ED SHERMAN

GETTING GROUNDED

Though seemingly inactive, a standards-compliant grounding system protects crew and equipment from lightning and electrical shock. It also wards off corrosion and RFI.

by Ed Sherman

In my work as a technical instructor and writer, I find there is more misunderstanding about the electrical grounding of boats than any other subject area. Confusion is not limited to the neophyte marine electrician, either. Perhaps this can be explained by the fact that in all but the smallest boat, proper grounding is a multifunction endeavor. Or maybe it is because two of the main reasons proper grounds are necessary—lightning and cathodic protection—are themselves shrouded in mystery.

The Multiple Roles of a Grounding System

The role of the grounding system on a boat can be narrowed down to four key areas. First and perhaps most significant, the grounding system must prevent electrical shock hazard to people on board. In the event of an electrical fault in an AC electrical appliance, for whatever reason, it is essential to provide a reliable path for this fault current back to its source of power. If not, the fault current will try to find its way back to source through the person coming into contact with the device.

A second job of the grounding system is to prevent stray-current corrosion, by equalizing voltage potentials among any dissimilar metal objects exposed to the seawater the boat is floating in. When underwater metal objects such as through-hulls and propeller shafts are tied together through a proper bonding system, those metals are effectively equalized electrically. Cathodic protection of underwater metals is furthered by one or more properly sized and placed anodes tied into the system.

Next, if the boat is struck by lightning, a good grounding system provides a path to conduct the lightning out of the boat. It also helps dissipate the extreme electrical charge equally throughout the boat, raising the electrical potential of large metal objects on board equally, and dispersing the charge to ground.

Finally, a proper grounding system minimizes problems with onboard electronic equipment that is sensitive to RFI (radio frequency interference), and may provide a satisfactory ground counterpoise for such gear as HF/SSB (high-frequency/single-sideband) radio antennas. On some boats, however, it may be necessary to add lengths of copper tape to the ground circuit to improve antenna performance.

Defining Ground

According to *Webster's Dictionary*, ground, as it applies to electricity, is defined as "a conducting connection with the Earth, whereby the Earth is made part of an electrical circuit." On a boat, the only way to achieve this connection with the Earth is by way of the seawater floating the boat (that is, when the boat is away from the dock and not plugged into shore power). The nature of current flow is such that in an electrical circuit, power must leave its source, whether it is a battery or a transformer on shore or an onboard AC generator, and *return* to it.

Current is the flow of electric charge (electrons, to be precise) and is usually measured in amperes, whereas voltage, as defined by *Webster's*, is "the difference in electrical charge [potential] between two points in a circuit." The more volts, the higher the driving force. Tying this definition into ground, one finds that ground is considered to be at zero volts, or *ground potential*. With the exception of grounding the metal chassis of electrical equipment and RF grounds in an HF radio antenna counterpoise, the grounding system does nothing to enhance the performance of onboard electrical equipment; in effect, it's just going along for the ride.

In a power supply situation, whether AC or DC, the potential difference is provided between the positive and negative terminals *at the source of power*. Each electrical circuit has a conductor supplying current to the load (appliance), and a conductor providing a current path back to the source of power. These two conductors are known as the ungrounded and grounded conductors, respectively.

Most people are easily confused by this ground*ed* vs. ground*ing* conductors thing. The ground*ed* conductor is normally current-carrying any time the circuit in question is activated. Any ground*ing* conductor associated with the same circuit is not normally current-carrying. It will only be called into action when there is a short circuit at the appliance (load) in question.

Old wives' tales suggest that the grounding conductor is going to be a more natural path for electrical current flow, and therefore it should not be a part of any electrical system, because it induces a more favorable—and often troublesome—alternate path for current flow. In a perfect world, this system never does anything until a problem occurs. Theoretically, the grounding system doesn't get called upon until something goes wrong. When needed, an effective electrical grounding system drains away any unwanted buildup of electrical charge. Assuming a point in a circuit is connected to a good ground, that point tends to stay at a constant voltage, regardless of what happens elsewhere in the electrical system. The Earth, which forms the ultimate ground, has the ability to absorb or dissipate an unlimited amount of electrical charge, including lightning potential.

So the question is: How does one go about providing ultimate ground potential on a boat, especially considering the multifaceted aspect of the system? This is certainly an area where controversy exists—some of it valid, and some of it based on bad information.

Tying It All Together

One of the best resources to provide a snapshot look at how all of the above might play itself out is the American Boat & Yacht Council's *Standards and Technical Reports*, Standard E-9, "Direct Current

Figure 1

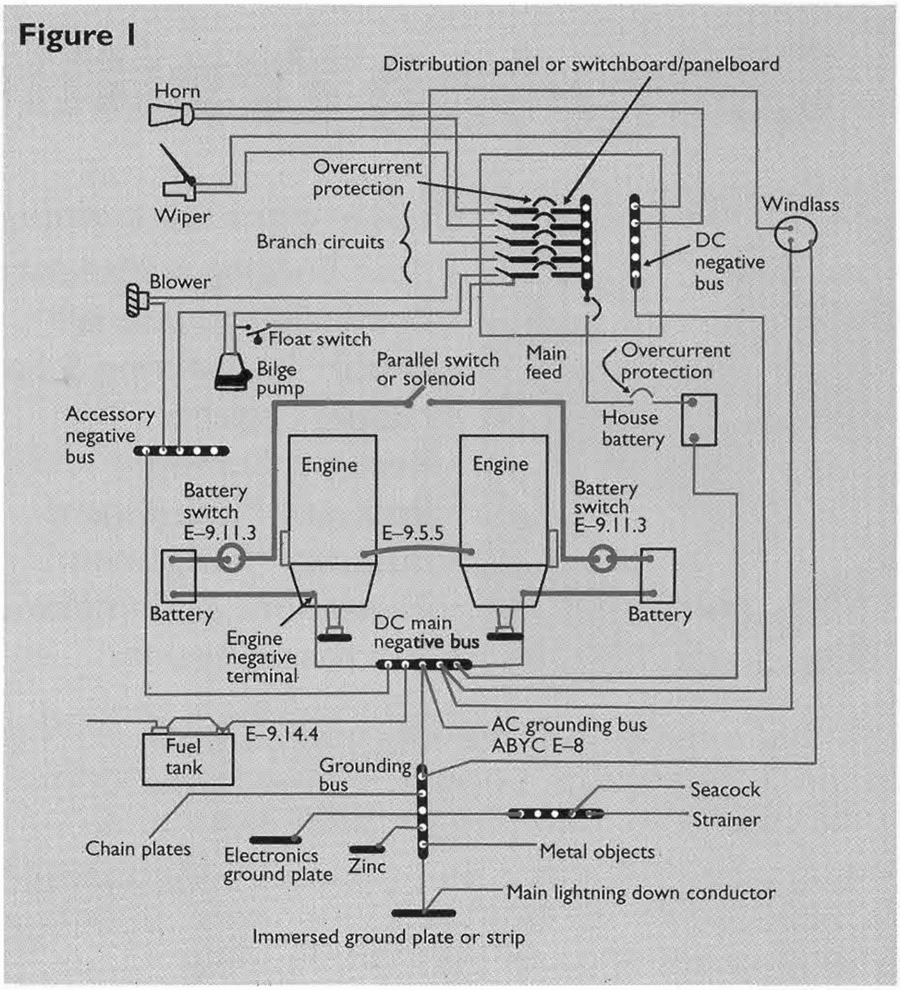

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Diagram 15 from the American Boat & Yacht Council Standards and Technical Reports, *Standard E-9, "Direct Current Electrical Systems," shows the bonding of metal objects inside a boat. This system is connected to the DC main negative bus. The lightning protection system is led directly to an immersed ground plate along with the bonding system.*

Figure 2

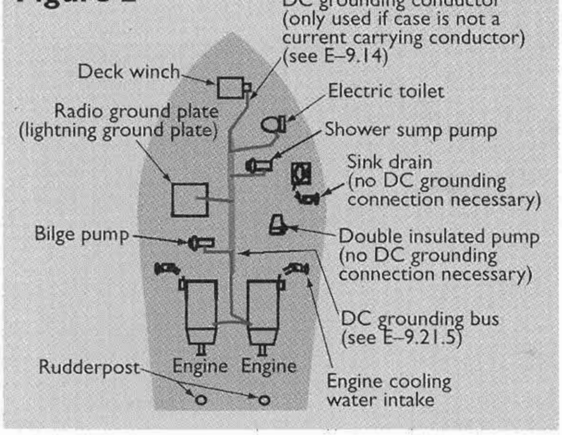
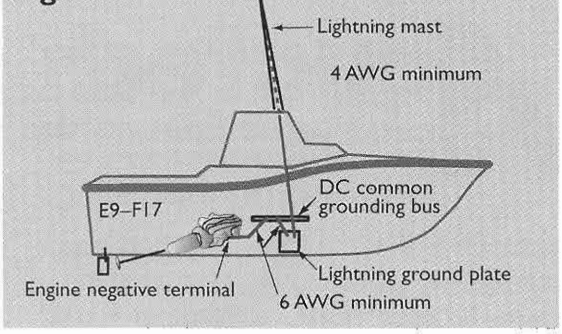


Figure 3



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***Top**—Diagram 16 from ABYC Standard E-9 illustrates the various onboard equipment that may be tied to a common ground. These include the bilge pump, windlass, and electric toilet, as well as large metal objects such as the engines and rudder posts.* ***Bottom**—Drawing 17 from ABYC Standard E-9 is of a powerboat fitted with a mast and air terminal. Note the straight run of 4 AWG copper cable from the air terminal to the lightning ground plate below the water and outside the hull. The mast must be sufficiently tall so that the cone of protection, emanating from the top, covers crew bow and stern. According to ABYC Standard E-4, the base of the protected zone "is a circle at the surface of the water having a radius of approximately two times the height of the conductor."*

Electrical Systems." Diagram 15, found at the back of the standard is shown on page 82 in **Figure 1.** This diagram illustrates one of the key (and often controversial) points regarding grounding: the tying together of grounding subsystems at a common point—namely, the DC main negative bus or the grounding bus (both shown in the diagram). The diagram depicts a boat with DC and AC electrical systems, a bonding system (more accurately described as a cathodic protection system) that includes zinc anodes, a lightning protection system, and an electronics ground plate, all linked together at one point.

Diagrams 16 and 17 (**Figures 2** and **3**) within E-9 illustrate various onboard components that are typically tied into a DC grounding system, and a basic lightning protection system. Tying together all of these systems and subsystems at that one point is where the rub lies—according to some well-regarded experts in the field. They advocate a completely isolated lightning system and radio grounding system on the theory that a bonding system provides a path for DC stray current in marinas to migrate through and out of a given boat. As you'll see in a moment, I happen to disagree.

Preventing Shocks

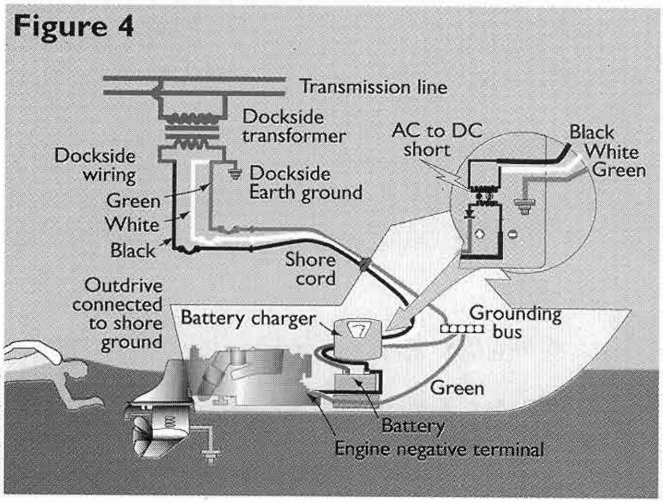
Okay: since grounding is the connection of non-current-carrying conductors to the engine negative terminal (and we know what a complete electrical system looks like), let's break down the subcircuits of the grounding system, and examine the reasons for and organization of each.

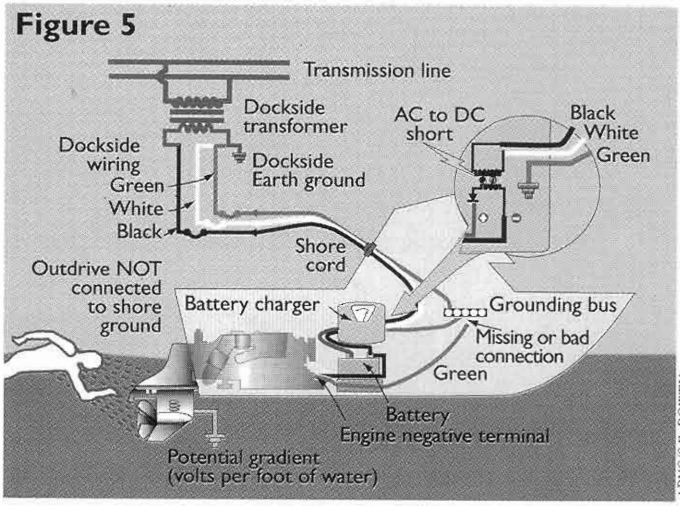
One of the most vital roles of the grounding system is to minimize the possibility of electrical shocks to crew. With AC devices it is clear to everyone that shocks can be lethal, yet marine electricians frequently argue about just how grounding of the AC system should be done. The primary point of contention is the tying together of the AC and DC grounding systems at a common point, as illustrated in Figure 1.

When an AC device such as an air conditioner develops a short circuit to the case of the appliance—for whatever reason—the case can become electrically "live." Given a metal-cased appliance, touching the case with a wet hand is a surefire way to get a good jolt. Hence the third wire in AC installations, traditionally a green insulated conductor attached to the metal case to provide an alternate path for electrical current flow back to the source of power, whether it is through the shorepower system or an onboard generator or perhaps a DC-to-AC inverter. Assuming the boat is wired properly at the source of power, the AC neutral conductor (typically, the white wire in 120V systems) and the green wire are tied together. Again, assuming the system or device in question is properly wired with an appropriately rated overcurrent-protection device (usually a circuit breaker in the case of AC systems), the fault current will travel full circle—back to source—and trip the breaker, effectively eliminating the shock hazard until a repair can be made. In the case of AC devices plugged into GFCI (ground fault circuit interrupt) receptacles, this happens quite rapidly. Most electricians understand and accept these concepts.

But what isn't clear to all is what can happen if a short circuit occurs inside a device that shares both AC and DC circuitry, such as battery chargers and DC–AC inverters, or DC circuits with defective wiring, moisture, and the like, in close proximity to AC wiring. Given these devices and situations, it is quite possible for a short circuit to occur between the AC and DC side of things. In such a case, a fault path for current flow on the DC side is needed to direct this lethal current back to the AC source of power. That's accomplished by the DC grounding system and linked back to the AC system at the common ground point in the system—the grounding bus/DC negative bus shown in Figure 1.

Without this all-important link, the AC fault current will still migrate through the DC grounding system, which is connected to metal underwater appendages of the boat, and will emit AC fault current into the water surrounding the boat, posing a shock hazard to any swimmers nearby (**Figures 4** and **5**). While the creation of a potentially lethal electrical field in the water surrounding the boat is generally only a problem when the boat is plugged into shore power, more than one drowning has occurred at marinas as a result of neglecting this critical detail. I can't emphasize enough the importance of tying these two grounding subsystems together at





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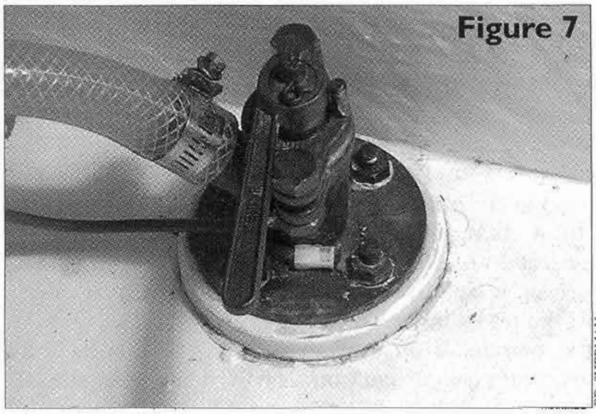
Left—*In-water shock hazard mitigated by engine AC grounding. When an AC-to-DC short occurs, say in the battery charger, on a boat hooked up to dockside shore power, the fault current is dissipated to ground through the engine.* ***Right***—*In-water shock hazard with engine AC-ground open. If the same boat does not have the engine grounded, or a connection in the grounding system has failed, then the AC-to-DC short shown in Figure 4 attempts to return to its shoreside source through the water, potentially harming anyone immersed.*

the one common point, thereby creating a path for AC fault currents back to their source by way of the boat's DC and AC wiring—rather than the water.

Now, the argument against this position holds that by tying together the AC and DC systems you almost ensure that any AC system fault current will be distributed out through the engine propeller shaft or the through-hull fittings tied into the bonding system. This is simply not true, but I say that with an important caveat. Back to my perfect-world

to reveal themselves), or show up immediately in the form of a blown fuse or circuit breaker. Again, this assumes the system has been wired correctly, which is often *not* the case. Based on ABYC Standards, DC equipment with metal cases that are exposed to either seawater or bilgewater are required to be tied into the DC grounding system, or the *bonding system*, as it is often referred to. The reason for this is that in the event of a short circuit within any of these devices, there will suddenly (or gradually, in some cases) be a difference in electrical potential between the devices. Which means current will flow in the seawater surrounding these devices, and the end result can be serious stray-current corrosion.

DC leakage current into the bilgewater will seek a path to ground by way of an unbonded metal through-hull also immersed in the same water. As this stray current exits the boat via the through-hull fitting, that through-hull will exhibit signs of accelerated corrosion. The reason the ABYC recommends tying together (by bonding) metals and devices that are exposed to either bilge- or seawater is that if a leak does occur, then the electrical potential between the two pieces is essentially the same, so current flow is minimized if not eliminated. These types of faults can be very difficult to trace, but common culprits include equipment such as bilge pump motors and their float switches. By tying such components together through the bonding system, the cases of the equipment are at the same voltage potential even if there is a fault, and no current will flow.



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This bronze seacock is connected to other metal objects by a bonding wire. Here, the cable connection to the stud is green with corrosion and should be replaced.

The point to remember here is that all of these rules and concepts work just fine so long as the bonding system stays in good condition, with high-quality, low-resistance connections—which is precisely where problems often appear. Think of the bonding conductors and terminations you've seen on boats that have been in service for a while. The wiring connections are usually the same color as the green insulation typically used on the bonding conductors. Electrical wiring needs periodic maintenance, but that rarely occurs until problems crop up. On new installations, I routinely recommend that a corrosion to reveal themselves), or show up immediately in the form of a blown fuse or circuit breaker. Again, this assumes the system has been wired correctly, which is often *not* the case. Based on ABYC Standards, DC equipment with metal cases that are exposed to either seawater or bilgewater are required to be tied into the DC grounding system, or the *bonding system*, as it is often referred to. The reason for this is that in the event of a short circuit within any of these devices, there will suddenly (or gradually, in some cases) be a difference in electrical potential between the devices. Which means current will flow in the seawater surrounding these devices, and the end result can be serious stray-current corrosion.

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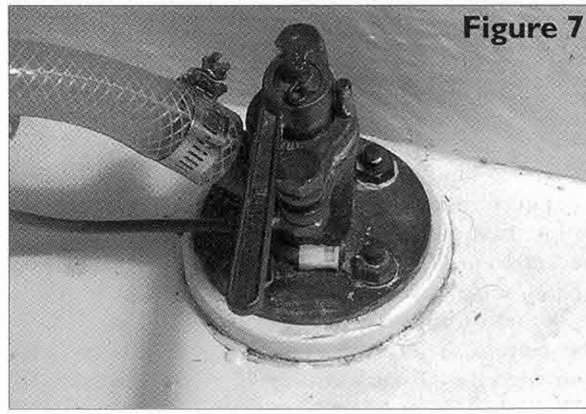

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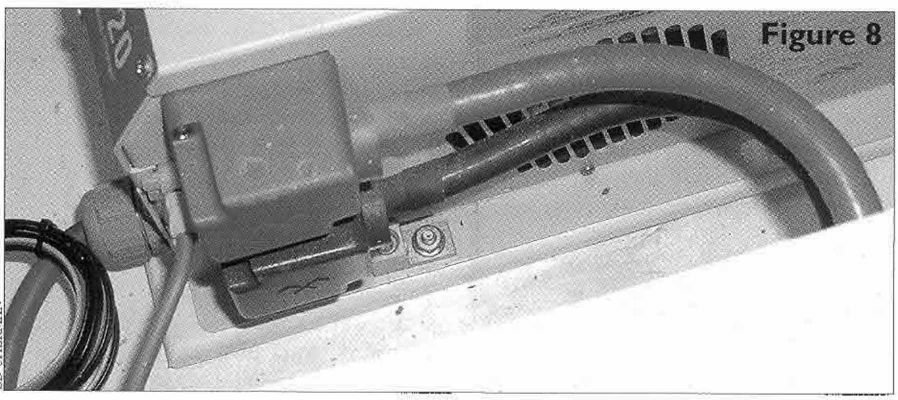

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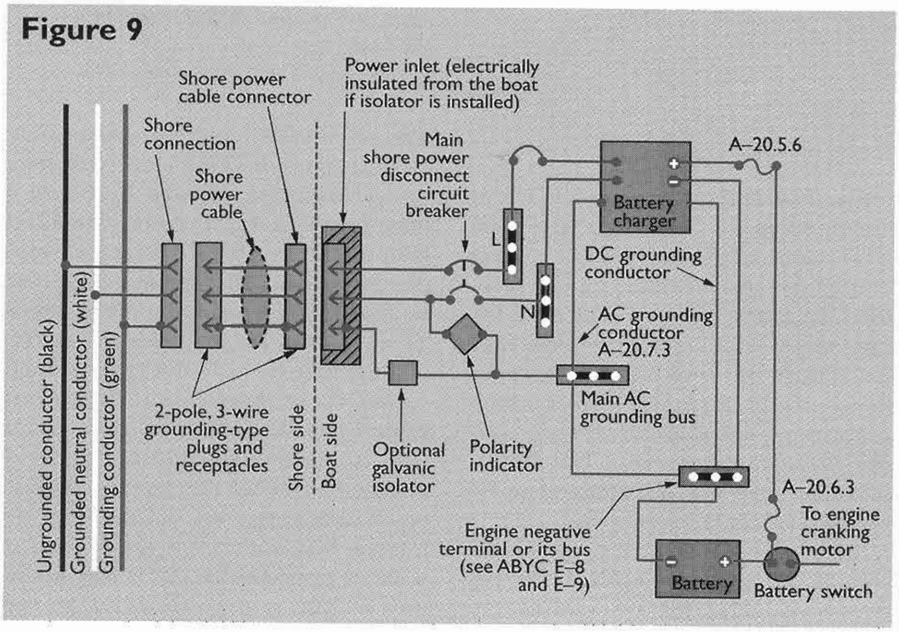
A Heart inverter comes from the factory with a lug for the third wire, but here the installer neglected to install the DC grounding conductor as recommended by both the ABYC and Heart. Some technicians erroneously believe that the AC grounding conductor, also attached to either the battery charger or inverter case, will protect in the event of a DC fault.

Another area of concern is potentially high-amperage DC faults at battery chargers and DC–AC inverters. Again, ABYC standards clearly recommend a third wire for the DC side of the circuitry on these devices, and that wire has to be gauged according to the DC positive (sometimes referred to as the "ungrounded") conductor servicing the device. The wire is recommended to be no less than one gauge smaller than the DC positive conductor. In the event of a DC case short, this third grounding wire will direct the fault current back to the source of power by way of a low-resistance, high-current-carrying conductor, and either trip a breaker or blow the fuse that is supposed to be installed in the DC feed wire.

Two common points of noncompliance with the ABYC standards exist here. Either the DC feed has no fuse or breaker installed (extremely dangerous), or the third wire was never installed. **Figure 8** shows a brand-new Heart inverter installed with the lug for the third wire as supplied by Heart. The installer neglected to install the DC grounding conductor as recommended by both the ABYC and the inverter manufacturer. Among some technicians the argument against installing this third wire is that the AC grounding conductor, also attached to either the battery charger or inverter case, will do the job. The truth is that under rare circumstances it may—provided the AC wiring to the unit in question happens to be the same size as the DC conductors. But this is extremely unlikely if wire sizing has been done properly and the amperage-carrying capacity of the wire has been considered. If wire sizing does conform with the standards, then the DC wiring will always be a much larger gauge than the AC wiring, and in that case the AC grounding conductor will be grossly undersized to handle a DC fault current. In the event of a fault, the wire will in all likelihood turn into nothing more than a fusible link, causing an electrical fire. The diagram in **Figure 9** appears in the ABYC Standard A-20, "Battery Chargers," and illustrates a third grounding conductor for the DC side of the charger.

Figure 9



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A diagram from the ABYC Standard A-20, "Battery Chargers," illustrating the third grounding conductor for the DC side of the charger.

To Bond or Not to Bond

The subject of bonding has fueled many heated debates and, at this rate, promises to do so until the end of time. I've owned boats that were not bonded, and had no trouble with underwater metal corrosion. I've also owned boats that *were* bonded and had no problems. Truth is, a case can be made either way, but I'll offer my personal opinion, realizing full well that there are dissenting views.

I'm a proponent of bonding underwater metals on boats. Considering some of what we have already discussed (DC stray current from an electrically "leaky" bilge pump, for example), I believe that the more electrically complex boats of today will *on average* be far better off if the underwater metal appendages are bonded together through the DC grounding system. But again, this belief is contingent on the system at hand having been properly designed *and maintained.*

Recall our *Webster's* definition of grounding and one of the definition's elements—"*potential difference.*" All metals when submersed in an electrolyte (the seawater around the boat, say) have an ever-so-slightly different electrical potential. By linking these metals together and connecting them to ground, their electrical potentials are equalized. Now, if appropriately sized anodes are tied in by way of this same grounding system, then the metals in an electrolytic solution are spared from the corrosive effects of natural galvanic activity. Why? Because the anodes, being less noble (and therefore having a difference in voltage potential from the more noble metals you're trying to protect), become the sacrificial lambs.

Several problems with this concept complicate matters a bit. One is that when a boat is plugged into a shorepower system, its grounding system is connected through the AC grounding conductor to the other boats plugged into the same shorepower system on the dock. That electrical link provides one of the key components of a galvanic cell—a hard-wire connection between dissimilar metals. Let's say one boat in a slip is equipped with an aluminum outdrive and is plugged into shore power, and the boat in the next slip has a bronze propeller and is also plugged in. All the elements of a perfect galvanic cell exist: dissimilar metals, the hard-wire connection of these metals, and an electrolyte (the seawater the boats are floating in). So, even if both boats have properly designed grounding systems and appropriately sized anodes, a problem could still arise due to *potential differences* between the two boats.

Several possible approaches can be employed to deal with the problem. One is the installation of a galvanic isolator, or the much more expensive and effective isolation transformer. *[For more on galvanic isolators, see "The Great Galvanic Isolator Debate," PBB no. 41, page 21—Ed.]* Although interesting, both of these devices go beyond the scope of this article. With a galvanic isolator or isolation transformer installed in the AC circuit, any low-level galvanic current flow from one boat is blocked from the other boat by the grounding system.

One argument against bonding brings us back to marina-related issues. The "hot marina," as it is known in the trade, is one where mysterious electrical happenings occur, sometimes above and sometimes below the water. This is another area where old wives' tales abound. Let me just say: There is absolutely no evidence to suggest that AC current flow from faulty shorepower cords or leaking dock wiring contributes to underwater metal corrosion. Shock hazard in the water at the marina, yes; metal deterioration, no.

Stray DC current is, however, another matter. The argument against bonding suggests that stray DC current in the water around docks can enter a boat by way of any of the underwater fittings, migrate through the bonding system, and exit through another of its connected underwater fittings, thereby causing rapid deterioration of that piece of metal. The premise is that if all the underwater metals are electrically isolated, then this particular path for current flow is eliminated. Fair enough; it's theoretically possible. But I contend that a better approach would be to identify the offending boat(s) and repair them, difficult as that might be.

Remember, if the boats and docks are all wired properly, then the *potential difference* should be equal, and of lesser resistance than the seawater the boats are floating in; therefore, DC current flow through the water should be mitigated. I understand that this may sound like my unreal perfect world again, but history has shown that although these problems can and do occur, they are sufficiently isolated for me to believe the advantages of bonding far outweigh excuses for not bonding. Consider that the un-bonded boat may still have underwater metal fittings connected electrically by way of any accumulated bilgewater. A better solution in my view is to fix the faulty boat(s) at the dock to eliminate DC stray-current sources at the marina. Granted, although there are indeed cases of DC stray current being distributed from one boat to another through seawater due to faulty equipment or wiring on a boat or boats at a dock, the problem is not rampant. If it were, we'd have boats sinking weekly in their slips.

And, before we move on, let's consider the so-called "natural" galvanic current flow potential between boats plugged into shore power. That flow potential is due to dissimilar underwater metals found on various boats, which are effectively linked via the green grounding conductor in the shorepower system to create an almost perfect galvanic cell. That is why I am a strong proponent of using either a galvanic isolator, or if size, space and resources allow, an isolation transformer to eliminate possible problems here.

Lightning Protection

Another role of the grounding system is lightning protection. As with bonding, here is a subject area that abounds in bad information. The classic example is the premise that installation of a lightning protection system can actually *attract* a lightning strike. In fact, quite the opposite may be true. If the lightning protection system is installed correctly, then the boat's potential difference is equalized with the surrounding seawater, making it somewhat stealthier, at least in terms of lightning-strike vulnerability. During the buildup of an electrical charge, a good LPS will bleed off ions at the tip of the air terminal, thereby helping to prevent a strike.

In reality, a lightning strike, as described by most insurers, is an "act of God." The ABYC Standard E-4, which covers lightning protection systems, opens with several disclaimers. In fact, a given boat with a completely ABYC-compliant lightning protection system can still be struck by lightning, and yes, damage may still occur. Even so, by installing the system and integrating it with a proper grounding system, damage to equipment during a strike will most likely be minimized—and crew safety enhanced, which is the primary concern.

The information above, though, is contrary to what seems to be going on in much of the recreational marine industry. Most boatbuilders I've worked with recently are firm: "We don't install lightning protection systems at the factory," they say. This is unfortunate, and I'm certain reflects an obvious fear of implied liability for having installed such a system in the first place. When lightning does eventually strike the boat, any resultant damage or personal injury is sure to raise questions about system design and ABYC standards compliance.

The idea behind a lightning ground system is twofold. First, one must create a highly conductive path for lightning current to enter the boat (usually by an air terminal at the top of a mast) and then be conducted out of the boat by a ground plate; or more commonly, a combination of the ground plate and the "bonded" underwater metal components. The second part of this subsystem is the interconnection of large metal components on the boat to minimize the risk of lightning side flashes. If lightning does strike the boat and everything conductive has its electrical potential elevated equally, then the strike is able to dissipate through a good *Earth ground* through the bottom of the boat into the seawater. That way, the risk of damage is minimized both to equipment and to crew standing in the path of one of these side flashes.

By elevating the voltage on all the circuits, the risk to some equipment, especially electronic equipment, may be increased. For equipment safety, one needs additional protection well beyond the current ABYC standard. ABYC E-4 recommends the use of a 4 AWG conductor connected from an air terminal at the top of a mast (on either a sailboat or powerboat) to a ground plate or its equivalent (a keelbolt on an externally ballasted sailboat, for example). Also, the standard accepts the use of aluminum or other metallic mast with an equivalent conductivity of 4 AWG copper wires as a down (primary) conductor. Carbon fiber spars are *not* acceptable as a potential equivalent, because though carbon is a good conductor, the resin encasing the fibers is an insulator. Also, a sailboat's stainless-steel standing rigging may be factored in so long as the cumulative conductivity has the equivalent conductivity of 4 AWG copper wire, which will depend on the rig. Stainless steel, which has just 10% the conductivity of copper, requires more surface area. And don't forget to factor in the resistance of terminals and connections. Each shroud or stay in the rig must be tied into the grounding system with a minimum 6 AWG copper conductor.

The tying together of shrouds, stays, lifeline stanchions, and pulpits into the grounding system to act as secondary lightning conductors raises a key point. Standard E-4 requires the use of 6 AWG wire to connect the rig to a ground plate or other connection.

But this subsystem will also be tied into the bonding system, which to be standards-compliant requires the use of only 8 AWG wire (where wire is used rather than copper stripping). Once the bonding system and lightning protection system are attached, all of the bonding conductors will have to be upgraded to 6 AWG wire, because experience has shown us that 8 AWG copper is marginal in this role—hence the recent change to 6 AWG for secondary conductors.

An opposing approach calls for isolating the lightning ground system from the rest of the boat's grounding system. Use the 4 AWG "down" conductor and tie it directly to a keelbolt or a minimum 1 sq ft (0.1 sq m) grounding plate sited as close to the base of the mast as possible. But then we're back to the perfect-world problem again. I agree with the premise: It *is* preferable to provide a nice, straight, vertical path to take the strike and conduct it directly through the bottom of the boat, never coming in contact with anything else on board. Unfortunately, this isn't always possible, and even when it is, lightning may behave unpredictably. The ABYC standards state that large metal objects within 6′ (1.8m) of any lightning conductor shall be connected to the grounding system, and ultimately, of course, that means the lightning conductor. Why? Because as lightning screams down the 4 AWG ground conductor to Earth, it sometimes "sees" these nearby alternate paths to a potential ground. Thus, side flashes. Tying together the grounding system(s) on board may minimize these side flashes.

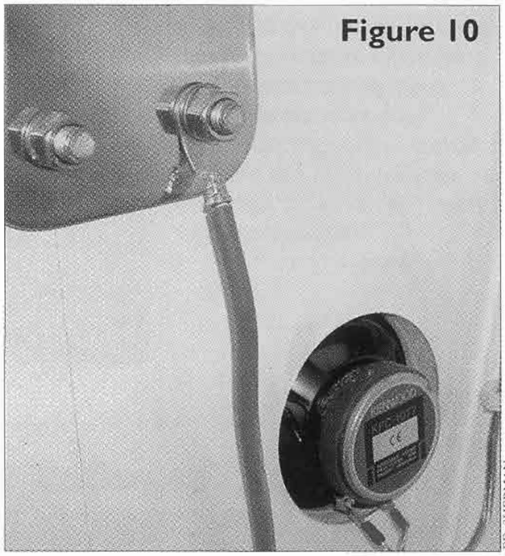
This phenomenon is difficult to understand, let alone predict, because during the buildup of a charge, the current flow develops RF (radio frequency) alternating currents. The frequencies and amount of energy associated with them change almost instantly. So when high current flow develops across resistances and reactances in the LPS, electrical, and electronic systems, or elsewhere in the boat, then side flashes can occur.

On a typical recreational boat, though, achieving the recommended 6′ "zone of separation" is virtually impossible. Also, in practice, all but the most serious offshore sailors with *internally* ballasted boats will be reluctant to install what is generally a rather obtrusive (hydrodynamically) lightning ground plate of the appropriate size on their boat's underbody. Fortunately, most sailboats today have external lead ballast keels and the ground connector can be a keelbolt, obviating the need for a ground plate. Of course this solution doesn't help the powerboater, who has little choice but to install a ground plate.

In any case, by tying together all of the underwater metal that's normally connected by the bonding system, you have a much better chance of achieving greater than 1 sq ft of exposed grounding surface area to the seawater, which is the minimum specified by ABYC E-4. This is important, because the 1-sq-ft area is really only acceptable in salt water. Brackish and fresh water will require a much greater exposed surface area to achieve an effective strike dissipation area due to the lower conductivity of fresh water. The ground plate, or a keelbolt on an exposed ballast keel, is without question preferred, with the through-hull metals acting as secondary conductors.

Remember, never tie the 4 AWG "down" conductor directly to a seacock or any other through-hull plumbing fitting. But, as illustrated in Figure 1, do tie it all together. That way you raise and lower electrical potential equally, minimizing the risk of side flashes, making this approach the safest bet we know of today.

Figure 10 shows a 6 AWG cable attached to a shroud chainplate on a new 46′ (14m) sailboat produced by a well-known, high-end builder that does not even want to discuss lightning protection. I can tell you that the only missing element of a standards-compliant system on this boat is an air terminal mounted at the top of the mast.



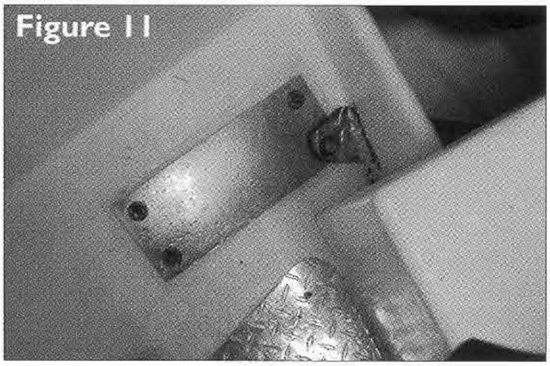
As part of a lightning protection system, the chainplate on this 46' (14m) sailboat is connected to a lightning ground plate by 6 AWG cable.

RF Ground

Finally, there's the matter of RF (radio frequency) ground. This is an area where I do believe in at least a partial "separation" from the rest of the grounding subsystems on board.

Referring back to Figure 1, we see a radio ground plate tied into the other subsystems. That ground plate could be easily substituted with a keelbolt on an externally ballasted sailboat. Regardless of how ground is achieved here, however, it is important to remember that RF ground is perhaps the only grounding subsystem on board that actually enhances equipment performance. Its function is to provide an effective ground for radio frequency signals. It never really needs to carry DC or high-amperage AC fault current, as the other grounding conductors may under various circumstances. (Note: This is true only when there is an additional grounding circuit; otherwise, the RF ground may serve double duty.) So, even though this system is linked to the others, it can be at least partially isolated from stray DC current—or from *emitting* stray current when the radio is in transmit mode—and still be effective.

In my opinion, such isolation is a



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Copper tape, used for a good RF (radio frequency) ground, helps prevent interference such as static on radios. Bolted to the right side of the ground plate, the tape has been fed through a slot in the adjacent stringer.

good way to minimize the risk of DC electrical back-feeding and possible equipment damage when things go crazy, and the other grounding systems get called upon, and when the radio is transmitting. Even so, you could argue that the amount of time spent in transmit mode is really not enough to induce any problems in the form of stray-current corrosion. I happen to believe that a minor isolation here is cheap insurance no matter which side of the argument you're on. Bear in mind, though, that this isolation method will not block AC current or lightning potential current. In effect, the isolator will consist of several small capacitors connected in series with the grounding *ribbon* (not wire), which you should be using for this purpose. A good radio-supply house can provide what's needed for this minor but worthwhile addition to the RF grounding conductor. Done right, the setup will in no way affect radio performance. **Figure 11** shows copper ribbon connected to a radio ground plate.

In conclusion, getting grounded can be a chore; how much of one depends on the complexity of the boat and the number of systems installed. Nevertheless, a good ground system is of paramount importance to the well-being of the crew, and to ensure a long life for installed equipment.

This seemingly inert system, which on the face of it makes nothing actually work, is perhaps the most neglected and overlooked part of any boat's electrical system. Keep up with it by making sure that all connections are clean, tight, and corrosion-free. Design it with this need in mind, and remember that when plugged into shore power, the onboard grounding system, in most cases, is only as good as the dock or marina wiring system. PBB

***About the Author**: A veteran marine electrician, Ed Sherman is the assistant education director for the American Boat & Yacht Council, and chairman of the board of directors of the Rhode Island Marine Trades Association. He is the author of—* Outboard Engines: Maintenance, Troubleshooting and Repair; The Powerboater's Guide to Electrical Systems; *and an update of Minor Brotherton's classic text,* The 12-Volt Bible for Boats.