ELECTRONICS 101

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WHAT IS ELECTRICITY?

Electricity is a form of energy resulting from the existence of charged particles: **Electrons** and **Protons**

Electrons and protons have equal and opposite electric charges, with electrons having the negative charge and protons the positive.
Note: Opposite charged particles are attracted to each other.

Although protons are relatively static, electrons tend to move from one object to another. Electrons can move through certain materials easier than others. These are conductors or semi-conductors. Some materials block the movement of electrons. These are insulators.

Resistance is the measure of the ability of electrons to move through a material.

The attractive force between positive and negative charges is an electromotive force called voltage. Negative electrons move toward a positive voltage by way of a conductor. This flow of electrons is referred to as an electric current.

ELECTRIC CURRENT TYPES

There are two types of electric current types:
Alternating Current (AC), and **Direct Current** (DC).

In AC, the direction electricity flows throughout the circuit is constantly reversing.
The frequency rate of this reversal is measured in Hertz (reversals per second).
So, when they say that the US power supply is 60 Hz, what they mean is that it is reversing 120 times per second (twice per cycle).

In DC, electricity flows in one direction between power and ground.
In this arrangement there is always a positive source of voltage and ground (0V) source of voltage.

Generally, any modern electronic device with computational ability uses DC.
The reason is that they use specific voltage levels to indicate binary/logical states.

CONDUCTORS, SEMI-CONDUCTORS, INSULATORS

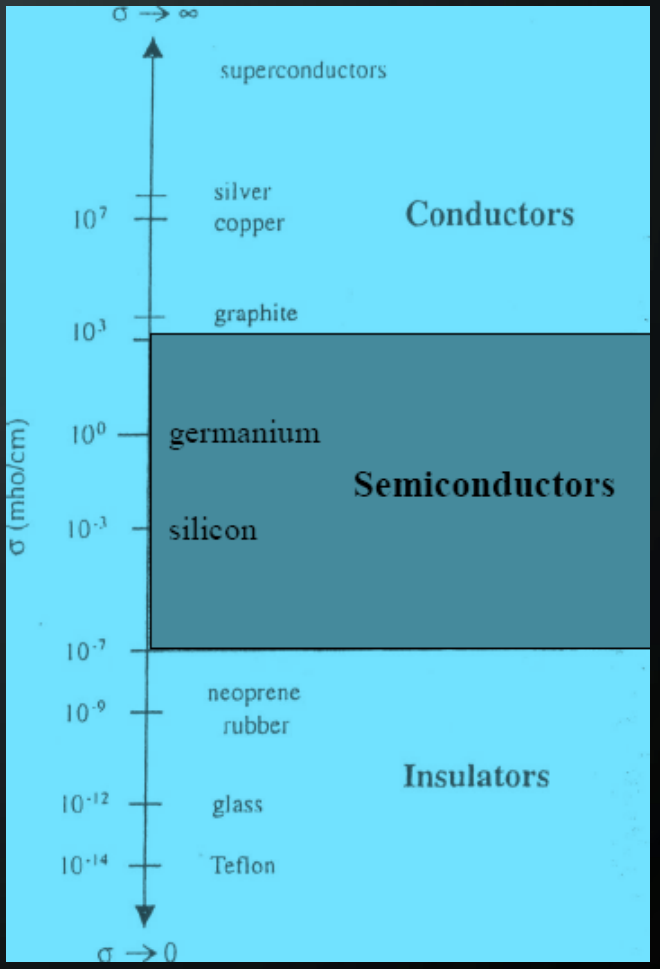
Materials that permit flow of electrons are called **Conductors** (e.g., gold, silver, copper, etc.).

Materials that block flow of electrons are called **Insulators** (e.g., rubber, glass, Teflon, mica, etc.).

Materials whose conductivity falls between those of conductors and insulators are called **Semiconductors**.

Semiconductors are "part-time" conductors whose conductivity can be controlled.

An **Electrode** is a solid conductor that carries electric current. (e.g. component lead wires)



SILICON SEMI-CONDUCTORS

Many electronic components contain semiconductors and Silicon is the most common material used to build semiconductor devices.

Si is spun and grown into a crystalline structure in wafers to make electronic devices. Materials like phosphorus (P) and boron (B) are added to Si to change its conductivity.

N-Type Silicon

- When phosphorus is added to Si the resulting mixture is called N-type silicon (N: negative charge carrier silicon).

P-Type Silicon

- When boron is added to Si to the resulting mixture is called P-type silicon (P: positive charge carrier silicon).

Semiconductor components can use one type or both types of Silicon.

Example: A Diode usually uses both types of silicone in what's called a **PN Junction**.

UNITS OF MEASURE

- **Current (I)**
  - Current is the quantity of electrons passing a given point. The unit of current is the **Ampere** or **Amp**.
- **Voltage (V or E)**
  - Voltage is electrical pressure or force. It's sometimes referred to as Potential. The unit is the **Volt**.
- **Resistance (R)**
  - Conductors are not perfect. They resist to some degree the flow of current. The unit of Resistance is the **Ohm**.
- **Capacitance (C)**
  - The ability of a system to store an electric charge is called Capacitance. The unit of Capacitance is the **Farad**.
- **Inductance (L)**
  - Inductance is the tendency of a conductor to oppose a change in the current flowing through it. The unit of Inductance is the **Henry**.
- **Power (P)**
  - The work performed by an electrical current is called Power. The unit of Power is the **Watt**.
- **Frequency (f)**
  - The rate at which alternating current reverses flow in a circuit. The unit of Frequency is the **Hertz** .
- **Load**
  - The part of the circuit which performs work (e.g. a motor, light bulb, LED, etc.) is called **Load**.

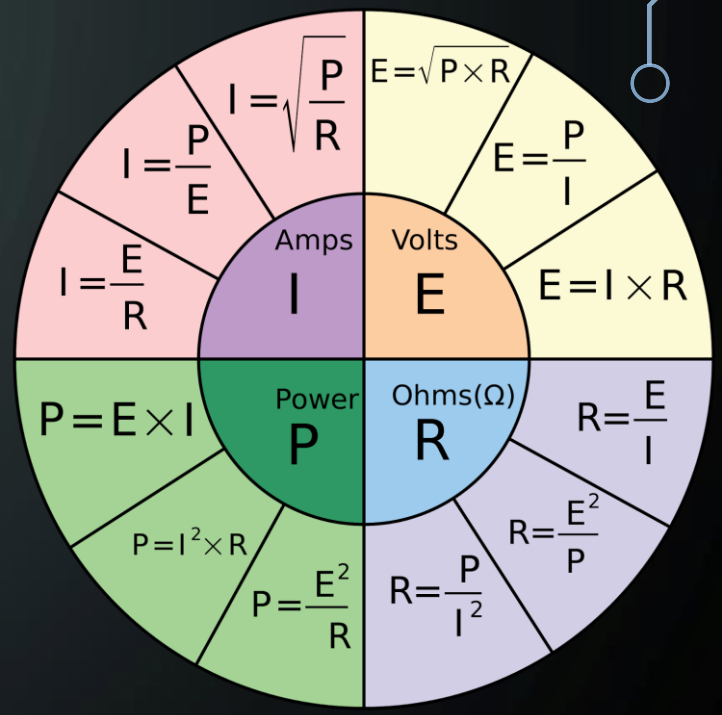
OHM'S LAW

Ohm's Law details relationships among:
Current (I), Voltage (E), Resistance (R) and Power (P).

This allows us to calculate a given value using any two others.

Here are the basic formulas:

- **E = I x R**
- **I = E / R**
- **R = E / I**
- **P = E x I**



The chart (right) shows how these basic formulas are expanded to use other values.

Why do I need to know this? - Simple Example:

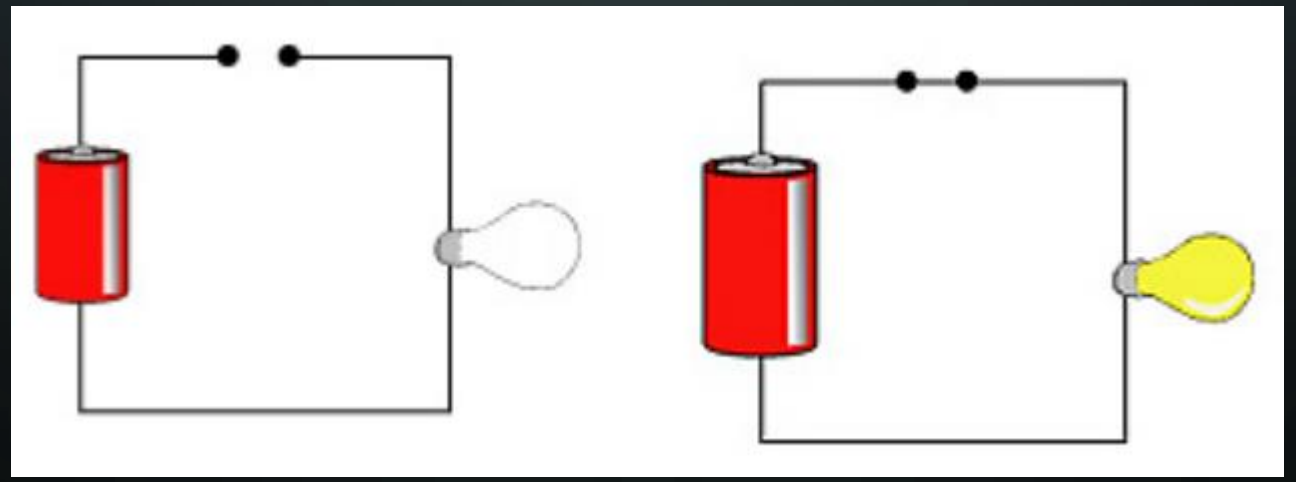
Say that you're wiring a circuit with a LED. You know the amount of current that the LED can withstand without blowing up and how much voltage the battery supplies. You can use Ohm's Law to determine the proper amount of resistance to use that will prevent your LED from blowing up.

OPEN AND CLOSED CIRCUITS

Electrons will not flow through an **open circuit** (left diagram)

Electrons will flow freely through a **closed circuit** (right diagram).

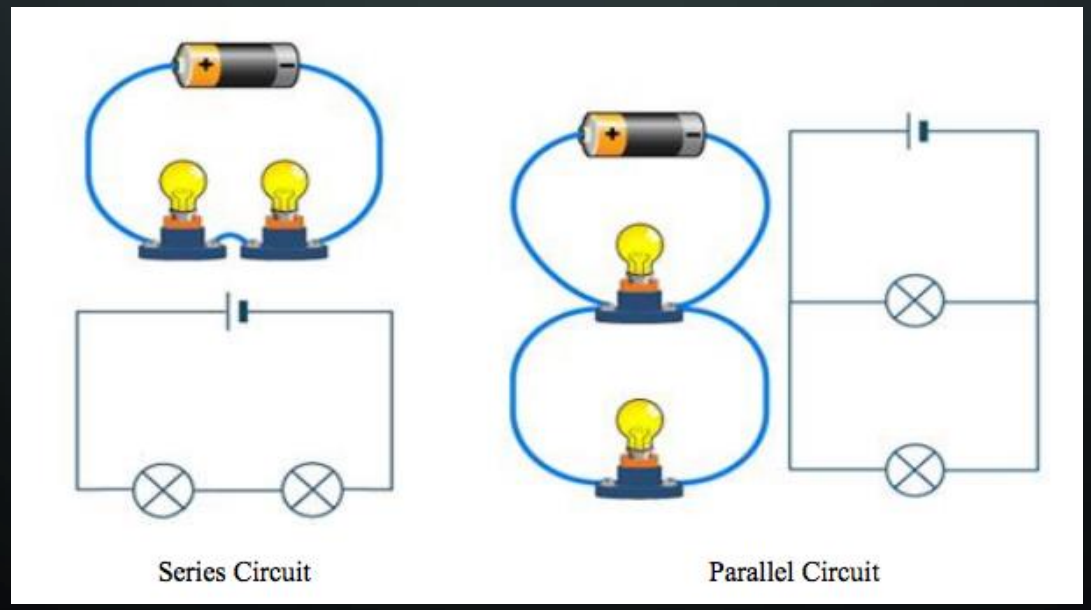
A **switch** is a device that allows for a circuit to be toggled between its open and closed states.



PARALLEL VS. SERIES CIRCUITS

In a **series circuit**, the current through each of the components is the same, and the voltage across the circuit is the sum of the voltages across each component.

In a **parallel circuit**, the voltage across each of the components is the same, and the total current is the sum of the currents through each component.



SWITCHES

A **Switch** allows a circuit to transition between open and closed states.

We will outline some of the different switch types here.

Switch mechanical types

- A **toggle switch** or **slide switch** can be moved easily between positions and remains where set.
- A **dip switch** is like a slide switch but is more difficult to move by design to prevent accidental state changes.
- A **tactile switch** also known as a **momentary switch** is a type of push button that changes state only while pressed moving back to original state when released.

Switch electrical types

- **SPST** (Single Pole, Single Throw)
  - Normal Open (NO) and Normal Closed (NC) refer to initial state.
- **SPDT** (Single Pole, Double Throw)
- **DPST** (Double Pole, Single Throw)
- **DPDT** (Double Pole, Double Throw)

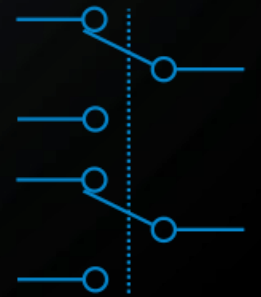
SPST-NO

SPST-NC

SPDT

DPST

DPDT



RESISTORS

A **Resistor** is a passive two-terminal electrical component that implements resistance as a circuit element.

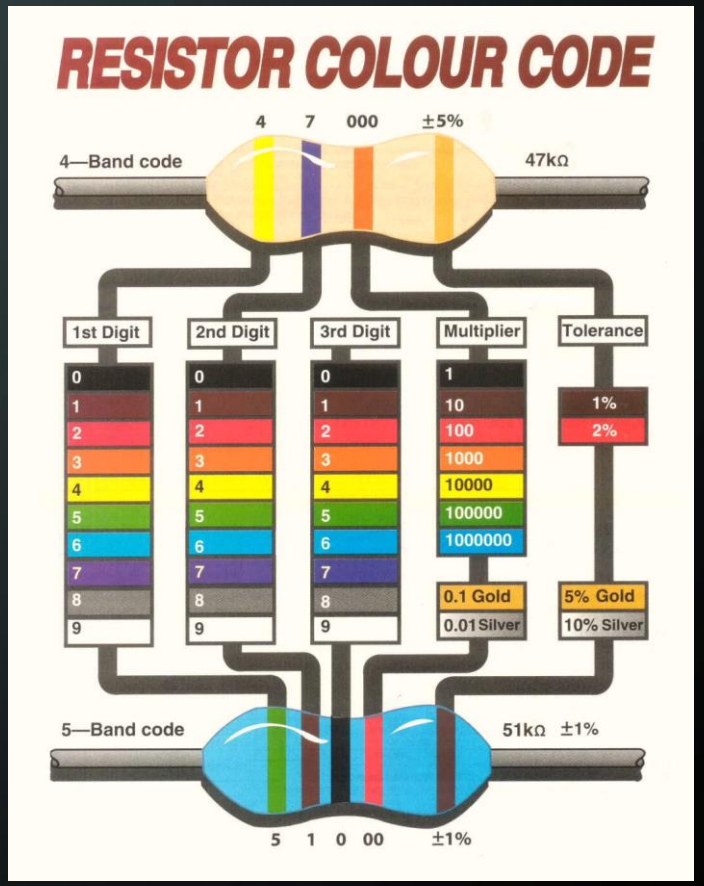
Resistors may be used to reduce current flow, and, at the same time, may act to lower voltage levels within circuits.

The amount of resistance a resistor adds to a circuit as measured in **ohms (Ω)**.

Resistors are **non-polar** components (i.e. can be placed in a circuit in either direction).

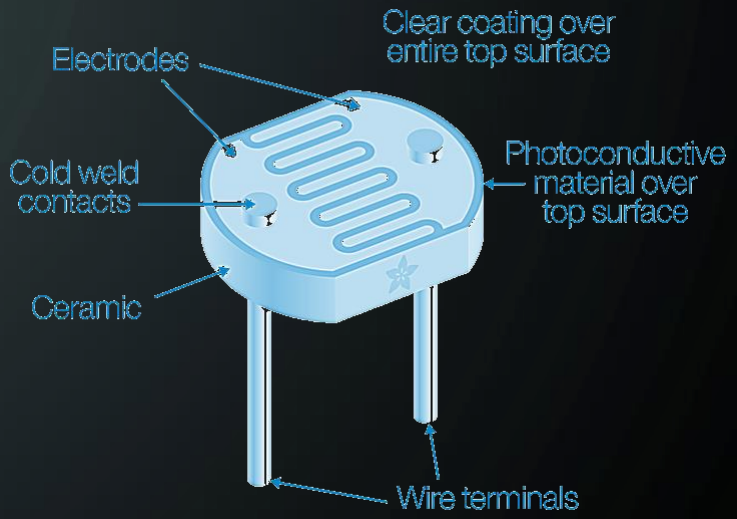
The resistance value is usually printed onto the component in the form of colored stripes. Some resistors have four stripes, and some have five.

The resistor color chart (right) can be used to determine the value.



PHOTORESISTORS

A **Photoresistor** also known as a Light Dependent Resistor (LDR) is a passive component that decreases resistance with respect to receiving luminosity (light) on the component's sensitive surface. The resistance of a photoresistor decreases with increase in light



Its resistance depends on the intensity of light incident upon it:

- Under dark conditions, resistance is very high (M Ω).
- Under bright condition, resistance is lowered (~100 - 200 Ω).

Photoresistors are **non-polar** components (i.e. can be placed in a circuit in either direction).

A photoresistor can be applied in light-sensitive detector circuits and light-activated and dark-activated switching circuits acting as a resistance semiconductor.

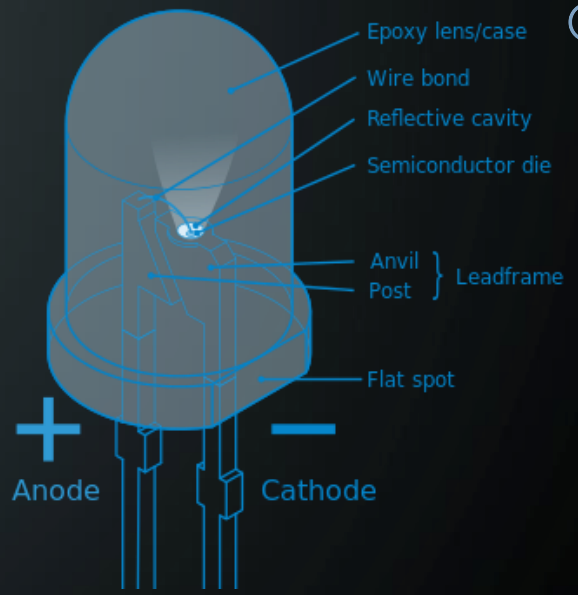
DIODES AND LIGHT EMITTING DIODES

A **Diode** is a two-terminal electronic component that conducts primarily in one direction; has low (ideally zero) resistance to current in one direction, and high (ideally infinite) resistance in the other.

This directionality indicates that diodes are polar components (i.e. must be placed in a circuit in the proper direction).

A diodes two electrodes are called Anode and Cathode.

- The **Anode** is the positively charged electrode
- The **Cathode** is the negatively charged electrode



A light-emitting diode (LED) emits light when activated.

When a suitable voltage is applied, electrons that pass through the device release energy in the form of photons. This effect is called electroluminescence, and the color of the light corresponds to the energy of the photons released.

CAPACITORS

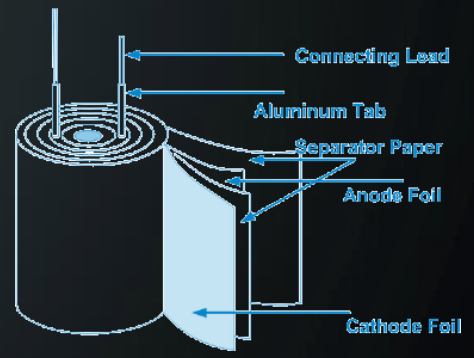
A **Capacitor** is a passive two-terminal electronic component that stores electrons in an electric field. The simplest capacitor is two conductors separated by an insulating material called dielectric.

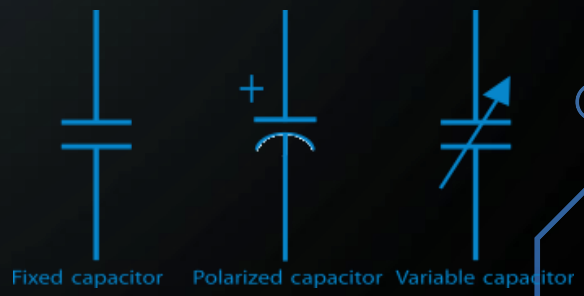
The effect of a capacitor is known as capacitance which is measured **farads (f)**.

Capacitors come in both **polar** and **non-polar** forms. Polarized capacitors are usually marked in some way to identify the Anode or Cathode terminals.

The cathode side of a capacitor is charged with electrons. These electrons in the charged capacitor will leak through the dielectric until both conductor plates have an equal charge. The capacitor is then discharged.

A capacitor oppose changes in voltage. It can have a smoothing effect on a circuit by filtering out voltage spikes.





INDUCTORS

An **Inductor** also called a coil, choke, or reactor, is a passive two-terminal electrical component that stores electrons in a magnetic field.

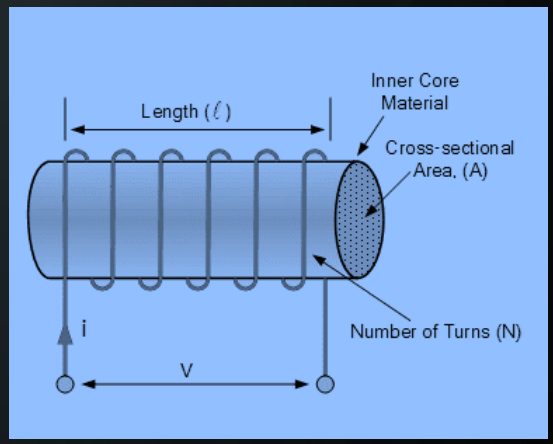
Inductors typically consists of an insulated wire wound into a coil around a core.

The current that flows through an inductor produces a magnetic flux that is proportional to it. But unlike a capacitor which oppose a change of voltage, an inductor opposes a change of current.

Inductors are **non-polar** in that they will work in either direction in a circuit. However, the direction the current flows will change the magnetic poles present around an inductor. Given that reversing connections can lead to opposite effects, some call this a **bi-polar** component.

An inductor is characterized by inductance, which is the ratio of the voltage to the rate of change of current. The unit of inductance is the **henry (H)**.

Inductors are widely used in electronic equipment, particularly in radio equipment. They are used to block AC while allowing DC to pass. They are also used in electronic filters to separate signals of different frequencies.



TRANSISTORS

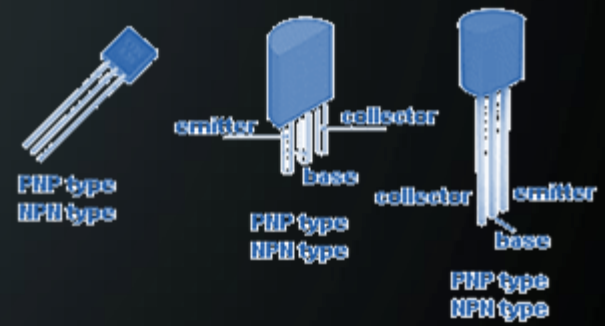
A **Transistor** is a semiconductor device used to amplify or switch electronic signals and electrical power.

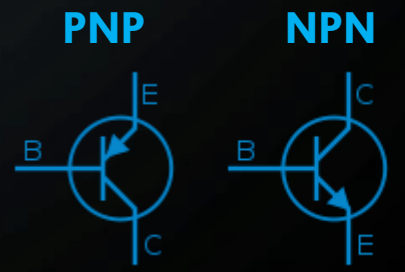
It is composed of semiconductor material usually with at least three terminals for connection to an external circuit.

A voltage or current applied to one pair of the transistor's terminals controls the current through another pair of terminals.

There are several different types of transistors. Each type has a specific layout required based on what result is needed in a circuit. However, transistors are **non-polar** as they will work in different layouts, just with different results. Given that reversing connections can lead to opposite effects, some call this a **bi-polar** component.

Since the output can be higher than the input, a transistor can be an amplifier. But it can also be used as a switch (as a small current in one place 'turns on' a big current in another).



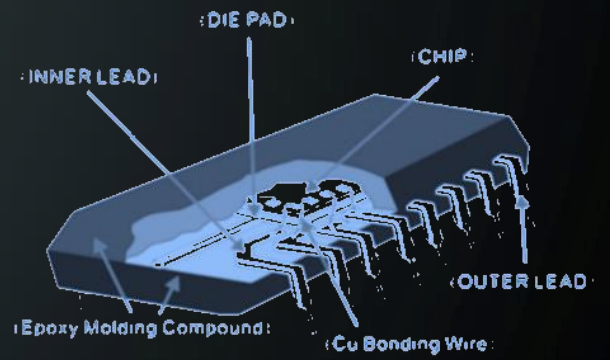


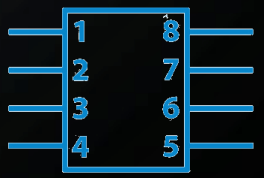
INTEGRATED CIRCUITS

An **Integrated Circuit** (also referred to as **IC**, chip, and microchip) is a set of electronic circuits on a small flat piece (or "chip") of semiconductor material (normally silicon).

The integration of large numbers of tiny transistors into a small chip results in circuits that are orders of magnitude smaller, faster, and less expensive than those constructed of discrete electronic components. ICs are now used in virtually all electronic equipment and have revolutionized electronics.

IC's tie internal circuits to external electrodes (pins or pads) allowing for their integration into other circuit designs. Since IC's come in many shapes / sizes and different internal circuit layouts, it's important to read the IC documentation. This will ensure you are properly connecting it into your circuit design.





WOULD YOU LIKE TO KNOW MORE?

I hope you found this deck helpful in learning electronics.

While I attempted to cover all the basic concepts of electronics here, there is much more to learn.

If you would like to know more, here are some resources.

I am a big fan of the "**Make:**" series of books.

- Make: Electronics
- Make: Learn Electronics with Arduino
- Make: Encyclopedia of Electronic Components

No Starch Press (**https://nostarch.com/**) has some great books.

- A Beginner's Guide to Circuits
- 10 LED Projects for Geeks
- Arduino Playground
- Electronics for Kids