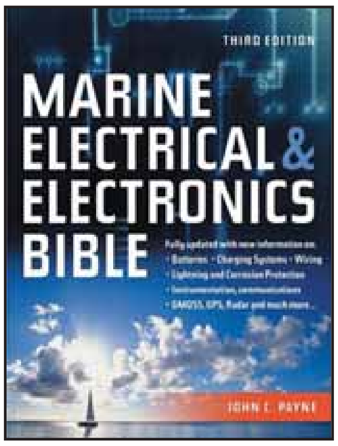
The ABC's of Electrical Work

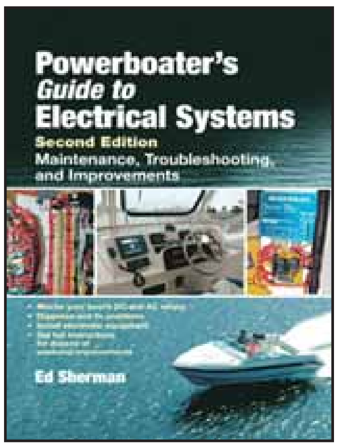
by Capt. Gary P. Joyce

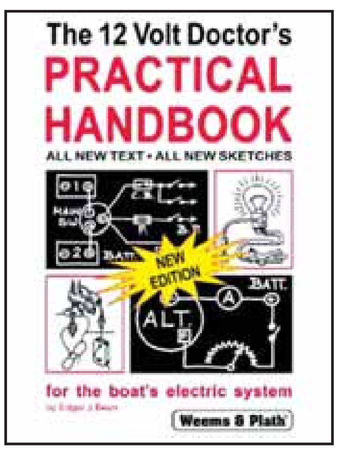
Working on electricity, whether on board or at home, is a scary prospect for many of us. For those who work with this invisible stuff on a regular basis— the folks who can change a wall switch *without* killing the power in the house and then having to reset every clock — don't understand why the rest of us are so mystified.

Following are some demystifying electrical basics you'll need to know to do-it-yourself (DIY) with the electronic instruments and systems on your boat. This article barely scratches the surface of the topic, but should provide you with information to pursue the subject further.



One book that I suggest you have is *Understanding Boat Wiring*, by John C. Payne (96pp, 2003, around $13.95). Payne has also written *Marine Electrical and Electronics Manual* (468pp, 2007, $55; 3rd Edition), which should be on your shelf as well (this is thorough, but more technical). Another good one is *Powerboater's Guide to Electrical Systems*, by Ed Sherman (212pp, 2007, around $22; 2nd Edition). *Understanding* is the easiest to understand (duh) and the *Powerboater's Guide* is more thorough, but less simple to follow. Another good book aimed at us electric simpletons is *The 12 Volt Doctor's Practical Handbook*, by Edgar J. Beyn (fifth edition; 232 pp, 1998, around $27; there may be a new edition. Look for the one with the starburst on the cover that states "New Edition." Best bet is from Weems and Plath; www.weemsandplath.com. The troubleshooting section in this book is pretty good.





Get one of the books mentioned above if you plan on DIYing your electronic systems.

BASIC KNOWLEDGE

First some terminology, not much, but some. AC/DC is not just a heavy metal rock band. Your house electricity is **AC** (Alternating Current); your 12-, 24-, etc., volt boat is **DC** (Direct Current). If you're plugged into dockside electricity, you're back on AC, which is why refrigerators and whatnot are "AC/DC."

The measure of resistance to the flow of electricity through (in our case) a circuit (every individual system is a circuit) is expressed in Ohm's. A **volt** is the amount of power causing current to move against resistance. **Current** (amperes) is a measure of the quantity of electrons moving in a single direction. These three items are the basis for everything you'll be doing with electrics and are interrelated (it's called Ohm's Law); if you know two values, you can figure out the third. It will also assist in determining the sizes of wire, connectors and fuses, among other things.

The three elements of Ohm's Law are expressed as R for Ohms (resistance), C for current and V for voltage (see Ohm's Triangle shown below). It's simple: volts divided by ohms gives you current (V ÷ R = C). Current times ohms gives you voltage (C x R = V). Voltage divided by current gives you resistance (V ÷ C = R).

There is a formula for power worth knowing as well and it, too, can be expressed as a triangle with W representing **watts** (a measure of power); V, **volts**; and A, **amperage**. Again, simple: watts equals volts times amps (W = V x A). Amps equals watts divided by volts (A = W ÷ V); and volts equals watts divided by amps (V = W ÷ A). This will/may also come into play when determining wire, connector and/or fuse size.

One other term you'll need to know is **parallel circuit**. This is when each appliance (think lights) is connected positive-to-positive and negative-to-negative through an entire system. Nearly every circuit you'll deal with is either a single circuit going to one appliance (which is still parallel, i.e., positive to positive and negative to negative) or a parallel circuit going to several items. The other type is called a **series circuit** where the positive of one appliance is connected to the negative of another. The only time you should see this is when batteries are connected to make higher voltage systems, i.e., two 12-volt batteries connected in series make 24 volts

TOOLS

Most of it you should have: a pair of wire strippers that have crimping jaws, a straight screwdriver (usually) and diagonal pliers. A mini torch to heat shrink-wrap coverings on connections is also nice to have. Pros use a double-crimp ratcheting crimp tool and a separate stripper tool.

You'll also want an electrician's "snake" (fishtape, feed rod, etc.) for feeding (or, better yet, pulling wire from one end of your boat (where the battery is) to where your appliance is. It's usually a fishing-rod-thin, jointed (three- and four-piece or more), stiff rod that can push or pull wire through a tight unseen space. An amazing variety of these can be found in electrical supply shops.

Ohm's Triangle with V for volts, C for Current (amperes) and R for Resistance. If you know two values, you can find a third.

However, the most important troubleshooting tool you'll need is a multimeter. This is named such because it can be used for a number of tests. Multimeters come in digital or analog versions (go for the digital), and auto ranging and self ranging (go for the auto ranging).

W for watts, V for volts and A for amperes (resistance). Like Ohm's Triangle, if you know two values you can find the third.

Ideally, you want a multimeter meant for working on DC systems rather than AC. Multimeters always work on both, but they tend to have more uses with one rather than the other. One purchased at a home center is probably more geared to AC current than one bought at an auto or boat shop. They run from around $40 to the thousands. Keep yours dry, don't drop it, and pay attention when using it because you can burn them up if used incorrectly. One of the biggest problems you'll find when using one is that it sort of requires three hands — one for each lead, and one to hold the multimeter somewhere you can read it while testing.

USING THE MULTIMETER

Despite what comes below, it behooves you to follow the instructions that come with *your* multimeter, but generally speaking, measuring voltage is accomplished by ensuring the multimeter is on the "DC volts" section. Touch the red lead (positive +) to the positive side of the appliance and the black negative (-) lead to the negative side. If your multimeter is self-ranging, set the control dial to the higher-than-expected voltage reading.

If nothing registers on the meter, either you're doing it wrong, the circuit is off, or the circuit has a fault in the switch, breaker or power line. Although multimeters can perform other tests, much of your troubleshooting will be done by measuring voltage.

To isolate a problem in a circuit you need to measure voltage drop. ABYC (American Boating and Yacht Council) the standard setters for the boat building biz) allows a 10 percent drop for non-critical appliances (lights, say) and a three percent drop for critical ones (pumps, say). Turn off everything except the circuit you're testing. Check the voltage at the battery and write it down. Next check and record the voltage at the appliance, if you're running through a breaker panel, check it and record it there as well. If everything registers essentially the same voltage (there is always *some* voltage drop in a circuit) fine, it's a good circuit.

This is also the simple way to find out why something *isn't* working and isolating where the "isn't" is … if you get my drift. Continually try to narrow down where a fault may be by taking readings wherever you can — switches, fuses, breakers, etc. If the voltage is fine at the battery connection and not at the breaker, you know your problem lies between the two. If it's fine at the fuse or breaker, but not at the appliance, ditto. You're looking for — in most cases — a lack of voltage rather than a drop in voltage (a big enough drop *can* cause the problem). The bottom line is that any drop should be minimal and if it isn't, you'll want to isolate the section in which your problem lies.

STRIPPING AND CRIMPING

Know your wire size and match the stripper hole or cutting edge to the wire's size, since too

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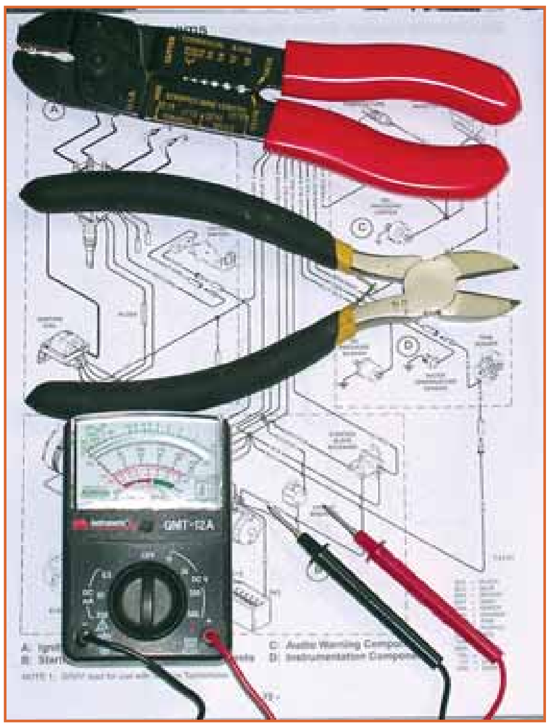
small a hole will cut wire strands (even nicks are to be avoided) and too big won't cut anything. Generally speaking it's a good idea to cut wires in a stagger) i.e., one wire on the appliance longer than the other and vice versa on the connecting wire. This avoids putting connections next to each other.

Crimping, whether using a specific tool or not, is critical. For a good crimp, first slide a shrink-wrap sleeve down the wire. Strip the length of wire to match the length of the connector stem (use ring connectors wherever and whenever possible) and add another sixteenth of an inch. Crimp the end nearest the ring first and then crimp the aft part. This provides pressure relief; a double-crimp tool will do both in one motion. Check the connection with a solid tug. Slide the shrink-wrap collar up to just cover the wire visible above the stem and heat. Done.

WIRE AND CONNECTORS

Wire and connectors all come in sizes that are determined (for our purposes) by the loads they have to carry. The only kind of wiring to use is stranded copper. Tinned stranded copper is even better. Use marine-specific wire whether tinned or un-tinned, period.

You want to see the letters AWG — American Wire Gauge —on the wire you're going to use. This is a measurement standard. Ideally, you'll want Type 3 (this has more strands than Type 2 and



Top to bottom, a combined stripping and crimping tool, diagonal pliers and an analog multimeter.

is more flexible) AWG tinned copper duplex cable for marine work.

Wire rule one: The smaller the AWG number the thicker the wire. Rule two: When measuring a circuit, it's the distance from source to appliance *and back*. If your radio is 15 feet from your battery, that's a 30-foot circuit. Rule three: When in doubt, go up a size

There are two ways to find out the size wire and connectors you'll need, the easy way and the hard way. For the easy way go to the Ancor Products Website at www.ancorproducts.com. They have a wire size calculator, lots of tables, etc., in their "Technical Information" section.

Failing that, you can calculate the size you'll need with the following formula: CM= K x I x L/E, in which CM is the **circular mill** area of the conductor (this is what you're trying to find); K is 10.75 (a **resistance standard** for copper wire); I is the **current in amps**; L is the **conductor length** (remember, there and back) and E is the **voltage drop** (E = K x I x L/CM). You'll end up with an answer that is between four and six digits long, which you *still* have to go to a table to convert to AWG size.

Match your fuses — everything runs through a fuse or circuit breaker — to your appliance's amperes. In a system with several different appliances on it, base the fuse on the *smallest* drawing appliance.

Fuses (the new auto-style blade fuses), connectors and wire all have ABYC standardized colors for size and/or use. In wiring, navigation lights and tachs will be grey; accessory feeds, orange; fuel gauge, pink; ignition and instrument panel feed, purple; bilge blowers, brown with a yellow

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