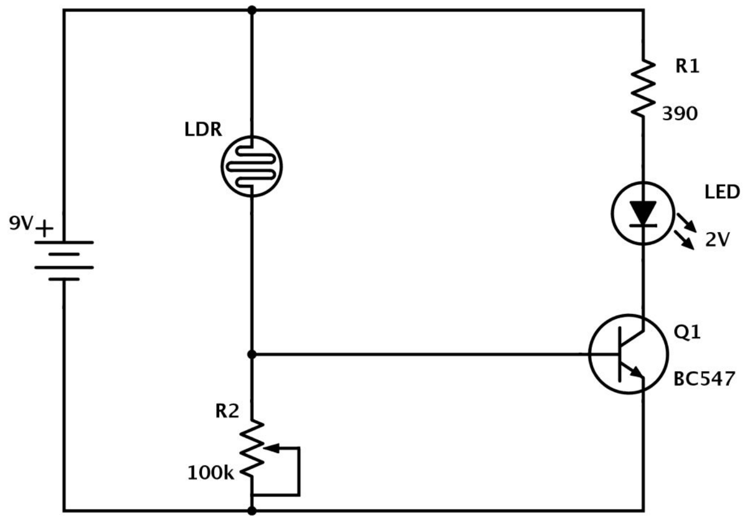
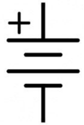
Schematics

- A **schematic** diagram defines the **connections between components** in a circuit
- Schematics also **summarize the components' values**
- Each component has a **unique symbol** associated with it

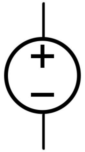


Schematic Symbols

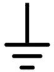
Battery



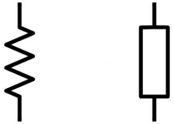
Voltage Source



Ground

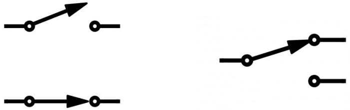


Resistor

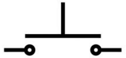


Potentiometer

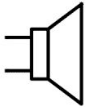
Switches



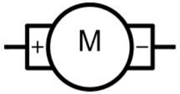
Pushbutton



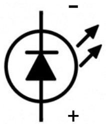
Speaker



DC Motor

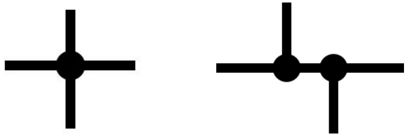


LED

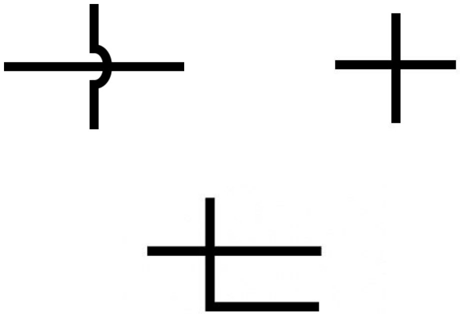


Schematic Connections

Connected Wires



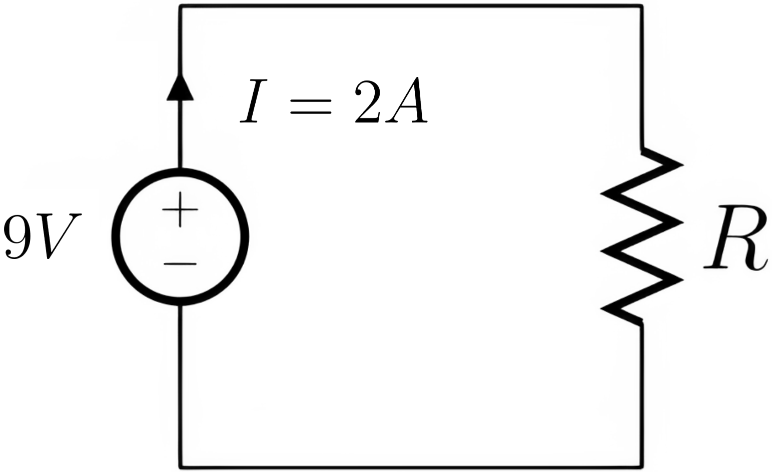
Unconnected Wires

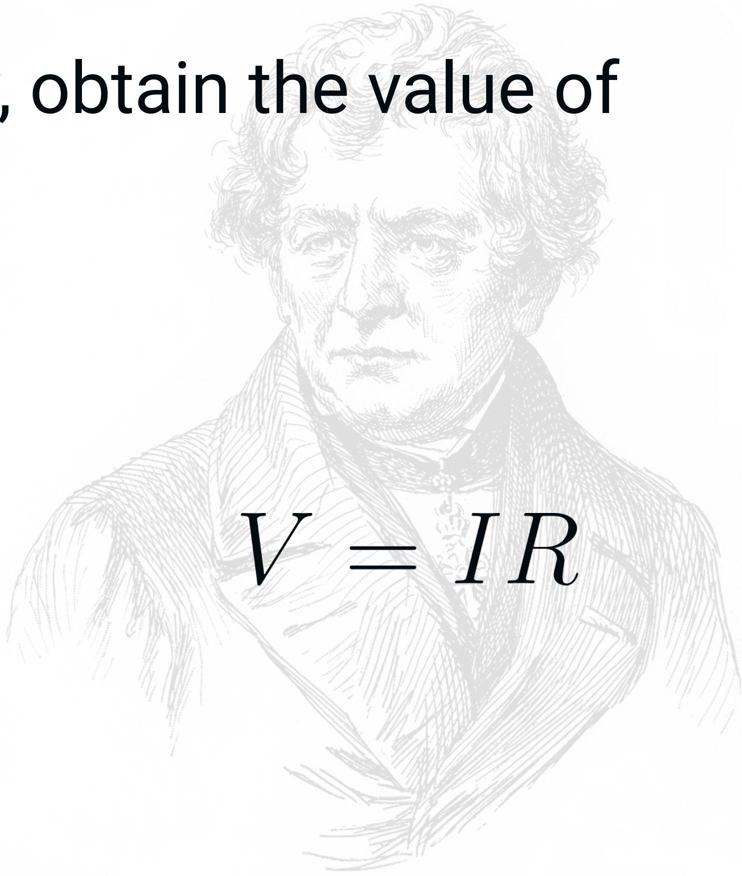


Applying Ohm’s Law

I/A

Given the circuit schematic below, obtain the value of resistor (**R**).

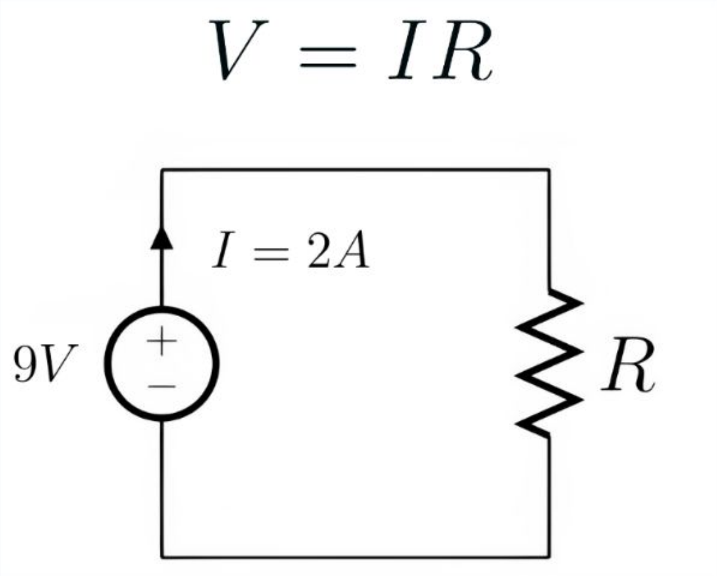




$$V = IR$$

Given the circuit schematic below, obtain the value of resistor (R).

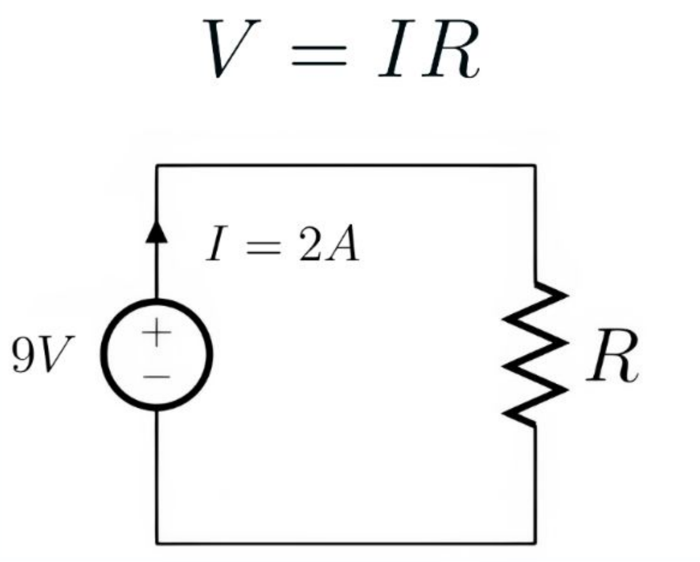
0



- 1.8
- 2.3
- 4.5
- 5.2
- None of the above

Given the circuit schematic below, obtain the value of resistor (R).

0



1.8 — 0%

2.3 — 0%

4.5 — 0%

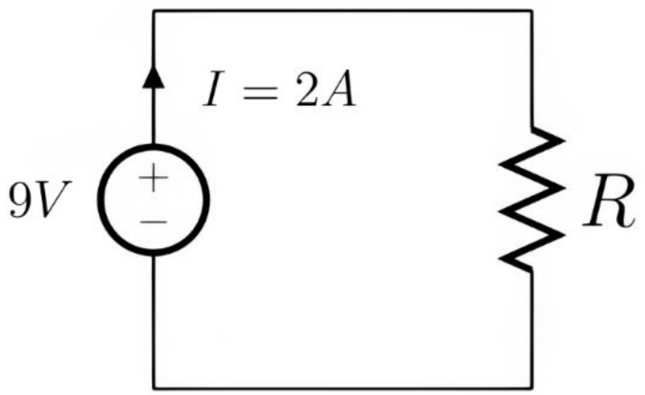
5.2 — 0%

None of the above — 0%

Given the circuit schematic below, obtain the value of resistor (R).

0

$$V = IR$$



1.8

0%

2.3

0%

4.5

0%

5.2

0%

None of the above

0%

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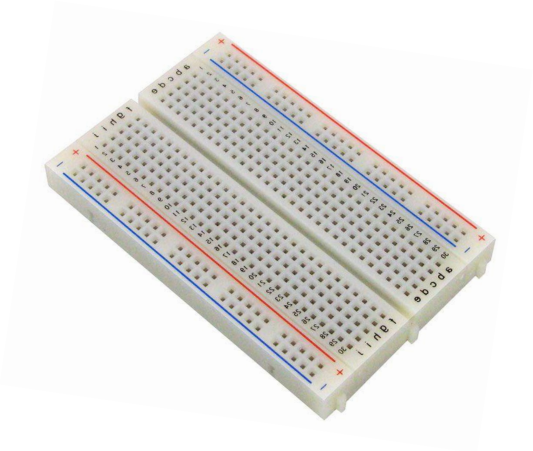
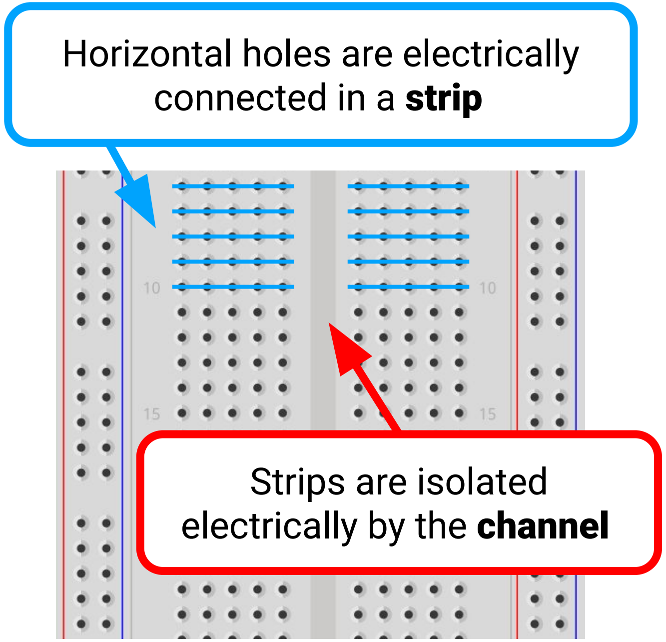
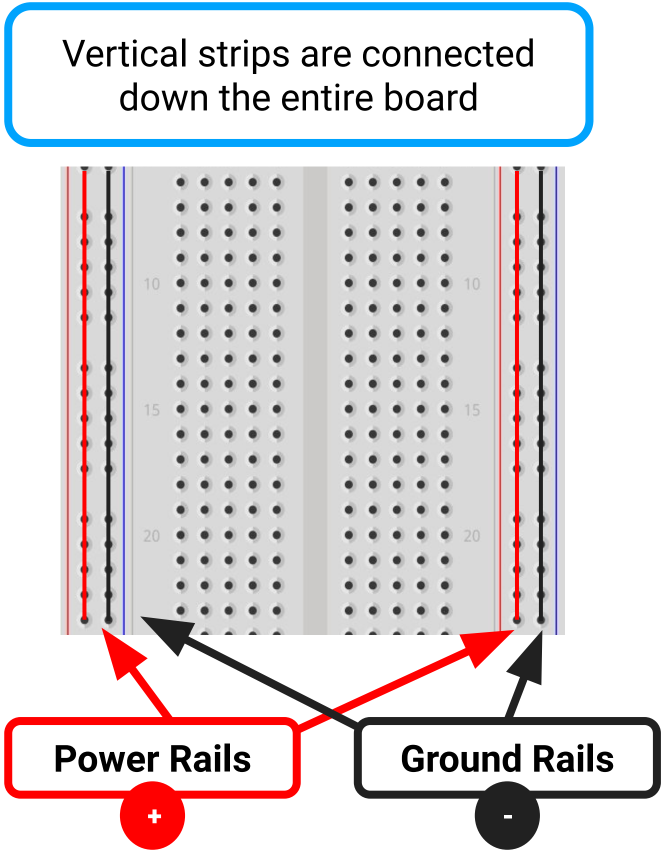
Breadboards

- A **breadboard** is a reusable board for **prototyping** your circuits
- Inside the breadboard are **conductive metal strips**
    - When you insert components into holes of the same strip, current can flow between those components



Breadboards

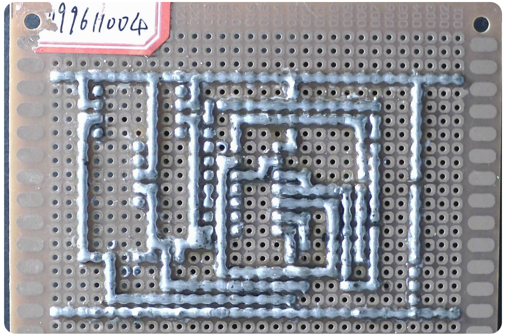




Soldering

- Final circuit designs are often soldered onto **printed circuit boards (PCBs)** or **perfboards**
- Soldering is a process that joins circuit components together with a filler metal called **solder**

Printed Circuit Board



Perfboard

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“In the matters of **soldering**, the **wide blade tip** is adequate for **removing components**. The **chisel-like, finer tip** is suited for **attaching components**. However, the **finest, most pointed tip** is to be **reserved for combat**.”

Miyamoto Musashi (circa 1620)

Famous Misquotes

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