LECTURE I

Introduction to Electrical Engineering and Embedded Systems

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

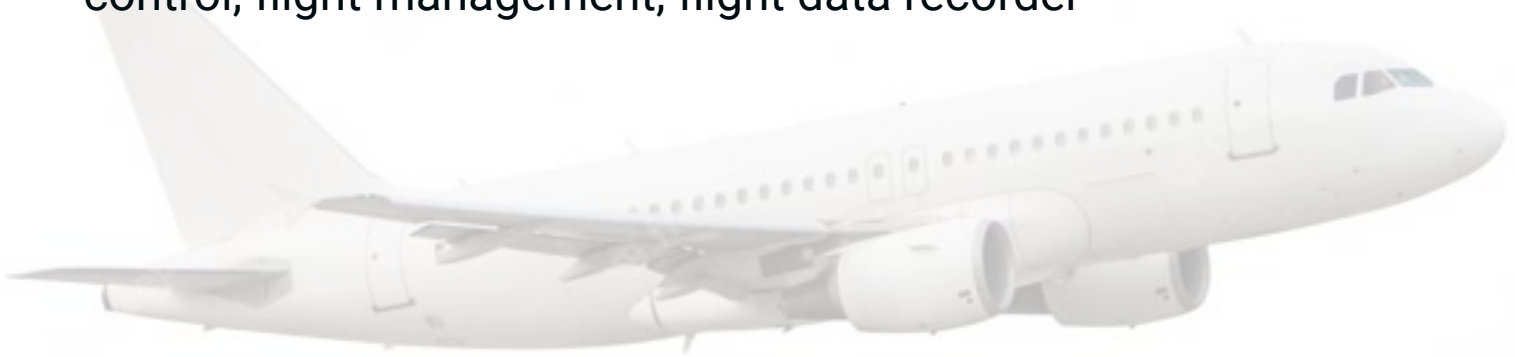
Embedded Systems

I/A

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

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

- 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…

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

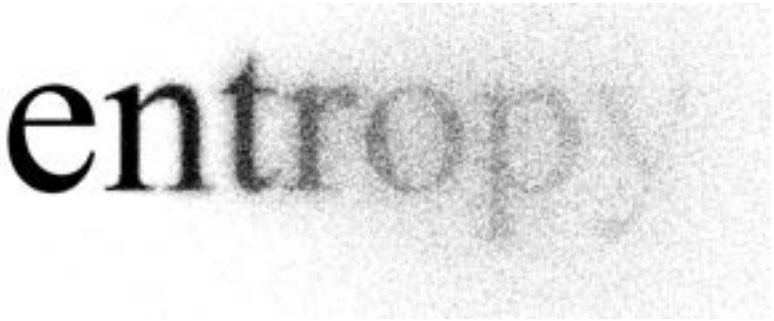
Energy

I/A

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

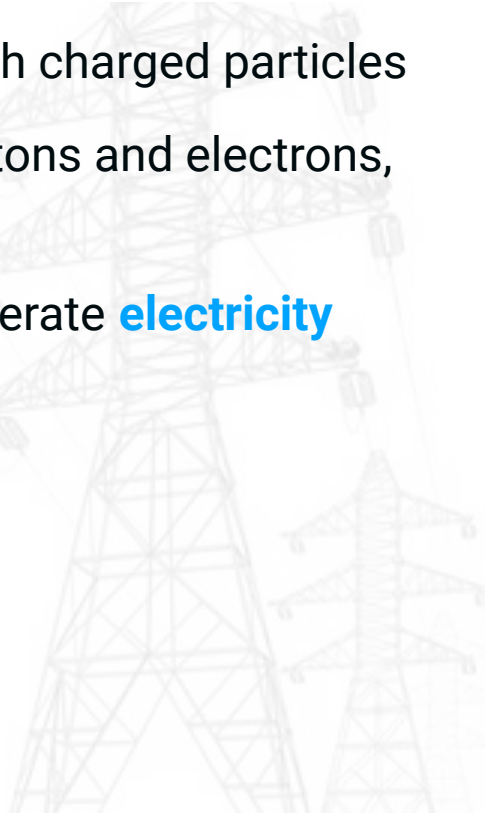
Entropy

- **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)



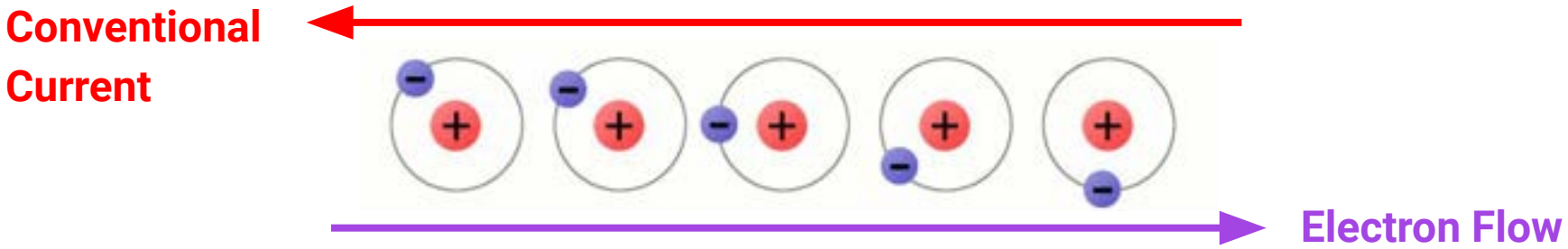
Electricity

- 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
- 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

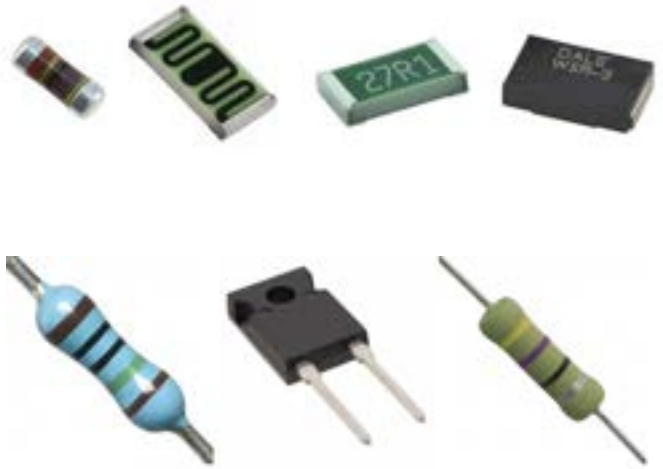
called “**Ground**”/”**GND**”

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**, measured in **ohms (Ω)**, is the ability to *resist* current

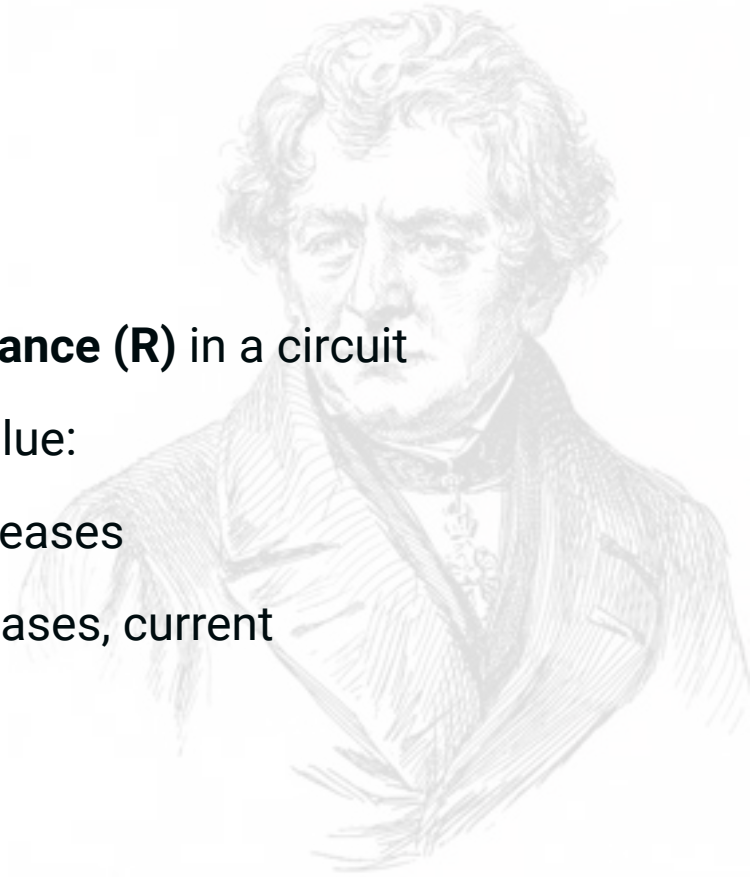


Circuits

- 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

SECTION III

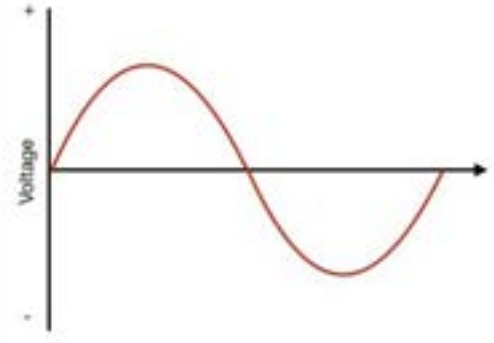
Building DC Circuits

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

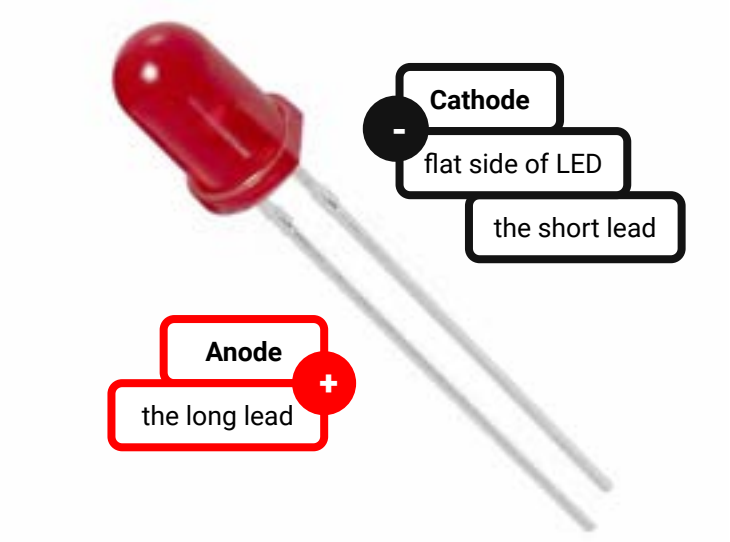
- All circuits require the following three components:
  - A **voltage source** to provide electrical energy and generate current
    - Ex) DC generators, batteries, solar cells
  - A **conductive path** for current to flow
    - Ex) wire, circuit board traces, occasionally air (lightning)
  - A **load**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

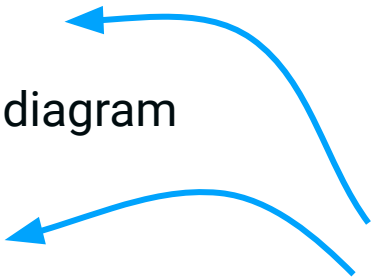
LEDs

- 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



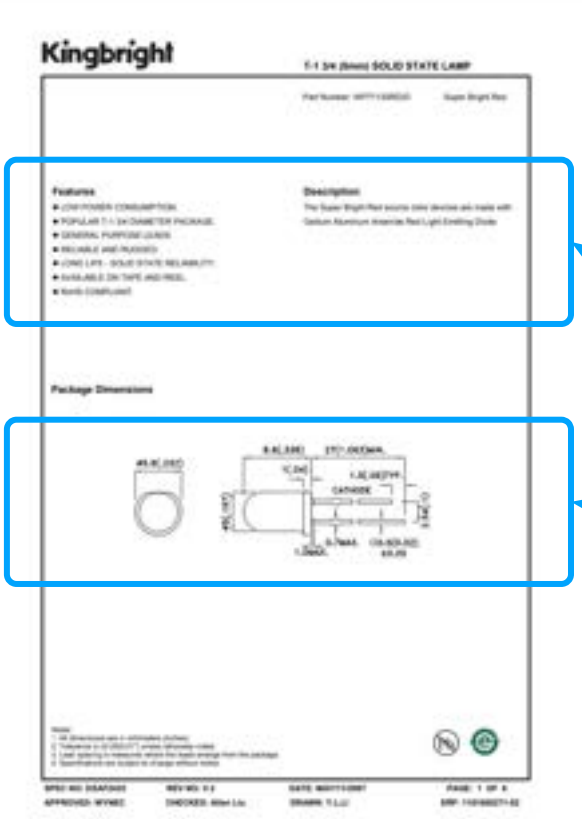
Datasheets

- 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

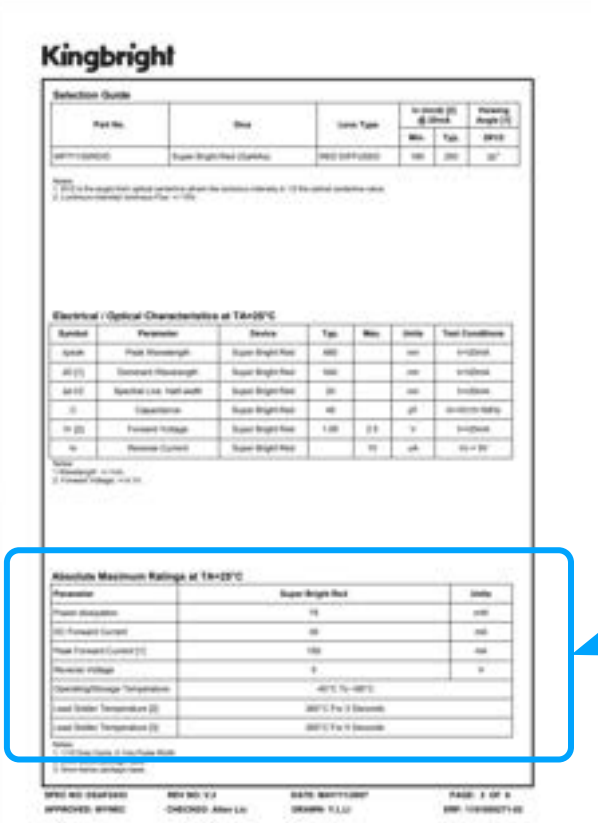
Datasheets



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

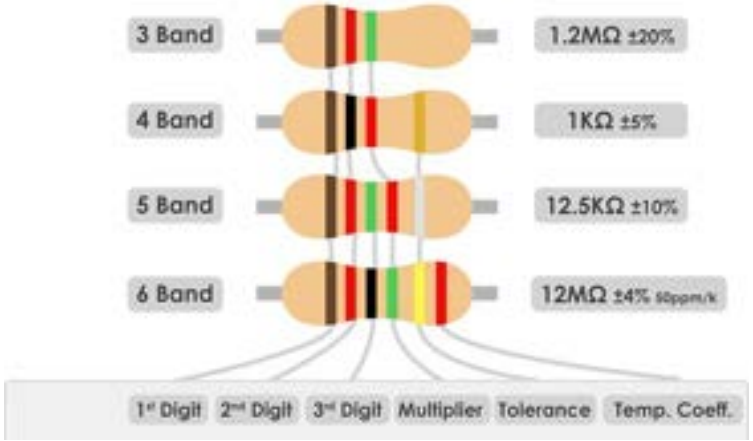


Recommended Operating Conditions

- 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

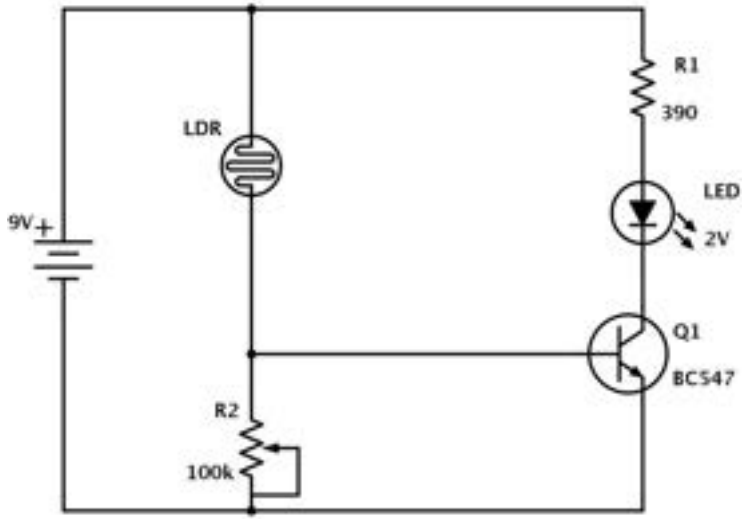
- The **resistance** of many **axial resistors** (which have a lead at either end of the resistor) can be determined using their **colored bands**



	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%	

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

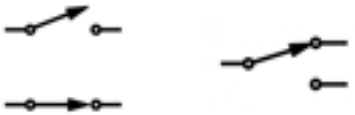
Voltage Source

Ground

Resistor

Potentiometer

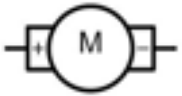
Switches



Pushbutton

Speaker

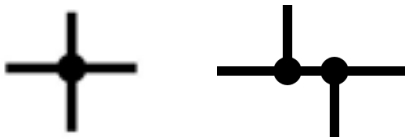
DC Motor



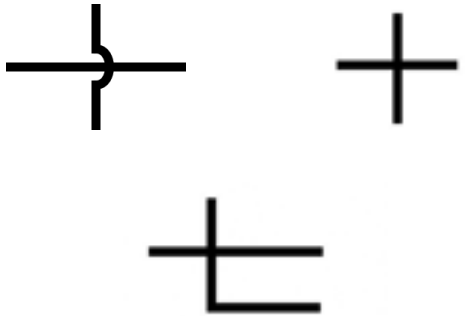
LED

Schematic Connections

Connected Wires



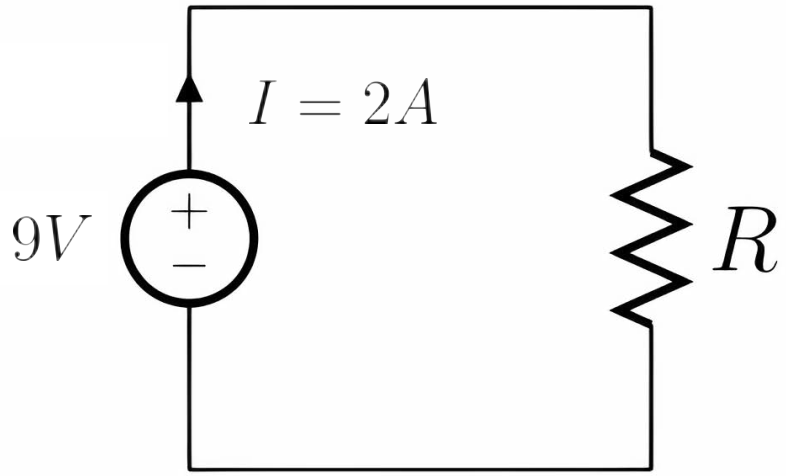
Unconnected Wires

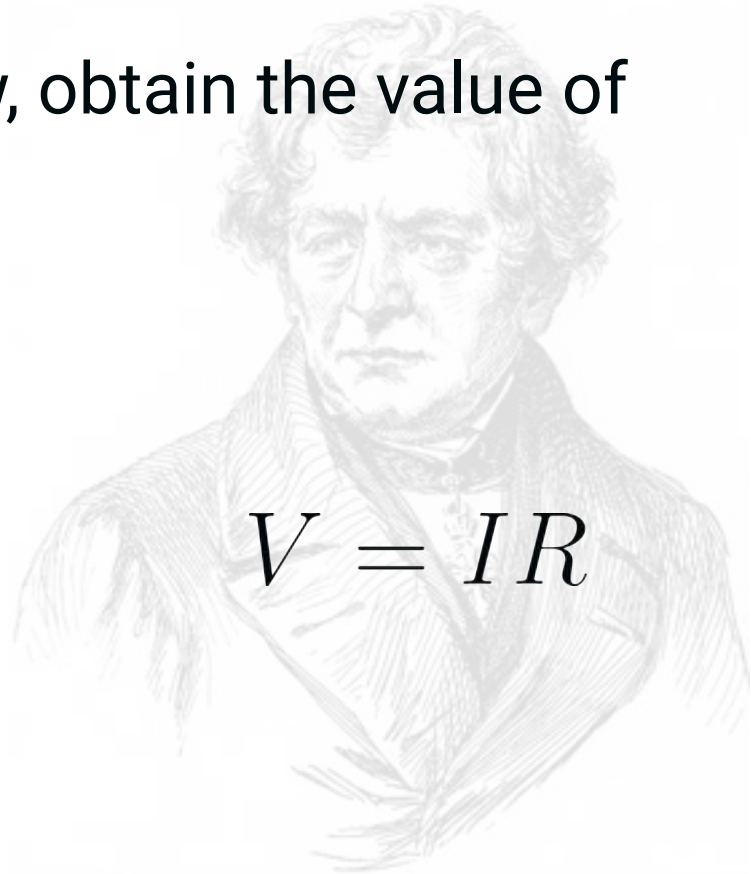


Applying Ohm's Law

I/A

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

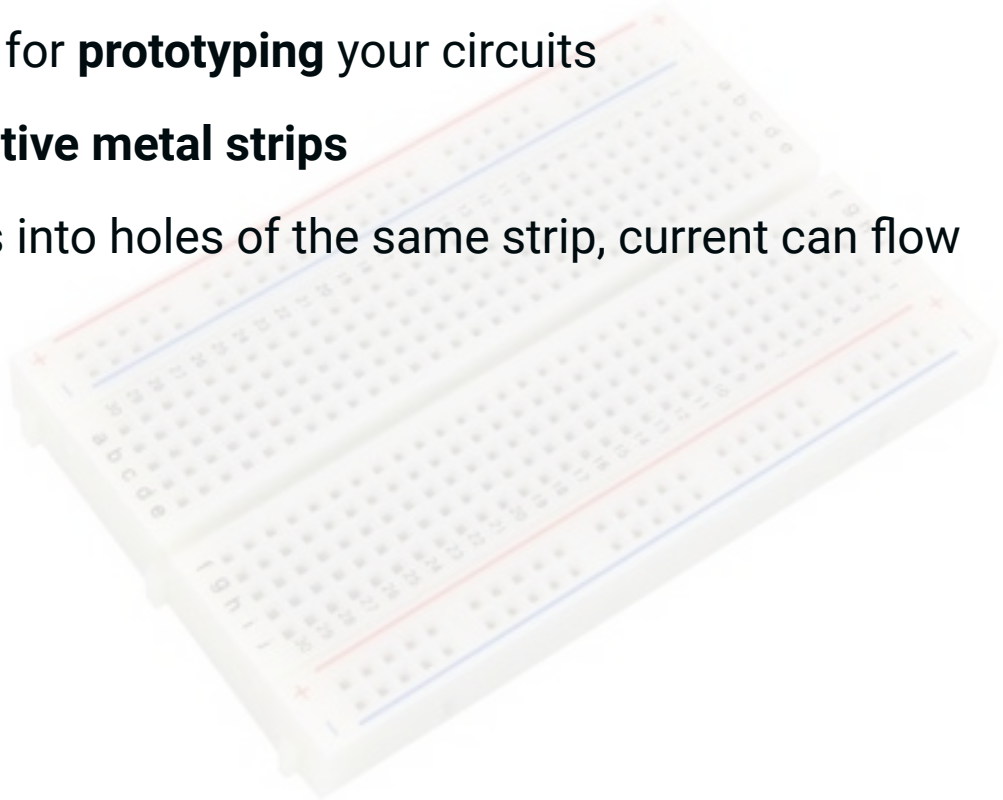




$$V = IR$$

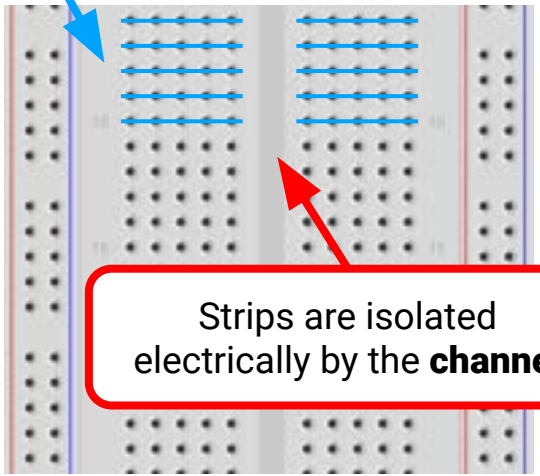
Breadboards

- 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



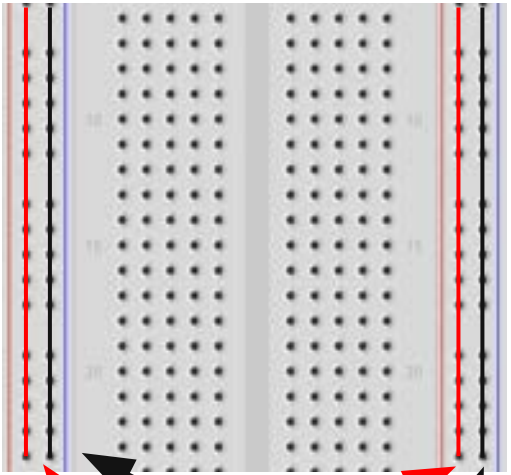
Breadboards

Horizontal holes are electrically connected in a **strip**



Strips are isolated electrically by the **channel**

Vertical strips are connected down the entire board



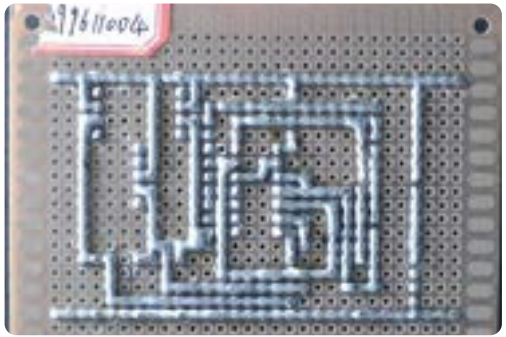
Power Rails (+)

Ground Rails (-)

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

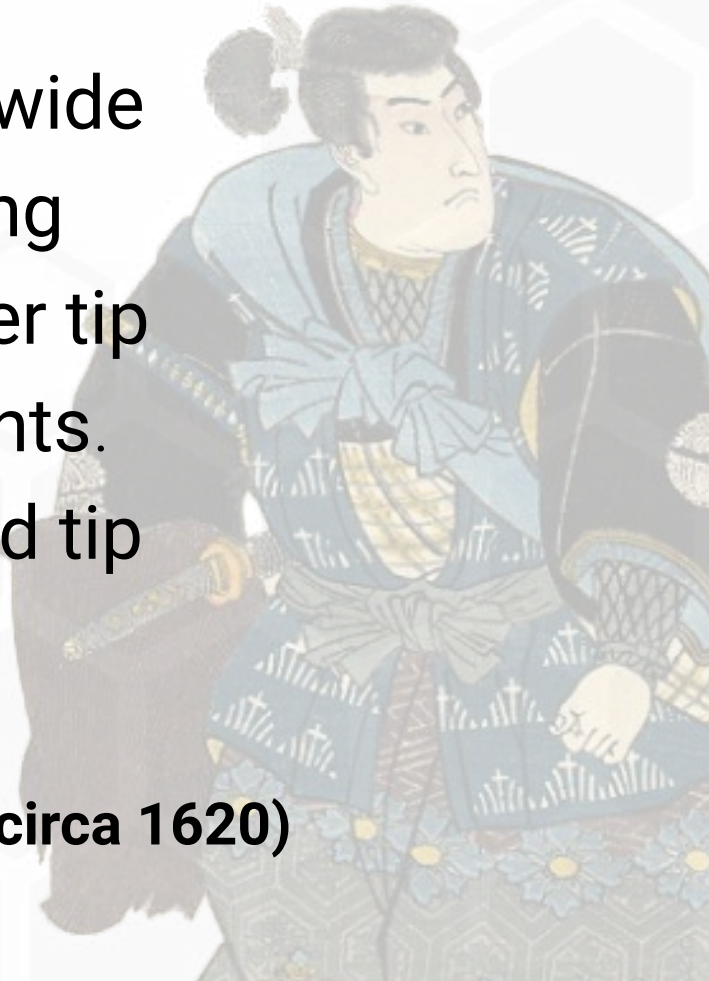


Perfboard

“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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