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THE COMPLETE GUIDE TO

HOME WIRING

A Comprehensive Manual from Basic Repairs to Advanced Projects

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THE COMPLETE GUIDE TO HOME WIRING

A Comprehensive Manual, from Basic Repairs to Advanced Projects

Contents

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Introduction

In everything from food preparation to climate control, from entertainment to work, electricity plays a critical role in our lives. Knowing about your electrical system and how it works will allow you to make sensible, effective, and economical decisions for your home's functionality, convenience, and safety.

This newly updated and revised edition of the top-selling *The Complete Guide to Home Wiring* is a comprehensive tour through the sometimes intimidating subject of electricity. With easy-to-understand definitions, step-by-step instructions, and clear color photos, you will recognize that most electrical work around your home, from basic repairs to advanced wiring projects, is work you yourself can easily accomplish.

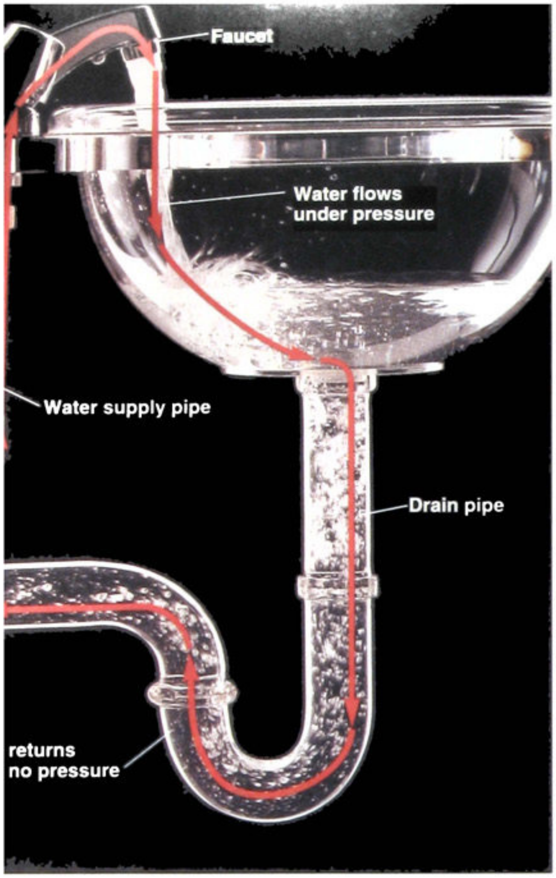
Even if you choose to hire professionals to replace fixtures or install new circuits, your increased understanding of what is required will help you work with these contractors and make the best use of your money. *The Complete Guide to Home Wiring* provides everything you need to know to understand and successfully do electrical work around your home.

The first section of the book covers basic electrical repairs. Each major component of your home's electrical system is clearly defined and thoroughly covered. Definitions for and discussions about all types of wires and cables, fuse boxes and breaker panels, switches and receptacles will help you identify and work with the existing materials and fixtures in your home. You will learn how to troubleshoot and fix virtually any switch, receptacle, lamp, ceiling fixture, or thermostat as problems arise. All the tools and materials necessary for performing the repairs are shown, as well as professional techniques for using them. You also see how mapping your home's electrical system makes it much simpler and safer to do work. There is also a review of the problems that an electrical inspector would point out and the instructions to fix them.

The second section of the book presents complete wiring projects for your home. Whether you are remodeling and working in new construction or making changes within the existing structure, these detailed projects can be easily adapted to your home's particular needs. There are 26 up-to-code circuit maps designed to simplify wiring layouts. You will also learn each step to planning a major wiring project, from learning electrical code requirements to designing a layout that best suits your needs. Whether your wiring project involves a kitchen, bathroom, basement, attic remodel, or room addition, all the information you need can be found.

The third section of the book features a new area in the home electrical system: the home network wiring system. Computer, video, and telecommunication needs in the home are rapidly expanding. This increased use of technology creates a new demand for stronger and faster transference of data. A low-voltage structured wiring system provides the pathway. After learning what a home network wiring system is and how it will benefit you, the discussions of components will help you put together a system tailored to your specific needs.

This newly revised edition of *The Complete Guide to Home Wiring* will help you navigate through all of your home electrical projects, whether in repair or improvement. The thorough instructions and helpful tips will make this book an invaluable resource for years to come.



Understanding Electricity

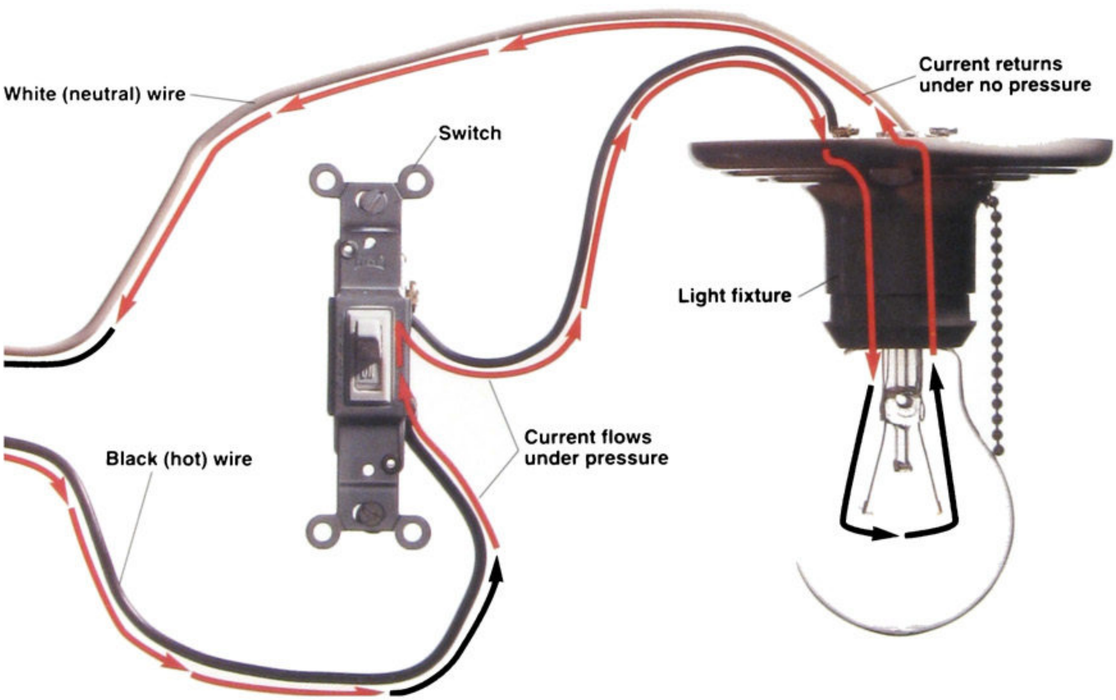
A household electrical system can be compared with a home's plumbing system. Electrical current flows in wires in much the same way that water flows inside pipes. Both electricity and water enter the home, are distributed throughout the house, do their "work, and exit.

In plumbing, water first flows through the pressurized water supply system. In electricity, current first flows along hot wires. Current flowing along hot wires also is pressurized. The pressure of electrical current is called **voltage.**

Large supply pipes can carry a greater volume of water than small pipes. Likewise, large electrical wires carry more current than small wires. This current-carrying capacity of wires is called **amperage.**

Water is made available for use through the faucets, spigots, and showerheads in a home. Electricity is made available through receptacles, switches, and fixtures.

Water finally leaves the home through a drain system, which is not pressurized. Similarly, electrical current flows back through neutral wires. The current in neutral wires is not pressurized and is said to be at zero voltage



ampere (or **amp**)**:** Refers to the rate at which electrical power flows to a light, tool, or appliance.

armored cable: Two or more wires that are grouped together and protected by a flexible metal covering.

box: A device used to contain wiring connections.

BX: See **armored cable.**

cable: Two or more wires that are grouped together and protected by a covering or sheath.

circuit: A continuous loop of electrical current flowing along wires or cables.

circuit breaker: A safety device that interrupts an electrical circuit in the event of an overload or short circuit.

conductor: Any material that allows electrical current to flow through it. Copper wire is an especially good conductor

conduit: A metal or plastic tube used to protect wires.

continuity: An uninterrupted electrical pathway through a circuit or electrical fixture.

current: The movement of electrons along a conductor.

duplex receptacle: A receptacle that provides connections for two plugs.

feed wire: A conductor that carries 120-volt current uninterrupted from the service panel.

fuse: A safety device, usually found in older homes, that interrupts electrical circuits during an overload or short circuit.

Greenfield: See **armored cable.**

grounded wire: See **neutral wire.**

grounding wire: A wire used in an electrical circuit to conduct current to the earth in the event of a short circuit. The grounding wire often is a bare copper wire.

hot wire: Any wire that carries voltage. In an electrical circuit, the hot wire usually is covered with black or red insulation.

insulator: Any material, such as plastic or rubber, that resists the flow of electrical current. Insulating materials protect wires and cables.

junction box: See **box.**

meter: A device used to measure the amount of electrical power being used.

neutral wire: A wire that returns current at zero voltage to the source of electrical power. Usually covered with white or light gray insulation. Also called the grounded wire.

outlet: See **receptacle.**

overload: A demand for more current than the circuit wires or electrical device was designed to carry. Usually causes a fuse to blow or a circuit breaker to trip.

pigtail: A short wire used to connect two or more circuit wires to a single screw terminal.

polarized receptacle: A receptacle designed to keep hot current flowing along black or red wires, and neutral current flowing along white or gray wires.

power: The result of hot current flowing for a period of time. Use of power makes heat, motion, or light.

receptacle: A device that provides plug-in access to electrical power.

Romex: A brand name of plastic-sheathed electrical cable that is commonly used for indoor wiring.

screw terminal: A place where a wire connects to a receptacle, switch, or fixture.

service panel: A metal box usually near the site where electrical power enters the house. In the service panel, electrical current is split into individual circuits. The service panel has circuit breakers or fuses to protect each circuit.

short circuit: An accidental and improper contact between two current-carrying wires, or between a current-carrying wire and a grounding conductor

switch: A device that controls electrical current passing through hot circuit wires. Used to turn lights and appliances on and off.

UL: An abbreviation for Underwriters Laboratories, an organization that tests electrical devices and manufactured products for safety.

voltage (or **volts**)**:** A measurement of electricity in terms of pressure.

wattage (or **watt**)**:** A measurement of electrical power in terms of total energy consumed. Watts can be calculated by multiplying the voltage times the amps.

wire connector: A device used to connect two or more wires together. Also called a wire nut.

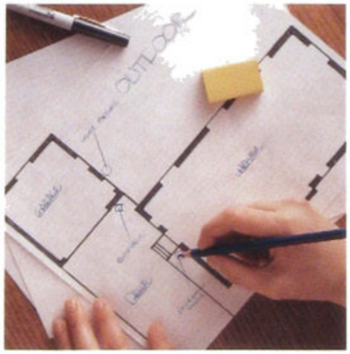
Electricity & Safety

Safety should be the primary concern of anyone working with electricity. Although most household electrical repairs are simple and straightforward, always use caution and good judgment when working with electrical wiring or devices. Common sense can prevent accidents.

The basic rule of electrical safety is: **Always turn off power to the area or device you are working on.** At the main service panel, remove the fuse or shut off the circuit breaker that controls the circuit you are servicing. Then check to make sure the power is off by testing for power with a neon circuit tester (page 18). Restore power only when the repair or replacement project is complete.

Follow the safety tips shown on these pages. Never attempt an electrical project beyond your skill or confidence level. Never attempt to repair or replace your main service panel or service entrance head (pages 12 to 13). These are jobs for a qualified electrician and require that the power company shuts off power to your house.

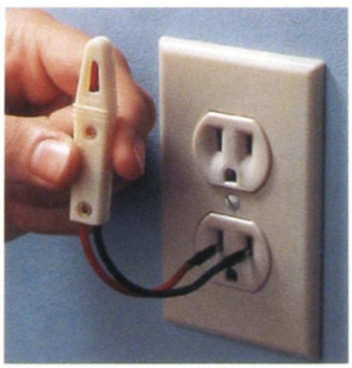
Shut off power to the proper circuit at the fuse box or main service panel before beginning work.



Make a map of your household electrical circuits (pages 30 to 33) to help you turn the proper circuits on and off for electrical repairs.

Close service panel door and post a warning sign to prevent others from turning on power while you are working on electrical projects.

Keep a flashlight near your main service panel. Check flashlight batteries regularly

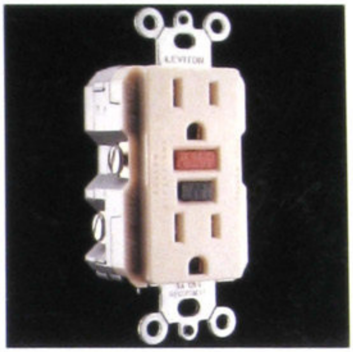


Always check for power at the fixture you are servicing before you begin any work.

Use only UL approved electrical parts or devices. These devices have been tested for safety by Underwriters Laboratories.

Wear rubber-soled shoes while working on electrical projects. On damp floors, stand on a rubber mat or dry wooden boards.

Use fiberglass or wood ladders when making routine household repairs near the service head.

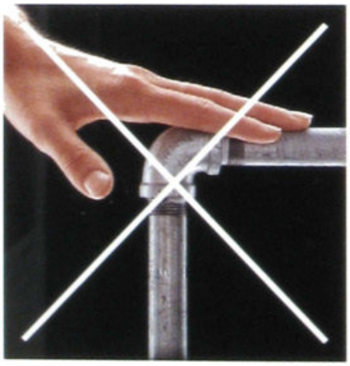


Use GFCI receptacles (ground-fault circuit-interrupters) where specified by local electrical codes (pages 74 to 77).

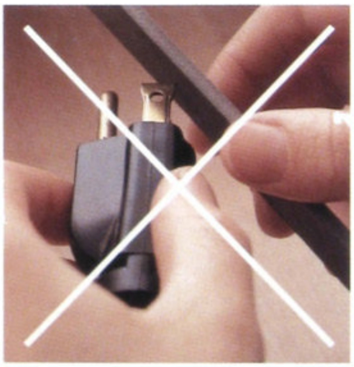
Protect children with receptacle caps or childproof receptacle covers (page 69).

Use extension cords only for temporary connections. Never place them underneath rugs or fasten them to walls, baseboards, or other surfaces.

Use correct fuses or breakers in the main service panel (pages 28 to 29). Never install a fuse or breaker that has a higher amperage rating than the circuit wires.



Do not touch metal pipes, faucets, or fixtures while working with electricity. The metal may provide a grounding path, allowing electrical current to flow through your body.



Never alter the prongs of a plug to fit a receptacle. If possible, install a new grounded receptacle.

Do not drill walls or ceilings without first shutting off electrical power to the circuits that may be hidden. Use double-insulated tools.

Electrical power that enters the home is produced by large **power plants.** Power plants are located in all parts of the country and generate electricity with turbines that are turned by water, wind, or steam. From these plants electricity enters large "step-up" transformers that increase voltage to half a million volts or more.

Electricity flows easily at these large voltages and travels through high-voltage transmission lines to communities that can be hundreds of miles from the power plants. "Step-down" transformers located at **substations** then reduce the voltage for distribution along street lines. On **utility power poles,** smaller transformers further reduce the voltage to ordinary 120-volt current for household use.

Lines carrying current to the house either run underground or are strung overhead and attached to a post called a **service head.** Most homes built after 1950 have three wires running to the service head: two power lines, each carrying 120 volts of current, and a grounded neutral wire. Power from the two 120-volt lines may be combined at the **service panel** to supply current to large, 240-volt appliances like clothes dryers or electric water heaters.

Many older homes have only two wires running to the service head, with one 120-volt line and a grounded neutral wire. This older two-wire service is inadequate for today's homes. Contact an electrical contractor and your local power utility company to upgrade to a three-wire service.

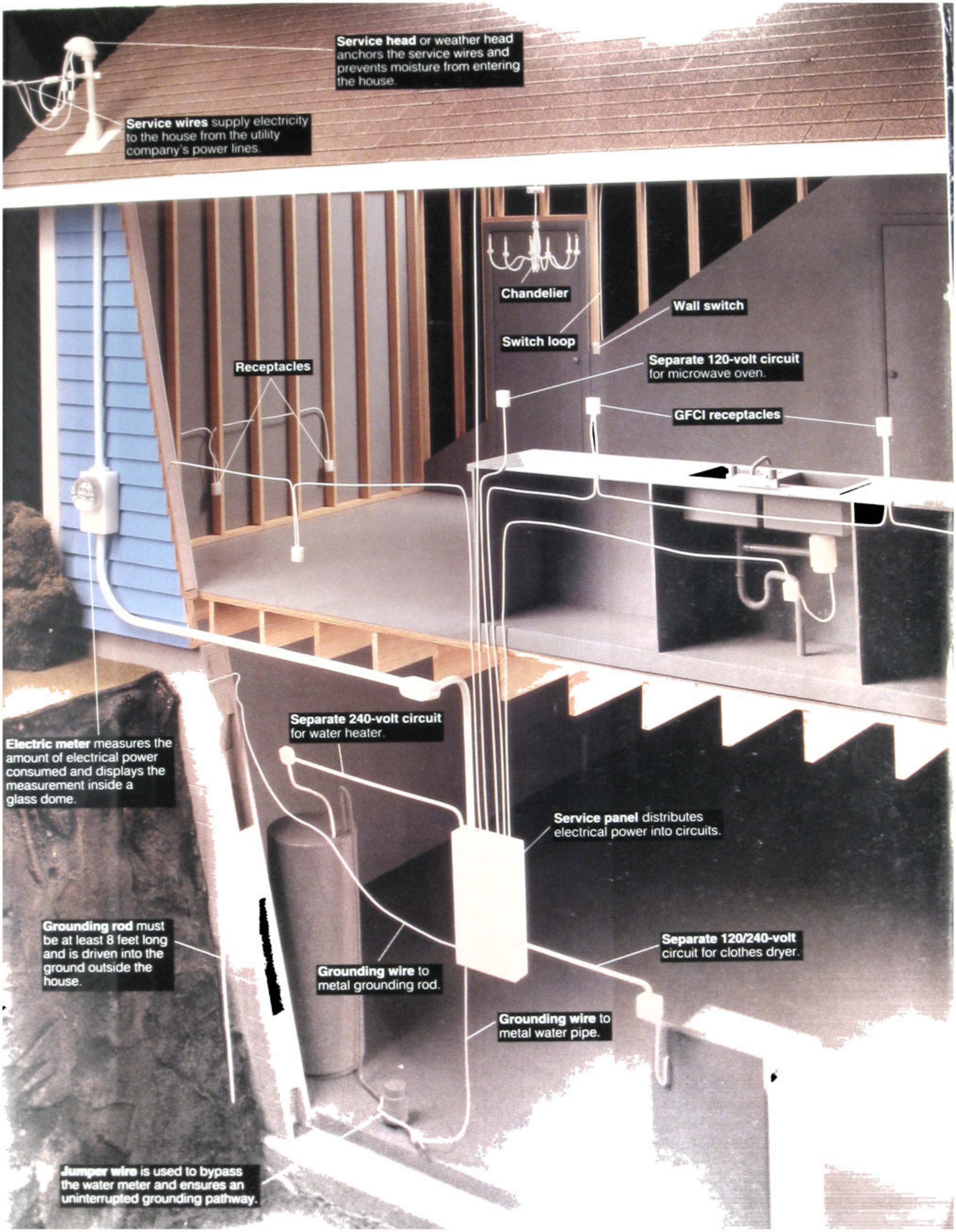
Incoming power passes through an **electric meter** that measures power consumption. Power then enters the service panel, where it is distributed to circuits that run throughout the house. The service panel also contains fuses or circuit breakers that shut off power to the individual circuits in the event of a short circuit or an overload. Certain high-wattage appliances, like microwave ovens, are usually plugged into their own individual circuits to prevent overloads.

Voltage ratings determined by power companies and manufacturers have changed over the years. Current rated at 110 volts changed to 115 volts, then 120 volts. Current rated at 220 volts changed to 230 volts, then 240 volts. Similarly, ratings for receptacles, tools, light fixtures, and appliances have changed from 115 volts to 125 volts. These changes will not affect the performance of new devices connected to older wiring. For making electrical calculations, such as the ones shown in "Evaluating Circuits for Safe Capacity" (pages 34 to 35), use a rating of 120 volts or 240 volts for your circuits.

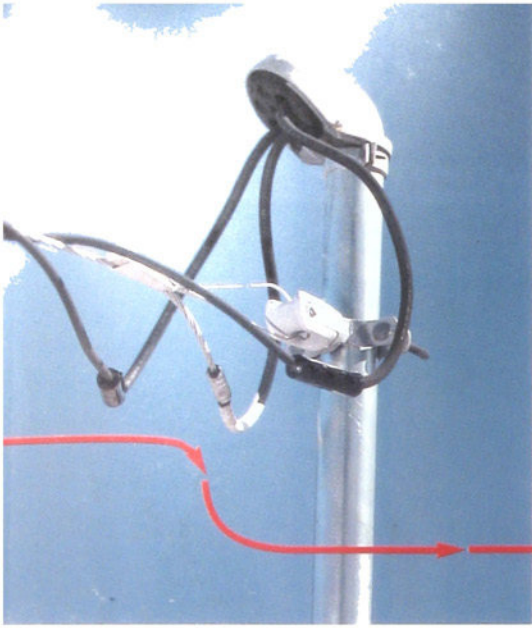
Power plants supply electricity to thousands of homes and businesses. Step-up transformers increase the voltage produced at the plant, making the power flow more easily along high-voltage transmission lines.

Substations are located near the communities they serve. A typical substation takes current from high-voltage transmission lines and reduces it for distribution along street lines.

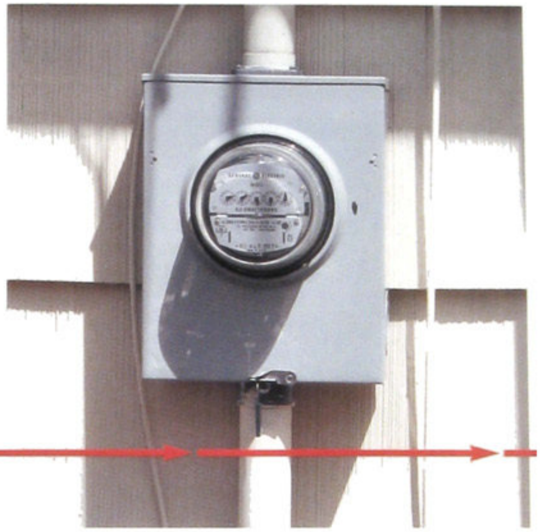
Utility pole transformers reduce the high-voltage current that flows through power lines along neighborhood streets. A utility pole transformer reduces voltage from 10,000 volts to the normal 120-volt current used in households.


Service head or weather head anchors the service wires and prevents moisture from entering the house.
Service wires supply electricity to the house from the utility company's power lines.
Chandelier
Wall switch
Switch loop
Receptacles
Separate 120-volt circuit for microwave oven.
GFCI receptacles
Electric meter measures the amount of electrical power consumed and displays the measurement inside a glass dome.
Separate 240-volt circuit for water heater.
Service panel distributes electrical power into circuits.
Grounding rod must be at least 8 feet long and is driven into the ground outside the house.
Separate 120/240-volt circuit for clothes dryer.
Grounding wire to metal grounding rod.
Grounding wire to metal water pipe.
Jumper wire is used to bypass the water meter and ensures an uninterrupted grounding pathway.

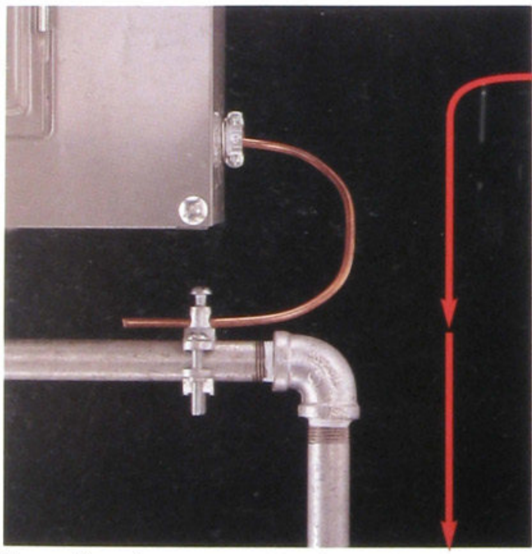
Parts of the Electrical System



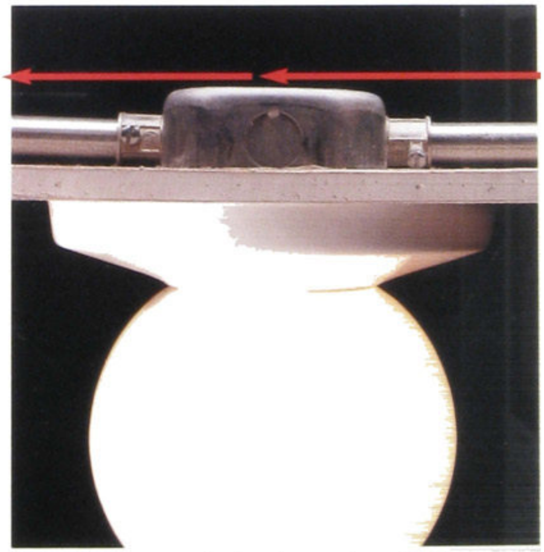
The service head, sometimes called the weather
anchors the service wires to the home Three
rovide the standard 240-volt service neces-
the average home Older homes may have
re service that provides only 120 volts of
T wire service should be upgraded to
service by an electrical contractor



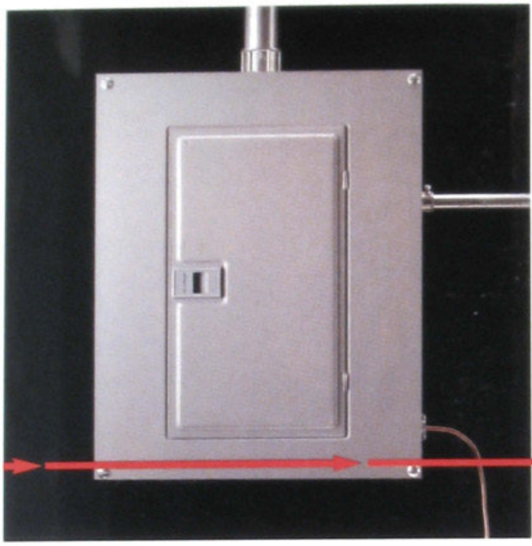
The electric meter measures the amount of electrical power consumed It is usually attached to the side of the house and connects to the service head A thin metal disc inside the meter rotates when power is used The electric meter belongs to your local power utility company If you suspect the meter is not functioning properly contact the power company



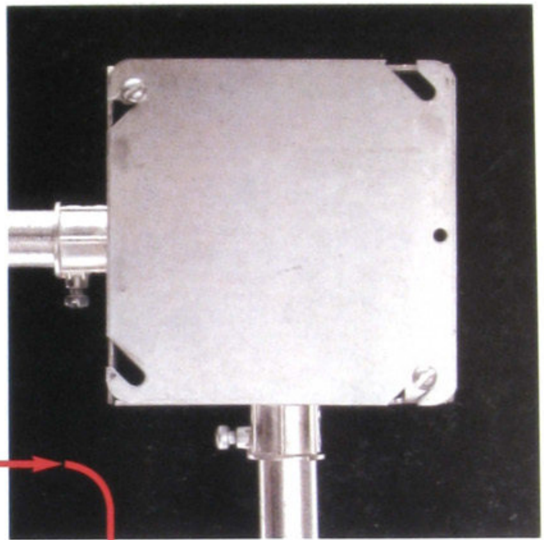
Grounding wire connects the electrical system to the earth through a cold water pipe and a grounding rod In the event of an overload or short circuit, the grounding wire allows excess electrical power to find its way harmlessly to the earth.



Light fixtures attach directly to a household electrical system They are usually controlled with wall switches The two common types of light fixtures ar **incandescent** (page 78) and **fluorescent** (page 90).



The main service panel, fuse
box breaker box



Electrical boxes
N
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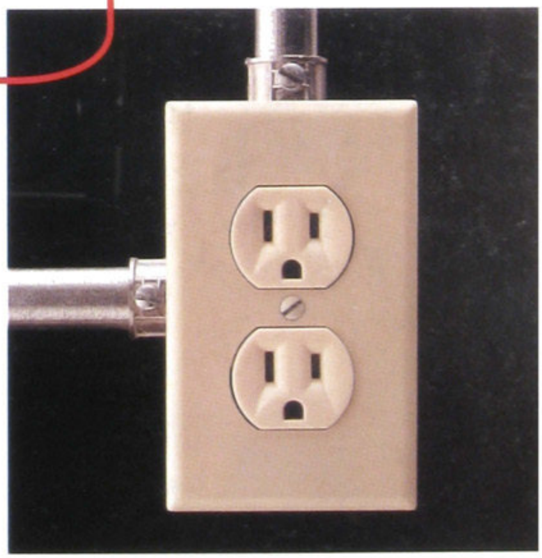
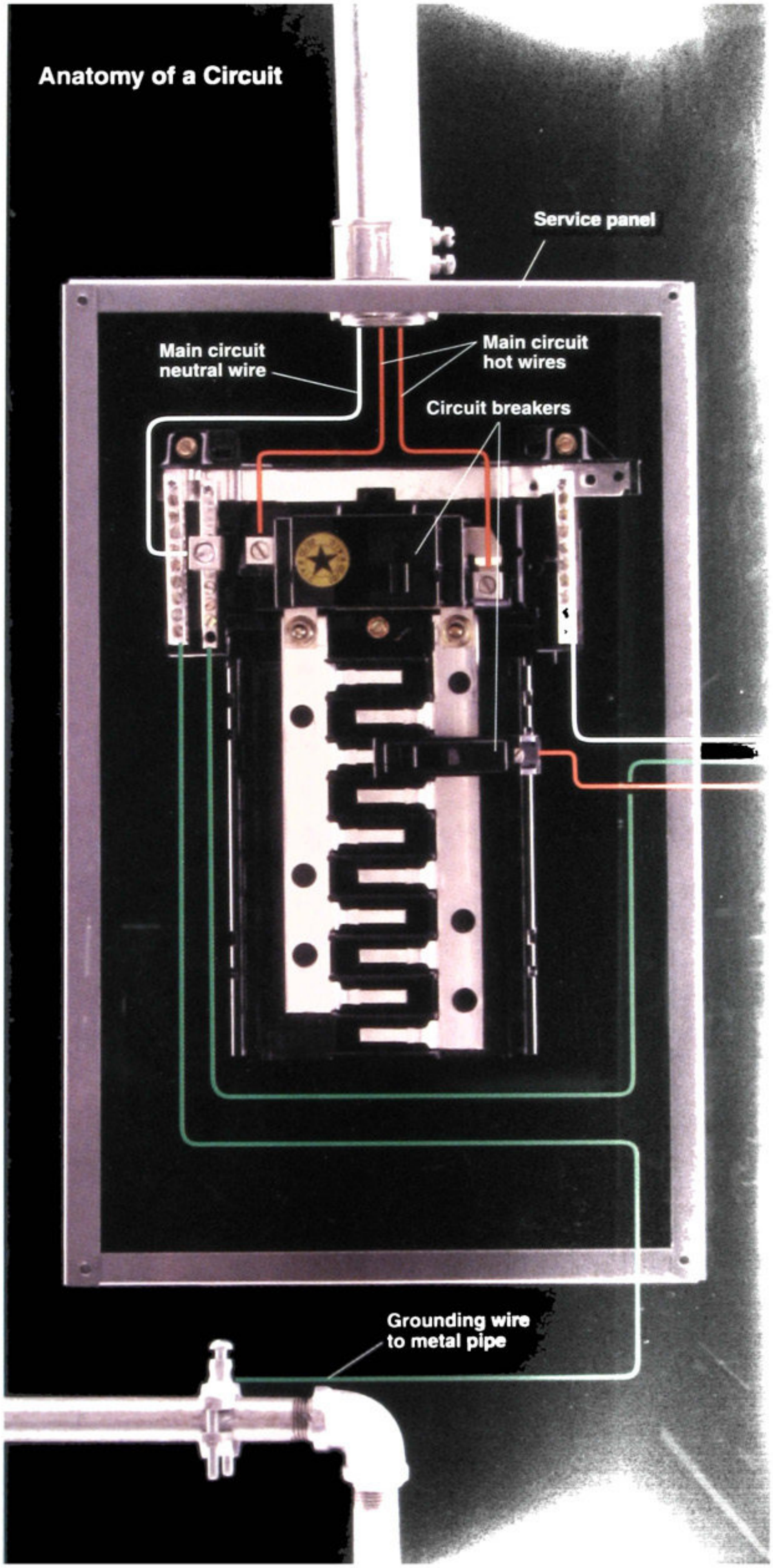
Switches



Receptacles, alled outlets.
access
receptacl
receptacle
Most receptacles e
called duplex receptacles.

Understanding Circuits

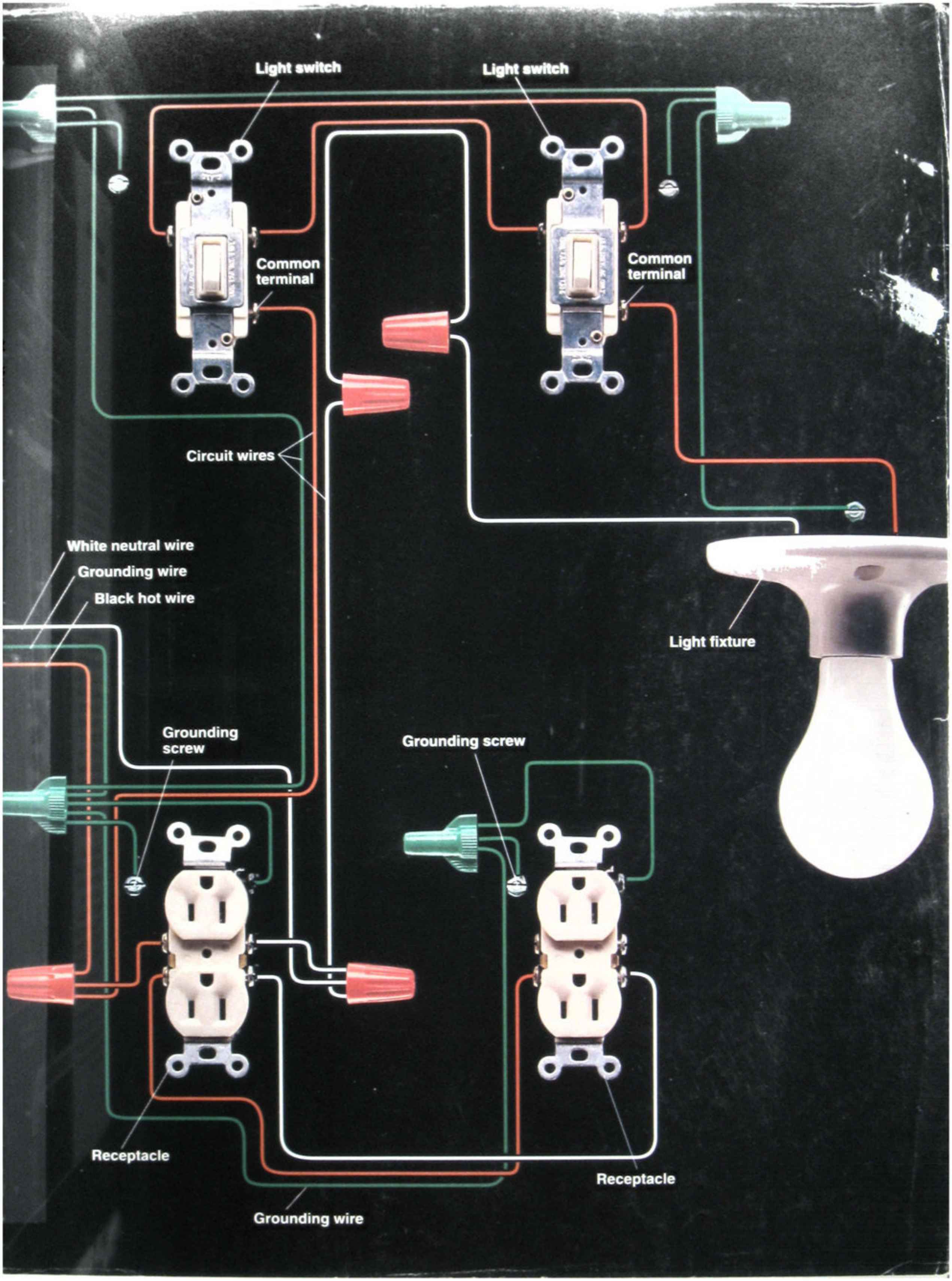


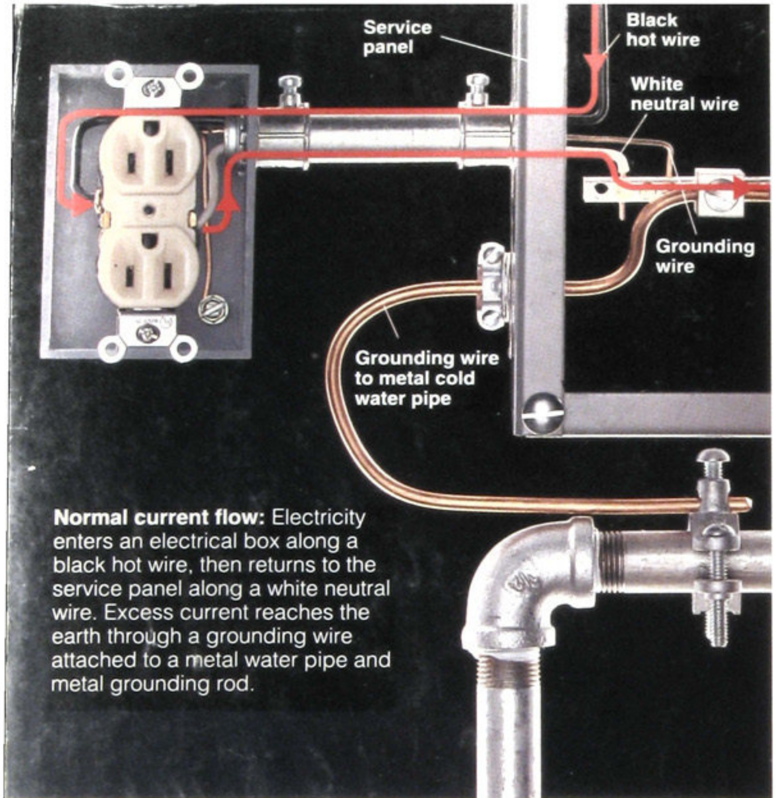
An electrical circuit is a continuous loop. Household circuits carry power from the main service panel, throughout the house, and back to the main service panel. Several switches, receptacles, light fixtures, or appliances may be connected to a single circuit.

Current enters a circuit loop on hot wires and returns along neutral wires. These wires are color coded for easy identification. Hot wires are black or red, and neutral wires are white or light gray. For safety, most circuits clude a bare copper or green insulated grounding wire. The grounding wire conducts current in the event of a short circuit or overload, and helps reduce the chance of severe electrical shock. The service panel also has a grounding wire connected to a metal water pipe and metal grounding rod buried underground (pages 16 to 17).

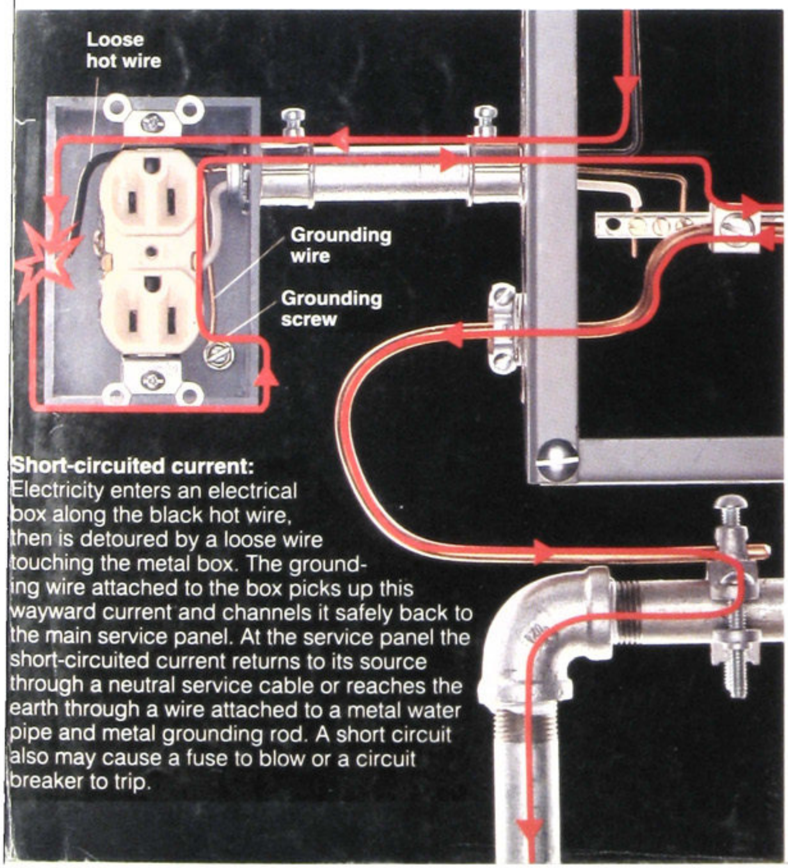
If a circuit carries too much power, it can overload. A fuse or a circuit breaker protects each circuit in case of overloads (pages 28 to 29). To calculate how much power any circuit can carry, see "Evaluating Circuits for Safe Capacity" (pages 34 to 35).

Current returns to the service panel along a neutral circuit wire. Current then becomes part of a main circuit and leaves the house on a large neutral service wire that returns it to the utility pole transformer.


Light switch
Light switch
Common terminal
Common terminal
Circuit wires
White neutral wire
Grounding wire
Black hot wire
Light fixture
Grounding screw
Grounding screw
Receptacle
Receptacle
Grounding wire



Normal current flow: Electricity enters an electrical box along a black hot wire, then returns to the service panel along a white neutral wire. Excess current reaches the earth through a grounding wire attached to a metal water pipe and metal grounding rod.



Short-circuited current: Electricity enters an electrical box along the black hot wire, then is detoured by a loose wire touching the metal box. The grounding wire attached to the box picks up this wayward current and channels it safely back to the main service panel. At the service panel the short-circuited current returns to its source through a neutral service cable or reaches the earth through a wire attached to a metal water pipe and metal grounding rod. A short circuit also may cause a fuse to blow or a circuit breaker to trip.

Grounding & Polarization

Electricity always seeks to return to its source and complete a continuous circuit. In a household wiring system, this return path is provided by white neutral wires that return current to the main service panel. From the service panel, current returns along a neutral service wire to a power pole transformer.

A **grounding wire** provides an additional return path for electrical current. The grounding wire is a safety feature. It is designed to conduct electricity if current seeks to return to the service panel along a path other than the neutral wire, a condition known as a **short circuit**.

A short circuit is a potentially dangerous situation. If an electrical box, tool, or appliance becomes short circuited and is touched by a person, the electrical current may attempt to return to its source by passing through that person's body.

However, electrical current always seeks to move along the easiest path. A grounding wire provides a safe, easy path for current to follow back to its source. If a person touches an electrical box, tool, or appliance that has a properly installed grounding wire, any chance of receiving a severe electrical shock is greatly reduced.

In addition, household wiring systems are required to be connected directly to the earth. The earth has a unique ability to absorb the electrons of electrical current. In the event of a short circuit or overload, any excess electricity will find its way along the grounding wire to the earth, where it becomes harmless.

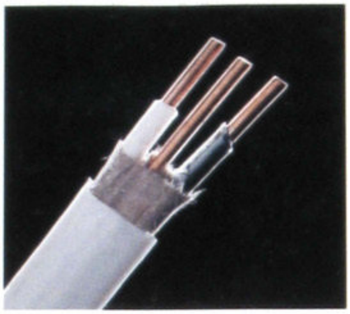
This additional grounding is completed by wiring the household electrical system to a metal cold water pipe and a metal grounding rod that is buried underground

After 1920, most American homes included receptacles that accepted **polarized plugs**. While not a true grounding method, the two-slot polarized plug and receptacle was designed to keep hot current flowing along black or red wires, and neutral current flowing along white or gray wires

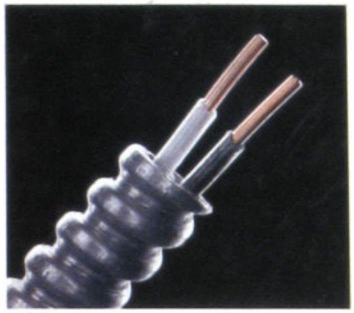
Armored cable and metal conduit, widely installed in homes during the 1940s, provided a true grounding path. When connected to metal junction boxes, it provided a metal pathway back to the service panel

Modern cable includes a green insulated or bare copper wire that serves as the grounding path This grounding wire is connected to all three-slot receptacles and metal boxes to provide a continuous pathway for any short-circuited current. By plugging a three-prong plug into a grounded three-slot receptacle, appliances and tools are protected from short circuits

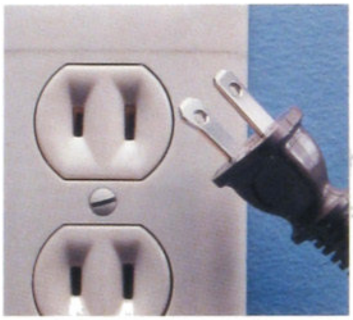
Use a receptacle adapter to plug three-prong plugs into two-slot receptacles, but use it only if the receptacle connects to a grounding wire or grounded electrical box Adapters have short grounding wires or wire loops that attach to the receptacle's coverplate mounting screw The mounting screw connects the adapter to the grounded metal electrical box.



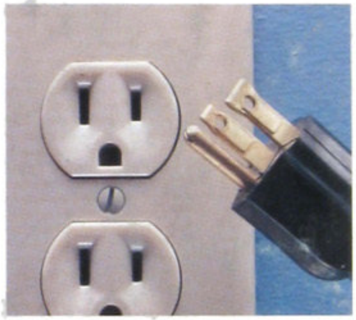
Modern NM (nonmetallic) cable, found in most wiring systems installed after 1965, contains a bare copper wire that provides grounding for receptacle and switch boxes



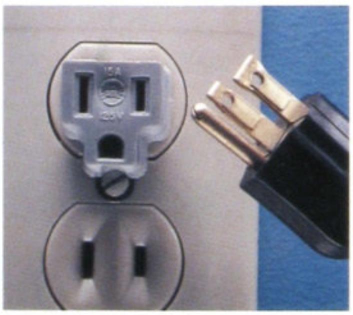
Armored cable, sometimes called BX or Greenfield cable has a metal sheath that serves as the grounding pathway Short-circuited current flows through the metal sheath back to the service panel



Polarized receptacles have a long slot and a short slot. Used with a polarized plug, the polarized receptacle keeps electrical current directed for safety



Three-slot receptacles are required by code for new homes They are usually connected to a standard two-wire cable with ground (above left)



Receptacle adapter allows three-prong plugs to be inserted into two-slot receptacles The adapter can be used only with grounded receptacles, and the grounding loop or wire of the adapter must be attached to the coverplate mounting screw of the receptacle.

Double-insulated tools have nonconductive plastic bodies to prevent shocks caused by short circuits. Because of these features, double-insulated tools can be used safely with ungrounded receptacles

Combination tool is essential for home wiring projects. It cuts cables and individual wires, measures wire gauges, and strips the insulation from wires. It has insulated handles.

Needlenose pliers bends and shapes wires for making screw terminal connections. Some needlenose pliers also have cutting jaws for clipping wires.

Continuity tester is used to check switches, lighting fixtures, and other devices for faults. It has a battery that generates current and a loop of wire for creating an electrical circuit (page 52).

Cordless screwdriver drives a wide variety of screws and fasteners. It is rechargeable and can be used in either a power or manual mode. A removable tip allows the cordless screwdriver to drive either slotted or Phillips screws.

Neon circuit tester is used to check circuit wires for power. Testing for power is an essential safety step in any electrical repair project (page 70).

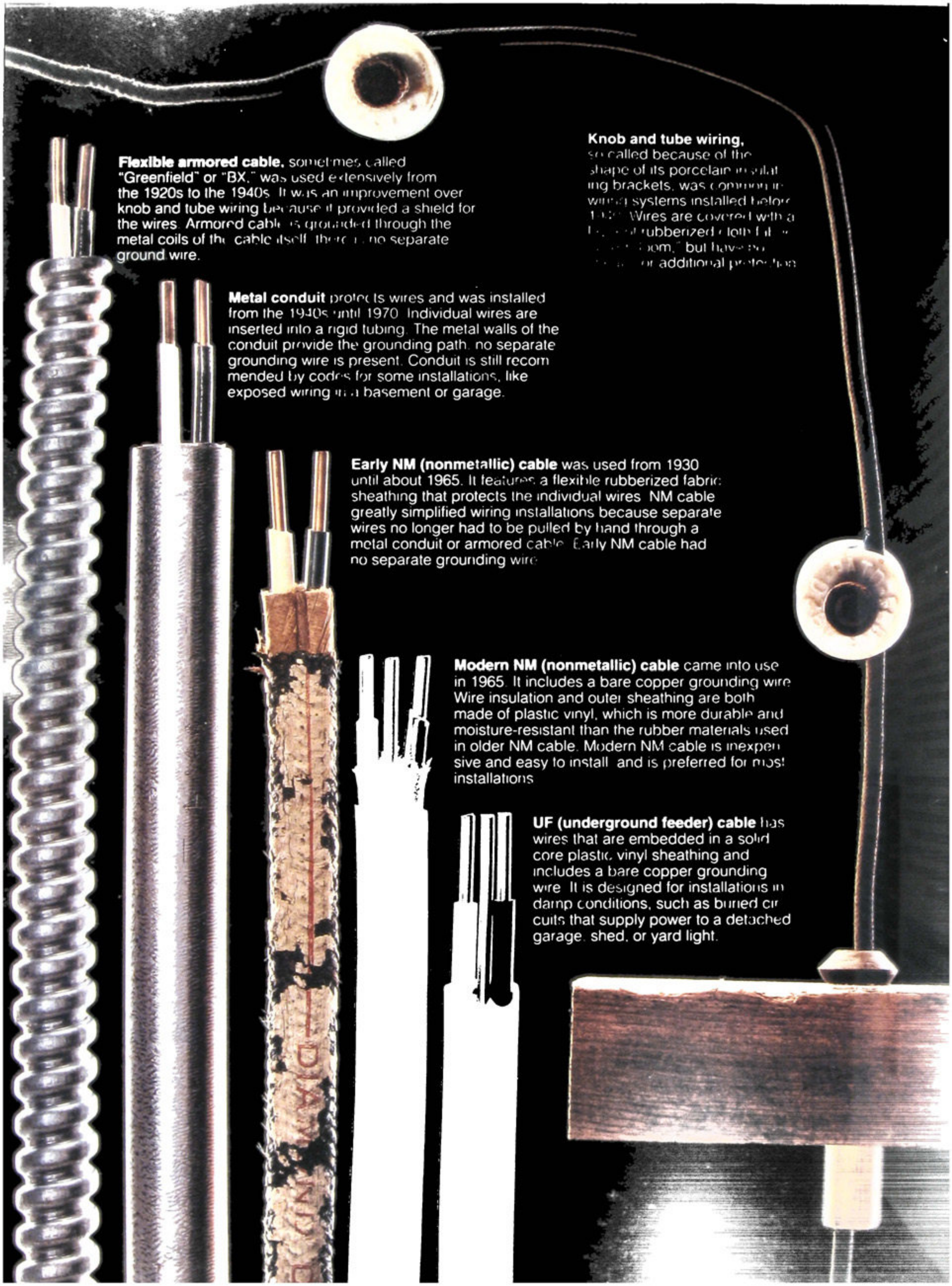
Tools for Electrical Repairs

Home electrical repairs require only a few inexpensive tools. As with any tool purchase, invest in quality when buying tools for electrical repairs.

Keep tools clean and dry, and store them securely. Tools with cutting jaws, like needlenose pliers and combination tools, should be resharpened or discarded if the cutting edges become dull.

Several testing tools are used in electrical repair projects. Neon circuit testers (page 70), continuity testers (page 52), and multi-testers (below) should be checked periodically to make sure they are operating properly. Continuity testers and multi-testers have batteries that should be replaced regularly.

Multi-tester is a versatile, battery-operated tool frequently used to measure electrical voltages. It also i used to test for continuity in switches, light fixtures, and other electrical devices. An adjustable control makes it possible to measure current ranging from 1 to 1000 volts. A multi-tester is an essential tool for measuring current in low-voltage transformers, like those used to power doorbell and thermostat systems (pages 100 to 113)



Knob and tube wiring, so called because of the shape of its porcelain insulating brackets, was common in wiring systems installed before [illegible]. Wires are covered with a [illegible] rubberized cloth [illegible] [illegible]oom," but have no [illegible] or additional protection.

Flexible armored cable, sometimes called "Greenfield" or "BX," was used extensively from the 1920s to the 1940s. It was an improvement over knob and tube wiring because it provided a shield for the wires. Armored cable is grounded through the metal coils of the cable itself; there is no separate ground wire.

Metal conduit protects wires and was installed from the 1940s until 1970. Individual wires are inserted into a rigid tubing. The metal walls of the conduit provide the grounding path; no separate grounding wire is present. Conduit is still recommended by codes for some installations, like exposed wiring in a basement or garage.

Early NM (nonmetallic) cable was used from 1930 until about 1965. It features a flexible rubberized fabric sheathing that protects the individual wires. NM cable greatly simplified wiring installations because separate wires no longer had to be pulled by hand through a metal conduit or armored cable. Early NM cable had no separate grounding wire.

Modern NM (nonmetallic) cable came into use in 1965. It includes a bare copper grounding wire. Wire insulation and outer sheathing are both made of plastic vinyl, which is more durable and moisture-resistant than the rubber materials used in older NM cable. Modern NM cable is inexpensive and easy to install, and is preferred for most installations.

UF (underground feeder) cable has wires that are embedded in a solid core plastic vinyl sheathing and includes a bare copper grounding wire. It is designed for installations in damp conditions, such as buried circuits that supply power to a detached garage, shed, or yard light.

Wires & Cables

Wires are made of copper, aluminum, or aluminum covered with a thin layer of copper. Solid copper wires are the best conductors of electricity and are the most widely used. Aluminum and copper-covered aluminum wires require special installation techniques. They are discussed on page 22.

A group of two or more wires enclosed in a metal, rubber, or plastic sheath is called a **cable** (photo, page opposite). The sheath protects the wires from damage. Metal conduit also protects wires, but it is not considered a cable.

Individual wires are covered with rubber or plastic vinyl insulation. An exception is a bare copper grounding wire, which does not need an insulation cover. The insulation is color coded (chart, right) to identify the wire as a hot wire, a neutral wire, or a grounding wire.

In most wiring systems installed after 1965, the wires and cables are insulated with plastic vinyl. This type of insulation is very durable and can last as long as the house itself.

Before 1965, wires and cables were insulated with rubber. Rubber insulation has a life expectancy of about 25 years (see "Evaluating Old Wiring, pages 134 to 137). Old insulation that is cracked or damaged can be reinforced temporarily by wrapping the wire with plastic electrical tape. However, old wiring with cracked or damaged insulation should be inspected by a qualified electrician to make sure it is safe.

Wires must be large enough for the amperage rating of the circuit (chart, right). A wire that is too small can become dangerously hot. Wire sizes are categorized according to the American Wire Gauge (AWG) system. To check the size of a wire, use the wire stripper openings of a combination tool (page 18) as a guide.

Everything You Need

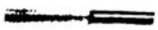
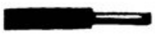
Tools: cable ripper, combination tool, screwdriver, needlenose pliers.

Materials: wire connectors, pigtail wires (if needed).

See Inspector's Notebook:

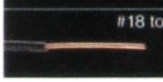
- Common Cable Problems (pages 124 to 125).
- Checking Wire Connections (pages 126 to 127).
- Electrical Box Inspection (pages 128 to 129).

Wire Color Chart

Wire color		Function
	White	Neutral wire carrying current at zero voltage.
	Black	Hot wire carrying current at full voltage.
	Red	Hot wire carrying current at full voltage.
	White, black markings	Hot wire carrying current at full voltage.
	Green	Serves as a grounding pathway.
	Bare copper	Serves as a grounding pathway.

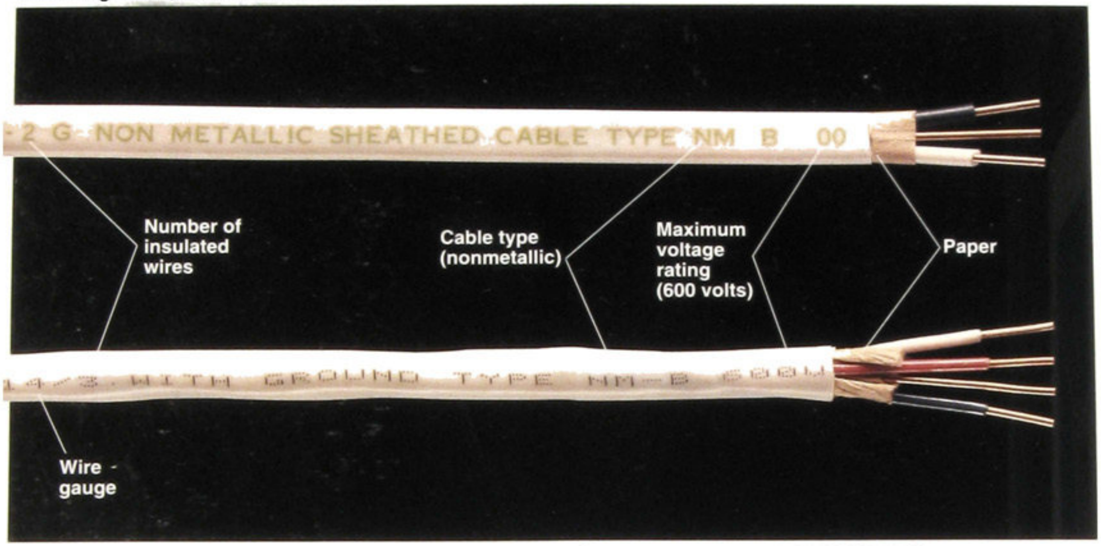
Individual wires are color coded to identify their function. In some circuit installations, the white wire serves as a hot wire that carries voltage. If so, this white wire may be labeled with black tape or paint to identify it as a hot wire.

Wire Size Chart

Wire gauge	Wire capacity & use
 #6	60 amps, 240 volts; central air conditioner, electric furnace.
 #8	40 amps, 240 volts; electric range, central air conditioner.
 #10	30 amps, 240 volts; window air conditioner, clothes dryer.
 #12	20 amps, 120 volts; light fixtures, receptacles, microwave oven.
 #14	15 amps, 120 volts; light fixtures, receptacles.
 #16	Light-duty extension cords.
 #18 to 22	Thermostats, doorbells, security systems.

Wire sizes (shown actual size) are categorized by the American Wire Gauge system. The larger the wire size, the smaller the AWG number.

Reading NM (Nonmetallic) Cable



NM (nonmetallic) cable is labeled Cabl 14 3 WITH GROUND
The bare unding

Aluminum Wire

Inexpensive aluminum wire was used in place of copper in many wiring systems installed during the late 1960s and early 1970s, when copper prices were high Aluminum wire is identified by its silver color

by the AL stamp on the cable sheathing A variation copper-clad aluminum wire has a thin coating of copper bonded to a solid aluminum core

By the early 1970s all-aluminum wire was found to pose a safety hazard if connected to a switch or receptacle ith brass or copper screw terminals Because umi expands and contracts at a different rate or brass the wire connections could In some instances, fires resulted

xisting aluminum wiring in homes is considered if proper installation methods have been followed and if the wires are connected to special switches and receptacles designed to be used with aluminum wire If you have aluminum wire in your home have a qualified electrical inspector review the system Copper-coated aluminum wire is not a hazard.

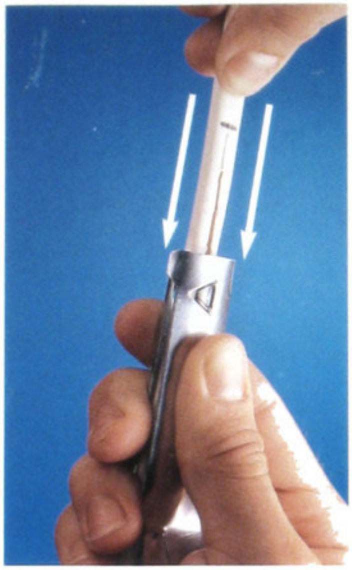
For a short while, switches and receptacles with an Underwriters Laboratories (UL) wire compatibility rating of AL-CU were used with both aluminum and copper wiring However these devices proved to be hazardous when connected to aluminum wire ALCU devices should not be used with aluminum wiring

In 1971 switches and receptacles designed for use with aluminum wiring were introduced They are marked CO/ALR This mark is now the only approved rating for aluminum wires If your home has aluminum wires connected to a switch or receptacle without a CO/ALR rating stamp replace the device with a switch or receptacle r ted CO/ALR

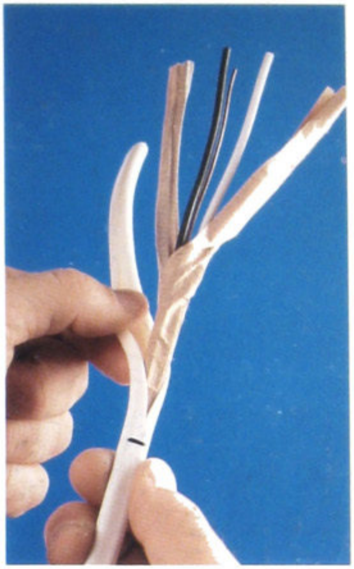
A switch r receptacle that has no wire compatibility rating printed on the mounting strap or casin should not be used with aluminum wires These devices are designed for use with copper wires only.

How to Strip NM (Nonmetallic) Cable & Wires

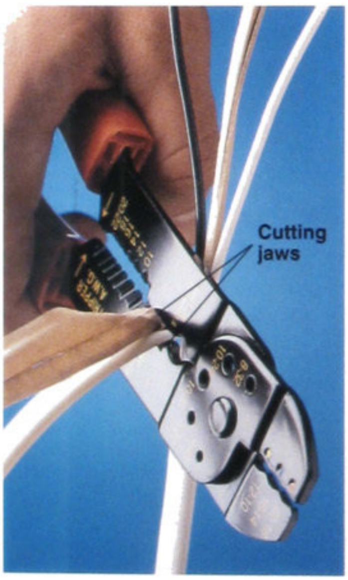
1 Measure and mark the cable 8" to 10" from end. Slide the cable ripper onto the cable, and squeeze tool firmly to force cutting point through plastic sheathing.



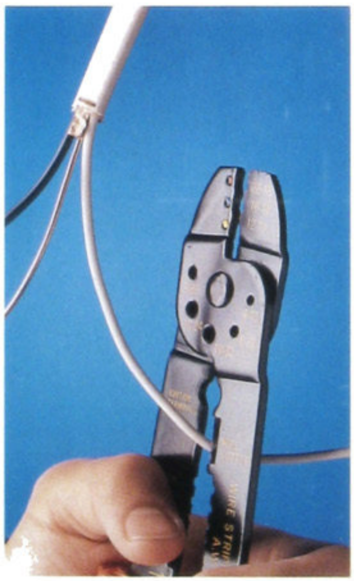
2 Grip the cable tightly with one hand, and pull the cable ripper toward the end of the cable to cut open the plastic sheathing



3 Peel back the plastic sheathing and the paper wrapping from the individual wires



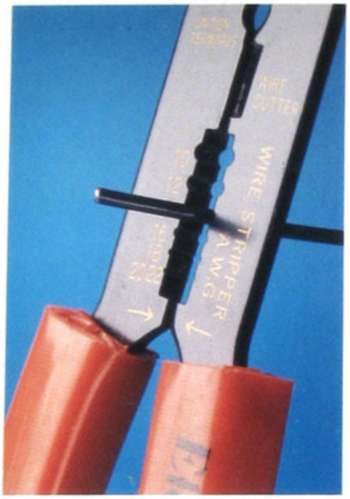
4 Cut away the excess plastic sheathing and paper wrapping, using the cutting jaws of a combination tool.

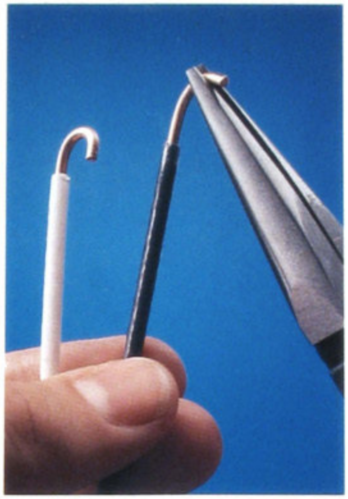


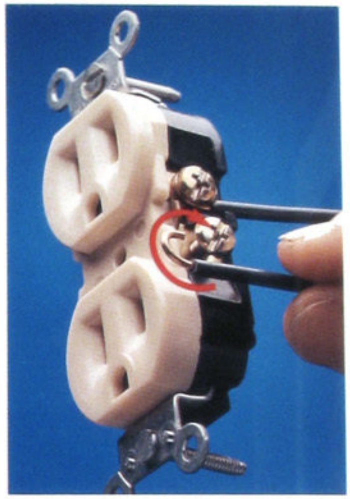
5 Cut the individual wires, if necessary, using the cutting jaws of the combination tool.

6 Strip insulation for each wire, using the stripper openings. Choose the opening that matches the gauge of the wire, and take care not to nick or scratch the ends of the wires.

How to Connect Wires to Screw Terminals





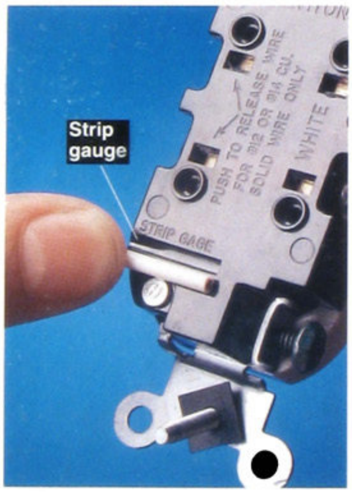


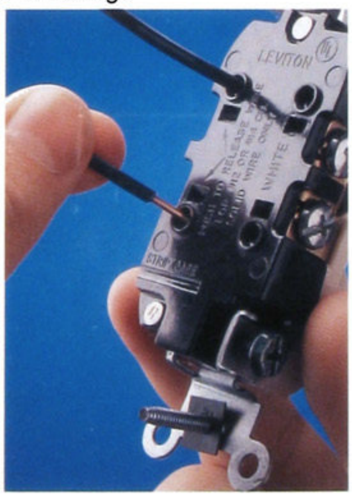
1 Strip about of insulation from each wire, using a combination tool. Choose the stripper opening that matches the gauge of the wire, then clamp wire in tool. Pull the wire firmly to remove plastic insulation.

2 Form a C-shaped loop in the end of each wire, using a needlenose pliers. The wire should have no scratches or nicks.

3 Hook each wire around the screw terminal so it forms a clockwise loop. Tighten screw firmly. Insulation should just touch head of screw. Never place the ends of two wires under a single screw terminal. Instead, use a pigtail wire (page opposite).

How to Connect Wires with Push-in Fittings





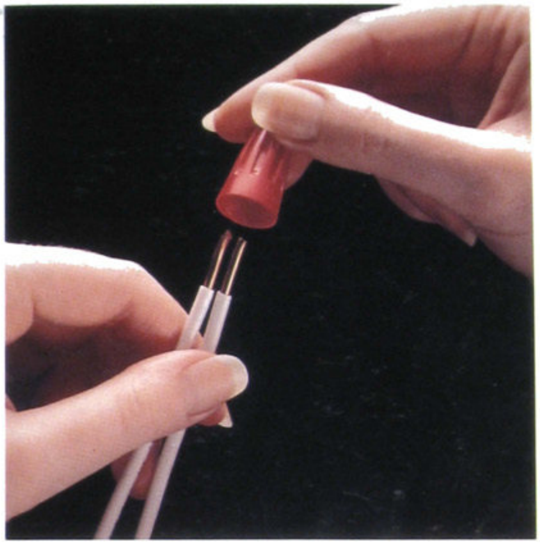
1 Mark the amount of insulation to be stripped from each wire, using the strip gauge on the back of the switch or receptacle. Strip the wires using a combination tool (step 1, above). Never use push-in fittings with aluminum wiring.

2 Insert the bare copper wires firmly into the push-in fittings on the back of the switch or receptacle. When inserted, wires should have no bare copper exposed. NOTE: Although push-in fittings are convenient, most experts believe screw terminal connections (above) are more dependable.

Remove a wire from a push-in fitting by inserting a small nail or screwdriver in the release opening next to the wire. Wire will pull out easily.

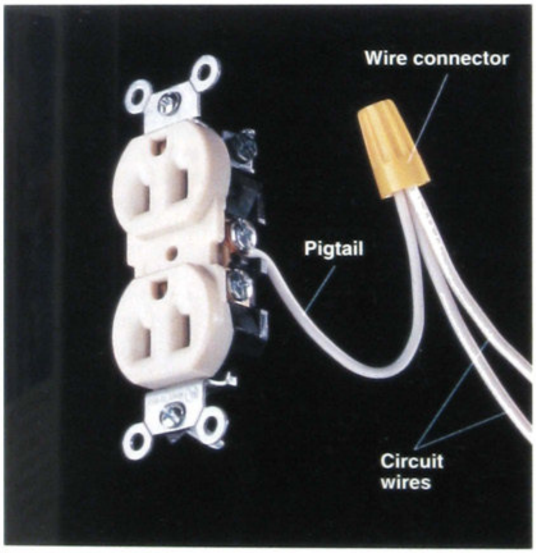
How to Connect Two or More Wires with a Wire Connector

1 .vire connector rated for the size and 'ires you are connecting. Wire con- color-coded by size but the coding ries according to manufacturer. Strip nsulation off each ire to be connect

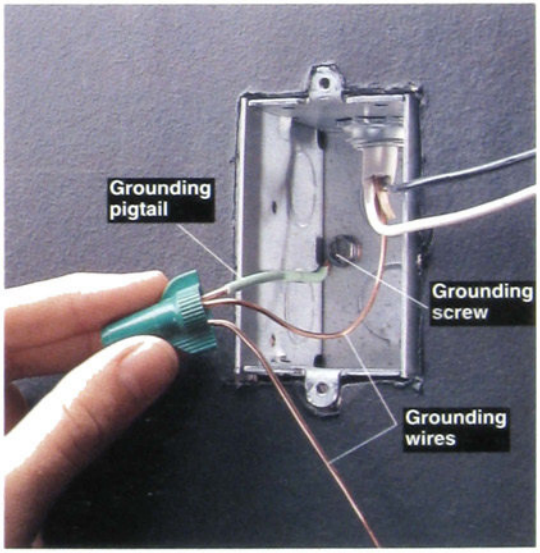


2 Hold the wires together down onto them and snug. Tug gently to make su In a proper connecti exposed

How to Pigtail Two or More Wires



Connect two or more wires to a single screw termi- ith a pigtail. A pigtail is a short piece of wire of the pigtail connects to a screw terminal, other end connects to circuit wires using a connector. A pigtail also can be used to circuit wires that are too short (page 128).



Grounding pigtail has green insulation and is available with a preattached grounding screw. This grounding screw connects to the grounded metal electrical box. The end of the pigtail wire connects to the bare copper grounding wires with a wire connector.

Service Panels

Every home has a main service panel that distributes electrical current to the individual circuits. The main service panel usually is found in the basement, garage, or utility area, and can be identified by its metal casing. Before making any repair to your electrical system, you must shut off power to the correct circuit at the main service panel. The service panel should be indexed (pages 30 to 33) so circuits can be identified easily.

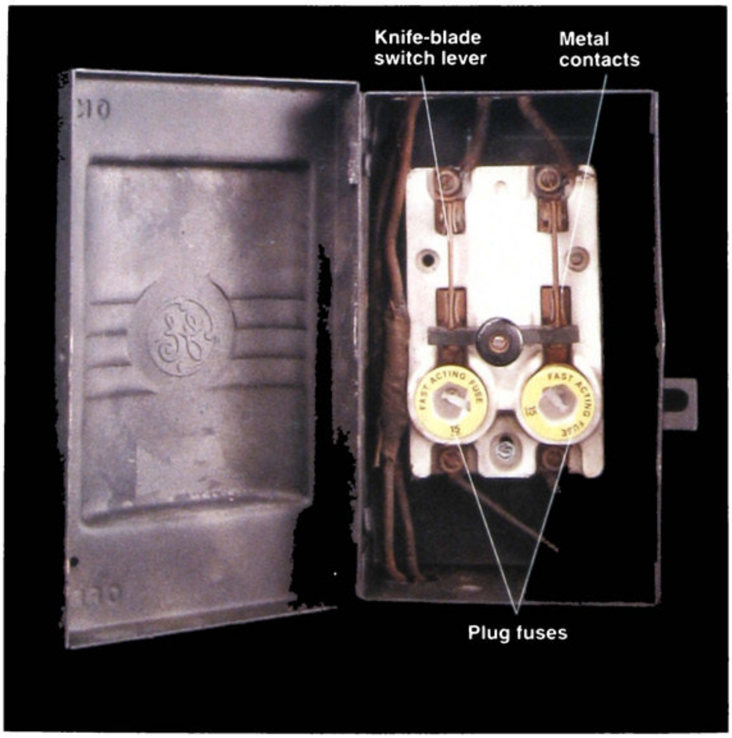
Service panels vary in appearance, depending on the age of the system. Very old wiring may operate on 30-amp service that has only two circuits. New homes can have 200-amp service with 30 or more circuits. Find the size of the service by reading the amperage rating printed on the main fuse block or main circuit breaker.

Regardless of age, all service panels have **fuses** or **circuit breakers** (pages 28 to 29) that control each circuit and protect them from overloads. In general, older service panels use fuses, while newer service panels use circuit breakers.

In addition to the main service panel, your electrical system may have a subpanel that controls some of the circuits in the home. A subpanel has its own circuit breakers or fuses, and is installed to control circuits that have been added to an existing wiring system.

The subpanel resembles the main service panel but is usually smaller. It may be located near the main panel, or it may be found near the areas served by the new circuits. Garages and attics that have been updated often have their own subpanels. If your home has a subpanel, make sure that its circuits are indexed correctly.

When handling fuses or circuit breakers, make sure the area around the service panel is dry. Never remove the protective cover on the service panel. After turning off a circuit to make electrical repairs, remember to always test the circuit for power before touching any wires.

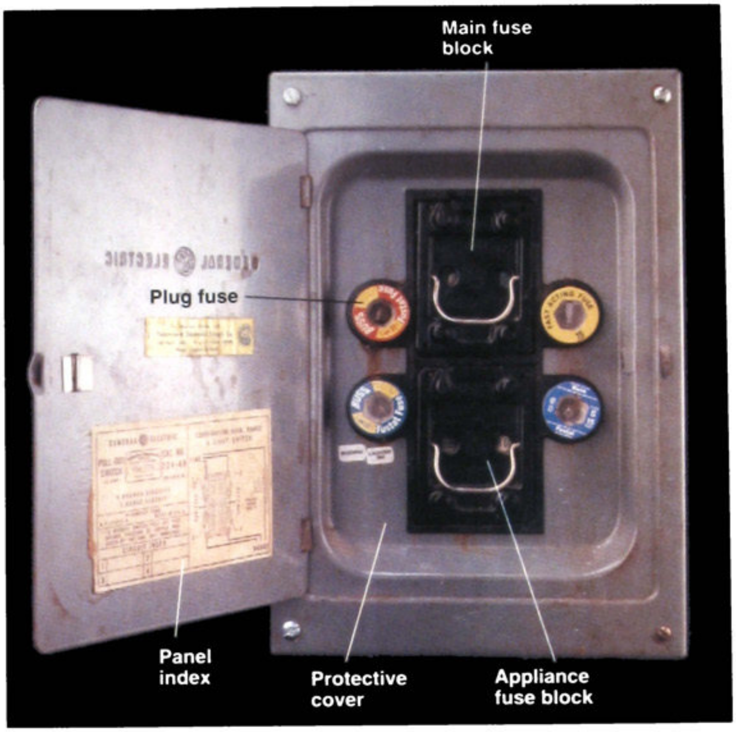


A 30-amp service panel, common in systems installed before 1950, is identified by a ceramic fuse holder containing two plug fuses and a "knife-blade" switch lever. The fuse holder sometimes is contained in a black metal box mounted in an entryway or basement. This 30-amp service panel provides only 120 volts of power and now is considered inadequate. For example, most home loan programs, like the FHA (Federal Housing Administration), require that 30-amp service be updated to 100 amps or more before a home can qualify for mortgage financing.

To shut off power to individual circuits in a 30-amp panel, carefully unscrew the plug fuses, touching only the insulated rim of the fuse. To shut off power to the entire house, open the knife-blade switch. Be careful not to touch the metal contacts on the switch.

A 60-amp fuse panel often is
wiring systems installed
1950 and 1965. It usually
ed a gray metal cabinet
contains four individual plug
plus one or two pull-out fuse
that hold cartridge fuses
ne of panel is regarded as
qu for a small 1100-square-
house that has no more than
0- appliance. Many
owners update 60-amp ser-
100 amps or more so that
itional lighting and appliance
circuits can be added to the sys-
ne loan programs also
require that 60-amp service
dated before a home can
for financing.

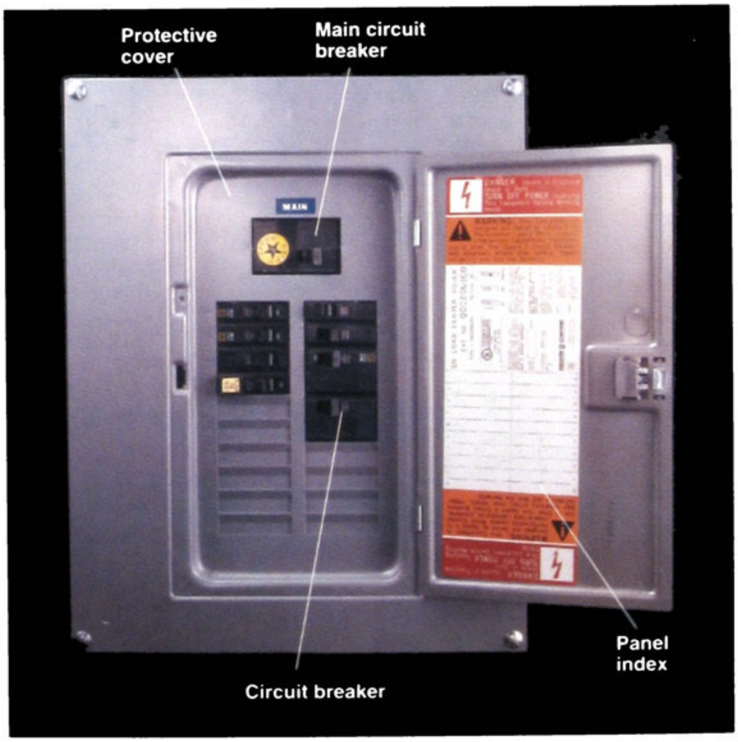
off power to a circuit, care-
unscrew the plug fuse, touch-
its insulated rim. To shut off
power to the entire house, hold the
handle of the main fuse block and
pull sharply to remove it. Major
appliance circuits are controlled
with another cartridge fuse block.
off the appliance circuit by
pulling out this fuse block.

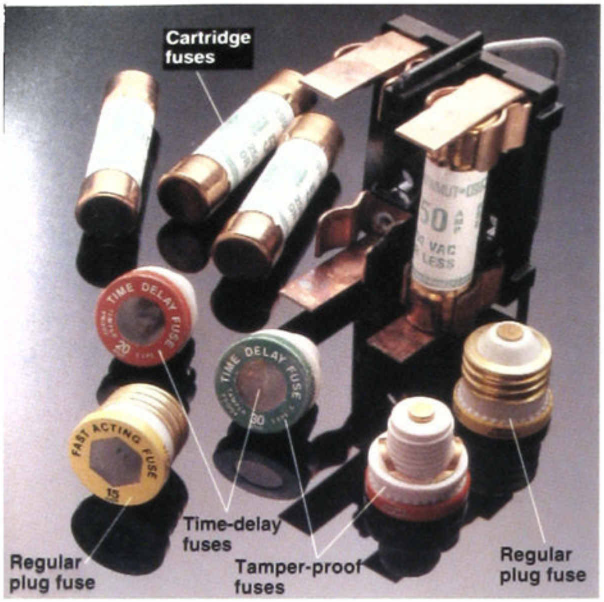


A circuit breaker panel providing 100 amps or more of power is common in wiring systems installed during the 1960s and later. A circuit breaker panel is housed in a gray metal cabinet that contains two rows of individual circuit breakers. The size of the service can be identified by reading the amperage rating of the main circuit breaker, which is located at top of the main service panel.

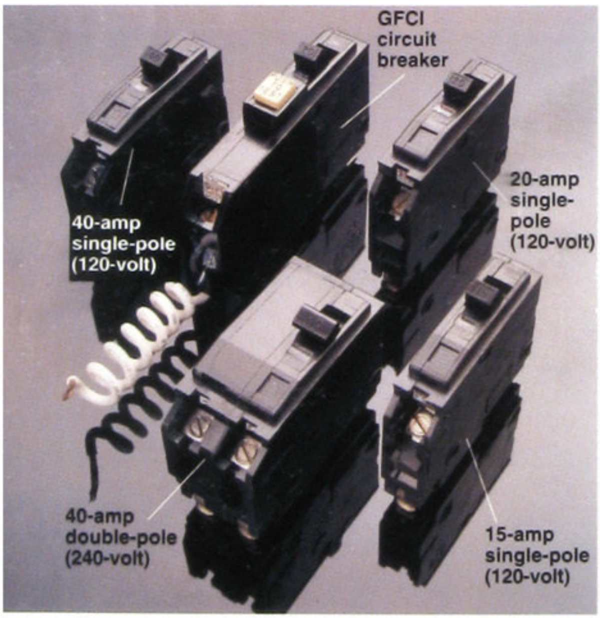
A 100-amp service panel is now the minimum standard for most housing. It is considered adequate for a medium-sized house with no more than three major electric appliances. However, larger houses with more electrical appli ces require a service panel that rovides 150 amps or more.

off power to individual circuit a circuit breaker panel, flip the le r on the appropriate circuit breaker to the OFF position. To off the power to the entire urn the main circuit the OFF position.





Fuses are used in older service panels. Plug fuses usually control 120-volt circuits rated for 15, 20, or 30 amps. Tamper-proof plug fuses have threads that fit only matching sockets, making it impossible to install a wrong-sized fuse. Time-delay fuses absorb temporary heavy power loads without blowing. Cartridge fuses control 240-volt circuits and range from 30 to 100 amps.



Circuit breakers are used in newer service panels. Single-pole breakers control 120-volt circuits. Double-pole breakers rated for 20 to 50 amps control 240-volt circuits. GFCI (ground-fault circuit-interrupter) breakers provide shock protection for the entire circuit.

Fuses & Circuit Breakers

Fuses and circuit breakers are safety devices designed to protect the electrical system from short circuits and overloads. Fuses and circuit breakers are located in the main service panel.

Most service panels installed before 1965 rely on fuses to control and protect individual circuits. Screw-in plug fuses protect 120-volt circuits that power lights and receptacles. Cartridge fuses protect 240-volt appliance circuits and the main shutoff of the service panel.

Inside each fuse is a current-carrying metal alloy ribbon. If a circuit is overloaded, the metal ribbon melts and stops the flow of power. A fuse must match the amperage rating of the circuit. Never replace a fuse with one that has a larger amperage rating.

In most service panels installed after 1965, circuit breakers protect and control individual circuits. Single-pole circuit breakers protect 120-volt circuits, and double-pole circuit breakers protect 240-volt circuits. Amperage ratings for circuit breakers range from 15 to 100 amps.

Each circuit breaker has a permanent metal strip that heats up and bends when voltage passes through it. If a circuit is overloaded, the metal strip inside the breaker bends enough to "trip" the switch and stop the flow of power. If a circuit breaker trips frequently even though the power demand is small, the mechanism inside the breaker may be worn out. Worn circuit breakers should be replaced by an electrician.

When a fuse blows or a circuit breaker trips, it is usually because there are too many light fixtures and plug-in appliances drawing power through the circuit. Move some of the plug-in appliances to another circuit, then replace the fuse or reset the breaker. If the fuse blows or the breaker trips again immediately, there may be a short circuit in the system. Call a licensed electrician if you suspect a short circuit.

Everything You Need

Tools: fuse puller and continuity tester (for cartridge fuses only).

Materials: replacement fuse.

How to Identify & Replace a Blown Plug Fuse

1 Go to the main service panel and locate the blown fuse. If the metal ribbon inside fuse is cleanly melted (right) the circuit was overloaded. If window in fuse is discolored (left) there was a short circuit in the system.

2 Unscrew the fuse, being careful to touch only the insulated rim of the fuse. Replace it with a fuse that has the same amperage rating.

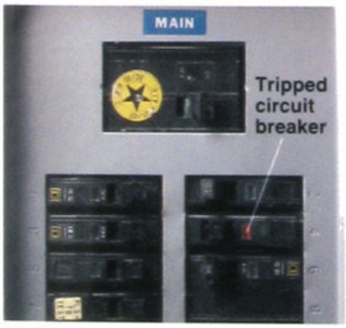
How to Remove, Test & Replace a Cartridge Fuse

1 Remove cartridge fuses by gripping the handle of the fuse block and pulling sharply.

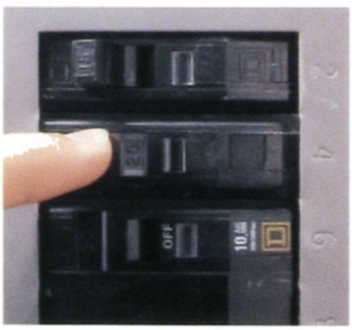
2 Remove the individual cartridge fuses from the block, using a fuse puller.

3 Test each fuse, using a continuity tester. If the tester glows, the fuse is good. If the tester does not glow, replace the fuse with one that has the same amperage rating.

How to Reset a Circuit Breaker

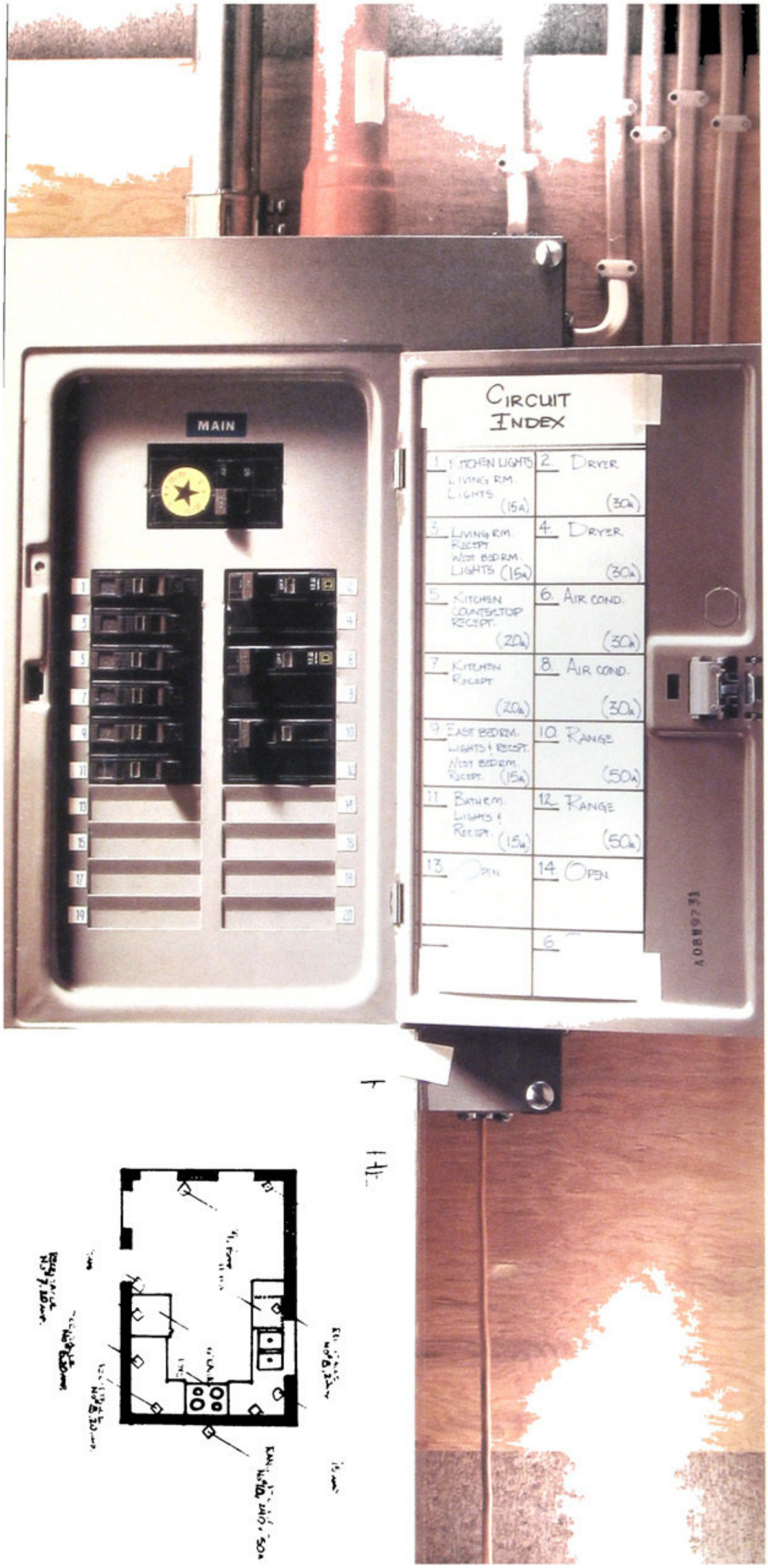


1 Open the service panel and locate the tripped breaker. The lever on the tripped breaker will be either in the OFF position, or in a position between ON and OFF.



2 Reset the tripped circuit breaker by pressing the circuit breaker lever all the way to the OFF position, then pressing it to the ON position.

Test GFCI circuit breakers by pushing the TEST button. Breaker should trip to the OFF position. If not, the breaker is faulty and must be replaced by an electrician.



Mapping Circuits & Indexing the Service Panel

Making repairs to an electrical system is easier and safer if you have an accurate, up-to-date map of your home's electrical circuits. A circuit map shows all lights, appliances, switches, and receptacles connected to each circuit. The map allows you to index the main service panel so that the correct circuit can be shut off when repairs are needed.

Mapping all the circuits and indexing the main service panel requires four to six hours. If your service panel was indexed by a previous owner, it is a good idea to make your own circuit map to make sure the old index is accurate. If circuits have been added or changed, the old index will be outdated.

The easiest way to map circuits is to turn on one circuit at a time and check to see which light fixtures, receptacles, and appliances are powered by the circuit. All electrical devices must be in good working condition before you begin.

A circuit map also will help you evaluate the electrical demands on each circuit (pages 34 to 35). This information can help you determine if your wiring system needs to be updated.

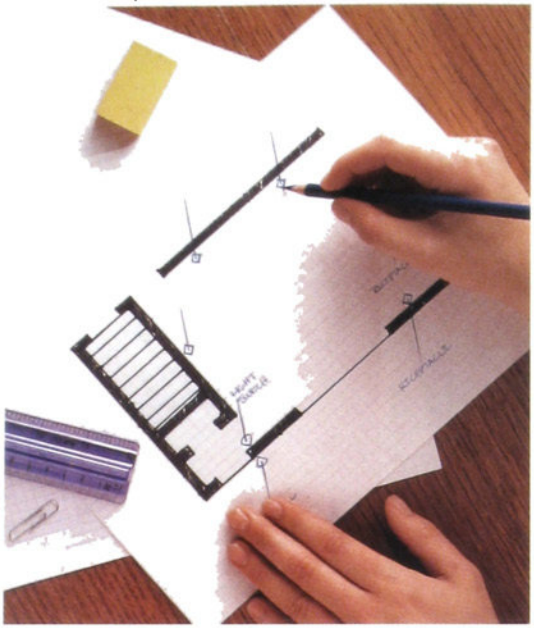
Everything You Need

Tools: pens, circuit tester.

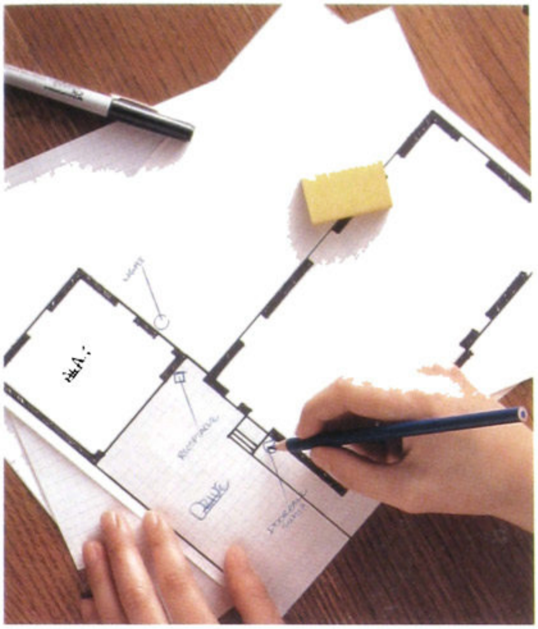
Materials: graph paper, masking tape.

See Inspector's Notebook:

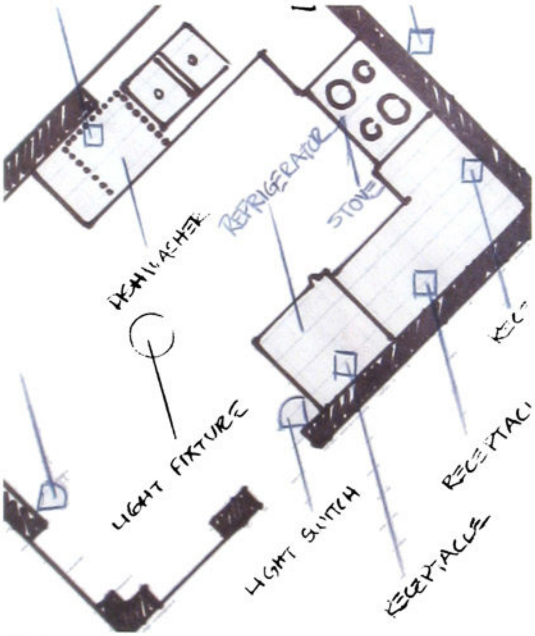
- Service Panel Inspection (page 123).



1 Make a sketch of each room in the house on graph paper. Include the hallways, basement and attic, and all utility areas. Or use a blueprint of your house.



2 Make a sketch of the outside of the house, the garage, and any other separate structures that wired for electricity.



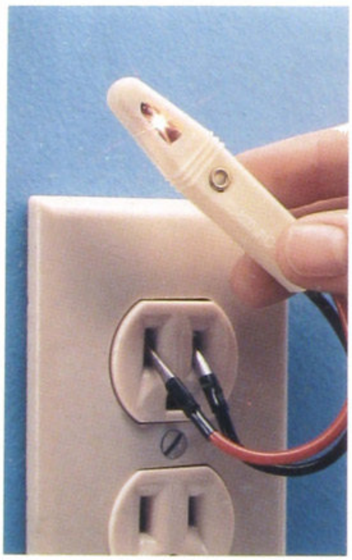
3 On each sketch, indicate the location of all receptacles, light fixtures, switches, appliances, doorbells, thermostats, heaters, fans, and air conditioners.

4 At the main service panel, number each circuit breaker or fuse. Turn off all the circuit breakers or loosen all the fuses, but leave the main shutoff in the ON position.

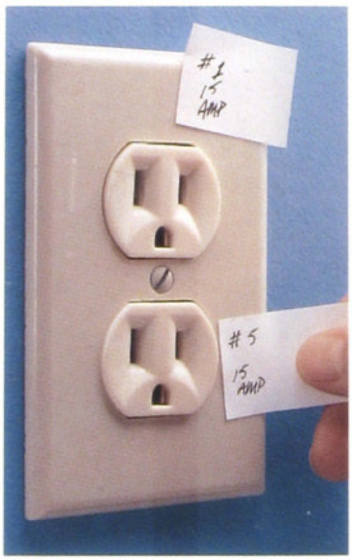
(continued next page)

5 Turn on one circuit at a time by flipping the circuit breaker lever or tightening the correct fuse. Note the amperage rating printed on the circuit breaker lever or on the rim of the fuse (page 28)

6 Turn on switches, lights, and appliances throughout the house, and identify those that are powered by the circuit. Write the circuit number and amperage rating on a piece of masking tape. The tape makes a handy temporary reference.

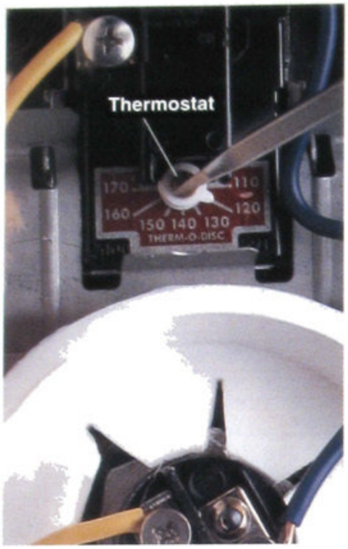


7 Test receptacles for power, using a neon circuit tester Make sure to check both halves of the receptacle.



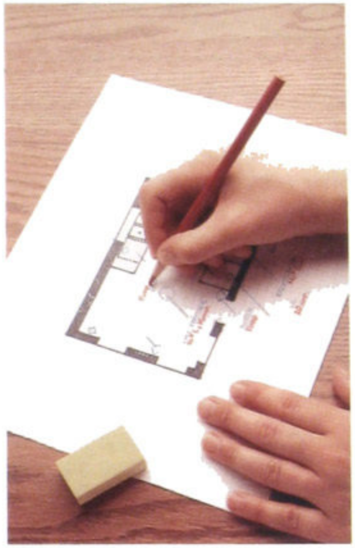
8 Indicate which circuit supplies power to each receptacle. Although uncommon, remember that receptacles can be wired so that each half of the receptacle is powered by a different circuit.

9 To check the furnace for power, set thermostat to highest temperature setting. Furnaces and their low-voltage thermostats are on the same circuit. If the circuit is hot, the furnace will begin running. The lowest temperature setting will turn on the central air conditioner.

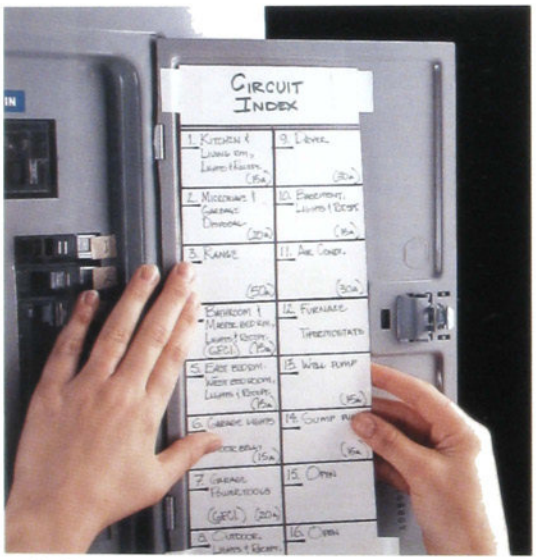


10 Check the electric water heater for power by setting its thermostat to highest temperature setting. Water heater will begin to heat if it is powered by the circuit.

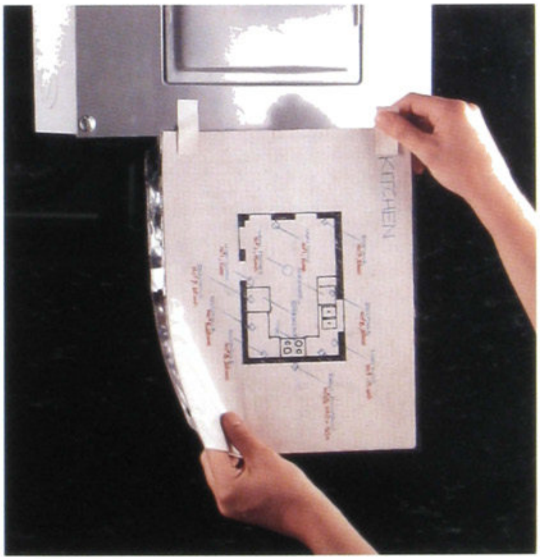
11 Check the doorbell system for power by ringing all of the doorbells.



12 On the circuit maps, indicate the circuit number, the voltage, and the amperage rating of each receptacle, switch, light fixture, and appliance.



13 On the door of the main service panel, tape an index that provides a brief summary of all the fixtures, receptacles, and appliances that are powered by each circuit.



14 Attach the completed circuit maps to the main service panel, and make sure the power is turned on for all the circuits.

Evaluating Circuits for Safe Capacity

Every electrical circuit in a home has a "safe capacity. Safe capacity is the total amount of power the circuit wires can carry without tripping circuit breakers or blowing fuses. According to the National Electrical Code, the power used by light fixtures, lamps, tools, and appliances, called the "demand, must not exceed the safe capacity of the circuit.

Finding the safe capacity and the demand of a circuit is easy. Make these simple calculations to reduce the chances of tripped circuit breakers or blown fuses, or to help plan the location of new appliances or plug-in lamps.

First, determine the amperage and voltage rating of the circuit. If you have an up-to-date circuit map (pages 30 to 33) these ratings should be indicated on the map. If not, open the service panel door and read the amperage rating printed on the circuit breaker or on the rim of the fuse. The type of circuit breaker or fuse (page 28) indicates the voltage of the circuit.

Use the amperage and voltage ratings to find the safe capacity of the circuit. Safe capacities of the most common household circuits are given in the table at right.

Safe capacities can be calculated by multiplying the amperage rating by voltage. The answer is the total capacity, expressed in watts, a unit of electrical measurement. To find the safe capacity, reduce the total capacity by 20%.

Next, compare the safe capacity of the circuit to the total power demand. To find the demand, add the wattage ratings for all light fixtures, lamps, and appliances on the circuit. For lights, use the wattage rating printed on the light bulbs. Wattage ratings for appliances often are printed on the manufacturer's label. Approximate wattage ratings for many common household items are given in the table on the opposite page. If you are unsure about the wattage rating for a tool or appliance, use the highest number shown in the table to make calculations.

Compare the power demand to the safe capacity. The power demand should not exceed the safe capacity of the circuit. If it does, you must move lamps or appliances to another circuit. Or make sure that the power demand of the lamps and appliances turned on at the same time does not exceed the safe capacity of the circuit.

Amps × Volts	Total capacity	Safe capacity
15 A × 120 V =	1800 watts	1440 watts
20 A × 120 V =	2400 watts	1920 watts
25 A × 120 V =	3000 watts	2400 watts
30 A × 120 V =	3600 watts	2880 watts
20 A × 240 V =	4800 watts	3840 watts
30 A × 240 V =	7200 watts	5760 watts

How to Find Wattage & Amperage Ratings

Light bulb wattage ratings are printed on the top of the bulb. If a light fixture has more than one bulb, remember to add the wattages of all the bulbs to find the total wattage of the fixture.

Appliance wattage ratings are often listed on the manufacturer's label. Or use the table of typical wattage ratings on the opposite page.

Amperage rating can be used to find the wattage of an appliance. Multiply the amperage by the voltage of the circuit. For example, a 13-amp, 120-volt circular saw is rated for 1560 watts.

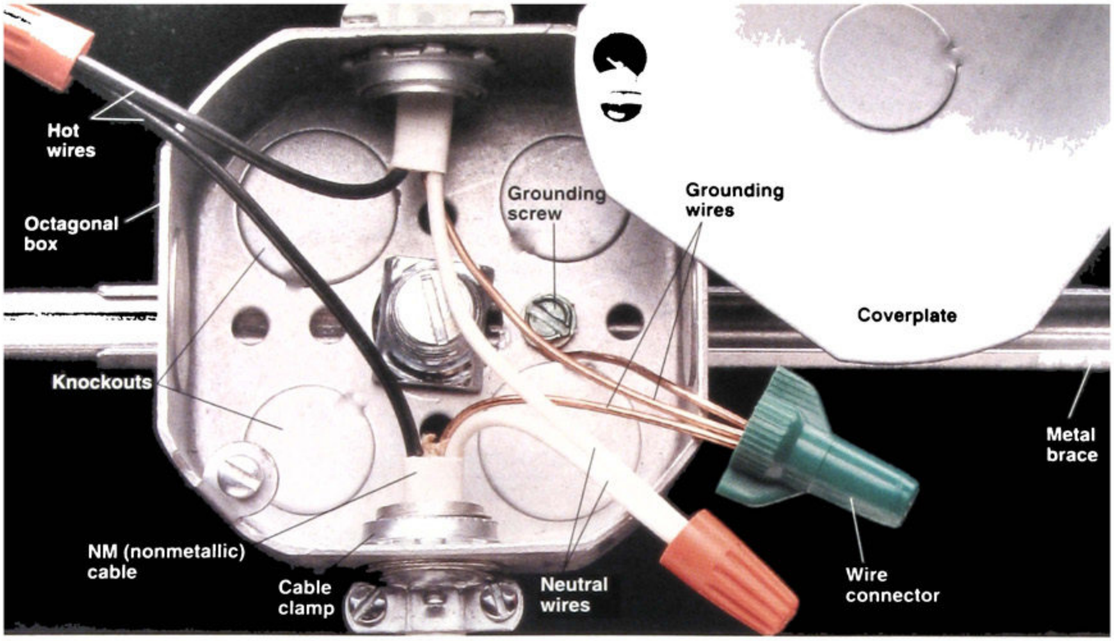
Sample Circuit Evaluation

Circuit #_____ Amps_____ Volts_____ Total capacity_______(watts) Safe capacity________(watts)		
Appliance or fixture	**Notes**	**Wattage rating**
	Total demand:	**(watts)**

Photocopy this sample circuit evaluation to keep a record of the power demand of each circuit. The words and numbers printed in blue will not reproduce on photocopies. In this sample kitchen circuit, the demand on the circuit is very close to the safe capacity Adding another appliance, such as an electric frying pan, could overload the circuit and cause a fuse to blow or a circuit breaker to trip.

Typical Wattage Ratings (120-volt Circuit Except Where Noted)

Appliance	Amps	Watts	Appliance	Amps	Watts
Air conditioner (central)	13 to 36 (240-v)	3120 to 8640	Garbage disposer	3.5 to 7.5	420 to 900
Air conditioner (window)	6 to 13	720 to 1560	Hair dryer	5 to 10	600 to 1200
Blender	2 to 4	240 to 480	Heater (portable)	7 to 12	840 to 1440
Broiler	12.5	1500	Microwave oven	4 to 10	480 to 1200
Can opener	1.2	144	Range (oven/stove)	5.5 to 10.8 (240-v)	1320 to 2600
Circular saw	10 to 12	1200 to 1440	Refrigerator	2 to 4	240 to 600
Coffee maker	4 to 8	480 to 960	Router	8	960
Clothes dryer	16.5 to 34 (240-v)	3960 to 8160	Sander (portable)	2 to 5	240 to 600
Clothes iron	9	1080	Saw (table)	7 to 10	840 to 1200
Computer	4 to 7	480 to 840	Sewing machine	1	120
Dishwasher	8.5 to 12.5	1020 to 1500	Stereo	2.5 to 4	300 to 480
Drill (portable)	2 to 4	240 to 480	Television (color)	2.5	300
DVD player	2.5 to 4	300 to 480	Toaster	9	1080
Fan (ceiling)	3.5	420	Trash compactor	4 to 8	480 to 960
Fan (portable)	2	240	Vacuum cleaner	6 to 11	720 to 1320
Freezer	2 to 4	240 to 600	Waffle iron	7.5	900
Frying pan	9	1080	Washing machine	12.5	1500
Furnace, forced-air gas	6.5 to 13	780 to 1560	Water heater	15.8 to 21 (240-v)	3800 to 5040



Octagonal boxes usually contain wire connections for ceiling fixtures. Cables are inserted into the box through knockout openings and are held with cable clamps. Because the ceiling fixture attaches directly to the box, the box should be anchored firmly to a framing member. Often, it is nailed directly to a ceiling joist. However, metal braces are available that allow a box to be mounted between joists or studs. A properly installed octagonal box can support a ceiling fixture weighing up to 35 pounds. Any box must be covered with a tightly fitting coverplate, and the box must not have open knockouts.

Electrical Boxes

The National Electrical Code requires that wire connections or cable splices be contained inside an approved metal or plastic box. This shields framing members and other flammable materials from electrical sparks. If you have exposed wire connections or cable splices, protect your home by installing electrical boxes.

Electrical boxes come in several shapes. Rectangular and square boxes are used for switches and receptacles. Rectangular (2" × 3") boxes are used for single switches or duplex receptacles. Square (4" × 4") boxes are used anytime it is convenient for two switches or receptacles to be wired or "ganged" in one box, an arrangement common in kitchens or entry hallways. Octagonal electrical boxes contain wire connections for ceiling fixtures.

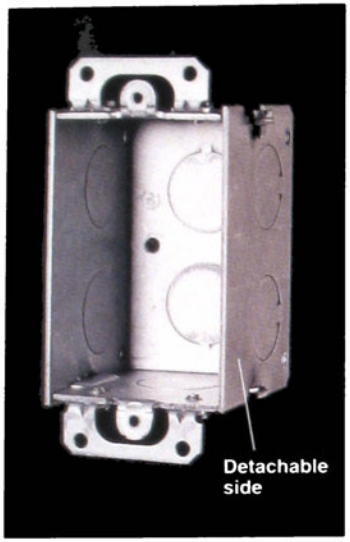
All electrical boxes are available in different depths. A box must be deep enough so a switch or receptacle can be removed or installed easily without crimping and damaging the circuit wires. Replace an undersized box with a larger box, using the Electrical Box Chart (right) as a guide. The NEC also says that all electrical boxes must remain accessible. Never cover an electrical box with drywall, paneling, or wallcoverings.

See Inspector's Notebook:
- Electrical Box Inspection (pages 128 to 129).
- Common Cable Problems (pages 124 to 125).

Electrical Box Chart

Box shape		Maximum number of individual wires in box*	
		14-gauge	12-gauge
2" × 3" rectangular	2½" deep	3	3
	3½" deep	5	4
4" × 4" square	1½" deep	6	5
	2⅛" deep	9	7
Octagonal	1½" deep	4	3
	2⅛" deep	7	6

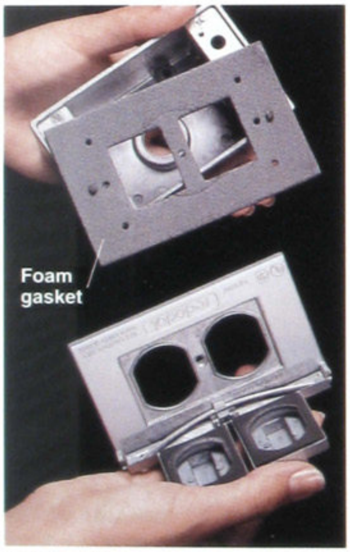
*Do not count pigtail wires or grounding wires.



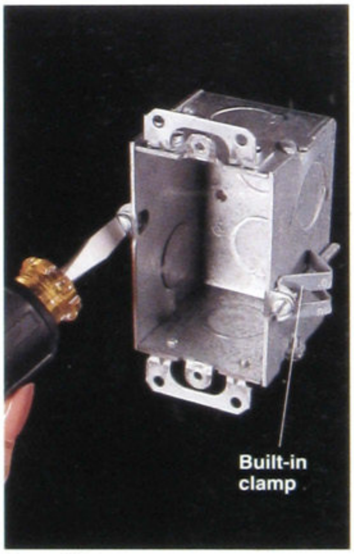
Rectangular boxes are used
tches and duplex recep-
ngle-size rectangular
shown above) may have
des that allow them
ganged together form
-size boxes

Square 4" × 4" boxes are
enough for most ing appli
ions They are used for cabl
splices and ganged receptacl
or switches To install one swit
or receptacle in a square box
an adapter ver

Braced octagonal boxes fit
between The
braces e
ng and
fram

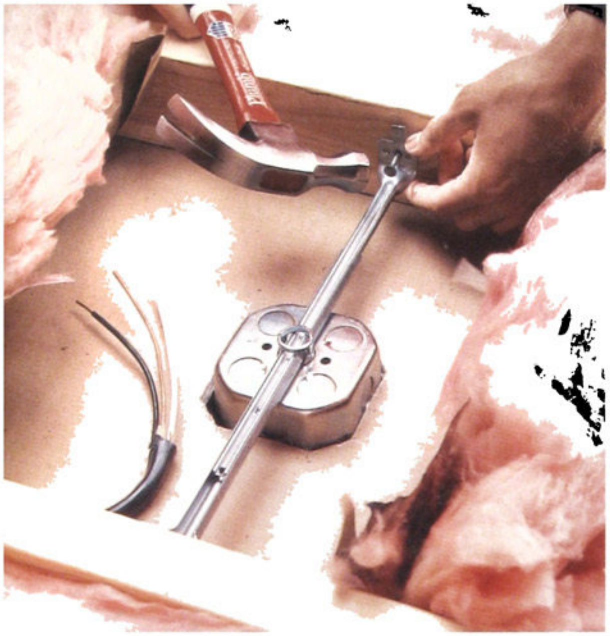


Outdoor boxes have sealed
and foam gaskets to guard
or receptacle against
Corrosion-resistant coat-
protect all metal parts.



Retrofit boxes upgrade older boxes to larger sizes. One type (above) has built-in clamps that tighten against the inside of a wall and hold the box in place. A retro-fit box with flexible brackets is shown on page 41.

Plastic boxes are common in new construction. They can be used only with NM (nonmetallic) cable. Box may include preattached nails for anchoring the box to framing members. Wall switches must have grounding screws if installed in plastic boxes.



Electrical boxes are required for all wire connections. The box protects wood and other flammable materials from electrical sparks (arcing). Electrical boxes should always be anchored to joists or studs.

Installing an Electrical Box

Install an electrical box any time you find exposed wire connections or cable splices. Exposed connections sometimes can be found in older homes, where wires attach to light fixtures. Exposed splices (page 125) can be found in areas where NM (nonmetallic) cable runs through uncovered joists or wall studs, such as in an unfinished basement or utility room.

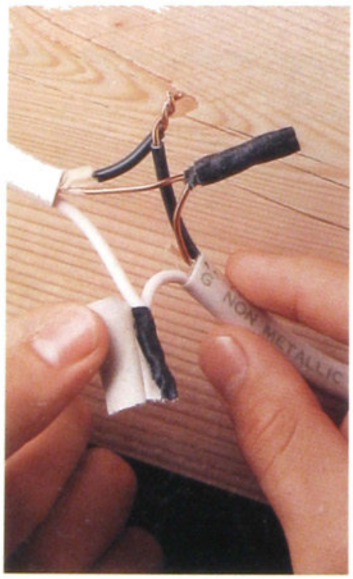
When installing an electrical box, make sure there is enough cable to provide about 8" of wire inside the box. If the wires are too short, you can add pigtails to lengthen them (page 128). If the electrical box is metal, make sure the circuit grounding wires are pigtailed to the box.

Everything You Need

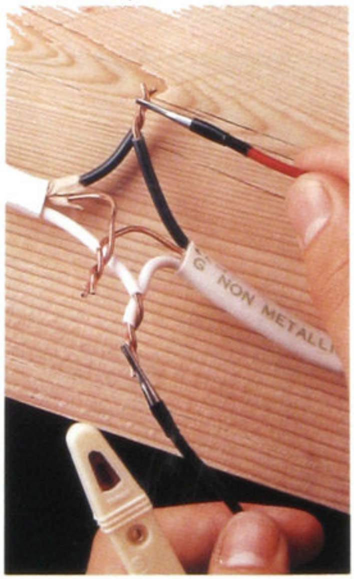
Tools: neon circuit tester, screwdriver, hammer.

Materials: screws or nails, electrical box, cable clamps, locknuts, pigtail wire, wire connectors.

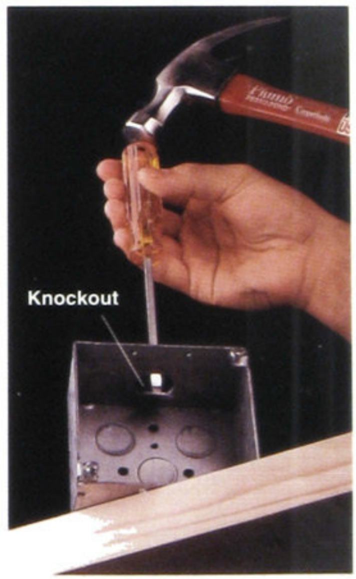
How to Install an Electrical Box for Cable Splices



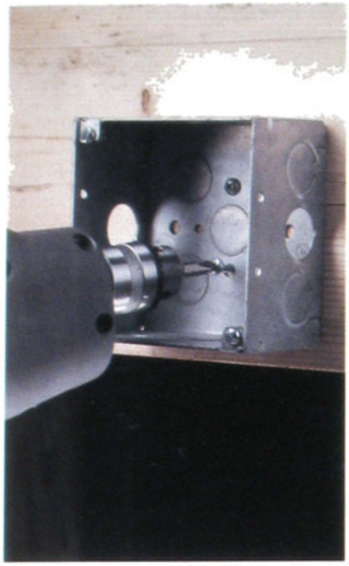
1 Turn off power to circuit wires at the main service panel. Carefully remove any tape or wire connectors from the exposed splice. Avoid contact with the bare wire ends until the wires have been tested for power.



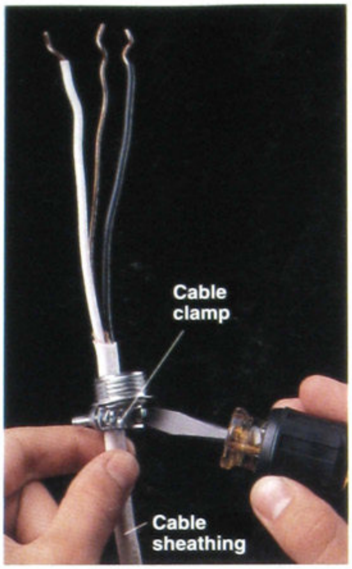
2 Test for power. Touch one probe of a circuit tester to the black hot wires, and touch other probe to the white neutral wires. The tester should not glow. If it does, the wires are still hot. Shut off power to correct circuit at the main service panel. Disconnect the spliced wires.



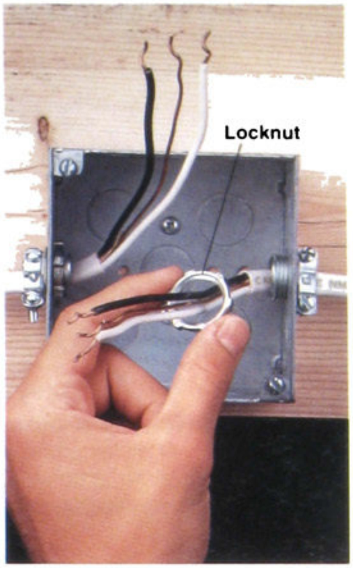
3 Open one knockout for each cable that will enter the box, using a hammer and screwdriver. Any unopened knockouts should remain sealed.



4 lectrical box to a ing member usi

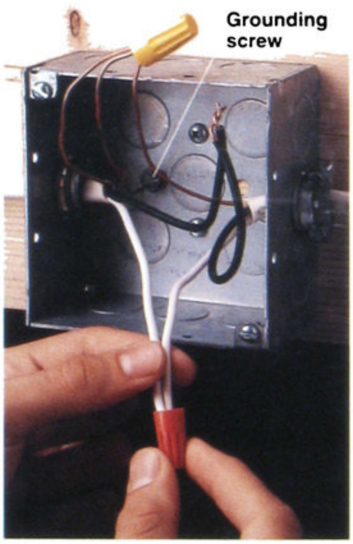


5 Thread each cable cable clamp Tighten with a screwdriv Do not nten O



6

7 T locknuts by pushing lugs with the blade



8 Use wire connectors to reconnect the wires. Pigtail the copper grounding wires to the green grounding screw in the back of the box.

9 Carefully tuck the wires into the box, and attach the coverplate. Turn on the power to the circuit at the main service panel. Make sure the box remains accessible, and is not covered with finished walls or ceilings.

Replacing an Electrical Box

Replace any electrical box that is too small for the number of wires it contains. Forcing wires into an undersized box can damage wires, disturb wire connections, and create a potential fire hazard.

Boxes that are too small often are found when repairing or replacing switches, receptacles, or light fixtures. If you find a box so small that you have difficulty fitting the wires inside, replace it with a larger box. Use the chart on page 36 as a guide when choosing a replacement box.

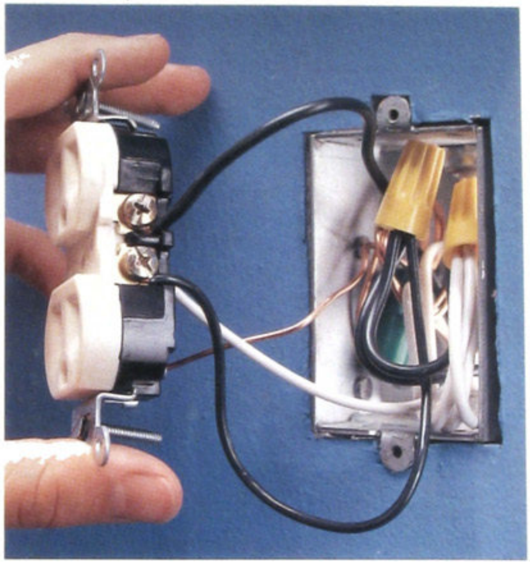
Metal and plastic retrofit electrical boxes are available in a variety of styles and can be purchased at any hardware store or home center. Most can be installed without damaging the wall surfaces.

Everything You Need

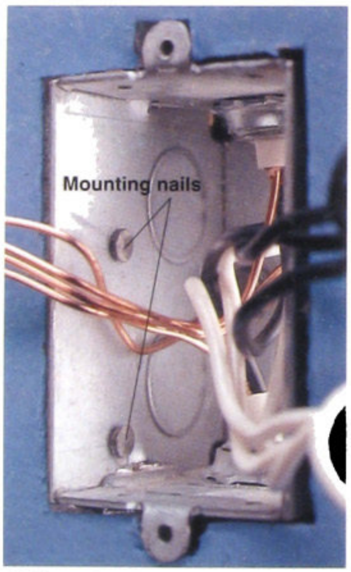
Tools: screwdriver, neon circuit tester, reciprocating saw, hammer, needlenose pliers.

Materials: string, electrical tape, retrofit electrical box with flexible brackets, grounding screw.

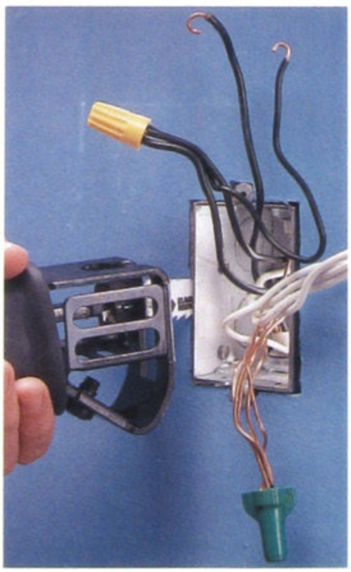
How to Replace an Electrical Box



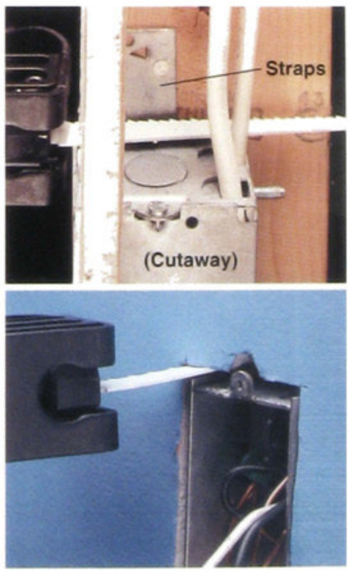
1 Shut off the power to the circuit at the main service panel. Test for power with a neon circuit tester (switches, page 57 receptacles, page 70; light fixtures, page 80). Disconnect and remove receptacle, switch, or fixture from the existing box.



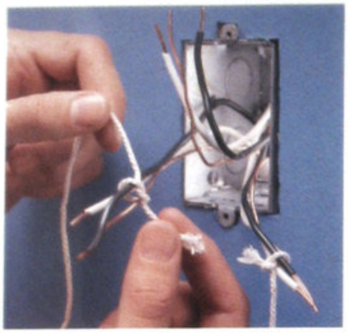
2 Examine the box to determine how it was installed. Most older metal boxes are attached to framing members with nails, and the nail heads will be visible inside the box.



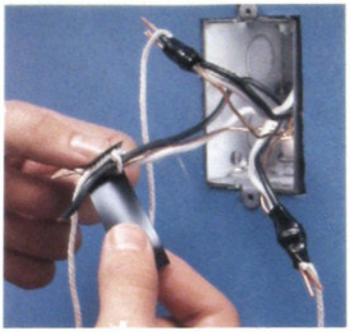
3 Cut through the mounting nails, using a reciprocating saw equipped with a metal-cutting blade. Take care not to damage the circuit wires. Disconnect wires.



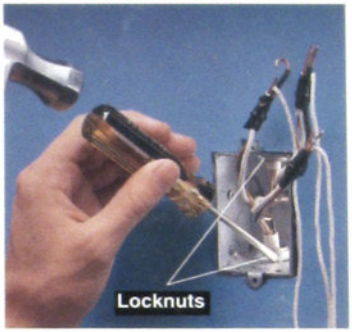
If box is mounted with straps (shown with wall cut away) remove the box by cutting through the straps, using a reciprocating saw and metal-cutting blade. Take care not to damage the wires.



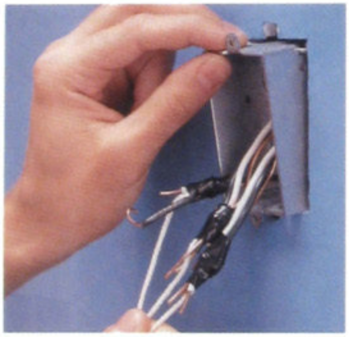
4 To prevent wires from falling into wall cavity, gather wires from each cable and tie them together, using pieces of string.



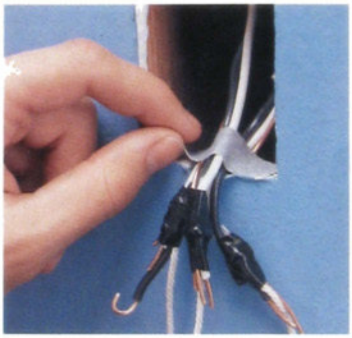
5 Secure the string to the wires, using a piece of plastic electrical tape.



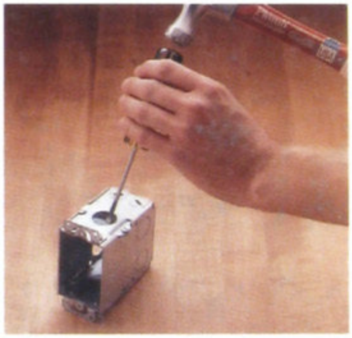
6 Disconnect the internal clamps or locknuts that hold the circuit cables to the box.



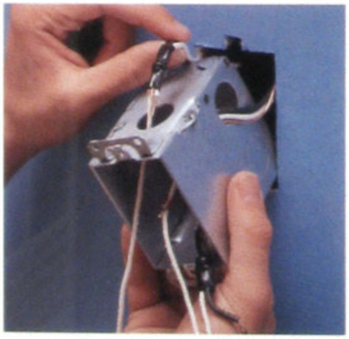
7 Pull old electrical box from wall. Take care not to damage insulation on circuit wires, and hold on to string to make sure wires do not fall inside wall cavity



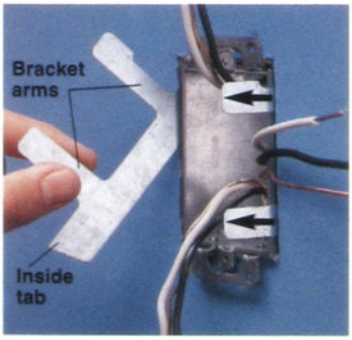
8 Tape the wires to the edge of the wall cutout.



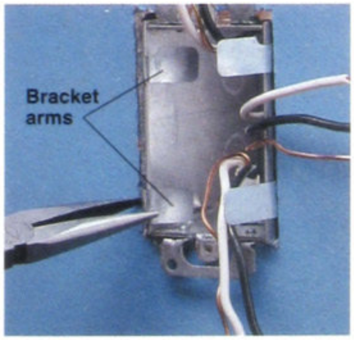
9 Punch out one knockout for each cable that will enter the new electrical box, using a screwdriver and hammer



10 Thread cables into the new electrical box, and slide the box into the wall opening. Tighten the internal clamps or locknuts holding the circuit cables to the electrical box. Remove the strings.



11 Insert flexible brackets into the wall on each side of the electrical box. Pull out bracket arms until inside tab is tight against inside of the wall.



12 Bend bracket arms around walls of box, using needlenose pliers. Reinstall the fixture, and turn on the power to the circuit at the main service panel.

Rotary snap switches are found ...many ...nstallations completed betw... 1900 ar... 1920. Handle is twisted cl...wise to ... light on and off. The sw... is encl... in a ceramic housing.

Push-button switches were widely used from 1920 until about 1940. Man... switches of this type are still in operation. Reproductions of this switch type are available for restoration projects.

Toggle switches were introduced ... the 1930s. This early design has a switch mechanism that ... mounted ... a ceramic housing sealed with ... of insulating paper.

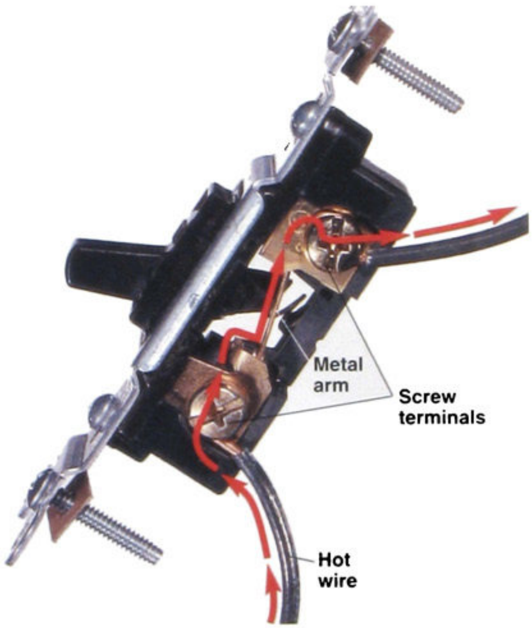
Common Wall-switch Problems

An average wall switch is turned on and off more than 1,000 times each year. Because switches receive constant use, wire connections can loosen and switch parts gradually wear out. If a switch no longer operates smoothly, it must be repaired or replaced.

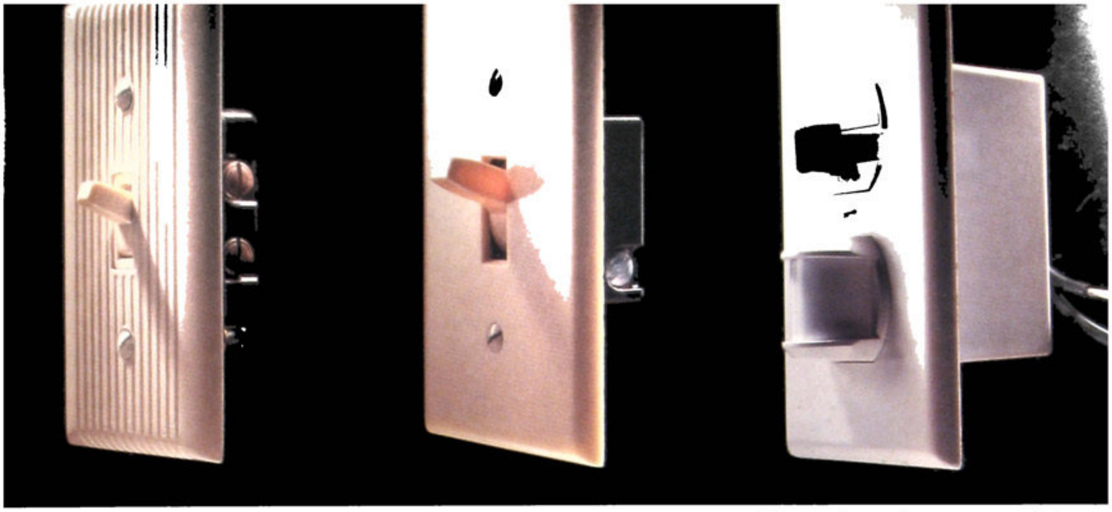
The methods for repairing or replacing a switch vary slightly, depending on the switch type and its location along an electrical circuit. When working on a switch, use the photographs on pages 44 to 51 to identify your switch type and its wiring configuration. Individual switch styles may vary from manufacturer to manufacturer, but the basic switch types are universal.

It is possible to replace most ordinary wall switches with a specialty switch, like a timer switch or an electronic switch. When installing a specialty switch (pages 50 to 51), make sure it is compatible with the wiring configuration of the switch box.

See Inspector's Notebook:
- Common Cable Problems (pages 124 to 125).
- Checking Wire Connections (pages 126 to 127).
- Inspecting Switches (page 133).



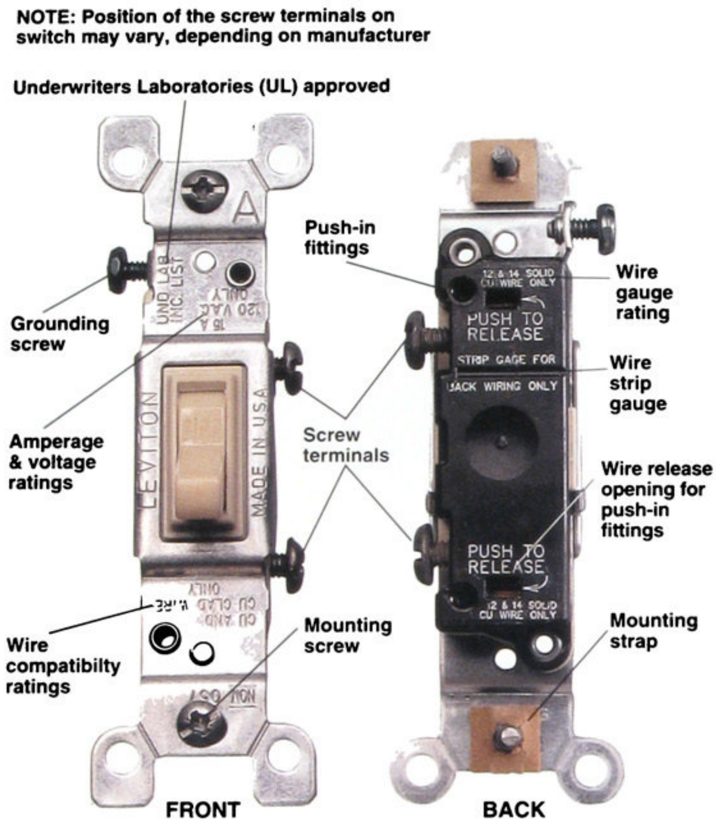
Typical wall switch has a movable metal arm that opens and closes the electrical circuit. When the switch is ON, the arm completes the circuit and power flows between the screw terminals and through the black hot wire to the light fixture. When the switch is OFF, the arm lifts away to interrupt the circuit, and no power flows. Switch problems can occur if the screw terminals are not tight or if the metal arm inside the switch wears out.



Toggle switches | Mercury switches | Electronic motion-sensor switch

Problem		Repair
	Fuse burns out or circuit breaker trips when the switch is turned on.	1 Tighten any loose wire connections on switch (pages 56 to 57). 2. Move lamps or plug-in appliances to other circuits to prevent overloads (page 34). 3. Test switch (pages 52 to 55), and replace, if needed (pages 56 to 59). 4. Repair or replace faulty fixture (pages 78 to 95) or faulty appliance.
	Light fixture or permanently installed appliance does not work.	1 Replace burned-out light bulb. 2. Check for blown fuse or tripped circuit breaker to make sure circuit is operating (pages 28 to 29). 3. Check for loose wire connections on switch (pages 56 to 57) 4. Test switch (pages 52 to 55), and replace, if needed (pages 56 to 59). 5. Repair or replace light fixture (pages 78 to 95) or appliance
	Light fixture flickers.	1 Tighten light bulb in the socket. 2. Check for loose wire connections on switch (pages 56 to 57) 3. Repair or replace light fixture (pages 78 to 95) or switch (pages 56 to 59).
	Switch buzzes or is warm to the touch.	1 Check for loose wire connections on switch (pages 56 to 57). 2. Test switch (pages 52 to 55), and replace, if needed (pages 56 to 59) 3. Move lamps or appliances to other circuits to reduce demand (page 34).
	Switch lever does not stay in position.	Replace worn-out switch (pages 56 to 59).

Wall-switch Basics



A wall switch is connected to circuit wires with screw terminals or with push-in fittings on the back of the switch. A switch may have a stamped strip gauge that indicates how much insulation must be stripped from the circuit wires to make the connections.

The switch body is attached to a metal mounting strap that allows it to be mounted in an electrical box. Several rating stamps are found on the strap and on the back of the switch. The abbreviation UL or UND. LAB. INC. LIST means that the switch meets the safety standards of the Underwriters Laboratories. Switches also are stamped with maximum voltage and amperage ratings. Standard wall switches are rated 15A, 125V Voltage ratings of 110, 120, and 125 are considered to be identical for purposes of identification.

For standard wall switch installations, choose a switch that has a wire gauge rating of #12 or #14. For wire systems with solid-core copper wiring, use only switches marked COPPER or CU. For aluminum wiring (page 22), use only switches marked CO/ALR. Switches marked AL/CU can no longer be used with aluminum wiring, according to the National Electrical Code.

Wall switches are available in three general types. To repair or replace a switch, it is important to identify its type.

Single-pole switches are used to control a set of lights from one location. **Three-way switches** are used to control a set of lights from two different locations and are always installed in pairs. **Four-way switches** are used in combination with a pair of three-way switches to control a set of lights from three or more locations.

Identify switch types by counting the screw terminals. Single-pole switches have two screw terminals, three-way switches have three screw terminals, and four-way switches have four.

Most switches include a grounding screw terminal, which is identified by its green color. Technically, grounded switches are required only when the switch is installed in a plastic box. However, many electricians make it a practice to always install grounded switches. When pigtailed to the grounding wires, a grounding screw provides added protection against shock.

When replacing a switch, choose a new switch that has the same number of screw terminals as the old one. The location of the screws on the switch body varies, depending on the manufacturer, but these differences will not affect the switch operation.

Whenever possible, connect switches using the screw terminals rather than push-in fittings. Some specialty switches (pages 50 to 51) have wire leads instead of screw terminals. They are connected to circuit wires with wire connectors.

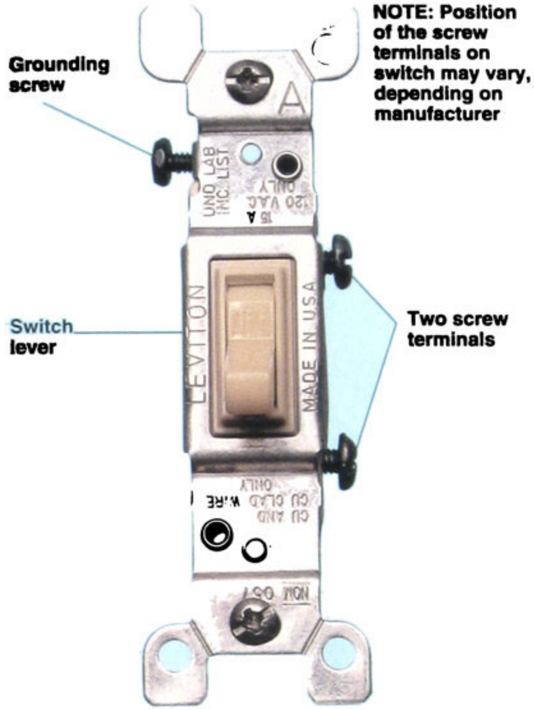
Single-pole Wall Switches

A single-pole switch is the most common type of wall switch. It usually has ON-OFF markings on the switch lever and is used to control a set of lights, an appliance, or a receptacle from a single location. A single-pole switch has two screw terminals and a grounding screw. When installing a single-pole switch, check to make sure the ON marking shows when the switch lever is in the up position.

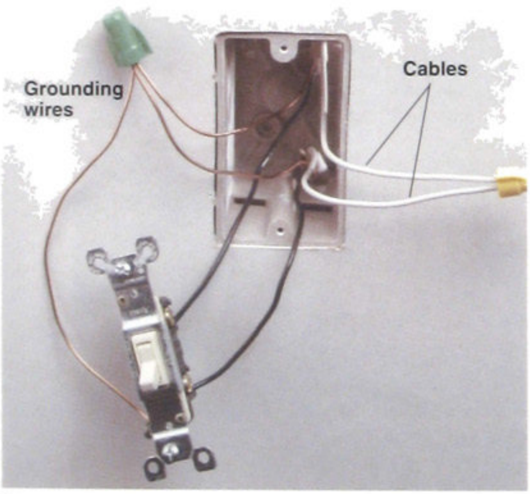
In a correctly wired single-pole switch, a hot circuit wire is attached to each screw terminal. However, the color and number of wires inside the switch box will vary, depending on the location of the switch along the electrical circuit.

If two cables enter the box, then the switch lies in the middle of the circuit. In this installation, both of the hot wires attached to the switch are black.

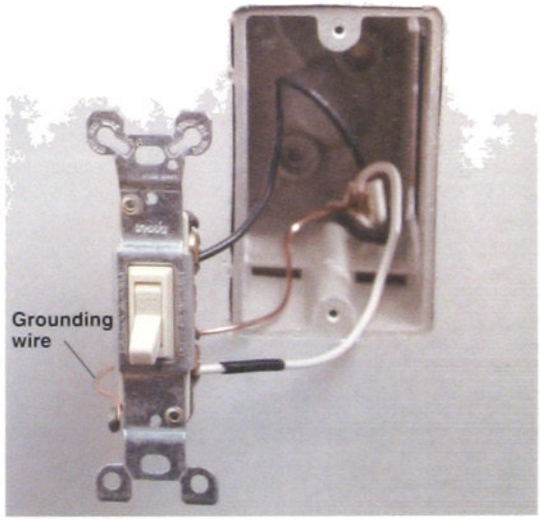
If only one cable enters the box, then the switch lies at the end of the circuit. In this installation (sometimes called a switch loop), one of the hot wires is black, but the other hot wire usually is white. A white hot wire sometimes is coded with black tape or paint.



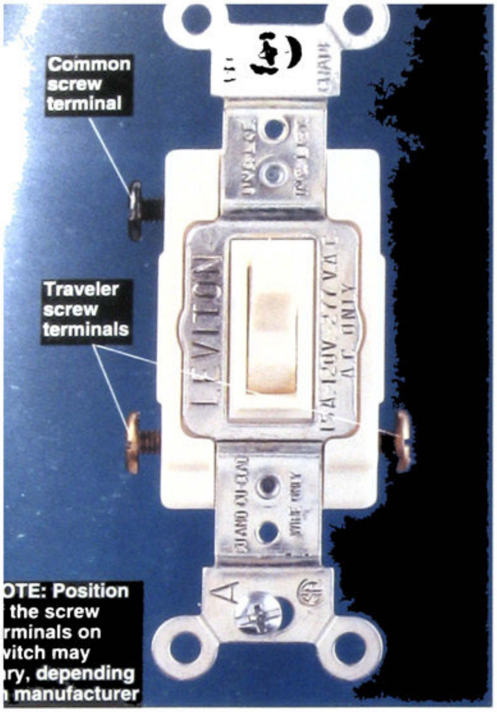
Typical Single-pole Switch Installations



Two cables enter the box when a switch is located in the middle of a circuit. Each cable has a white and a black insulated wire, plus a bare copper grounding wire. The black wires are hot and are connected to the screw terminals on the switch. The white wires are neutral and are joined together with a wire connector. Grounding wires are pigtailed to the switch.



One cable enters the box when a switch is located at the end of a circuit. The cable has a white and a black insulated wire, plus a bare copper grounding wire. In this installation, both of the insulated wires are hot. The white wire may be labeled with black tape or paint to identify it as a hot wire. The grounding wire is connected to the switch grounding screw.



Three-way Wall Switches

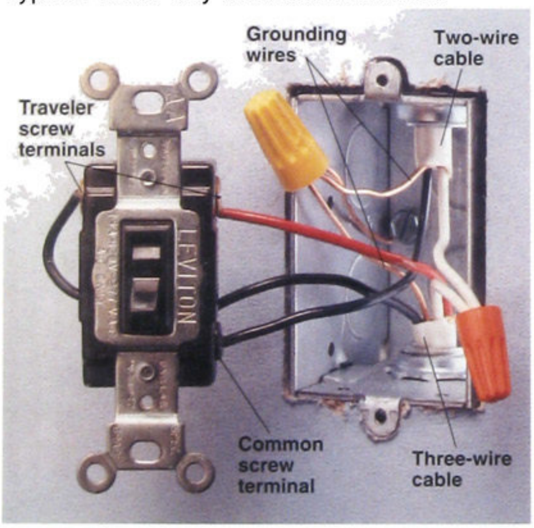
Three-way switches have three screw terminals and do not have ON-OFF markings. Three-way switches are always installed in pairs and are used to control a set of lights from two locations.

One of the screw terminals on a three-way switch is darker than the others. This screw is the **common screw terminal.** The position of the common screw terminal on the switch body may vary, depending on the manufacturer. Before disconnecting a three-way switch, always label the wire that is connected to the common screw terminal. It must be reconnected to the common screw terminal on the new switch.

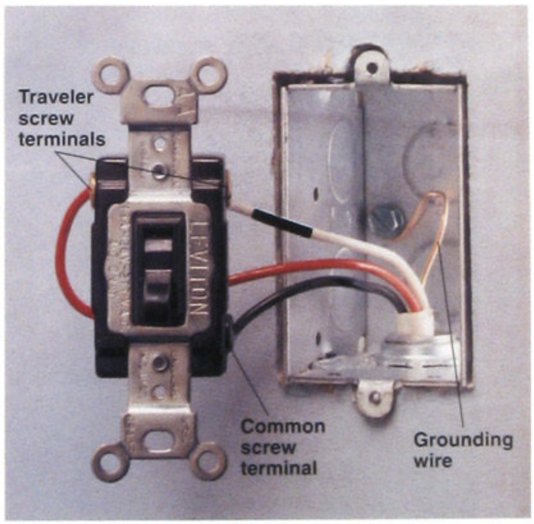
The two lighter-colored screw terminals on a three-way switch are called the **traveler screw terminals.** The traveler terminals are interchangeable, so there is no need to label the wires attached to them.

Because three-way switches are installed in pairs, it sometimes is difficult to determine which of the switches is causing a problem. The switch that receives greater use is more likely to fail, but you may need to inspect both switches to find the source of the problem.

Typical Three-way Switch Installations



Two cables enter the box if the switch lies in the middle of a circuit. One cable has two wires, plus a bare copper grounding wire; the other cable has three wires, plus a ground. The black wire from the two-wire cable is connected to the dark, common screw terminal. The red and black wires from the three-wire cable are connected to the traveler screw terminals. The white neutral wires are joined together with a wire connector, and the grounding wires are pigtailed to the grounded metal box.

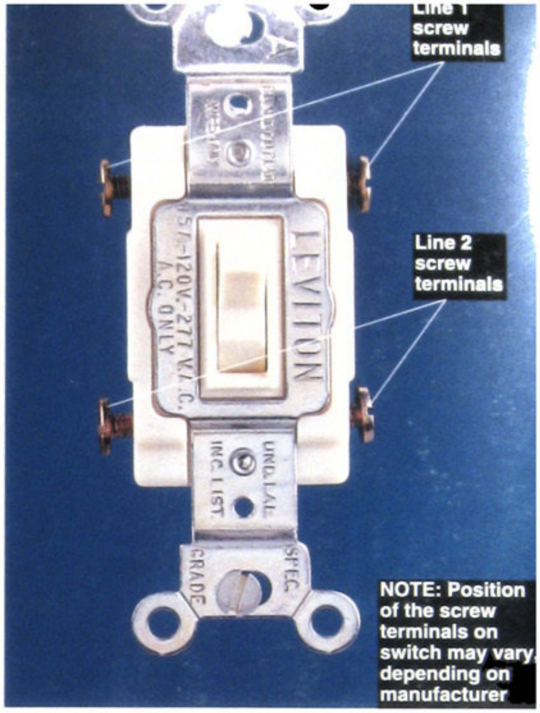


One cable enters the box if the switch lies at the end of the circuit. The cable has a black wire, red wire, and white wire, plus a bare copper grounding wire. The black wire must be connected to the common screw terminal, which is darker than the other two screw terminals. The white and red wires are connected to the two traveler screw terminals. The bare copper grounding wire is connected to the grounded metal box.

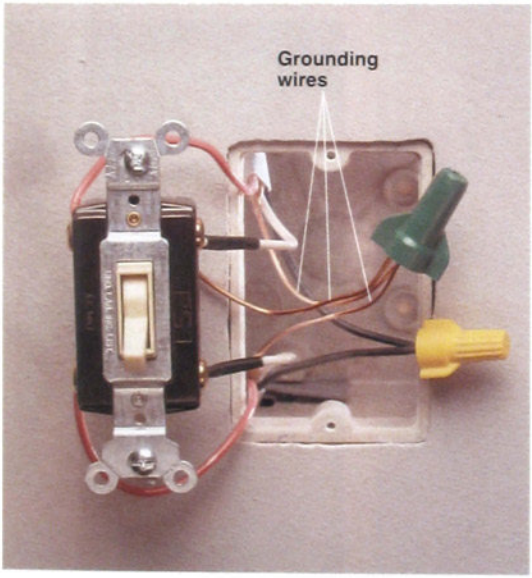
Four-way Wall Switches

Four-way switches have four screw terminals and do not have ON-OFF markings. Four-way switches are always installed between a pair of three-way switches. This switch combination makes it possible to control a set of lights from three or more locations. Four-way switches are common in homes where large rooms contain multiple living areas, such as a kitchen opening into a dining room. Switch problems in a four-way installation can be caused by loose connections or worn parts in a four-way switch or in one of the three-way switches (page opposite).

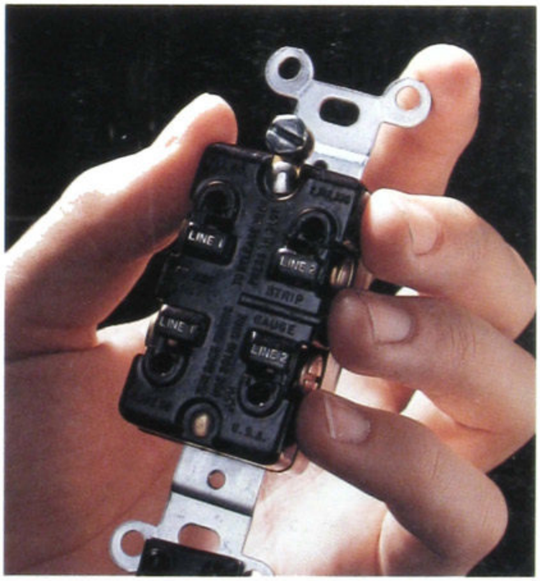
In a typical installation, there will be a pair of three-way cables that enter the box for the four-way switch. With most switches, the white and red wires from one cable should be attached to the bottom or top pair of screw terminals, and the white and red wires from the other cable should be attached to the remaining pair of screw terminals. However, not all switches are configured the same way, and wiring configurations in the box may vary, so always study the wiring diagram that comes with the switch.



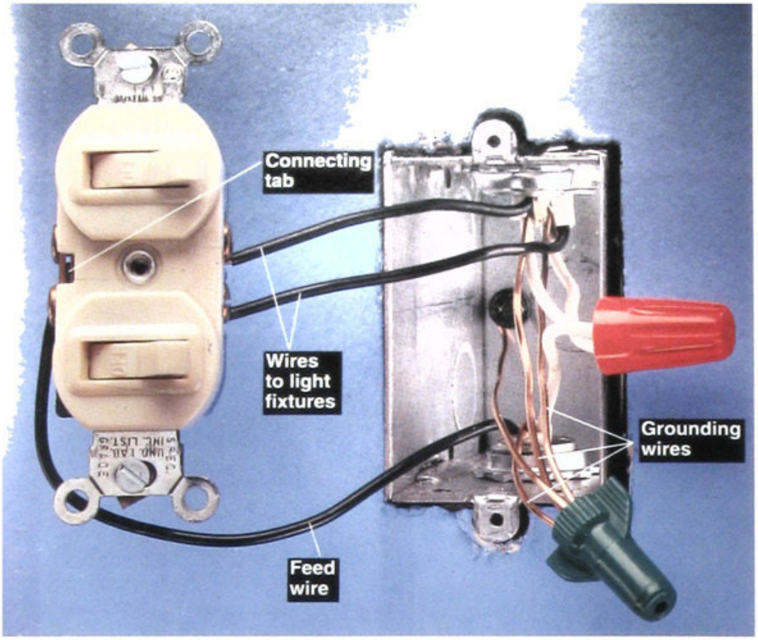
Typical Four-way Switch Installation



Four wires are connected to a four-way switch. The red and white wires from one cable are attached to the top pair of screw terminals, while the red and white wires from the other cable are attached to the bottom screw terminals.



Switch variation: Some four-way switches have a wiring guide stamped on the back to help simplify installation. For the switch shown above, one pair of color-matched circuit wires will be connected to the screw terminals marked LINE 1, while the other pair of wires will be attached to the screw terminals marked LINE 2.



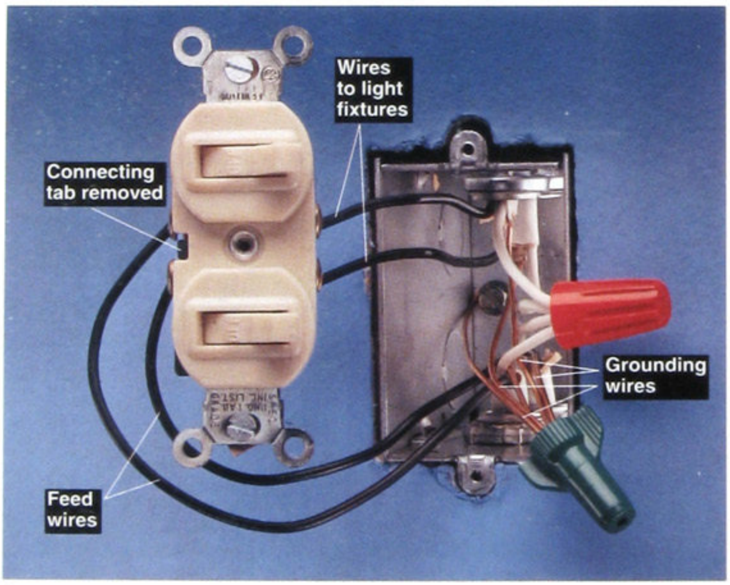
Single-circuit wiring: Three black wires are attached to the switch. The black feed wire bringing power into the box is connected to the side of the switch that has a connecting tab The wires carrying power out to the light fixtures or appliances are connected to the side of the switch that **does not** have a connecting tab The white neutral wires are connected together with a wire connector

Double Switches

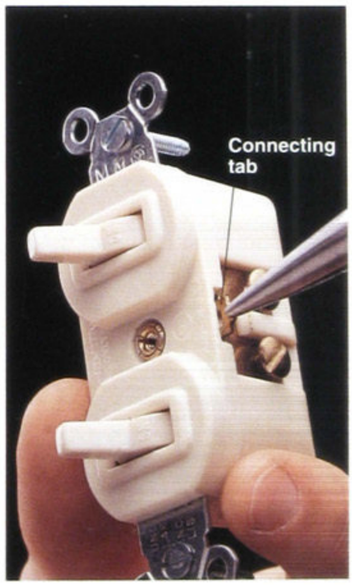
A double switch has two switch levers in a single housing It is used to control two light fixtures or appliances from the same switch box.

In most installations, both halves of the switch are powered by the same circuit. In these **single-circuit** installations, three wires are connected to the double switch. One wire, called the "feed" wire, supplies power to both halves of the switch. The other wires carry power out to the individual light fixtures or appliances.

In rare installations, each half of the switch is powered by a separate circuit. In these **separate-circuit** installations, four wires are connected to the switch, and the metal connecting tab joining two of the screw terminals is removed (photo below).



Separate-circuit wiring: Four black wires are attached to the switch. Feed wires from the power source are attached to the side of switch that has a connecting tab, and the connecting tab is removed (photo, right). Wires carrying power from the switch to light fixtures or appliances are connected to the side of the switch that **does not** have a connecting tab. White neutral wires are connected together with a wire connector.

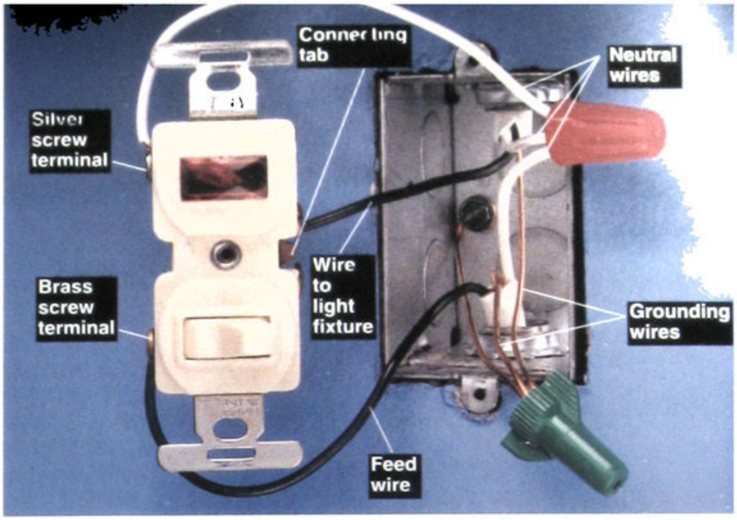


Remove the connecting tab on a double switch when wired in a separate-circuit installation. The tab can be removed with needle-nose pliers or a screwdriver.

Pilot-light Switches

A pilot-light switch has a built-in bulb that glows when power flows through the switch to a light fixture or appliance. Pilot-light switches often are installed for convenience if a light fixture or appliance cannot be seen from the switch location. Basement lights, garage lights, and attic exhaust fans frequently are controlled by pilot-light switches.

A pilot-light switch requires a neutral wire connection. A switch box that contains a single two-wire cable has only hot wires and cannot be fitted with a pilot-light switch.



Pilot-light switch wiring: Three wires are connected to the switch. One black wire is the feed wire that brings power into the box. It is connected to the brass screw terminal on the side of the switch that **does not** have a connecting tab. The white neutral wires are pigtailed to the silver screw terminal. Black wire carrying power out to light fixture or appliance is connected to screw terminal on side of the switch that has a connecting tab.

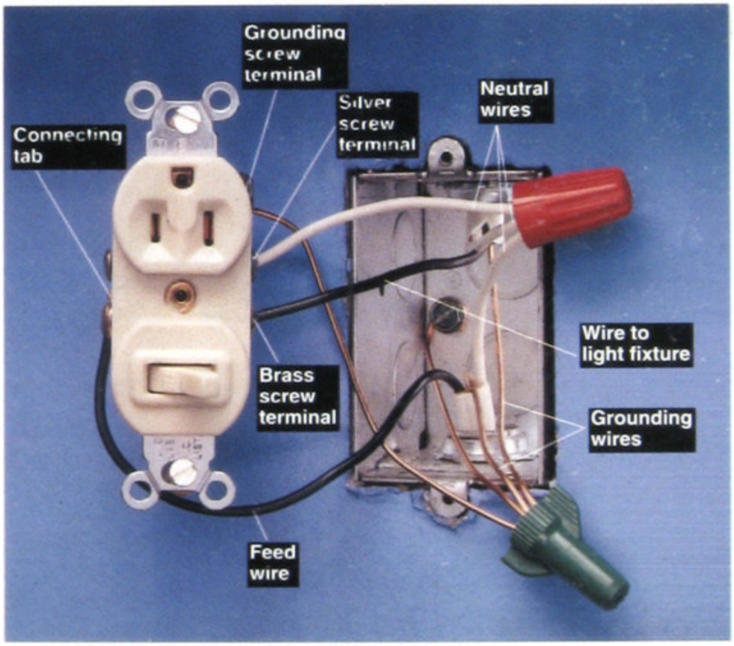
Switch/receptacles

A switch/receptacle combines a grounded receptacle with a single-pole wall switch. In a room that does not have enough wall receptacles, electrical service can be improved by replacing a single-pole switch with a switch/receptacle.

A switch/receptacle requires a neutral wire connection. A switch box that contains a single two-wire cable has only hot wires and cannot be fitted with a switch/receptacle.

A switch/receptacle can be installed in one of two ways. In the most common installations, the receptacle is hot even when the switch is off (photo, right).

In rare installations, a switch/receptacle is wired so the receptacle is hot only when the switch is on. In this installation, the hot wires are reversed, so that the feed wire is attached to the brass screw terminal on the side of the switch that does not have a connecting tab.



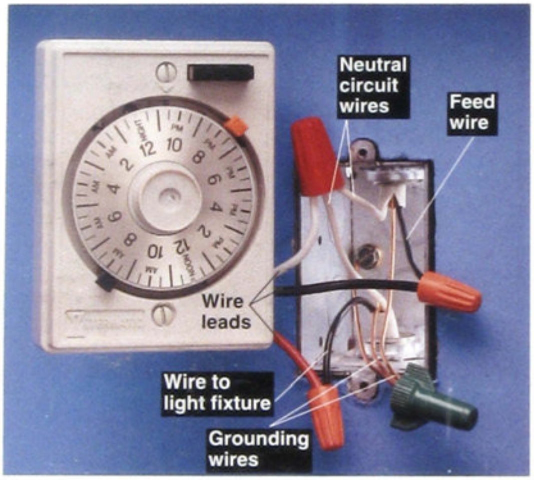
Switch/receptacle wiring: Three wires are connected to the switch/receptacle. One of the hot wires is the feed wire that brings power into the box. It is connected to the side of the switch that has a connecting tab. The other hot wire carries power out to the light fixture or appliance. It is connected to the brass screw terminal on the side that **does not** have a connecting tab. The white neutral wire is pigtailed to the silver screw terminal. The grounding wires must be pigtailed to the green grounding screw on the switch/receptacle and to the grounded metal box.

Specialty Switches

Specialty switches are available in several types. **Dimmer switches** (pages 60 to 61) are used frequently to control light intensity in dining and recreation areas. **Timer switches** and **time-delay switches** (below) are used to control light fixtures and exhaust fans automatically. New **electronic switches** (page opposite) provide added convenience and home security, and are easy to install. Electronic switches are durable, and they rarely need repair.

Most standard single-pole switches can be replaced with a specialty switch. Most specialty switches have preattached wire leads instead of screw terminals and are connected to circuit wires with wire connectors. Some motor-driven timer switches require a neutral wire connection and cannot be installed in switch boxes that have only one cable with two hot wires.

If a specialty switch is not operating correctly, you may be able to test it with a continuity tester (pages 52 to 55). Timer switches and time-delay switches can be tested for continuity, but dimmer switches cannot be tested. With electronic switches, the manual switch can be tested for continuity (page 55), but the automatic features cannot be tested.

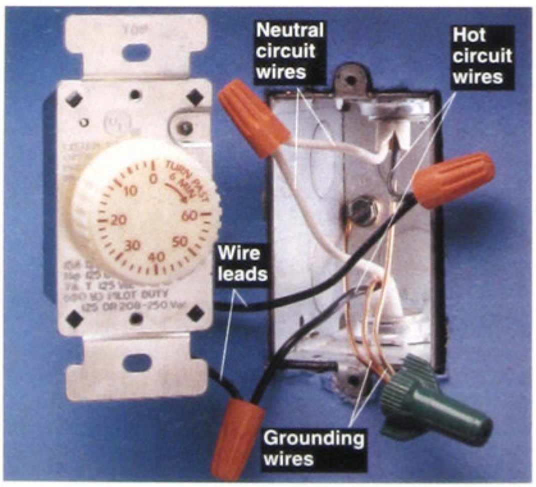


Timer Switches

Timer switches have an electrically powered control dial that can be set to turn lights on and off automatically once each day. They are commonly used to control outdoor light fixtures.

Timer switches have three preattached wire leads. The black wire lead is connected to the hot feed wire that brings power into the box, and the red lead is connected to the wire carrying power out to the light fixture. The remaining wire lead is the neutral lead. It must be connected to any neutral circuit wires. A switch box that contains only one cable has no neutral wires, so it cannot be fitted with a timer switch.

After a power failure, the dial on a timer switch must be reset to the proper time.



Time-delay Switches

A time-delay switch has a spring-driven dial that is wound by hand. The dial can be set to turn off a light fixture after a delay ranging from 1 to 60 minutes. Time-delay switches often are used for exhaust fans, electric space heaters, bathroom vent fans, and heat lamps.

The black wire leads on the switch are connected to the hot circuit wires. If the switch box contains white neutral wires, these are connected together with a wire connector. The bare copper grounding wires are pigtailed to the grounded metal box.

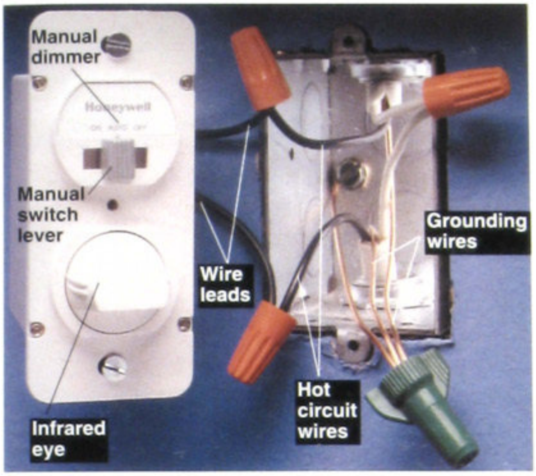
A time-delay switch needs no neutral wire connection, so it can be fitted in a switch box that contains either one or two cables.

Automatic Switches

An automatic switch uses a narrow infrared beam to detect movement. When a hand passes within a few inches of the beam, an electronic signal turns the switch on or off. Some automatic switches have a manual dimming feature.

Automatic switches can be installed wherever a standard single-pole switch is used. Automatic switches are especially convenient for children and persons with disabilities.

Automatic switches require no neutral wire connections. For this reason, an automatic switch can be installed in a switch box containing either one or two cables. The wire leads on the switch are connected to hot circuit wires with wire connectors.

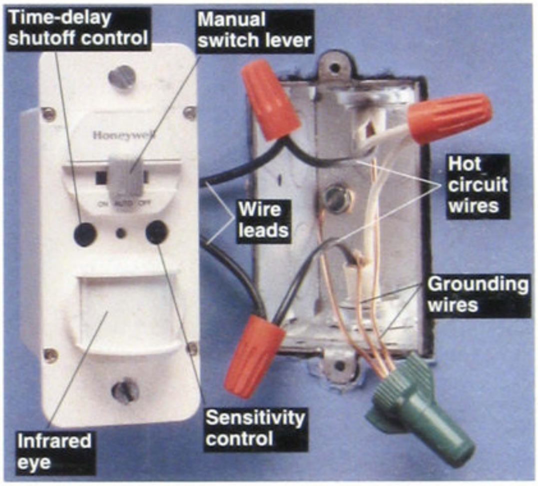


Motion-sensor Security Switches

A motion-sensor switch uses a wide-angle infrared beam to detect movement over a large area and turns on a light fixture automatically. A time-delay feature turns off lights after movement stops.

Most motion-sensor switches have an override feature that allows the switch to be operated manually. Better switches include an adjustable sensitivity control and a variable time-delay shutoff control.

Motion-sensor switches require no neutral wire connections. They can be installed in switch boxes containing either one or two cables. The wire leads on the switch are connected to hot circuit wires with wire connectors.

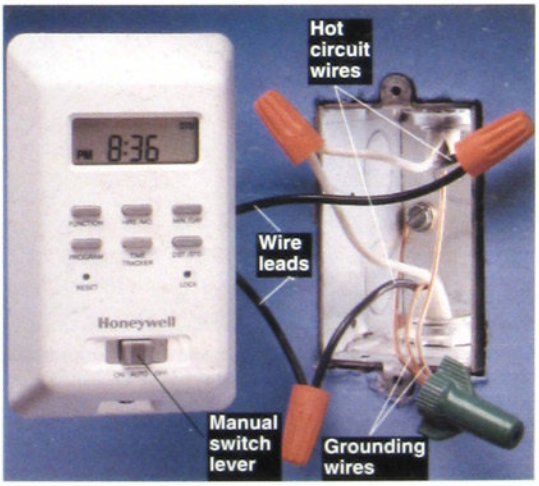


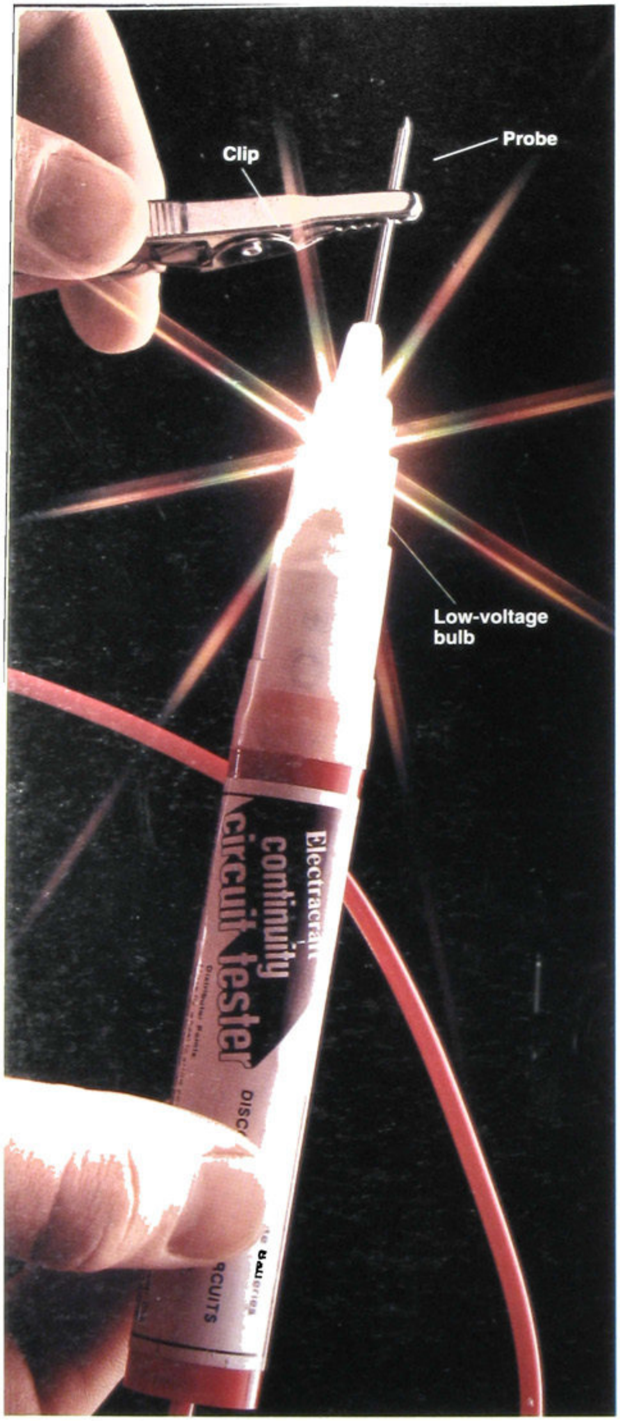
Programmable Switches

Programmable switches represent the latest in switch design. They have digital controls and can provide four on-off cycles each day.

Programmable switches frequently are used to provide security when a homeowner is absent from the house. Law enforcement experts say that programmed lighting is a proven crime deterrent. For best protection, programmable switches should be set to a random on-off pattern.

Programmable switches require no neutral wire connections. They can be installed in switch boxes containing either one or two cables. The wire leads on the switch are connected to hot circuit wires with wire connectors.





Continuity tester uses battery-generated current to test the metal pathways running through switches and other electrical fixtures. Always "test" the tester before use. Touch the tester clip to the metal probe. The tester should glow. If not, then the battery or light bulb is dead and must be replaced.

Testing Switches for Continuity

A switch that does not work properly may have worn or broken internal parts. Test for internal wear with a battery-operated continuity tester. The continuity tester detects any break in the metal pathway inside the switch. Replace the switch if the continuity tester shows the switch to be faulty.

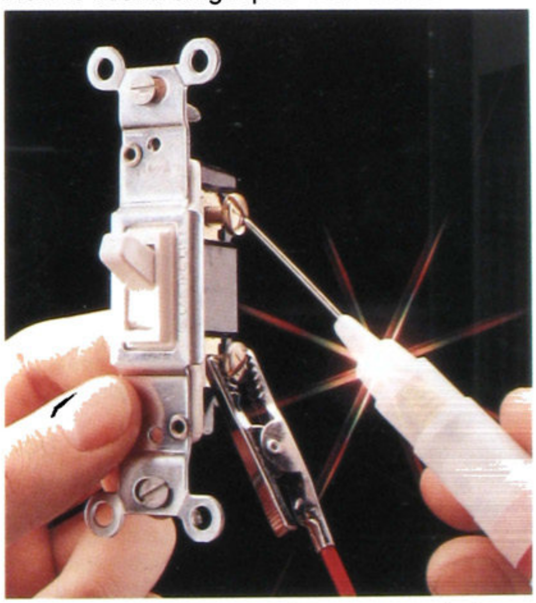
Never use a continuity tester on wires that might carry live current. Always shut off the power and disconnect the switch before testing for continuity.

Some specialty switches, like dimmers, cannot be tested for continuity. Electronic switches can be tested for manual operation using a continuity tester, but the automatic operation of these switches cannot be tested.

Everything You Need

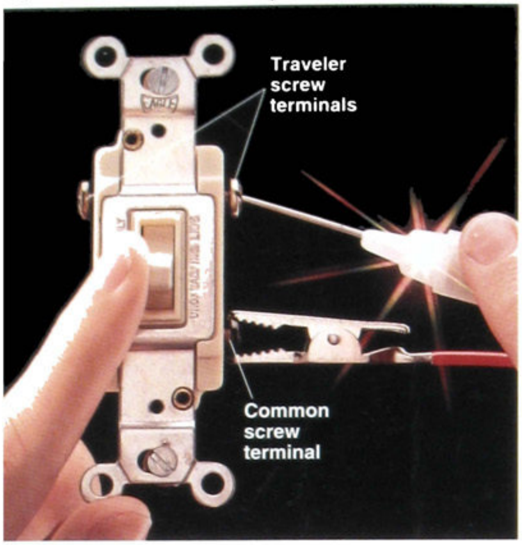
Tools: continuity tester.

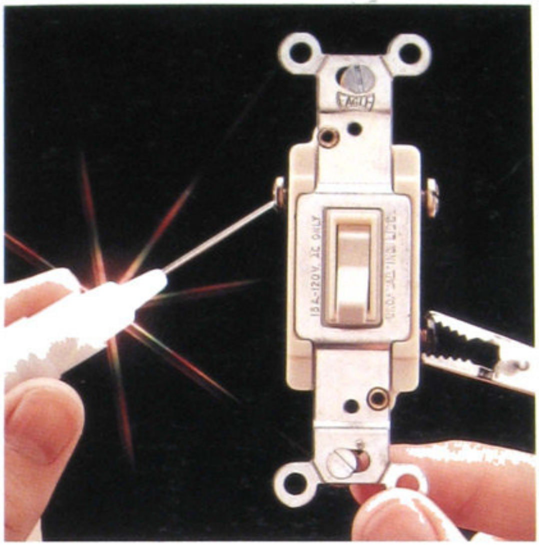
How to Test a Single-pole Wall Switch



Attach clip of tester to one of the screw terminals. Touch the tester probe to the other screw terminal. Flip switch lever from ON to OFF If switch is good, tester glows when lever is ON, but not when OFF

How to Test a Three-way Wall Switch





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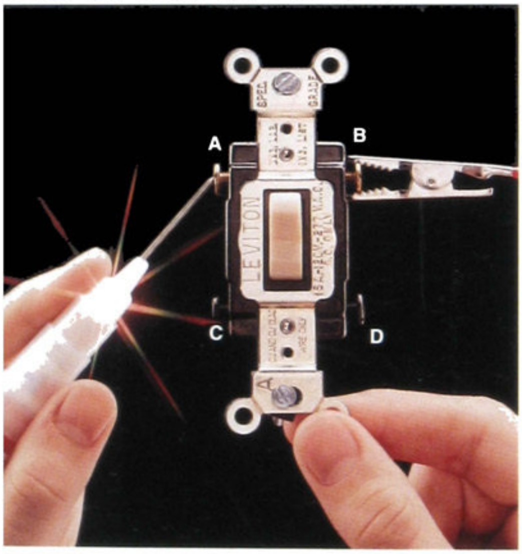
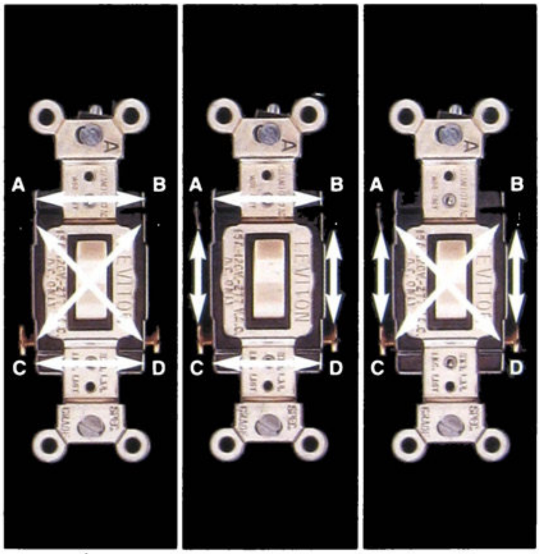
How to Test a Four-way Wall Switch





1 s..itch b. touc robe and clip of continuity
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B-D) The test should show continuous
diff rent pairs of screw termi-
ite position and repeat test
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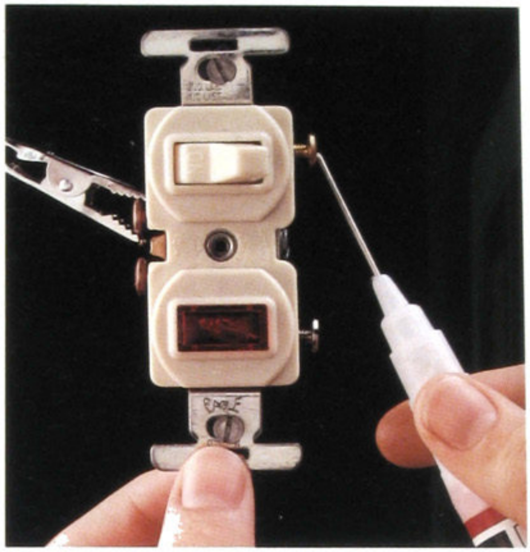
als

2 witch is good test show total of fou
uous pathways between scr terminals—
pathways for each lever position If not then switch
faulty and must be replaced (The arrangement of the
pathways may differ depending on the switch manu-
facturer The photo above shows the three possible
pathway arrangements

How to Test a Pilot-light Switch

1



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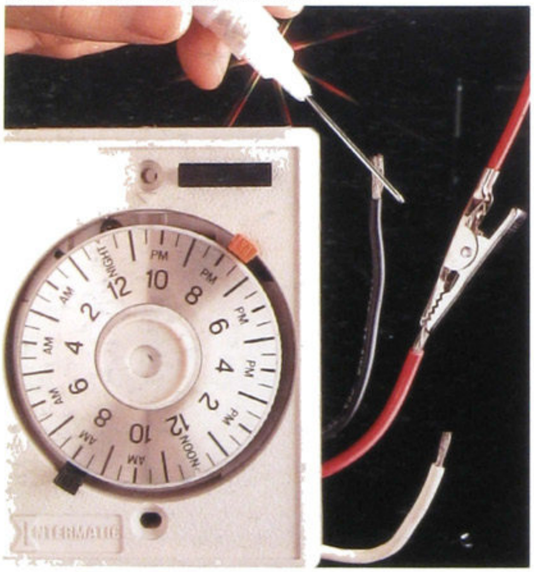
How to Test a Timer Switch



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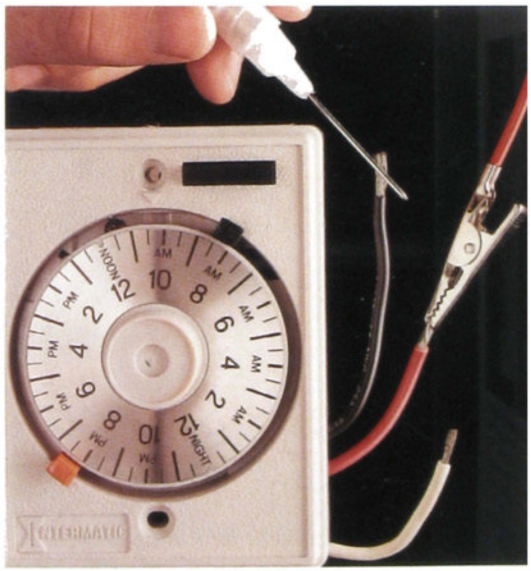
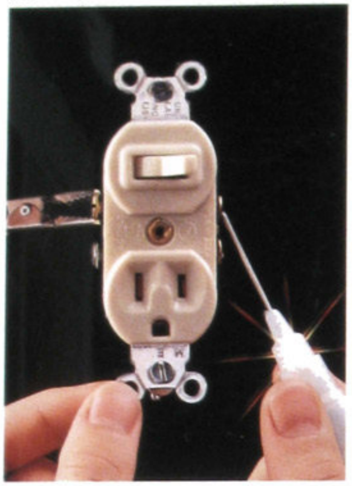


2 Rotate the dial clockwise until the OFF tab pass marker Tester should not glow. If does, the switch is faulty and must be replac

How to Test Switch/receptacle



Attach tester clip
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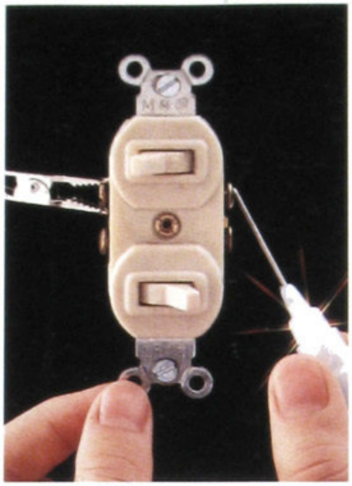
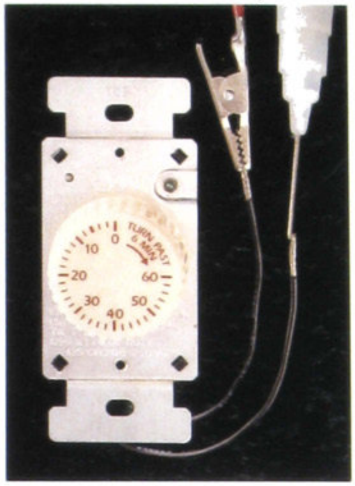
How to Test a Double Switch



Test each half of switch b
ing the

How to Test a Time-delay Switch



Attach tester clip
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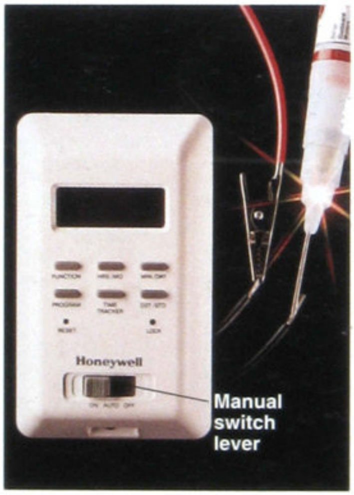
probe

How to Test Manual Operation of Electronic Switches

Automatic switch:
pl ck



Programmable switch: Att the
to a ire lead
the tes probe to the
Flip the manual itch
ON to OFF position. If the switch
working correctly, the tester will
when the switch lever is ON
when OFF

Motion-sensor switch:
tester d

Fixing & Replacing Wall Switches

Most switch problems are caused by loose wire connections. If a fuse blows or a circuit breaker trips when a switch is turned on, a loose wire may be touching the metal box. Loose wires also can cause switches to overheat or buzz.

Switches sometimes fail because internal parts wear out. To check for wear, the switch must be removed entirely and tested for continuity (pages 52 to 55). If the continuity test shows the switch is faulty, replace it.

Everything You Need

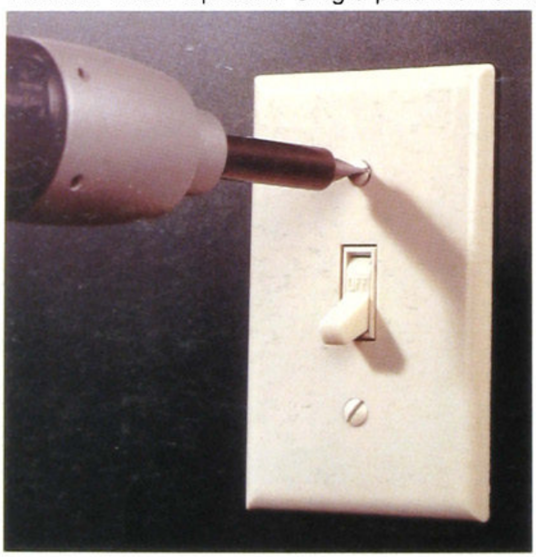
Tools: screwdriver, neon circuit tester, continuity tester, combination tool.

Materials: fine sandpaper, antioxidant paste (for aluminum wiring), masking tape.

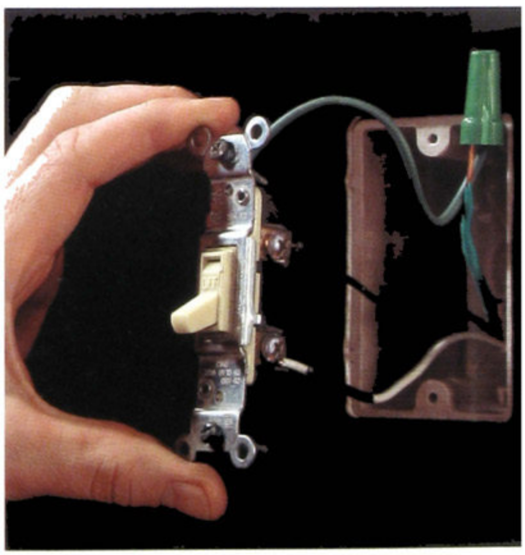
See Inspector's Notebook:

- Common Cable Problems (pages 124 to 125).
- Checking Wire Connections (pages 126 to 127).
- Electrical Box Inspection (pages 128 to 129).
- Inspecting Switches (page 133).

How to Fix or Replace a Single-pole Wall Switch



1 Turn off the power to the switch at the main service panel, then remove the switch coverplate.



2 Remove the mounting screws holding the switch to the electrical box. Holding the mounting straps carefully, pull the switch from the box. Be careful not to touch any bare wires or screw terminals until the switch has been tested for power.

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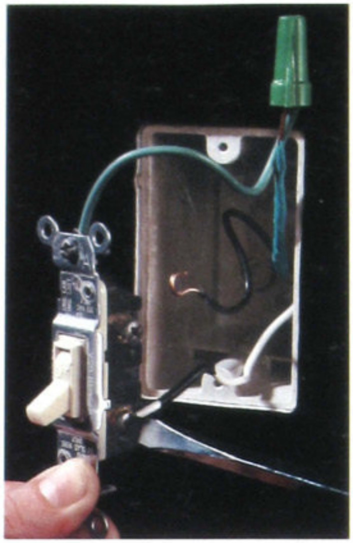

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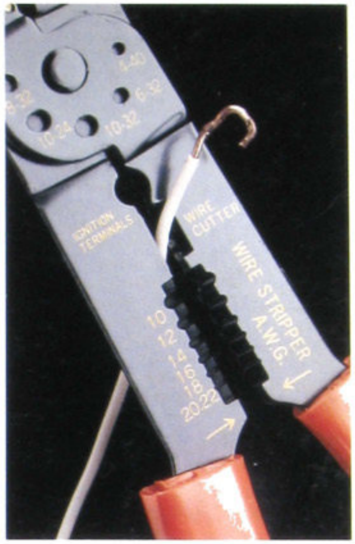

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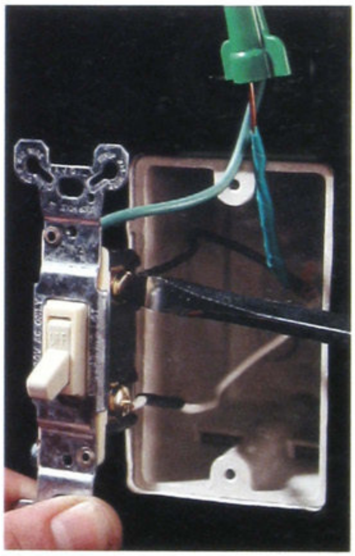
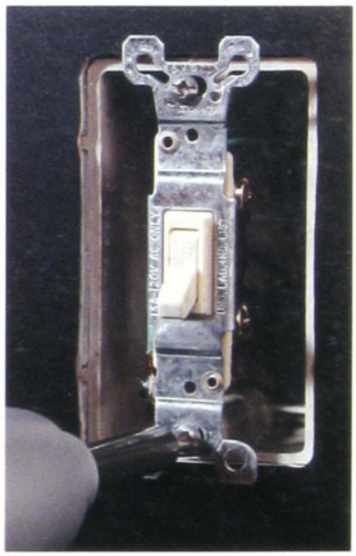
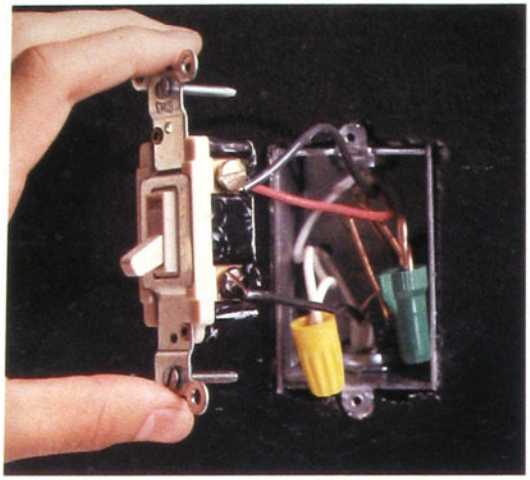


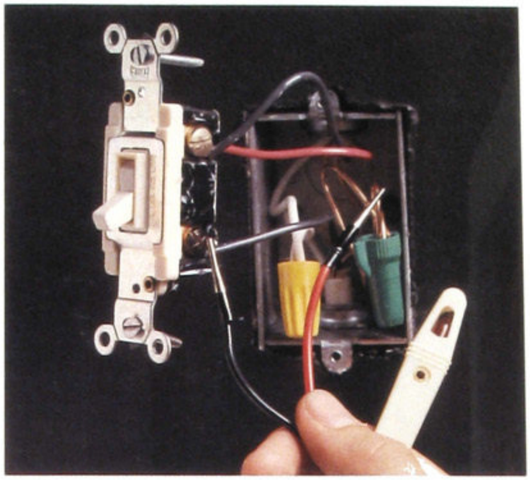
7 Connect the wires to the screw terminals on the switch Tighten the screws firmly but do not overtighten Overtightening may strip the screw threads



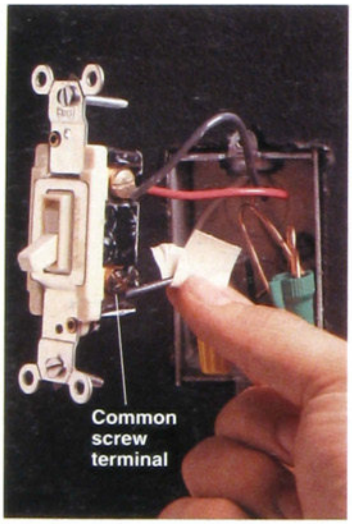
8 Remount the switch carefully tucking the wires inside the box Reattach the switch coverplate and turn on the power to the switch at the main service panel



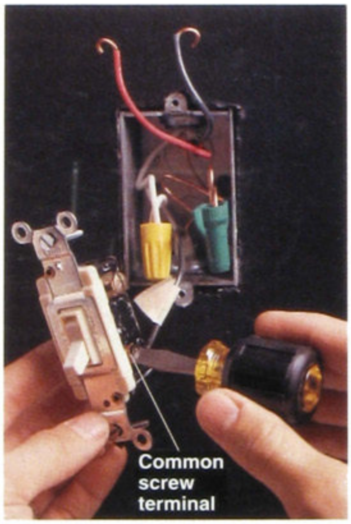
1 Turn off the power to the switch at the main servi panel then remove the switch coverplate and mounting screws Holding the mounting strap carefully pull the switch from the box Be careful not to touch the bare wires or screw terminals until they have been tested for power



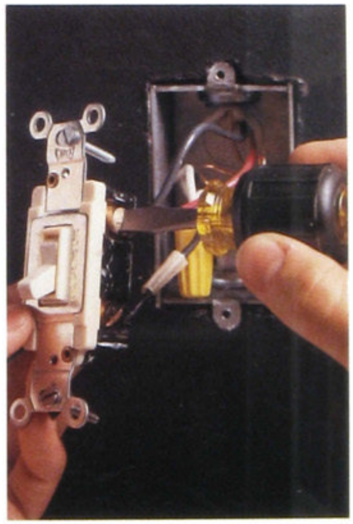
2 Test for power by touching one probe of the neon circuit tester to the grounded metal box or to the bare copper grounding wire and touching the other probe to each screw terminal Tester should not glow If it does there is still power entering the box Return to the service panel and turn off the correct circuit



3 Locate dark common screw terminal. and use masking tape to label the "common wire attached to it Disconnect wires and remove switch Test switch for continuity (page 53) If it tests faulty,buy a replacement Inspect wires for nicks and scratches If necessary clip damaged wires and strip them (page 23).

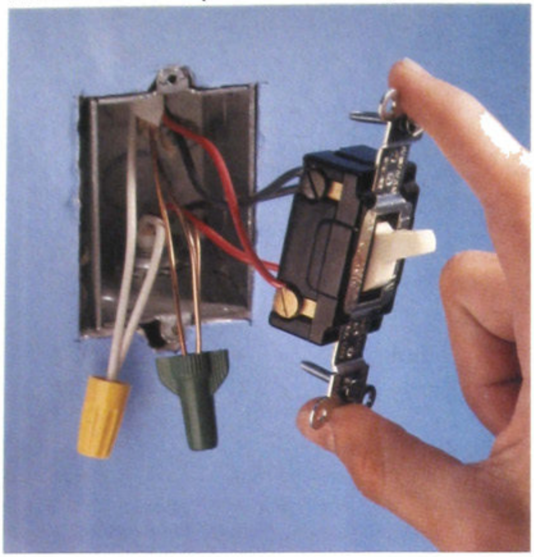


4 Connect the common wire to the dark common screw terminal on the switch On most three-way switches the common screw terminal is copper Or it may be labeled with the word COMMON stamped on the back of the switch If the switch has a grounding screw connect it to the circuit grounding wires with a pigtail.

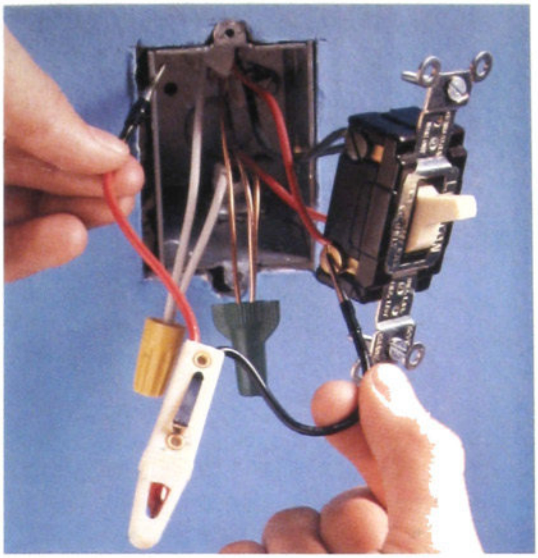


5 Connect the remaining two circuit wires to the screw terminal These wires are interchangeable and can be connected to either screw terminal Carefully tuck the wires into the box Remount the switch, and attach the coverplat Turn on the power at the main service panel.

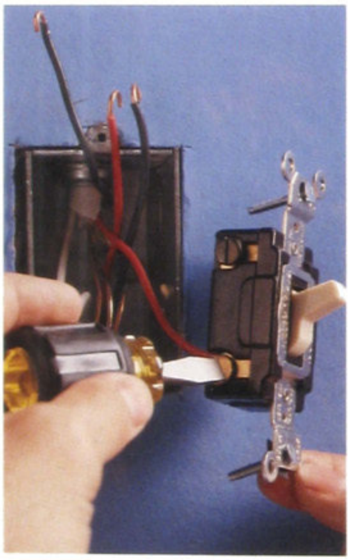
How to Fix or Replace a Four-way Wall Switch



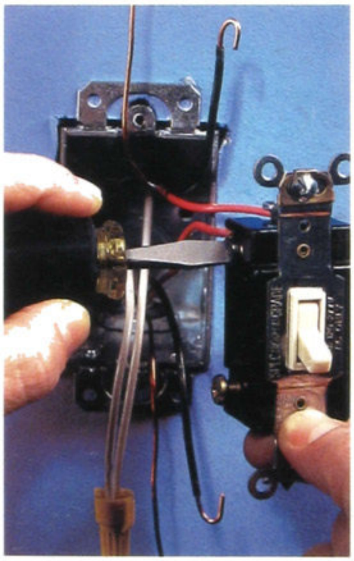
1 Turn off the power to the switch at the main service panel, then remove the switch coverplate and mounting screws. Holding the mounting strap carefully, pull the switch from the box. Be careful not to touch any bare wires or screw terminals until they have been tested for power.



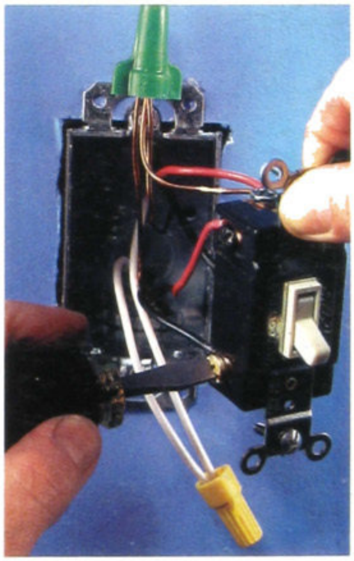
2 Test for power by touching one probe of the neon circuit tester to the grounded metal box or bare copper grounding wire, and touching the other probe to each of the screw terminals. Tester should not glow. If it does, there is still power entering the box. Return to the service panel, and turn off the correct circuit.



3 Disconnect the wires and inspect them for nicks and scratches. If necessary, clip damaged wires and strip them (page 23). Test the switch for continuity (page 53). Buy a replacement if the switch tests faulty.



4 Connect two wires from one incoming cable to the top set of screw terminals.



5 Attach remaining wires to the other set of screw terminals. Pigtail the grounding wires to the grounding screw. Carefully tuck the wires inside the switch box, then remount the switch and coverplate. Turn on power at main service panel.

Toggle-type dimmer resembles standard switches. Toggle dimmers are available in both single-pole and three-way designs.

Dial-type dimmer is the most common style. Rotating the dial changes the light intensity.

Slide-action dimmer has an illuminated face that makes the switch easy to locate in the dark.

Automatic dimmer has an electronic sensor that adjusts the light fixture to compensate for the changing levels of natural light. An automatic dimmer also can be operated manually.

Dimmer Switches

A dimmer switch makes it possible to vary the brightness of a light fixture. Dimmers are often installed in dining rooms, recreation areas, or bedrooms.

Any standard single-pole switch can be replaced with a dimmer as long as the switch box is of adequate size. Dimmer switches have larger bodies than standard switches. They also generate a small amount of heat that must dissipate. For these reasons, dimmers should not be installed in undersized el trical boxes or in boxes that are crowded with circuit wires. Always follow the manufacturer specifications for installation.

In lighting configurations that use three-way switches (pages 46 to 47), one of the three-way switches can be replaced with a special three-way dimmer. In this arrangement, all switches will turn the light fixture on and off, but light intensity will be controlled only from the dimmer switch.

Dimmer switches are available in several styles (photo, left). All types have wire leads instead of screw terminals, and they are connected to circuit wires using wire connectors. Some types have a green grounding lead that should be connected to the grounded metal box or to the bare copper grounding wires.

Everything You Need

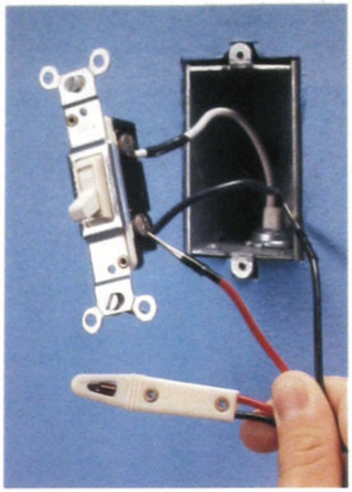
Tools: screwdriver, neon circuit tester, needlenose pliers.

Materials: wire connectors, masking tape.

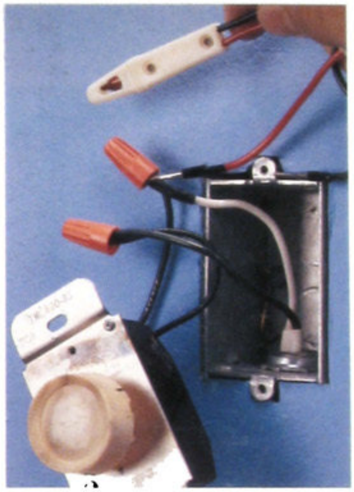
See Inspector's Notebook:

- Electrical Box Inspection (pages 128 to 129).

1 Turn off power to switch at the main service panel, then remove the coverplate and mounting screws. Holding the mounting straps carefully pull switch from the box. Be careful not to touch bare wires or screw terminals until they have been tested for power

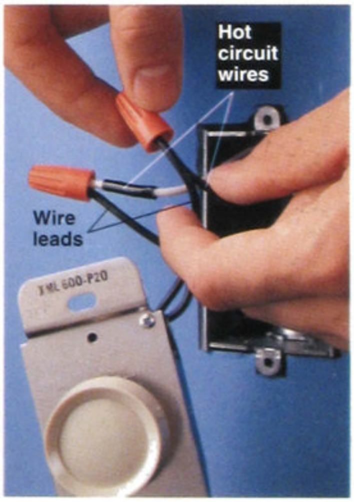


2 Test for power by touching one probe of neon circuit tester to the grounded metal box or to the bare copper grounding wires, and touching other probe to each screw terminal. Tester should not glow If it does, there is still power entering the box. Return to the service panel and turn off the correct circuit.

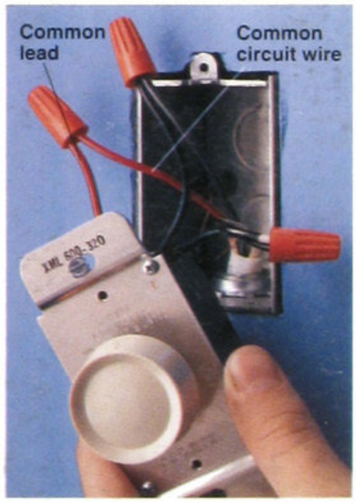


If replacing an old dimmer, test for power by touching one probe of circuit tester to the grounded metal box or bare copper grounding wires, and inserting the other probe into each wire connector Tester should not glow If it does, there is still power entering the box Return to the service panel, and turn off the correct circuit.

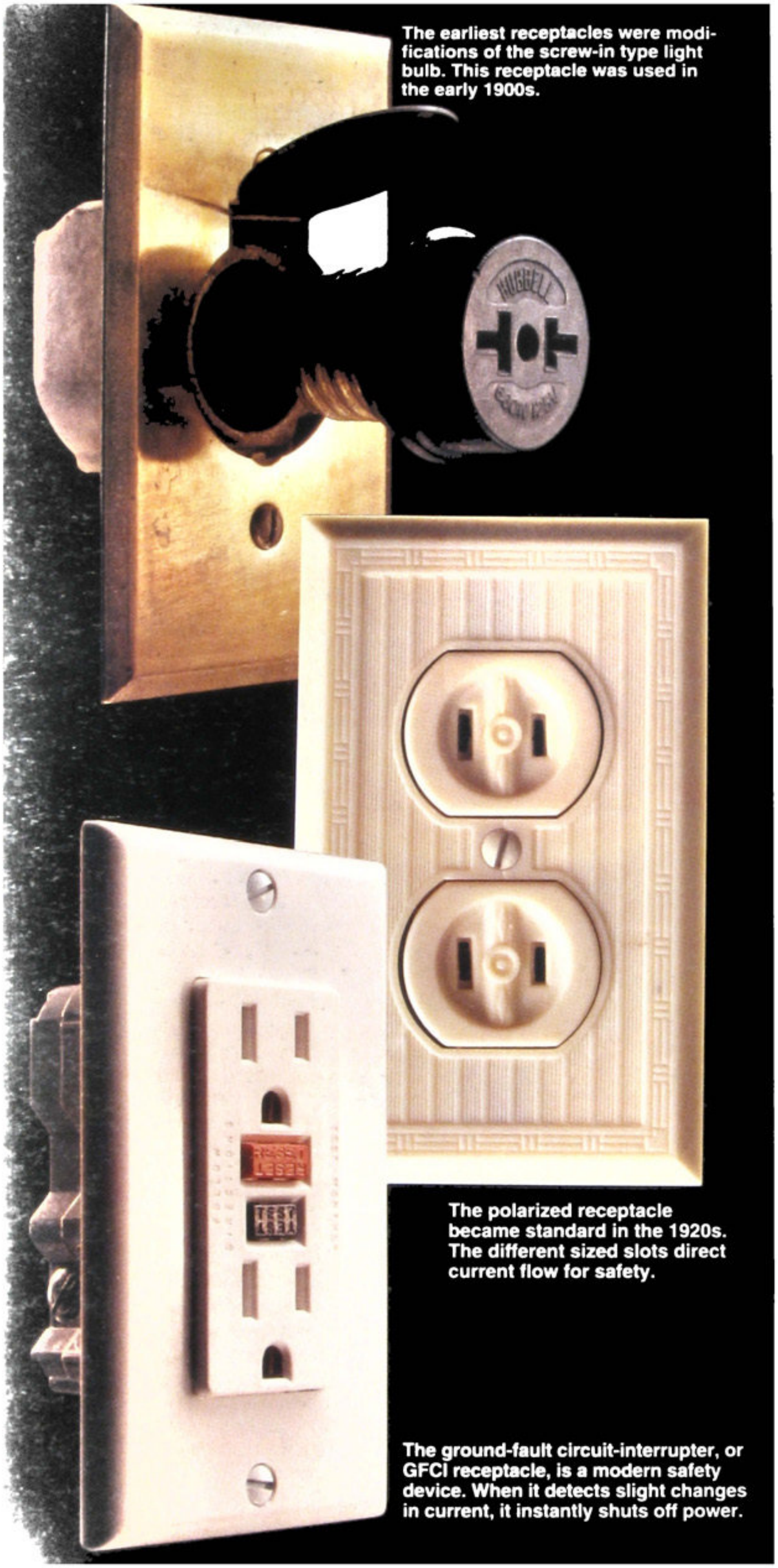
3 Disconnect the circuit wires and remove the switch. Straighten the circuit wires, and clip the ends, leaving about ½" of the bare wire end exposed.



4 Connect the wire leads on the dimmer switch to the circuit wires, using wire connectors. The switch leads are interchangeable and can be attached to either of the two circuit wires.



Three-way dimmer has an additional wire lead. This "common" lead is connected to the common circuit wire. When replacing a standard three-way switch with a dimmer, the common circuit wire is attached to the darkest screw terminal on the old switch (page 58).



The earliest receptacles were modifications of the screw-in type light bulb. This receptacle was used in the early 1900s.

The polarized receptacle became standard in the 1920s. The different sized slots direct current flow for safety.

The ground-fault circuit-interrupter, or GFCI receptacle, is a modern safety device. When it detects slight changes in current, it instantly shuts off power.

Common Receptacle Problems

Household receptacles also called outlets have no moving parts to wear out and usually last for many years without servicing Most problems associated with receptacles are actually caused by faulty lamps and appliances or their plugs and cords However the constant plugging in and removal of appliance cords can wear out the metal contacts inside a receptacle Any receptacle that does not hold plugs firml should be replaced

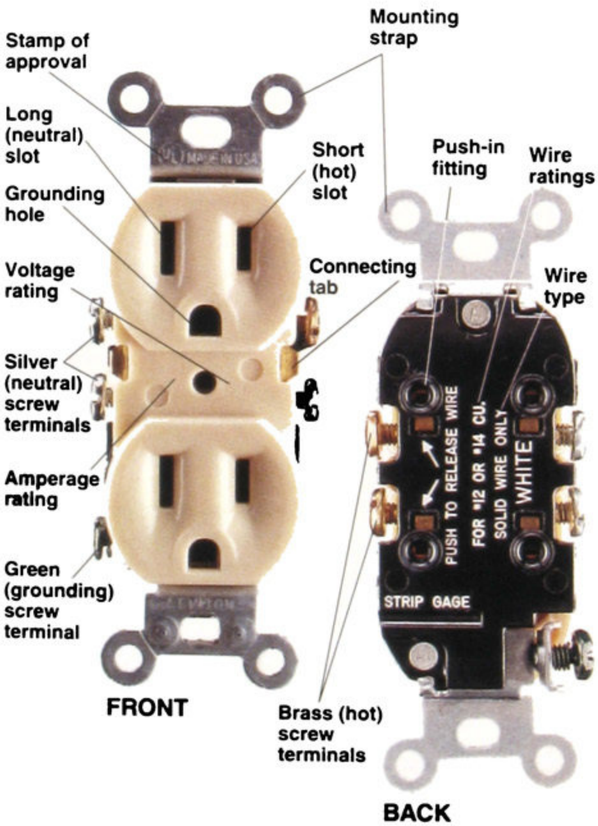
A loose wire connection is another possible problem A loose connection can spark (called arcing) trip a circuit breaker or cause heat to build up in the receptacle box creating a potential fire hazard

Wires can come loose for a number of reasons Everyday ibrations caused by walking across floors or from nearby street traffic may cause a connection to shake loose In addition because wires heat and cool with normal use the ends of the wires will expand and contract slightly This mov ment also may cause the to come loose from the scr terminal connections

See Inspector's Notebook:

- Checking Wire Connections (pages 126 to 127).
- Electrical Box Inspection (pages 128 to 129).
- Inspecting Receptacles (pages 132 to 133).

Problem		Repair
	Circuit breaker trips repeatedly, or fuse burns out immediately after being replaced.	1. Repair or replace worn or damaged lamp or appliance cord. 2. Move lamps or appliances to other circuits to prevent overloads (page 34). 3. Tighten any loose wire connections (pages 72 to 73). 4. Clean dirty or oxidized wire ends (page 72).
	Lamp or appliance does not work.	1. Make sure lamp or appliance is plugged in. 2. Replace burned-out bulbs. 3. Repair or replace worn or damaged lamp or appliance cord. 4. Tighten any loose wire connections (pages 72 to 73). 5. Clean dirty or oxidized wire ends (page 72). 6. Repair or replace any faulty receptacle (pages 72 to 73).
	Receptacle does not hold plugs firmly.	1. Repair or replace worn or damaged plugs (pages 96 to 97). 2. Replace faulty receptacle (pages 72 to 73).
	Receptacle is warm to the touch, buzzes, or sparks when plugs are inserted or removed.	1. Move lamps or appliances to other circuits to prevent overloads (page 34). 2. Tighten any loose wire connections (pages 72 to 73). 3. Clean dirty or oxidized wire ends (page 72). 4. Replace faulty receptacle (pages 72 to 73).

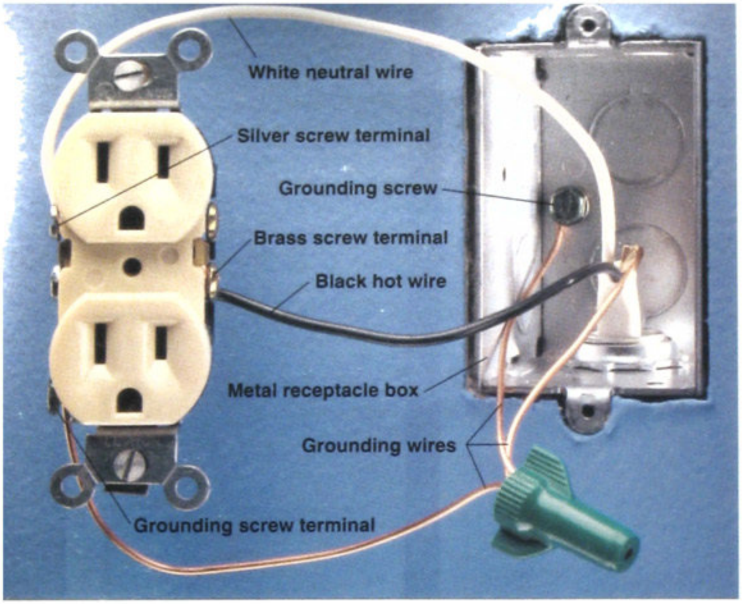


The standard duplex receptacle has two halves for receiving plugs. Each half has a long (neutral) slot, a short (hot) slot, and a U-shaped grounding hole. The slots fit the wide prong, narrow prong, and grounding prong of a three-prong plug. This ensures that the connection between receptacle and plug will be polarized and grounded for safety (page 16).

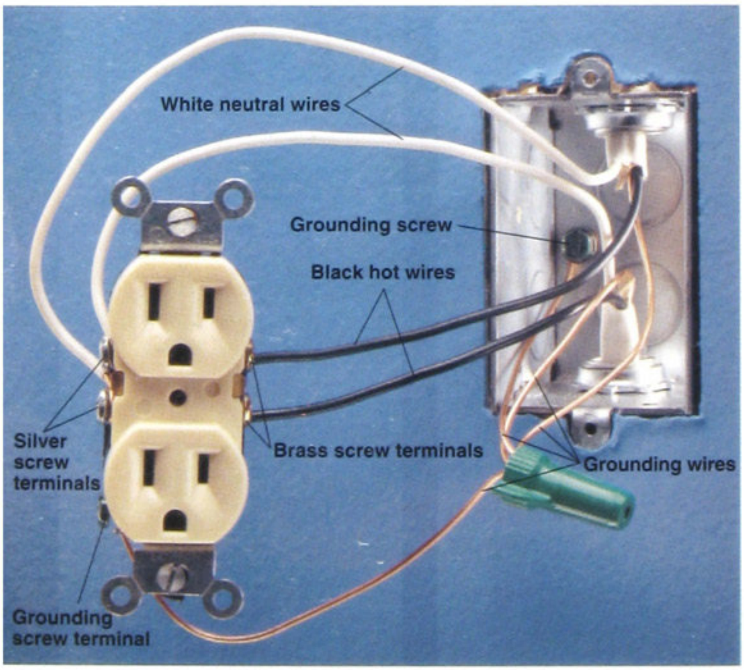
Wires are attached to the receptacle at screw terminals or push-in fittings. A connecting tab between the screw terminals allows a variety of different wiring configurations. Receptacles also include mounting straps for attaching to electrical boxes.

Stamps of approval from testing agencies are found on the front and back of the receptacle. Look for the symbol UL or UND. LAB. INC. LIST to make sure the receptacle meets the strict standards of Underwriters Laboratories.

The receptacle is marked with ratings for maximum volts and amps. The common receptacle is marked 15A, 125V Receptacles marked CU or COPPER are used with solid copper wire. Those marked CU-CLAD ONLY are used with copper-coated aluminum wire. Only receptacles marked CO/ALR may be used with solid aluminum wiring (page 22). Receptacles marked AL/CU no longer may be used with aluminum wire, according to code.



Single cable entering the box indicates end-of-run wiring. The black hot wire is attached to a brass screw terminal, and the white neutral wire is connected to a silver screw terminal. If the box is metal, the grounding wire is pigtailed to the grounding screws of the receptacle and the box. In a plastic box, the grounding wire is attached directly to the grounding screw terminal of the receptacle.



Two cables entering the box indicate middle-of-run wiring. Black hot wires are connected to brass screw terminals, and white neutral wires to silver screw terminals. The grounding wire is pigtailed to the grounding screws of the receptacle and the box.

Receptacle Wiring

A 125-volt duplex receptacle can be wired to the electrical system in a number of ways. The most common are shown on these pages.

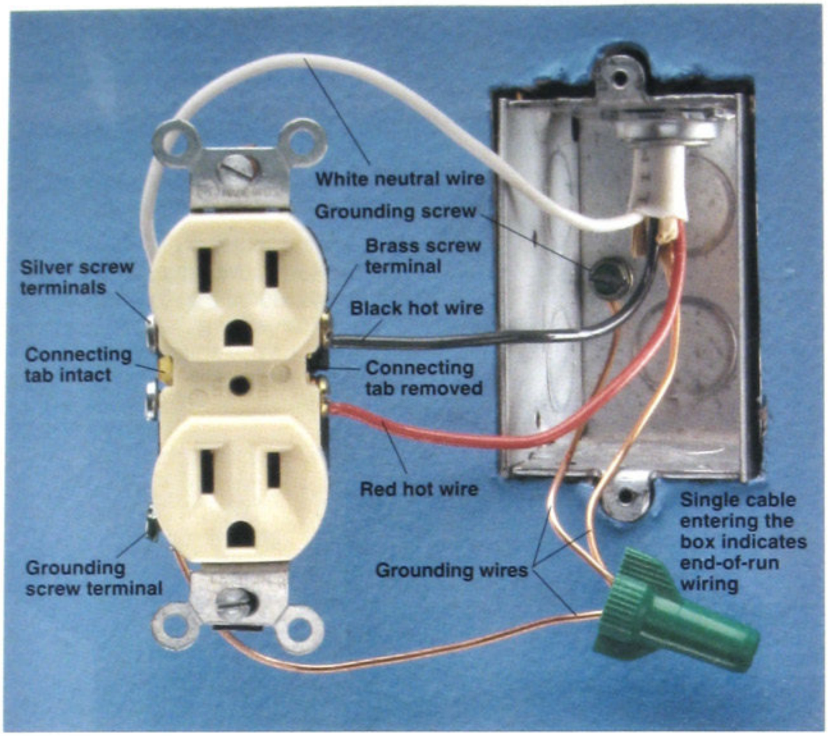
Wiring configurations may vary slightly from these photographs, depending on the kind of receptacles used, the type of cable, or the technique of the electrician who installed the wiring. To make dependable repairs or replacements, use masking tape and label each wire according to its location on the terminals of the existing receptacle.

Receptacles are wired as either **end-of-run** or **middle-of-run.** These two basic configurations are easily identified by counting the number of cables entering the receptacle box. End-of-run wiring has only one cable, indicating that the circuit ends. Middle-of-run wiring has two cables, indicating that the circuit continues on to other receptacles, switches, or fixtures.

A split-circuit receptacle is shown on the opposite page. Each half of a split-circuit receptacle is wired to a separate circuit. This allows two appliances of high wattage to be plugged into the same receptacle without blowing a fuse or tripping a breaker. This wiring configuration is similar to a receptacle that is controlled by a wall switch. Code requires a **switch-controlled receptacle** in any room that does not have a built-in light fixture operated by a wall switch.

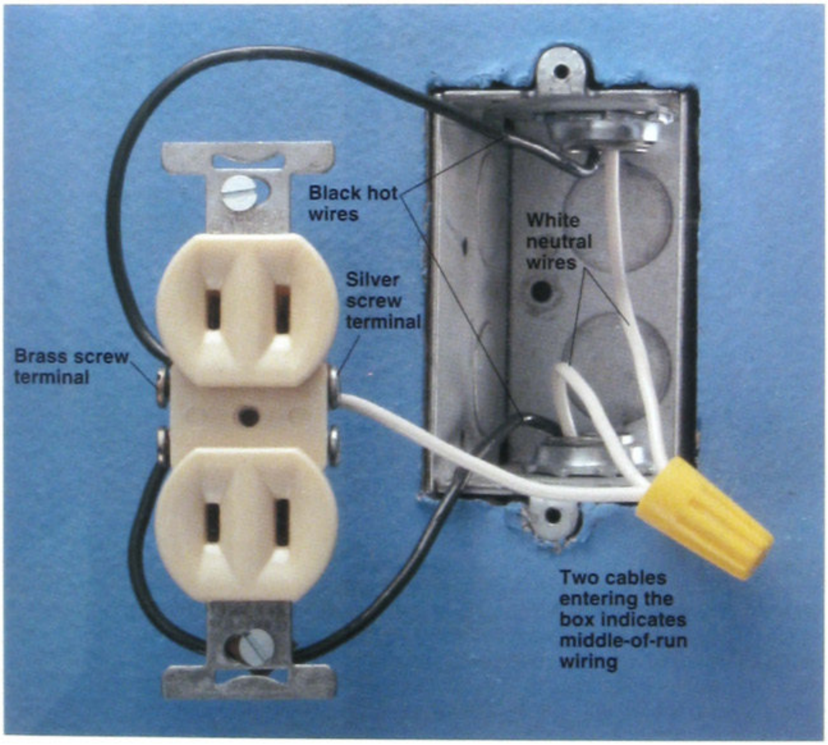
Split-circuit and switch-controlled receptacles are connected to two hot wires, so use caution during repairs or replacements. Make sure the connecting tab between the hot screw terminals is removed.

Two-slot receptacles are common in older homes. There is no grounding wire attached to the receptacle, but the box may be grounded with armored cable or conduit (page 20).



Split-circuit receptacle is attached to a black hot wire, a red hot wire, a white neutral wire, and a bare grounding wire. The wiring is similar to a switch-controlled receptacle.

The hot wires are attached to the brass screw terminals, and the connecting tab or fin between the brass terminals is removed. The white wire is attached to a silver screw terminal, and the connecting tab on the neutral side remains intact. The grounding wire is pigtailed to the grounding screw terminal of the receptacle and to the grounding screw attached to the box.



Two-slot receptacle is often found in older homes. The black hot wires are connected to the brass screw terminals, and the white neutral wires are pigtailed to a silver screw terminal

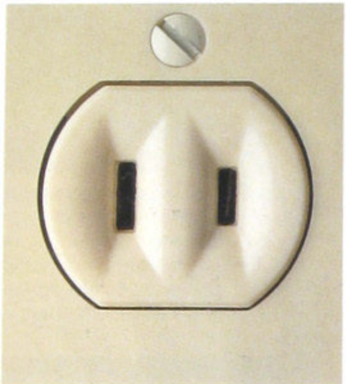
Two-slot receptacles may be replaced with three-slot types, but only if a means of grounding exists at the receptacle box.

Basic Types of Receptacles

Several different types of receptacles are found in the typical home. Each has a unique arrangement of slots that accepts only a certain kind of plug, and each is designed for a specific job.

Household receptacles provide two types of voltage: normal and high voltage. Although voltage ratings have changed slightly over the years, normal receptacles should be rated for 110, 115, 120, or 125 volts. For purposes of replacement, these ratings are considered identical. High-voltage receptacles are rated at 220, 240, or 250 volts. These ratings are considered identical

When replacing a receptacle, check the amperage rating of the circuit at the main service panel, and buy a receptacle with the correct amperage rating (page 28).



15 amps, 125 volts. Polarized two-slot receptacle is common in homes built before 1960 Slots are different sizes to accept polarized plugs.

15 amps, 125 volts. Three-slot grounded receptacle has two different size slots and a U-shaped hole for grounding. It is required in all new wiring installations.

20 amps, 125 volts. This three-slot grounded receptacle features a special T-shaped slot. It is installed for use with large appliances or portable tools that require 20 amps of current.

15 amps, 250 volts. This receptacle is used primarily for window air conditioners. It is available as a single unit or as half of a duplex receptacle with the other half wired for 125 volts.

30 amps, 125/250 volts. This receptacle is used for clothes dryers. It provides high-voltage current for heating coils and 125-volt current to run lights and timers.

50 amps, 125/250 volts. This receptacle is used for ranges. The high-voltage current powers heating coils, and the 125-volt current runs clocks and lights.

Older Receptacles

Older receptacles may look different from more modern types, but most will stay in good working order. Follow these simple guidelines for evaluating or replacing older receptacles:

- Never replace an older receptacle with one of a different voltage or higher amperage rating.
- Any two-slot, unpolarized receptacle should be replaced with a two- or three-slot polarized receptacle.
- If no means of grounding is available at the receptacle box, install a GFCI (pages 74 to 77).
- If in doubt, seek the advice of a qualified electrician.

Never alter the prongs of a plug to fit an older receptacle. Altering the prongs may remove the grounding or polarizing features of the plug.

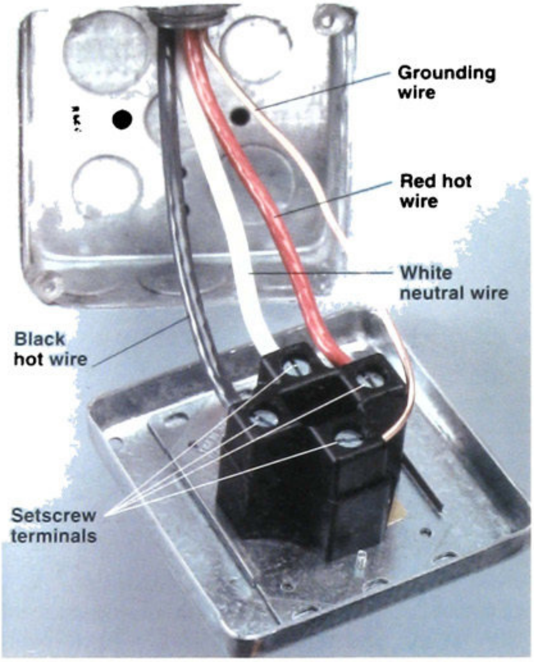
Unpolarized receptacles have slots that are the same length. Modern plug types may not fit these receptacles. Never modify the prongs of a polarized plug to fit the slots of an unpolarized receptacle

Surface-mounted receptacles were popular in the 1940s and 1950s for their ease of installation Wiring often ran in the back of hollowed-out base moldings. Surface-mounted receptacles are usually ungrounded

Ceramic duplex receptacles were manufactured in the 1930s. They are polarized but ungrounded, and they can be wired for either 125 volts or 250 volts.

Twist-lock receptacles are designed to be used with plugs that are inserted and rotated. A small tab on the end of one of the prongs prevents the plug from being pulled from the receptacle.

Ceramic duplex receptacle has a unique hourglass shape. The receptacle shown above is rated for 250 volts but only 5 amps, and would not be allowed by today's electrical codes.



A receptacle rated for 125/250 volts
carrying 125 vol'
copper groundi
setscre.. terminal

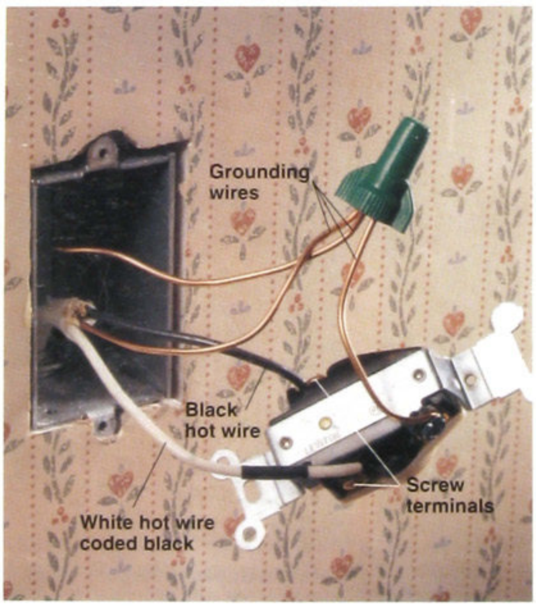
High-voltage Receptacles

High-voltage receptacles provide current to large appliances like clothes dryers, ranges, water heaters, and air conditioners The slot configuration of a high-voltage receptacle (page 66) will not accept a plug rated for 125 volts

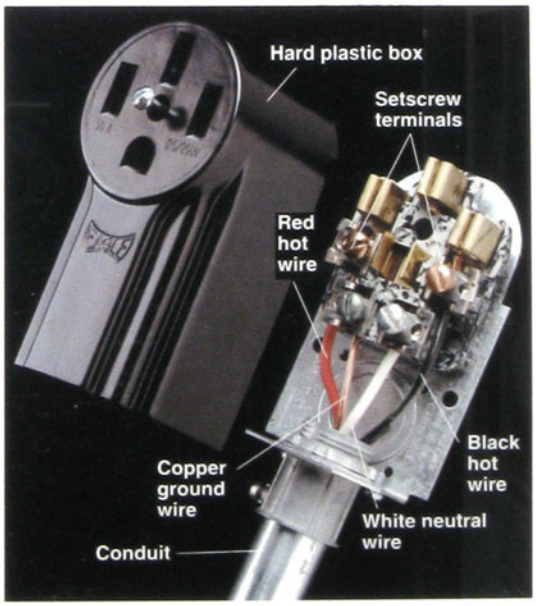
A high-voltage receptacle can be wired in one of two ways In a standard high-voltage receptacle voltage is brought to the receptacle with two hot wires, each carrying a maximum of 125 volts No white neutral wire is necessary but a grounding wire should be attached to the receptacle and to the metal receptacle box Conduit can also act as a ground from the metal receptacle box back to the service panel

A clothes dryer or range also may require normal current (a maximum of 125 volts) to run lights, timers and clocks If so, a white neutral wire will be attached to the receptacle The appliance itself will split the incoming current into a 125-volt circuit and a 250-volt circuit

Repair or replace a high-voltage receptacle using the techniques shown on pages 72 to 73 It is important to identify and tag all wires on the existing receptacle so that the new receptacl will be properly wired



Standard receptacle rated for 250 volts has two incoming hot wires and no neutral wire A grounding wire is pigtailed to the receptacle and to the metal receptacle box.



Surface-mounted receptacle rated for 250 volts has a hard plastic box that can be installed on concrete or block walls Surface-mounted receptacles are often found in basements and utility rooms.

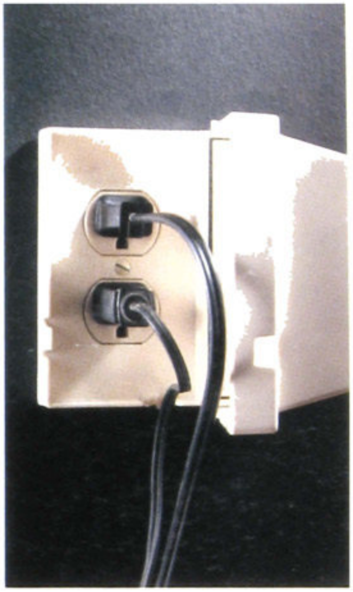
Childproof Receptacles & Other Accessories

Childproof your receptacles or adapt them for special uses by adding receptacle accessories Before installing an accessory, be sure to read the manufacturer's instructions

Homeowners with small children should add inexpensive caps or covers to guard against accidental electric shocks.

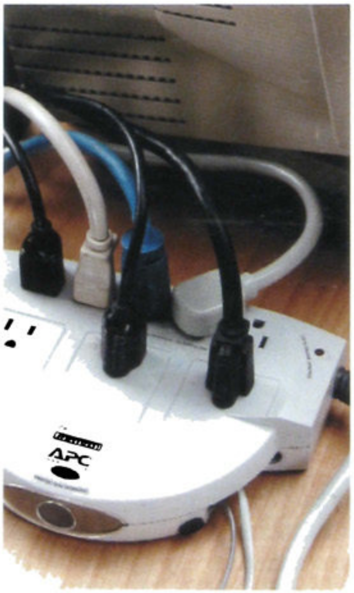
Plastic caps do not conduct electricity and are virtually impossible for small children to remove A receptacle cover attaches directly to the receptacle and fits over plugs, preventing the cords from being removed

Protect children against the possibility of electrical shock Place protective caps in any receptacles that are not being used



Prevent accidents b, receptacle cover to pre and plugs from being

Install more than two plugs in a single duplex receptacle by using a multi-outlet power strip A multi-outlet strip should have a built-in circuit breaker or fuse to protect against overloads.



Protect electronic equipment, such as a home computer or stereo, with a surge protector The surge protector prevents any damage to sensitive wiring or circuitry caused by sudden drops or surges in power.

Recessed wall receptacle permits a plug-in clock to be hung flush against a wall surface

Testing Receptacles for Power, Grounding & Polarity

Test for power to make sure that live voltage is not reaching the receptacle during a repair or replacement project.

Test for grounding to plan receptacle replacements. The test for grounding will indicate how an existing receptacle is wired and whether a replacement receptacle should be a two-slot polarized receptacle, a grounded three-slot receptacle, or a GFCI

If the test indicates that the hot and neutral wires are reversed (page 133), make sure the wires are installed correctly on the replacement receptacle.

Test for hot wires if you need to confirm which wire is carrying live voltage

An inexpensive neon circuit tester makes it easy to perform these tests. It has a small bulb that glows when electrical power flows through it.

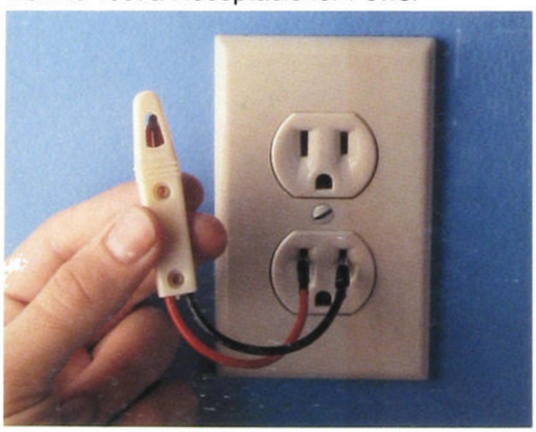
Remember that the tester only glows when it is part of a complete circuit. For example, if you touch one probe to a hot wire and do not touch anything with the other probe, the tester will not glow, even though the hot wire is carrying power. When using the tester, take care not to touch the metal probes.

When testing for power or grounding, always confirm any negative (tester does not glow) results by removing the coverplate and examining the receptacle to make sure all wires are intact and properly connected. Do not touch any wires without first turning off the power at the main service panel.

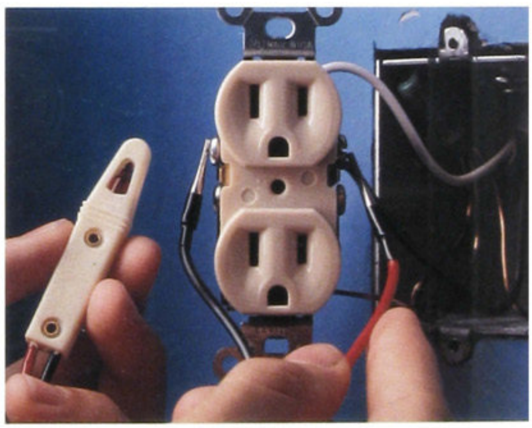
Everything You Need

Tools: neon circuit tester, screwdriver.

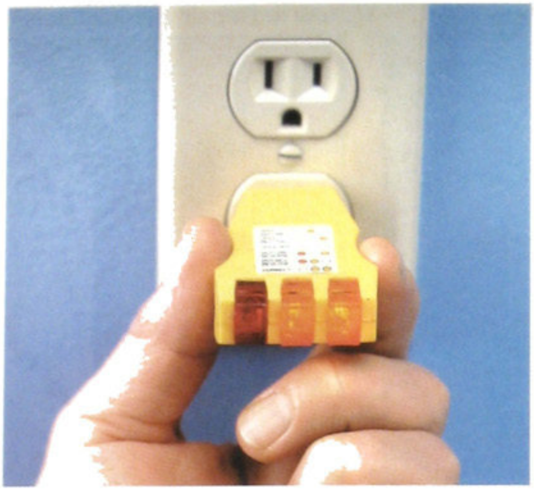
How to Test a Receptacle for Power



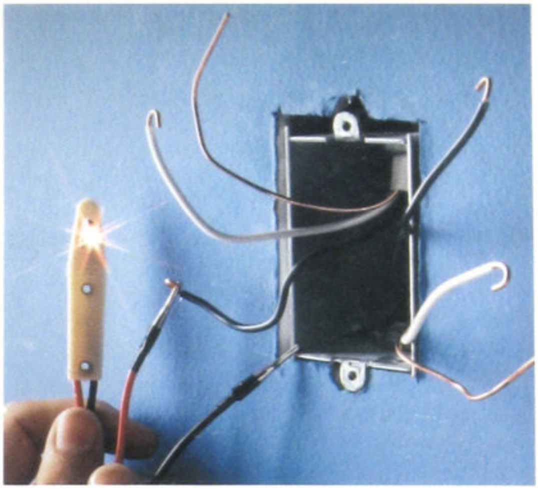
1 Turn off power at the main service panel. Place one probe of the tester in each slot of the receptacle. The tester should not glow If it does glow, the correct circuit has not been turned off at the main service panel. Test both ends of a duplex receptacle. Remember that this is a preliminary test. You must confirm that power is off by removing the coverplate and testing for power at the receptacle wires (step 2).



2 Remove the receptacle coverplate. Loosen the mounting screws and carefully pull the receptacle from its box. Take care not to touch any wires. Touch one probe of the neon tester to a brass screw terminal and one probe to a silver screw terminal. The tester should not glow If it does, you must shut off the correct circuit at the service panel. If wires are connected to both sets of terminals, test both sets.

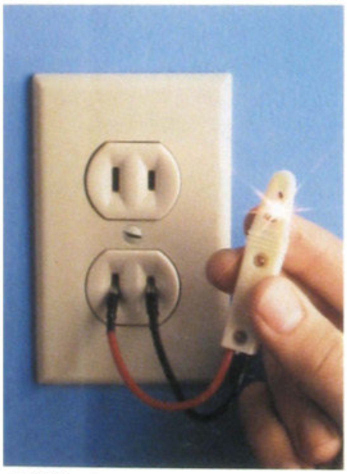


Use a plug-in tester to test a three-slot receptacle. With the power on, insert the tester into the suspect outlet. The face of the tester has three colored lights that will light up in different combinations, according to the outlet's problem. A reference chart is provided with tester, and many have a chart on the tester itself.

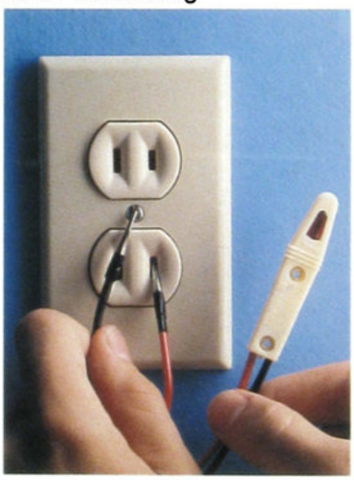


Test for hot wires. Occasionally, you may need to determine which wire is hot. With the power turned off, carefully separate all ends of wires so that they do not touch each other or anything else. Restore power to the circuit at the main service panel. Touch one probe of the neon tester to the bare grounding wire or grounded metal box, and the other probe to the ends of each of the wires. Check all wires. If the tester glows, the wire is hot. Label the hot wire for identification, and turn off power at the service panel before continuing work.

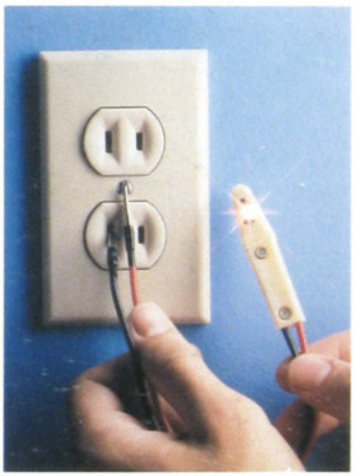
How to Test a Two-slot Receptacle for Grounding



1 With the power turned on, place one probe of the neon tester in each slot. The tester should glow If it does not glow, then there is no power to the receptacle.



2 Place one probe of the tester in the short (hot) slot, and touch the other probe to the coverplate screw. The screw head must be free of paint, dirt, and grease. If the tester glows, the receptacle box is grounded. If it does not glow, proceed to step 3.



3 Place one probe of the tester in the long (neutral) slot and touch the other to the coverplate screw. If the tester glows, the receptacle box is grounded but hot and neutral wires are reversed (page 133). If tester does not glow, the box is not grounded.

Repairing & Replacing Receptacles

Receptacles are easy to repair. After shutting off power to the receptacle circuit, remove the coverplate and inspect the receptacle for any obvious problems such as a loose or broken connection, or wire ends that are dirty or oxidized. Remember that a problem at one receptacle may affect other receptacles in the same circuit. If the cause of a faulty receptacle is not readily apparent, test other receptacles in the circuit for power (page 70).

When replacing a receptacle, check the amperage rating of the circuit at the main service panel, and buy a replacement receptacle with the correct amperage rating (page 34).

When installing a new receptacle, always test for grounding (pages 70 to 71). Never install a three-slot receptacle where no grounding exists. Instead, install a two-slot polarized or GFCI receptacle.

Everything You Need

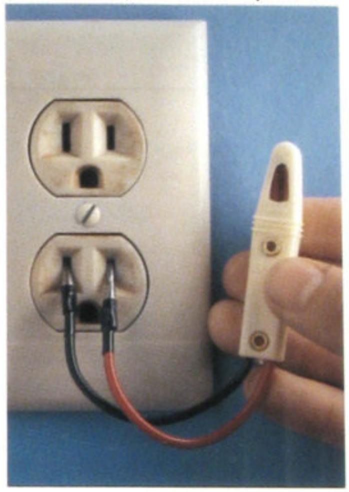
Tools: neon circuit tester, screwdriver, vacuum cleaner (if needed).

Materials: fine sandpaper, antioxidant paste, masking tape (if needed).

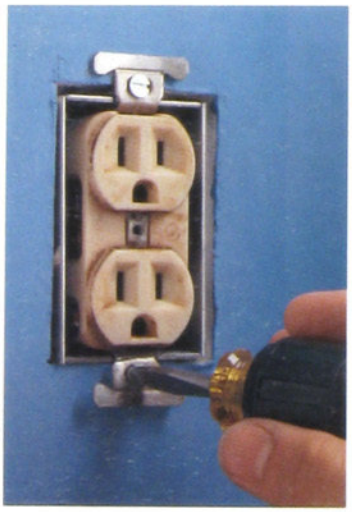
See Inspector's Notebook:

- Electrical Box Inspection (pages 128 to 129).
- Inspecting Switches and Receptacles (pages 132 to 133).

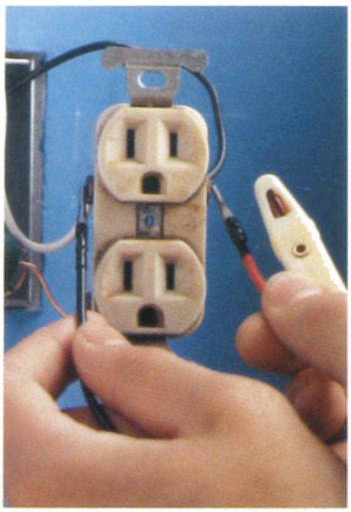
How to Repair a Receptacle



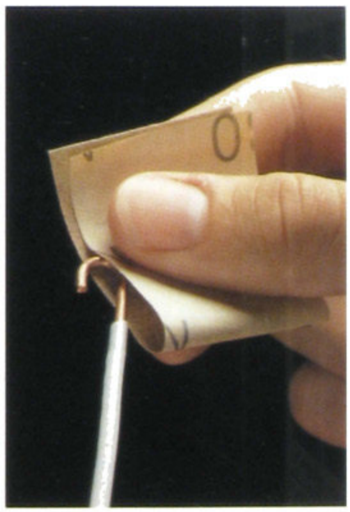
1 Turn off power at the main service panel Test the receptacle for power with a neon circuit tester (page 70) Test both ends of a duplex receptacle Remove the coverplate, using a screwdriver



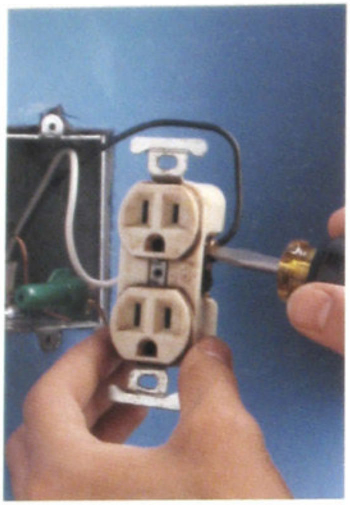
2 Remove the mounting screws that hold the receptacle to the box. Carefully pull the receptacle from the box. Take care not to touch any bare wires.



3 Confirm that the power to the receptacle is off (page 70), using a neon circuit tester If wires are attached to both sets of screw terminals, test both sets. The tester should not glow If it does, you must turn off the correct circuit at the service panel.

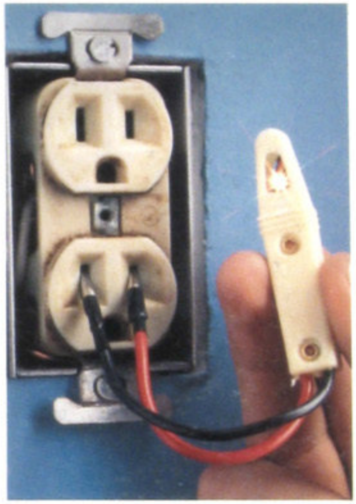


4 If the ends of the wires appear darkened or dirty, disconnect them one at a time, and clean them with fine sandpaper If the wires are aluminum, apply an antioxidant paste before reconnecting. Antioxidant paste is available at hardware stores.



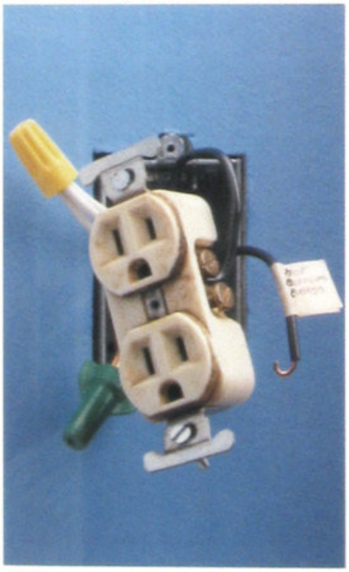
5 Tighten all connections, using a screwdriver. Take care not to overtighten and strip the screws.

6 Check the box for dirt or dust and, if necessary, clean it with a vacuum cleaner and narrow nozzle attachment.

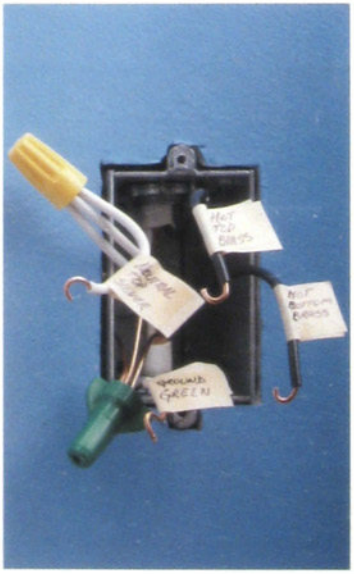


7 Reinstall the receptacle, and turn on power at the main service panel. Test the receptacle for power with a neon circuit tester. If the receptacle does not work, check other receptacles in the circuit before making a replacement.

How to Replace a Receptacle

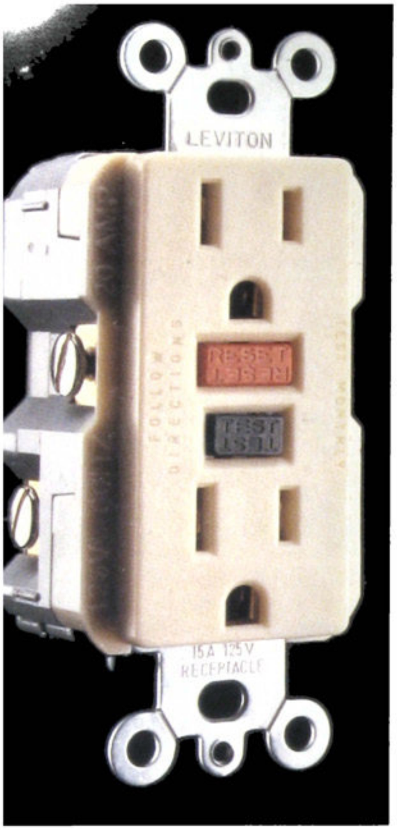


1 To replace a receptacle, repeat steps 1 to 3 on the opposite page. With the power off, label each wire for its location on the receptacle screw terminals, using masking tape and a felt-tipped pen.



2 Disconnect all wires and remove the receptacle.

3 Replace the receptacle with one rated for the correct amperage and voltage (page 28). Replace coverplate, and turn on power. Test receptacle with a neon circuit tester (pages 70 to 71).



GFCI Receptacles

The ground-fault circuit-interrupter (GFCI) receptacle protects against electrical shock caused by a faulty appliance, or a worn cord or plug It senses small changes in current flow and can shut off power in as little as   of a second

GFCIs are now required in bathrooms, kitchens, garages, crawl spaces, unfinished basements, and outdoor receptacle locations Consult your local codes for any requirements regarding the installation of GFCI receptacles Most GFCIs use standard screw terminal connections, but some have wire leads and are attached with wire connectors. Because the body of a GFCI receptacle is larger than a standard receptacle, small crowded electrical boxes may need to be replaced with more spacious boxes (pages 40 to 41)

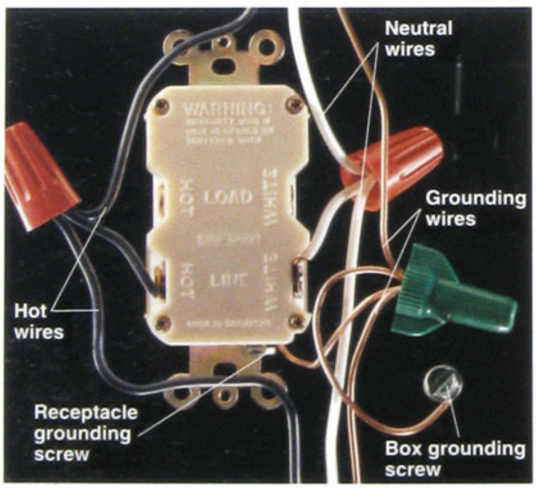
The GFCI receptacle may be wired to protect only itself (single location), or it can be wired to protect all receptacles, switches, and light fixtures from the GFCI "forward" to the end of the circuit (multiple locations)

Because the GFCI is so sensitive it is most effective when wired to protect a single location The more receptacles any one GFCI protects, the more susceptible it is to "phantom tripping, shutting off power because of tiny normal fluctuations in current flow

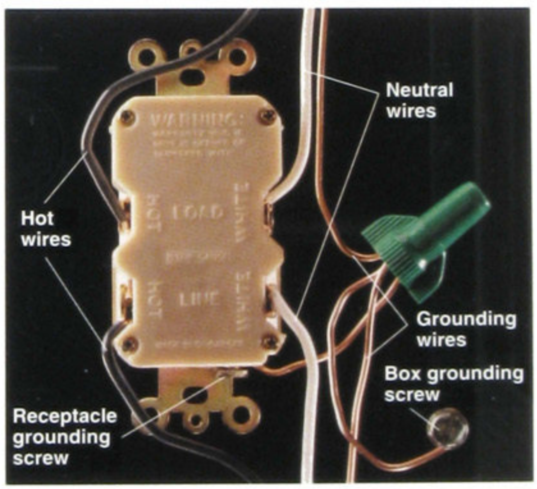
Everything You Need

Tools: neon circuit tester, screwdriver.

Materials: wire connectors, masking tape.

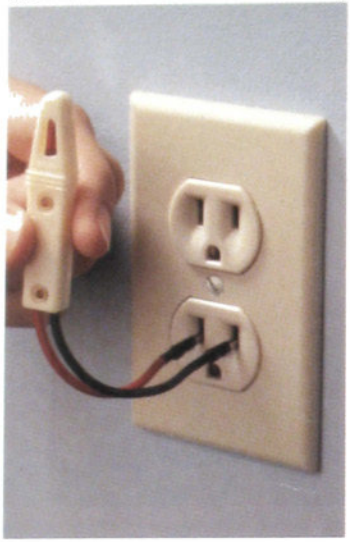


A GFCI wired for single-location protection (shown from the back) has hot and neutral wires connected only to the screw terminals marked LINE A GFCI connected for single-location protection may be wired as either an end-of-run or middle-of-run configuration (page 64).



A GFCI wired for multiple-location protection (shown from the back) has one set of hot and neutral wires connected to the LINE pair of screw terminals and the other set connected to the LOAD pair of screw terminals A GFCI receptacle connected for multiple-location protection may be wired only as a middle-of-run configuration.

How to Install a GFCI for Single-location Protection

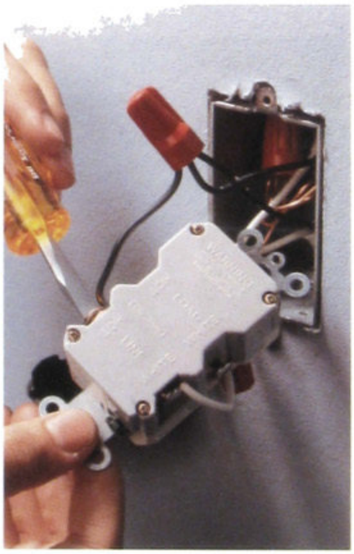


1 Shut off power to the receptacle at the main service panel. Test for power with a neon circuit tester (page 70). Be sure to check both halves of the receptacle.

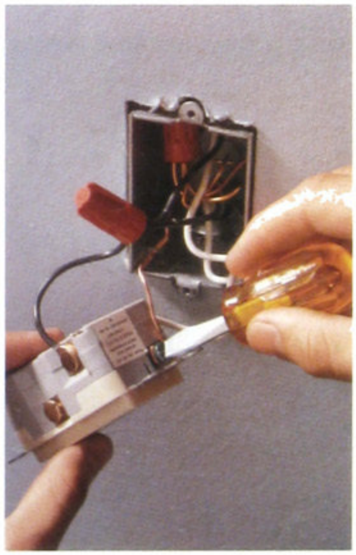
2 Remove coverplate. Loosen mounting screws, and gently pull receptacle from the box. Do not touch wires. Confirm power is off with a circuit tester (page 70).

3 Disconnect all white neutral wires from the silver screw terminals of the old receptacle.

4 Pigtail all the white neutral wires together, and connect the pigtail to the terminal marked WHITE LINE on the GFCI (see photo on opposite page).



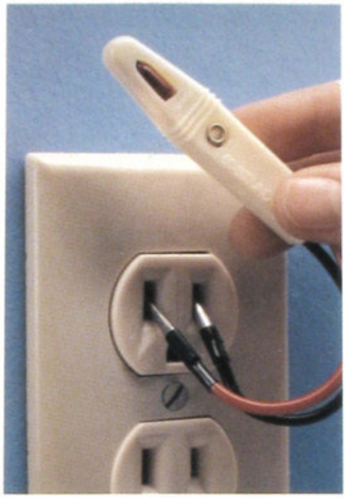
5 Disconnect all black hot wires from the brass screw terminals of the old receptacle. Pigtail these wires together, and connect them to the terminal marked HOT LINE on the GFCI.



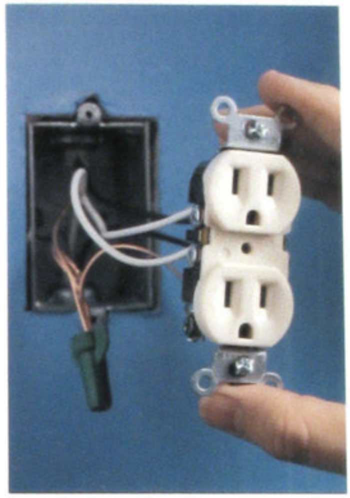
6 If a grounding wire is available, connect it to the green grounding screw terminal of the GFCI. Mount the GFCI in the receptacle box, and reattach the coverplate. Restore power, and test the GFCI according to the manufacturer's instructions.

How to Install a GFCI for Multiple-location Protection

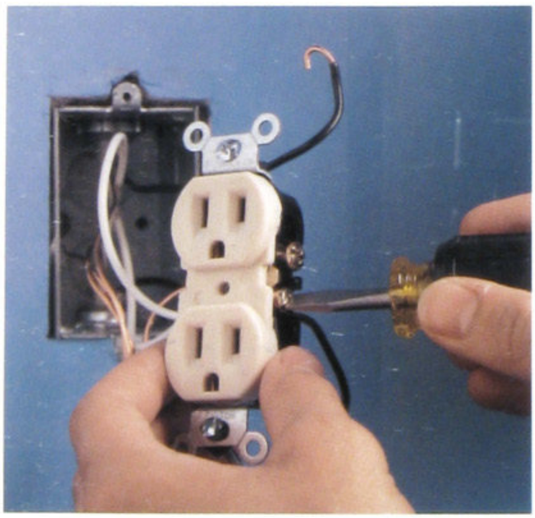
1 Use a map of your house circuits (pages 30 to 33) to determine a location for your GFCI. Indicate all receptacles that will be protected by the GFCI installation.



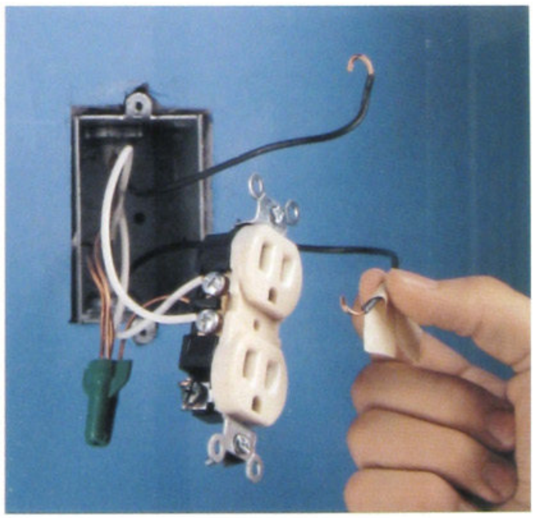
2 Turn off power to the correct circuit at the main service panel. Test all the receptacles in the circuit with a neon circuit tester to make sure the power is off. Always check both halves of each duplex receptacle.



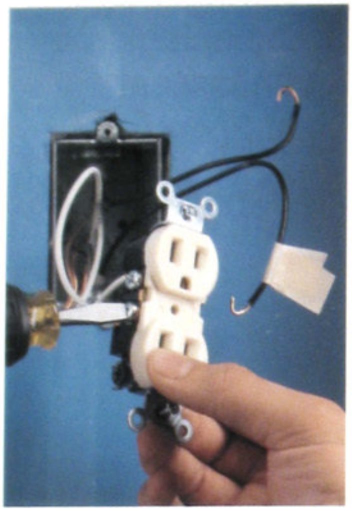
3 Remove the coverplate from the receptacle that will be replaced with the GFCI. Loosen the mounting screws and gently pull the receptacle from its box. Take care not to touch any bare wires. Confirm the power is off with a neon circuit tester (page 70).



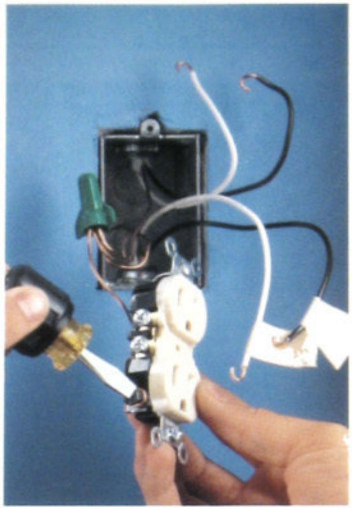
4 Disconnect all black hot wires. Carefully separate the hot wires and position them so that the bare ends do not touch anything. Restore power to the circuit at the main service panel. Determine which black wire is the "feed" wire by testing for hot wires (page 71). The feed wire brings power to the receptacle from the service panel. Use caution: This is a "live" wire test, during which the power is turned on temporarily.



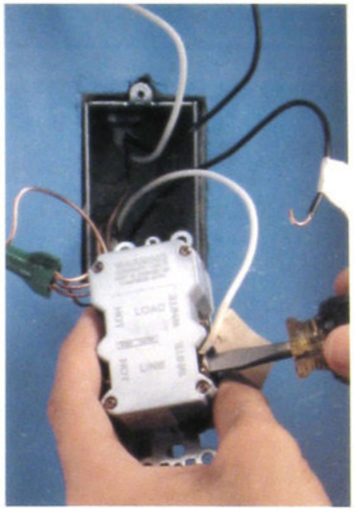
5 When you have found the hot feed wire, turn off power at the main service panel. Identify the feed wire by marking it with masking tape.



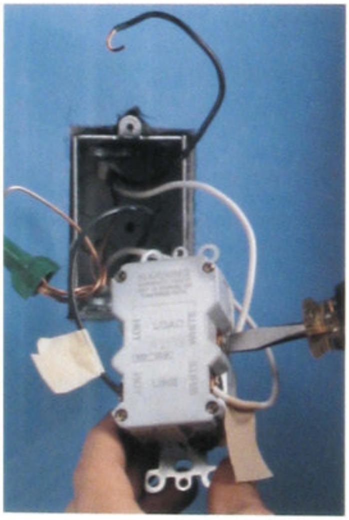
6 Disconnect the white neutral wires from the old receptacle. Identify the white feed wire and label it with masking tape. The white feed wire will be the one that shares the same cable as the black feed wire.



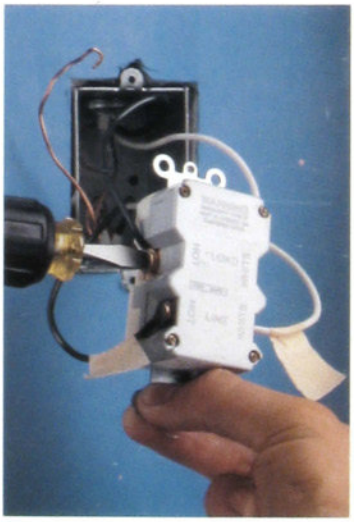
7 Disconnect the grounding wire from the grounding screw terminal of the old receptacle. Remove the old receptacle. Connect the grounding wire to the grounding screw terminal of the GFCI.



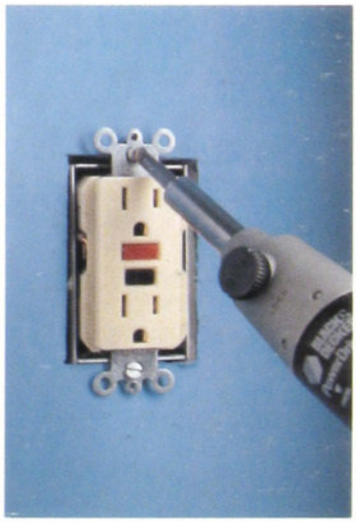
8 Connect the white feed wire to the terminal marked WHITE LINE on the GFCI Connect the black feed wire to the terminal marked HOT LINE on the GFCI



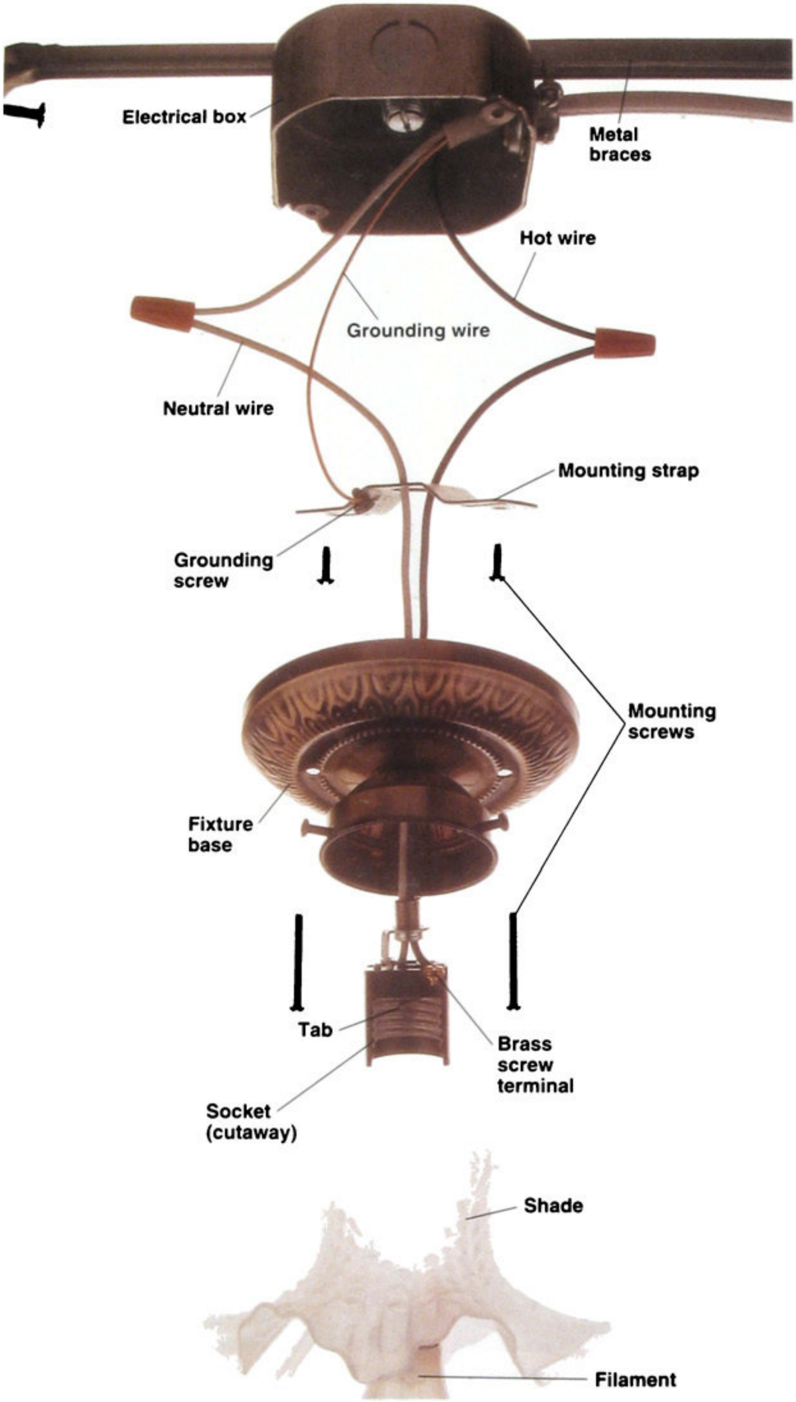
9 Connect the other white neutral wire to the terminal marked WHITE LOAD on the GFCI.



10 Connect the other black hot wire to the terminal marked HOT LOAD on the GFCI.



11 Carefully tuck all wires into the receptacle box. Mount the GFCI in the box and attach the coverplate. Turn on power to the circuit at the main service panel. Test the GFCI according to the manufacturer's instructions.



In a typical incandescent light fixture, a black hot wire is connected to a brass screw terminal on the socket. Power flows to a small tab at the bottom of the metal socket and through a metal filament inside the bulb. The power heats the filament and causes it to glow The current then flows through the threaded portion of the socket and through the white neutral wire back to the main service panel.

Repairing & Replacing Incandescent Light Fixtures

Incandescent light fixtures are attached permanently to ceilings or walls. They include wall-hung sconces, ceiling-hung globe fixtures, recessed light fixtures, and chandeliers. Most incandescent light fixtures are easy to repair, using basic tools and inexpensive parts.

If a light fixture fails, always make sure the light bulb is screwed in tightly and is not burned out. A faulty light bulb is the most common cause of light fixture failure. If the light fixture is controlled by a wall switch, also check the switch as a possible source of problems (pages 42 to 61).

Light fixtures can fail because the sockets or built-in switches wear out. Some fixtures have sockets and switches that can be removed for minor repairs. These parts are held to the base of the fixture with mounting screws or clips. Other fixtures have sockets and switches that are joined permanently to the base. If this type of fixture fails, purchase and install a new light fixture.

Damage to light fixtures often occurs because homeowners install light bulbs with wattage ratings that are too high. Prevent overheating and light fixture failures by using only light bulbs that match the wattage ratings printed on the fixtures.

Techniques for repairing fluorescent lights are different from those for incandescent lights. Refer to pages 90 to 95 to repair or replace a fluorescent light fixture.

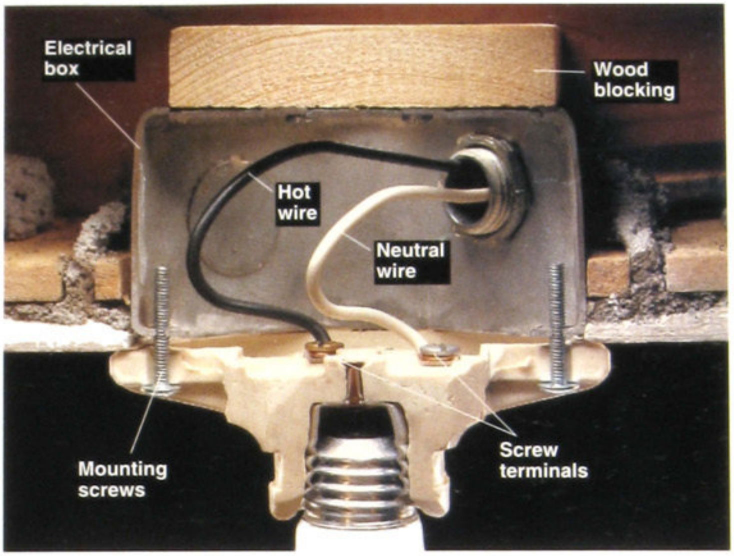
Everything You Need

Tools: neon circuit tester, screwdriver, continuity tester, combination tool.

Materials: replacement parts, as needed.

See Inspector's Notebook:

- Common Cable Problems (pages 124 to 125).
- Checking Wire Connections (pages 126 to 127).
- Electrical Box Inspection (pages 128 to 129).

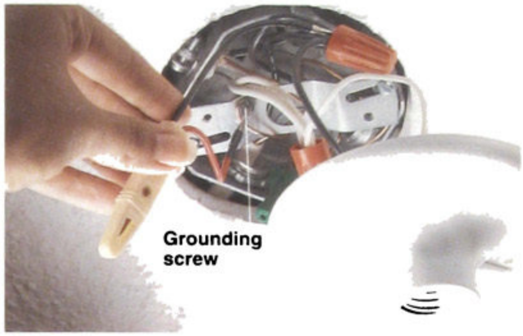


Before 1959, incandescent light fixtures (shown cut away) oft mounted directly to an electrical box or to plaster lath. Electric now require that fixtures be attached to mounting straps tha anchored to the electrical boxes (page opposite). If you have a fixture attached to plaster lath, install an approved electrical box a mounting strap to support the fixture (pages 38 to 41).

Problem		Repair
	Wall- or ceiling-mounted fixture flickers or does not light.	1. Check for faulty light bulb. 2. Check wall switch, and repair or replace, if needed (pages 42 to 61). 3. Check for loose wire connections in electrical box. 4. Test socket, and replace, if needed (pages 80 to 81). 5. Replace light fixture (page 82).
	Built-in switch on fixture does not work.	1. Check for faulty light bulb. 2. Check for loose wire connections on switch. 3. Replace switch (page 81). 4. Replace light fixture (page 82).
	Chandelier flickers or does not light.	1. Check for faulty light bulb. 2. Check wall switch, and repair or replace, if needed (pages 42 to 61). 3. Check for loose wire connections in electrical box. 4. Test sockets and fixture wires, and replace, if needed (pages 86 to 87).
	Recessed fixture flickers or does not light.	1. Check for faulty light bulb. 2. Check wall switch, and repair or replace, if needed (pages 42 to 61). 3. Check for loose wire connections in electrical box. 4. Test fixture, and replace, if needed (pages 83 to 85).

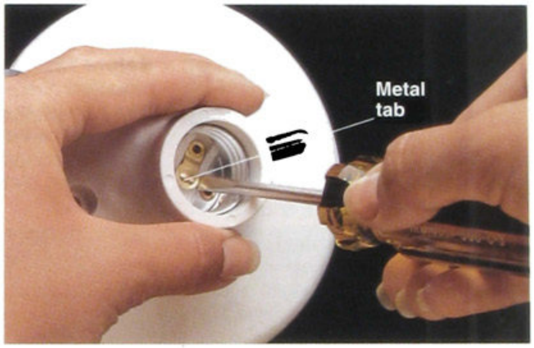
How to Remove a Light Fixture & Test a Socket

1 Turn off the power to the light fixture at the main service panel. Remove the light bulb and any shade or globe, then remove the mounting screws holding the fixture base to the electrical box or mounting strap. Carefully pull the fixture base away from box.

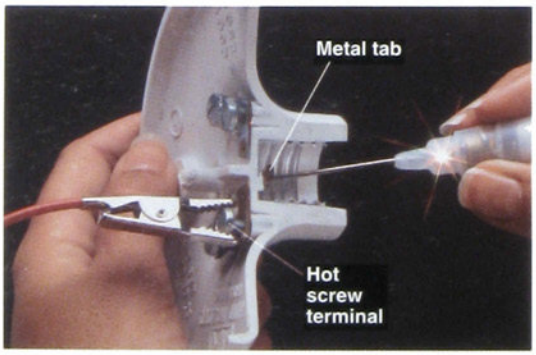


2 Test for power by touching one probe of a neon circuit tester to green grounding screw, then inserting other probe into each wire connector. Tester should not glow. If it does, there is still power entering box. Return to the service panel, and turn off power to correct circuit.

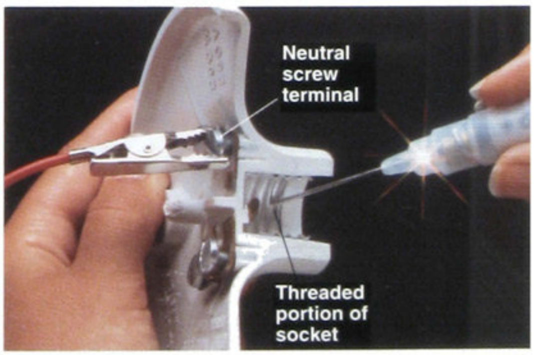
3 Disconnect the light fixture base by loosening the screw terminals. If fixture has wire leads instead of screw terminals, remove the light fixture base by unscrewing the wire connectors.



4 Adjust the metal tab at the bottom of the fixture socket by prying it up slightly with a small screwdriver. This adjustment will improve the contact between the socket and the light bulb.

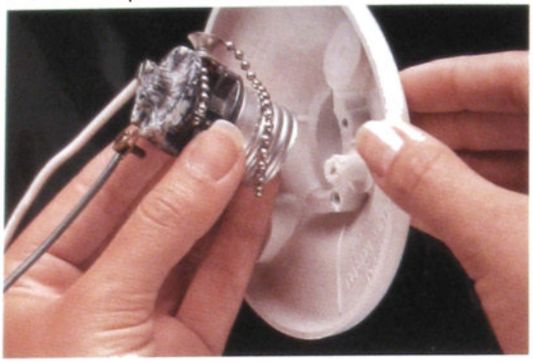


5 Test the socket (shown cut away) by attaching the clip of a continuity tester to the hot screw terminal (or black wire lead) and touching probe of tester to metal tab in bottom of socket. Tester should glow. If not, socket is faulty and must be replaced.



6 Attach tester clip to neutral screw terminal (or white wire lead), and touch probe to threaded portion of socket. Tester should glow. If not, socket is faulty and must be replaced. If socket is permanently attached, replace the fixture (page 82).

How to Replace a Socket



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2 Purch
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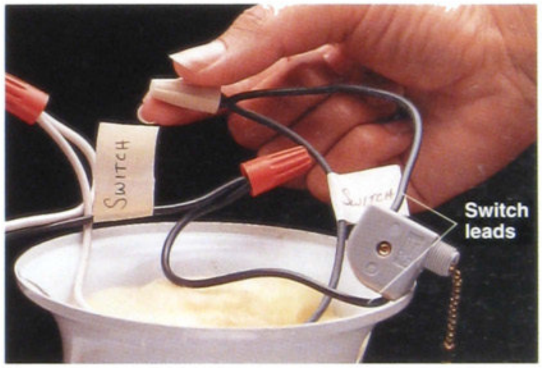
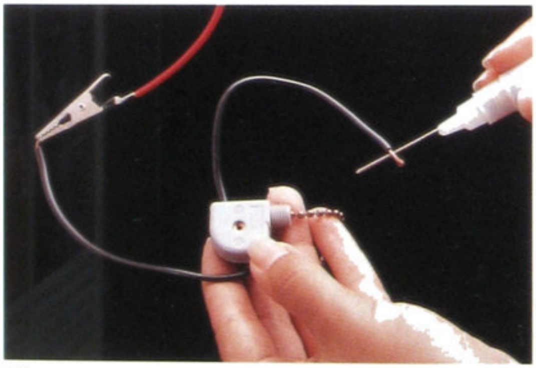
Attach

How to Test & Replace a Built-in Light Switch

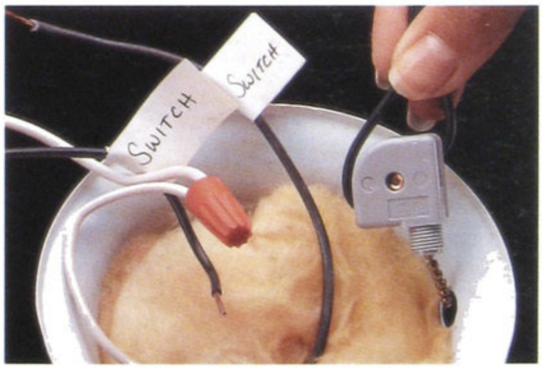
1 light to 3 page opposit
the holding the switch



2 Label the
Disconnect



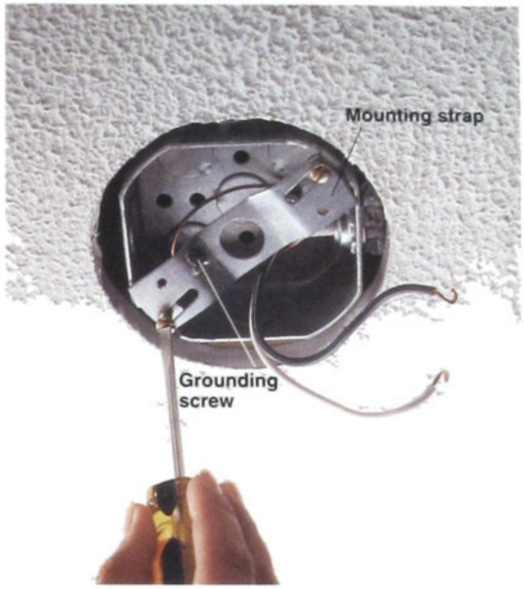
3 itch by attaching clip of continuity tester to
e switch leads and holding tester probe
lead Operate switch control If switch is
glow when switch is in one position.



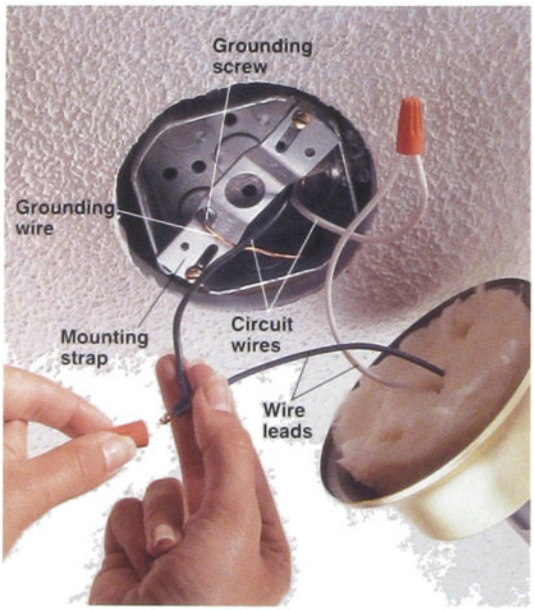
4 If the switch is faulty purchase and install an exact duplicate switch Remount the light fixtur and turn on the power at the main service panel

How to Replace an Incandescent Light Fixture

1 Turn off the power and remove the old light fixture, following the directions for standard light fixtures (page 80, steps 1 to 3) or chandeliers (pages 86 to 87 steps 1 to 4)



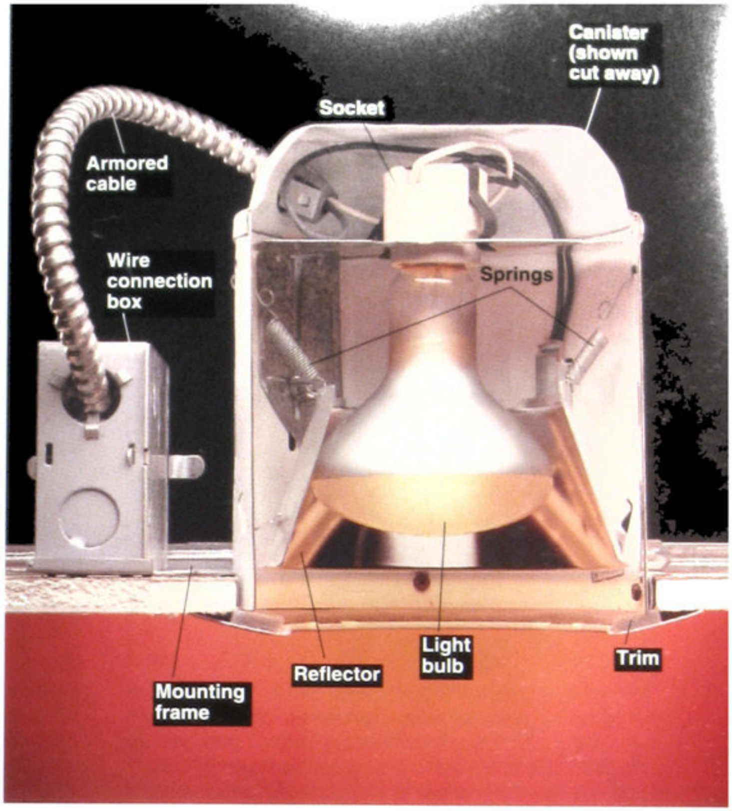
2 Attach a mounting strap to the electrical box, if box does not already have one. The mounting strap, included with the new light fixture, has a pre-installed grounding screw



3 Connect the circuit wires to the base of the new fixture, using wire connectors. Connect the white wire lead to the white circuit wire, and the black wire lead to the black circuit wire. Pigtail the bare copper grounding wire to the grounding screw on the mounting strap.

4 Attach the light fixture base to the mounting strap, using the mounting screws. Attach the globe, and install a light bulb with a wattage rating that is the same or lower than the rating indicated on the fixture. Turn on the power at the main service panel.

Repairing & Replacing Recessed Light Fixtures



Most problems with recessed light fixtures occur because heat builds up inside the metal canister and melts the insulation on the socket wires. On some recessed light fixtures, sockets with damaged wires can be removed and replaced. However, most newer fixtures have sockets that cannot be removed. With this type, you will need to buy a new fixture if the socket wires are damaged.

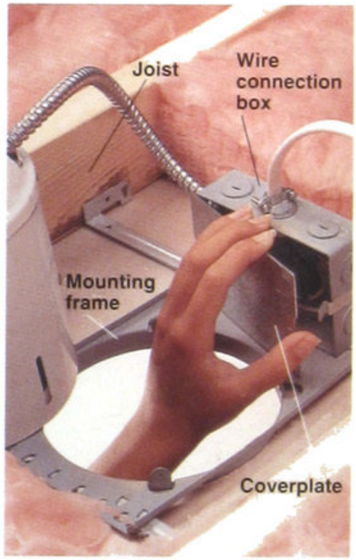
When buying a new recessed light fixture, choose a replacement that matches the old fixture. Install the new fixture in the metal mounting frame that is already in place.

Unless the fixture is rated IC (insulated covered), make sure building insulation is at least 3" away from the canister to dissipate heat.

How to Remove & Test a Recessed Light Fixture

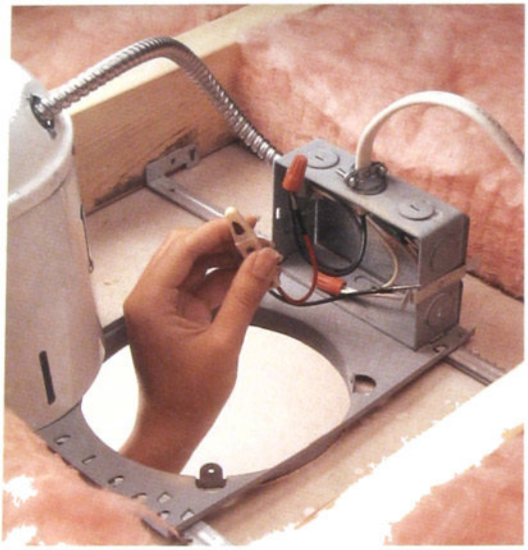
1 Turn off the power to the light fixture at the main service panel. Remove the trim, light bulb, and reflector The reflector is held to the canister with small springs or mounting clips.

2 Loosen the screws or clips holding the canister to the mounting frame. Carefully raise the canister and set it away from the frame opening.

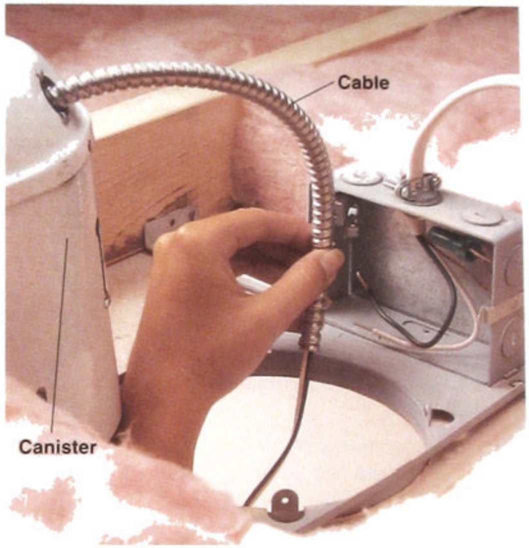


3 Remove the coverplate on the wire connection box. The box is attached to the mounting frame between the ceiling joists.

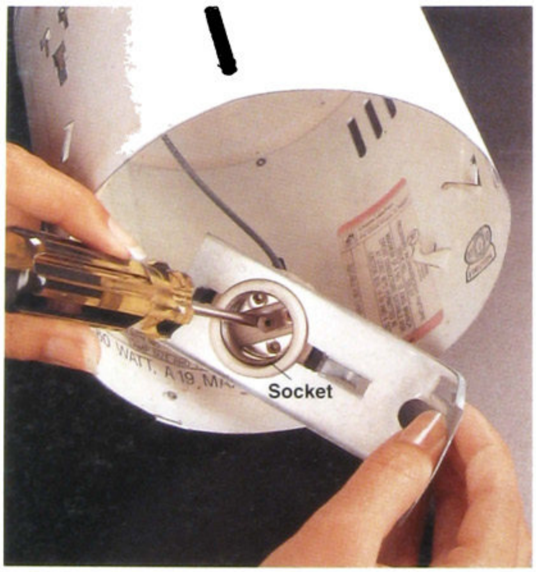
(continued next page)



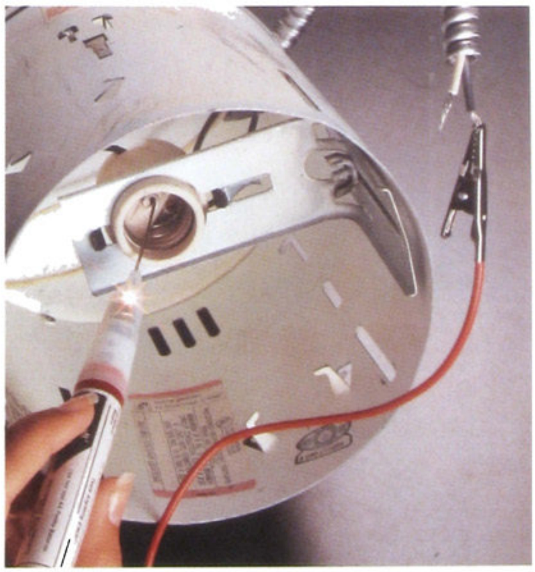
4 Test for power by touching one probe of neon circuit tester to grounded wire connection box and inserting other probe into each wire connector Tester should not glow If it does, there is still power entering box. Return to the service panel and turn off correct circuit.



5 Disconnect the white and black circuit wires by removing the wire connectors. Pull the armored cable from the wire connection box. Remove the canister through the frame opening.



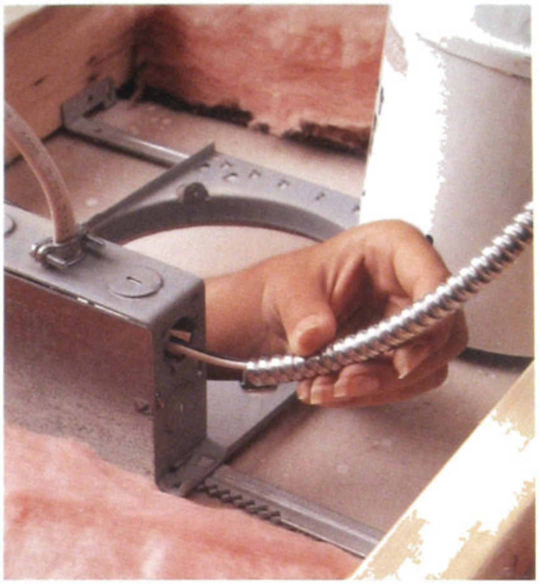
6 Adjust the metal tab at the bottom of the fixture socket by prying it up slightly with a small screwdriver This adjustment will improve contact with the light bulb.



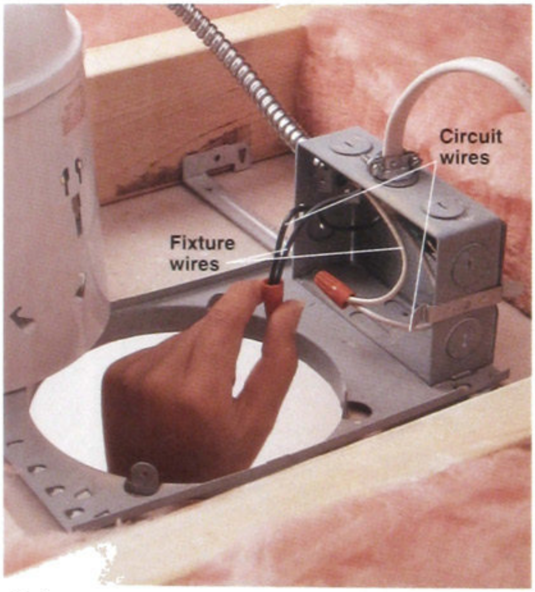
7 Test the socket by attaching the clip of a continuity tester to the black fixture wire and touching tester probe to the metal tab in bottom of the socket. Attach the tester clip to white fixture wire, and touch probe to the threaded metal socket. Tester should glow for both tests. If not, then socket is faulty Replace the socket (page 81), or install a new light fixture (page opposite).

How to Replace a Recessed Light Fixture

1 Remove the old light fixture (pages 83 to 84). Buy a new fixture that matches the old fixture. Although new light fixture comes with its own mounting frame, it is easier to mount the new fixture using the frame that is already in place

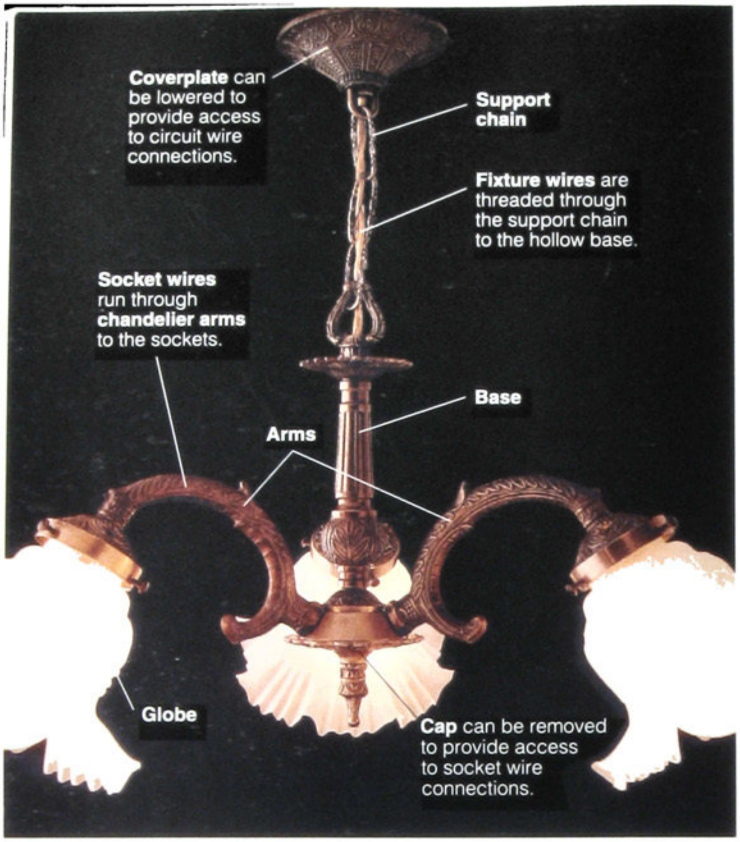


2 Set the fixture canister inside the ceiling cavity and thread the fixture wires through the opening in the wire connection box Push the armored cable into the wire connection box to secure it



3 Connect the white fixture wire to the white circuit wire, and the black fixture wire to the black circuit wire, using wire connectors. Attach the coverplate to the wire connection box. Make sure any building insulation is at least 3" from canister and wire connection box.

4 Position the canister inside the mounting frame, and attach the mounting screws or clips. Attach the reflector and trim. Install a light bulb with a wattage rating that is the same or lower than rating indicated on the fixture. Turn on power at main service panel.



Repairing Chandeliers

Repairing a chandelier requires special care. Because chandeliers are heavy, it is a good idea to work with a helper when removing a chandelier. Support the fixture to prevent its weight from pulling against the wires.

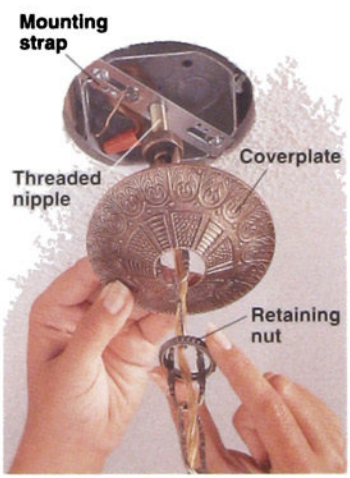
Chandeliers have two fixture wires that are threaded through the support chain from the electrical box to the hollow base of the chandelier. The socket wires connect to the fixture wires inside this base.

Fixture wires are identified as hot and neutral. Look closely for printed lettering or a colored stripe on one of the wires. This is the neutral wire that is connected to the white circuit wire and white socket wire. The other, unmarked, fixture wire is hot and is connected to the black wires.

If you have a new chandelier, it may have a grounding wire that runs through the support chain to the electrical box. If this wire is present, make sure it is connected to the grounding wires in the electrical box.

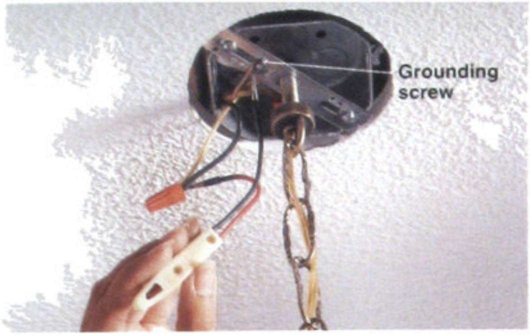
How to Repair a Chandelier

1 Label any lights that are not working, using masking tape. Turn off power to the fixture at the main service panel. Remove light bulbs and all shades or globes.

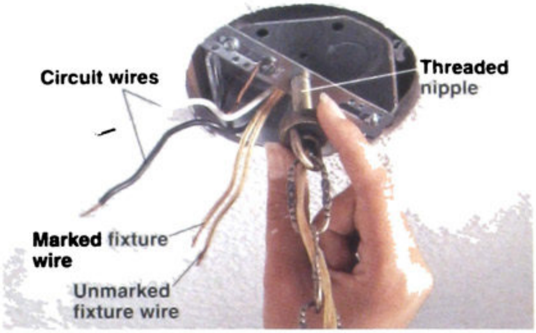


2 Unscrew the retaining nut and lower the decorative coverplate away from the electrical box. Most chandeliers are supported by a threaded nipple attached to a mounting strap.

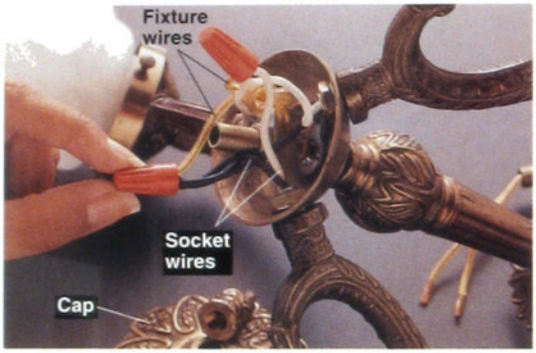
Mounting variation: Some chandeliers are supported only by the coverplate that is bolted to the electrical box mounting strap. These types do not have a threaded nipple.



3 Test for power by touching one probe of neon circuit tester to the green grounding screw and inserting other probe into each wire connector Tester should not glow If it does, there is still power entering box Return to service panel, and turn off power to correct circuit.

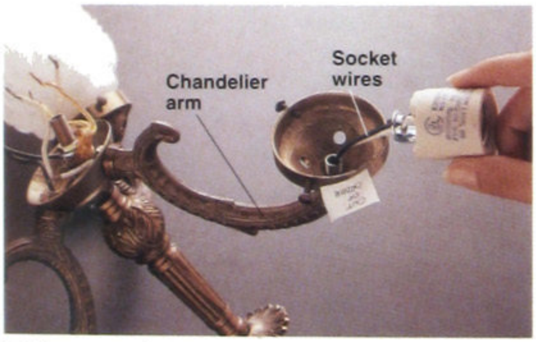


4 Disconnect fixture wires by removing the wire connectors Marked fixture wire is neutral, and is connected to white circuit wire Unmarked fixture wire is hot, and is connected to black circuit wire Unscrew threaded nipple, and carefully place chandelier on a flat surface

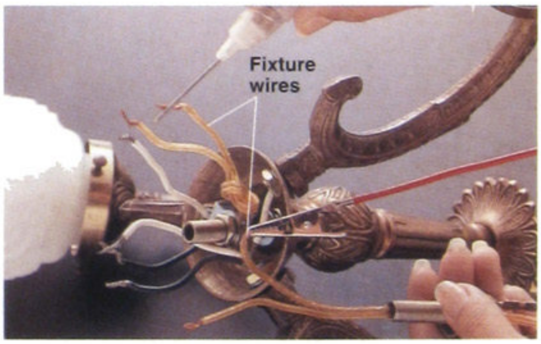


5 Remove the cap from the bottom of the chandelier exposing the wire connections inside the hollow base Disconnect the black socket wires from the unmarked fixture wire, and disconnect the white socket wires from the marked fixture wire

6 Test socket by attaching clip of continuity tester to black socket wire and touching probe to tab in socket. Repeat test with threaded portion of socket and white socket wire Tester should glow for both tests. If not, the socket is faulty and must be replaced



7 Remove a faulty socket by loosening any mounting screws or clips, and pulling the socket and socket wires out of the fixture arm. Purchase and install a new chandelier socket, threading the socket wires through the fixture arm.



8 Test each fixture wire by attaching clip of continuity tester to one end of wire and touching probe to other end. If tester does not glow, wire is faulty and must be replaced. Install new wires, if needed, then reassemble and rehang the chandelier.

Repairing Track Lights

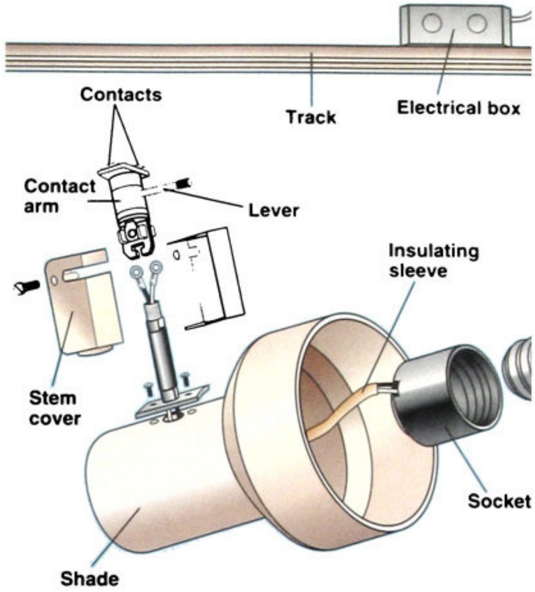
Like other light fixtures, track lights are connected to an electrical box in the ceiling. The circuit wires in the box provide power to the entire track, and the current runs along two metal power strips inside the track. Each fixture on the track has a contact arm with metal contacts that draw current from the strips to power the fixture.

Common fixture problems are dirty or corroded contacts or power strips, and bad sockets. Track lights are easy to work on because you can quickly remove individual fixtures to get to the source of the problem.

Everything You Need

Tools: screwdriver, continuity tester, combination tool.

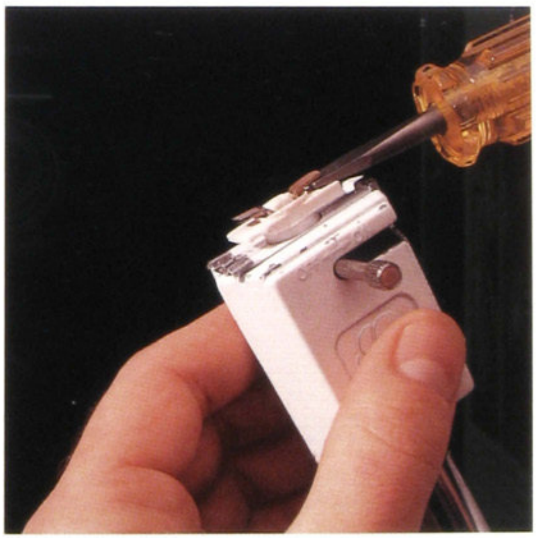
Materials: fine sandpaper, crimp-style wire connectors.



Track lights are powered by an electrical box connected to the middle of, or at the end of, a track. With multiple track sections, special connectors provide the links to power the entire system.

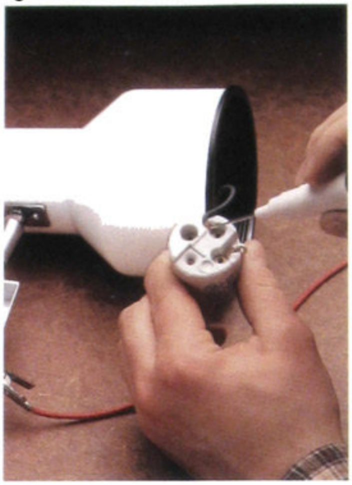
How to Clean Track Light Contacts

1 Turn off the power to the circuit at the main service panel. Shift the lever on the fixture stem to release the fixture from the track. Use fine sandpaper to clean the metal power strips inside the track in the general area where the fixture hangs.

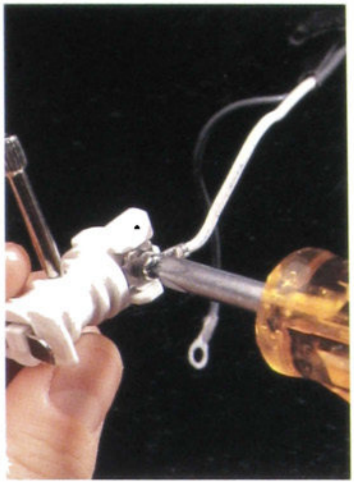


2 Sand the metal contacts on the top of the fixture's contact arm, then use a screwdriver to pry up the tabs slightly. Reattach the fixture to the track, and restore the power. If the fixture doesn't light, test the socket (page opposite).

1 Turn off the power to the circuit at the main service panel Remove the problem fixture from the track (page opposite) Loosen the screws on the stem cover and remove the cover



2 Remove the screws securing the socket, and test the socket with a continuity tester Attach the clip to the brass track contact, and touch the tester probe to the black wire connection on the socket Repeat the test with the white contact and white wire connection If the tester fails to light in either test, replace the socket.

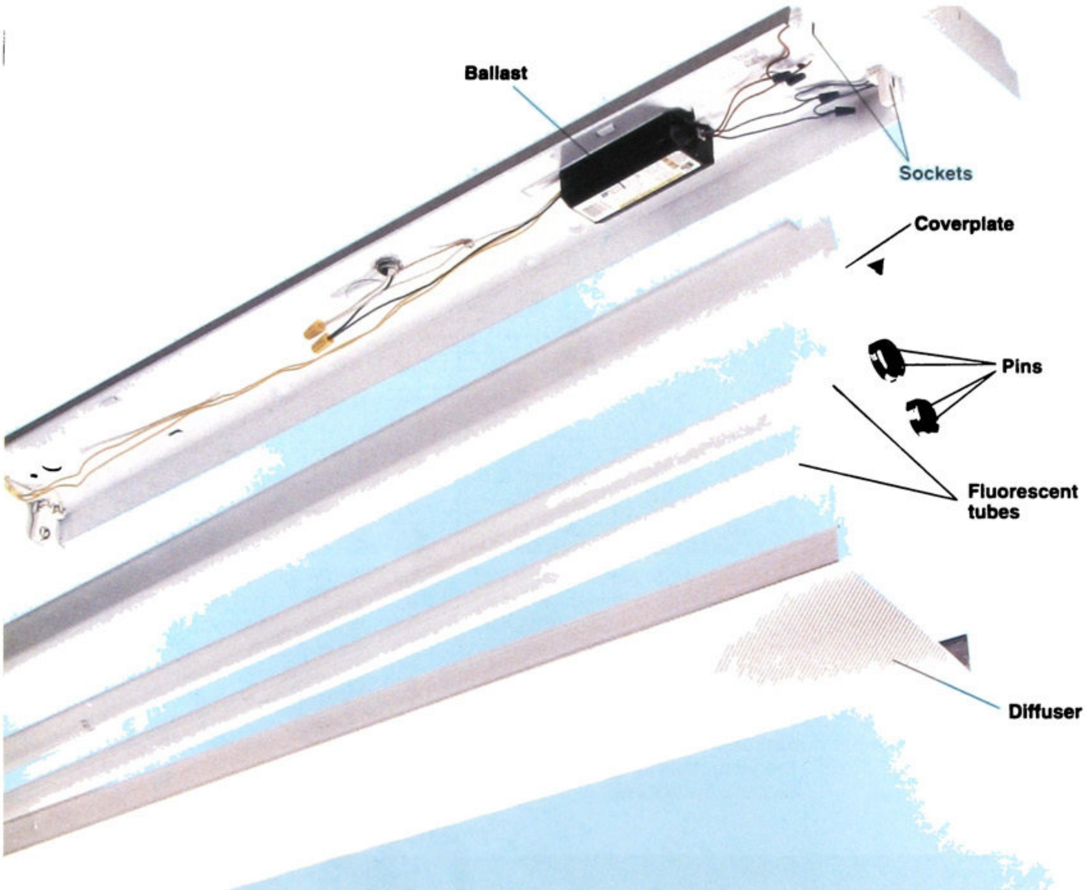


3 To remove the old socket, pull the contact arm from the stem housing, and disconnect the socket wires from the screw terminals Pull the socket and wires from the shade If the wires have an insulating sleeve remove it and set it aside

4 Buy a replacement socket with the same wattage rating as the old one Feed the wires of the new socket into the shade and up through the stem Attach the socket to the shade.

5 Use a combination tool to strip of insulation from each wire end, and attach a crimp-style wire connector to each wire Fasten the connectors to the proper screw terminals on the contact arm.

6 Reinstall the socket and contact arm, and reattach the stem cover. Remount the fixture



A fluorescent light works by directing electrical current through a special gas-filled **tube** that glows when energized. A white translucent **diffuser** protects the fluorescent tube and softens the light. A **coverplate** protects a special transformer, called a **ballast**. The ballast regulates the flow of 120-volt household current to the **sockets.** The sockets transfer power to metal **pins** that extend into the tube.

Repairing & Replacing Fluorescent Lights

Fluorescent lights are relatively trouble-free and use less energy than incandescent lights. A typical fluorescent tube lasts about three years and produces two to four times as much light per watt as a standard incandescent light bulb.

The most frequent problem with a fluorescent light fixture is a worn-out tube. If a fluorescent light fixture begins to flicker, or does not light fully, remove and examine the tube. If the tube has bent or broken pins, or black discoloration near the ends, replace it. Light gray discoloration is normal in working fluorescent tubes. When replacing an old tube, read the wattage rating printed on the glass surface, and buy a new tube with a matching rating. Never dispose of old tubes by breaking them. Fluorescent tubes contain a small amount of hazardous mercury. Check with your local environmental control agency or health department for disposal guidelines.

Fluorescent light fixtures also can malfunction if the sockets are cracked or worn. Inexpensive replacement sockets are available at any hardware store and can be installed in a few minutes.

If a fixture does not work even after the tube and sockets have been serviced, the ballast probably is defective. Faulty ballasts may leak a black, oily substance and can cause a fluorescent light

Problem		Repair
	Tube flickers, or lights partially.	1. Rotate tube to make sure it is seated properly in the sockets. 2. Replace tube (page 92) and the starter (where present) if tube is discolored or if pins are bent or broken. 3. Replace the ballast (page 94) if replacement cost is reasonable. Otherwise, replace the entire fixture (page 95).
	Tube does not light.	1. Check wall switch, and repair or replace, if needed (pages 42 to 61). 2. Rotate the tube to make sure it is seated properly in sockets. 3. Replace tube (page 92) and the starter (where present) if tube is discolored or if pins are bent or broken. 4. Replace sockets if they are chipped or if tube does not seat properly (page 93). 5. Replace the ballast (page 94) or the entire fixture (page 95).
	Noticeable black substance around ballast.	Replace ballast (page 94) if replacement cost is reasonable. Otherwise, replace the entire fixture (page 95).
	Fixture hums.	Replace ballast (page 94) if replacement cost is reasonable. Otherwise, replace the entire fixture (page 95).

fixture to make a loud humming sound. Although ballasts can be replaced, always check prices before buying a new ballast. It may be cheaper to purchase and install a new fluorescent fixture rather than to replace the ballast in an old fluorescent light fixture.

Everything You Need

Tools: screwdriver, ratchet wrench, combination tool, neon circuit tester.

Materials: replacement tubes, starters, or ballast (if needed); replacement fluorescent light fixture (if needed).

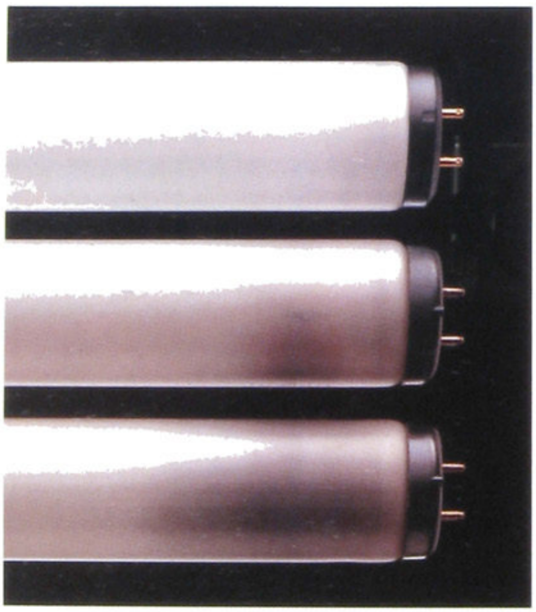
See Inspector's Notebook:

- Common Cable Problems (pages 124 to 125).
- Checking Wire Connections (pages 126 to 127).
- Electrical Box Inspection (pages 128 to 129).

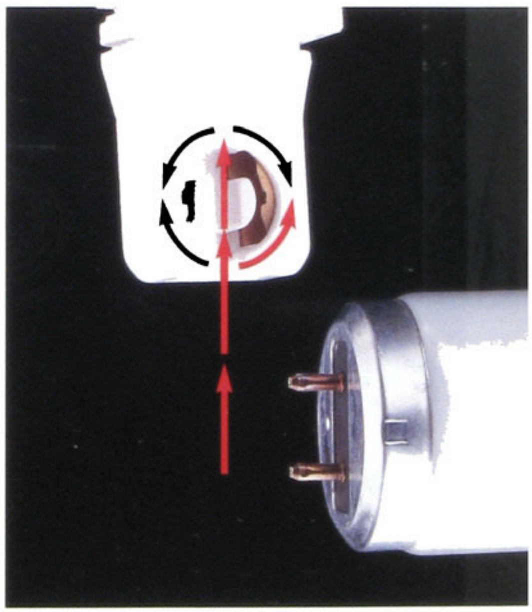
Older fluorescent lights may have a small cylindrical device, called a starter located near one of the sockets. When a tube begins to flicker, replace both the tube and the starter Turn off the power then remove the starter by pushing it slightly and turning counterclockwise. Install a replacement that matches the old starter

1

2 Remove th rescent tube by rotating in either dir and sliding the tube out of sockets. Inspect ins at the end of the tube. Tubes with bent roken pins should be repl

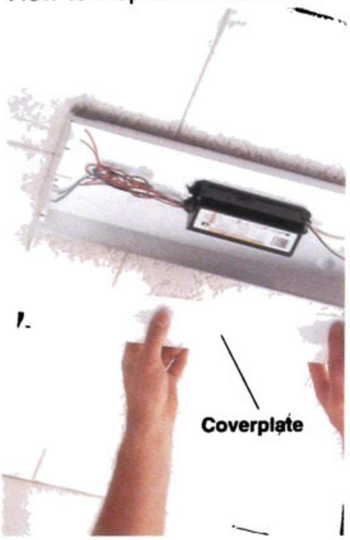


3 Inspect the ends of the fluorescent tube for discoloration. New tube in good working order (top) shows no discoloration. Normal, working tube (middle) may have gray color. A worn-out tube (bottom) shows black discoloration.

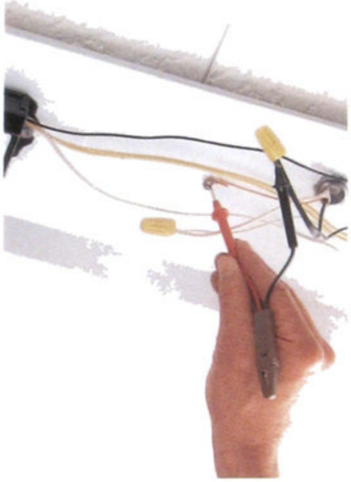


4 Install a new tube with the same wattage rati the old tube. Insert the tube so that pins slide fully into sockets, then twist tube turn in either direction until it is locked securely. Reattach the diffuser, and turn on the power at the main service panel.

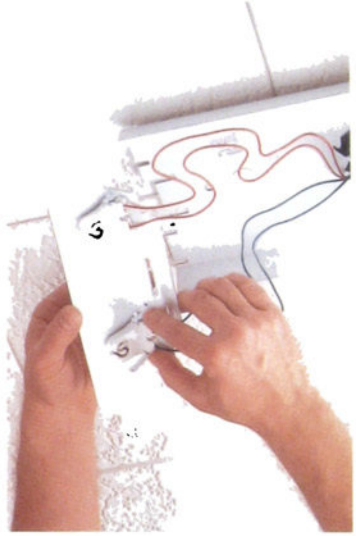
How to Replace a Socket



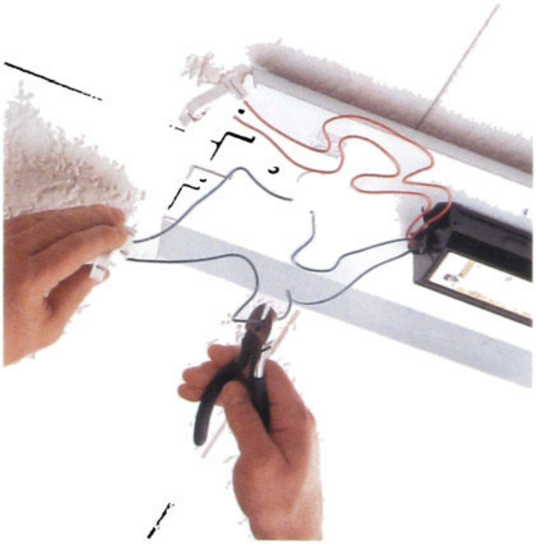
1 Turn off the power at the main service panel. Remove the diffuser, fluorescent tube, and the coverplate.



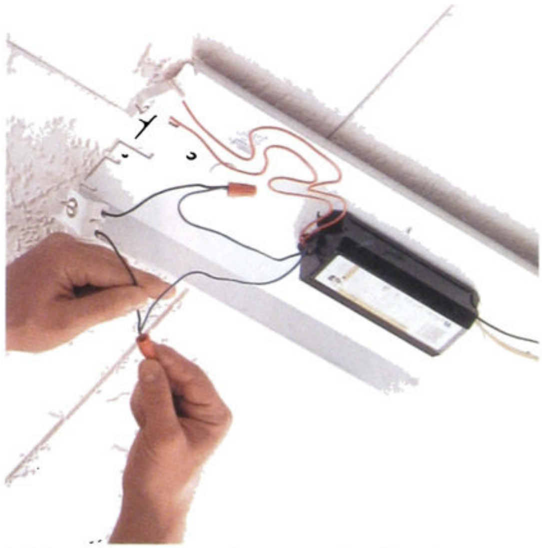
2 Test for power by touching one probe of a neon circuit tester to the grounding screw and inserting the other probe into each wire connector Tester should not glow If it does, power is still entering the box. Return to the service panel, and turn off correct circuit.



3 Remove the faulty socket from the fixture housing. Some sockets slide out, while others must be unscrewed.



4 Disconnect wires attached to socket. For push-in fittings (above) remove the wires by inserting a small screwdriver into the release openings. Some sockets have screw terminal connections, while others have preattached wires that must be cut before the socket can be removed.

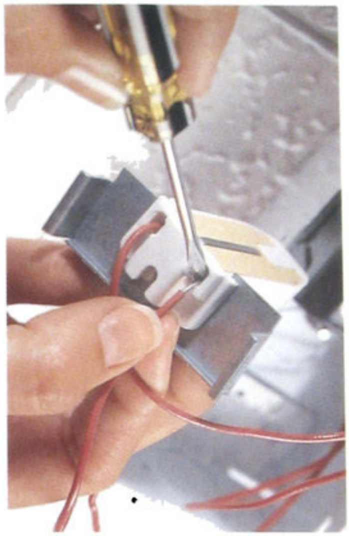


5 Purchase and install a new socket. If socket has preattached wire leads, connect the leads to the ballast wires using wire connectors. Replace coverplate, then the fluorescent tube, making sure that it seats properly. Replace the diffuser Restore power to the fixture at the main service panel.

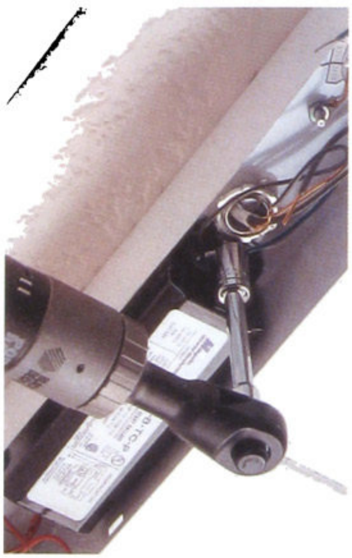
How to Replace a Ballast

1 Turn off the power at the main service panel, then remove the diffuser, fluorescent tube, and coverplate. Test for power, using a neon circuit tester (step 2, page 93).

2 Remove the sockets from the fixture housing by sliding them out, or by removing the mounting screws and lifting the sockets out.



3 Disconnect the wires attached to the sockets by pushing a small screwdriver into the release openings (above), by loosening the screw terminals, or by cutting wires to within 2" of sockets.



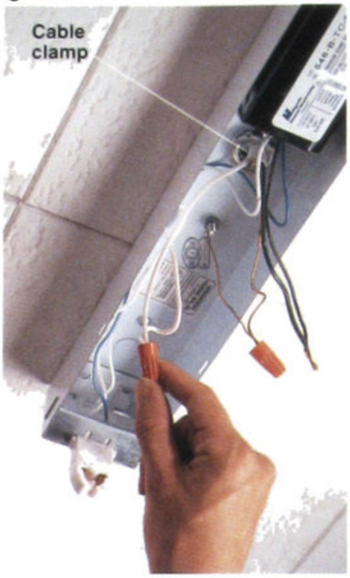
4 Remove the old ballast, using a ratchet wrench or screwdriver Make sure to support the ballast so it does not fall.

5 Install a new ballast that has the same ratings as the old ballast.

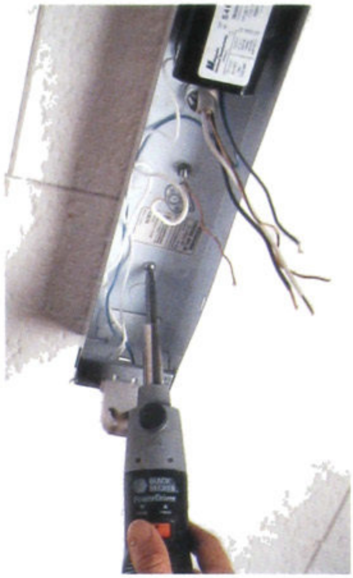
6 Attach the ballast wires to the socket wires, using wire connectors, screw terminal connections, or push-in fittings. Reinstall the coverplate, fluorescent tube, and diffuser Turn on power to the light fixture at the main service panel.

How to Replace a Fluorescent Light Fixture

1 Turn off power to the light fixture at the main service panel. Remove the diffuser, tube, and coverplate. Test for power, using a neon circuit tester (step 2, page 93).

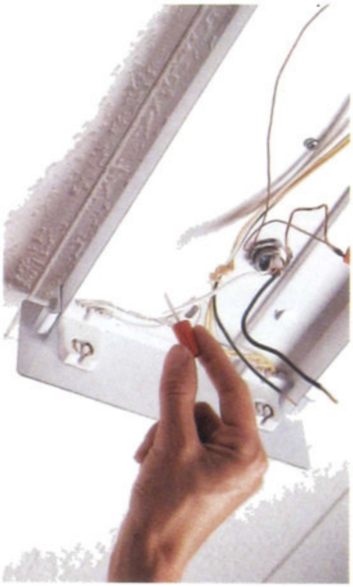


2 Disconnect the insulated circuit wires and the bare copper grounding wire from the light fixture. Loosen the cable clamp holding the circuit wires.



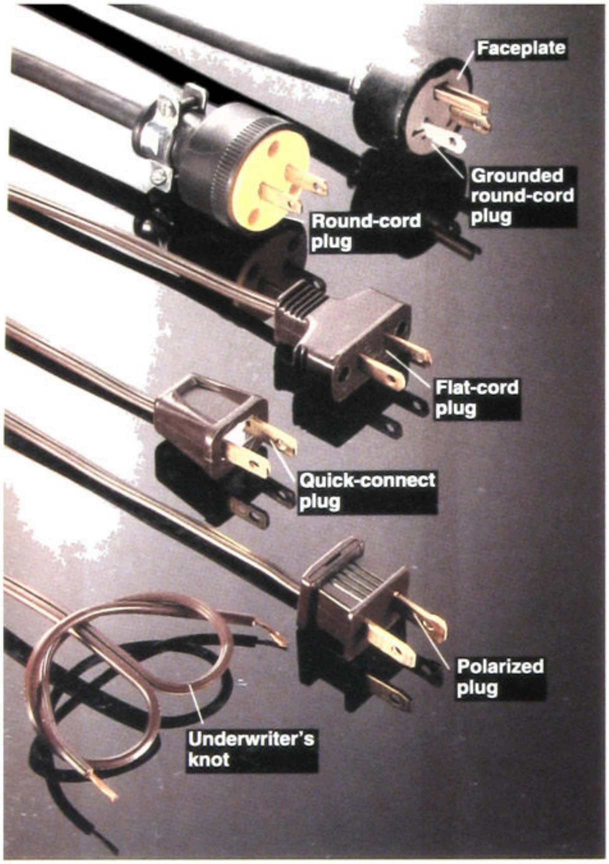
3 Unbolt the fixture from the wall or ceiling, and carefully remove it. Make sure to support the fixture so it does not fall.

4 Position the new fixture, threading the circuit wires through the knockout opening in the back of the fixture. Bolt the fixture in place so it is firmly anchored to framing members.



5 Connect the circuit wires to the fixture wires, using wire connectors. Follow the wiring diagram included with the new fixture. Tighten the cable clamp holding the circuit wires.

6 Attach the fixture coverplate, then install the fluorescent tubes, and attach the diffuser Turn on power to the fixture at the main service panel.



Replacing a Plug

Replace an electrical plug whenever you notice bent or loose prongs, a cracked or damaged casing, or a missing insulating faceplate. A damaged plug poses a shock and fire hazard.

Replacement plugs are available in different styles to match common appliance cords. Always choose a replacement that is similar to the original plug. Flat-cord and quick-connect plugs are used with light-duty appliances, like lamps and radios. Round-cord plugs are used with larger appliances, including those that have three-prong grounding plugs.

Some tools and appliances use polarized plugs. A polarized plug has one wide prong and one narrow prong, corresponding to the hot and neutral slots found in a standard receptacle.

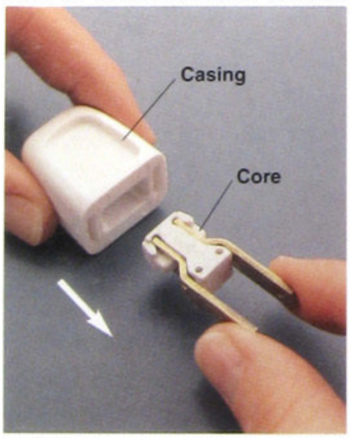
If there is room in the plug body, tie the individual wires in an **underwriter's knot** to secure the plug to the cord.

Everything You Need

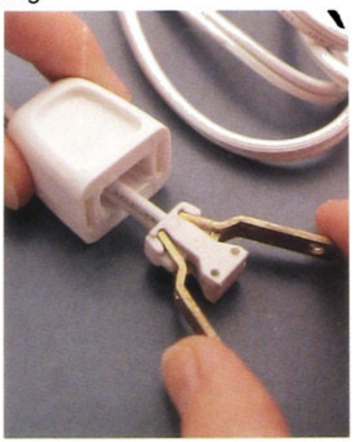
Tools: combination tool, needlenose pliers, screwdriver.

Materials: replacement plug.

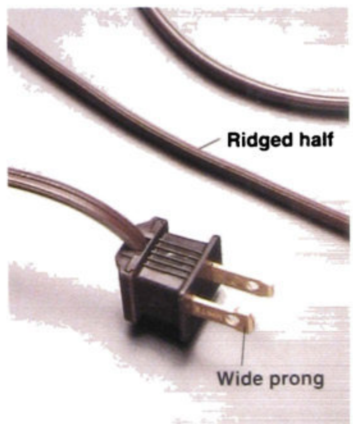
How to Install a Quick-connect Plug



1 Squeeze the prongs of the new quick-connect plug together slightly and pull the plug core from the casing. Cut the old plug from the flat-cord wire with a combination tool, leaving a clean cut end



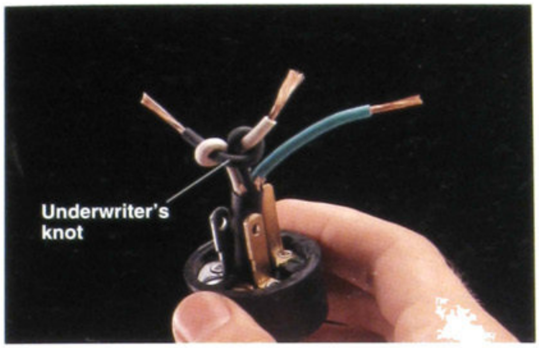
2 Feed unstripped wire through rear of plug casing. Spread prongs, then insert wire into opening in rear of core. Squeeze prongs together: spikes inside core penetrate cord. Slide casing over core until it snaps into place.



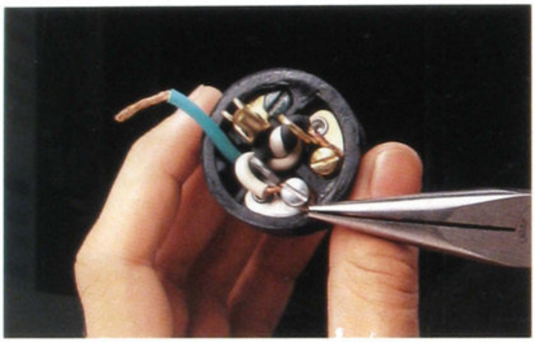
When replacing a polarized plug, make sure that the ridged half of the cord lines up with the wider (neutral) prong of the plug

How to Replace a Round-cord Plug

1 nd cord near the old plug using a com-
Remove the insulating faceplate on
and feed cord through rear of plug
of outer insulation from the round cor
tion from the individual wires



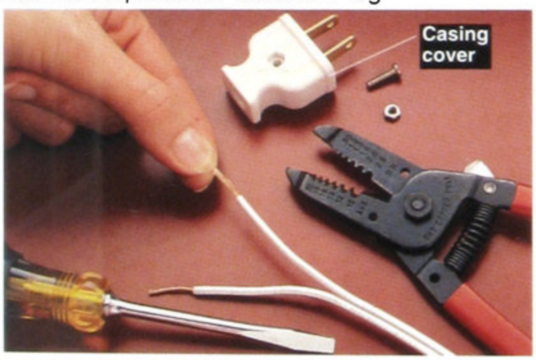
2 Tie under
ires Make sure the knc
edge of the stripped outer
that the knot slides



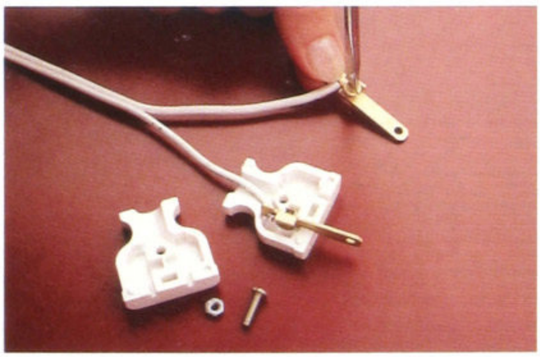
3 Hook end of black wire clockwise around brass screw and white wire around silver screw On a three-prong plug attach third wire to grounding screw necessary excess grounding ire can be cut away

4 Tighten the screws securely maki
copper wires do not touch each oth
the insulating facepl te

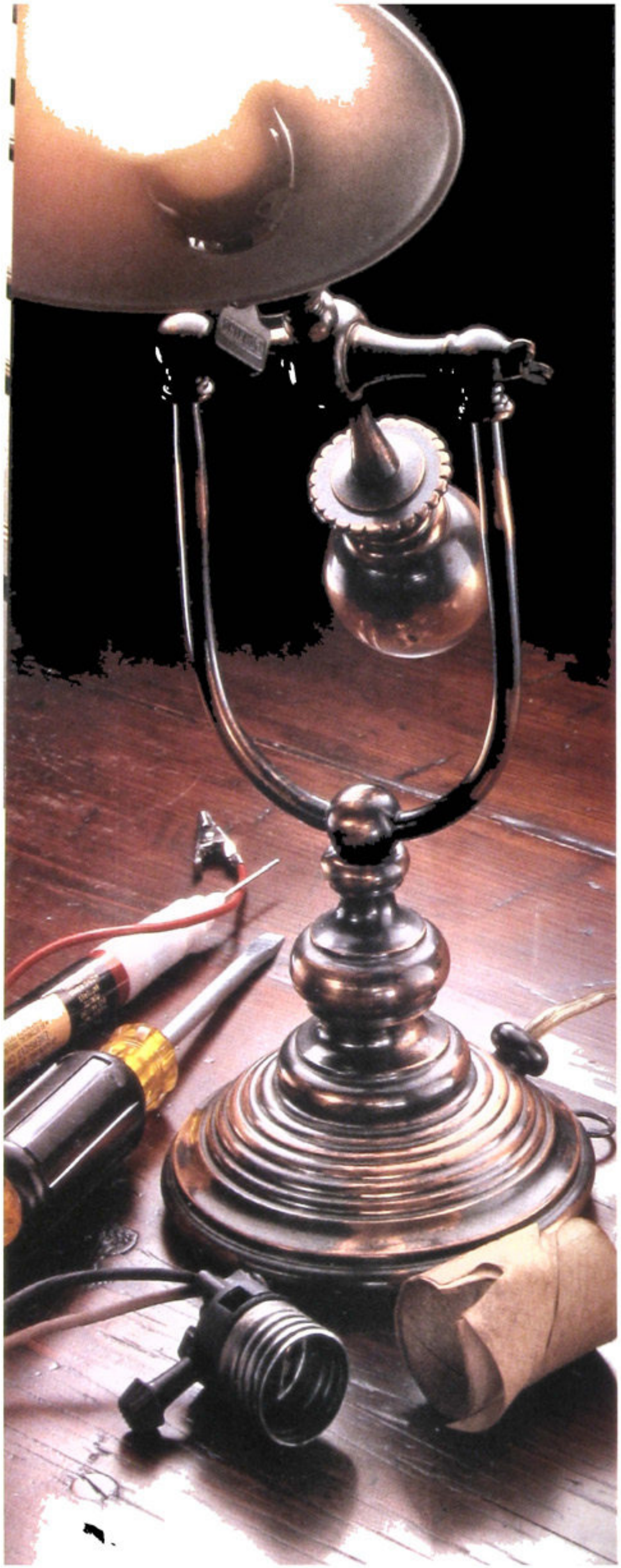
How to Replace a Flat-cord Plug



1 old plug from cord using a combination tool
apart the two halves of the flat cord so that
about 2 of wire are separated Strip insulation from
half Remove casing cover on new plug



2 Hook ends of wires clockwise around the screw terminals and tighten the screw terminals secur Reassemble the plug casing Some plugs may hav an insulating faceplate that must be installed



Replacing a Lamp Socket

Next to the cord plug the most common source of trouble in a lamp is a worn light bulb socket When a lamp socket assembly fails, the problem is usually with the socket-switch unit, although replacement sockets may include other parts you do not need

Lamp failure is not always caused by a bad socket You can avoid unnecessary repairs by checking the lamp cord plug and light bulb before replacing the socket

Everything You Need:

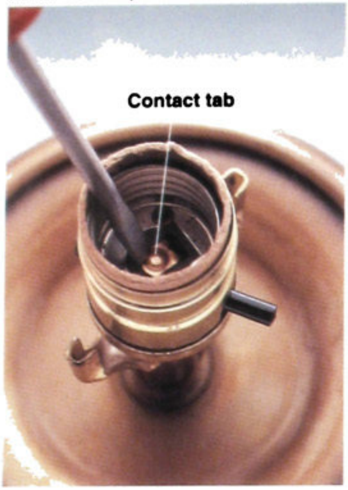
Tools & Materials: replacement socket, continuity tester, screwdriver.

Tip: When replacing a lamp socket, you can improve a standard ON-OFF lamp by installing a three-way socket.

Types of Sockets

Socket-mounted switch types are usually interchangeable choose a replacement you prefer Clockwise from top left twist knob, remote switch, pull chain, push lever

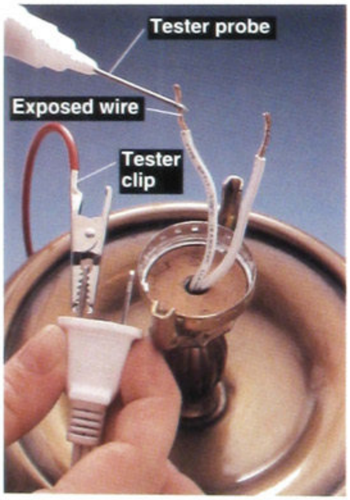
How to Repair or Replace a Lamp Socket



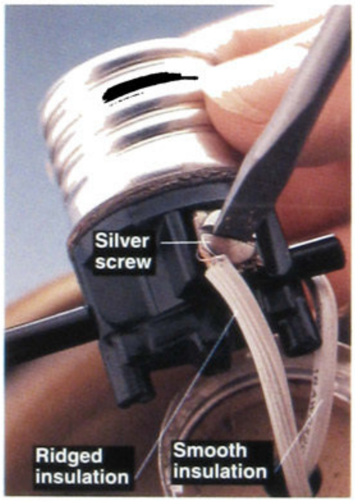
1 Unplug lamp. Remove shade, light bulb, and harp (shade bracket). Scrape contact tab clean with a small screwdriver. Pry contact tab up slightly if flattened inside socket. Replace bulb, plug in lamp, and test. If lamp does not work, unplug, remove bulb, and continue with next step.

2 Squeeze outer shell of socket near PRESS marking, and lift it off. On older lamps, socket may be held by screws found at the base of the screw socket. Slip off cardboard insulating sleeve. If sleeve is damaged, replace entire socket.

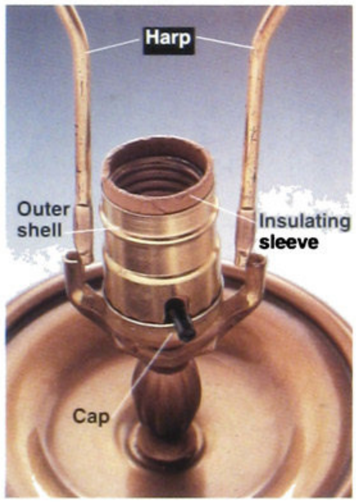
3 Check for loose wire connections on screw terminals. Refasten any loose connections, then reassemble lamp and test. If connections are not loose, remove the wires, lift out the socket, and continue with the next step.



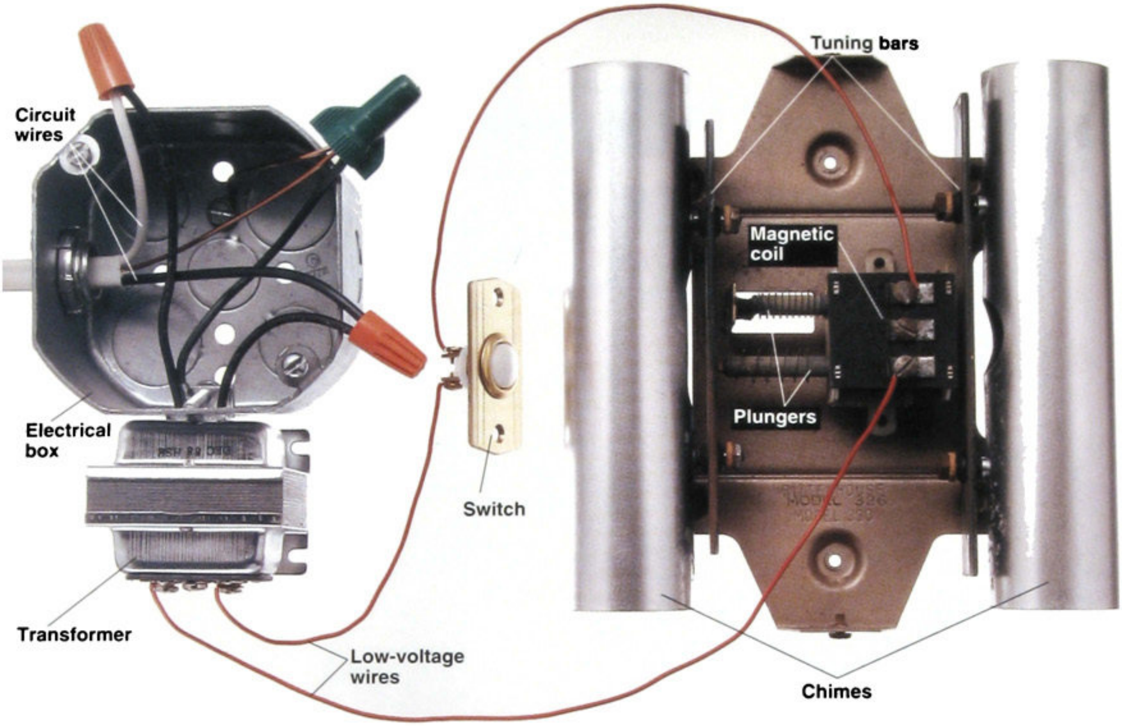
4 Test for lamp cord problems with continuity tester. Place clip of tester on one prong of plug. Touch probe to one exposed wire, then to the other wire. Repeat test with other prong of plug. If tester fails to light for either prong, then replace the cord and plug. Retest the lamp.



5 If cord and plug are functional, then choose a replacement socket marked with the same amp and volt ratings as the old socket. One half of flat-cord lamp wire is covered by insulation that is ridged or marked: attach this wire to the silver screw terminal. Connect other wire to brass screw.



6 Slide insulating sleeve and outer shell over socket so that socket and screw terminals are fully covered and switch fits into sleeve slot. Press socket assembly down into cap until socket locks into place. Replace harp, light bulb, and shade.



Home doorbell system is powered by a transformer that reduces 120-volt current to low-voltage current of 20 volts or less. Current flows from the transformer to one or more push-button switches. When pushed, the switch activates a magnet coil inside the chime unit, causing a plunger to strike a musical tuning bar

Fixing & Replacing Doorbells

Most doorbell problems are caused by loose wire connections or worn-out switches. Reconnecting loose wires or replacing a switch requires only a few minutes. Doorbell problems also can occur if the chime unit becomes dirty or worn, or if the low-voltage transformer burns out. Both parts are easy to replace. Because doorbells operate at low voltage, the switches and the chime unit can be serviced without turning off power to the system. However, when replacing a transformer, always turn off the power at the main service panel.

Most houses have other low-voltage transformers in addition to the doorbell transformer. These transformers control heating and air-conditioning thermostats (page 106 to 113), or other low-voltage systems. When testing and repairing a doorbell system, it is important to identify the correct transformer. A doorbell transformer has a voltage rating of 20 volts or less. This rating is printed on the face of the transformer. A doorbell transformer often is located near the main service panel and in some homes is attached directly to the service panel. The transformer that controls a heating/air-conditioning thermostat system is located near the furnace and has a voltage rating of 24 volts or more.

Occasionally, a doorbell problem is caused by a broken low-voltage wire somewhere in the system. You can test for wire breaks with a battery-operated multi-tester. If the test indicates a break, new low-voltage wires must be installed between the transformer and the switches, or between the switches and chime unit. Replacing low-voltage wires is not a difficult job, but it can be time-consuming. You may choose to have an electrician do this work.

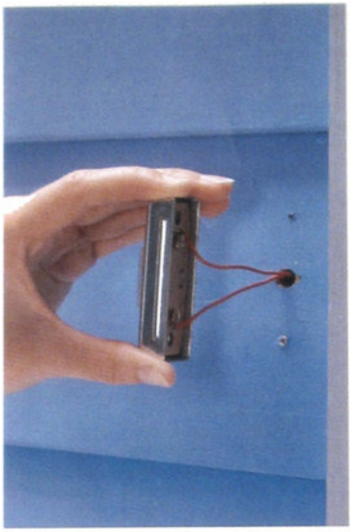
Everything You Need:

Tools: continuity tester, screwdriver, multi-tester, needlenose pliers.

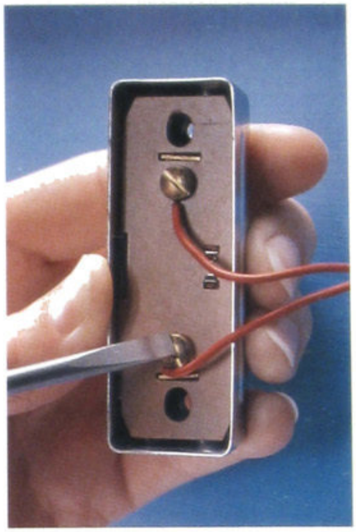
Materials: cotton swab, rubbing alcohol, replacement doorbell switch (if needed), masking tape, replacement chime unit (if needed).

How to Test a Doorbell System

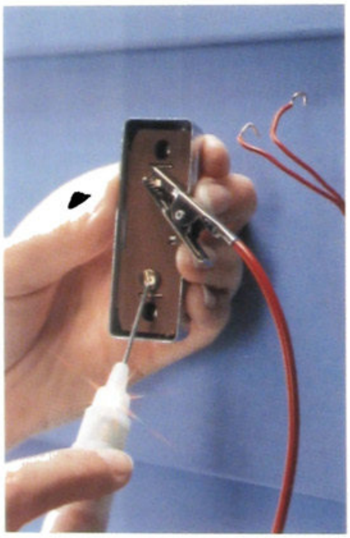
1 Remove the mounting screws holding the doorbell switch to the house



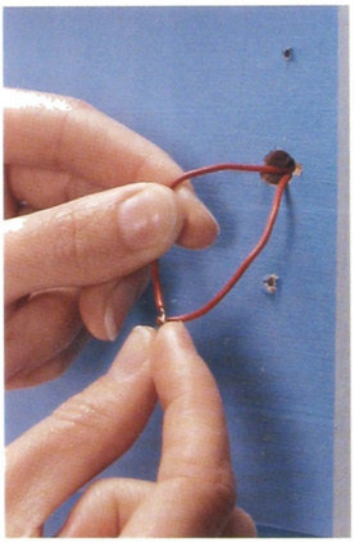
2 Carefully pull the switch away from the wall.



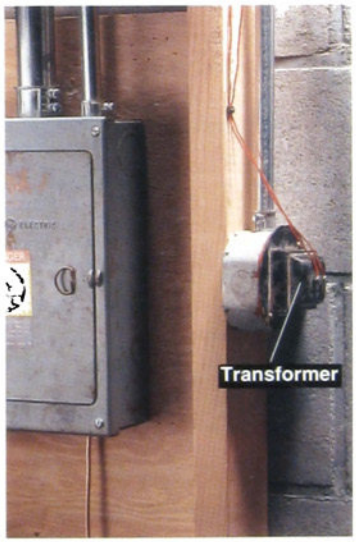
3 Check wire connections on the switch. If wires are loose, reconnect them to the screw terminals. Test the doorbell by pressing the button. If the doorbell still does not work, disconnect the switch and test it with a continuity tester



4 Test the switch by attaching the clip of a continuity tester to one screw terminal and touching the probe to the other screw terminal. Press the switch button. Tester should glow. If not, then the switch is faulty and must be replaced (page 104).



5 Twist the doorbell switch wires together temporarily to test the other parts of the doorbell system.



6 Locate the doorbell transformer, often located near the main service panel. Transformer may be attached to an electrical box, or may be attached directly to the side of the service panel.

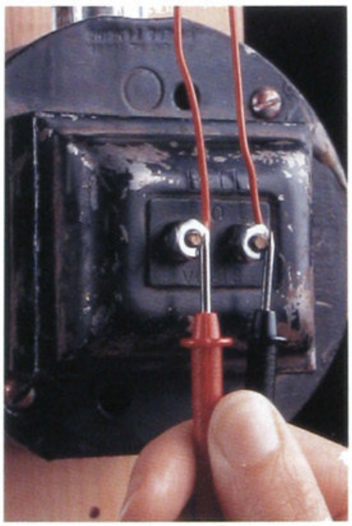
(continued next page)

7 Identify the doorbell transformer by reading its voltage rating Doorbell transformers have a voltage rating of 20 volts or less

8 Turn off power to transformer main service panel Remove cover on electrical box and test wires for power (step 3 page 111) Reconnect any loose wires Replace taped connections with wire connectors Reattach coverplate

9 Inspect the low-voltage wire connections and reconnect any loose wires, using needlenose pliers Turn on power to the transformer at the main service panel

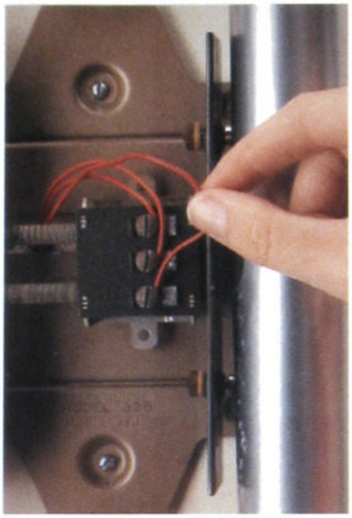
10 Set the dial of multi-tester to the 50-volt (AC) range



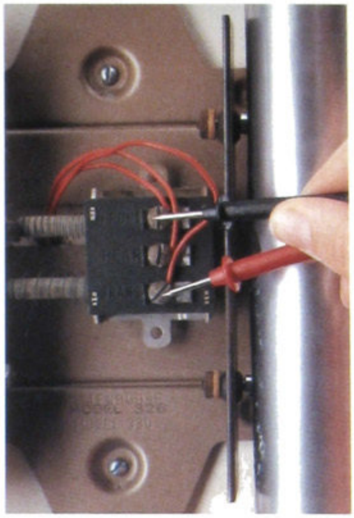
11 Touch the probes of the multi-tester to the low-voltage screw terminals on the transformer

12 If transformer is operating properly multi-tester will detect power that is within 2 volts of transformer's rating If not the transformer is faulty and must be replaced (page 111)

13 Remove the coverplate on the doorbell chime unit

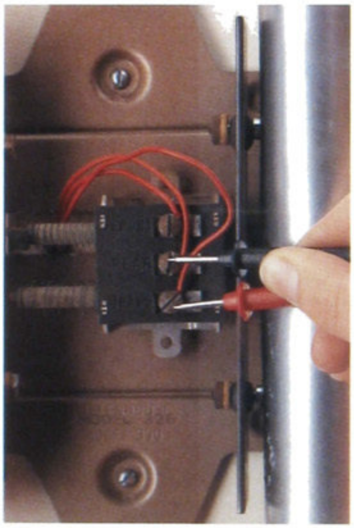


14 Inspect the low-voltage wire connections, and reconnect any loose wires

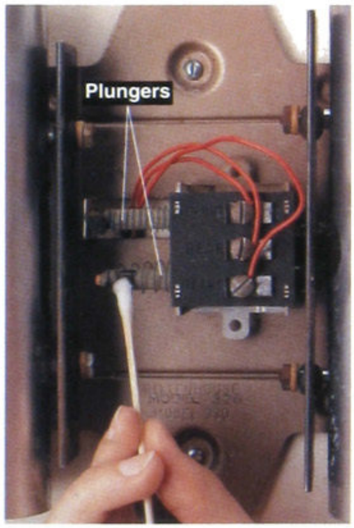


15 Test to make sure chime unit is receiving proper current with a multi-tester set to 50-volt (AC) range Touch probes of tester to screw terminals marked TRANS-FORMER (or TRANS) and FRONT

16 If the multi-tester detects power within 2 volts of the transformer rating, then the chime unit is receiving proper current If multi-tester detects no power or very low power then there is a break in the low-voltage wiring, and new wires must be installed.

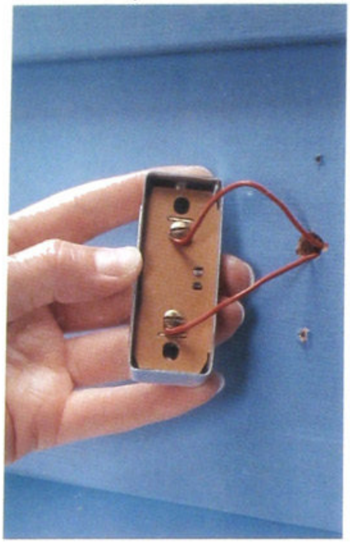


17 If necessary repeat test for rear doorbell wires. Hold probes to terminals marked TRANS-FORMER (or TRANS) and REAR. Multi-tester should detect power within 2 volts of transformer's rating. If not, there is a break in wiring, and new wires must be installed.

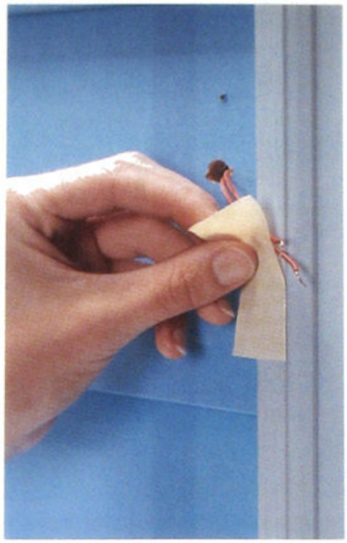


18 Clean the chime plungers with a cotton swab dipped in rubbing alcohol Reassemble doorbell switches, then test the system by pushing one of the switches. If doorbell still does not work, then the chime unit is faulty and must be replaced (page 104).

How to Replace a Doorbell Switch



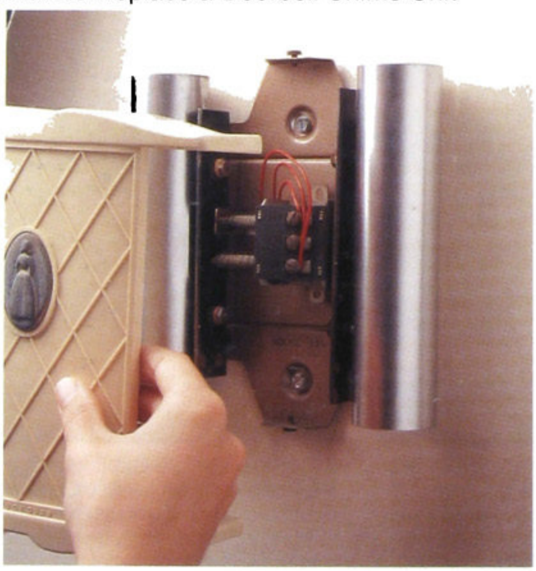
1 Remove the doorbell switch mounting screws, and carefully pull the switch away from the wall.



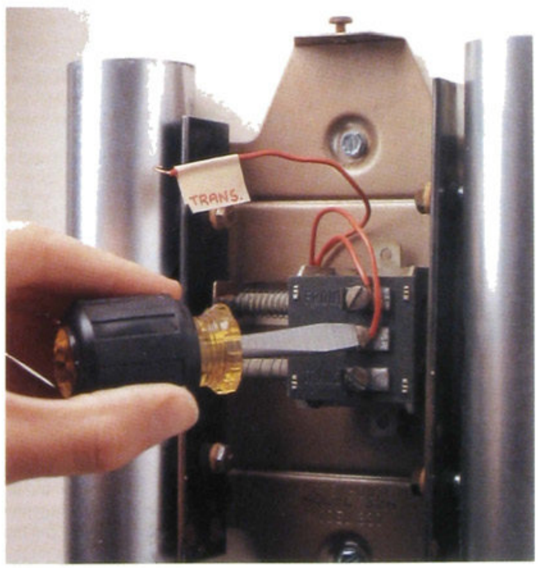
2 Disconnect wires from switch. Tape wires to the wall to prevent them from slipping into the wall cavity. Purchase a new doorbell switch, and connect wires to screw terminals on new switch. (Wires are interchangeable and can be connected to either screw terminal.)

3 Anchor the switch to the wall with the mounting screws.

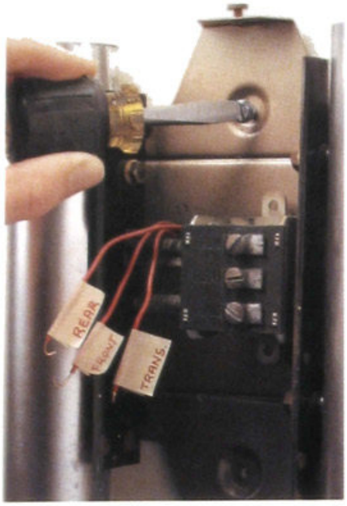
How to Replace a Doorbell Chime Unit



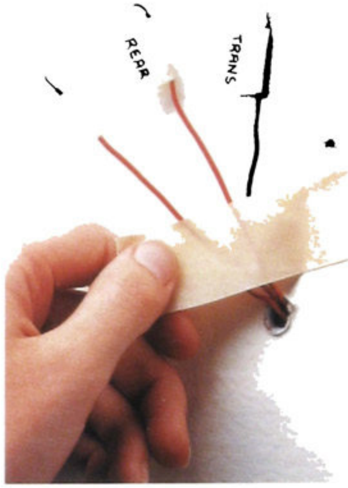
1 Turn off power to the doorbell system at the main service panel. Remove the coverplate from the old chime unit.



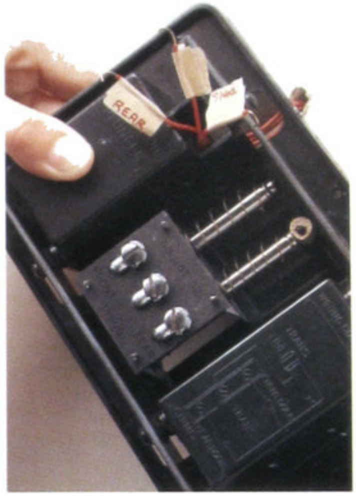
2 Using masking tape, label the low-voltage wires FRONT, REAR, or TRANS to identify their screw terminal locations. Disconnect the low-voltage wires.



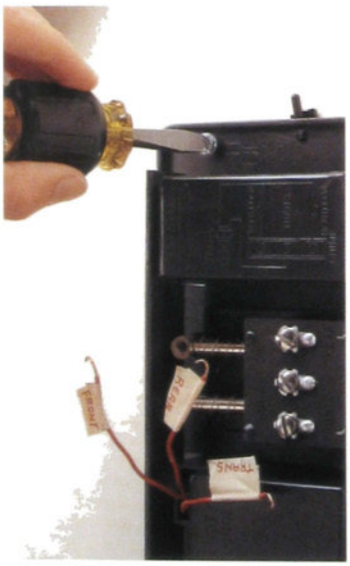
3 Unscrew the mounting screws, and remove the old chime unit



4 Tape the wires to the wall to prevent them from slipping i the wall cavity

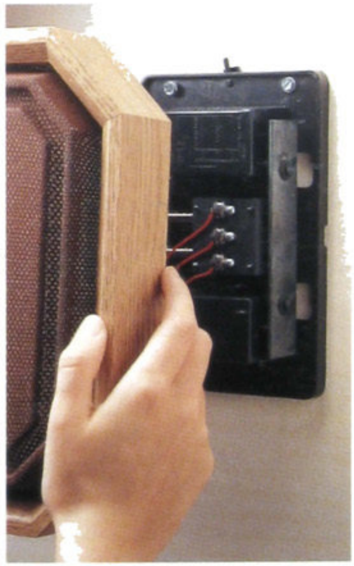


5 Purchase a new chime unit that matches the voltage rating of the old unit Thread the low-voltage wires through the base of the new chime unit



6 Attach the chime unit to the wall using the mounting screws included with the installation kit.

7 Connect the low-voltage wires to the screw terminals on the new chime unit.



8 Attach the coverplate and turn on the power at the main service panel.

Electronic programmable thermostats can be set to make up to four temperature changes each day. They are available in low-voltage designs (right) for central heating/cooling systems and in line-voltage designs (left) for electric baseboard heating. Most electronic programmable thermostats have an internal battery that saves the program in case of a power failure.

Fixing & Replacing Thermostats

A thermostat is a temperature-sensitive switch that automatically controls home heating and air-conditioning systems. There are two types of thermostats used to control heating and air-conditioning systems. **Low-voltage thermostats** control whole-house heating and air conditioning from one central location. **Line-voltage thermostats** are used in zone heating systems, where each room has its own heating unit and thermostat.

A low-voltage thermostat is powered by a transformer that reduces 120-volt current to about 24 volts. A low-voltage thermostat is very durable, but failures can occur if wire connections become loose or dirty, if thermostat parts become corroded, or if a transformer wears out. Some thermostat systems have two transformers. One transformer controls the heating unit, and the other controls the air-conditioning unit.

Line-voltage thermostats are powered by the same circuit as the heating unit, usually a 240-volt circuit. Always make sure to turn off the power before servicing a line-voltage thermostat.

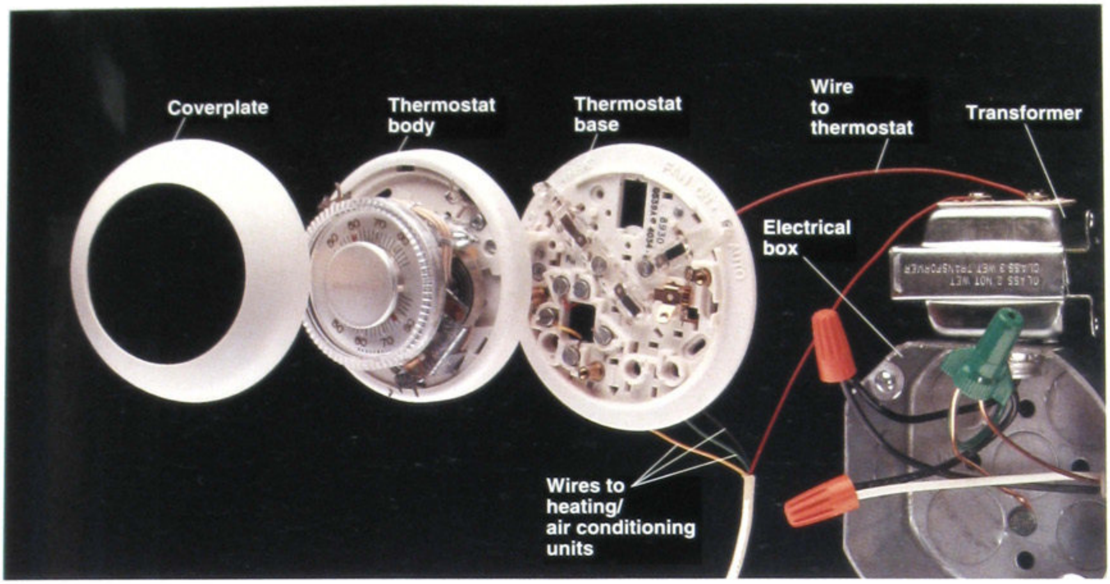
A thermostat can be replaced in about one hour. Many homeowners choose to replace standard low-voltage or line-voltage thermostats with programmable setback thermostats. These programmable thermostats can cut energy use by up to 35%.

When buying a new thermostat, make sure the new unit is compatible with your heating/air-conditioning system. For reference, take along the brand name and model number of the old thermostat and of your heating/air-conditioning units. When buying a new low-voltage transformer, choose a replacement with voltage and amperage ratings that match the old thermostat.

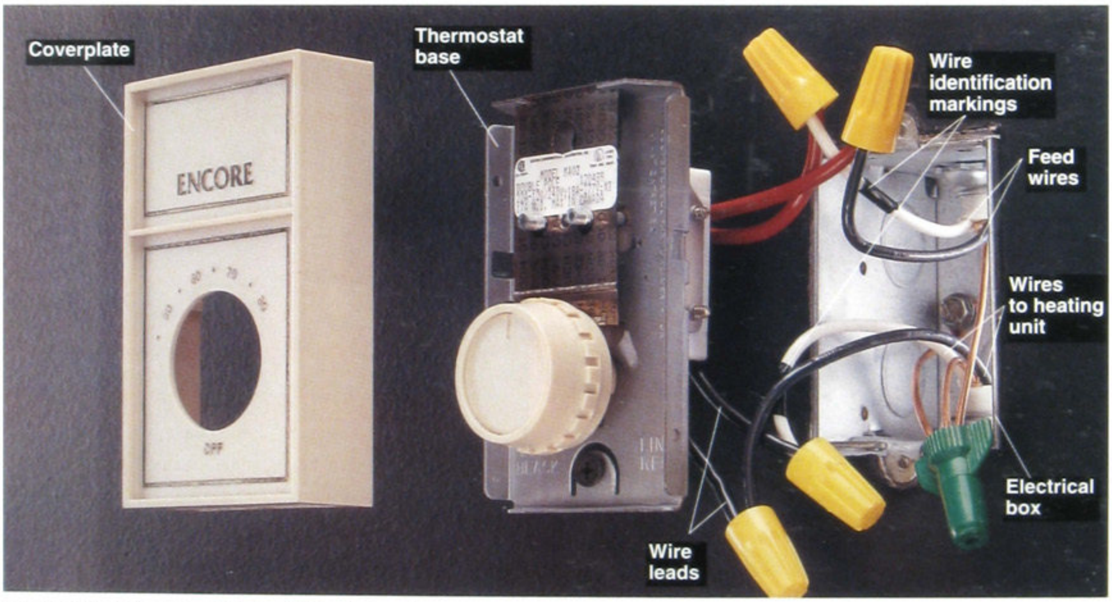
Everything You Need:

Tools: soft-bristled paint brush, multi-tester, screwdriver, combination tool, neon circuit tester, continuity tester.

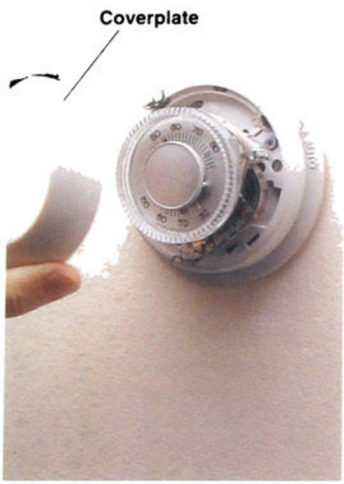
Materials: masking tape, short piece of wire.



Low-voltage thermostat system transformer
ar
thermostat

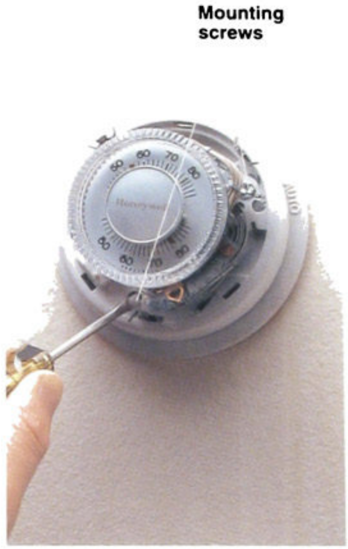


Line-voltage thermostat for 240-v lt baseboard heat- leads lthough some On -wire thermostat nes marked LINE or L) are attached to the two hot feed wires bringing into the box from the service pan The blac leads (sometimes marked LOAD) are connecte the circuit wires that carry power to the heatin

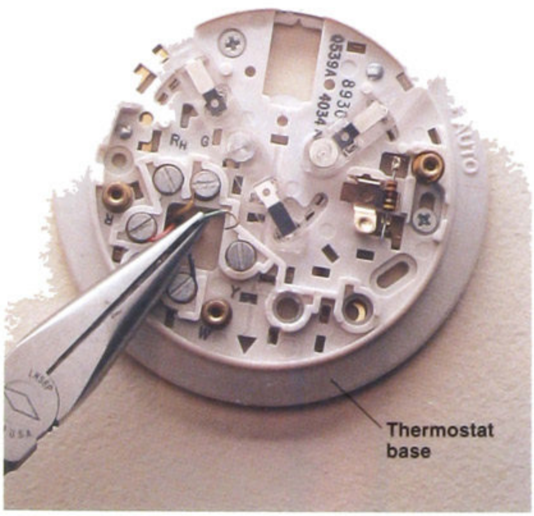


1 Turn off power to the heating/air-conditioning system at the main service panel Remove the thermostat coverplate

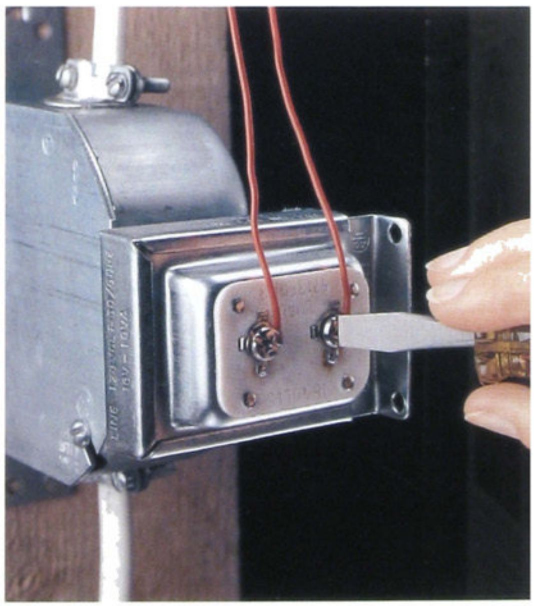
2 Clean dust from the thermostat parts using a small, soft-bristled paint brush



3 Remove the thermostat body by loosening the mounting screws with a screwdriver



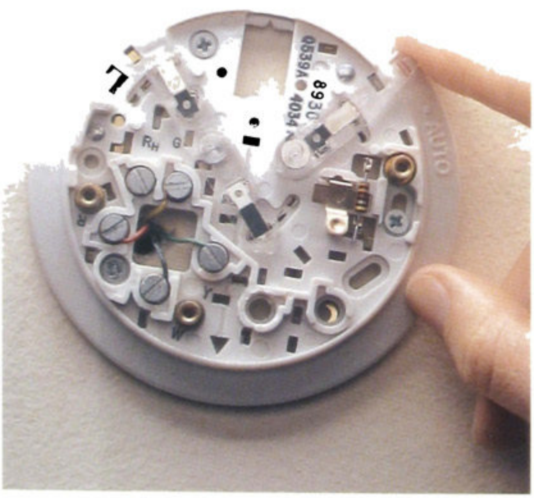
4 Inspect the wire connections on the thermostat base Reattach any loose wires. If wires are broken or corroded, they should be clipped, stripped, and reattached to the screw terminals.



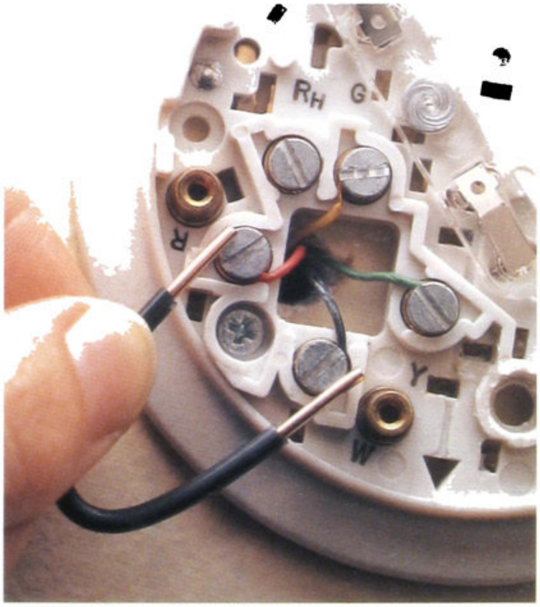
5 Locate the low-voltage transformer that powers the thermostat. This transformer usually is located near the heating/air-conditioning system or inside a furnace access panel. Tighten any loose wire connections.

6 Set the control dial of multi-tester meter to the 50-volt (AC) range Turn on power to the heating/ ir-conditioning system at the main service panel

7 Touch one probe of multi-test r to each of the low-voltage screw terminals If tester does not detect current then the transfor r is defective and must be replaced (page 111)

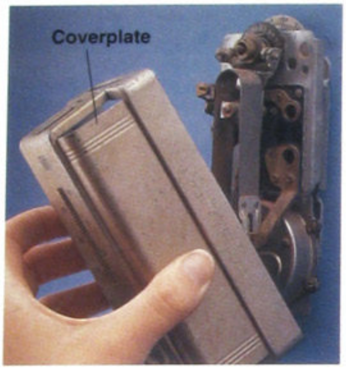


8 Turn on power to heating system Set thermostat control levers to AUTO and HEAT.

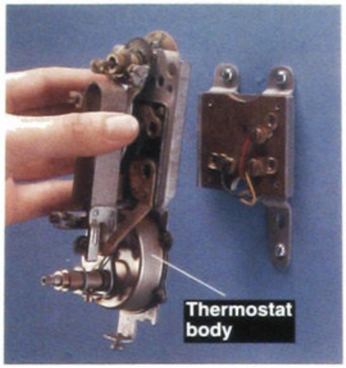


9 Strip from each end of a short piece of insulated wire Touch one end of the wire to terminal marked W and the other end to terminal marked R If heating system begins to run, then the thermostat is faulty and must be replaced (page 110).

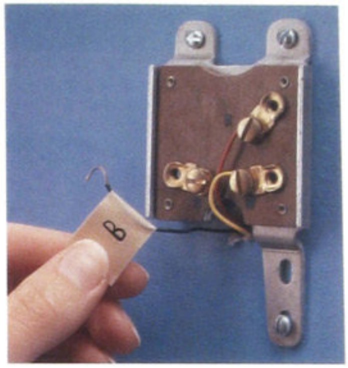
How to Install a Programmable Low-voltage Thermostat



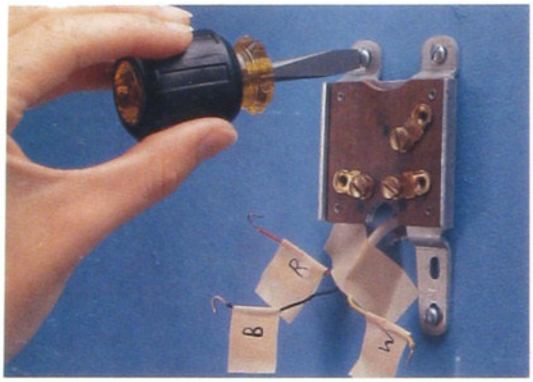
1 Turn off power to the heating/ air-conditioning system at the main service panel Remove the thermostat coverplate



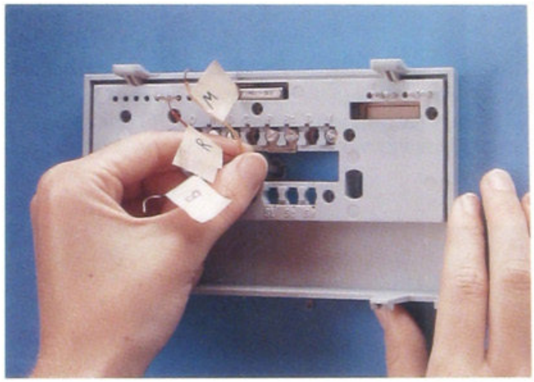
2 Unscrew the thermostat mounting screws, and remove the thermostat body



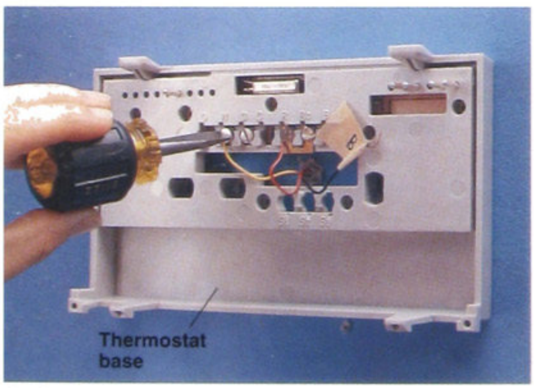
3 Label the low-voltage wires to identify their screw terminal locations, using masking tape. Disconnect all low-voltage wires.



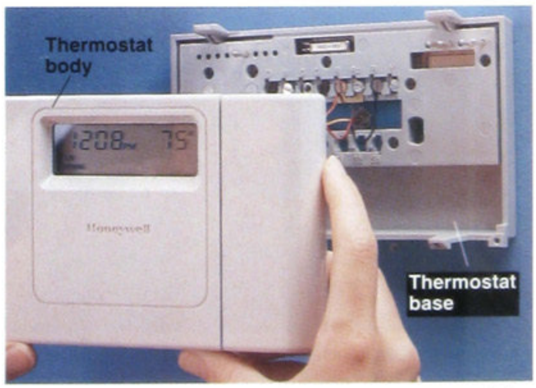
4 Remove the thermostat base by loosening the mounting screws Tape the wires against the wall to make sure they do not fall into the wall cavity



5 Thread the low-voltage wires through base of new thermostat. Mount the thermostat base on the wall, using the screws included with the thermostat.

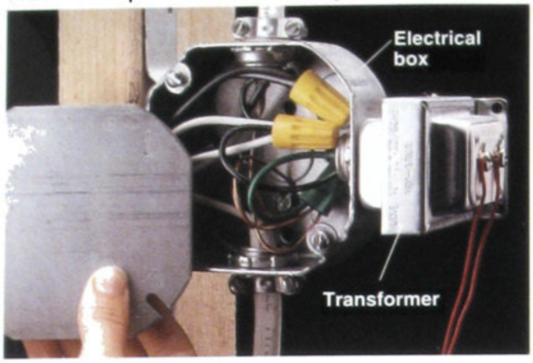


6 Connect the low-voltage wires to the screw terminals on the thermostat base. Use the manufacturer's connection chart as a guide.

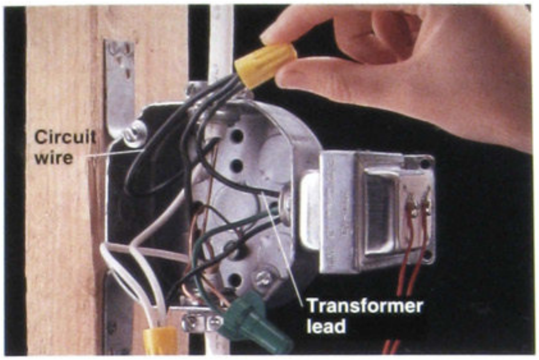


7 Install batteries in thermostat body, then attach the body to thermostat base. Turn on power, and program the thermostat as desired.

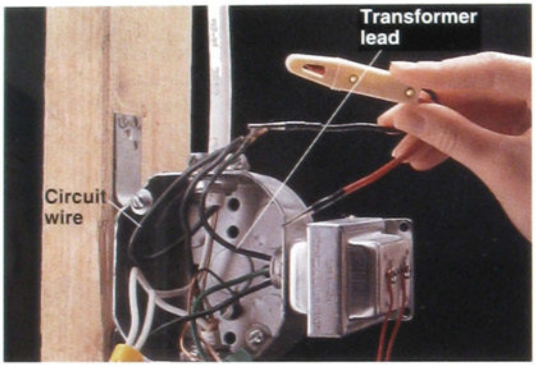
How to Replace a Low-voltage Transformer



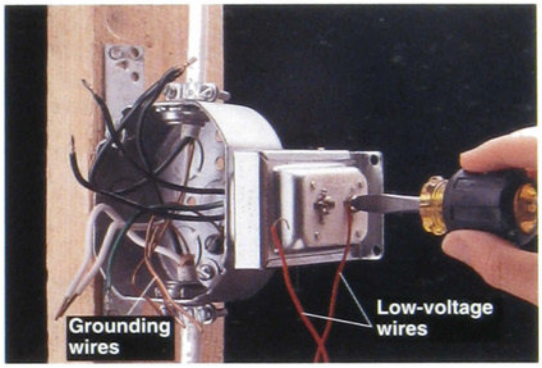
1 ing -conditioning
rvice panel. Remove the
electrical box.



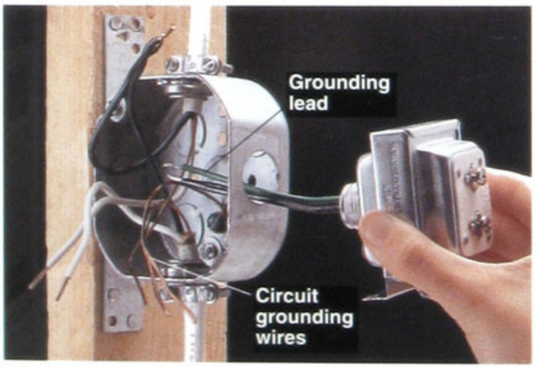
2 Carefully remov oining
black circuit Be
ful not to touch



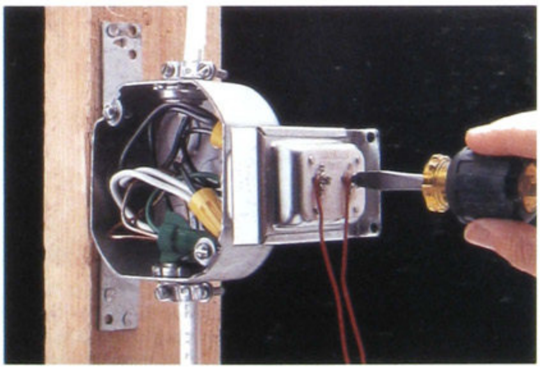
3 wer by touching one probe of neon cir-
r to grounded metal box and other probe
wires. Remove ire connector from white
repeat test. Test r should not glow for
If it does, power is still entering box.
rvice panel and turn off correct circuit.



4 Disconnect the grounding inside
then disconnect low-voltage wires attach
screw terminals on the transformer. Unscrew
transformer mounting bracket inside the box
remove transformer. Purchase a new
the same voltage ratin



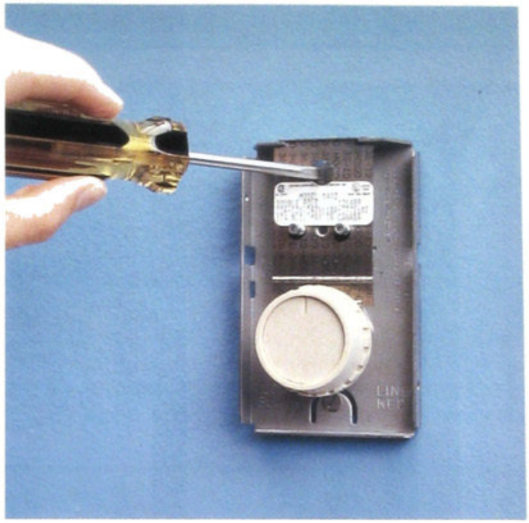
5 rmer to electrical box. Recon-
transformer leads. Connect
wires to transformer grounding lead.



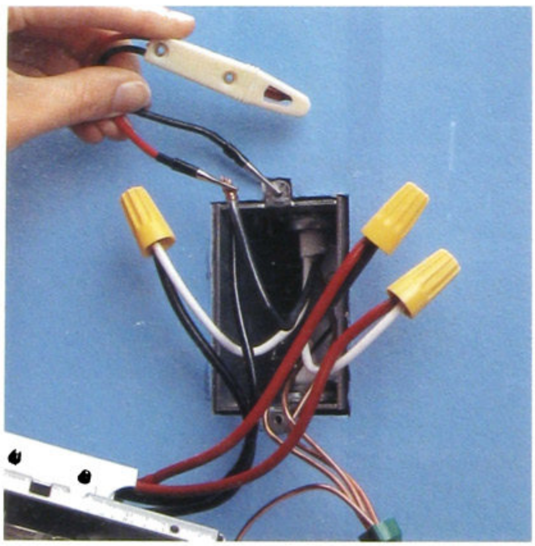
6 Connect the low-voltage wires to the tr
and reattach the electrical box cover. I
on the power at the main service panel.

How to Test & Replace a Line-voltage Thermostat

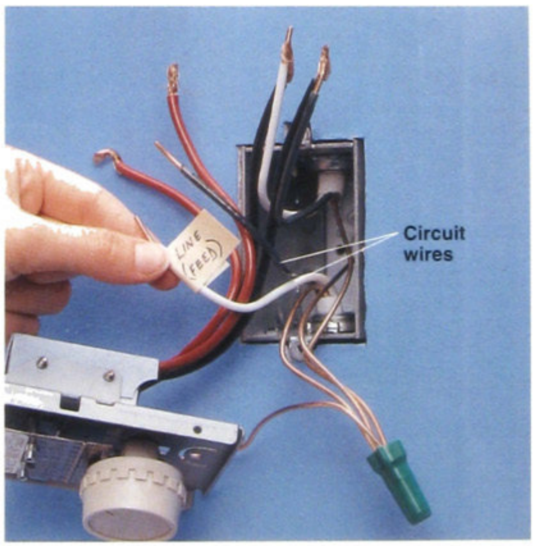
1 Turn off power to the heating unit at the main service panel. Remove the thermostat coverplate.



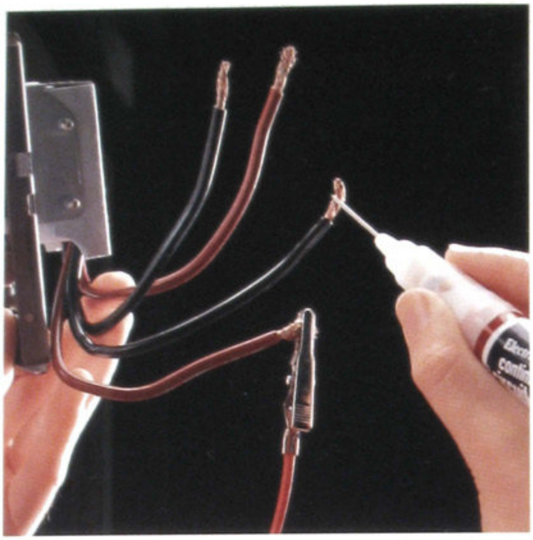
2 Loosen the thermostat mounting screws, and carefully pull the thermostat from the electrical box.



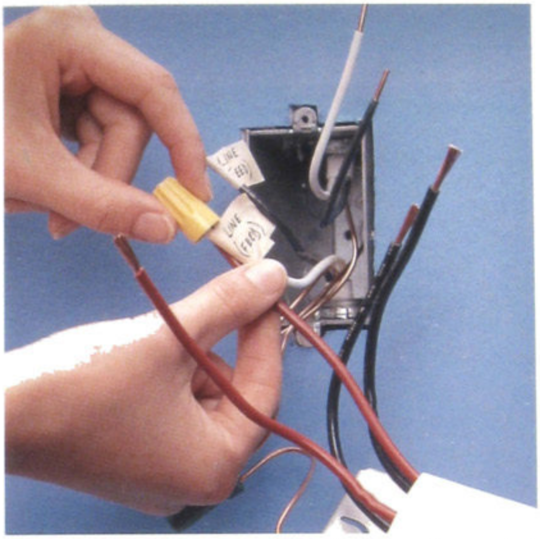
3 Unscrew one wire connector Test for power by touching one probe of neon circuit tester to grounded metal box and touching other probe to exposed wires. Tester should not glow. Repeat test with other wire connections. Tester should not glow. If it does, then power is still entering box. Return to service panel, and turn off correct circuit.



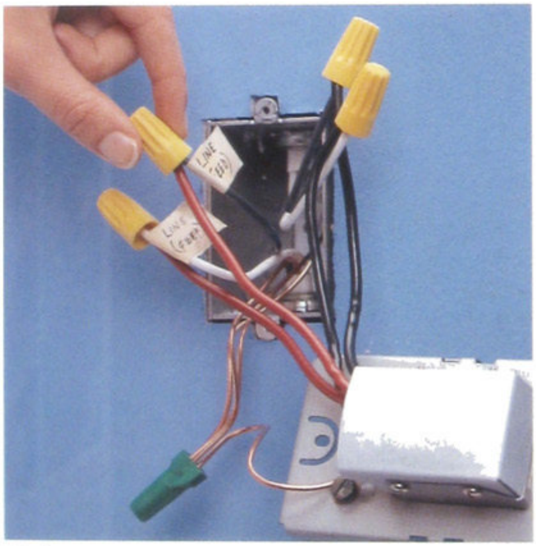
4 Identify the two circuit wires that are attached to the thermostat leads marked LINE. The circuit wires attached to the LINE leads bring power into the box and are known as feed wires. Label the feed wires with masking tape, then disconnect all wires.



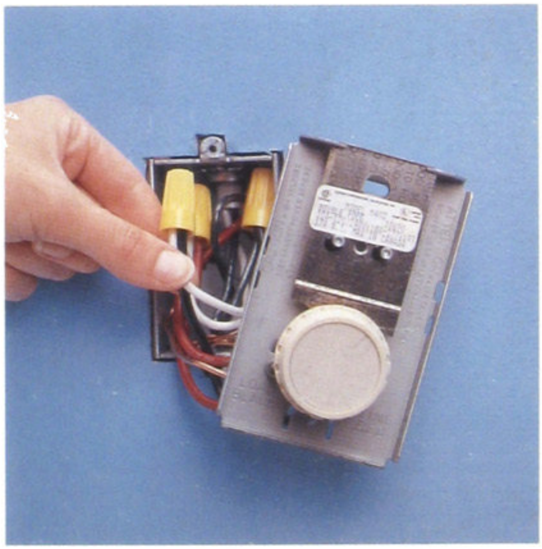
5 Test thermostat by attaching the clip of a continuity tester to one of the two leads marked LINE then touching probe to wire lead marked LOAD on same side of thermostat. Turn temperature dial from HIGH to LOW Tester should glow in both positions. Repeat test with other pair of wire leads. If tester does not glow for both positions, thermostat is faulty and must be replaced.



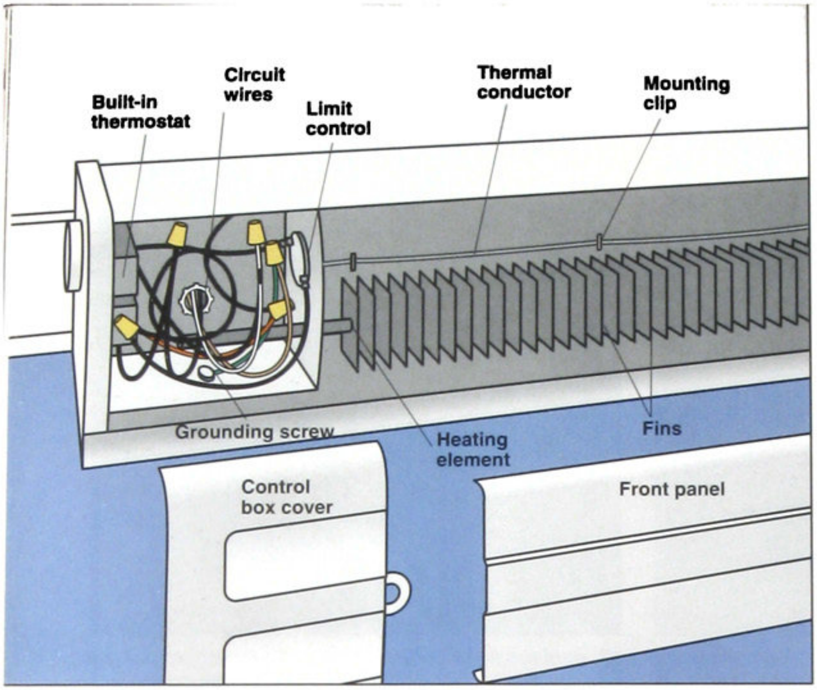
6 Replace a faulty thermostat with a new thermostat that has the same voltage and amperage ratings as the old one. Connect the new thermostat by attaching the circuit feed wires to the wire leads marked LINE, using wire connectors.



7 Connect the remaining circuit wires to the thermostat leads marked LOAD, using wire connectors. Connect the grounding wires together with a wire connector.



8 Carefully fold the wires inside the electrical box, then attach the thermostat mounting screws and the coverplate. Turn on the power at the main service panel. If new thermostat is programmable (page 106), set the program as desired.



Repairing Electric Baseboard Heater

Baseboard heaters are simple electrical units consisting of a heating **element** with attached metal **fins** for transferring heat, and a **limit control**—a switch that prevents the element from overheating. To control the temperature, some models have a built-in thermostat; others are controlled by a **line voltage**, or *zone* thermostat (page 106)—a wall mounted thermostat that is wired directly to the heater.

Most heaters are wired to a 240-volt circuit, which means both the black and white circuit wires are hot and carry voltage. Others use 120 volts and are wired to a circuit or plugged into a standard receptacle. The tests for all three types are nearly the same.

If the heater is wired to a household circuit, shut off the power at the main service panel, and test for power before proceeding (left).

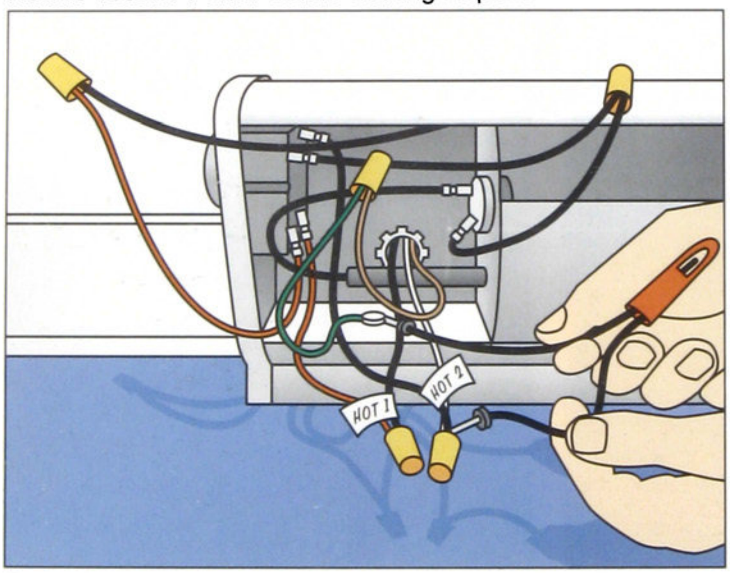
NOTE: Wiring for heaters and thermostats vary. For the best—and safest—results, check the manufacturer's wiring instructions, and label all wires before disconnecting.

Everything You Need

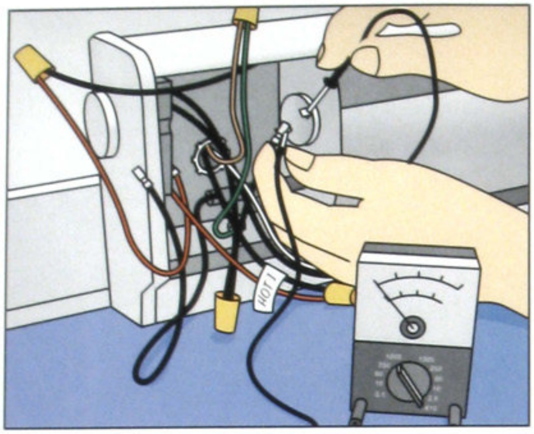
Tools: screwdriver, neon circuit tester, multi-tester, vacuum or brush, needlenose pliers.

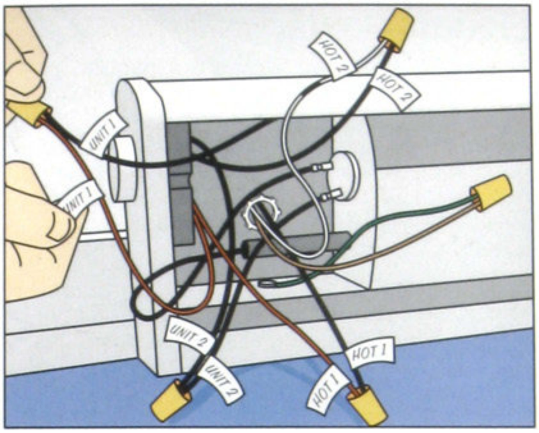
Materials: (as needed) replacement parts, masking tape, pen.

How to Test for Power Before Making Repairs



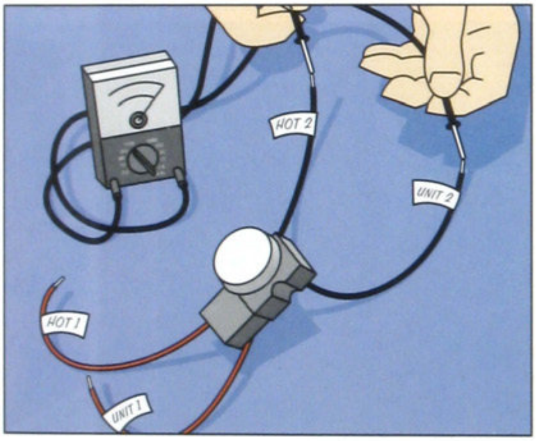
Turn off the power to the heater at the main service panel. Remove the heater's control box cover, and label the black hot circuit wire. Insert one probe of a neon circuit tester into the wire connector at the end of the circuit wire, and touch the other probe to the grounding screw on the heater casing. Then, label the other circuit wire (with a 240-volt heater, this wire will also carry voltage). Insert the tester probe into its wire connector, and touch the other probe to the grounding screw. Finally, insert one probe into each of the wire connectors you've just tested. If the tester glows for any of the tests, the power is still on. Return to the service panel, and turn off the correct circuit.

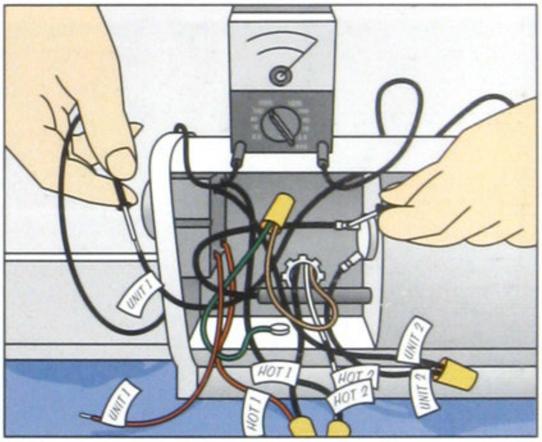




1 Begin by testing the limit control. Shut off the power at the main service panel, and confirm it is off by testing the unit (page 114). Pull a limit control lead from its terminal. Set multi-tester to test continuity Touch one probe to each limit control terminal. If the tester needle moves to ZERO, it means the limit control is working correctly, and you should move on to testing the thermostat (step 2). If the needle does not move to ZERO, remove the limit control and thermal conductor from the unit, and replace it with a duplicate part from the manufacturer

2 To test the thermostat, start by labeling each thermostat lead and wire connected to it, giving both wires the same name. Designate circuit wires and their respective leads as HOT, and heater wires and their respective leads as UNIT





3 Disconnect wires, and remove thermostat. Turn thermostat dial to highest (hottest) setting. Set multi-tester to test continuity. Touch one probe to a HOT wire lead and the other to each UNIT wire. Tester needle should move to ZERO to indicate continuity in one of the connections. Repeat test for the other HOT wire lead and each UNIT wire. If there is continuity for both HOT wires, move on to step 4. If the thermostat fails either test, replace with duplicate part from manufacturer.

4 Test the heating element. Find the heating element wire that connects to a thermostat lead. (This wire may come from the far end of the element.) Unscrew wire connector, and separate wires. Set multi-tester to test continuity Touch one probe to the free heating element wire and the other to the wire running from limit control to the other end of the element. Tester needle should move to ZERO to indicate continuity, meaning element is sound and the problem may lie in the circuit. If not, the element is bad, and the entire unit should be replaced.

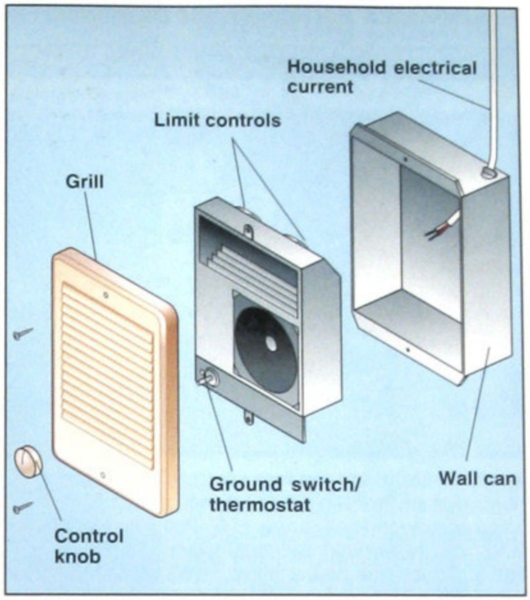
Repairing Wall-mounted Electric Heater

Wall-mounted electric heaters are installed between studs in an interior wall, typically in small areas, such as entryways or bathroom additions, where no other heat source is available. They work on the same principles as electric baseboard heaters (pages 114 to 115), generating heat by running electrical current through a heating element.

Wall-mounted heaters often contain a fan to help distribute heat to the room. If the heater won't turn on or shut off when the room temperature changes or when you turn the control knob, minor repairs may solve the problem.

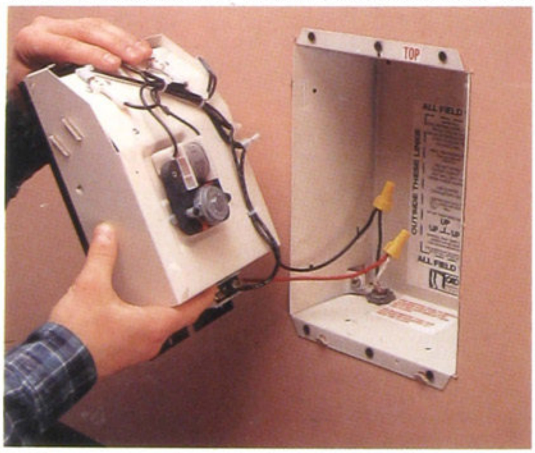
The heater may have one or two limit controls near the heating element. They are designed to shut off the heater if it overheats. If there is a slight burning smell and the heater doesn't shut itself off, one or both limit controls may be faulty.

If the heater doesn't respond when adjusting the control knob, the thermostat may be faulty. Starting at OFF, turn the thermostat knob, and listen for a click. If the unit doesn't click, test the thermostat for continuity, using a multi-tester. Replace the thermostat if it is faulty.

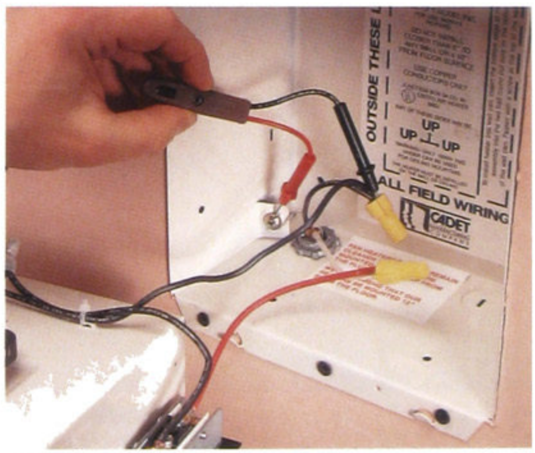


Inspect a wall-mounted heater before the start of the heating season. Dirt and dust can build up around the heating element, resulting in a burning smell when the heater is back in service. A careful cleaning with a soft-bristled brush is important for safe, reliable use.

How to Remove the Heater and Check for Power

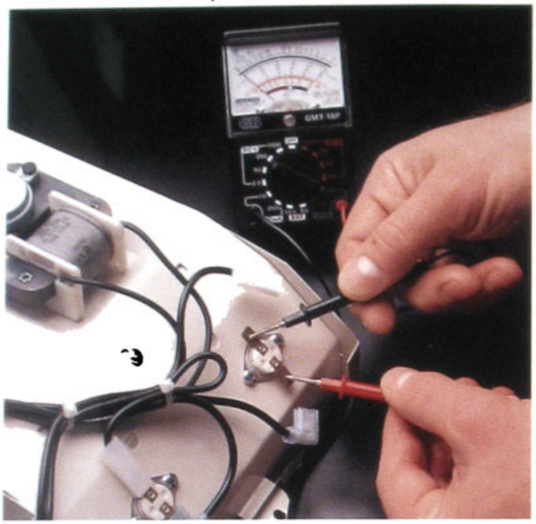


1 To remove and test the heater, shut off the power to the heater at the main service panel. Remove the control knob. Loosen the mounting screws on the grill, and slide the heater out of the wall can. Lift the top out first, disengaging the tabs at the base.

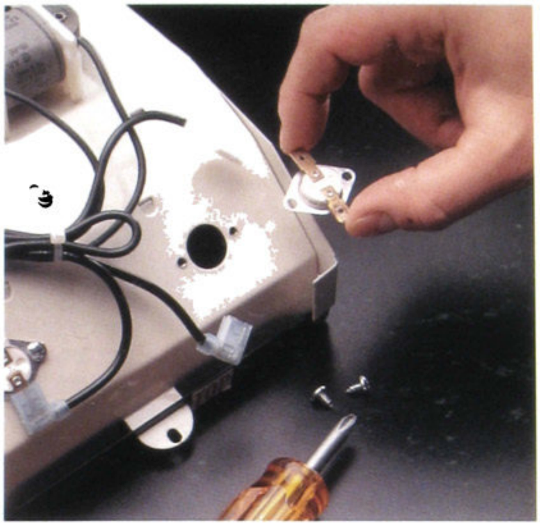


2 Insert one end of a neon circuit tester into the wire connector holding the black circuit wire, and touch the other probe to the grounding screw. Repeat, touching the probes to the white circuit connector and grounding screw. Finally, insert one probe into each of the wire connectors. The tester should not glow for any of these tests. If it does, shut off the correct circuit breaker on the main service panel. Repeat the tests until the tester does not glow.

How to Test & Replace a Limit Control

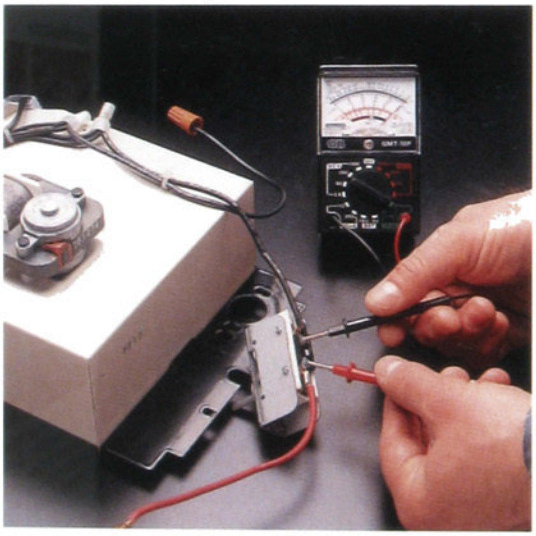


1

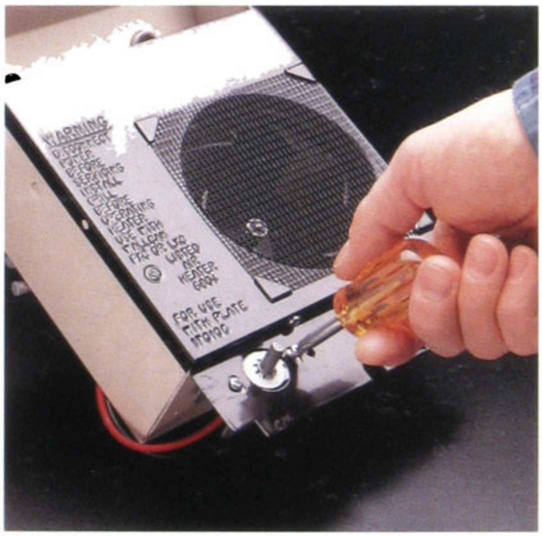


2 If th doesn the ntrol and from th When p

How to Test & Replace a Thermostat



1 off the power to the heater at the main ice panel and check for power (page 116) Disconnect one lead from the back of the control hermostat unit by prying it loose with a ose pliers or unscrewing With the multi-test for continuity place one probe on



2 If the multi-tester doesn t indicate continuity remove the other lead and unscrew the contr switch/thermostat unit from the base of the heater Install an identical replacement unit

Home Telephone System

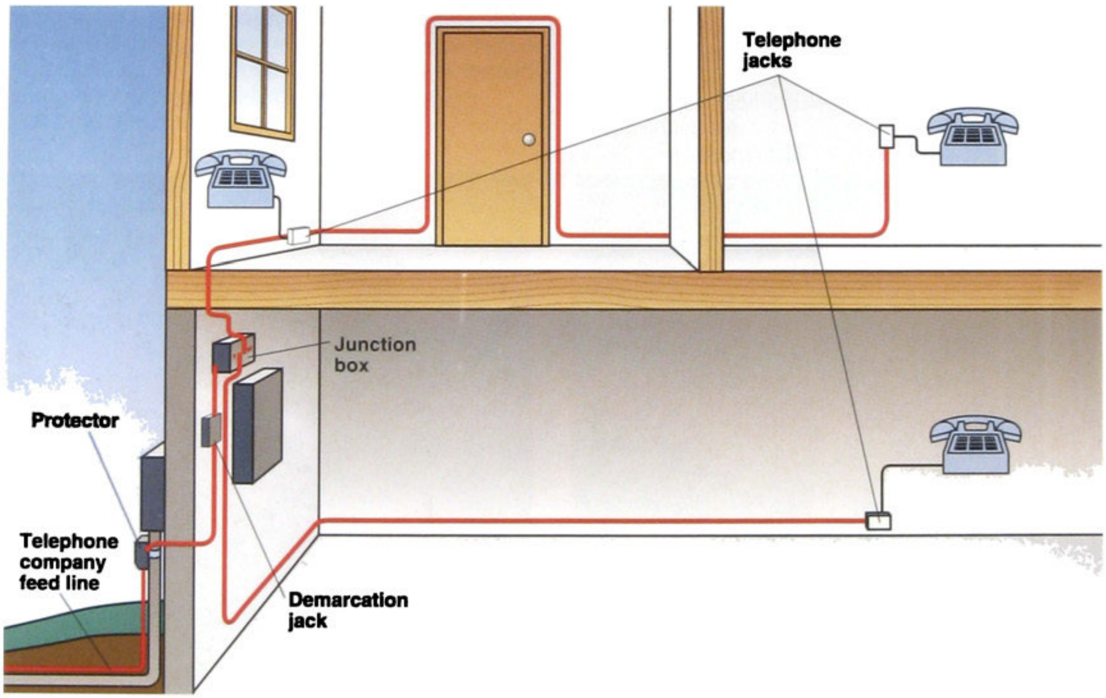
Although the telephone company owns the wires that bring telephone service to the house, repair and new installation can take place in any part of the telephone system that extends past the company's demarcation jack. The demarcation jack is usually located in a basement or utility area, although it may also be mounted on a baseboard in a home's living quarters.

Because the voltage running through telephone wires is very low, there is little danger of shock when working on the wiring. Still, it is best not to work in wet conditions when repairing any wiring. Also, do not work on a phone system if you wear a cardiac pacemaker, because the mild electrical currents in phone lines can interfere with the device.

Common telephone repairs include replacing a loose or broken modular connection, installing a modular jack in place of an outdated jack, and installing a junction box that allows additional phone jacks to be run anywhere in the house.

A phone can be plugged directly into the demarcation jack to find out if a problem lies in the house wiring or in the phone company's wires and equipment. If there is no dial tone at the demarcation jack, the problem lies outside the home and should be fixed by the phone company. If there is a dial tone, however, this means that any problem lies inside the house.

NOTE: As the needs for Internet service and network data links in the home become increasingly important, larger and stronger telecommunication cables are needed in place of standard two-way telephone lines. Pages 272 to 293 contain information on telecommunication cable and home network systems available for home installation that allow faster and more reliable pathways for data and telephone transference.



Two methods are used to wire phone systems. Relatively new systems are wired using the **home run** method (shown above), in which a wire distribution hub, or junction box, feeds individual lines to various phone jacks in the house. A junction box allows new jacks to easily be added by running new wires from the box to the new location. If one line becomes damaged, the other jacks will still operate. Older systems use a **continuous loop** method. With this method, various jacks are installed along a single loop of wire running throughout the house. A continuous loop is easier to install but less reliable since a single problem in the wire can render all the jacks inoperable.

Troubleshooting Phone Problems

Problems	Possible causes	Solutions
Dead air sound on line	Wires may be crossed.	Make sure bare copper wires inside jack aren't touching.
	Wires may be wet.	Check for moisture in phon
	Wire connections may be loose.	Check all connections.
Buzzing on lin	Wires may be touching metal.	Check all wires and connections
	Wires may be connected to wrong terminals.	Check color coding of connections.

Wire Assignments

Most phone cords have four wires: red, green, yellow, and black. But there are two other possible color schemes. Use the following as a guide to connecting wires:

The red terminal will accept:
- a red wire
- a blue wire
- a blue wire w/white stripe

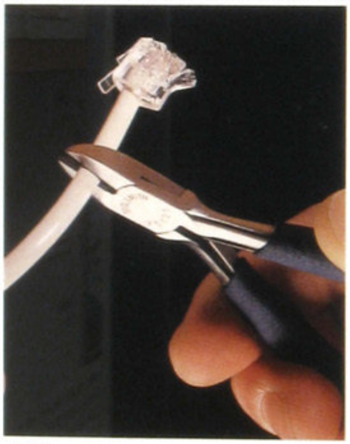
The green terminal will accept:
- a green wire
- a white wire w/blue stripe

The yellow terminal will accept:
- a yellow wire
- an orange wire
- an orange wire w/white stripe

The black terminal will accept:
- a black wire
- a white wire w/orange stripe

there are extra wires in the cord (usually these will be green and white), they can be tucked into the jack nd left unconnected The phone company will use these wires to connect additional phone lines if you should ever need them

How to Replace a Modular Connector



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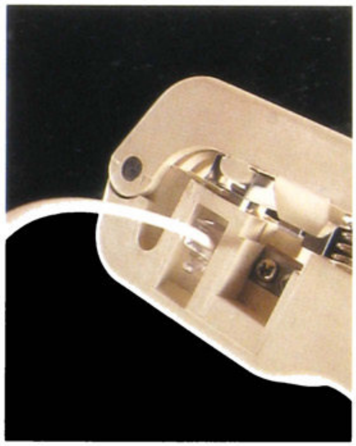
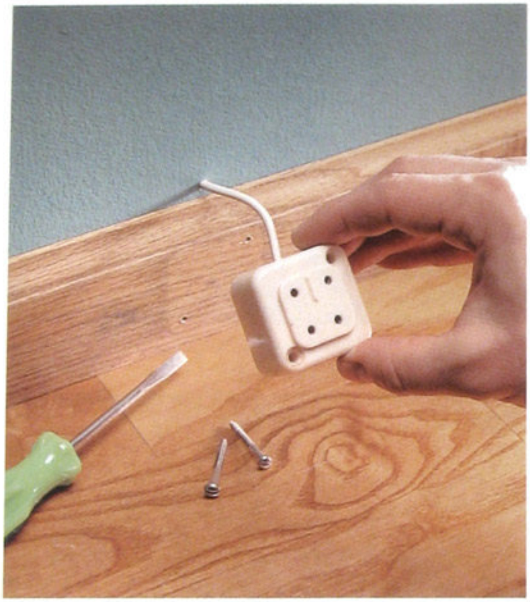
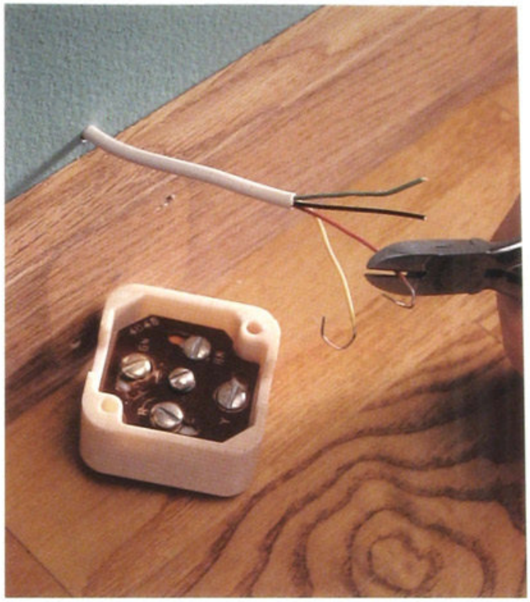


3

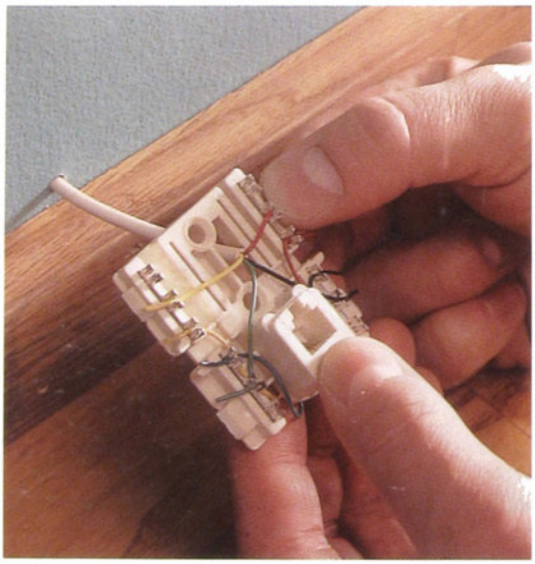
How to Install a Modular Jack



1 Disconnect the phone cord from the jack. Unscrew the phone jack from the wall or baseboard with a screwdriver. Gently pull the jack away from the wall.



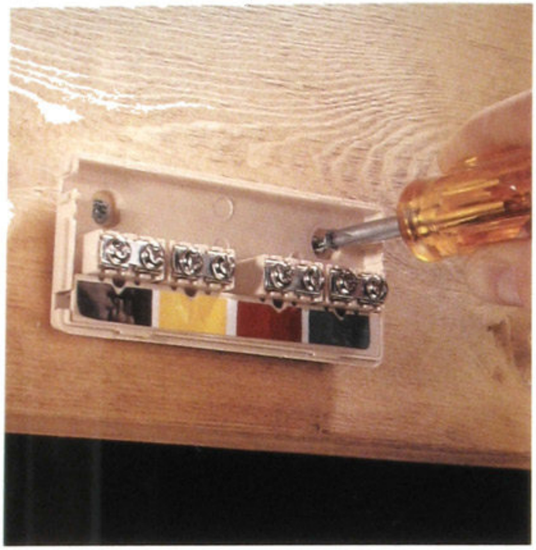
2 Disconnect the individual wires from the terminals on the jack. Clip off the bare copper ends of the wire, using a wire cutter.



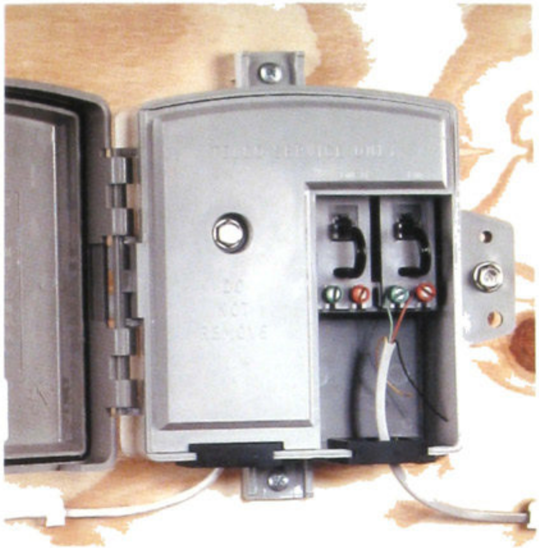
3 Remove casing from the connection block on the new modular jack, and feed phone cables through the back of the base piece. Force each colored wire into one of the metal slots on the terminal block that has a wire of the same or acceptable color (page 119). About ½" of wire should extend through the slot.

4 Screw the connection block to the wall with the screw included with the jack, and snap cover-plate in place. Attach a phone to the new jack, and test it to make sure it works.

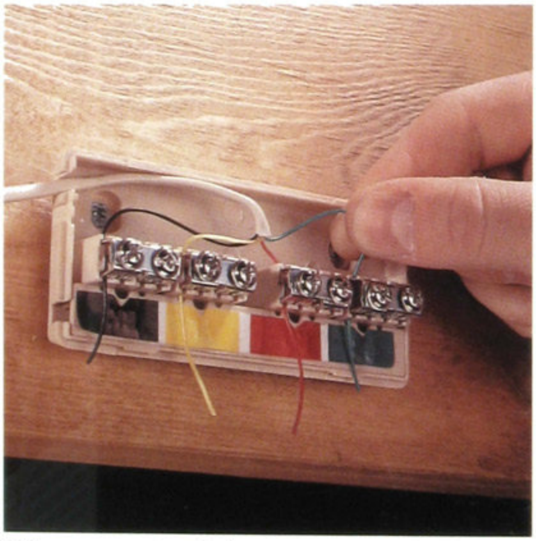
How to Install a Telephone Junction Box



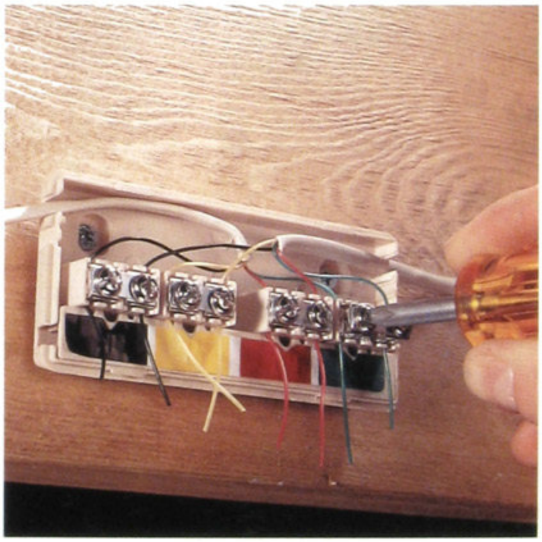
1 Select a location that allows the cable for the junction box to reach the demarcation jack. Snap off the cover of the junction box. Attach the box to a wall, baseboard, or framing member, using the mounting screws that are included with it. Run phone cable to the demarcation jack. Secure to wall or framing members with staples every 24".



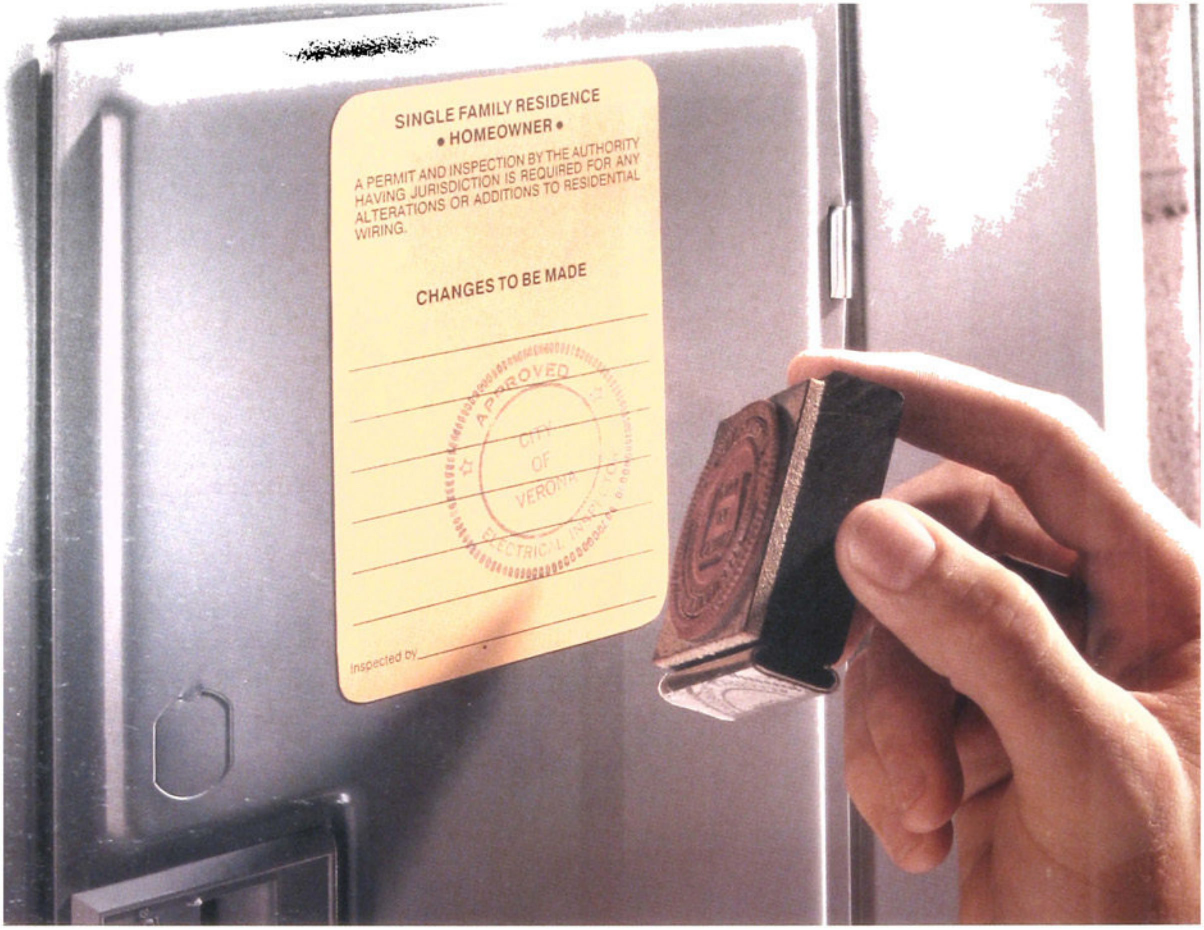
2 Trim all but 5" of cable, and strip off 3" of outer insulation, using a crimper. Strip 1 of inner insulation from each of the four individual wires, using a utility knife. Loop the bare copper wires clockwise around demarcation jack screw terminals, matching the colors. Tighten screws. NOTE: Some junction boxes have attached cords with modular connections that plug directly into demarcation jacks.



3 Loosen one terminal screw on each of the four color-coded sections of the junction box. Insert each wire into a slot in the corresponding section. About of wire should extend through the slot.



4 For each phone extension line, attach the cable to the junction box following the same procedure used for the cable running to the demarcation jack. Screw the terminals down tight, then bend the wires upright so they don't touch each other. Snap the cover back on the junction box.



Inspector's Notebook

An electrical inspector visiting your home might identify a number of situations that are not "up to code." These situations may not be immediate problems. In fact, it is possible that the wiring in your home has remained trouble-free for many years.

Nevertheless, any wiring or device that is not up to code carries the potential for problems, often at risk to your home and your family. In addition, you may have trouble selling your home if it is not wired according to accepted methods.

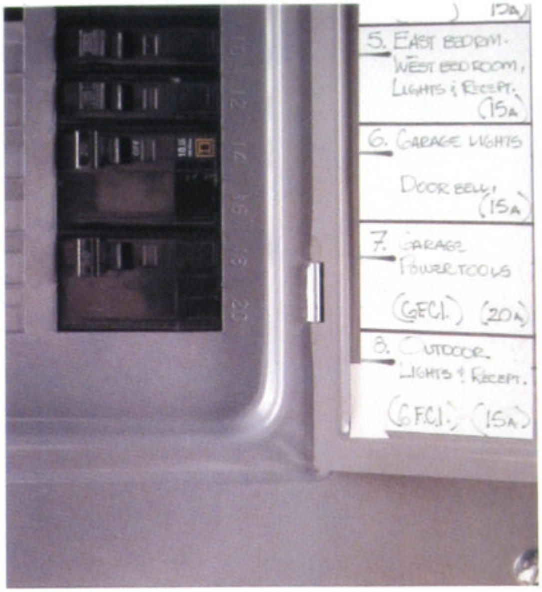
Most local electrical codes are based on the National Electrical Code (NEC), a book updated and published every three years by the National Fire Protection Agency. This code book contains rules and regulations for the proper installation of electrical wiring and devices. Most public libraries carry reference copies of the NEC.

All electrical inspectors are required to be well versed in the NEC. Their job is to know the NEC regulations and to make sure these rules are followed in order to prevent fires and ensure safety. If you have questions regarding your home wiring system, your local inspector will be happy to answer them.

While a book like *The Complete Guide to Home Wiring* cannot possibly identify all potential wiring problems in your house, we have created the "Inspector's Notebook" to help you identify some of the most common wiring defects and show you how to correct them. When working on home wiring repair or replacement projects, refer to this section to help identify any conditions that may be hazardous.

;ervice Panel Inspection

roblem:

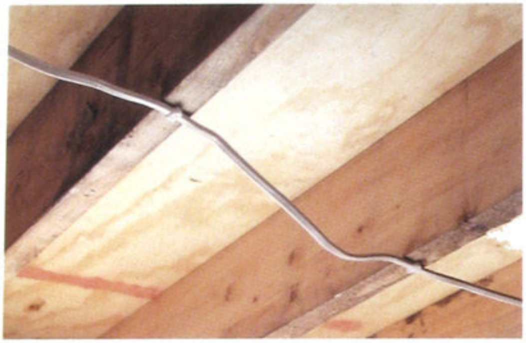


Solution:

ıspecting the Grounding Jumper Wire

'roblem: ...ire is missing or ...rounding jumper ...side of the water ...broken this is a ...should be fixed immediately

Solution: Attach a jumper wire to the water either side of the water meter using pipe cl Use #6-gauge or #4-gauge bare copper jumper wire

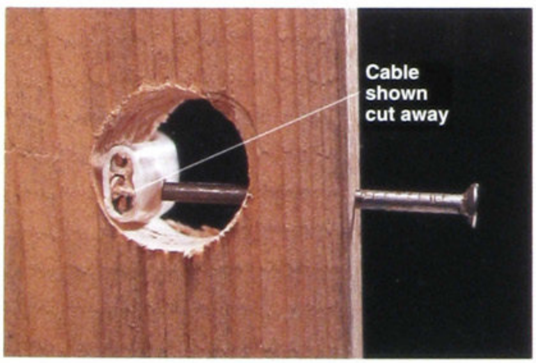


Problem: Cable running across joists or studs is attached to the edge of framing members. Electrical codes forbid this type of installation in exposed areas, like unfinished basements or walk-up attics.

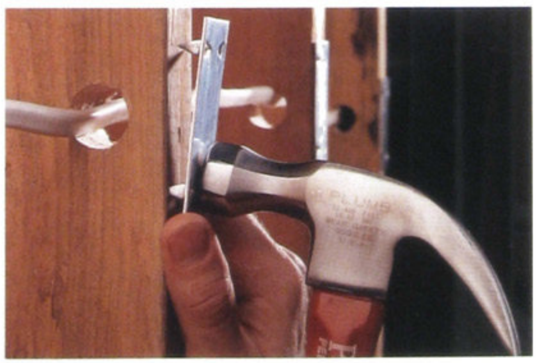
Solution: Protect cable by drilling holes in framing members at least 2" from exposed edges, and threading the cable through the holes.

Problem: Cable running along joists or studs hangs loosely. Loose cables can be pulled accidentally, causing damage to wires.

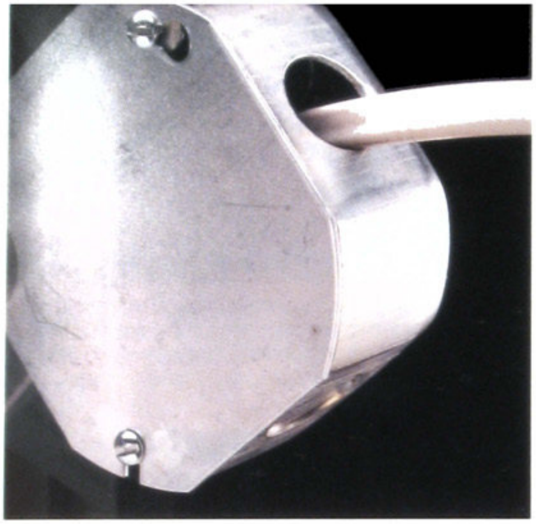
Solution: Anchor the cable to the side of the framing members at least 1¼" from the edge, using plastic staples. NM (nonmetallic) cable should be stapled every 4½ feet and within 12" of each electrical box.



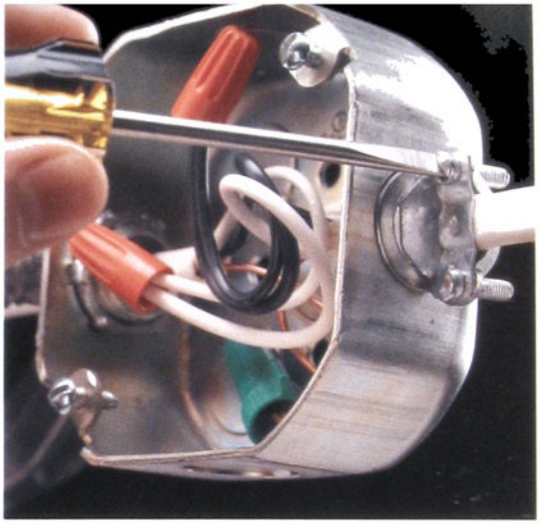
Problem: Cable threaded through studs or joists lies close to the edge of the framing members. NM (nonmetallic) cable (shown cut away) can be damaged easily if nails or screws are driven into the framing members during remodeling projects.



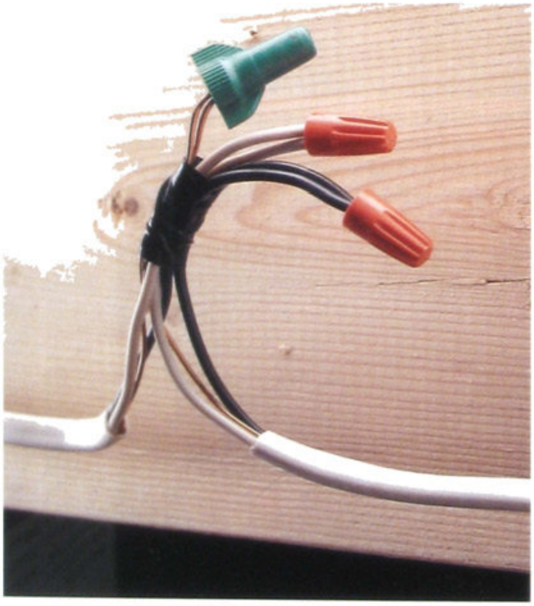
Solution: Install metal nail guards to protect cable from damage. Nail guards are available at hardware stores and home centers.



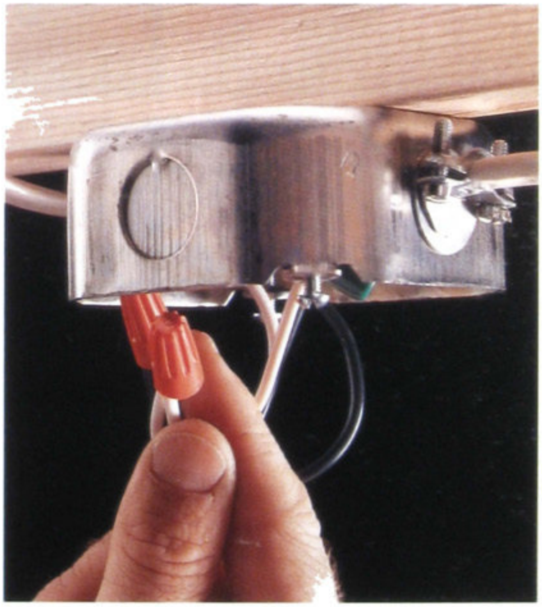
Problem:



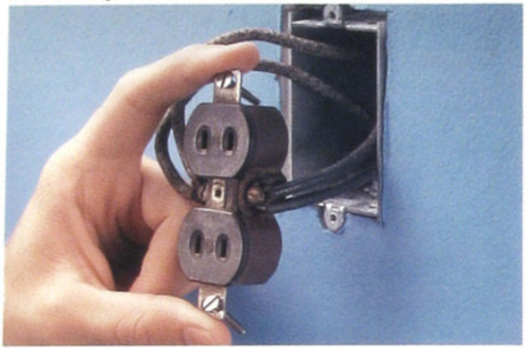
Solution:



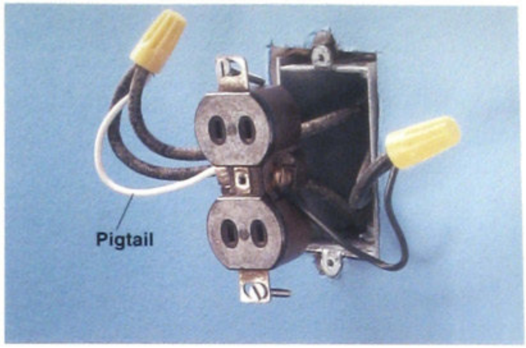
Problem: ide an electri and create c



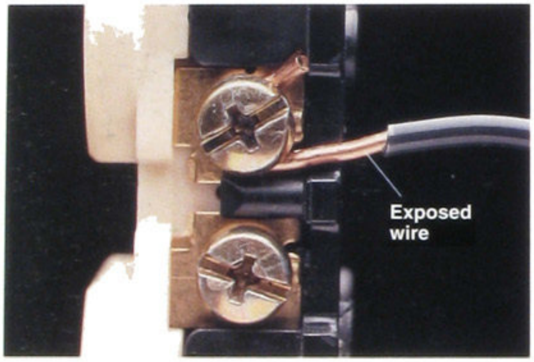
Solution: Bring installation up to code the splice inside a metal or plastic electric (pages 38 to 39). Make sure the box is large eno for the number of wires it contains (page 36).



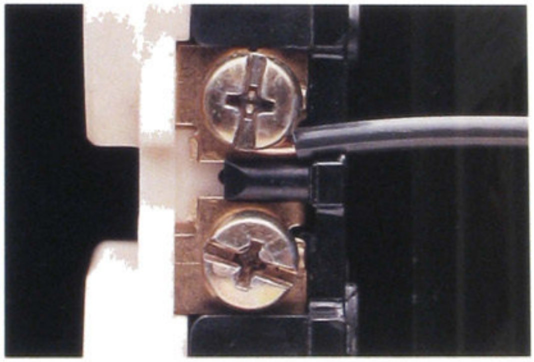
Problem: Two or more wires are attached to a single screw terminal This type of connection is seen in older wiring but is now prohibited by the National Electri l Code



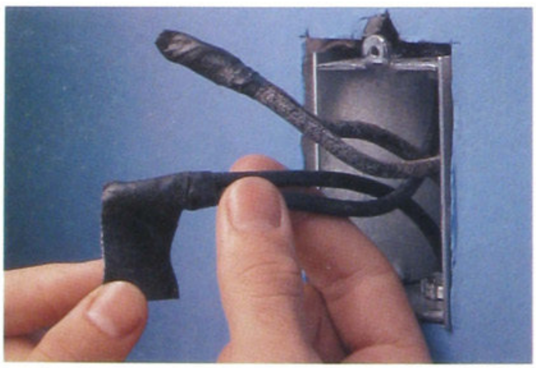
Solution: Disconnect the wires from the screw termi-nal, then join them to a short length of wire (called a pigtail), using a wire connector (page 25) Connect the other end of the pigtail to the screw t rminal



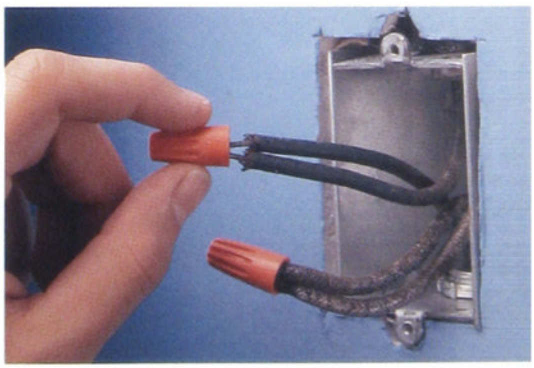
Problem: Bare wire extends past a scr terminal Exposed wire can cause a short circuit it touches the metal box or another circuit wire



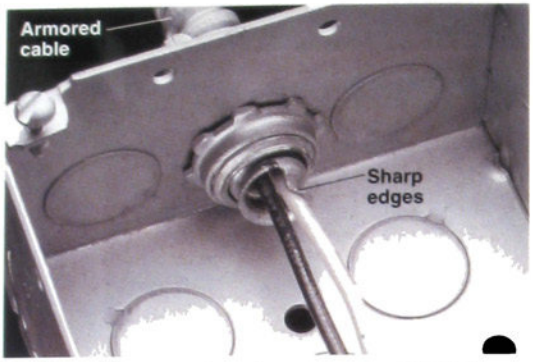
Solution: Clip the wire and reconnect it to the screw terminal In a proper connection, the bare wire wraps completely around the screw terminal and the plastic insulation just touches the screw head (page 24)



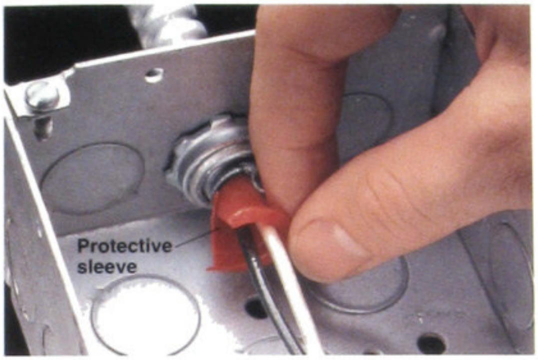
Problem: Wires are connected with electrical tape Electrical tape was used frequently in older installa-tions, but it can deteriorate over time leaving bare wires exposed inside the electrical box.



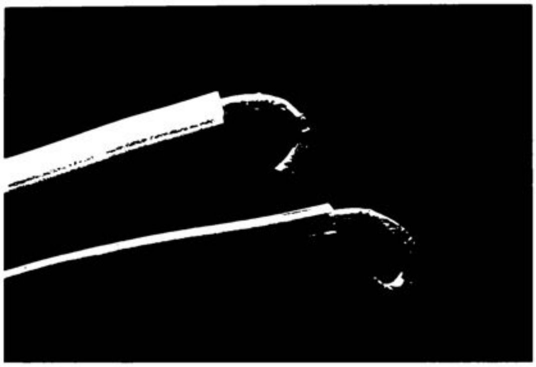
Solution: Replace electrical tape with wire connec-tors (page 25) You may need to clip away a small portion of the wire so the bare end will be covered completely by the connector.



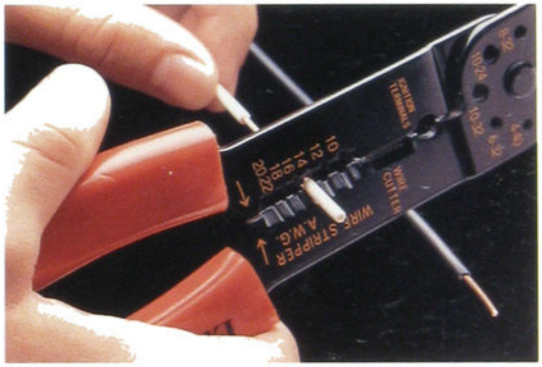
Problem: No protective sleeve on armored cabl Sharp edges of the cable can damage the wire creating a shock hazard and fire risk



Solution: Protect the wire insulation by installing plastic or fiber sleeves around the wires Sleeves are available at hardware stores Wires that are damaged must be replaced



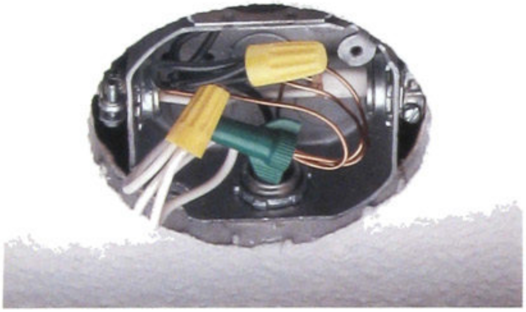
Problem: Nicks and scratches in bare wires interfere the flow of current This can cause the wires to



Solution: Clip away damaged portion of wir restrip about of insulation and reconnect t to the screw terminal (page 24)

Problem: Insulation on wires is cracked or damaged If damaged insulation exposes bare wire a short cir- . can occur posing a shock hazard and fire risk.

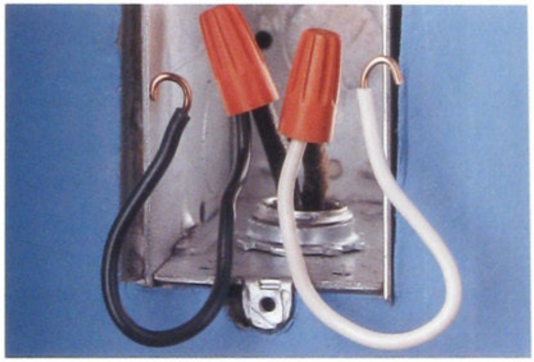
Solution: Wrap damaged insulation temporarily with plastic electrical tape Damaged circuit wires should be replaced by an electrician.



Problem: Open electrical boxes create a fire hazard if a short circuit causes sparks (arcing) inside the box.

Solution: Cover the open box with a solid metal cover-plate, available at any hardware store. Electrical boxes must remain accessible and cannot be sealed inside ceilings or walls.

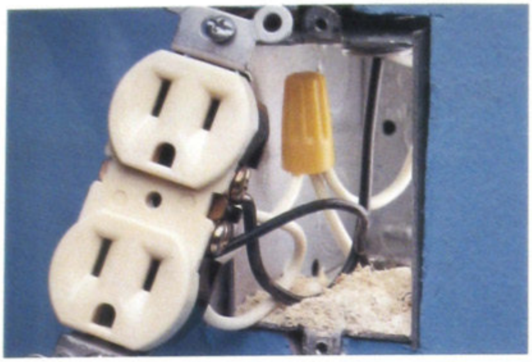
Problem: Short wires are difficult to handle. The National Electrical Code (NEC) requires that each wire in an electrical box have at least 6" of workable length.



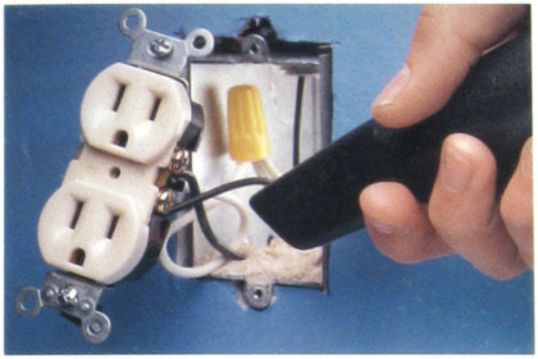
Solution: Lengthen circuit wires by connecting them to short pigtail wires, using wire connectors (page 25). Pigtails can be cut from scrap wire, but should be the same gauge and color as the circuit wires.

Problem: Recessed electrical box is hazardous, especially if the wall or ceiling surface is made from a flammable material, like wood paneling. The National Electrical Code prohibits this type of installation.

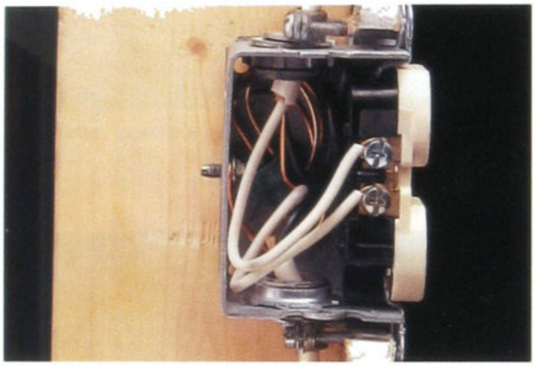
Solution: Add an extension ring to bring the face of the electrical box flush with the surface. Extension rings come in several sizes, and are available at hardware stores.



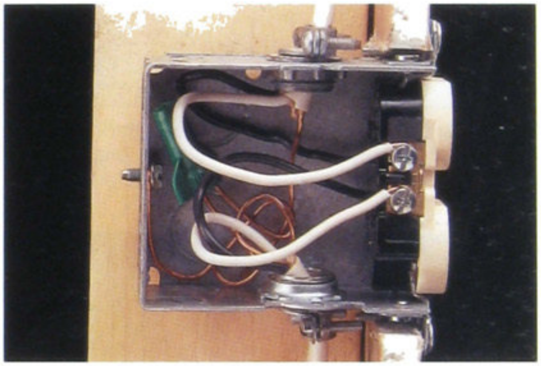
Problem: Dust and dirt in electrical box can cause hazardous high-resistance short circuits (pages 134 to 137). When making routine electrical repairs, always check the electrical boxes for dust and dirt buildup



Solution: Vacuum electrical box clean, using a narrow nozzle attachment. Make sure power to box is turned off at main service panel before vacuuming



Problem: Crowded electrical box (shown cut away) makes electrical repairs difficult. This type of installation is prohibited because wires can be damaged easily when a receptacle or switch is installed



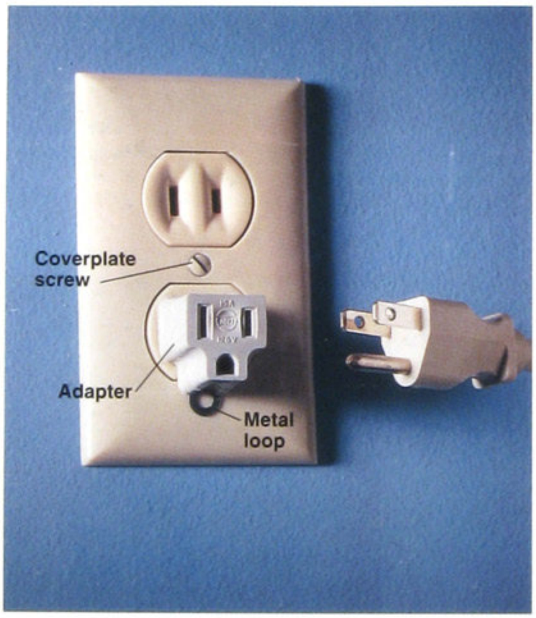
Solution: Replace the electrical box with a deeper electrical box (pages 36 to 39)

Problem: Light fixture is installed without an electrical box. This installation exposes the wiring connections, and provides no support for the light fixture.

Solution: Install an approved electrical box (pages 36 to 39) to enclose the wire connections and support the light fixture.

Problem: Lamp or appliance cord runs underneath a rug. Foot traffic can wear off insulation, creating a short circuit that can cause fire or shock.

Solution: Reposition the lamp or appliance so that cord is visible. Replace worn cords.



Problem: Three-prong appliance plugs do not fit two slot receptacle. Do not use three-prong adapters unless the metal loop on the adapter is tightly connected to the coverplate screw on receptacle (page 17).

Solution: Install a three-prong grounded receptacle if a means of grounding exists at the box (pages 70 to 71). Install a GFCI (ground-fault circuit-interrupter) receptacle (pages 74 to 77) in kitchens and bathrooms, or if the electrical box is not grounded.

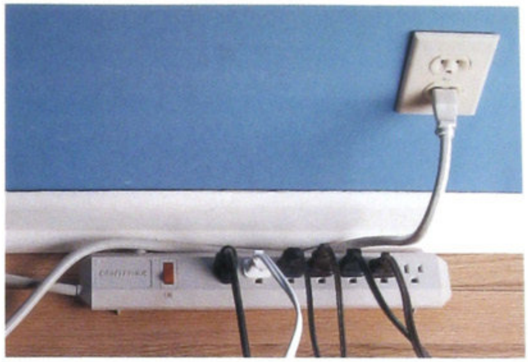
Problem:

Solution: C[illegible]
[illegible] new plug
[illegible] vail[illegible]le a[illegible]

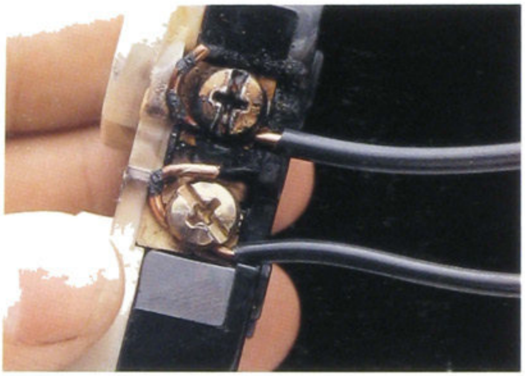
Problem: Extension cord is too small for the power load dr[illegible] by a tool or appliance. Undersized exten- [illegible] cords can overheat, melting the insulation and lea[illegible]g bare wires exposed.

Solution: Use an extension cord with wattage and amperage ratings that meet or exceed the rating of the tool or appliance. Extension cords are for temporary use only. Never use an extension cord for a permanent installation.

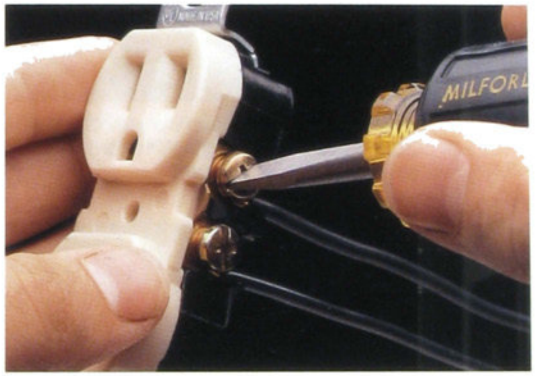
Problem: Octopus receptacle attachments used permanently can overload a circuit and cause overheating of the receptacle.



Solution: Use a multi-receptacle power strip with built-in overload protection. This is for temporary use only If the need for extra receptacles is frequent, upgrade the wiring system.



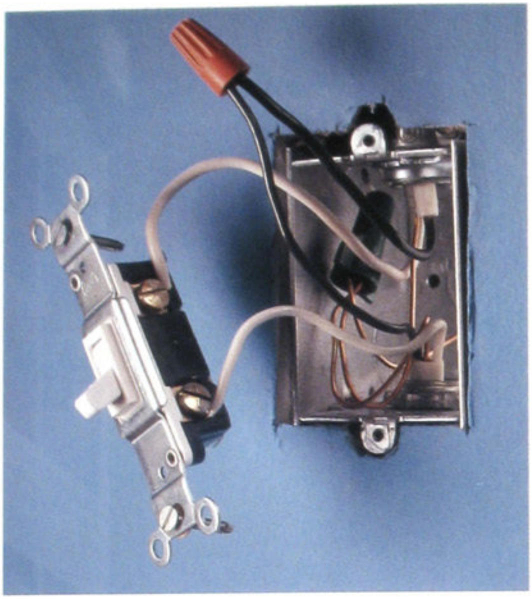
Problem: Scorch marks near screw terminals indicate that electrical arcing has occurred Arcing usually is caused by loose wire connections.



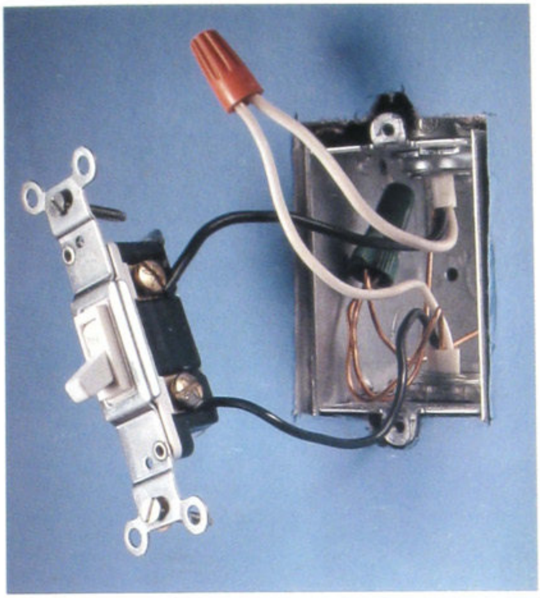
Solution: Clean wires with fine sandpaper, and replace the receptacle if it is badly damaged. Make sure wires are connected securely to screw terminals.

Problem: Two-slot receptacle in outdoor installation is hazardous because it has no grounding slot. In case of a short circuit, a person plugging in a cord becomes a conductor for current to follow to ground.

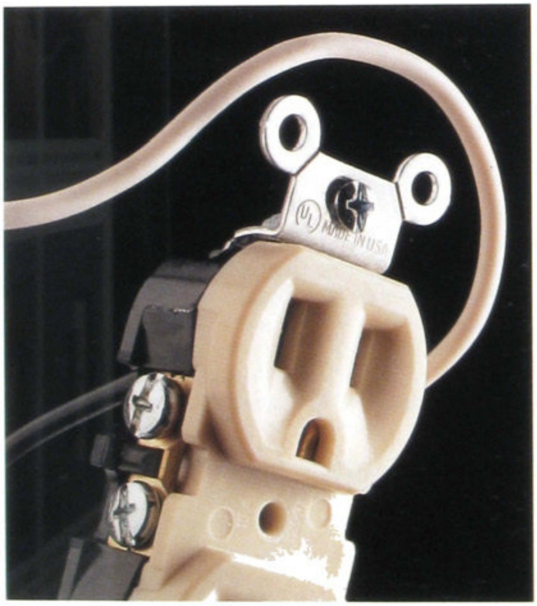
Solution: Install a GFCI (ground-fault circuit-interrupter) receptacle. Electrical codes now require that GFCIs be used for all outdoor receptacles, as well as for basement, kitchen, and bathroom receptacles.



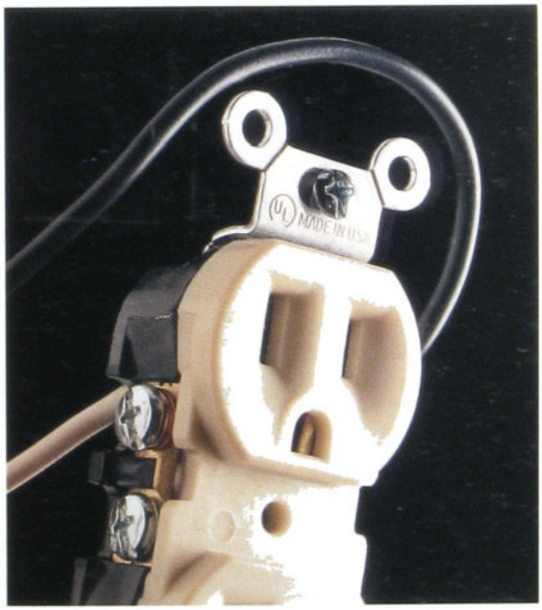
Problem:



Solution:



Problem: utral re connected to the
inals on t receptacle and black
are attached to screw terminals This
hazardous because live voltage flows
eutral slot on the receptacle



Solution: Rev rse the wire connections so th
black hot wires are attached to brass screw
and white neutral wires are attached to silver screw
terminals Live voltage now flows into the short slot
the receptacle.

Evaluating Old Wiring

If the wiring in your home is more than 30 years old, it may have a number of age-related problems. Many problems associated with older wiring can be found by inspecting electrical boxes for dirty wire connections (page 72), signs of arcing (page 132), cracked or damaged wire insulation (page 127), or dirt buildup (page 129).

However, it is difficult to identify problems with wiring that is hidden inside the walls. If old wires are dusty and have damaged insulation, they can "leak" electrical current. The amount of current that leaks through dust usually is very small, too small to trip a breaker or blow a fuse. Nevertheless, by allowing current to leave its normal path, these leaks consume power in much the same way that a dripping faucet wastes water.

This kind of electrical leak is called a high-resistance short circuit. A high-resistance short circuit can produce heat and should be considered a fire hazard.

It is possible to check for high-resistance short circuits by using your electric meter to test the wires of each circuit. The goal of the test is to determine if electricity is being consumed even if none of the lights and appliances are drawing power. To do this, you must turn on all wall switches to activate the hot circuit wires, then stop power consumption by removing light bulbs and fluorescent tubes, and disconnecting all lamps and appliances.

Then examine the electric meter, usually located on the outside of the house near the service head (page 12). If the flat, circular rotor inside the meter is turning, it means that a high-resistance short circuit is causing an electrical leak somewhere in the wiring. High-resistance short circuits consume very small amounts of power, so you should watch the rotor for a full minute to detect any movement.

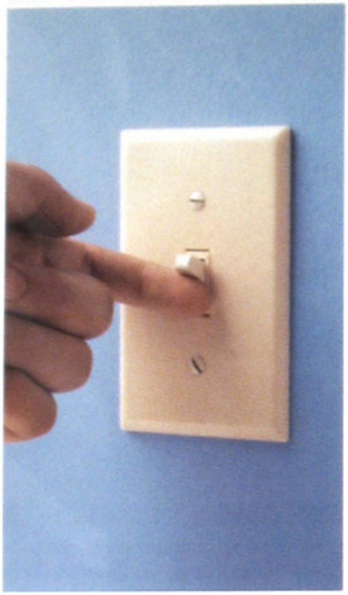
If the test shows there is a high-resistance short circuit in your wiring, contact a licensed electrician to have it repaired.

Everything You Need

Tools: screwdriver.

Materials: wire connectors, masking tape, pen.

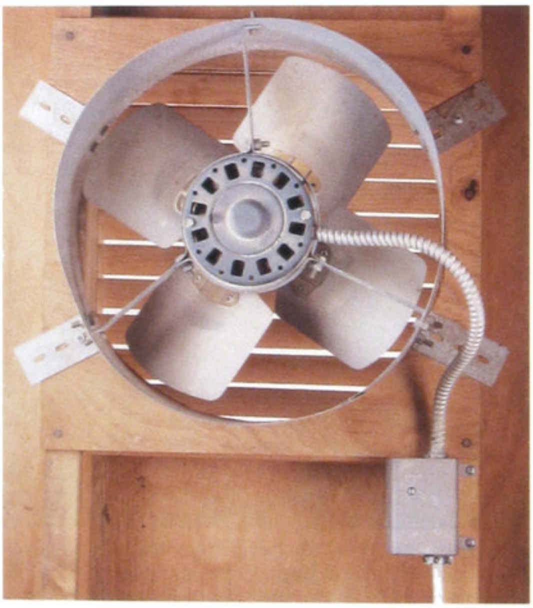
How to Evaluate Old Wiring for High-resistance Short Circuits



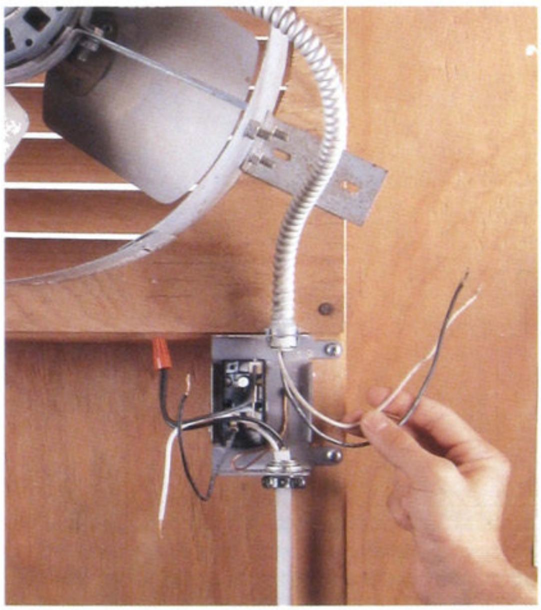
1 Switch on all light fixtures Remember to turn on closet lights basement lights, and exterior lights

2 Stop all power consumption by removing all light bulbs and fluorescent tubes Turn off all thermostats

3 Disconnect all plug-in lamps and appliances from the receptacles



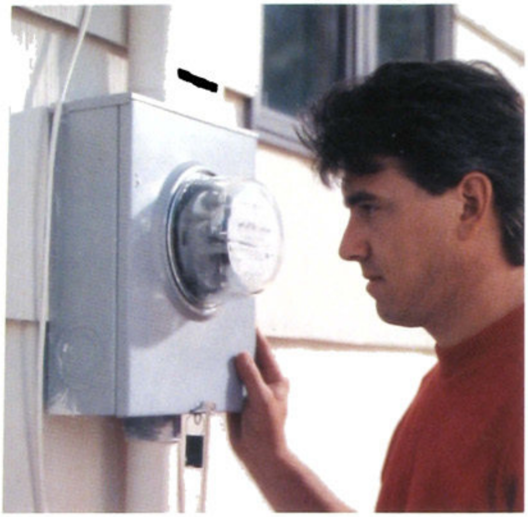
4 Shut off power to all permanently wired appliances by turning off the correct breakers or removing the correct fuses at the service panel. Permanently wired appliances include attic fans, water heaters, garage door openers, and ceiling fans.



5 With the power turned off, disconnect circuit wires from each permanently wired appliance. Cap the wire ends with wire connectors. Next, turn on power and make sure all appliance wall switches are turned on.

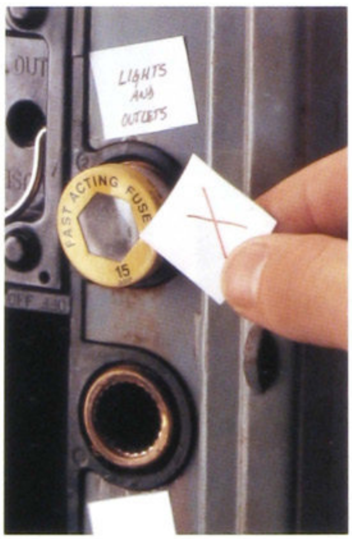
(continued next page)

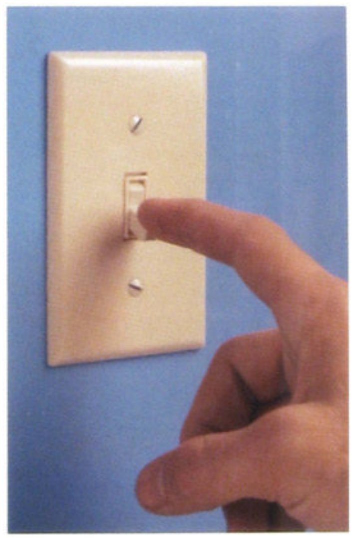
How to Evaluate Old Wiring for High-resistance Short Circuits (continued)



6 Watch the circular rotor located inside the electric meter for at least one minute. If the rotor does not move, then your wiring is in good condition. If the rotor moves, it means there is a high-resistance short circuit somewhere in the wiring system; proceed to step 7.

7 Turn off power to all circuits at the main service panel by switching off circuit breakers or removing fuses. Do not turn off main shutoff. Watch the rotor inside the meter. If rotor moves, then the high-resistance short circuit is located in the main service panel or service wiring. In this case, consult a licensed electrician. If rotor does not move, proceed to step 8.

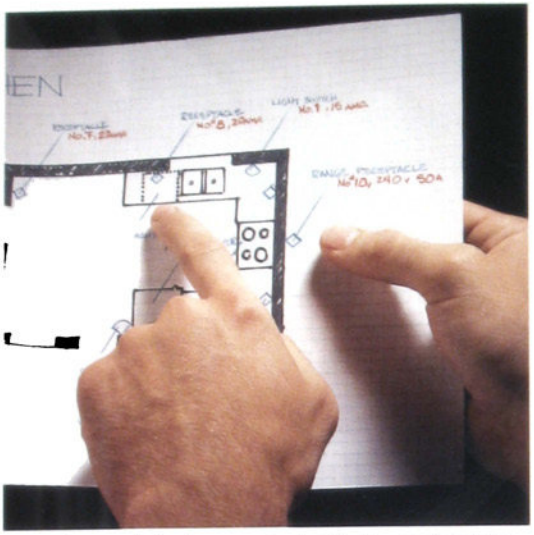




8 Turn on individual circuits, one at a time, by switching on the circuit breaker or inserting the fuse. Watch for rotor movement in the electric meter. If rotor does not move, wiring is in good condition. Turn off power to the circuit, then proceed to the next circuit.

9 If the rotor is moving, then use masking tape to mark the faulty circuit. Turn off power to the circuit, then proceed to the next circuit.

10 If circuit contains three-way or four-way switches, flip the lever on each switch individually and watch for rotor movement after each flip of a switch.



11 For each faulty circuit, identify the appliances lights switches, receptacles and electrical junction boxes powered by the circuit Use a map of your home wiring system as a guide (pages 30 to 33)

12 Recheck all lights and appli faulty circuit to make sure th power If they are disconnect th

13 Inspect the electrical boxes along each faulty circuit for dirty wire connections (page 72), damaged wire insulation (page 127), dirt buildup (page 129) or signs of arcing (page 132).

14 If no problems are found in electrical boxes, then the high-resistance short circuit is in wiring contained inside the walls In this case consult a licensed electrician.

1. Examine your main service (page 140) The amp rating of the electrical service and the size of the circuit breaker panel will help you determine if a service upgrade is needed

2. Learn about codes (pages 141 to 145) The National Electrical Code, and local Electrical Codes and Building Codes, provide guidelines for determining how much power and how many circuits your home needs. Your local electrical inspector can tell you which regulations apply to your job

Planning a Wiring Project

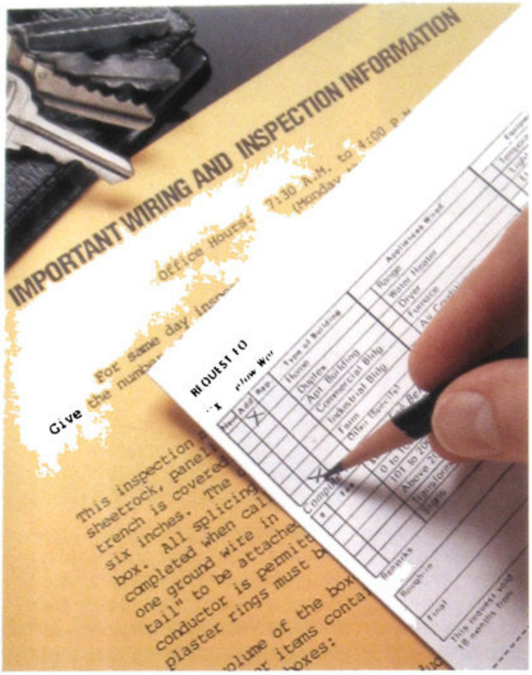
Careful planning of a wiring project ensures you will have plenty of power for present and future needs. Whether you are adding circuits in a room addition, wiring a remodeled kitchen, or adding an outdoor circuit, consider all possible ways the space might be used, and plan for enough electrical service to meet peak needs.

For example, when wiring a room addition, remember that the way a room is used can change. In a room used as a spare bedroom, a single 15-amp circuit provides plenty of power, but if you ever choose to convert the same room to a family recreation space, it will need at least two 20-amp circuits.

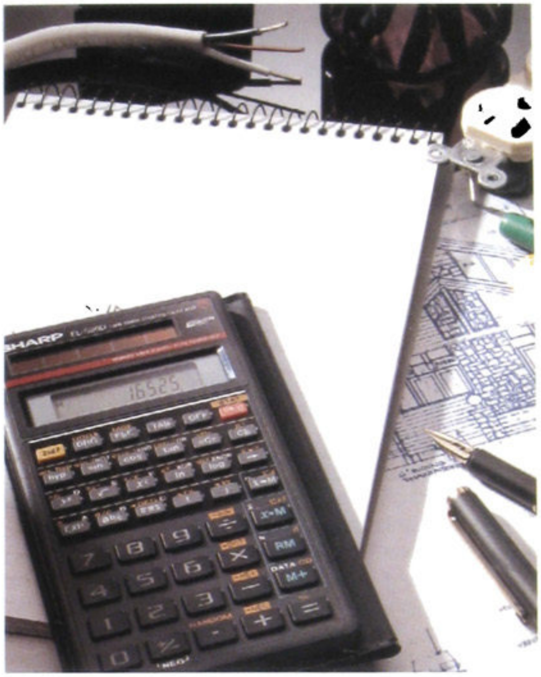
When wiring a remodeled kitchen, it is a good idea to install circuits for an electric oven and countertop range, even if you do not have these electric appliances. Installing these circuits now makes it easy to convert from gas to electric appliances at a later date.

A large wiring project adds a considerable load to your main electrical service. In about 25% of all homes, some type of service upgrade is needed before new wiring can be installed For example, many homeowners will need to replace an older 60-amp electrical service with a new service rated for 100 amps or more. This is a job for a licensed electrician but is well worth the investment. In other cases, the existing main service provides adequate power, but the main circuit breaker panel is too full to hold any new circuit breakers. In this case it is necessary to install a circuit breaker subpanel to provide room for hooking up added circuits. Installing a subpanel is a job most homeowners can do themselves (pages 194 to 197)

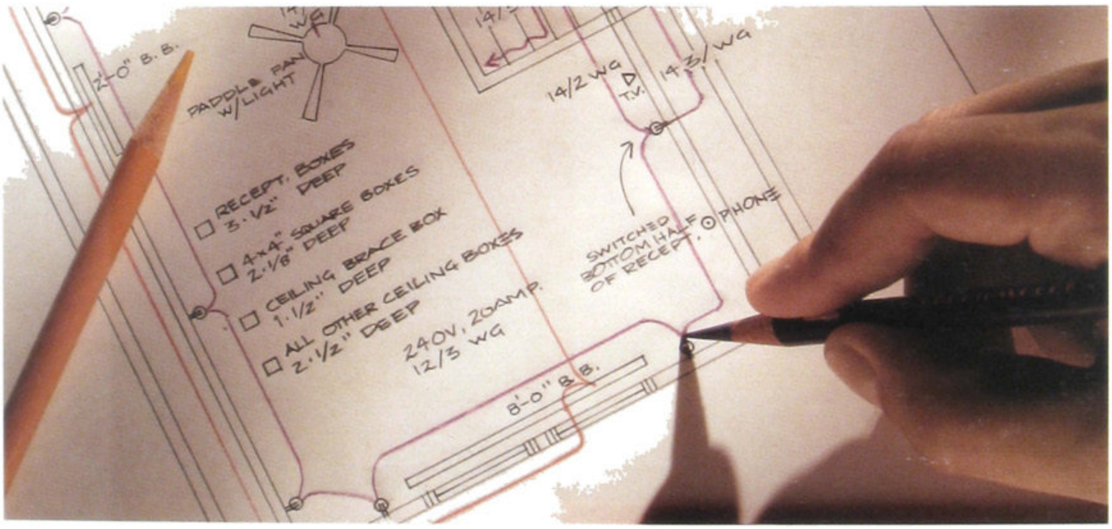
This chapter gives an easy five-step method for determining your electrical needs and planning new circuits.



3. Prepare for inspections (pages 146 to 147) Remember that your work must be reviewed by your local electrical inspector. When planning your wiring project, always follow the inspector's guidelines for quality workmanship.



4. Evaluate electrical loads (pages 148 to 151) New circuits put an added load on your electrical service. Make sure that total load of the existing wiring and the planned new circuits does not exceed the main service capacity.

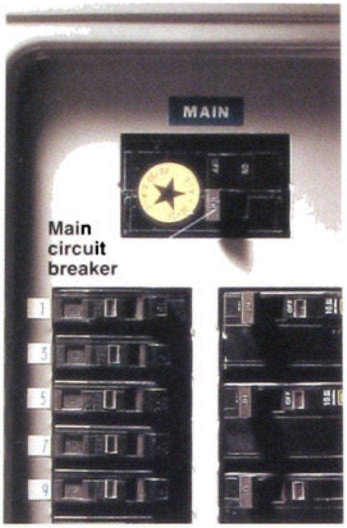


5. Draw a wiring diagram and get a permit (pages 152 to 153) Your inspector needs to see an accurate wiring diagram and materials list before he will issue a work permit for your project. This wiring plan also helps you organize your work.

1: Examine Your Main Service

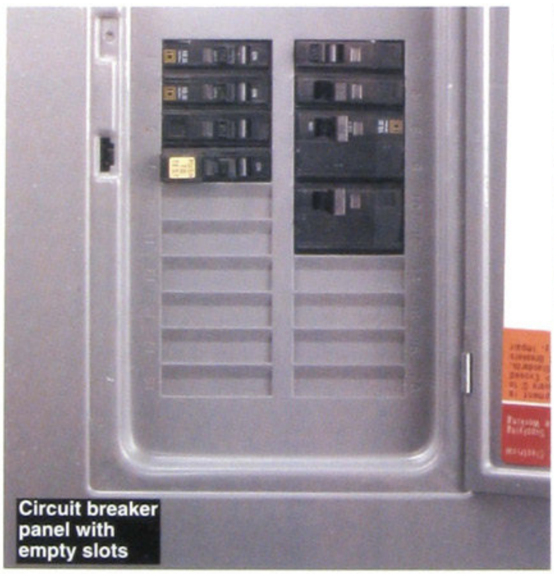
The first step in planning a new wiring project is to look in your main circuit breaker panel and find the size of the service by reading the amperage rating on the main circuit breaker. As you plan new circuits and evaluate electrical loads, knowing the size of the main service helps you determine if you need a service upgrade.

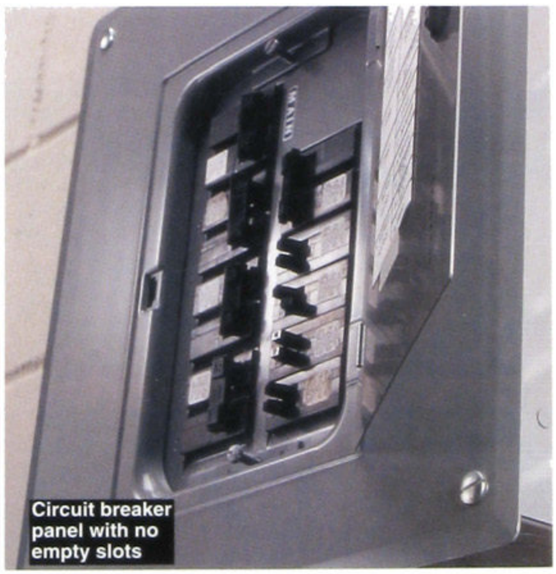
Also look for open circuit breaker slots in the panel The number of open slots will determine if you need to add a circuit breaker subpanel.



Find the service size by opening the main service panel and reading the amp rating printed on the main circuit breaker In most cases, 100-amp service provides enough power to handle the added loads of projects like the ones shown in this book. A service rated for 60 amps or less may need to be upgraded.

Older service panels use fuses instead of circuit breakers. Have an electrician replace this type of panel with a circuit breaker panel that provides enough power and enough open breaker slots for the new circuits you are planning





Look for open circuit breaker slots in the main circuit breaker panel or in a circuit breaker subpanel, if your home already has one You will need one open slot for each 120-volt circuit you plan to install and two slots for each 240-volt circuit. If your main circuit breaker panel has no open breaker slots, install a subpanel (pages 194 to 197) to provide room for connecting new circuits.

2: Learn about Codes

To ensure public safety, your community requires that you get a permit to install new wiring and have the completed work reviewed by an appointed inspector. Electrical inspectors use the National Electrical Code (NEC) as the primary authority for evaluating wiring, but they also follow the local Building Code and Electrical Code standards.

As you begin planning new circuits, call or visit your local electrical inspector and discuss the project with him. The inspector can tell you which of the national and local code requirements apply to your job, and may give you a packet of information summarizing these regulations. Later, when you apply to the inspector for a work permit, he will expect you to understand the local guidelines as well as a few basic National Electrical Code requirements.

The National Electrical Code is a set of standards that provides minimum safety requirements for wiring installations. It is revised every three years. The national code requirements for the projects shown in this book are thoroughly explained on the following pages. For more information, you can find copies of the current NEC, as well as a number of excellent handbooks based on the NEC, at libraries and bookstores.

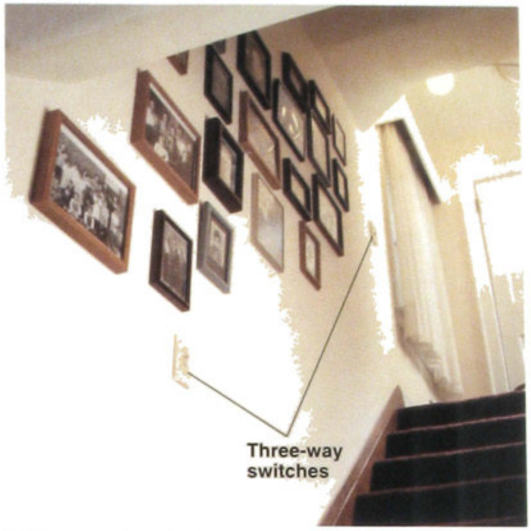
In addition to being the final authority of code requirements, inspectors are electrical professionals with years of experience. Although they have busy schedules, most inspectors are happy to answer questions and help you design well-planned circuits.

Basic Electrical Code Requirements

Electrical Code requirements for living areas: Living areas need at least one 15-amp or 20-amp basic lighting/receptacle circuit for each 600 square feet of living space and should have a "dedicated" circuit for each type of permanent appliance, like an air conditioner, computer, or a group of baseboard heaters. Receptacles on basic lighting/receptacle circuits should be spaced no more than 12 feet apart. Many electricians and electrical inspectors recommend even closer spacing. Any wall more than 24" wide also needs a receptacle. Every room should have a wall switch at the point of entry to control either a ceiling light or plug-in lamp. Kitchens and bathrooms must have a ceiling-mounted light fixture.

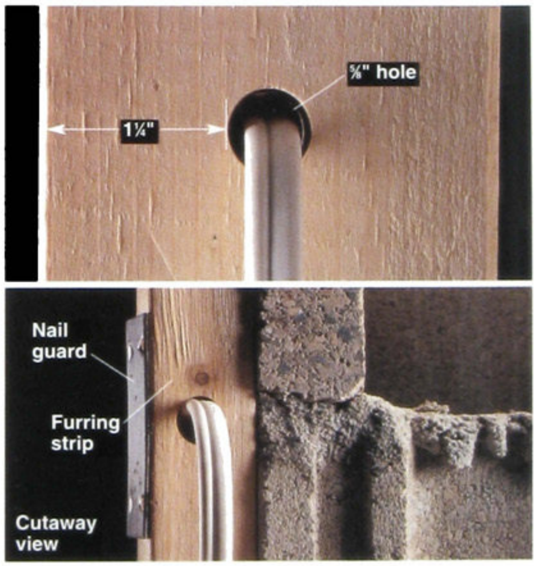
(continued next page)

Measure the living areas of your home, excluding closets and unfinished spaces. A sonic measuring tool gives room dimensions quickly and contains a built-in calculator for figuring floor area. You will need a minimum of one basic lighting/receptacle circuit for every 600 sq. ft. of living space. The total square footage also helps you determine heating and cooling needs for new room additions (page 147).



Stairways with six steps or more must have lighting that illuminates each step. The light fixture must be controlled by three-way switches at the top and bottom landings.

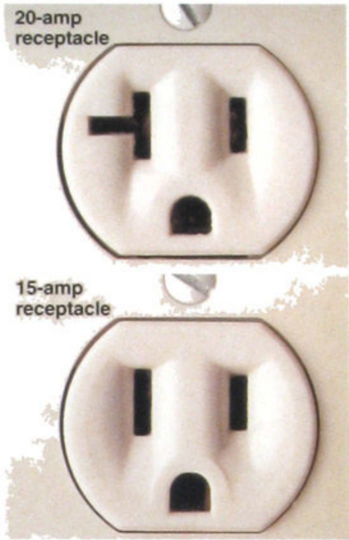
Kitchen and bathroom receptacles must be protected by a ground-fault circuit-interrupter (GFCI). Also, all outdoor receptacles and general-use receptacles in an unfinished basement or crawl space must be protected by a GFCI.



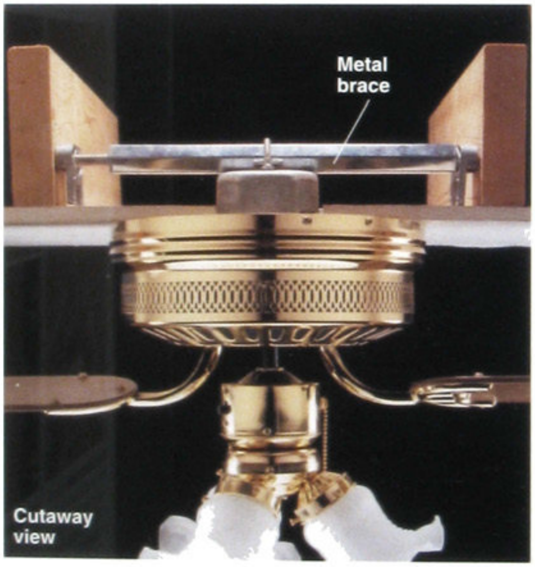
Cables must be protected against damage by nails and screws by at least 1¼" of wood (top). When cables pass through 2 × 2 furring strips (bottom), protect the cables with metal nail guards.

Closets and other storage spaces need at least one light fixture that controlled by a wall switch near nce. Prevent fire hazards positioning the light fixtures so outer globes are at least 12" from all shelf areas.

Hallways more than 10 feet long need at least one receptacle. All hallways should have a switch-controlled light fixture.



Amp ratings of receptacles must match the size of the circuit. A common mistake is to use 20-amp receptacles (top) on 15-amp circuits—a potential cause of dangerous circuit overloads.



A metal brace attached to framing members is required for ceiling fans and large light fixtures that are too heavy to be supported by an electrical box.

Label new circuits on an index attached to the circuit breaker panel. List the rooms and appliances controlled by each circuit. Make sure the area around the panel is clean, well lighted, and accessible.

Common Electrical Code Requirements

By Material

Service Panel (pages 26 to 33)
- Maintain a minimum 30" × 36" of clearance in front of the service panel.
- Ground all 120-volt and 240-volt circuits.
- Match the amperage rating of the circuit when replacing fuses.
- Locate service panels and subpanels a maximum of 79" above floor level.
- Use handle-tie breakers for 240-volt loads (line to line).
- Close all unused service panel openings.
- Label each fuse and breaker clearly on the panel.

Electrical Boxes (pages 36 to 41)
- Use boxes that are large enough to accommodate the number of wires entering the box.
- Locate all receptacle boxes 12" above the finished floor (standard).
- Locate all switch boxes 48" above the finished floor (standard).
  For special circumstances, inspectors will allow switch and location measurements to be altered, such as a switch at 36" above the floor in a child's bedroom or receptacles at 24" above the floor to make them more accessible for someone in a wheelchair.
- Install all boxes and conduit fittings so they remain accessible.
- Leave no gaps greater than ⅛" between wallboard and front of electrical boxes.
- Place receptacle boxes flush with combustible surfaces.
- Leave a minimum of 8" of usable cable or wire extending past the front of the electrical box.

Wires & Cables (pages 20 to 25)
- Use wires that are large enough for the amperage rating of the circuit (see Wire Size Chart, page 21).
- Drill holes at least 2" back from the exposed edge of joists to run cables through. Do not attach cables to the bottom edge of joists.
- Do not run cables diagonally between framing members.
- Run cable between receptacles 20" above the floor.
- Use nail plates to protect cable that is run through holes drilled or cut into studs less than 1¼" from front edge of stud.
- Do not crimp cables sharply.
- Contain spliced wires or connections entirely in a plastic or metal electrical box.
- Use wire connectors to join wires.
- Use staples to fasten cables within 8" of an electrical box and every 48" along its run.
- Leave a minimum ¼" (maximum 1") of sheathing where cables enter an electrical box.
- Clamp cables and wires to electrical boxes with approved NM clamp. No clamp is necessary for one-gang plastic boxes if cables are stapled within 8".
- Label all cables and wires at each electrical box to show which circuits they serve for the rough-in inspection.
- Connect only a single wire to a single screw terminal. Use pigtails to join more than one wire to a screw terminal.

Switches (pages 42 to 61)
- Use a switch-controlled receptacle in rooms without a built-in light fixture operated by a wall switch.
- Use three-way switches at the top and bottom on stairways with six steps or more.
- Use switches with grounding screw with plastic electrical boxes.
- Locate all wall switches within easy reach of the room entrance.

Receptacles (pages 62 to 77)
- Match the amp rating of a receptacle with the size of the circuit.
- Include receptacles on all walls 24" wide or greater.
- Include receptacles so a 6-feet cord can be plugged in from any point along a wall or every 12-feet along a wall.
- Include receptacles in any hallway that is 10-feet long or more.
- Use three-prong, grounded receptacles for all 15- or 20-amp, 120-volt branch circuits.
- Include a switch-controlled receptacle in rooms without a built-in light fixture operated by a wall switch.
- Install GFCI-protected receptacles in bathrooms, kitchens, garages, crawl spaces, unfinished basements, and outdoor receptacle locations.
- Install an isolated-ground circuit to protect sensitive equipment, like a computer, against tiny power fluctuations. Computers should also be protected by a standard surge protector.

Lighting Fixtures (pages 78 to 95)
- Use mounting straps that are anchored to the electrical boxes to mount ceiling fixtures.
- Keep recessed light fixtures 3" from insulation and ½" from combustibles.
- Include at least one switch-operated lighting fixture in every room.

Grounding (pages 16 to 17)
- Ground all receptacles by connecting receptacle grounding screws to the circuit grounding wires.
- Use switches with grounding screws whenever possible. Always ground switches installed in plastic electrical boxes and all switches in kitchens, bathrooms, and basements.

By Room

Kitchens/Dining Rooms

- Install a dedicated 40- or 50-amp, 120/240-volt circuit for a range (or two circuits for separate oven and countertop units).
- Install two 20-amp small appliance circuits.
- Install dedicated 15-amp, 120-volt circuits for dishwashers and food disposals (required by many local codes).
- Use GFCI receptacles for all accessible countertop receptacles; receptacles behind fixed appliances do not need to be GFCIs.
- Position receptacles for appliances that will be installed within cabinets, such as microwaves or food disposals, according to the manufacturer's instructions.
- Include receptacles on all counters wider than 12"
- Space receptacles a maximum of 48" apart above countertops and closer together in areas where many appliances will be used.
- Locate receptacles 18" above the countertop. If the backsplash is more than the standard 4" or the bottom of the cabinet is less than 18" from the countertop, center the box in the space between the countertop and the bottom of the wall cabinet.
- Mount one receptacle within 12" of the countertop on islands and peninsulas that are 12" × 24" or greater.
- Locate at least one receptacle at table height in the dining areas for convenience in operating a small appliance.
- Do not put lights on small appliance circuits.
- Install additional lighting in work areas at a sink or range for convenience and safety.

Bathrooms

- Install a separate 20-amp circuit.
- Ground switches in bathrooms.
- Use GFCI-protected receptacles.
- Install at least one ceiling-mounted light fixture.
- Place blower heaters in bathrooms well away from the sink and tub.

Utility/Laundry Rooms

- Install a separate 20-amp circuit for a washing machine.
- Install a minimum feed 30-amp #10 THHN wire (see page 154) for the dryer, powered by a separate 120/240-volt major appliance circuit.
- Install metal conduit for cable runs in unfinished rooms.
- Use GFCI-protected receptacles, *except* for fixed appliances, such as freezers or dryers.

Living Room/Entertainment Rooms/Bedrooms

- Install a minimum of two 20-amp circuits in living rooms.
- Install a minimum of one 15- or 20-amp basic lighting/receptacle circuit for each 600 square feet of living space.
- Install a dedicated circuit for each permanent appliance, like an air conditioner, computer, or group of electric baseboard heaters.
- Do not use standard electrical boxes to support ceiling fans.
- Include receptacles on any wall that is 24" wide or more.
- Space receptacles on basic lighting/receptacle circuits a maximum of 12 feet apart. For convenience you can space them as close as 6 feet.
- Position permanent light fixtures in the center of the room's ceiling.
- Install permanently wired smoke alarms in room additions that include sleeping areas.

Outdoors

- Check for underground utilities before digging.
- Use UF cable for outdoor wiring needs.
- Run cable in rigid metal or schedule 40 PVC plastic (see page 154), as required by local code.
- Bury cables 12" if the circuit is no larger than 20 amps. Bury the cable at least 18" deep if the circuit is larger than 20 amps.
- Use weatherproof electrical boxes with watertight covers.
- Use GFCI-protected receptacles.
- Install receptacles a minimum of 12" above ground level.
- Anchor freestanding receptacles not attached to a structure by embedding the rigid metal conduit or schedule 40 PVC plastic conduit in a concrete footing, so that it is at least 12", but no more than 18" above ground level.
- Plan on installing a 20-amp, 120-volt circuit if the circuit contains more than one light fixture rated for 300 watts or more than four receptacles.

Stairs/Hallways

- Use three-way switches at the top and bottom on stairways with six steps or more.
- Include receptacles in any hallway that is 10 feet long or more.
- Position stairway lights so each step is illuminated.

3: Prepare for Inspections

Electrical inspectors who issue the work permit for your wiring project will also visit your home to review the work Make sure to allow time for these inspections as you plan the project. For most projects, inspectors make two visits

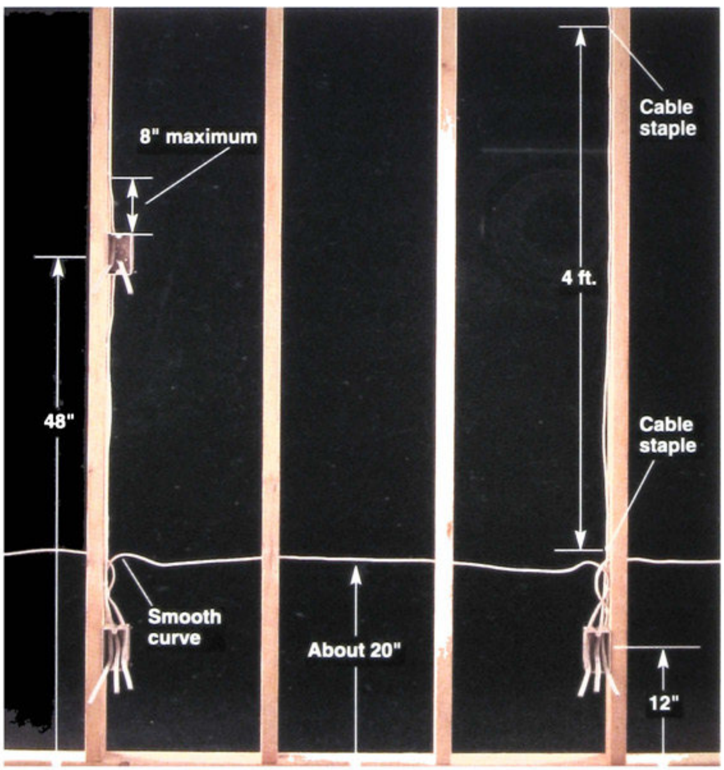
The first inspection, called the **rough-in**, is done after the cables are run between the boxes, but before the insulation, wallboard, switches, and fixtures are installed The second inspection, called the **final**, is done after the walls and ceilings are finished and all electrical connections are made

When preparing for the rough-in inspection, make sure the area is neat. Sweep up sawdust and clean up any pieces of scrap wire or cable insulation Before inspecting the boxes and cables, inspectors will check to make sure all plumbing and other mechanical work is completed Some electrical inspectors will ask to see your building and plumbing permits

final inspection inspectors check random to make sure the wire connections are correct If they see good workmanship at the selected boxes, the inspection will be over quickly However, if they spot a problem, inspectors may choose to inspect every connection

Inspectors have busy schedules, so it is a good idea to arrange for an inspection several days or weeks in advance In addition to basic compliance with code, inspectors expect your work to meet their own standards for quality When you apply for a work permit, make sure you understand what the inspectors will look for during inspections

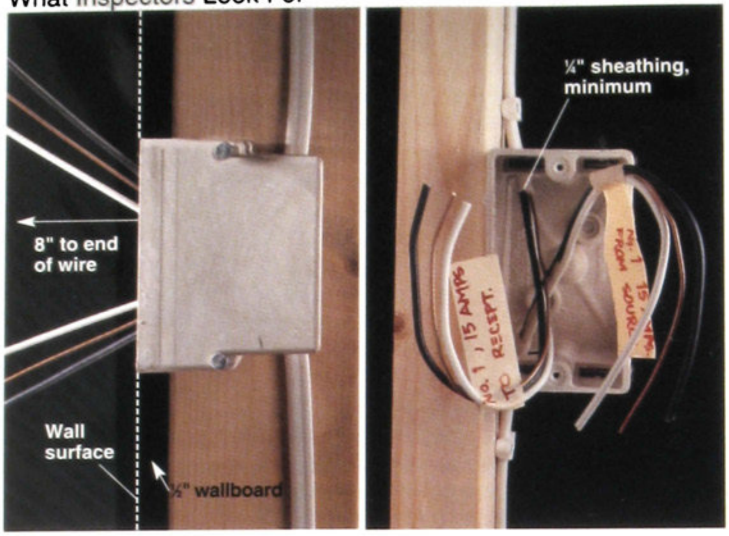
You cannot put new circuits into use legally until an inspector approves them at the final inspection Because inspectors are responsible for the safety of all wiring installations, their approval means that your work meets professional standards If you have planned carefully and done your work well, electrical inspections are routine visits that give you confidence in your own skills



Inspectors measure to see that electrical boxes are mounted at consistent heights Measured from the center of the boxes, receptacles in living areas typically are located 12" above the finished floor and switches at 48" For special circumstances, inspectors allow you to alter these measurements For example, you can install switches at 36" above the floor in a child s bedroom, or set receptacles at 24 to make them more convenient for someone in a wheelchair

Inspectors will check cables to see that they are anchored by cable staples driven within 8 of each box and every 4 feet thereafter when they run along studs When bending cables form the wire in a smooth curve Do not crimp cables sharply or install them diagonally between framing members Some inspectors specify that cables running between receptacle boxes should be about 20" above the floor.

What Inspectors Look For



Electrical box faces should extend past the front of framing members so the boxes will be flush with finished walls (left). Inspectors will check to see that all boxes are large enough for the wires they contain. Cables should be cut and stripped back so that 8" of usable length extends past the front of the box, and so that at least of sheathing reaches into the box (right). Label all cables to show which circuits they serve: inspectors recognize this as a mark of careful work. The labels also simplify the final hookups after the wallboard is installed.

Install an isolated-ground circuit and receptacle if recommended by your inspector. An isolated-ground circuit protects sensitive electronic equipment, like a computer, against tiny current fluctuations. Computers also should be protected by a standard surge protector.

Heating & Air Conditioning Chart (compiled from manufacturers' literature)

Room addition living area	Recommended total heating rating	Recommended circuit size	Recommended air-conditioner rating	Recommended circuit size
100 sq. feet	900 watts	15-amp (240 volts)	5,000 BTU	15-amp (120 volts)
150 sq. feet	1350 watts		6,000 BTU	
200 sq. feet	1800 watts		7,000 BTU	
300 sq. feet	2700 watts		9,000 BTU	
400 sq. feet	3600 watts	20-amp (240 volts)	10,500 BTU	
500 sq. feet	4500 watts	30-amp (240 volts)	11,500 BTU	20-amp (120 volts)
800 sq. feet	7200 watts	two 20-amp	17,000 BTU	15-amp (240 volts)
1,000 sq. feet	9000 watts	two 30-amp	21,000 BTU	20-amp (240 volts)

Electric heating and air-conditioning for a new room addition will be checked by an inspector. Determine your heating and air-conditioning needs by finding the total area of the living space. Choose electric heating units with a combined wattage rating close to the chart recommendation above. Choose an air conditioner with a BTU rating close to the chart recommendation for your room size. NOTE: These recommendations are for homes in moderately cool climates, sometimes referred to as "Zone 4" regions. Cities in Zone 4 include Denver, Chicago, and Boston. In more severe climates, check with your electrical inspector or energy agency to learn how to find heating and air-conditioning needs.

4: Evaluate Electrical Loads

Before drawing a plan and applying for a work permit, make sure your home's electrical service provides enough power to handle the added load of the new circuits. In a safe wiring system, the current drawn by fixtures and appliances never exceeds the main service capacity.

To evaluate electrical loads, use the work sheet on page 151 or whatever evaluation method is recommended by your electrical inspector. Include the load for all existing wiring as well as that for proposed new wiring when making your evaluation.

Most of the light fixtures and plug-in appliances in your home are evaluated as part of general allowances for basic lighting/receptacle circuits (page 141) and small-appliance circuits. However, appliances that are permanently installed require their own "dedicated" circuits. The electrical loads for these appliances are added in separately when evaluating wiring.

If your evaluation shows that the load exceeds the main service capacity, you must have an electrician upgrade the main service before you can install new wiring. An electrical service upgrade is a worthwhile investment that improves the value of your home and provides plenty of power for present and future wiring projects.

Tips for Evaluating Appliance Loads

Add 1500 watts for each small appliance circuit required by the local Electrical Code. In most communities, three such circuits are required—two in the kitchen and one for the laundry—for a total of 4500 watts. No further calculations are needed for appliances that plug into small-appliance or basic lighting/receptacle circuits.

Find wattage ratings for permanent appliances by reading the manufacturer's nameplate. If the nameplate gives the rating in kilowatts, find the watts by multiplying kilowatts times 1000. If an appliance lists only amps, find watts by multiplying the amps times the voltage—either 120 or 240 volts.

Electric water heaters are permanent appliances that require their own dedicated 30-amp, 240-volt circuits. Most water heaters are rated between 3500 and 4500 watts. If the nameplate lists several wattage ratings, use the one labeled "total connected wattage" when figuring electrical loads.

Food disposers are considered permanent appliances and require their own dedicated 15-amp, 120-volt circuits. Most disposers are rated between 500 and 900 watts.

Dishwashers installed permanently under a countertop need dedicated 15-amp, 120-volt circuits. Dishwasher ratings are usually between 1000 and 1500 watts. Portable dishwashers are regarded as part of small appliance circuits and are not added in when figuring loads.

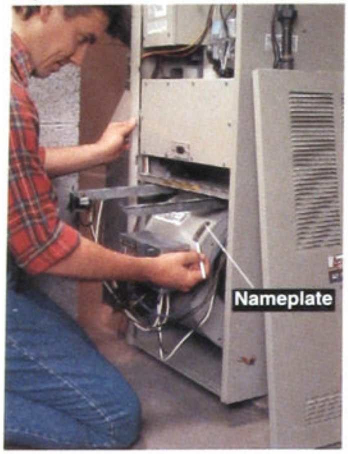
Electric ranges can be rated for as little as 3000 watts or as much as 12,000 watts. They require dedicated 120/240-volt circuits. Find the exact wattage rating by reading the nameplate, found inside the oven door or on the back of the unit.

Microwave ovens are regarded by many local codes as permanent appliances. If your inspector asks you to install a separate 20-amp, 120-volt circuit for the microwave oven, add in its wattage rating when calculating loads. The nameplate is found on the back of the cabinet or inside the front door. Most microwave ovens are rated between 500 and 800 watts.

Freezers are permanent appliances that require dedicated 15-amp, 120-volt circuits. Freezer ratings are usually between 240 and 480 watts. But combination refrigerator-freezers rated for 1000 watts or less are plugged into small appliance circuits and do not need their own dedicated circuits. The nameplate for a freezer is found inside the door or on the back of the unit, just below the door seal.

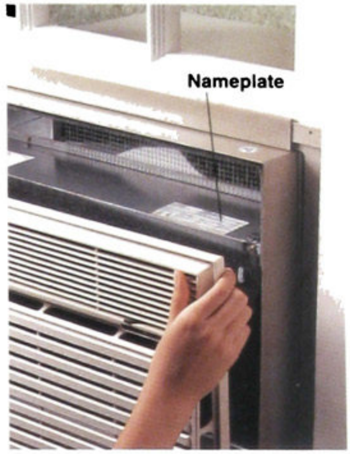
Electric clothes dryers are permanent appliances that need dedicated 30-amp, 120/240-volt circuits. The wattage rating, usually between 4500 and 5500 watts, is printed on the nameplate inside the dryer door. Washing machines, and gas-heat clothes dryers with electric tumbler motors, do not need dedicated circuits. They plug into the 20-amp small-appliance circuit in the laundry room.

(continued next page)



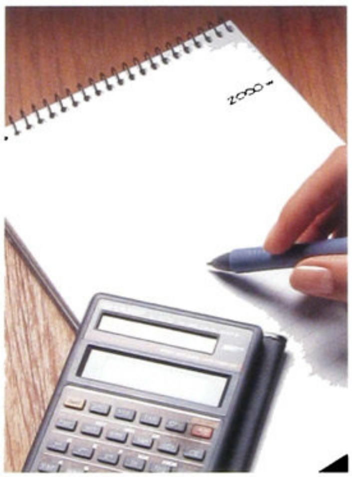
Forced-air furnaces have electric fans and are considered permanent appliances. They require dedicated 15-amp, 120-volt circuits. Include the fan wattage rating, printed on a nameplate inside the control panel, when figuring wattage loads for heating.

A central air conditioner requires a dedicated 240-volt circuit. Its wattage rating, usually between 2300 and 5500 watts, is printed on a metal plate near the electrical hookup panel. If the air conditioner relies on a furnace fan for circulation, add the fan wattage rating to the air-conditioner rating.



Window air conditioners, both 120-volt and 240-volt types, are permanent appliances that require dedicated 15-amp or 20-amp circuits. The wattage rating, which can range from 500 to 2000 watts, is found on the nameplate located inside the front grill. Make sure to include all window air conditioners in your evaluation.

Electric room heaters that are permanently installed require a dedicated circuit, and must be figured into the load calculations. Use the maximum wattage rating printed inside the cover. In general, 240-volt baseboard-type heaters are rated for 180 to 250 watts for each linear foot.

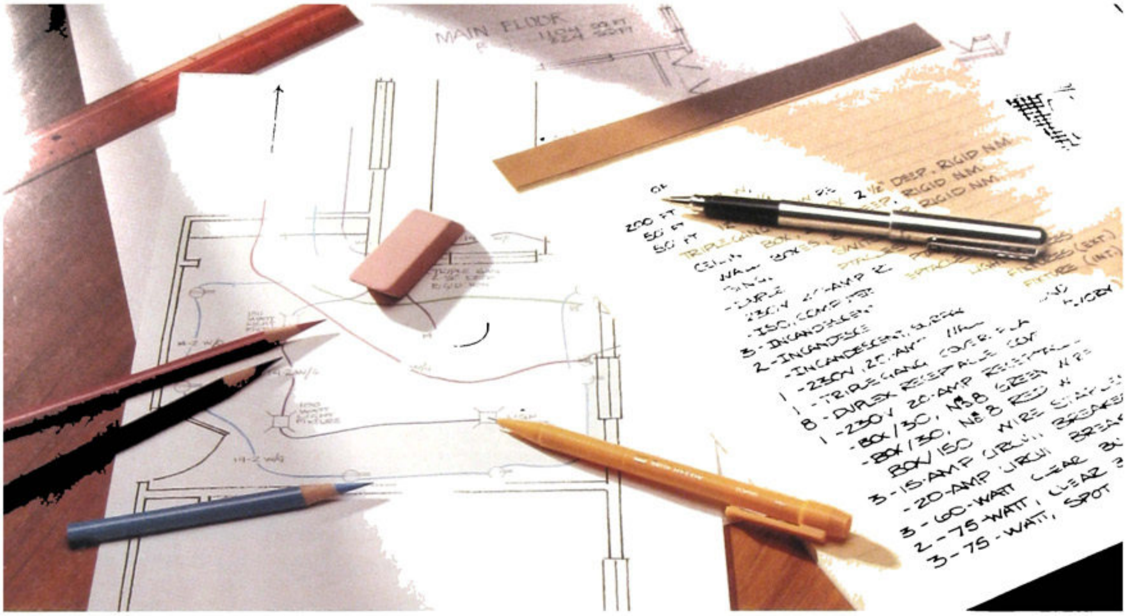


Air-conditioning and heating appliances are not used at the same time, so figure in only the larger of these two numbers when evaluating your home's electrical load.

Outdoor receptacles and fixtures are not included in basic lighting calculations. When evaluating electrical loads, add in the nameplate wattage rating for each outdoor light fixture, and add in 180 watts for each outdoor receptacle. Receptacles and light fixtures in garages also are considered to be outdoor fixtures when evaluating loads.

How to Evaluate Electrical Loads (photocopy this work sheet as a guide; blue sample calculations will not reproduce)

1. Find the basic lighting/receptacle load by multiplying the square footage of all living areas (including any room additions) times 3 watts.	Existing space: ______________square ft. New additions: ______________square ft. __________total square ft. × 3 watts =	watts
2. Add 1500 watts for each kitchen small-appliance circuit and for the laundry circuit.	__________ circuits × 1500 watts =	watts
3. Add ratings for permanent electrical appliances, including: range, food disposer, dishwasher, freezer, water heater, and clothes dryer.		watts
		watts
		watts
		watts
		watts
Find total wattages for the furnace and heating units, and for air conditioners. Add in only the larger of these numbers.	Furnace heat: _______ watts Space heaters: _______ watts Total heating = ______ watts Central air conditioner: ______ watts Window air conditioners: ______ watts Total cooling = ______ watts	watts
4. For outdoor fixtures (including those in garages) find the nameplate wattage ratings.	Total fixture watts =	watts
Multiply the number of outdoor receptacles (including those in garages) times 180 watts.	______ receptacles × 180 watts =	watts
5. Total the wattages to find the gross load.		watts
6. Figure the first 10,000 watts of the gross load at 100%.	100% × 10,000 = 10,000	10,000 watts
7. Subtract 10,000 watts from the gross load, then figure the remaining load at 40%.	______watts - 10,000 = _______ watts _________ watts × .40 =	watts
8. Add steps 6 and 7 to estimate the true electrical load.		watts
9. Convert the estimated true electrical load to amps by dividing by 230.	_______ watts ÷ 230 =	amps
10. Compare the load with the amp rating of your home's electrical service, printed on the main circuit breaker (page 140). If the load is less than main circuit breaker rating, the system is safe. If the load exceeds the main circuit breaker rating, your service should be upgraded.		OK ☐ Upgrade ☐



A detailed wiring diagram and a list of materials is required before electrical inspectors will issue a work permit. If blueprints exist for the space you are remodeling, start your electrical diagram by tracing the wall outlines from the blueprint. Use standard electrical symbols (page opposite) to clearly show all the receptacles, switches, light fixtures, and permanent appliances. Make a copy of the symbol key, and attach it to the wiring diagram for the inspectors' convenience. Show each cable run, and label its wire size and circuit amperage.

Planning a Wiring Project

5: Draw a Wiring Diagram & Get a Permit

Drawing a wiring diagram is the last step in planning a circuit installation. A detailed wiring diagram helps you get a work permit, makes it easy to create a list of materials, and serves as a guide for laying out circuits and installing cables and fixtures. Use the circuit maps on pages 155 to 167 as a guide for planning wiring configurations and cable runs. Bring the diagram and materials list when you visit electrical inspectors to apply for a work permit.

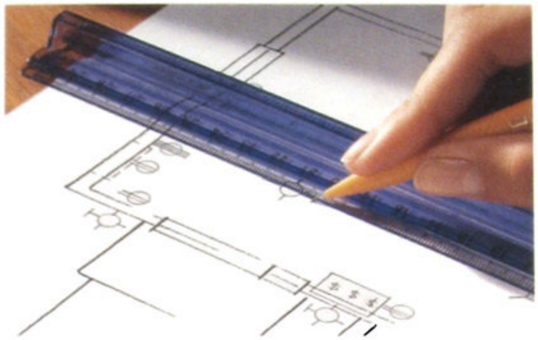
Never install new wiring without following your community's permit and inspection procedure. A work permit is not expensive, and it ensures that your work will be reviewed by a qualified inspector to guarantee its safety. If you install new wiring without the proper permit, an accident or fire traced to faulty wiring could cause your insurance company to discontinue your policy and can hurt the resale value of your home.

When electrical inspectors look over your wiring diagram, they will ask questions to see if you have a basic understanding of the Electrical Code and fundamental wiring skills. Some inspectors ask these questions informally, while others give a short written test. Inspectors may allow you to do some, but not all, of the work. For example, they may ask that all final circuit connections at the circuit breaker panel be made by a licensed electrician, while allowing you to do all other work.

A few communities allow you to install wiring only when supervised by an electrician. This means you can still install your own wiring but must hire an electrician to apply for the work permit and to check your work before inspectors review it. The electrician is held responsible for the quality of the job.

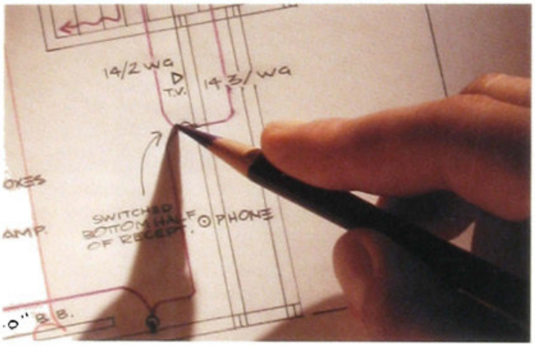
Remember that it is the inspectors' responsibility to help you do a safe and professional job. Feel free to call them with questions about wiring techniques or materials.

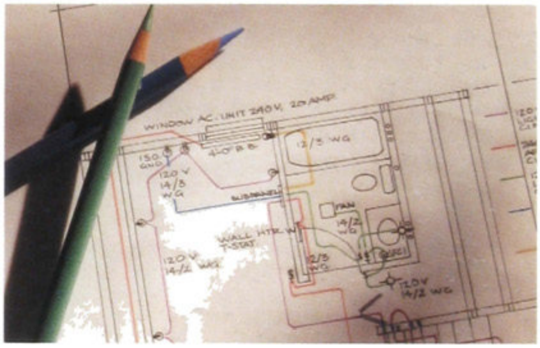
How to Draw a Wiring Plan



1 Draw a scaled diagram of the space you will be wiring, showing walls, doors, windows, plumbing pipes and fixtures, and heating and cooling ducts. Find the floor space by multiplying room length by width, and indicate this on the diagram. Do not include closets or storage areas when figuring space.

2 Mark the location of all switches, receptacles, light fixtures, and permanent appliances, using the electrical symbols shown below. Where you locate these devices along the cable run determines how they are wired. Use the circuit maps on pages 155 to 167 as a guide for drawing wiring diagrams.





3 Draw in cable runs between devices. Indicate cable size and type, and the amperage of the circuits. Use a different-colored pencil for each circuit.

4 Identify the wattages for light fixtures and permanent appliances, and the type and size of each electrical box. On another sheet of paper make a detailed list of all materials you will use.

Electrical Symbol Key (copy this key and attach it to your wiring plan)

	240-volt receptacle
*	Isolated ground receptacle
	Duplex receptacle
D	240-volt dryer receptacle
	Singleplex receptacle
	Fourplex receptacle
GFCI	GFCI duplex receptacle
	Switched receptacle
WP	Weatherproof receptacle
S_{TH}	Thermostat
S_P	Pilot-light switch
S	Single-pole switch
S_T	Timer switch
S_3	Three-way switch
J	Junction box
S	Ceiling pull switch
	Surface-mounted light fixture
R	Recessed light fixture
	Fluorescent light fixture
	Wall-mounted light fixture
WP	Weatherproof light fixture
CF	Ceiling fan
D	Electric door opener
BT	Low-voltage transformer
TV	Television jack
	Telephone outlet
D	Smoke dectector
VF	Vent fan

Ampacity: A measurement of how many amps can be safely carried by a wire or cable. Ampacity varies according to the diameter of the wire (page 177).

Common wire: The hot circuit wire that brings current from the power source to a three-way switch or that carries current from a three-way switch to a light fixture. A common wire is always connected to the darker screw terminal on the switch, sometimes labeled COMMON.

Dedicated circuit: An electrical circuit that serves only one appliance or series of electric heaters.

EMT: Electrical Metallic Tubing. A type of metal conduit used for exposed indoor wiring installations, such as wiring in an unfinished basement.

Feeder cable: The length of cable that carries power from the main circuit breaker panel to the first electrical box in a circuit or from the main panel to a circuit breaker subpanel. Also known as a **home run**.

GFCI: A duplex receptacle or circuit breaker rated as a Ground-Fault Circuit-Interrupter. GFCI receptacles provide extra protection against shock and are required by code in some locations.

Home run: See Feeder *cable.*

IMC: Intermediate Metallic Conduit. Sturdier than EMT, IMC conduit is used for exposed wiring both indoors and outdoors.

Isolated-ground circuit: A 120-volt circuit installed with three-wire cable that protects sensitive electronic equipment, like a computer, against power surges.

Isolated-ground receptacle: A special-use receptacle, orange in color, with an insulated grounding screw. Used to protect computers or other sensitive electronic equipment against power surges.

Line side wires: Circuit wires that extend "upstream" from an electrical box, toward the power source.

Load side wires: Circuit wires extending "downstream" from an electrical box toward end of circuit.

NM cable: Non-Metallic sheathed cable. The standard cable used for indoor wiring inside finished walls.

Pigtail: A short length of wire used to join two or more circuit wires to the same screw terminal on a receptacle, switch, or metal electrical box. Pigtails are color-coded to match the wires they are connected to.

PVC: Poly-Vinyl Chloride. A durable plastic used for electrical boxes and conduit. Can be used instead of metal conduit to protect outdoor wiring.

Shared Neutral: When two 120-volt small-appliance circuits are wired using a single three-wire cable, the white circuit wire is a **shared neutral** that serves both circuits.

Split receptacle: A duplex receptacle in which the connecting tab linking the brass screw terminals has been broken. A split receptacle is required when one half of a duplex receptacle is controlled by a switch or when each half is controlled by a different circuit.

THHN/THWN wires: The type of wire that is recommended for installation inside metal or plastic conduit. Available as individual conductors with color-coded insulation.

Three-wire cable: Sheathed cable with one black, one white, and one red insulated conductor, plus a bare copper grounding wire.

Traveler wires: In a three-way switch configuration, two *traveler wires* run between the pairs of traveler screw terminals on the three-way switches.

Two-wire cable: Sheathed cable with one black and one white insulated conductor, plus a bare copper grounding wire.

UF Cable: Underground Feeder cable. Used for outdoor wiring, UF cable is rated for direct contact with soil.

Circuit Maps for 26 Common Wiring Layouts

The arrangement of switches and appliances along an electrical circuit differs for every project. This means that the configuration of wires inside an electrical box can vary greatly, even when fixtures are identical.

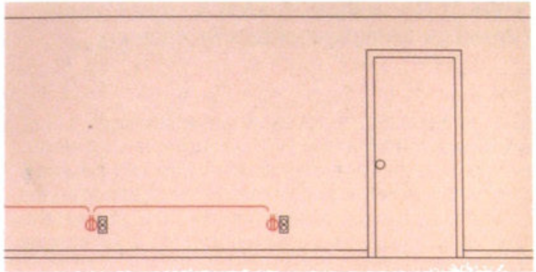
The circuit maps on the following pages show the most common wiring variations for typical electrical devices. Most new wiring you install will match one or more of the examples shown. By finding the examples that match your situation, you can use these maps to plan circuit layouts.

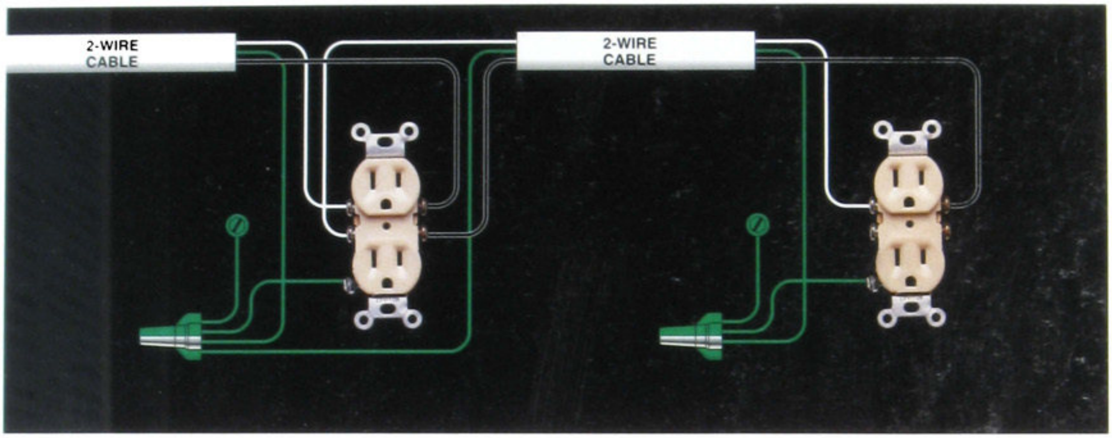
The 120-volt circuits shown on the following pages are wired for 15 amps, using 14-gauge wire and receptacles rated at 15 amps. If you are installing a 20-amp circuit, substitute 12-gauge cables and use receptacles rated for 20 amps.

In configurations where a white wire serves as a hot wire instead of a neutral, both ends of the wire are coded with black tape to identify it as hot. In addition, each of the circuit maps shows a box grounding screw. This grounding screw is required in all metal boxes, but plastic electrical boxes do not need to be grounded.

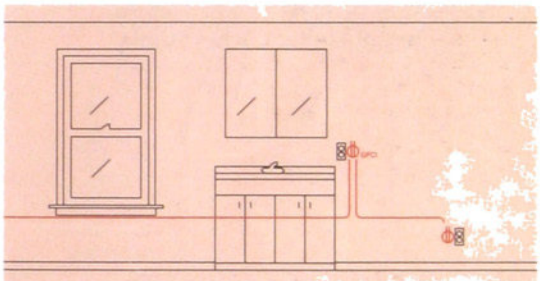
NOTE: For clarity, all grounding conductors in the circuit maps are colored green. In practice, the grounding wires inside sheathed cables usually are bare copper.

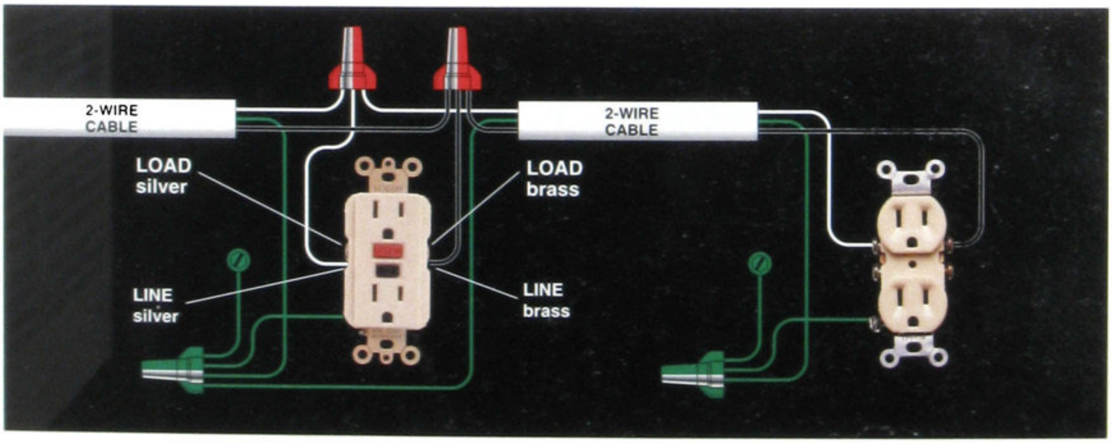
1 120-volt Duplex Receptacles Wired in Sequence





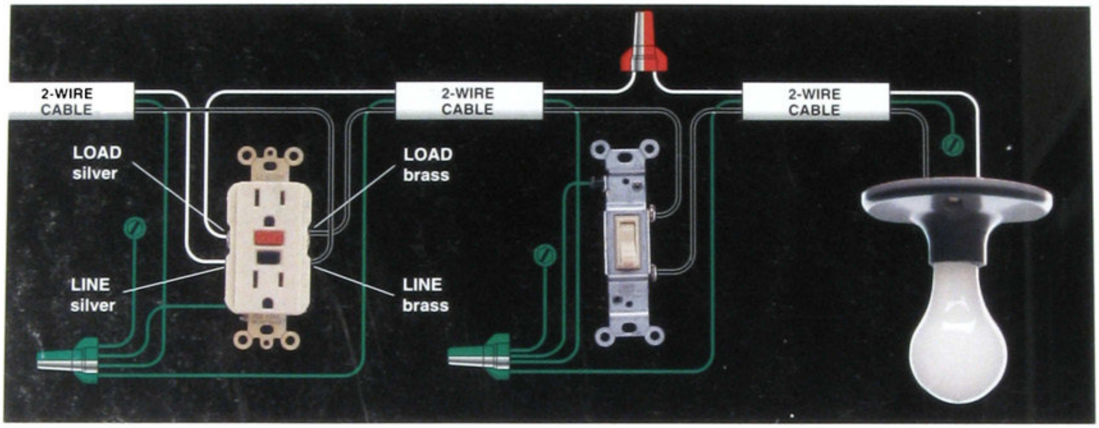
2 GFCI Receptacles (Single-location Protection)



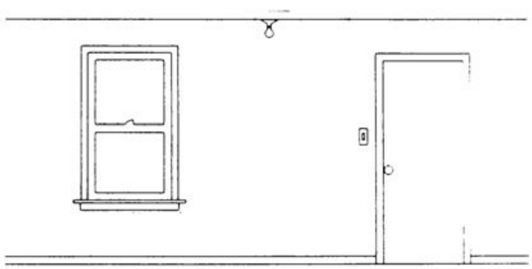


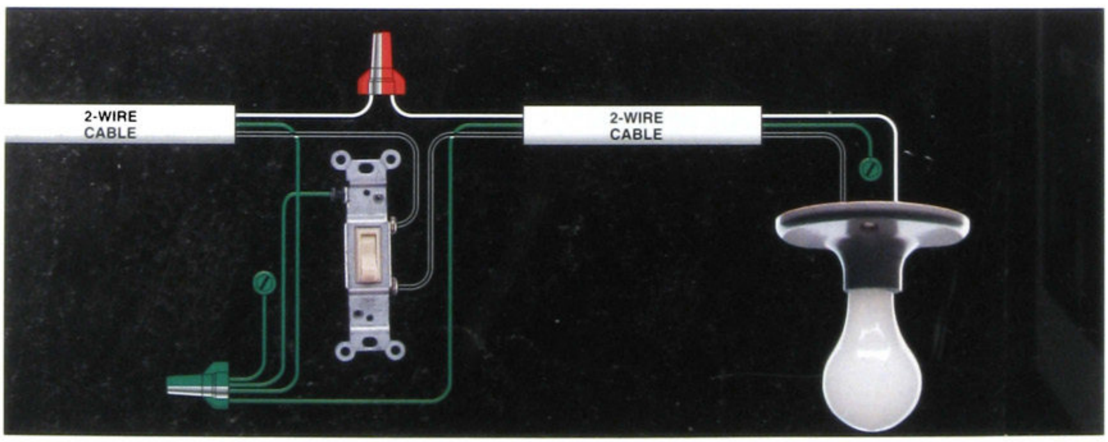
3. GFCI Receptacle, Switch & Light Fixture
(Wired for Multiple-location Protection)

such as an outdoor circuit it is a
connect a GFCI receptacle so it also
ction the wires and fixtures
nd of the circuit Wires from th
connected to the LINE screw termi-
cted to LOAD screw



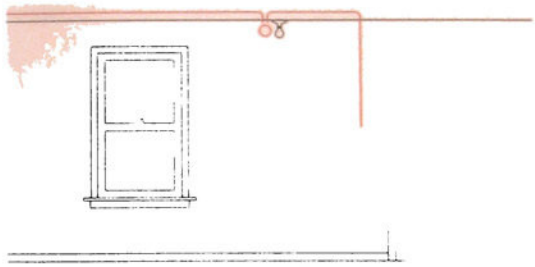
4 Single-pole Switch & Light Fixture
(Light Fixture at End of Cable Run)

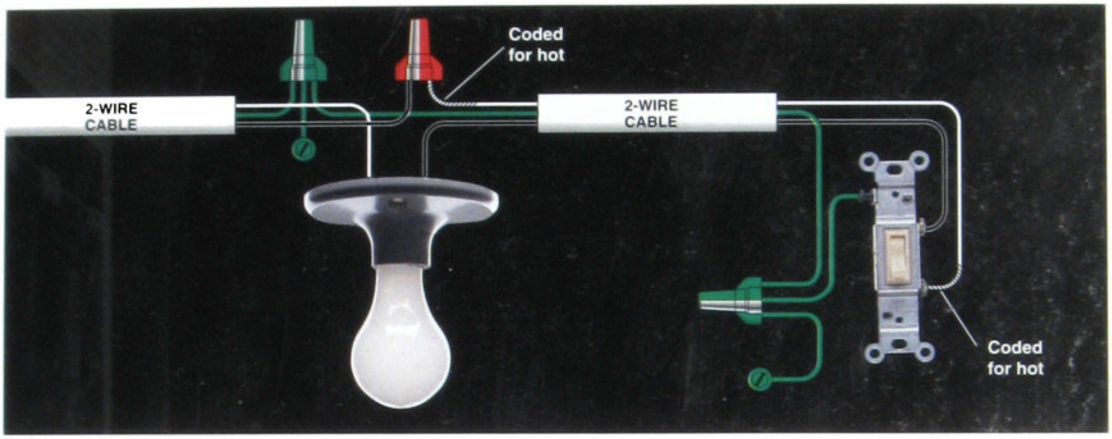




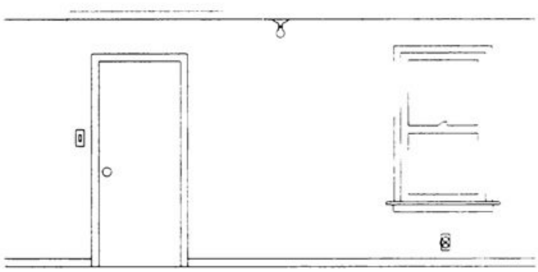
5 Single-pole Switch & Light Fixture (Switch at End of Cable Run)

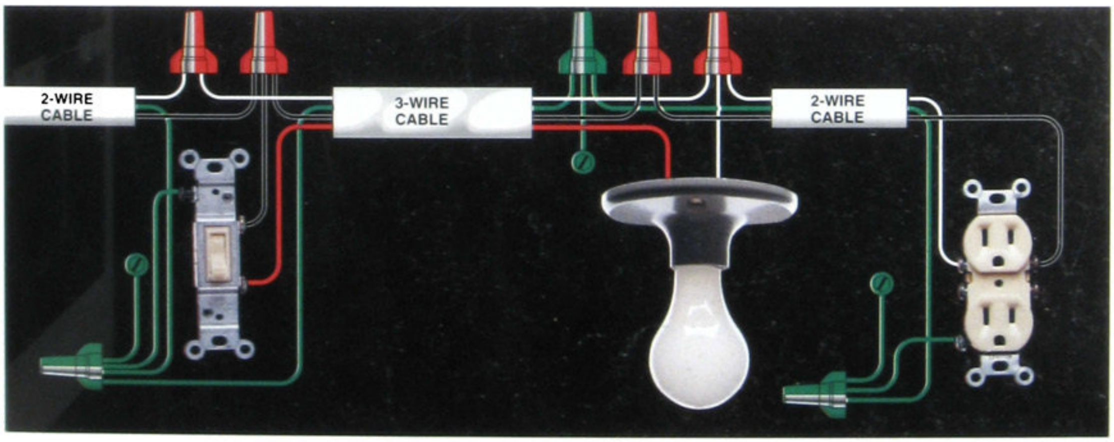
switch loop
at th





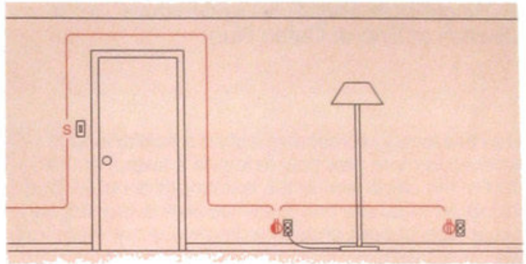
6 Single-pole Switch & Light Fixture, Duplex Receptacle (Switch at Start of Cable Run)

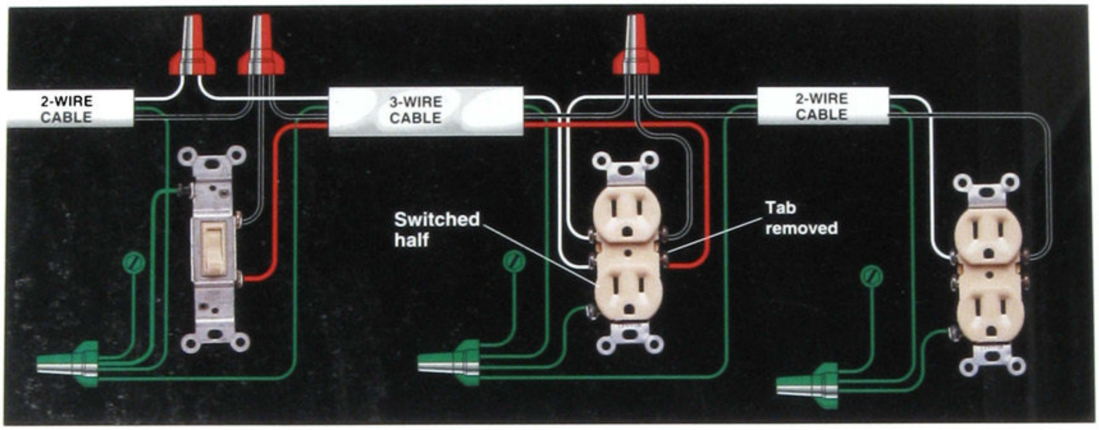




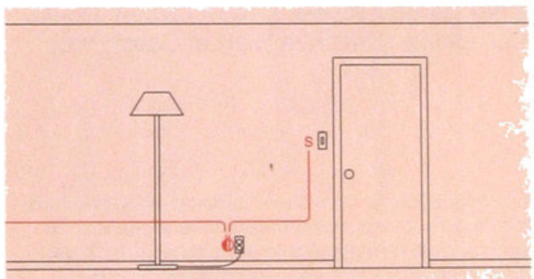
7 Switch-controlled Split Receptacle, Duplex Receptacle (Switch at Start of Cable Run)

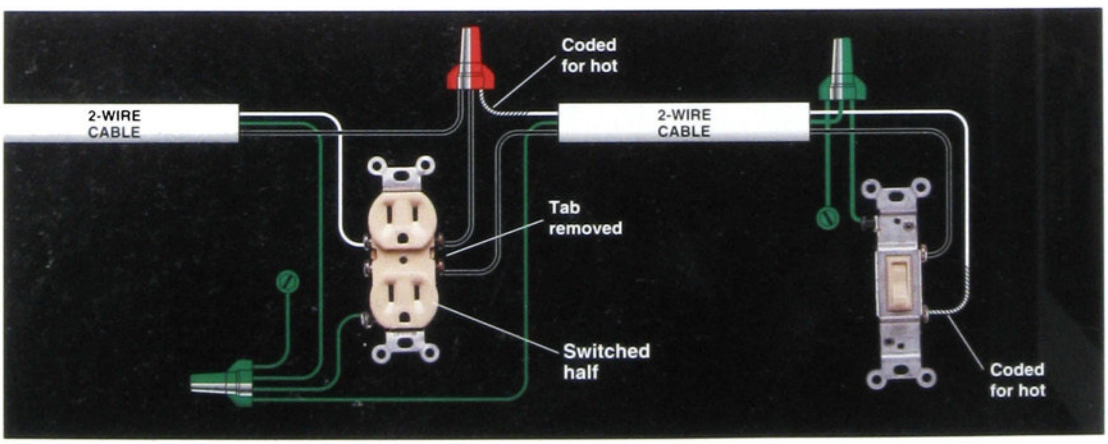
This layout lets you use a wall switch to control a lamp plugged into a wall receptacle This configur tion is required by code for any room that does not have a switch-controlled ceiling fixture Only the bot- half of the first receptacl is controlled by the the top half of th receptacle and all receptacles on th ircuit are always h two-wire and three-wire cables



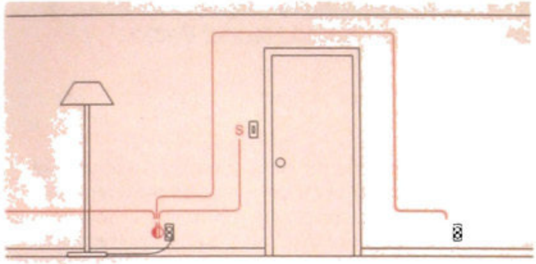


8. Switch-controlled Split Receptacle (Switch at End of Cable Run)

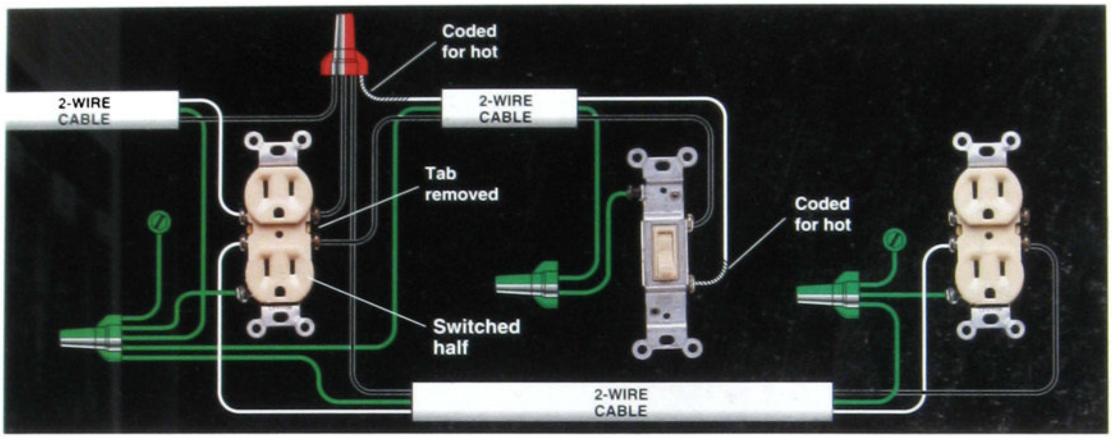




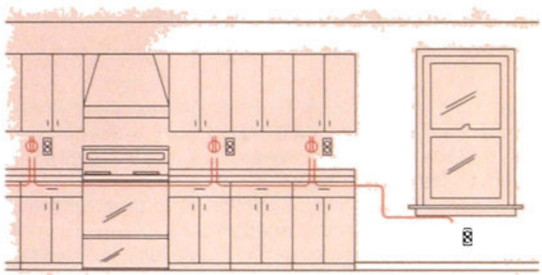
9 Switch-controlled Split Receptacle, Duplex Receptacle (Split Receptacle at Start of Run)

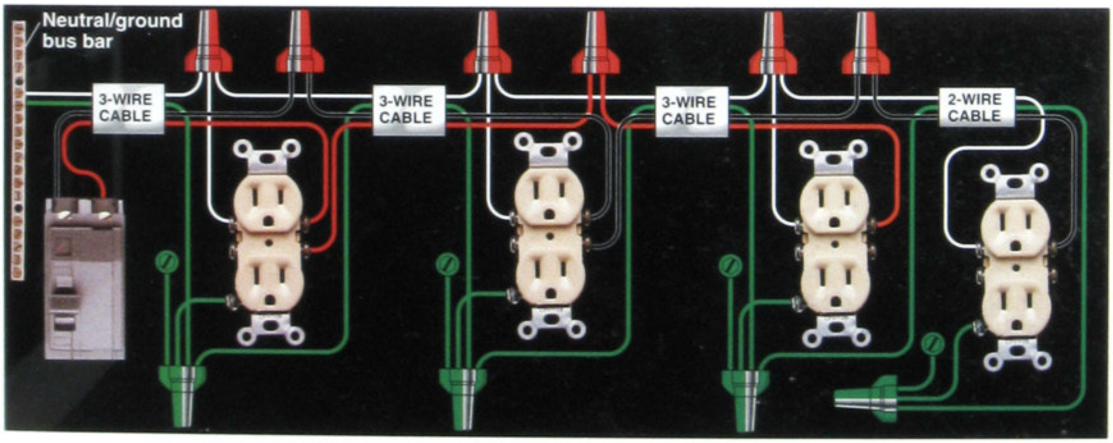


receptacles
Requires two-wir

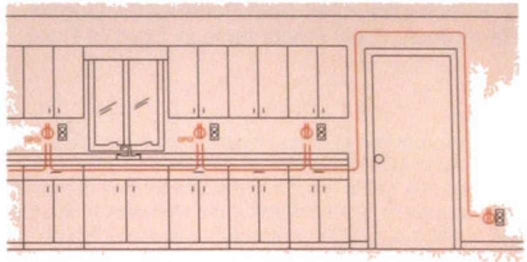


10. Double Receptacle Circuit with Shared Neutral Wire (Receptacles Alternate Circuits)

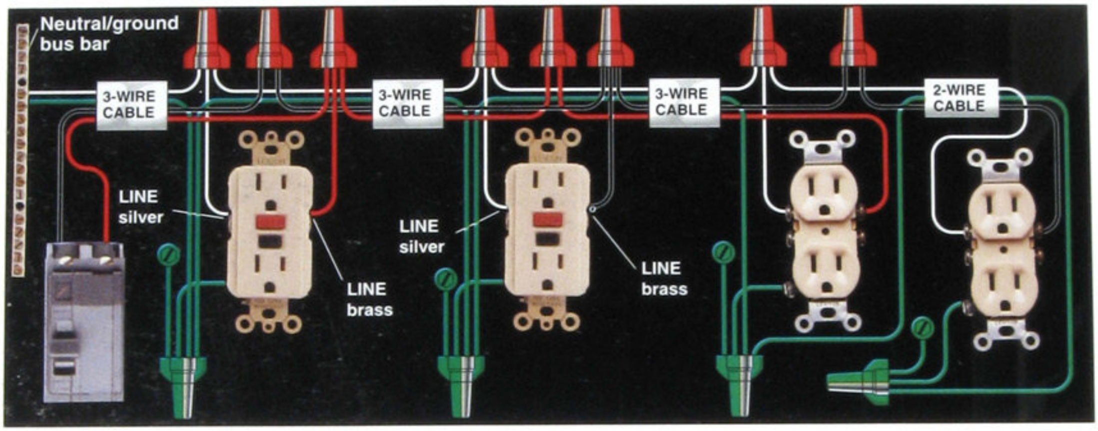




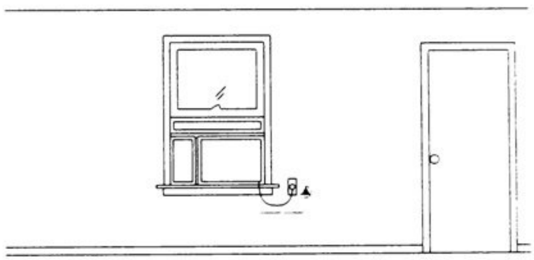
11. Double Receptacle Circuit with GFCIs & Shared Neutral Wire

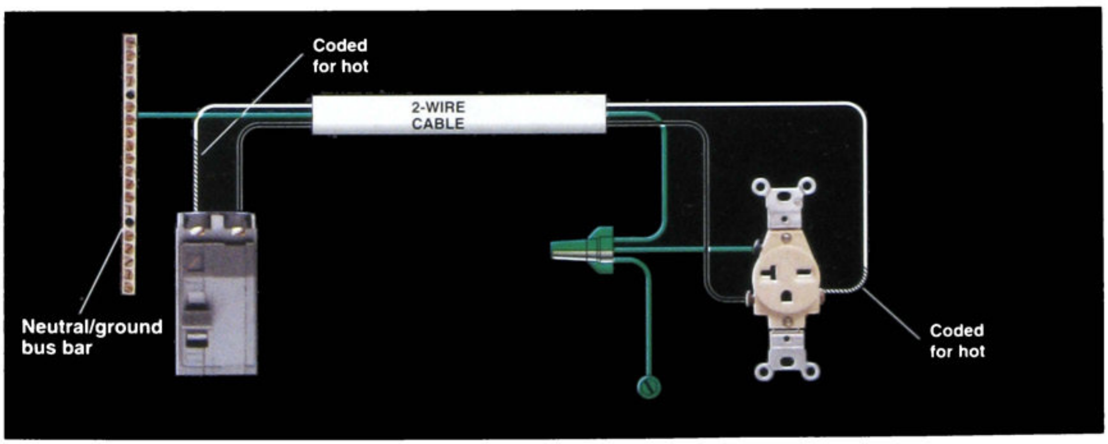


Use this layout variation of circuit map 10 to wire a double receptacle circuit when code requires that some of the receptacles by GFCIs. The GFCIs should be wired for single-location protection (see circuit map 2). Requires three-wire and two-wire cables.

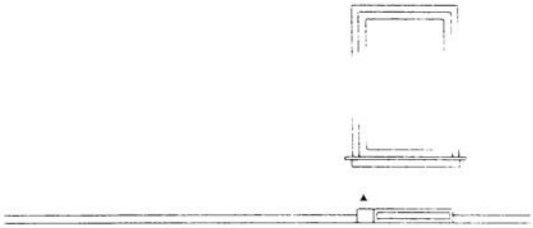


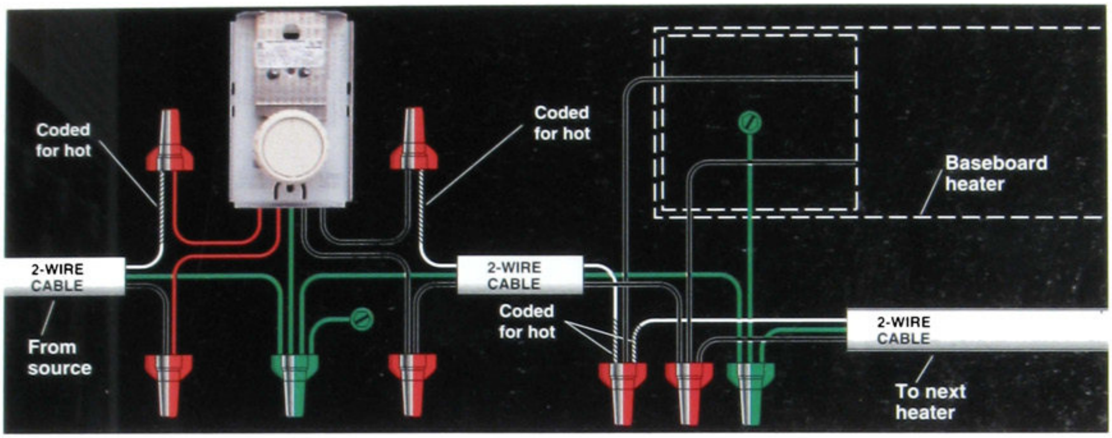
12. 240-volt Appliance Receptacle



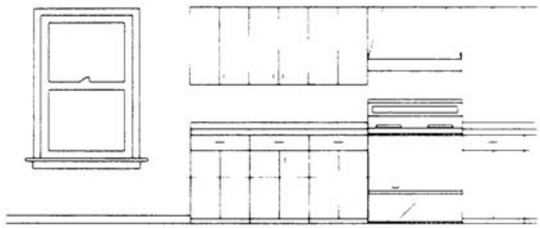


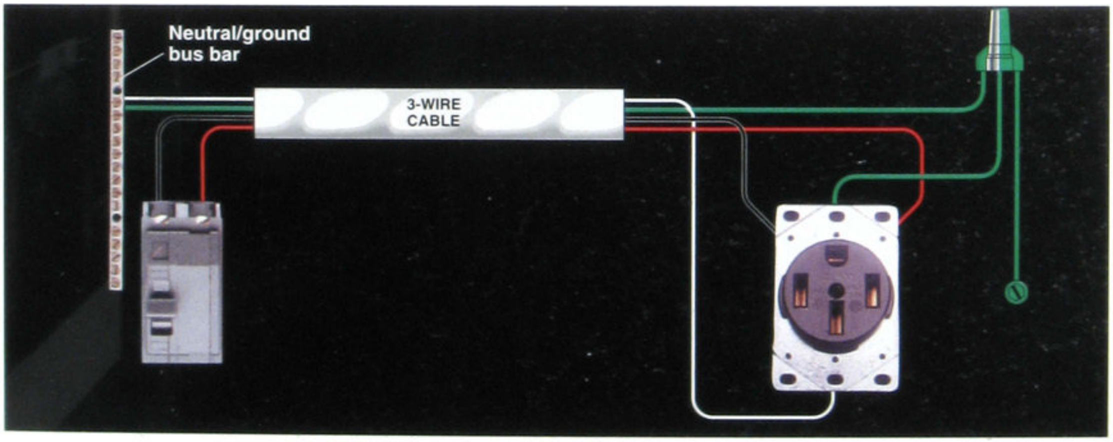
13. 240-volt Baseboard Heaters, Thermostat





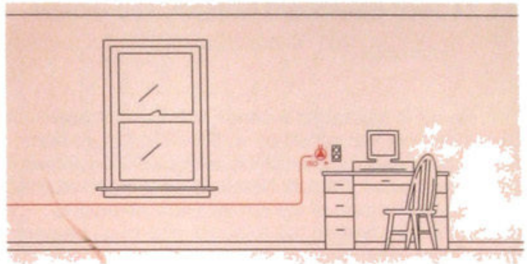
14 120/240-volt Appliance Receptacle

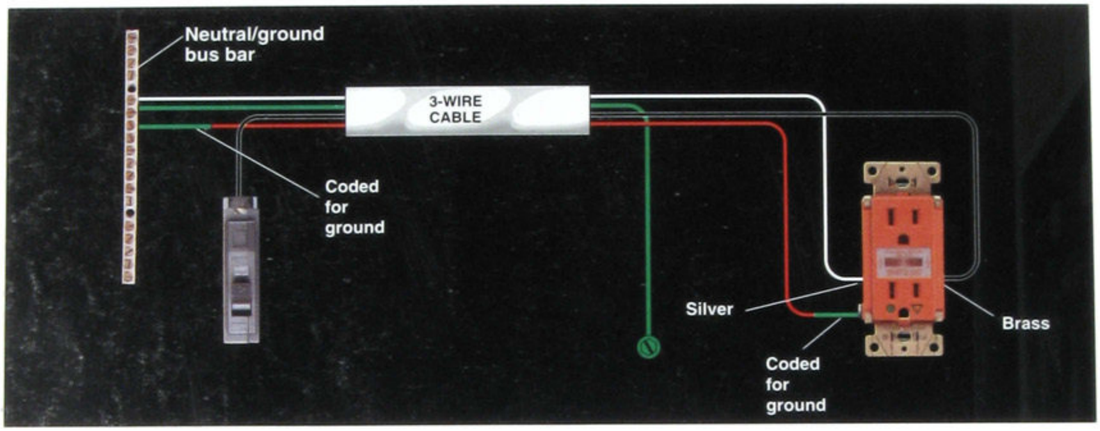




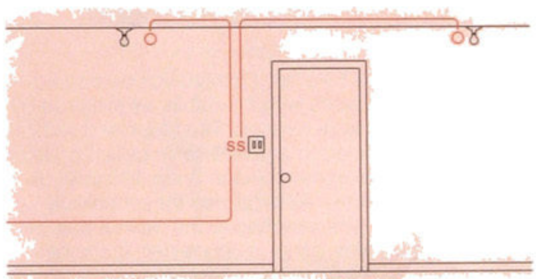
15. Dedicated 120-volt Computer Circuit, Isolated-ground Receptacle

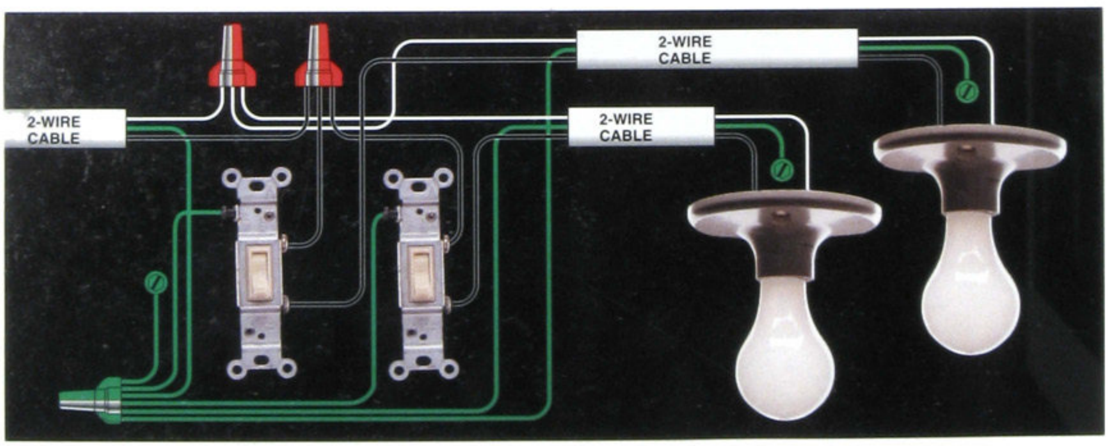
This 15-amp circuit provides extra protection against power surges that can harm computers. It uses 14/3 cable in which the red wire serves as an extra grounding conductor. The red wire is tagged with green tape for identification. It is connected to the grounding …rew… an isolated-ground receptacle and runs …k to the grounding bus bar … the circuit breaker without touching any other house wiring.





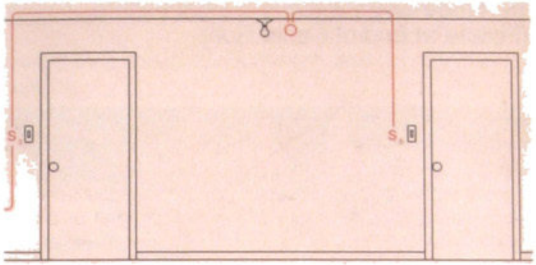
16. Ganged Single-pole Switches Controlling Separate Light Fixtures

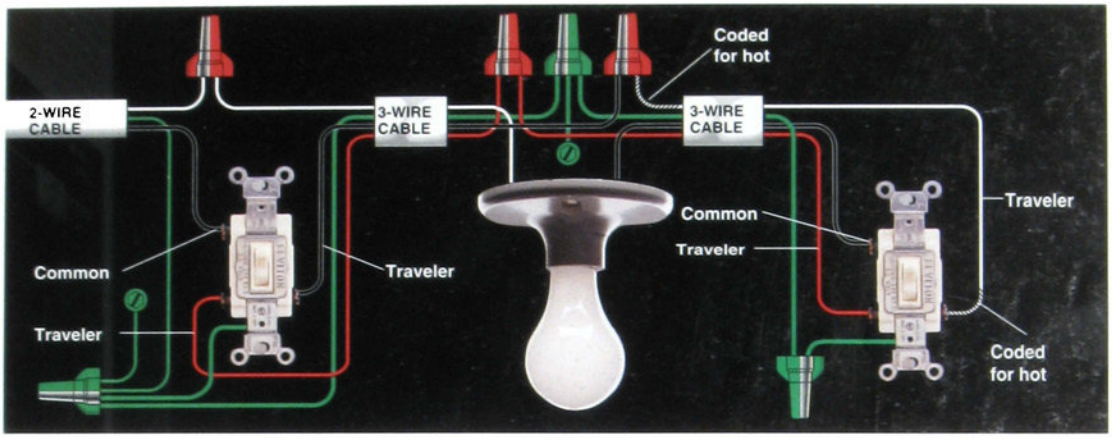




17. Three-way Switches & Light Fixture
(Fixture Between Switches)

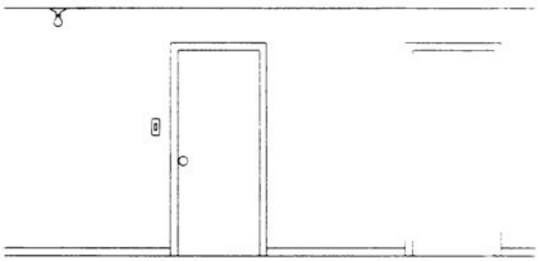
lets
ach switch has
TRAVELER
TRAVELER
and t

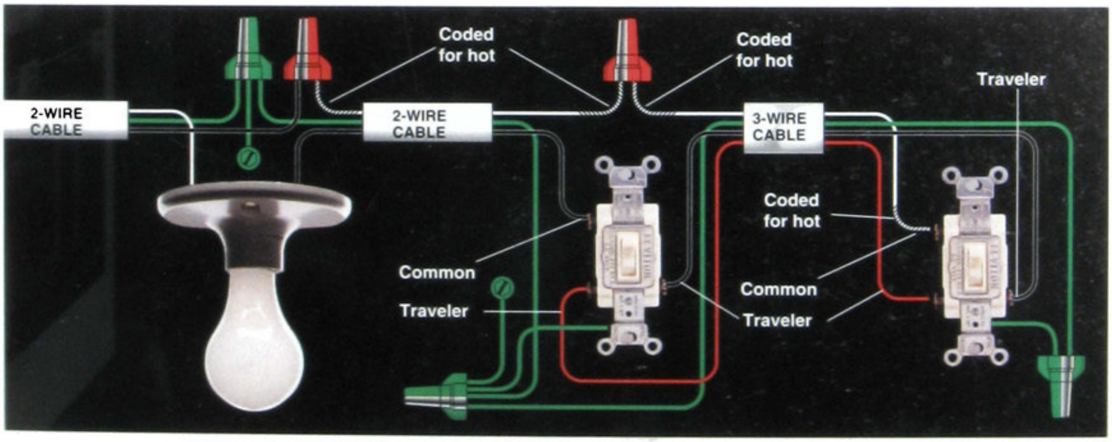




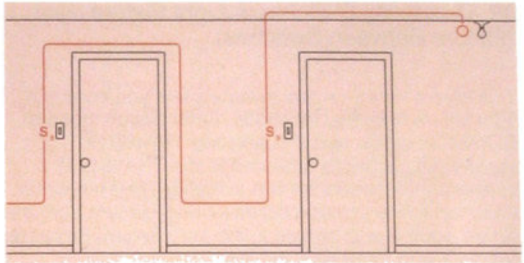
18. Three-way Switches & Light Fixture
(Fixture at Start of Cable Run)

map
ixture ahead
Requires

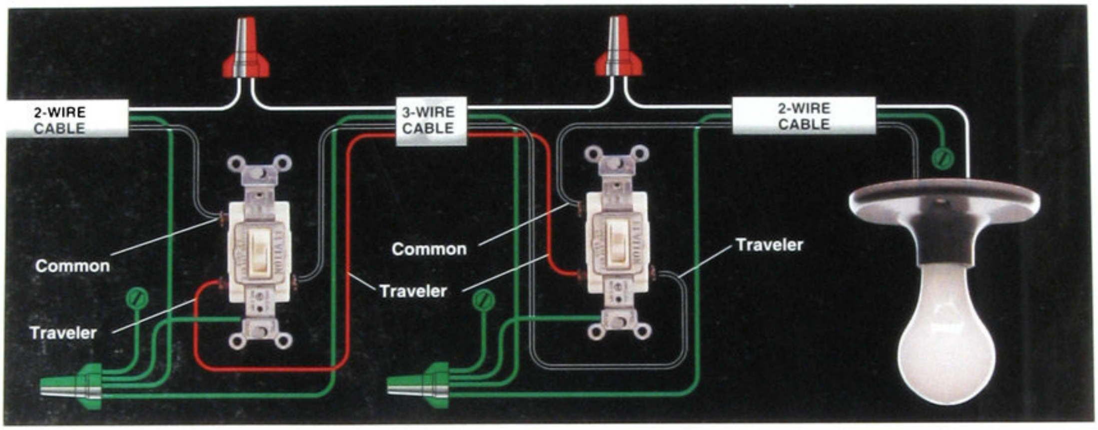




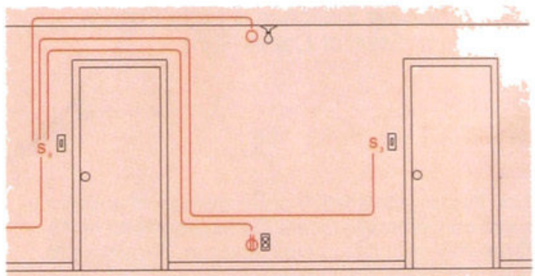
19. Three-way Switches & Light Fixture (Fixture at End of Cable Run)



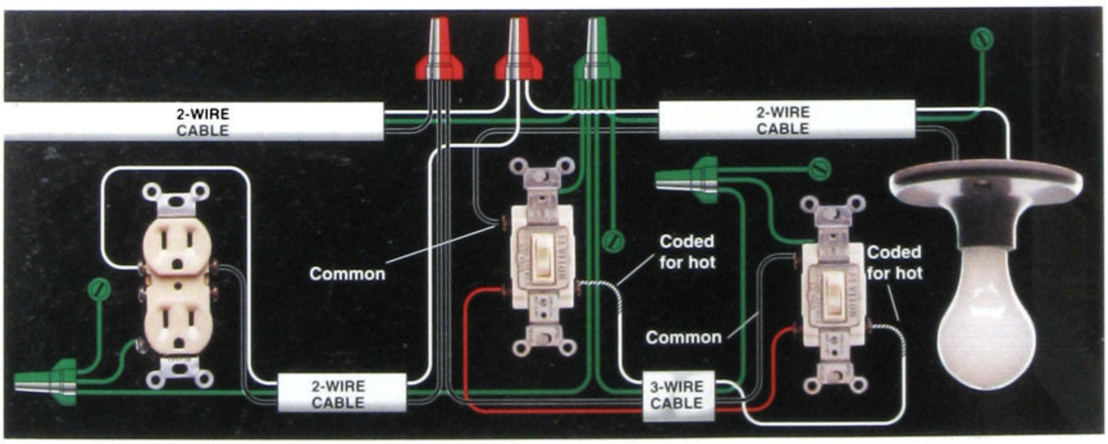
This variation of the three-way switch layout (circuit map 17) is used where it is more practical to locate the fixture at the end of the cable run Requires two- nd three-wire cables



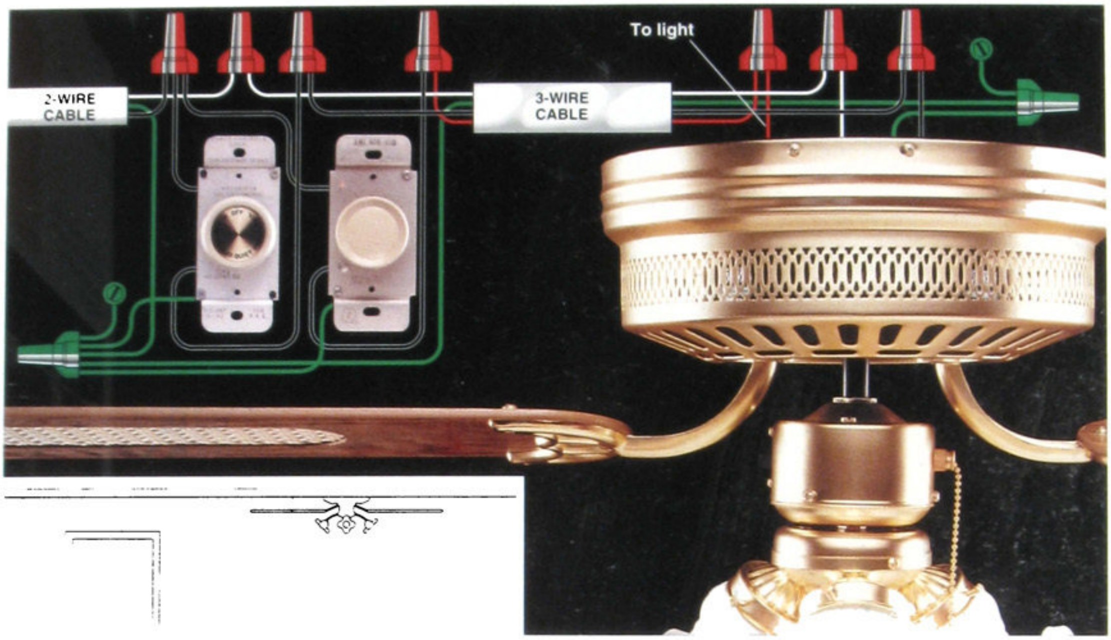
20. Three-way Switches & Light Fixture with Duplex Receptacle



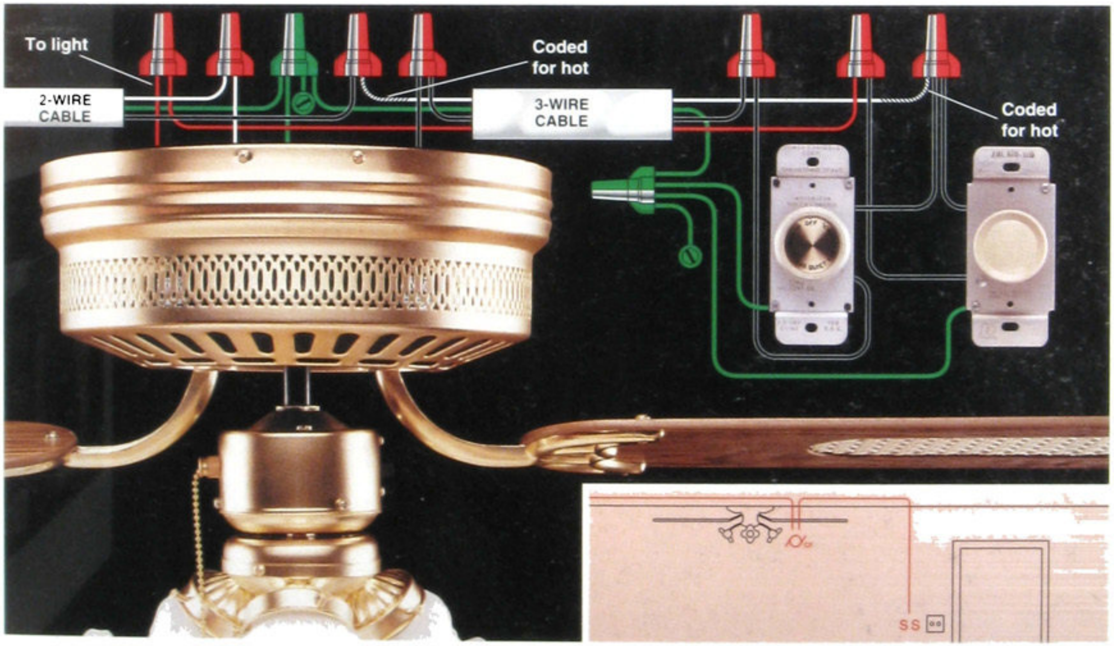
tacle to a
map 17) Require



21 Ceiling Fan/Light Fixture Controlled by Ganged Switches (Fan at End of Cable Run)

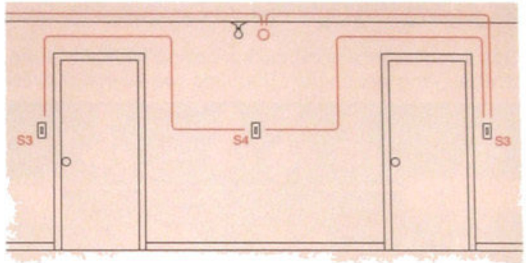


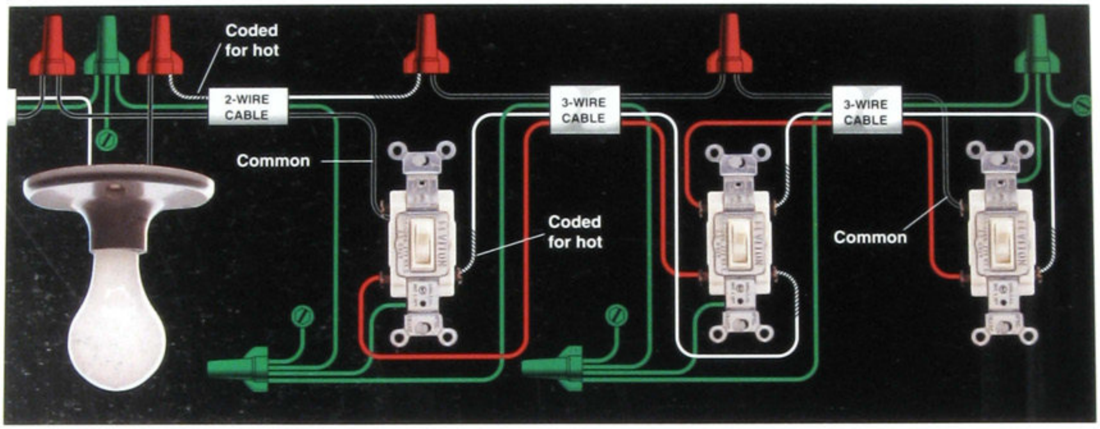
22 Ceiling Fan/Light Fixture Controlled by Ganged Switches (Switches at End of Cable Run)



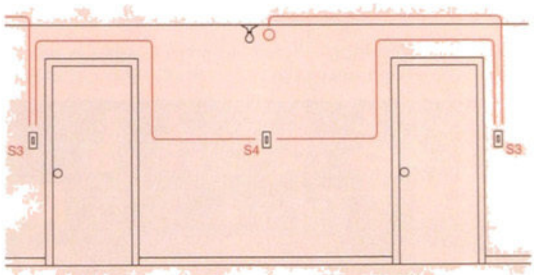
23. Four-way Switches & Light Fixture (Fixture at Start of Cable Run)

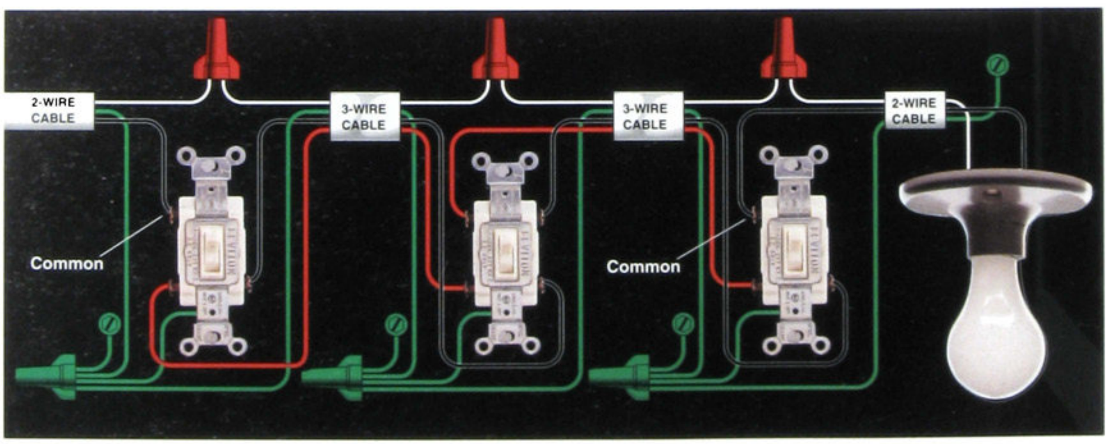
layout for ur ay switches lets you control light fixture from three locations A pair of three-wir ables enter the box of the four-way switch The white and red wires from one cable attach to the top of screw terminals (line 1) and the white and red the oth cable attaches to the bottom terminals (line 2) Requires two-wire and abl





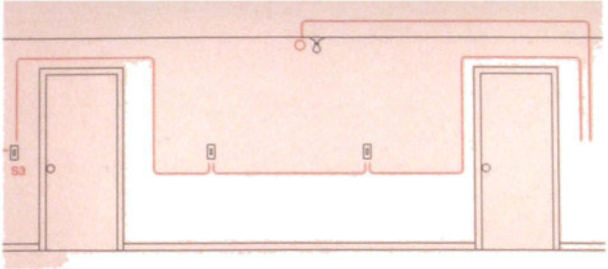
24 Four-way Switches & Light Fixture (Fixture at End of Cable Run)

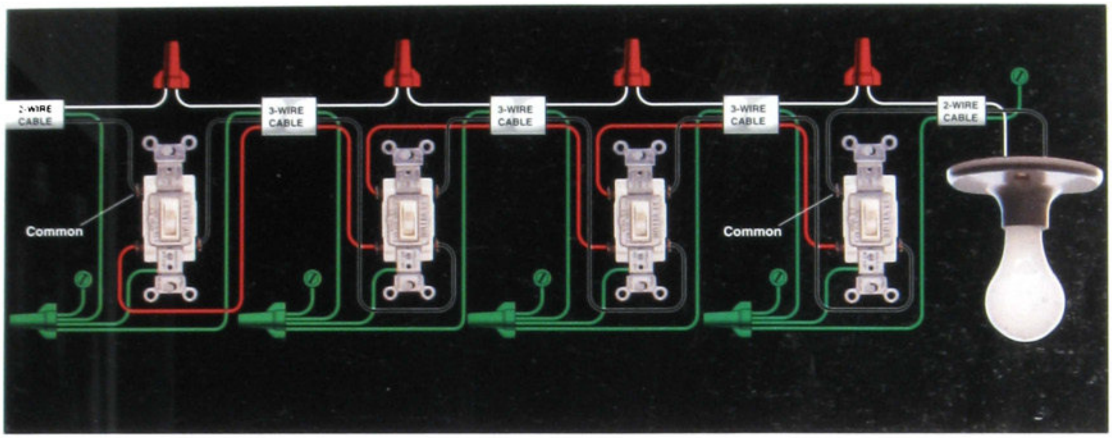




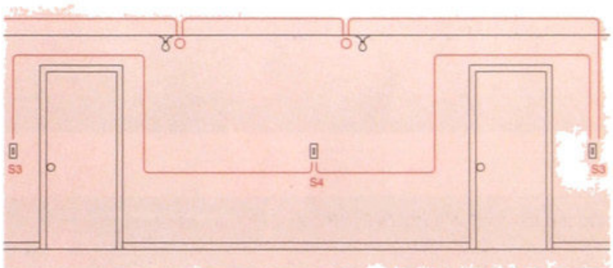
25 Multiple Four-way Switches Controlling a Light Fixture

Rec





26 Four-way Switches & Multiple Light Fixtures

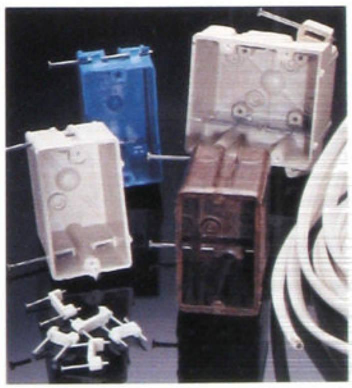


Tools, Materials & Techniques for Projects

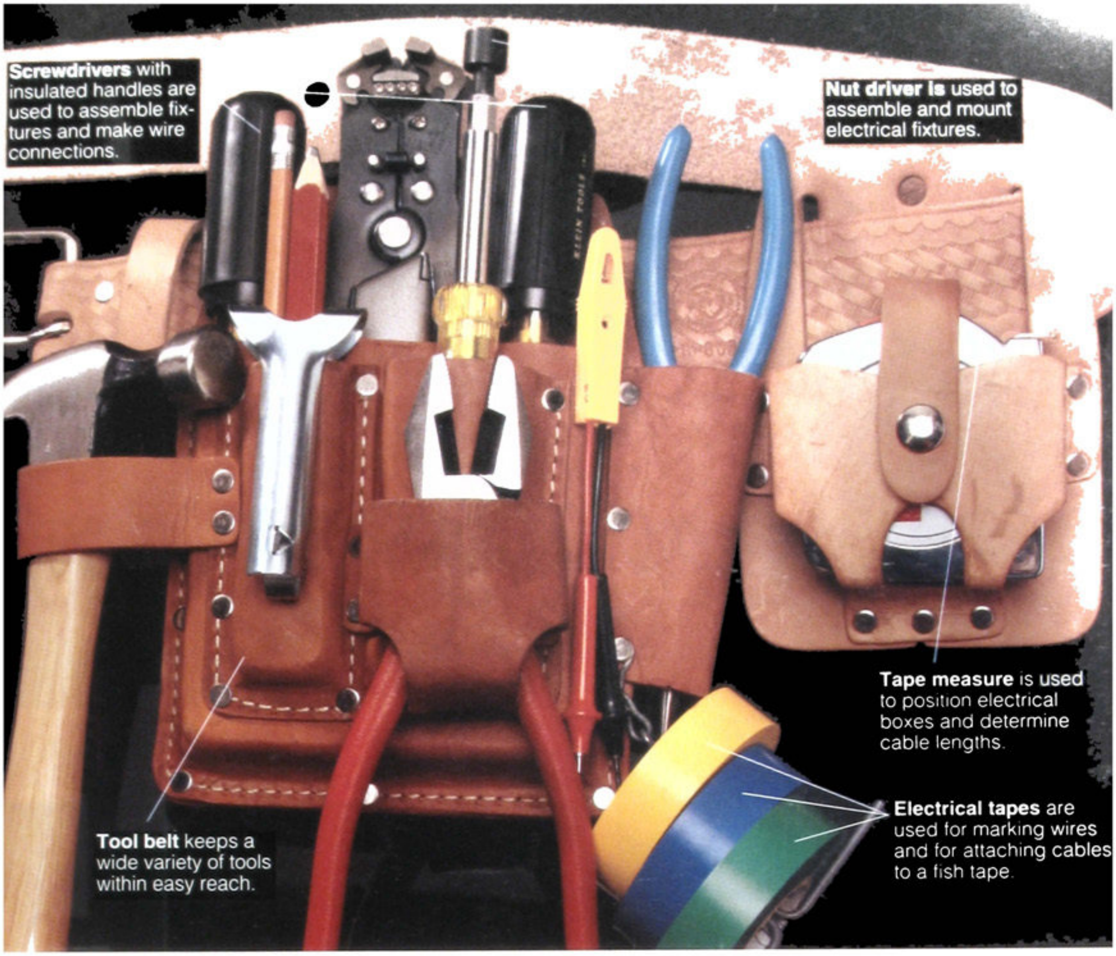
To complete the wiring projects shown in this book, you need a few specialty electrical tools (above), as well as a collection of basic tools (page opposite) As with any tool purchase, invest in good-quality products when you buy tools for electrical work. Keep your tools clean, and sharpen or replace any cutting tools that have dull edges

The materials used for electrical wiring have changed dramatically in the last 20 years, making it much easier for homeowners to do their own electrical work. The following pages show how to work with the following components for your projects.

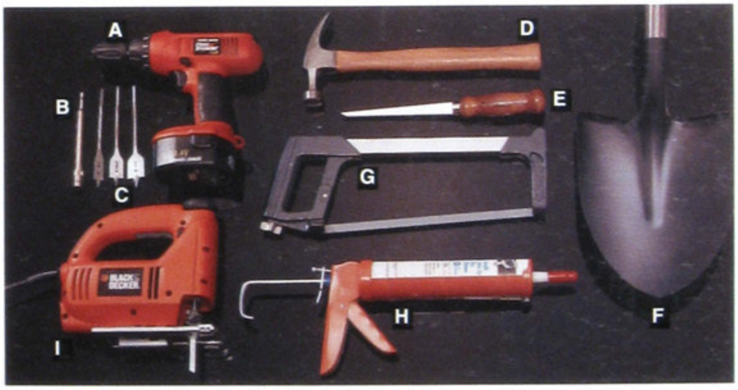
- Electrical Boxes. Projects (pages 170 to 175)
- Wires & Cables Projects (pages 176 to 183)
- Conduit (pages 184 to 189)
- Circuit Breaker Panels (pages 190 to 191)
- Circuit Breakers (pages 192 to 193)
- Subpanels (pages 190 to 191, 194 to 197).



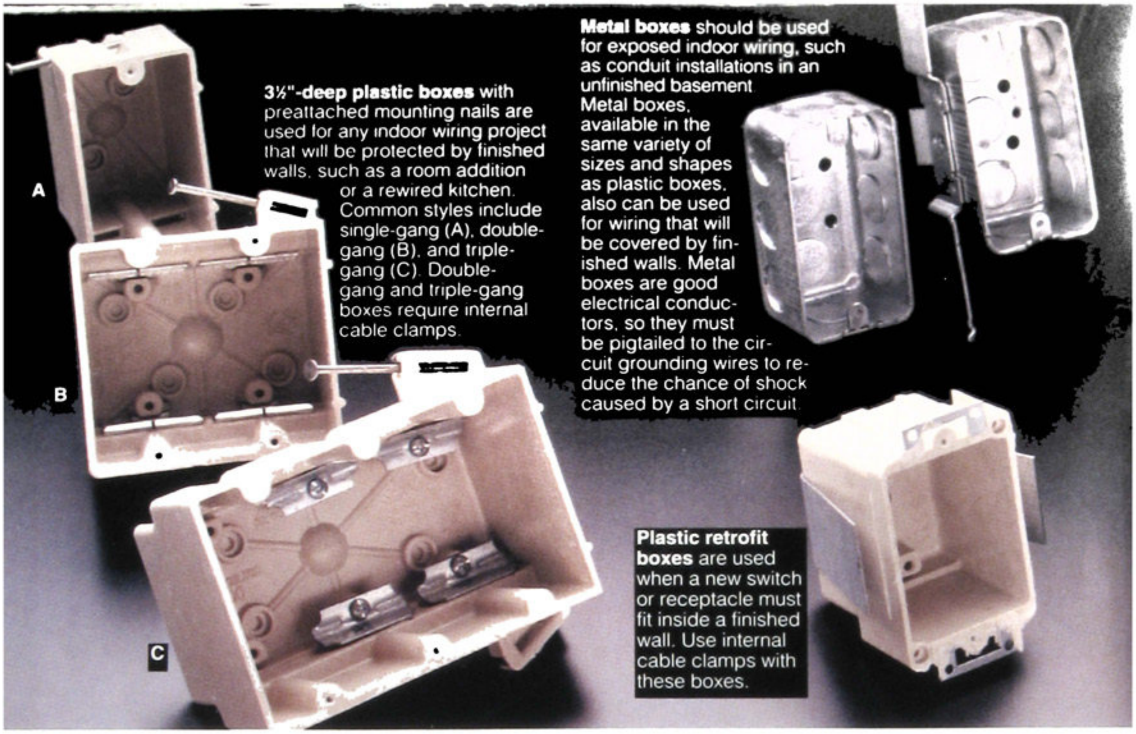
Plastic electrical boxes for indoor installations are ideal for do-it-yourself electrical work They have preattached mounting nails for easy installation and are much less expensive than metal boxes.



A fish tape is useful for installing cables in finished wall cavities and for pulling wires through conduit. Products designed for lubrication reduce friction and make it easier to pull cables and wires.



These basic tools are used for advanced wiring projects: drill (A), drill bit extension (B), and spade bits (C) for boring holes in framing members, hammer (D) for attaching electrical boxes, wallboard saw (E) for making cutouts in indoor walls, shovel (F) to dig trenches for outdoor wiring, hacksaw (G) for cutting conduit, caulk gun (H) for sealing gaps in exterior walls, jig saw (I) for making wall cutouts.



3½"-deep plastic boxes with preattached mounting nails are used for any indoor wiring project that will be protected by finished walls, such as a room addition or a rewired kitchen. Common styles include single-gang (A), double-gang (B), and triple-gang (C). Double-gang and triple-gang boxes require internal cable clamps.

Metal boxes should be used for exposed indoor wiring, such as conduit installations in an unfinished basement. Metal boxes, available in the same variety of sizes and shapes as plastic boxes, also can be used for wiring that will be covered by finished walls. Metal boxes are good electrical conductors, so they must be pigtailed to the circuit grounding wires to reduce the chance of shock caused by a short circuit.

Plastic retrofit boxes are used when a new switch or receptacle must fit inside a finished wall. Use internal cable clamps with these boxes.

Electrical Boxes: Projects

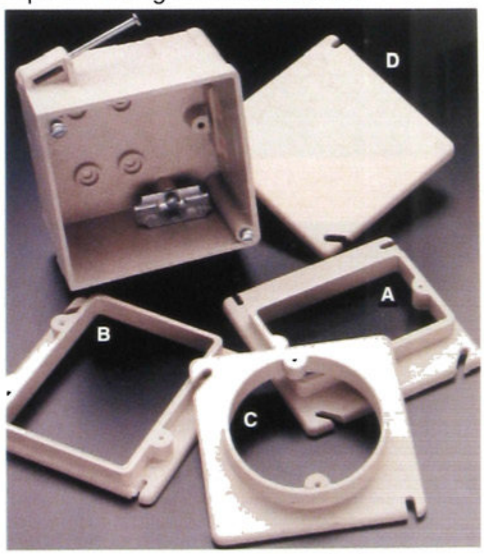
Use the chart below to select the proper type of box for your wiring project. For most indoor wiring done with NM cable, use plastic electrical boxes. Plastic boxes are inexpensive, lightweight, and easy to install.

Metal boxes also can be used for indoor NM cable installations and are still favored by some electricians, especially for supporting heavy ceiling light fixtures.

If you have a choice of box depths, always choose the deepest size available. Wire connections are easier to make if boxes are roomy. Check with your local inspector if you have questions regarding the proper box size to use.

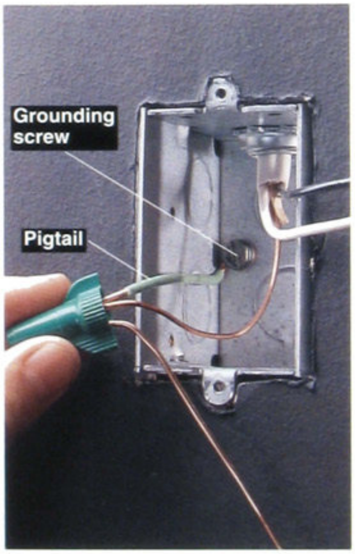
Box type	Typical uses
Plastic	• Protected indoor wiring, used with NM cable. • Not suited for heavy light fixtures and fans.
Metal	• Exposed indoor wiring, used with metal conduit. • Protected indoor wiring, used with NM cable.
Cast aluminum	• Outdoor wiring, used with metal conduit.
PVC plastic	• Outdoor wiring, used with PVC conduit. • Exposed indoor wiring, used with PVC conduit.

Tips for Using Electrical Boxes

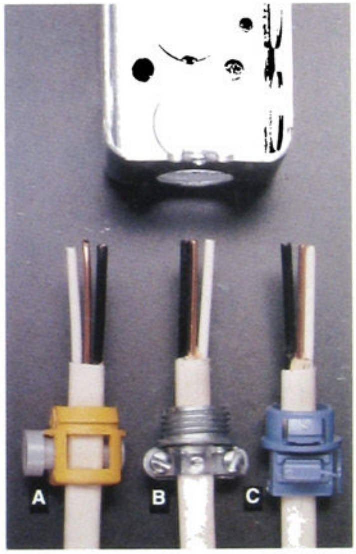


A square plastic box, 4" × 4 × 3" deep provides extra space for making wire connections. It has preattached nails for easy mounting. A variety of adapter plates are available for 4 × 4 boxes, including single-gang (A), double-gang (B), light fixture (C), and junction box coverplate (D). Adapter plates come in several thicknesses to match different wall constructions.

Boxes larger than 2" × 4", and all retrofit boxes, must have internal cable clamps. After installing cables in the box, tighten the cable clamps over the cables so they are gripped firmly but not so tightly that the cable sheathing is crushed.



Metal boxes must be grounded to the circuit grounding system. Connect the circuit grounding wires to the box with a green insulated pigtail wire and wire connector (as shown) or with a grounding clip (page 184).



Cables entering a metal box must be clamped. A variety of clamps are available, including plastic clamps (A, C) and threaded metal clamps (B).

Electrical boxes in adjacent rooms should be positioned close together when they share a common wall and are controlled by the same circuit. This simplifies the cable installations and also reduces the amount of cable needed.

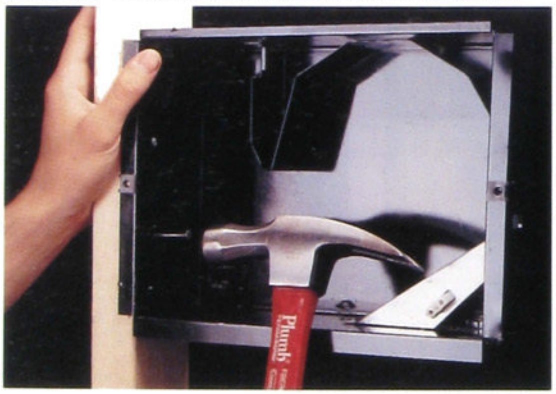
Installing Electrical Boxes

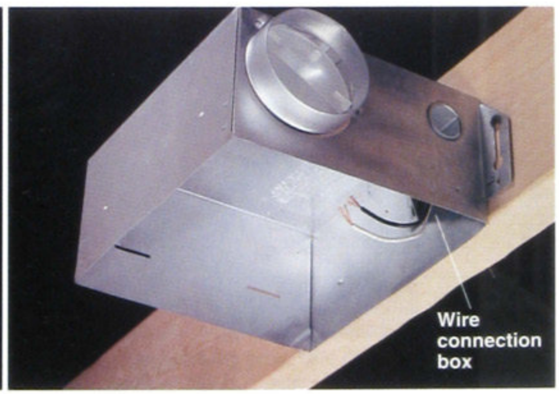
Install electrical boxes for receptacles, switches, and fixtures only after your wiring project plan has been approved by your inspector. Use your wiring plan as a guide, and follow electrical code height and spacing guidelines when laying out box positions.

Always use the deepest electrical boxes that are practical for your installation. Using deep boxes ensures that you will meet code regulations regarding box volume and makes it easier to make the wire connections.

Some electrical fixtures, like recessed light fixtures, electri heaters, and exhaust fans, have built-in wire connection boxes. Install the frames for these fixtures at the same time you are installing the other electrical boxes.

Fixtures That Do Not Need Electrical Boxes

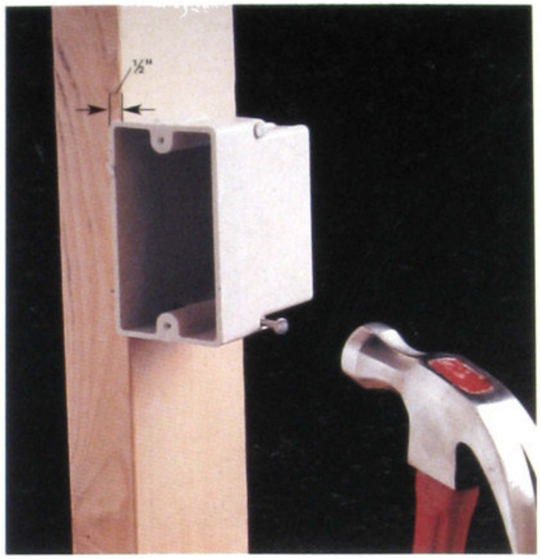




Recessed fixtures that fit inside wall cavities have built-in wire connection boxes and require no additional electrical boxes. Common recessed fixtures include electric blower-heaters (left), bathroom vent fans (right) and recessed light fixtures (page 236). Install the frames for these fixtures at the same time you are installing the other electrical boxes along the circuit. Surface-mounted fixtures, like electric baseboard heaters (page 225) and under-cabinet fluorescent lights (page 243), also have built-in wire connection boxes. These fixtures are not installed until it is time to make the final hookups.

How to Install Electrical Boxes for Receptacles

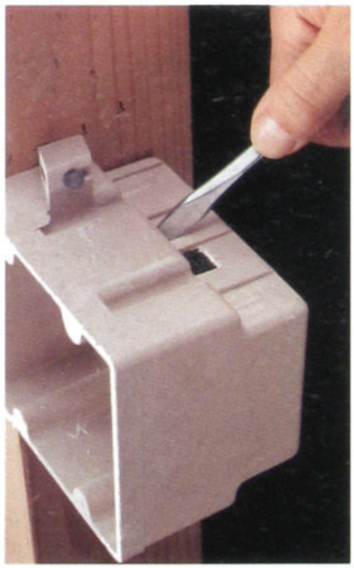
1



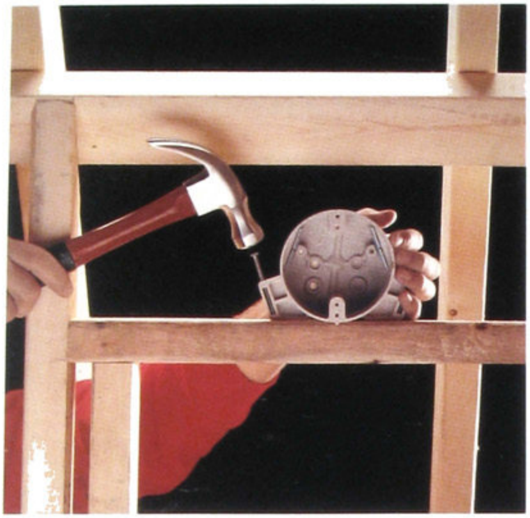
2 P

3

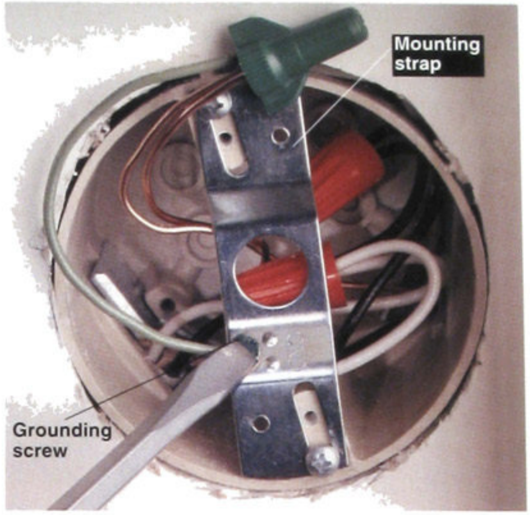
4 Open cabl



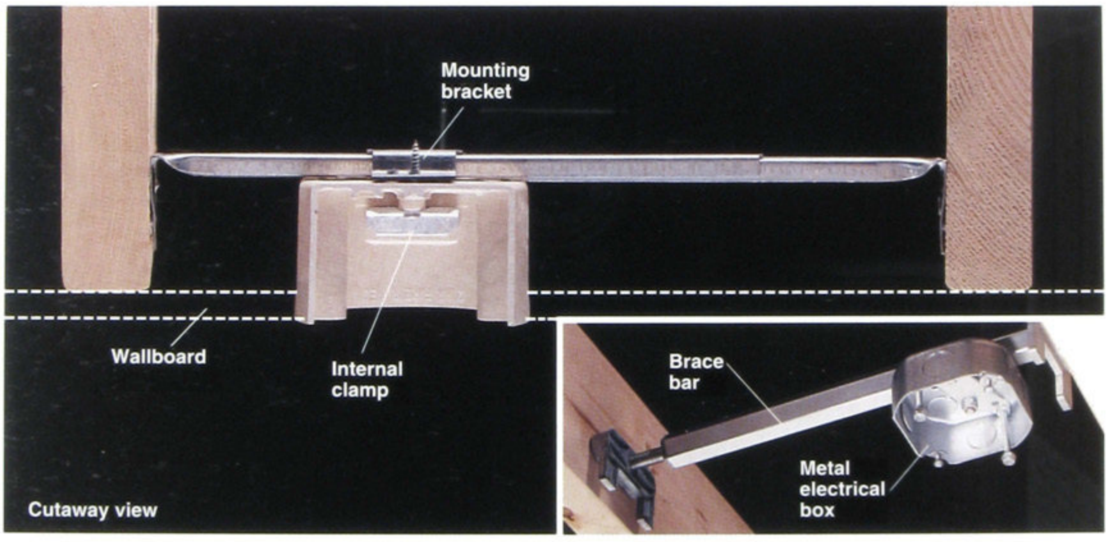
5 Break off ny sh rp edges might damage cabl sheathing by rotating a scr driver in the knockout



Position the light fixture box abov ınet of th

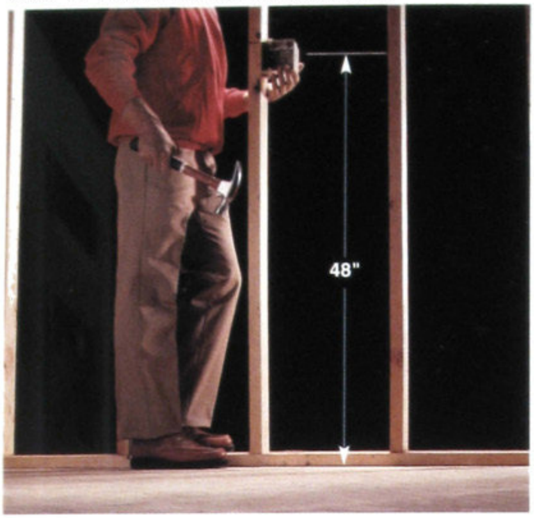


Attach a mounting strap by the light-fixtu anufact needed match

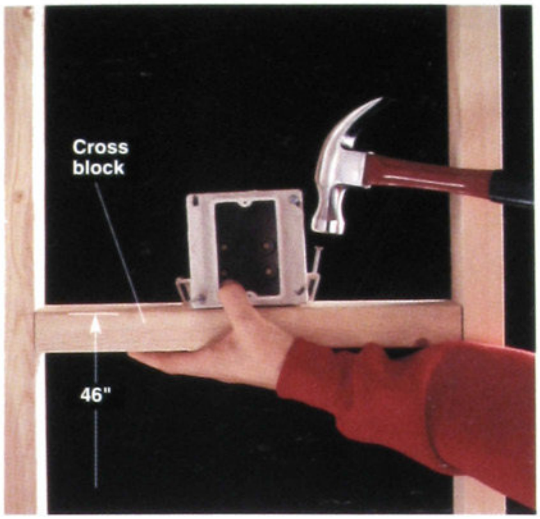


To position a light fixture between joists, attach electric box ar adjustable brace bar Nail th ce bar to joists so the face of the box the fi ished ceiling surface Slide along the brace bar to the desired position, then tighten th mounting scr ws Use rnal clamps when ing a box a brace bar N ceiling fans and heavy fixtures use a metal box a heavy-duty brace bar rated for heavy loads (inset photo)

How to Install Boxes for Switches

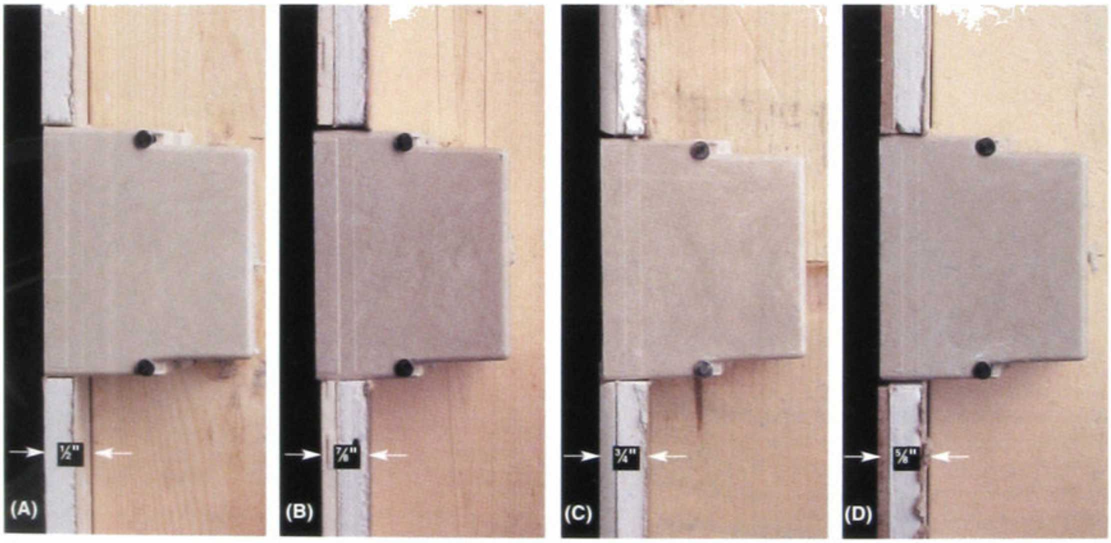


Install switch boxes



To install a switch box between studs,
a cross bl be
abo. the Pos

How to Install Electrical Boxes to Match Finished Wall Depth



Consider the thickness of finished walls when
boxes against framing members
front t oxes be flush
you install box
ll finish that
lls will be finished with
wallboard (A) ttach the boxes so the front faces extend past the front of the fr ing member With ceramic tile and wall board (B) extend the boxes past the framing members With Corian over board (C) boxes should extend and with wall-board and laminate (D), boxes extend

NM (non-metallic) sheathed cable should be used for most indoor wiring projects in dry locations, such as a room addition (pages 198 to 225) or kitchen (pages 226 to 243). NM cable is available in a wide range of wire sizes, and in either "2-wire with ground" or "3-wire with ground" types. NM cable is sold in boxed rolls that contain from 25 to 250 feet of cable.

Coaxial cable is used to connect cable television jacks (page 216). Coaxial cable is available in lengths up to 25 ft. with preattached fittings called F-connectors (A). Or you can buy bulk coaxial cable (B) in any length and attach your own F-connectors.

Large-appliance cable is used for kitchen ranges (page 240) and other 40-amp or 50-amp appliances that require 8-gauge or 6-gauge wire. Large-appliance cable is similar to NM cable, but each individual conducting wire is made from fine-stranded copper wires so the cable is easier to bend. Large-appliance cable is available in both 2-wire and 3-wire types.

THHN/THWN wire is a versatile product that can be used in all conduit applications (pages 184 to 189). Each conducting wire, purchased individually, is covered with a color-coded thermoplastic insulating jacket similar to the insulation on the wires inside NM cable. Make sure the wire you buy has the THHN/THWN rating. Other wire types have a similar appearance but are less resistant to heat and moisture than THHN/THWN wire.

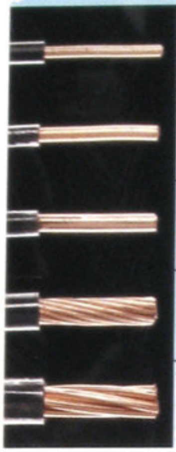
UF (underground feeder) cable is used for wiring in damp or wet locations, such as in an outdoor circuit (pages 248 to 267). It has a white or gray solid-core vinyl sheathing that protects the conducting wires and ground wire inside. Most Codes allow UF cable to be buried directly in the ground. It also can be used indoors wherever NM cable is allowed.

Telephone cable is used to connect telephone outlets (page 217). Your phone company may recommend four-wire cable (shown below) or eight-wire cable, sometimes called **four-pair**. Telephone outlet connections are identical for both types of cable, but eight-wire cable has extra wires that are left unattached. These extra wires allow for future expansion of the system.

Wire & Cables: Projects

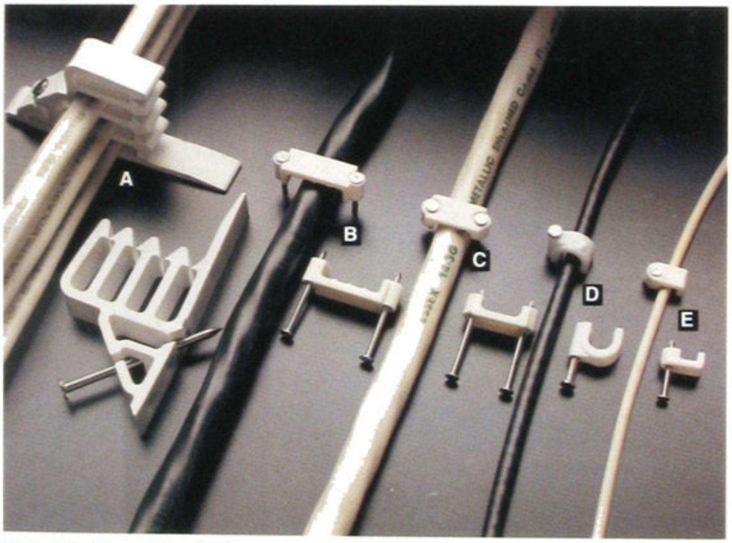
Many types of wire and cable are available at home centers, but only a few are used in most home wiring projects. Check your local electrical code to learn which type of wire to use, and choose wire large enough for the circuit ampacity (page opposite). Cables are identified by the wire gauge and number of insulated circuit wires they contain. In addition, all cables have a grounding wire. For example, a cable labeled "12/2 W G" contains two insulated 12-gauge wires, plus a grounding wire.

Use NM cable for new wiring installed inside walls. NM cable is easy to install when walls and ceilings are unfinished; these techniques are shown throughout the book. However, some jobs require that you run cable through finished walls, such as when you make the feeder cable connection linking a new circuit to the circuit-breaker panel. Running cable in finished walls requires extra planning and often is easier if you work with a helper. Sometimes cables can be run through a finished wall by using the gaps around a chimney or plumbing soil stack. Other techniques for running NM cable inside finished walls are shown on pages 182 to 183.

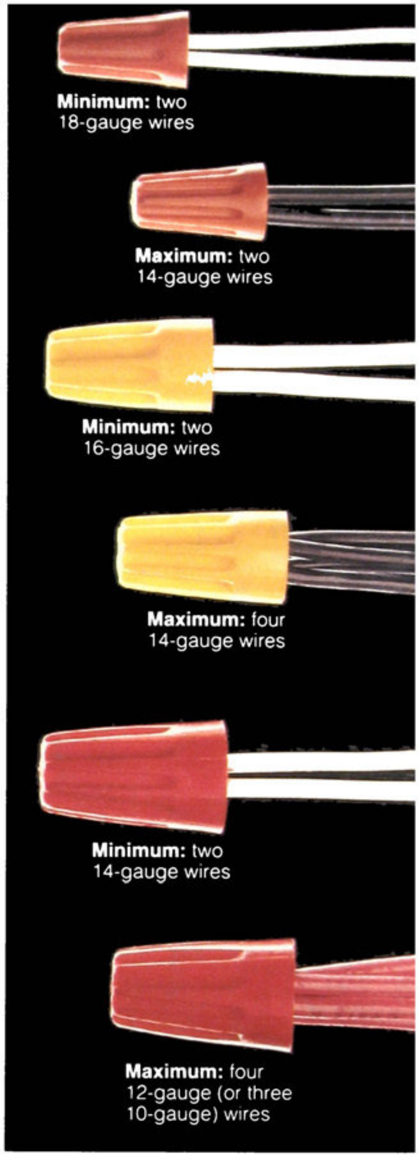


Wire gauge	Ampacity	Maximum wattage load
14-gauge	15 amps	1440 watts (120 volts)
12-gauge	20 amps	1920 watts (120 volts) 3840 watts (240 volts)
10-gauge	30 amps	2880 watts (120 volts) 5760 watts (240 volts)
8-gauge	40 amps	7680 watts (240 volts)
6-gauge	50 amps	9600 watts (240 volts)

Wire "ampacity" is a measuremen' safel, Ampacity varies accor When installing a new circuit in the circuit size For dedi ting of the appliance an wattage load of the circui



Use plastic cable staples to anchor cables to the sides of framing mem- Choose staples sized to match the cables they anchor Stack-It attaching up to four 2-wire cables to the side of a framing les B) for 12/2 12/3 and all 10-gauge cables staples 3 or 12/2 cables coaxial staples (D) for anchoring cables bell wire staples (E) for attaching telephone cables ould be anchored within 8" of each electrical box, and every hereafter



Use wire connectors
wires you are nnectin ire connectors are color-coded by size but the coding scheme varies according to manufacturer The connectors shown above come from one major manufacturer To ensur safe connections each connector i rated for both minimum and maximum wire capacity These connectors can be used to connect both conducting wires and grounding wires Green wire connectors are used only for grounding wires

Pulling cables through studs
straight holes the sam
straightening the cable befc
the studs

Installing NM Cable

NM cable is used for all indoor wiring projects except those requiring conduit (see pages 184 to 189) Cut and install the cable after all electrical boxes have been mounted Refer to your wiring plan (page 152) to make sure each length of cable is correct for the circuit size and configuration

Cable runs are difficult to measure exactly, so leave plenty of extra wire when cutting each length Cable splices inside walls are not allowed by code When inserting cables into a circuit breaker panel, make sure the power is shut off (page 192)

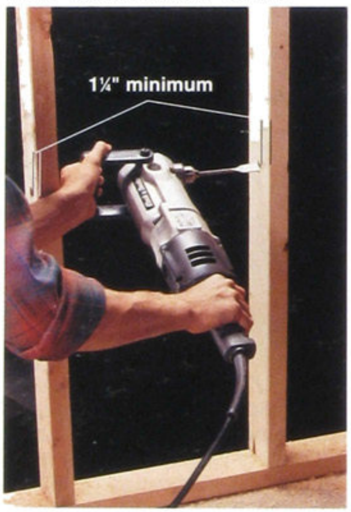
After all cables are installed, call your electrical inspector to arrange for the rough-in inspection Do not install wallboard or attach light fixtures and other devices until this inspection is done

Everything You Need

Tools: drill, bits, tape measure, cable ripper, combination tool, screwdrivers, needlenose pliers, hammer, fish tape.

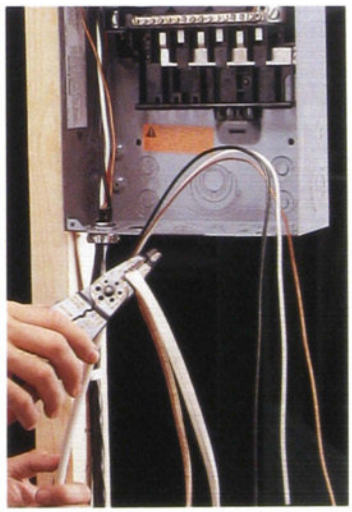
Materials: NM cable, cable clamps, cable staples, masking tape, grounding pigtails, wire connectors, cable-pulling lubricant.

How to Install NM Cable

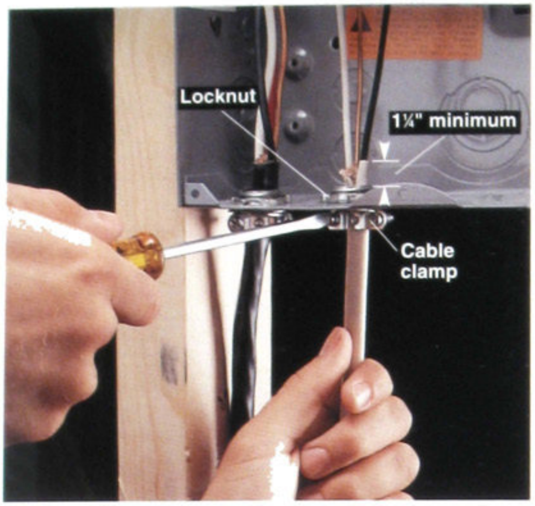


1 Drill holes in framing members for the cable runs This is done easily with a right-angle drill available at rental centers Holes should be set back at least 1 from the front face of the framing members

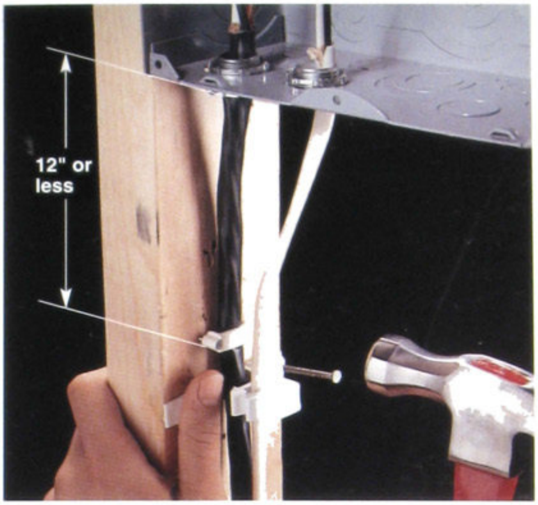
2 Where cables will turn corners (step 6, page opposite), drill intersecting holes in adjoining faces of studs Measure and cut all cables, allowing 2 feet extra at ends entering breaker panel and 1 foot for ends entering electrical box.



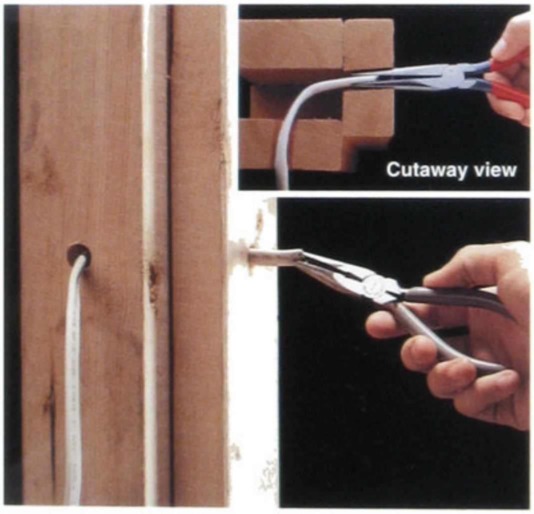
3 Shut off power to circuit breaker panel (page 192) a cable ripper to strip cable ing at least of sheathing to the circuit breaker panel Clip away the excess sheathing



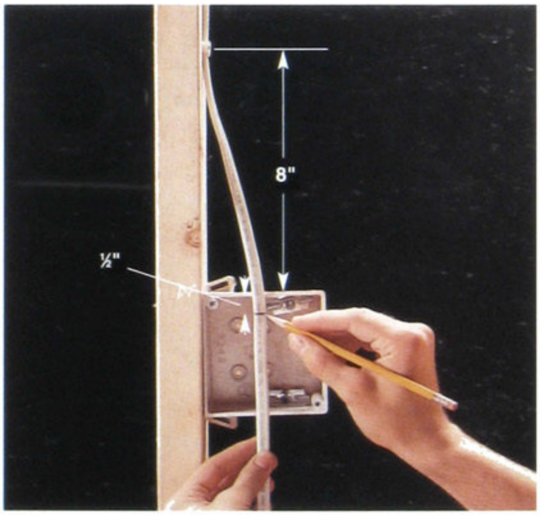
4



5 An cable
12 of th
ck-It
be

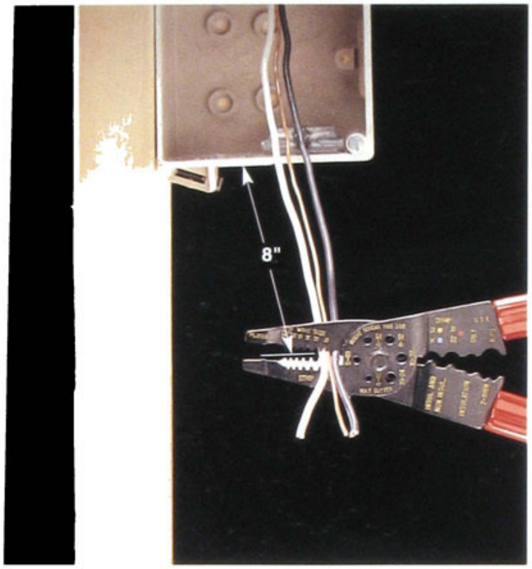


6 form a slight L-shaped bend nd
le and insert it into one hole Retri
he other hole. using needleno

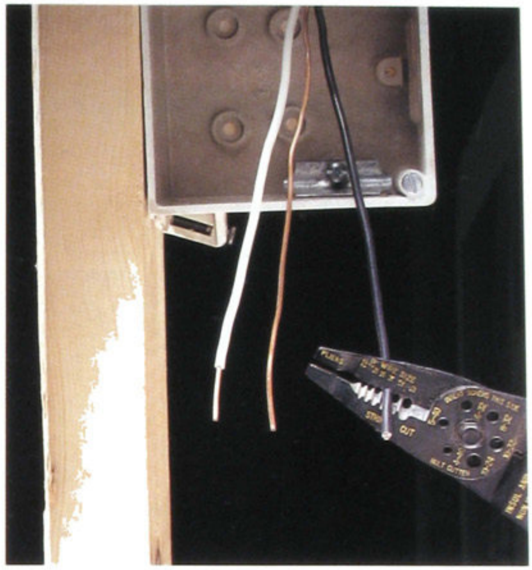


7 At the electrical box cable
member 8 from the able
against the front of the box
sheathing past the box edge
marked line to the end using a
away excess sheathing with
the cable through the knockout

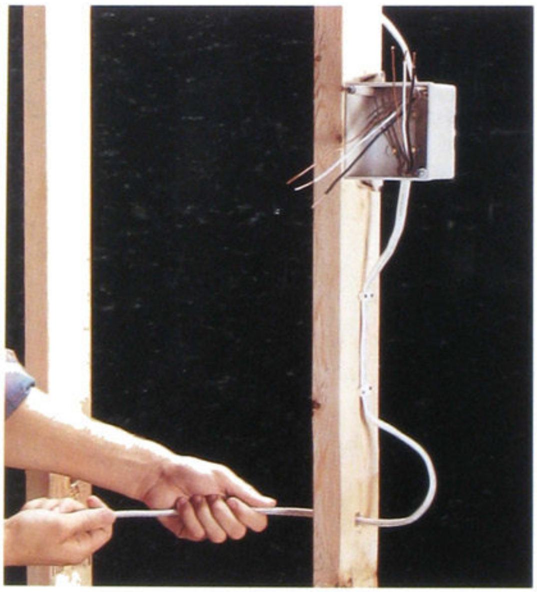
(continued next page)



8



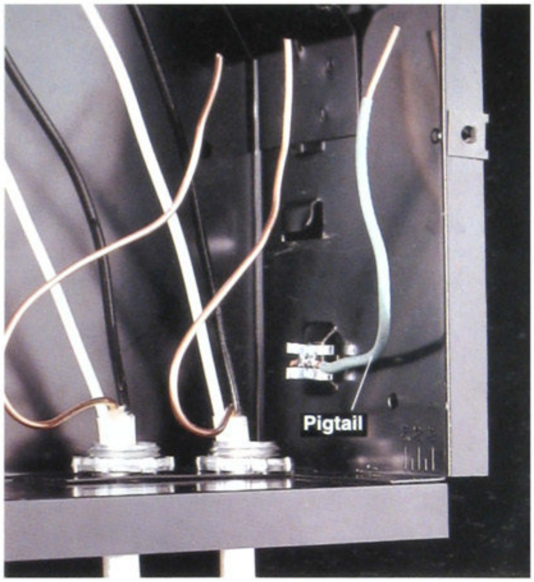
9 Str
box



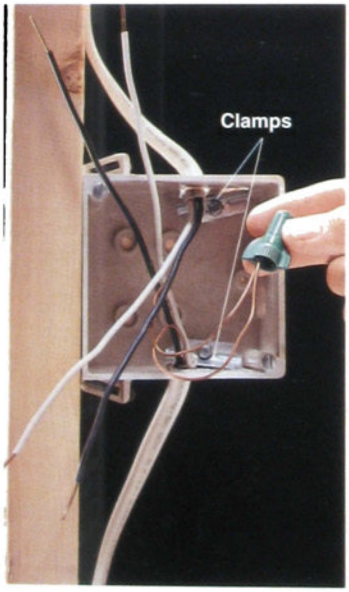
10 Continue the ircuit by nning cable between each pair of electrical boxes, leaving an extra foot of cable at each end

11 At metal boxes and knockouts and attach clamps. From inside fixture sheathing. Clip back length, then strip

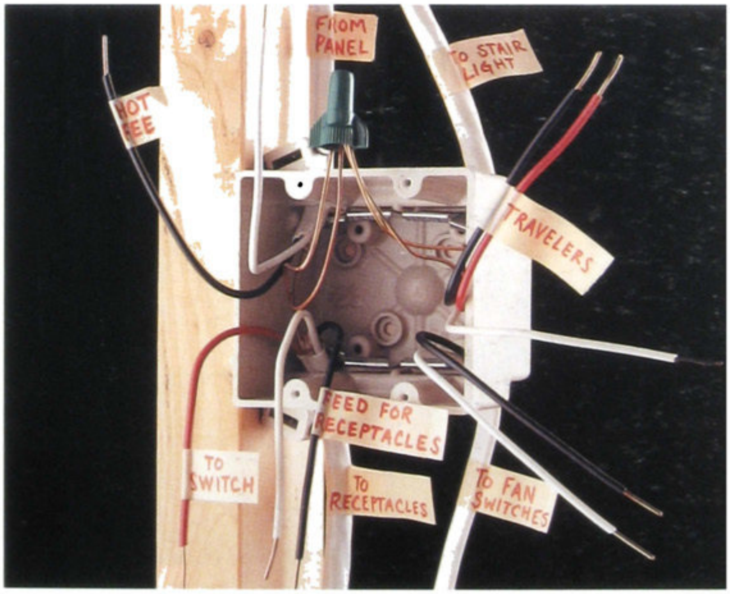
12



13 box

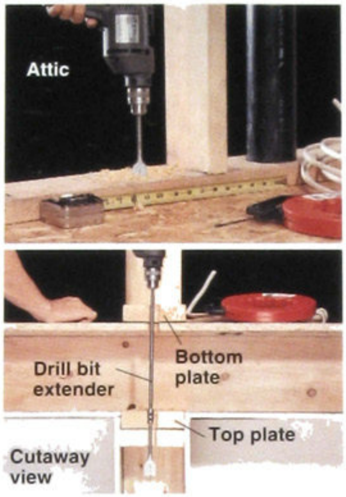


14 box

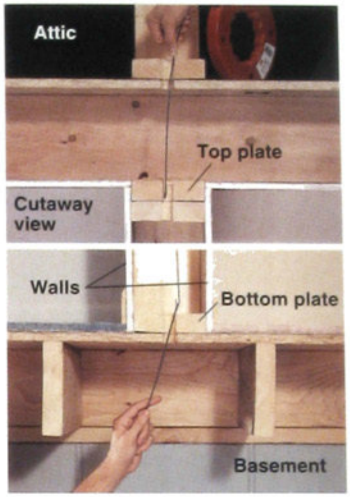


15 Label the cabl- ring each box to indicat in boxes wiring conti wires to make fin ier After rough-in work is viewed by

1

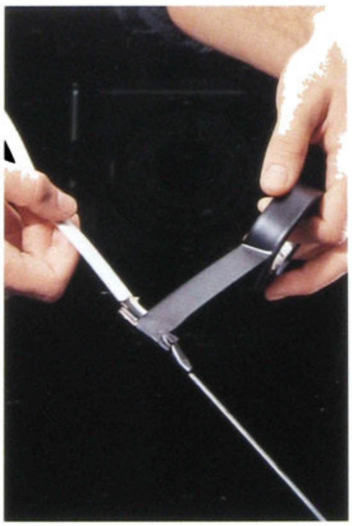


2 Fro
above

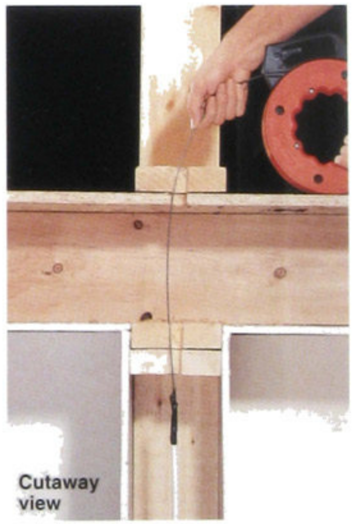


3 Extend a fish tape do
through the top plate
the tape reaches
of the stud cavity. From
ished space below
piece of stiff wire
one end to retrieve
through the drilled hol
bottom plate

4 Trim

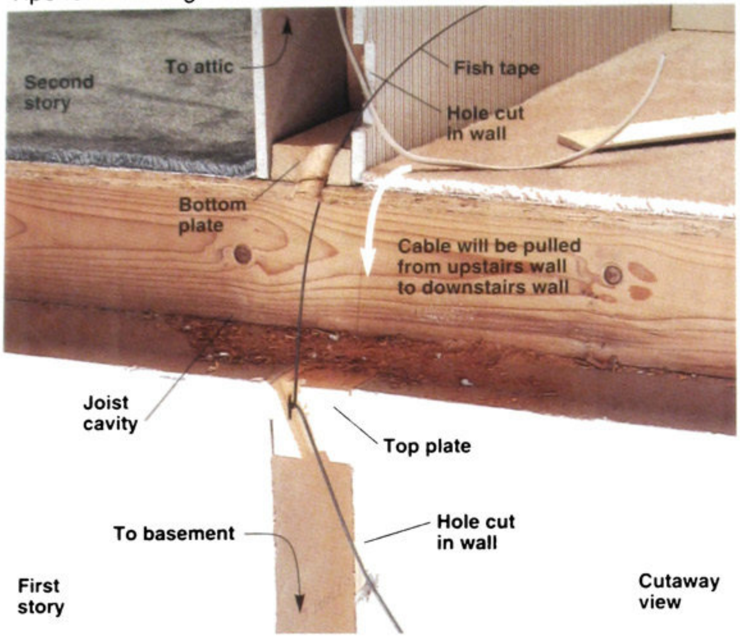


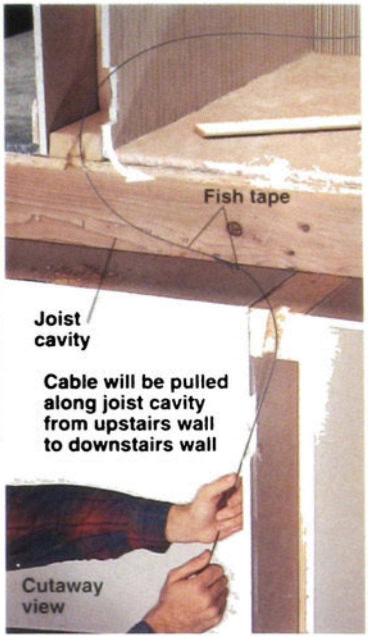
5 Bend the
cable the
bind them
pulling lubric
of the fish t



6 From the finished
pull steadily on the fish tape
draw the cabl up through the
cavity. This job will be eas
if you have a helper feed the cable
fro below as you pull

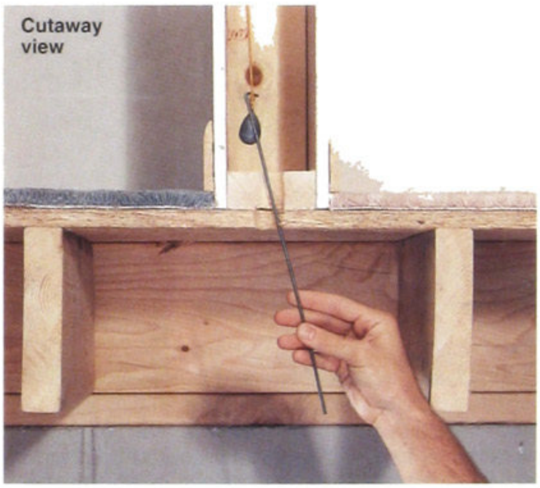
Tips for Running Cable Inside Finished Walls



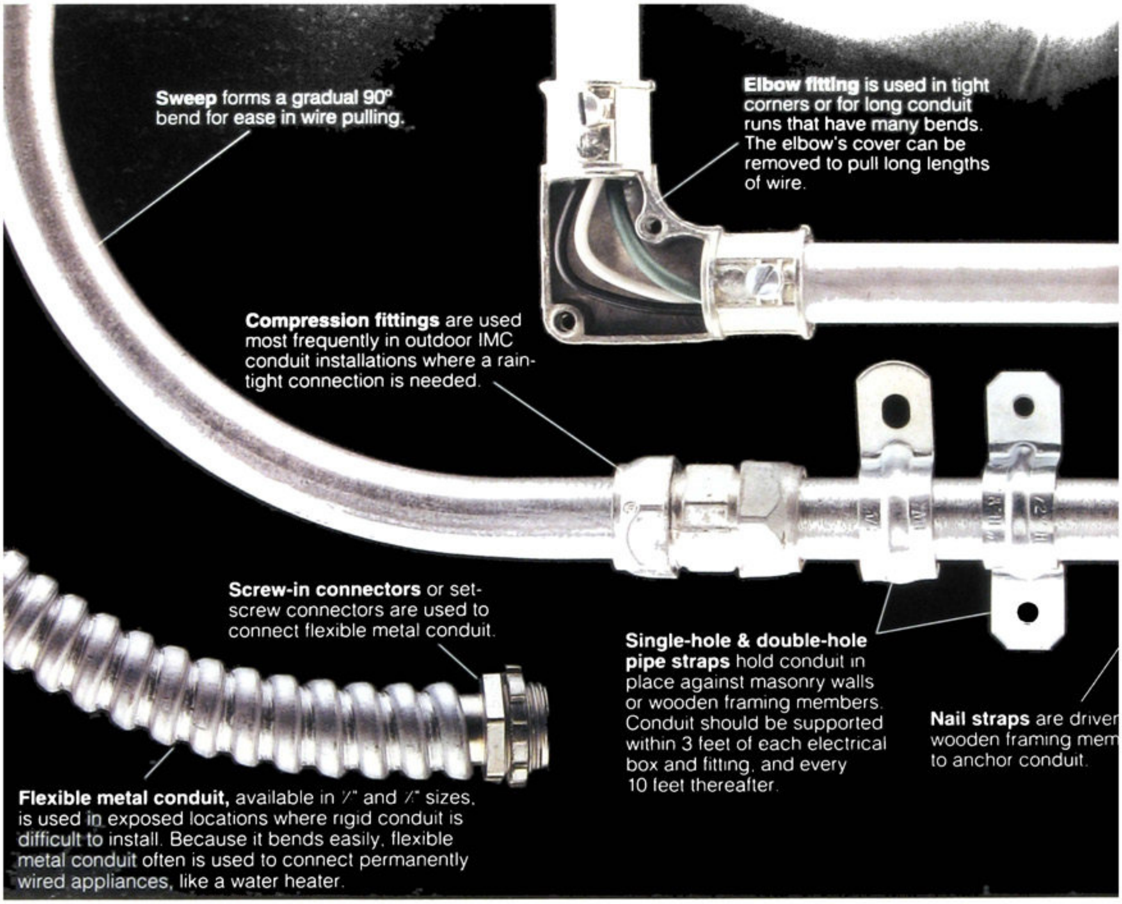


If there is no access space above and below a wall (page opposite), cut openings in the finished walls to a cable. This often occurs in two-story homes a cable is extended from an upstairs wall to a downstairs wall. Cut small openings in the wall near the top and bottom plates, then drill an angled 1" hol through each plate. Extend a fish tape into the joist cavity between the walls and use it to pull from one wall to the next. If the walls line up the other (left), you can retrieve the fish tape using a piece of stiff wire. If walls do not line up (right), use a second fish tape. After running the cabl repair the holes in the walls with patching plaster lliboard scraps and taping compound.

Apply cable-pulling lubricant to the taped end of the fish tape when a cable must be pulled through a sharp bend. Do not use oil or petroleum jelly as a lubricant, because they can damage the thermoplastic cable sheathing.



If you do not have a fish tape, use a length of sturdy mason's string and a lead fishing weight or heavy washer to fish down through a stud cavity. Drop the line into the stud cavity from above, then use a piece of stiff wire to hook the line from below.



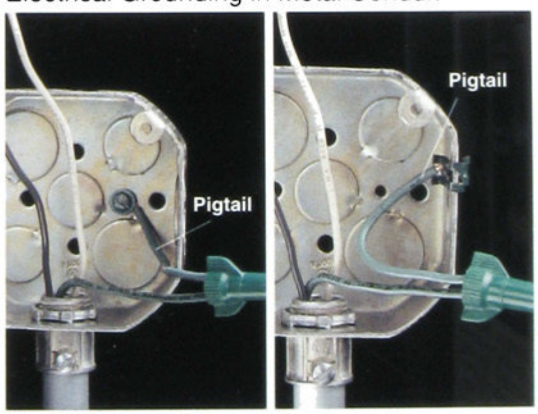
Conduit

ing that in exposed locations be protected by rigid tubing called **conduit** example conduit is used for wiring that runs asonry wall a basement laundry and exposed outdoor ing (pages 248 to 267) THHN THWN wire (page 176) normally is installed inside conduit although UF or NM cabl can also be installed in conduit

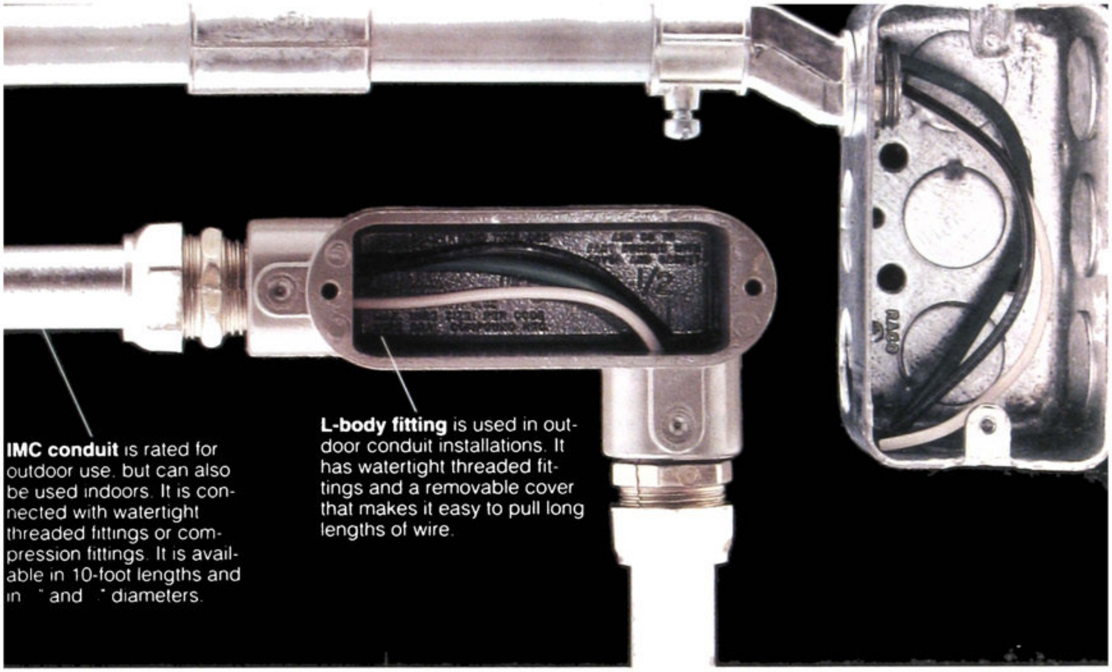
There are several types of conduit available so check with your electrical inspector to find out which type meets code requirements in your area Condui installed outdoors must be rated for exterior use Metal conduit should be used only with metal boxes never ith plastic boxes

At one time conduit could only be fitted by using elaborate bending techniques and special tools Now however a variety of shaped fittings are avail le to let a homeowner join conduit easily

Electrical Grounding in Metal Conduit



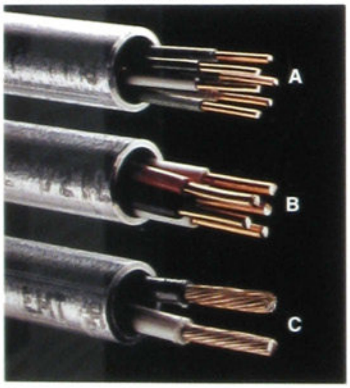
Install a green insulated grounding wire for an circuit that runs through metal conduit Although code allows the metal conduit to serve as the groun ing conductor most electricians install a green lated wire as a more dependable means of gro the system The grounding wires must be connecte to metal boxes with a pi tail nd grounding screw (left) or groun clip (right)



IMC conduit is rated for outdoor use, but can also be used indoors. It is connected with watertight threaded fittings or compression fittings. It is available in 10-foot lengths and in " and " diameters.

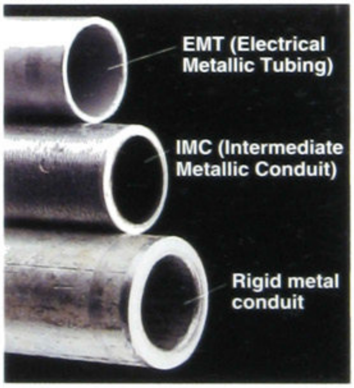
L-body fitting is used in outdoor conduit installations. It has watertight threaded fittings and a removable cover that makes it easy to pull long lengths of wire.

Wire Capacities of Conduit



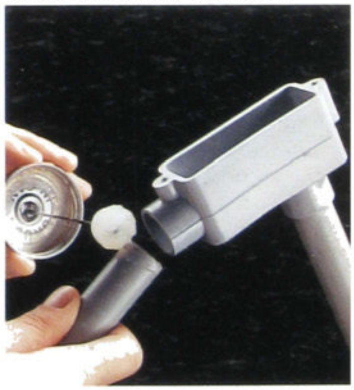
Conduit ½" in diameter can hold -gauge 12-gauge THHN THWN B

Three Metal Conduit Variations



EMT lightweight and easy to install ut should not be used her can be damaged. IMC icker galvanized walls an ood choice for exposed out- use. Rigid metal conduit pr ides the greatest protection for but is more expensive an uires threaded fittings.

Plastic Conduit Variation

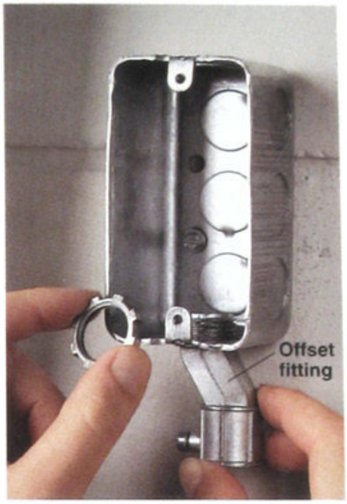


Plastic PVC conduit is allowed by many local codes. It is assembled with solvent lue and PVC fi that resembl metal conduit. PV ttached metal bo C

How to Install Metal Conduit & THHN/THWN Wire on Masonry Walls

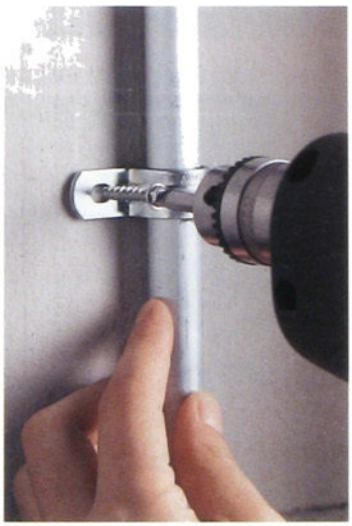
1 Measure from floor to position electrical boxes on wall, and mark location for mounting screws. Boxes for receptacles in an unfinished basement or other damp area are mounted at least 2 feet from the floor. Laundry receptacles usually are mounted at 48"

2 Drill pilot holes with a masonry bit, then mount the boxes against masonry walls with masonry anchors. Or use masonry anchors and pan-head screws.



3 Open one knockout for each length of conduit that will be attached to the box. Attach an offset fitting to each knockout, using a locknut.

4 Measure the first length of conduit and cut it with a hacksaw Remove any rough inside edges with a pipe reamer or a round file Attach the conduit to the offset fitting on the box, and tighten the setscrew

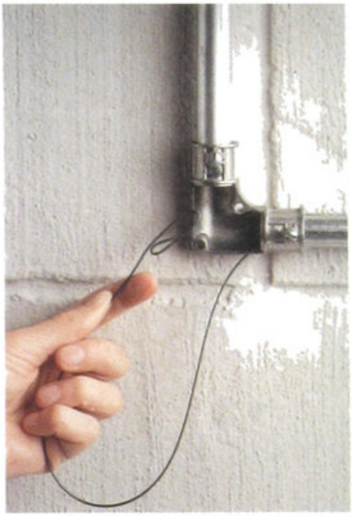


5 Anchor the conduit against the wall with pipe straps and masonry anchors. Conduit should be anchored within 3 feet of each box and fitting, and every 10 feet thereafter.

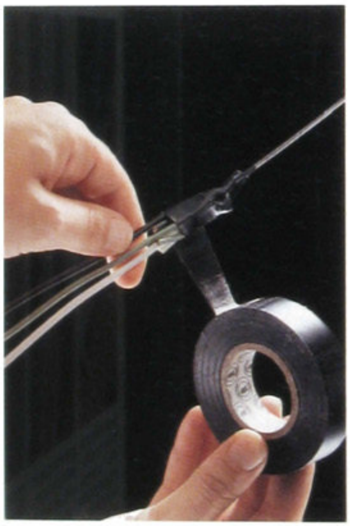
6 Make conduit bends by attaching a sweep fitting, using a setscrew fitting or compression fitting. Continue conduit run by attaching additional lengths, using setscrew or compression fittings.

7 Use an elbow fitting in conduit ns that have many bends, or t require very long wires r on the elbow fitting can ved to make it easier to fish tape and pull wires

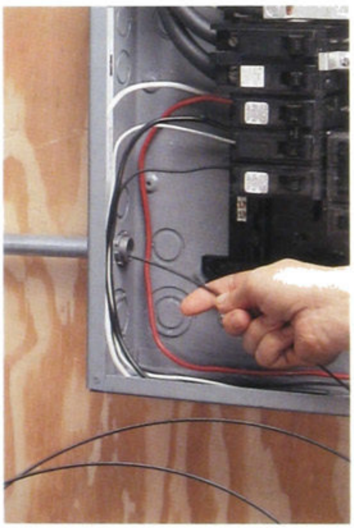
8 At the service breaker panel **turn the power OFF, then remove the cover and test for power** (page 192) Open a knockout in the panel then attach a setscrew fitting and install the last length of conduit



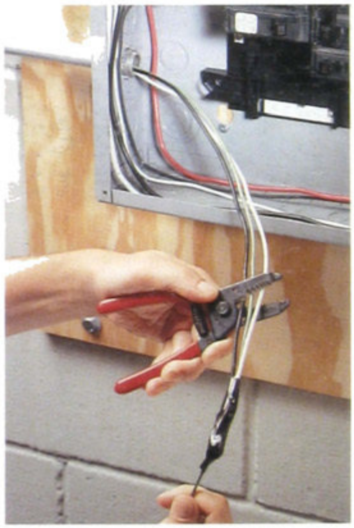
9 Unwind the fish tape and extend it through the conduit from the circuit breaker panel outward Remove the cover on an elbow fitting when extending the fish tape around tight corners



10 Trim back 2" of outer insulation from the end of the NM cable then insert the wires through the loop at the tip of the fish tape.

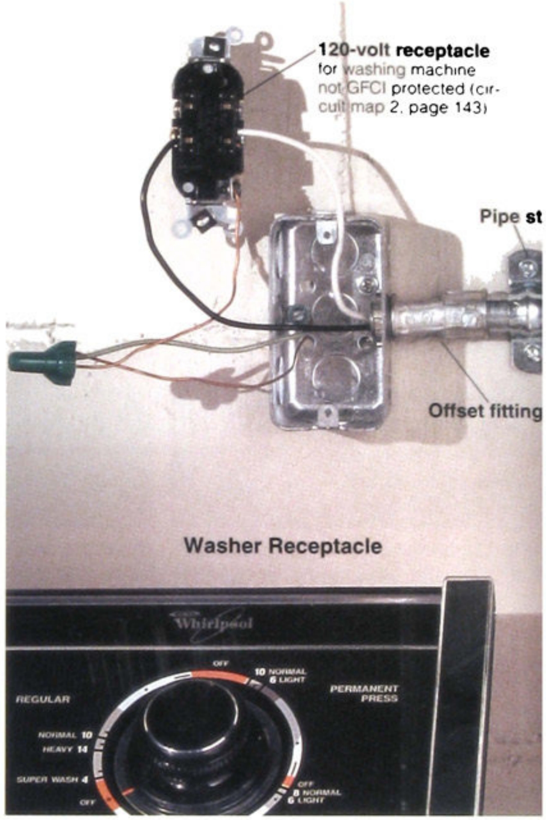


11 Retrieve the wires through the conduit by pulling on the fish tape with steady pressure **NOTE: Use extreme care** when using a metal fish tape inside a circuit breaker panel, even when the power is turned OFF.



12 Clip off the taped ends of the wires Leave at least 2 feet of wire at the service panel and 8" at each electrical box

Wiring a Laundry with Conduit



A typical home laundry has three electrical circuits. A 20-amp, 120-volt small-appliance circuit wired with 12-gauge THHN/THWN wire supplies power for the washing machine receptacle and all other general-use receptacles in the laundry area. A basic lighting circuit, often extended from another part of the house, powers the laundry light fixture. Finally, a 240-volt, 30-amp circuit wired with 10-gauge THHN/THWN wire provides power for the dryer.

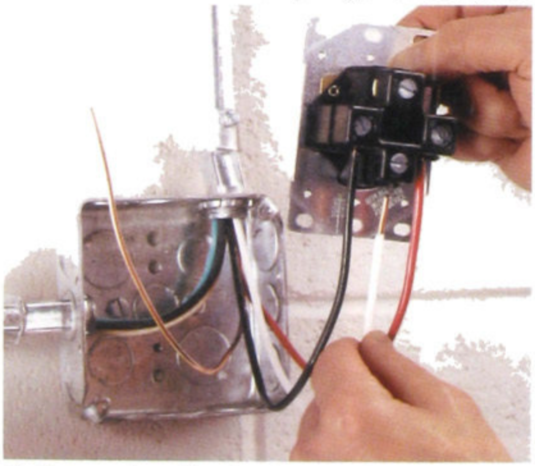
Follow the directions on pages 186 to 187 when installing the conduit. For convenience, you can use the same conduit to hold the wires for both the 120-volt circuit and the 240-volt dryer circuit.

Everything You Need

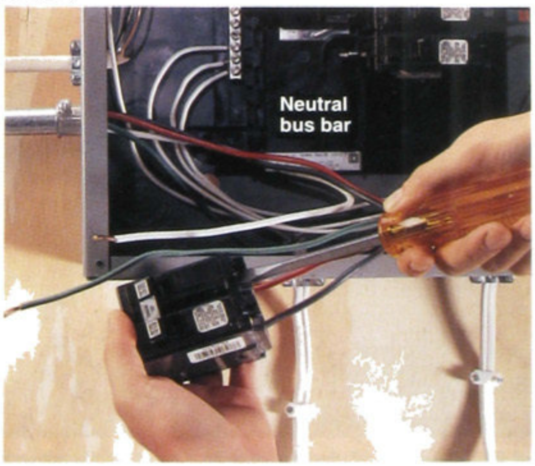
Tools: hacksaw, drill and ⅛" masonry bit, screwdriver, fish tape, combination tool.

Materials: conduit, setscrew fittings, masonry anchors, THHN/THWN wire, electrical tape, wire connectors, receptacles (GFCI, 120-volt, 120/240-volt), circuit breakers (30-amp double-pole, 20-amp single-pole).

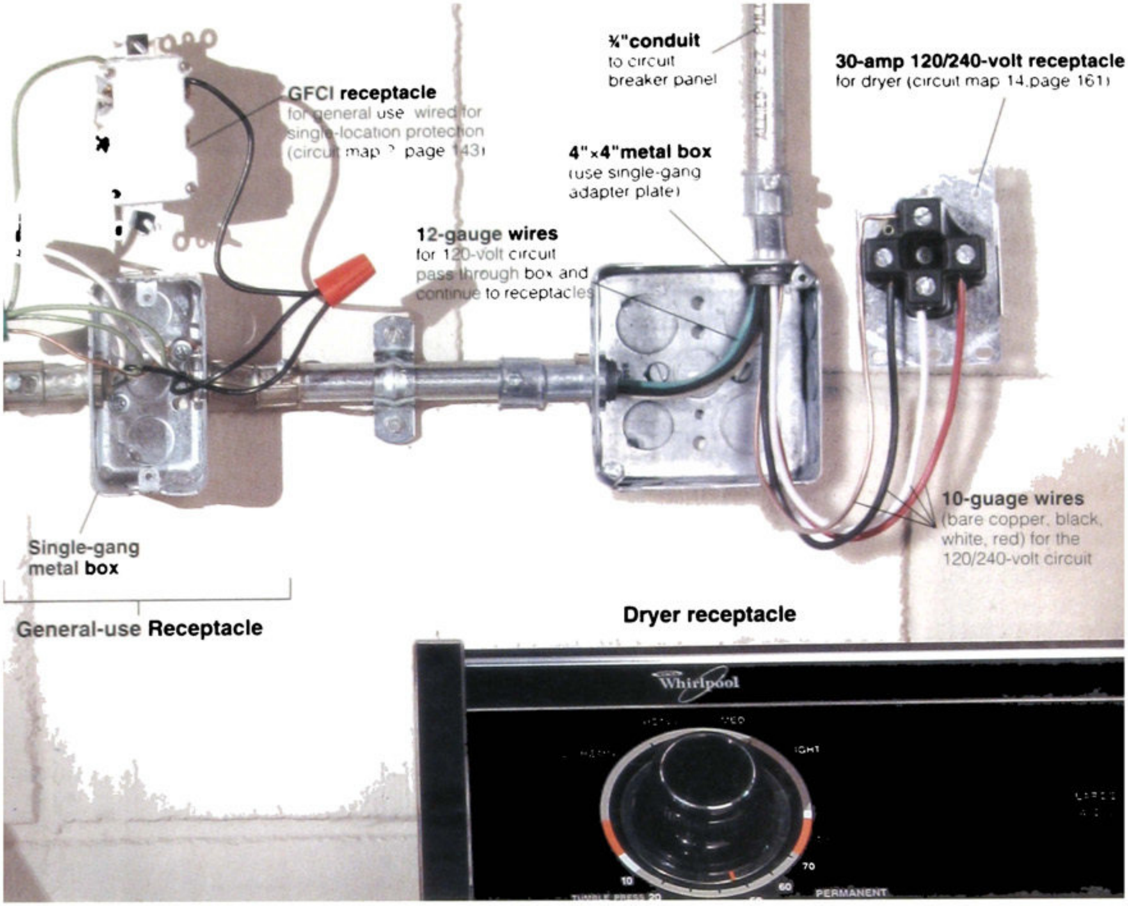
How to Connect a 30-amp Dryer Circuit (conduit installation)



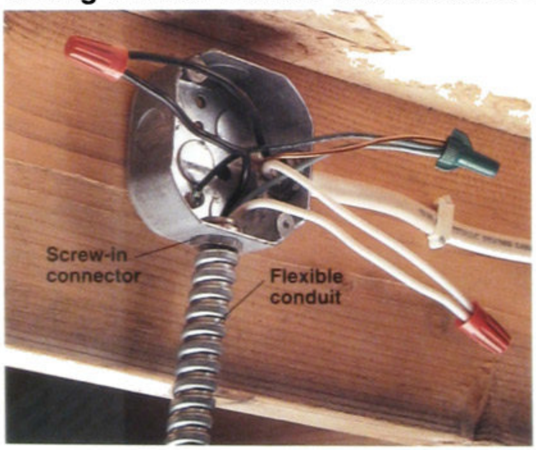
1 Connect the white circuit wire to the neutral setscrew terminal on the receptacle. Connect the black and red wires to the remaining setscrew terminals, and connect the grounding wire to the receptcle grounding screw. Attach the coverplate.

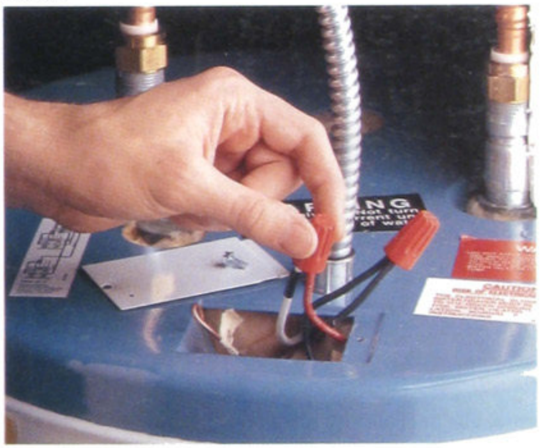


2 With the main breaker shut OFF, connect the red and black circuit wires to the setscrew terminals on the 30-amp double-pole breaker. Connect the white wire to the neutral bus bar. Attach the grounding wire to the grounding bus bar. Attach the breaker panel cover, and turn the breakers ON.



Wiring a Water Heater with Flexible Conduit



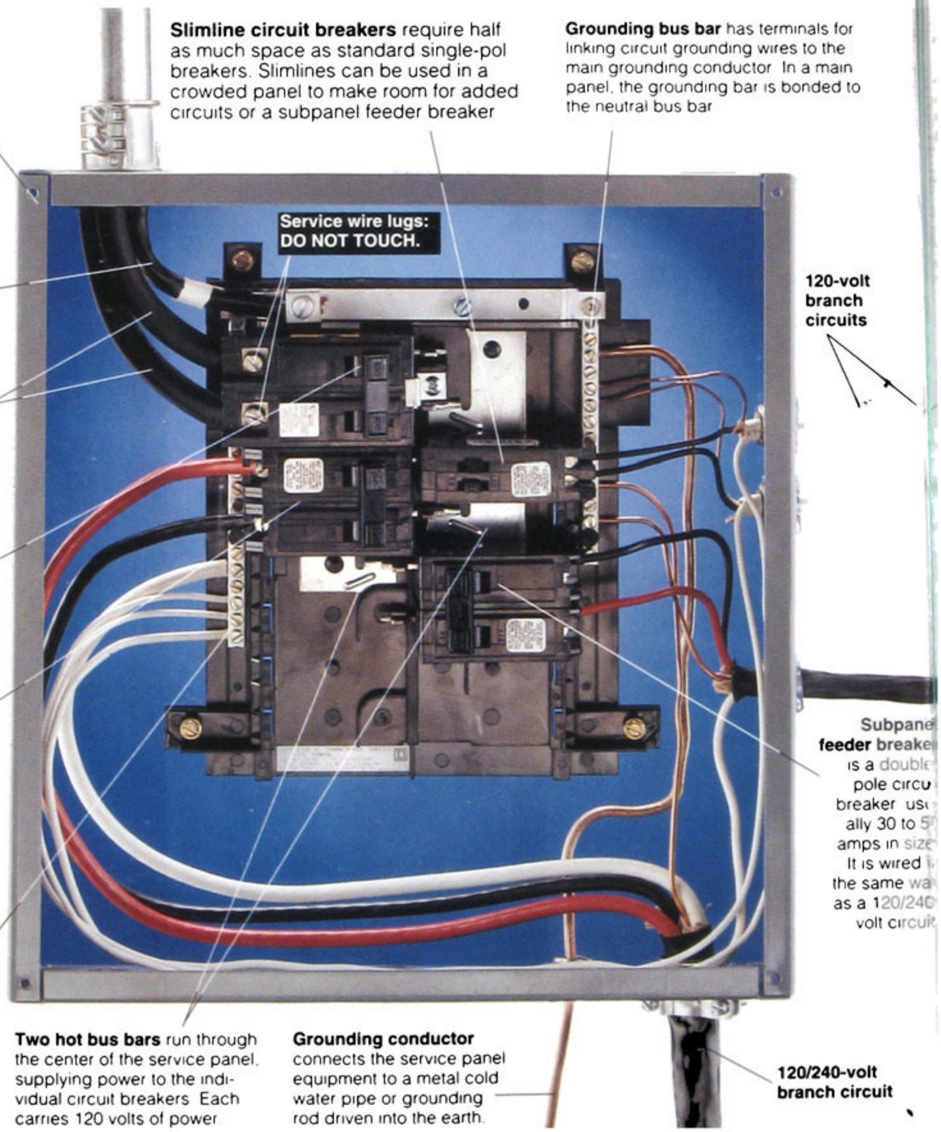


Install a 30-amp, 240-volt circuit for most electric water heaters. A water heater circuit is wired in much the same way as an air conditioner circuit (circuit map 12, page 160). Install a junction box near the water heater then use 10/2 NM cable to bring power from the service panel to the junction box (left). Use flexible metal conduit and 10-gauge THHN/THWN wires to bring power from the junction box to the water heater wire connection box (right). Connect black and red water heater leads to the white and black circuit wires. Connect the grounding wire to the water heater grounding screw.

Circuit Breaker Panels

The circuit breaker panel is the electrical distribution center for your home. It divides the current into branch circuits that are carried throughout the house. Each branch circuit is controlled by a circuit breaker that protects the wires from dangerous current overloads. When installing new circuits, the last step is to connect the wires to new circuit breakers at the panel. Working inside a circuit breaker panel is not dangerous if you follow basic safety procedures. Always shut off the main circuit breaker and test for power before touching any parts inside the panel, and **never touch the service wire lugs.** If unsure of your own skills, hire an electrician to make the final circuit connections. (If you have an older electrical service with fuses instead of circuit breakers, always have an electrician make these final hookups.)

If the main circuit breaker panel does not have enough open slots to hold new circuit breakers, install a subpanel (pages 194 to 197). This job is well within the skill level of an experienced do-it-yourselfer, although you can also hire an electrician to install the subpanel.

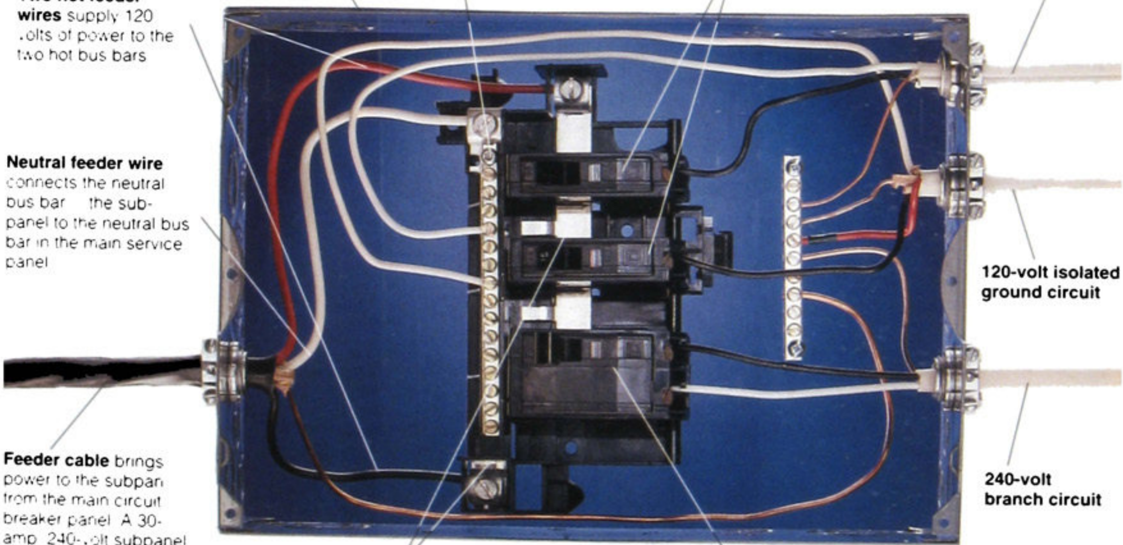


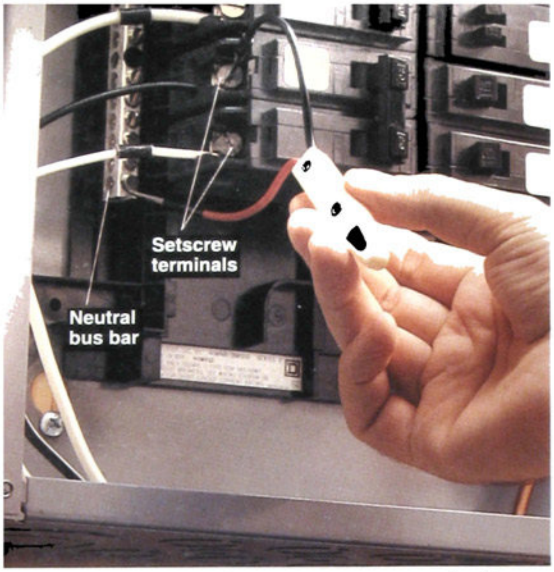
Before installing any new wiring, evaluate your electrical service to make sure it provides enough current to support both the existing wiring and any new circuits (pages 148 to 151). If your service does not provide enough power, have an electrician upgrade it to a higher amp rating. During the upgrade, the electrician will install a new circuit breaker panel with enough extra breaker slots for the new circuits you want to install.

Safety Warning:

Never touch any parts inside a circuit breaker panel until you have checked for power (page 192). Circuit breaker panels differ in appearance, depending on the manufacturer. Never begin work in a circuit breaker panel until you understand its layout and can identify the parts.

Circuit breaker subpanel be installed when the main circuit nel does not have enough space circuit breakers for new circuits you nstall. (Some circuit breakers have been removed for clarity.)





Test for current before touching any parts inside a circuit breaker panel With main breaker turned OFF but all other breakers turned ON, touch one probe of a neon tester to the neutral bus bar and touch other probe to each setscrew on one of the double-pole breakers (not the main breaker) If tester does not light for either setscrew it is safe to work in the panel.

Connecting Circuit Breakers

The last step in a wiring project is connecting circuits at the breaker panel. After this is done, the work is ready for the final inspection.

Circuits are connected at the main breaker panel, if it has enough open slots, or at a circuit breaker subpanel (pages 194 to 197). When working at a subpanel, make sure the feeder breaker at the main panel has been turned OFF, and test for power (photo, left) before touching any parts in the subpanel.

Make sure the circuit breaker amperage does not exceed the "ampacity" of the circuit wires you are connecting to it (page 177). Also be aware that circuit breaker styles and installation techniques vary according to manufacturer. Use breakers designed for your type of panel.

Everything You Need

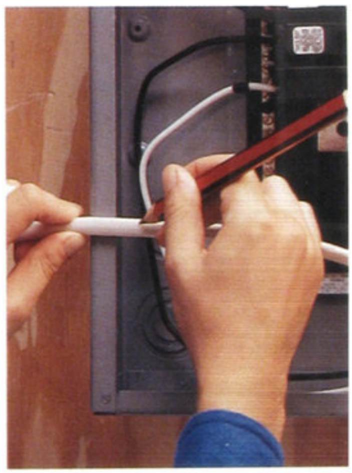
Tools: screwdriver, hammer, pencil, combination tool, cable ripper, neon circuit tester, pliers.

Materials: cable clamps, single- and double-pole circuit breakers.

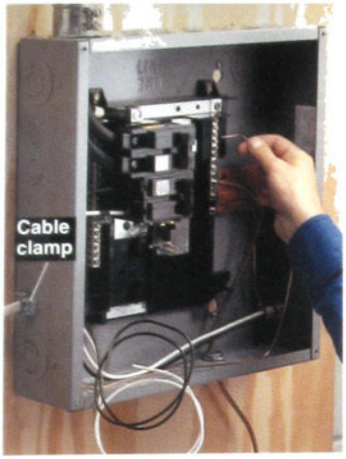
How to Connect Circuit Breakers

1 Shut off the main circuit breaker in the main circuit breaker panel (if you are working in a subpanel, shut off the feeder breaker in the main panel). Remove the panel coverplate, taking care not to touch the parts inside the panel. Test for power (photo, top).

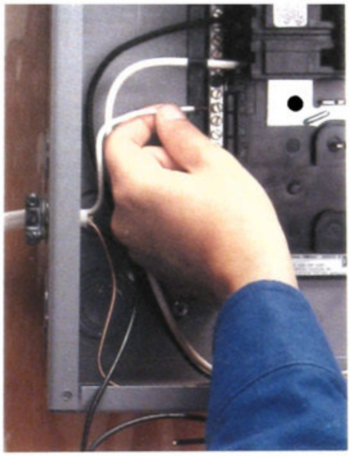
2 Open a knockout in the side of the circuit breaker panel, using a screwdriver and hammer Attach a cable clamp to the knockout.



3 Hold cable across the front of the panel near the knockout, and mark sheathing about inside the edge of the panel. Strip the cable from marked line to end, using a cable ripper (There should be 18" to 24" of excess cable) Insert the cable through the clamp and into the service panel, then tighten the clamp

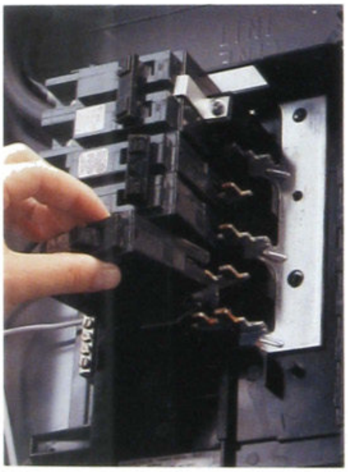


4 Bend the bare copper grounding wire around the inside edge of the panel to an open setscrew terminal on the grounding bus bar. Insert the wire into the opening on the bus bar, and tighten the set- Fold excess wire around inside edge of the panel

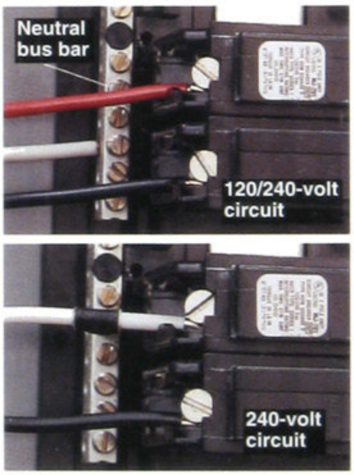


5 For 120-volt circuits bend the white circuit wire around the outside of the panel to an open setscrew terminal on the neutral bus bar. Clip away excess wire then strip of insulation from the wire using a combination tool. Insert the wire into the terminal opening, and tighten the setscrew

6 Strip of insulation from the end of the black circuit. Insert the wire into the setscrew terminal on a new single-pole circuit breaker and tighten the setscrew

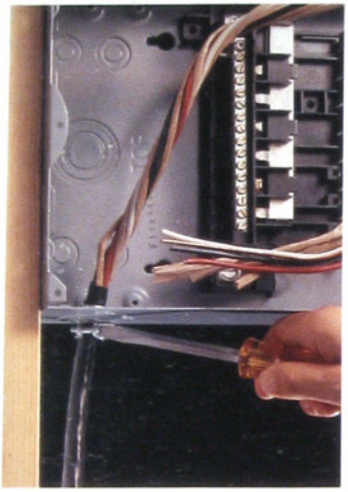


7 Slide one end of the circuit breaker onto the guide hook then press it firmly against the bus bar until it snaps into place. (Breaker installation may vary depending on the manufacturer.) Fold excess black wire around the inside edge of the panel.

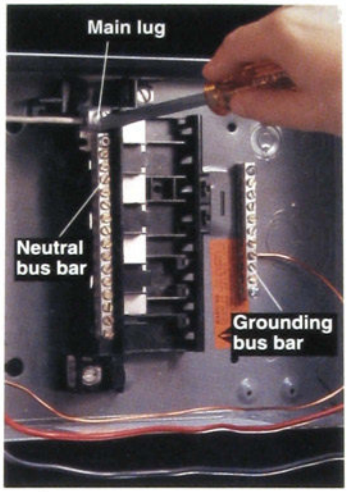


8 **120/240-volt circuits (top):** Connect red and black wires to double-pole breaker. Connect white wire to neutral bus bar and grounding wire to grounding bus bar. **240-volt circuits (bottom):** Attach white and black wires to double-pole breaker, tagging white wire with black tape. There is no neutral bus bar connection on this circuit.

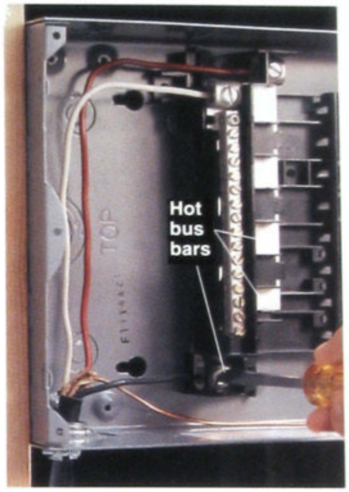
9 Remove the appropriate breaker knockout on the panel cover-plate to make room for the new circuit breaker. A single-pole breaker requires one knockout, while a double-pole breaker requires two knockouts. Reattach the cover-plate and label the new circuit on the panel index.



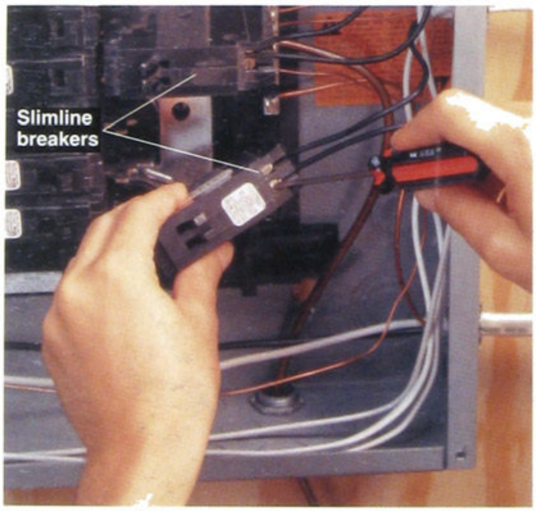
4 Strip away out r sheathing from the feeder cable using a cable ripper Leave at least of sheathing extending into the subpanel Tighten the cable clamp screws so cable is held securely but not so tightly that the wire sheathing is crushed



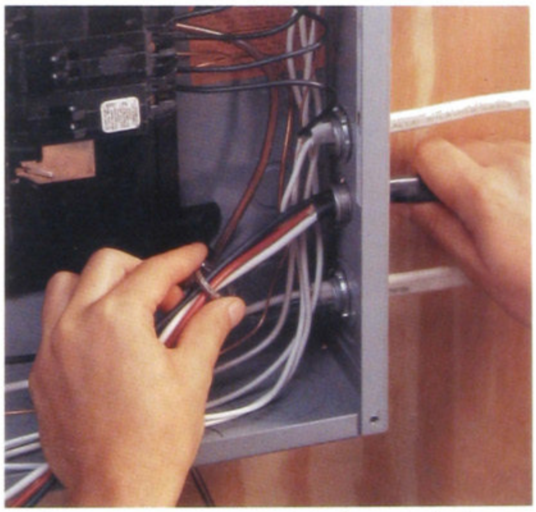
5 Strip of insulation from the white neutral feeder wire, and attach it to the main lug on the subpanel neutral bus bar Connect the grounding wire to a setscrew terminal on the grounding bus bar Fold excess wire around the inside edge of the subpanel



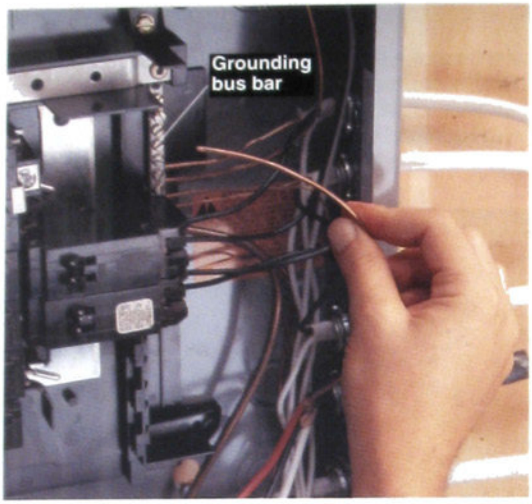
6 Strip away of insulation from the red and black feeder wires Attach one wire to the main lug on each of the hot bus bars Fol excess wire around the inside edge of the subpanel



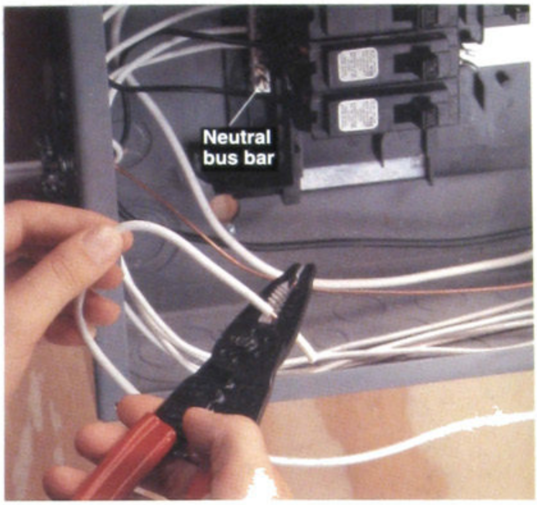
7 At the main circuit breaker panel, shut off the main circuit breaker then remove the coverplate and test for power (page 192) If necessary make room for the double-pole feeder breaker by removing single-pole breakers and reconnecting the wires to slimline circuit breakers Open a knockout for the feeder cable, using a hammer and screwdriver.



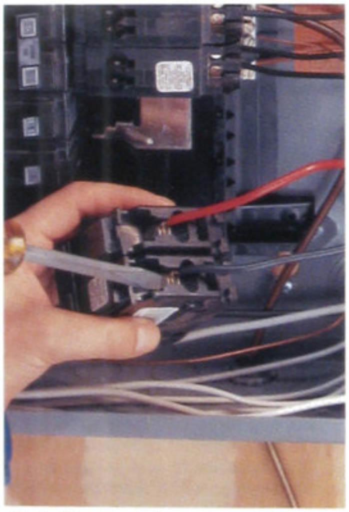
8 Strip away the outer sheathing from the feeder cable so that at least of sheathing will reach into the main service panel Attach a cable clamp to the cable, then insert the cable into the knockout, and anchor it by threading a locknut onto the clamp Tighten the locknut by driving a screwdriver against the lugs Tighten the clamp screws so cable is held securely but not so tightly that the cable sheathing is crushed.



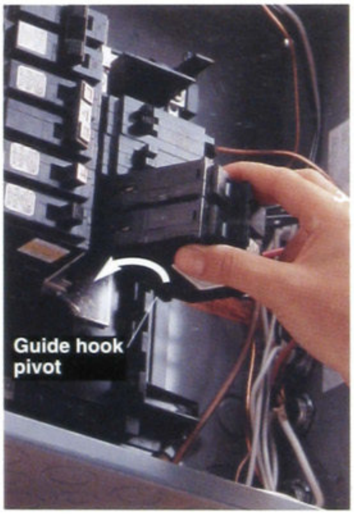
9 Bend the bare copper wire from the feeder cable around the inside edge of the main circuit breaker panel and connect it to one of the setscrew terminals the grounding bus bar



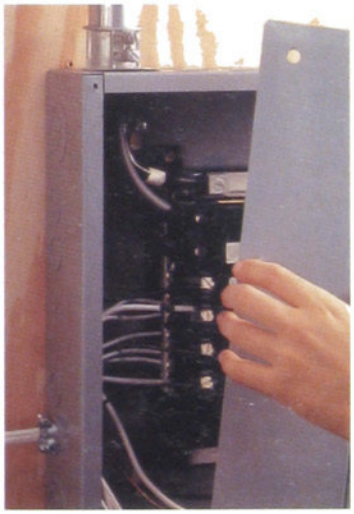
10 Strip away of insulation from the white feeder wire Attach the wire to one of the setscrew terminals on the neutral bus bar Fold excess wir around the inside edge of the service panel



11 Strip of insulation from the red and black feeder wires Attach one wire to each of the setscrew terminals on the double-pole feeder breaker.



12 Hook the end of the feeder circuit breaker over the guide hooks on the panel, then push the other end forward until the breaker snaps onto the hot bus bars (follow manufacturer's directions) Fold excess wire around the inside edge of the circuit breaker panel.



13 If necessary open two knockouts where the double-pole feeder breaker will fit, then reattach the coverplate Label the feeder breaker on the circuit index Turn main breaker ON, but leave feeder breaker OFF until all sub-panel circuits have been connected and inspected

Wiring a Room Addition

This chapter shows how to wire an unfinished attic space that is being converted to a combination bedroom, bathroom, and study. In addition to basic receptacles and light fixtures, you will learn how to install a ceiling fan, permanently wired smoke alarm, bathroom vent fan, computer receptacle, air-conditioning receptacle, electric heaters, telephone outlets, and cable television jacks. Use this chapter and the circuit maps on pages 155 to 167 as a guide for plan-

Choose the Fixtures You Need

A. Computer receptacle (circuit #2) is connected to a 120-volt isolated-ground circuit. It protects sensitive computer equipment from power surges. See page 220.

B. Air-conditioner receptacle (circuit #3) supplies power for a 240-volt window air conditioner See page 220. Some air conditioners require 120-volt receptacles.

D. Thermostat (circuit #5) controls 240-volt baseboard heaters in the bedroom and study areas. See page 224.

E. Fully wired bathroom (circuit #1) includes vent fan with timer switch, GFCI receptacle, vanity light, and single-pole switch. See pages 218 to 219. The bathroom also has a 240-volt blower-heater controlled by a built-in thermostat (circuit #5, page 224).

C. Circuit breaker subpanel controls all attic circuits and fixtures, and is connected to the main service panel. For a more finished appearance, cover the subpanel with a removable bulletin board or picture. See pages 194 to 197.

F. Closet light fixture (circuit #1) makes a closet more convenient. See page 219.

G. Smoke alarm (circuit #4) is an essential safety feature of any sleeping area. See page 223.

ning and installing your own circuits. Our room addition features a circuit breaker subpanel that has been installed in the attic to provide power for five new electrical circuits. Turn the page to see how these circuits look inside the walls.

Three Steps for Wiring a Room Addition:

1. Plan the Circuits (pages 204 to 205).
2. Install Boxes & Cables (pages 206 to 217).
3. Make Final Connections (pages 218 to 225).

H. Double-gang switch box (circuit #4) contains a three-way switch that controls stairway light fixture and single-pole switch that controls a switched receptacle in the bedroom area. See page 221.

I. Fan switches (circuit #4) include a speed control for ceiling fan motor and dimmer control for the fan light fixture. See page 221

J. Ceiling fan (circuit #4) helps reduce summer cooling costs and winter heating bills. See page 222.

K. Stairway light (circuit #4) illuminates the stairway It is controlled by three-way switches at the top and bottom of the stairway See page 223.

L. Cable television jack completes the bedroom entertainment corner. See page 216.

M. Telephone outlet is a convenient addition to the bedroom area. See page 217

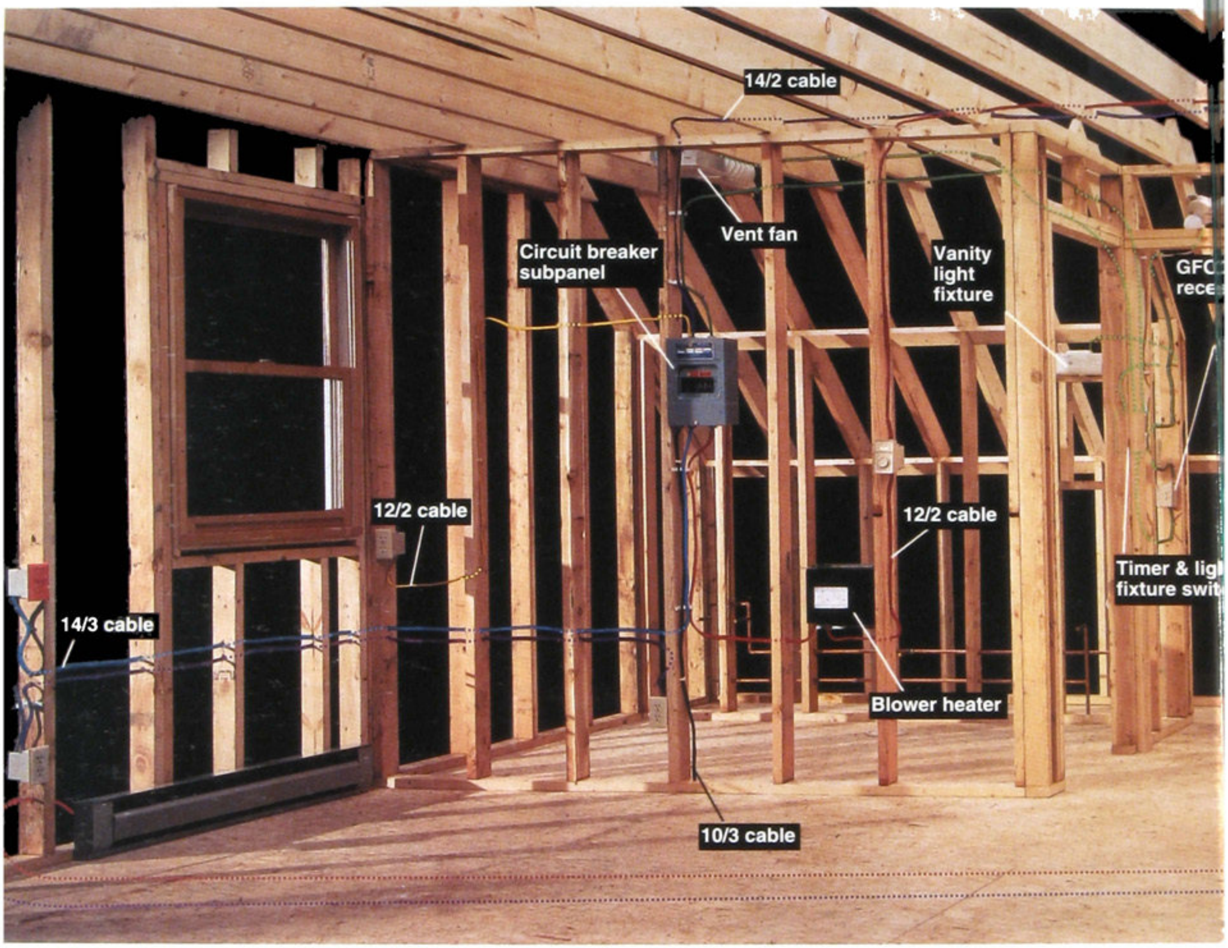
N. Switched receptacle (circuit #4) lets you turn a table lamp on from a switch at the stairway. See page 222.

O. Receptacles (circuit #4) spaced at regular intervals allow you to plug in lamps and small appliances wherever needed. See page 222.

P. Baseboard heaters (circuit #5) connected to a 240-volt circuit provide safe, effective heating. See page 225.

Wiring a Room Addition: Construction View

The room addition wiring project on the following pages includes the installation of five new electrical circuits two 120-volt basic lighting/receptacle circuits, a dedicated 120-volt circuit with a special "isolated" grounding connection for a home computer, and two 240-volt circuits for air conditioning and heaters The photo below shows how these circuits look behind the fi ished walls of a room addition



Learn How to Install These Circuits & Cables

#1: Bathroom circuit. This 15-amp 120- ircuit suppli power to bathroom fixtures and to fixtures in the adjacent closet All general-use receptacles in a bathroom must be protected by a GFCI

■ **#2: Computer circuit.** A 15-amp volt dedicated circui with an extra isolated grounding wire that protects computer equipment

Circuit breaker subpanel receives po through a 10-gauge three-wire feeder cable connected to a 30-amp 240-volt circuit breaker at the mai circuit breaker panel Larger room additions may require a 40-amp or a 50-amp "feeder circuit breaker

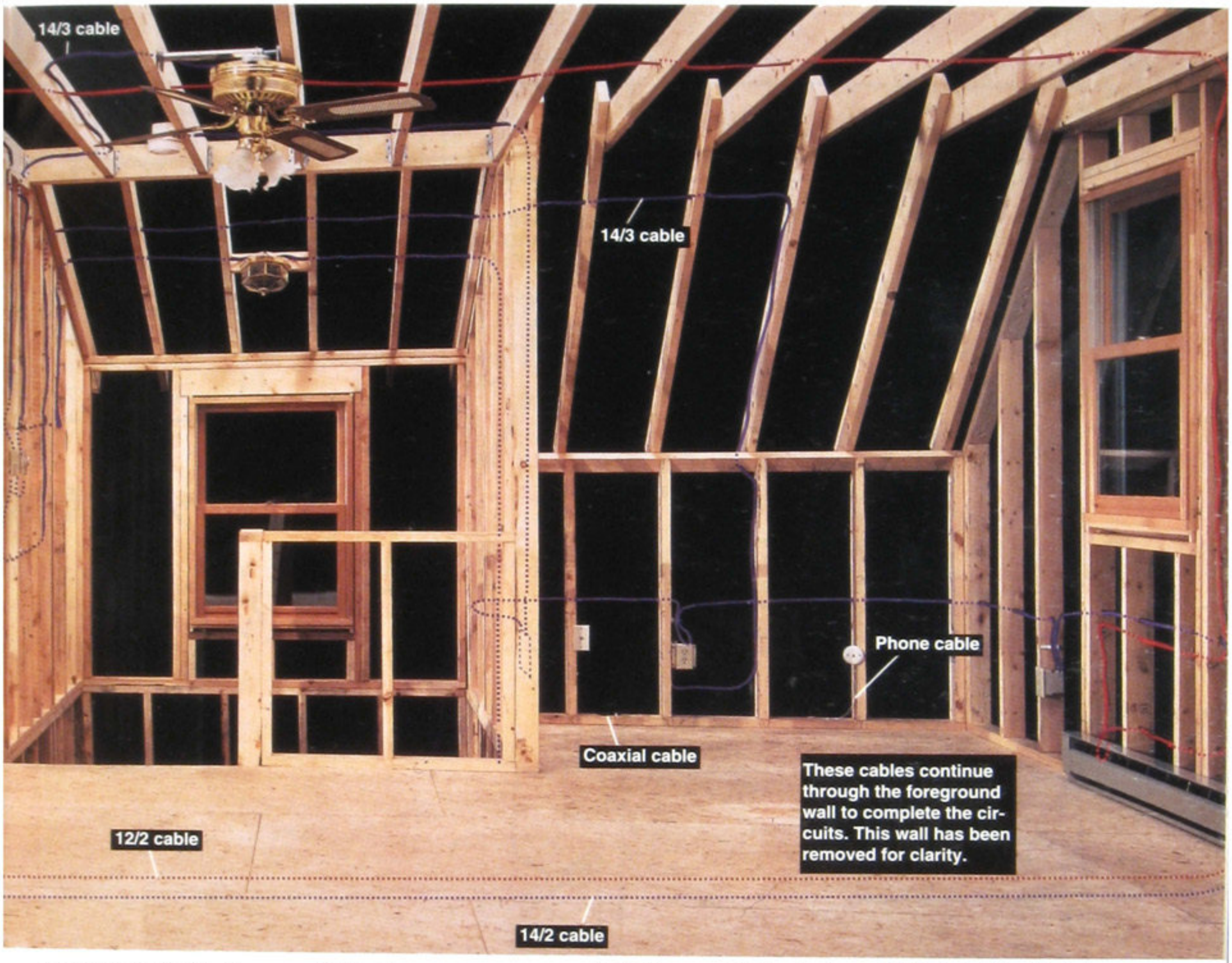
#3: Air-conditioner circuit. A 20- 240- dedi

in a small you may need an conditioner and rated for only 120 (page 147)

Wiring a room addition is a complex project that is made simple by careful planning and a step-by-step approach. Divide the project into convenient steps, and complete the work for each step before moving on to the next.

Tools You Will Need

Marker, tape measure, calculator, screwdriver, hammer, crescent wrench, jig saw or reciprocating saw, caulk gun, power drill with ⅝" spade bit, cable ripper, combination tool, wallboard saw, needlenose pliers.



■ **#4: Basic lighting/receptacle circuit.** This 15-amp, 120-volt circuit supplies power to most of the fixtures in the bedroom and study areas.

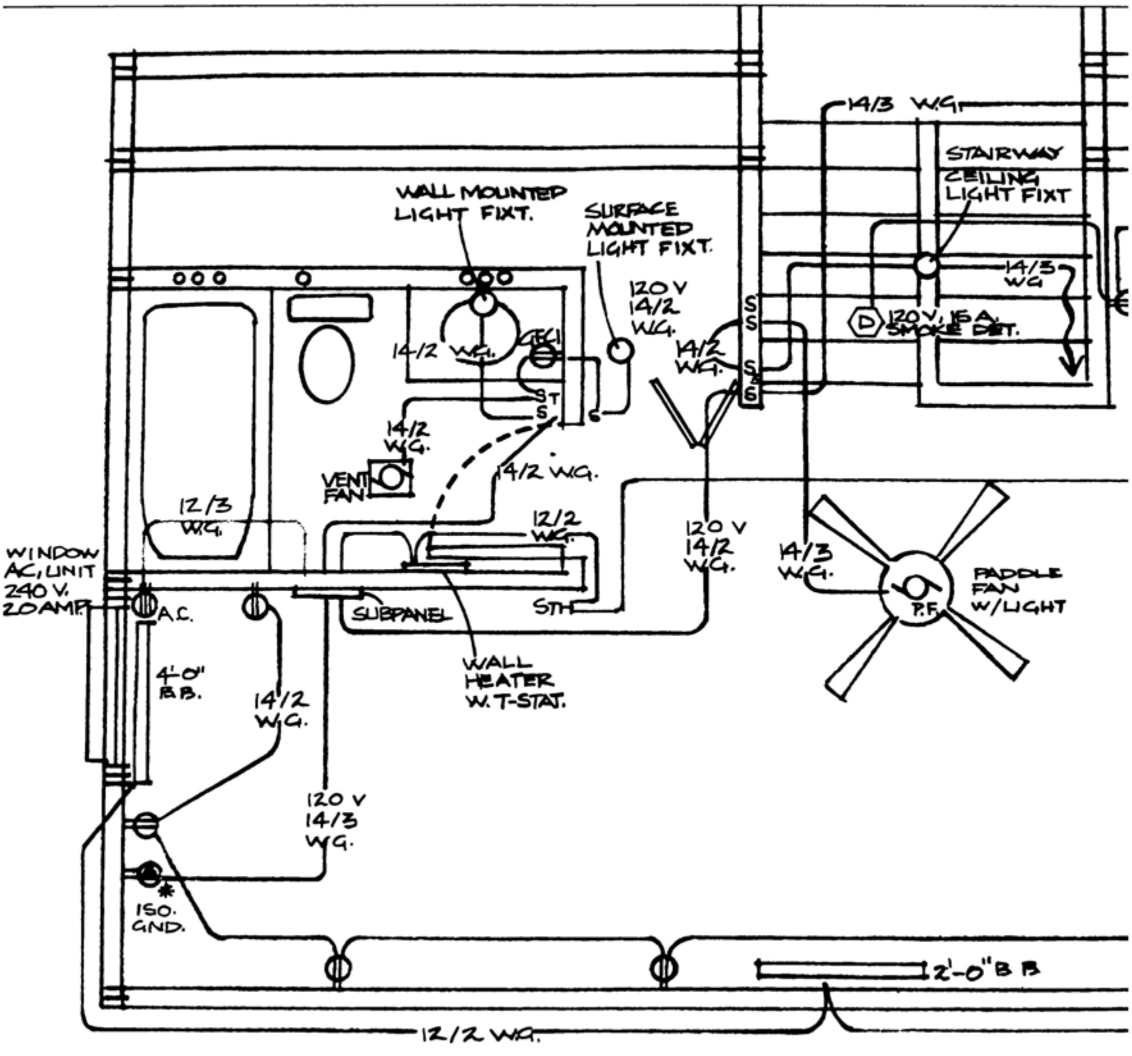
■ **#5: Heater circuit.** This 20-amp, 240-volt circuit supplies power to the bathroom blower-heater and to the baseboard heaters. Depending on the size of your room and the wattage rating of the baseboard heaters, you may need a 30-amp, 240-volt heating circuit.

Telephone outlet is wired with 22-gauge four-wire phone cable. If your home phone system has two or more separate lines, you may need to run a cable with eight wires, commonly called "four-pair" cable.

Cable television jack is wired with coaxial cable running from an existing television junction in the utility area.

Wiring a Room Addition: Diagram View

This diagram view shows the layout of five circuits and the location of the switches, receptacles, lights, and other fixtures in the attic room addition featured in this chapter. The size and number of circuits, and the list of required materials, are based on the needs of this 400-sq. ft. space.

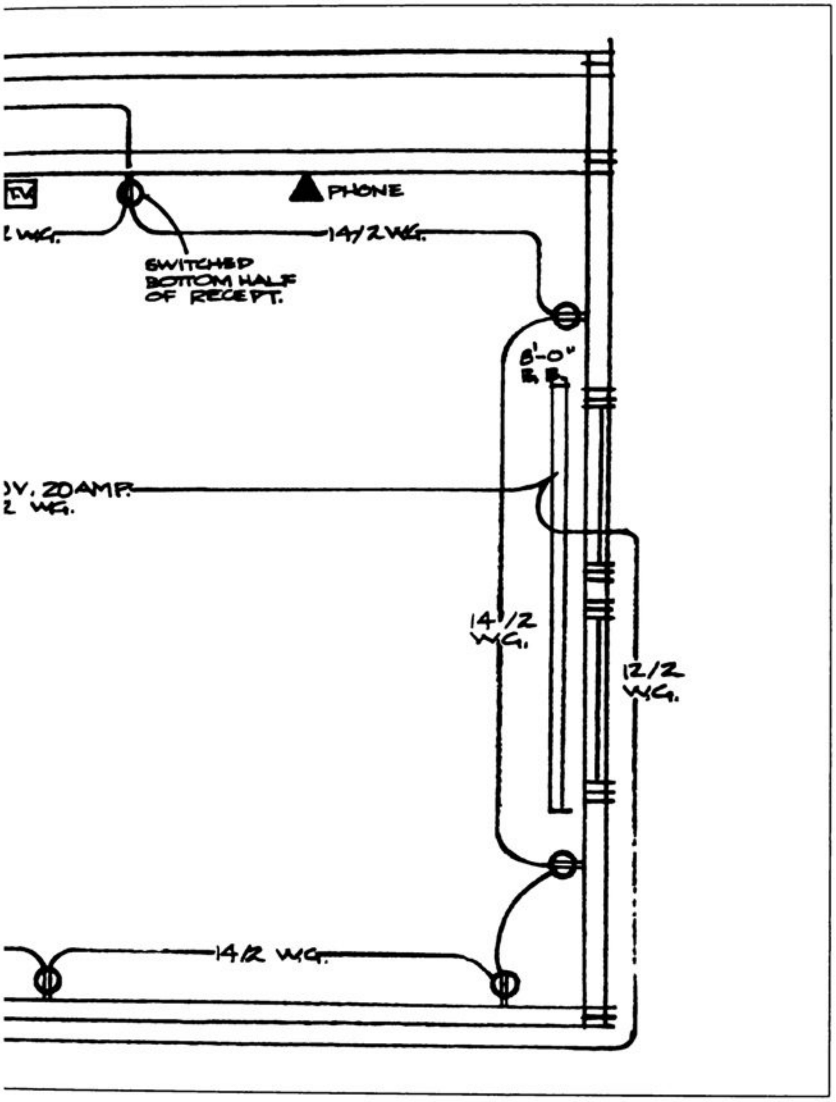


■ **Circuit #1:** A 15-amp, 120-volt circuit serving the bathroom and closet area. Includes: 14/2 NM cable, double-gang box, timer switch, single-pole switch, 4" × 4" box with single-gang adapter plate, GFCI receptacle, 2 plastic light fixture boxes, vanity light fixture, closet light fixture, 15-amp single-pole circuit breaker.

■ **Circuit #2:** A 15-amp, 120-volt computer circuit. Includes: 14/3 NM cable, single-gang box, 15-amp isolated-ground receptacle, 15-amp single-pole circuit breaker.

No two room additions are alike, so you will need to create a separate wiring diagram to serve as a guide for your own wiring project.

Note:
See pages 152 to153 for a key to the common electrical symbols used in this diagram and to learn how to draw your own wiring diagrams.



▶ **Telephone outlet:** 22-gauge four-wire phone cable (or eight-wire cable, if required by your telephone company), flush-mount telephone outlet.

TV **Cable television jack:** Coaxial cable with F-connectors, signal splitter, cable television outlet with mounting brackets.

■ **Circuit #5:** A 20-amp, 240-volt circuit that supplies power to three baseboard heaters controlled by a wall thermostat, and to a bathroom blower-heater controlled by a built-in thermostat. Includes: 12/2 NM cable, 750-watt blower-heater, single-gang box, line-voltage thermostat, three baseboard heaters, 20-amp double pole circuit breaker.

■ **Circuit #3:** A 20-amp, 240-volt air-conditioner circuit. Includes: 12/2 NM cable; single-gang box; 20-amp, 240-volt receptacle (duplex or singleplex style); 20-amp double-pole circuit.

■ **Circuit #4:** A 15-amp, 120-volt basic lighting/receptacle circuit serving most of the fixtures in the bedroom and study areas. Includes: 14/2 and 14/3 NM cable, 2 double-gang boxes, fan speed-control switch, dimmer switch, single-pole switch, 2 three-way switches, 2 plastic light fixture boxes, light fixture for stairway, smoke detector, metal light fixture box with brace bar, ceiling fan with light fixture, 10 single-gang boxes, 4" × 4" box with single-gang adapter plate, 10 duplex receptacles (15-amp), 15-amp single-pole circuit breaker.

1: Plan the Circuits

Your plans for wiring a room addition should reflect how you will use the space. For example, an attic space used as a bedroom requires an air-conditioner circuit, while a basement area used as a sewing room needs extra lighting. See pages 138 to 143 for information on planning circuits, and call or visit your city building inspector's office to learn the local code requirements. You will need to create a detailed wiring diagram and a list of materials before the inspector will grant a work permit for your job.

The National Electrical Code requires receptacles to be spaced no more than 12 feet apart, but for convenience you can space them as close as 6 feet apart. Also consider the placement of furniture in the finished room, and do not place receptacles or baseboard heaters where beds, desks, or couches will cover them.

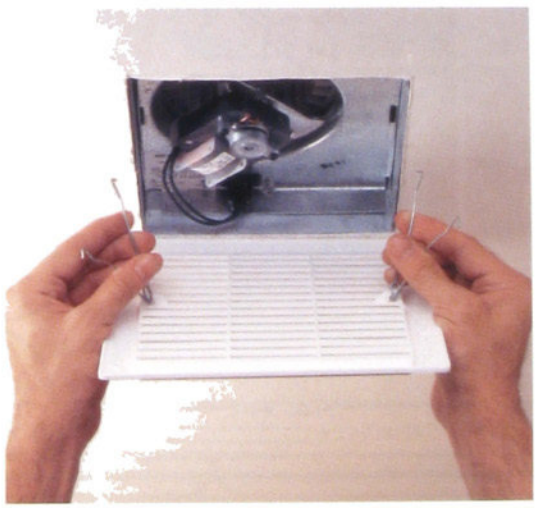
Electric heating units are most effective if you position them on the outside walls, underneath the windows. Position the receptacles to the sides of the heating units, not above the heaters where high temperatures might damage electrical cords.

Room light fixtures should be centered in the room, while stairway lights must be positioned so each step is illuminated. All wall switches should be within easy reach of the room entrance. Include a smoke alarm if your room addition includes a sleeping area.

Installing a ceiling fan improves heating and cooling efficiency and is a good idea for any room addition. Position it in a central location, and make sure there is plenty of headroom beneath it. Also consider adding accessory wiring for telephone outlets, television jacks, or stereo speakers.

Tips for Planning Room Addition Circuits

A permanently wired smoke alarm (page 223) is required by local building codes for room additions that include sleeping areas. Plan to install the smoke alarm just outside the sleeping area, in a hallway or stairway. Battery-operated smoke detectors are not allowed in new room additions.



A bathroom vent fan (pages 208 to 211) may be required by your local building code, especially if your bathroom does not have a window. Vent fans are rated according to room size. Find the bathroom size in square feet by multiplying the length of the room times its width, and buy a vent fan rated for this size.

If your room addition includes a bathroom, it will have special wiring needs. All bathrooms require one or more GFCI receptacles, and most need a vent fan. An electric blower-heater will make your bathroom more comfortable.

Before drawing diagrams and applying for a work permit, calculate the electrical load (pages 148 to 151). Make sure your main service provides enough power for the new circuits.

Refer to pages 152 to 167 when drawing your wiring diagram. Using the completed diagram as a guide, create a detailed list of the materials you need. Bring the wiring diagram and the materials list to the inspector's office when you apply for the work permit. If the inspector suggests changes or improvements to your circuit design, follow that advice. These suggestions can save you time and money, and will ensure a safe, professional wiring installation.

A wiring plan for a room addition should show the location of all partition walls, doorways, and windows. Mark the location of all new and existing plumbing fixtures, water lines, drains, and vent pipes. Draw in any chimneys and duct work for central heating and air-conditioning systems Make sure the plan is drawn to scale, because the size of the space will determine how you route the electrical cables and arrange the receptacles and fixtures.

Blower-heaters with built-in thermostats (page 206 and 224) work well in small areas like bathrooms, where quick heat is important. Some models can be wired for either 120 or 240 volts. A bathroom blower-heater should be placed well away from the sink and tub, at a comfortable height where the controls are easy to reach. In larger rooms, electric baseboard heaters controlled by a wall thermostat are more effective than blower-heaters.

Telephone and cable television wiring (pages 216 to 217) is easy to install at the same time you are installing electrical circuits. Position the accessory outlets in convenient locations, and keep the wiring at least 6" away from the electrical circuits to prevent static interference.

2: Install Boxes & Cables

For efficiency, install the electrical boxes for all new circuits before running any of the cables After all the cables are installed, your project is ready for the rough-in inspection Do not make the final connections until your work has passed rough-in inspection

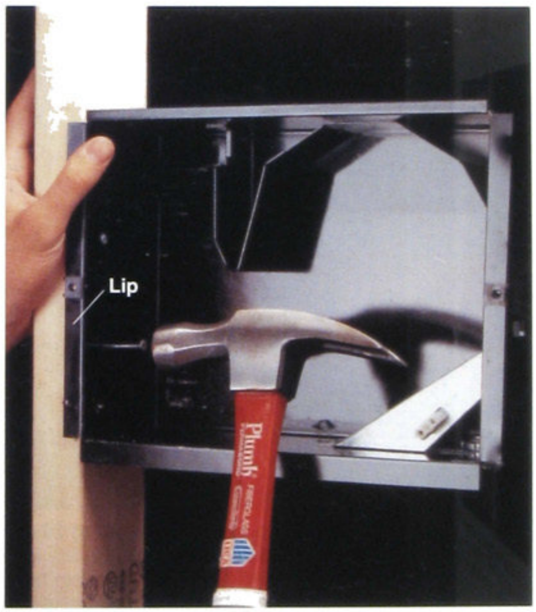
Boxes: See pages 170 to 175 for information on choosing and installing standard electrical boxes In addition, your room addition may have recessed fixtures, like a blower-heater (photo, right) or vent fan (pages 208 to 211) These recessed fi tures have built-in wire connection boxes and should be installed at the same time you are installing the standard electrical boxes. For a ceiling fan or other heavy ceiling fixture, install a metal box and brace bar (page opposite)

Cables: See pages 178 to 183 to install NM cable In addition you can install the necessary wiring for telephone outlets and cable television jacks (pages 216 to 217) This wiring is easy to install at the same time you are running electrical circuits and is not subject to formal inspection

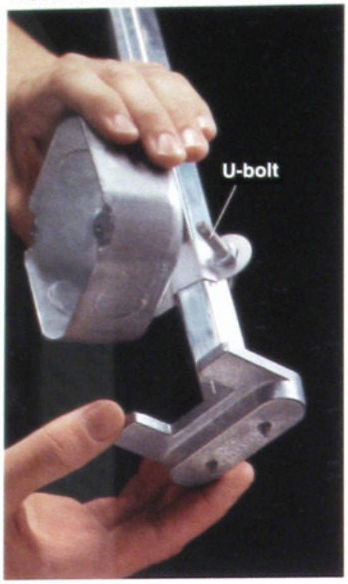
How to Install a Blower-Heater

1 Disconnect th lug from the bu tacle that exten the motor pl the wire connection

2 Take out the motor unit by removing the mounting screw and sliding the unit out of the frame



3 Open one knockout for each cable that will enter the wire connection box Attach a cable clamp to each knockout Position frame against a wall stud so the front lip will be flush with the finished wall surface Attach the frame as directed by the manufacturer.



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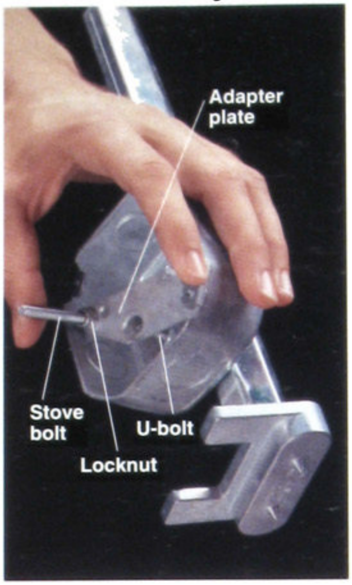

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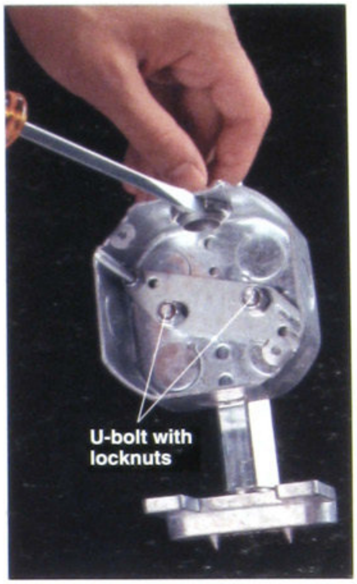

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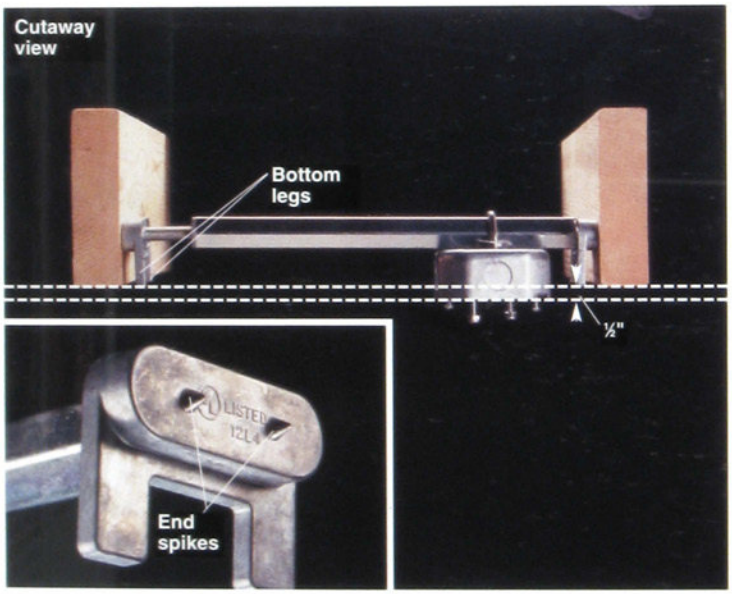

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5 Tigh
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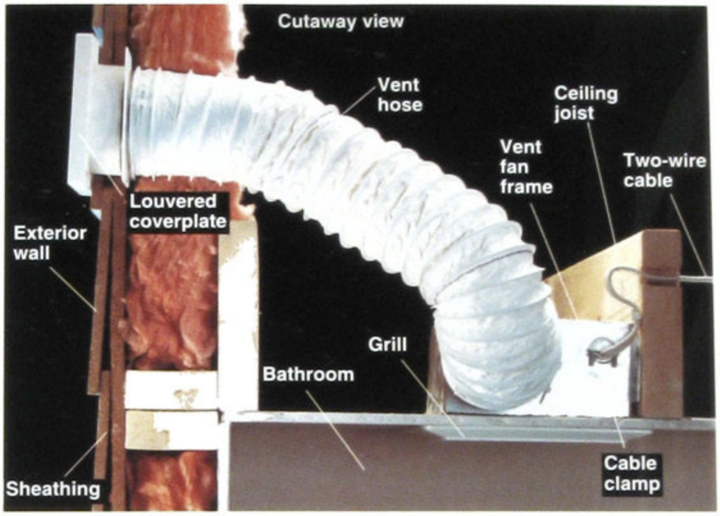
Installing a Vent Fan

A vent fan helps prevent moisture damage to a bathroom by exhausting humid air to the outdoors. Vent fans are rated to match different room sizes. A vent fan can be controlled by a wall-mounted timer or single-pole switch Some models have built-in light fixtures.

Position the vent fan in the center of the bathroom or over the stool area. In colder regions, building codes require that the vent hose be wrapped with insulation to prevent condensation of the moist air passing through the hose

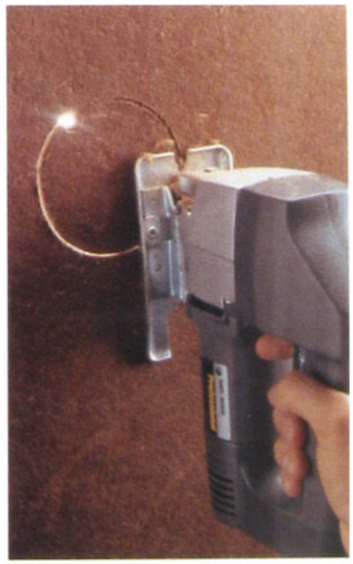


A vent fan has a built-in motor and blower that exhaust moisture-laden air from a bathroom to the outdoors through a plastic vent hose A two-wire cable from a wall-mounted timer or single-pole switch is attached to the fan wire connection box with a cable clamp A louvered coverplate mounted on the outside wall seals the vent against outdoor air when the motor is stopped

How to Install a Vent Fan in New Construction

1 Disassemble the fan, following manufacturer's directions. Position the frame against a rafter so edge extends ¼" below bottom edge of rafter to provide proper spacing for grill cover Anchor frame with wallboard screws.

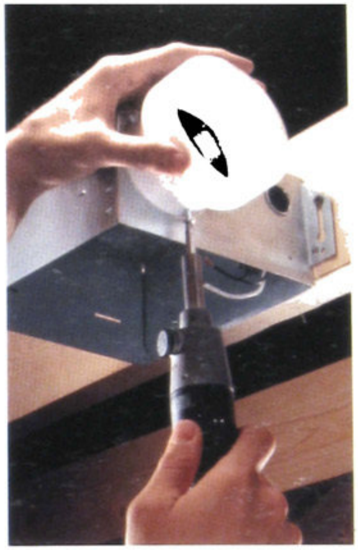
2 Choose the exit location for the vent. Temporarily remove any insulation, and draw the outline of the vent flange opening on the wall sheathing



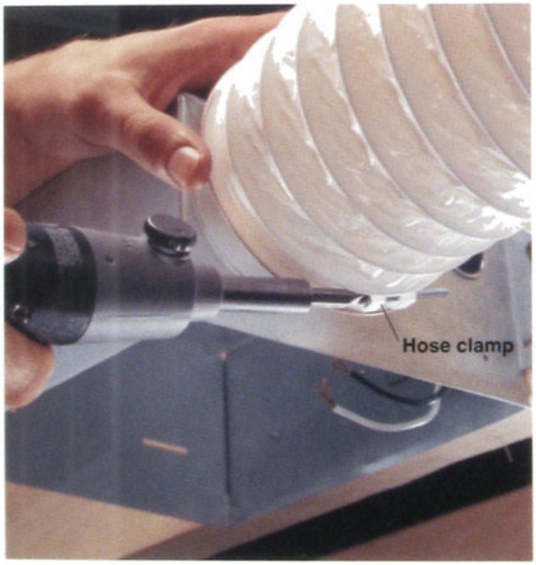
3 Drill a pilot hole, then make the cutout by sawing through the sheathing and siding with a jig saw Keep the blade to the outside edge of the guideline.

4 Insert the vent tailpiece into the cutout, and attach it to the wall by driving wallboard screws through the flange and into the sheathing.

5 Slide one end of vent hose over the tailpiece. Place one of the hose clamps around the end of the vent hose, and tighten it with a screwdriver. Replace insulation against sheathing.



6 Attach a hose adapter to the outlet on the fan frame by driving sheet-metal screws through the adapter and into the outlet flange. (NOTE: On some fans a hose adapter is not required.



7 Slide the vent hose over the adapter. Place a hose clamp around the end of the hose and tighten it with a screwdriver. Your building code may require that you insulate the vent hose to prevent condensation problems.

8 On the outside wall of the house, place the louvered vent cover over the vent tailpiece, making sure the louvers are facing down. Attach the cover to the wall with galvanized screws. Apply a thick bead of caulk around the edge of the cover.

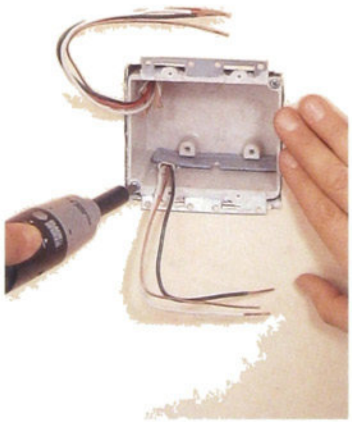
How to Install a Vent Fan in an Existing Ceiling

1 Position the vent fan unit against a ceiling joist. Outline the vent fan onto the ceiling, from above Remove unit, then drill pilot holes at the corners of the outline and cut out the area with a jig saw or wallboard saw

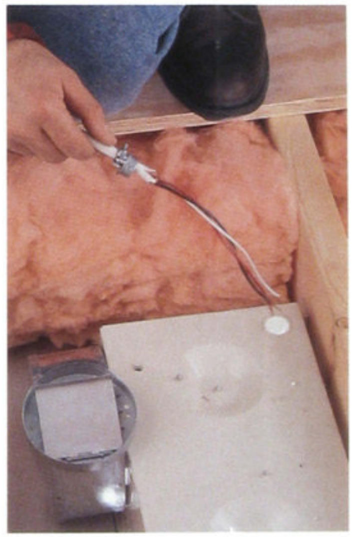
2 Remove the grille from the fan box, then position box against a joist, with the edge recessed ¼" from the finished surface of the ceiling (so the grille can be flush-mounted). Attach box to joist, using wallboard screws.

Vent fans with heaters or light fixtures: Some manufacturers recommend using 2" dimension lumber to build dams between the ceiling joists to keep insulation at least 6" away from the vent fan unit.

3 Mark and cut an opening for the switch box on the wall next to the latch side of the bathroom door, then run a 14-gauge, 3-wire NM cable from the switch cutout to the vent fan unit.

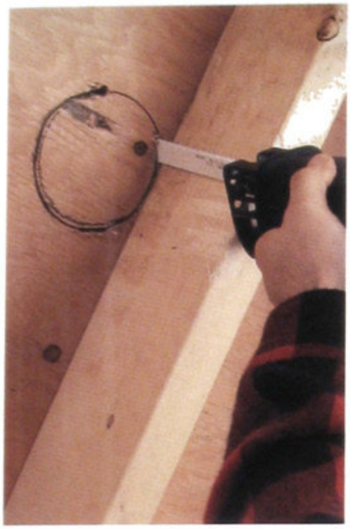


4 Strip 10" of sheathing from the end of the cable, then feed cable into switch box so at least ½" of sheathing extends into the box. Tighten mounting screws until box is secure.



5 Strip 10" of sheathing from the end of the cable at the vent box, then attach the cable to a cable clamp. Insert the cable into the fan box. From inside of box, screw a locknut onto the threaded end of the clamp.

How to Install a Vent Cover Flange on the Roof



1 Mark the exit location in the roof for the vent hose, next to a rafter. Drill a pilot hole, then saw through the sheathing and roofing material with a reciprocating saw to make the cutout for the vent tailpiece.

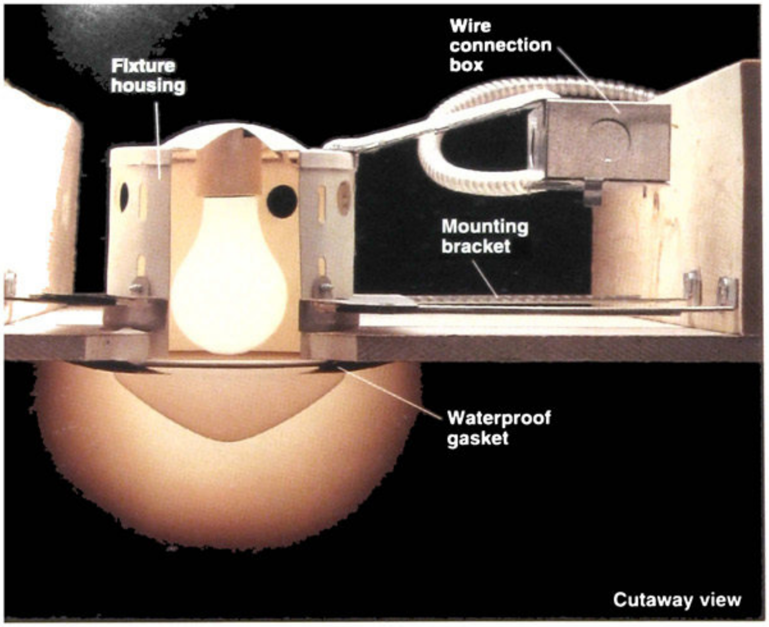
2 From outside, remove section of shingles from around the cutout, leaving roofing paper intact. Removed shingles should create an exposed area the size of the vent cover flange. Use caution when working on a roof.

3 Attach a hose clamp to the rafter next to the roof cutout, about 1" below the roof sheathing (top photo). Insert the vent tailpiece into the cutout and through the hose clamp, then tighten the clamp screw (bottom photo).

4 Slide one end of vent hose over the tailpiece, and slide the other end over the outlet on the fan unit. Slip hose clamps or straps around each end of the vent hose, and tighten to secure hose in place.

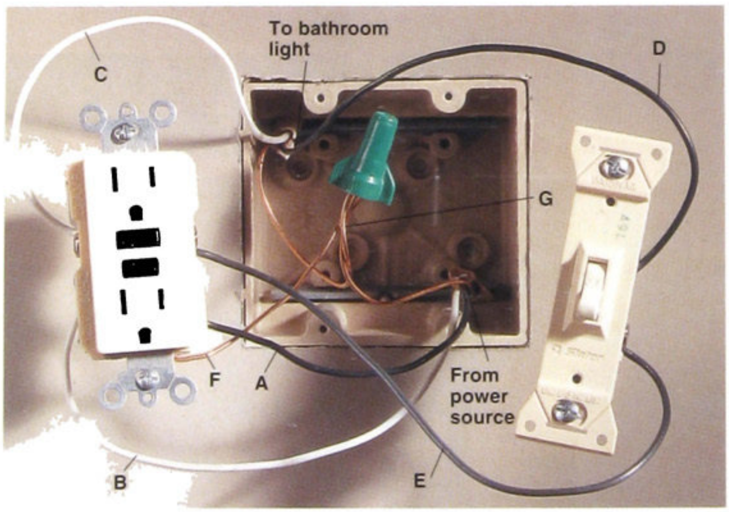
5 Wrap the vent hose with pipe insulation. Insulation prevents moist air inside the hose from condensing and dripping down into the fan motor.

6 Apply roofing cement to the bottom of the vent cover flange, then slide the vent cover over the tailpiece. Nail the vent cover flange in place with self-sealing roofing nails, then patch in shingles around cover.



Installing most bathroom lights the Adding new nd can even like hts have over

installing lights in any other makes a bathroom safer oms seem larger In showers that have been UL rated gasket that fits between



Install a GFCI receptacle and switch by making the following connections black wire from power source (A) to brass screw marked LINE on GFCI white wire from power source (B) to silver screw marked LINE. white wire to light (C) to silver GFCI screw marked LOAD black wire to light (D) to a screw terminal on switch Cut a short length of black wire (E) and attach one end to brass GFCI screw marked LOAD and other end to a screw terminal on switch Connect a bare grounding pigtail wire to GFCI grounding screw (F) and join all bare grounding wires (G) with a wire connector Tuck wires into box, then attach switch, receptacle and coverplate Use the circuit maps on pages 155 to 167 as a guide for making connections.

Installing Electrical Fixtures

Running cables for new electrical fixtures is easiest if wall surfaces have been removed Make the final wiring hookups at the fixtures after wall surfaces are finished

Follow local code requirements for wiring bathrooms. Reduce shock hazard by protecting the entire bathroom circuit with GFCI receptacles. Install only electrical fixtures that are UL approved

If it is not practical to remove wall surfaces, "retrofit" techniques can be used to install vent fans and other fixtures Most wiring connections for bathroom fixtures are easy to make, but wiring configurations in electrical boxes vary widely depending on the type of fixture and the circuit layout

If you are not confident in your skills, have an electrician install and connect fixtures Unless you are very confident, leave the job of making circuit connections at the main service panel to an electrician

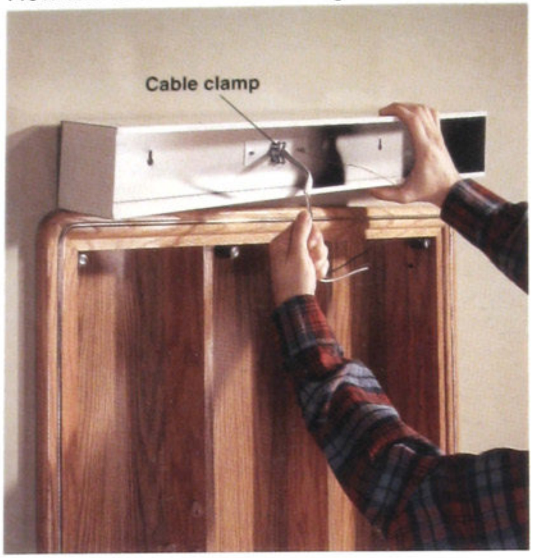
CAUTION: Always shut off electrical power at the main service panel, and test for power (page 8) before working with wires.

Everything You Need

Tools: neon circuit tester, wire stripper, cable ripper, screwdriver, level.

Materials: NM cable, wire staples, wire connectors, screws.

How to Install a Bathroom Light Fixture

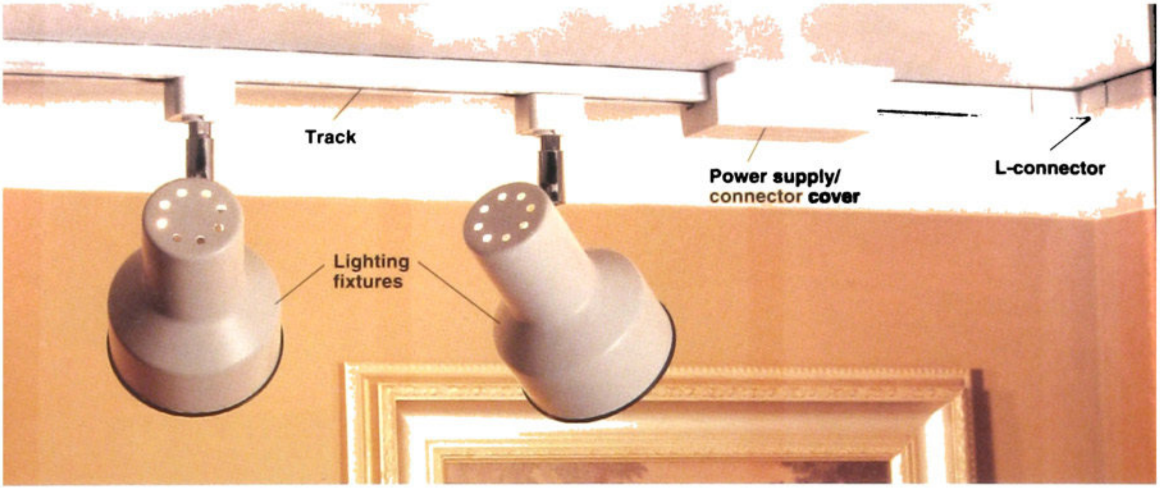


1 Turn power off Remove coverplate from light fixture and feed the electrical cable through the hole in the back of the fixture NOTE Some bathroom lights like the shower light on page 212, have a connection box that is separate from the light fixture

2 Position the fixture in the planned location, and adjust it so it is level (Center the fixture if it is being installed over a medicine cabinet.) If possible, attach the box at wall stud locations. If studs are not conveniently located, anchor the box to the wall, using toggle bolts or other connectors

3 Make electrical connections: attach white wire from cable (A) to white fixture wire (B), using a wire connector; attach black wire from cable (C) to black fixture wire (D); connect bare copper grounding wire from cable (E) to the fixture grounding wire (F) (or attach to grounding screw in some fixtures).

4 Tuck the wires into the back of the box, then attach the fixture coverplate. Install unprotected light bulbs only after the rest of the remodeling project is completed.



Installing Track Lighting

Track lighting allows you to create custom indoor lighting at a small cost. Use it to highlight a wall, illuminate a sculpture, or brighten a dark corner; the possibilities and effects are limitless. You can purchase track lighting kits at most home improvement retail outlets. They come in a variety of styles, which allows you to mix and match components to suit your needs. Installation is easy. All you need are a few household tools. While not necessary, it is helpful to have a second person to assist in positioning and attaching the track.

Track lighting can be installed anywhere. Determining where to place track lighting depends on the room's layout, the areas you want illuminated, and the power source. The easiest way to install it is near an existing light fixture. If no wiring is in place in a finished ceiling, it is best to hire a licensed electrician to add a box. If your wiring project is in new construction, you can install the ceiling box where you need it. The installation of the track and fixtures occurs after the finished ceiling is in place.

The first track section should start at an existing switched ceiling box. From there, you can install track along one side of the room or around the entire room. Use T and L track connectors for more flexibility or to branch tracks. For the best effect, place tracks parallel to the house wall closest to the fixture.

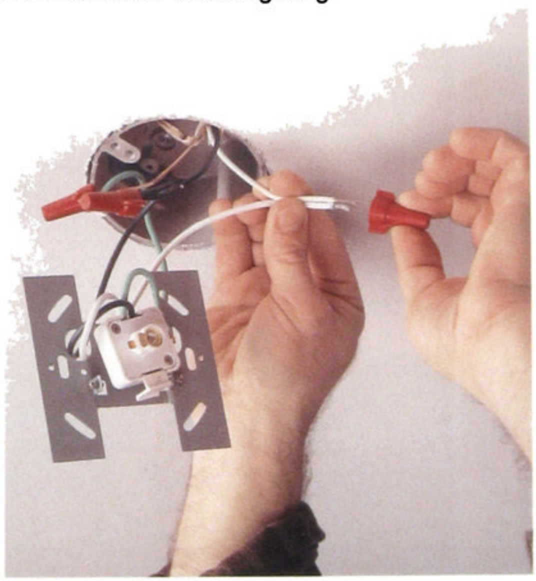
Since track lighting manufacturers and models vary, it is important to always follow product instructions.

Everything You Need

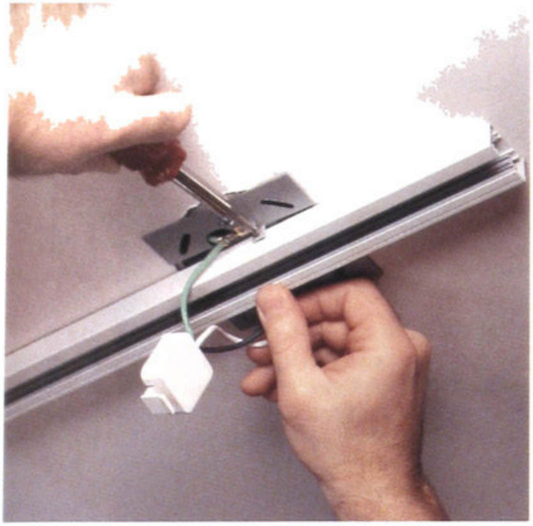
Tools: ladder, tape measure, circuit/voltage tester, drill, screwdrivers, straightedge.

Materials: pencil, wire connectors, toggle bolts, screws.

How to Install Track Lighting



1 Turn off power to ceiling box outlet. Remove existing fixture and disconnect wires. Attach green grounding fixture wire to bare copper grounding wire, and pigtail to electrical box, if required. Attach white circuit wire to white fixture wire. Then attach black circuit wire to black fixture wire. Carefully tuck wires into the electrical box.

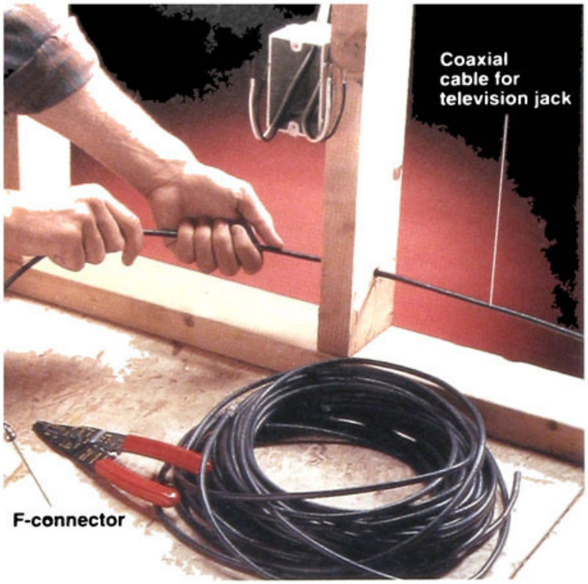


2 With pencil and straightedge, mark track location line from the power source to the end of the track. If possible, position tracks underneath ceiling joists for sturdy installation. Attach mounting plate to ceiling box. Snap first track onto the mounting plate and position track. Fasten track loosely with screws (or toggle bolts, if fastening to ceiling wallboard).

3 Insert connector into track, and twist into positi (connector installation may vary according to manufacturer). Attach power supply/connector cover Continue inserting connectors and attaching connector covers to each track section, using the L-connector for corners and the T-connector to join three tracks.

4 Hold each track section in place and mark screw or toggle bolt hole locations on ceiling. Remove track and drill holes. Install bolts in track and hang all units, waiting to tighten until all tracks are hung. After all tracks are installed, tighten screws or bolts until tracks are flush with ceiling. Close open ends with dead-end pieces.

5 Insert lighting fixtures into the track, and twist-lock into place. Install appropriate bulbs, and turn on power to ceiling box. Turn on power to the fixture at wall switch, and adjust beams for the desired effect.

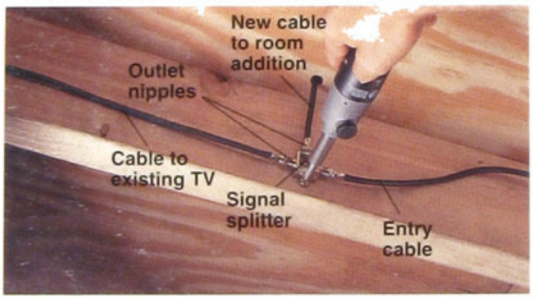


Installing Telephone & Cable Television Wiring

Telephone outlets and television jacks are easy to install while you are wiring new electrical circuits. Install the accessory cables while framing members are exposed, then make the final connections after the walls are finished.

Telephone lines use four- or eight-wire cable, often called **bell wire**, while television lines use a shielded coaxial cable with threaded end fittings called F-connectors. To splice into an existing cable television line, use a fitting called a signal splitter. Signal splitters are available with two, three, or four outlet nipples.

How to Install Coaxial Cable for a Television Jack

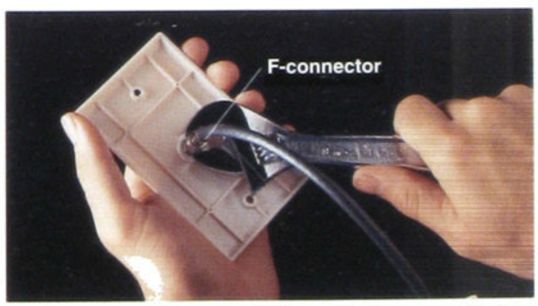


1 Install a signal splitter where the entry cable connects to indoor TV cables, usually in the basement or another utility area Attach one end of new coaxial cable to an outlet nipple on the splitter Anchor splitter to a framing member with wallboard screws

2 Run the coaxial cable to the location of the new television jack. Keep coaxial cable at least 6" away from electrical wiring to avoid electrical interference. Mark the floor so the cable can be found easily after the walls are finished

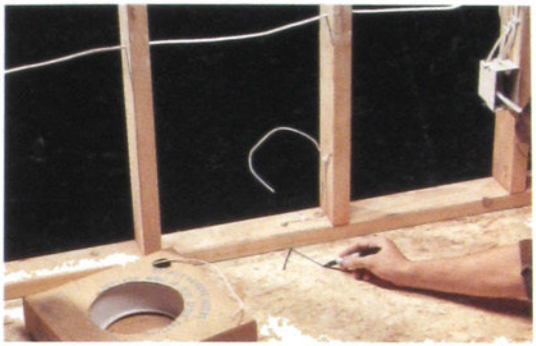
How to Connect a Television Jack

1 After walls are finished, make a cutout opening 1½" wide and 3¾" high at the television jack location. Pull cable through the opening, and install two television jack mounting brackets in the cutout.



2 Use a wrench to attach the cable F-connector to the back of the television jack. Attach the jack to the wall by screwing it onto the mounting brackets

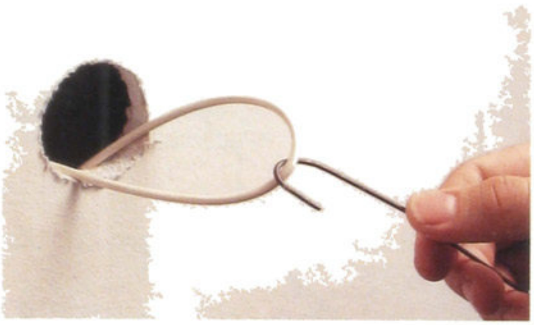
How to Install Cable for a Telephone Outlet



1 a telephone junction in your basement or utility area. Remove the junction cover. Use staples to anchor one end of the cable to a member near the junction, leaving 6" to 8" of excess cable.

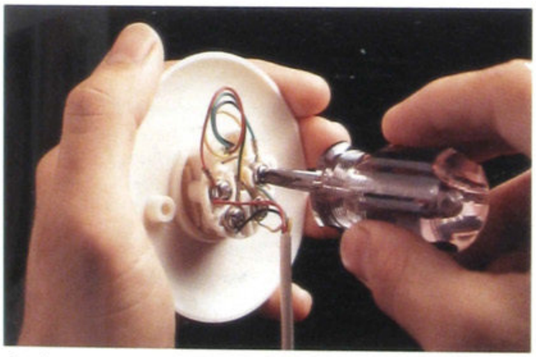
2 Run the cable from the juncti outlet location. Keep the cabl from circuit wiring to avoid electri Mark the floor so the cable can after the walls are finished.

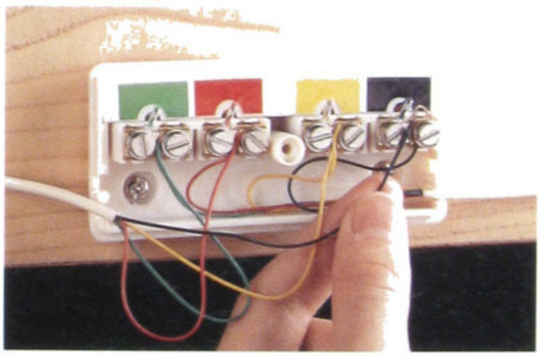
How to Connect a Telephone Outlet



1 walls are finished, cut a hol in the wallboard phone outlet location, using a wallboard saw. Retr e the cable, using a piece of stiff wire.

2 At each cable end, remove about 2 sheathing. Remove about of each wire, using a combination tool.





3 Connect wires to similarly colored wire leads in phone outlet. If there are extra wires, tape them to of the outlet, out of the way. Put the telephone r the wall cutout, and attach it to the wall-

4 At the telephone junction, connect the cable to the color-coded screw terminals. If there ar extra wires, wrap them with tape and tuck them inside the junction. Reattach the junction cover.

3: Make Final Connections

Make the final connections for receptacles, switches, and fixtures only after the rough-in inspection is done, and all walls and ceilings are finished. Use the circuit maps on pages 155 to 167 as a guide for making connections. The circuit maps are especially useful if your wiring configurations differ from those shown on the following pages. The last step is to hook up the new circuits at the breaker panel (pages 192 to 193).

After all connections are done, your work is ready for the final inspection. If you have worked carefully, the final inspection will take only a few minutes. The inspector may open one or two electrical boxes to check wire connections, and will check the circuit breaker hookups to make sure they are correct.

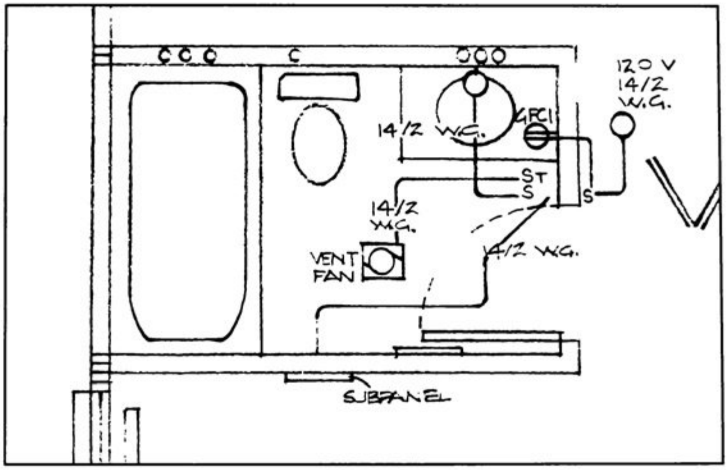
Everything You Need

Tools: combination tool, screwdrivers, needlenose pliers, nut driver.

Materials: pigtail wires, wire connectors, green & black tape.

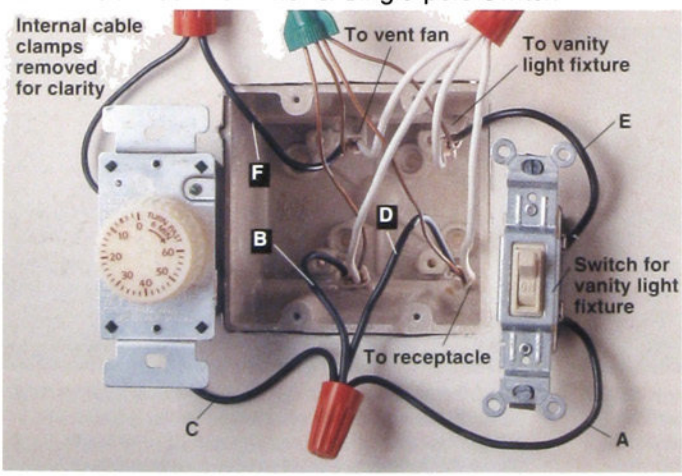
Circuit #1

A 15-amp, 120-volt circuit serving the bathroom & closet.



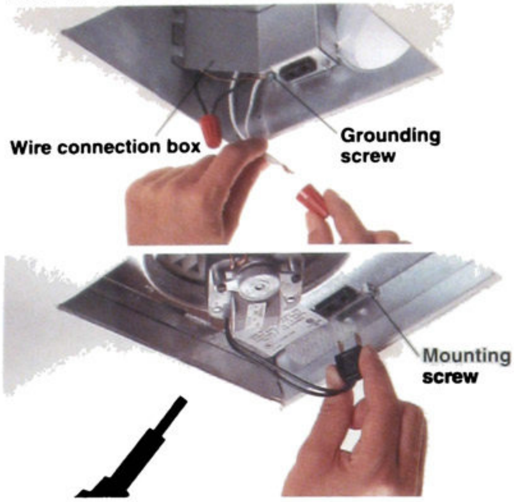
- Timer & single-pole switch
- Vent fan
- Two light fixtures
- GFCI receptacle
- Single-pole switch
- 15-amp single-pole circuit breaker (see pages 192 to 193 for instructions on hooking up the circuit at the circuit breaker panel)

How to Connect the Timer & Single-pole Switch



Attach a black pigtail wire (A) to one of the screw terminals on the switch. Use a wire connector to connect this pigtail to the black feed wire (B), to one of the black wire leads on the timer (C), and to the black wire carrying power to the bathroom receptacle (D). Connect the black wire leading to the vanity light fixture (E) to the remaining screw terminal on the switch. Connect the black wire running to the vent fan (F) to the remaining wire lead on the timer Use wire connectors to join the white wires and the grounding wires. Tuck all wires into the box, then attach the switches, coverplate, and timer dial. (See also circuit map 4, page 156; and circuit map 16, page 162.)

How to Connect the Vent Fan

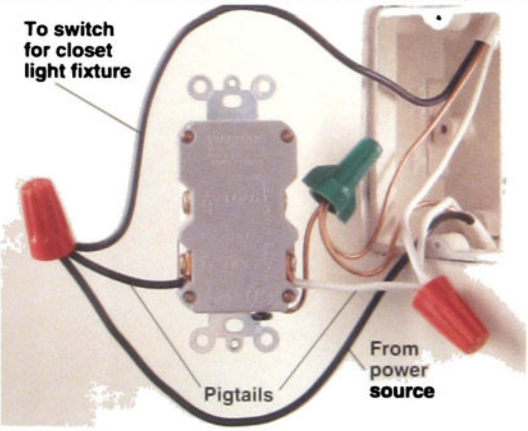


In the wire connection box (top) connect black circuit wire to black wire lead on fan, using a wire connector Connect white circuit wire to white wire lead. Connect grounding wire to the green grounding screw **Insert the fan motor unit** (bottom), and attach mounting screws. Connect the fan motor plug to the built-in receptacle on the wire connection box. Attach the fan grill to the frame, using the mounting clips included with the fan kit (page 208).

How to Connect Light Fixtures

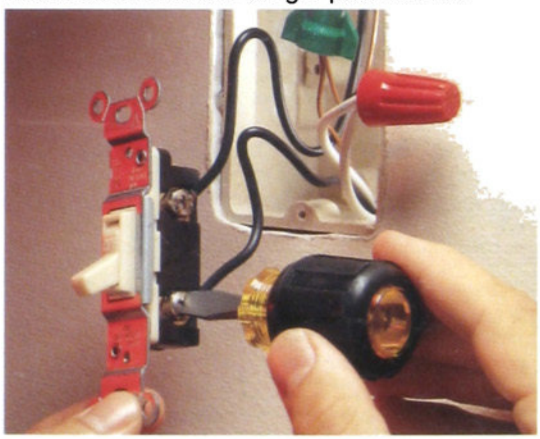
Attach a mounting strap with threaded nipple to the box, if required by the light fixture manufacturer Connect the black circuit wire to the black wire lead on the light fixture, and connect the white circuit wire to the white wire lead. Connect the circuit grounding wire to the grounding screw on the mounting strap Carefully tuck all wires into the electrical box, then position the fixture over the nipple, and attach it with the mounting nut. (See also circuit map 4, page 156)

How to Connect the Bathroom GFCI Receptacle



Attach a black pigtail wire to brass screw terminal marked LINE. Join all black wires with a wire connector Attach a white pigtail wire to the silver screw terminal marked LINE, then join all white wires with a wire connector Attach a grounding pigtail to the green grounding screw, then join all grounding wires. Tuck all wires into the box, then attach the receptacle and the coverplate. (See also circuit map 2, page 155.)

How to Connect the Single-pole Switch

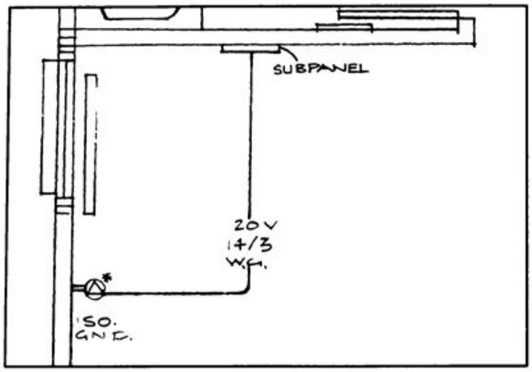


Attach the black circuit wires to the brass screw terminals on the switch. Use wire connectors to join the white neutral wires together and the bare copper grounding wires together Tuck all wires into the box, then attach the switch and the coverplate. (See also circuit map 4, page 156.)

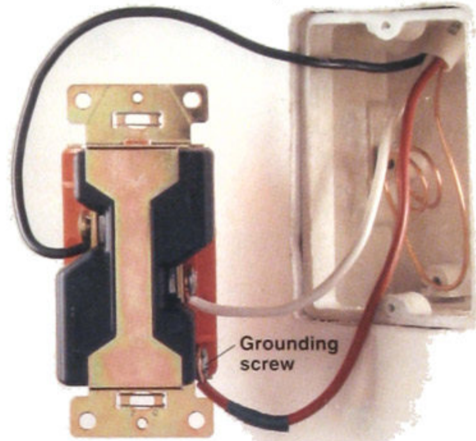
Circuit #2

A 15-amp, 120-volt isolated-ground circuit for a home computer in the office area.

- 15-amp isolated-ground receptacle
- 15-amp single-pole circuit breaker (see pages 192 to 193 for instructions on hooking up the circuit at the circuit breaker panel)



How to Connect the Computer Receptacle

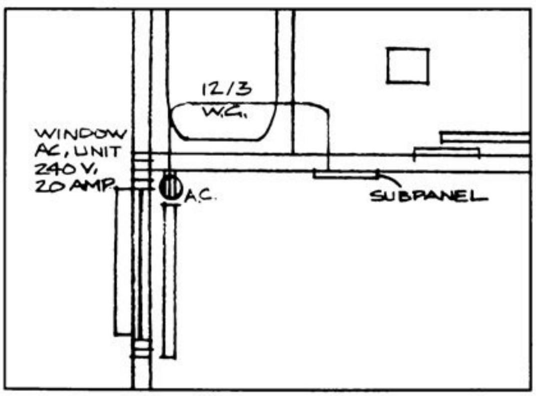


Tag the red wire with green tape to identify it as a grounding wire. Attach this wire to the grounding screw terminal on the isolated-ground receptacle. Connect the black wire to the brass screw terminal, and the white wire to the silver screw. Push the bare copper wire to the back of the box. Carefully tuck all wires into the box, then attach the receptacle and coverplate. (See also circuit map 15, page 162.)

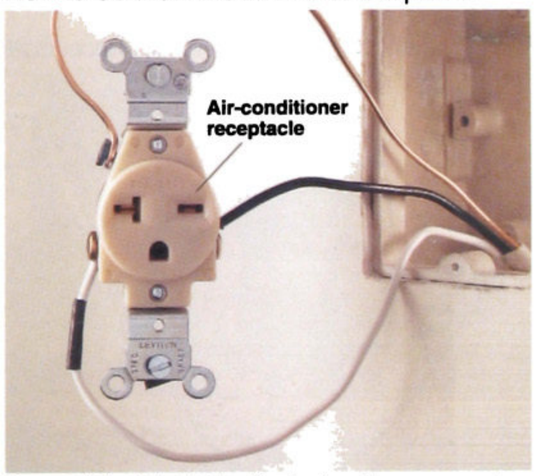
Circuit #3

A 20-amp, 240-volt air-conditioner circuit.

- 20-amp 240-volt receptacle (singleplex or duplex style)
- 20-amp double-pole circuit breaker (see pages 192 to 193 for instructions on hooking up the circuit at the circuit breaker panel)



How to Connect the 240-volt Receptacle

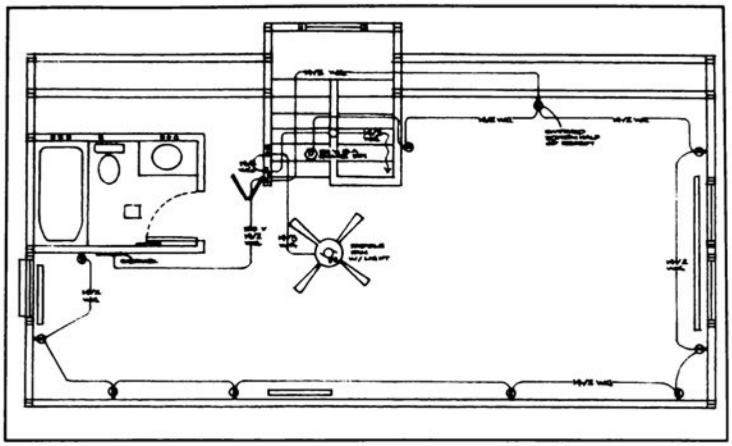


Connect the black circuit wire to a brass screw terminal on the air-conditioner receptacle, and connect the white circuit wire to the screw on the opposite side. Tag white wire with black tape to identify it as a hot wire. Connect grounding wire to green grounding screw on the receptacle. Tuck in wires, then attach receptacle and coverplate. (See also circuit map 12, page 160.) A 240-volt receptacle is available in either singleplex (shown above) or duplex style.

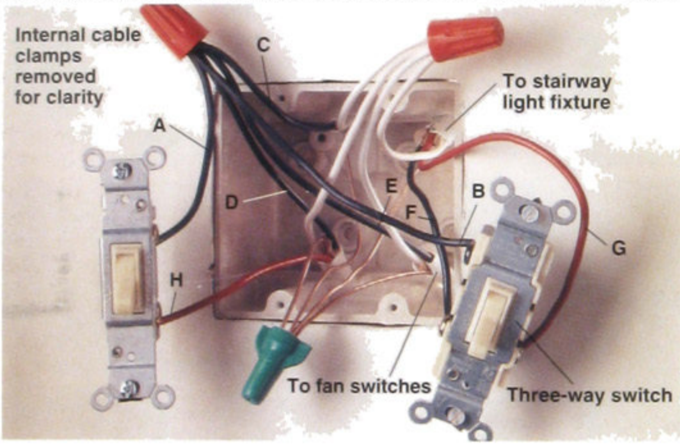
Circuit #4

A 15-amp, 120-volt basic lighting/ receptacle circuit serving the office and bedroom areas.

- Single-pole switch for split receptacle, three-way switch for stairway light fixture
- Speed-control and dimmer switches for ceiling fan
- Switched duplex receptacle
- 15-amp, 120-volt receptacles
- Ceiling fan with light fixture
- Smoke detector
- Stairway light fixture
- 15-amp single-pole circuit breaker (see pages 192 to 193)

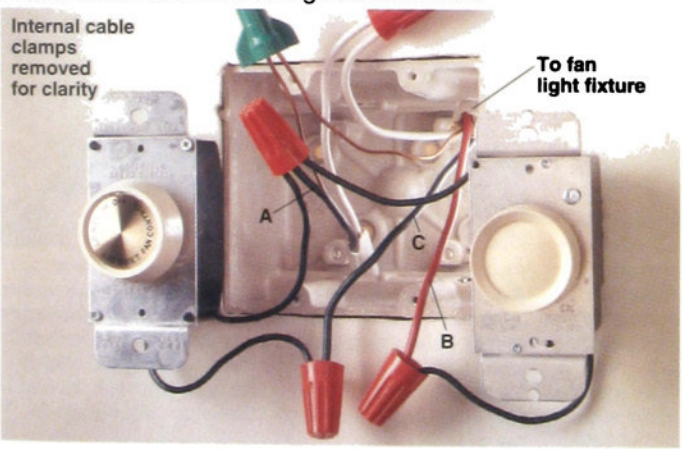


How to Connect Switches for Receptacle & Stairway Light



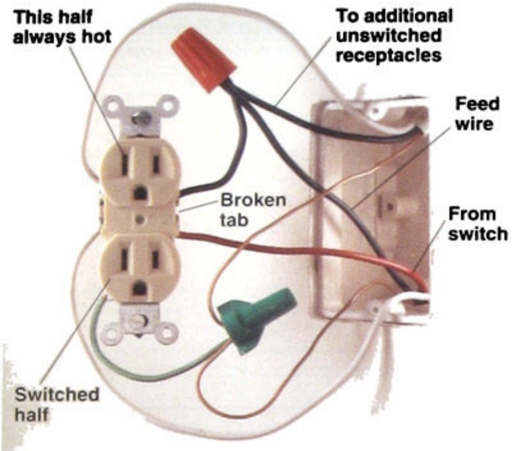
Attach a black pigtail wire (A) to one of the screws on the single-pole switch and another black pigtail (B) to common screw on three-way switch. Use a wire connector to connect pigtail wires to black feed wire (C), to black wire running to unswitched receptacles (D), and to the black wire running to fan switches (E). Connect remaining wires running to light fixture (F, G) to traveler screws on three-way switch. Connect red wire running to switched receptacle (H) to remaining screw on single-pole switch. Use wire connectors to join white wires and grounding wires. Tuck all wires into box, then attach switches and coverplate. (See also circuit map 7 page 158; and map 17 page 163.)

How to Connect the Ceiling Fan Switches



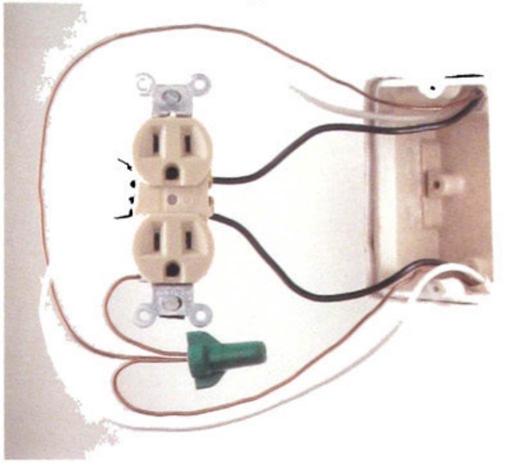
Connect the black feed wire (A) to one of the black wire leads on each switch, using a wire connector Connect the red circuit wire (B) running to the fan light fixture to the remaining wire lead on the dimmer switch. Connect the black circuit wire (C) running to the fan motor to the remaining wire lead on the speed-control switch. Use wire connectors to join the white wires and the grounding wires. Tuck all wires into the box, then attach the switches, coverplate, and switch dials. (See also circuit map 21, page 165.)

How to Connect a Switched Receptacle



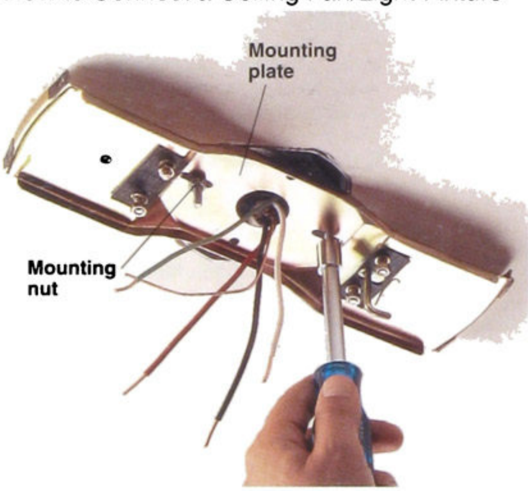
Break the connecting tab between the brass screw terminals on the receptacle, using needlenose pliers. Attach the red wire to the bottom brass screw. Connect a black pigtail wire to the other brass screw, then connect all black wires with a wire connector. Connect white wires to silver screws. Attach a grounding pigtail to the green grounding screw, then join all the grounding wires, using a wire connector. Tuck the wires into the box, then attach the receptacle and coverplate. (See also circuit map 7, page 158.)

How to Connect Receptacles

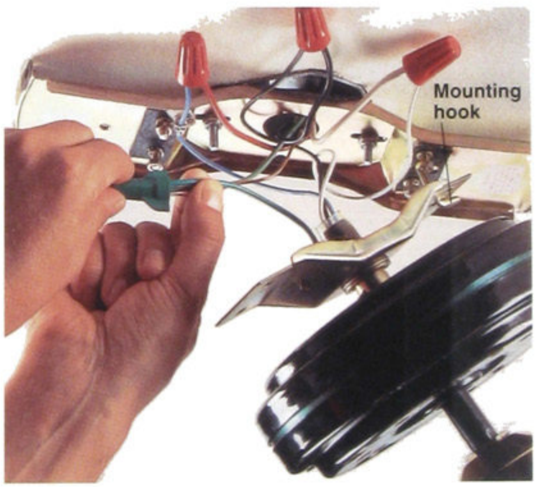


Connect the black circuit wires to the brass screw terminals on the receptacle, and the white wires to the silver terminals. Attach a grounding pigtail to the green grounding screw on the receptacle, then join all grounding wires with a wire connector. Tuck the wires into the box, then attach the receptacle and coverplate. (See also circuit map 1, page 155.)

How to Connect a Ceiling Fan/Light Fixture



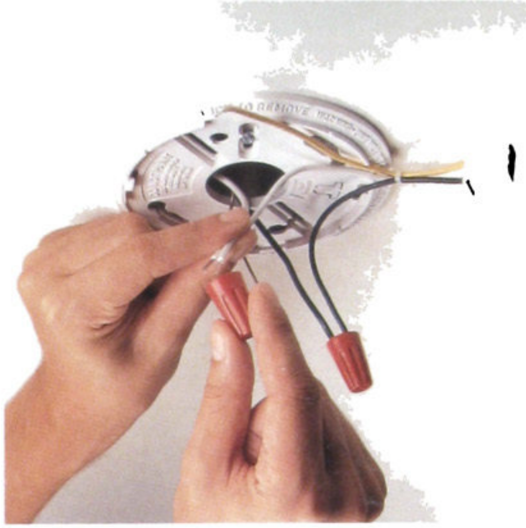
1 Place the ceiling fan mounting plate over the stove bolts extending through the electrical box. Pull the circuit wires through the hole in the center of the mounting plate. Attach the mounting nuts, and tighten them with a nut driver.



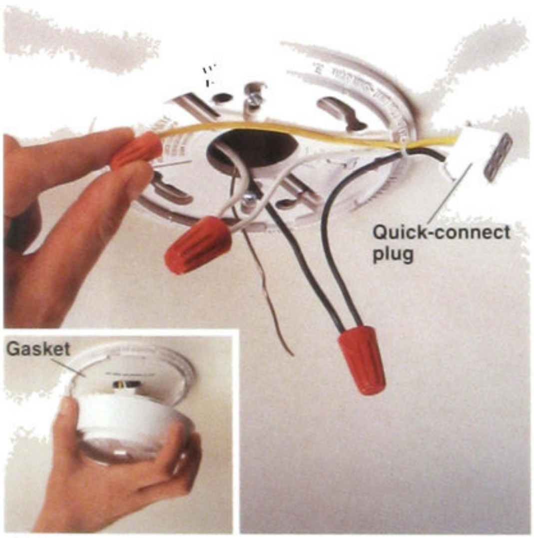
2 Hang fan motor from mounting hook. Connect black circuit wire to black wire lead from fan, using a wire connector. Connect red circuit wire from dimmer to blue wire lead from light fixture, white circuit wire to white lead, and grounding wires to green lead. Complete assembly of fan and light fixture, following manufacturer's directions. (See also circuit map 21, page 165.)

How to Connect a Smoke Alarm

1 Attach the smoke alarm mounting plate to the electrical box, using the mounting screws provided with the smoke alarm kit.

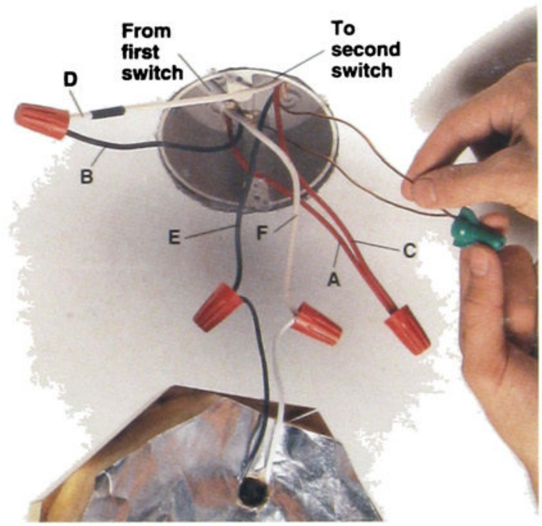


2 Use wire connectors to connect the black circuit wire to the black wire lead on the smoke alarm and the white circuit to the white wire lead



3 Screw a wire connector onto the end of the yellow wire, if present. (This wire is used only if two or more alarms are wired in series.) Tuck all wires into the box. Place the cardboard gasket over the mounting plate. Attach the quick-connect plug to the smoke alarm. Attach the alarm to the mounting plate, twisting it clockwise until it locks into place (inset).

How to Connect a Stairway Light Fixture

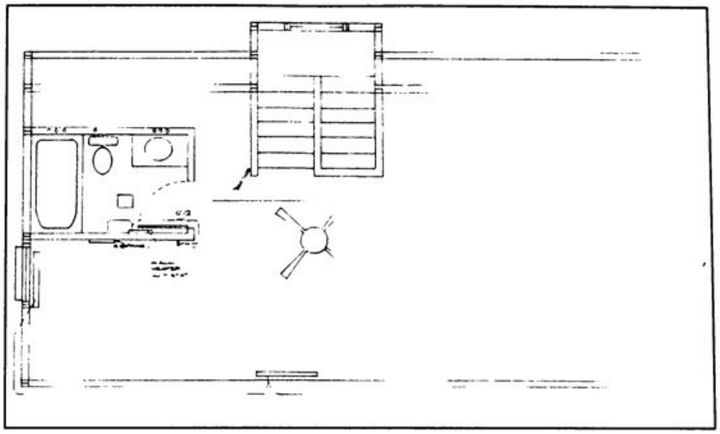


Connect the traveler wires entering the box from the first three-way switch (red wire [A] and black wire [B]) to the traveler wires running to the second three-way switch (red wire [C] and white wire tagged with black tape [D]). Connect the common wire running to the second switch (E) to the black lead on the light fixture. Connect the white wire from the first switch (F) to the white fixture lead. Join the grounding wires. Tuck wires into box, and attach the light fixtures. (See also circuit map 17, page 163.)

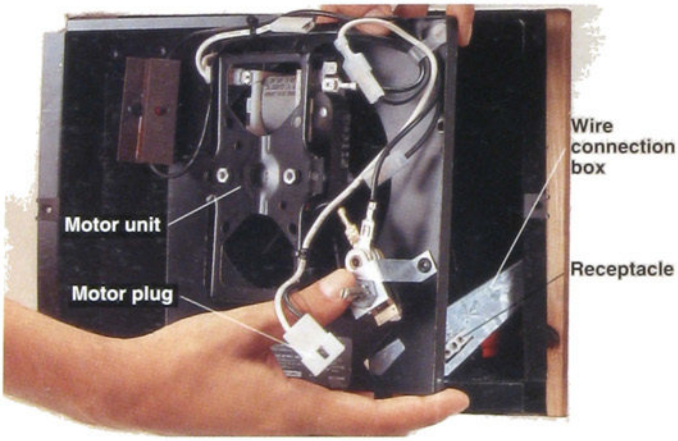
Circuit #5

A 20-amp, 240-volt circuit serving the bathroom blower-heater and three baseboard heaters controlled by a wall thermostat.

- 240-volt blower-heater
- 240-volt thermostat
- 240-volt baseboard heaters
- 20-amp double-pole circuit breaker (see pages 192 to 193 for instructions on hooking up the circuit at the circuit breaker panel)

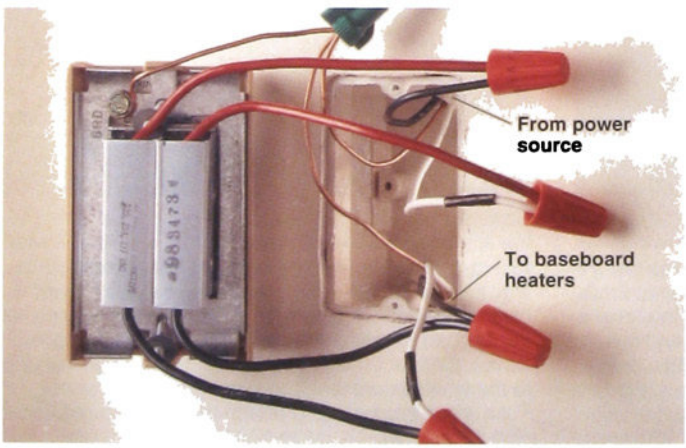


How to Connect a 240-volt Blower-Heater



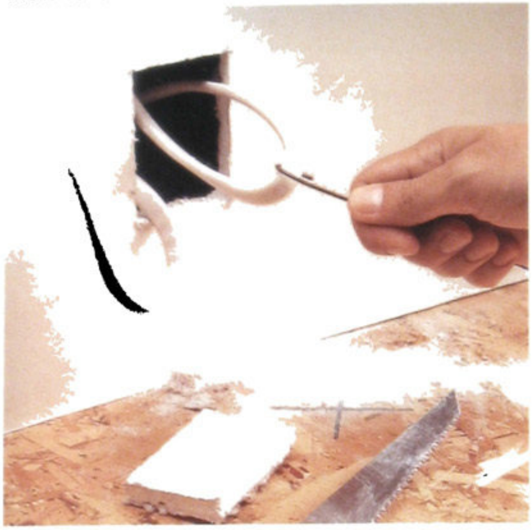
Blower-heaters: In the heater's wire connection box, connect one of the wire leads to the white circuit wires, and the other wire lead to the black circuit wires, using same method as for baseboard heaters (page, opposite). Insert the motor unit, and attach the motor plug to the built-in receptacle Attach the coverplate and thermostat knob. NOTE: Some types of blower-heaters can be wired for either 120 volts or 240 volts. If you have this type, make sure the internal plug connections are configured for 240 volts.

How to Connect a 240-volt Thermostat

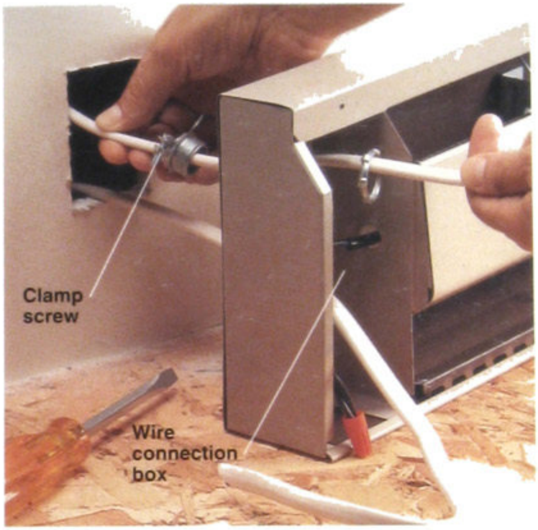


Connect the red wire leads on the thermostat to the circuit wires entering the box from the power source, using wire connectors. Connect black wire leads to circuit wires leading to the baseboard heaters. Tag the white wires with black tape to indicate they are hot. Attach a grounding pigtail to the grounding screw on the thermostat, then connect all grounding wires Tuck the wires into the box, then attach the thermostat and coverplate (See also circuit map 13, page 161) Follow manufacturer's directions: the color coding for thermostats may vary

How to Connect 240-volt Baseboard Heaters

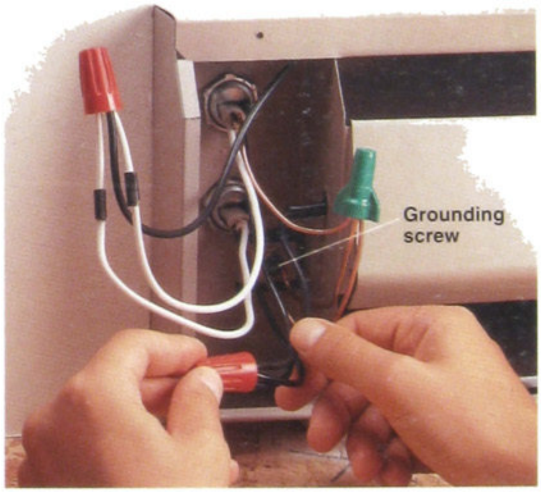


1 At the cable location, cut a small hole in the wallboard 3" to 4" above the floor using a wallboard saw Pull the cables through the hole, using a piece of stiff wire with a hook on the end Middle-of-run heaters will have 2 cables, while end-of-run heaters have only 1 cable



2 Remove the cover on the wire connection box Open a knockout for each cable that will enter the box, then feed the cables through the cable clamps and into the wire connection box Attach the clamps to the wire connection box and tighten the clamp screws until the cables are gripped firmly

3 Anchor heater against wall, about 1" off floor by driving flat-head screws through back of housing and into studs Strip away cable sheathing so at least of sheathing extends into the heater Strip $\frac{3}{4}$" of insulation from each wire, using a combination tool.



4 Use wire connectors to connect the white circuit wires to one of the wire leads on the heater Tag white wires with black tape to indicate they are hot. Connect the black circuit wires to the other wire lead Connect a grounding pigtail to the green grounding screw in the box, then join all grounding wires with a wire connector Reattach cover (See also circuit map 13, page 161)

Make hookups at circuit breaker panel (page 192), and arrange for final inspection

Choose the Fixtures You Need

A. Range receptacle ircuit #3) suppli

B. 20-amp receptacles (circuits #1 & #2) suppl power for small appli- ances See page 238

C. Under-cabinet task lights (circuit #7) pro- vide fluorescent light for counterto ork 243

D. Microwave receptacle (circuit #4) supplies powe on dic

E. GFCI receptacles (circuits #1 & #2) provide protection against shock See page

Wiring a Remodeled Kitchen

The kitchen is the greatest power user in your home. Adding new circuits during a kitchen remodeling project will make your kitchen better serve your needs. This section shows how to install new circuit wiring when remodeling. You learn how to plan for the many power requirements of the modern kitchen, and techniques for doing the work before the walls and ceiling are finished.

This section takes you through all phases of the project: evaluating your existing service, planning the new work and getting a permit, installing the circuits, and having your work inspected.

You learn how to install circuits and fixtures for recessed lights, under-cabinet task lights, and a ceiling light controlled by three-way switches. You also learn how to install circuits and receptacles for a range, microwave, dishwasher, and food disposer. Methods for installing two small-appliance circuits are also shown.

While your kitchen remodeling project will differ from this one, the methods and concepts shown apply to any kitchen wiring project containing any combination of circuits. The next two pages show the circuits in place with the walls and ceiling removed.

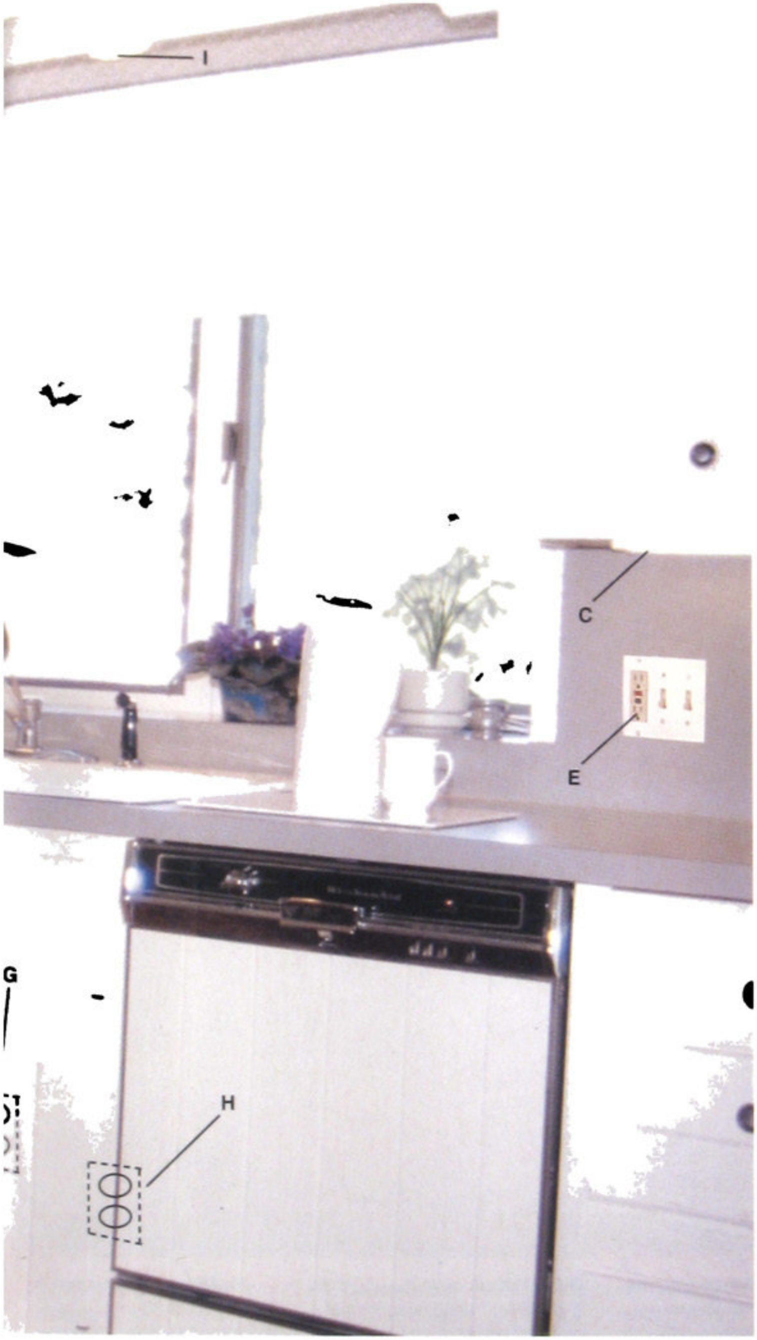


Photo courtesy of Kitchens by Krengel, Inc.

F. Ceiling fixture (circuit #7) provides general lighting for the entire kitchen. It is controlled by two three-way switches located by the doors to the room. See page 242.

G. Food disposer receptacle (circuit #5) is controlled by a switch near the sink and supplies power to the disposer located in the sink cabinet. See page 241.

H. Dishwasher receptacle (circuit #6) supplies power for the dishwasher on a dedicated circuit. See page 241.

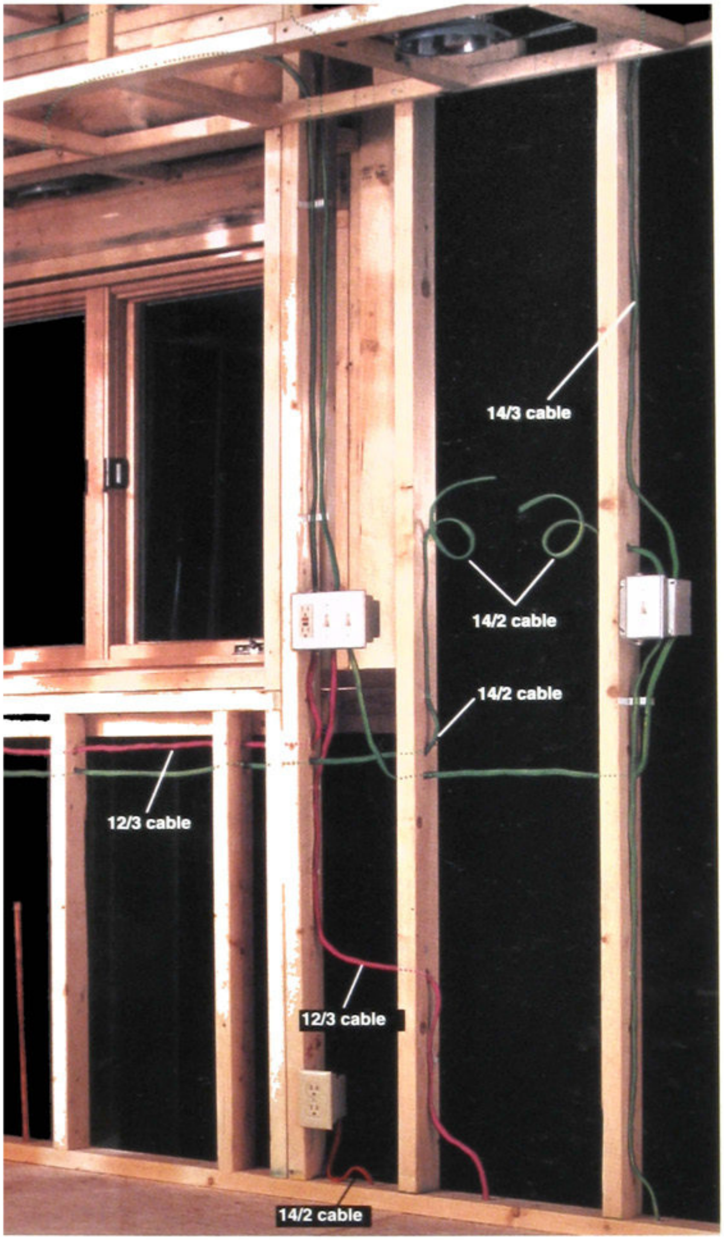
I. Recessed fixtures (circuit #7) controlled by switches near the sink provide additional lighting for work areas at sink, range, and countertop. See page 243.

Learn How to Install These Circuits

■ **#1 & #2: Small-appliance circuits.** Two 20-amp, 120-volt circuits supply power to countertop and eating areas for small appliances. All general-use receptacles must be on these circuits. One 12/3 cable, fed by a 20-amp double-pole breaker, wires both circuits. These circuits share one electrical box with the disposer circuit (#5), and another with the basic lighting circuit (#7).

■ **#3: Range circuit.** A 50-amp, 120/240-volt dedicated circuit supplies power to the range/oven appliance. It is wired with 6/3 cable.

#4: Microwave circuit. A dedicated 20-amp, 120-volt circuit supplies power to the microwave. It is wired with 12/2 cable. Microwaves that use less than 300 watts can be installed on a 15-amp circuit or plugged into the small-appliance circuits.



■ #5: Food disposer circuit.

■ #6: Dishwasher circuit.

#7: Basic lighting circuit.

Wiring a Remodeled Kitchen:
Construction View

The kitchen remodeling wiring project shown on the foll wing pages includes the installation of seven new circuits Four of these are dedicated ci its a 50-amp circuit suppl ing the range a 20-amp ci power ing the microwave an 15-amp circuits supplying th dishwasher and food dispose In addition two 20-amp circuits for small appliances supply power to all receptacles above the countertops and in the eating area Finally a 15-amp basic lighting ci contro the ceiling fixture f the recessed fixtures an the under-cabinet task ights

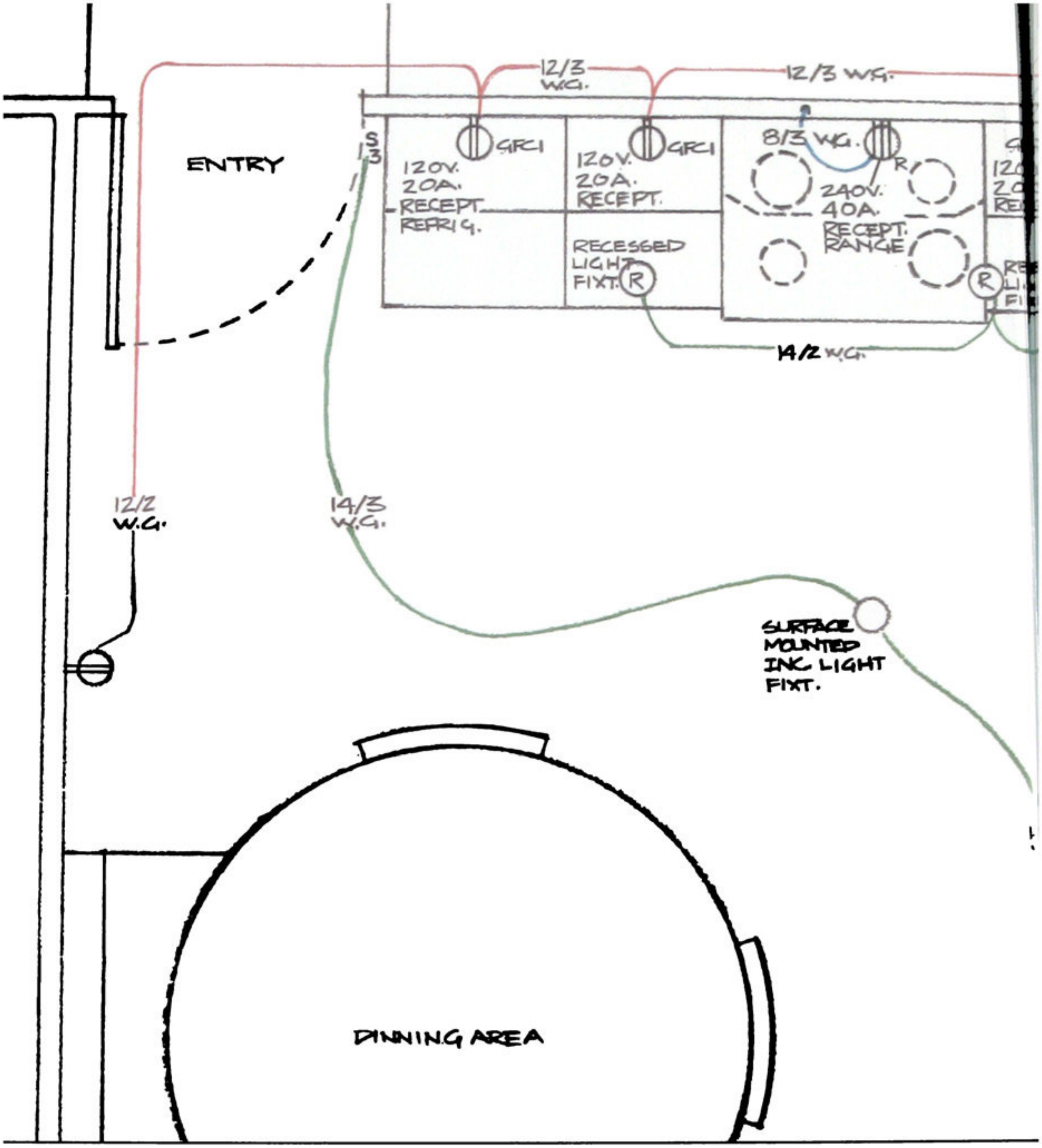
All rough construc and plumbing work should be finished and inspected before beginning the elec work Divide the project nto steps and complete eac tep befor beginning the nex

Three Steps for Wiring a Remodeled Kitchen:

1. Plan the Circuits (pages 232 to 233)
2. Install Boxes & Cables (pages 234 to 237).
3. Make Final Connections (pages 238 to 243).

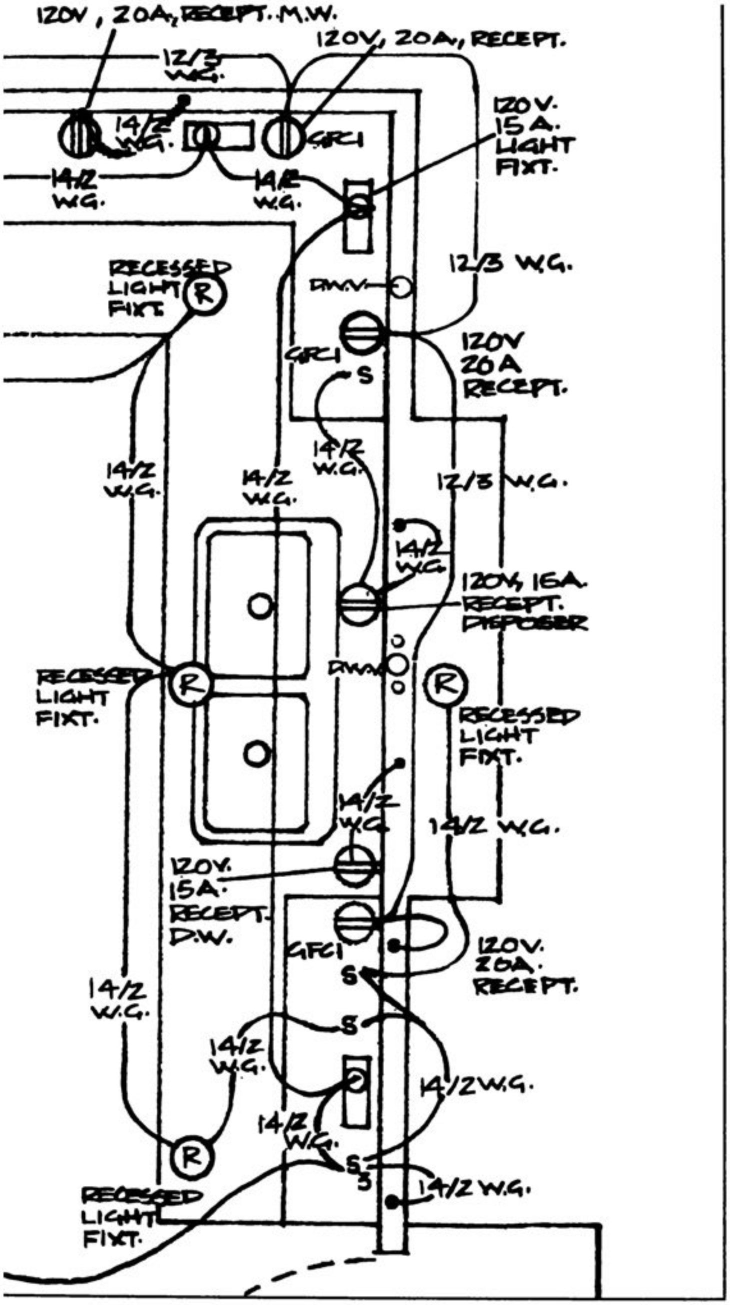
Tools You Will Need

Marker, tape measure, calculator, masking tape, screwdriver, hammer, power drill with ⅝" spade bit, cable ripper, combination tool, needlenose pliers, fish tape.



■ Circuits #1 & #2: Two 20-amp, 120-volt small-appliance circuits wired with one cable. All general-use receptacles must be on these circuits, and they must be GFCI units. Includes: 7 GFCI receptacles rated for 20 amps, 5 electrical boxes that are 4" × 4", and 12/3 cable. One GFCI shares a double-gang box with circuit #5, and another GFCI shares a triple-gang box with circuit #7.

■ Circuit #3: A 50-amp, 120/240-volt dedicated circuit for the range. Includes: a 4" × 4" box; a 120/240-volt, 50-amp range receptacle; and 6/3 NM cable.



Wiring a Remodeled Kitchen:

Diagram View

This diagram view shows the layout of seven circuits and the location of the switches, receptacles, lights, and other fixtures in the remodeled kitchen featured in this section. The size and number of circuits, and the specific features included, are based on the needs of this 170-sq. ft. space. No two remodeled kitchens are exactly alike, so create your own wiring diagram to guide you through your wiring project.

Note:

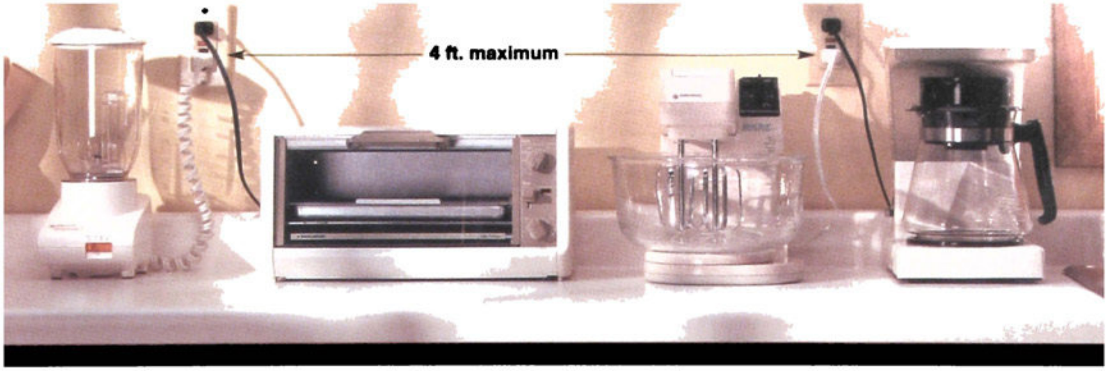
See pages 152 to 153 for a key to the common electrical symbols used in this diagram and to learn how to draw your own wiring diagrams.

■ **Circuit #7:** A 15-amp, 120-volt basic lighting circuit serving all of the lighting needs in the kitchen. Includes: 2 single-pole switches, 2 three-way switches, single-gang box, 4" × 4" box, triple-gang box (shared with one of the GFCI receptacles from the small-appliance circuits), plastic light fixture box with brace, ceiling light fixture, 4 fluorescent under-cabinet light fixtures, 6 recessed light fixtures, 14/2 and 14/3 cables.

■ **Circuit #6:** A 15-amp, 120-volt dedicated circuit for the dishwasher Includes: a 15-amp duplex receptacle, one single-gang box, and 14/2 cable.

■ **Circuit #4:** A 20-amp, 120-volt dedicated circuit for the microwave. Includes: a 20-amp duplex receptacle, a single-gang box, and 12/2 NM cable.

■ **Circuit #5:** A 15-amp, 120-volt dedicated circuit for the food disposer. Includes: a 15-amp duplex receptacle, a single-pole switch (installed in a double-gang box with a GFCI receptacle from the small-appliance circuits), one single-gang box, and 14/2 cable.



Code requires receptacles above countertops to be no more than 4 feet apart. Put receptacles closer together in areas where many appliances will be used. Any section of countertop that is wider than 12" must have a receptacle located above it. (Countertop spaces separated by items such as range tops, sinks, and refrigerators are considered separate sections.) All accessible receptacles in kitchens (and bathrooms) must be GFCI-protected. On walls without countertops, receptacles should be no more than 12 feet apart.

Wiring a Remodeled Kitchen

1: Plan the Circuits

A kitchen generally uses the most power in the home because it contains many light fixtures and appliances. Where these items are located depends upon your needs. Make sure the main work areas have plenty of light and enough receptacles. Try to anticipate future needs: for example, install a range receptacle when remodeling, even if you currently have a gas range. It is difficult and expensive to make changes later. See pages 138 to 153 for more information on planning circuits.

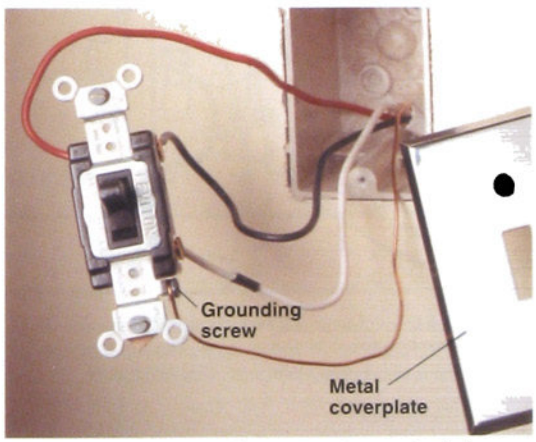
Contact your local Building and Electrical Code offices before you begin planning. They may have requirements that differ from the National Electrical Code. Remember that codes contain minimum requirements primarily concerning safety, not convenience or need. Work with the inspectors to create a safe plan that also meets your needs.

To help locate receptacles, plan carefully where cabinets and appliances will be in the finished project. Appliances installed within cabinets, such as microwaves or food disposers, must have their receptacles positioned according to manufacturer's instructions. Put at least one receptacle at table height in the dining areas for convenience in operating a small appliance.

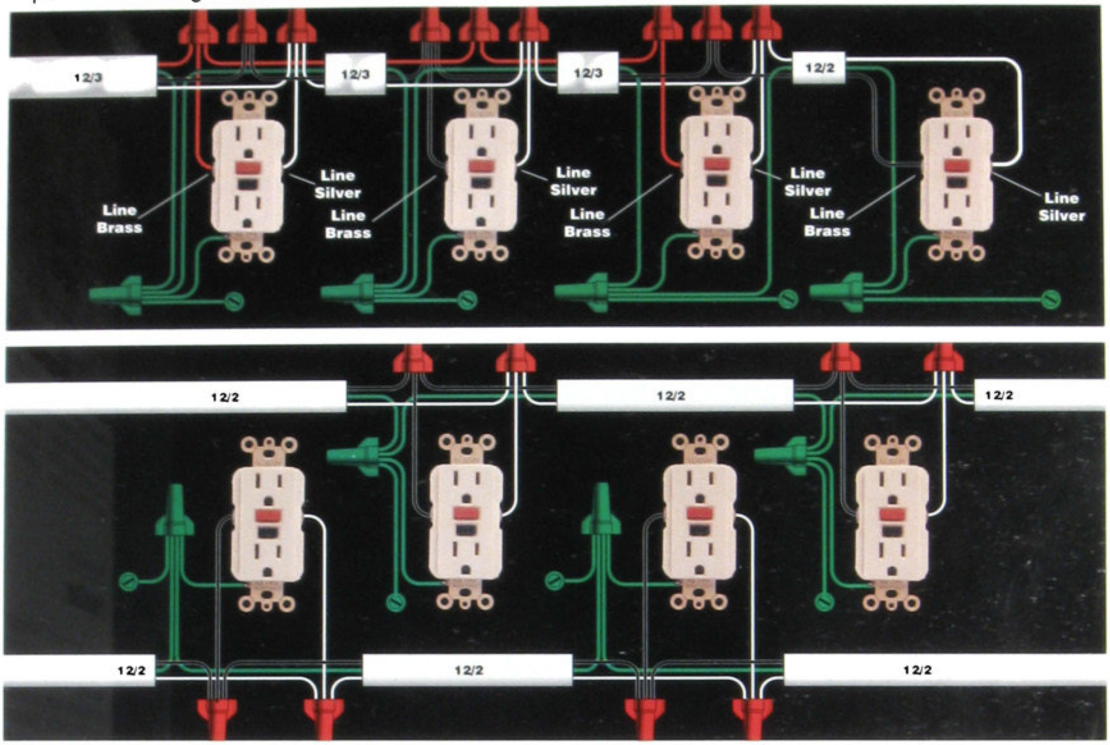
The ceiling fixture should be centered in the kitchen ceiling. Or, if your kitchen contains a dining area or breakfast nook, you may want to center the light fixture over the table. Locate recessed light fixtures and under-cabinet task lights where they will best illuminate main work areas.

Before drawing diagrams and applying for a permit, evaluate your existing service and make sure it provides enough power to supply the new circuits you are planning to add (pages 148 to 151). If it will not, contact a licensed electrician to upgrade your service before beginning your work. See pages 152 to 153 for more information on drawing wiring plans.

Bring the wiring plan and materials list to the inspector's office when applying for the permit. If the inspector suggests improvements to your plan, follow that advice.



A switch with a grounding screw is required when metal coverplates are used and when the switch is installed in a plastic box.

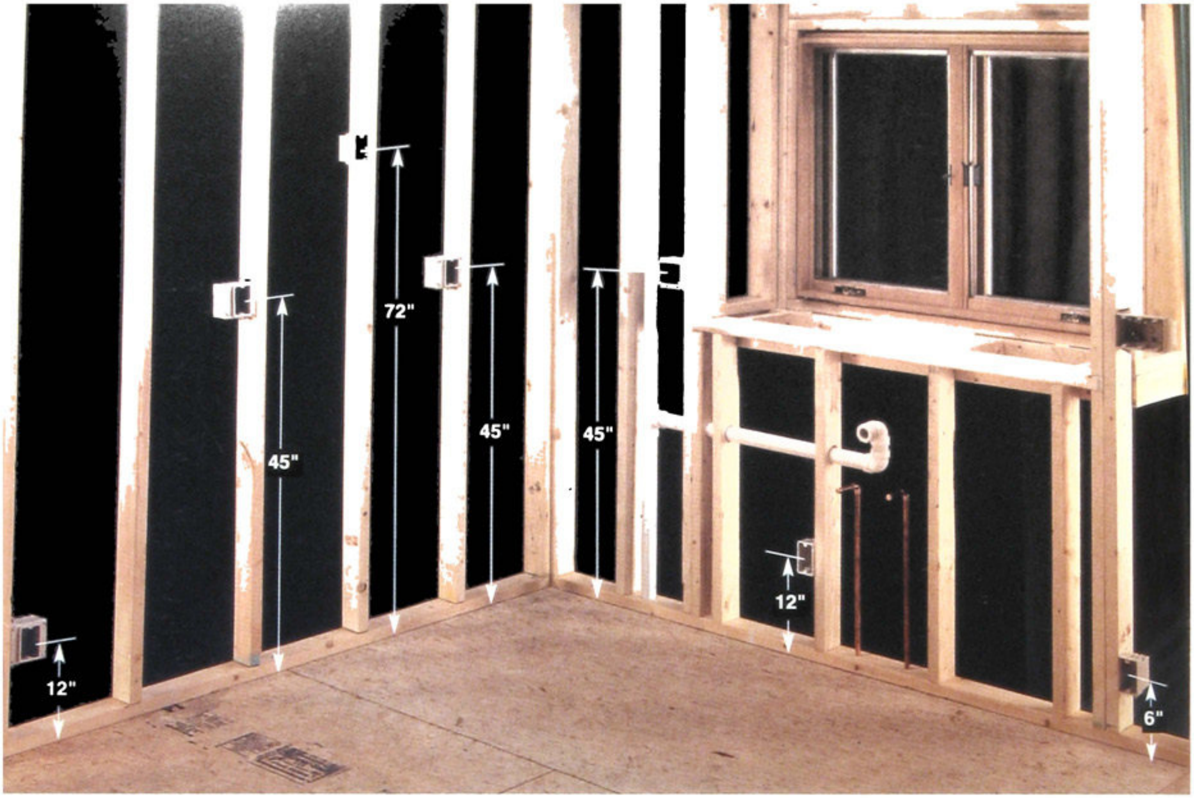


Two 20-amp small-appliance circuits c be map 159
3 upplying power with a p
separate 12 2 nnected
nd conta
wer

Work areas range
con

Ranges require a dedicated 40- or 50-amp 120 240-volt circuit two ci its for separate oven and countertop units) Even if you do not ha e an electric range it is a good idea to install the circuit when remodeling

Dishwashers and food disposers require dedicated 15-amp 120-volt circuits most local codes Some inspectors allow these appliances to share one circuit



Heights of electrical boxes

center of the box for the mi wave receptacl the floor where it will fit between the cabinets cen-ters of the boxes for the range and food disposer recep-tacles are 12" off the floor but the center of the box for the dishwasher receptacle is 6 off the floor next to the space the appliance will occupy

Wiring a Remodeled Kitchen

2: Install Boxes & Cables

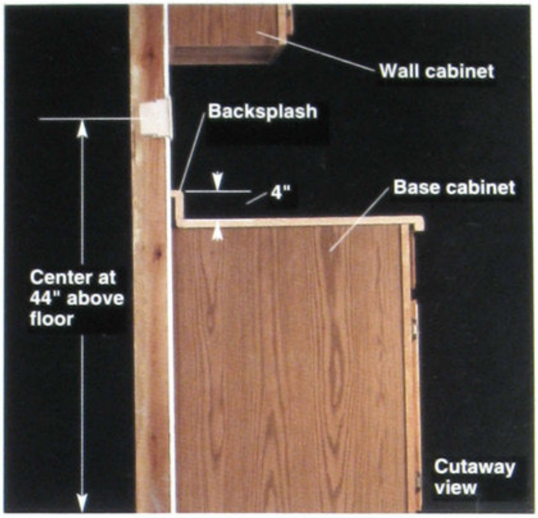
After the inspector issues you a work permit, you can begin installing electrical boxes for switches, receptacles and fixtures Install all boxes and frames for recessed fixtures, such as vent fans and recessed lights, before cutting and installing any cable However some surface-mounted fixtures such as under-cabinet task lights, have self-contained wire connection boxes These fixtures are installed after the walls are fi ished and the cabinets are in place

First determine locations for the boxes above the countertops (page opposite) After establishing the height for these boxes install all of the other visible wall boxes at this height Boxes that will be behind appliances or inside cabinets should be located according to appliance manufacturer's instructions For example, the receptacle for the dishwasher cannot be installed directly behind the appliance, it is often located in the sink cabinet for easy access

Always use the largest electrical boxes that are practical for your installation Using large boxes ensures that you will meet code regulations concerning box volume and simplifies making the connections See pages 170 to 175 for more information on choosing and installing standard electrical boxes

After all the boxes and recessed fixtures are installed you are ready to measure and cut the cables First install the feeder cables that run fro the circuit breaker panel to the first electrical box in each circuit Then cut and install the remaining cables to complete the circuits See pages 178 to 183 for information on installing NM cable.

Use masking tape to outline
abb



Standard backsplash height
installed abov th a
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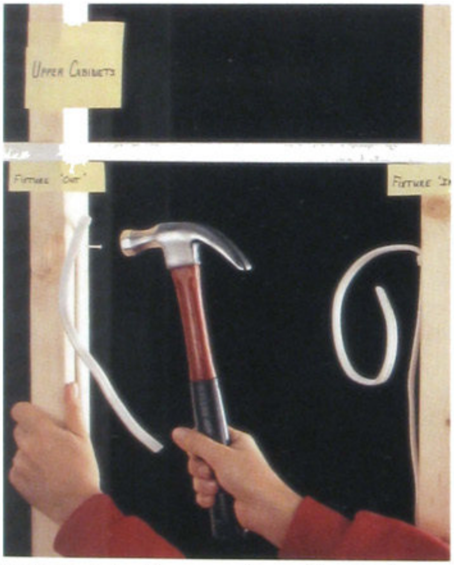

Install cables for an under-cabinet light at
the knockouts
installed after
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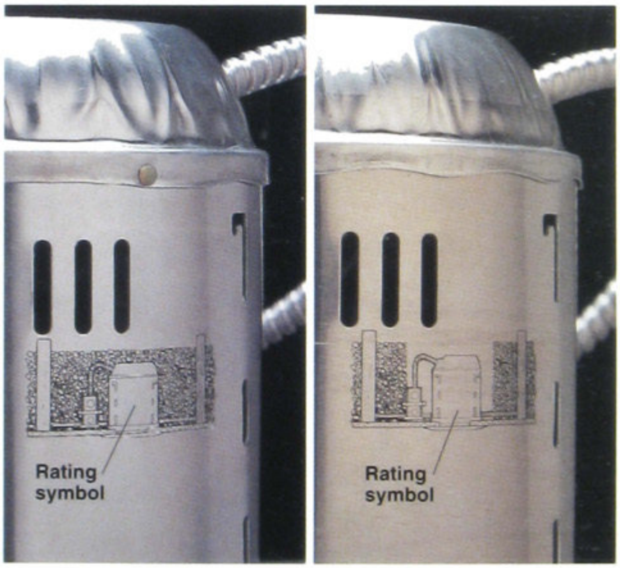


Choose the proper type of recessed light fixture for your project. There are two types of fixtures: those rated for installation within insulation (left), and those which must be kept at least 3" from insulation (right). Self-contained thermal switches shut off power if the unit gets too hot for its rating. A recessed light fixture must be installed at least from combustible materials.

How to Mount a Recessed Light Fixture

1 Extend the mounting bars on the recessed fixture reach the framing members. Adjust the position of light unit on the mounting bars to locate it properly. lign the bottom edges of the mounting bars the bottom face of the framing members.

2 Nail or screw the mounting bars to the fr members.

3 Remove the wire connection box cover and open one knockout for each cable entering the box.

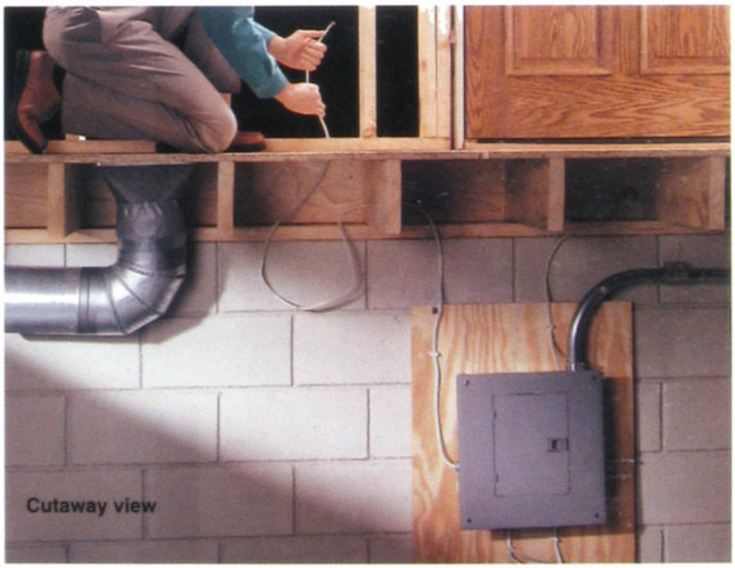
4 Install a cable clamp for each open knockout, and tighten locknut, using a screwdriver to drive the lugs.

How to Install the Feeder Cable

1 Drill access holes through the sill plate where the feeder cables will enter from the circuit breaker panel. Choose spots that offer easy access to the circuit breaker panel as well as to the first electrical box on the circuit.

2 Drill holes through framing members to allow cables to pass from the circuit breaker panel to access holes. Front edge of hole should be at least 1 from front edge of framing member.

3 For each circuit, measure and cut enough cable to run from circuit breaker panel, through access hole into the kitchen, to the first electrical box in the circuit. Add at least 2 feet for the panel and 1 foot for the box.



4 Anchor the cable with a cable staple within 12" of the panel. Extend cable through and along joists to access hole into kitchen, stapling every 4 feet where necessary. Keep cable at least 1¼" from front edge of framing members. Thread cable through access hole into kitchen and on to the first box in the circuit. Continue circuit to rest of boxes (pages 178 to 181).

Arrange for the rough-in inspection before making the final connections.

3: Make Final Connections

Make the final connections for switches, receptacles, and fixtures after the rough-in inspection. First make final connections on recessed fixtures (it is easier to do this before wallboard is installed). Then finish the work on walls and ceiling, install the cabinets, and make the rest of the final connections. Use the photos on the following pages and the circuit maps on pages 155 to 167 as a guide for making the final connections. The last step is to connect the circuits at the breaker panel (pages 192 to 193). After all connections are made, your work is ready for the final inspection.

Everything You Need

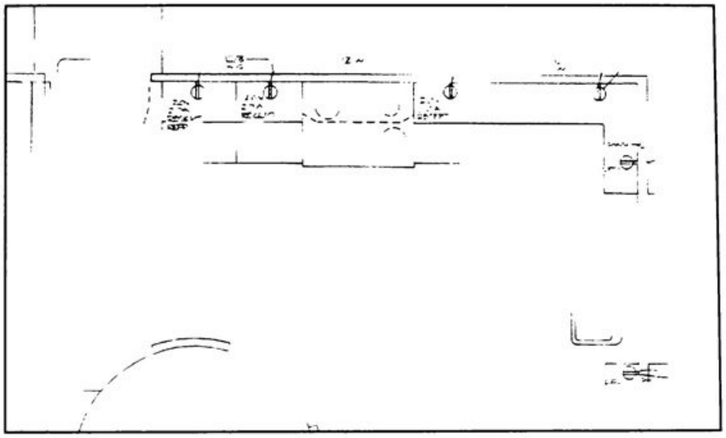
Pigtail wires, wire connectors, black tape.

Circuits #1 & #2

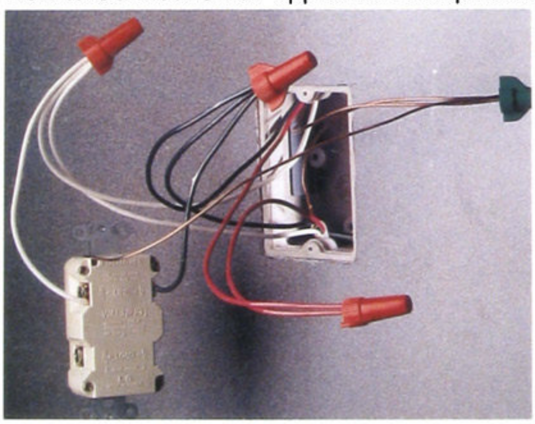
Two 20-amp, 120-volt small-appliance circuits.

- 7 GFCI receptacles
- 20-amp double-pole circuit breaker (see pages 192 to 193 for instructions on making final connections at the circuit breaker panel)

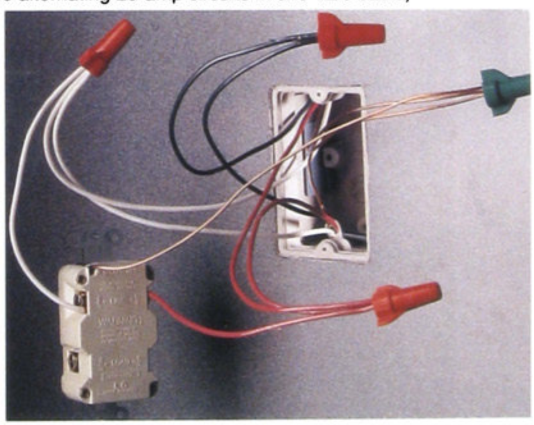
NOTE: In this project, two of the GFCI receptacles are installed in boxes that also contain switches from other circuits (page opposite).



How to Connect Small-appliance Receptacles (two alternating 20-amp circuits in one 12/3 cable)

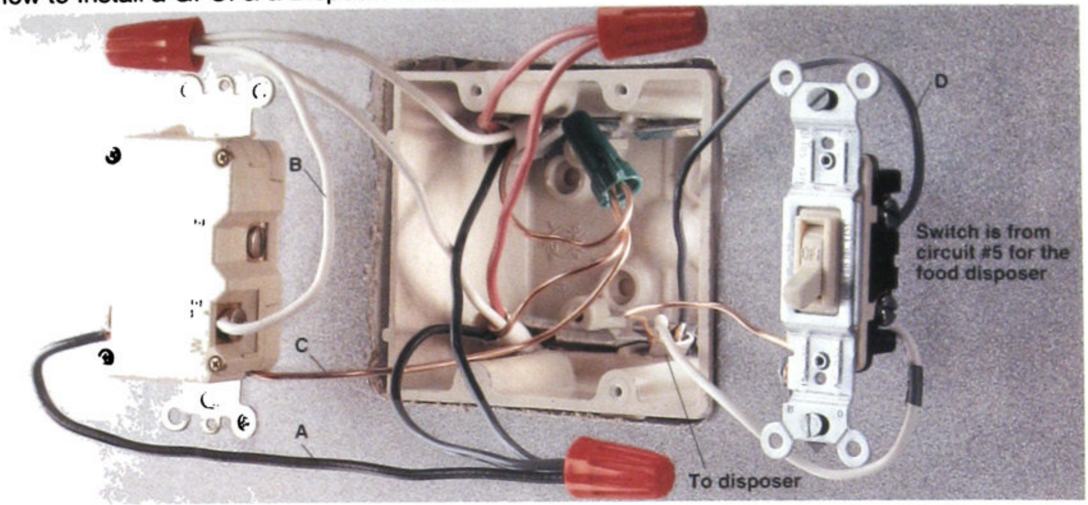


1 At alternate receptacles in the cable run (first, third, etc.), attach a black pigtail to a brass screw terminal marked LINE on the receptacle and to black wire from both cables. Connect a white pigtail to a silver screw (LINE) and to both white wires. Connect a grounding pigtail to the grounding screw and to both grounding wires. Connect both red wires together Tuck wires into box, then attach the receptacle and coverplate. (See circuit map 10, page 159.)



2 At remaining receptacles in the run, attach a red pigtail to a brass screw terminal (LINE) and to red wires from the cables. Attach a white pigtail to a silver screw terminal (LINE) and to both white wires. Connect a grounding pigtail to the grounding screw and to both grounding wires. Connect both black wires together Tuck wires into box, attach receptacle and coverplate. (see page 233 for optional method of GFCI protection.)

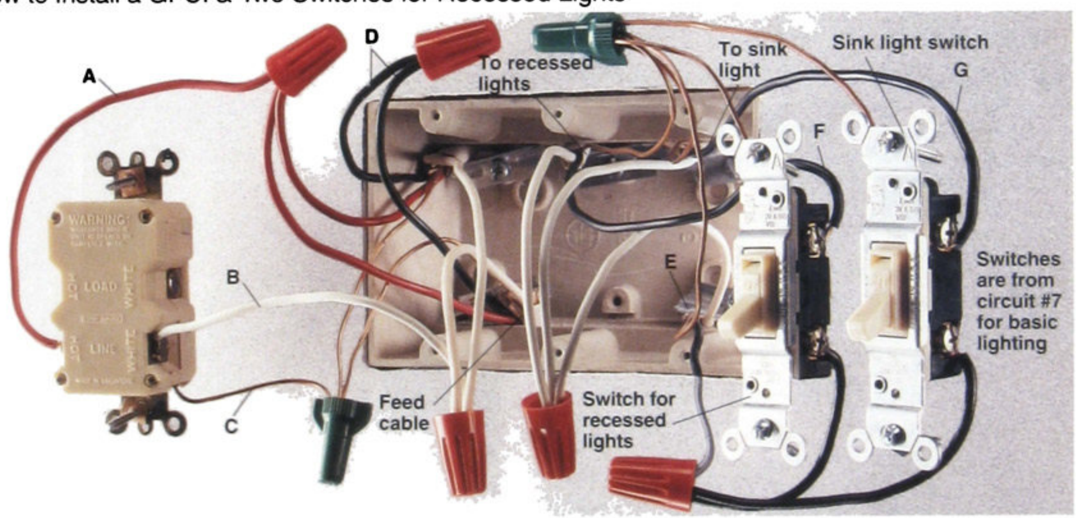
How to Install a GFCI & a Disposer Switch



Connect black pigtail (A) to GFCI brass terminal marked LINE, and to black wires from three-wire cables. Attach white pigtail (B) to silver terminal marked LINE, and to white wires from three-wire cables. Attach grounding pigtail (C) to GFCI grounding screw and to grounding wires from three-wire cables. Connect both red wires together. (See circuit map 11, page 160.)

Connect black wire from two-wire cable (D) to one switch terminal. Attach white wire to other terminal, and tag it black indicating it is hot. Attach grounding wire to switch grounding screw. (See circuit map 5, page 157.) Tuck wires into box, attach switch, receptacle, and coverplate.

How to Install a GFCI & Two Switches for Recessed Lights

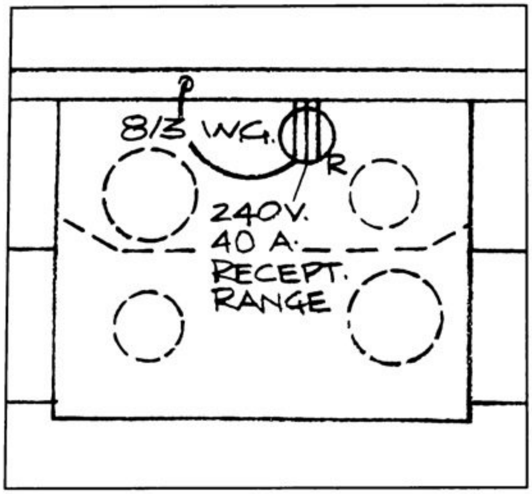


Connect red pigtail (A) to GFCI brass terminal labeled LINE, and to red wires from three-wire cables. Connect white pigtail (B) to silver LINE terminal and to white wires from three-wire cables. Attach grounding pigtail (C) to grounding screw and to grounding wires from three-wire cables. Connect black wires from three-wire cables (D) together. (See circuit map 11, page 160.) Attach a black pigtail to one screw on each switch and to black wire from two-wire feed cable (E). Connect black wire (F) from the two-wire cable leading to recessed lights to remaining screw on the switch for the recessed lights. Connect black wire (G) from two-wire cable leading to sink light to remaining screw on sink light switch. Connect white wires from all two-wire cables together. Connect pigtails to switch grounding screws and to all grounding wires from two-wire cables. (See circuit map 4, page 156.) Tuck wires into box; attach switches, receptacle, and coverplate.

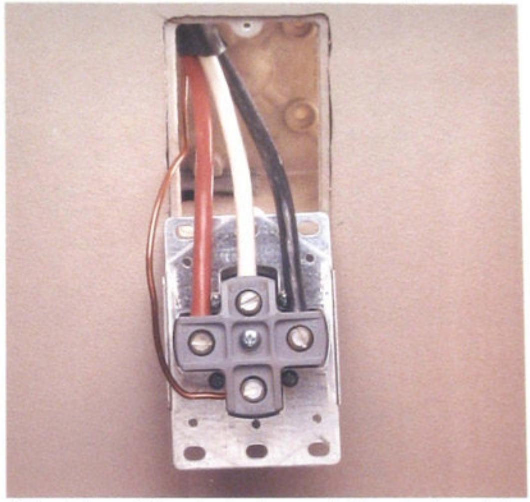
Circuit #3

A 50-amp, 120/240-volt circuit serving the range.

- 50-amp receptacle for range
- 50-amp double-pole circuit breaker (see pages 192 to 193 for instructions on making final connections at the circuit breaker panel)



How to Install 120/240 Range Receptacle

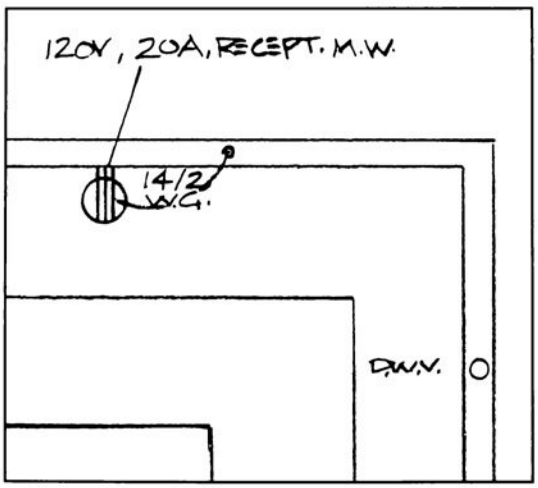


Attach the white wire to the neutral terminal, and the black and red wires to the remaining terminals. Attach the bare copper grounding wire to the grounding screw on the receptacle. Attach receptacle and coverplate. (See circuit map 14, page 161)

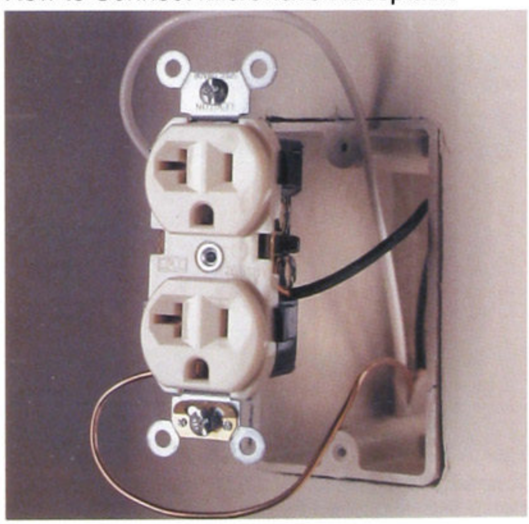
Circuit #4

A 20-amp, 120-volt circuit for the microwave.

- 20-amp duplex receptacle
- 20-amp single-pole circuit breaker (see pages 192 to 193 for instructions on making final connections at the circuit breaker panel)



How to Connect Microwave Receptacle



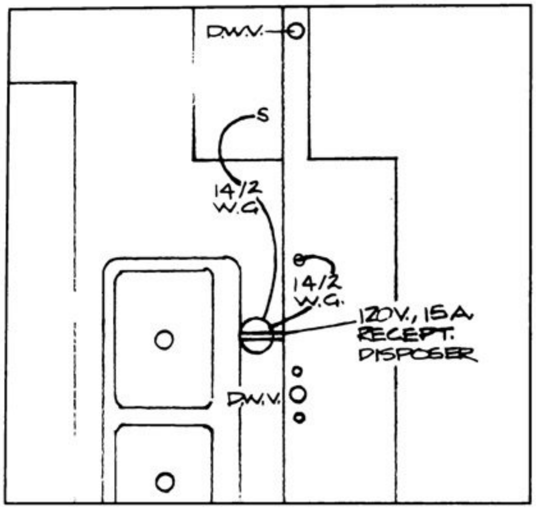
Connect black wire from the cable to a brass screw terminal on the receptacle. Attach the white wire to a silver screw terminal and the grounding wire to the receptacle's grounding screw Tuck wires into box, then attach the receptacle and the coverplate. (See circuit map 1, page 155.)

Circuit #5

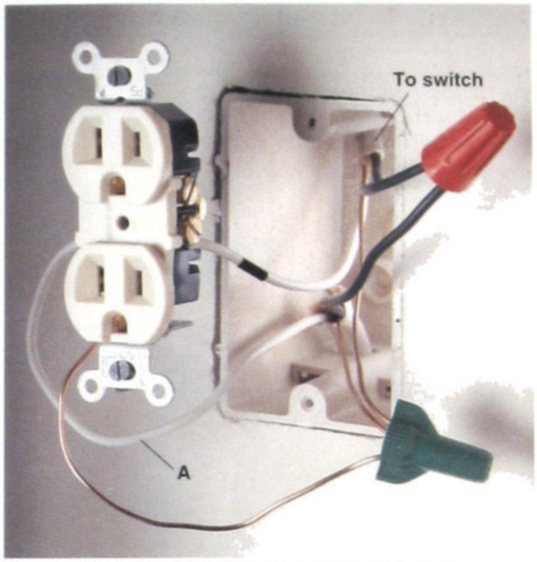
A 15-amp, 120-volt circuit for the food disposer.

- 15-amp duplex receptacle
- Single-pole switch
- 15-amp single-pole circuit breaker (see pages 192 to 193 for instructions on making the final connections at the circuit breaker panel)

NOTE: Final connection of the single-pole switch controlling the disposer is shown on page 239.



How to Connect Disposer Receptacle

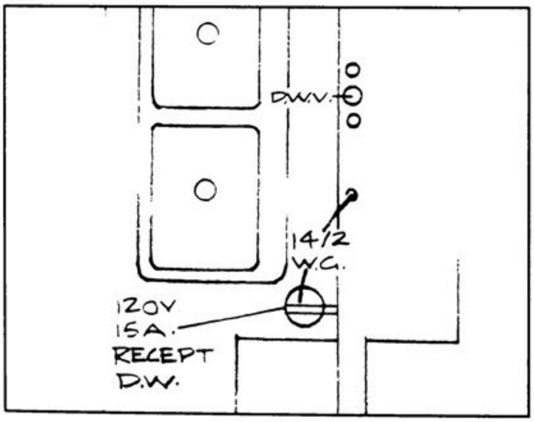


Connect black wires together. Connect white wire from feed cable (A) to silver screw on receptacle. Connect white wire from cable going to the switch to a brass screw terminal on the receptacle, and tag the wire with black indicating it is hot. Attach a grounding pigtail to grounding screw and to both cable grounding wires. Tuck wires into box, then attach receptacle and coverplate. (See circuit map 5, page 157.)

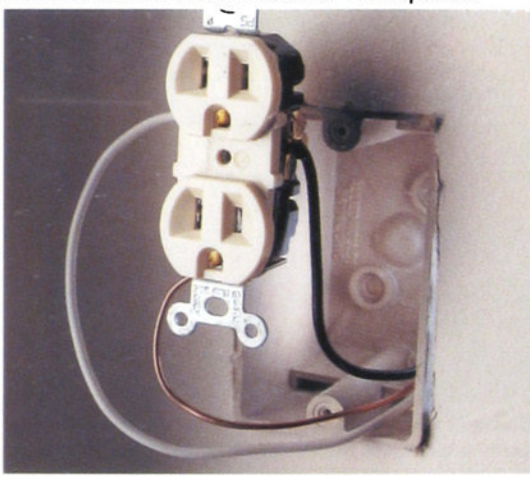
Circuit #6

A 15-amp, 120-volt circuit for the dishwasher.

- 15-amp duplex receptacle
- 15-amp single-pole circuit breaker (see pages 192 to 193 for instructions on making final connections at the circuit breaker panel)



How to Connect Dishwasher Receptacle



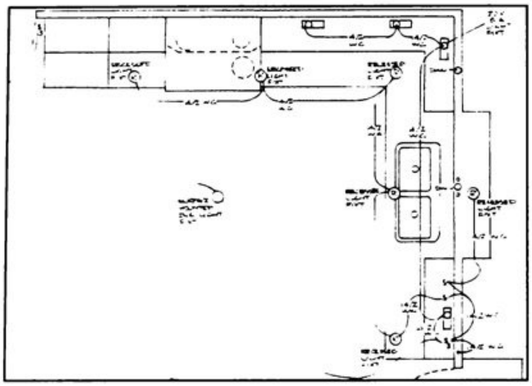
Connect the black wire to a brass screw terminal. Attach the white wire to a silver screw terminal. Connect the grounding wire to the grounding screw. Tuck wires into box, then attach receptacle and coverplate. (See circuit map 1, page 155.)

Circuit #7

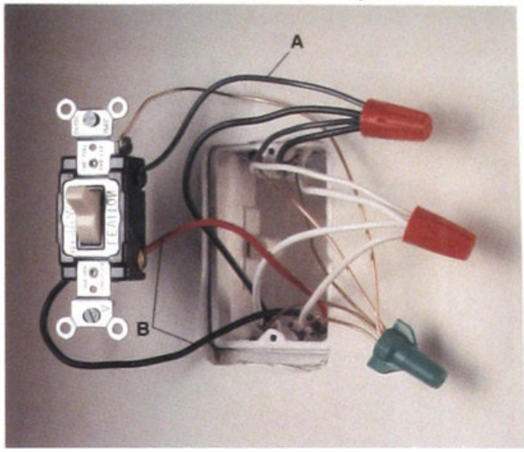
A 15-amp basic lighting circuit serving the kitchen.

- 2 three-way switches with grounding screws
- 2 single-pole switches with grounding screws
- Ceiling light fixture
- 6 recessed light fixtures
- 4 fluorescent under-cabinet fixtures
- 15-amp single-pole circuit breaker (pages 192 to 193)

NOTE: Final connections for the single-pole switches are shown on page 239.

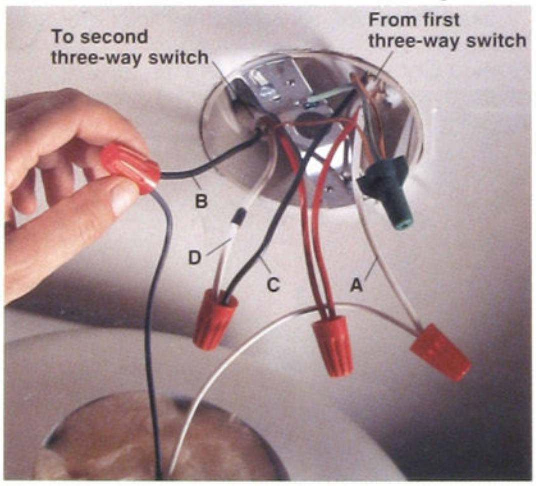


How to Connect First Three-way Switch



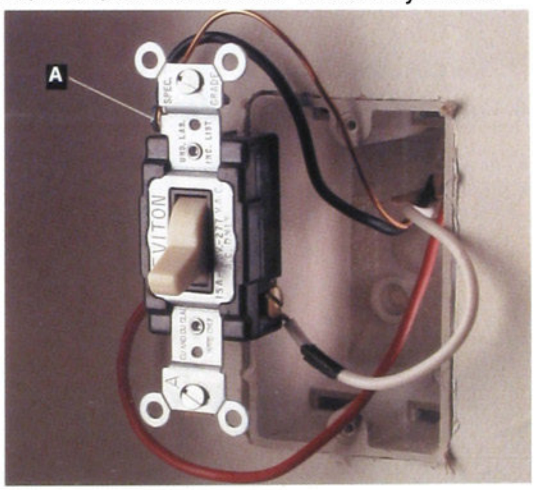
Connect a black pigtail to the common screw on the switch (A) and to the black wires from the two-wire cable. Connect black and red wires from the three-wire cable to traveler terminals (B) on the switch Connect white wires from all cables entering box together Attach a grounding pigtail to switch grounding screw and to all grounding wires in box. Tuck wires into box, then attach switch and coverplate (See circuit map 17 page 163.)

How to Connect Surface-mounted Ceiling Fixture



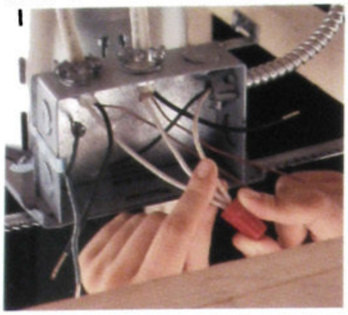
Connect white fixture lead to white wire (A) from first three-way switch. Connect black fixture lead to black wire (B) from second three-way switch. Connect black wire (C) from first switch to white wire (D) from second switch, and tag this white wire with black. Connect red wires from both switches together Connect all grounding wires together Mount fixture following manufacturer's instructions. (See circuit map 17, page 163.)

How to Connect Second Three-way Switch

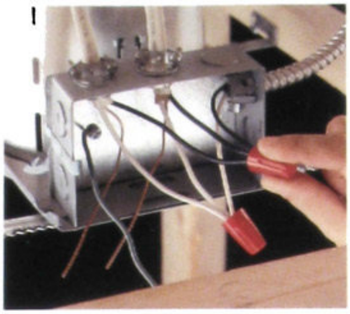


Connect black wire from the cable to the common screw terminal (A). Connect red wire to one traveler screw terminal. Attach the white wire to the other traveler screw terminal, and tag it with black indicating it is hot. Attach the grounding wire to the grounding screw on the switch. Tuck wires in box, then attach switch and coverplate. (See circuit map 17, page 163.)

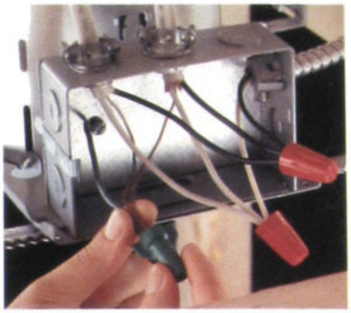
How to Connect Recessed Light Fixtures



1 Make connections before installing wallboard the work must be inspected first, and access to the junction box is easier Connect white cable wires to white fixture lead



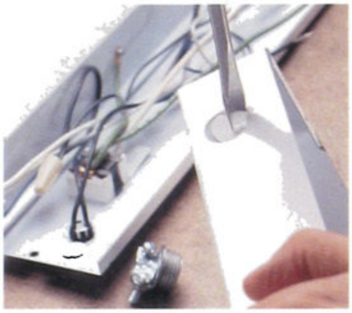
2 Connect black wires to black lead from fixture



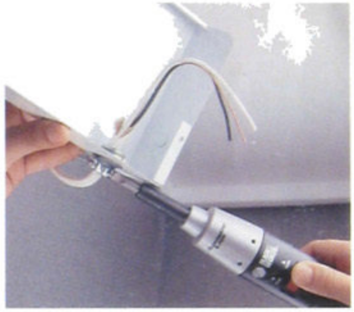
3 Attach a grounding pigtail to the grounding screw on the fixture, then connect all grounding wires Tuck wires into the junction box, and replace the cover

How to Connect Under-cabinet Fluorescent Task Light Fixtures

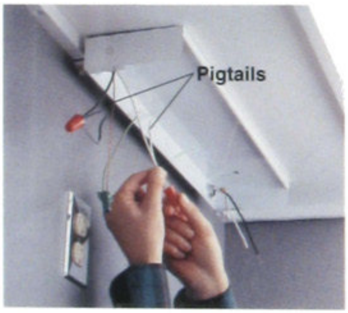
1 Drill holes through wall and cabinet at locations that line up with knockouts on the fixture, and retrieve cable ends (page 235)



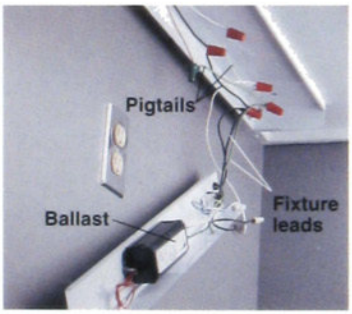
2 Remove access cover on fixture Open one knockout for each cable that enters fixture box, and install cable clamps.



3 Strip 8" of sheathing from each cable end Insert each end through a cable clamp leaving of sheathing in fixture box



4 Screw fixture box to cabinet. Attach black, white, and green pigtails of THHN/THWN wire (page 176) to wires from one-cable entering box Pigtails must be long enough to reach the cable at other end of box.

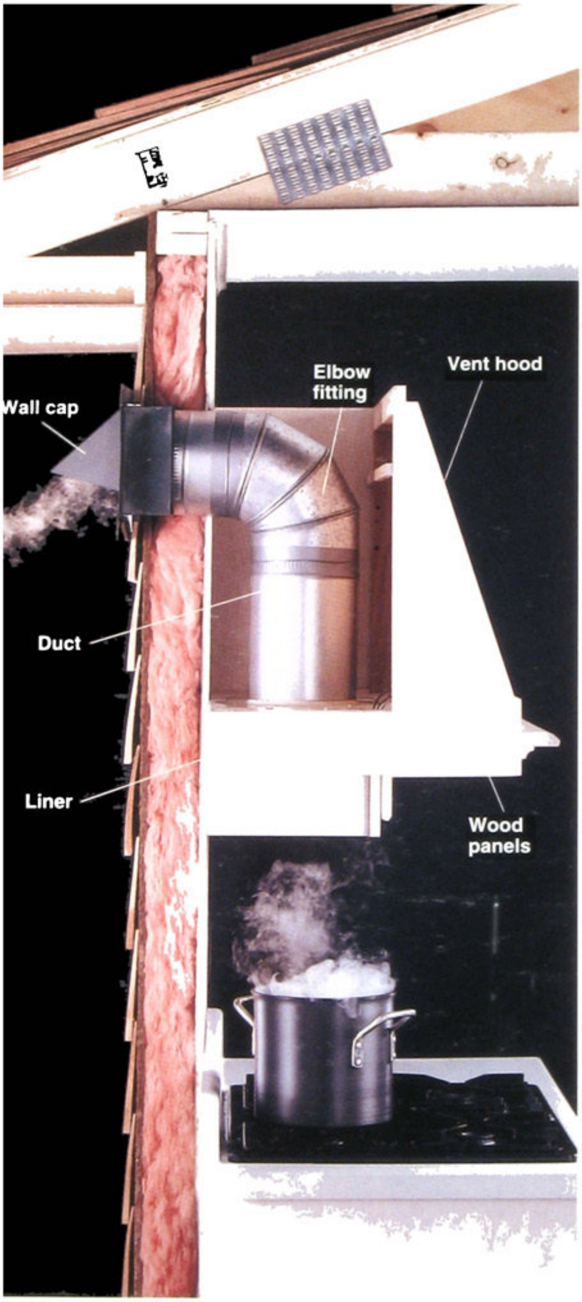


5 Connect black pigtail and circuit wire to black lead from fixture Connect white pigtail and circuit wire to white lead from fixture. Attach green pigtail and copper circuit wire to green grounding wire attached to the fixture box.

6 Tuck wires into box, and route THHN/THWN pigtails along one side of the ballast. Replace access cover and fixture lens.

Make hookups at circuit breaker panel (page 192) and arrange for final inspection.

Installing a Vent Hood



Wall-mounted vent hood (shown cut away) is installed between wall cabinets. Fan unit is fastened to a metal liner that is anchored to cabinets. Duct and elbow fitting exhaust cooking vapors to the outdoors through a wall cap. Vent fan and duct are covered by wood or laminate panels that match cabinet finish.

A vent hood eliminates heat, moisture, and cooking vapors from your kitchen. It has an electric fan unit with one or more filters, and a system of metal ducts to vent air to the outdoors. A ducted vent hood is more efficient than a ductless model, whi filters and recirculates air without removing it.

Metal ducts for a vent hood can be round or rectangular. Elbows and transition fittings are available for both types of ducts. These fittings let you vent around corners, or join duct components that differ in shape or size.

In the project shown here, the hood is installed i existing walls. If your project is in new construction, you can do the work more easily.

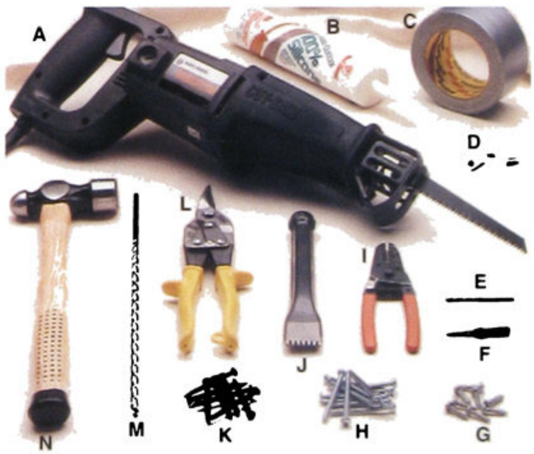
Everything You Need

Basic Hand Tools: tape measure, screwdrivers, hammer, eye protection, pencil.

Basic Power Tools: drill.

Basic Materials: duct sections, duct elbow, duct cap, vent hood, 1½" sheetmetal screws, 1¼" wallboard screws.

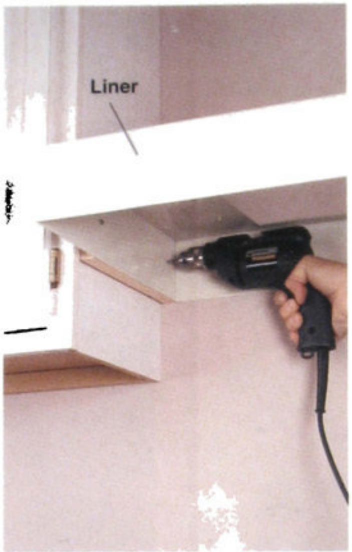
Specialty Tools & Supplies: photo, below.



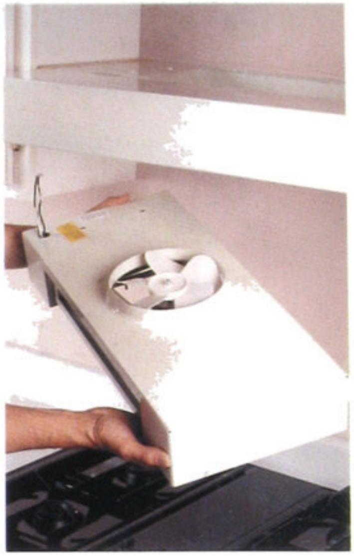
Specialty tools & supplies include reciprocating saw with coarse wood-cutting blade (A), silicone caulk (B), duct tape (C), wire connectors (D) twist bit (E), No. 9 counterbore drill bit (F) sheetmetal screws (G), 2 sheetmetal screws (H), combination tool (I), masonry chisel (J) 2" masonry nails (K) metal snips (L), masonry drill bit (M), ball-peen hammer (N).

How to Install a Wall-mounted Vent Hood

1 Attach ¾" × 4" × 12" wooden cleats to sides of the cabinets with 1¼" wallboard screws. Follow manufacturer's directions for proper distance from cooking surface.

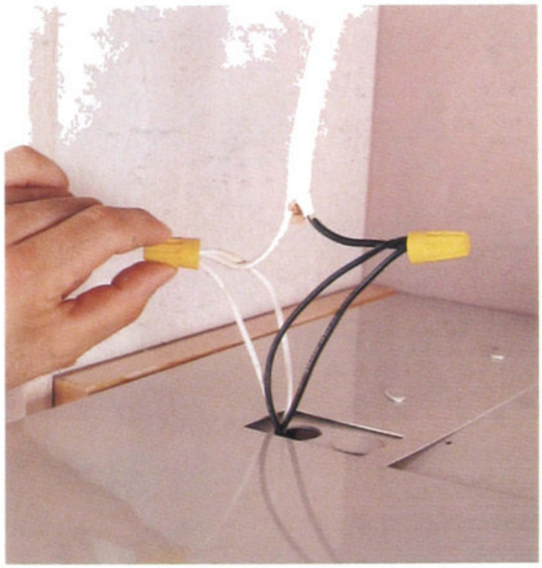


2 Position the hood liner between the cleats, and attach with ¾" sheetmetal screws.



3 Remove cover panels for light, fan, and electrical compartments on fan unit, as directed by manufacturer. Position fan unit inside liner and fasten by attaching nuts to mounting bolts inside light compartments.

4 Locate studs in wall where duct will pass, using a stud finder. Mark hole location. Hole should be ½" larger than diameter of duct. Complete cutout with a reciprocating saw or jig saw. Remove any wall insulation. Drill a pilot hole through outside wall.



5 Strip about ½" of plastic insulation from each wire in the circuit cable, using combination tool. Join the black wires, using a wire connector. Connect the white wires. Gently push the wires into the electrical box. Replace the coverpanels on the light and fan compartments.

(continued next page)

How to Install a Wall-mounted Vent Hood (continued)

6 Make duct cutout on exterior wall. On masonry drill a series of holes around outline of cutout. Remove waste with a masonry chisel and ball-peen hammer. On wood siding, make cutout with a reciprocating saw.

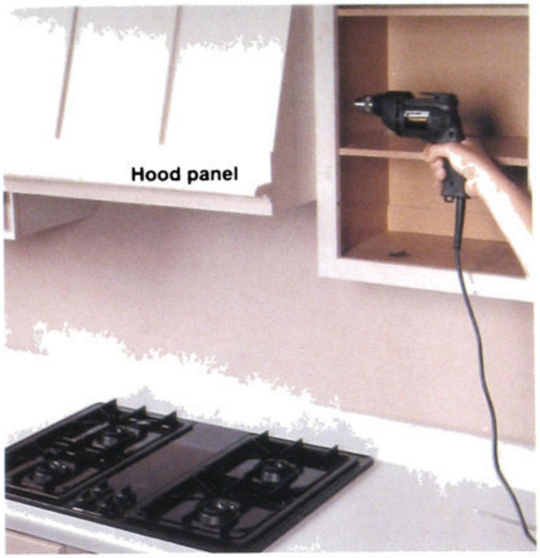
7 Attach first duct section by sliding the smooth end over the outlet flange on the vent hood. Cut duct sections to length with metal snips.

8 Drill three or four pilot holes around joint through both layers of metal, using ⅛" twist bit. Attach duct with ⅜" sheetmetal screws. Seal joint with duct tape.

9 Join additional duct sections by sliding smooth end over corrugated end of preceding section. Use an adjustable elbow to change directions in duct run. Secure all joints with sheetmetal screws and duct tape.

10 Install duct cap on exterior wall. Apply a thick bead of silicone caulk to cap flange. Slide cap over end of duct.

11 with 2 masonry nails or 1 ws on wood siding Wipe away

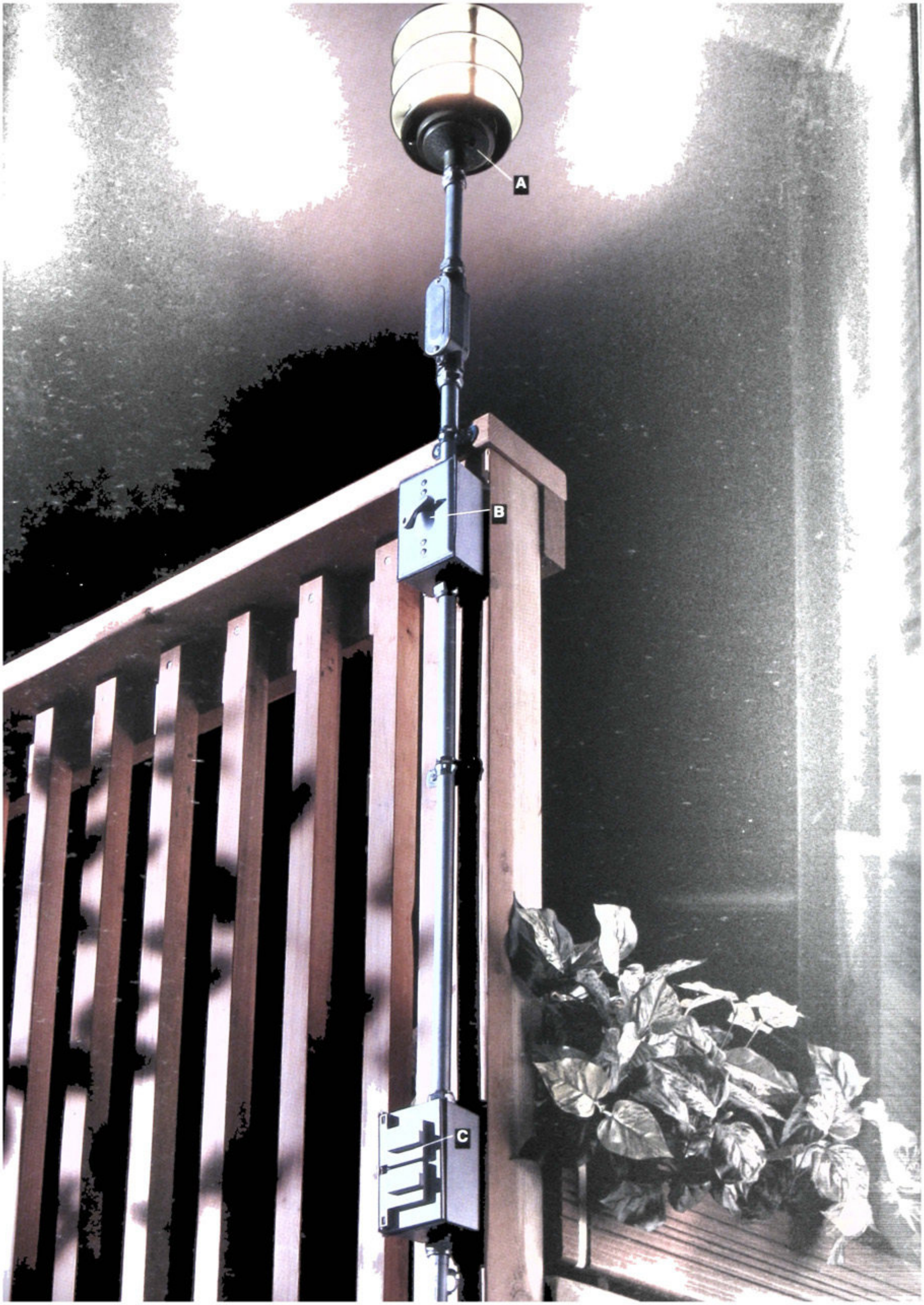


12 Slide the decorative hood pan between the wall cabinets Drill through the cabinet face frame with bit Attach the hood panel to th sheetmetal screws

Vent Hood Variations

Downdraft cooktop has a built-in blower unit that vents through the back or the bottom of a base cabi- A downdraft cooktop is a good choice for a itchen island or peninsula

Cabinet-mounted vent hood is attached to the bottom of a short 12" to 18 tall wall cabinet Metal ducts run inside this wall cabinet.


A
B
C

Installing Outdoor Wiring

Adding an outdoor circuit improves the value of your property and lets you enjoy your yard more fully. Doing the work yourself is also a good way to save money. Most outdoor wiring projects require digging underground trenches, and an electrician may charge several hundred dollars for this simple but time-consuming work.

Do not install your own wiring for a hot tub, fountain, or swimming pool. These outdoor water fixtures require special grounding techniques that are best left to an electrician.

In this chapter you learn how to install the following fixtures:

Decorative light fixtures (A) can highlight attractive features of your home and yard, like a deck, ornamental shrubs and trees, and flower gardens. See page 267

A weatherproof switch (B) lets you control outdoor lights without going indoors. See page 264

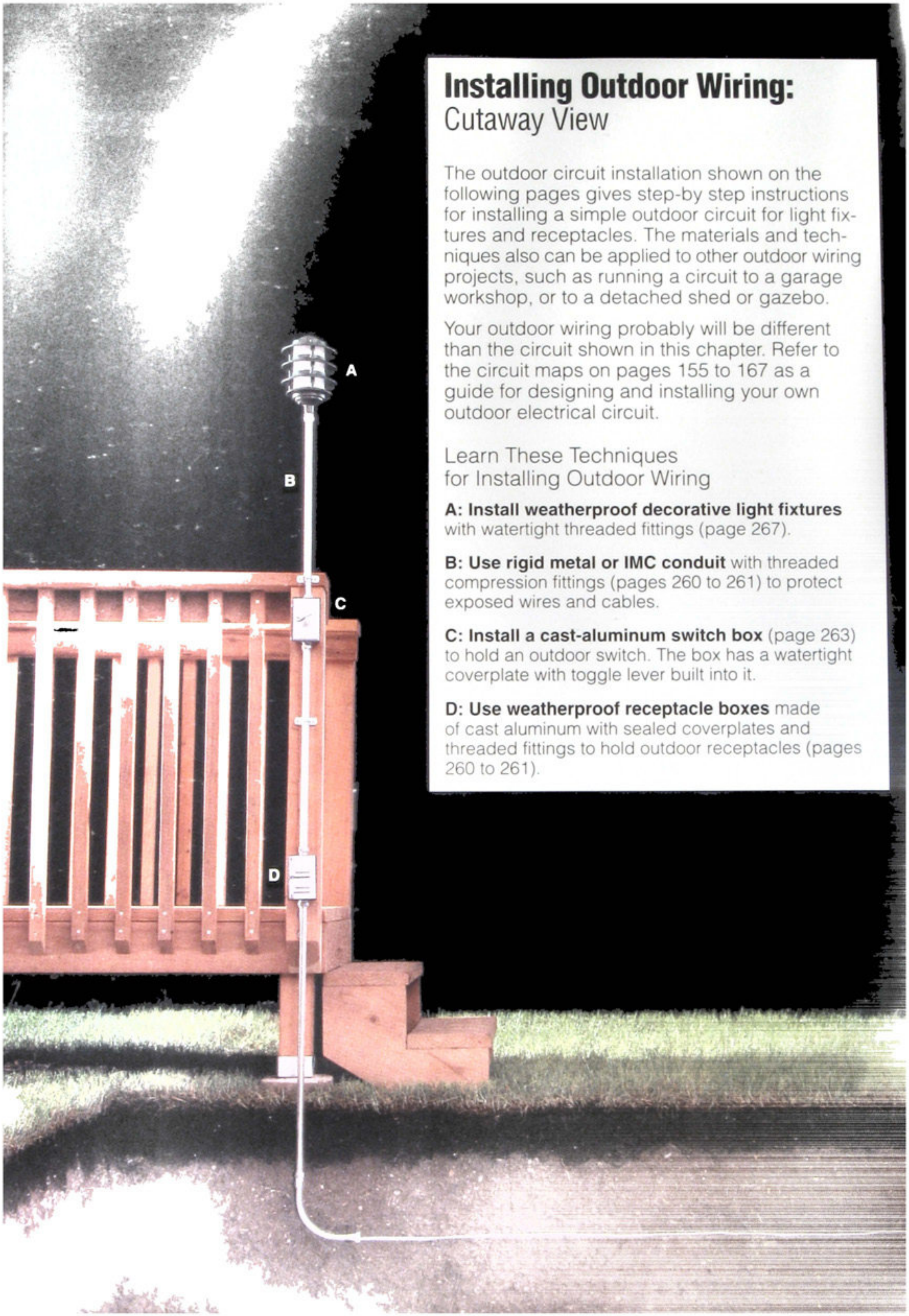
GFCI-protected receptacles (C) let you use electric lawn and garden tools, and provide a place to plug in radios, barbecue rotisseries, and other devices that help make your yard more enjoyable. See page 266.

A manual override switch (D) lets you control a motion-sensor light fixture from inside the house. See page 264

Five Steps for Installing Outdoor Wiring:

1. Plan the Circuit (pages 254 to 255).
2. Dig Trenches (pages 256 to 257).
3. Install Boxes & Conduit (pages 258 to 261).
4. Install UF Cable (pages 262 to 263).
5. Make Final Connections (pages 264 to 267).

A motion-sensor light fixture (photos, right) provides inexpensive and effective protection against intruders. It has an infrared eye that triggers the light fixture when a moving object crosses its path. Choose a light fixture with a photo cell (E) that prevents the fixture from triggering in daylight. Look for an adjustable timer (F) that controls how long the light keeps shining after motion stops. Better models have range controls (G) to adjust the sensitivity of the motion-sensor eye. See pages 264 to 265



Installing Outdoor Wiring:
Cutaway View

The outdoor circuit installation shown on the following pages gives step-by step instructions for installing a simple outdoor circuit for light fixtures and receptacles. The materials and techniques also can be applied to other outdoor wiring projects, such as running a circuit to a garage workshop, or to a detached shed or gazebo.

Your outdoor wiring probably will be different than the circuit shown in this chapter. Refer to the circuit maps on pages 155 to 167 as a guide for designing and installing your own outdoor electrical circuit.

Learn These Techniques for Installing Outdoor Wiring

A: Install weatherproof decorative light fixtures with watertight threaded fittings (page 267).

B: Use rigid metal or IMC conduit with threaded compression fittings (pages 260 to 261) to protect exposed wires and cables.

C: Install a cast-aluminum switch box (page 263) to hold an outdoor switch. The box has a watertight coverplate with toggle lever built into it.

D: Use weatherproof receptacle boxes made of cast aluminum with sealed coverplates and threaded fittings to hold outdoor receptacles (pages 260 to 261).

E: Install a retrofit light fixture box (page 259) to hold a motion-sensor security light. Retrofit boxes are used to install electrical fixtures that fit inside existing finished walls. The box is sealed with a foam gasket that fits between the light fixture and the box.

F: Run NM cable (pages 182 to 183, 259) through walls to provide power to electrical boxes that fit inside finished walls.

G: Install retrofit single-gang boxes (page 259) to hold a manual override switch for the motion-sensor light and the GFCI receptacle.

H: Attach a cast-aluminum extension ring to a retrofit receptacle box (page 260) to hold a GFCI receptacle.

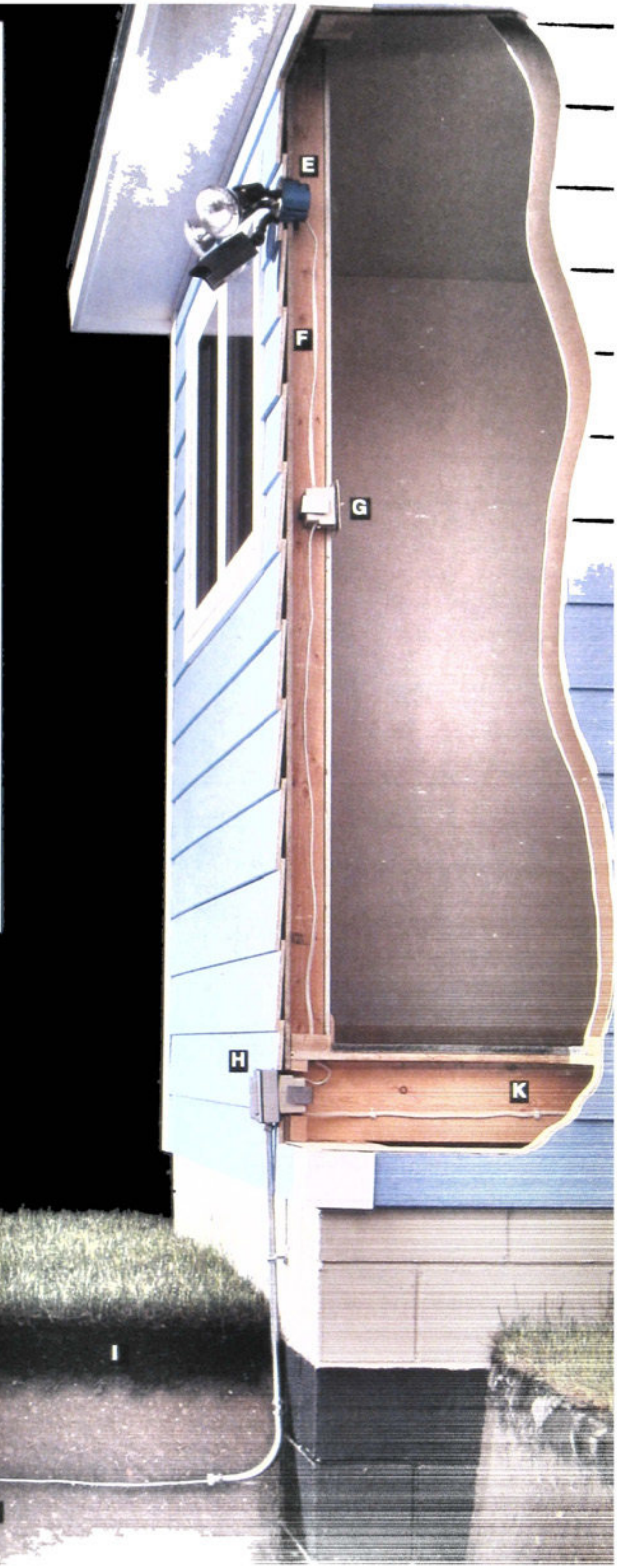
I: Dig trenches (pages 256 to 257) to hold underground cables bringing power from the house to yard fixtures.

J: Install UF (underground feeder) cable (pages 262 to 263) to bring power from the house to the outdoor fixtures.

K: Run a feeder cable to connect the outdoor circuit to the circuit breaker panel (page 260).

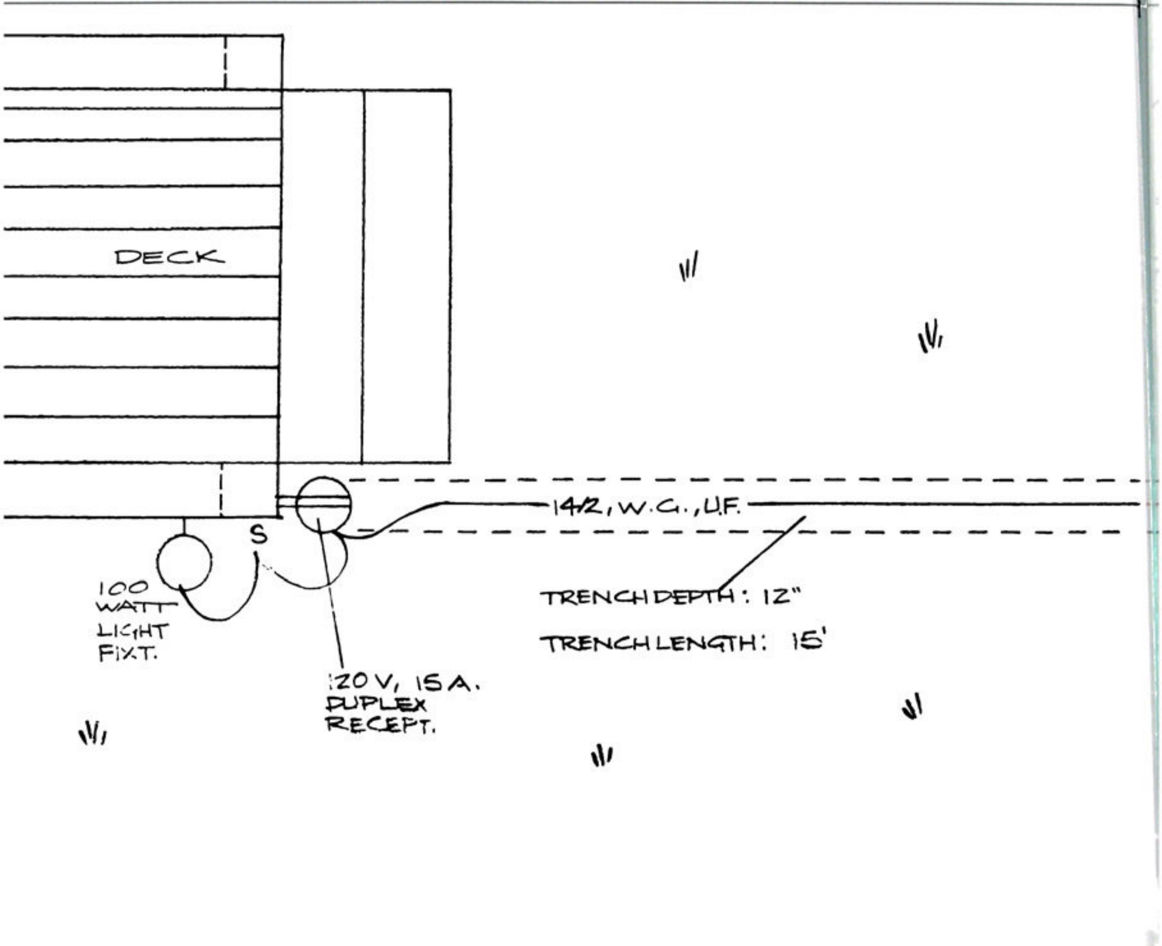
Tools You Will Need

Tape measure, drill with masonry bits and twist bits, jig saw or reciprocating saw, shovel, hammer, screwdriver, caulk gun, ball-peen hammer or masonry hammer, masonry chisel, hacksaw, fish tape, cable ripper, combination tool, utility knife, needlenose pliers.



Installing Outdoor Wiring: Diagram View

This diagram view shows the layout of the outdoor wiring project featured on these pages. It includes the location of the switches, receptacles, light fixtures, and cable runs you will learn how to install in this chapter. The layout of your yard and the location of obstacles will determine the best locations for lights, receptacles, and underground cable runs. The wiring



Yard is drawn to scale, with the lengths of trenches and cable runs clearly labeled.

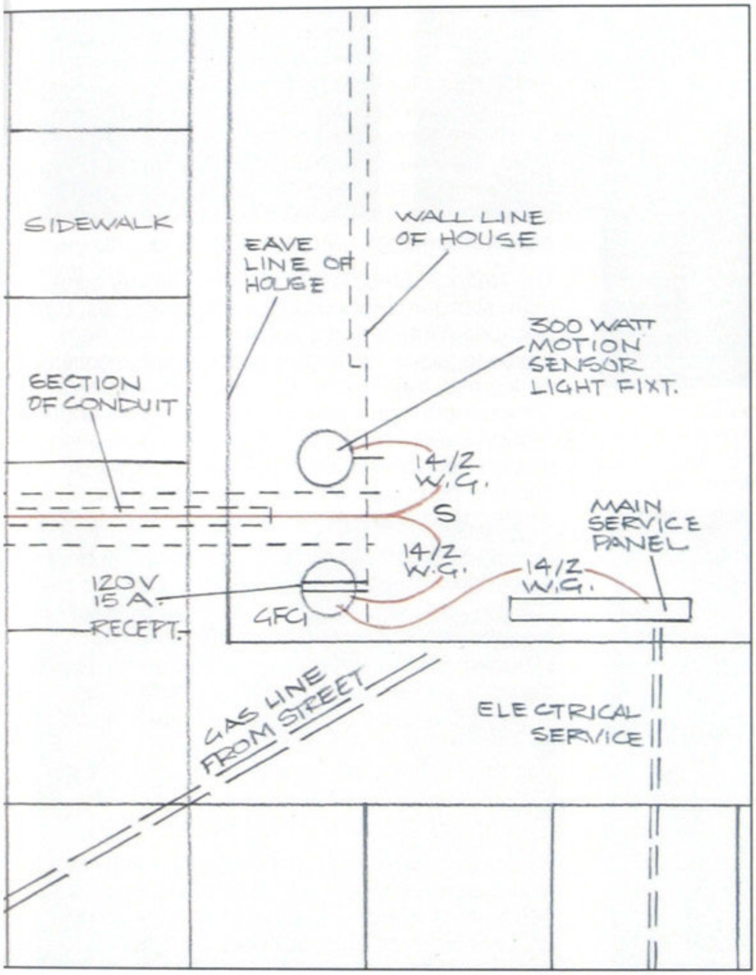
Decorative light fixture is positioned to highlight the deck. Decorative fixtures should be used sparingly, to provide accent only to favorite features of your yard, such as flower beds, ornamental trees, or a patio.

Outdoor receptacle is positioned on the deck post, where it is accessible yet unobtrusive. Another good location for a receptacle is between shrubs.

diagram for your own project may differ greatly from the one shown here, but the techniques shown on the following pages will apply to any outdoor wiring project.

Note:

See pages 152 to 153 for a key to the common electrical symbols used in this diagram, and to learn how to draw your own wiring diagrams.



Motion-sensor security light is positioned so it has a good "view" of entryways to the yard and home, and is aimed so it will not shine into neighboring yards.

Manual override switch for motion-sensor light is installed at a convenient indoor location. Override switches are usually mounted near a door or window.

Entry point for circuit is chosen so there is easy access to the circuit breaker panel. Basement rim joists or garage walls make good entry points for an outdoor circuit.

Yard obstacles, like sidewalks and underground gas and electrical lines, are clearly marked as an aid to laying out cable runs.

Underground cables are laid out from the house to the outdoor fixtures by the shortest route possible to reduce the length of trenches.

GFCI receptacle is positioned near the start of the cable run and is wired to protect all wires to the end of the circuit.

Check for underground utilities when planning trenches for underground cable runs. Avoid lawn sprinkler pipes, and consult your electric utility office, phone company gas and water department, and cable television vendor for the exact locations of underground utility lines. Many utility companies send field representatives to show homeowners how to avoid dangerous underground hazards.

Choosing Cable Sizes for an Outdoor Circuit

Circuit length		
Less than 50 ft.	**50 ft. or more**	**Circuit size**
14-gauge	12-gauge	15-amp
12-gauge	10-gauge	20-amp

Consider the circuit length when choosing cable sizes for an outdoor circuit. In very long circuits, normal wire resistance leads to a substantial drop in voltage. If your outdoor circuit extends more than 50 feet, use larger-gauge wire to reduce the voltage drop. For example, a 15-amp circuit that extends more than 50 feet should be wired with 12-gauge wire instead of 14-gauge. A 20-amp circuit longer than 50 feet should be wired with 10-gauge cable.

1: Plan the Circuit

As you begin planning an outdoor circuit, visit your electrical inspector to learn about local code requirements for outdoor wiring. The techniques for installing outdoor circuits are much the same as for installing indoor wiring. However, because outdoor wiring is exposed to the elements, it requires the use of special weatherproof materials, including UF cable (page 176), rigid metal or schedule 40 PVC plastic conduit (pages 184 to 185), and weatherproof electrical boxes and fittings (pages 170 to 171).

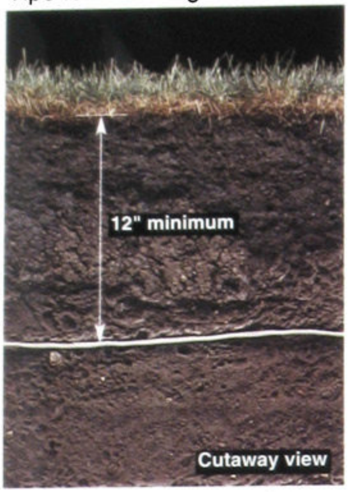
The National Electrical Code (NEC) gives minimum standards for outdoor wiring materials, but because climate and soil conditions vary from region to region, your local building and electrical codes may have more restrictive requirements. For example, some regions require that all underground cables be protected with conduit, even though the National Electrical Code allows UF cable to be buried without protection at the proper depths (page opposite).

For most homes, an outdoor circuit is a modest power user. Adding a new 15-amp, 120-volt circuit provides enough power for most outdoor electrical needs. However, if your circuit will include more than three large light fixtures (each rated for 300 watts or more) or more than four receptacles, plan to install a 20-amp, 120-volt circuit. Or, if your outdoor circuit will supply power to heating appliances or large workshop tools in a detached garage, you may require several 120-volt and 240-volt circuits.

Before drawing wiring plans and applying for a work permit, evaluate electrical loads (pages 148 to 151) to make sure the main service provides enough amps to support the added demand of the new wiring.

A typical outdoor circuit takes one or two weekends to install, but if your layout requires very long underground cables, allow yourself more time for digging trenches, or arrange to have extra help. Also make sure to allow time for the required inspection visits when planning your wiring project. See pages 138 to 147 for more information on planning a wiring project.

Tips for Planning an Outdoor Circuit



Bury UF cables deep if the
y a GFCI
r than 20 amps
18 deep if the
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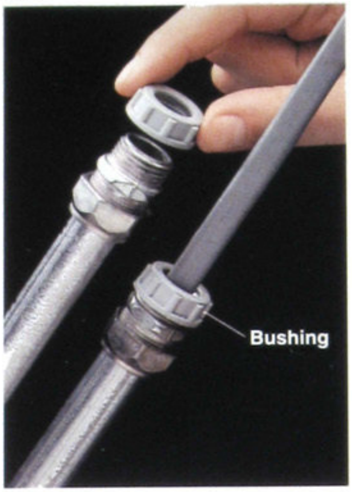
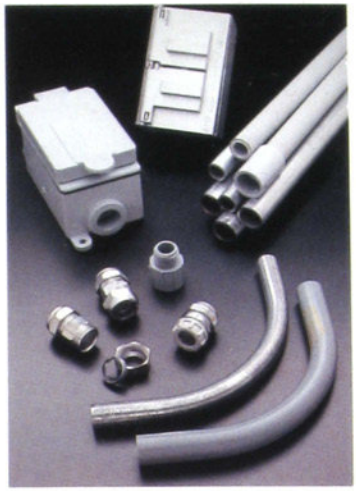
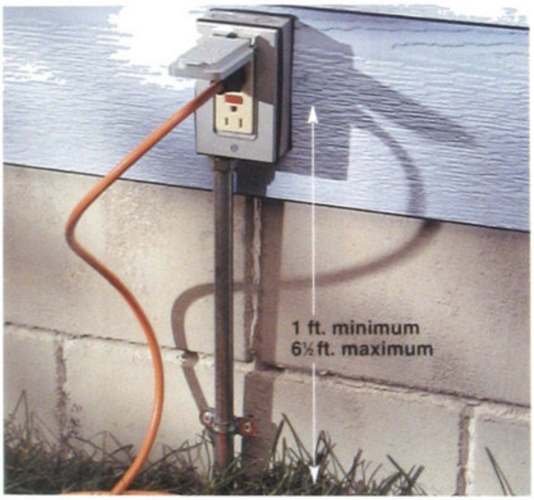
20



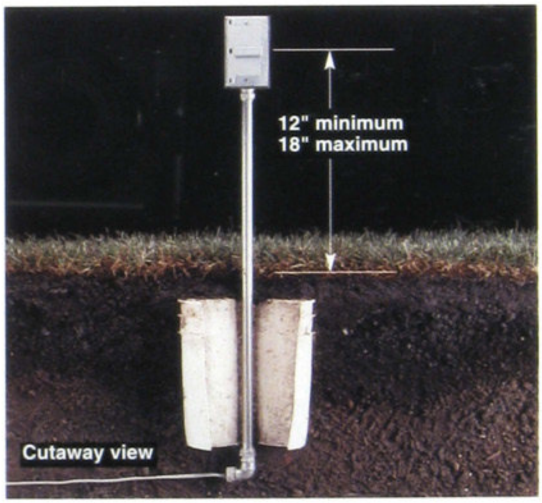
Protect cable entering conduit by attaching a plastic bushing to the nd of Th



Protect exposed wiring ground rigic



Prevent shock by making sure all outdoor recepta- rotected by GFCIs (page 74). A single GFCI can be wired to protect other fixtures on Outdoor receptacles should be at least round level and enclosed in weather- oxes with watertight covers.



Anchor freestanding receptacles that are not attached to a structure by embeddin the ric id metal conduit or schedule 40 PVC plastic conduit in a concrete footing. One way to do this is by running conduit through a plastic bucket, then filling the bucket with concrete. Freestanding receptacles should be least 12" but no more than 18 above ground level—requirements vary, so check with your local inspector.

Installing Outdoor Wiring

2: Dig Trenches

When laying underground cables, save time and minimize lawn damage by digging trenches as narrow as possible. Plan the circuit to reduce the length of cable runs.

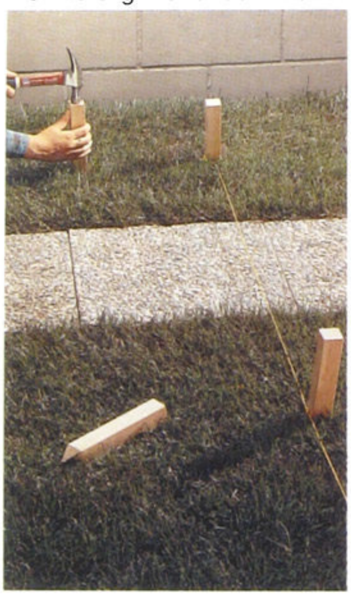
If your soil is sandy, or very hard and dry, water the ground thoroughly before you begin digging Lawn sod can be removed, set on strips of plastic, and replaced after cables are laid Keep the removed sod moist but not wet, and replace it within two or three days. Otherwise, the grass underneath the plastic may die.

If trenches must be left unattended, make sure to cover them with scrap pieces of plywood to prevent accidents and to keep water out.

Materials You Will Need

Stakes, string, scrap piece of conduit, compression fittings, plastic bushings.

How to Dig Trenches for Underground Cables



1 Mark the outline of trenches with wooden stakes and string

2 Cut two 18"-wide strips of plastic, and place one strip on each side of the trench outline

3 Remove blocks of sod from the trench outline, using a shovel Cut sod 2" to 3" deep to keep roots intact Place the sod on one of the plastic strips, and keep it moist.

4 nches to the depth your local code Head the second stri

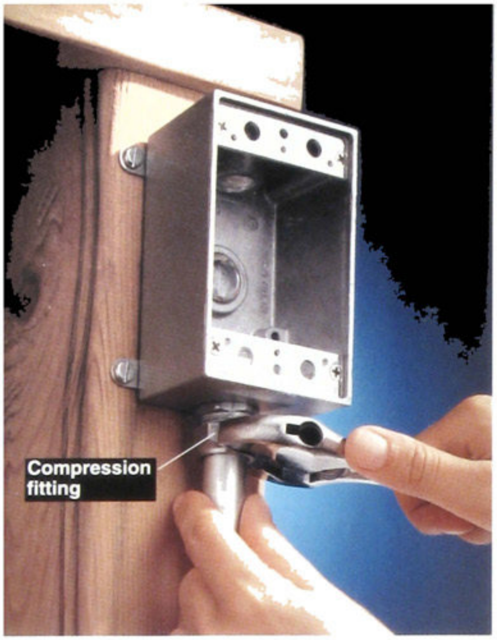
5 To cable under a sidew cut a length of metal conduit about 1 foot longer than width sidewalk then flatten one en the conduit to form a sharp

6 Dri soi ball-peen wood bi the p

7 Cut off the ends of the conduit with a hacksaw leaving about 2 exposed conduit on each side Underground cable will run through the conduit

8 Attach a compression fitting and plastic bushing to each end of the conduit The plastic fittings will prevent the sharp edges of the conduit from damaging the cable sheathing

9 If trenches must be left unattended temporarily cover them with scrap plywood to prevent accidents.



Electrical boxes for an outdoor circuit must be weatherproof. This outdoor receptacle box made of cast aluminum has sealed seams and is attached to conduit with threaded, watertight compression fittings.

Installing Outdoor Wiring

3: Install Boxes & Conduit

Use cast-aluminum or PVC plastic boxes for outdoor fixtures, and install approved conduit to protect exposed cables. Standard metal and plastic electrical boxes are not watertight, and should never be used outdoors. Some local codes require you to install conduit to protect all underground cables, but in most regions this is not necessary. Many local codes allow you to use boxes and conduit made with PVC plastic (page 171), while others allow only cast-aluminum boxes and metal conduit.

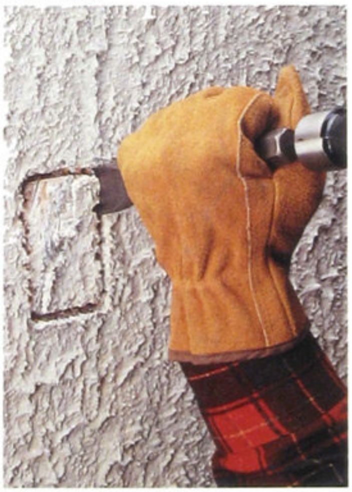
Begin work by installing the retrofit boxes and the cables that run between them inside finished walls. Then install the outdoor boxes and conduit.

Materials You Will Need

NM two-wire cable, cable staples, plastic retrofit light fixture box with grounding clip, plastic single-gang retrofit boxes with internal clamps, extension ring, silicone caulk, IMC or rigid metal conduit, pipe straps, conduit sweep, compression fittings, plastic bushings, masonry anchors, single-gang outdoor boxes, galvanized screws, grounding pigtails, wire connectors.

How to Install Electrical Boxes & Conduit

1 Outline the GFCI receptacle box on the exterior wall. First drill pilot holes at the corners of the box outline, and use a piece of stiff wire to probe the wall for electrical wires or plumbing pipes. Complete the cutout with a jig saw or reciprocating saw.



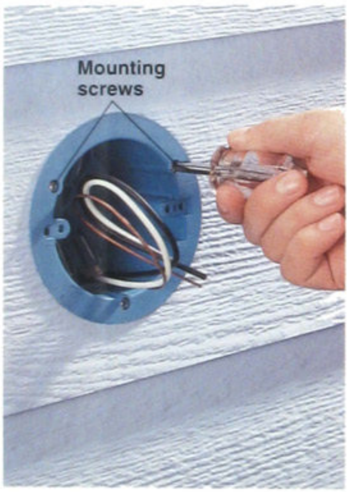
Masonry variation: To make cutouts in masonry, drill a line of holes inside the box outline, using a masonry bit, then remove waste material with a masonry chisel and ball-peen hammer.

2 From inside house, make the cutout for the indoor switch in the same stud cavity that contains the GFCI cutout. Outline the box on the wall, then drill a pilot hole and complete the cutout with a wallboard saw or jig saw.

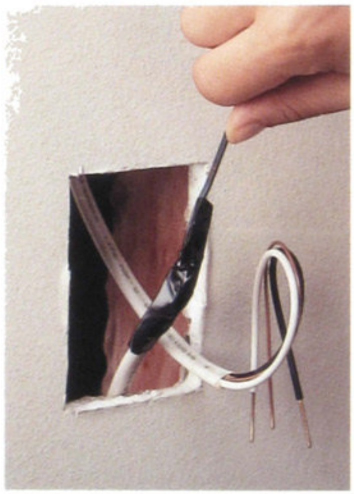
3 On outside of house, make the cutout for the motion-sensor light fixture in the same stud cavity with the GFCI cutout. Outline the light fixture box on the wall, then drill a pilot hole and complete the cutout with a wallboard saw or jig saw

4 Estimate the distance between the indoor switch box and the outdoor motion-sensor box, and cut a length of NM cable about 2 feet longer than this distance. Use a fish tape to pull the cable from the switch box to the motion-sensor box. See pages 182 to 183 for tips on running cable through finished walls.

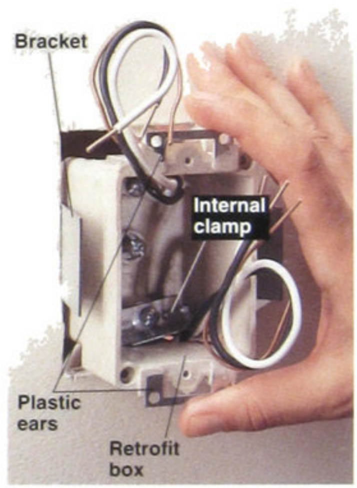
5 Strip about 10" of outer insulation from the end of the cable, using a cable ripper. Open a knockout in the retrofit light fixture box with a screwdriver. Insert the cable into the box so that at least ¼" of outer sheathing reaches into the box.



6 Insert the box into the cutout opening, and tighten the mounting screws until the brackets draw the outside flange firmly against the siding.



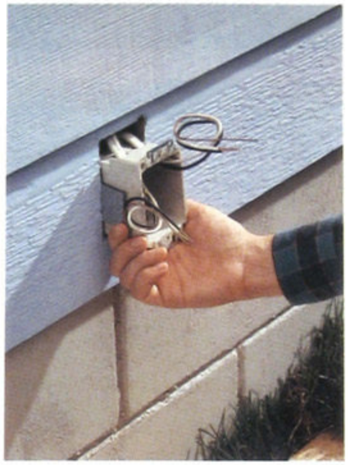
7 Estimate the distance between the outdoor GFCI cutout and the indoor switch cutout, and cut a length of NM cable about 2 feet longer than this distance. Use a fish tape to pull the cable from the GFCI cutout to the switch cutout. Strip 10" of outer insulation from both ends of each cable.



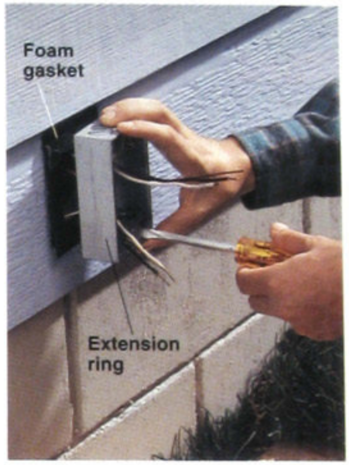
8 Open one knockout for each cable that will enter the box. Insert the cables so at least of outer sheathing reaches inside box. Insert box into cutout, and tighten the mounting screw in the rear of the box until the bracket draws the plastic ears against the wall. Tighten internal cable clamps.

(continued next page)

9 Install NM cable from circuit breaker panel to GFCI cutout Allow an extra 2 feet of cable at panel end and an extra foot at GFCI end Attach cable to framing members with cable staples Strip 10' of outer sheathing from the GFCI end of cable and of insulation from each wire



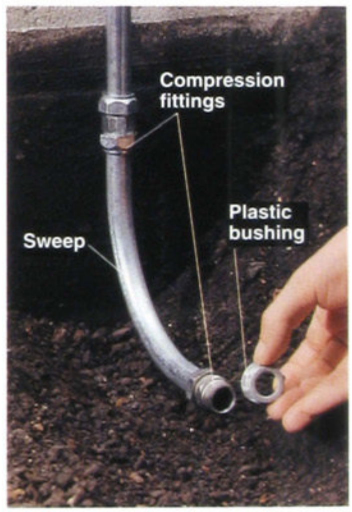
10 Open one knockout for each cable that will enter the GFCI box Insert the cables so at least of sheathing reaches into the box Push the box into the cutout, and tighten the mounting screw until the bracket draws the plaster ears tight against the wall



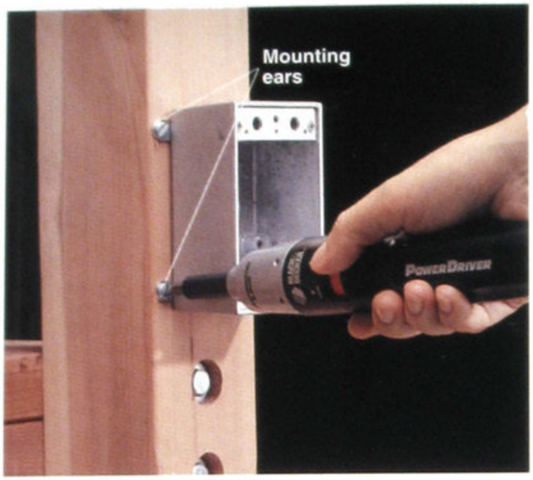
11 Position a foam gasket over the GFCI box, then attach an extension ring to the box, using the mounting screws included with the extension ring Seal any gaps around the extension ring with silicone caulk

12 Measure and cut a length of IMC conduit to reach from the bottom of the extension ring to a point about 4 from the bottom of the trench Attach the conduit to the extension ring using a compression fitting

13 Anchor the conduit to the wall with a pipe strap and masonry screws Or use masonry anchors and pan-head screws. Drill pilot holes for anchors, using a masonry drill bit.



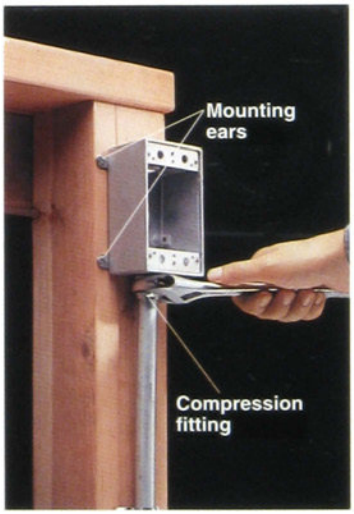
14 Attach compression fittings to the ends of metal sweep fitting, then attach the sweep fitting to the end of the conduit Screw a plastic bushing onto the exposed fitting end of the sweep to keep the metal edges from damaging the cable.



15 Attach mounting ears to the back of a weather-proof receptacle box then attach the box to the frame by driving galvanized screws through the nto the post

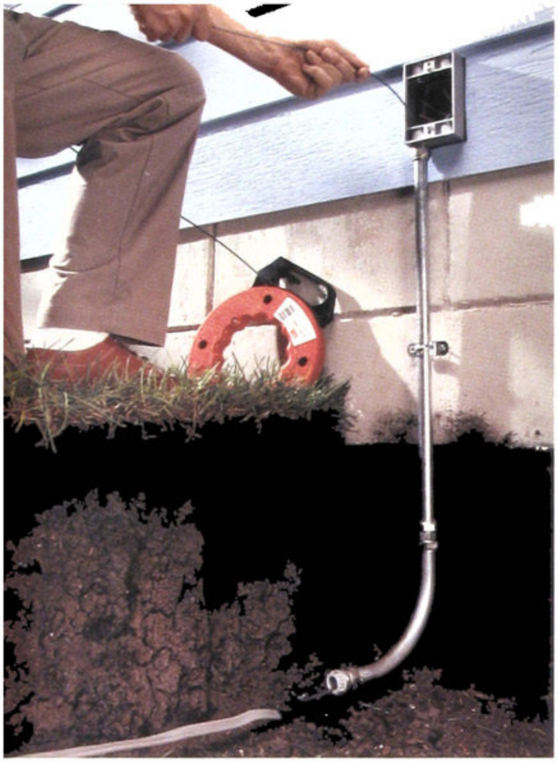
16 Measure and cut a length of IMC conduit reach from the bottom of the receptacle box a point about 4 from the bottom of the trench the conduit to the box ith a compression Attach a sweep fitting and plastic bushing bottom of the conduit using compression (see step 14)

17 Cut a length of IMC conduit to reach from the top of the receptacle box to the switch box location Attach the conduit to the receptacle box with a compression fitting Anchor the conduit to e deck frame with pipe straps



18 Attach mounting ears to the back of switch box, then loosely attach the box to the conduit with a compression fitting Anchor the box to the deck frame by driving galvanized screws through the ears and into the wood Then tighten the compression fitting with a wrench.

19 Measure and cut a short length of IMC conduit to reach from the top of the switch box to the deck light location Attach the conduit with a compression fitting



Installing Outdoor Wiring

4: Install UF Cable

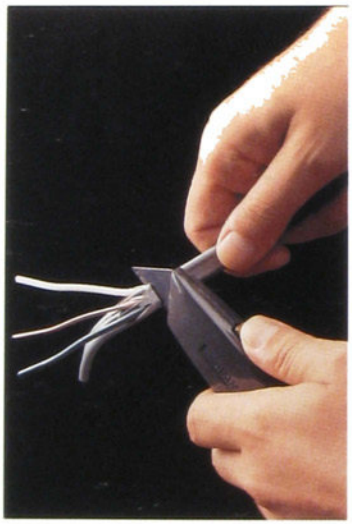
Use UF cable for outdoor wiring if the cable will come in direct contact with soil. UF cable has a solid-core vinyl sheathing and cannot be stripped with a cable ripper. Instead, use a utility knife and the method shown (steps 5 & 6, page opposite). Never use NM cable for outdoor wiring. If your local code requires that underground wires be protected by conduit, use THHN/THWN wire (page 176) instead of UF cable.

After installing all cables, you are ready for the rough-in inspection. While waiting for the inspector, temporarily attach the weatherproof coverplates to the boxes or cover them with plastic to prevent moisture from entering. After the inspector has approved the rough-in work, fill in all cable trenches and replace the sod before making the final connections.

Materials You Will Need

UF cable, electrical tape, grounding pigtails, wire connectors, weatherproof coverplates.

How to Install Outdoor Cable



1 Measure and cut all UF cables, allowing an extra 12" at each box. At each end of the cable, use a utility knife to pare away about 3" of outer sheathing, leaving the inner wires exposed.

2 Feed a fish tape down through the conduit from the GFCI box. Hook the wires at one end of the cable through the loop in the fish tape, then wrap electrical tape around the wires up to the sheathing. Carefully pull the cable through the conduit.

3 Lay the cable along the bottom of the trench, making sure it is not twisted. Where cable runs under a sidewalk, use the fish tape to pull it through the conduit.

4

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6 Pull back
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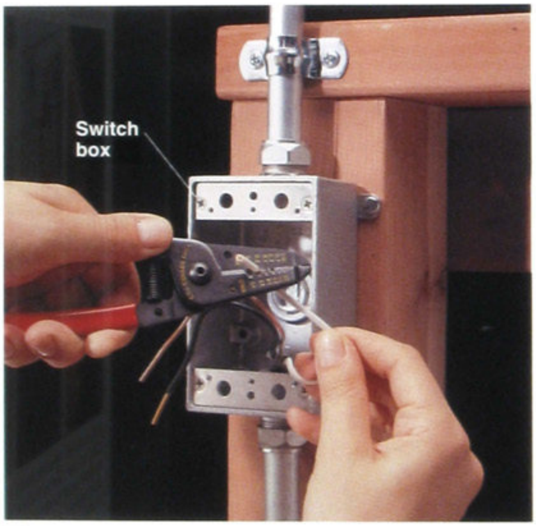
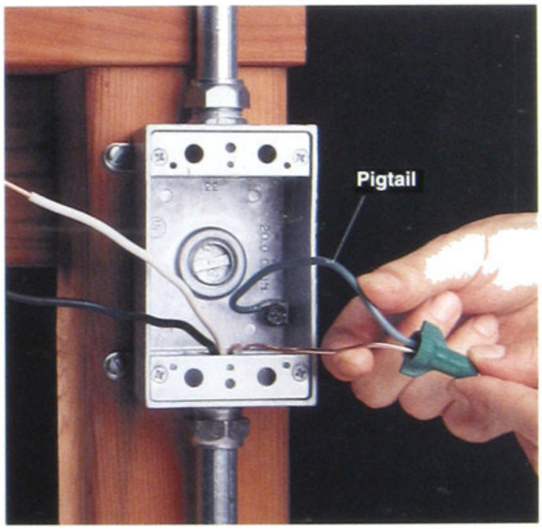
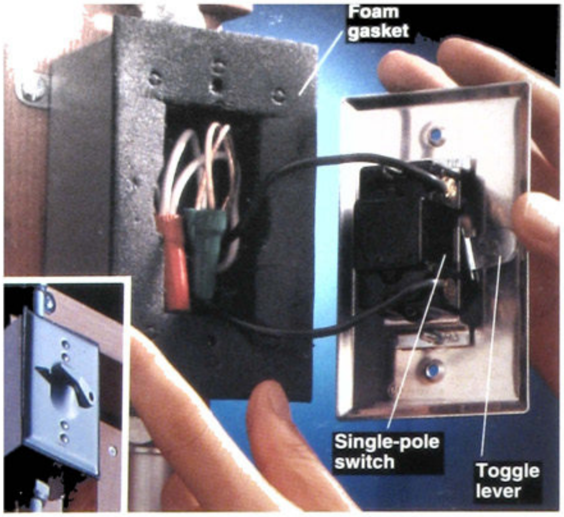


7 cut nd install a cable from the deck
ie box to the outdoor switch box using
10 of sheathing from each end of
ip of insulation from the end of
using a combination tool



8 Attach a grounding pigtail to the back of each metal box and extension ring Join all grounding wires with a wire connector Tuck the wires inside the boxes and temporarily attach the weatherproof coverplates until the inspector arrives for the rough-i inspection

Arrange for the rough-in inspection before making the final connections.



Switches for outdoor use have weatherproof cover-plates with built-in toggle levers. The lever operates a single-pole switch mounted to the inside of the cover-plate. Connect the black circuit wire to one of the screw terminals on the switch, and connect the black wire lead from the light fixture to the other screw terminal. Use wire connectors to join the white circuit wires and the grounding wires. To connect the manual override switch for the motion-sensor light fixture, see circuit map 4 on page 156.

5: Make Final Connections

Make the final hookups for the switches, receptacles, and light fixtures after the rough-in cable installation has been reviewed and approved by your inspector, and after all trenches have been filled in. Install all the light fixtures, switches, and receptacles, then connect the circuit to the circuit breaker panel (pages 192 to 193).

Because outdoor wiring poses a greater shock hazard than indoor wiring, the GFCI receptacle (page 266) in this project is wired to provide shock protection for all fixtures controlled by the circuit.

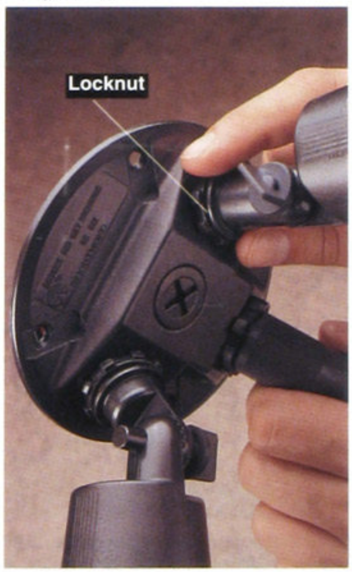
When all work is completed and the outdoor circuit is connected at the service panel, your job is ready for final review by the inspector.

Materials You Will Need

Motion-sensor light fixture, GFCI receptacle, 15-amp grounded receptacle, outdoor switch, decorative light fixture, wire connectors.

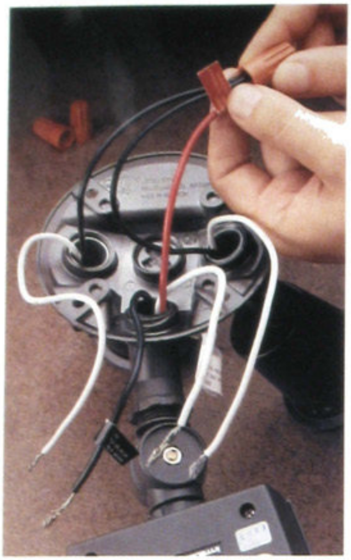
How to Connect a Motion-sensor Light Fixture

1 Assemble fixture by threading the wire leads from the motion-sensor unit and the bulb sockets through the faceplate knockouts. Screw the motion-sensor unit and bulb sockets into the faceplate.

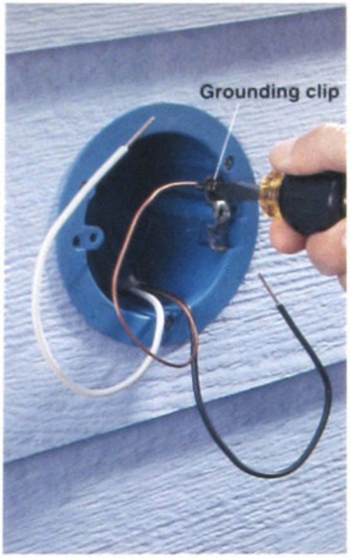


2 Secure the motion-sensor unit and the bulb sockets by tightening the locknuts.

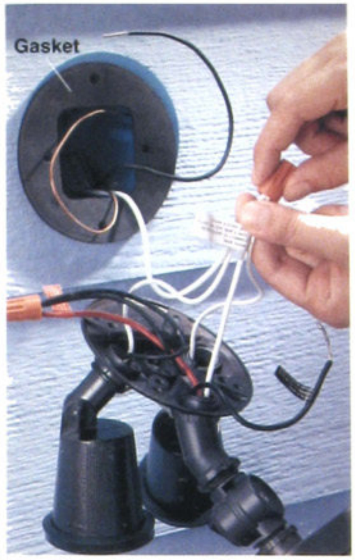
3 Insert the fiber washers into the sockets, and fit a rubber gasket over the end of each socket. The washers and gaskets ensure that the fixture will be watertight.



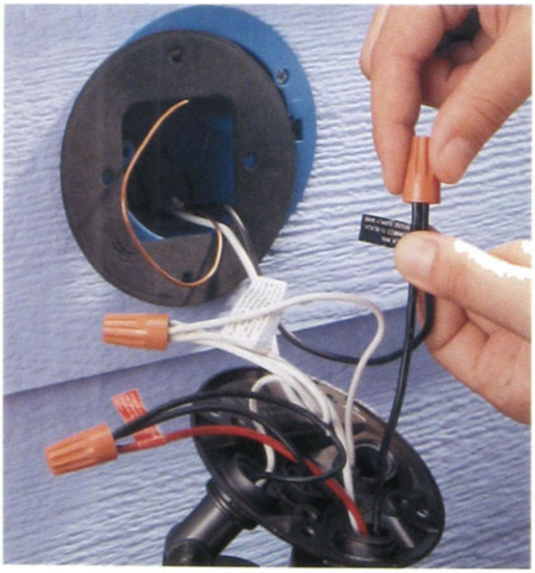
4 Connect the red wire lead from the motion-sensor unit to the black wire leads from the bulb sockets, using a wire connector. Some light fixtures have pre-tagged wire leads for easy installation.



5 Attach the bare copper grounding wire to the grounding clip on the box.



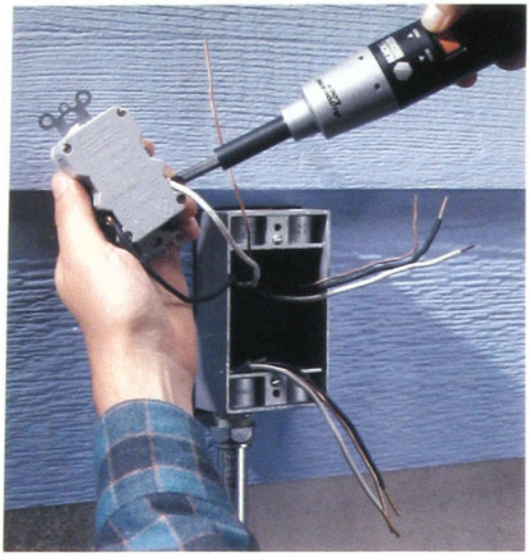
6 Slide the foam gasket circuit wires at the el box. Connect the white to the white wire leads fixture, using a wire conn



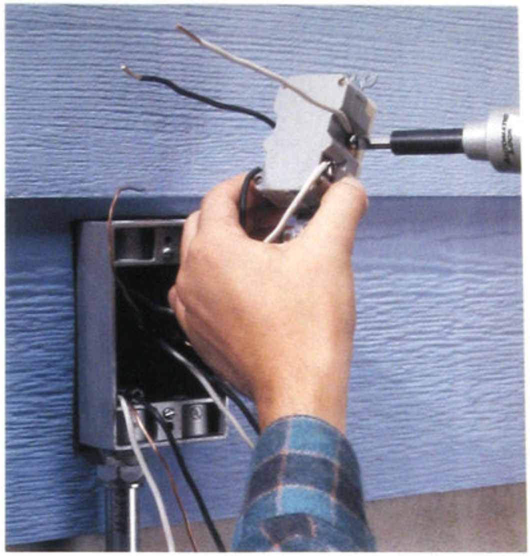
7 Connect the black circuit wire to the black wire lead on the light fixture, using a wire connector.

8 Carefully tuck the wires into the box, then position the light fixture and attach the faceplate to the box, using the mounting screws included with the light fixture. (See also circuit map 4, page 156.)

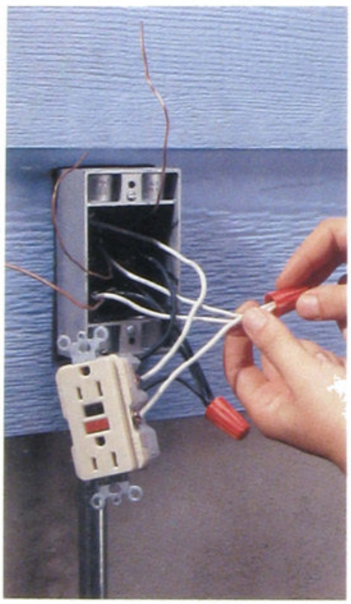
How to Connect the GFCI Receptacle



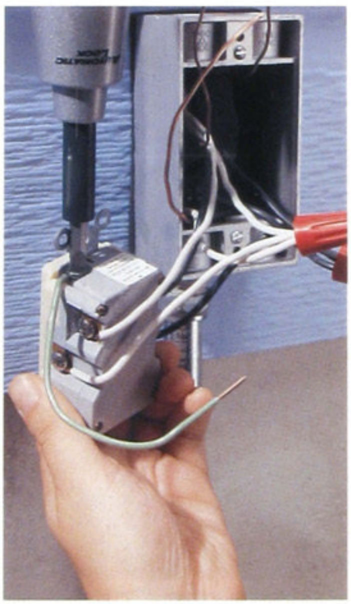
1 Connect the black feed wire from the power source to the brass terminal marked LINE Connect the white feed wire from the power source to the silver screw terminal marked LINE



2 Attach the short white pigtail wire to the silver screw terminal marked LOAD, and attach a short black pigtail wire to the brass screw terminal marked LOAD



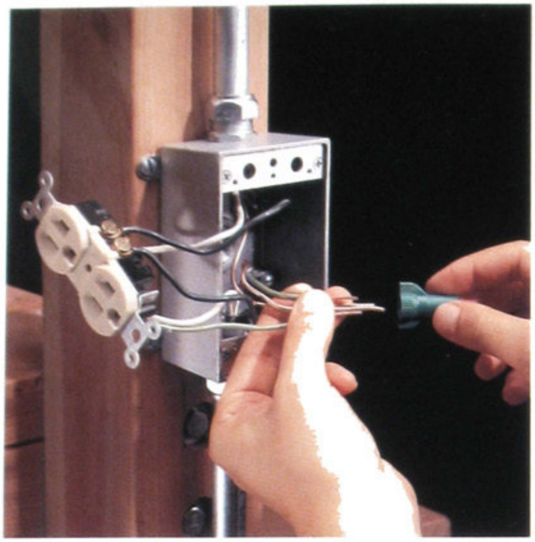
3 Connect the black pigtail wire to all the remaining black circuit wires, using a wire connector Connect the white pigtail wire to the remaining white circuit wires.



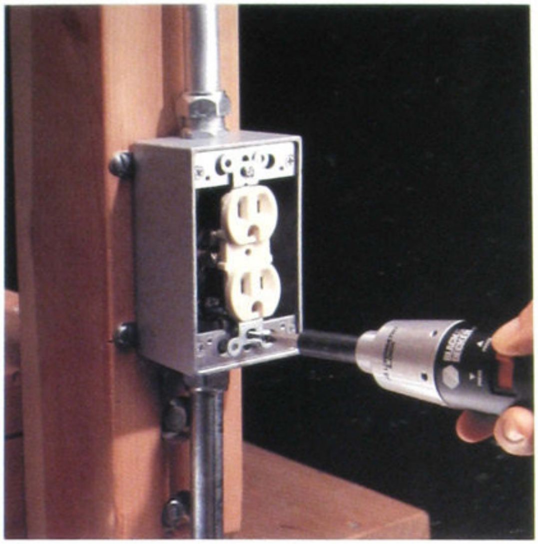
4 Attach a grounding pigtail to the grounding screw on the GFCI Join the grounding pigtail to the bare copper grounding wires, using a wire connector.

5 Carefully tuck the wires into box. Mount GFCI, then fit a foam gasket over the box and attach the weatherproof coverplate. (See also circuit map 3, page 156)

How to Connect an Outdoor Receptacle



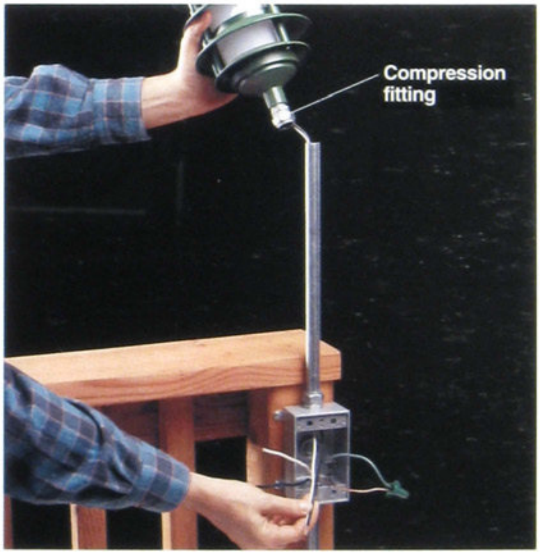
1



2

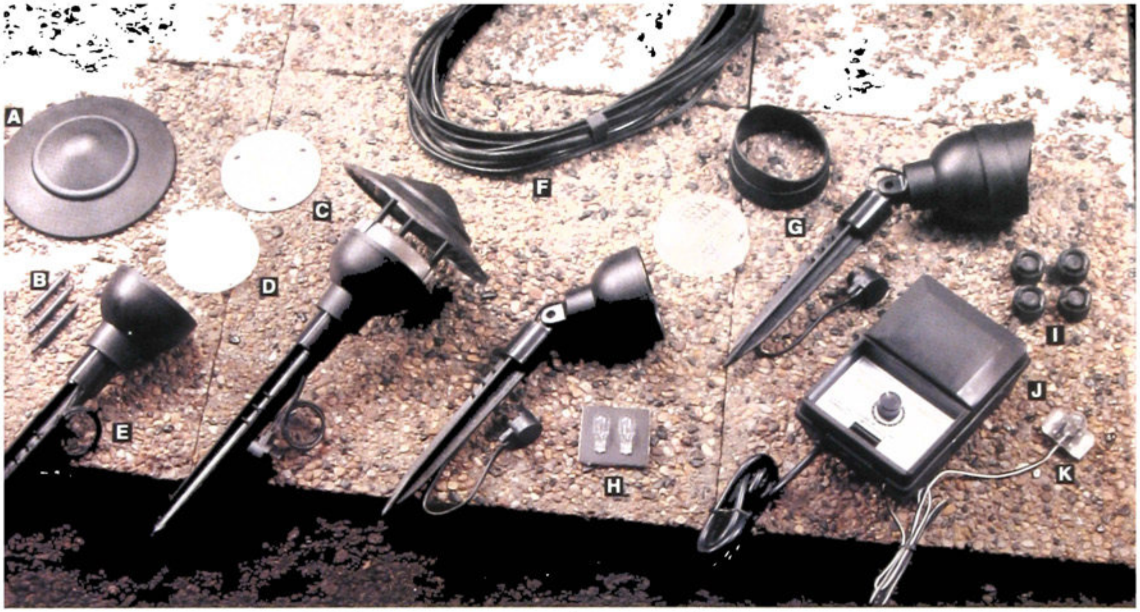
How to Connect a Decorative Light Fixture

1 through the union



2 Feed wire leads through conduit nd box. Slide light fixture onto conc an compression fitting. Connect black screw terminal on switch and conn lead to white circuit wire (See also circuit page 156

Make hookups at circuit breaker panel (page 192), and arrange for final inspection.



Typical low-voltage outdoor lighting system consists of lens cap (A), lens cap posts (B), upper reflector (C), lens (D), base/stake/cable connector assembly (contains lower reflector) (E), low-voltage cable (F), lens hood (G) 7-watt 12-volt bulbs (H), cable connector caps (I), control box containing transformer and timer (J), light sensor (K)

Low-voltage Outdoor Lighting

An alternative to 120-volt outdoor landscape lighting is to purchase and install a low-voltage outdoor wiring kit. These kits have several advantages over 120-volt lighting systems. They are safe and easy to install, use less energy, and don't require complicated hazard precautions. You can buy kits with low-profile fixtures to illuminate your deck, tier or globe lights for landscaping or lining paths, or flood-lamps to illuminate a larger area.

Inexpensive kits, which are self-contained but usually have only six to eight lamp heads, are available at retail outlets that cater to the do-it-yourselfer Some manufacturers offer additional lights to expand your kit.

More expensive lighting systems available at specialty lighting retailers offer homeowners greater flexibility in creating more elaborate lighting designs. The fixtures are usually sold individually rather than in kit form and are often more complicated to install

Yard size, landscape design, and your layout plan will influence the type and number of kits or fixtures you buy After you decide where to place the lights, measure the distance from the control box to each lamp location to determine how much cable you will need.

Most kits contain lights to line walks or drives as well as floodlights. There are other kits available that include fixtures designed for decks. Some manufacturers offer different types of heads that are adjustable, which can provide greater flexibility and different effects.

Before starting, check to see if local codes have specific requirements for low-voltage installations. Also, if you are doing landscaping, install outdoor lighting before laying sod.

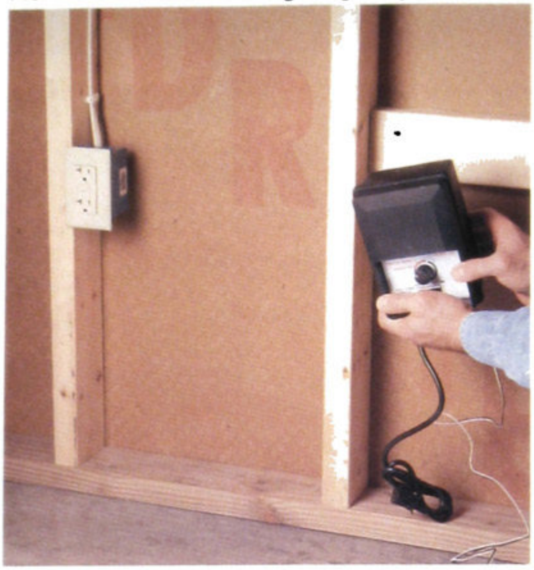
Control boxes in low-voltage kits usually have a transformer that plugs into 120-volt house current via a standard 3-prong plug. You install the control box near a receptacle and simply plug the box into the receptacle. It is best to use a receptacle located inside the house or garage, protected from the weather.

Everything You Need

Tools: tape measure, drill, hammer, screwdriver, shovel, paint-stirring stick.

Materials: low-voltage lighting kit, PVC conduit, conduit straps, caulk.

How to Install Low-voltage Lighting



1 Mount the control box on a wall (inside the house or garage) within 24" of the chosen receptacle, positioning it at least 12" above the floor. Drill a hole through the wall or rim joist large enough for the light sensor and cable to pass through.

2 Push the sensor through the hole and mount it on the outside wall. Make sure it will not be covered by plants or other obstructions.

3 At the base of the outside wall beneath the hole, begin a narrow trench about 6" to 8" deep. Pass cable through the hole. Protect the cable between the hole and bottom of trench by running it through PVC or metal conduit. Secure conduit to wall with conduit strap. Seal the hole with caulk.

4 Fasten the cable to the terminals on the control box. Tighten screws to secure. Set lighting program based on your needs according to manufacturer's instructions.

(continued next page)

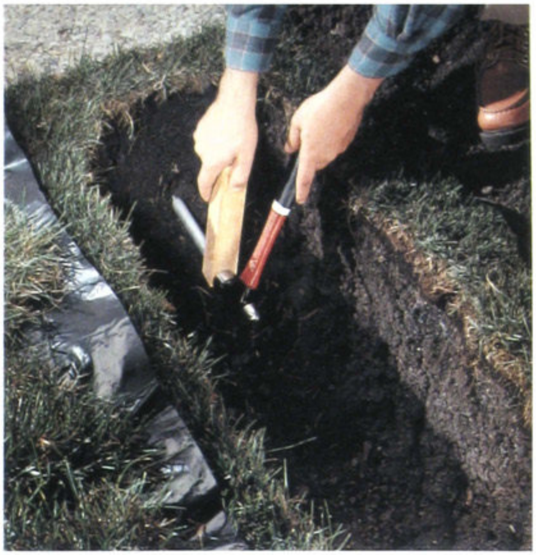
5 Lay out cable in desired locations At each lamp location attach the base/stake assembly to the cable with the cable connector Tightening the connector cap forces the pin terminals to pierce the cable and contact the wires inside (Some kits use sliding clips to accomplish this)

6 Insert a bulb securely into the lamp socket Then assemble the lens and hood (if making a floodlight) to the base/stake assembly

7 Adjust the direction of the floodlight according to the manufacturer's instructions.

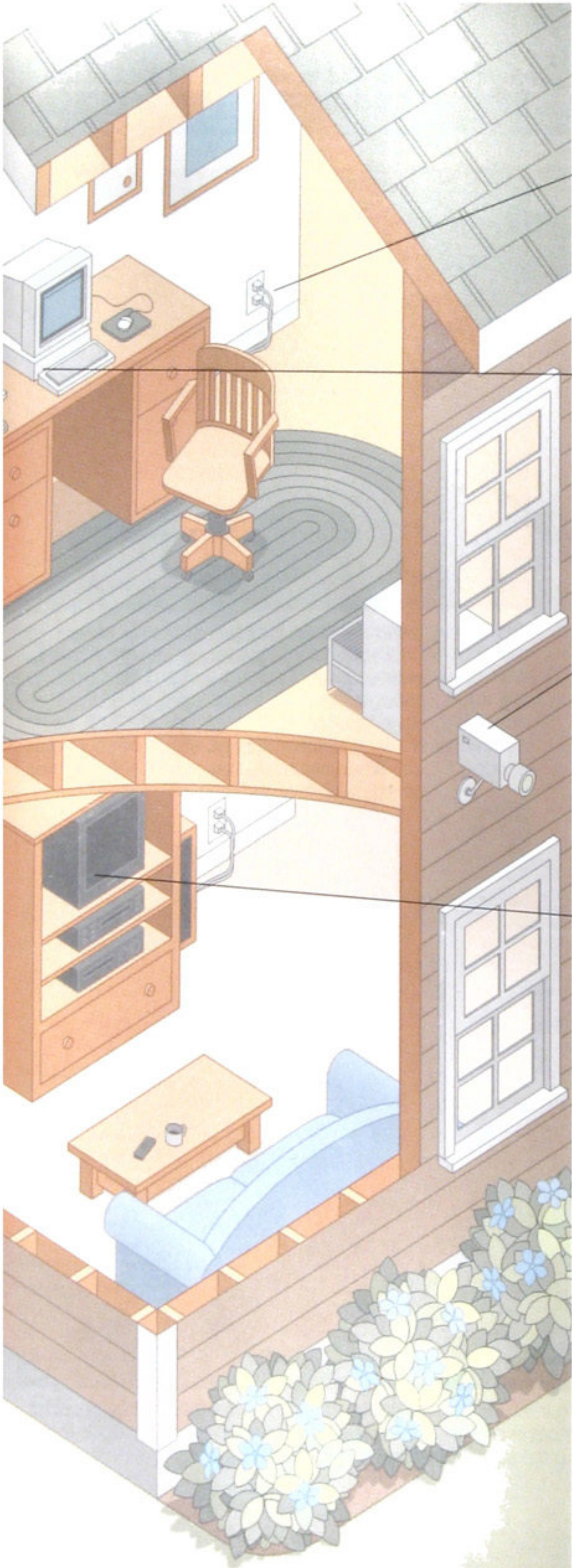
8 Complete the layout, making floodlights or pathlights as necessary In most kits the same base unit is used to make either light; the different style is created by choosing the appropriate arrangement of caps, posts, hoods, and reflectors.

9 Starting at the wall and continuing along the cabl path slice into the ground about 6" to 8" deep a flat-nose spade levering to create a narrow nch At each lamp location slice across the cable with the spade



TIP: To run cable under a sidewalk metal conduit about 1 foot longer than walk, then flatten one end to form a shar the trench enough to provide room to conduit through the ground under the si a hammer or maul protecting end of a wood block When sharp tip has com side cut it off so cable can pass throu

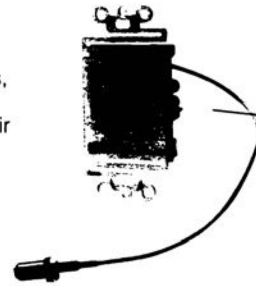
10 Use a paint-stirring stick to gently force the cable into the slice until the cable is at least 6" below ground level At lamp locations, press the stake end into center of the crossed slices until lamp is at proper level After all lamps are positioned and cable is buried, tamp trench shut. Insert the plug from the control box into receptacle.



Multimedia outlets use modular jacks, connectors, and terminals to allow homeowners to customize outlets according to the network needs of each room.

Voice/data jacks can accommodate any pin-size telecommunication jack to allow for standard phone and data lines, or the ability to create multi-line phone, data, and computer networks for the home office. Reassigning any line is quick and easy.

Accessories, such as closed-circuit cameras, allow homeowners to tailor the system to their specific needs.

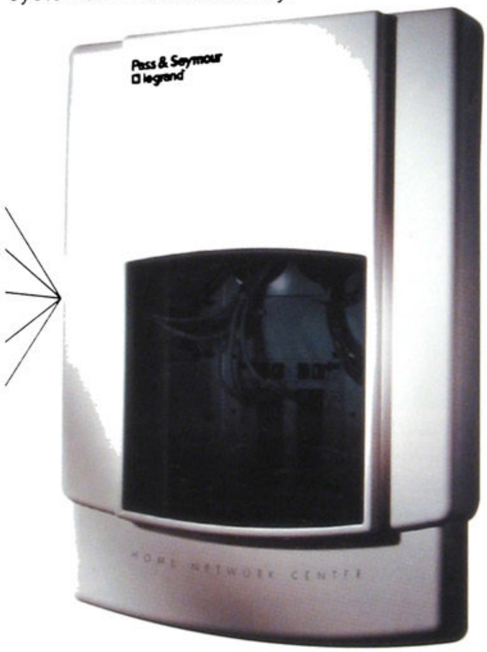


Video F-connectors provide every room in your house with the ability to receive and redistribute antenna, cable TV, and satellite signals, as well as internal transmission signals from DVD, VCR, and closed-circuit cameras.

Audio terminals or a recessed speaker system can be installed for a home theater system or to create an internal audio system with localized volume control.

Home Network Wiring Systems

The ability to send and receive information electronically has become an important part of our lives. Internet access, multiple phone lines, cable television, satellites, home computer networks, and security systems are commonplace in many homes. And as our telecommunications needs grow, a better, faster, and more convenient way to manage these separate systems will be necessary.



A **home network system** brings all these single systems together at one central location. It provides a transmission path for **electronic information** rather than for electricity. Electronic information can be voice, video, audio, or computer data. Network wiring is about moving this electronic information to wherever you need it.

Older phone and cable TV wiring use a continuous loop wiring method. With this method, various jacks and connectors are installed along a single loop of cable or wire running throughout the house. Though easier to install, this method is unreliable, especially with the large demands placed upon the lines by computers and other electronic devices.

In this traditional method, the cable or wire that is split runs from the demarcation point, Network Interface Device (NID), or service entrance—the point where the service providers transfer ownership of the lines to the homeowner The transmission signals are strongest at the point they enter the home. But repeatedly splitting cables and wires throughout the run degrades the strength of the signal. Also, if there is a problem in the line, all the jacks and connectors in the run are affected.

New home network wiring systems resolve this problem. The system employs a **star topology**, in which all cables and wires are distributed from a central point. All inputs are brought to a centralized distribution center that contains modules designed to maintain the strength of voice, data, and video (VDV) transmission signals. High-performance cable and wires are routed to any room in the house where VDV capability is necessary. Plug-and-play multimedia outlets provide easy access to a variety of signals.

The system can be used to create home computer networks, multi-room audio systems, multiple phone lines for home offices, and distribution for DVD, VCR, or closed-circuit television signals to any room of the house.

Installing a system is a project that any homeowner can accomplish. Many home centers carry all the components and materials necessary for installation.

It is much easier to run cables and wires before the walls are finished in the construction phase, but retrofit installations are quite manageable if you carefully plan the system needs, determine the optimal location for each unit, and map out the cable and wire routes.

Though installation methods and techniques for network wiring systems are generally the same, there are some differences between the different manufacturers' systems. Always carefully read and follow both the instruction and operation manuals provided by the manufacturer of your specific network wiring system.

Installing a Home Network System

With the increasing need for networking capabilities in the home for work and entertainment, standards have been developed by the Telecommunications Industry Association (TIA) and the Electronic Industry Alliance (EIA) in accordance with the Federal Communications Commission (FCC). These standards are becoming the code requirements for home network wiring installation across the country. Make sure to check with your local building inspector for the current codes in this new and changing area of home wiring.

There are four components to a network wiring system: the **distribution center,** the **distribution modules, cables and wires,** and the **multimedia outlets.** Each component serves a particular function in the distribution of VDV (voice, data, video) signals throughout your home network system.

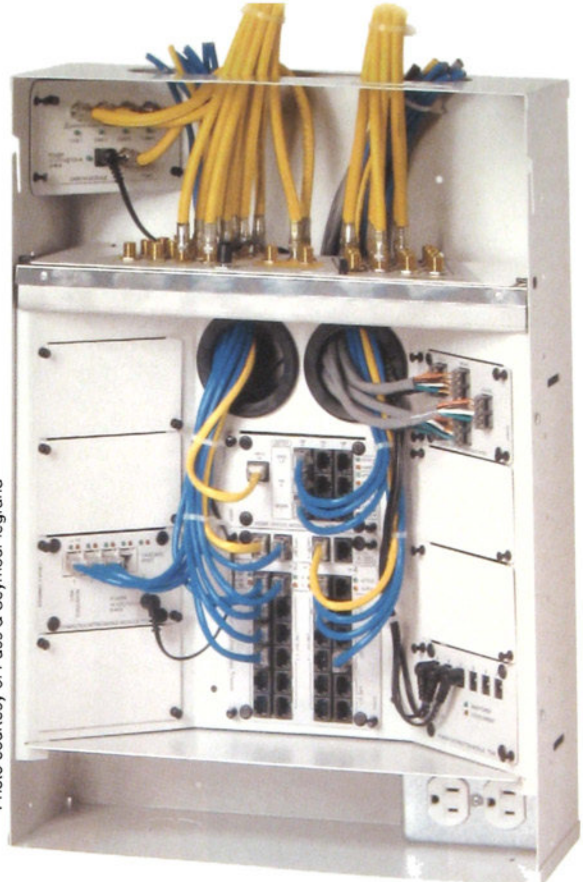


Photo courtesy of Pass & Seymour legrand

Installing a Home Network System

Distribution Center

The distribution center is the central hub of the network wiring system, housing the distribution modules and the cable and wire connections that link the entire network. All service cables from outside your home (antenna, cable TV, telecommunication lines, etc.) are routed from the service entrance to the distribution center, where their signals are then distributed to every room in your house. In addition, signals generated within your home (such as DVD, VCR, audio, or computer networks) can be routed back to the center and redistributed to the multimedia outlets in the rooms of your choice.

Distribution centers are designed to allow easy access to the modules and cable connections. This makes reconfiguring outlets in any room quick and simple. Most distribution centers are heavy-gauge steel boxes with plastic covers, sized to fit between standard stud spans of 16" on-center. These enclosure-style centers have open tops or holes to accommodate the many cables and wires routed to and from the modules contained inside. Smaller distribution centers that hold only a few of the most basic modules are also available. These centers are generally not enclosed, so care must be taken to keep all cables and wires together.

Typically, the lower portion of the distribution center houses the electrical transformer that supplies power to the system. A dedicated 15 amp, 120-volt, non-switchable duplex receptacle must be installed, either in the enclosure itself or within 60" of the distribution center.

The upper portion of the center is reserved for video distribution modules, while a mounting bracket or brackets are fastened at the middle section to hold various home network modules.

Distribution Modules

The distribution modules are the interface devices used to maintain and strengthen the signal for further routing throughout the system. Each module contains at least one INPUT port for receiving the incoming signal to be distributed (or redistributed), and a series of OUTPUT ports for routing the desired signal to the desired locations. Each module is designed to serve a particular function.

Video distribution modules receive and distribute cable, satellite, UHF VHF and other coaxial signals throughout the network. Video modules are also used to create internal video networks through the use of a modulator, a device that receives signals from a source (DVD, VCR, or video camera) and assigns those signals to the unused channels in the cable or satellite system.

Telecommunication modules distribute voice and data signals received from various RJ45 jacks throughout the network home and out to the world.

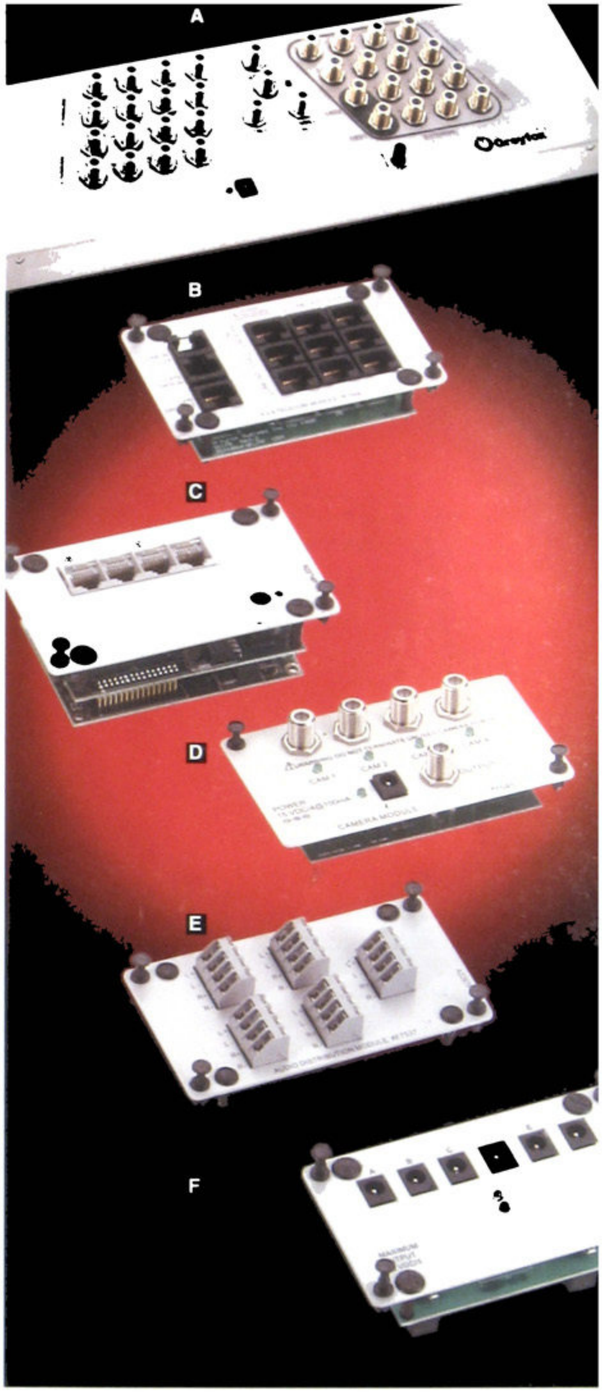
Computer network modules are used to create home computer networks when used with, and properly configured to, Ethernet network cards and software. Many **home office modules** are available that combine the best attributes of the telecommunication and computer network modules for convenient transference of information.

Camera modules distribute video and audio signals received from closed circuit monitoring cameras to all external TV outlets for viewing. This module typically works in conjunction with a video distribution module.

Audio distribution modules route audio signals received from your stereo receiver or amplifier to speakers or terminals mounted in various locations.

Power distribution modules supply power for all internal DC power patch cords to the amplifier or panel, as well as to those modules requiring a source of electricity.

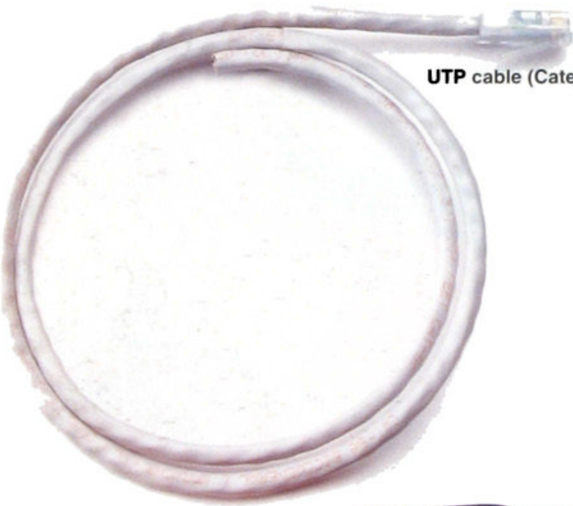
Manufacturers continually develop new interface modules to support a greater range of systems, from security to internal intercom. Modules compatible with home automation systems (pages 294 to 295) will receive and distribute the signals for lighting control or localized climate control options.



Video distribution modules (A), telecommunication modules (B), computer network modules (C), camera modules (D), audio distribution modules (E), power distribution modules (F).

Cables & Wires

Series 6 coaxial cable



UTP cable (Category **5**)

Audio speaker wire

Cables and wires carry signals dispatched from a source to their intended location. The growing need to transfer larger amounts of data faster requires that cables and wires be capable of carrying a high volume of data.

Cables and wires are rated based on their **bandwidth**, the amount of data that can flow through the cable or wire in a specified unit of time. The greater the bandwidth, the faster data can be transferred.

There are four basic types of cable:

Coaxial cable is used for the distribution of audio/video signals throughout the system. Series 6 cable (or RG-6) is a higher-grade coaxial cable and is preferred for home network systems.

Unshielded twisted-pair (UTP) cables are used to carry phone and data signals throughout the system. The most common UTP cable in use is Category 5. It is a higher-grade cable with a large bandwidth and meets all standards requirements.

Audio speaker wire is used to route audio signals throughout the system to create a home theater or a multi-room audio system.

Fiber-optic wire (not pictured) uses a transducer that converts the electrical signal into light to pass through the glass or plastic optical fiber wires. At the other end, another transducer converts the light back to an electrical signal. It is less common in residential applications.

Multimedia Outlets & Accessories

work is accessed at various multimedia installed throughout the home Each let contains a series of jacks and connectors for plug-and-play connection of phones computers televisions VCRs. DVDs. and stereo systems

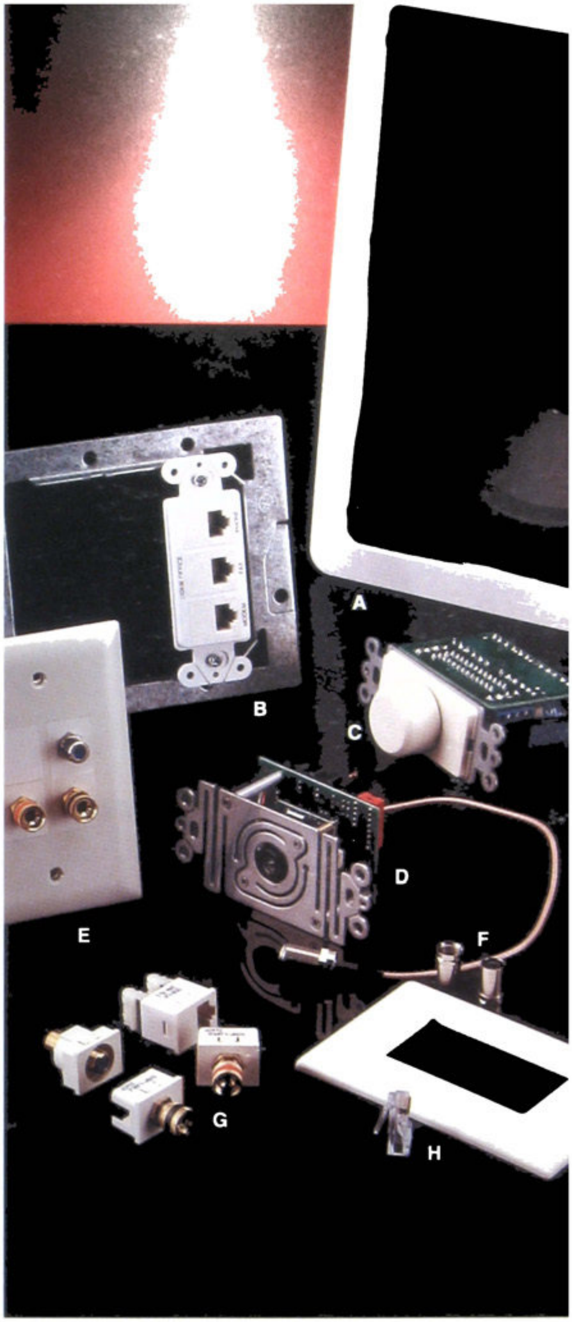
RJ45 jacks are the ports for connecting phone and data devices to the network system RJ45 cks are wired to a universal pin/pair assignnt standard (standard T568A) This configuran allows any size telecommunication plug to be used with the jack For example your 4-pin phone plug can be inserted (and will fit) into the 8-pin RJ45 jack That phone jack can then be removed and an 8-pin Ethernet data line plug be inserted once the jack has been reconured at the distribution box

F-connectors are threaded terminals for nnecting video equipment to the system -connector fittings on coaxial cable ends imply screw onto the terminal

Binding posts are the terminals for tying an audio system into the network The posts are color coded for polarity Red or + is used to ignify positive terminals and black or for negative terminals Crossing polarity may cause the speakers to be out of phase in which case the sound ill lack some of its bass

Multimedia outlets can be tailored to the specific needs of the room in which they are located Outlets in a home office could contain a dedicated RJ45 jack for each phone fax and modem line to allow each device to send and receive data more efficiently

Accessory options are available with all network iring systems though most will require a spelized distribution module The most common video cameras sized to fit in 4" × 4 gang boxes for a closed-circuit television system and recess-mounted stereo speaker systems for multi-room audio systems with volume control i each room



Audio speaker with bracket for recess mounting (A) multimedia outlet with bracket for mounting to electrical receptacles (B) audio system volume control (C) video camera (D) multimedia outlet with au io binding posts (E) F-connectors (F) odule jacks and connectors for multimedia outlets (G) RJ45 jack plug (H)

A home office

*he many network-
Installing Grade
tacles will pro-
mmuni tion

Home entertainment systems also can use many of the networks in the system. Installing Grade 2 multimedia outlets on each wall of the room will help ease future remodeling or redecorating projects, or the addition of new components to the system.

Installing a Home Network System

Assessing Needs

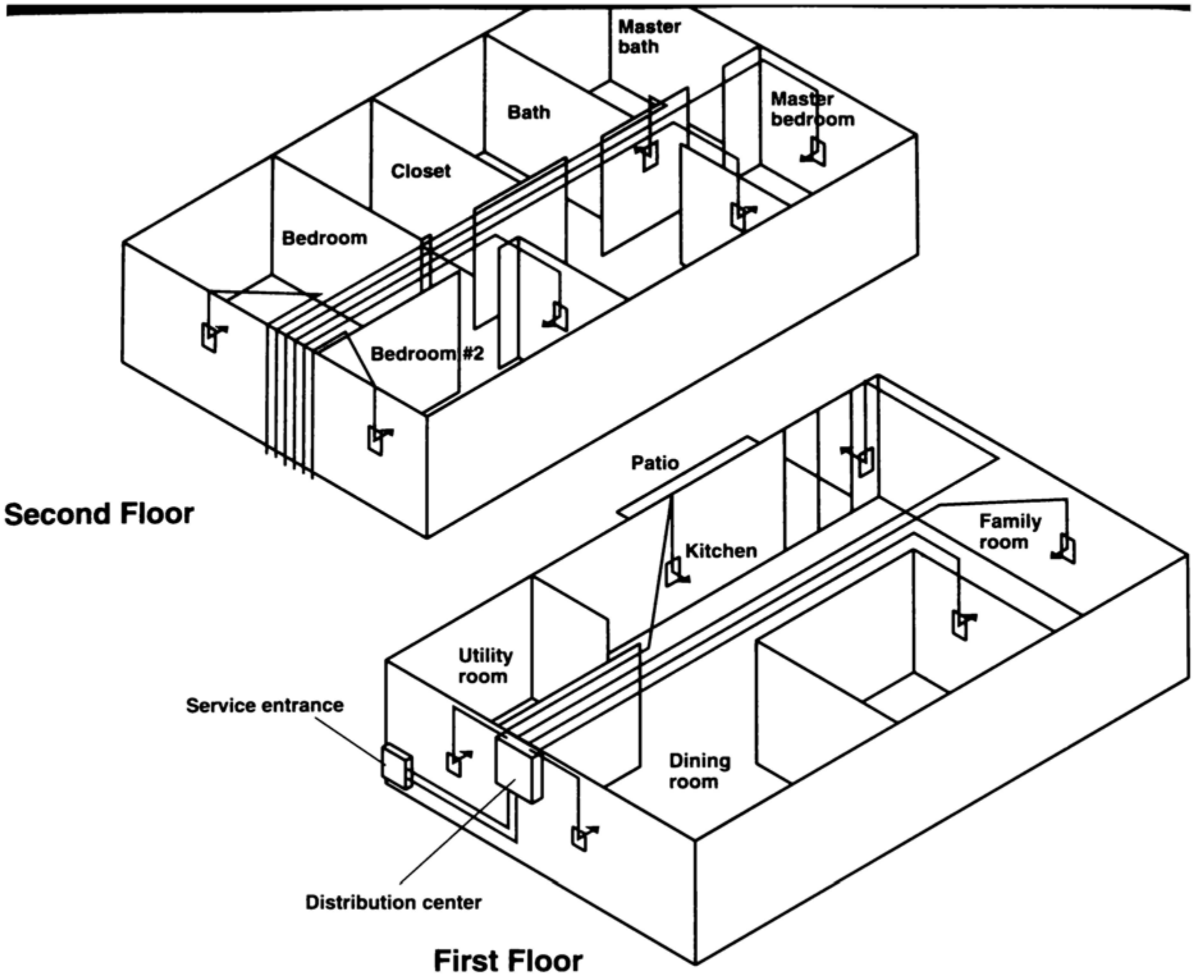
When assessing your network system needs, it is always a good idea to install more than you currently think you will use. Routing extra cables and wires to large appliances, such as furnaces and refrigerators, will make it easier to add future home automation features. Extra outlets in rooms will let you connect new telecommunication devices to the network.

Two standard grades of residential cabling installation currently exist.

Grade 1 is a generic cabling system that meets only the minimum requirements for telecommunication services. Each multimedia outlet is provided with one 4-pair UTP cable (minimum category 3, category 5 recommended) as a voice/data line, and one 75-ohm coaxial cable as a video line.

Grade 2 installation meets the requirements for basic, advanced, and multimedia telecommunication services. Two 4-pair UTP cables (minimum category 5, Category 5e recommended) are routed to outlets, for one voice line and one data line, as well as two 75-ohm coaxial cables (one input and one output) for video lines. Grade 2 installation standards also suggest 2-fiber optical fiber cabling for future applications, though this is entirely optional.

Installing multiple Grade 2 outlets in various locations of a room is recommended, especially in entertainment areas and the home office.



Installing a Home Network System

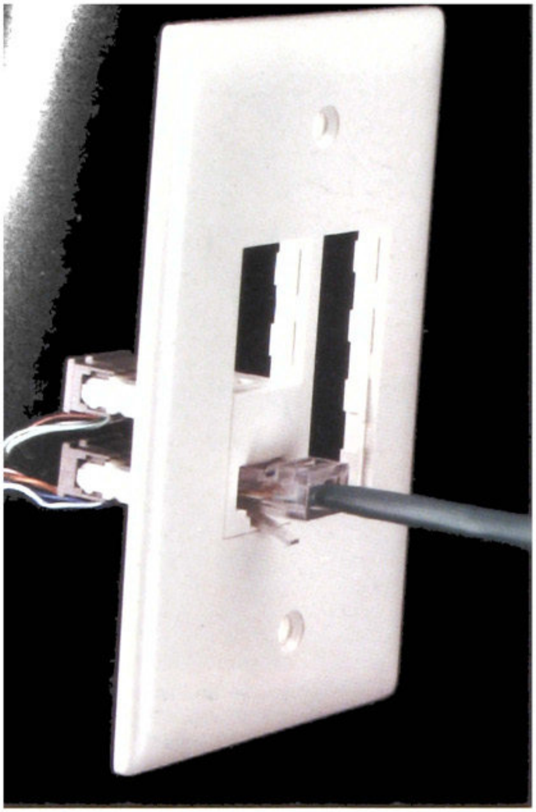
Determining Locations

A home network system is designed to be installed in a **star topology,** where all cables and wires are distributed from one central point, the distribution center. The center should be installed in an accessible, central location (such as a basement or utility room) and near the demarcation point, NID, or service entrance. Easy access to the distribution center will not only simplify the current installation, but also future alterations to the system. The central location will make cable lengths less likely to extend past their recommended routing length (295 ft.).

Low-voltage cable and wire routes should be carefully planned. Making sketches and routing maps will save time and help determine the best possible path with the least number of turns and bends. Refer to pages 284 to 285 for other cable and wire needs and restrictions.

The living room, home office, bedroom, entertainment room, recreation or game room, and den are all obvious places for multimedia outlets. But outlets in rooms such as the kitchen, bathroom, laundry and utility room, or at large appliances, will help ready your home for future conveniences.

When determining outlet locations within a room, consider the needs of that particular room. Home offices will benefit from multiple phone and data lines for Internet access on the computer. Plan for these outlets to be mounted alongside a 120-volt receptacle to centralize computer connections.



Preparing Multimedia Outlets

Multimedia outlets are installed much like electrical receptacles, though the connections do not need to be contained in a box The outlets should be mounted at the same height as receptacles, according to local code

Extension brackets allow multimedia outlets and electrical receptacles to be placed side by side The location of the 120-volt receptacle/switch box will always determine the height and location of the bracket Make sure to choose the correct bracket for the outlet type to be installed Some manufacturers offer specialized alignment tools for lining up the extension brackets with the existing electrical boxes

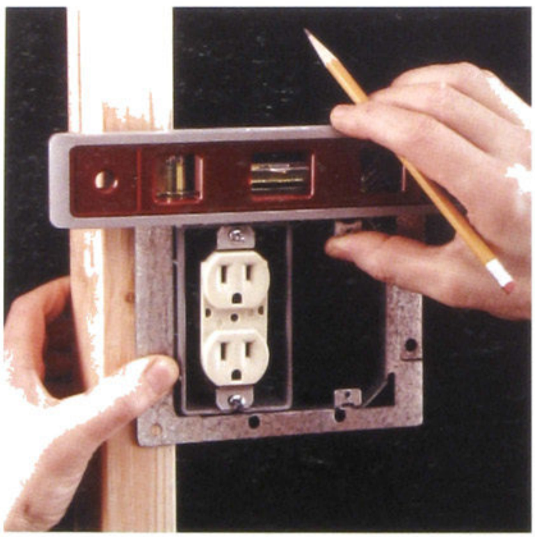
For retrofit installations, hollow-backed gang boxes or 4" × 4" gang boxes are used to prevent damage to cables and wires due to bending or twisting

Everything You Need

Tools: level, screwdriver, wallboard saw.

Materials: extension brackets, hollow-back boxes, wallboard screws.

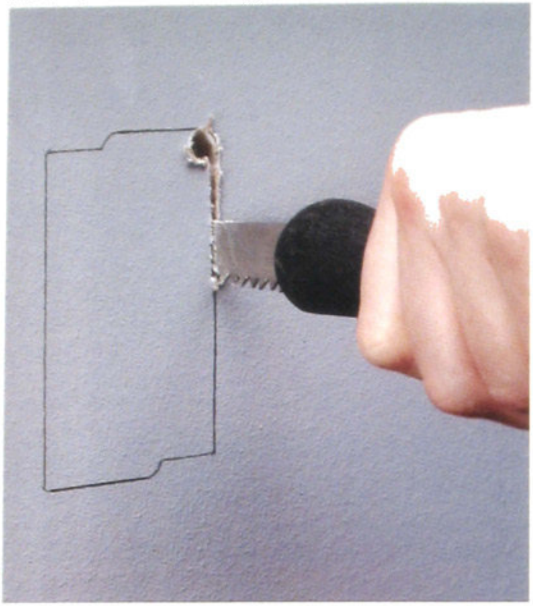
How to Mount a Multimedia Outlet Next to an Existing Electrical Receptacle



1 Fit the extension bracket over the existing electrical receptacle box Align the bracket so that it is level and square and properly spaced from the existing box Use an aligning tool, if provided, or a faceplate as a guide

2 Fasten the bracket to the stud with two screws The multimedia outlet box is then attached to the mounting ears on the extension bracket

How to Retrofit a Single Multimedia Outlet



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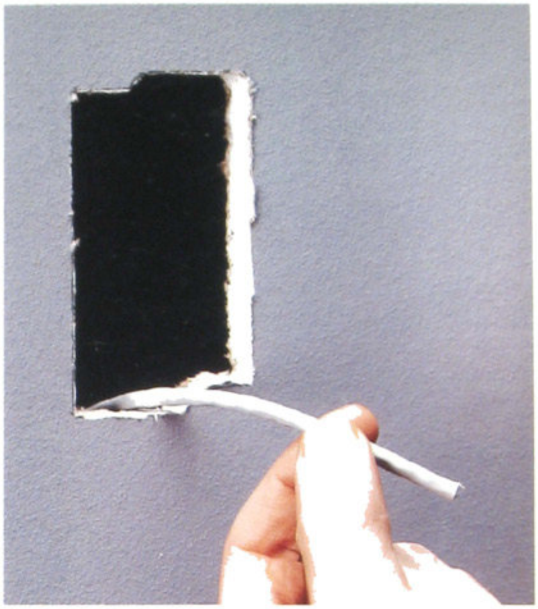

2 Route
di

3 r through the gang
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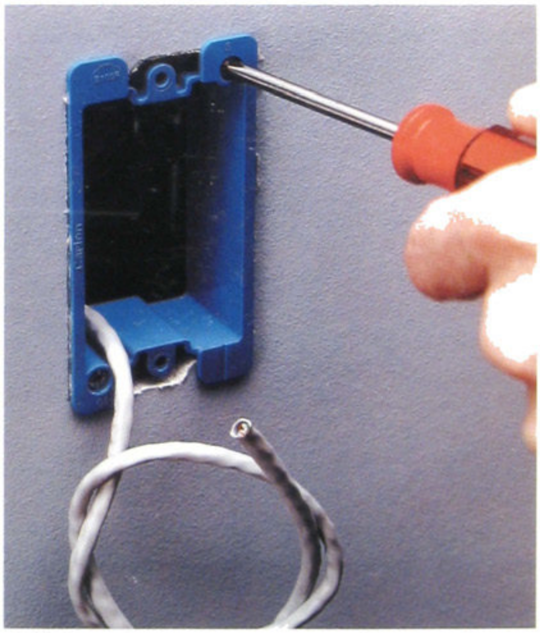
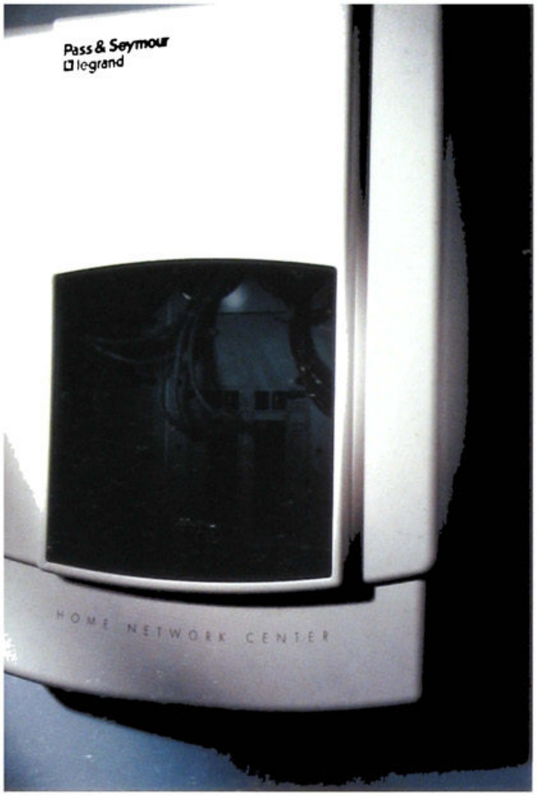


4 Tighten the mounting screws until snug to the wall. Avoid over-tightening the screws to avoid damaging the wallboard.



Mounting the Distribution Center

Most distribution centers are designed to fit between standard stud spans of 16" on-center For stud bays of different dimensions you'll need to install blocking to support the distribution center Retrofit installations will require that you remove a large portion of finished wall and then refinish it once installation of the entire system is complete

The bottom of the enclosure should be installed at least 48" above the floor Most models require a gap behind the enclosure to accommodate the modules and fastening hardware The front should protrude 1 plus the thickness of the dry wall from the studs to allow the cover to fit

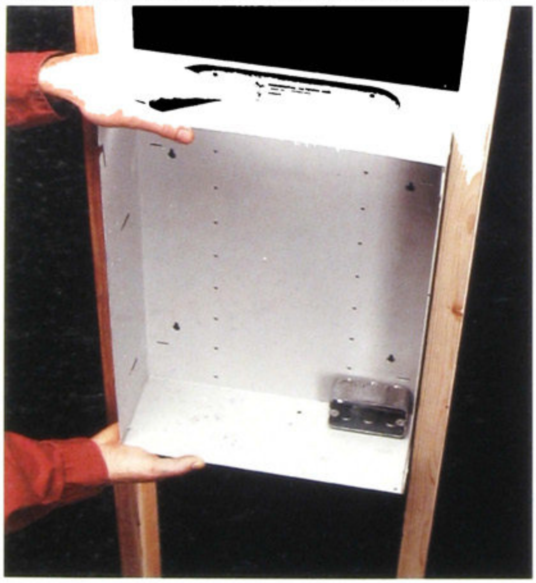
A dedicated 15-amp 120-volt electrical receptacle is suggested, and may be required depending on the grade of installation

Everything You Need

Tools: screwdriver, level.

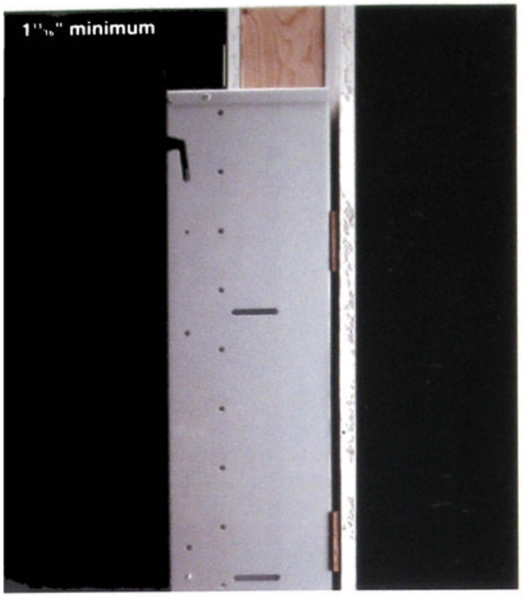
Materials: wood screws; distribution center wood shims; cable clamp; 15-amp, 120-volt receptacle.

How to Recess Mount a Distribution Center



1 Install the distribution center at least 48" above the floor Position between two studs with a standard span of 16" on-center

2 Use wood screws one for each of the m slots located on the sides of the distributi to fasten to the studs Do not fully tighten th



3

Alternative Method: Sur
center. Lea gap be
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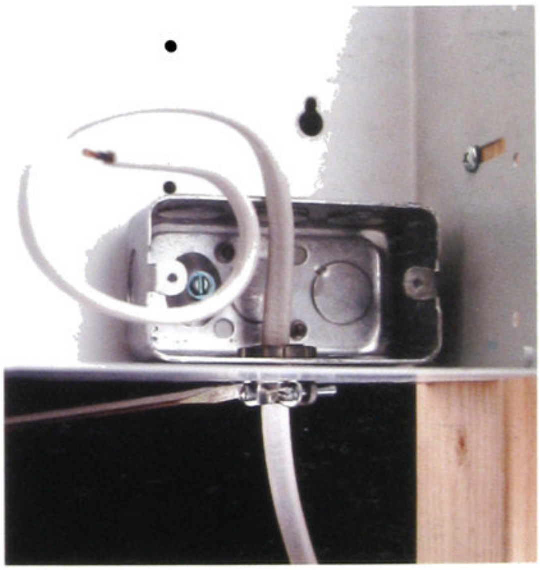
with spacer

How to Install the Power Supply

1 cable
using c
Drill a 1
4 below



2 Feed the NM cable through the hole and into gang box of the distribution center. Attach the cable with a cable clamp. Install a grounded 15-amp 120-volt receptacle (page 64) before completing the rest of the installation.

Routing Cables & Wires

Routing cable and wire of any kind requires drilling holes through framing members throughout the home Drill holes no closer than 2" from the top or bottom edge of joists Use nail plates to protect holes in studs within 2" of the edge Always check your local building codes for requirements in your area

Low-voltage cable can run a maximum of 295 feet from the distribution center without any significant signal loss The cable cannot run within 6" of electrical wires and can cross only from a 90 angle 6" from them

To route cables and wires, begin at the outlet bracket or box locations, and feed to the distribution center The maximum allowable pulling tension for UTP cable is 25 pounds Use electrical tape to hold the tips of all cables and wires together as they are fed and avoid knots and kinks Leave at least 12" of slack at bracket or box locations for making connections

ice connections are outside the home, drill 1 holes through to the outside near the service entrance location Insert a 1" PVC conduit, and feed cables and wires through it Leave 36" of slack, and attach notice tags to the ends for utility workers

At the distribution center mark each cable and wire according to its routing location Feed each through the top of the enclosure, and cut the lead ends so they hang even with the bottom of the distribution center When routing is complete, tuck all cables and wires neatly inside the distribution center and finish wall construction For tips on routing cables and wires in finished walls, refer to pages 178 to 183

Everything You Need

Tools: drill, RJ45 crimp tool, F-connector crimp tool.

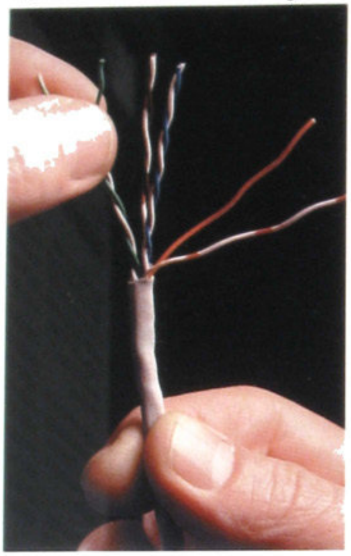
Materials: tape, cables, RJ45 plugs, F-connectors.

[redacted]

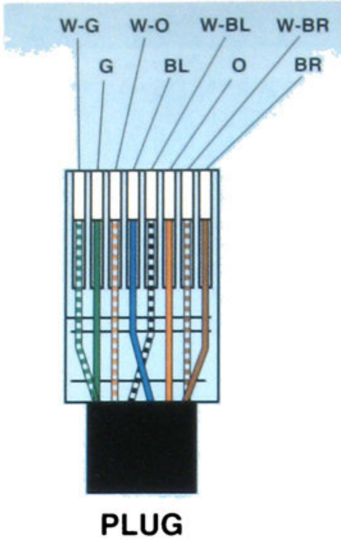
Drill 1 holes through the top plate above the distribution center Drill holes in floor joists for running cabl along the underside of house levels and from the service entrance to the distribution center.

Label each run of cable and wire at the distribution center with the room and location within the room All cables should hang even with the bottom of the distribution center

How to Attach RJ45 Plugs to a UTP Cable



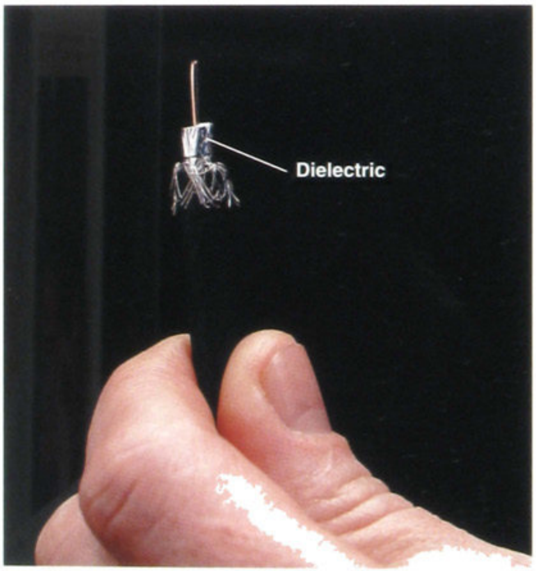
1



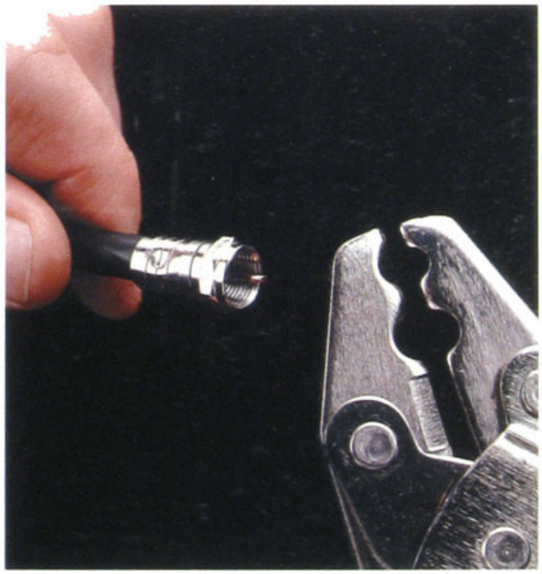
2

3

How to Attach F-connectors to Coaxial Cable



1



2 Slide th F-
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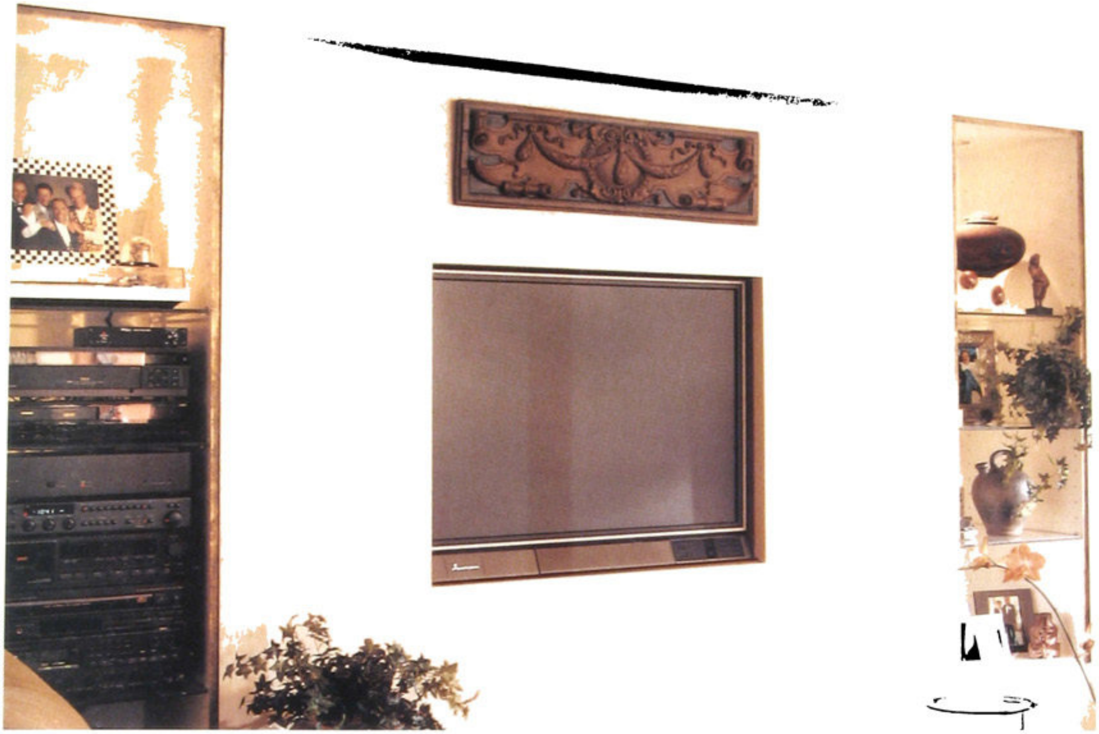


© Karen Melvin

Installing an Audio System

A home audio system routes speaker wire from a central receiver or amplifier, through the network distribution center, and back through to any room in the house. Each room can then be outfitted with either binding posts for an external speaker system or a recessed speaker system that is wired directly.

A volume control knob can be installed, typically at or near a light switch, to control the input level to the speakers in rooms wired to an external stereo system. Use a standard 4 × 4" gang box to house the module, and install as for an electrical switch.

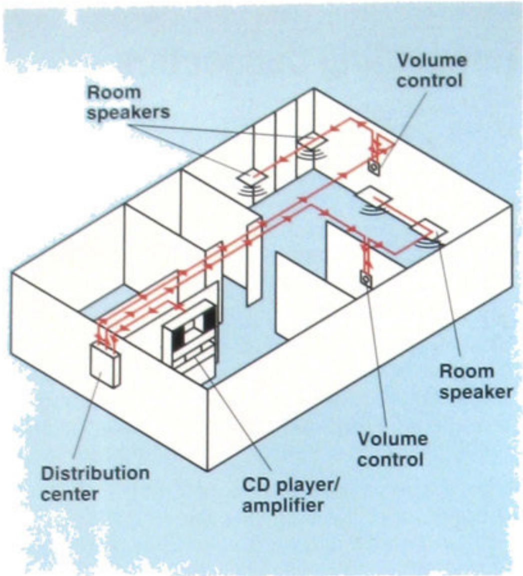
Everything You Need

Tools: screwdriver.

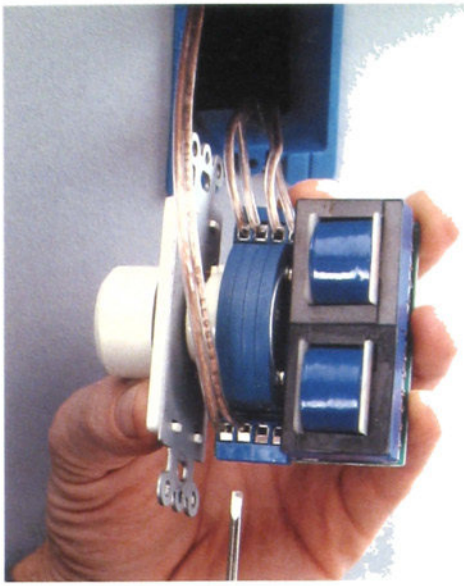
Materials: speaker mounting brackets, screws, volume control box, speakers.

How to Install a Recessed Speaker System

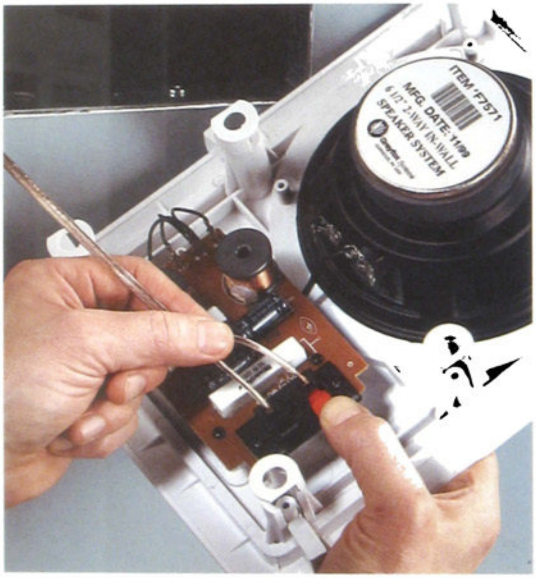
1 Loosely fasten the speaker mounting brackets to the rails with the provided screws or sheet-metal screws. Attach the assembled brackets to the studs with 1½" screws. Align the loose bracket in the rails, so that the outer edge of the bracket will be flush with the outside face of the wallboard. Fully tighten the screws.



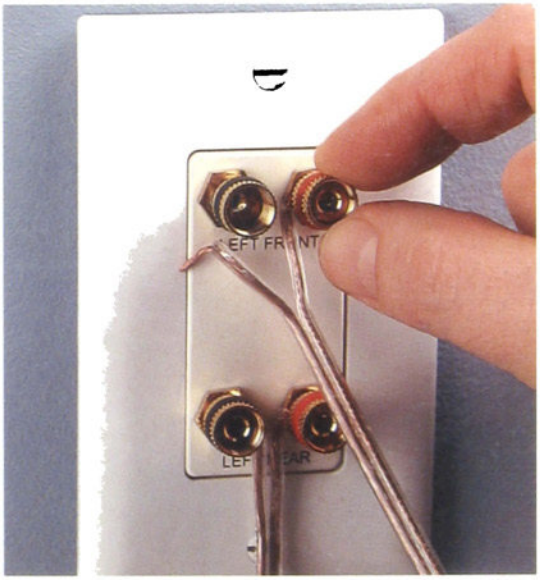
2 Run stereo speaker wire from each speaker location to the volume control box location. From the volume control box, run wire to the distribution center (page 284 to 285). Leave 8" to 12" of slack at each location.



3 Connect the wires at the volume control, with positive to positive (+ or red) and negative to negative (– or black). Position the module in the gang box, and screw into place. Attach the coverplate.

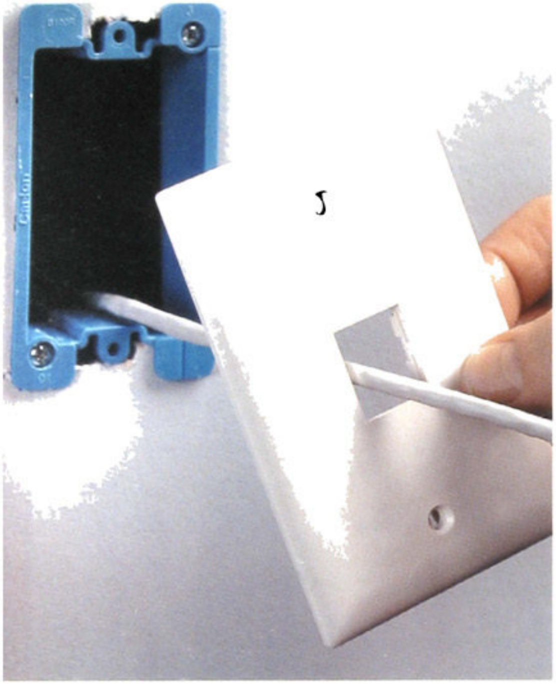


4 Connect the wires at each speaker. Keep positive to positive (+ or red) and negative to negative (– or black). Attach the speaker to the bracket. Some recessed speakers have plastic mounting arms that swing into place and clamp to the bracket when the front screws are tightened. Follow the manufacturer's directions.



Alternate Method: If not installing a recessed speaker system, install speaker binding posts. The network speaker wire is connected to the back of the binding posts. Run positive to positive (+ or red) and negative to negative (– or black).

Terminating Connectors



Before terminating a connector, pull all cables and wires for all multimedia outlets through the coverplate leaving 8" to 12" of slack for termination. Attach the coverplate in place with the screws provided.

With the distribution center and multimedia outlets placed, and all the cables and wires routed, finish the walls in each room before terminating the connectors. Most connectors and jacks are designed to snap into the coverplate.

Any style of telecommunication plug will fit in an RJ45 jack. UTP cable is terminated to the eight pins of the jack in an industry standard configuration, referred to as the T568A wiring standard. A 110-punchdown tool is used to terminate the wires to the corresponding terminals.

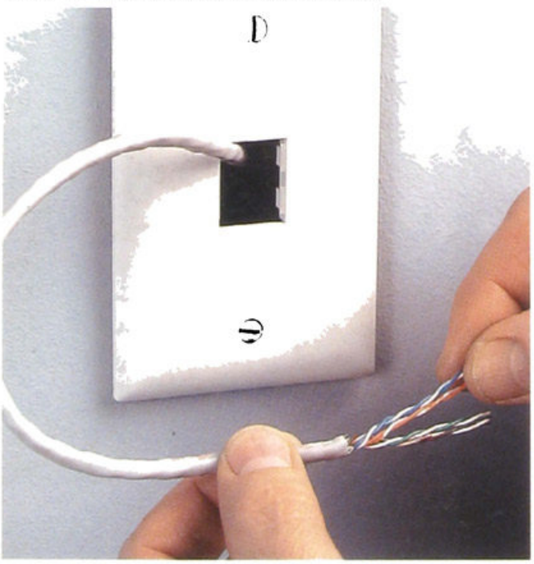
To terminate video connectors, crimp an F-connector to the coaxial cable end (page 285), and screw it to the backside of the self-terminating F-connector at the coverplate.

Everything You Need

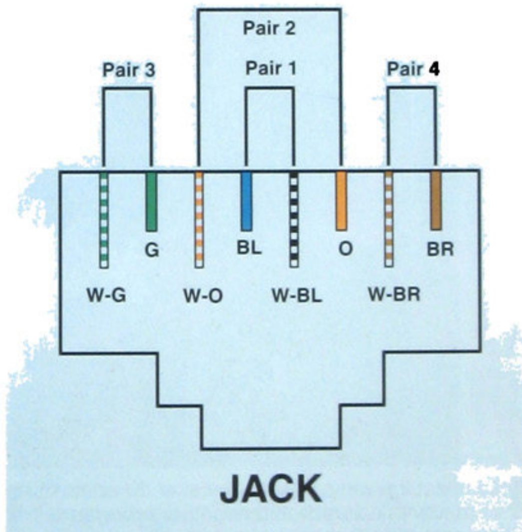
Tools: wire stripper, screwdriver, 110-punchdown tool.

Materials: RJ45 jacks, F-connector terminals.

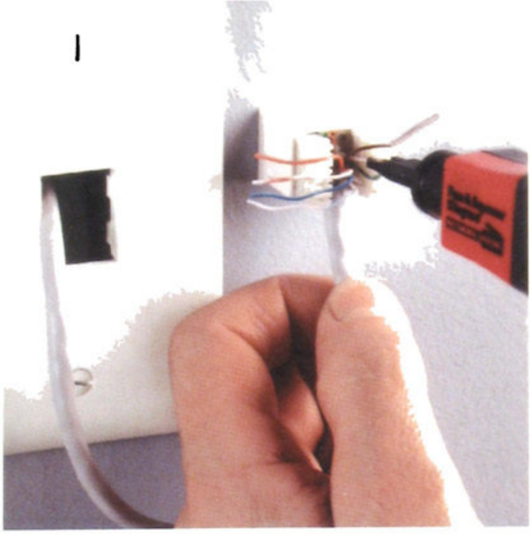
How to Terminate an RJ45 Jack



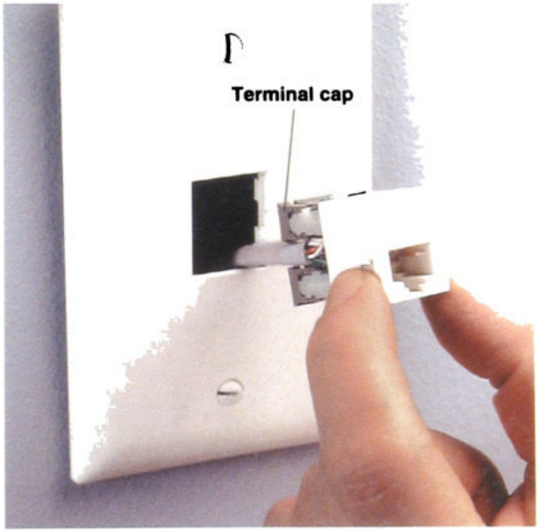
1 Strip 2" of outer insulation from the UTP cable. Be careful not to cut through the twisted pairs within. Untwist each pair of individual wires.



2 The backside of most RJ45 jacks are color-coded in the T568A wiring standard, so the proper colored wire from the UTP cable can be easily terminated to the proper terminal of the jack.



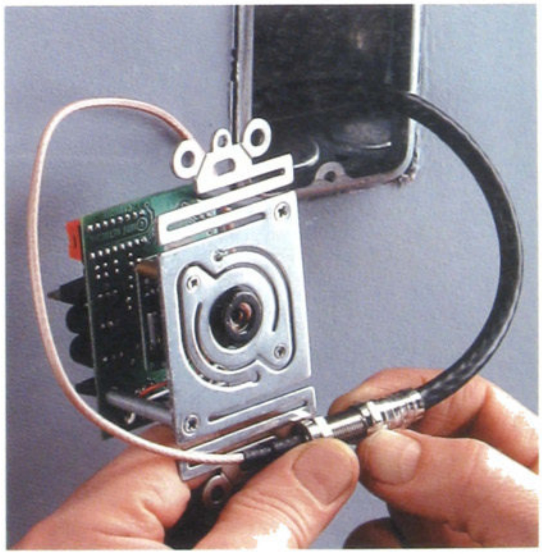
3 Place each wire into the groove of the appropriate terminal on the RJ45 jack, then use a 110-punch-down tool to seat the wire completely The tool has a spring-tension head that forces the wire down and trims off the end There should be no more than ½" of wire from the terminal to the outer cable insulation.



4 Fit a terminal cap over the ends of the jack terminals, then snap the jack into the coverplate

How to Terminate Video Connectors

All coaxial video cables have plug-and-play connectors. The F-connector cable end is simply screwed to the back of the self-terminating F-connector terminal, and then snapped into the coverplate.



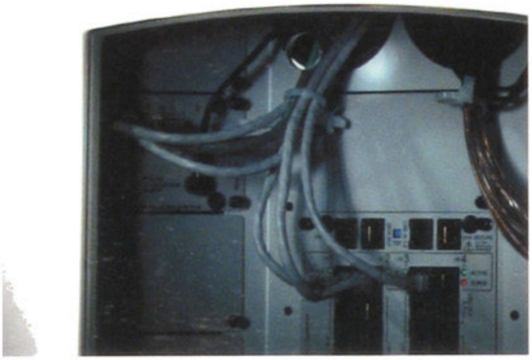
Video cameras also have plug-and-play, self-terminating F-connector connections. Consult the manufacturer's installation guide for setup and playback of your particular camera.

Making Final Connections

To house the distribution modules, mounting brackets are installed within the distribution center. Some brackets and modules will require screws for installation, while others use plastic push-pin grommets.

For easy connection to modules, RJ45 plugs are attached to UTP cable ends and F-connectors to coaxial cable ends (pages 288 to 289). All cables and wires should be clearly marked for easy identification and installation. It is best to keep all cables and wires routed to the same modules in neat, organized groupings. Bind the groupings with tie wraps where appropriate.

Once all the connections are made and the system is in working order, a cover is attached to protect the electronic modules and cable connections.

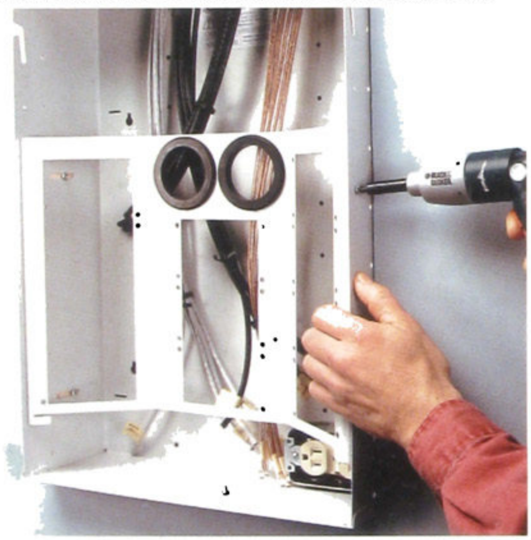


Everything You Need

Tools: screwdriver.

Materials: modules; RJ45 plugs; F-connectors; screws or push-pin grommets (as required).

How to Install Distribution Center Brackets

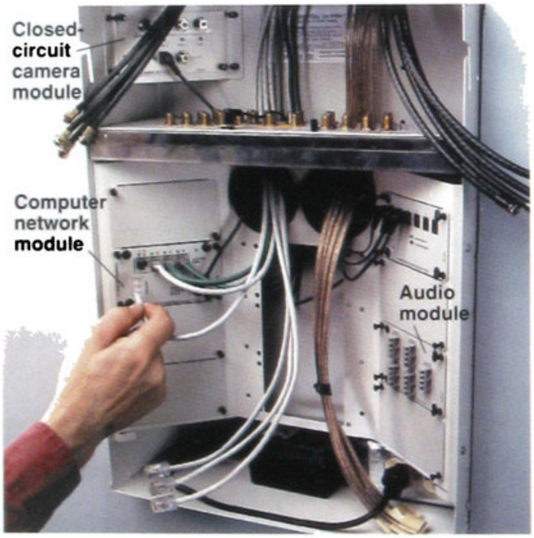


1 Attach the module mounting bracket to the distribution center Align the mounting holes of the bracket panel with the pre-routed holes in the sides of the distribution center and attach, using the screws provided.

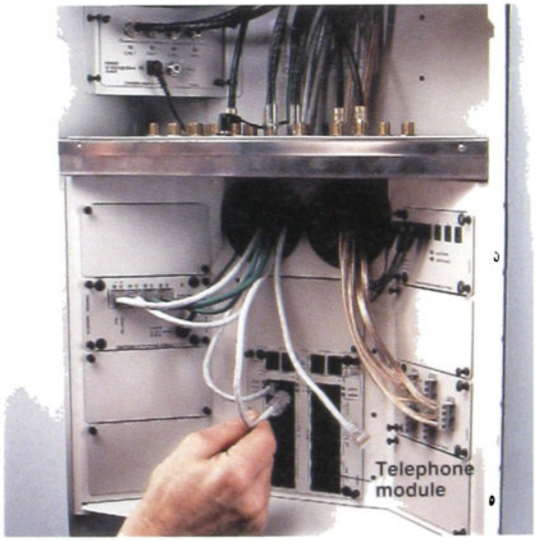
2 Attach any additional single brackets that may be necessary for specialized modules or keeping power transformers separate. Some brackets require screws for installation, while others use push-pin grommets.

1 Determine where each module will be placed in the mounting brackets. Route any cables and wires through the mounting brackets to their corresponding module.

2 Plug the power transformer into the power distribution module, then snap the power modul in place. The methods for module installation differ among network wiring manufacturers. Some require screws, while others use convenient push-pin grommets. Plug the power transformer into the 120-volt receptacle of the distribution center.



3 Use patch cords to connect the power module to those modules that require power, such as the video distribution, computer network, and video camera modules. Then, install the remaining modules in their chosen locations.



4 Trim the ends of all cables and wires, and attach the appropriate plugs or connectors (pages 284 to 285). Refer to the labels to connect the proper cable to the proper module OUTPUT port, in order to route the desired function to the desired location. Make sure all cables and wires from the service entrance are connected to an INPUT port.

Testing the System & Troubleshooting Problems

Before connecting to the home network system, do a quick recheck of the connections at the distribution center. Make sure that every module requiring power is patched to the power distribution module. Make sure the service lines from the service entrance are connected to the proper module INPUT port. Check that each cable and wire from the room outlets are hooked up to the proper module OUTPUT ports.

Cables and wires that are intended for future use should be gathered and loosely tied together. Run the grouping down one side of the distribution center, out of the way of the other connections. The system is now installed. Attach the cover and plug in the power distribution transformer to the receptacle for power.

To check the quality of signals at multimedia outlets, use a standard 2-way phone and phone cord for RJ45 jacks, and a small television and short length of coaxial cable for F-connectors. The signals should be clear and strong.

If an RJ45 jack does not work, remove the jack from the coverplate and check the pin/pair assignments on the back of the jack. If any wires are terminated to the wrong post, trim the wire ½" from the base and re-terminate the jack.

A variety of hand-held testers can be used to check cables and wires in the network system for continuity, network capabilities, and pin/pair assignments. If a cable or wire is bad, it will have to be replaced.

Network system problems can be traced to one of a few simple causes: a bad connection, a bad cable or wire, a problem with a module, or a bad signal routed to the outlet.

Connectors: First, check that plugs and connection ends, and jack and connector terminations, are correct. A visual inspection of pin/pair alignment on an RJ45 jack or plug will quickly tell you whether it is in working order. If any of the wires of the UTP cable are terminated to the wrong posts, trim the cable ½" from the base and re-terminate the jack or plug. The center conductor of coaxial cables should be straight and extend ⅟₁₆" from the F-connector end. Coaxial cables should be tightly attached to the outlet F-connector. Recheck the connections at the distribution center to make sure the desired signal is routed to the proper outlet.

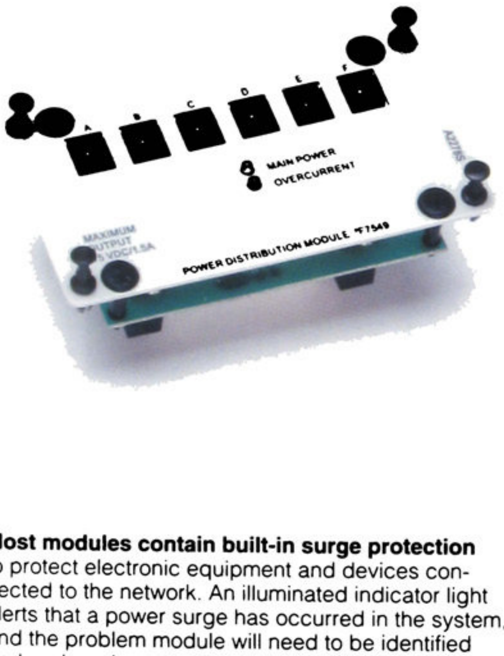
Cables and wires: Damage to cables and wires can easily occur during installation if the proper routing techniques are not observed (pages 284 to 285).

A variety of hand-held testers can be used to check cables and wires for continuity, network and performance capabilities, and pin/pair assignments. However, these testers are quite expensive and are not readily available at rental centers. For this reason, if a cable or wire is suspected to be faulty, it may be more economical to forgo testing and just replace the cable.

Modules: If none of the outlets in a particular network are functioning, check the power distribution module to see if there has been a power surge. The module contains a fuse that automatically resets, protecting the system against power trouble. If the LED light appears red, there has been an abnormal and significant electrical surge in the system. Disconnect all the modules from the power module. Begin reconnecting the modules one at a time, until the LED light on the power module appears red again, indicating the problem module. Disconnect the module, and replace it. Modules for video distribution and computer networks are typically power surge-protected to keep your sensitive and expensive computer and entertainment equipment from damage.

Signals: If, after replacing any damaged modules, there still is no signal or only a very poor signal, test the incoming cables from the service entrance on the interior of the house only. If they are good and problems persist, contact your telecommunication and service providers to check the exterior lines and connections.

Another resource is the growing number of electrical contractors that work with and install network wiring systems. Call around or stop by a home center—many home centers that sell network wiring systems can also help you find a reputable contractor in your area.



Most modules contain built-in surge protection to protect electronic equipment and devices connected to the network. An illuminated indicator light alerts that a power surge has occurred in the system, and the problem module will need to be identified and replaced.

An NID box is located on the outside of the home. It is where the service providers transfer the lines to the homeowner Test the incoming cable lines on the interior of the house only If they are good and problems persist, contact your telecommunication providers to have them check the exterior lines and connections from the NID back to the source.

Home Automation

We live in an age where hand-held data managers communicate with home and work computers, and electronic messages are sent via cable and satellite to televisions and cellular phones. So it should come as no surprise that similar technology is being used to enhance the convenience, comfort, and safety of our homes.

Home automation makes your house "smarter." It integrates a home's communication, computer, audio/visual, entertainment, security, lighting, utility, and environmental systems. You can program lights to go on and off at set times, activate security systems during work and evening hours, and set heating systems to raise and lower temperatures automatically. Even appliances such as washing machines and dishwashers can be programmed to run during off-peak hours, saving energy and money.

Automation systems can also handle everyday tasks, such as ordering groceries, making coffee, and answering the door, which may allow seniors and people with disabilities to remain independent longer.

Photo courtesy of Doormate Corporation

Your system can be programmed to E-mail you at work if a window breaks in your home or to notify you if your child does not arrive home at the expected time. More elaborate systems can link closed-circuit security cameras to motion detectors, child monitors, pagers, emergency personnel, and lighting and alarm systems.

Whole-house automation takes these types of conveniences to the next level, by integrating separate systems, through a home network system (pages 272 to 293). And because system components are modular, smaller systems can be installed to coordinate one or more aspects of your home environment, such as heating, lighting, or security. Additional components can be added as desired.

Automation systems are often run through a home computer. Just as you can instruct your computer to print, you can instruct it to complete tasks in the home, using automation software. Signals are forwarded to components—such as lighting or appliances—that are plugged into the system. The system is then accessed and programmed through control panels, remote controls, computer keyboards, voice activation, and even over the Internet. An X-10 controller (a receiving device) and plug-in modules are required but run on standard 120-volt current.

With the many systems available, there are three main categories: network wired, existing wires, and wireless. A **network wired system** uses a home network system with high-performance cables to distribute transmission signals throughout the home (see pages 272 to 273). Using **existing wiring,** the system communicates with your computer through standard phone lines. **Wireless systems** often operate without computer programming, instead using remote controllers.

An optimal home automation network may utilize components of each type of system. For example, a home may be wired for a network, then expanded with

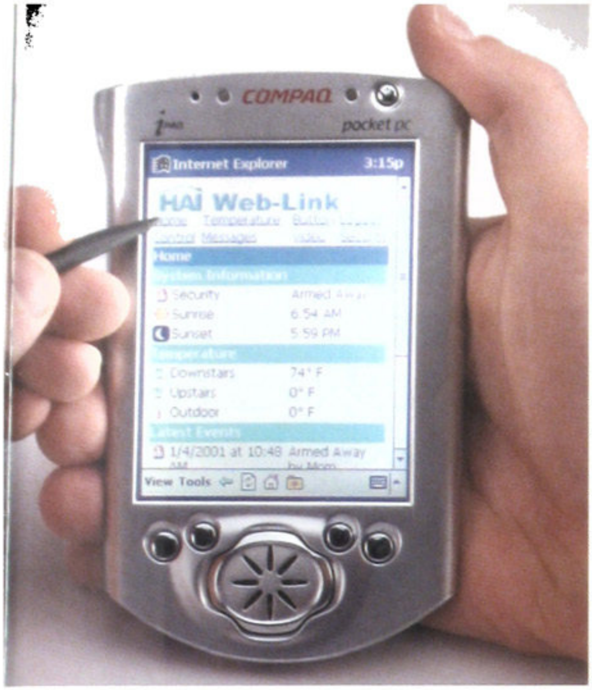


Photo courtesy of Home Automation, Inc.

(above) Hand-held data managers can be used to activate different features of your home automation system from outside the house.

(below) An automation system that uses a network wiring system to route signals throughout the home accessed through control panels or key pads mounted in convienent locations around your home.

wireless transmitters, or extended with existing phone and power lines.

Do-it-yourself home automation systems are available at home centers, electronic retailers, software distributors, and online. Cost varies, depending upon the scale of the system. Many systems offer upgrades and options for future expansion and enhancement. A unified network that supports every automation feature does not yet exist. Right now, home automation is a combination of systems that run voice, data, video, audio, and Internet services.

It might be wise to consider adding fiber-optic cable or installing conduit to make future wiring easier. If you need help designing your system, contact alarm and telecommunications wiring contractors, home entertainment specialists, or low-voltage electrical wiring specialists.

Home automation is an investment that can usually be included in a home mortgage. The automation market is projected to continue growing at a steady rate as homeowners and buyers become accustomed to the convenience, comfort, and security of home automation. In addition, many homeowners have home offices that require automated networking. As these factors continue to affect our lives, home automation improvements will enhance a home's retail value. What is now considered an added feature may soon be a household requirement.

Photo courtesy of Home Automation, Inc.

Conversion Chart

Converting Measurements

To Convert:	To:	Multiply by:
Inches	Millimeters	25.4
Inches	Centimeters	2.54
Feet	Meters	0.305
Yards	Meters	0.914
Square inches	Square centimeters	6.45
Square feet	Square meters	0.093
Square yards	Square meters	0.836
Cubic inches	Cubic centimeters	16.4
Cubic feet	Cubic meters	0.0283
Cubic yards	Cubic meters	0.765
Ounces	Milliliters	30.0
Pints (U.S.)	Liters	0.473 (Imp. 0.568)
Quarts (U.S.)	Liters	0.946 (Imp. 1.136)
Gallons (U.S.)	Liters	3.785 (Imp. 4.546)
Ounces	Grams	28.4
Pounds	Kilograms	0.454

To Convert:	To:	Multiply by:
Millimeters	Inches	0.039
Centimeters	Inches	0.394
Meters	Feet	3.28
Meters	Yards	1.09
Square centimeters	Square inches	0.155
Square meters	Square feet	10.8
Square meters	Square yards	1.2
Cubic centimeters	Cubic inches	0.061
Cubic meters	Cubic feet	35.3
Cubic meters	Cubic yards	1.31
Milliliters	Ounces	.033
Liters	Pints (U.S.)	2.114 (Imp. 1.76)
Liters	Quarts (U.S.)	1.057 (Imp. 0.88)
Liters	Gallons (U.S.)	0.264 (Imp. 0.22)
Grams	Ounces	0.035
Kilograms	Pounds	2.2

Metric Equivalents

Inches (in.)	1/64	1/32	1/25	1/16	1/8	1/4	3/8	2/5	1/2	5/8	3/4	7/8	1	2	3	4	5	6	7	8	9	10	11	12	36	39.4
Feet (ft.)																								1	3	3 1/12
Yards (yd.)																									1	1 1/12
Millimeters (mm)	0.40	0.79	1	1.59	3.18	6.35	9.53	10	12.7	15.9	19.1	22.2	25.4	50.8	76.2	101.6	127	152	178	203	229	254	279	305	914	1,000
Centimeters (cm)							0.95	1	1.27	1.59	1.91	2.22	2.54	5.08	7.62	10.16	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	91.4	100
Meters (m)																								.30	.91	1.00

Index

Resources

Photo Contributors

Doormate Corporation
1-905-669-6494
www.doormate.com

Home Automation, Inc.
1-800-229-7256
www.homeauto.com

Pass & Seymour legrand
1-800-223-4185
www.passandseymour.com

Materials Contributors

Pass & Seymour legrand
Commercial & Residential
Network Wiring
P.O. Box 4822
Syracuse, NY 13221
1-800-223-4186
www.passandseymour.com

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