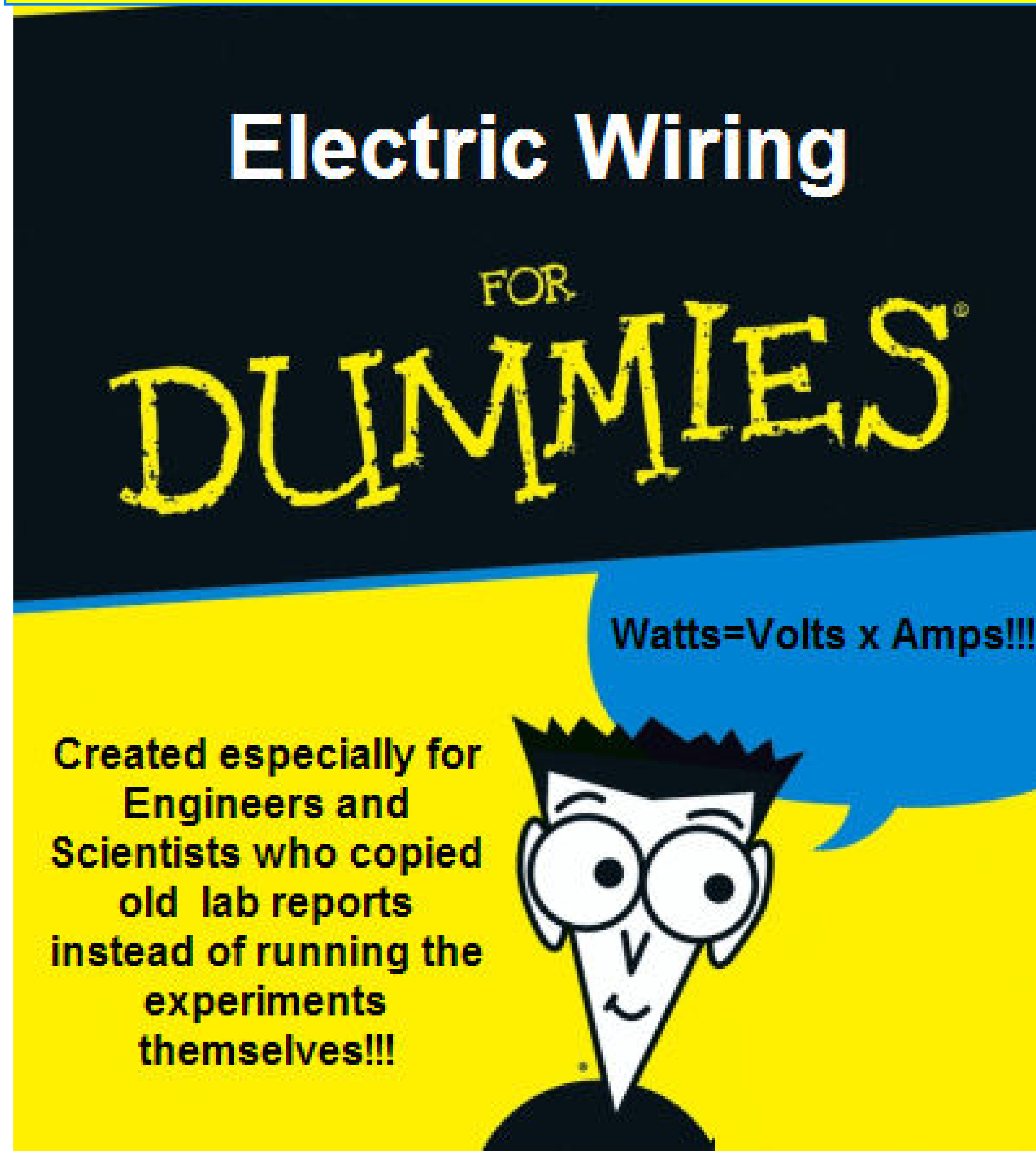
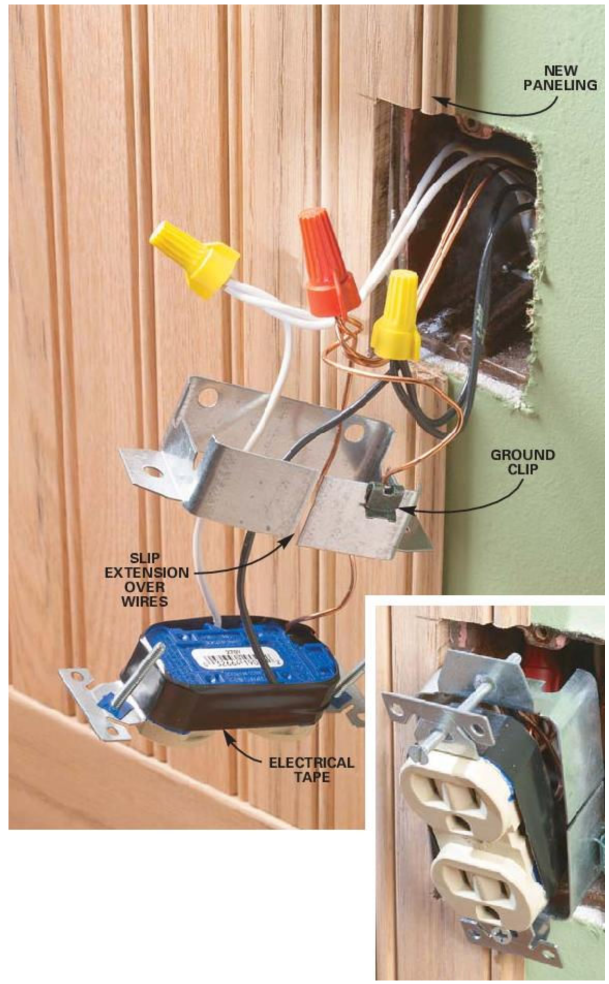
Plus telephone wiring stuff ....



Electrical Wiring Informatiom

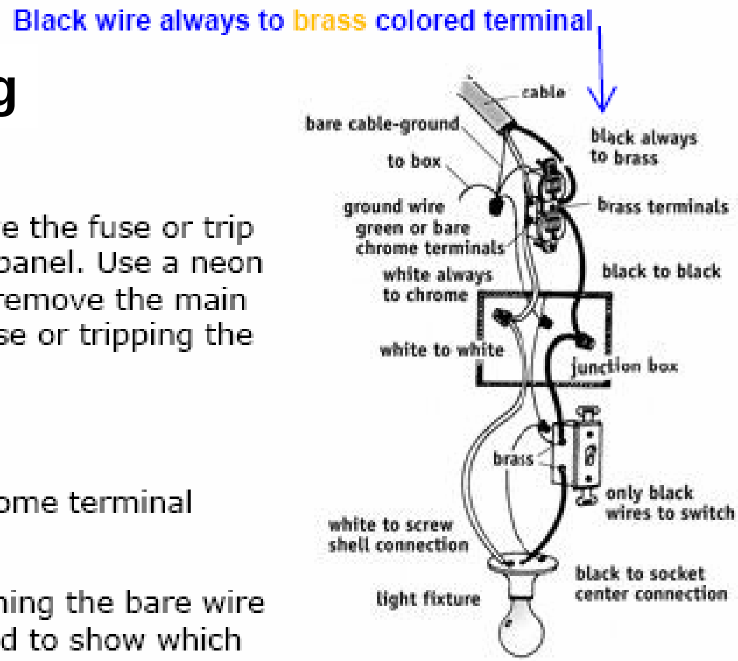


Key points to remember:

- 4 wires at the breaker box …
  - Black … hot … 110-120 volts
  - Red … hot ….. 110-120 volts
  - White … neutral … just grounds
  - Green or bare … protection from “shorts” ground
  - Red and Black at an outlet …. 220 volts
- 3 wires at a wall outlet
  - Black … hot … 110-120 volts
  - White … neutral … just grounds
  - Green or bare … protection from “shorts” ground
- Wire sizes determine the safe amount of current….

  example… #14 wire carries 15 Amps
- Ground Fault outlets ... GFCIs .... keep you from getting killed when things get wet!!!!!!
- Call 911 when you set your house on fire!

Basic Principles of Good Electrical Wiring



- Before beginning any electrical repair, shut off the power. Remove the fuse or trip the breaker for the circuit you will be working on in your service panel. Use a neon tester to be sure the power is off. If there is any doubt, you can remove the main fuse or trip the main breaker. Remember: Removing the main fuse or tripping the main breaker will usually shut off the power to the entire house.
- Electrical wires are color coded to prevent wiring errors.
- White wires almost always connect to other white wires or to chrome terminal screws on switches and receptacles.
- Some wiring devices–such as receptacles–are back-wired by pushing the bare wire end into spring grip holes. These wiring devices are plainly labeled to show which color goes into each spring grip hole.
- Switches are nearly always connected into black wires in cables. The only exception is where a cable is extended, making it necessary for the white wire to play the role of the black wire. When this is necessary, the white wires should be painted black to prevent future wiring errors.
- Study the wiring diagram. This will help you understand the basic principles of good wiring. Also, find a good electrical how-to book. It's one book every homeowner should keep on hand for ready reference.
- Most home wiring is complete with either No. 14 gauge or No. 12 gauge wiring. No. 14 is the smallest wiring permitted under most codes.
- Always use the same size cable for a continuation of any extended wiring circuit.

Useful Terms

- **Ampere.** Measures the number of electrically charged particles that flow past a given point on a circuit (per second).
- **Breaker box (breaker panel).** Houses the circuit breakers or fuses, distributes power to various parts of your house.
- **Circuit.** All wiring controlled by one fuse or circuit breaker.
- **Circuit breaker.** Protective device for each circuit, which automatically cuts off power from the main breaker in the event of an overload or short. Only a regulated amount of current can pass through the breaker before it will "trip."
- **Main breaker.** Turns the power entering your home through the breaker box on or off. This is sometimes found in the breaker box, or it may be in a separate box and at another location.
- **Neutral bus bar.** The bar to which the neutral wire is connected in the breaker box.
- **Roughing-in.** Placement of outlets, switches and lights prior to actual electrical hook-up.
- **Volt.** Measures the current pressure at receptacles and lights. Average household voltage is 120.
- **Watt.** The rate at which an electrical device (light bulb, appliance, etc.) consumes energy. Watts=volts x amps.

A 1200 watt appliance plugged into a 120 volt outlet pulls about 10 amps!!!

Cable ….. Wire

- Refers to a collection of two or more strands of wire or conductors. Basically, cable has a "hot" line to carry the current and a "neutral" line to complete the loop. They often have a third wire as that acts as a grounding wire.
- Classified according to the number of wires it contains and their size or gauge.
- All cables are marked with a series of letters followed by a number, a dash and another number. The letters indicate the type of insulation (cord, wire and insulation). The first number indicates the resistance of the wires in the cable, and the number following the dash indicates the number of individual conductors in the cable.
- If the designator "G" follows the series it means that the cable is also equipped with a non-current-carrying ground wire. Hence, the designator USE 12-3/G indicates an underground cable containing three separately insulated wires capable of carrying 20 amps of current plus a grounding wire.
- The most common jackets are NM-B (Non-Metallic Building Indoor), UF-B (Underground Feed) and BX, which is flexible metallic cable.

- **Two-conductor cable** contains one black wire and one white wire. The black wire is always the "hot" wire and must be fused. The white is always neutral and must never be fused. When current bridges the gap from the 110V hot wire to the neutral, it results in a 110V input to the appliance.
- **Three-conductor cable** contains a red wire in addition to black and white. The black and red wires are "hot," carrying 110V each, and both must be fused. The white remains neutral. This three-wire circuit is increasingly common in home wiring; it accommodates major 220V appliances, such as ranges and air conditioners.
- **BX cable** is armored metallic cable. It consists of two or three insulated wires individually wrapped in spiral layers of paper. The steel casing acts as a ground wire. There is also a bond wire included in the casing that acts as a ground if the casing breaks.
- **Romex™ cable** is a flat, beige thermoplastic jacket surrounding two or three wires. Each wire is wrapped in insulation and a spiral paper tape. Type NM means it can be used indoors. Type NMC means it can be used indoors or outdoors. Type UF means it is suitable for use underground outdoors.

Wire Gage	Amp Capacity
10	30
12	20
14	15
16	10
18	5
20	3.3

Copper wire resistance table

AWG	Ampacity	Feet/Ohm	Ohms/100ft
10	30	490.2	.204
12	20	308.7	.324
14	15	193.8	.516
16	10	122.3	.818
18	5	76.8	1.30
20	3.3	48.1	2.08
22	2.1	30.3	3.30
24	1.3	19.1	5.24
26	0.8	12.0	8.32
28	0.5	7.55	13.2

Cable ….. Wire

Wire sizes ---- USA --- inside wall

- For a 20 amp circuit, use 12 gauge wire.
- For a 15 amp circuit, use 14 gauge wire (in most locales).
- For a long run, though, you should use the next larger size wire, to avoid voltage drops. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Wire Gage	Amp Capacity
10	30
12	20
14	15
16	10
18	5
20	3.3

Here's a quick table for normal situations.

Gauge	Amps
14	15
12	20
10	30
8	40
6	65

Copper wire resistance table

AWG	Ampacity	Feet/Ohm	Ohms/100ft
10	30	490.2	.204
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22	2.1	30.3	3.30
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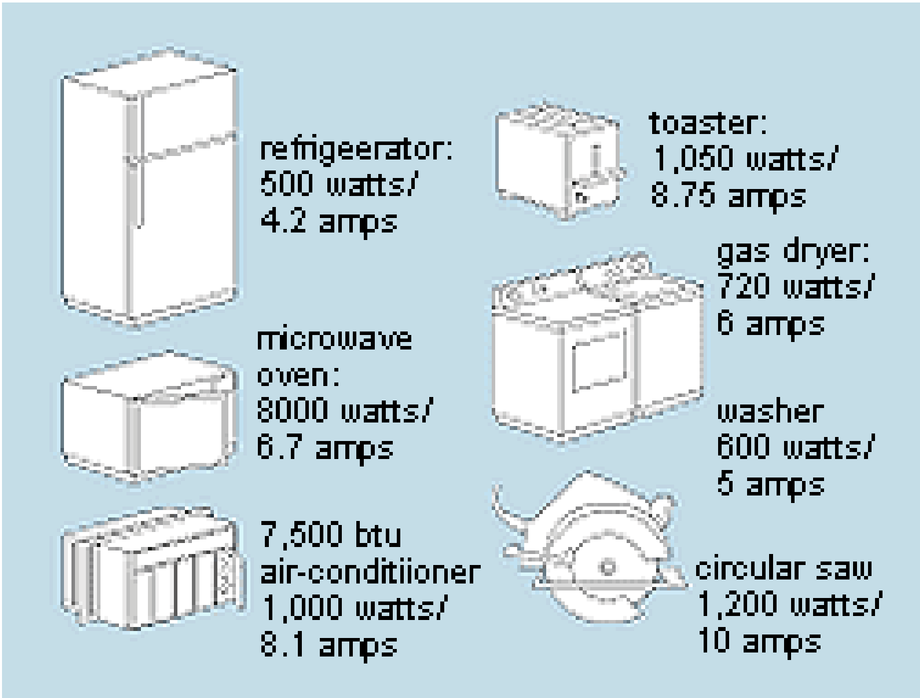
26	0.8	12.0	8.32
28	0.5	7.55	13.2

Amps drawn by certain appliances & amp capacities by wire gages



Wire gage	Amps
14	15
12	20
10	30
8	40
6	65

Wiring inside walls

- For a 20 amp circuit, use 12 gauge wire.
- For a 15 amp circuit, use 14 gauge wire (in most locales).
- For a long run, use next larger size wire, to avoid voltage drops. (Go up a size for more than 100 foot runs, when the cable is in conduit, or grouped with other wires in a place where they can't dissipate heat easily.)

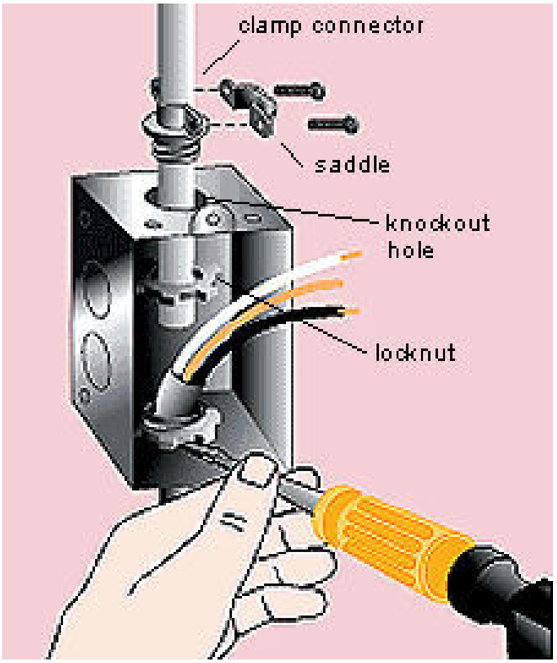
Wiring colors:

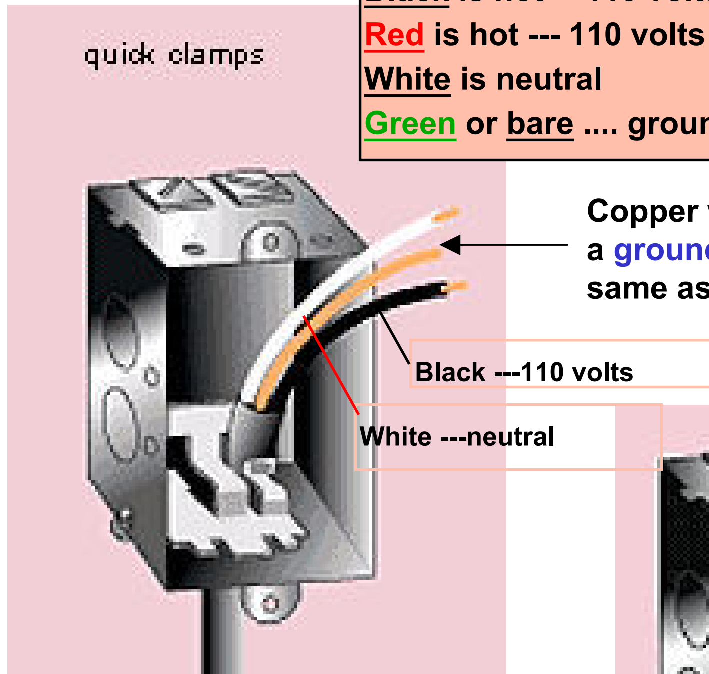
Black is hot ---110 volts

Red is hot --- 110 volts ... 180 degrees out of phase with black

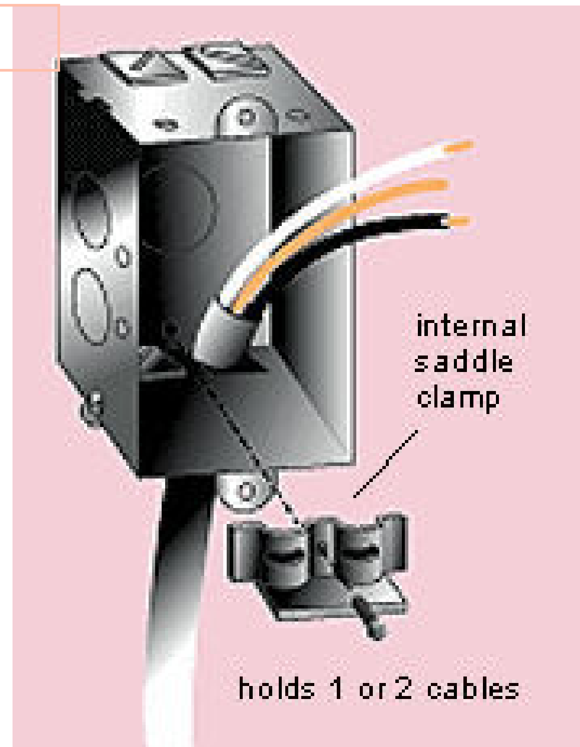
White is neutral

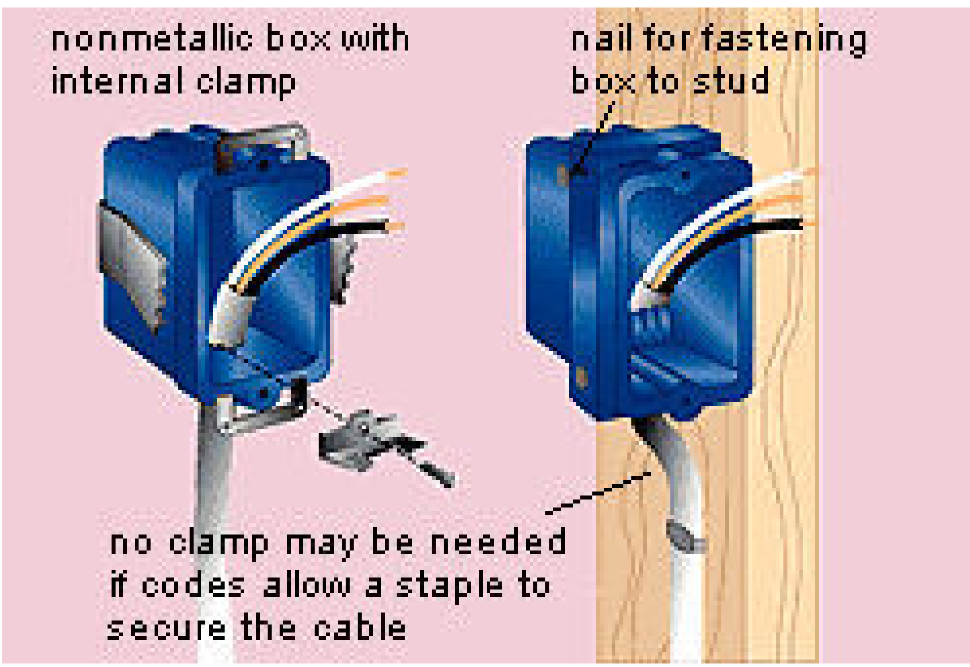
Green or bare .... ground





Copper wire is
a ground;
same as green





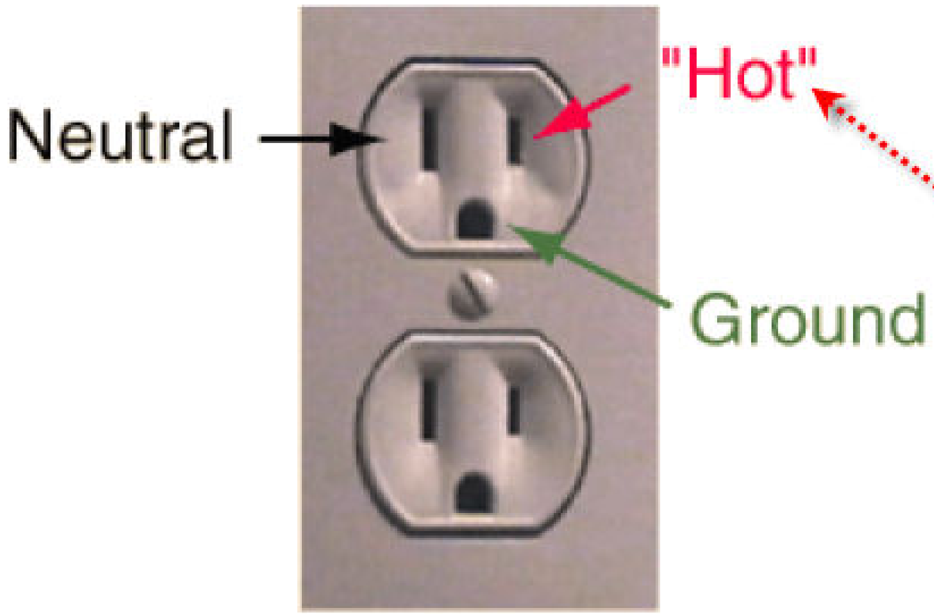
White wire to silver screw … "neutral" … not hot

Black wire to copper screw … "hot"

Green wire or bare copper wire … "ground"

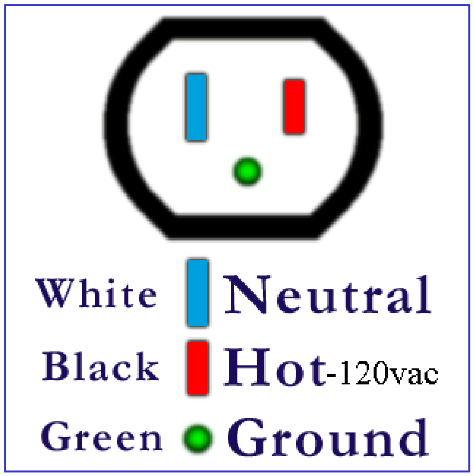
3 & 5 … Silver color screws, this is where your grounded leg {aka neutral} wire goes, this by North America standards should be a white wire, however it can be white or gray.

10 & 12 … Brass color screws, this is where the ungrounded leg [aka hot conductor] wire is attached, the most frequently used wire colors are black & red but can be {any color in rainbow but white, gray, bare or green]



The high voltage (about 120 volts effective, 60 Hz AC) is supplied to the smaller prong of the standard polarized U.S. receptacle. It is commonly called the "hot wire". If an appliance is plugged into the receptacle, then electric current will flow through the appliance and then back to the wider prong, the neutral.

The neutral wire carries the current back to the electrical panel and from there to the earth (ground). The ground wire is not a part of the electrical circuit, but is desirable for prevention of electric shock.



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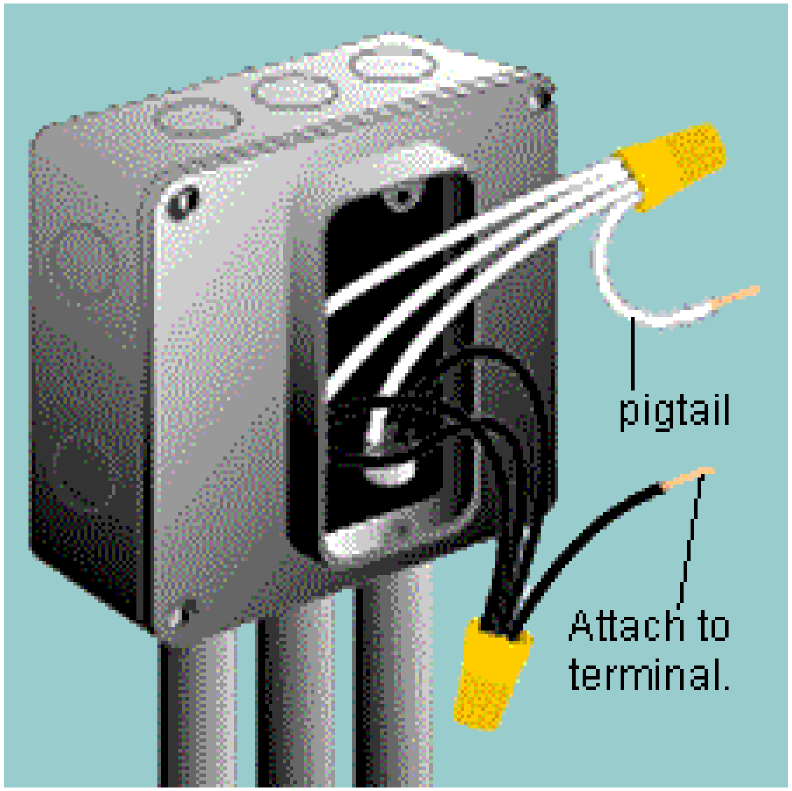
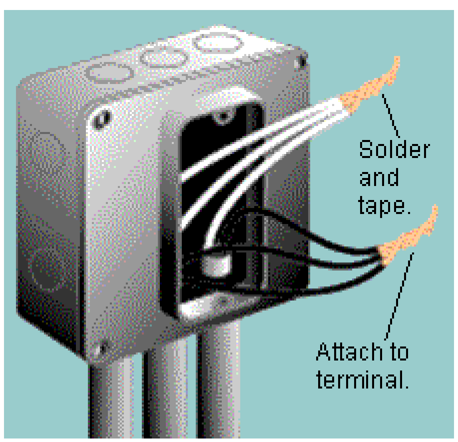
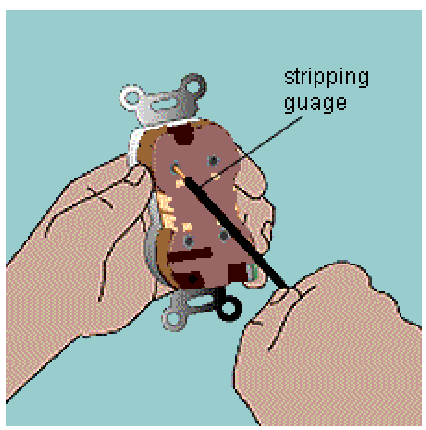
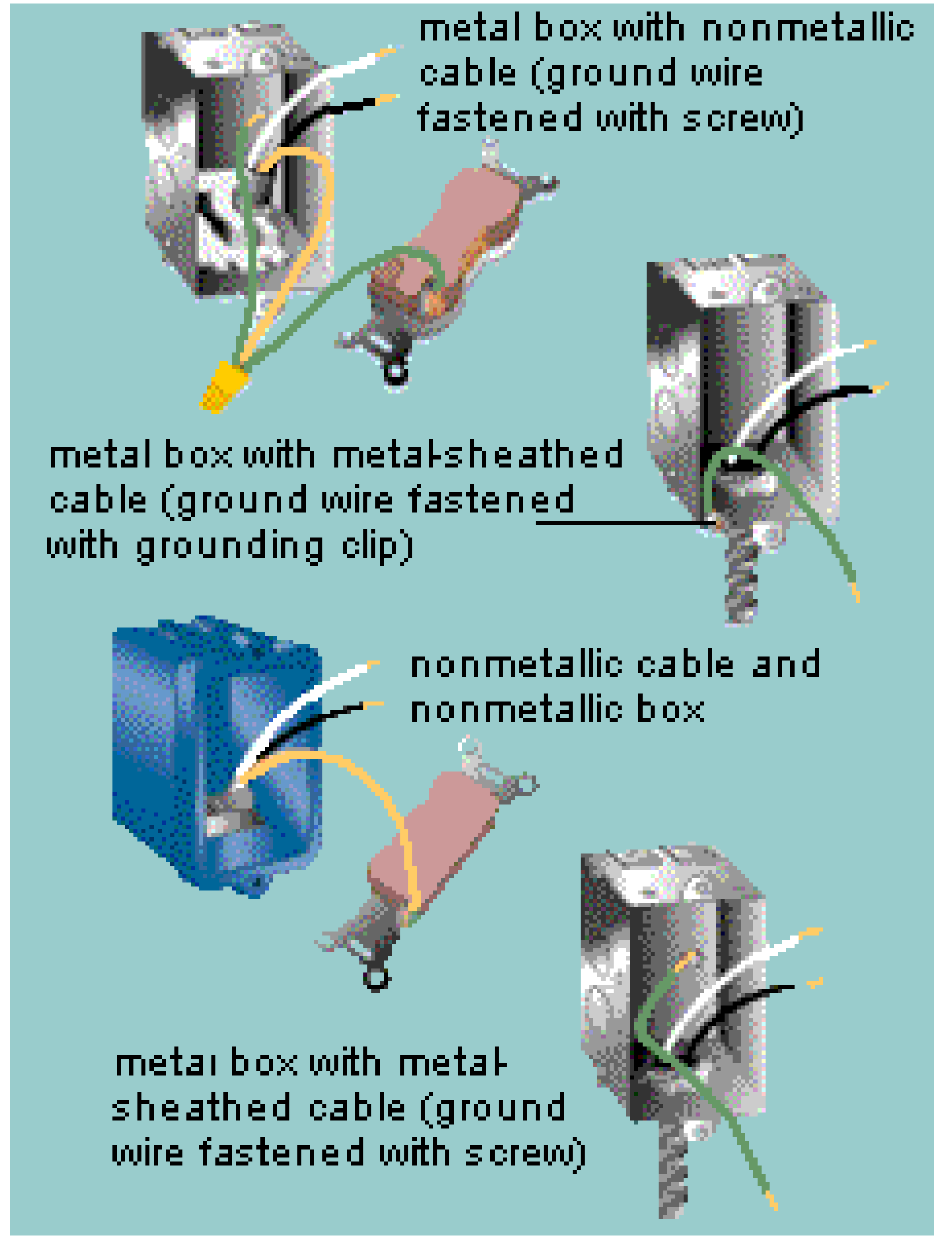
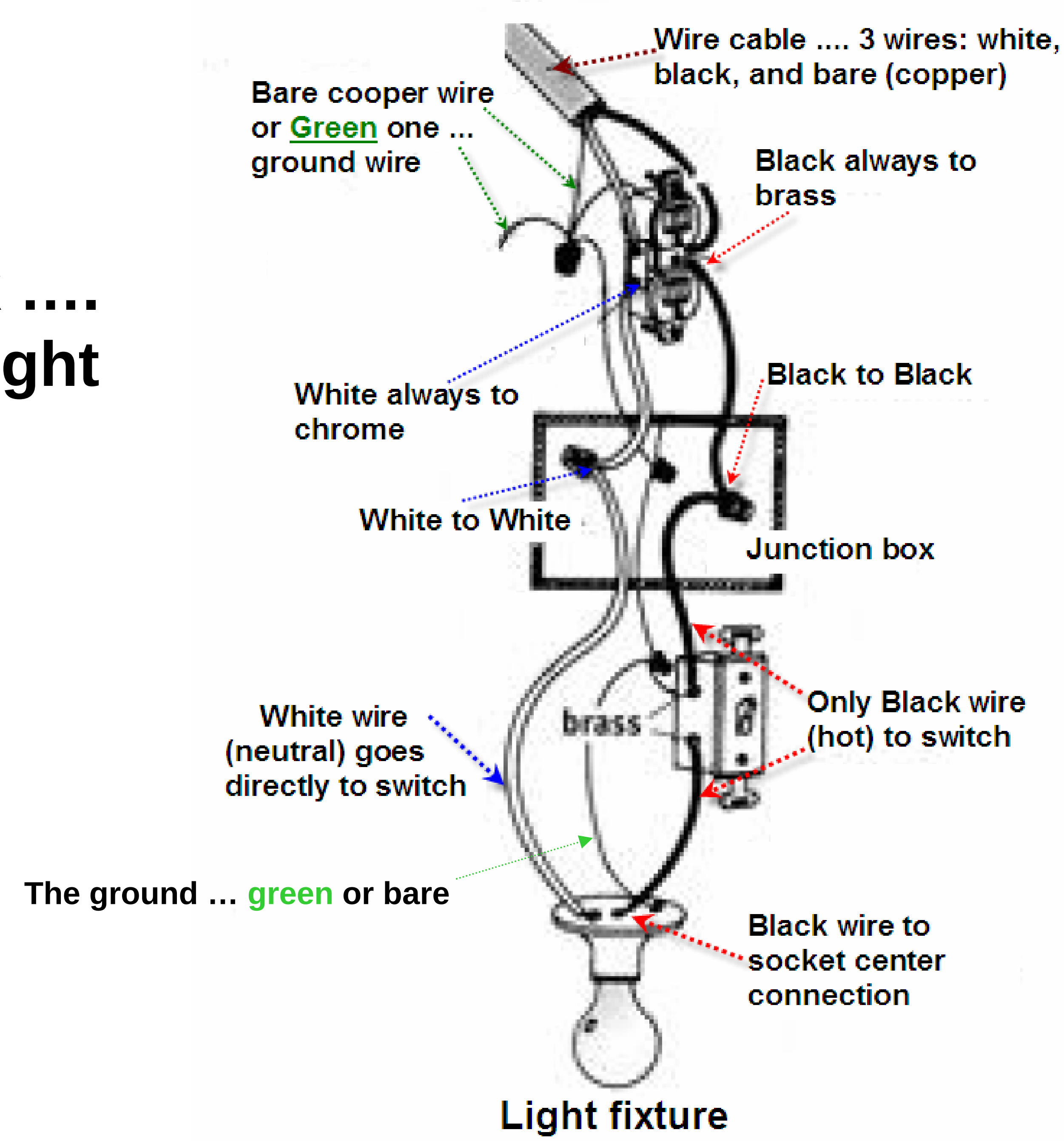

pigtail
Attach to terminal.


Solder and tape.
Attach to terminal.

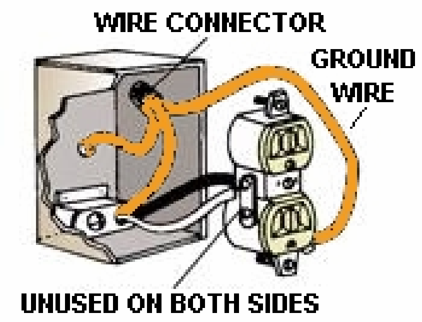

stripping guage


metal box with nonmetallic cable (ground wire fastened with screw)
metal box with metal-sheathed cable (ground wire fastened with grounding clip)
nonmetallic cable and nonmetallic box
metal box with metal sheathed cable (ground wire fastened with screw)

A closer look ….
Wiring up a light



CONNECT NEW WIRING TO LAST OUTLET IN CABLE

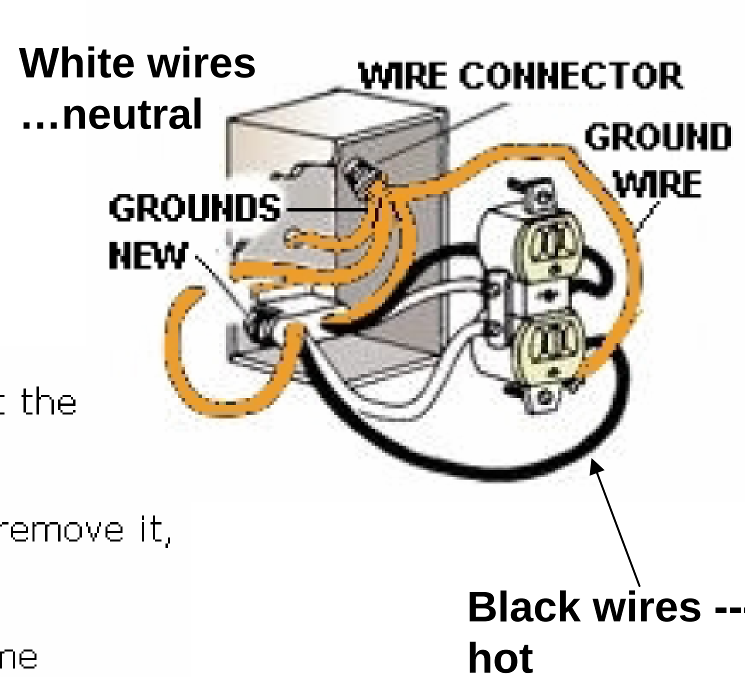


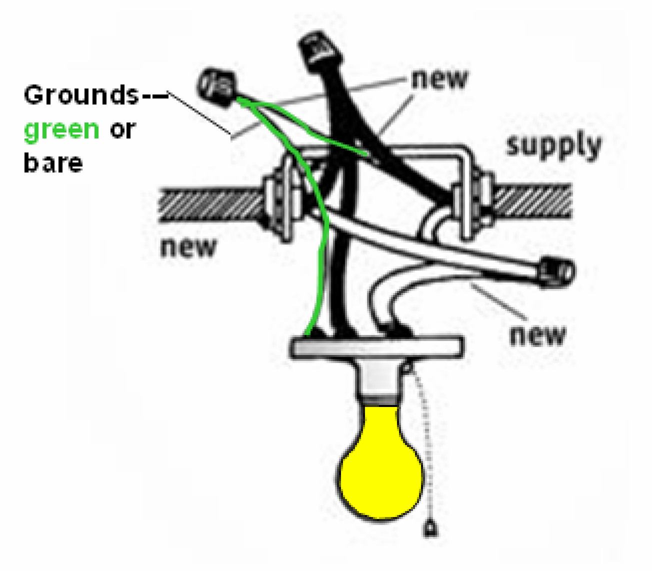
- New wiring should be connected to the last outlet in a run of cable. To locate the last outlet in the run, shut off the current. Remove the cover plates from each outlet on the circuit. The last outlet in the run has wires connected to only two of the four terminal screws.
- The two unused terminal screws on the last receptacle serve as a starting point for wiring to a new outlet.

See next page …

ATTACHING CABLE FOR NEW WIRING

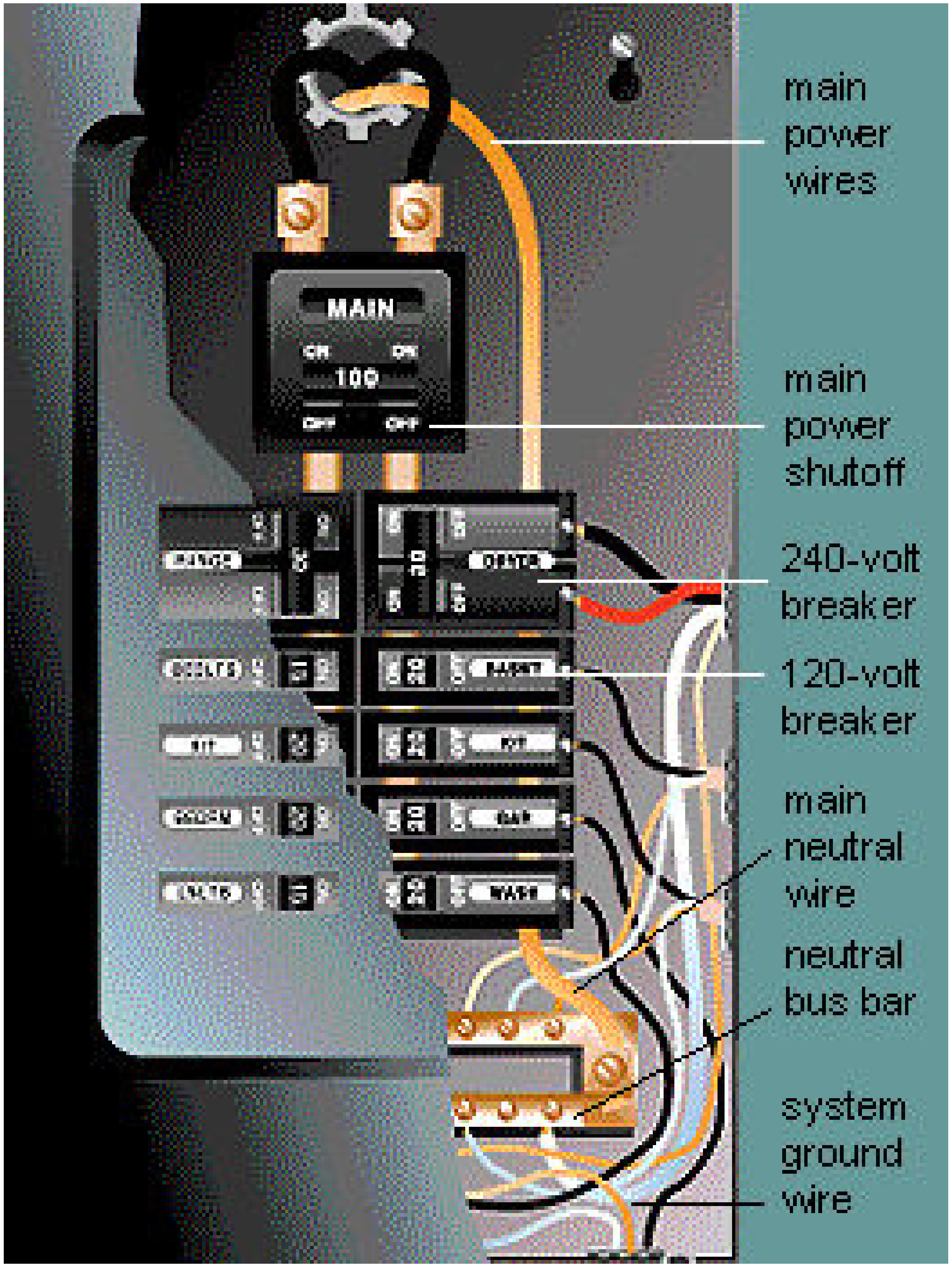
- Shut off the power to the circuit you will be working on at the service panel.
- Loosen the screws holding the receptacle in the box and remove it, as shown.
- Attach the the earth wire (the bare or green) to the chrome terminal. The yellow (or green in some instances) wire should be connected to the receptacle and the box maintaining the equipotential bonding on the earth system. The earth wires should only be connected to the correct screw terminals on the recepticle to the brass terminal on the receptacle and to the box, if the box is metal.
- Use care to match the size of the original cable. If No. 12 wire is used, continue with No. 12. If No. 14 wire is used, use No. 14 for continuing the cable. The size of the cable is usually stamped on the side of the cable.
- New wiring can be connected to continue the run beyond the last receptacle. Note that the new wires are pulled through knockout plugs in the back of the outlet box.





TYING IN NEW WIRING AT A CEILING LIGHT

- You can tie in new wiring at a ceiling light if the light is not controlled by a switch.
- Shut off the current at the service panel.
- Tie white wires to white wires and black wires to black wires, as illustrated.
- Connect the ground wires as illustrated. If you are using a metal box, attach them to the box as well as the light fixture.
- Knock out an opening in the outlet box, and continue the new wiring as illustrated.



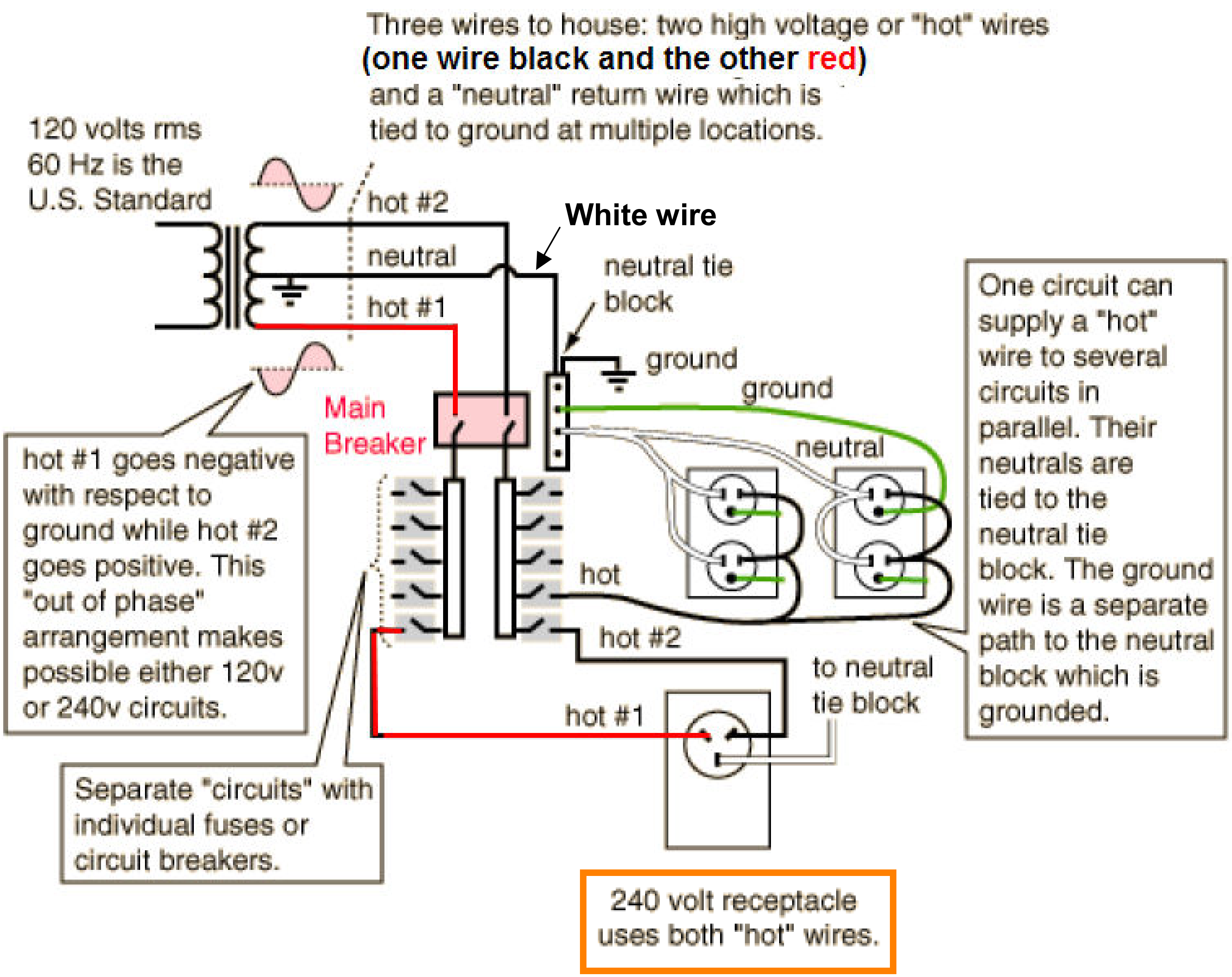
Distributing current throughout the house:

A look at the mysterious "breaker box" ...

Home Service "Breaker Box"

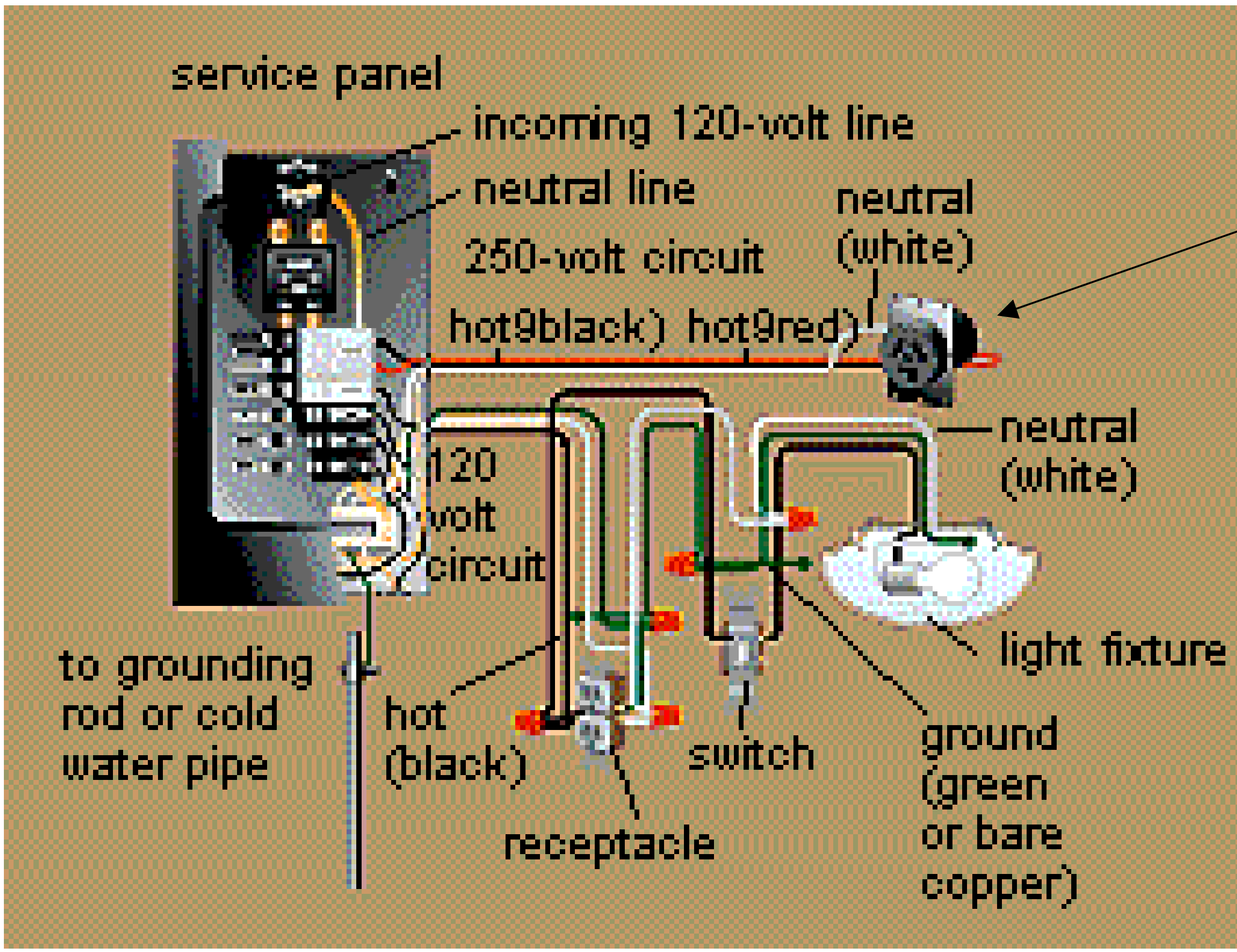
Usually 200 Amp service

Power pathway ... from the service to the outlet



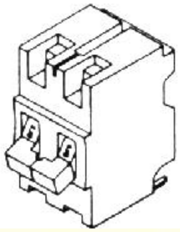
Wiring from the service panel

- Red and black wires are hot … and probably 180 degrees out of phase
- White wires are neutral … not hot
- Green is a ground … it grounds "shorts" in appliances, etc

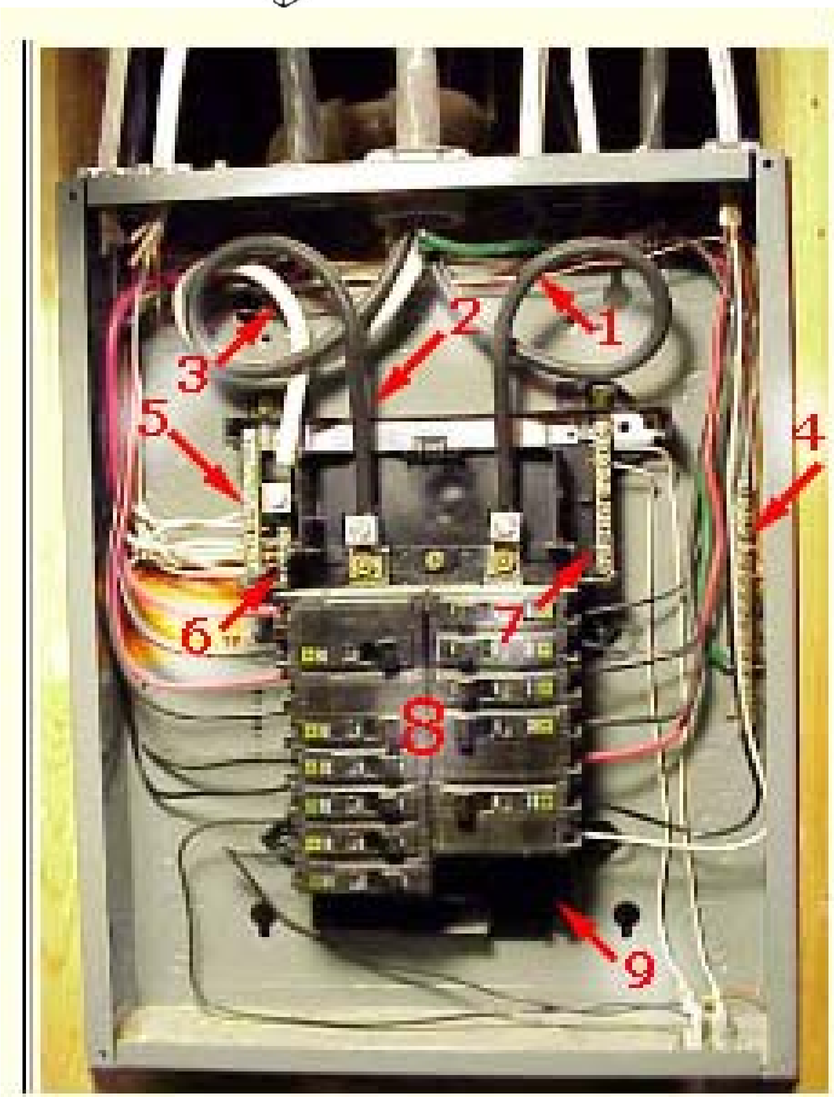


- Red and black wires in an outlet =220 volts

Grab the red and black wires together and you become a "french fry!"



Breakers and Breaker Boxes



A Bit Of Anatomy:

1, 2. Incoming Hot wires. There is 240 volts between these wires, or 120 volts between either wire and the neutral line.

3. Neutral wire. This is at the same electrical potential as the ground. At the main breaker only, the neutral is connected to ground.

4. Ground Bus Bar. This strip of metal has a row of screws for connecting the ground wires of the various circuits.

5, 6, 7. Neutral Bus Bars. This panel has 3 short bus bars for neutral wire connections. Some panels have only one long bar.

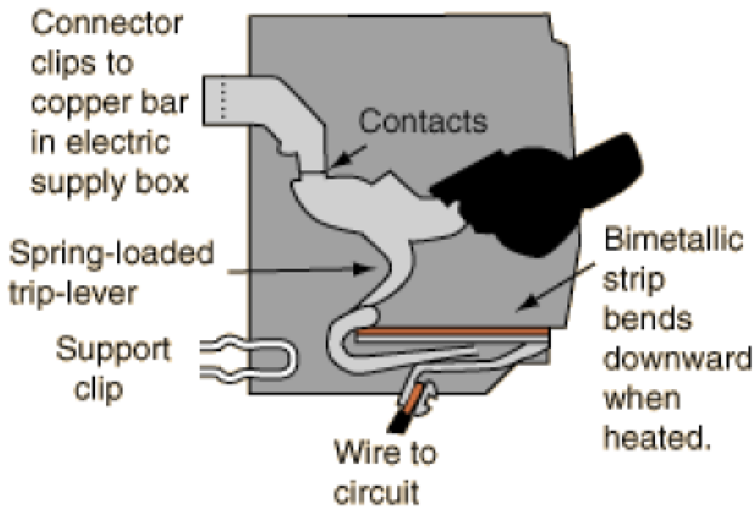
8. Circuit Breakers. Each single-pole breaker connects to one of the two hot bus bars. Each double-pole breaker connects to both of the bus bars (thus providing 240 volts between hot wires).

9. The last available space in this panel. Our new breaker will go here.

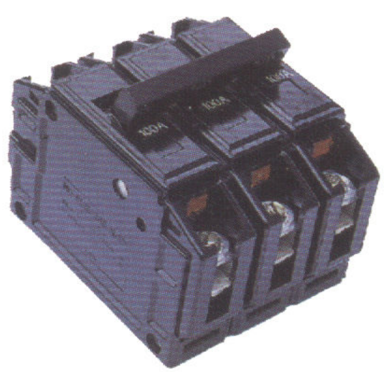
The Circuit-Breaker

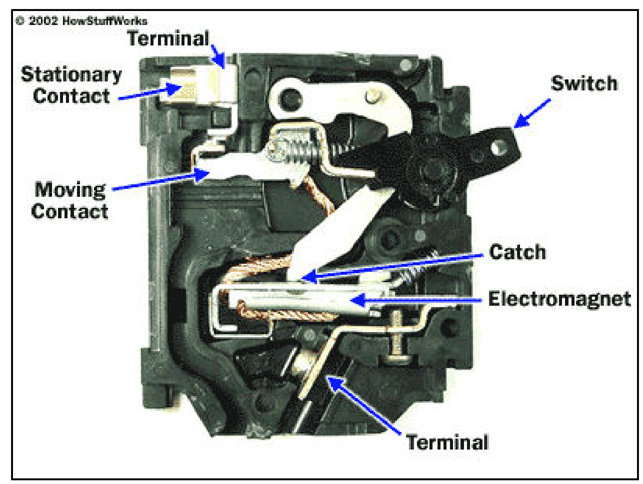
For when you plug a toaster and an iron in the same outlet!!! .....

Circuit breakers act to limit the current in a single circuit in most household applications. Typically a single circuit is limited to 20 amperes, although breakers come in many sizes. This means that 20 amps of current will heat the bimetallic strip to bend it downward and release the spring-loaded trip-lever. Since the heating is fairly slow, another mechanism is employed to handle large surges from a short circuit. A small electromagnet consisting of wire loops around a piece of iron will pull the bimetallic strip down

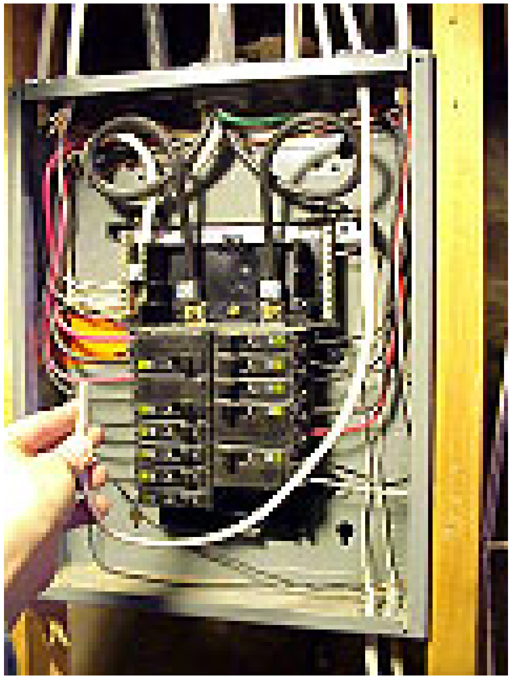


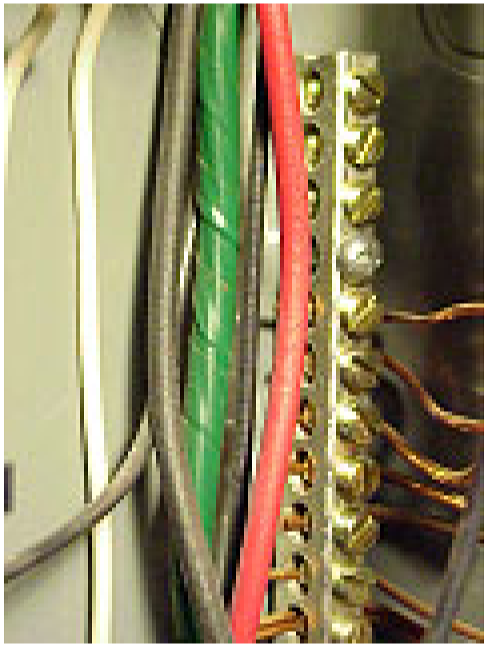
This is a simplified mechanism. the standard breaker has several springs and levers.

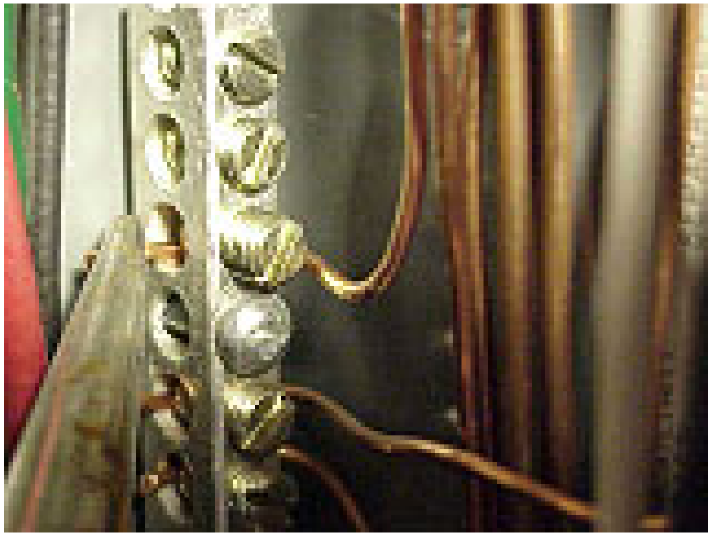


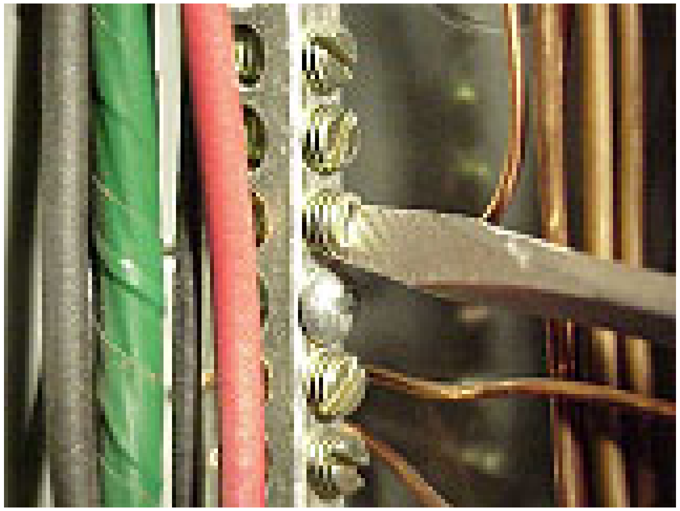


Connecting the Ground Wires

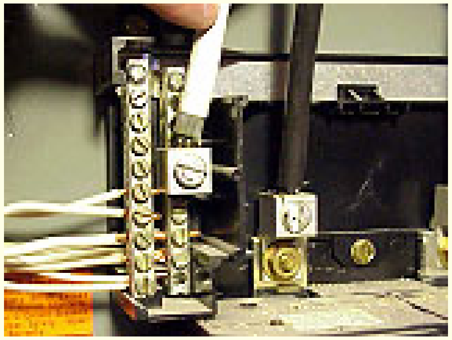






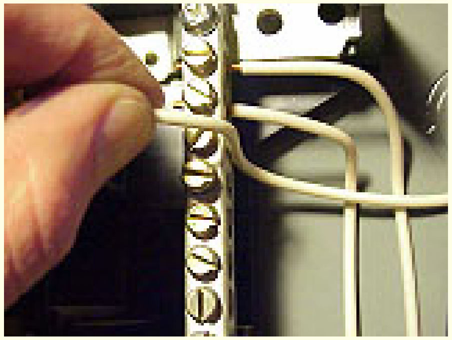


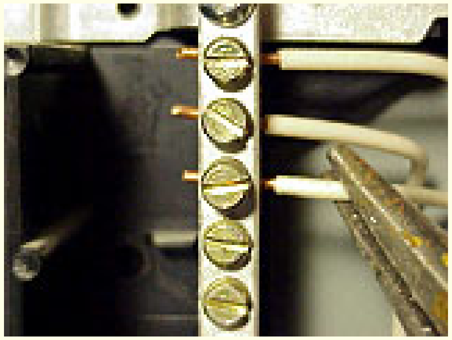
Connecting The Neutral Wire



The neutral line feeding the panel is supposed to be marked white (this one was covered with white electrical tape, which is OK).

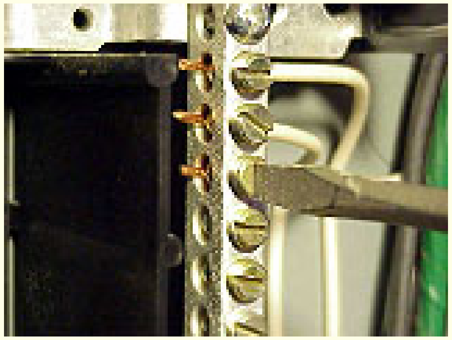
I routed the wire neatly and made some bends.

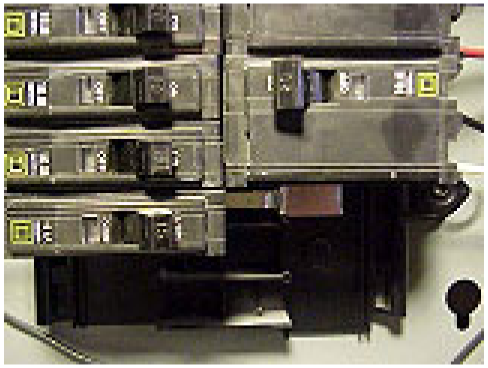


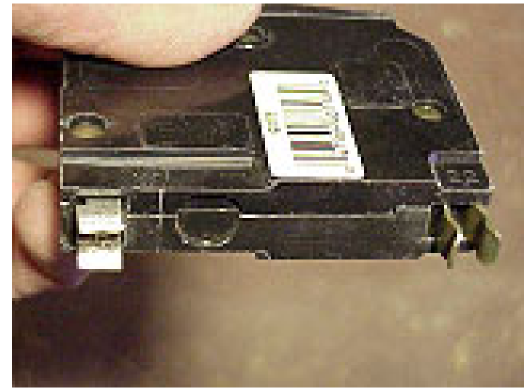


I stripped the insulation from the end of the wire and inserted the bare end into a connection terminal.

The screw was tightened.







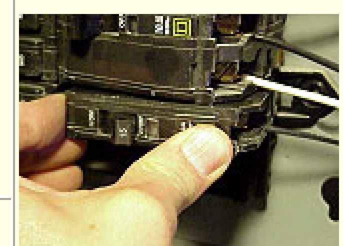
Wiring in a breaker on the “hot line”

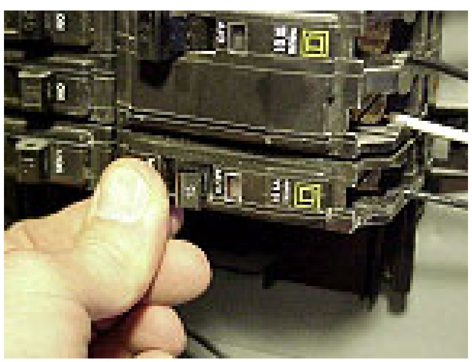
The hot wire was stripped and secured under the screw.

Note the metal bus bar. The circuit breaker grabs on here.

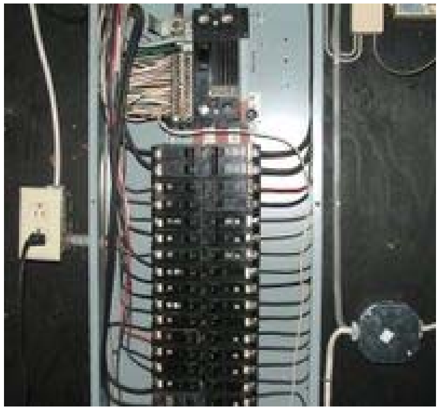
The installation sequence. First the hold-on clip is pushed onto the plastic bar. (I angled the breaker so a photo could be taken. In practice the breaker is parallel to its neighbor.)

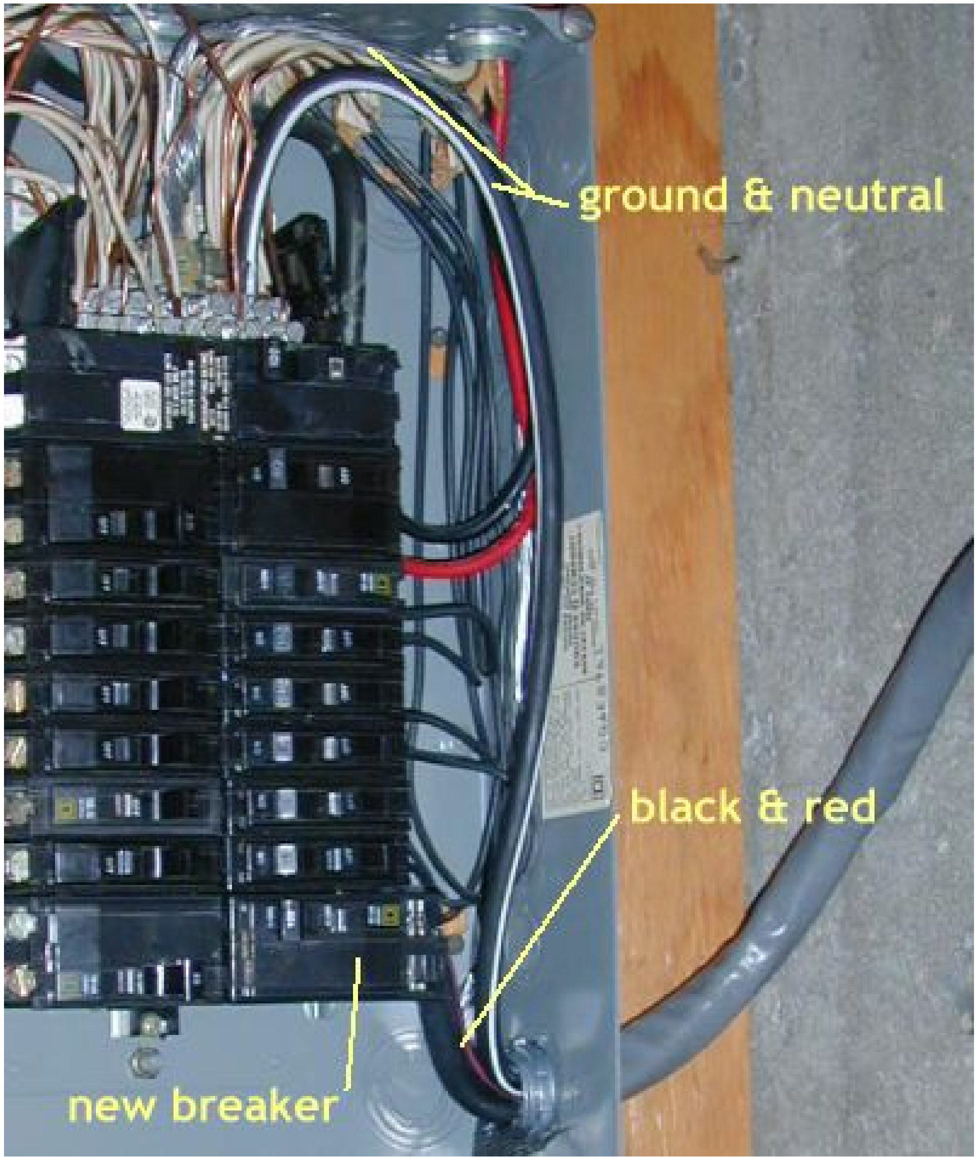
With my thumb I pushed firmly until the breaker was seated. The left end was still not connected.





Another view ....





"Stuff" you might need when doing your own electric wiring .....

Wall Box

- Used for housing switches and receptacles.
- Made of metal or plastic and have the capability to be mounted to a wall or stud.
- The holes in the side of the box where the conduit enters the box are called knockouts. In metal boxes, conduit can also be secured to the holes.
- One type is a Four-Inch Square box that is only 1-1/2" or 2"deep for places too shallow to mount a standard box.
- A *Handy box* is surface mounted and has rounded corners for safety.
- A *Drywall box* has expandable arms and can be mounted on drywall.
- A *Plastic box* is best for new installation and often has a nail built-in for quick attachment to the stud.
- A *Gem box* is a commonly made box, usually 2" wide, 3"high and 2-1/2" deep and made of metal. Deeper boxes are available.

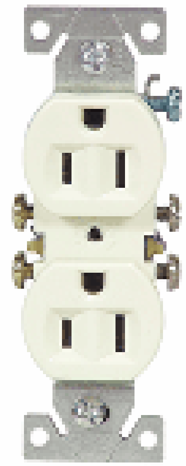
"Stuff" you might need when doing your own electric wiring .....

Ceiling Box

- Also known as a junction box or splice box.
- Used to anchor ceiling fixtures and serves as a junction box where wires can meet and run to other areas of the room.
- They are either 4" octagonal or round shaped, and either 1-1/2" or 2-1/8" deep.
- They also may include adjustable mounting hangers that attach to rafters in the ceiling and allow the box to be placed anywhere between.
- Hangers also provide the short nipple or threaded rod that secures lighting fixtures.

"Stuff" you might need when doing your own electric wiring .....

Receptacle



- Taps the electrical circuit to provide power at a given location.
- Available in flush- or surface-mounted designs.
- A single- or double-wipe contact refers to the area of the inserted prong where the contact is made.

GFCI Receptacle

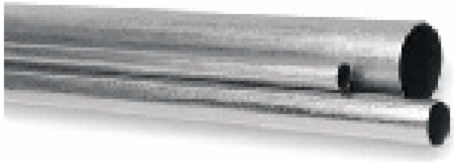
- Stands for Ground Fault Circuit Interrupter.
- Also known as a GFI or ground fault interrupter
- Used to protect against ground faults, which occur when a person comes into contact with a live electrical wire. This may be caused by worn insulation on a wire or by operating a faulty appliance or power tool.
- The GFCI interrupts power quickly enough to help prevent a lethal dose of electricity.
- To turn the GFCI back on after it trips, push the reset button located in the middle of the switch.
- They can be installed as a receptacle or at the main power panel.

"Stuff" you might need when doing your own electric wiring .....

Wire Channels

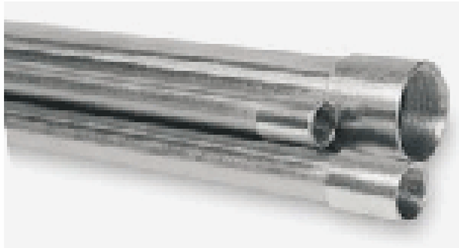
- Also known as raceway.
- Metal or plastic channels used to house wiring installed on the surface, instead of behind walls.

Thin-Wall Conduit



- Also known as EMT (electric metallic tubing).
- Steel pipe used to carry house wiring in places where it is exposed.
- Comes in inside diameters of 1/2" to 4". 1/2" is most common.
- Do not use underground.

Heavy-Wall Conduit



- Also known as rigid conduit.
- Comes in the same sizes as EMT but has thicker walls.
- Has threaded ends for connections.
- Use for carrying wire outdoors and underground.

"Stuff" you might need when doing your own electric wiring .....

Plastic Conduit

- Easy to use.
- Use inside and outside.
- Best for burying underground as it will not corrode with water.

Greenfield Conduit

- Also known as flex conduit.
- A hollow spiral metal jacket that resembles BX cable.
- Use for installing wiring in the home

Conduit Connectors

- Used to connect lengths of conduit.
- Can make straight or bent connections.
- Conduit can also be bent to a 90º curve using a conduit bender

LB Fitting

- Connects at a 90º angle.
- Has thick gaskets to make it impervious to moisture.
- Generally, an LB fitting is placed outside at the point where the conduit leaves the house.
- This fitting should not be used to make wire connections

Conduit Fasteners

- Use to fasten conduit to a wall or other framing member.
- Staples can be used to fasten conduit or bare cable.
- Straps are another type. They can be either one-hole or two-hole.
- Generally, staples are best used inside the house, straps are best used outside.

Pig-tailing

Pig-tailing connects two or more wires together with another 6" pigtail wire that has been stripped 3/4" on each end. The pigtail wire will be the wire you connect to the outlet or switch. This reduces the number of wires to be connected at the receptacle. Below are some of the common uses of pig-tailing.

Note: Most manufactures recommend cutting the wires so that they are even on the end, then applying the nut. When the nut is tightened, it will twist the wires and make a secure connection.

Connecting wires at a duplex receptacle. Strip all wires 3/4" and then hold all of the wires of like color together with another 6" wire of the same color. Twist the ends of the wires being connected with the pigtail wire tightly together. Then screw on a wire nut of the appropriate size. You can check the security of your connection by holding the wire nut and giving a good tug to each wire.

Now it is a simple matter to connect the pigtail portion of the connection to the terminal black to brass, white to silver, and the bare grounding wire to the grounding screw. Once pigtailed, it is easier to bundle all of the wires together to fit them into the box. Then you can simply screw the duplex receptacle (outlet) onto the electrical box with the screws provided.

Watch out for water!!!!!! .....

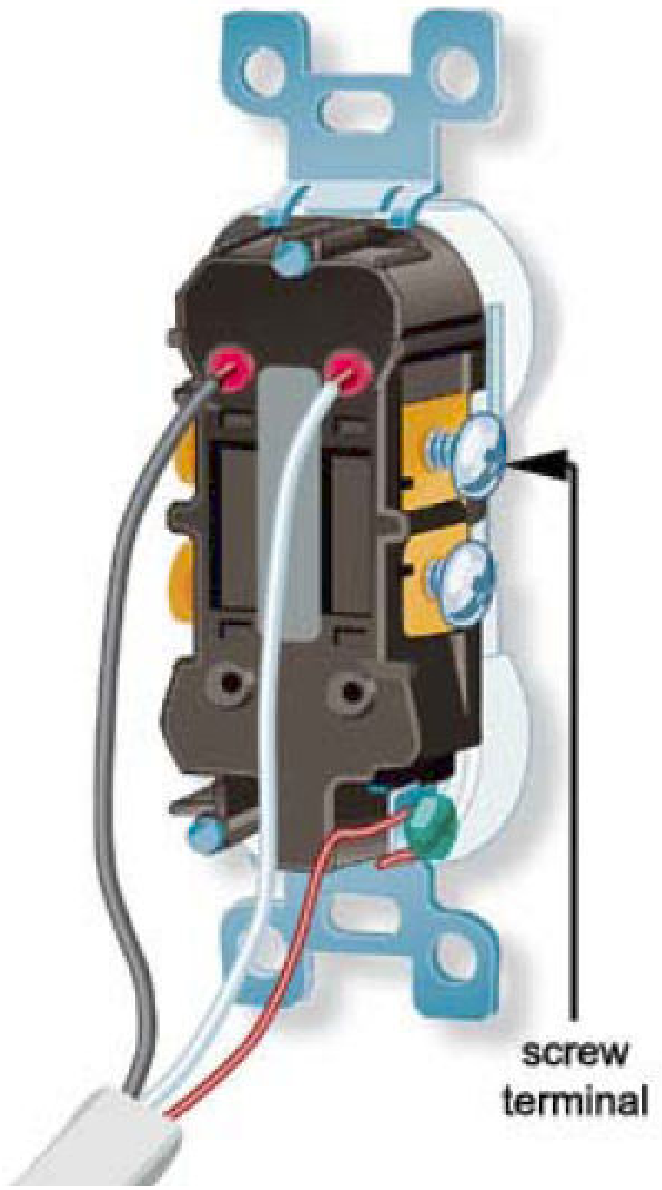
Outdoor Wiring

Basically, wiring fixtures suited for exterior use is the same as wiring indoor fixtures. However, exterior moisture-proof coated wires and boxes must be used. If possible, choose an outdoor outlet location that is convenient to get to, as well as close to an indoor receptacle. This will simplify the installation.

Outside outlets (or those in the bathroom, or garage) must also include ground fault interrupters. GFIs measure the amount of power the hot wire brings in and the neutral wire returns. If there is a 5 milliamp difference or more, due to excessive moisture, the outlet automatically shuts off. This reduces your chances of shock in wet or high-moisture areas. A GFI is usually a type of circuit breaker that is installed in the breaker box, whereupon you then use a normal outlet or an exterior light, the circuit of which is attached into a GFI breaker. However, GFIs also come built directly into the receptacle. The circuit of that receptacle can then be attached to a standard breaker or fuse.

Ground Fault ... GFCI .... keeps you from getting killed when things get wet!!!!!!

.... more than you ever wanted to know.....



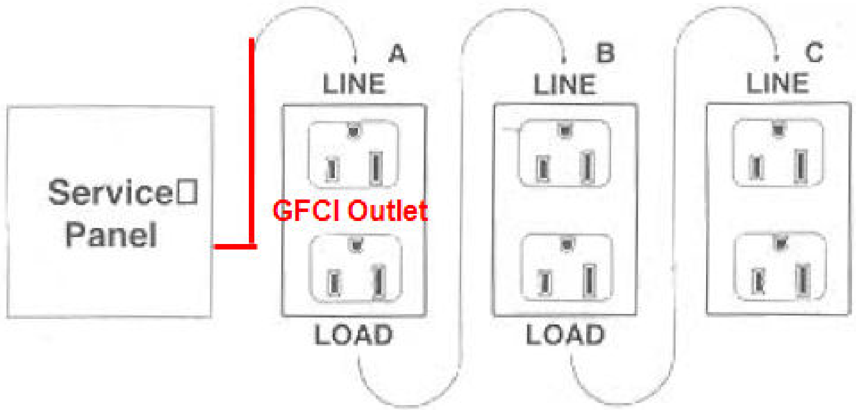
Ground Fault Interrupter

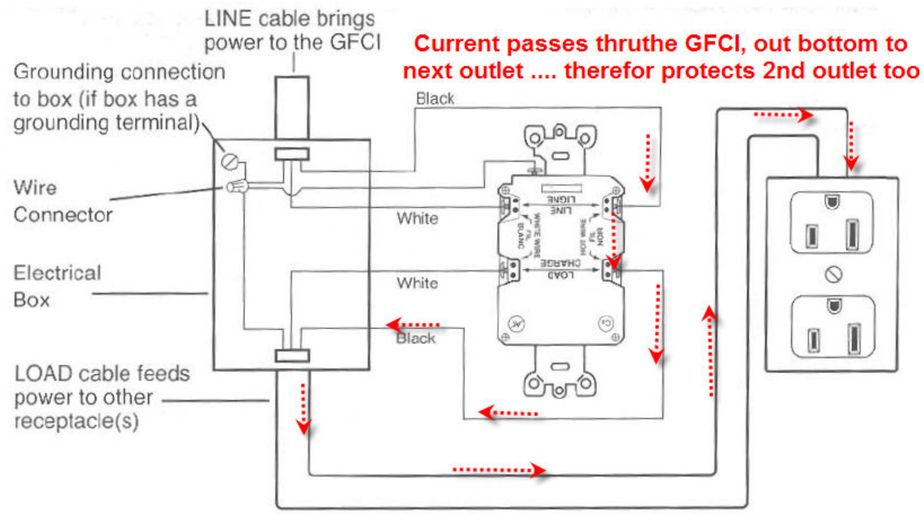
Ground fault interrupters are designed to protect from electrical shock by interrupting a household circuit when there is a difference in the currents in the "hot" and neutral wires. Such a difference indicates that an abnormal diversion of current from the "hot" wire is occuring. Such a current might be flowing in the ground wire, such as a leakage current from a motor or from capacitors. More importantly, that current diversion may be occuring because a person has come into contact with the "hot" wire and is being shocked. When a circuit is functioning normally, all the return current from an appliance flows through the neutral wire, so the presence of a difference between "hot" and neutral currents represents a malfunction which in some circumstances could produce a dangerous or even lethal shock hazard.

The GFI is designed to detect currents of a few milliamperes and trip a breaker at the receptacle or at the breaker panel to remove the shock hazard.

The GFI has a "Test" button which causes a small difference between "hot" and neutral currents to test the device. In an example given by John de Armond, the test button put the 120 volt supply across a 14.75 K resistor, producing a current of 8.2 mA. The UL requirement for a GFI is that it trip when there is 5 mA of leakage current. There is also a reset button to use after it has been tripped.

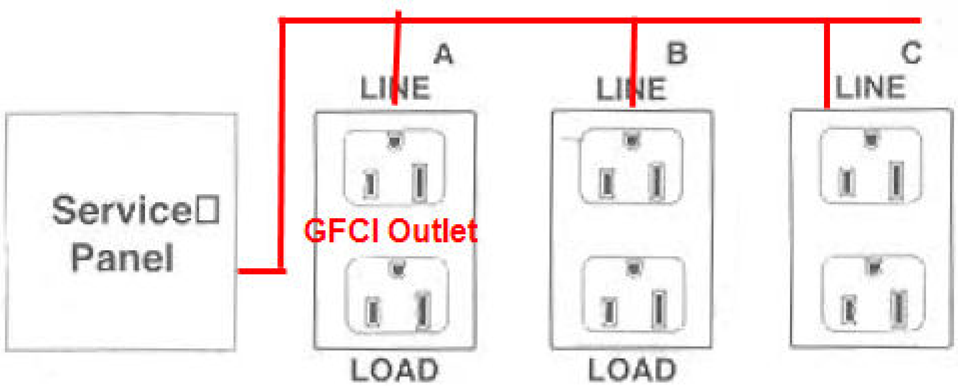
Wiring thru one GFCI to protect 3 outlets

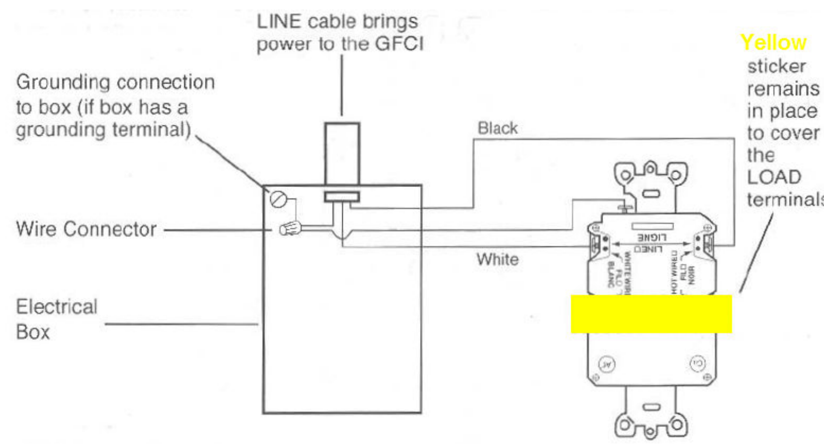




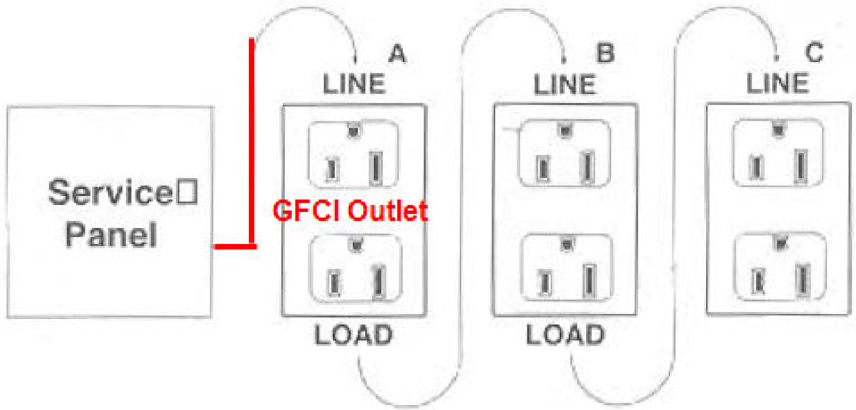
Placing the GFCI in position A will provide protection to "load side" receptacles B and C.

Wiring to one GFCI ... no protection to other 2 outlets

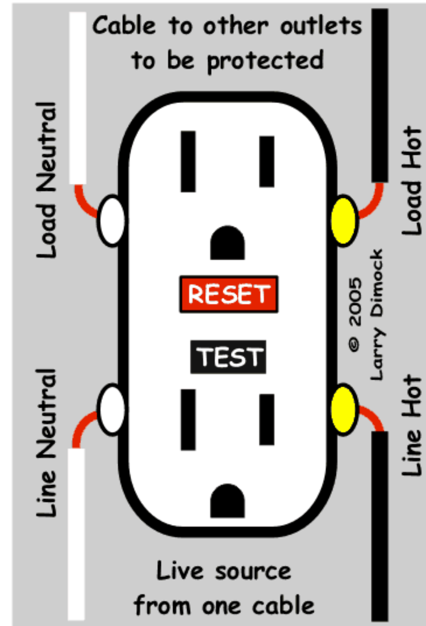




Wiring thru one GFCI to protect 3 outlets

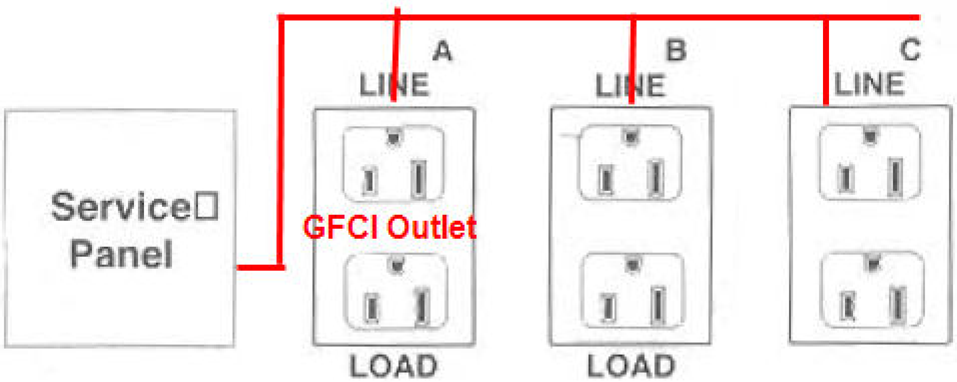


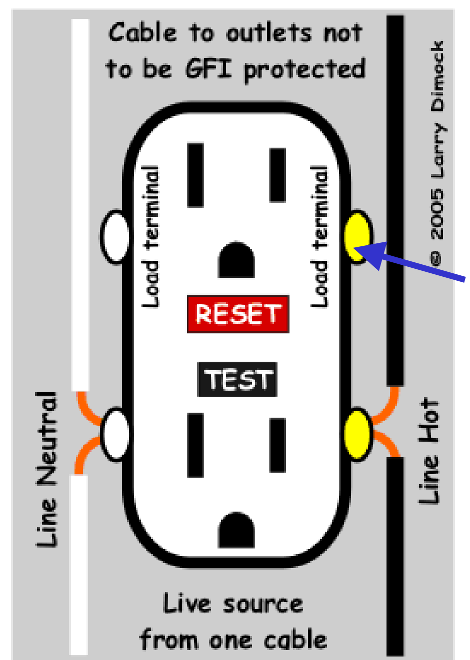
Placing the GFCI in position A will provide protection to "load side" receptacles B and C.



Load passes thru the sensor

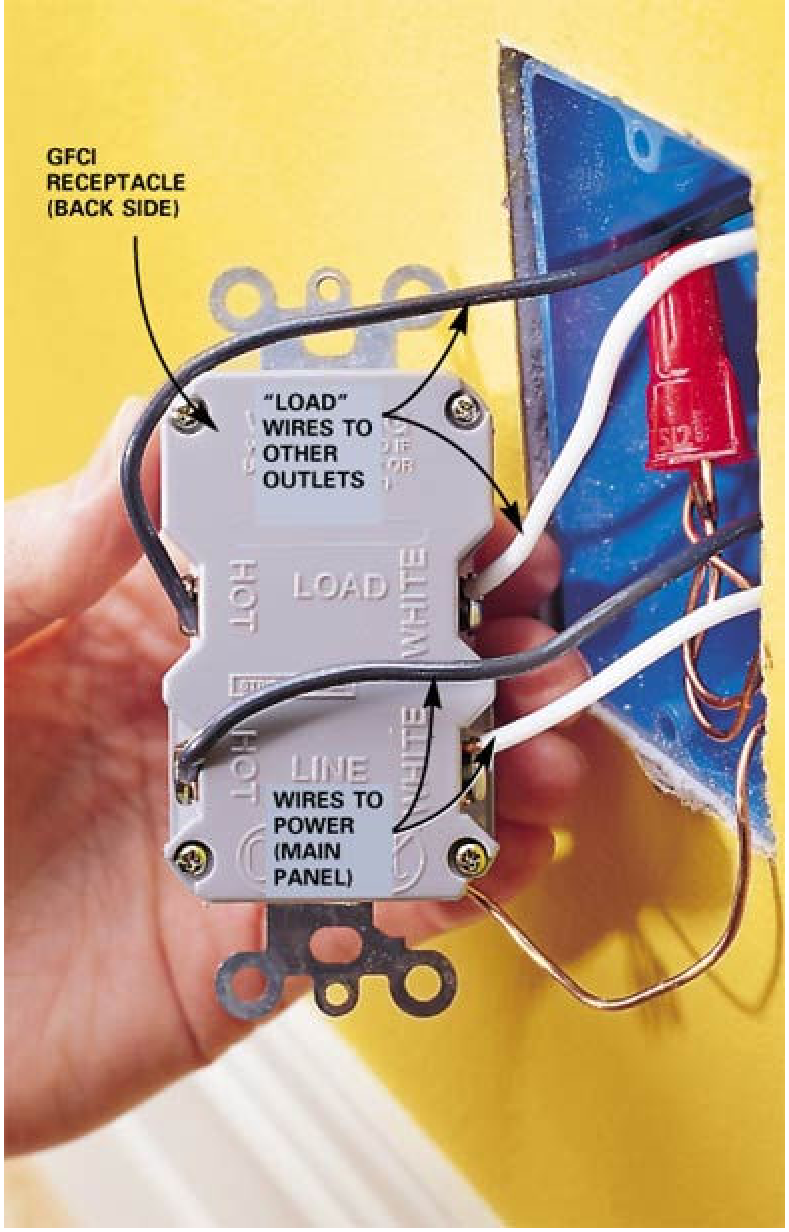
Wiring to one GFCI ... no protection to other 2 outlets

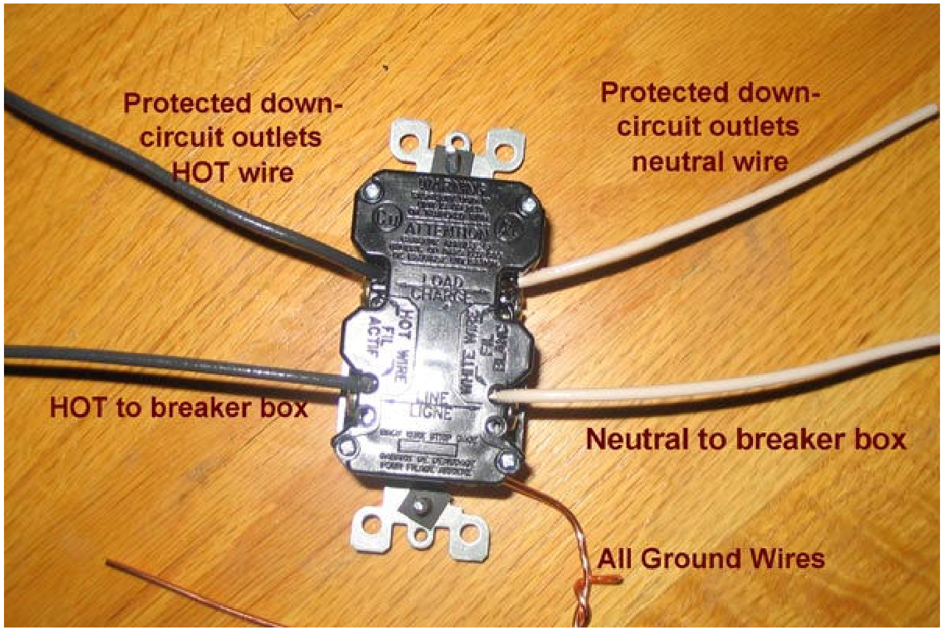




Bypass the sensor

GFCI receptacles
(more)





Ohm's Law

For many conductors of electricity, the electric current which will flow through them is directly proportional to the voltage applied to them. When a microscopic view of Ohm's law is taken, it is found to depend upon the fact that the drift velocity of charges through the material is proportional to the electric field in the conductor. The ratio of voltage to current is called the resistance, and if the ratio is constant over a wide range of voltages, the material is said to be an "ohmic" material. If the material can be characterized by such a resistance, then the current can be predicted from the relationship:

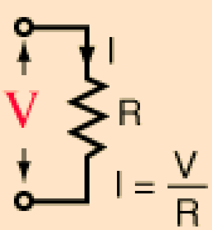
Ohm's Law

$$I = \frac{V}{R}$$

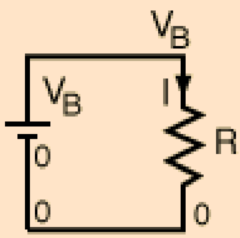
Electric current = Voltage / Resistance

Voltage

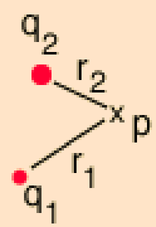
Voltage is electric potential energy per unit charge, measured in joules per coulomb (= volts). It is often referred to as "electric potential", which then must be distinguished from electric potential energy by noting that the "potential" is a "per-unit-charge" quantity. Like mechanical potential energy, the zero of potential can be chosen at any point, so the difference in voltage is the quantity which is physically meaningful. The difference in voltage measured when moving from point A to point B is equal to the work which would have to be done, per unit charge, against the electric field to move the charge from A to B.



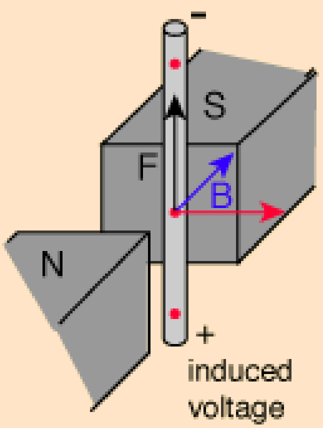
Used to calculate current in Ohm's law.



Used to express conservation of energy around a circuit in the voltage law.

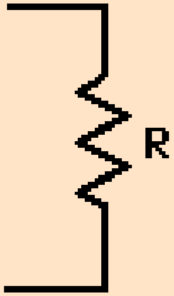


Used to calculate the potential from a distribution of charges.



Is generated by moving a wire in a magnetic field.

Resistance



The electrical resistance of a circuit component or device is defined as the ratio of the voltage applied to the electric current whichflows through it:

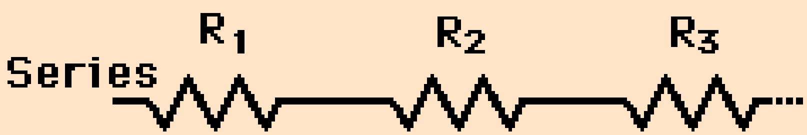
$$R = \frac{V}{I}$$

If the resistance is constant over a considerable range of voltage, then Ohm's law, I = V/R, can be used to predict the behavior of the material. Although the definition above involves DC current and voltage, the same definition holds for the AC application of resistors.

Whether or not a material obeys Ohm's law, its resistance can be described in terms of its bulk resistivity. The resistivity, and thus the resistance, is temperature dependent. Over sizable ranges of temperature, this temperature dependence can be predicted from a temperature coefficient of resistance.

Resistor Combinations

The combination rules for any number of resistors in series or parallel can be derived with the use of Ohm's Law, the voltage law, and the current law.

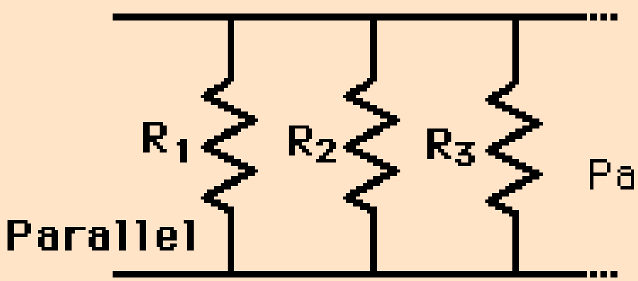


Series

$$R_{equivalent} = R_1 + R_2 + R_3 + \dots$$

Series: $$R_{equivalent} = \frac{V}{I} = \frac{V_1 + V_2 + V_3 + \dots}{I} = \frac{V_1}{I_1} + \frac{V_2}{I_2} + \frac{V_3}{I_3} + \dots = R_1 + R_2 + R_3 + \dots$$

Key Idea: The current is the same in each resistor.



Key Idea: The voltage is the same across each resistor.

Parallel

$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

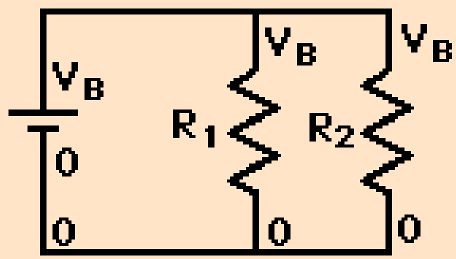
Parallel: $$\frac{V}{R_{equivalent}} = I = I_1 + I_2 + I_3 = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + \dots$$

$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

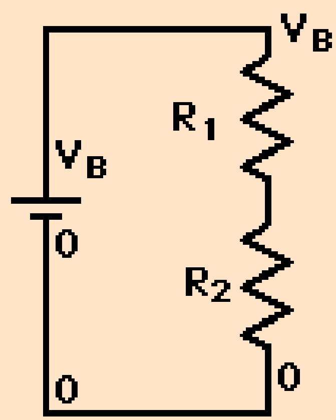
Voltage Law

The voltage changes around any closed loop must sum to zero. No matter what path you take through an electric circuit, if you return to your starting point you must measure the same voltage, constraining the net change around the loop to be zero. Since voltage is electric potential energy per unit charge, the voltage law can be seen to be a consequence of conservation of energy.

The voltage law has great practical utility in the analysis of electric circuits. It is used in conjunction with the current law in many circuit analysis tasks.



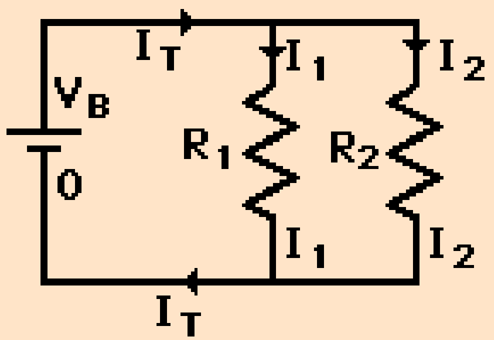
The voltages across elements in parallel are equal. This is one of the implications of the voltage law - since the change across either R_1 or R_2 must be equal to the battery voltage V_B, then they are equal to each other.



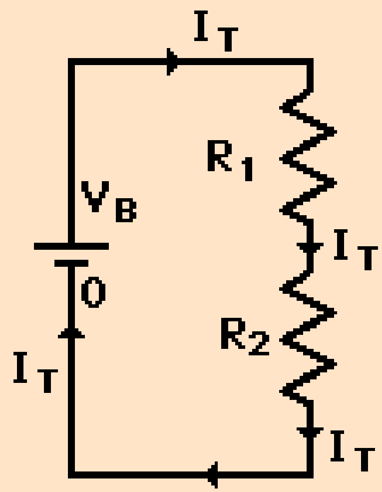
For a series combination, the sum of the voltage drops across R_1 & R_2 must sum to equal V_B .

Current Law

The electric current in amperes which flows into any junction in an electric circuit is equal to the current which flows out. This can be seen to be just a statement of conservation of charge. Since you do not lose any charge during the flow process around the circuit, the total current in any cross-section of the circuit is the same. Along with the voltage law, this law is a powerful tool for the analysis of electric circuits.



For a parallel circuit the current divides such that $I_T = I_1 + I_2$



The current is the same at all points in a series circuit.

DC Electric Power

Power: Watts = Volts x Amps

The electric power in watts associated with a complete electric circuit or a circuit component represents the rate at which energy is converted from the electrical energy of the moving charges to some other form, e.g., heat, mechanical energy, or energy stored in electric fields or magnetic fields. For a resistor in a D C Circuit the power is given by the product of applied voltage and the electric current:

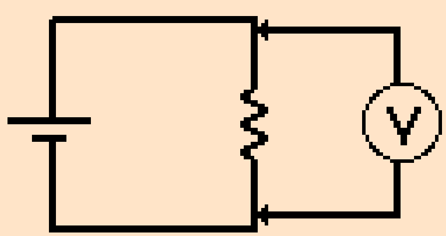
$$P = VI$$

Power = Voltage x Current

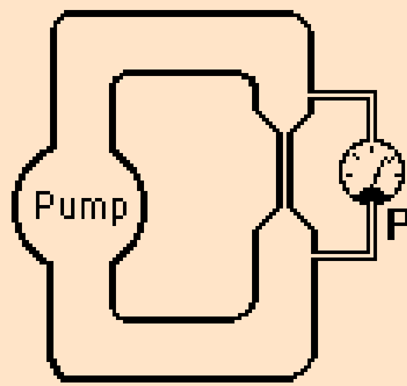
[ ] watts = [ ] volts x [ ] amperes

Voltmeter

A voltmeter measures the change in voltage between two points in an electric circuit and therefore must be connected in parallel with the portion of the circuit on which the measurement is made. By contrast, an ammeter must be connected in series. In analogy with a water circuit, a voltmeter is like a meter designed to measure pressure difference. It is necessary for the voltmeter to have a very high resistance so that it does not have an appreciable affect on the current or voltage associated with the measured circuit. Modern solid-state meters have digital readouts, but the principles of operation can be better appreciated by examining the older moving coil meters based on galvanometer sensors.



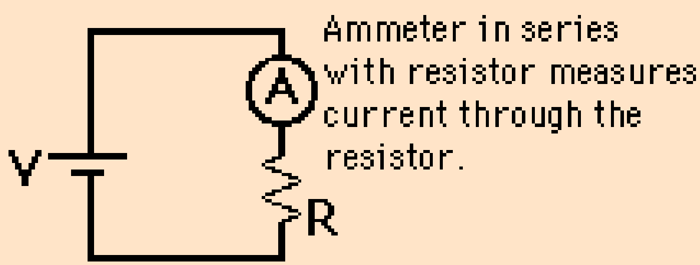
A voltmeter is connected in parallel to measure the voltage change across a circuit element

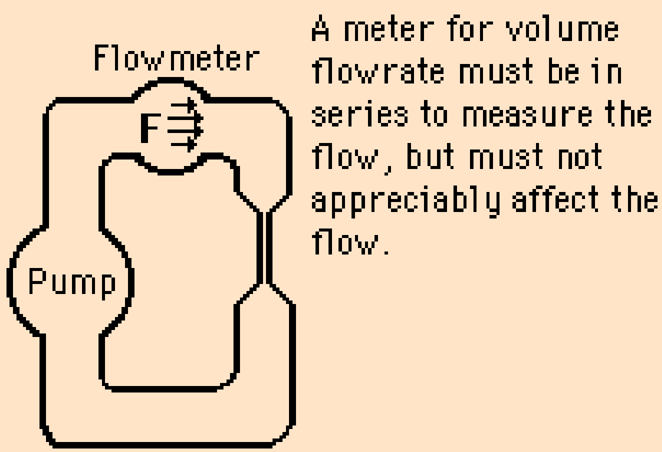


A pressure gauge is connected in parallel to measure the pressure drop across the resistance.

Ammeter

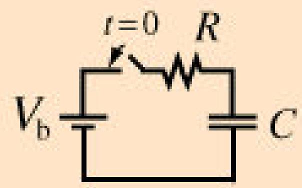
An ammeter is an instrument for measuring the electric current in amperes in a branch of an electric circuit. It must be placed in series with the measured branch, and must have very low resistance to avoid significant alteration of the current it is to measure. By contrast, an voltmeter must be connected in parallel. The analogy with an in-line flowmeter in a water circuit can help visualize why an ammeter must have a low resistance, and why connecting an ammeter in parallel can damage the meter. Modern solid-state meters have digital readouts, but the principles of operation can be better appreciated by examining the older moving coil meters based on galvanometer sensors.





Charging a Capacitor

When a battery is connected to a series resistor and capacitor, the initial current is high as the battery transports charge from one plate of the capacitor to the other. The charging current asymptotically approaches zero as the capacitor becomes charged up to the battery voltage. Charging the capacitor stores energy in the electric field between the capacitor plates. The rate of charging is typically described in terms of a time constant RC.



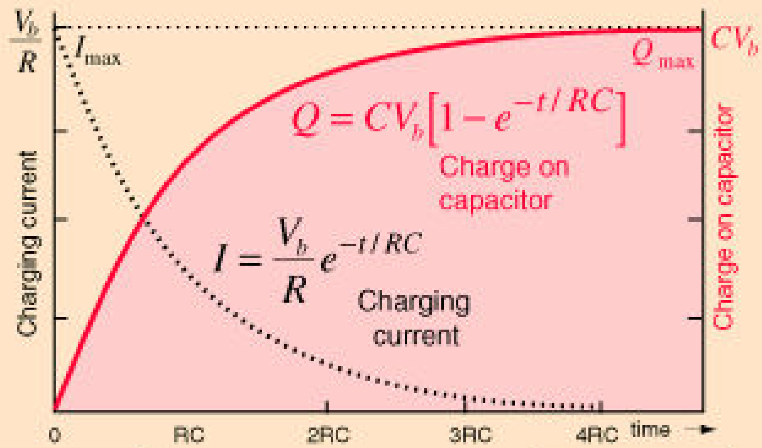
$$V_b = V_R + V_C$$

$$V_b = IR + \frac{Q}{C}$$

As charging progresses,

$$V_b = IR + \frac{Q}{C}$$

current decreases and charge increases.



At $t = 0$

$Q = 0$

$V_C = 0$

$I = \frac{V_b}{R}$

As $t \to \infty$

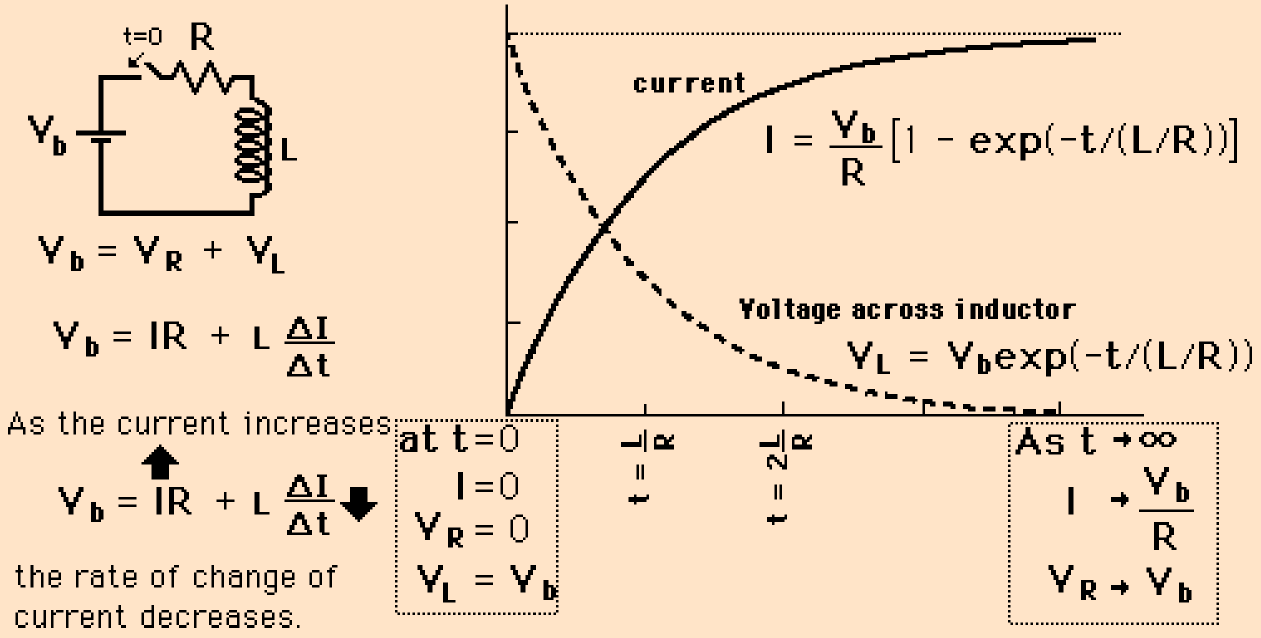
$Q \to CV_b$

$V_C \to V_b$

$I \to 0$

Inductor Transient

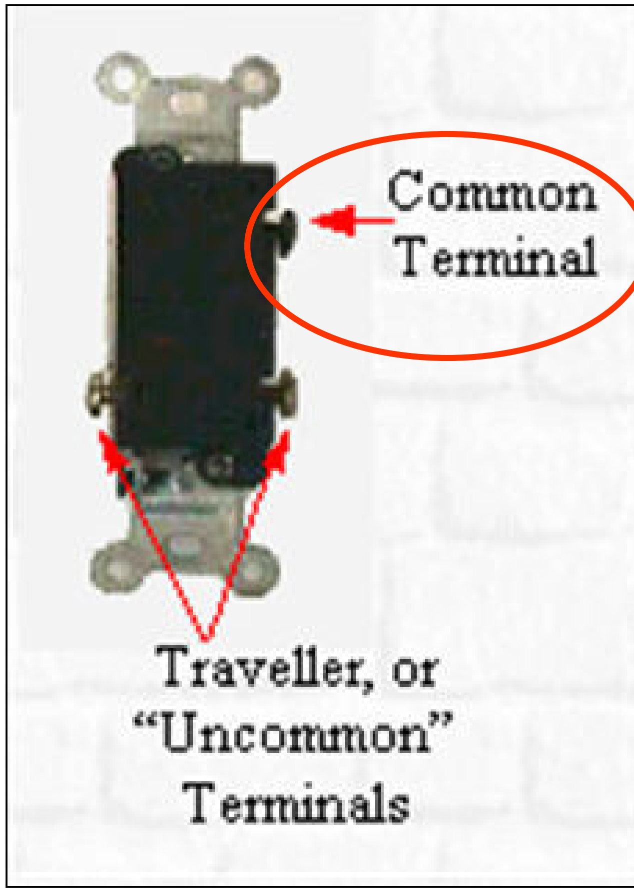
When a battery is connected to a series resistor and inductor, the inductor resists the change in current and the current therefore builds up slowly. Acting in accordance with Faraday's law and Lenz's law, the amount of impedance to the buildup of current is proportional to the rate of change of the current. That is, the faster you try to make it change, the more it resists. The current builds up toward the value it would have with the resistor alone because once the current is no longer changing, the inductor offers no impedance. The rate of this buildup is often characterized by the time constant L/R . Establishing a current in an inductor stores energy in the magnetic field formed by the coils of the inductor.



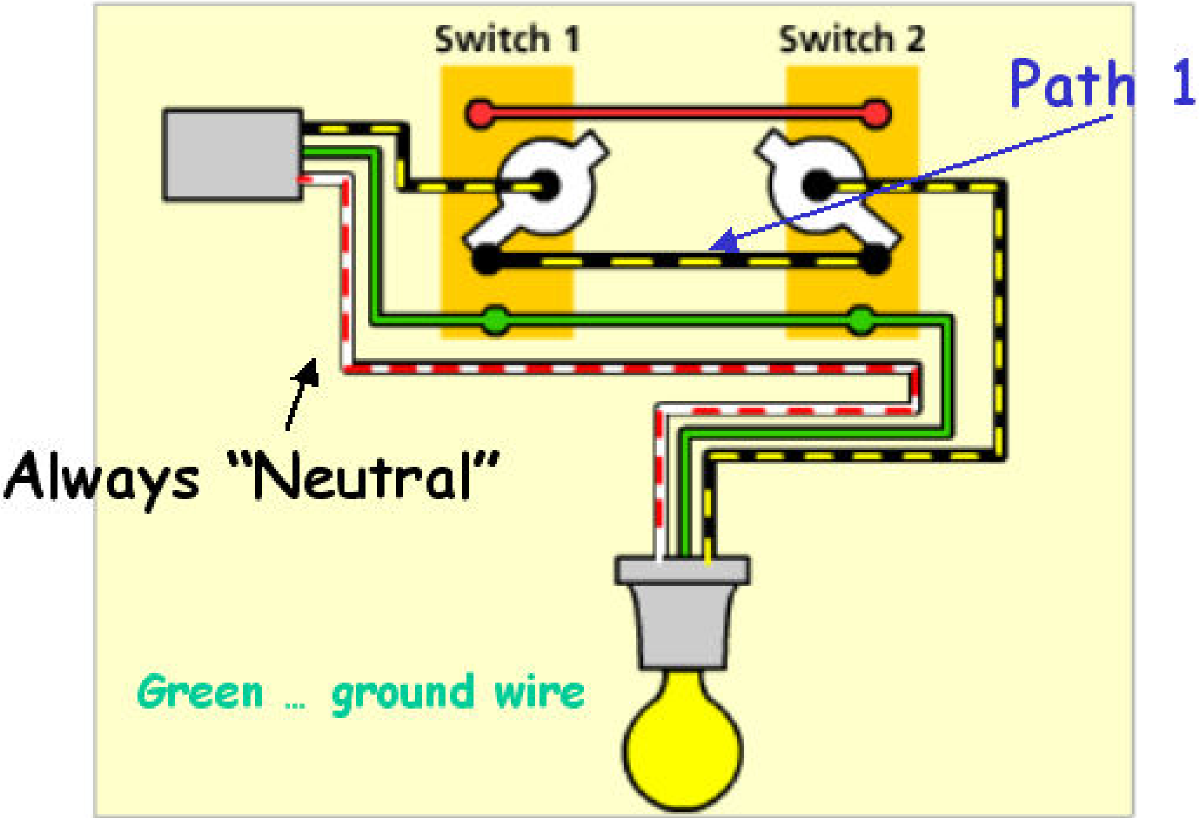
3-way switch …

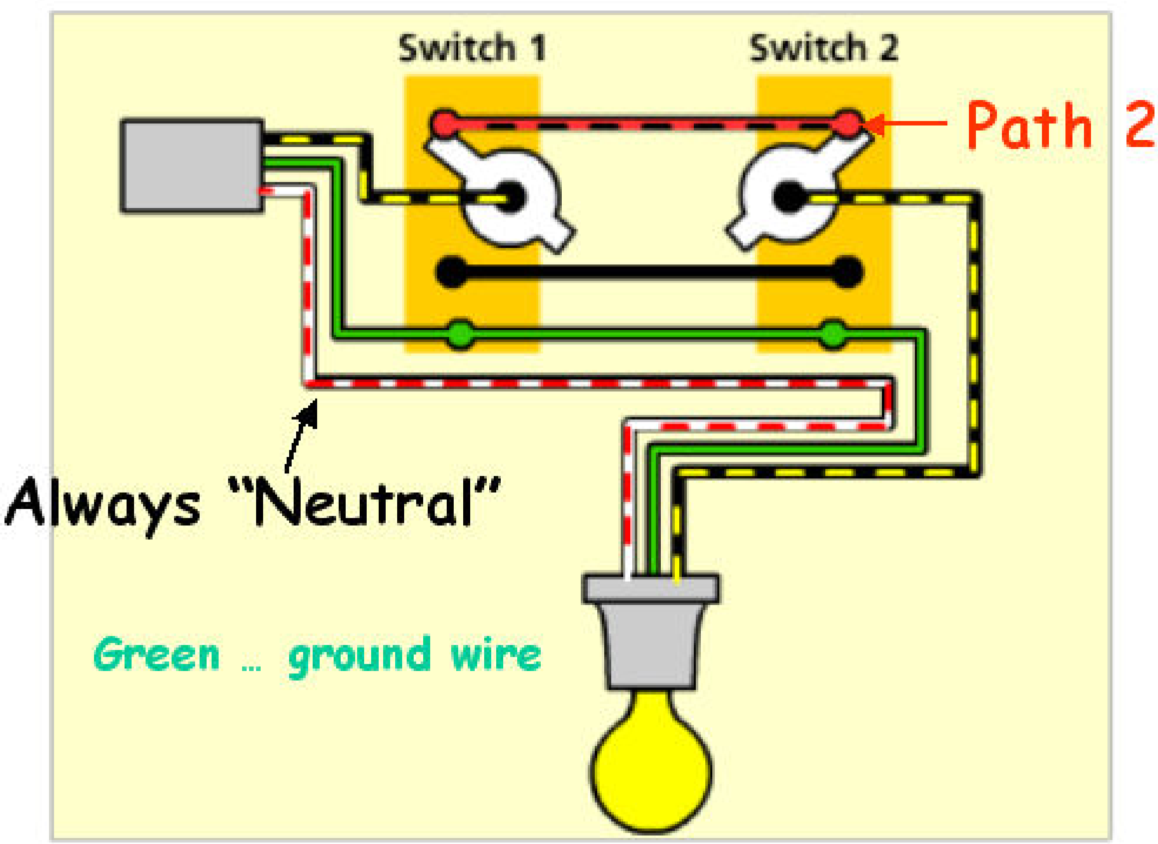
Wire that attaches to the <u>common terminal</u> is either (1) a hot wire from the main board or (2) leads to the load (fixture).

Travellers are two wires connecting the two 3-way switches together. **Either traveler wire can be connected to either traveler terminal... it doesn't matter!**



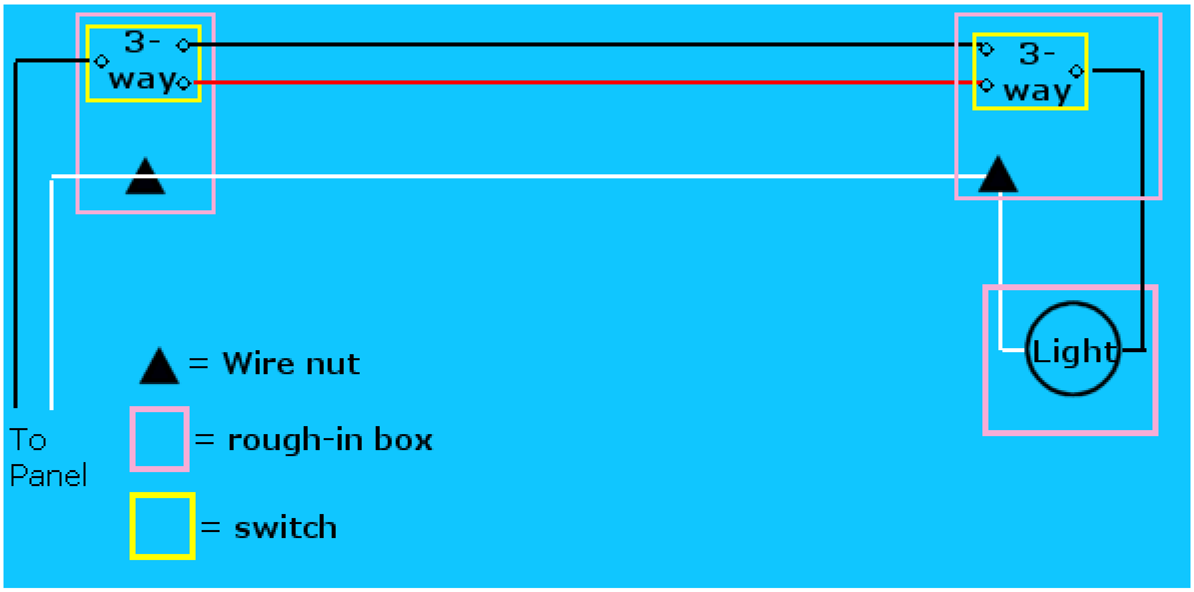
The heart of a 3-way circuit is the **3-way switch**. Unlike a common wall switch, the 3-way switch has three active terminals (plus a ground in up-to-date installations). Only one of them is important to identify for the purposes of replacement… the <u>COMMON TERMINAL</u>. Though our graphic (left) shows the common terminal in a certain position, the fact is that it could be any terminal on your individual switch.
Sometimes the toughest thing to do is identify it. If there is no labeling on the switch, there may be a different color fastening screw used for the common terminal… **usually brass colored**.


Switch 1
Switch 2
Path 1
Always "Neutral"
Green … ground wire


Switch 1
Switch 2
Path 2
Always "Neutral"
Green … ground wire

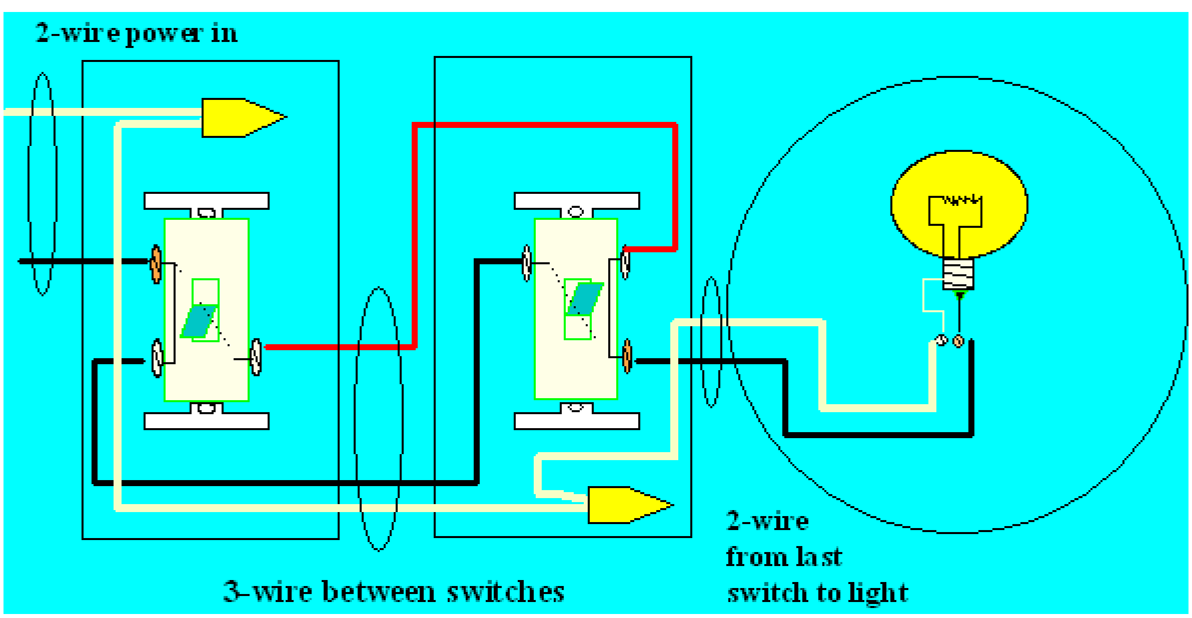
3-way switch

Below is perhaps the simplest arrangement, panel to switch to switch to light:



The 3-way circuit is a very common system found within most residential installations.

3-ways are used any time that you want two switches to operate one light (or lights).




Remember…call 911
when you set your house on fire!!!
Now …on to telephone wiring stuff ….
Watts=Volts x Amps!!!
Created especially for Engineers and Scientists who copied old lab reports instead of running the experiments themselves!!!
Phone colors …
Red-Green
Yellow-Black

Telephone wire codes

- In a typical home, the telephone cables connecting your phones within you home contain four wires... red, green, yellow and black.

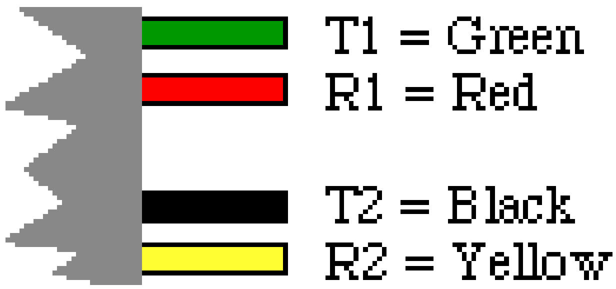
- They are used in pairs for each phone line you have. Repairmen in fact refer to the wires in terms of "pairs", so technically a standard four wire telephone line has two pairs.

LINE 1 uses the red-green pair.
LINE 2 uses the yellow-black pair.

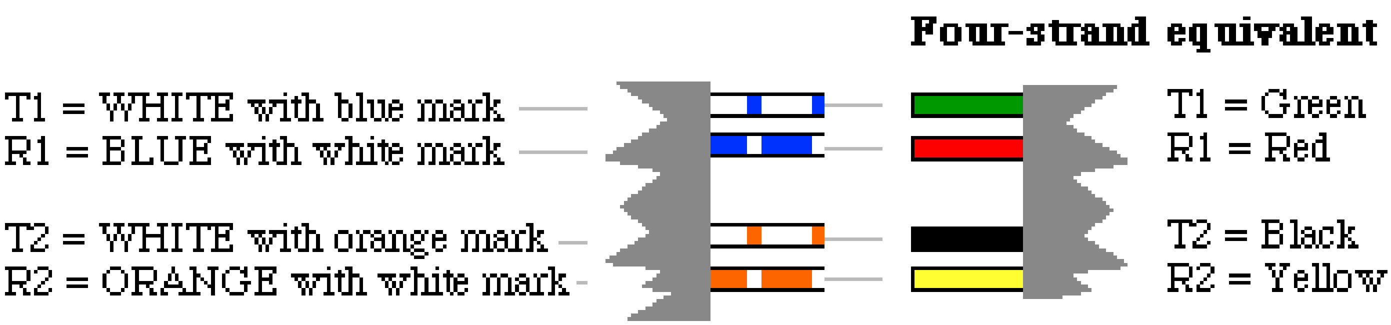
- Multiwire cable with 4 pair (8 colored wires) has four lines, the wiring convention is the same as above, with LINE 3 using BLUE + WHITE and LINE 4 using ORANGE + BROWN.

Telephone wire codes

Four-strand wire:



For newer telephone wiring projects, you use Cat 5 cable…. and employ the following color coding:



One phone line only requires two of these strands. *In the vast majority of cases, the other two wires go unused*

More ...

Telephone Wire Color Codes

Standard Quad-Wire Color codes		
Pair 1	T R	Green Red
Pair 2	T R	Black Yellow
NOTE:Presented for historical reasons-nobody uses quad wire anymore.		

Standard 4-Pair Wiring Color codes		
Pair 1	T R	White/Blue Blue/White
Pair 2	T R	White/Orange Orange/White
Pair 3	T R	White/Green Green/White
Pair 4	T R	White/Brown Brown/White
NOTE:For 6-wire jacks use pair 1, 2 and 3 color codes. For 4-wire jacks use pair 1 and 2 color codes.		

More …

Telephone Wire Color Codes

Function	New Color	Old Color
Tip 1	Green	White/Blue
Ring 1	Red	Blue/White
Tip 2	Black	White/Orange
Ring 2	Yellow	Orange/White

Many phone companies have updated their color standards due to the use of CAT5 cable for most phone line installs. In this new standard, there are no green, red, black or yellow wires, they have been replaced by white/blue, blue/white, white/orange, and orange/white.

To know how to identify the wire color is a simple matter. Wire is going to be primarily one color, with small stripes of a secondary color on it. If the wire is primarily orange with white stripes then that color is orange/white. The table above will help you understand what colors match.

A two-line installation example …

POTS line …. Plain Old Telephone Service

One of the wires of your POTS line is called the tip wire and the other is the ring wire (see chart).

Tip Wire	Ring Wire
Green	Red
Black	Yellow
Blue	White
Secondary Color with Primary Color Stripes	Primary Color with Secondary Color Stripes

In a modular jack you have red/green and yellow/black. Most of the time you only use the red/green pair.

The green wire is the tip and the red wire is the ring.

A little about wires …

- Most telephone wires are one or more twisted pairs of copper wire. The most common type is the 4-strand (2 twisted pair). This consists of red and green wires, which make a pair, and yellow and black wires, which make the other pair.

- One telephone line needs only 2 wires. Therefore it follows that a 4-strand wire can carry 2 separate phone lines.

- Telephone wire comes in 2 gauges, 22 gauge and 24 gauge, 24 gauge being today's standard.

- There are 2 types of common modular plugs, the RJ-11 and the RJ-14. The most common is the RJ-11 which uses only 2 of the wires in a 4 (or more) strand wire. This is the same kind of plug that you use to plug your telephone into the wall. This is a 1-line plug. The RJ-14 uses 4 wires and is used to handle 2 lines, or 2-line phones.

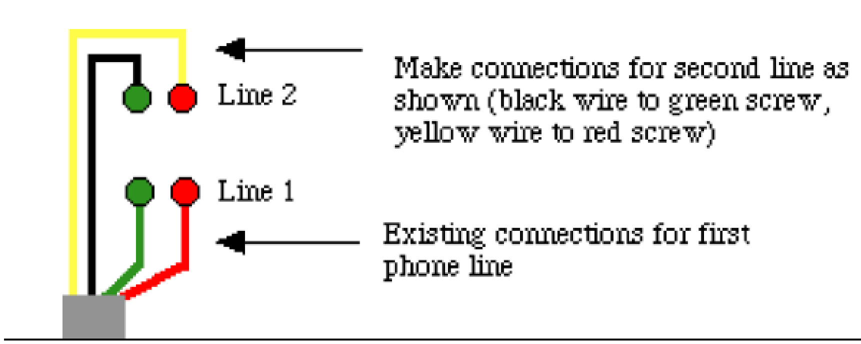
What is CAT 5 ….

Cat 5, short for Category 5, is the current preferred industry standard for network and telephone wiring.

Cat 5 is an unshielded twisted pair type cable exclusively designed for high signal integrity. The cable consists of four pairs of 24-guage twisted copper pairs terminating in an RJ-45 jack.

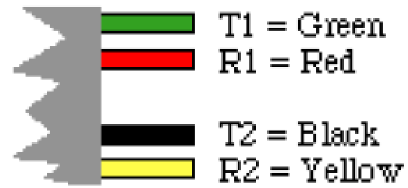
If a wire is certified as Category 5 and not just twisted pair wire, then it will have "Cat 5" printed on the shielding.

The actual Cat 5 standard describes specific electrical properties of the wire, but Cat 5 is most widely known as being rated for its Ethernet capability of 100 Mbit/s.



Telephone line colors

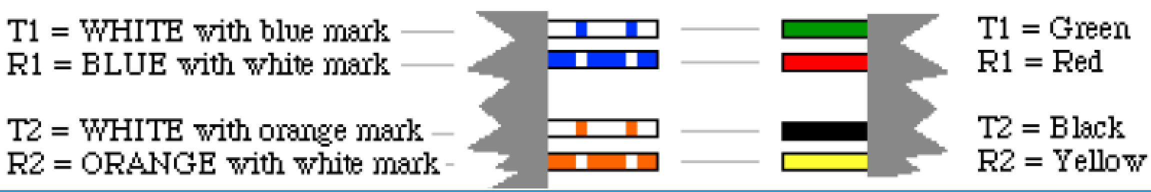
Four-strand wire:



The kind of wire shown above has recently become obsolete

For all new telephone wiring projects, you should use Cat 5 cable.
Cat 5 wire uses the following color coding:

Four-strand equivalent



Two wires (normally referred to as a "pair") are needed for most telephone connections. One of the wires in a pair is referred to as the "tip" and the other is called the "ring". Color code schemes are used to identify wires within a cable.

You may encounter two different wire color schemes while working on your phone wiring.

The simplest color scheme is used on normal station cable (what your phone tech may call "JK"), which has only two pairs of wire.
The first pair has one **green** wire ("tip") and one **red** wire ("ring"). For a single phone line, only the green and red pair are normally used.
The second pair has one **black** wire ("tip") and one **yellow** wire ("ring").
The black and yellow pair is normally spare and available to install a second phone line.

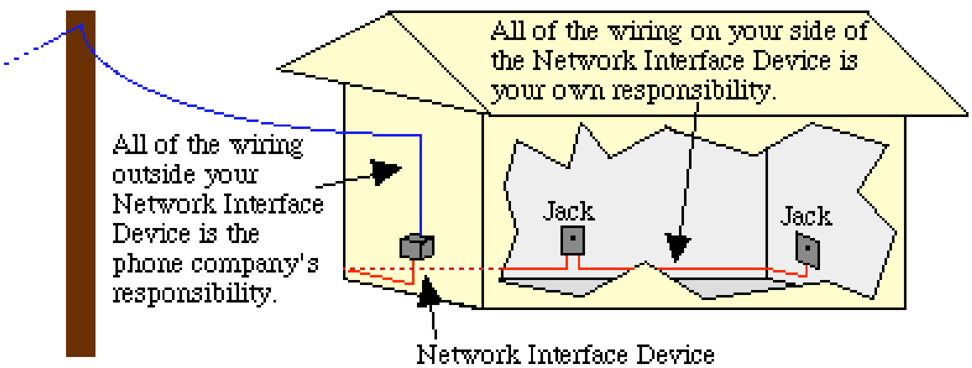
The other color scheme is somewhat more complicated and is based on a primary color and a secondary color.
The "tip" wire is mostly the secondary color, with marks of the primary color (i.e., **white** with **blue** marks).
The "ring" wire is mostly the primary color, with marks of the secondary color (i.e., **blue** with **white** marks).
The primary colors are **blue**, **orange**, **green**, **brown**, and **slate** (or **gray**, if you're not a phone tech!).
The secondary colors are **white**, **red**, **black**, **yellow**, and **violet** (or **purple**, if you're not a phone tech!).

Doing your own telephone wiring

Note: this page describes the phone wiring conventions in the United States. I'm not familiar with the phone wiring conventions outside the U.S., so the information here may not apply in your country.

Residential phone wiring: whose responsibility?

In years gone past, it was the responsibility of the phone company not only to bring phone service to your house but to do the phone wiring within your house as well. This is no longer the case. When you order phone service to your house, the local phone company installs a **network interface device**, a sturdy grey plastic box usually mounted either in your basement or on an outside wall.



You can do your inside wiring yourself, or you can pay the local phone company or a third party (such as an electrician) to do it for you. Doing residential phone wiring is easy, however, and the local phone company's charges for this service are steep. Even if you have to buy wire and modular jacks, you're going to come out way ahead if you do your own work.

Installing extra lines can be a problem if you rent an apartment in a multi-unit building. The wiring between the network interface device and the apartment is not the phone company's responsibility, so you'll have to work out with your landlord who's going to do the in-between wiring if you need additional lines. Your landlord may not want you to do the wiring for fear you don't know what you're doing; but the landlord may also object to picking up the tab if the phone company does the work. Whose responsibility it actually is probably depends on your lease.

I once had a deadbeat landlord who I didn't even bother approaching when I needed a second line installed. Instead, I just ran my own wire out thru a hole I drilled in the window frame and down a six-story fire escape in the alley to the basement, where I had the phone company representative install an ordinary residential network interface device for me next to the big panel. When I moved, I just unhooked my piece of wire and rolled it up for my next wiring project, and then I spackled over the hole I had drilled. The landlord was none the wiser.

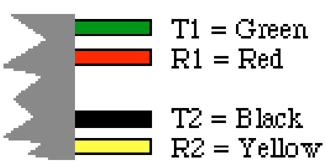
What this page is about

This page is mainly about installing additional phone lines, which is one of the most common phone wiring tasks in this age of modems and fax machines. What's described here are the color coding conventions for phone wiring, and how to make the connections. It's assumed that you know how to use a screwdriver and a drill.

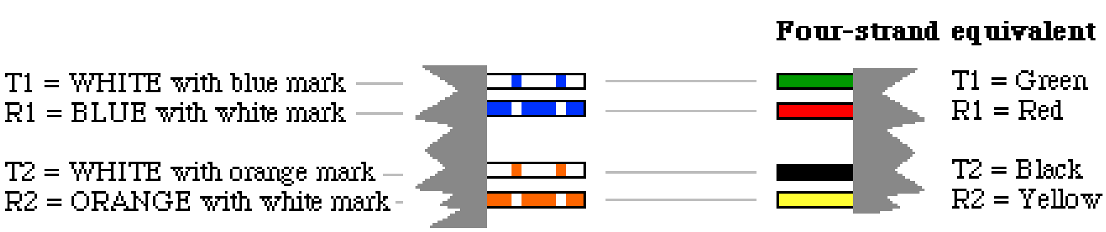
It's also assumed that you have at least a rudimentary understanding of electrical safety. Phone wires carry low-voltage electricity, but you probably already know better than to do your wiring barefoot on a wet floor, for example. If you're touching the wires when the phone rings, you *can* get a substantial jolt; enough current goes thru to ring the old-type mechanical ringing devices consisting of a heavy clapper and some rather large bells, even though most modern phones no longer require so much current. Best policy is to disconnect your house at the Network Interface Device (see below) before working on wiring. Even a small shock can interfere with a pacemaker, according to one person who wrote to me. Also, for everybody, it's a bad idea to work on your phone wiring during thunderstorms.

In most residential phone wiring, the cable contains four individual wires. Most phone wire installed in the U.S. during the second half of the 20th century is of the following kind:

Four-strand wire:



The kind of wire shown above has recently become obsolete. For all new telephone wiring projects, you should use Cat 5 cable. All of the Cat 5 wire I've seen uses the following color coding:



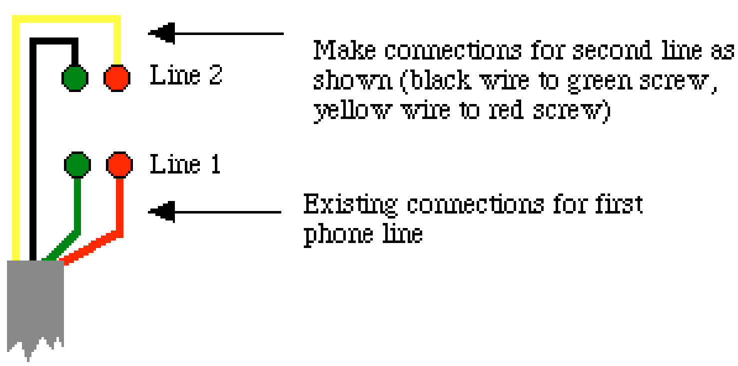
In either case, the important point is this: one phone line only requires **two** of these strands. In the vast majority of cases, the other two wires go unused-- but if you choose, you can certainly use them for a second line (i.e., a totally separate line with its own phone number, which the local phone company will connect to a second terminal in your network interface device). This means that if you are installing a second line for a fax, modem, etc., you usually don't have to actually physically run new wires; you can connect the extra two wires to the second phone line at the network interface device. Assuming that everything is wired properly thruout your house (i.e., nobody has cut corners by not bothering to connect the extra two wires somewhere along the way), this will give you "Line 2" service thruout the house.

If you're going to buy a two-line phone, there's nothing more you need to do, since a two-line phone expects "Line 2" to run on the yellow/black wires. For ordinary phone equipment such a modem, however, you have to convert a "Line 1" jack to a "Line 2" jack. One way you can do this is with a plug-in adapter, but the method described here involves swapping around a few wires in the jack.

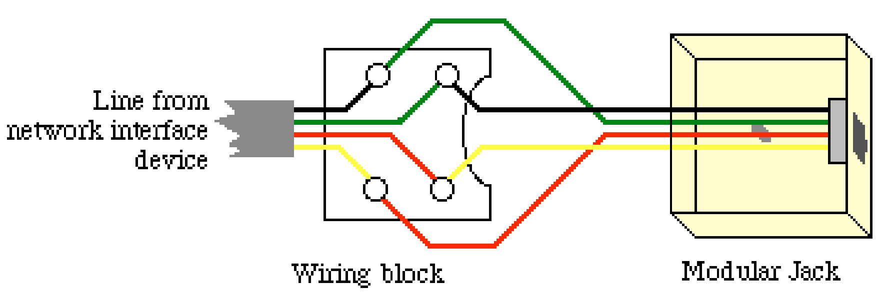
Wiring at the network interface device

Don't be squeamish about poking around inside the Network Interface Device. It may look forbidding and official, but you have every right to be there.

The following two diagrams show the color coding scheme for the old kind of wire. This probably applies to your house if you're not running any new cable, and are simply running a second line thru the existing unused yellow/black wires. If you're running Cat 5 cable, you'll need to make the appropriate color conversions.



Converting a "Line 1" jack to a "Line 2" jack

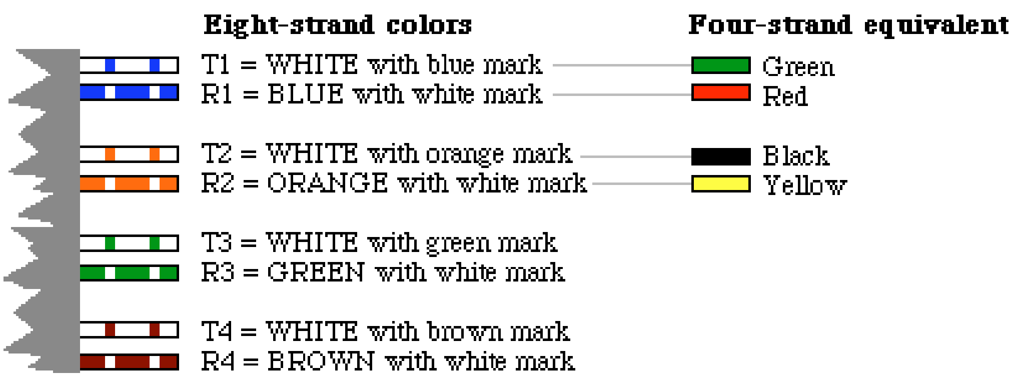


Note that black is swapped for green, and yellow is swapped for red. Of course, it would also work if you consistently swapped the black and yellow wires the other way (black for red, yellow for green) but that is not the standard. Given that you have to be consistent between the two ends of the wire, you might as well follow the standard.

Converting a jack to Line 2 means that you will no longer be able to use it for Line 1. In practice, you'll probably want to install a second wiring block beside the first, and use a short piece of four-strand wire to extend the system from the existing block to the new one. This way, you can have a Line 1 jack right beside the Line 2 jack.

Caveat: It occasionally happens that the red and/or green wires become damaged and unusable, but that the black and yellow wires are intact. Repairpersons have sometimes remedied this by running the one phone line across the black and yellow wires rather than replacing the cabling. If this has happened, you won't be able to run a second line thru the four-strand wire. (This is uncommon, but it is a gotcha to be aware of).

Four-strand wire supports up to two phone lines. If you are installing three or four lines, you might also consider buying eight-strand wire. The color coding conventions for this kind of wire are as follows:



(There's also six-strand wire, which is the same as eight-strand wire with the brown pair left out. This color system actually extends up thru other colors to distinguish 25 different pairs, but even the most techno-geeky of us will probably never have that many phone lines in our homes. If you're interested, you can get the details to this system at Phone-Man's Home Page)

The conventions for eight-strand wire are as follows:

- Colored pairs match; e.g. WHITE with blue mark goes with BLUE with white mark for one phone line, etc.
- WHITE with whatever color mark corresponds to the green line of four strand wire.
- The pairs are used in the order pictured: thus, for the first line, you use blue; for the second, you use orange, etc. (My mnemonic is as follows: the colors run from sky to earth. Blue sky comes first; orange sunset on the horizon comes second; green trees come third; and brown earth comes fourth).

If you have very old existing wiring in your house, it may not follow the conventions described above, but new wiring should follow them.

Troubleshooting

If you think you've got everything hooked up correctly, but one or more of your lines is "dead" (no dial tone), the problem might be the local phone company's problem, or it might be in your own wiring. Be **sure** that the problem isn't in your own wiring or in one of your own phones before you call the phone company to check on the problem. If they determine that the problem is on their side of the network interface device, they have to fix the problem at no charge to you; but if they determine that the problem is on your side of the network interface device, they'll charge you just for having determined this, and they'll charge you a second time if you have them make the fix in your wiring for you.

So how can you tell whose problem it is? This is easy: when you open your network interface box, notice that there is a modular jack for each phone line. You can unplug the jack for the line in question (note that doing this unplugs your whole house from the phone company's network) and plug a working phone into the jack instead. This phone is now hooked directly into the phone company's network. If the phone works properly when connected in this manner, then the problem is in your own wiring. If the phone doesn't work, either your phone is broken or there's a problem in the phone company's network. Try a second phone which you know to work, and if there still seems to be no service on the line, the problem is probably on the phone company's side of the network interface device.

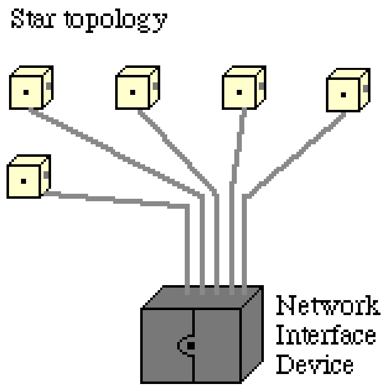
If the problem is in your own wiring, the following things might be wrong:

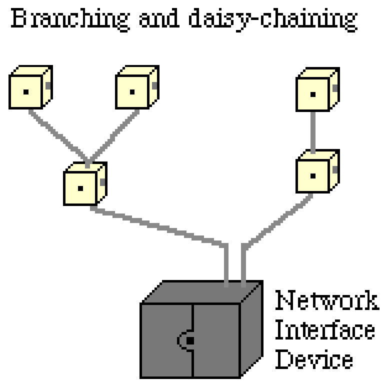
- You might have colors reversed at some point. Check your connections.
- A wire may have come loose from a screw in the network interface device or in one of your jacks. Check your connections.
- You may have a damaged wire. Depending on where the damage is, you might have service to some jacks in your house but not to others; you'll have to trace the wiring thru your house and figure out which stretch of wire contains the damage.

If you're getting static on the line, it's possible that there's a hole somewhere in the wire insulation which is letting in moisture and causing a short. Follow the wire from the network interface device to the jack and look for holes. For example, if you've used staples to fasten the wire to the wall, check for a staple puncturing the insulation.

Topology

There isn't any one right way to plan your house wiring. Some people prefer to run a separate wire all the way from the Network Interface Device to each jack (star topology); others prefer a system with branching at points other than the NID, and/or with one jack daisy-chained to the next:





Star topology potentially uses a good bit more wire, but it is easier to troubleshoot because each jack is independent of the others.

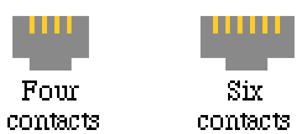
I use the branching/daisy chaining approach myself. Fishing the wire is probably the most time-consuming part of the whole job, so if I'm just putting in one new jack, I'd usually rather just jump off of an existing jack than take the time to run a whole new wire all the way from the basement to the second floor. However, if the house has old, premodern wiring, the advantage to running a whole new wire is that I know exactly what I'm dealing with.

Tips on buying phone wiring materials

This section doesn't attempt to cover all the gadgets and parts related to phone wiring. For the wiring jobs described above, you usually only need to buy wire and modular jacks.

Modular jacks

Two gotchas when buying modular jacks. First, for ordinary residential wiring, you should buy the kind of modular jack with *four* contacts inside the jack; don't make the mistake of buying the wider modular jack with *six* contacts unless you're sure it's what you need (you've got to look closely to see the difference).



Second, you can buy modular jacks either with or without the wiring block (this is the heavy plastic piece which you mount to the wall, with screws to attach the wires to; see the picture higher up on the page). If you're installing a totally new jack, then you need the wiring block. If you're upgrading an existing, old-fashioned (pre-modular) connection to a modular jack, you might be able to use the existing wiring block, in which case you *don't* need to buy the kind of jack with the wiring block included; sometimes you can take the old cover off and just put a new modular cover over the old wiring block. In the store, it's hard to tell from outside the sealed package whether the block is included. Read the label carefully! More than once I've gotten home and realized I bought the wrong kind; it's an easy mistake to make.

Wire

As mentioned above, you should buy Cat 5 wire for all new phone wiring projects. The older four-color type allows more crosstalk between wires; this might be only a minor annoyance for voice lines, but it's a bigger problem for modems or DSL lines. Even if you don't have immediate plans to transmit this kind of data across your line, it's better to plan for flexibility in the future. Cat 5 is now the national standard.

Other handy gadgets

A reader tells me that Radio Shack sells a handy two-line tester for $5 which allows you to make sure the polarity (red/green, yellow/black) isn't reversed anywhere (I generally don't recommend Radio Shack since their products tend to be of shoddy quality, but for $5 it's hard to go wrong). You can also check at the Network Interface Device to make sure the phone company doesn't have the polarity reversed; if they do, you should call them to have it fixed at no charge, since reversed polarity can reportedly damage some kinds of phone equipment.

Contacting Sean

If you have a **question or need help,** click here.

If you want to send Sean a message of **thanks** for this page, click here.

If you want to point out a **mistake** in the page content, click here.

If want to find out more about the nice guy who wrote this page for you, click here.