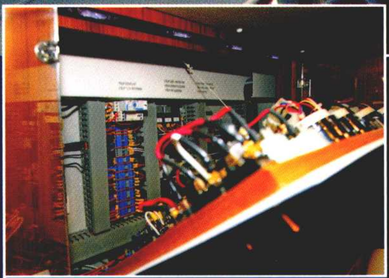
A Manual for Boatowners and Marine Technicians

Advanced Marine Electrics and Electronics Troubleshooting



- Troubleshoot today's complex boat systems
- Eliminate starting and charging problems
- Protect electronics installations from interference
- Track down bonding, grounding, wiring, antenna, and corrosion problems

Ed Sherman Senior Writer, *American Boat and Yacht Council*

Advanced Marine Electrics and Electronics Troubleshooting

A Manual for Boatowners and Marine Technicians

Ed Sherman

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FOREWORD

In 1996 I had the good sense to enroll in a course on diesel maintenance at New England Institute of Technology; that much I can take credit for. What I can't take credit for was my exquisite good luck at landing in a class taught by Ed Sherman. It only slowly dawned on me that I was in the presence of one of the country's great teachers and communicators of marine technology. What I knew immediately, though, was that I was getting my money's worth. In the intervening years Ed has moved on to the American Boat and Yacht Council, where he teaches the teachers on boat technology, and for nearly a decade now, he's brought his incomparable teaching into *Cruising World*'s pages to the benefit of us all.

You hold in your hand a fine example of his teaching. As our boats have grown more complex, truly competent skippers are part systems operators as well as navigators and boat handlers. Consequently, the line between recreational boaters and technicians has blurred. *Advanced Marine Electrics and Electronics Troubleshooting* may aim at the professional technician—and it hits that target squarely—but for the dedicated boatowner who really wants to be self-sufficient, this book provides the guidance to solve the most vexing problems in electrical and electronic systems. If you're like me and you're serious about wanting to understand all the details that make up today's boats, you'll find more than ample payback for every moment spent in Ed Sherman's company. You'll certainly come away smarter.

—Tim Murphy
Executive Editor, *Cruising World*

PREFACE

Unlike the first two books I've published that discuss marine electrical installations—*The Powerboater's Guide to Electrical Systems* and the revision work for the second edition of the classic *12-Volt Bible* by Miner Brotherton—*Advanced Marine Electrics and Electronics Troubleshooting* is intended to help serve the needs of marine electrical technicians and experienced boatowners who want to use the latest technology and techniques to troubleshoot onboard electrical problems. These earlier works were intended for the less experienced boater; this one is not. You won't see information in this book that explains Ohm's law or how circuits are designed. Rather I've assumed you've already grasped those concepts and have more than a rudimentary understanding of how electrical power, both DC and AC, is distributed around a boat.

Over the years, many have accused me of being somewhat of a "gadget freak" because I'm always conducting seminars or writing magazine articles that discuss the use of sophisticated "toys" of the sort that are mentioned in this book.

It's true that I am continually employing new and often unrecognized equipment in my work—not because I feel any particular need to always have the latest gadgets at hand, but rather because I'm always looking for easier, more efficient, and more exact ways to accomplish the everyday tasks of the marine electrician. In addition, I'm acutely aware that modern boats are not getting any easier to work on—at least not in regard to their electrical systems. As the level of sophistication of the modern boat's electrical system continues to increase, and the convergence of traditionally distinct electrical and electronic systems continues, many of the techniques found within this book are going to become as mainstream as checking the electrolyte level in a battery cell used to be.

I'd like to point out that most of the equipment discussed in this book is really not all that new, and many readers who have perhaps migrated into boating from information technology (IT) or telecommunications may recognize some of this equipment and feel right at home. The new thing here is my application of this equipment to the marine environment and the implications of the findings generated by the equipment.

As boat electrical and electronic systems continue to evolve and to look more like the computer network of a modern business office, the techniques described in *Advanced Marine Electrics and Electronics Troubleshooting* will increasingly become the best—and in some cases, the only—way to get the job done. The digital volt-ohm meter is not dead, of course, but if it's the only tool at your disposal for electrical troubleshooting, you simply will not be able to compete as a professional marine technician. And if you're not a technician, but rather the owner of an electronically sophisticated boat, you'll find techniques here that will make you the master of your boat, not its slave.

If you are looking for ways to save money on equipment for electrical troubleshooting, or want to learn how to diagnose electrical problems with a traditional, low-cost 12-volt test light, this book is not for you. But if you want to see how the pros are beginning to do things, read on. The equipment available to the marine troubleshooter keeps getting better and more sophisticated as more and more microprocessor capabilities are integrated into new meters. The value that you derive from the use of this equipment will quickly outweigh the initial purchase price, and the benefits will continue to accrue as time goes on. I hope you benefit from the information and approaches I've presented in this book and, as always, happy boating.

ACKNOWLEDGMENTS

Besides the many technicians I've had the pleasure of working with, this book would not have been possible without the help and guidance of several individuals and two organizations in particular.

First, I'd like to thank the American Boat and Yacht Council in general, and most especially for the technical guidance provided by its *Standards and Technical Reports for Small Craft*. Without these standards we (boaters, field technicians, and I) would be flying blind when performing electrical installations.

Next I'd like to thank the National Marine Electronics Association for its *Installation Standards for Marine Electronic Equipment Used on Moderate-Sized Vessels*. This document is the guiding light for the proper installation of the electronic equipment discussed in the book.

I'd especially like to express gratitude to three individuals for their peer review work and suggestions. Mickey Smith of Boat Systems in Stuart, Florida, is one of the most innovative electrical systems designers working today, and has provided me with much insight into today's advanced marine electrical systems, and what is just around the corner for tomorrow. Jim Vander Hey of Cay Electronics, Portsmouth, Rhode Island, is one of my former students, and has advanced to the leading edge of electronics installation, and currently serves as a member of the board of directors for the NMEA. I'm sure he has no idea how proud it makes me to see his successes. Finally, I'd like to thank Dan Cox of Midtronics, who got me interested in battery conductance testing methodologies and, most recently, in the applications of this technology for troubleshooting voltage drop problems.

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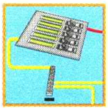
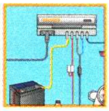




CHAPTER
1

Marine Troubleshooting the Modern Way

Advanced Marine Electrics and Electronics Troubleshooting introduces the technician or boatowner to some new equipment for troubleshooting electrical systems. With this equipment, some of the traditional techniques used by marine electricians over the years can now be altered or vastly improved upon. The new gear provides more accurate information, and many of the traditional troubleshooting steps can be eliminated altogether. The microprocessors in these new devices simplify diagnoses that used to require multiple steps and painstaking labor.

Because much of the information in this book may be new to many readers, it seems prudent that we first look at some common problems related to electrical and electronic systems, and then move on to finding solutions to these problems. Rather than using the traditional tools of electrical troubleshooting, however, I will identify the new equipment and point you to the chapter that describes how the equipment is used.

My goal throughout this book is to elevate your skills to the next level in diagnostic work, using the latest in equipment and techniques. If you're a professional electrician, you will certainly need these skills as boats continue to evolve into increasingly more complex electrical/electronic marvels. And if you're the owner of a sophisticated boat, learning to use this equipment will greatly simplify your life when it comes to diagnosing a problem quickly and with minimal electrical expertise. The equipment really does most of the detective work for you. Your part consists of understanding and applying the results generated by the gear, and I hope this book gives you much greater insight into that.

With only a few exceptions, all of the instruments discussed cost less than $500—some of them are less than $100 (and one is under $10!). For anyone who works on boats with complex electrical systems and lots of electronics, these costs can be easily and quickly justified by savings in time and increased effectiveness over old troubleshooting methods. As for the more expensive gear, even that can generate relatively quick payback for professionals, while some advanced amateurs who readily drop thousands of dollars on boat "toys" should have no trouble finding practical applications for these useful and highly capable tools.

To help you build your high-tech toolbox, I've placed Toolbox sidebars in every chapter describing an instrument. In them, I've listed some models and brands that have a good track record to give you a good place to start.

Throughout this book, I've included extensive descriptions of specific instruments to demonstrate the functionalities and basic operations for a *class* of equipment. My use of these instruments is not an endorsement for any particular brand. Instruments from other manufacturers may offer comparable or superior functionality to the ones I've used here. If you are considering the purchase of a specific piece of equipment, carefully weigh all factors: pricing, service, warranty terms, availability, and your specific needs for an instrument's functions and capabilities.

Caution: AC circuitry is dangerous! Extreme shock hazards exist. If you are not experienced and comfortable around AC equipment and troubleshooting, call in a specialist.

FINDING YOUR WAY

How is this book set up? I've divided it into two parts, each with specific goals.

Part 1, Electrical Systems Troubleshooting:

- Identifies new methods for troubleshooting electrical circuits (including the engine starting and battery charging systems and the AC and DC distribution systems).
- Introduces you to test instruments you may not have seen before, such as the time domain reflectometer, megohmmeter, and amp clamp, and explains their capabilities and applications.
- Provides step-by-step instructions, with accompanying photos, on how to use these instruments and apply the results.
- Explains the importance of grounding systems from the multiple perspectives of equipment functionality, shock prevention, corrosion minimization, and lightning protection.

Part 2, Marine Electronics Installation and Troubleshooting:

- Addresses the relationship between the electrical system and marine electronics.
- Looks at numerous installation factors that influence the functionality of electronic equipment, and tells you how to anticipate and avoid problems before you cut holes and run wires.
- Gives special attention to antennas and coaxial cable, as they are critical to the proper functioning of many types of equipment.
- Introduces the cutting edge of onboard wiring—networked systems—to give you a taste of what to expect in the near future.

Let's begin, then, with a discussion of the types of electrical circuits on modern boats, and how to troubleshoot the modern way.

ELECTRICS VERSUS ELECTRONICS

Today's typical modern boat, whether power or sail, has the potential for carrying a wide variety of circuits and equipment:

- AC-supplied battery chargers
- anchor windlass
- audio system
- bilge pumps and blowers
- bow or stern thrusters
- electric galley (stove and oven)
- electric head sanitation system
- electric winches
- engine-driven charging circuit
- engine instrumentation
- engine starter circuit
- hot-water heater
- inverters
- lighting, including navigation lights and general illumination
- navigation and communications electronics
- television

- trim tabs
- refrigeration and air-conditioning system
- shore-power transformers (isolation transformers) and AC generators

All of these devices can be divided into two broad categories: *electrical systems*, which include such things as basic shore-power service or the navigation light circuit on your boat; and *electronics*, which we can generally categorize as circuits that distribute data, such as between a GPS receiver and an autopilot.

The common characteristics of these devices are that they all have a power source, either AC or DC, as well as a path for the electrical current to flow. And inevitably, at some point during their service life, they will need to be repaired, upgraded, or replaced.

Beyond these, few factors apply across all of the devices, so it is convenient to organize them into the categories listed below:

1 Electrical systems
   - high-amperage motor circuits
   - low-amperage motor circuits
   - engine-driven alternator
   - lighting circuits
   - engine instrumentation
   - AC resistive loads (heating elements)
   - battery chargers and inverters
   - AC power sources

2 Electronics
   - communications equipment
   - navigation aids
   - entertainment equipment

Using these categories, I've created flowcharts to identify some common problems, the equipment or instrument to use to troubleshoot those problems, and the general step-by-step testing procedures. (Each test instrument walks you through the process via on-screen prompts, so I won't repeat all those steps here.) I've also included, for comparison, the old method of troubleshooting, so you can see the greater efficiency and effectiveness of the new method. Finally, each flowchart gives you a quick reference to the chapter that offers more detailed information on the instrument's use and application.

Flowcharts: Electrical Systems

High-Amperage Motor Circuits

The first category consists of motor circuits with high current draws. These are really dual circuits, with a low-amperage control circuit side to activate a relay or solenoid, which then activates the high-amperage side to run the motor. Examples include:

- starter motors
- anchor windlass
- thrusters
- electric winches

The troubleshooting procedure is summarized in the flowchart on page 4.

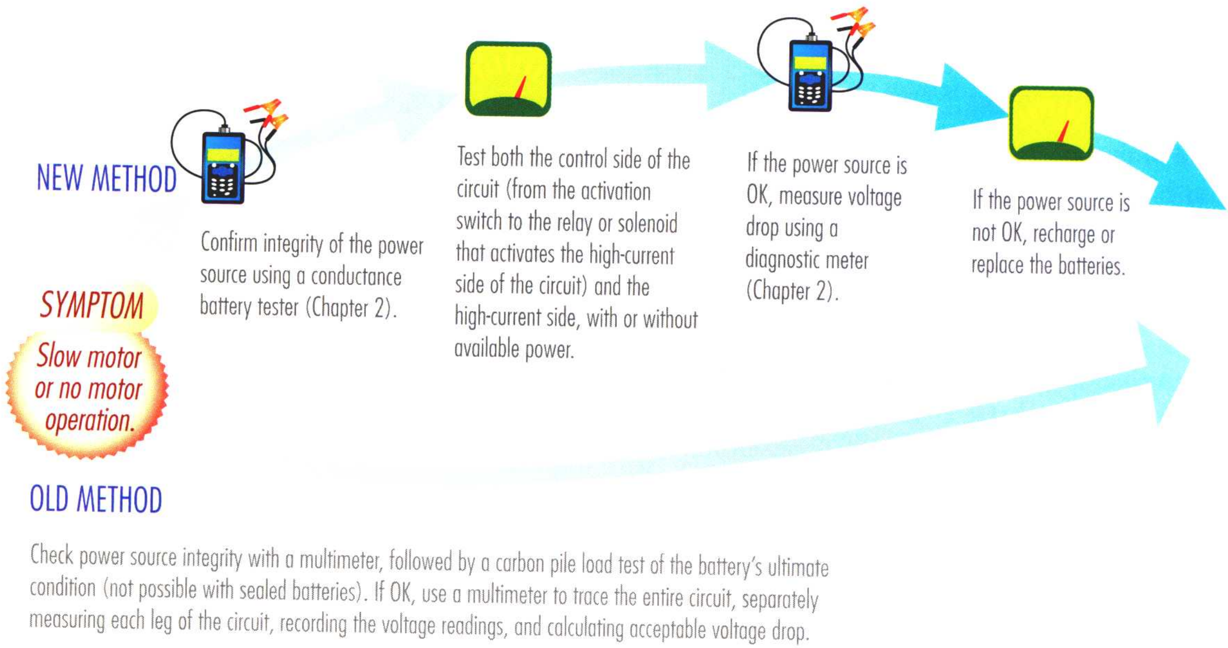
Low-Amperage Motor Circuits

This category includes AC and DC motor circuits of low current draw (relative to the high-amperage motors above):

- refrigeration systems (AC or DC)
- bilge pumps
- bilge blowers
- trim tabs
- electric heads and macerator pumps

Unlike the circuits for high-amperage motors, low-amperage motor circuits typically do not have a control side and a high-current side, and they are usually fed directly by a DC power supply (although refrigeration systems may be powered by AC or DC, or both).

High-Amperage Motor Circuits

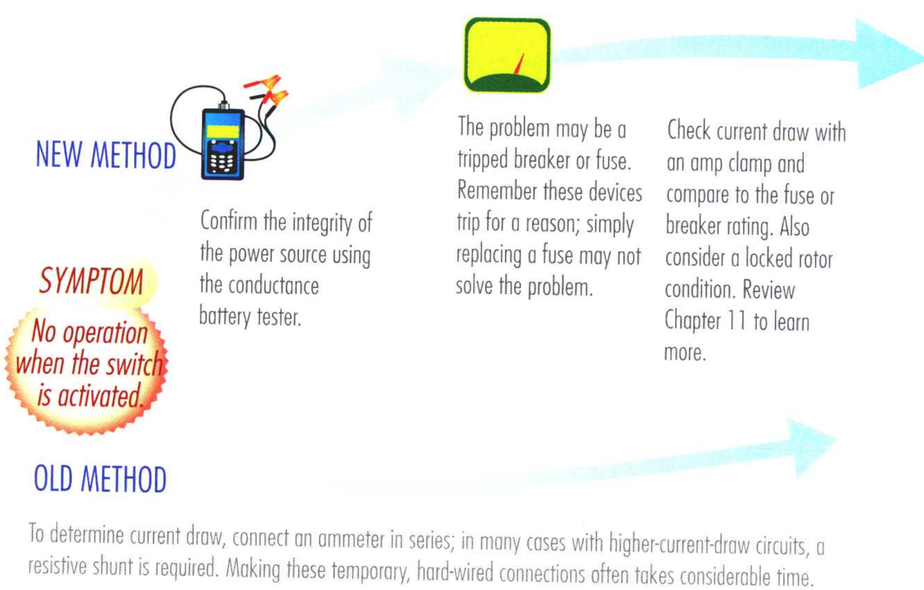


Typical problems with this category of circuits include the following:

- No operation when the switch is activated.
- Abnormally slow motor operation.
- Frequent tripping of an overcurrent protection device (such as a circuit breaker or fuse).

The troubleshooting procedure is summarized in the flowcharts on pages 4 and 5.

Low-Amperage Motor Circuits (1)



Low-Amperage Motor Circuits (2)

NEW METHOD

Assuming no mechanical problem (such as a seized armature bearing) or extreme solids situation (as in the case of a macerator pump), this is probably a voltage drop issue. A diagnostic meter will pinpoint this in one easy step (Chapter 2). An infrared heat gun (Chapter 5) will also be helpful here.

SYMPTOM

Slow motor operation.

OLD METHOD

Perform point-by-point voltage drop tests with a multimeter.

The Engine-Driven Alternator

The engine-driven alternator is a unique device—both in its electrical properties and in its function—so it is treated separately.

We'll assume the mechanical side of the alternator is in good order, the drive belts are tight, and the alternator is securely mounted to the engine. The flowcharts also assume that the problem is new, and that previously all was well with the charging system. There are several symptom sets related to alternators that need to be considered:

1. Undercharging will be manifested as poor battery performance.
2. Overcharging will show up as either a foul odor in the battery compartment, or swelling of the battery cases or low electrolyte levels (if the problem is of long standing). With sealed batteries, of course, this cannot be checked, nor can you replenish levels. If a cell of a sealed battery gasses itself dry, the situation becomes dangerous. The cell can short itself out, and an arc inside the battery can cause an explosion.
3. Electronic "noise" emitted from the alternator may interfere with the performance of other electronic equipment on board the boat.

The troubleshooting procedure is summarized in the flowcharts on page 6.

Lighting Circuits

This category includes all lighting circuits, both AC and DC, with their different power supply considerations:

- cabin lights
- navigation lights
- convenience lights

Light circuits are simple. All you need is power supplied from a source and a good return path to ground. The primary concerns are of course electrical continuity and sufficient voltage throughout the circuit, especially in the case of navigation lights, which are governed by both U.S. Coast Guard regulations and American Boat and Yacht Council (ABYC) standards. The equipment can be very basic (e.g., a multimeter) or extremely sophisticated (e.g., a time domain reflectometer, or TDR). I now use a TDR almost exclusively for this sort of work.

The troubleshooting procedure is summarized in the flowcharts on page 7.

Engine-Driven Alternator (1)

NEW METHOD

SYMPTOM

Undercharging or overcharging.

Determine battery condition with a conductance battery tester or diagnostic meter (Chapter 2). This may require connecting the batteries to another charge source to get them to a state of charge that will allow a valid test.

If the battery is serviceable, look for a voltage differential from no-run to engine running at idle.

If no differential exists, then the alternator is not producing. But why?

Verify that field excitation voltage is being supplied to the alternator: measure the magnetic field strength at the alternator with the engine running versus not running. Use a gauss meter for this step (Chapter 9). *No measurable field* indicates either a fault in the supply circuit to the field or a faulty voltage regulator. *A measurable magnetic field* and *no voltage differential* indicate a fault within the alternator.

The voltage differential between no-run and run should be between 0.5 to 2.5 volts (V). *More than 2.5 V* indicates an overcharge and a faulty voltage regulator. *Less than 0.5 V* (with the alternator running and a lot of DC loads turned on) may indicate an underrated alternator, in which case an upgrade is indicated. To determine if alternator output is enough to meet the demand, perform a DC load analysis by adding the amperage draws for the various appliances.

OLD METHOD

Determine open-circuit voltage across the battery posts to determine state of charge. If low, charge battery to at least 70% state of charge, then perform a carbon pile load test (not feasible with sealed batteries). If you don't have access to a carbon pile load tester, disarm the engine so it can't start, and test voltage across the terminals while cranking the engine with the starter motor (this is not as precise as a carbon pile test, but it will indicate an extremely weak battery). Use a multimeter to test voltage output; use an ammeter to test current output.

Engine Instrumentation

Here I've grouped the engine instrumentation and related gauges as follows:

- voltmeter
- tachometer
- oil pressure gauge
- fuel gauge
- temperature gauge

These devices need battery power to function, but they often work on a variable ground principle from a sending unit, or in the case of tachometers, also receive a signal from the

Engine-Driven Alternator (2)

NEW METHOD

SYMPTOM

Electronic noise heard in radio equipment or indicated by a bad signal-to-noise ratio on a Loran-C system.

With the alternator running, test for noise emissions using a transistor radio set off scale on both the AM and FM bands to "home in" on noise (Chapter 9). The frequency of the noise will change proportionally with engine rpm.

Correcting this may require overhauling the alternator or adding a capacitor-type filter on the alternator output.

OLD METHOD

Use process of elimination: shut off one piece of equipment at a time to determine the source of noise.