

For example, assume a running light circuit with two bulbs and 40 feet of wire draws 4 amps. The wiring in the circuit is 12 AWG. The voltage drop in the wiring is:

$$(1.6 \div 1000) \times 40 \text{ feet} \times 4 \text{ amps} = 0.256 \text{ V,}$$

which is less than 3 % of the 12.6 V battery voltage, so the wire is adequate. Smaller voltage drops in the wires mean brighter lighting and less power wasted in the wires, so it is always OK to use a heavier gauge of wire for the circuit, for example using 12 AWG instead of 14 AWG. Oddly enough, the smaller the gauge number (12 vs 14) the “heavier” the gauge.

### 6. Preventing Galvanic Corrosion:

Galvanic or electrolytic corrosion, sometimes called “electrolysis,” occurs whenever two metals of different types are immersed in water, especially salt water. This is why underwater metal parts such as propeller shafts need a sacrificial zinc anode attached to them. Zinc is more active than steel, copper, or bronze and thus will corrode away instead of the other metal hardware.

All underwater metal parts should be electrically bonded together inside the hull with heavy solid copper grounding wire and secure ground straps or screws. With all the metal electrically bonded, every zinc anode installed below the waterline protects all the other metal parts from corrosion. Make sure to keep an eye on the zinc anodes and replace them before they have fully corroded away.

### 7. Where to Go From Here:

With the help of the tips and techniques in this booklet, you should be able to troubleshoot most of the common electrical problems on your boat. When troubleshooting electrical systems, it’s important to use a logical process of deductive reasoning to solve the problem. Jumping to conclusions can be expensive and time consuming. Just use this simple approach: check for power, check fuses and switches, check connections, and check for good grounds.

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### How-to Test it Yourself

# Boat electrical



**Boat #15**

### Typical Problems:

If your boat is kept in the water, especially if it is in salt water, it is a prime candidate for electrical problems caused by corrosion of the wiring terminals, light bulb sockets, switches, and even the wiring. Corrosion causes resistance in electrical circuits leading to unreliable, intermittent and eventually failing 12-volt equipment on your boat.

### Task Summary:

This booklet will help you diagnose and fix common electrical problems in your boat. When troubleshooting electrical systems, it’s important to use a logical process of deductive reasoning to solve the problem. This process is most important since, unlike mechanical devices, you can’t see inside or dismantle the majority of electrical components to tell whether they’re functioning. We’ll start with the battery and charging circuit, then look at bad grounds and other electrical connections, then finish by checking for failed components.

### Recommended Tools:

You will need a DMM that measures dc volts, ac volts, resistance, and continuity. You will also need a current clamp accessory that measures dc current. As an alternative, use a clamp-on multimeter that combines all the above measurement capabilities. You may also want to look for a meter that is waterproof. It is assumed you have basic knowledge of how to make electrical measurements and how to operate a DMM or clamp meter. If not, you should start by reading “Basic DMM Measurements” and your DMM or clamp meter owner’s manual.

## Step by step troubleshooting:

### 1. Measuring Battery Voltage:

If your battery becomes discharged it will be unable to provide sufficient voltage or current to the starter, hence the engine won’t crank. The first step is to test the battery and charge it if necessary. (see figure 1)

Verify that the connections to the battery look clean and are tight. With the engine off, bleed the surface charge from the battery by turning on multiple accessories for a minute. Now with the accessories turned off, set your DMM to the dc voltage function, 20 volt range, and measure the voltage across the battery terminals by touching the red probe tip to the “+” termi-

nal and the black probe tip to the “-” terminal. If you have multiple batteries connected in parallel, measure one battery at a time. Use the chart at below to determine the approximate percent charge on the battery. If the battery voltage reads low, the battery may be damaged or worn out, or the charging system is not working correctly. (see figure 2) Verify the alternator is working. A more complete load test should be done

#### No-Load Test

Readings obtained at 80 °F (27 °C)

Voltage	Percent Charge
12.60 V to 12.72 V	100 %
12.45 V	75 %
12.30 V	50 %
12.15 V	25 %



to indicate battery performance under load and determine if the battery is damaged.

## 2. Verifying a Good Alternator:

To perform this test, the battery must be fully charged. (see figure 1) Run the engine at idle and verify that no-load voltage is 13.8 - 15.3 volts dc (check as in step 1). Next, load the alternator to rated output current by turning on as many accessories as possible (e.g. running lights, pumps, motors, fans, etc.). Increase engine speed to about 2000 RPM. Check the output current of the alternator with a dc current clamp (see Figure 2) to see if it is at or near the rated output current. Now check the alternator output voltage. (see Figure 3) The alternator must maintain at least 12.6 volts dc output at rated alternator current output. As additional accessories are added to the electrical system, the current required from the charging system increases. You may have to install a larger alternator or generator to keep pace with the modifications.

## 3. Checking Ripple Voltage:

The alternator generates ac voltage that is converted to dc voltage through a group of diodes called a rectifier bridge. The output of a properly functioning alternator will show a small amount of ac voltage called “ripple”, or leakage past the diodes. A good alternator should measure less than 0.5 volts ac ripple with the engine running and loads applied.

Run the engine at fast idle and turn on accessories to load the alternator. Measure the ripple voltage by switching your DMM to the ac volts function, 2 volt range, and connecting the black lead to a good ground (such as the engine block) and the red lead to the “BAT” terminal on the back of the alternator. (not at the battery)

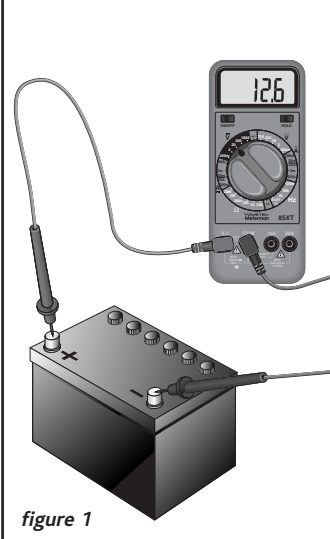


figure 1

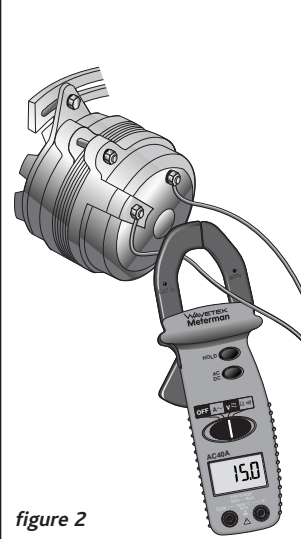


figure 2

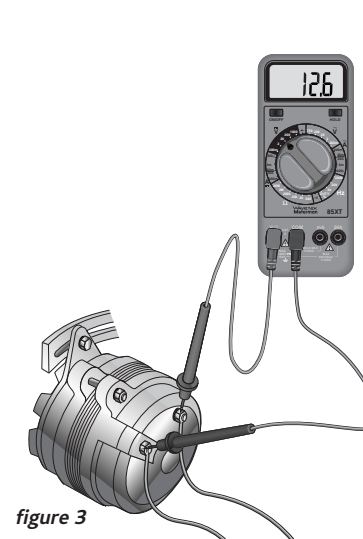


figure 3

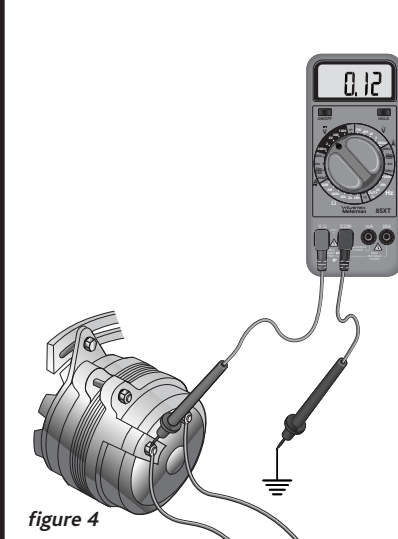


figure 4

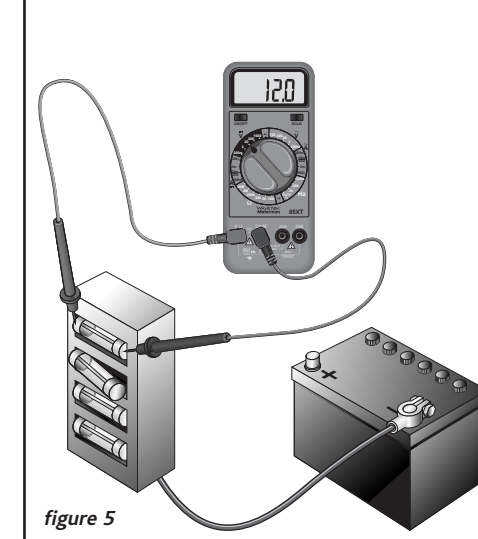


figure 5

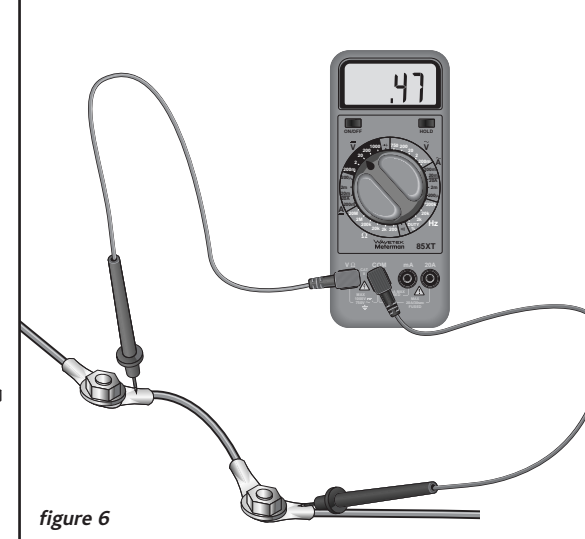


figure 6

# Troubleshooting boat electrical systems

(see figure 4) A reading higher than 0.5 volts ac may indicate damaged alternator diodes.

To rule out wiring as the source of the trouble, check all the wire connections between the alternator and the battery terminals. Refer to the section 5 “Voltage Drops in Wiring”. If the wiring is OK, have the engine’s charging circuit serviced by a professional.

## 4. Testing for Circuit Integrity:

Electrical devices need good, solid connections in order to operate properly. This is particularly true in boats since the power source is a battery. Vibration, temperature extremes, and corrosion from salt and rain can cause good connections to go bad in your boat. Loose connectors, build-up of rust and corrosion, broken wires, and damaged switches are all examples of bad connections.

If a device is not working properly, first check to make sure it is getting power. Set your DMM to the dc voltage function, 20 volt range. Connect the black lead to a good ground and probe with the red lead on the “+”

input of the device. (Make sure the ignition switch is turned ON. Many accessories do not operate with the ignition turned off.) If the reading is zero, there is no power to the device. This could be an indication of a blown fuse or tripped circuit breaker.

To check for a blown fuse, first locate the fuse panel and remove the cover.

To test the fuse, set the DMM to the dc voltage function and connect the black lead to a good ground, then probe both sides of the fuse for 12 volts dc. (see figure 5) A good fuse will show 12 volts on both sides. A blown fuse will show 12 volts on one side only. If you cannot easily probe both sides of the fuse, as an alternative you can remove the fuse and check it for continuity. Set the DMM to the continuity (ohms) function and probe one side with the black lead and the other side with the red lead. A good fuse will sound the continuity beeper and show almost zero ohms of resistance. A bad fuse will not sound the beeper and will show “OL” for resistance. Replace any blown fuse only with one of the same type and current rating.

## 5. Voltage Drops in Wiring:

A bad, or high resistance, connection robs some of the voltage required by the device you want to run. A typical 12V battery will actually output about 12.6 volts dc when fully charged. A voltage drop of up to 3 % (0.38 V or 380 mV) for electronics and running lights, and 10 % (1.26 V) for non-critical circuits such as cabin lights is normal. But if the voltage at a running bilge pump or light is more than 10 % lower than the voltage at the battery terminals you could have a bad connection.

If a device is not operating properly, check all the connections leading up to that device, and back to the battery. First look for a connector that has become oxidized and is adding too much resistance in the circuit. Suspect connections include terminal posts, crimp connectors, bulb sockets, switches, and even the wiring itself.

With all the accessories in the circuit turned on, probe with your meter, in the dc voltage function, on either side of a suspected connector. (see figure 6)

Record the voltage reading displayed on the meter. If the voltage drop you measure is too high (more than 10 % of the battery voltage), try cleaning the contacts by removing any rust or corrosion, scraping the metal or wires to expose bare, clean metal, reseating the connectors, and securely tightening all screws or nuts.

Repeat this for long runs of wiring as well. Use your DMM in the dc voltage function and measure the voltage drop between the ends of every section of wire in the circuit. If you find one section of wiring with too high a voltage drop it could be the wire is damaged or corroded, or the wire may not be the right gauge (size) for the intended load. Replace that section of wire, perhaps with a heavier gauge of wire (see the table to the right).

You can calculate the right gauge of wire to use in a circuit by adding up the current draw of every device in the circuit then calculating the maximum voltage drop caused by the wire itself. If the calculated voltage drop is too big (more than 380 mV) then a heavier gauge wire is needed.

The current draw of a device will either be shown on the device itself, or for a light bulb, simply divide the wattage by the nominal voltage, 12.6 volts. Then use this simple formula to determine maximum voltage drop you will have in the length of wire. (See accompanying chart).

**(Ohms per foot from table below) x (feet of wire) x (max circuit current) = voltage drop**

Do this calculation for the total wire length in the circuit from the positive battery terminal all the way through the boat back to the negative battery terminal.

Wire size, or gauge (AWG)	Ohms per 1000 feet
16	4.1 Ω
14	2.6 Ω
12	1.6 Ω
10	1.0 Ω
8	0.7 Ω

(continued on back)

Work safely!



Electricity can be dangerous. Protect yourself and your boat by remembering to follow a few simple rules when working with electrical circuits:

- Make sure your meter is working with a 3-point check: Measure a known live circuit, next measure the circuit you’re working on and finally re-check the known live circuit.
- Only use a meter that has the proper voltage ranges for the job at hand and make sure the meter has the proper safety ratings and protection.
- Use caution when reaching inside the engine compartment. Parts of the engine may be very hot, and the fan may start automatically
- Don’t wear loose fitting clothing, jewelry or a tie that can become caught in moving pulleys and belts. Make sure test leads are safely out of the way of all moving parts of the engine