Electricity Basics – The Relationship of Voltage: Current and Resistance

Tom Parks

Coastroad Hearth and Patio

Part One of Electricity Basics
Practically every type of indoor hearth product uses electricity whether it's a circulating fan on a wood burner or a pilot assembly on a gas manual control. Electricity is used by both the simplest and most complex systems. A familiarity with the basics of electricity is crucial to troubleshooting and servicing hearth products. This is the first module of three, which will include electrical concepts and also discuss some typical wiring and component issues on gas, wood and pellet products. Parts Two and Three will cover gas millivolt and electronic ignition systems.

2020 HPBExpo Education
Sponsored by:

ELECTRICITY BASICS PART 1

CONCEPTS

PRACTICAL APPLICATIONS FOR HEARTH PRODUCTS

Tom Parks
COASTROAD

NATIONAL FIREPLACE INSTITUTE
MHP
MASTER HEARTH PROFESSIONAL

PURPOSES AND LIMITATIONS

This presentation has been prepared for informational purposes only and does not reflect the views of the Hearth, Patio & Barbecue Education Foundation (HPBEF) or the contributing agencies and companies, nor constitute an endorsement of any commercial product or person. Neither HPBEF nor its officers, employees, or agents makes any warranty with respect to this presentation or assumes any liability arising from the use of this presentation.

REMINDER

Do not perform any work that you are not qualified or licensed to perform. The information provided during this presentation does not in any way encourage anyone to risk their professional status or personal health by engaging in work that they are unqualified to do. Merely attending this presentation will not make someone qualified to do electrical work.

Working with electricity can be extremely dangerous. Do not put yourself or others at risk by doing work that you shouldn't.

OVERVIEW

The ability to troubleshoot hearth products has become increasingly dependent on an understanding of electricity and electronics. Some technicians have tried to avoid those aspects of our work because of a lack of confidence or outright fear. Knowledge and experience will allow any technician to successfully troubleshoot the electronic systems we encounter.

That being said, we are going to try to cram year of information into 60 minutes . . .

OVERVIEW

Terminology & concepts

Voltage, resistance, current & power

Millivolt systems (part 2)

Electronic ignition (part 3)

OVERVIEW

- It is important to have a basic understanding of these topics:
  - The relationship between voltage, current and resistance
  - Open and closed circuits
  - Continuity and conductivity
  - How to use basic diagnostic tools
  - Electromagnetism & the Seebeck effect (part 2)
  - Electronic flame sensing (part 3)

TERMINOLOGY

Electricity is the movement of free atomic particles – electrons – through materials. The ability of a material to let electrons flow freely is **<u>conductivity</u>**.

Some materials are *very* conductive: gold, copper, steel, etc.

Some are not: glass, ceramic, silicone (insulators).

In some cases, dirt, corrosion, oxidation, condensation and other foreign matter can make conductive materials less conductive *and vice versa*.

TERMINOLOGY

A **source** is the power supply, either alternating current (AC) or direct current (DC).

A wall outlet is AC, a battery pack is DC, a transformer can be either one.

Voltage is the *force* that drive the electrons, analogous to water ***pressure***.

(Low voltage (under 50 v) can be handled safely because it does not have the strength to overcome the resistance of our skin)

Line voltage (110-120VAC) is powerful enough to break the skin resistance and give a person a shock, which can be fatal.

High voltage (thousands of volts) can jump through the air, as in a piezo ignitor or other spark ignition.

A millivolt is one thousandth of a volt, so 500 MV = ½ volt

TERMINOLOGY

Current is the volume of electricity, measured in amperes.

Amperage is analogous to water ***volume***. Trying to get 1500 gallons per minute through a garden hose is pretty much impossible, but a firehose should be able to handle it.

Likewise, small gauge wiring cannot carry high amperage. It will overheat, causing other issues.

TERMINOLOGY

Although you can be shocked with a 40,000 volt spark and only experience discomfort, amperage will kill a person. It may take less than ½ an amp to stop a person's heart.

We are usually only concerned with amperage when installing units with electric heating elements (which may need a separate circuit) or with hot surface ignition systems (glow plugs). Most of the things we focus on only produce/use milliamps (1/1,000th) or microamps 1/1,000,000th).

SAFETY - CURRENT

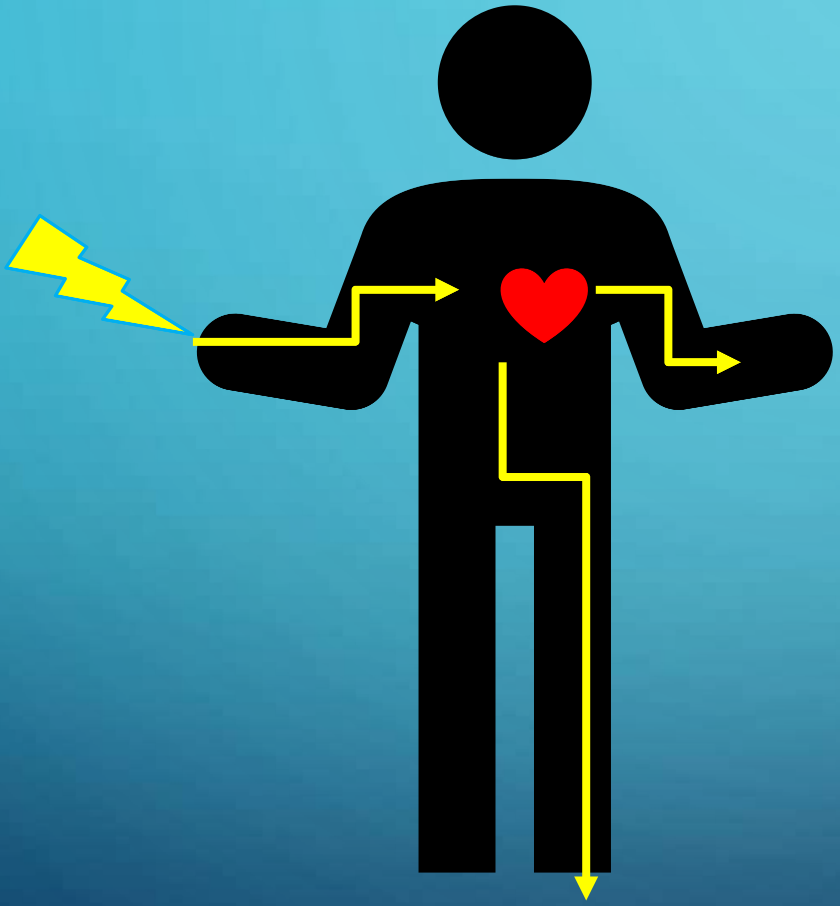
1 mA	Mild sensation
2 mA	Painful
10 mA	Cannot release
30 mA	Breathing stops (fatal)
75 mA	Ventricular fibrillation
200 mA	Severe burns

SAFETY

What is a typical breaker rated for? What are these designed to protect?

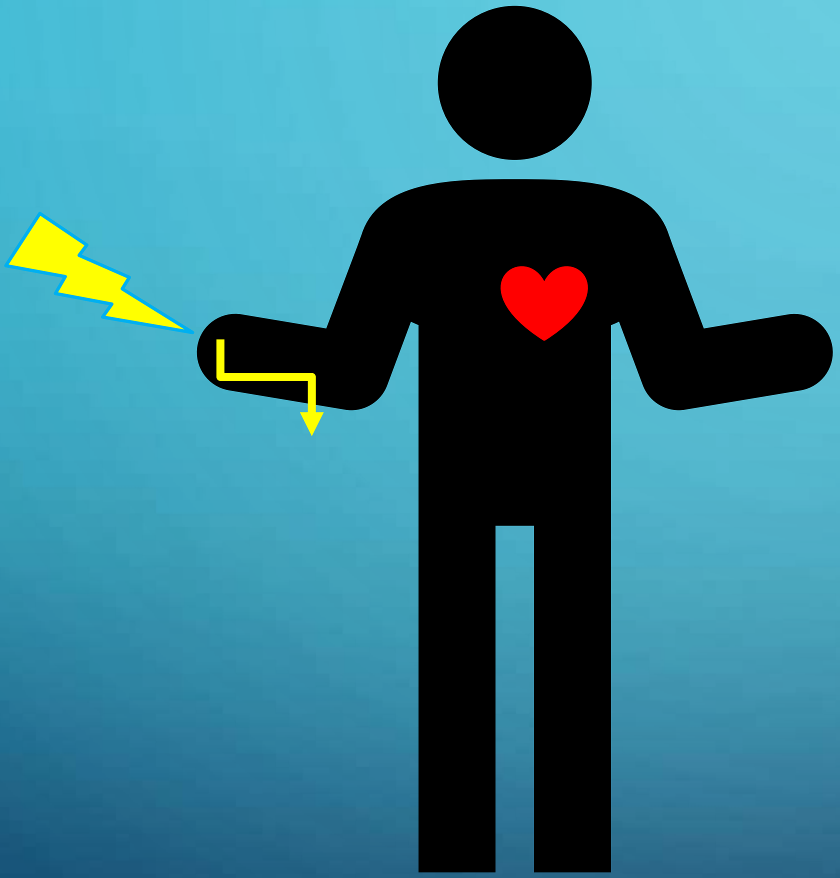
Not you.

SAFETY



Going from hand to hand or hand to foot likely means crossing vital organs

SAFETY



Going from hand to arm and not through torso probably means just discomfort

SAFETY RULES

- Only diagnose or troubleshoot 110V + with equipment energized.
- All installation, repairs, and service should be done with equipment de-energized.
- Best Practice: Lock out circuit

Electricity takes the path of least resistance.

True or False?

Electricity takes all paths available to it.

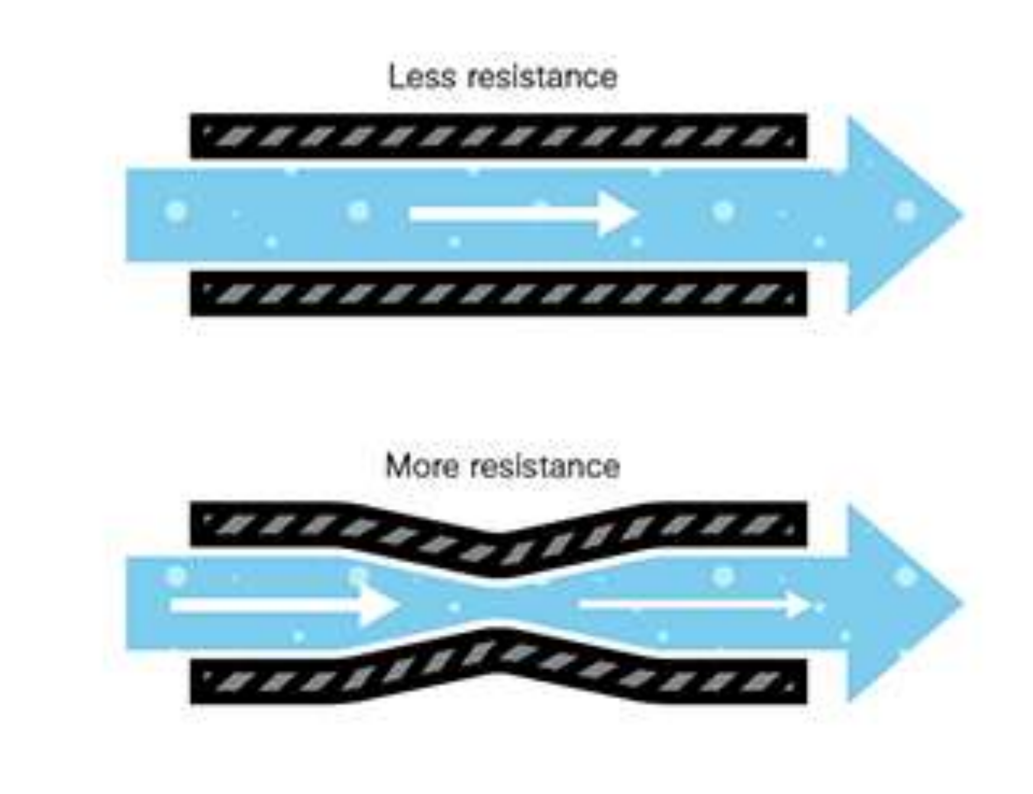
TERMINOLOGY

Resistance is exactly what is sounds like, resistance to the flow of electricity, measured in Ohms (Ω).

Measuring resistance can be helpful during troubleshooting to check whether a component is working according to specification. Excessive resistance will cause functional issues, particularly in millivolt systems. Age and oxidation can cause some components to become more resistant over time.

Continuity is related to resistance. There are many instances where we need to make sure there is a clear, continuous path for electrons.

ELECTRICITY ≈ WATER ANALOGY



Using water to illustrate the flow of electrical current helps to visualize the concepts

$V = I \times R$ (Ohm's Law)

V = Voltage (pressure) - constant

I= Current in Amperes (volume)

R= Resistance in Ohms (restriction)

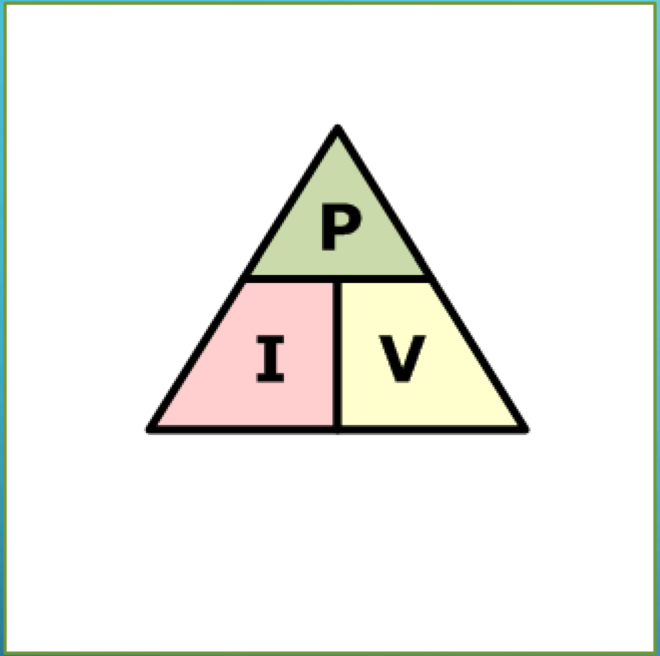
POWER

How much does it cost to run ___________?

Does this need its own circuit breaker?

Clients, electricians and inspectors may need answers.

POWER RELATIONSHIP



P= I x V

(or P=IE)

P = Power in watts

I = Current in amps

V = Volts

(E = electromotive force)

POWER RELATIONSHIP

P=IE

1500 watt electric fireplace

120 volts

How much current does it use?

Does it need its own breaker?

POWER RELATIONSHIP

P=IE

1500 watts = amps x 120 VAC

Divide both sides by 120

12.5 = amps

How much current does it use?

12 -1/2 amps

Does it need its own breaker?

Probably.

POWER RELATIONSHIP

How much does it cost to use?

Kilowatts x \$/kw/hr = cost per hour

1500 watts = 1.5 kilowatts

How much is local utility?

\$0.11 per kw/hour

1.5 x \$0.11 = \$0.165 per hour

POWER RELATIONSHIP

How much does it cost to use just the fan?

Fan uses 0.3 amps

P= IE

Watts = 0.3A x 120 VAC = 36 watts

Kilowatts x $/kw/hr = cost per hour
36 watts = .36 kilowatts

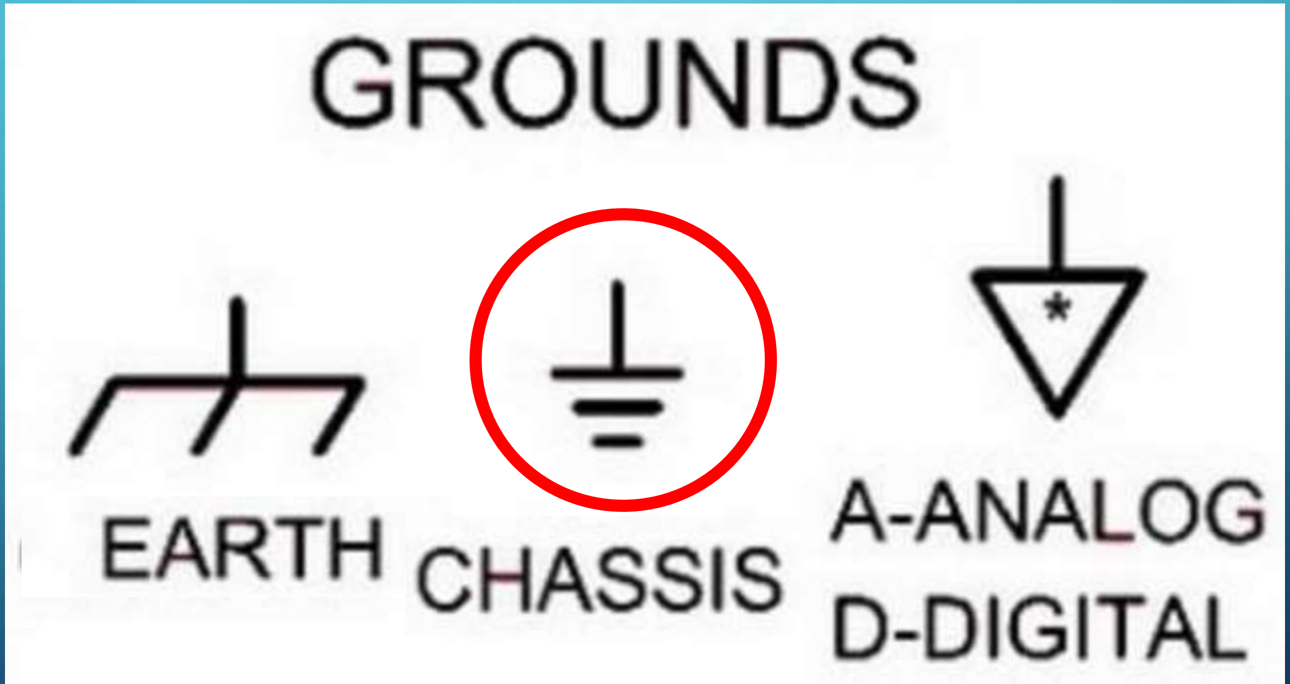
How much is local utility?

$0.11 per kw/hour

.36 x . x $0.11 = $0.0396 per hour (4¢)

TERMINOLOGY - GROUNDS

A **ground** may mean a current path to the earth, as in a grounding rod, but usually we are referring to a chassis ground, which is generally used as a common connection for low voltage in electronic ignition systems



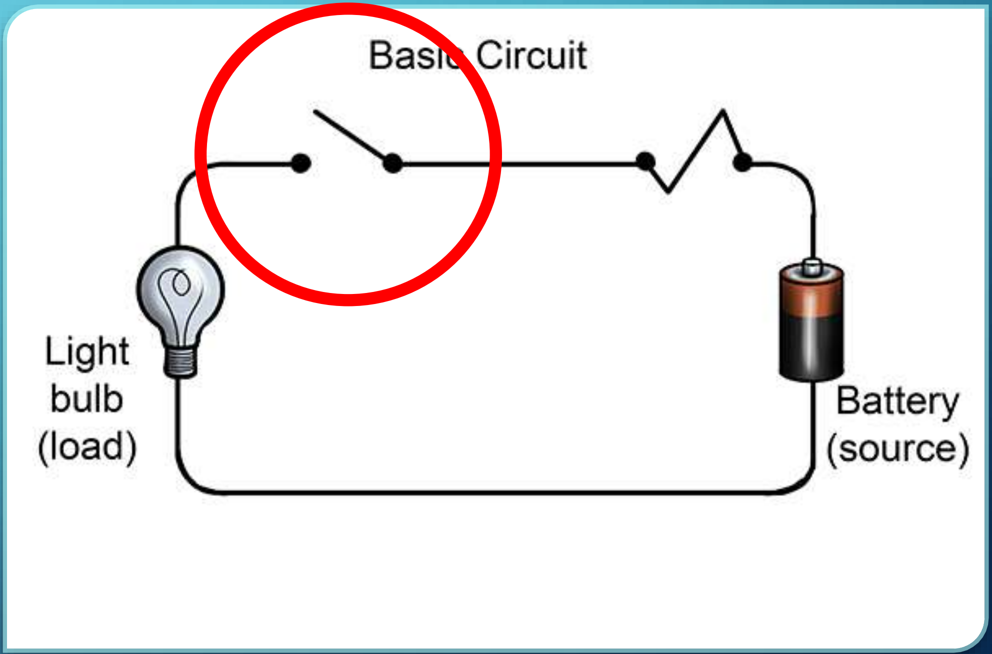
TERMINOLOGY – OPEN AND CLOSED CIRCUITS

A circuit is a current path, or loop.

When the switch is turned off, the circuit is open, no current can flow.

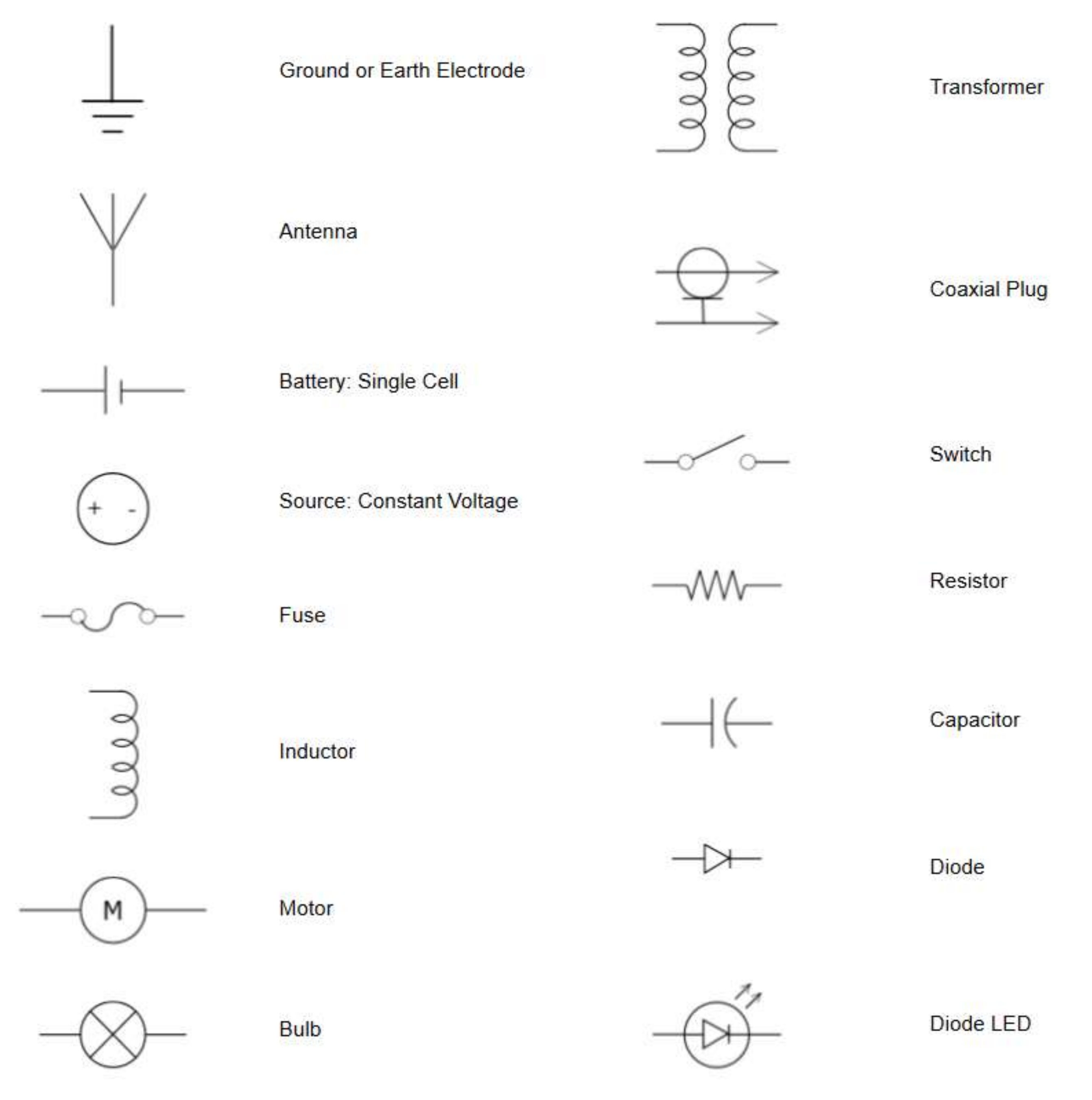
When the switch is turned on, the circuit is closed, and current can flow in the loop

Is this an open or closed circuit?



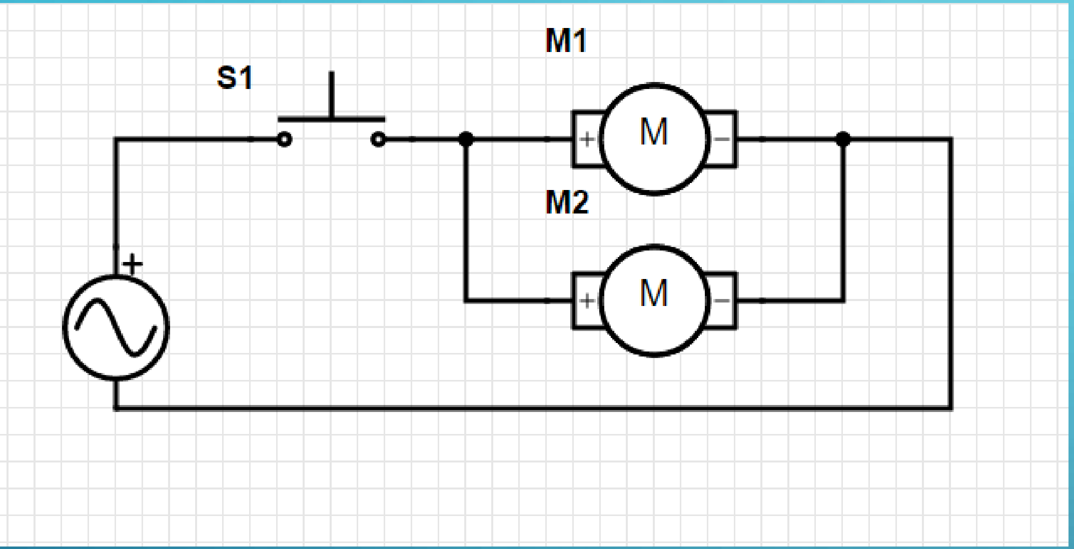
ELECTRICAL SYMBOLS

Google the basics

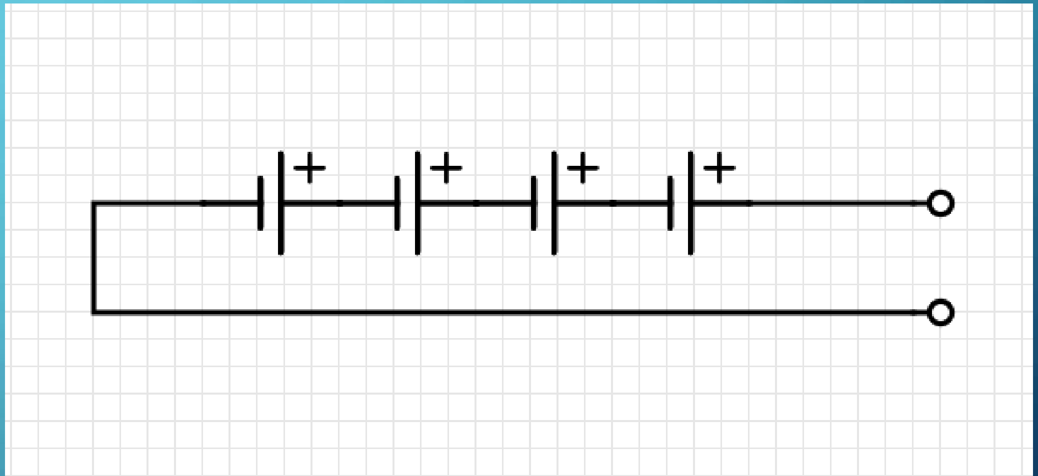


TERMINOLOGY: SERIES VS. PARALLEL

CURRENT TAKES ALL PATHS AVAILABLE FOR IT



A typical fan circuit with the normally open switch (snapdisk) in **series** and the fan motors in **parallel** (more than one path for current)



A typical battery backup, with four 1.5V batteries in **series** to make 6 VDC

(what if batteries were in parallel?)

TERMINOLOGY

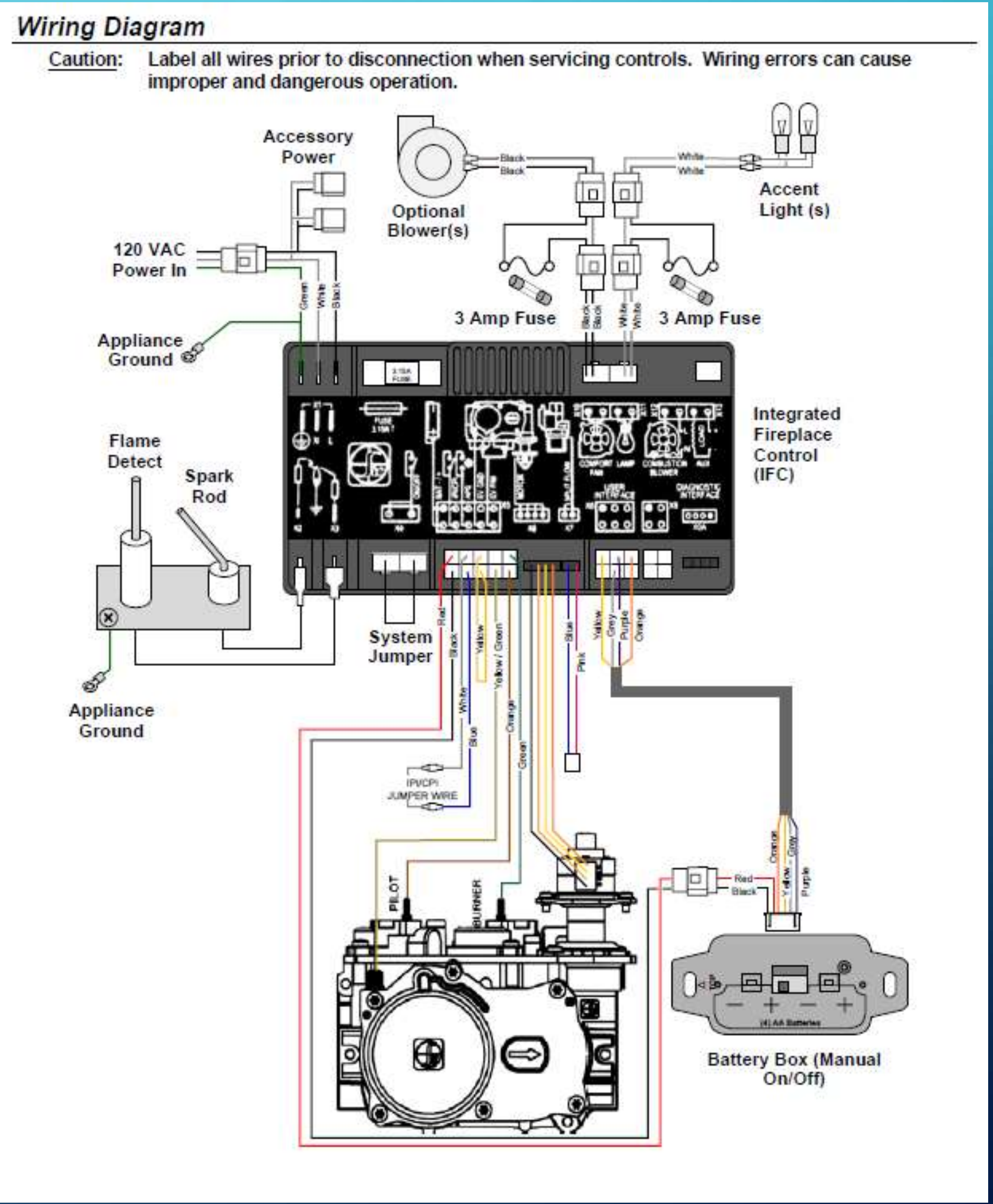
junction boxes

Nail-on for new construction

Metal for firebox installation

VISUAL IDENTIFICATION

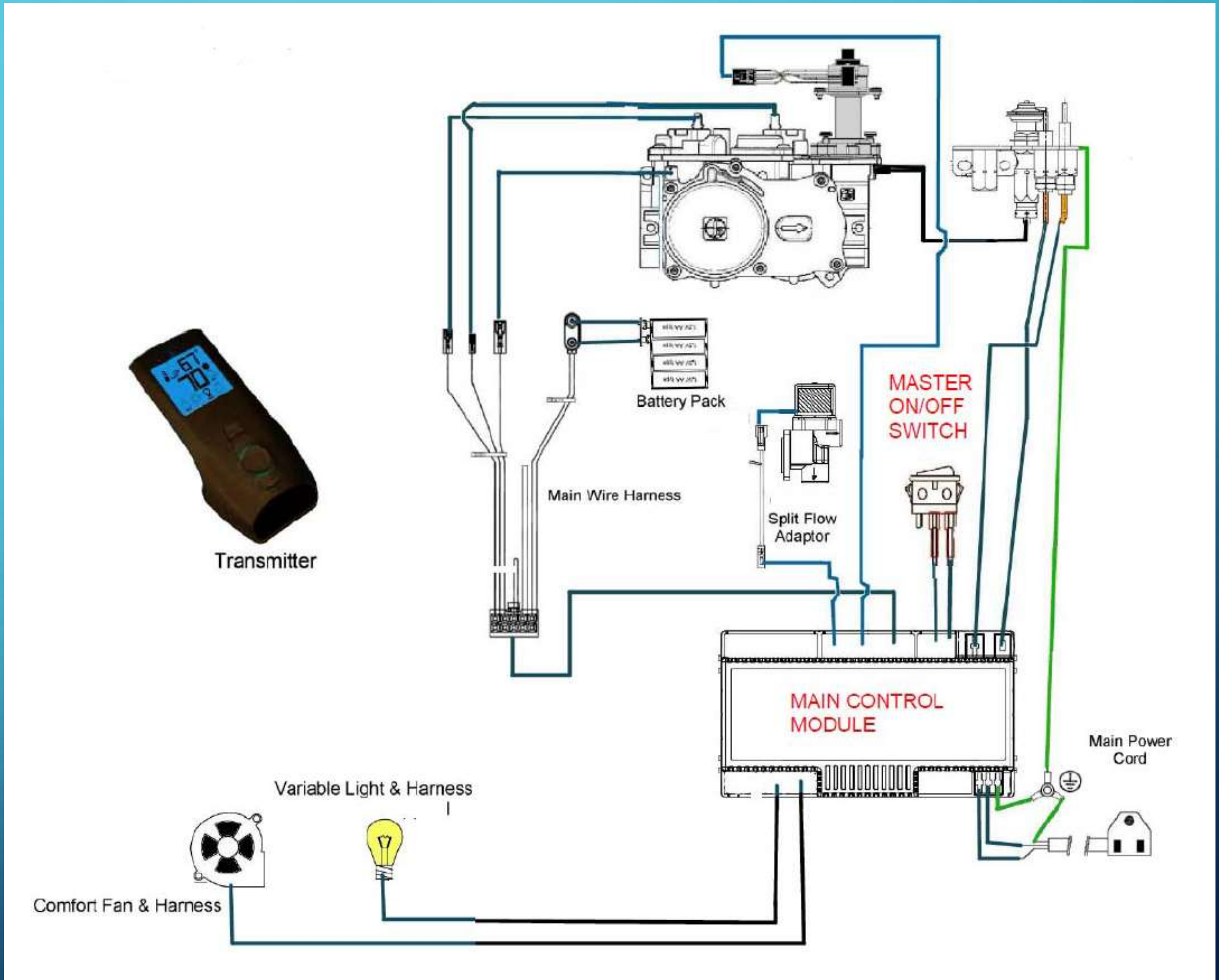
Understanding wiring diagrams and procedures for troubleshooting is very important



VISUAL ID

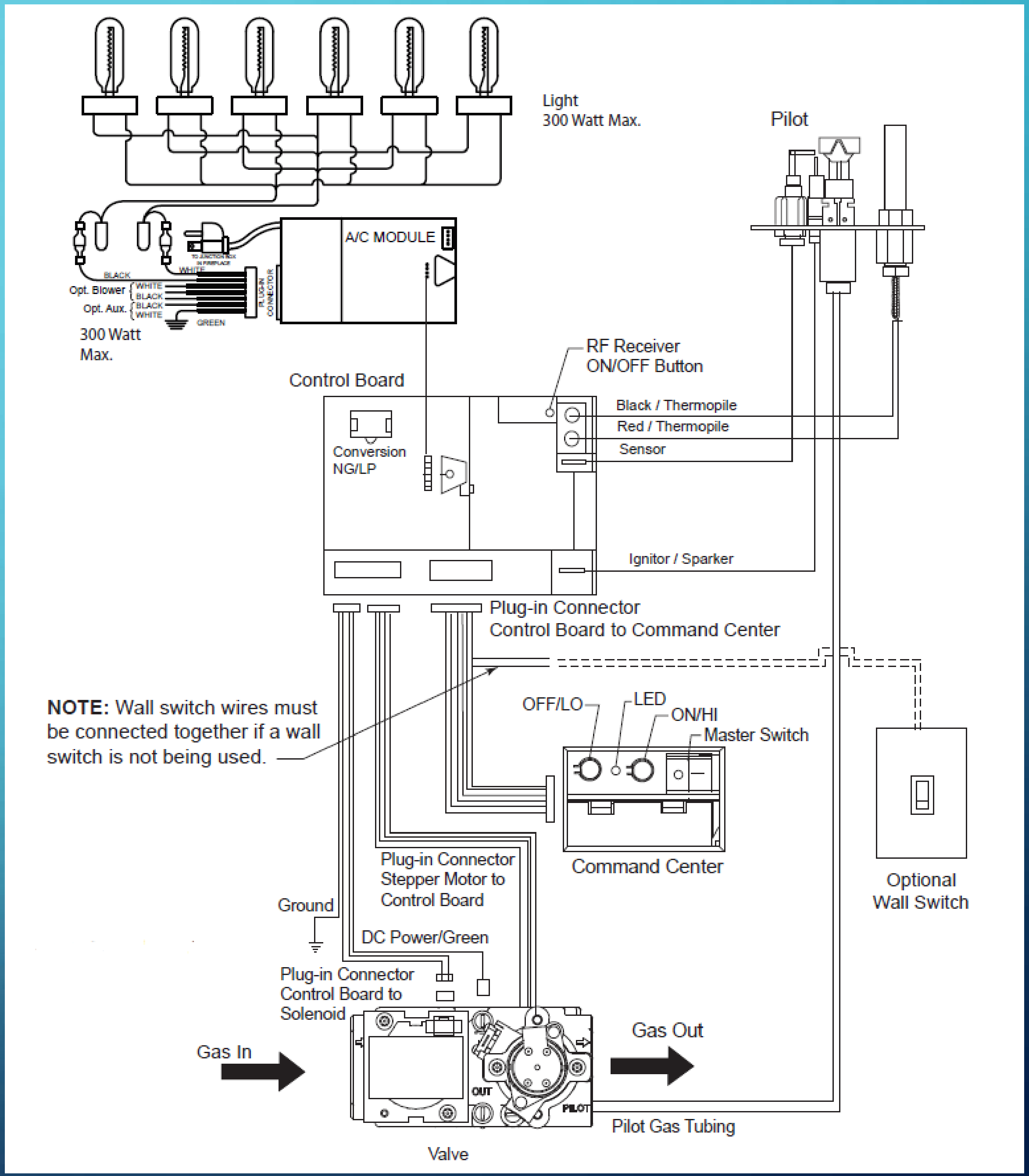
Understanding wiring diagrams and procedures for troubleshooting is very important.

Some diagrams are not very helpful



VISUAL IDENTIFICATION

- Understanding wiring diagrams and procedures for troubleshooting is very important



DIGITAL MULTIMETER

- Need Direct Current **volts**. down to millivolts (thermocouples, thermopiles)
- Need Alternating Current **volts** (house current, transformers)
- Need **Ohms** (resistance)
- Continuity is nice
- Rarely need Amps (current) except for HSI systems

TERMINOLOGY – SHORT CIRCUIT

Everybody knows it's bad, but very few know what it is.

A short circuit is similar to *short-cut*.
It means current takes a shorter path than intended, usually to ground.
On a 120V circuit, a short circuit will usually pop a circuit breaker.

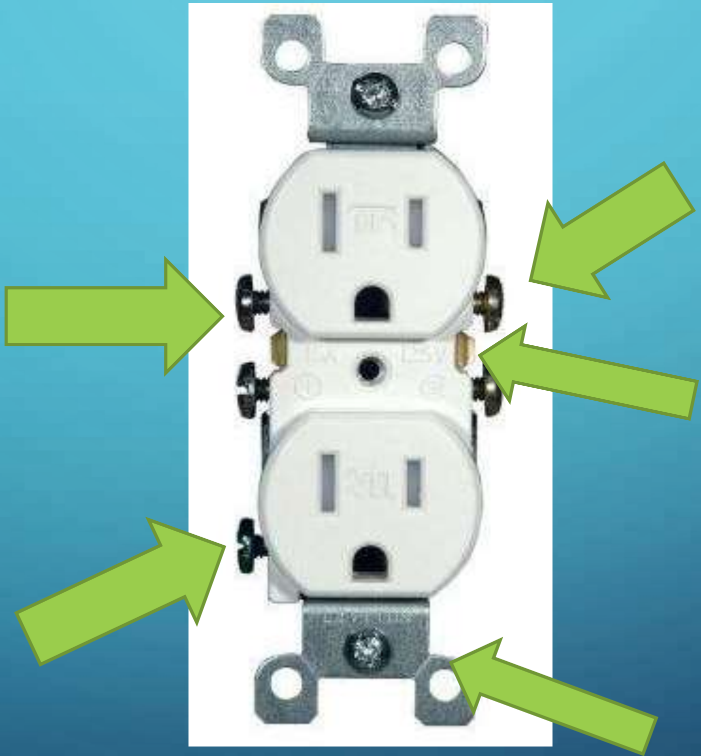
If a component is "shorted" it means current is flowing directly through it with no resistance.

Sometimes when something is "shorted out" it means that the component had too much current run through it and it was damaged. It is no longer "shorted", it is "open".

BASIC ELECTRICAL OUTLET

Silver screws
neutral side
connect to white wires

Green screw
grounding terminal
connect to green or
bare wires



Gold screws
hot side
connect to black wires
(skinny slot)

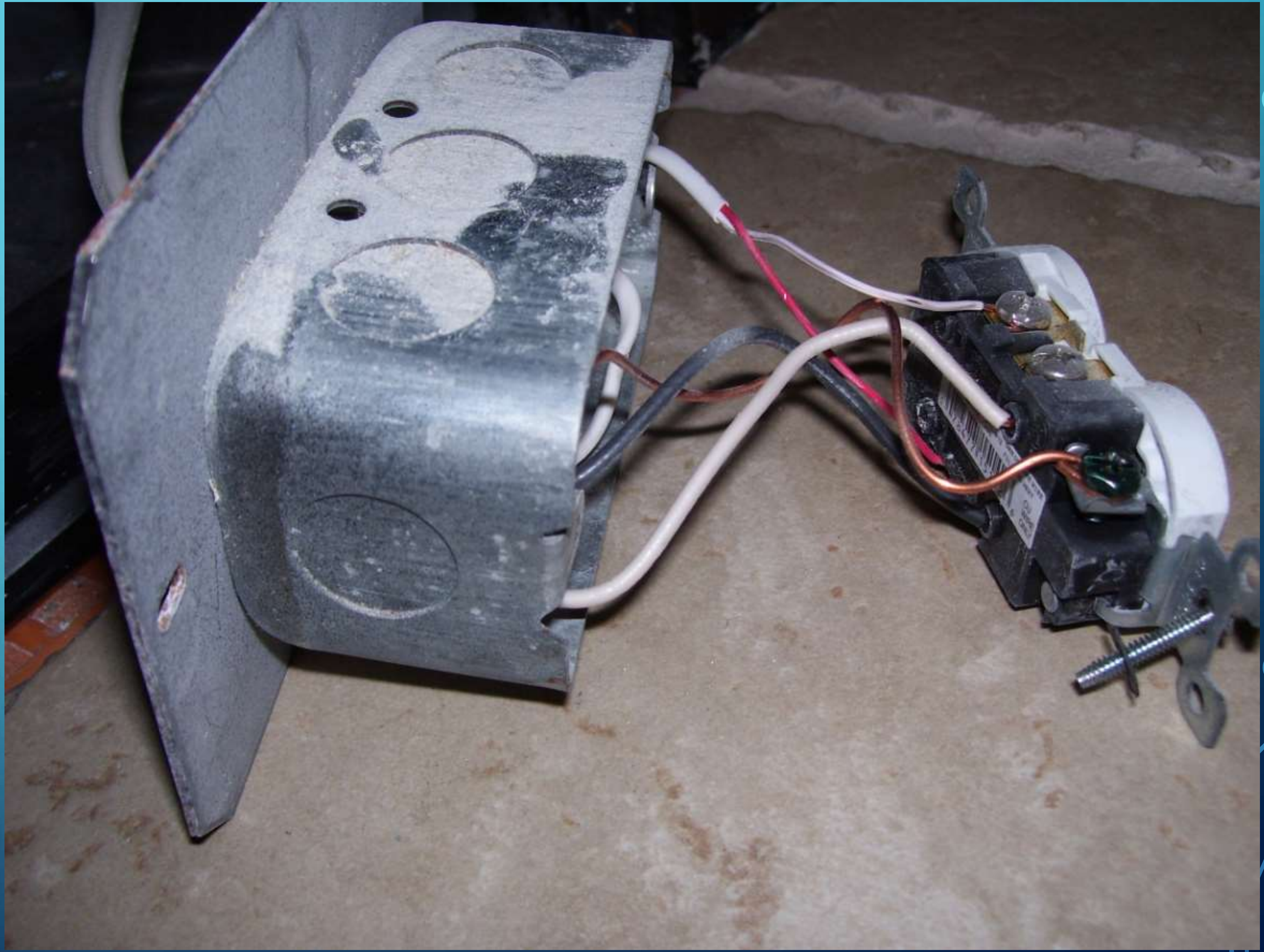
Breakout tab to
separate outlets

mounting tab is
grounded

OH, MY.

Wall switch wired to outlet.
What do you think happened when they turned their wall switch on?

The circuit breaker popped, because the wall switch shorted the hot to neutral



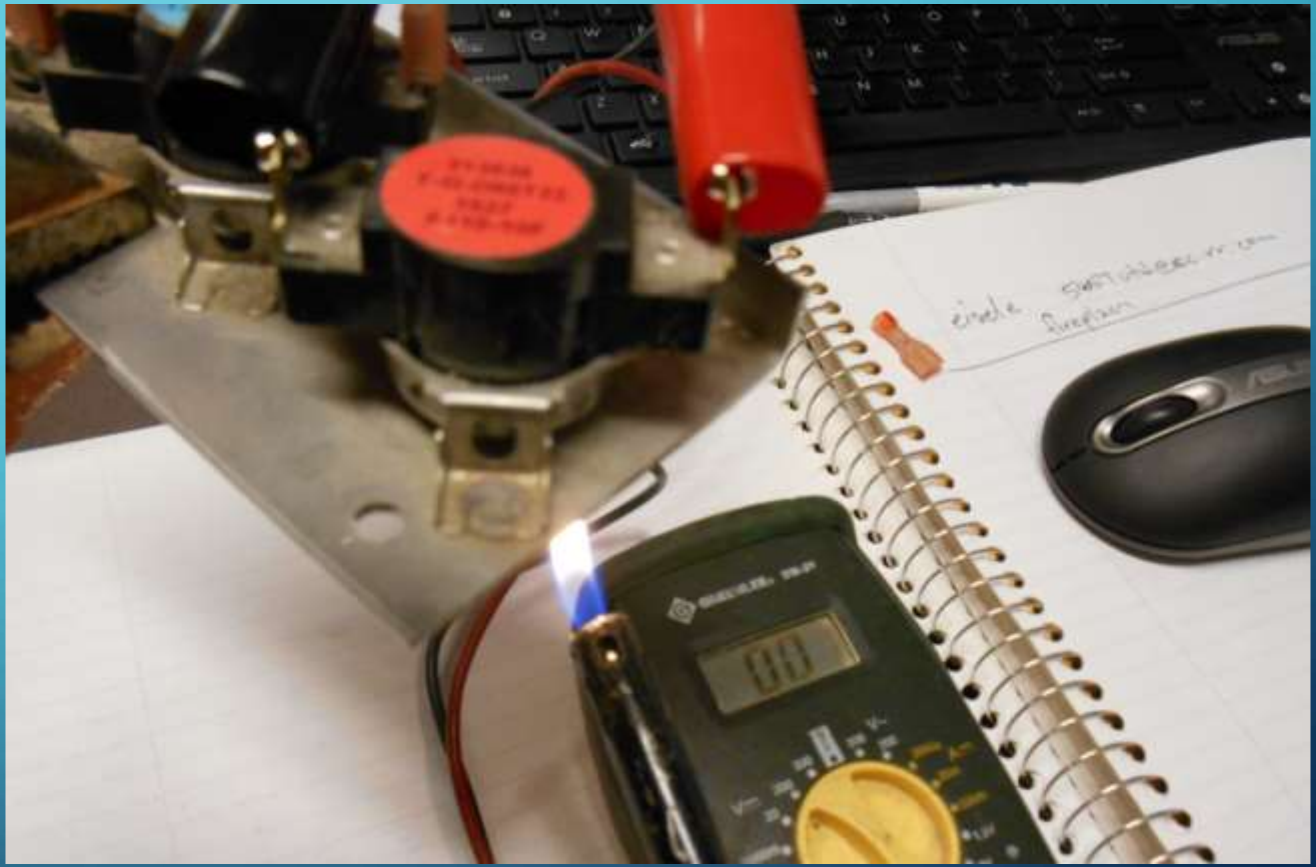
SNAPDISK OPERATION

- Snapdisks are common on all three major types of hearth products:
  - Wood
  - Gas
  - Pellet

- A snapdisk can be normally **open**, as in a thermostatic fan control, which only operates after the unit heats up.
- It can also be normally **closed**, as in a b-vent spill switch that will interrupt the circuit when it gets too hot, or an exhaust temperature sensor on a pellet stove that turns off the ignitor once the exhaust gets hot enough.

SNAPDISK TEST

- A blower snapdisk can be tested with a butane lighter and a multimeter set to continuity.
- Hold it with pliers to keep from toasting your fingertips.



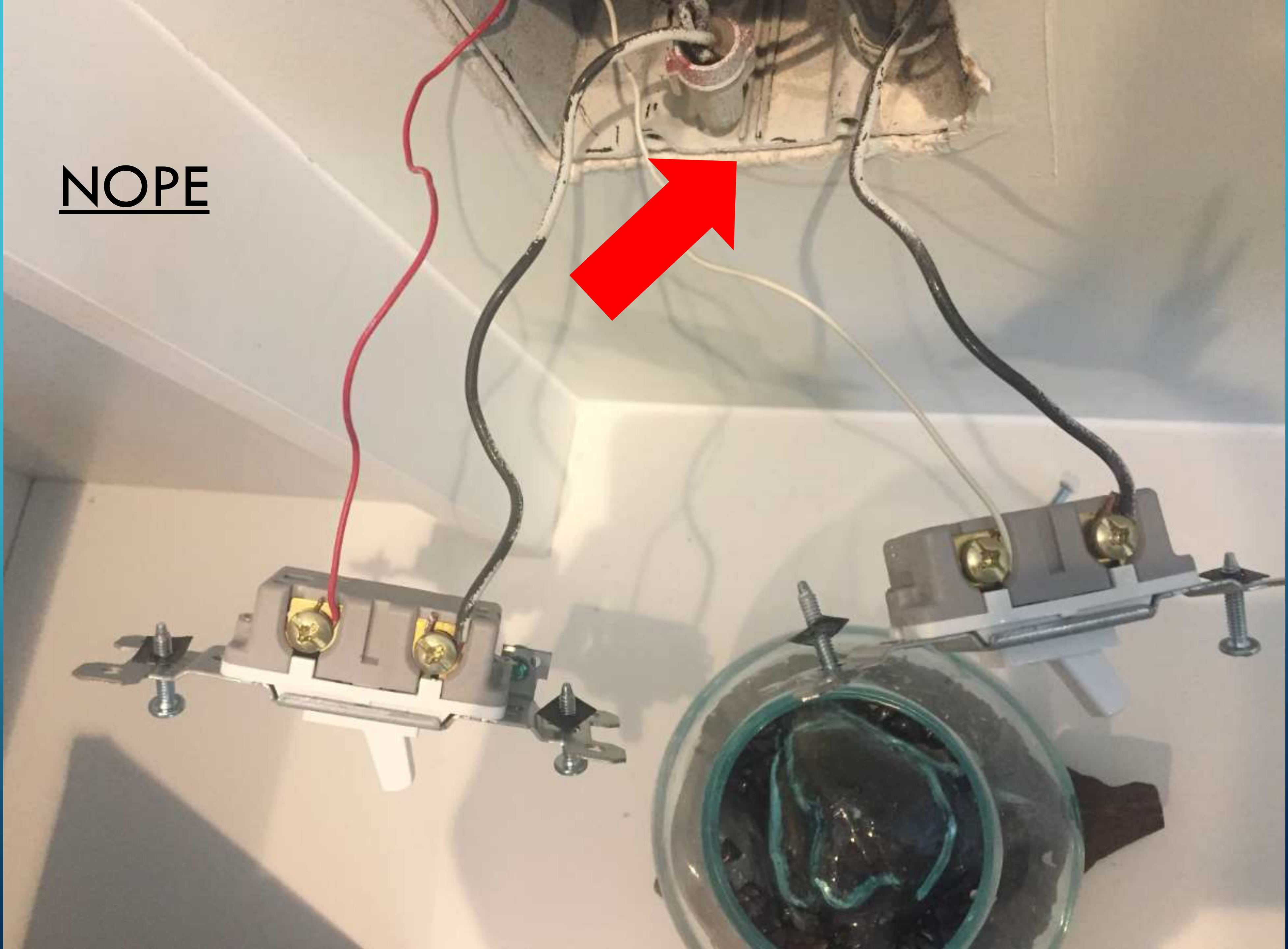
FAN MOTOR SPEED CONTROLS

- Fan speed controls turn on at “high”, to get fan going, then turn down.
- Long story short: use the control designed to go with the fan.
- Snapdisks must be wired in **series** with the speed control or switch. If there is more than one fan, they should be wired in parallel, or they will run at a lower speed.
- Do not use a light dimmer to control fan speed. A dimmer can turn down too far and possibly burn up the motor.

110-120VAC SYSTEMS

- Reminder: Don't work on any connections while a circuit is live. Mistakes can lead to shock or damaging components.
- Use a tester to verify whether a circuit is de-energized.
- Do not terminate low voltage and line voltage (120VAC) in the same junction box (risk of damage to gas valve components, and illegal).

NOPE



USEFUL TOOLS

BREAKER FINDER

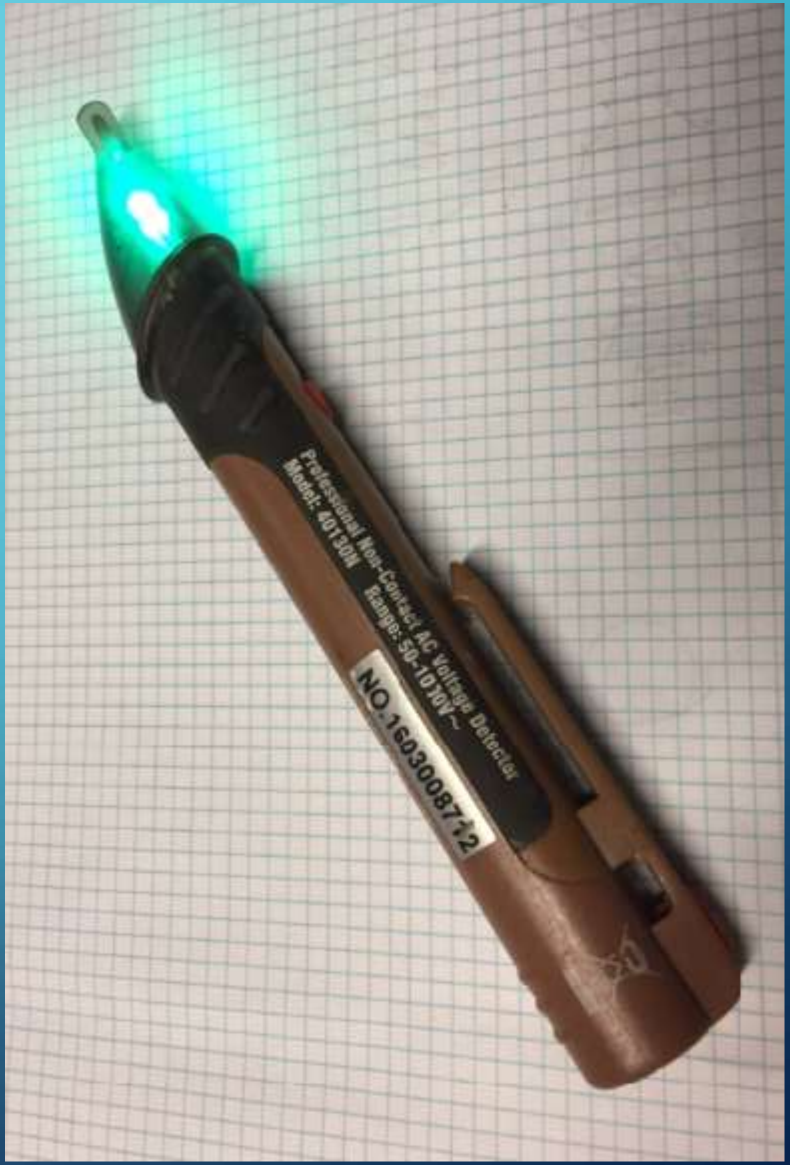
TRANSMITTER AND RECEIVER

USEFUL TOOLS

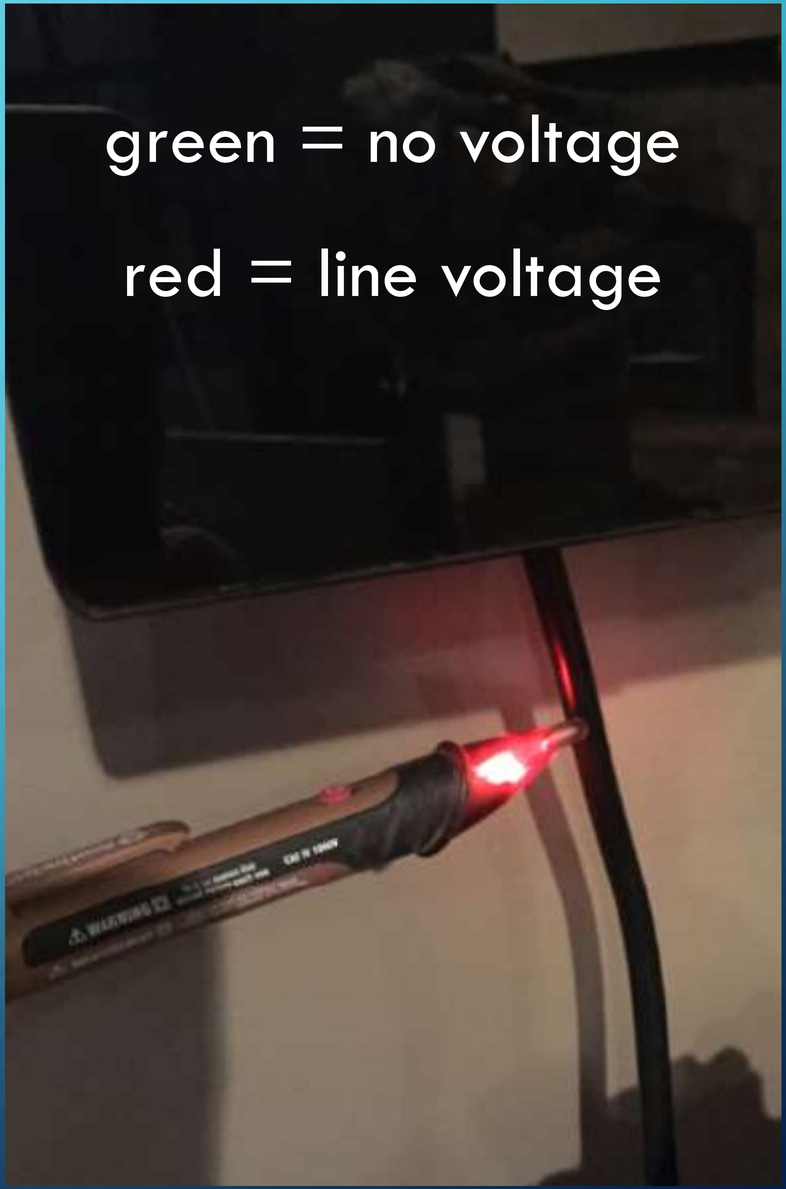
A receptacle tester will allow you to check an outlet for power as well as identify common wiring issues.

USEFUL TOOLS

- A non-contact voltage checker will allow you to check outlets, cords, or wire-nutted connections for power without exposing a bare conductor



USEFUL TOOLS



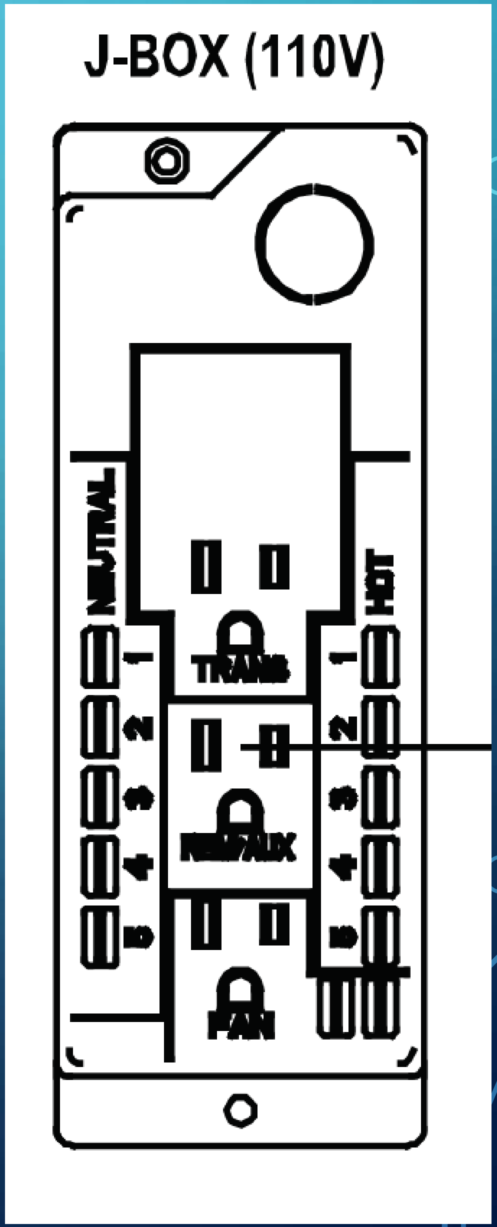
110-120VAC SYSTEMS

- Common issues

  Switched 120VAC to electronic ignition modules (can cause issues with module)

  Misconnected, damaged wiring harness

  defective switching components



110-120VAC SYSTEMS

Use jumpers across components to isolate problems by bypassing snapdisks or speed controls.

Connect the jumper in parallel with the component or replace the component with a jumper.

SPLIT SWITCHED OUTLET

Need a hot side for E.I. module and switched side for fan speed control?

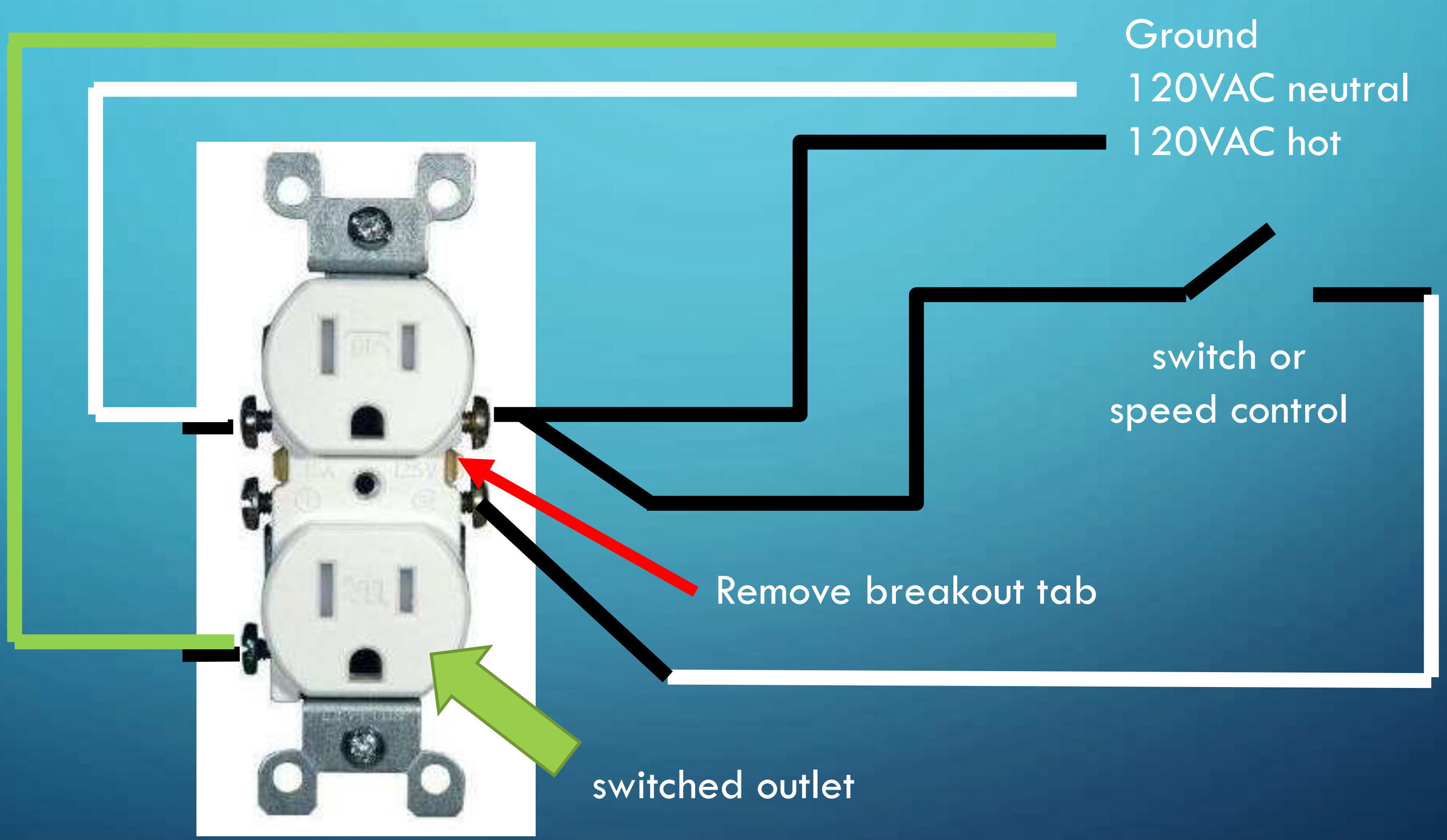
Silver screws
neutral side
connect to white wires

Green screw
grounding terminal
connect to green or bare wires

Gold screws
hot side
connect to black wires

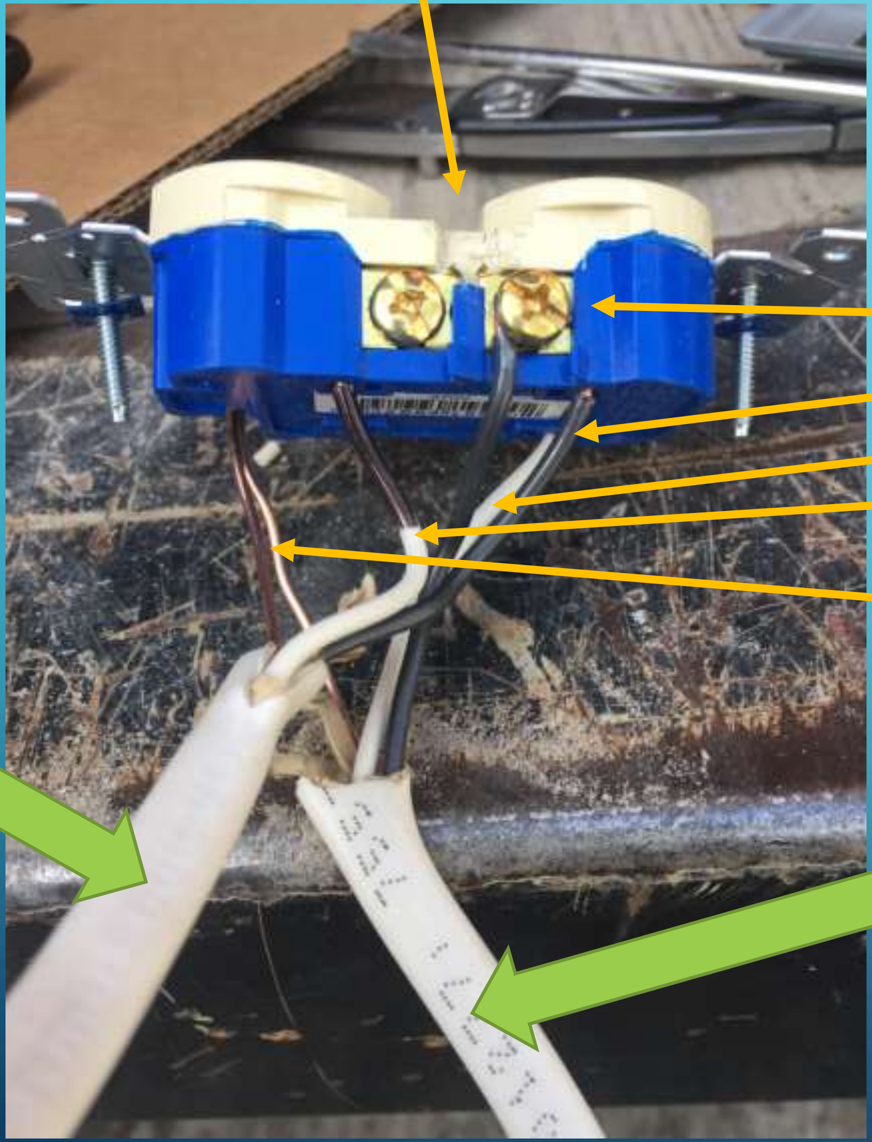
Breakout tab to separate outlets

CREATING SWITCH LEG ELECTRICAL OUTLET



SWITCHED OUTLET

Broken tab

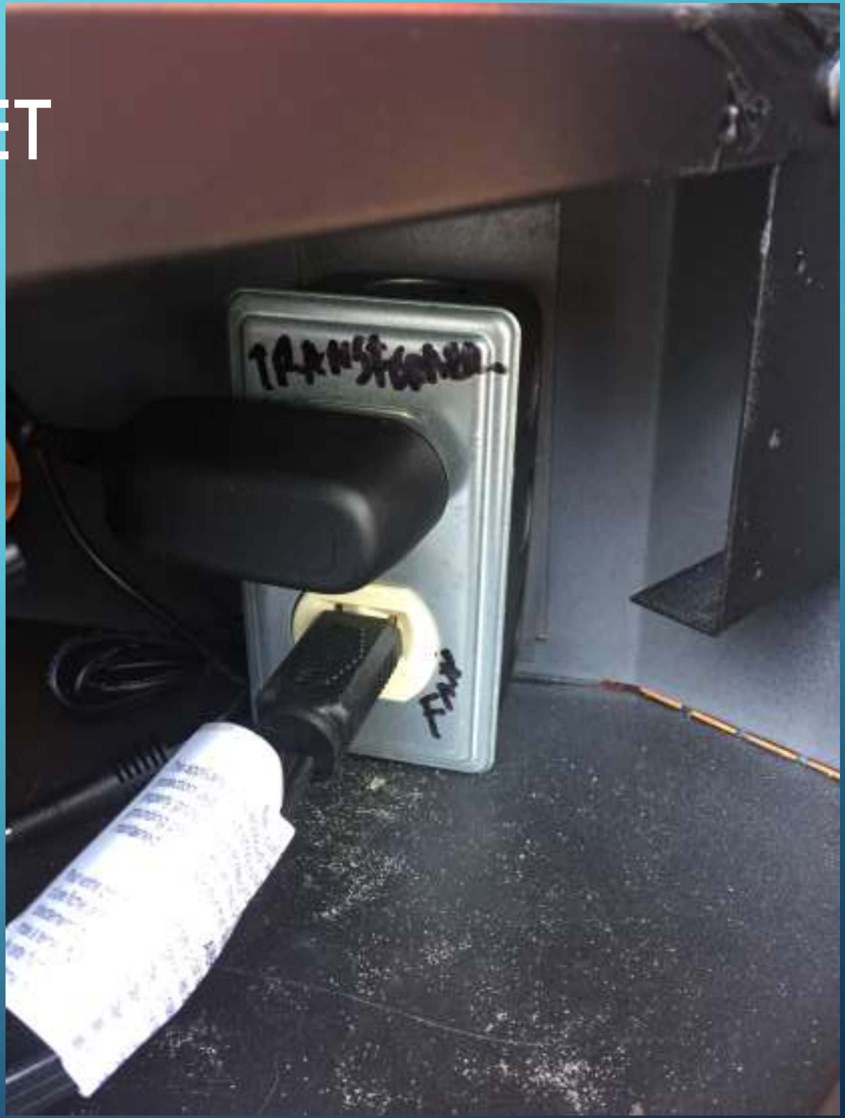


120VAC hot (side terminal)
120VAC to switch (speed connector)
120VAC neutral (speed connector)
Switch leg return (speed connector (black marker)
grounds

Wire to switch (switch leg)

120VAC supply

FINISHED SWITCHED OUTLET



GOOD PRACTICES

ISN'T TECHNOLOGY GREAT?

Snap a photo of a correct setup before you take it apart. You can use it for reference when you put it back together.

Labels and wiring diagrams are good, but not foolproof.

CHECK BATTERIES

"I just put in new batteries" is just as helpful as "I just had my gas tank filled"

You need to measure the actual voltage (on every battery) just like you need to check the actual gas pressure.

A brand new single cell is usually about 1.6 volts, and will work until is gets down to about 1.3 volts, but systems vary.

CHECK TRANSFORMER/ADAPTORS

3VAC

- Be sure to set your meter to AC or DC depending on what type of transformer or adaptor you have

TAKE BATTERIES OUT AT THE END OF THE SEASON

- People often forget batteries in the battery backup or remote control receiver and the may ruin a perfectly good unit with leaking batteries over the summer.

ROUGH-IN WIRING

Clearly mark all pigtails during rough-in

Do not connect to anything (unless you are qualified, and even then with permission)

ROUGH-IN WIRING

Clearly mark all pigtails during rough-in

Do not connect to anything (unless you are qualified, and even then with permission)

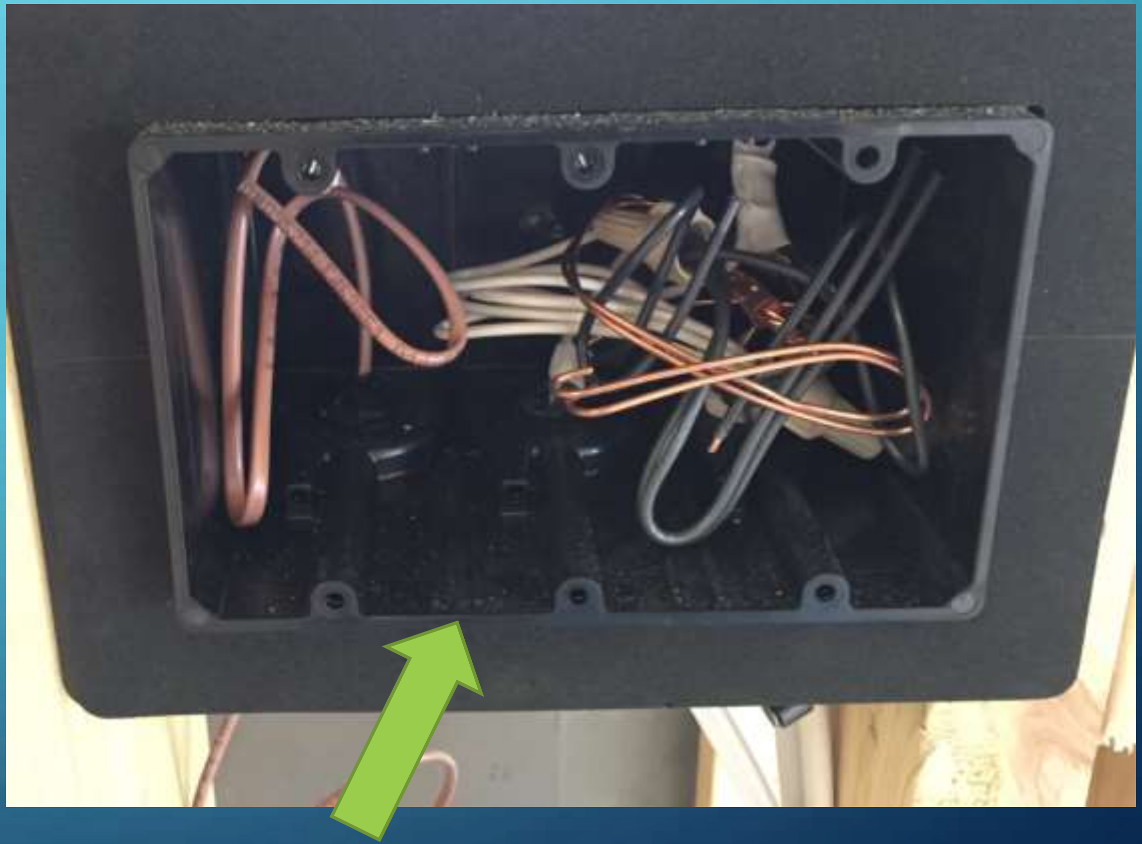
ROUGH-IN WIRING

Clearly mark all pigtails during rough-in

Do not connect to anything (unless you are qualified, and even then with permission)

SEPARATE LOW VOLTAGE AND LINE VOLTAGE

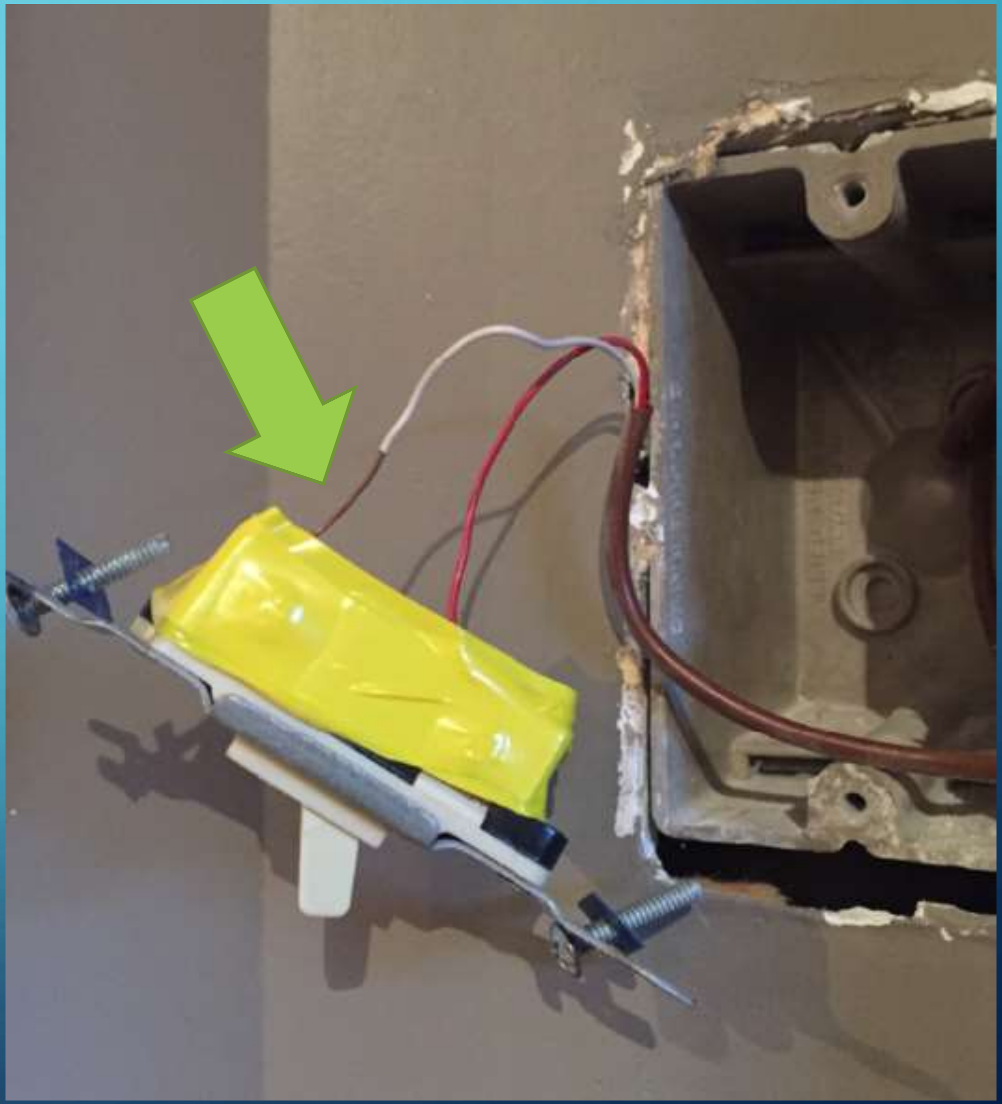
We can't seem to prevent electricians from running low voltage and line voltage next to each other. There is a space for a septum, but there is another thing you can do to prevent shorting your valve to line voltage.



TAPE SWITCHES & OUTLETS

This is what keeps a $1 switch from destroying a $180 valve.

Tape the bare contacts on the switch (don't strip too much either)

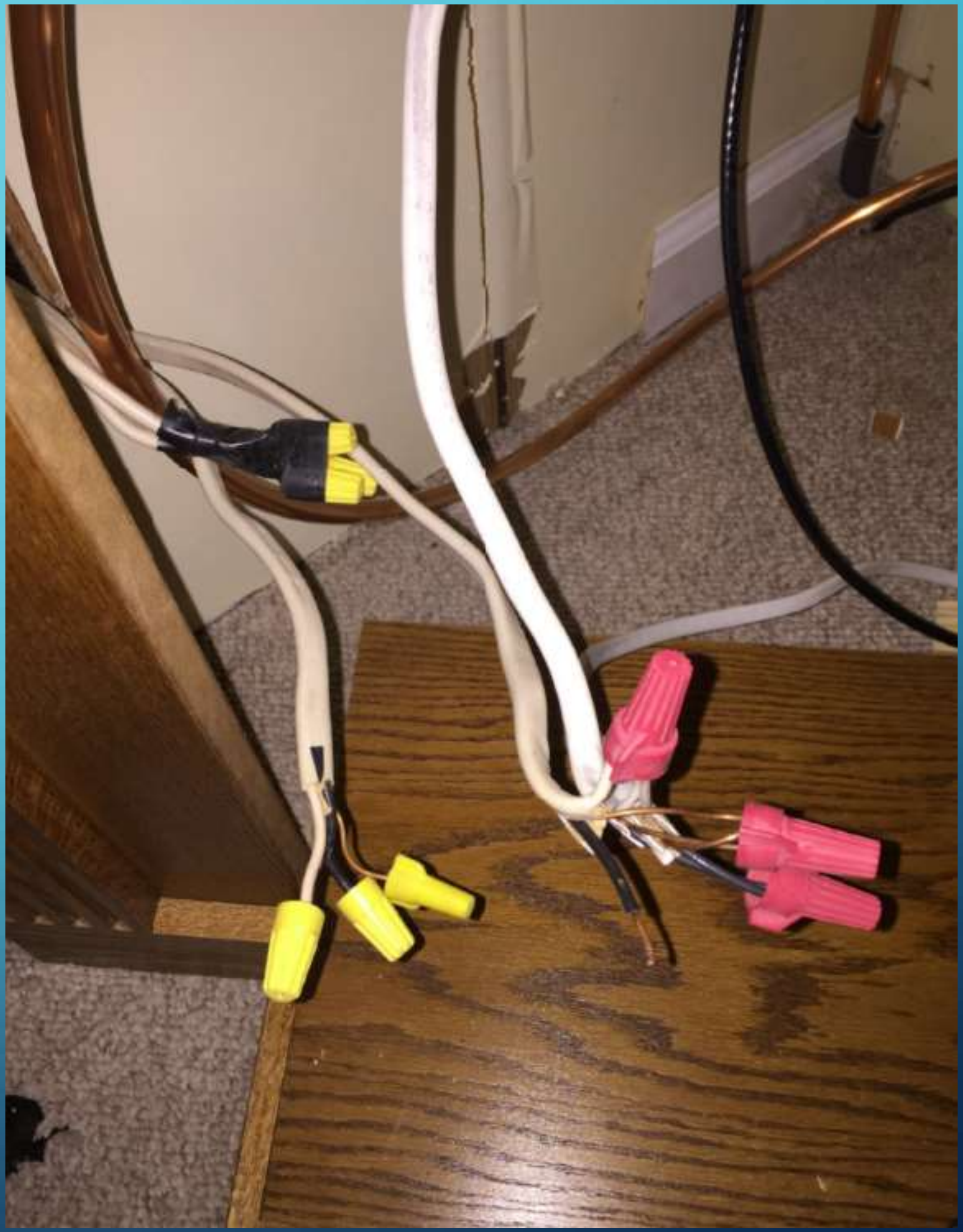


TAPE SWITCHES & OUTLETS

Taping contacts on outlets will also prevent accidentally shorting them out to the bare copper ground or the metal junction box.

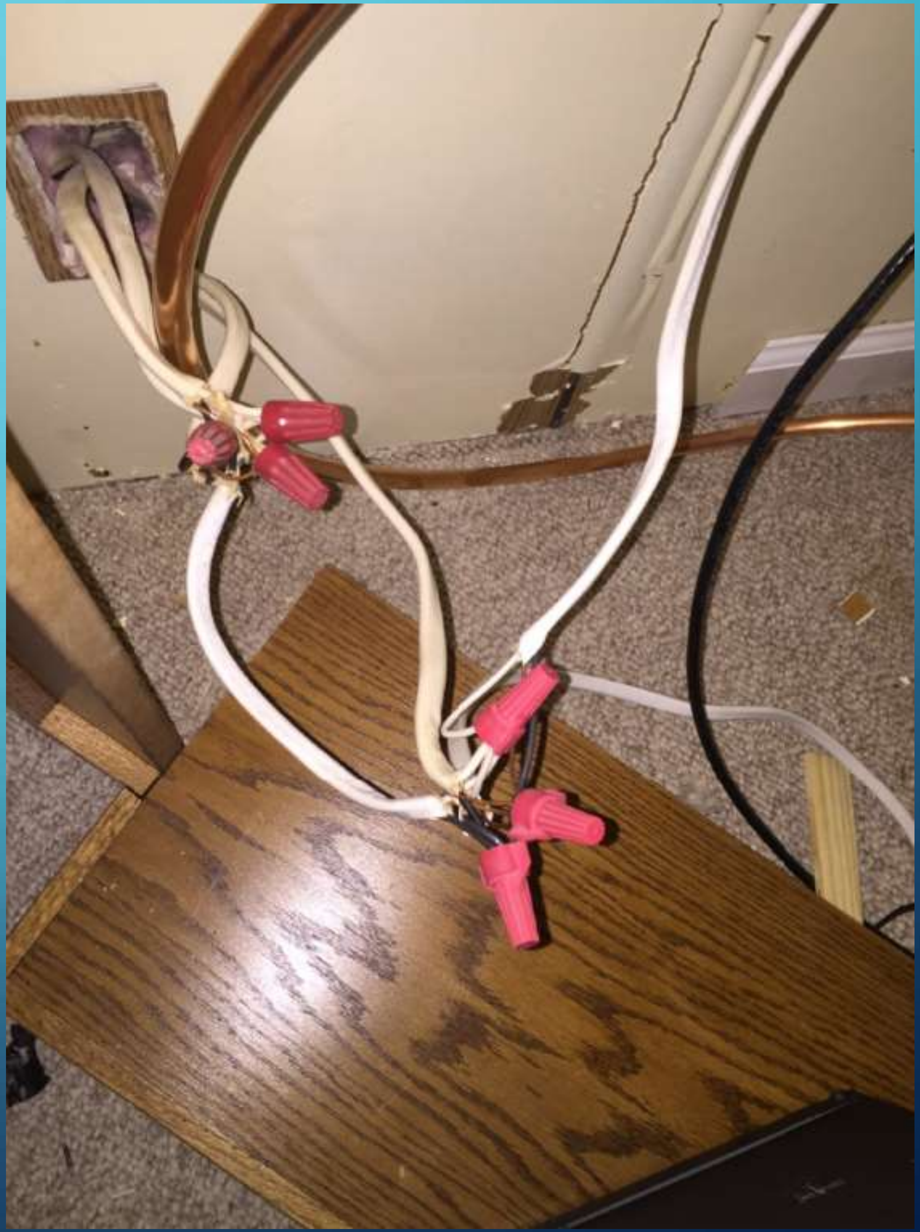
OH, DEAR.

What's wrong with this picture?
Only one of the outlets in the room worked after this technician was finished doing this.
Are you surprised?



OH, DEAR.

Not that difficult to figure out . . .
All of the hots (black) are connected, all of the neutrals (white) are connected, all of the grounds (bare copper) are connected. Now to get them stuffed into a junction box




NOPE


NOPE

SUMMARY

Many professionals in our business are uncomfortable dealing with electrical issues, but most issues are easy to understand and troubleshoot once the concepts are clear.

SUMMARY

It is important to understand these topics:

- The relationship between voltage, current and resistance
- Open and closed circuits
- Magnetism and thermogeneration (Part 2)
- Electronic flame sensing (Part 3)
- How to use basic diagnostic tools

QUESTIONS?