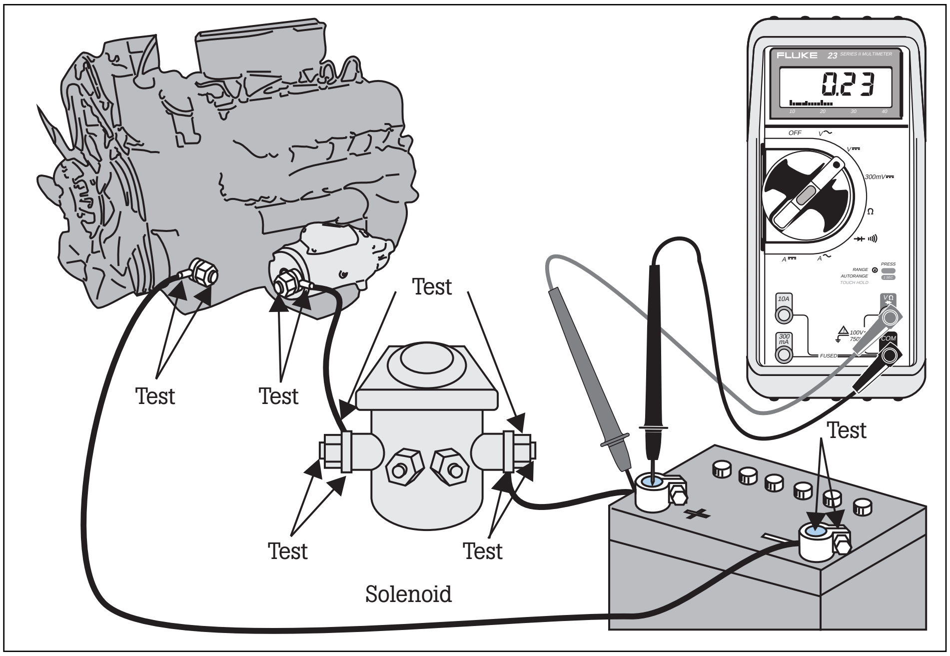
Troubleshooting Marine Engine Electrical Systems

Application Note



Troubleshooting tools

The marine environment can be especially harsh on the components of your boat's electrical system. When trouble occurs you will want the capability to make accurate and reliable measurements quickly. The basic tool for this job is a Fluke digital multimeter. Digital because of the better resolution... Fluke because it is more accurate, rugged and reliable.

This application note provides guidelines for testing some basic electrical components commonly found on inboard marine engines including batteries, starters, alternators, and ignition systems.

But the applications don't end here. Once you own a Fluke digital multimeter, you will be able to check the wiring on your boat trailer, perform corrosion potential testing on your zinc/bonding system, and even check the wiring in your house and car. When you think of the various electrical items that you want to add to your boat, you quickly realize that a good quality digital multimeter is an essential part of your boat's tool kit. A list of recommended Fluke multimeters is included at the end of this application note.

Work safety

The voltages and currents present in electrical power systems can cause serious injury or death by electrocution. Consequently, when testing or troubleshooting, carefully adhere to all industry standard safety rules that apply to the situation. Read and follow directions and safety warnings provided by the equipment manufacturer.

Fluke cannot anticipate all possible precautions that you must take when performing the test described in this application note. At a minimum, however, you should:

- Be sure that all power has been turned off, locked out, and tagged in any situation where you will be in direct physical contact with live circuit components - and be certain that the power can not be turned on by anyone but you.
- Use only well maintained test equipment. Inspect all test leads and probes and fuses before use. Repair or replace any test leads or probes with damaged insulation.
- Be very cautious when working on electrical systems when fuel vapors are present. Remember that vapor from gasoline and propane are heavier than air and will collect in the bottom of bilges and other closed compartments. Sparks generated by making connections with live electrical components can start a fire or cause an explosion when fuel vapors are present.
- Be aware that charging of unsealed, lead-acid batteries generates hydrogen gas. This hydrogen can explode if exposed to a spark generated at the battery terminals when connecting or disconnecting a battery charger. Always verify that the battery charger power is off before connecting or disconnecting the charger leads at the battery terminals.

Batteries

Often the first sign of a battery problem will occur when the starter won't turn the engine over. Use your multimeter to get a rough idea of the battery's state of charge. To perform a no-load test, set the digital multimeter switch function to Volts DC (V⎓) and measure across the terminals. Compare your readings to the graph in Figure 1.

The voltage test tells only the state of charge, not the battery condition. To gain additional information about the battery's condition, test the specific gravity of the electrolyte in each cell using a hydrometer. If the specific gravity is low but relatively the same across all cells, recharging may be able to bring the battery back to good health, unless the plates are sulfated. If one cell shows a specific gravity much lower than the rest, the cell is probably dead and recharging will not help.

In a lead-acid battery, each cell produces about 2.1 volts at full charge. Therefore, a 12V battery has 6 cells in series. If the no-load test reads 10V instead of 12V, a dead cell is likely and the battery should be replaced.

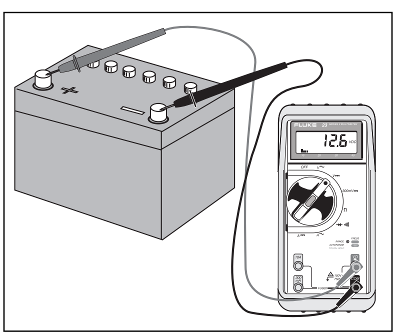
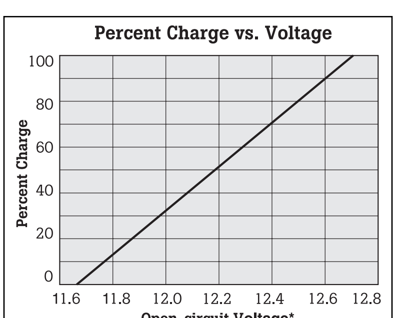


Figure 1: Measuring System Voltage
Measure the voltage across the battery terminals (see chart). Voltage tests only tell the state of charge, not the battery condition.



*Measured after battery has been at rest for at least 24 hours.

Sulfated plates can be detected by measuring the output voltage under load (after the battery has been charged). Typical results for a good battery are given in Figure 2 below.

Load test @ 1/2 CCA Rating
8.5V @ 0 °F (-18 °C)
8.8V @ 30 °F (-1 °C)
9.4V @ 50 °F (10 °C)
9.6V @ 70 °F (21 °C)

Figure 2: Battery test voltages for a good battery at 1/2 cold cranking ampere rating.

Alternators

A Digital Multimeter's accuracy and display make regulator/alternator diagnosing and adjusting easy. First determine if the system has an integral (internal) regulator, then whether it's type A or B*. Type-A has one brush connected to battery + and the other brush grounded through the regulator. Type-B has one brush directly grounded and the other connected to the regulator.

Next, isolate the problem to alternator or regulator by bypassing the regulator (full-fielding). Ground Type-A field terminal. Connect Type-B field terminal to Battery +. If the system now charges, the regulator is faulty. Use a rheostat in series with the field connection if possible. Otherwise, just idle the engine (lights on) so the voltage doesn't exceed 15V.

*Type A is sometime referred to as P-Type and Type B is sometimes referred to as N-Type

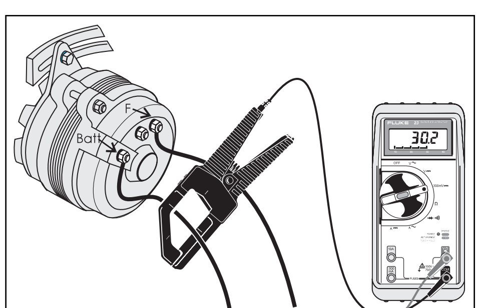


Figure 3: Verifying a good alternator
The battery must be fully charged (see Figure 1). Run the engine and verify that no-load voltage is 13.8 to 15.3V (check as in Figure 1). Next load the alternator by turning on dc loads such as lights, radio, etc. Run the engine at 2000 RPM. Check the current with an i410 or i1010 current clamp.

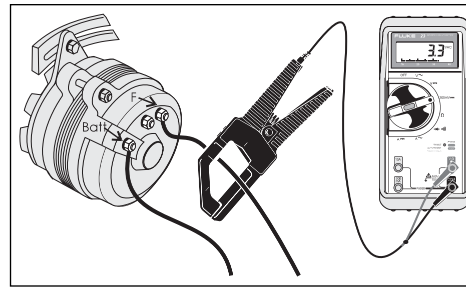


Figure 4: Checking field current
Worn brushes limit field current, causing low alternator output. To test: load unit as in Figure 3 and measure field current with current clamp or use 10A jack on DMM. Readings range from 3 to 7 amps. On integral GM units: with alternator not turning, jump terminals #1 & #2 together and connect both to Batt + with DMM in series set to measure 10 amps. Field current should be between 2 & 5 amps, higher current with lower battery voltage. Control battery voltage by turning on lights, radio, etc.

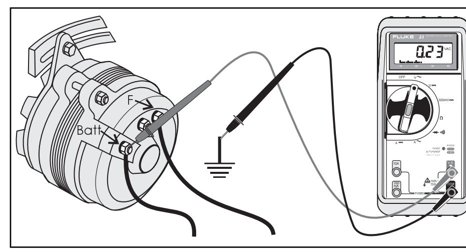


Figure 5: Checking ripple voltage
Ripple voltage (AC voltage) can be measured by switching your DMM to AC and connecting the black lead to a good ground and the red lead to the "BAT" terminal on the back of the alternator, (not at the battery). A good alternator should measure less than 0.5 VAC with the engine running. A higher reading indicates damaged alternator diodes.

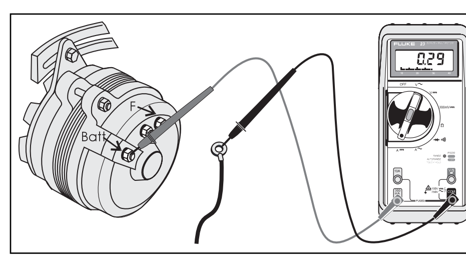


Figure 6: Alternator leakage current
To check alternator diode leakage, connect the multimeter in series with the alternator output terminal when the engine is not running. Leakage current should be a couple of milliamps at most; more often, it will be on the order of 0.5 milliamps. Use care when disconnecting the alternator output wire; make sure the battery is disconnected first. A leaking diode can discharge the battery when the engine is off.

Starting systems

Starting system troubles are often confused with charging system problems. Many dead batteries have been replaced when the real cause was a faulty charging system. Be sure that the charging system is functioning properly before you replace the battery. Make sure the battery is charged and passes a load test, then look for resistance in the starter circuit if the engine still cranks slowly.

Investigate excessive current draw; check for worn-through insulation, a seized or tight engine, a faulty starter, etc. If the starter turns the engine slowly, the current draw is not high, and the battery is in good condition, check the resistance in the starter circuit.

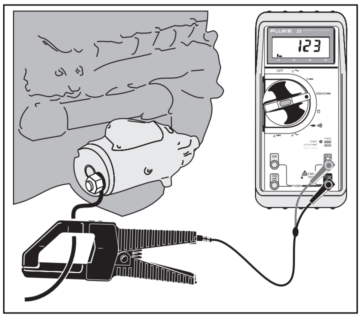


Figure 7: Measuring starter current draw
Determine how much current the starter is drawing by using Fluke's i1010 Inductive Current Clamp on the starter cable. This accessory will allow the multimeter to measure starter current up to 1000 amps. Check manufacturer's specs for exact figures.

Starter circuit voltage drop

Ohm's law (E=IxR) tells us that even very low resistance in the starter circuit will cause the starter to turn slowly, because of low voltage. For example: in a system drawing 200 amps, 0.01 ohms resistance in the starter cable will cause a 2 volt drop in voltage at the starter; 0.01 ohms is too little for all but the most expensive and sophisticated ohmmeters to measure, but measurements of voltage drop will indicate where there is excessive resistance (Figure 8).

Ignition systems

Fluke digital multimeters will measure from tenths of an ohm to several million ohms, making ignition tests easy to interpret. If your engine has breaker points in the distributor, use your multimeter to measure the resistance across the contacts when the points are closed. The reading should be very low, typically 0.1 to 0.3 ohms. Subtract the test lead resistance for best accuracy.

The primary and secondary windings in the ignition coil can also be measured as described in Figure 9. Use the manual ranging feature on the multimeter to avoid any oscillations between ranges that can sometimes be caused by the inductance of the coil. Ballast resistors in series with the coil primary can also be measured. Look for low values in the range of 0.5 ohm.

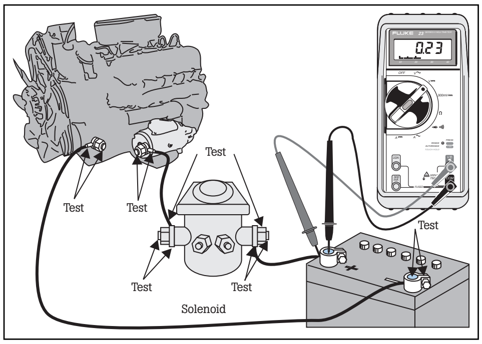


Figure 8: Testing for excessive voltage drop
Determine if there is resistance in the circuit by measuring the voltage drop across each connection and component in the starter circuit while cranking the engine. Measure the voltage drop between the battery post and the connecting cable, the solenoid posts and the wires that attach to them, and across the solenoid itself. Also check the connection on the starter, alternator (feed and ground side) and the ground strap connection to the engine block. A logical test sequence would be to start by first measuring the battery voltage between + and – terminals when the starter is cranking. Then measure the voltage between the starter terminal and engine block when cranking. If the starter voltage is significantly less, use the above procedure to isolate the voltage drop.

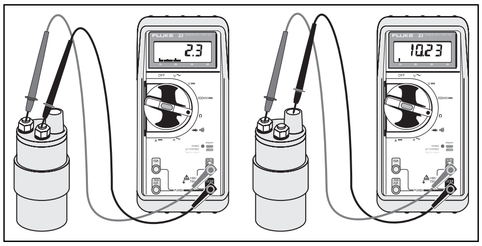


Figure 9: Measuring internal coil resistance
If you suspect a malfunctioning ignition coil, check the resistance of primary and secondary windings. Do this when the coil is hot, and again when it is cold. Also measure from the case to each connector. The primary windings should have a very low resistance, typically from a few tenths of an ohm to a few ohms. The secondary windings have a higher resistance, typically in the 10 kΩ to 13 kΩ range. To get the actual figures for a specific coil, check the manufacturer's specs. But as a rule of thumb, primary windings range from a few tenths of an ohm to a few ohms, and secondary winding may be 10 kΩ or more.

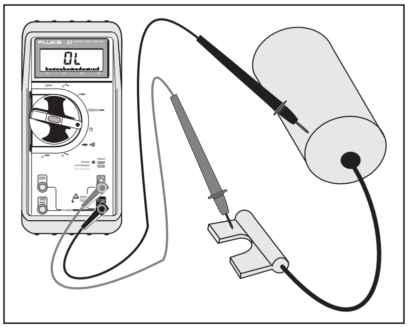


Figure 10: Checking condenser leakage
Check for leaking condensers with the Ohms function. As the condenser charges up, the resistance should increase to infinity. Any other reading indicates that you should replace the condenser.

Condensers

Fluke analog/digital multimeters can also be used for checking automotive capacitors (condensers). The movement of the bar graph will show that the DMM is charging the condenser. You'll see the resistance increase from 0 to infinity. Be sure to switch the leads and check both ways. Also make sure to check condensers both hot and cold.

Spark plug wires

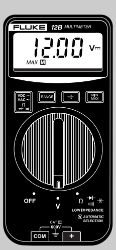
Most modern gasoline engines have resistance wire for the high voltage connections between the distributor cap to the spark plugs. The resistance reduces radio interference and produces a cleaner spark.

Plug wires should be checked for open circuits if they are more than a couple years old. Not all wires indicate the date they were manufactured. Due to the heat of the spark plug insulator, a spark plug boot may bond to the spark plug. Pulling a spark plug boot straight off the spark plug can damage the delicate conductor inside the insulated wire. Rotate the boot to free it before pulling it off.

If you suspect bad wires, test the resistance of the wire while gently twisting and bending it. Resistance values should be about 10 kΩ per foot (30 kΩ per meter), depending on the type of wire being tested; some may be considerably less. You should compare readings to other spark plug wires on the engine to provide a relative reference for a typical good reading.

Fluke Multimeters for Marine Applications

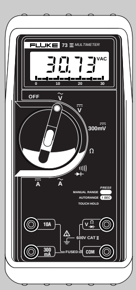
The following Fluke Digital Multimeters are recommended for use in marine applications.



Fluke 12B

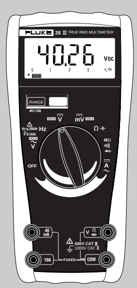
Put basic tests on automatic

- VCheck™ automatically switches from measuring ohms/continuity to ac or dc volts
- Capacitance, to 10k microfarads
- Continuity capture locates intermittent opens and shorts
- Min/Max recording with relative time stamp



Fluke 73 Series III

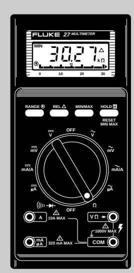
- Touch Hold® captures stable readings
- Auto and manual ranging
- Holster with Flex-Stand™ included
- Volts ac and dc
- Resistance
- Diode test/continuity beeper
- AC/DC current with ranges from 32 mA to 10A



Fluke 26 Series III

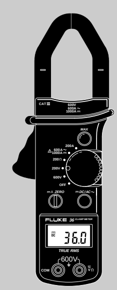
Same features as Fluke 73 Series III, plus:

- Rugged, overmolded case
- Tough, electrical test lead set with silicone insulation and alligator clip
- True-rms ac voltage
- AC/DC current with ranges from 4.0 mA to 10A
- Lo Ohms



Fluke 27

- Fully sealed, waterproof case
- Touch Hold® captures stable readings
- Volts, ohms, amps, continuity, diode test
- Current with ranges from 320 µA to 10A



Fluke 36 ClampMeter

- True-rms responding
- AC current to 600A
- DC current to 1000A
- AC and DC voltage to 1000 Volts
- Max Hold
- Continuity beeper

Other marine application notes available from Fluke:

- Testing Corrosion Protection Systems
- Troubleshooting Outboard Motor Magneto Ignitions

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