Voltmeters, “Peak Voltmeters”, and DVAs

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There’s an old saying that I’m fond of, which states: "To a man that only has a hammer, every problem looks like a nail”. Now, hammers are terrific at dealing with nails. However, if you have a nut to tighten, a hammer won't be of much use to you. OK, you could use a wrench on the nut, and you could also use a wrench as a hammer (in a pinch), but the results you’ll get on the nail won’t be all that great.

This is a long way of saying that there are tools that are very well suited for specific tasks, but don’t do well on others. This is very true in the realm of doing electrical testing on outboard motors; there are a number of electrical testing devices that are great at one specific task, but are really lousy at other types of tests. Today, we’ll be looking at three specific devices; your standard Volt/Ohmmeter, "Peak Voltmeters", and DVAs (Direct Voltage Adapters), and compare how they work on some specific electrical tests on outboard motors. See Fig. 1, below, for some examples:

Cheap Volt-Ohmmeter

Merc-0-Tronic Model 172A "Peak Voltmeter"

Cheap Voltmeter with External DVA (Direct Voltage Adapter)

Fig. 1: Various Voltmeter Types

Let's look at how these different meters work, when testing the charging system on your typical small boat. Most motors that use a battery for electric starting have some kind of charging system, like you can see in Fig. 2, below. Your simple, $10 Digital Volt-Ohmmeter can do a lot of testing on a charging system like this. You can check the battery status, and the status of the alternator (charging system) separately, per the chart shown on Fig. 2. **To test the battery, first make sure the battery has been on a charger for enough time that is SHOULD be fully charged.** Disconnect the charger. Make sure your motor is NOT running, and you have NO electrical devices turned “on" in your boat, and let the system sit for 30 minutes. Then set the Voltmeter to “DC Volts …. 20V range", and put the test leads across your battery terminals. Compare what you measure, to the "Battery Voltage / Battery Status" results in Fig. 2. That's all there is to testing your battery!

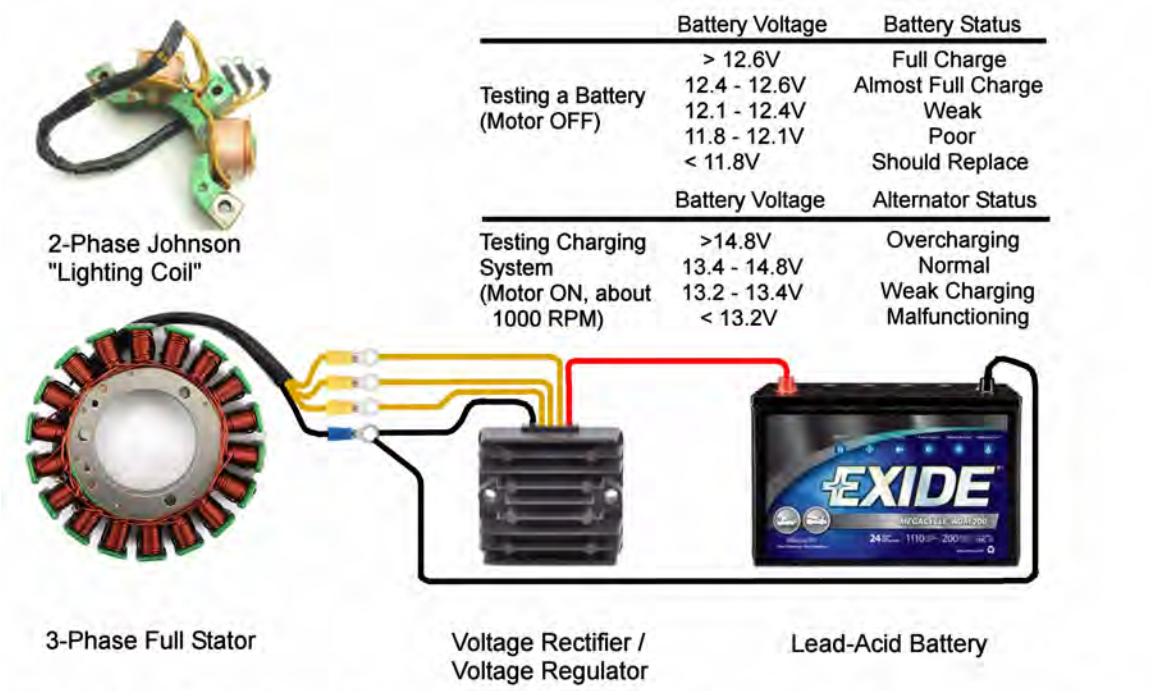


Fig. 2: Testing Batteries and Charging Systems

Testing your alternator (or charging system) is a little bit more involved than simply looking up some numbers on a chart. To test your charging system, first do the basic "battery test", as described earlier. Record your battery's voltage, while it's sitting with the engine off. Then, turn your motor ON, and "rev it up" a little bit….to about 1,000 RPM or so. (Many alternators, and especially small "lighting coils", don't generate enough voltage at idle to actually charge your battery at low RPM. Some engines have to be running at far above idle for the battery to actually start charging.) When you rev the engine up a bit, look at the battery voltage with your DC Voltmeter. You SHOULD see the battery voltage rise by a few tenths of a volt. For a STRONG charging system, the battery voltage might rise a full volt or more. For a smaller charging system on a large battery, you might see the voltage only rise a few tenths of a volt. But, as long as you see the voltage rise by at least a few tenths of a volt, your charging system is probably OK. If the DC voltage across your battery does NOT RISE AT ALL, then you've got a problem with either your stator (or lighting coil), or your Voltage Rectifier / Voltage Regulator module.

So, let's say your battery is OK, but it isn't holding a charge on your motor alone, and your initial testing with your DC Voltmeter shows that the battery voltage is NOT rising when the engine is running. Now what? OK, you're going to have to check the voltage output of your Stator (or Lighting Coil), where it enters the Voltage Rectifier / Voltage Regulator module. And, as it turns out, you CANNOT DO THIS with your simple, cheap digital (or analog) voltmeter. Why? Because the output of your Stator or Lighting Coils is an ALTERNATING CURRENT (AC) waveform, and it can't be read by a DC Voltmeter. AHA…(you might think)…….my Voltmeter has settings for AC voltages….so won't that work for measuring the Stator or Lighting Coil voltages?

Well….actually....NO, it won't work very well at all. This is where a "Peak Voltmeter" or a standard voltmeter with a "DVA" is required. Here, you have to measure PEAK voltages, and your stock, unmodified Voltmeter is only built to measure AVERAGE voltages (or "RMS" voltages, on more expensive voltmeters). Let's take a closer look at AC voltages, and how different meter types will measure them.

The type of Alternating Current that people are most aware of is the voltage at the outlets in your house. The voltage in your house is about 120Volts AC, 60 cycles per second, and looks like the "Input Voltage Waveform" in Fig. 3, below.

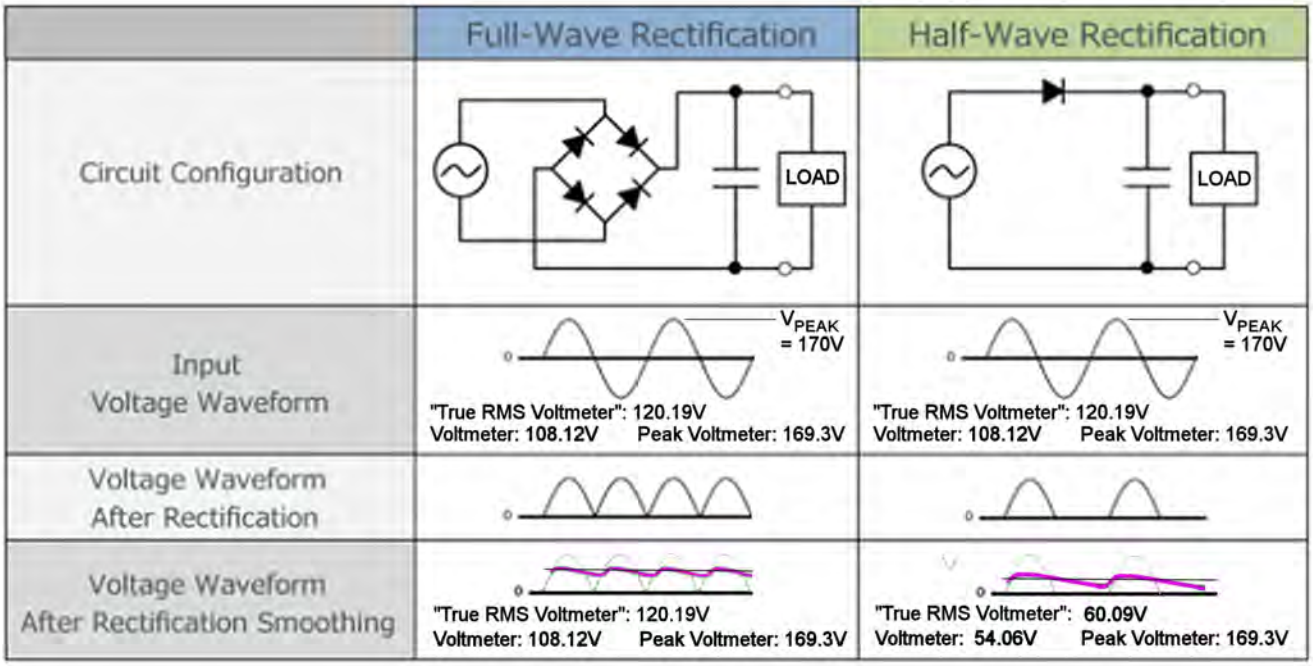


Fig. 3: Voltmeter Readings on AC Waveforms

Now, if you measure this AC voltage with your cheap Volt-Ohmmeter (on the AC Volts scale, 200V range), you'll probably read about 110VAC. (If you have a more expensive "True RMS Voltmeter", you'll read a little higher, about 120VAC). All of your standard "Voltmeters" read some kind of "average voltage potential"; they don't actually give you the maximum (or "peak" voltage). So, for example, the "peak" voltage at the AC outlet in your house is probably around 170V peak. (From the top peak to the bottom peak, that's 340V peak to peak, or "Vp-p"). If you measure this with a Merc-O-Tronic Peak Voltmeter, or a standard voltmeter with a "External DVA" adapter plugged into it, you'll read about 169V or so....within about 1 volt of the actual peak voltage.

Now, if this AC voltage is run through a "Full Wave Rectifier" (see the circuit details in Fig. 3) and you take all the voltage measurements again, you'll read the same thing.

Your “True RMS Voltmeter” will read about 120V, your "Standard Voltmeter" will read 108 to 110V, and your Peak Voltmeter will read about 169V.

Now, if you run this AC voltage instead through a “Half Wave Rectifier” (see the circuit details in Fig. 3) you’ll find something VERY unexpected. Your “True RMS Voltmeter will read about 60V, your Standard Voltmeter will read about 54V…..but your "Peak Voltmeter” (or standard Voltmeter plus external DVA)….will STILL read about 169V**.** This is because the "Peak Meter" is capturing and holding the PEAK voltage values, instead of trying to figure out some kind of “average" voltage for you to see.

This unique characteristic of Peak Voltmeters (and standard Voltmeters with external DVAs) allows them to do testing on your outboard motor’s charging system, that simply cannot be done with a simple, standard voltmeter. Let’s go back to our earlier example, where our charging system is NOT charging up the battery. Assuming we used an external battery charger, and our battery CAN be charged up to a full 12.5 or 12.6V, we can rule out the battery itself being bad…..and if this is the case, then either our Voltage Rectifier / Voltage Regulator module is bad, or the windings in our Stator (or Lighting Coils) are defective. So, how can we tell which of the two is bad?

Well, the voltage output of your Stator or Lighting coil is an AC voltage, similar to the voltage in the outlet in your house. (OK….please, for those of you “technical types" out there, ...yes, I know the AC signal from a stator or lighting coils looks VERY different from a sine wave, but I’m simplifying the explanation here for readers that don’t have your technical background. Please bear with me here!) We need to know if the output of the Stator (or Lighting Coils) is good or not. If **that** voltage is good, then our Voltage Rectifier / Voltage Regulator must be bad. But, if the voltage output from our Stator or Lighting Coils is too low to charge a battery, then the Stator or Lighting Coils are bad, and not the Voltage Rectifier / Voltage Regulator.

So, how do you measure the output of your Stator or Lighting Coils? Well, going back to our example, let’s say the battery voltage is a nice 12.5 or 12.6 Volts. The output of our Stator or Lighting Coils must be above that 12.6 volts, or we can’t charge our battery. And, the Voltage Rectifier / Voltage Regulator needs a bit of voltage as well for it to work with as well, **so we really need to see about 13 or 14 volts PEAK, minimum, at the output of our Stator or Lighting Coils, for them to be “good”.**

Let's say (for sake of example), that the peak output voltage of your Stator or Lighting Coils measures about 16 to 17 volts on your Peak Voltmeter, (or Standard Voltmeter plus external DVA). 16 volts is will above the 14 volts your Voltage Rectifier / Voltage Regulator needs to run on, so your Stator or Lighting Coils are good, and that means your Voltage Rectifier / Voltage Regulator must be bad. **But note, if you measured that same AC voltage using a standard Voltmeter on the AC Volts scale, you would have read 10.8 to 12V (depending on your specific meter). As that voltage is well UNDER the 14V your charging system needs to work on, you might assume that the output of your Stator or Lighting Coils is too low, and that they need to be**

replaced….but you would be wrong! So now you can see the value of a “Peak Reading Voltmeter”, when troubleshooting the charging system on your boat!

Incidentally, some manufacturers put the "rectifier" (either full wave or half wave) right inside the Stator or Lighting Coils themselves. This will REALLY screw up trying to measure these voltages with your standard voltmeter, but it will have little effect on your “Peak Reading Voltmeter” (or standard voltmeter plus external DVA).

Now, since reading “Peak Voltages” is so handy, where can you get a “Peak Voltmeter” or an “External DVA”? Well, ..."Peak Voltmeters” are kind of a specialty item, and are a bit expensive. (My Merc-O-Tronic 172 was $200, used, on e-bay). Fortunately, external DVAs are relatively cheap; about $20 or so on e-bay. See Fig. 4, below, for an example:

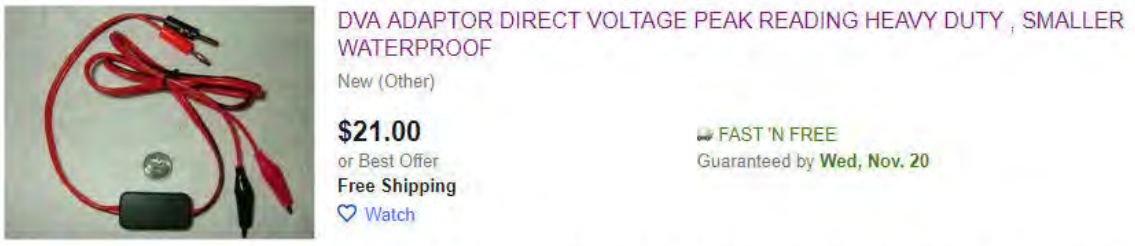


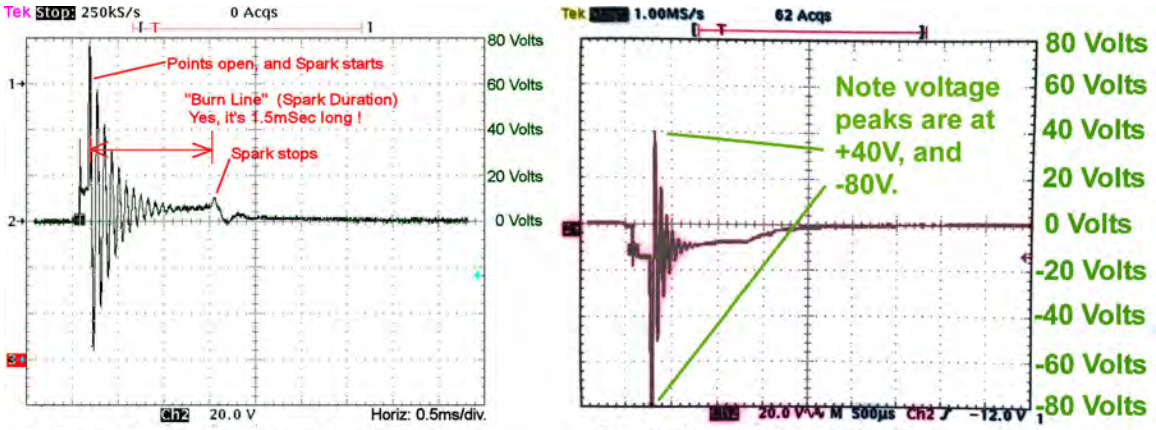
Fig. 4: Example DVA Listing on e-Bay.

However.....if you look closely, you’ll note that my Merc-O-Tronic Peak Voltmeter had a switch, that allows the user to select “Positive” or "Negative" peak voltage readings. Most of the cheap “DVAs" you'll find on the Internet do NOT have such a switch**. Now, if you're only testing charging systems on outboards, you’ll only be dealing with POSITIVE peak voltages, and these cheap DVAs will work just fine for you.** But, if you ever have to measure NEGATIVE peak voltages, then you’re kind of out of luck. (You may note in Fig. 1, that the DVA in that picture DOES have a switch, to select positive and negative voltages. But, that’s a DVA I designed and built at home, not one you can commercially buy. However, if you have the ability to build devices like this, I'll include a schematic diagram and construction notes later in this article. It will set you back about $25, but that's far less expensive than any other solution you can buy that I am aware of).

Back to our discussion!

So, WHERE on a outboard motor’s electrical systems would you ever encounter the need to measure NEGATIVE peak voltages? Really good question, I’m glad you asked! (You did ask, right?) **Well, you are likely to encounter large, HIGH peak positive AND negative voltages, if you measure the voltage across the points in your outboard motor, right at the connection to your condenser**. You probably never thought of measuring voltages across your points or condenser. (If you ever actually tried it, your standard voltmeter would have just gone crazy, as the voltages are too

erratic for standard voltmeters to measure at all.) Let's take a look at what the voltages across your points actually look like. See Fig. 5, below:



Wizard WA3 Outboard: POSITIVE ring wave across the points.

Scott Atwater 3.6 H.P. Outboard: NEGATIVE ring wave.

Fig. 5: Positive and Negative Primary "Ring" Voltages

Most books on ignition systems only show pictures of POSITIVE ring waves, because that's what you'll see on all battery-powered ignition systems with points. However, magnetos are a different case altogether; you might see either a positive OR A NEGATIVE ring wave across your points. (In the Wizard example, most of the voltage was POSITIVE, above the ground level. In the Scott Atwater example, the voltage of the ring wave was mostly NEGATIVE. You would need a DVA with the capability to read both positive AND negative peak voltages, to measure this correctly!)

Now, if you don't happen to have a expensive oscilloscope to view these voltages, you are probably asking yourself…."so what?" Well, you CAN measure these voltages with a GOOD, high-quality DVA……and they CAN be of some assistance in troubleshooting your really odd ignition problem cases! Take a close look at the picture above, of the Scott Atwater motor. I was able to make the following voltage measurements:

Expensive Oscilloscope: POSITIVE PEAK: **40 volts**, and the
NEGATIVE PEAK: a little over **–80 volts**.

Standard Voltmeter: AC Volts, about 3 to 5 volts, jumping around a lot.
A worthless, garbage measurement.

Cheap e-bay DVA: POSITIVE PEAK: **+17 to +20V** (Not good data….)
NEGATIVE PEAK: (couldn't do this measurement at all!)

My homebuilt DVA: POSITIVE PEAK: **+ 35V** ← **LOW, but CLOSE!**
NEGATIVE PEAK: **– 63V**. ← **LOW, but CLOSE!**

OK, my "homebuilt DVA" wasn't terribly accurate….about 20% low in measurement, **but it WAS able to measure the POSITIVE and NEGATIVE voltage peaks across the points in outboard motors, accurately enough to be of some use, and it only costs about $25 to build.** So, let's look at EXACTLY how it can be used.

Let's say you have a motor, and you check the spark by pulling out your spark plug, and holding it against the engine block, while pulling on the start cord. You get no spark at all. That means ANYTHING could be dead….the magnets in your flywheel could be shot, the primary or secondary of your spark coil could be open or shorted, your points could be stuck open or shorted, and / or your condenser could be shorting out at higher voltages. You're really up a creek here. Now, you COULD just start swapping parts, or pulling everything out and testing your coil and condenser with external COIL and CONDENSER checkers. **But, if you put a high-quality DVA across the points, and measure either a POSITIVE or NEGATIVE PEAK voltage reading of over 50 volts, you KNOW that everything on the PRIMARY side of your coil is working. Magnets, points, condenser, primary winding…..<u>all</u> of that is verified to be working correctly, or you would NOT see that 50 volt "ring" across your points!** So, if there is still no spark across your plug, either your spark coils' secondary is open (easy to check with a ohmmeter)…..or you are arcing over through some gap in your spark plug wire to some nearby piece of metal on your motor. However, you could have saved yourself a lot of time by doing this quick check…..especially if you do not have a Coil / Condenser tester available that you can use.

So, if you are interesting in "rolling your own high-quality DVA", I drew up a schematic of the one I built. All of the electrical parts are available from DigiKey ….although they do charge a lot for test leads, which is why I recommend getting them from some cheap Chinese supplier on e-bay. But, all the rest of the parts are listed, with DigiKey part numbers, in the schematic diagram below:

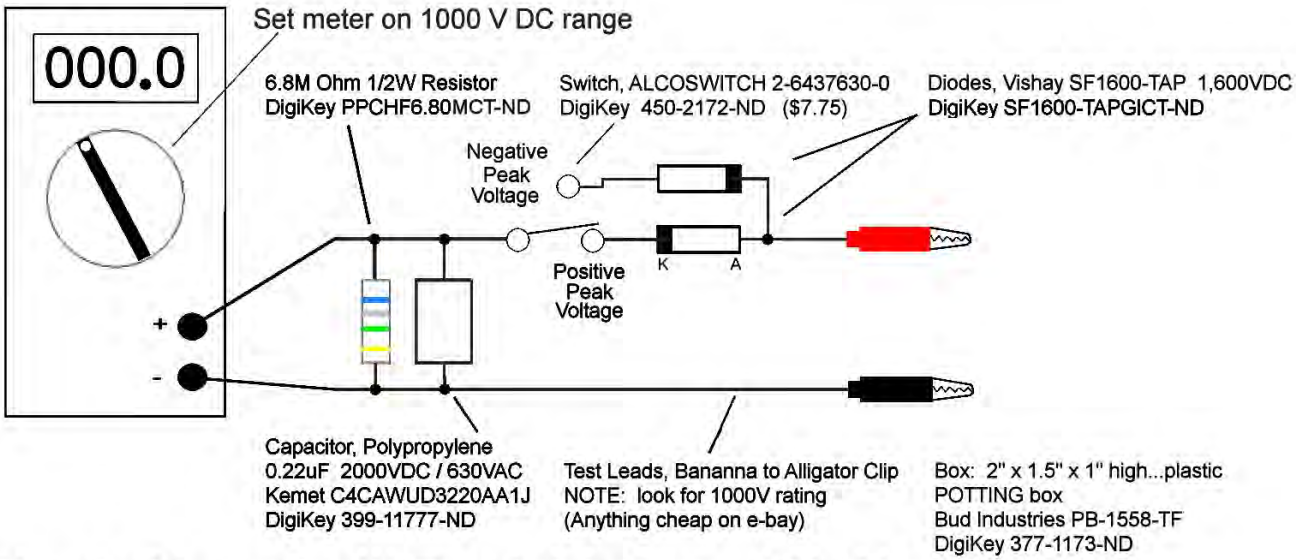


Fig. 6: Homebuilt Peak Voltage (DVA) Adapter

I built my prototype DVA inside that small plastic box, as shown in Fig. 7, below.

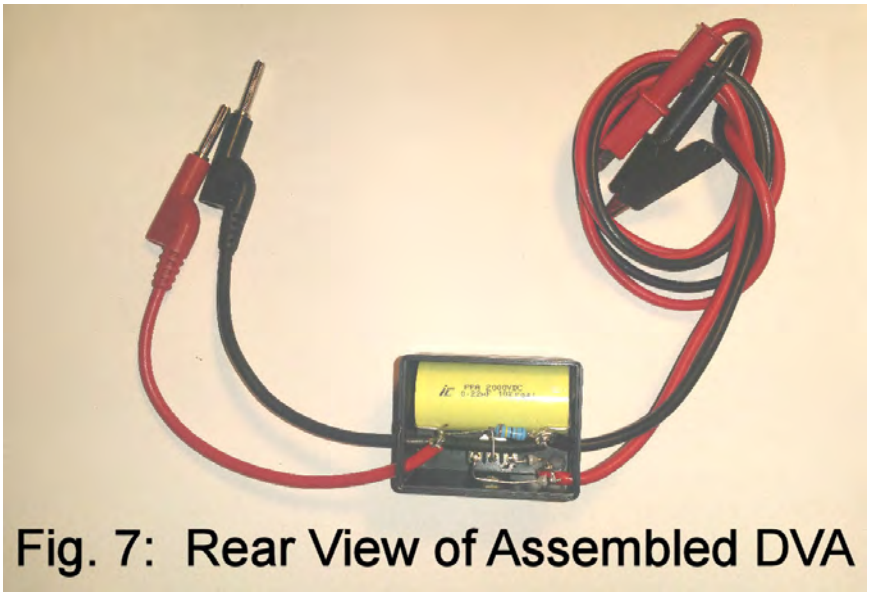


Fig. 7: Rear View of Assembled DVA

Once assembled, I then sealed up all the parts using "GOOP" adhesive, (available at any hardware store).

Fig. 8: Sealing the Assembled DVA

I hope that some readers will be able to make use of this information. Even if you only invest in a cheap "Positive DVA" from e-bay, it will still make it MUCH easier for you to test batteries and charging systems on outboard motors. But, if you do built my

"higher quality" DVA design, there will be a future article on "Sizing Condensers for Antique Outboards" that will make use of it….so, look for that in a future issue *of "The Antique Outboarder"* magazine!

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