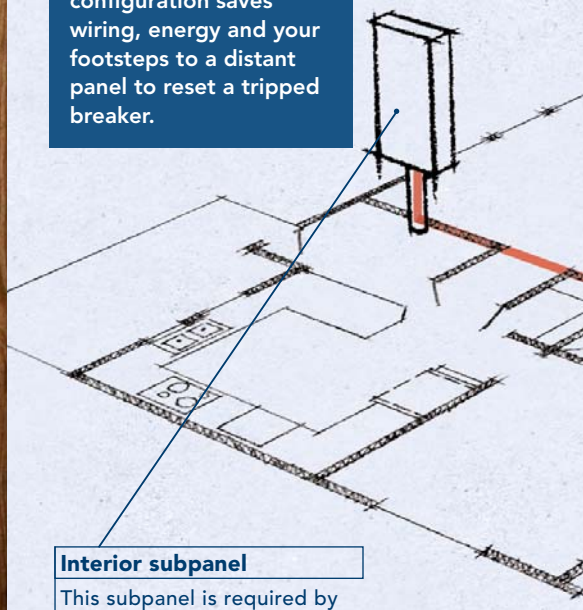
Subpanels



A subpanel is a secondary breaker box

Instead of originating at the main service panel, electrical circuits can begin at a nearby subpanel that is powered from the main panel through one heavy-gauge cable. This configuration saves wiring, energy and your footsteps to a distant panel to reset a tripped breaker.



Interior subpanel

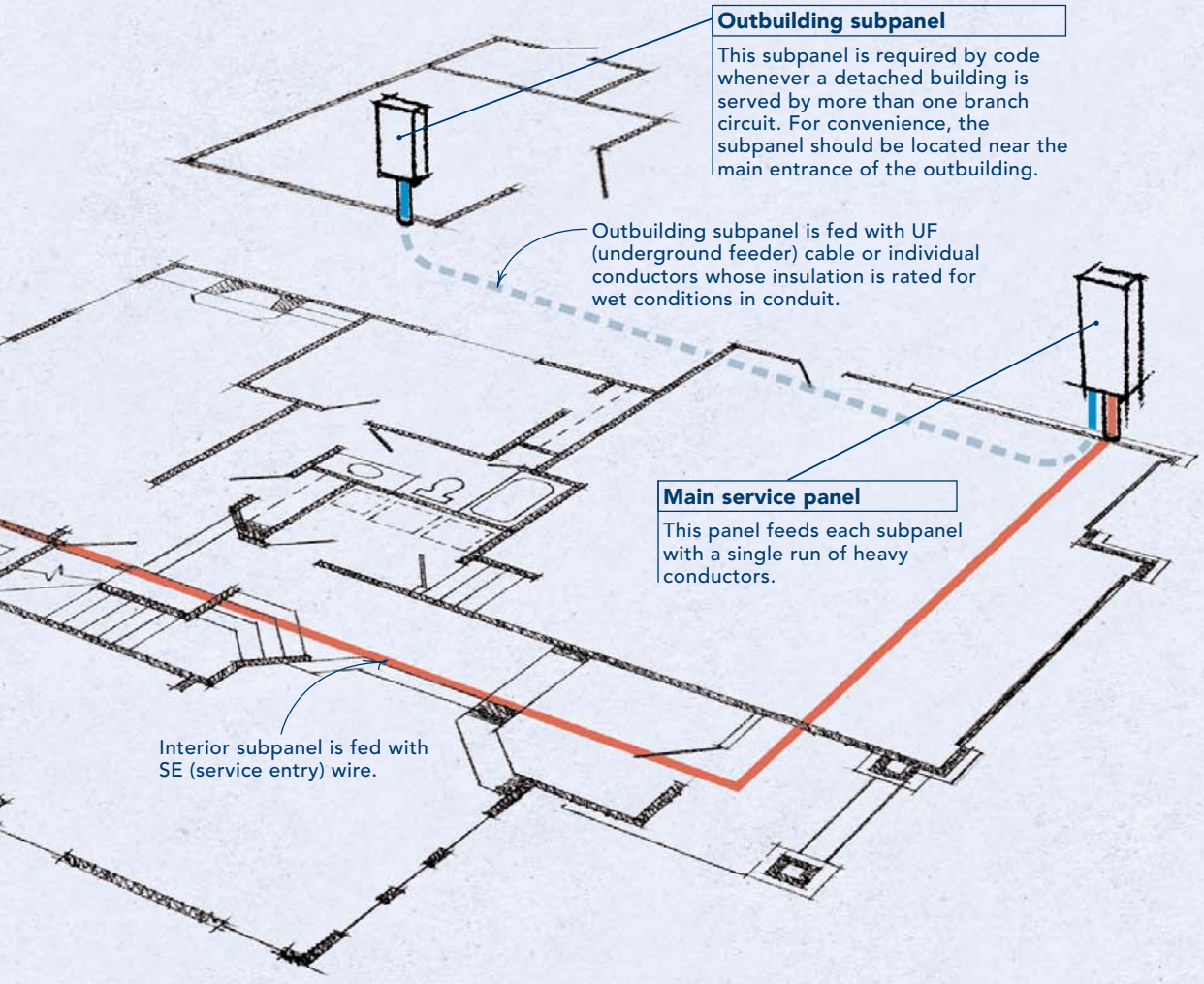
This subpanel is required by code only when a house has more than 42 circuits. If a heavily circuited area such as a kitchen is far away from the main panel, a nearby subpanel adds convenience and reduces wasted energy.

Bring Big Amps to Distant Spaces

BY CLIFFORD A. POPEJOY

Drawings: Mark Hannon

If the kitchen's a long way from the service entrance or if you need to electrify an outbuilding, a subpanel can add convenience and save energy



A properly located subpanel saves energy

When electricity travels a long distance on a wire, some of its energy is lost before it reaches its destination. The smaller the wire, the greater the resulting power loss, or voltage drop. If, for example, the kitchen circuits are more than 80 ft. away from the main service panel, adding a subpanel could substantially reduce the voltage drop. Less voltage is lost by the heavy-gauge wires that feed a subpanel than would be lost by the equivalent number of light-gauge branch-circuit wires running back to the main panel.

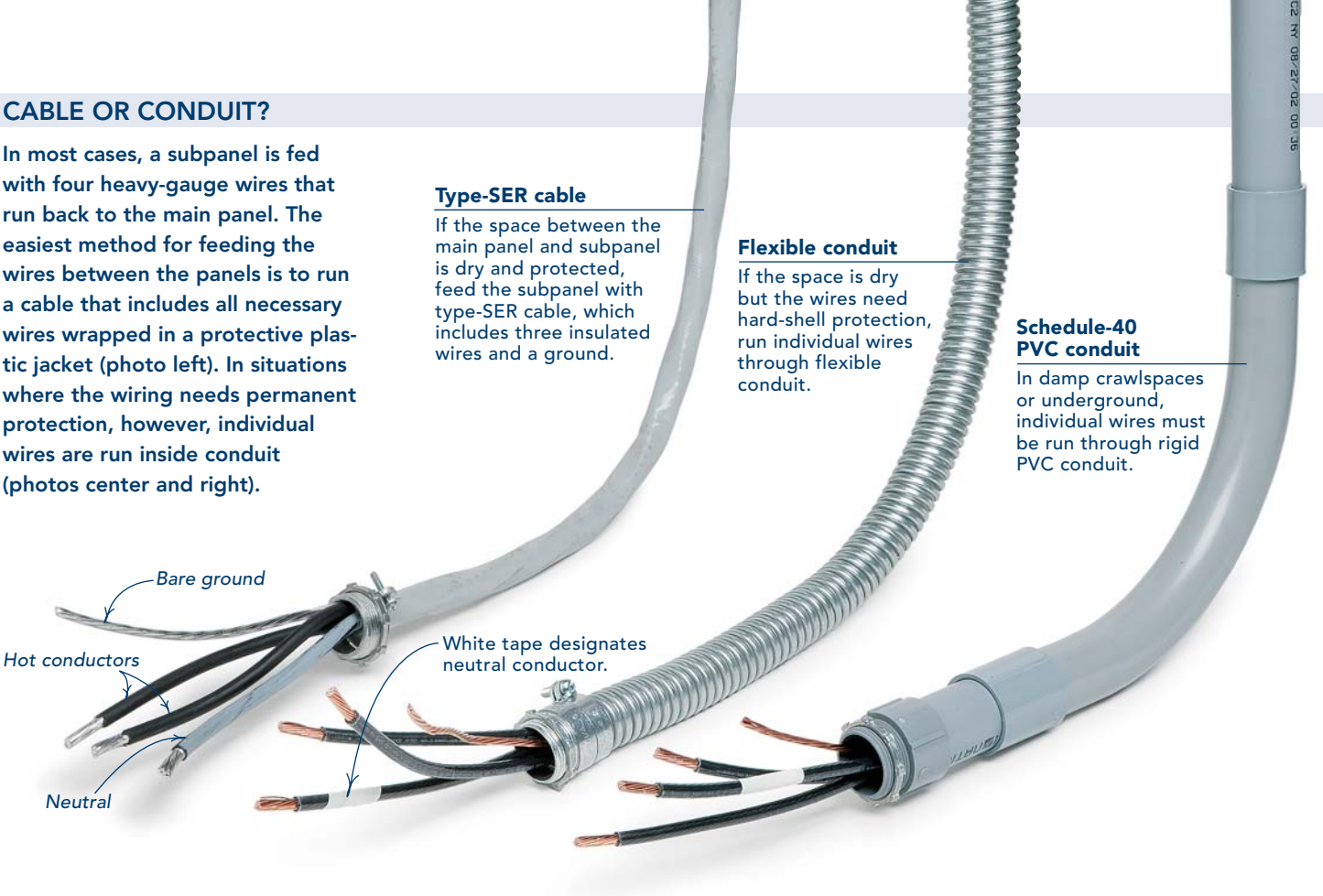
Every modern house has a main electrical panel that houses the circuit breakers. These days, many houses also have a secondary breaker panel, commonly called a subpanel. This setup—two power-distribution centers—offers real advantages in some situations. If you understand a few key differences between the wiring in a main panel and that in a subpanel, installing a subpanel can be an easy way to improve the convenience as well as the overall performance of a home's electrical system.

In some cases, the National Electrical Code (NEC) mandates the installation of a subpanel (drawing above). Most of the ones that I install, however, are voluntary. If the kitchen—with all its heavily loaded appliance circuits—is located far away from the main service panel, a nearby subpanel is a convenient feature, especially if a breaker trips in the middle of the night.

More important, a subpanel can cut down substantially on voltage drop because less power is lost in the large wires that feed a subpanel than would be lost by the equivalent number of smaller branch-circuit wires each running back to the main panel. I think of voltage drop as electricity that is being paid for but that doesn't provide any useful work; it's energy wasted as heat generated by the electricity traveling through the wires. Providing full voltage at the receptacle means appliances will run more efficiently and motors will last longer. Code

CABLE OR CONDUIT?

In most cases, a subpanel is fed with four heavy-gauge wires that run back to the main panel. The easiest method for feeding the wires between the panels is to run a cable that includes all necessary wires wrapped in a protective plastic jacket (photo left). In situations where the wiring needs permanent protection, however, individual wires are run inside conduit (photos center and right).



Type-SER cable
If the space between the main panel and subpanel is dry and protected, feed the subpanel with type-SER cable, which includes three insulated wires and a ground.

Flexible conduit
If the space is dry but the wires need hard-shell protection, run individual wires through flexible conduit.

Schedule-40 PVC conduit
In damp crawlspaces or underground, individual wires must be run through rigid PVC conduit.

recommends that total voltage drop from the main panel to the point of use be 5% or less. For heavily loaded circuits, such as those that serve kitchen or bathroom receptacles, this could translate to as little as 80 ft. of cable.

To reduce voltage drop for long circuits, you could increase the gauge of the branch-circuit wiring. But it takes more time and effort to work with heavier wires, and they take up more space in crowded electrical boxes (see *FHB* #144, p. 79). I always recommend putting a subpanel in a house if it is larger than 4000 sq. ft. or in a smaller one if the kitchen is more than 80 ft. from the main panel. For convenience, I also recommend installing a subpanel in any house that has two or more floors that are above the main panel, or in a house that has a basement workshop.

Sizing and locating a subpanel

As with the main panel, I consider two things when I'm selecting a subpanel: the current capacity (i.e., amperage) and the number of circuits. Both of these factors depend on the size and the variety of the loads that the panel will supply. A subpanel that serves lighting and receptacle circuits in the same house as the service panel generally would be rated for 60 amps or 100 amps, and it would include 12 to 24 spaces for circuit breakers. A subpanel that serves a separate building, however, might be rated for 100 amps or 150 amps or more, and it could include spaces for as many as 42 breakers. (See "Installing an Electrical Service," *FHB* #150, pp. 78-85, for a discussion on load calculations and panel sizing.)

You can get a subpanel with or without a main breaker. Although code does not require a main breaker unless the panel serves a separate building and has more than six breaker spaces, every subpanel that I install includes a main breaker for safety reasons.

The subpanel should supply the circuits farthest from the main panel. The only exceptions to this rule are circuits that serve large motorized appliances, such as refrigerators and air-conditioner compressors. These circuits should be run directly back to the main panel, or the current draw during motor start-up will cause lights fed from the subpanel to flicker.

When I install a subpanel in the main house, I try to find a location about two-thirds of the way from the main panel to the end of the farthest circuit (drawing pp. 96-97) and that's close to heavy loads (usually the kitchen). Unfortunately, I can't hang the subpanel box just anywhere. Panel doors are designed strictly for function, not decorative appeal, and in addition to aesthetic concerns, I have to comply with code requirements that address location and access clearance (sidebar p. 101).

Ground and neutral never meet in a typical subpanel

Once I have settled on a location and have mounted the subpanel, I need to feed power to

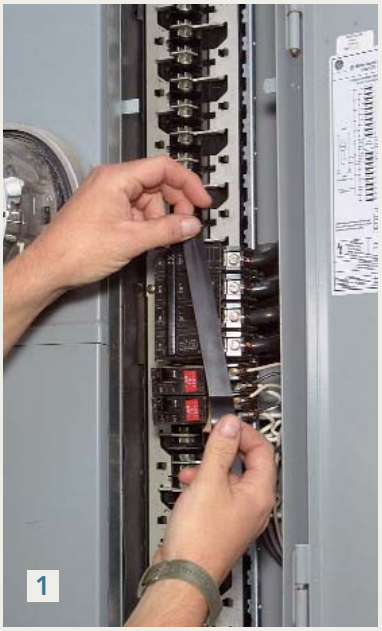
SAFETY TIP

LOCK THE COVER SO THAT NO ONE FLIPS THE SWITCH

After the subpanel feeder cables have been wired into the main panel, the main panel is locked and labeled to make sure no one energizes the system until after the subpanel wiring is completed.



Top photos this page: Scott Phillips


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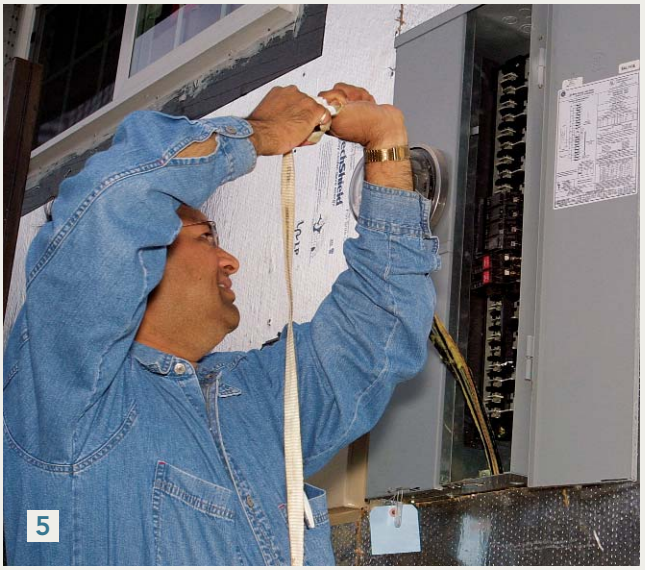
How do you get the wires through the conduit?

After cutting power and taping off all exposed live conductors in the main panel (photo 1), the author runs an electrician's fish tape (Greenlee Textron; 800-435-0786; www.greenlee.textron.com) from the subpanel back to the main (photo 2). Plenty of cable-pulling lube (Ideal Industries Inc.; 800-435-0705; www.idealindustries.com) makes the entire process less strenuous (photo 3). Back at the main, a helper attaches conduit-pulling tape (Greenlee) to the end of the fish, and the author yanks it back. After stripping the ends of the insulated conductors, he ties all four wires to the pulling tape (photo 4); then he wraps the connection in electrical tape and yells for the helper to haul it back (photo 5).



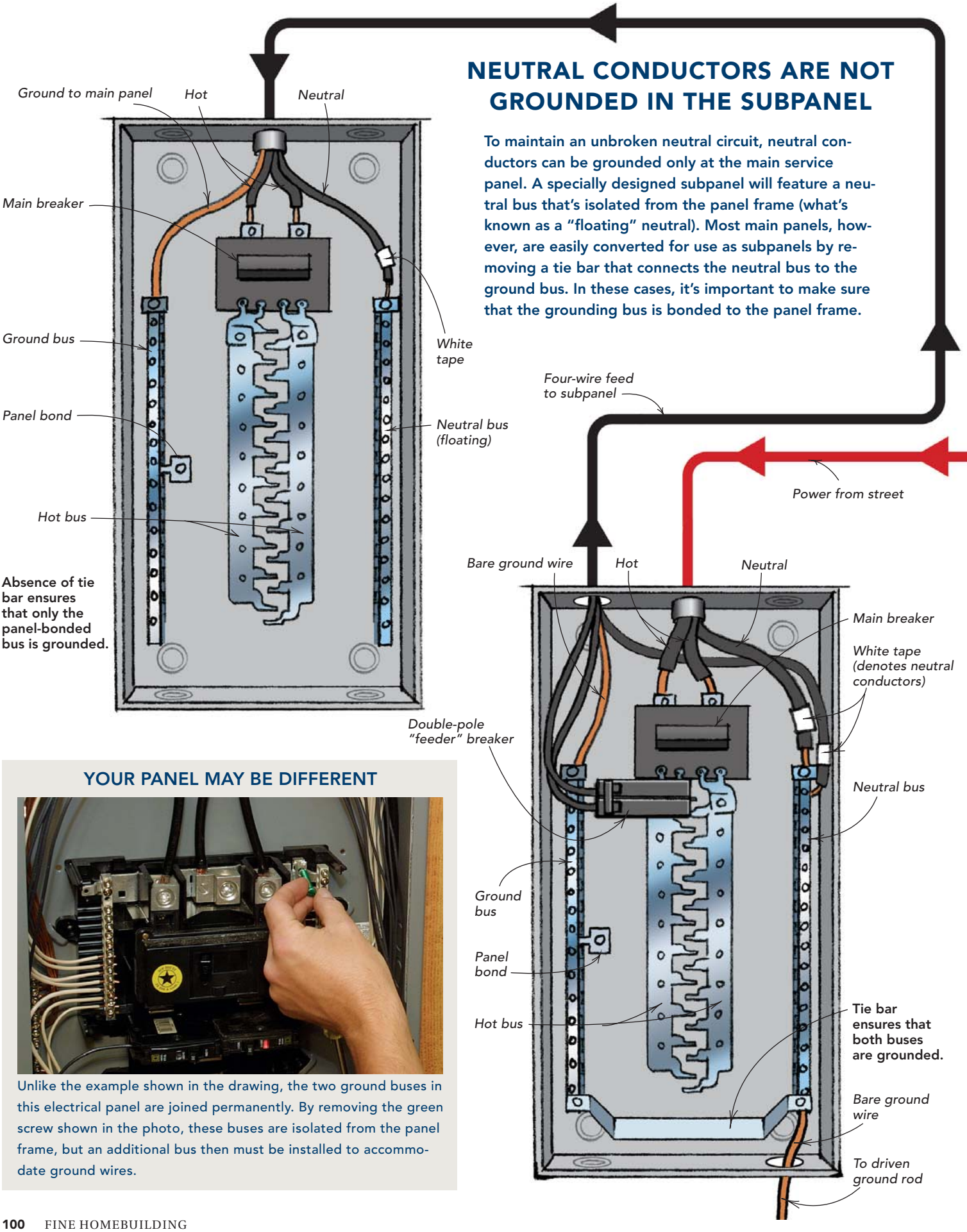
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NEUTRAL CONDUCTORS ARE NOT GROUNDED IN THE SUBPANEL

To maintain an unbroken neutral circuit, neutral conductors can be grounded only at the main service panel. A specially designed subpanel will feature a neutral bus that's isolated from the panel frame (what's known as a "floating" neutral). Most main panels, however, are easily converted for use as subpanels by removing a tie bar that connects the neutral bus to the ground bus. In these cases, it's important to make sure that the grounding bus is bonded to the panel frame.



YOUR PANEL MAY BE DIFFERENT

Unlike the example shown in the drawing, the two ground buses in this electrical panel are joined permanently. By removing the green screw shown in the photo, these buses are isolated from the panel frame, but an additional bus then must be installed to accommodate ground wires.

it. I usually feed a panel within the main house with nonmetallic sheathed cable: three insulated wires and one bare ground in a protective jacket (photo top left, p. 98).

I sometimes have to use conduit, however. On the job shown in the photos, the feeder had to run most of the way beneath a concrete slab. To protect the conductors, I ran schedule-40 PVC conduit (photo top right, p. 98) from the service panel to the point where the conduit comes out of the slab into the crawlspace. From there, I simplified the installation by running flexible metal conduit to the subpanel. After the conduit was in place between the panels, I pulled individual wires through the conduit (sidebar p. 99).

In most cases, a subpanel is fed with four wires (drawing facing page). Two insulated hot wires, one from each hot bus in the main panel, provide 120v of power to each subpanel hot bus. With a double-pole breaker, they can combine to power 240v circuits if needed. The insulated neutral carries "spent" electrical current back to its source, and the ground is a safety feature, meant to carry current only if something goes wrong. (For more about neutrals and grounds, see "What's the Difference," p. 128.)

The neutral conductor should be grounded only at the main panel for the system to function properly. If you've purchased a true subpanel, the neutral terminal bus will be insulated from the panel by a plastic spacer; this setup is what's known as a "floating" neutral bus.

Most main panels can be converted easily for use as subpanels. In a main panel, the ground and neutral buses are bonded at the factory by means of a wire or a flat metal strip. In most cases, all you have to do is remove this "tie bar," and you've got a floating neutral bus.

Wiring a subpanel

Apart from the need to keep the neutral and the grounding conductors separate, the connections for a subpanel are the same as those for a main panel (see "Installing an Electric Service," *FHB* #150, pp. 78-85). After shutting off the power, I connect the two hot wires to an appropriate-size double-pole (220v) breaker in the main panel; then I land the neutral and ground wires on the neutral/grounding bus in the main panel (drawing facing page). When I'm finished making these connections, I turn off the feeder breaker and padlock the main panel cover to ensure that a careless tradesperson never has the opportunity to re-energize the system while I'm working on it (bottom photo, p. 98).

Back at the subpanel, I connect the two hot wires to the main breaker, the neutral to the neutral bus and the ground wire to the grounding terminal bus. After I run the branch-circuit wires back to the subpanel, I separate the neutrals from the grounds and direct each to its corresponding terminal bus. Once I've made all these connections, I use a torque screwdriver to tighten each one to the torque value listed on the panel label. (For a discussion about the importance of torque, see *FHB* #150, p. 81.)

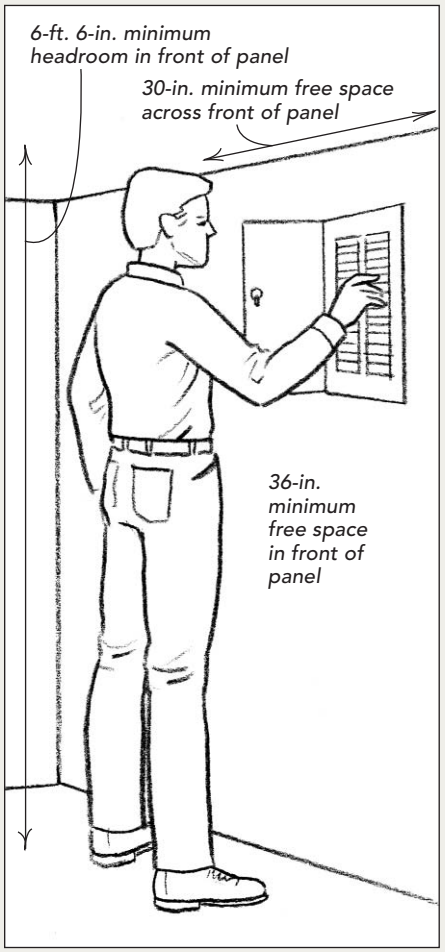
Whenever the subpanel is set in a wall that is to be finished on both sides, I run an empty 1-in. dia. conduit from the panel to either the basement or the attic; then I plug both ends with electricians' putty so that it's not a draft source. This will make someone's life a lot easier if a new circuit is ever needed. Finally, I always label the panel cover with brief but descriptive circuit names. It drives me nuts when I see a panel with six circuits, each of which is labeled "lights and plugs." □

Clifford A. Popejoy wires houses for Habitat for Humanity in Sacramento, CA. Photos by Tom O'Brien, except where noted.

Code checklist

The National Electrical Code sets safety standards for electrical-wiring methods and materials. Here are some key code requirements for subpanels.

- Neutral conductors must be isolated from equipment grounds except at the service entrance.
- Breakers must not be located in bathrooms or near flammable materials such as you'd find in clothes closets.
- Main breaker is required for any subpanels that serve separate buildings (if there are more than six breakers).



WIRE SIZE (NON-METALLIC CABLE)

- A 60-amp panel can be fed with 4/3 wg (#4 AWG, three wires, copper, with a #10 ground).
- A 100-amp panel can be fed with 2/3 wg (#2 AWG, three wires, copper, with a #8 ground).

WIRE SIZE (INDIVIDUAL WIRES)

- A 60-amp panel can be fed with three #6 copper wires with THWN insulation, with a #10 bare copper ground; the minimum conduit size (schedule-40 PVC conduit or flexible metal conduit) for these wires is ¾ in.
- A 100-amp panel can be fed with three #3 copper wires with THWN insulation and a #8 bare copper ground; minimum conduit size is 1 in. (schedule 40) or 1¼ in. (flexible metal).

CONDUIT

- Whenever conduit runs below grade, the cable insulation must be rated for wet conditions (THHW or THWN).
- If there are more than four 90° bends (or equivalent), the run must be broken by an access point, such as a pull box, which is an empty panel inserted in a long run of conduit that enables a worker to grab hold of the wires and pull.

—C. A. P.