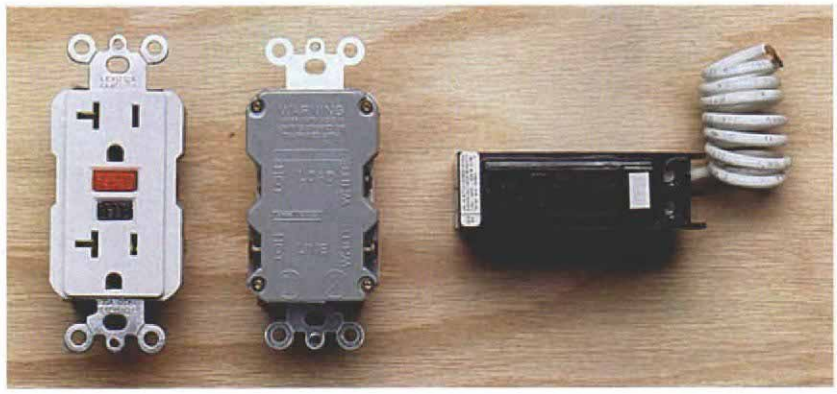
Ground-Fault Protection

An inexpensive electrical device saves lives and is required by building codes



Telltale differences. **GFCI receptacles are easy to reset but can be affected by moisture. GFCI circuit breakers may be a better choice outdoors.**

by Rex Cauldwell

There's not much of a trick to electrocuting yourself while working with a power tool. Take, for instance, a builder using an electric drill outside on a clear, dry day—the drill with a frayed cord he's been meaning to replace. The black wire in the cord, flexed once too often, could break easily and create a short circuit to the drill's metal handle. If that were to happen, electricity would flow instantly through the builder's hand, contracting muscles and tightening his grip on the drill. The current could continue through his body and into the ground beneath his feet, sending his heart into ventricular fibrillation, a wildly erratic rhythm. In a few minutes the builder would be dead.

This kind of pointless accident isn't as far-fetched as it may sound; it almost happened to me. But my drill was plugged into a ground-fault circuit interrupter (GFCI). Instead of being killed, I just felt a sharp jab, like a needle prick, before the GFCI shut off the current in the circuit powering my drill. The circuit breaker wouldn't have helped; it is designed to save the wiring, not me. A 20-amp breaker won't shut off the circuit until the current in the line exceeds 20 amps. That won't do anything for someone grounded by a frayed wire.

GFCIs are inexpensive, easy to install and available as either receptacles or breakers (photo above). GFCI circuit breakers are designed to be installed in the main electric panel and will, if wired correctly, protect all the receptacles on the circuit. Receptacle-type GFCIs fit into a standard receptacle box and will protect any receptacle wired downstream. Some extension cords come with GFCIs already installed in them. Even some hair dryers and other appliances used in potentially wet environments now come with GFCIs in their plugs. Because older GFCIs tripped too easily, some people may have been discouraged from using them; fortunately, the new GFCIs are a lot more reliable.

How GFCIs work—Regular 120v household circuits usually consist of three wires—a black wire, a white wire and a bare neutral, or ground, wire. The two colored wires make up the circuit. Current flows through one wire (typically the black one) to the load, which is the appliance that consumes power. Then the current flows back to the source through the other wire (the white one). A GFCI compares the current flowing to the load with the current coming from the load. The current, or amperage, should be identical. If there's a difference, the electrons must be flowing somewhere other than through the load (such as through you to ground), and the GFCI will open the circuit. GFCIs detect differences of as little as .006 amps and don't need a grounding wire to work. A GFCI responds in 1/25 to 1/30 of a second—25 to 30 times faster than a heartbeat.

As good as they are, GFCIs aren't foolproof. As long as the current flowing through the black wire equals the current flowing through the white one, everything is fine as far as the GFCI is concerned. If you are unlucky enough to be standing on an insulator or nonconductive surface, such as a dry board, and place yourself between the black and white wires, the electricity will flow out of the black wire through you and back into the white wire. No electricity will leak through you to ground, so a ground fault won't exist. And because a GFCI can't tell the difference between you and a light bulb, you'll be just as dead as if there were no GFCI on the circuit at all.

Where to use GFCIs—Generally, the National Electric Code requires GFCIs to be used outdoors, in garages and basements, within 6 ft. of a kitchen sink, around wet bars, in fans and lights above tubs or showers, in spa and whirlpool electrical equipment and in bathroom receptacles. The 1993 code also requires that GFCIs be installed in older homes any time you're replacing a receptacle where the current code requires a GFCI. When a portable tool is used outside the house, even on a porch, a GFCI should be used. (I think it's a good practice to use a GFCI extension cord on all portable tools inside or out.) A licensed electrician should be able to provide a list of all the locations where GFCIs are required. The list is too long to be included here.

Because GFCIs are very sensitive, even modern ones are prone to false tripping. So they should not be installed when life or property would be in jeopardy should power be cut off. For example, don't use them to hook up freezers, sump pumps or medical equipment.

GFCIs, both receptacle and circuit-breaker types, are widely available and should be sized the same way you would a regular receptacle or breaker. A 20-amp GFCI circuit breaker, for instance, goes with a circuit containing 12-ga. wire. Single and double-pole (120v and 240v, respectively) GFCI circuit breakers are available from most manufacturers up to 30 amps, and a few of them make GFCI circuit breakers rated to 60 amps. Above 60 amps, they are hard to find.

Watertight covers—Outdoors, if the GFCI is to be used on something that is always hooked up (like outdoor Christmas-tree lights or an electrically charged garden fence), a waterproof while-in-use cover must be used (left photo, facing page). These covers look like bubbles on the front of the receptacle. Some models are designed to be flush with the outside surface of the house (right photo, facing page).

Installed outside, even in boxes that are supposed to be watertight, receptacle-type GFCIs

Photo this page: Scott Gibson

have a short life span. Somehow, enough moisture creeps into outdoor receptacles to upset the mechanism that makes a GFCI work. These receptacles will continue to provide power, but the life-protection feature may not work (I wish manufacturers would correct this). That's why it is imperative that you test outdoor GFCIs with a plug-in tester that has a test button before using the receptacle (middle photo, right).

The potential failure of outdoor GFCI receptacles is one reason why I recommend using the circuit-breaker type of GFCI for permanent outdoor installations. These are safer but are more expensive and less convenient; you have to reset them at the service panel when they trip.

Check the wiring carefully—Some GFCI receptacles will provide power even if they are wired backward (power from the service panel is wired to the load side instead of to the line side). They will test normally, but they may not provide life protection. Some incorrectly wired GFCI breakers will test as if they're working properly, but the problem will show up when you test protected receptacles wired into them.

Only the first receptacle on a circuit needs to be a GFCI to give the same ground-fault protection to every other receptacle downstream—as long as the receptacles are wired correctly (drawing right). If the downstream receptacles are wired from the line side of the GFCI, they will not work correctly—that is, they won't be able to sense a current imbalance. The downstream outlets must be wired from the load side of the GFCI.

Some spas and hot tubs don't come with GFCIs, even though they are needed. Most spas require a 240v double-pole GFCI of 50 amps or 60 amps, which might cost from $200 to $400 (your instruction manual will tell you which one to use). I was once asked to hook up a spa that came without a GFCI. The manufacturer of the customer's service panel didn't make a GFCI breaker in the size the spa required; I found a way to solve the problem, but it was very expensive. So it pays to double check this point before you buy a spa or a hot tub.

Testing—Always test GFCIs with their own test buttons and then with a special plug-in tester equipped with an integral test button, which puts a current imbalance on the line. It's also smart to test every protected outlet regularly. When you buy a house, carry a GFCI tester during the final walk-through. Check every protected receptacle and push the test and reset buttons on the GFCIs to verify that the outlets work properly. A GFCI breaker will have to be thrown all the way off and then returned to the "on" position to return power. There is no reset button. Testing is a good idea, but beware of children pushing the test button on a receptacle GFCI just to see and hear the reset button pop out. To the child's delight, and to your dismay, the reset button and the spring behind it will eventually break and fly across the room. □

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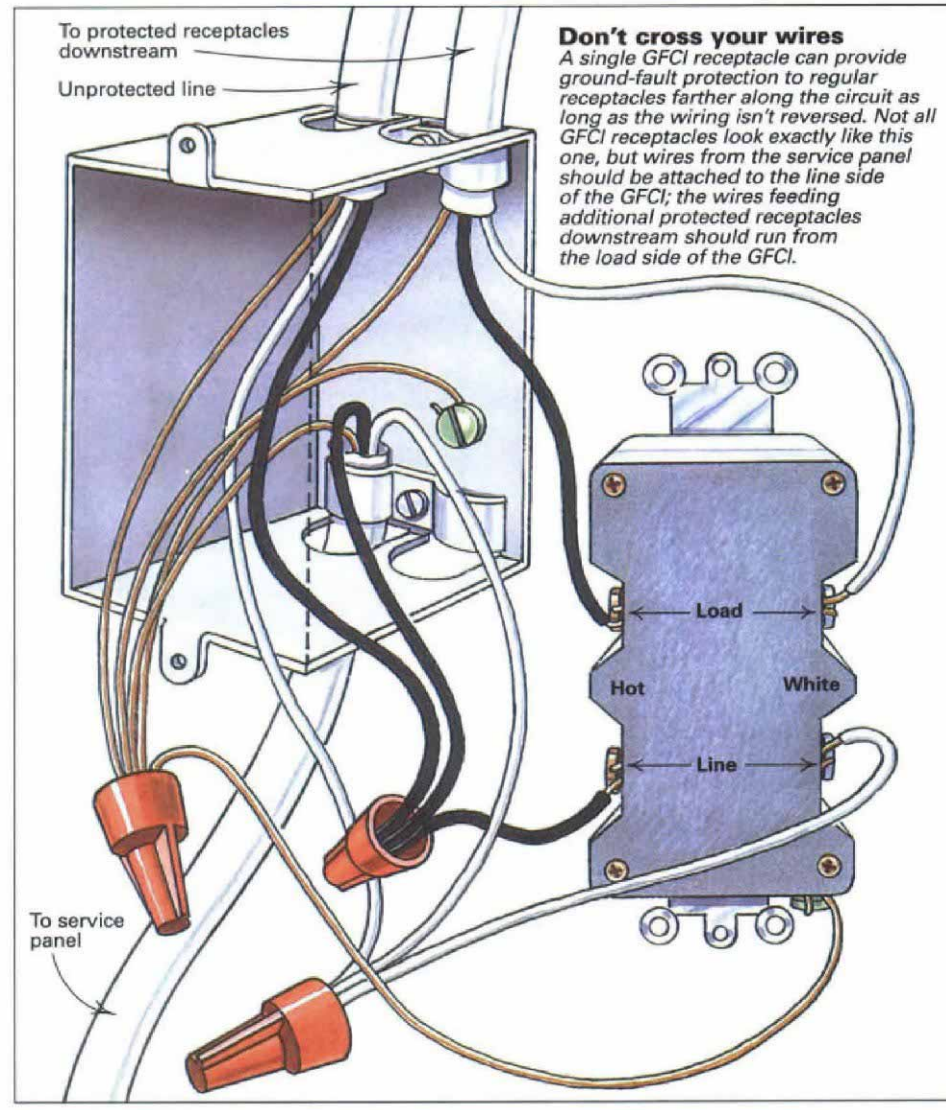
For use outside. **A GFCI receptacle used continuously outside should have a box or lid that keeps the connection between extension cord and receptacle dry. The receptacle above is surface-mounted.**

Circuit tester. **A simple tester that plugs into a GFCI receptacle creates a current imbalance. If the GFCI receptacle is working properly, the circuit should trip.**

Flush-mount unit. **Newer outdoor boxes for GFCI receptacles are not as conspicuous as older units. The receptacle is recessed, and the watertight door is nearly flush to the wall when it is closed.**



Don't cross your wires

A single GFCI receptacle can provide ground-fault protection to regular receptacles farther along the circuit as long as the wiring isn't reversed. Not all GFCI receptacles look exactly like this one, but wires from the service panel should be attached to the line side of the GFCI; the wires feeding additional protected receptacles downstream should run from the load side of the GFCI.

Drawing: Mark Hannon