



HOW-TO BOOKLET #3005

WIRES & WIRING



TOOL & MATERIAL CHECKLIST

- Wire Needed for Project
- Wire Strippers
- Wire Cutters
- Standard Screwdriver
- Electrician's Tape
- Solderless Connectors
- Knife
- Cable Ripper

Read This Entire How-To Booklet for Specific Tools and Materials Not Noted in the Basics Listed Above.

To hookup any electrical circuit from scratch, you will need a conductor to connect the power (electricity) to a switch, outlet, and/or fixture, such as a ceiling light. The type and size is the prime consideration. Switches, outlets, and fixtures — along with in-wall and ceiling boxes in which the switches, outlets, and fixtures are connected — are matched to the conductor. For example, No. 6 wire for an electric range would not be used to connect a lighting circuit that requires a No. 12 wire.

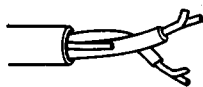
TYPES OF CONDUCTORS

Technically, the metal through which electricity flows is called a conductor. In the real world, it's called wire, cord, and cable. That is how it is referred to in the stores that sell it.

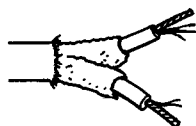
Wire. For practical purposes, a wire is a single strand of conductive material enclosed in protective insulation. You can buy single-strand wire off of a roll in any length you want. It is sometimes precut and packaged in standard lengths.

Cord. A cord is stranded wires encased in some type of insulation, such as plastic, rubber, and cloth (**Fig. 1**). Zip cord, for example, is two wires, encased in a rubber-like insulation and held together with a thin strip between the wires. You can easily separate the wires by pulling them apart, hence the name zip cord. You zip it apart. Cord is used for lamps, small appliances, and cord sets that have plugs and/or receptacles on one or both ends of the cord. It is sometimes precut and packaged, but is usually sold off of the roll. All conductors are priced by the lineal foot.

Fig. 1



Type SO — Heavy-duty flexible cord, used for power tools and high capacity appliances.



Type HPD — Flexible heater cord, used for toasters, irons and heaters. The cord is protected against heat.



Type SPT — Flexible lamp cord. Light duty cord used for lamps, small appliances and extension cords.

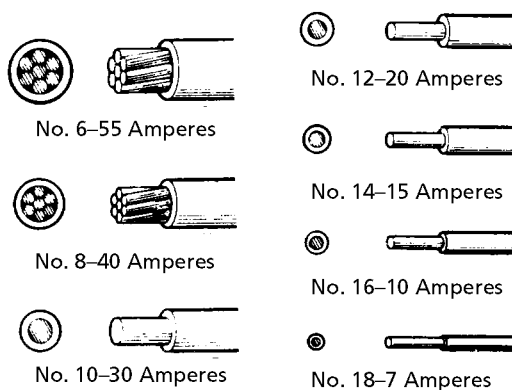
Types of Cords

Cable. A cable has two or more color-coded insulated wires grouped together within a protective sheathing of plastic or metal. Black (or sometimes red) is the insulation color code for power or hot wires. White is the code for neutral; green or green and yellow stripes for ground. Or the green wire may be substituted with a plain bare copper wire. It too is “ground.” Cable is normally sold in precut lengths of 25', 50', 100' or 250'.

WIRE SIZE AND TYPE

The size of wire and its type is the prime consideration when doing any electrical work (**Fig. 2**). Wires that carry electrical current are similar to pipes that carry water: the larger its diameter, the more current (amperes) it can carry. The American Wire Gauge (AWG) system is the standard system used for measuring wire size (gauge). Gauge numbers are inverse to their size; thus, for example, No. 12 wire is smaller than No. 10 wire. Large wire is usually stranded; smaller gauge wire is usually solid. Nos. 16, 18, and 20 contain multiple strands twisted or braided together.

Fig. 2



Wire Size Guide

No. 12 wire has replaced No. 14 as the standard residential wire, and it is now required by National code for all new residential wiring to be No. 12 with ground unless, of course, specified otherwise. Exceptions to this are the wiring used in lighting fixtures, furnace controls, doorbells, and other low-energy or amperage circuits.

The electrical wire in your home may be made from three different types: copper, copper-clad aluminum, and aluminum. For any project, you should always use the same type of wire that is installed in your home. You can determine this by opening a switch or outlet box, pulling out the wires, and noting the information printed on the insulation. The method of reading wire markings is given later in this booklet.

Special care must be used with aluminum wire. It does not behave like copper wire. Aluminum wire tends to expand and contract, working itself loose from terminal screws. This can cause trouble — mainly electrical fires. If your home uses copper-clad aluminum wires, do not add aluminum wire to it. Use copper or copper-clad aluminum wire.

If your home has aluminum wire, check to make sure that the switches and receptacles are marked CO/ALR or CU/AL. The CO/ALR marking is used on switches and receptacles rated up to 20 amps. The CU/AL marking is used on switches and receptacles rated at more than 20 amps. If the switches and receptacles do not bear these markings, replace them with those that do. Never use aluminum wire with any back-wired switch or receptacle that requires pushing the wire into the device. Aluminum wire must connect to terminal screws.

Since recommendations for wire sizes are generally for copper and copper-clad aluminum wires, you must readjust the designation to the next larger size when using aluminum wire. For example, if No. 12 copper wire is recommended but you are using aluminum wire, you must use No. 10 instead.

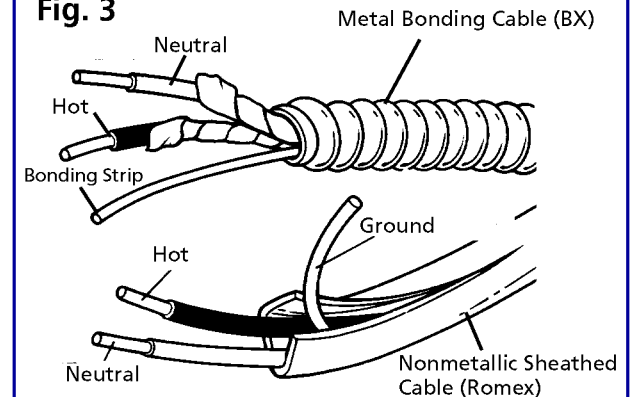
CABLE CLASSIFICATION

House electrical circuits are wired with metal-armored (BX) cable, nonmetallic sheathed (ROMEX) cable, or with insulated wires running through metal or plastic pipe called conduit.

Metal-Armored Cable. Armor-wrapped cable is commonly called BX, a trade name. It has an outer layer of flexible galvanized steel that contains two or three wires. Each wire is individually wrapped with paper. If the cable does not have a ground wire, the metal sheathing serves as a ground whenever it comes in contact with a metal junction, switch, and outlet box.

Use of BX cable (**Fig. 3**) sometimes is restricted by electrical codes. Check the local codes where the material is sold. BX also is restricted to use indoors in dry locations. It is sometimes specified for use where power wires need extra sheathing protection from nails used in carpentry or decorating.

Fig. 3



Many kinds of wire and cable are sold to meet all project needs. Package label or wire insulation gives data on wire size or gauge, type of insulation, and power capacity.

Nonmetallic Cable. You probably will buy and work with nonmetallic plastic-sheathed cable (**Fig. 3**) more than any other conductor or wire. It is often called by a trade name, Romex, which has almost become synonymous with any nonmetallic electrical cable. Local codes may allow nonmetallic cable only in certain locations, or may specify that you use another type, such as metallic armored cable, or wires running in conduit.

The outer sheath of nonmetallic cable is usually a moisture-resistant, flame-retardant material. Inside, there are two or three insulated power wires, and perhaps a grounding wire. For most residential wiring, two types are often used.

📌 **Type NM.** This is based only in dry locations. Each wire, with the possible exception of the ground wire, is wrapped in its own plastic sheath. The three wires are then wrapped in a paper insulator, and the wrapping is covered with plastic.

The wire in Type NM is either AWG No. 12 or AWG No. 14 for house circuits. Larger sizes such as No. 10 or more are used for heavy appliances. NM is available in two or three conductors, plus the ground.

📌 **Type UF.** For use in wet locations, including underground, UF cable is an alternative to conduit. The cable has individual wires embedded in water-resistant solid plastic. The cable is available in AWG No. 12 and No. 14, with the ground.

Conduit. According to code, conduit can be galvanized steel pipe or plastic pipe. Metal conduit comes in three types: rigid (often preferred for outdoor use), intermediate, and electrical metal tubing (EMT) — a newer type popular for house wiring. Standard conduit diameters are 1/2", 3/4", 1", and 1-1/4". There are fittings to join conduit for straight runs and at 45-degree angles. The material is bent with a tool called a hickey.

In some areas, by code, short lengths of BX cable may be enclosed in a conduit.

UNDERSTANDING THE MARKINGS

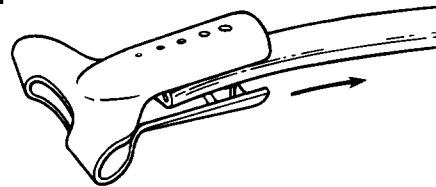
Markings on the insulation, plastic sheathing, and on nonmetallic cable explain what is inside and identify the type of insulation covering. Consider the following designation:

12/2 With Ground, Type NMC, 600(UL)

The first number tells you the size of the wires inside the insulation or cable, in this case No. 12 gauge. The second number tells you that there are two conductors (wires) in the cable. There also is an equipment grounding wire, as indicated. The type of cable is given; the number following indicates the maximum voltage allowed through the cable. Finally, the UL notation assures you that the cable has been rated as safe for the uses for which it was designed.

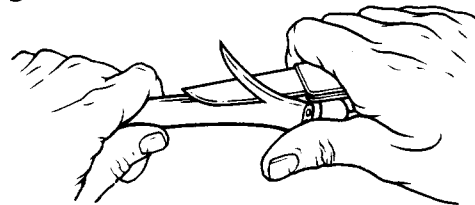
To connect 3-way switches — switches that control a light from two points — use No. 12/3 with ground cable. No. 12/3 has a black, white, red, and ground wire. The red wire is called a “traveler” wire and runs the power between both switches.

Fig. 4



Cut the sheath insulation.

Fig. 5



Trim and remove the sheath insulation.

ESTIMATING WIRE NEEDS

To estimate the amount of wire or cable you will need for a project, measure the distance between the new outlet and the power source. Add an extra foot for every connection you will make. Then, to provide a margin for error, add 20% to this figure.

For example, if you measure 12' between a new and existing receptacle, add another 2' for the two connections, making a total of 14'. Then add 20% (about 3') to the total. To do the job, start working with 17' of cable. The same formula is used for wire, with the exception of lamp/appliance cord.

MECHANICS OF WIRING

The mechanics of wiring — attaching the wire to switches, outlets, and fixtures — are fairly simple: cutting wire, stripping insulation, and connecting wires to the proper terminals.

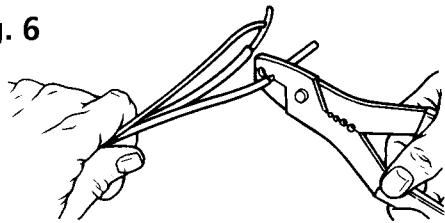
To prepare non-metallic sheathed cable:

- 1 Cut the cable to the proper length. Use lineman's pliers or a hacksaw.
- 2 Cut the sheath insulation (**Fig. 4**). Place the cable on a flat surface, such as a workbench. Measure about 8" from the end of the cable and make a mark. Then insert the cable in a cable ripper at the marked point. Press the cable ripper together with your fingers and pull the cable through the ripper to the end of the cable.

If you use a knife instead of a ripper, start cutting the sheath, being extremely careful not to cut the insulated wires inside the cable (**Fig.5**). It may take several shallow cuts with a knife to part the plastic sheath. If you damage the wire, cut that part off and start again.

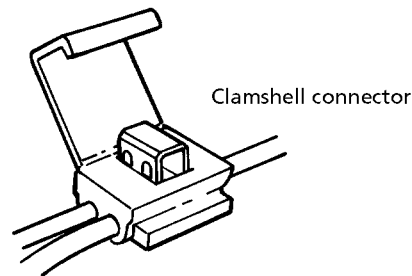
- 3 Trim the sheath insulation. With your fingers, peel back the sheath and then use a knife to trim away the excess sheath material at the first cutting mark.

Fig. 6



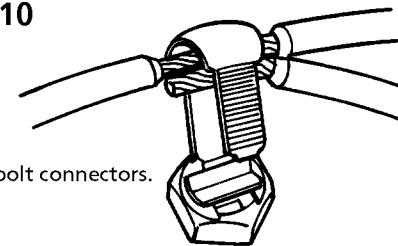
Remove the individual wire insulation.

Fig. 8



Clamshell connector

Fig. 10



Split bolt connectors.

- 4** Cut the wire insulation (**Fig. 6**). With the wire strippers, remove about 1/2" to 3/4" of insulation from the black-insulated power wire, the white-insulated neutral wire, and the green or green and yellow grounding wire (if it is insulated). As you work, check to make sure that you did not cut the wire insulation with the ripper or knife as you removed the sheath insulation. If you did cut the insulation on the wires, trim off all wires at the cutting mark and start over. The insulation on the wires inside the cable must be completely sound in order to prevent hazards, such as an electrical short circuit or, worse, an electrical fire.

To Prepare Metal-Armored Cable

- 1** To strip armored cable, make a hacksaw cut about 8" from the end of the cable. Firm the cable in a vise, or hold it flat on a rigid surface. Push the hacksaw diagonally across a crowned section of the cable (not in a groove).

Hacksaws cut on the forward stroke if the blade is properly mounted on the frame of the saw. Use some pressure, but not a lot on the saw. Be careful to prevent sawing too far through the cable and cutting the wires inside the cable.

- 2** When the cut is made, snap the cable at the cut with your hands. It will break. Then insert a BX plastic collar around the cut to protect your hands.
- 3** Strip insulation on the wires inside the cable the same way as previously detailed.

A spliced wire must be as good as a continuous conductor. While there are many different splicing techniques, the two-wire splices shown in (**Fig. 7**) are the most common.

Wires may also be connected by using solderless connectors such as:

Clamshell Connector. This connector (**Fig. 8**) is molded from a single piece of plastic with a pointed metal insert. Simply insert the wires and close the lid; the metal points will make a good contact with the metal wire.

Wire Nut. This connector (**Fig. 9**) is used to splice two stranded wires. Strip away about 1/2" to 1" of the insulation on each wire, twist them together, and screw on the nut. Then wrap the wire nut and an inch or so of the wire with electrician's tape.

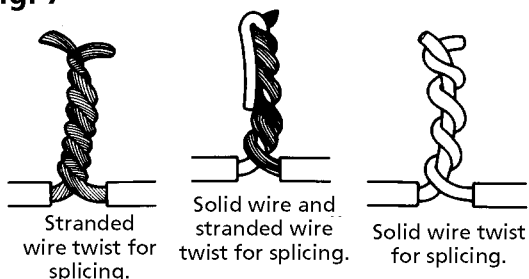
Split Bolt Connectors. This connector (**Fig. 10**) is ordinarily used for heavy, stranded wires. Make sure the connector is made of a metal that is compatible with the wire to prevent corrosion. Wrap bare wires with electrician's tape.

By code, wire cannot be spliced outside a junction, switch, or outlet box.

SPlicing AND JOINING WIRES

A good connection should be mechanically and electrically secured without any soldering. You should regard soldering or splicing devices as extra protection against insecure connections.

Fig. 7

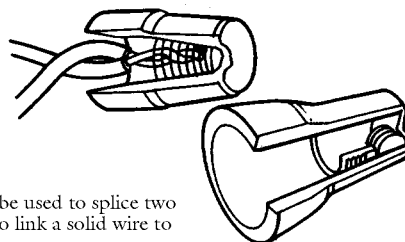


Stranded wire twist for splicing.

Solid wire and stranded wire twist for splicing.

Solid wire twist for splicing.

Fig. 9



Wire nuts can be used to splice two solid wires, or to link a solid wire to a braided wire.

CONNECTING TO A TERMINAL

To connect to a terminal, remove the insulation from the wire and twist the end into an open loop; hook the loop around the terminal with the opening to the right. Then tighten the screw, making sure that the wire is in full contact with the screw and contact plate. The screw must be tight.