Story And Photography By STEVE C. D'ANTONIO

ELECTRICAL TROUBLESHOOTING

Become An Electrically Self-Reliant Cruiser

Make no mistake about it: There's no way you can become an expert mechanic or electrician overnight. Top-flight, crackerjack marine technicians are few and far between, and the really good ones usually have two things going for them.

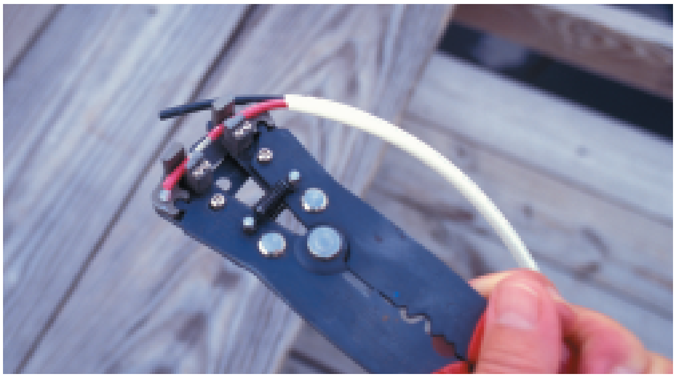
One, they are usually natural-born gearheads—the babies who figured out how to escape from their cribs through a process of disassembly. They usually grew up to be the preteens who were forever asking questions like, "Why do planes fly?" and "What's inside a TV set?" They later became the teens who got their hands on old cars or boats, figured out what made them run, and then learned how to keep them running. These folks have what I like to call a naturally curious mind; they aren't content with repairing or replacing the broken or failed part. They want to know why it failed and how to improve the installation or design.

Two, they have experience. These men and women have been troubleshooting and repairing things for a long time, and not just marine mechanical and electrical systems. When the family washing machine, VCR, refrigerator, or car gives up, they dive in with tools and service manuals in hand, intent on fixing whatever is broken. It's an easy leap for that type of mind to wrap itself around a malfunctioning battery charger, instrument system, or engine that won't turn over.

Where does this leave the electrically inexperienced but ambitious cruiser who isn't a gearhead? Fortunately, it's not as bad as it sounds, and there are a few options. You can do much to improve or hone your electrical troubleshooting and technical communication skills. (These communication skills are important, as you frequently must be able to accurately explain your problem or symptoms to others to get help.) If you can carry out basic diagnostic troubleshooting and repairs using commonly available tools and communicate efficiently with someone more knowledgeable than yourself, your chances of resolving your electrical problems improve considerably. In what follows, I'll attempt to impart the necessary information and wisdom so that you'll have a fighting chance when an electrical failure rears its ugly head.

TOOLS OF THE TRADE

Before you begin your career as an electrical troubleshooter, you'll have to invest in a few essential tools. Begin with a good set of wire cutters, strippers, and crimpers. A variety of both manual and automatic strippers is available. My preference is for the manual type; however, if you don't do a lot of stripping, you might opt for the convenience and foolproof quality of the automatic variety. Choose a set that does its stripping forward or ahead of the pivot point. This makes it easier to reach into a space with limited access to do your stripping. Avoid tools that claim to be an all-in-one stripper, cutter, and crimper; I've never found one that did all the tasks well. Get a dedicated version of each that feels right in your hand and works well. Use each one of these tools *before* you need to.



Left: The right tool for the job, a good set of wire cutters, crimpers, and strippers are critical for proper electrical repairs. Right: One of several automatic wire strippers that are available, these are nearly fool-proof and ideal for those who strip wires infrequently.

Another valuable but often overlooked electrical troubleshooter's tool is the once ubiquitous 12-volt test light (or 24-volt, if that's how your boat is wired). When I first began working in the industry, this was the marine electrician's primary troubleshooting tool. It's nothing more than a 12-volt lightbulb housed within the handle of what looks like a transparent screwdriver. A pointed metal tip allows the user to probe electrical connections while a ground is achieved through a short cord attached to an alligator clip.

For ordinary electrical troubleshooting—as opposed to electronic troubleshooting or instances where exact voltages must be ascertained—as well as for tracking down poor or broken connections, this tool is ideal. Place the alligator clip on a good ground, such as the battery negative post, a negative buss bar, or equipment chassis/engine block, and then use the tip to probe connections, and you are in business. These tools were originally designed for automotive applications, and I find that the lead (the wire between the screwdriver-like illuminating handle and the alligator ground clip) is too short. It's designed to work on a car, where there's always a good ground (the body) nearby. If you decide to add one of these handy devices to your cruising toolbox, consider lengthening the lead to 20 or

30 feet (longer or shorter, depending on the length of your vessel). This will allow you to connect the alligator clip to a known good ground, such as the battery, while you do your probing elsewhere: under the dash, on the bridge, in the bilge, and so on. Keep in mind that the

Left: Inexpensive and useful, the 12-volt test light was the mechanic's primary electrical troubleshooting tool for many years. At less than $10, it's worth having aboard. Right: The DMM on the left is compact, comparatively inexpensive and it incorporates a built-in inductive amp feature while the unit on the right has more features and options as well as a higher price tag and it requires a separate amp clamp for inductive amp measurements. Either will perform most on board troubleshooting tasks.

test light can be used to find a good ground, or troubleshoot a poor ground, rather than a positive by simply connecting the alligator clip to a positive source, such as the battery post, and then probing suspect grounds with the tool's pointy end.

For more serious troubleshooting and repair operations, you may need more serious tools, the most useful and important of which is undoubtedly the digital multimeter (DMM), also known as a volt/ohm meter (VOM). This tool has revolutionized and simplified marine electrical and electronic troubleshooting and repair work. While its needle-equipped analogue predecessor is also useful, performing many of the same troubleshooting and measurement functions as the DMM, today's digital versions are accurate, versatile, affordable, and somewhat easier to use than the older analogue models, particularly for the less experienced user.

Scores of different makes and models of DMMs are available, and many cost less than $100. Nearly all will carry out the most common and useful measurements: AC and DC volts and amps, as well as resistance and continuity. With these functions, you will be able to troubleshoot 95 percent of all onboard electrical faults.

More advanced DMMs—and advanced doesn't necessarily mean exorbitantly expensive—will also allow you to measure, among other things, frequency. Measuring frequency can be useful when troubleshooting or repairing a generator or inverter, or if you suspect something out of the ordinary with dockside-supplied power, which may be the case in less developed regions of the world. Although a number of high-quality, affordable DMMs are available, my preference has been for those manufactured by the Fluke Corporation of Everette, Washington. Fluke's multimeters are renowned for their accuracy, durability, and reliability. The unit I currently own has seen hard marine service for over a decade and has yet to suffer a malfunction. For more information, visit them at fluke.com, or call 800.44.FLUKE.

It would be difficult to overstate the value of not only owning a DMM but also learning how to use one. Here's an example of just how useful and important this tool can be. The very week that I was writing this article, I was corresponding by email with a full-time liveaboard cruiser/customer who was sailing among a group of islands off the east coast of Belize. (These islands contain two of only four atolls in the Western Hemisphere, one of which, Lighthouse Reef, was this vessel's destination.) Several months ago, the boatyard I manage replaced this vessel's 5kW AC generator with a 175-amp, 12-volt DC model. (For more on DC versus AC power, see "The Integrated Energy System," *PMM* July/Aug '02 and Sept/Oct '02.)

The cruiser's first email indicated that he could not get the generator to crank (that is, turn over), much less start. Because this savvy cruiser owned and knew how to use a DMM, I was able, through half a dozen emails, to guide him through the electrical troubleshooting process of checking voltage and continuity at a number of locations throughout his electrical system. This task was made easier by the fact that we both had a set of schematics for the installation; but even if I hadn't had a set, the troubleshooting process could have proceeded, albeit at a slower pace. We eventually ascertained that a wiring connection supplying the key switch, and thus the cranking circuit, had failed, probably as a result of corrosion caused by a defective, leaking exhaust elbow.

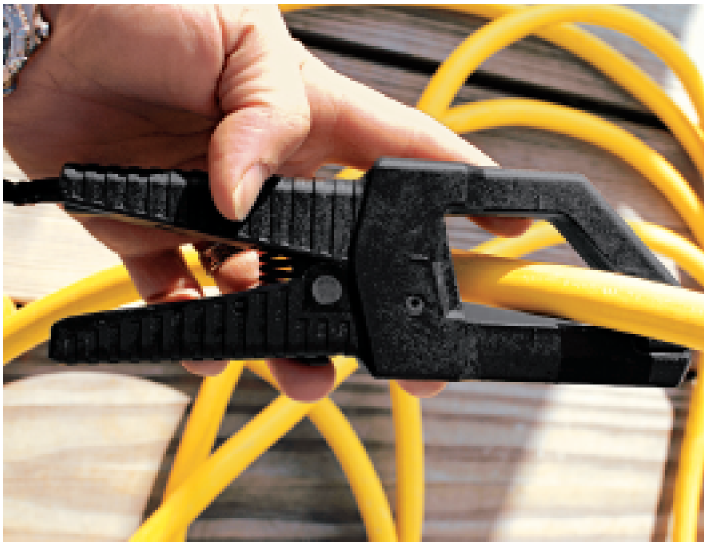
A temporary jumper wire attached to this terminal (a terminal is an electrical connection) had the generator humming away in no time. The cruiser planned to work on tracking down the problem and applying a permanent fix as soon he had completed his 10-day passage. It was a happy ending to a potentially vexing problem to be sure, particularly since this vessel relies on DC power for all of its refrigeration needs.

On average, I receive one call or email each week from vessels as near as my own backyard, the Chesapeake Bay, and as far away as the Indian Ocean seeking troubleshooting assistance. More often than not, these pleas are electrical in nature. Invariably, my first question is, "Do you have aboard and know how to use a multimeter?" If the answer is "yes," chances are excellent that I or someone who is a skilled troubleshooter can talk the user through a process that will resolve, or at least discover the source of, the problem. (Even better, with a little bit of experience, the user can carry out the troubleshooting sequence on his or her own.) If the answer is "no," then there is often very little that can be done other than to say, "Wiggle all the connections and check for loose wires." Regrettably, the "no" answers far outnumber the "yes" answers, but I hope to change that with this article.

A useful accessory or addition to the DMM is an inductive amp clamp. In some cases this may be integrated into the multimeter, while others are stand-alone units. Because even the best DMMs will measure only about 10 amps of load through the meter's own circuitry, any device drawing more amperage than this cannot be measured with the standard meter. With the addition of an amp clamp, however, loads measured in the hundreds of amps can safely be measured. Using inductance or magnetism generated by electric current, amp clamps are able to make these measurements without physically touching the cable or wire whose current is being measured. (This is the same way most electrical panel meters measure amperage.) This makes them particularly convenient and easy to use.

Amp clamps are ideal for measuring everything from the current your engine's starter draws while it's cranking to the loads imposed by inverters and bow thrusters, and most are capable of measuring AC or DC amperage. (It's a good idea to measure and record the starter's own draw when everything is working properly so you'll have a reference for future troubleshooting.) One especially useful safety-related task an amp clamp can perform is checking shorepower installations for fault

Top: The amperage output for a single solar panel is usually small enough that it can be measured directly through most DMMs. Know the maximum through-the-meter amperage measurement your DMM is capable of, as most units top out at 10 amps. Above: Using a DMM, this technician is verifying the output of a solar panel that may be malfunctioning. Starting at the source and working your way back until the problem is found is a tried and proven troubleshooting method.



An inductive amp clamp is capable of measuring current passing through a wire without having to actually make contact with the wire itself. If the clamp is placed around two wires within the same circuit, the positive and negative or hot and neutral for instance, then the current reading will be cancelled and read zero, provided the circuit is functioning properly.

FINDING THE TOOLS

- Wire cutters, strippers, and crimpers can be found in the tool departments at most of the home improvement warehouses. The quality brands to look for are Channellock, Klein, and Knipex.

- Quality 12-volt test lights, the type that look vaguely like a screwdriver with a clear handle that houses a bulb, can be purchased at nearly any auto-parts store. Better units can be had from specialty tool suppliers such as MAC Tools, Snap-On, MATCO etc, and on-line auto parts suppliers such as IPD, .ipdusa.com, (they sell aftermarket Volvo parts) and The Eastwood Company offer the better units as well. IPD's part number for this tool is CBT1003

- DMM/VOM/Multimeters with integral amp clamps can be obtained from nearly all of the home improvement warehouses, Lowes, Home Depot, Sears etc. They typically do not carry Fluke, but they carry other quality brands. Fluke brand multimeters and stand-alone amp clamps can be obtained from a number of sources, a web search will yield numerous retailers selling this equipment.

or leakage current that is traveling through the water surrounding the boat. Placing an amp clamp around an entire energized and loaded shorepower cable (normally, the clamp is placed around a single conductor rather than multiple conductors) should balance or cancel all readings, so the meter will show zero or no amperage load, provided everything is wired and operating correctly. However, if some of the shorepower current is returning to ground via the bonding system and sea water, then an imbalance will occur, which the meter will read. This is an interesting and worthwhile assessment you can perform on your own vessel and on others on your dock. And you don't even have to touch the shorepower cable in order to do it. Make no mistake about it: If the meter shows any current reading, then this is a dangerous situation that requires the immediate attention of a qualified marine electrician.

"EXPERT" TROUBLESHOOTING TECHNIQUES

We've already discussed digital multimeters and the important role they play in electrical troubleshooting. While that's an important subject, let's step back for a moment and detail a few basic electrical concepts that you may find useful when routing out your own electrical gremlins.

Volts (both AC and DC), amperes, and ohms are all electrical units of measure. While I could go into scientific and technical descriptions to help explain these terms, I'll opt instead to offer a more practical—and, I hope, understandable—approach.

Several types of voltage may be found aboard a cruising vessel. Battery voltage is usually either 12 or 24 volts and sometimes 32 volts, and it is always DC, which stands for direct current. This type of voltage powers everything from your engine's starter to cabin lights and electronics. Any voltage (whether it's AC or DC) below about 45 volts is typically considered nonlethal. There are, of course, exceptions to every rule, so don't take this as an absolute. Always show electricity the respect it deserves. As a rule of thumb, however, you don't have to worry about being electrocuted by battery voltages. (Unless they are powering an inverter, which does produce shorepower-like and thus lethal voltages.)

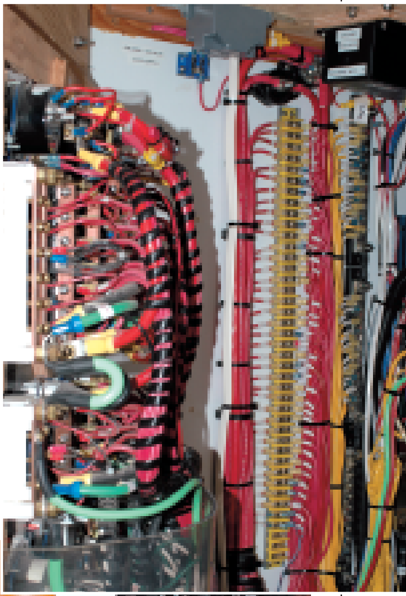
Shorepower voltage is typically associated with generators, inverters, and shorepower cables. It is usually found aboard a boat in two voltages, 120 and/or 240, and is always AC (alternating current). These lethal voltages are used to power such appliances as air conditioning compressors, microwave ovens, electric galley ranges, refrigeration systems, and, in some cases, hoists or cranes. AC shorepower voltages are the same voltages found in your home or business, and unless you have a thorough working knowledge of how they operate and their potential for injuring or killing people, troubleshooting these circuits is probably best left to a professional.

If you are troubleshooting DC electrical circuitsthat are in the vicinity of AC circuits (at the electrical panel, for instance), it's best to disconnect shorepower cables (by unplugging them rather than simply shutting off the circuit breaker) and your inverter. If the inverter doesn't have a main battery disconnect switch (it should), either remove the main DC supply fuse or disconnect the inverter's 12-volt DC connection to the batteries. Once again, don't rely on a circuit breaker or panel control to de-power one of these devices.

Amperes are a measure of how much work or effort a given voltage is being called on to produce. If your electrical panel is equipped with volt and ampere meters, watch what happens as you energize different devices. If you turn on the shorepower main circuit breaker and no appliances or branch circuits are on, the voltmeter will come up to 120 and the ampere meter will read zero. Once you switch on an appliance (a water heater or air conditioner, for instance), the ampere meter will quickly register 10 or 20 amps, while the voltmeter will remain unchanged at 120. (It may fall slightly; this is known as voltage drop, and it often occurs when a circuit is under load.) The more work an appliance is called on to do, the greater its ampere draw, and this is true for either AC and DC loads. The average diesel engine starter may draw 300 amps DC when it's cranking, while a navigation light may only draw an ampere or two. Because the voltage is higher, AC appliances typically draw less amperage, which is why their associated wiring is usually much smaller. (The size of a wire is directly related to its ability to carry amperage, not voltage.) For example, an air conditioning compressor may draw 10 or 20 amps AC, while a 5kW generator may produce 40 amps of AC current.

Ohms are a measure of resistance. (The symbol often used to represent this unit of measure is the Greek omega, see symbol highlighted on right.) Virtually every DMM will have a selection for measuring ohms. But what is an ohm, and why is it important to you as a cruiser/electrical troubleshooter? Here's an example: The length of wire between your windlass and its power supply at the house batteries may be 20 or 30 feet long. If the wire is in good condition and the connections are clean, tight, and corrosion free, when you use your DMM to measure the resistance or ohms present in that wire from one end to the other, the result should be 0 ohms. (You would do this with the cable disconnected from the batteries; resistance measurements must always be made on de-energized circuits.)

That's right. In the case of resistance, less is more. Resistance is just that: a blockage or impediment to the flow of electricity. Thus, unless a specific device or design calls for something otherwise, it's best for every cable, wire, and connection aboard your vessel,



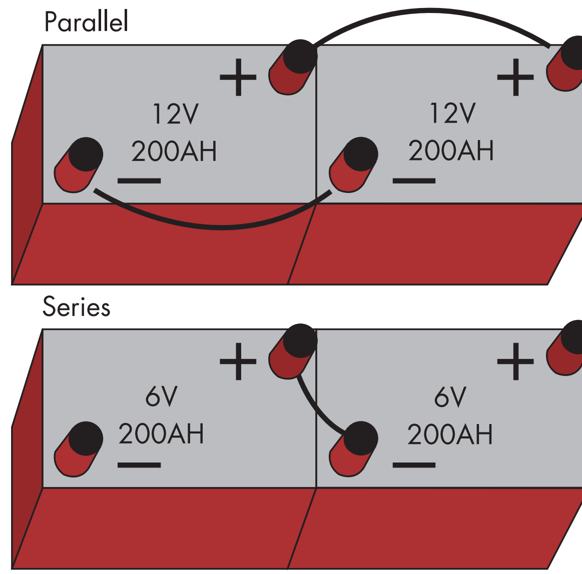
Above: Modern marine electrical systems are complex. Establishing a working familiarity with your vessel's wiring, before a problem occurs, will help you trace and identify an electrical problem without having to undergo on the job training. Above: Although AC circuits should be safely insulated when collocated with DC wiring at the back of an electrical panel, it's best to make sure the panel is disconnected from all AC sources, shore power, generators, and inverters. If you are troubleshooting an AC problem, use extreme caution when taking measurements and assume all conductors are energized with lethal voltage and current.

particularly bonding and safety-ground connections, to possess as little resistance as possible, preferably zero. In some cases, this perfect score is difficult to achieve, so an ohm or two may be considered acceptable, but certainly no more than this. (Before making any resistance measurement, carry out this test: Set your DMM to the ohms scale and touch the meter's probes together, simulating a dead short. The meter should read zero, or no resistance within the probes, which is normal. If it reads anything else, check the probes for corrosion or the DMM's battery—it may be fading.)

Suppose, however, that the same windlass wasn't working and you wanted to determine whether the power-supply cable was the culprit. You might perform a resistance or continuity test and find the DMM reading to be open or of unlimited resistance; essentially, the reading would be unchanged, as if the probes were still not touching anything, which would indicate a broken cable or separated connection. Or, the DMM may read very high resistance, hundreds or thousands of ohms, which would seriously impede the flow of electricity to the windlass. Thus, ohms are simply a measurement of the ease or difficulty with which electricity flows through a given path. (When you are making resistance measurements or any other readings with a DMM, be sure your fingers are not touching the metal portion of the probes. The resistance of your body will skew the measurement.)

Two terms worth defining within the realm of electrical troubleshooting are series and parallel (see diagram). A connection that is made in series is one in which, if you remove the connection from the circuit, the circuit will no longer be complete and it will not work. An example of a series connection is a switch for a light, a horn, or virtually anything else. With the switch on (the electrical term for a switch that is on or completing a circuit is "closed"), the device operates; when the switch is "opened" (that is, the switch is off), the device does not operate. This is a series circuit. Another example of a series circuit may be a vessel's batteries. When batteries are connected in series (that is, the positive and negative terminals of two separate 12-volt batteries as in the diagram), their remaining positive and negative terminals then become the power source, doubling their output voltage to 24 volts, while their cranking ampere and 200 amp-hour capacity remains the same. There's no free lunch with electricity.

A parallel connection, on the other hand, if removed from a circuit, often will not prevent the circuit from operating. Examples of parallel connections include nearly all lighting circuits; each light fixture is connected to the power supply wiring in parallel. If one fixture is



This diagram shows a simple illustration of parallel and series battery connections. (Adapted from Charlie Wing's Electrical Handbook, International Marine/McGraw-Hill).

removed or turned off, or the bulb burns out, the remaining fixtures continue to operate. Christmas tree lights of old were often wired in series, which was why the entire string would go out if one bulb failed. Modern lights, however, are wired in parallel, which means individual lights can burn out while the rest continue to illuminate.

The battery analogy is, once again, useful and important when discussing parallel circuits. Most cruising vessels use paralleled batteries to increase cranking and house battery capacity. Two 12-volt, 200 amp-hour, 1,000 cold-cranking ampere batteries that are connected in parallel—that is, the positive and negative posts of each battery as in the diagram—will yield 12 volts and 400 amp hours. The same two batteries will also provide 2,000 cold-cranking amps for starting purposes. A final note on parallel versus series: Voltage measurements are nearly always made in parallel. That is, the probes of your DMM should access the positive and negative portions of a circuit in order to read voltage correctly. Conversely, ampere measurements are nearly always made in series. That is, the positive *or* negative conductor of a circuit is separated, usually at a convenient junction, and the DMM probes are connected to or inserted into each portion of the circuit.

A few other terms that are worthy of definition include voltage drop, hot, neutral, safety ground, and conductor versus cable. Voltage drop is a phenomenon that occurs when voltage passes through a connection or conductor that offers some resistance. For example, if you place your DMM on the terminals of your house battery, you may read 12.8 volts, provided no charge source (an alternator or battery charger) is operating. If you then go up to the flybridge and touch the DMM probes to the bulb socket's contacts, you may read 12.4 volts. This means the circuit has a voltage drop of 0.4 volts, which may be the result of undersized wiring, poor connections, or corrosion within the fixture. Another example of voltage drop involves a circuit under load. If you measure 12.6 volts at the terminals on your bow thruster's connections while it's at rest, you might conclude that the wire between the batteries and the windlass is in good condition and, thus, that the wiring is not the problem. However, if you carry out the same test while the thruster is operating and you notice that the voltage falls precipitously to just 10.9 volts, you've just experienced a severe case of voltage drop. I've run across precisely this scenario, and it was the result of a cable that had been run through bilge water—a practice that should be avoided. The cable jacket had been pierced, allowing the conductor within to corrode heavily.

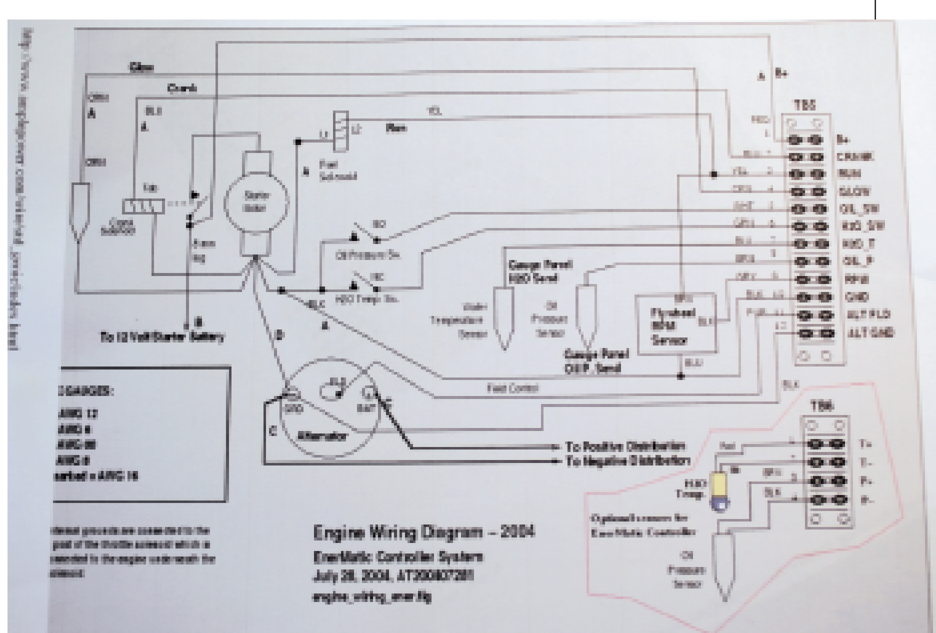
There is an allowable degree of voltage drop. Critical circuits such as bilge pumps and navigation lights, to name just two, should have no more than a 3 percent voltage drop, while less critical items such as cabin lights are allowed as much as a 10 percent voltage drop. Less is always better, and you should always strive for the 3 percent figure where practical, even for noncritical loads, particularly for motor circuits such as windlasses, starters, and thrusters.

The terms hot, neutral, and safety ground all refer to wiring found within the AC side of your vessel's electrical system. Once again, unless you have specialized training or a great deal of familiarity with utility company voltages, leave this work toa pro. Even if you don't plan to do this work yourself, however, it will behoove you to understand the terminology. A hot—under normal circumstances this is a figurative rather than literal term—AC conductor, which is typically covered in black or red insulation (50-amp, 240-volt systems will have both), can be compared to a DC circuit's positive conductor and will carry 120 or 240 volts AC. (These are lethal voltages.) This is the conductor from which you will receive a shock. The neutral conductor, on the other hand, will be insulated with a white jacket, and it can be compared to a DC circuit's negative conductor; it essentially is at ground potential. Typically, you would not receive a shock if you touched a neutral conductor. The safety ground will be insulated with a jacket that is either green or green with a yellow stripe. This conductor is designed to carry fault current safely to ground, which will prevent equipment damage and injury to the crew. It should be at ground potential, along with all of the vessel's other grounded circuits, such as bonding and DC negative cabling.

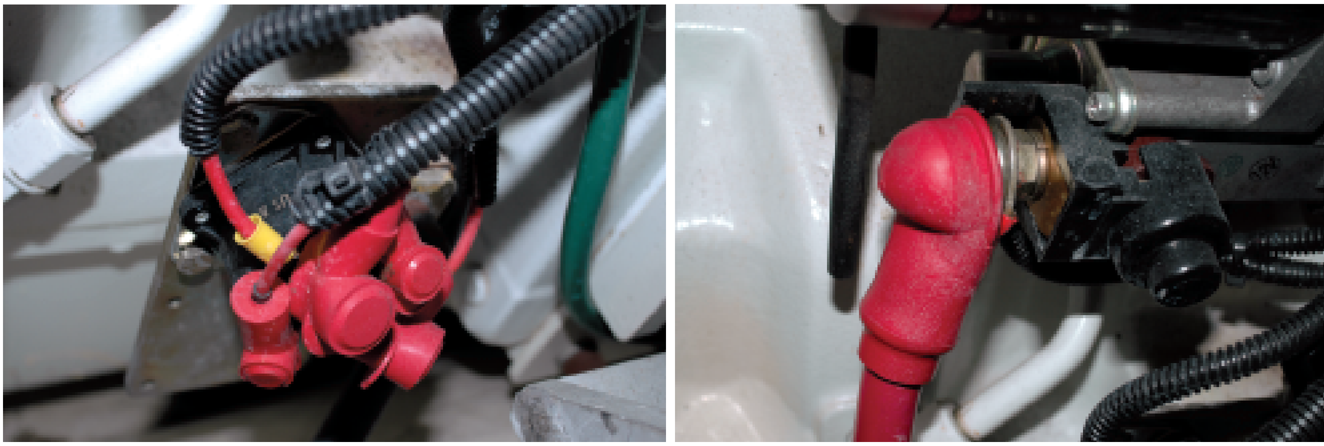
If you are following troubleshooting instructions in equipment manufacturers' literature, you may see the terms wire, conductor, and cable. Typically, conductor refers to a single wire that carries one-half of a circuit—ground or positive, hot or neutral—while a cable may refer to a series of conductors that share the same outer jacket. An example of a cable is a cord or cable that supplies power to a water heater or air conditioning compressor. From the exterior, the cable represents a single wire; however, beneath the outer jacket lay individual insulated conductors—a hot, neutral, and safety ground in this example.

MORE ELECTRICAL TROUBLESHOOTING

Although a number of electrical troubleshooting scenarios have already been mentioned, it's worth discussing a few additional recommendations for electrical troubleshooting. If you are ambitious and serious in your endeavors to become a reasonably proficient electrical troubleshooter, then you should learn how to read an electrical schematic or diagram.



Schematics or wiring diagrams can provide invaluable assistance during an electrical troubleshooting session. It's best to have these for all onboard gear and the boat as well, before you need them.



Left: An auxiliary starter solenoid is mounted remotely from the starter itself, so you may have to follow the large, secondary wire from the starter to locate it. It's usually not more than a foot or two away from the starter. Right: The secondary output from a starter solenoid is always a large cable, usually the size of your pinky or larger. When it's energized, the starter should be turning.

Left: This DMM is being used to verify that battery voltage is available at the starter solenoid's primary terminal. This starter solenoid is an auxiliary and is remotely mounted, many are attached directly to the starter. Right: This alternator is not charging and the DMM tells the whole story. Connected to the alternator's output stud, the voltage is a mere 12.3 volts, well under a properly operating alternator's expected output of 13 or more volts.

Being able to trace a wiring run on one of these documents and then superimpose it onto the equipment or vessel on which you are working is valuable indeed. At first, this may seem like a daunting task; in some ways, it's like learning another language. There are a number of symbols and designs that will appear foreign at first. With some practice and a little study (visit for a guide to commonly used electrical and electronic schematic symbols), these will become more understandable. Many electrical products today offer schematics "lite," which are closer to wiring diagrams than true schematics. They are geared toward the consumer rather than the electrical engineer and are larger, clearer, and easier to follow and read.

One of the more common electrical troubleshooting scenarios involves an engine that will not start. If you are facing this problem, then you should understand the professional terminology associated with troubleshooting such a situation, particularly if you are communicating with someone via email, radio, or telephone for assistance. An engine that will not "crank" or turn over is an engine that does absolutely nothing when the key is turned or the starter button is pushed. Some folks confuse the term "crank" with "run." An engine that cranks but does not run is an engine that turns over or rotates when the key switch is turned to the run position, but it will not develop combustion or become self-sustaining. When you release the key switch, it stops turning or cranking. If you are seeking outside assistance with an engine that won't start and a professional asks you, "Does it crank?" he or she wants to know if the engine rotates when the starter is engaged. This will help him or her determine very quickly whether it's an electrical or mechanical problem.

If the engine does not crank, then the problem is almost certainly electrical in nature. This is an easy and straightforward test to perform with your DMM set to the DC volts scale. Place the negative probe on the DC ground cable where it is bolted to the engine. (In some cases, this cable may be bolted to the starter, but make certain it's the ground and not the positive cable.) Then, place the positive probe on the starting battery positive post. If it shows 12.6 volts or more, this will confirm that you have a good ground connection and voltage at the battery. Next, place the positive probe on the large post on the starter; it's usually about three-eighths inch or one-half inch in diameter, about the size of your pinky, and will have a large-sized battery cable connected to it. If you get 12.6 volts or more there, then you have confirmed that the starter solenoid's primary winding is receiving power. Finally, place the positive probe on the smaller stud on the starter solenoid; it's usually about 3/16 inch or one-quarter inch in diameter, a little smaller than the diameter of a pencil. It will usually have one or two small-gauge (no. 12 or 14) wires connected to it. With this connection made, ask a helper to turn the key to the crank position. (Make certain you are clear of all belts, pulleys, and other moving engine parts.) If the meter reads 12.6 volts, chances are good that you have a defective starter. If it does not show any voltage, then the problem is between the starter and the key switch or between the key switch and its power supply, which sometimes originates at the engine itself or at the electrical panel. You would then carry out the same voltage test procedures and process of elimination on the wiring at the back of the key switch and, if necessary, at the electrical panel and engine ignition supply.

The technique described above can be applied to any number of electrical troubleshooting scenarios. As you can see, however, electrical troubleshooting can be tedious and time consuming. (It's why many yards and shops charge extra for this, and fees are on a time-and-materials basis.) The good news is that with some understanding of your vessel's electrical system and the right tools (either a DMM or a test light could have been used for the entire starter troubleshoot described above), along with a degree of persistence, every electrical fault and gremlin can eventually be tracked down and resolved.

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