

Animators Guide to Electricity: The Basics

By

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Presented at
Christmas Expo 2019



Safe Harbor Statement

DEFINITION: A statement typically found in the fine print at the end of a corporation's press release that says that the "forward-looking statements" are based on a number of events and assumptions. It cautions investors not to put too much reliance on these statements because they are subject to a number of uncertainties that the company can't control and that may cause the results to differ from the statements. The readers of the release are referred to the company's filings with the SEC for further information.

Therefore:

- Any opinions expressed here are my own and not necessarily coherent
- This presentation introduces basic concepts and definitions
 - It will not dive deeply into explaining all aspects of electrical theory or safety
 - You are still responsible to comply with your local laws and codes
 - Contact a licensed professional if you have any doubts or feel any task is beyond your understanding
- This presentation makes no claim to increase your intelligence
- This presentation will not whiten your teeth
- This presentation will not prepare you to pass a professional engineers exam
- This presentation will not make you rich in just 30 days
- This presentation will not give you any super powers or Jedi mind tricks
- No animals were harmed in the making of this presentation
- Like most things in life, you get what you pay for and I wasn't paid to do this



What Is Electricity?

- Put simply, electricity is a form of energy and most common definitions involve the flow (movement) or accumulation of charge
- In most situations, this movement is carried by free-flowing electrons
- Convention is that this movement of charge will flow from a point having a high potential to a point having a lower potential

Some Basic Definitions

- **Voltage** – The total charge difference between two points. This difference is potential energy that can be used to perform work.
 - Abbreviated as V or E (Electromotive Force)
 - Measured in Volts (V)
- **Current** – The rate of flow of charge from a high potential point to a lower potential point.
 - Abbreviated as I
 - Measured in Amperes or Amps (A)
- **Resistance** – An opposition to current flow in an electrical circuit
 - Abbreviated as R
 - Measured in Ohms, symbolized by the Greek letter Omega (Ω)

Disputed sources for the naming convention, but most often attributed to the French "*intensite de courant*" or "Intensity of Current"

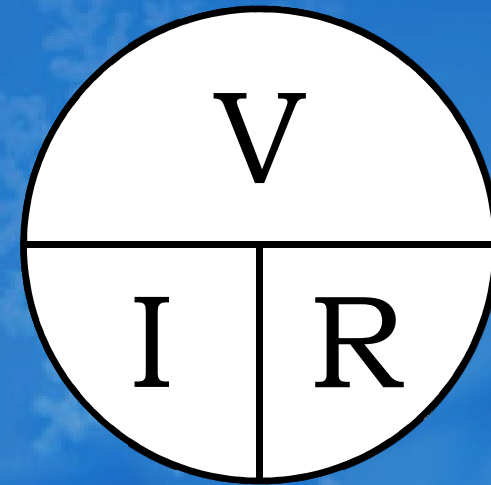


More Basic Definitions

- **Power** – The rate at which energy is generated or consumed (energy amount per time period)
 - Abbreviated as P
 - Measured in Watts (W)
- **Insulator** – Materials with a very high resistance which results in negligible current flow
- **Conductor** – Materials with a very low resistance which readily supports current flow
- **Ground** – Commonly used reference for measuring voltage, where the current wants to go to in most systems

V, I & R – How Are They Related?

- Remember:
 - Current is the flow of charge
 - Voltage is a potential or force
 - A higher force produces more flow
 - Resistance opposes the flow
 - Higher opposition reduces the flow



- Ohm's Law tells us

$$V = I * R$$

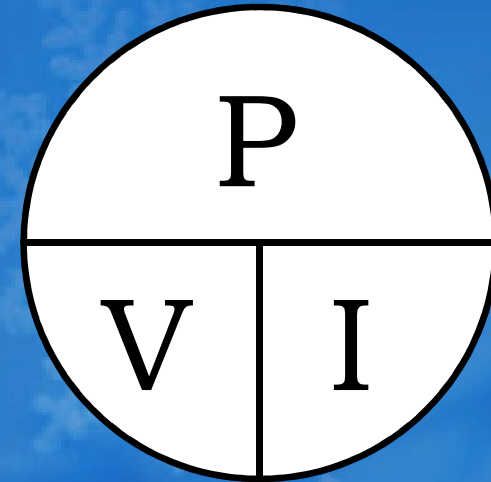
(Voltage = Current * Resistance)

$$V = 5 \text{ Amps} * 0.1 \text{ Ohm}$$

- If 5 Amps is flowing through a wire with a resistance of 0.1 Ohm, how much voltage is there from one end of the wire to the other? **0.5 Volts**

You've Got the Power

- Remember
 - Power is the rate at which energy is consumed
 - It is a function of how much energy is supplied and how fast
 - Voltage Potential and Current Flow are the electrical components for determining the amount of Power



- Watt's Law tells us

$$P = V * I$$

(Power = Voltage * Current)
 $1800 \text{ W} = 120 \text{ Volts} * I$

- If an 1800W Hair Dryer is connected to a 120 VAC outlet, how much current will it use on full power? **15 Amps**

Power & Resistance Relationship

- We saw that: $P = V * I$ And that: $V = I * R$
- Combining these two, we see that
 $P = (I * R) * I$ $P = V * (V / R)$
or
 $P = I^2 * R$ $P = V^2 / R$
- The first equation tells us that wherever current flows, there is some amount of power being dissipated
- The second equation illustrates why light bulbs are rated in Watts
 - By selecting different resistance values, the manufacturer can control how much power they will dissipate, as both light & heat energy, for a given operating voltage



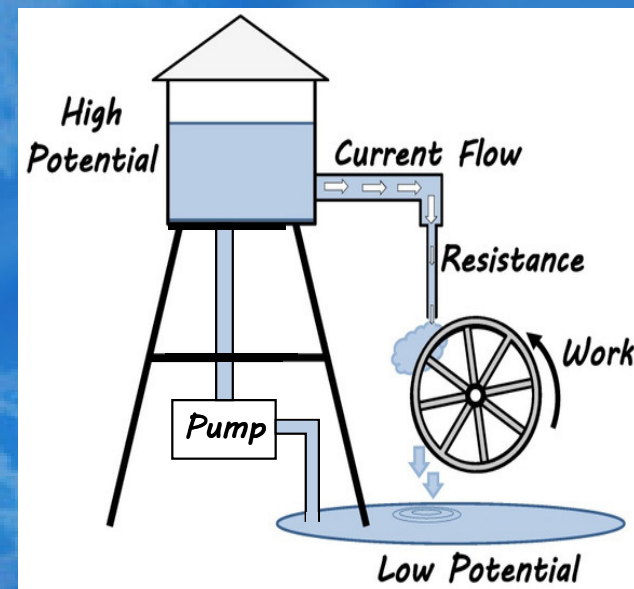
Types of Electricity

- DC – Direct Current
 - Voltage is ‘steady’ and Current only flows in one direction
 - We typically get this from a Battery or a “Power Supply”
 - Used in low voltage applications (RGB, computers, stepper motors, etc.)
- AC – Alternating Current
 - Voltage and Current alternate between positive and negative values
 - Used for Domestic and Industrial Power distribution
 - How often they alternate is called the Frequency and is measured in Hertz (Hz)
 - US systems use 60 Hz, while European systems use 50 Hz

DC Circuit Analogy

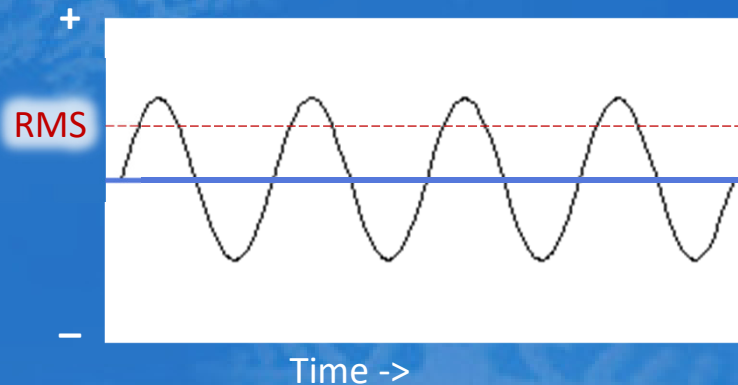
- The concept of a moving charge can be difficult to understand, and impossible to actually see in action
- Instead we will look to a similar system for comparison:
-> **THE FLOW OF WATER** <-

- The reservoir provides potential energy (voltage)
 - The fuller the tank the more pressure
- The flow of water is like the current
 - Flowing from a higher potential to a lower potential
- The pipe provides resistance
 - Larger pipes -> More Flow -> Less Resistance
- A faucet or valve acts as a switch
 - Either allowing or blocking the flow
- However, electricity will not flow if there is no pipe



Alternating Current

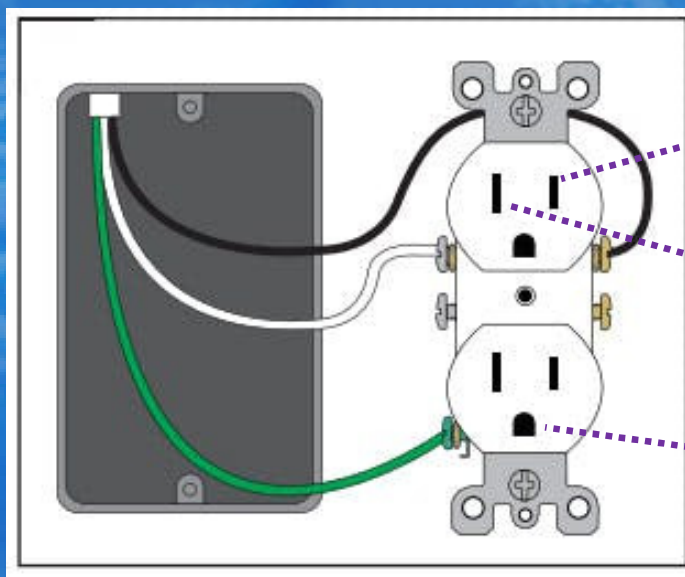
- In AC circuits the direction and amplitude (size) of the current changes with time
- Since an instantaneous voltage reading or even a simple average is meaningless, the convention is to express the amplitude using the 'Root Mean Square' (RMS) average
 - This is the 110 – 120 VAC provided by your power company
- RMS is the 'effective value' of an AC voltage or current
 - The RMS value is equivalent to the steady DC (constant) value which will give the same effect
 - For example, a lamp connected to 12V RMS AC will shine with the same brightness when connected to a 12V DC supply



Your Local Outlet Described

- HOT – AC power from your local Power Company
- NEUTRAL – The return path for the current
- GROUND – Provided as protection for the user
 - **CURRENT SHOULD NEVER FLOW THROUGH THIS LEAD**

This style of outlet is rated for a max of 15 Amps



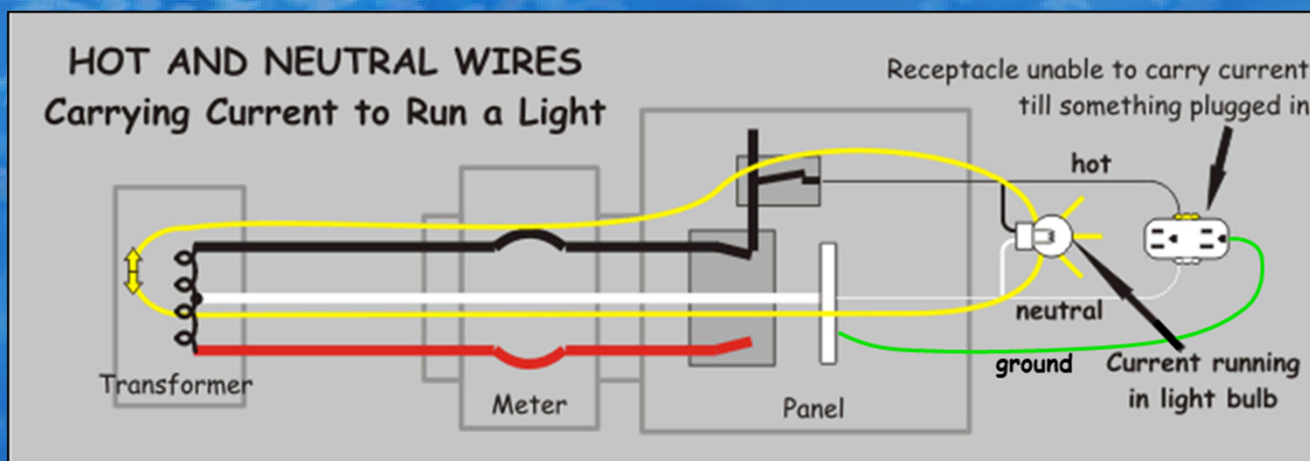
'Hot'
Short Slot
Black Wire
Brass Screw

'Neutral'
Longer Slot
White Wire
Silver Screw

'Ground'
Green Wire
Green Screw

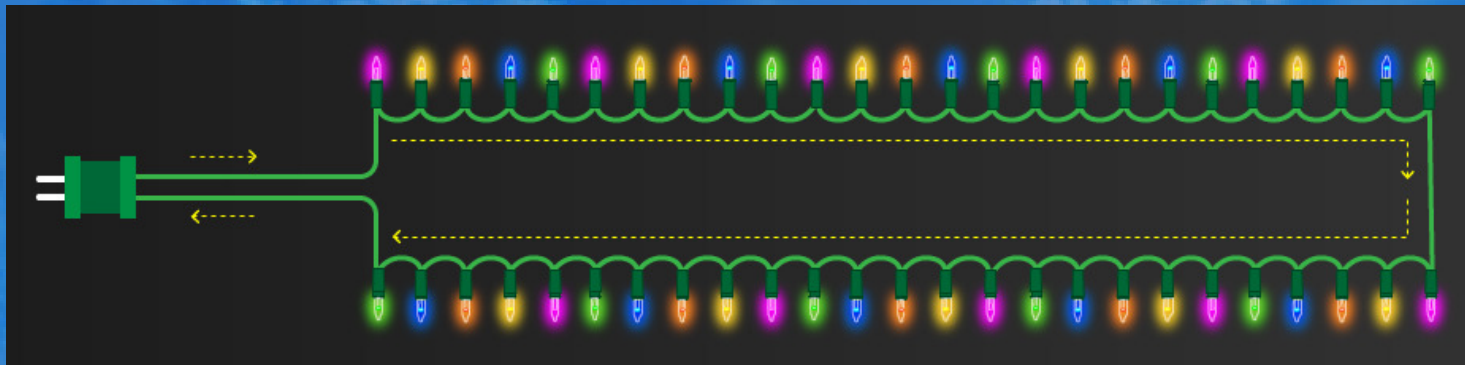
AC Power Distribution (Simplified)

- The local power company delivers 120 VAC to your power panel
- Wires connect this to the HOT terminal of the outlet or the fixture
- The NEUTRAL is connected through a wire to a common return plate
- The GROUND is also connected to the common return, but should only carry current if there is a fault



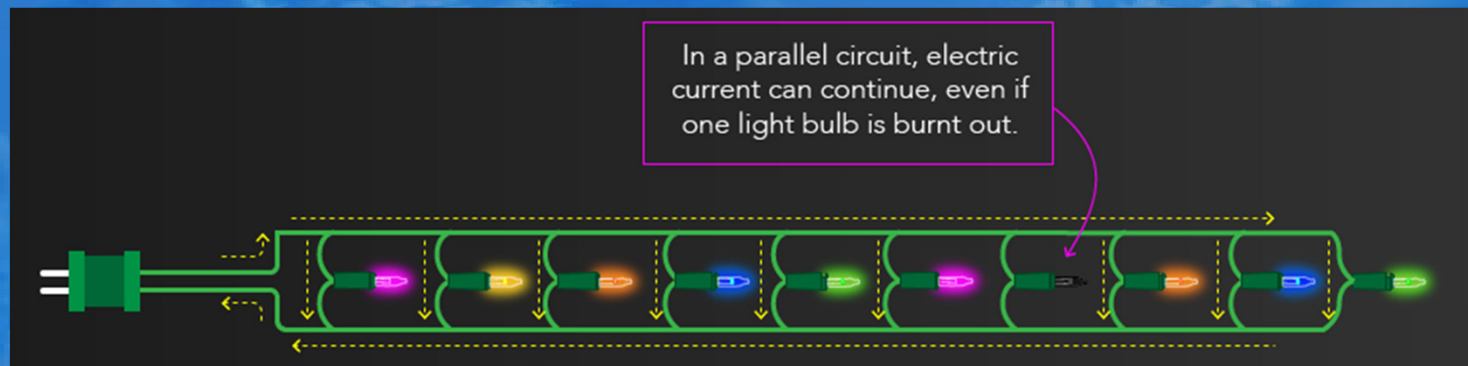
Serial and Parallel Connections?

- SERIAL – All loads see the same CURRENT
 - When there is only one current path, it's a serial connection
 - Each load can have different voltages
 - If all loads are the same, the voltage on each is the same value
 - Think of mini strings
 - Remove one bulb and they all go off



Serial and Parallel Connections?

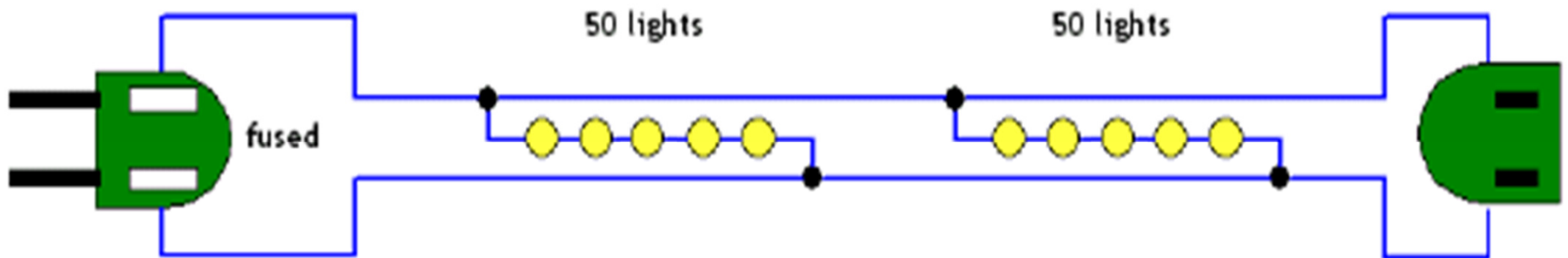
- PARALLEL – All loads see the same VOLTAGE
 - When there is more than one current path, it's a parallel connection
 - Each load can have different currents
 - Total current is the sum of all load currents
 - Think of C7 / C9 strings with vampire sockets
 - Removing one bulb has no effect on other bulbs



- This is also the configuration for power outlets in a room
 - Multiple outlets can be wired in parallel to one breaker

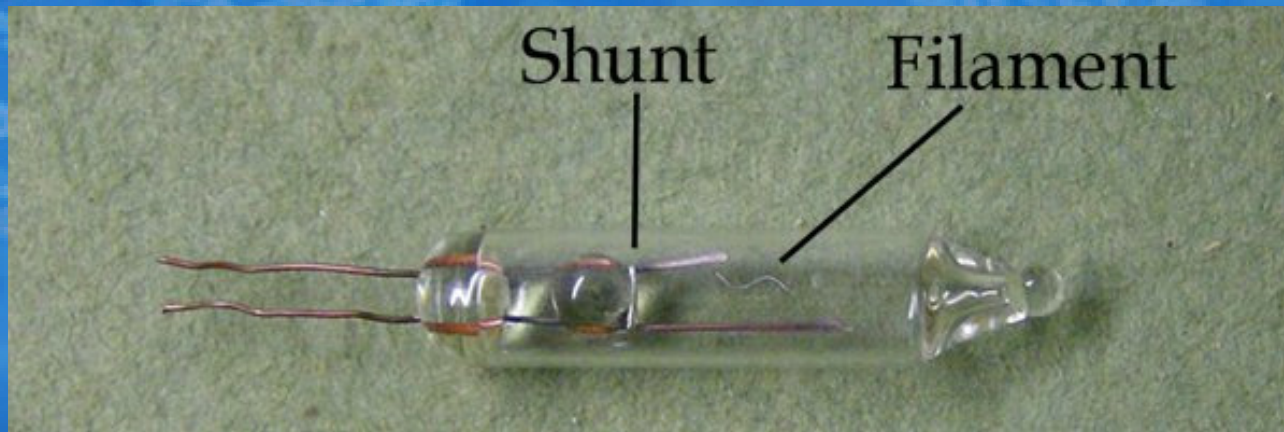
Serial and Parallel Connections?

- COMBINATION – Connection methods can be combined in many different configurations
 - Incandescent mini strings over 50 bulbs are actually a combination of strings
 - A missing/bad bulb will disable all the lights in that half, but will not effect the other half



Another Example of a Combination Circuit

- A simple string of mini-lights has each bulb wired in series
- Modern mini-lights include a 'shunt wire' in parallel with the filament
 - The shunt wire is a higher resistance than the filament, so only a little current normally flows through it
 - When a bulb burns out all of the current now flows through the shunt wire, keeping the rest of the light string active



Electrical Safety

- The saying is that “Voltage doesn’t kill, Current does”
 - Electrical impulses within our bodies make our muscles contract
 - An externally applied current can override our ability to control our muscles

Current level (milliamperes)	Probable Effect on Human Body
1 mA	Perception level. Slight tingling sensation. Still dangerous under certain conditions.
5 mA	Slight shock felt; not painful but disturbing. Average individual can let go. Strong involuntary reactions to shocks may lead to injuries.
6 mA	Class A GFCI opens the circuit.
6 mA – 16 mA	Painful shock, begin to lose muscular control. Commonly referred to as the freezing current, or maximum level a person can grasp and still “let-go.”
17 mA – 99 mA	Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go. Death is possible.
100 mA – 2000 mA	Death is likely.
> 2000 mA	Death is probable.
15, 20, 30, or 50 amps	Common fuse or breaker opens the circuit.

1000 milli-Amps = 1 Amp

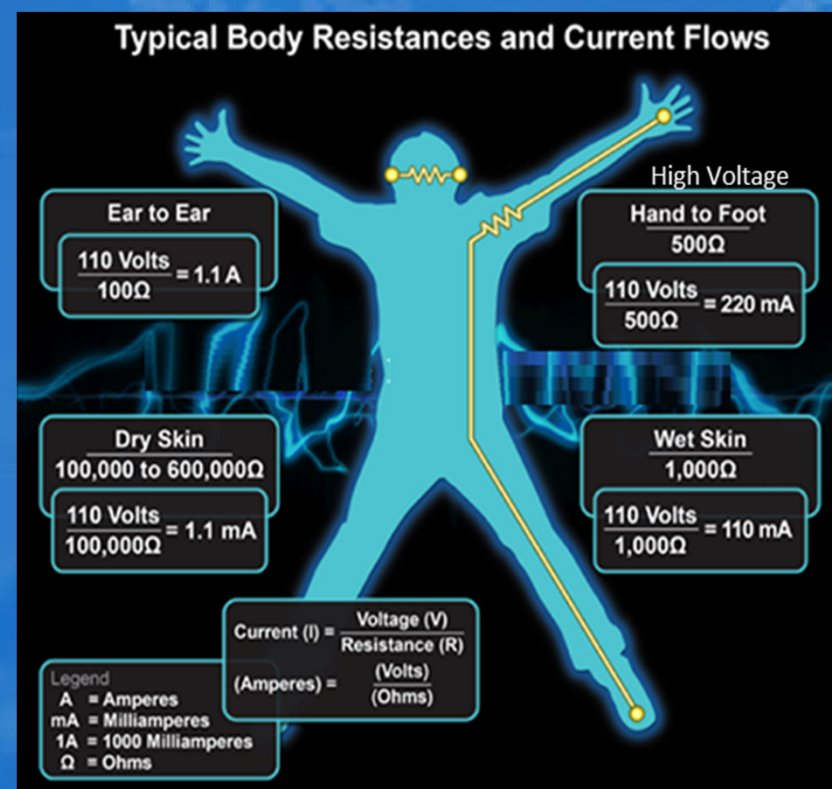
Electrical Safety

- So how much current is in a Christmas Light?

- It's not the current in the lights, but how much current can flow through you
- That depends on both the source voltage and your body/skin resistance
- Everybody is different, and Men generally have a lower resistance than Women

- For 12V systems (General Population)

- Dry Skin: 0.12 mA
(imperceptible)
- Wet Skin: up to 12 mA
(slight to painful shock)



Based on data from the National Institute for Occupational Safety and Health

Circuit Protection Devices

- Provides protection from excessive current
 - High current in wires causes them to heat up & start fires (think of a toaster)
 - These devices disconnect the circuit when too much current flows
 - Rated current is stamped or printed on each device
 - Keep your total load below 80% of the rating

- **Fuses**

- Fuses are 'Single Use' devices
- When too much current flows through the internal wire, it melts and opens the circuit

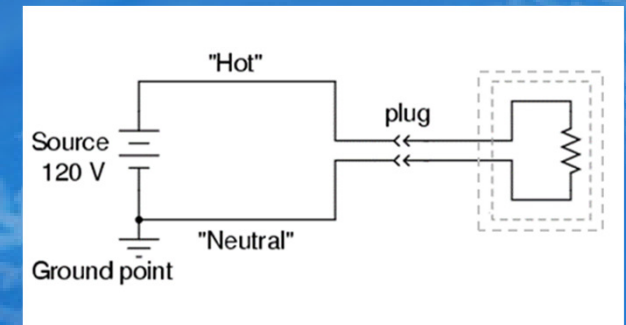
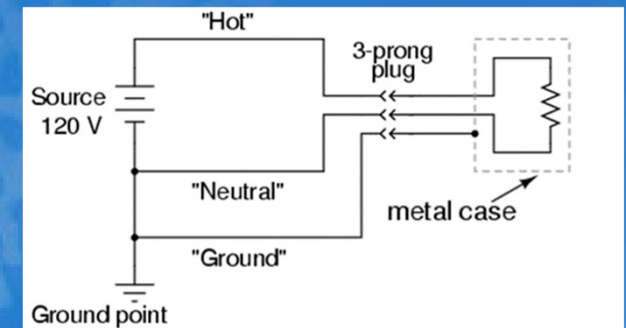
- **Circuit Breakers**

- Acts as an automatic switch
- Can be reset once fault is cleared



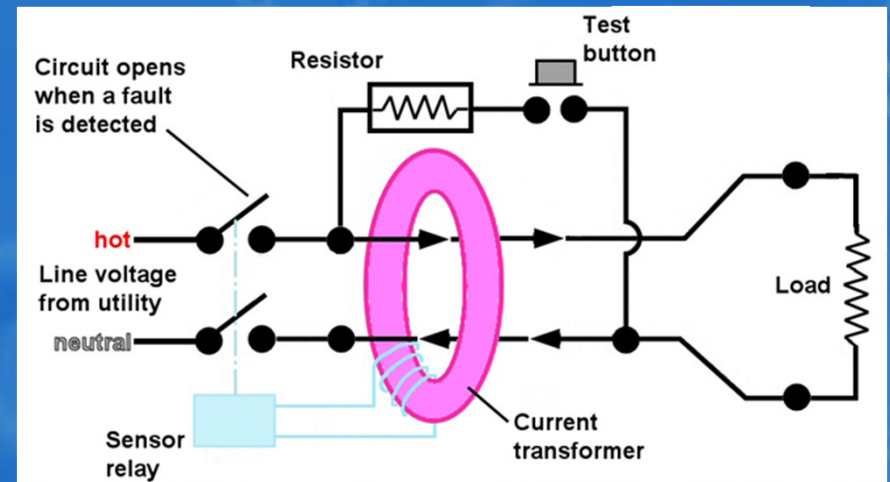
Shock Prevention Techniques

- Modern consumer appliances are designed to use one of two methods to prevent user shock
- **Grounded Surfaces**
 - Appliance uses an outer barrier which is connected to the 3rd prong ground lead
 - Any fault current will flow through low resistance ground path rather than the user
- **Double Insulated**
 - Uses two isolated barriers
 - A fault would have to compromise BOTH layers to impact the user
 - Still uses 2-prong outlets



Ground Fault Circuit Interrupter (GFCI)

- Protects from alternate and unexpected current paths
- The GFCI monitors both the current flow going out and the current flow that is returning
- Will NOT protect from overloads (shorts)
- When everything is working right, the total current flowing through the pink ring is ZERO
 - If there is a difference, then the current is also going somewhere it shouldn't be (possibly through you)
 - Class A GFCI devices open if this difference is over 5 milli-amperes



Common GFCI Issues

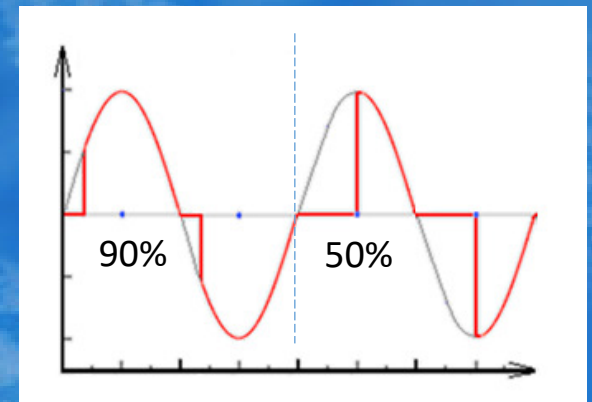
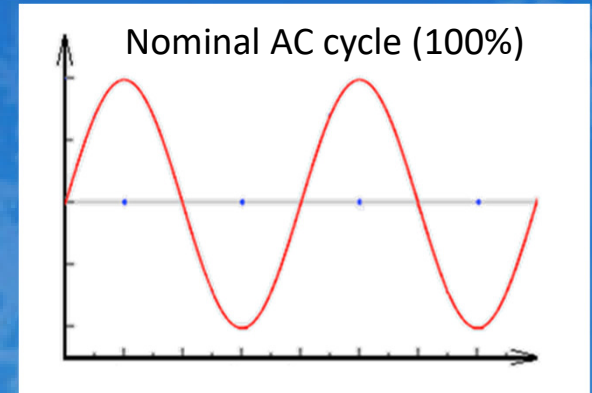
- Problem
 - Rain/Moisture reduces the resistance from Hot or Neutral to Ground
 - Too much total leakage current will trip the GFCI detector
- Suggestions
 - Raise the connections above the grass/ground using plastic stakes
 - Lengthens/breaks the path, increasing resistance and reducing current
 - Tape connections to keep moisture out
 - Effectivity is widely debated, as it can also trap moisture
 - Split circuits/props across multiple GFCI's
 - Leakage is cumulative for each prop or light string in the circuit
 - Spreading the props across other circuits reduces the number and amount of leakage current for each GFCI device
 - Reduce the amount of electrical pressure
 - Lowering the pressure (voltage) reduces current leakage

For the safety of you and your guests – fix the issues

DO NOT BYPASS THE GFCI

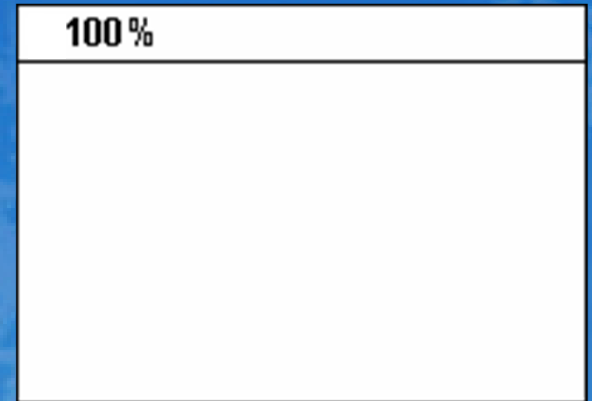
How Our AC Controllers 'Dim' Lights

- Most dimmer circuits work using a technique called “Phase Control Dimming” or “Triac Dimming”
- By changing the point where the output switch turns on, we can control the total amount of power being delivered
 - Note that the amount of time delay is not linear with the amount of power decreased
- This approach does **NOT** work well with more complex electronics
 - Strobes, Fog Machines, etc.



What About RGB Dimming?

- RGB dimming is performed using the same basic principle, but with a few minor differences
- RGB LEDs use DC voltages
 - Typically 5V or 12V
 - There is no inherent AC waveform
- Instead, the RGB controllers use an internal clock to create a repeating time period
 - This frequency is much higher than the 60Hz power line
- As before, the dimming is controlled by choosing when to turn on power within this period
 - Since there is no sine wave this time, the percentage of 'on time' is linear to the total brightness



Additional Resources

https://www.windows2universe.org/physical_science/physics/physics.html

<https://learn.sparkfun.com/tutorials/voltage-current-resistance-and-ohms-law/electricity-basics>

<https://www.energy.gov/articles/how-do-holiday-lights-work>

<https://www.electronics-tutorials.ws>

(Select “AC Circuits”, “DC Circuits”, “Resistors” or any of the more in depth topics)



Thank you for participating

- You can download this presentation from the 'Expo 2019' link on the 'How To' page of my website:

www.obewanproductions.com

The background of the slide is a solid blue color with a repeating pattern of white, stylized snowflakes. The snowflakes are of various sizes and orientations, creating a subtle, wintry texture.

Bonus Materials

