SHOPSMITH MOTOR GUIDE

Table of Contents

Forward

As always I must acknowledge the contributions of many to my knowledge though their knowledge and experience. My late friend and mentor Bill Mayo, James Grange Sr., John Burger, Dusty, Ed and many others who tirelessly share their time and knowledge with us all in the Shopsmith Forums. My passion and interest in many things came from my early mentoring by my grandfather and my uncle, who piqued my interest in science and electronics when vacuum tubes were still the rage.

Getting Started

As in the bearings guide developed earlier this year, there is foundational material that some may find beneficial to know to help understand more of the how and why things work the way they do.

Safety

I cannot over stress the importance of reading the foundational material as it is not relative to just Shopsmith Motors, but discusses all sorts of issues regarding safety of you, your children, your grandchildren, and employees, customers or guests who may be in your home or shop through your lifetime. Few of these topics are discussed much less taught in local schools, and where it is, only to a handful of students engaged in a particular elective or vocational training. It affects us all however, no matter where we go in life. It is all around us.

How it is presented

Rather than present material in an overarching background, body, summary style Motors will be presented in a topic by topic, precept by precept, building upon the subject by layering in the technologies as they were first applied then refined through the years, stopping along the way to introduce some of the science, lessons learned, what it means to you today, and the safety issues that affect us.

Just as Shopsmith equipment manufactured over the last seven (7) decades has changed through the years, so has the construction of our homes and businesses in which we now operate that equipment through the same period. A seventy year old home unless it has been renovated, restored and remodeled will not have the same things as a home now being built. It is the same with your Shopsmith.

We have learned things through the decades, invented and introduced new things, and while in years past that knowledge was passed on through the trades so to speak, public education dropped it almost entirely. It is as if education believes we all live in the same types of homes, work in the same types of industries in newly manufactured business locations.

Nothing could be further from the truth as many still work in 50- 100 year old buildings, live in homes made half a century or more ago, and have a workshop that we hope someday evolves from the garden shed or old garage we converted to work in.

Understanding what is there vs. what should be is vital foundational knowledge, some of which will make your tools work better, last longer, restore them to service, or perhaps save your life.

Disclaimer: **The topics presented are a discussion of the issues, not a procedural manual or how to guide. I assume no responsibility whatever for your safety in what you elect to do, or not do with the information. There are always several types of readers: those who are trained and experienced, those who are inquisitive and want to know if this is something they can learn, those who are thrill seekers and will do it their way, and those who have no clue.**

Considering the topic Shopsmith Motors and the inherent danger electricity introduces, it is vital that everything that can be performed with the equipment not only powered-off, but physically unplugged, <u>is actually done with the unit unplugged</u>, and visually verified each time you approach it.

Let's get started with a discussion of motors in the most general terms.

Electric Motors generally spin using the function of a magnet in combination with an electromagnet or combination of electromagnets.

Electric Motors use electrical power in the form of Direct Current such as a battery/power supply, or by Alternating Current such as AC power in our homes, shops and businesses.

Through the years the vast majority of Shopsmith equipment has used AC motors, though the current Mark 7 Power Pro uses new technology; a Digital Variable Reluctance (DVR) motor. Shopsmith Mark Mounted Planers and Professional Planers employ a DC Gear-motor to feed the stock through the planer.

For purposes of this Guide, we will focus on the AC Motors, and briefly touch on the other two.

It starts with a Magnet

Merriam-Webster Dictionary defines magnetism as:

- A class of physical phenomena that include the attraction for iron observed in lodestone and a magnet, are inseparably associated with moving electricity, are exhibited by both magnets and electric currents, and are characterized by fields of force

- A science that deals with magnetic phenomena

That is the dictionary description, and there is nothing much to add. That's what it is.

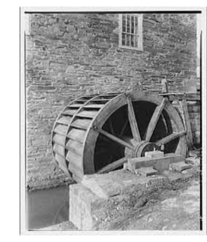
Indeed it is this very property of magnets that allowed us the ability to:

1. generate electricity through mechanical rotation of a magnet in the presence of coiled conductors (generators)
2. convert electricity back into mechanical rotation through the presence coiled conductors in the presence of magnets or electro-magnets (motors)
3. step voltage up or down through coiled conductors surrounding an iron core to move it to do work somewhere else (transformers)

To do work somewhere else

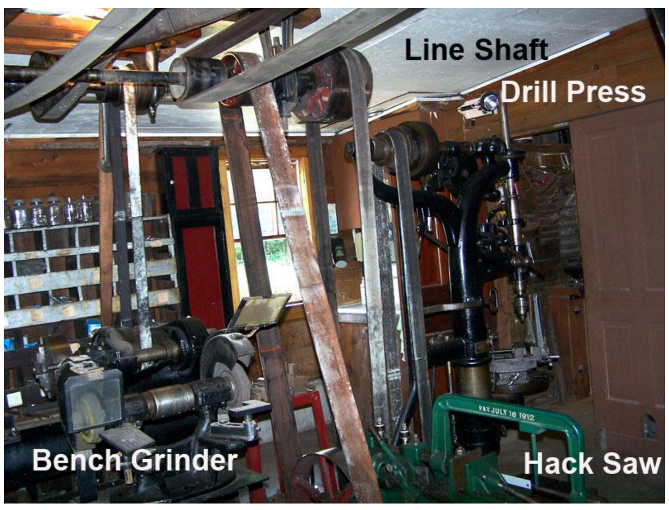
Mankind has always worked to invent methods to improve his ability to do more work powered by forces other than himself. It is the somewhere else component that has inspired invention.

Windmills and Waterwheels were geared down and tasked to grind grains in mills, and a host of other things. As the work needs grew, so did the waterwheel.



In keeping with that inventive and creative usage of technology, steam was harnessed to create motion, and it is still in use today in many modern power generating systems. What do you suspect coal powered or natural gas powered generation plant uses today to turn impellers? Steam. Yes, the nuclear power plants as well, generate movement through steam to turn those magnets by turning impellers with steam, in the coils of wire we call generators.

Back in the day of waterwheels and steam power, man created something else combining them to reproduce motion, and you can still find that Steamship technology in use. We adapted the concept even further creating Combines to harvest crops, and invention continued rolling on.



Workshops and manufacturing each found ways to harness the output of the waterwheel by transmitting that power through belts and shafts to other locations, and transforming the speed to do physical work.

With all those open belts, wheels and pulleys OSHA would have had a field day. Accidents did happen. People were killed or severely injured.

Water Powered Sawmill with Wooden Gears at Kings Landing Canada.

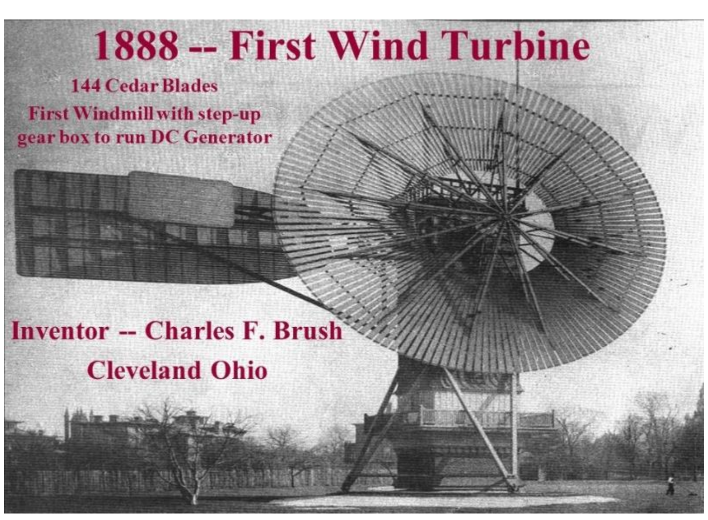
Click photo for a YouTube Video.

Wind powered sawmill Zandijk, Netherlands:

Click photo for a YouTube Video.

New Inventions were commonplace in a period of history we refer to as the Industrial Revolution, but by no means did it stop.

The more things change, the more they stay the same in mankind's pursuit to produce…. Horsepower.



First Wind Turbine (Left) had 144 Cedar Blades and the First Windmill with step-up gear box to run DC Generator, Inventor -- Charles F. Brush Cleveland Ohio 1888, some 128 years ago.

The science behind it all is sound, and has been utilized in a myriad of ways though history.

Horsepower

Merriam-Webster Dictionary defines one (1) horsepower as:

- The power that a horse exerts in pulling
- A unit of power equal in the U.S. to 746 watts and nearly equivalent to the English gravitational unit of the same name that equals 550 foot-pounds of work per second

Cars, planes, ships, trains, water well pumps, garbage disposers, lawnmowers, tractors, and yes motors are all categorized by their ability to do something relative to a standard measurement called, horsepower.

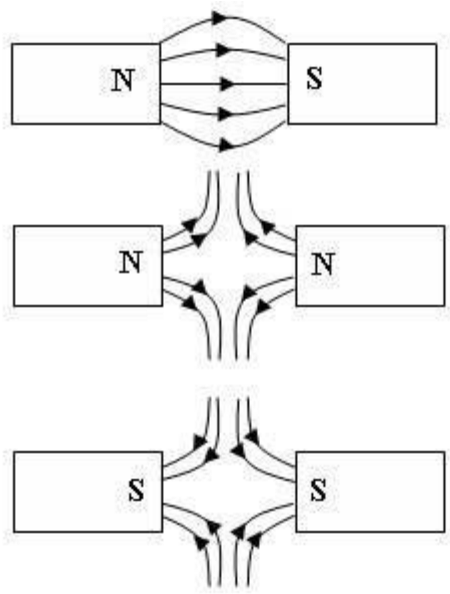
Motors

First things First: We generally understand what an electric motor does in the concept that it rotates to produce power to accomplish work of some nature.

How it goes about doing that and the components configured inside or even outside them to achieve that varies based on the motor manufacturers design, some rooted in the time period of its design.

Not knowing where the reader of this document has attended or is attending school, a quick review of basic concepts that enable a motor to work is in order. I did not say "how long it has been since the reader was in those classes", but that too could have some relevance if they weren't particularly interested in the subject at the time they attended, or were just never exposed to the subject.

Through the years, new inventions and application of different technologies have dramatically changed motor design in some areas, though accomplishing the same thing. We will even dig into the term "Phase" to get some background on what it is and how it is manipulated to achieve motor rotation. Be patient. We will get there.

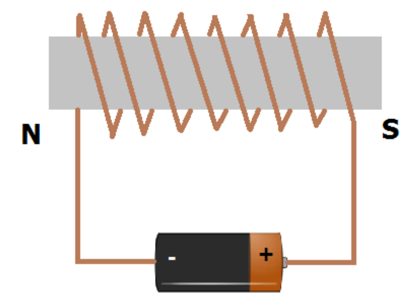


It is doubtful that we could find many folks who have never toyed with a magnet, or perhaps two magnets to verify they can have strong attraction to each other, or repel each other, somewhat like the carbon based units we know as humans…. But I digress.

If one were to take two permanent magnets and examine their relationship to each other they could prove the North Poles repel other North Poles and South Poles repel other South Poles, while North attracts South and South attracts North. Simple to prove and visually verify. Likely somewhere in your science classes in school, we all did something of that nature in class.

It was this concept that allows us to envision the movement of electrons in atoms, and define areas in valence electrons and in chemical compound bonds in the science of physics and chemistry. We are not going that deep by any means.

We likely wrapped copper wire around a nail or other metal rod and connected a battery to produce a simple electro magnet in those early science classes.



It is that concept in magnetic properties that enabled electrical generation, power distribution and inventions such as the telegraph, the telephone, the microphones, speakers, televisions, cell phones, computers, tablets, game consoles, garage door openers, water extraction from wells, treatment and distribution, garbage disposals, hair dryers' even pacemakers and the myriad of other technologies that makes our world work today. And it is the Electro-Magnetic Pulse (EMP) that is a threat to those technologies that we discuss in threats to our lives today.

Alternating Current

With AC (Alternating Current) the polarity swaps (cycles) from one polarity to the other at 60Hz [Hertz] (formerly known as 60 CPS or 60 times per second) which has the electrical effect of flipping the battery over, which accordingly would reverse the North and South poles of the electromagnet 60 times a second.

Obviously we don't use batteries and move them, we use electrical power generation plants, turning the turbine by steam as shown at right, or by water if hydro-electrically generated, governing the speed to produce exactly 60 cycles per second. (Europe uses 50 cycles per second as their standard as an example)

Transformers

The power grid uses transformers (electrical device that transfers electrical energy between two or more circuits through electromagnetic induction). A varying current in one coil of the transformer (Primary Side) produces a varying magnetic field, which in turn induces a voltage in a second coil (Secondary Side) to help distribute the power to where it is needed.

Power can be transferred between the two coils through the magnetic field, without a metallic connection between the two circuits. If you studied physics or electronics you briefly discussed Faraday's Law of Induction, which enabled transformers. There are step-up transformers, step-down transformers and isolation transformers (which I will discuss later as a safety device you need to be aware exists)

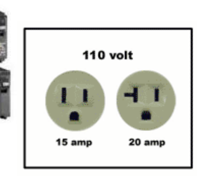
Power Distribution

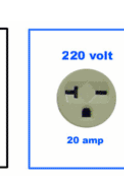
Power distribution in the electrical grid has to overcome obstacles such as great distance by flowing through wires which offer resistance to that flow. Engineers found that by increasing the voltage dramatically from the 110 or 220 that we need in our homes, they could reduce the power it took to push that power through the lines. The photo shows 500kV Three Phase electrical transmission lines at Grand Coulee Dam in Grand Coulee, Washington.

Power travels across the country and is stepped down at intermediate locations flowing in to cities and is stepped down yet again in local power substations where the power flows to either neighborhood pole mounted step-down transformers or underground transformers at voltages between 4000 volts to 25000 volts, where it is stepped down the last time, then delivered through your electric meter into your home power panel as two separate 110 vac. Legs, that when combined, delivers 220 vac., or when used separately, 110 vac.









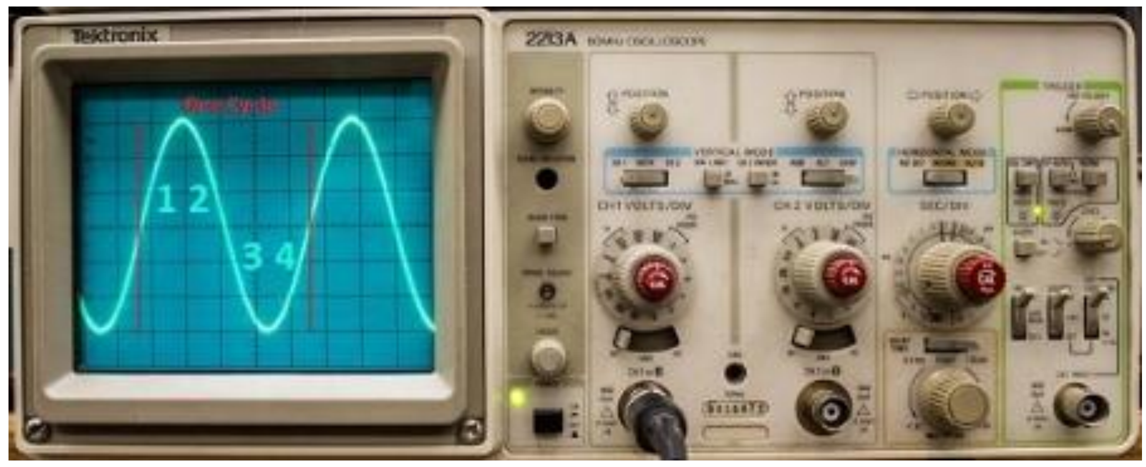
Now the power is in your home and ready to use to run that motor. If we were to take an oscilloscope, we could visually see a representation of the Alternating Current expressed in the rising and falling of voltage over time. In the United States the alternation (repeating cycles) occurs at the same rate over a period of time expressed in a rate per second, or Cycles per Second (CPS) as it formerly was known.

With the organization of the International System of Units in 1960, the cycle per second reference was officially replaced by the term hertz, to honor Heinrich Rudolf Hertz 1857 – 1894, a German physicist who first conclusively proved the existence of the electromagnetic waves theorized by James Clerk Maxwell's electromagnetic theory of light. The unit of frequency — cycle per second — was named the "hertz" in his honor.

Without dredging up all the manual graphing or graphing calculator lessons we perhaps studied in school, I believe most of us understand the concept of a full circle being 360°. I believe that we likely understand our concept of angles based upon that the terms of an angle referenced in trigonometry are based upon rotation from a point. We use those in woodworking all the time to build and construct things.

Taking up on that a full cycle of AC will start at 0, rise at a rate over the first period of time to a peak, then fall over time back to the baseline over the second period of time (crossing 0 if you will), then fall below 0 to a valley over the third period of time, then rise back to 0 during the fourth period of time, completing one (1) cycle. US AC voltage does this full cycle of four equal blocks of time, sixty (60) times in one (1) second.

An Oscilloscope allows us to measure and represent visually, what is happening on a graph screen. I have attached a screen shot of an oscilloscope, annotating the four (4) equal periods of that one (1) cycle of the 60 htz. 110 v AC voltage, known as a Sine Wave.

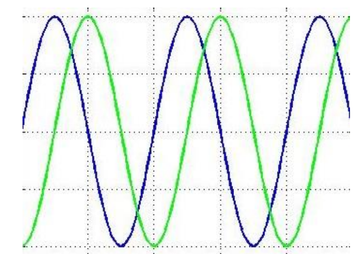


No we are not going into Sine, Cosine, Tangent etc. but the graphic representation of the sine and cosign function are represented on the scope screen just as if you had graphed them from discrete measurements over time to plot them.

So if we were to divide that 360° into four segments we could express them as 90°, 180°, 270° and 360° for 1,2,3, and 4.

It is exactly this terminology in degrees that we will use to express the term 'phase'.

If one were to add a second signal on the scope to plot simultaneously, if it were directly on top of the first sine wave we would say they are "in phase", and they would appear indistinguishable from one another.



If the second signal was occurring behind the first in time (delayed in start point by some mechanism) there would be two sine waves appearing synchronous in time because they repeat at the same frequency, but visually and electrically "out of phase" with each other. We would express the distance apart in time by stating they are 5°, 10°, or 20° out of phase.

It is exactly this phase difference we will exploit in our motor start circuit to electrically get the rotor moving in one direction (or the other in the case of a reversible motor).

It is magnetically moving the opposing force (temporarily) to one side or the other of the magnet if you will, then removing power from the start circuit, allowing the run windings (now alternating 60 times per second) to sustain the rotation of the now rotating mass of the rotor which has inertia help keep it in motion.

We employ a start capacitor, motor start windings, and either a motor start centrifugal (rotating) switch with a spring loaded governor or a motor start relay, which will disconnect the circuit once up to a speed, or the coil of the relay energizes.

Think of the motor start capacitor in the terms of a 'discharged storage battery' that will take a fraction of second charge, discharge, charging in the other direction. Accordingly you can envision how that charging time (however brief) will *delay the voltage building up* shifting that second signal out of phase with the first signal which is connected to the Run windings that received the same power, but applied it instantly making the start and run windings out of phase with each other. That is the temporarily used motor start circuit in a nutshell.

Is the motor reversible? If it is designed to be, the manufacturer will have provided and documented terminals allowing a toggle switch to temporarily reverse the electrical connections to a different point to allow the magnetic repulsion to start mechanically on the opposite point of reference to where it was (from off), pushing it to rotate initially the opposite way. If you just need it to spin the other way all the time, you just connect it by moving the wires between terminals they designate opposed to adding a toggle switch to swap the connection points.

These connections are made at specific point in the start windings, and on some motors (NOT ALL MOTORS) they can have windings wires accessible that can be located to attach an additional connection point not provided by the motor manufacturer, making it reversible.

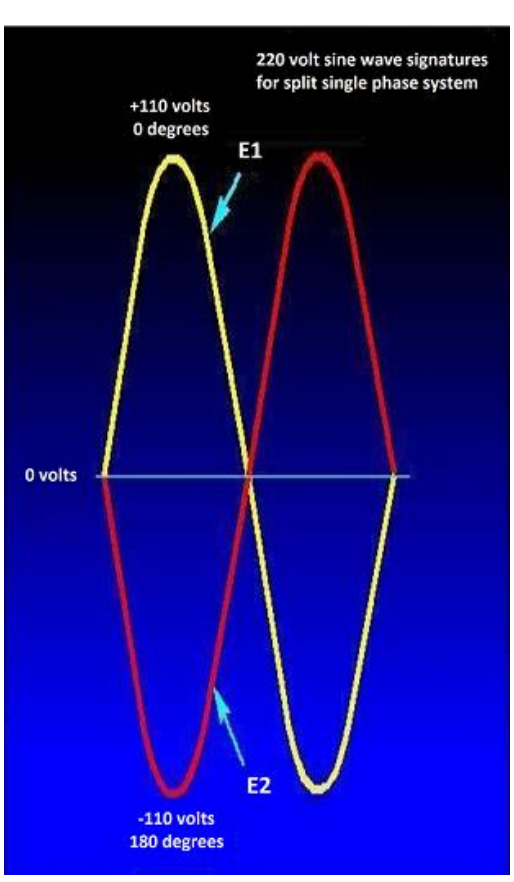
You are at your own risk attempting this and needless to say it not only voids manufacturer's warranty, but their product liability as well. You made unauthorized alterations releasing them from liability, and assumed it yourself. Remember that when you sell it too. The liability may endure the sale in some states.

There are discussions in various Shopsmith forum posts that document how others have done it. I will not repeat those here as they speak very well for themselves.

220 Volts how does that work?

Some motors may have the ability to operate on 110 or 220. If they are originally made to do so, there will be a connection diagram on the motor that illustrates how to connect the wiring on respective terminals for each voltage.

So how does 220v work? Sine wave(s) to the rescue for the illustration….



Let's go back to the concept of 'phase' to explain 220 volt power itself. The Power Company provides two separate 110 v connections that are called "split-phase" with each other providing 220 v when an appropriate device connected properly to both. They are exactly 180° apart in time (360° split-in-half if you will, hence the name split-phase).

E1 Yellow - The first 110 v signal climbs to +110 v, first in the upper section, and then falls to -110 v in the lower section as it alternates. It is still 110 v. by itself

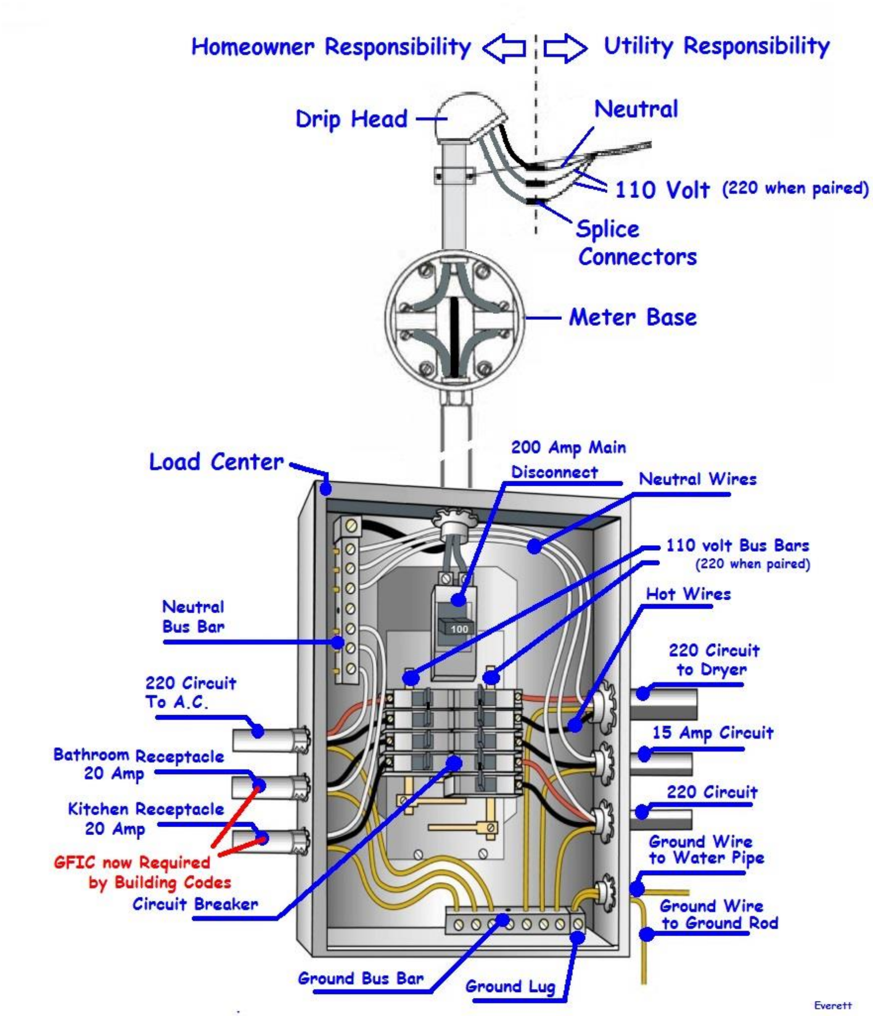
E2 Red - The second 110 v signal simultaneously falls to -110 v, first in the lower section, and then rises +110 v in the upper section as it alternates. It is still 110 v. by itself.

The key to understanding this is that they are there at the same time 180° out of phase, making the difference between them 220v when connected to both sides at the same time, totally synchronized to the same frequency but 180° out of phase (known as split, single phase).

In the Load Center diagram below, understand that there are two wires connected to separate points in a 220 v breaker, and the breaker itself physically spans connections to both sides of the bus bars, providing a connection point to both sides.

If you blow up the Load Center picture, you will see that the 220 v breakers are made as one piece, with two circuits, with the trip levers pinned together forcing them to trip both sides if over current condition exists.
Do not remove this connection that ties the two sides of a 220v breaker together and never use two separate 110 breakers on opposite bus connections to simulate one, even if you pin them. It is not code. Buy a true 220 breaker.

Ok, let's get in the house and bring this home so to speak…. Yes, I did mean literally "In the House".



Load Centers Illustration depicts how power enters your home or shop from the utility company, where their responsibility ends and yours as the owner begins. A 100 Amp Load Center is illustrated. More common today are 200 Amp Load Centers with many more traditional and GFCI breakers inside, as required by local building codes and insurance standards. Installing the meter competes the circuit.

Homes today have more appliances and accordingly, have more receptacles (outlets) than ever before, and have more 220 volt circuits than the three 220 v circuits depicted here. *We have not even discussed the garage or workshop.*

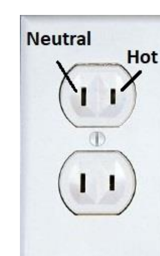
It is very typical today to have a 220 v Electric Cooktop, 220 v Oven, 220 v Water Heater, 220 v Dryer, 220 v Air Conditioner, 220 v Furnace, 220 v Hot Tubs, 220 v Saunas, 220 v Pool Pumps, 220 v Pool Heaters plus all sorts of 110 v kitchen appliances, dishwashers, trash compactors, refrigerators, freezers, washing machines, heat lamps in bathrooms, hair dryers and entertainment device centers in almost every other room, plus outdoor receptacles around the home or on the patio. Yes there are lighting circuits and ceiling fans in the mix as well.

Fire codes have mandated more 110 v circuits be added as new homes are constructed, with less number of receptacles per circuit.

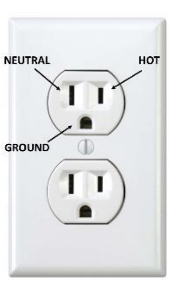
This was done in an attempt to reduce the need for extension cords which were very common to be overloaded and known to create house fires.

Fire safety mandated the upgrades to electrical as well as smoke detectors to help protect our families considering we are often asleep 8 out of every 24 hours inside. Clearly that has saved lives in newer homes and continues to costs lives in older ones that have not been upgraded. Most major remodeling requires building permits, and codes mandate electrical upgrades, and is inspected when complete.

Fire safety improvement saved lives, yet did nothing to improve the shock hazards introduced by using more and more electrical appliances near areas where water, water pipes, and faucets provide a quick path to ground for anyone who might touch them and be in simultaneous contact with something plugged in.



In earlier homes, wiring often consisted of just two wires coming out of the receptacle, mounted in a metal box in the wall to which the bare copper ground wire (if one was even present) was connected to a screw in the metal box, grounding it. The metal mounting tabs of the electrical receptacle, attached to the metal box would ground the housing of the receptacle, but still only two wires came out to connect to.



Receptacles went through a transition through the years trying to keep up with changes introduced by manufacturers trying to make their equipment safe for the consumer. Once houses were built, unless there was a remodel that required an electrical inspection, and changes in the new additions to bring the new construction up to code nothing in existing houses changed much.

Newer homes had the current standards when initially built, but older homes remained essentially the same, even though the owners were bringing home all those new appliances, and the cord on the appliance didn’t fit the outlet. You can well imagine what happened. Non-qualified people made unauthorized modifications to receptacles, or to the plugs to make them connect. Owners, and tenants alike, made changes. Maybe you own your home. Perhaps it is new, perhaps you have been there for decades, or by chance you bought a pre-existing home. How safe are you today? We will get there. Be patient. You need this knowledge, your children and grandchildren need this knowledge.

There were a variety of electrical plugs manufacturers used on their equipment over time. Some were two tabs, exactly the same size, others two tabs with one oversize that could only be plugged into a receptacle one way to help insure the Hot (Black) leg was connected to the connector the power switch would open when the device was turned off. Note the grey arrow in the center photo below.

We all likely have seen the ground lug broken off to make a 3 wire plug fit a 2 prong receptacle. We will examine why this is a dangerous thing to do. First thing seems obvious, you can’t put it back. Doing it on a tool makes using the tool more dangerous. Doing it on an extension cord makes everything you use with it more dangerous.

We likely all have seen the two prong to three prong adapters before. They are certainly more preferable to use than breaking off the ground lug on the plug, but what is that tab with a hole in it for? Yes, if you take the screw out of the receptacle cover, and screw it back in after you plug in the adapter it will keep it there, but what is that tab there for anyway? In fact, why do we even have the 3 wire ground lug plug in the first place? The answer is electrical safety. Let’s explore why it’s there in the first place and what it is supposed to do with the adapter.

Did you know that the round ground lug just sits there and never has anything flowing through it in normal operation of a tool or an appliance? It is true. It’s only there and used when something is wrong inside the tool or appliance that causes electricity to come in contact with the case, and anyone holding it. That can put your life at risk by electrocution.

Just as we buckle our seat belt to protect us from more severe injury or death in a vehicle accident, or use eye protection when using tools, we connect our ground lugs to properly wired, grounded receptacles to protect us from more severe injury or death from accidentally having an electrical current kill us by passing through our body and stopping our heart. In a moment we will discuss mounting the adapter on a receptacle vs. actually connecting it to the ground on that receptacle.

Can someone get shocked and not die? Of course. It depends on how the current flows through your body based on where your contact to the electrical source and contact with ground source connect. If the circuit stays energized your muscles may contract, holding you connected (you can’t let go) resulting in severe burns, muscle or nerve damage. You can have a heart attack from the fright that comes when you realize you are being nailed to the electrical circuit and can’t let go. You weren’t electrocuted, you just died from the heart attack it caused you to have from fear.

If you are say wiring the Christmas lights on your house when you find the unwanted electrical connection to your body, you may not die from electrocution, but the sudden stop from falling off the 2nd floor of your home, or out of the tree you are trimming. The shock can be just as devastating if you fall off something or into something such as your saw etc. We want to avoid those things, and can if we are prepared. If you were a Boy Scout or Girl Scout, you understand that concept.

How does that ground lug protect me?

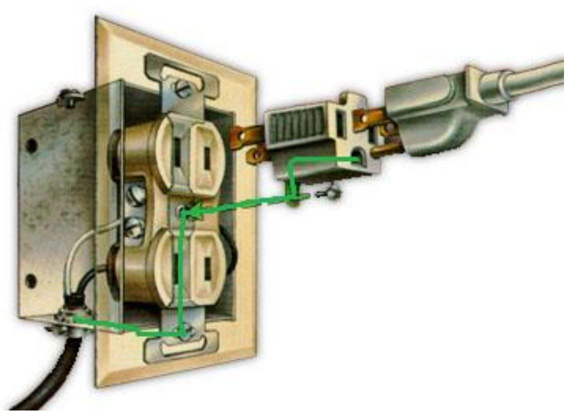
I would imagine many of us have picked up an electrical cord and plugged it in at some point in our lives (or someday will) and have the connector almost blow up as we plug it in, leaving the receptacle charred with smoke, and tripping the breaker, shutting off power. After a quick trip to the bathroom and bedroom for unsoiled clothing, we find the tripped breaker and restore power if prudent. No we don't try the tool again…..

The ground lug in the plug is connected by the green wire in the power cord to the housing, case or frame of the tool we plugged in. Let's presume we were using a rented carpet shampooer as I was the last time this happened to me. The internal connection to the case, that is grounded caused the over current condition (direct short) that tripped the breaker, protecting me somewhat when I plugged it in, but destroyed the receptacle and the plug on the shampooer.

Had that ground connection not been there, I could have held that tool or touched that appliance and not felt a shock until I came in contact with the water spout on the sink to fill it up and was grounded. It's a good idea if you rent tools or equipment to check those things before you leave the rental yard, and plug it in to known grounded circuits when home. It can save your life.

Here is why it happened. Electrical appliances and tools may wear in ways in which a portion of the wiring inside actually comes into contact with the metal housing of the tool, or the case of the appliance. Something inside the carpet shampooer was shorted to the case. Mine was connected to a properly grounded receptacle when I plugged it in, tripping the breaker and startling the heck out of me.

You likely can envision your son or daughter renting a carpet shampooer to clean the carpet in their new apartment when they leave home. Do you think this sort of information might help them be better prepared in life? It is part of why I am spending the time documenting this. It simply isn't being taught to our kids. It may not have been taught to you.



Let's take a look at that 2 prong to 3 prong adapter with that in mind. I think that you will see the path the ground (green) wire will need back to the ground in the load center. This is a metal box which is connected to the bare copper wire in the cable, and the adapter is screwed in with a metal screw through that lug. It is safe, if the circuit to ground is complete. Can you know by looking? No. Can you know by plugging in an appliance? No. Can you know by plugging in a low cost tester? Yes. We will talk about that in a bit.

Have you purchased a face plate cover recently? Was the screw plastic? That will not conduct. Is the existing screw mounted in a hole that has been painted over through the years? That likely will not conduct either. It is the same as not being there at all. You need a clean metal screw, and clean metal threads in the receptacle housing and properly connected in the load center for this to work.

In modern buildings, we have moved from metal boxes to plastic with receptacles that have the 3rd wire ground.

Just because it is there, does that mean it is connected to the ground screw?

No.

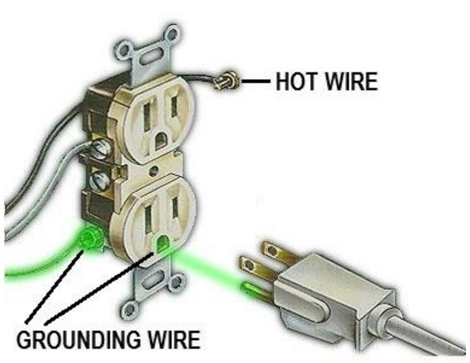
Just because one receptacle is connected to the ground screw, does that mean that all the rest in the house are?

No.

Does the building inspector on the electrical inspection of a new home check every single outlet after they are connected?

No. Should you?

I say yes, you should. It is the only way you will know what is there and what is safe. Your desktop computer systems and some laptops with 3rd wire grounded plug for example likely will complain if not connected to a properly grounded receptacle. It will not tell you what is wrong, it just may have issues, gremlins of sorts that crop up from time to time…. But I digress.

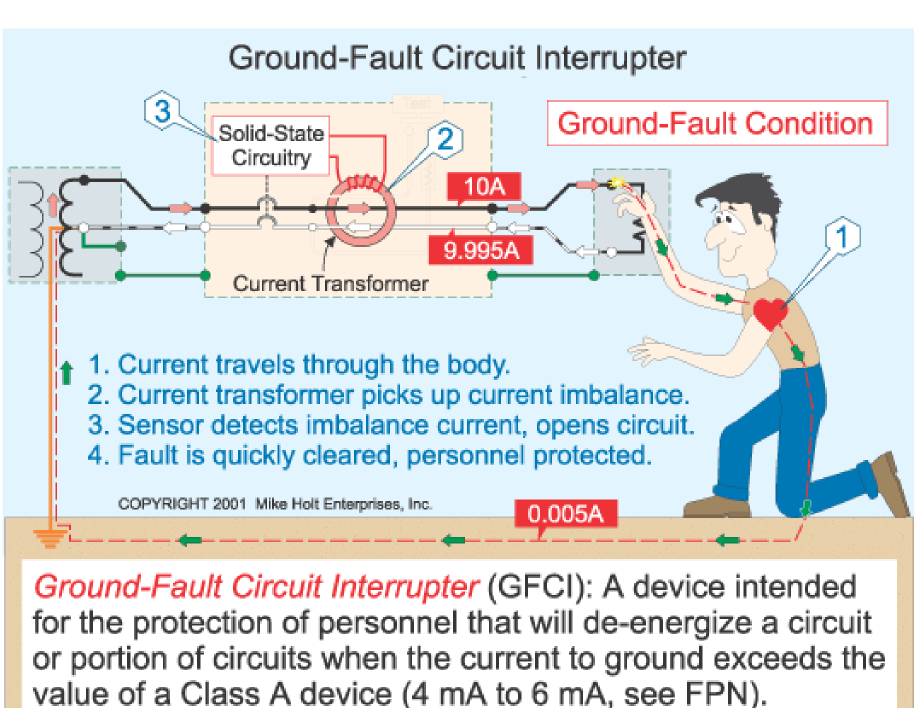


Let's take a quick peek at the 3 wire grounded outlet that hopefully we all have in our homes and workshops. By now you don't need much explanation. You can see how it functions and how it connects….. Or at least should connect.

The Tester

You will remember I mentioned a low cost test tool one can buy that will tell you with a series of three lights if everything is in order as connected, and based on what lights up, or fails to, will tell you exactly what is wrong if wired incorrectly. I did say low cost. This one is $4.97 at Home Depot on-line. You can get one on Amazon Prime for the same, plus free 2 day shipping. Really handy to have. Tests receptacles, and the extension cords once connect to a properly wired receptacle.

How does GFCI Work?

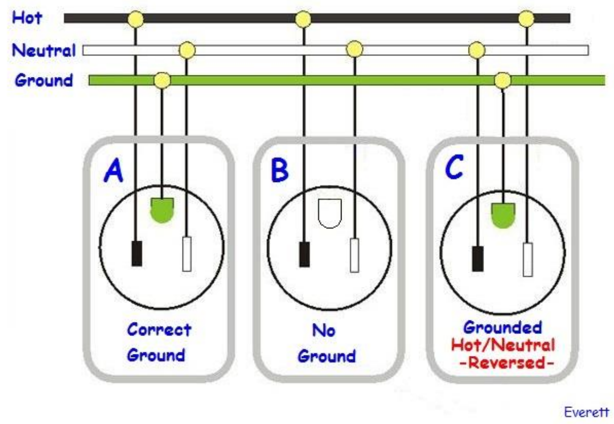


As good as 3 wire grounded outlets are, if someone is grounded really well to a work bench, is in a wet area and comes in contact with an energized circuit as the tool fails in use, there can still be a major amount of current pass through your body until the breaker trips. To prevent that, the industry developed Ground Fault Circuit Interrupters (GFCI) that upon detecting a 4/1000 to 6/1000 of an amp (4 mA – 6 mA) current flowing to ground, will trip the breaker in 1/40th of a second, protecting you from electrocution or severe shock. It is so fast, you may not feel it at all.

It's mandatory now in kitchens, bathrooms, outdoors, pools, spas etc. The GFCI will not protect you from line contact hazards (i.e. a person holding two "hot" wires, a hot and a neutral wire in each hand, or contacting an overhead power line).

However, it protects against the most common form of electrical shock hazard, the ground-fault. It also protects against fires, overheating, and destruction of wire insulation. It's a good thing.

Ok, how do I know that GFCI is working? There's a tool for that and it resembles the other tester in that it test all those functions, and can safely create a ground fault condition to 'prove' your GFIC is working. This one is $28.50 on Amazon Prime. It's what I have.



Simply because a circuit is connected correctly in the Load Center in no way means it is connected correctly at all the receptacles in the chain of receptacles in a string on the individual circuit.

A – Is right
B – Has no ground
C – Is backwards

A, B and C will power up the equipment you plug into them and operation will appear normal.

Either of the two testers will find these faults.

GFCI Tester

We need to understand what the connections are for and what they should connect to.

The purpose of designating hot from neutral allows us to have a method to identify and switch off power at the breaker, at wall switches and switches on appliances reliably. Many manufacturers are now switching only the Black or Hot leg inside their equipment. (Both Hot Legs if 220)

Consider what flows through the Ground Connector in normal operation: Absolutely Nothing.

It is a safety connection, required by UL (Underwriters Laboratories) to protect the user of equipment from electrocution when a connection inside their equipment inappropriately comes into contact with the frame or housing of the appliance or tool. They cover terminals and locations inside their equipment where you or even a technician might come into contact with them. The neutral side, not so much. Frequently those are not as physically protected, as when the hot is switched off, everything down-line is safe.

What about Receptacle C above. Hot and Neutral are reversed. Even though your equipment may be switched off (black wire side only) and every single white wire outcropping (normally safe) are fully energized, and the case or frame is grounded. That is a lethal combination if you are holding it and come into contact with the neutral side, even with the switch off it creates an immediate short inside the tool or appliance, tripping the breaker. If you are holding onto it and grounded to something else yourself, you will likely still be shocked. It could still stop your heart if you are well grounded.

The breaker will trip, disconnecting you from the circuit which is designed to disconnect you from the current, opposed to your muscles contracting and not being able to break away. The damage may already be done to you however as it did not trip quickly enough. That's is the purpose of a Ground Fault Circuit Interrupter, breaking the circuit when 4 to 6 thousandths of an amp current flows to ground from the circuit, but it has to be connected correctly at every receptacle to work.

What about B? There is no ground. If you are grounded somewhere else on your body….. holding on to a metal workbench, touching another grounded piece of equipment and just holding a tool in your hand that has an internal short to case, you have nothing to trip the breaker and all the current will flow through your body, and the body of someone trying to help you, until someone cuts off the power manually.

Manufacturers tried to negate this by doing what's called double insulation, wrapping the outside of the tool with a plastic or rubber insulator to help isolate you if an internal short to case ever exists. OK! Cool, I am now safe.

Not so fast. You have a faulty double insulated drill that has an internal short. You're holding the body of the drill in your hand, your forearm resting on that workbench, and reach for the drill chuck key. Is the drill chuck metal, or plastic? Is it by chance touching something metal internally that you were otherwise protected from before trying to manipulate the chuck? You get the idea

It is readily understandable, and proper awareness and procedures will make you safer. That is why I spent so much time an effort here.

Think about that for a moment. Let it sink in. How valuable is that knowledge now to you personally, especially if you plan on diagnosing or servicing your own motor?

With regard to all wiring on you premises, how safe is your spouse, children, grand-children, even visitors in your home? Remember that Homeowner Responsibility notation in the drawing? You are not only responsible, but legally liable. If something bad happens, some insurance will disallow coverage if things are not done to code and they can prove, or reasonably suggest that contributed to the accident.

It doesn't matter what you are working on Shopsmith or not, electricity has to be connected correctly or it is unsafe. Tools have to be connected right, and maintained or they are unsafe to use. Inspect them periodically for damage or wear.

Now let's wrap up the final pieces on the electricity itself and how 110 and 220 relate to each other, in the concept of phase, which will help us understand how we make the motor move in the first place, even how we control with direction it rotates.

Back to the Motors

In Review

How do we start the motion in one direction only?

As discussed above, bring the opposing force in from one side. By moving a manual magnet, or by shifting the phase of Start Windings to be slightly out of phase with another set Run Windings. We do that with a capacitor start circuit that is present on power on which is delayed by charge time of start capacitor, then disconnects by centrifugal switch opening circuit, or a motor start relay.

How might we reverse that motion in the opposite direction?

Again as discussed above bring the opposing force in from the other side which is pre-wired by the manufacturer with clear labels on how to connect for desired rotation.

How do we sustain the motion?

Fortunately, the properties of the sine wave produced by alternating current (changes from one polarity to the other) coupled with a rotating mass of the rotor we first enticed to begin moving in a specific direction, motion is sustained in that direction.

Just Getting Started in Specific Motors

Much More to come - Everett