DIY Test Fixture to Measure Motor Resistance (Rm)

rcgroups.com/forums/showthread.php

Mini-HowTo

I promised to do this for everyone a few days ago, and here it is. A simple Do-It-Yourself test fixture that will allow you to measure the DC resistance (Rm) of RC Model Electric Motors. When I started the project I had several design goals that I wanted to achieve.

1. It should be relatively inexpensive to make (Under $50.00), and be made from common off-the-shelf electronics parts.

2. It should be self contained, needing no external DC power source for operation.

3. It should provide an accuracy of al least 2%, and even better if it could be 1%.

4. It should be very easy to use, and only require 1 external DVM to complete the test.

5. An finally, it should be easy enough to build that anyone with a little soldering experience could duplicate my efforts and build their own Motor Test Meter.

Well, I am happy to say that it meets all of my guidelines and works great!

For those of you that have a few electronic builds under your belt, this will be a piece of cake. If you have never built anything like this before, please enlist the help of a friend with more experience. OK, for all the lawyers out there, here are the legal disclaimers:

This test fixture contains high voltage components with 120 volts of AC (240 for those overseas) and can cause injury or death if not handled properly. The writer of this article, (that would be me), assumes no responsibility for any accidents or injuries that may occur as the result of someone trying to duplicate the test fixture shown here in this article. Anyone following these directions and building one of these units will do so at their own risk.

Now that we have gotten that out of the way, let's begin!

To begin, I want to get into a little bit about the theory of operation so you all know where I am coming from. As we all know, it is a good thing to be able to measure the resistance (Rm) of our motors. This is very useful data to put into MotorCalc or other similar type programs for predicting motor performance. Unfortunately, as you well know, it is extremely difficult to measure resistances in the sub 1 Ohm range. Traditional DVM's are really only accurate for resistances of around 10 ohms or higher. To accurately measure a very small resistance, on the order of 20 to 100 milli-Ohms, you need a lab quality Bridge Meter, and they cost hundreds if not thousands of dollars, which makes them unavailable to the vast majority of us. So how can we cheaply and accurately measure the resistance of something that is less than 1 Ohm?

The easiest way to do this is to consult the Electrical Engineers best friend, good old Ohms Law. Even though the very low resistances are difficult to measure directly, the effect they have on current flow can be measured very easily and accurately if we use the proper method. Ohms Law is the Universal relationship between Voltage, Current and Resistance that all electronic components exhibit.

Ohms law shows up in many forms, but the most common ones are:

1. Voltage = Current X Resistance,

2. Current = Voltage / Resistance, and finally

3. Resistance = Voltage / Current, and this is the one that my Do-It-Yourself Motor Resistance Meter will employ.

According to Ohms law, if you push a known current through a resistor, and then measure the voltage across it, you can calculate the resistance by taking the measured voltage and dividing that by the known current. An interesting thing happens when you make the known current exactly 1 amp. Since the formula for Resistance is equal to Voltage / Current, if you make the current 1 Amp, then The formula becomes Resistance = Voltage / 1 which is the same as Resistance = Voltage. How cool is that!

So, If we make a test fixture that pushes a known current of exactly 1.00 Amps through a motor, we can measure the voltage drop across the motor winding (in milli-volts) and the number we get is equal to the motor resistance in milli-Ohms! So if we hook up this magical test fixture to a motor and pump 1.00 Amps of current through the motor, and measure 38.7 milli-Volts across the motor, then the resistance of the motor is 38.7 Milli-Ohms or 0.0387 Ohms. (Insert a drum roll here) Ta-Da!

OK, now that we know all that, how do we construct this wonderful meter, and how do we make a perfect 1.00 amp current source?

This is actually pretty easy, and can be done with common off the shelf parts. When I added up the total for mine, it cost me $27.00 and change to build. This is because I am an electronics geek, and I have a few parts lying around the house, but if you had to buy every single part, it would cost about $40.00 to build.

The main part that makes the meter possible is the common LM317T or LM117T Adjustable Voltage Regulator. This part is normally used to make adjustable power supplies, and can put out a maximum of 1.5 amps of current over a range of 1.25 to 37 volts DC. The neat feature of the LM 317T regulator is that it contains a very high precision 1.25 volt reference source inside. If we take advantage of this, and use the regulator in a fixed current mode, we can use it to provide a very precise 1.00 Amp current source.

The LM317T regulator always keeps exactly 1.25 volts between the adjustment pin and the output pin. If we put a resistor that measures exactly 1.25 Ohms in between the Adjustment pin and output pin, then the regulator will put out exactly 1.00 amps of current into whatever load we put on it. This 1.25 ohm resistor has to be able to handle the full current of 1.00 amps that the regulator puts out, and be large enough to dissipate the 1.25 watts of heat that will be generated inside it during operation.

The problem is that they don't make a 1.25 Ohm resistor. The common values are 1.2 Ohms and 1.5 Ohms. The 1.2 Ohm resistor would give us 1.04166 amps, and the 1.5 Ohm resistor would give us 0.8333 Amps, but we need exactly 1.25 Ohms to get exactly 1.00 amps. How can we do this?

Again, we turn to out friend Ohms Law. Most of you know that if you put 2 resistors in parallel, the resistance goes down, and the new resistance Rt is equal to 1 / ((1 / R1) + (1 / R2)). So I needed to put a resistor in parallel with the 1.5 Ohm resistor to make it into a 1.25 Ohm resistor. Simple enough, but there is a slight snag. No resistor is exactly the value that is stamped on it. Most ceramic power resistors have a tolerance range of plus or minus 5% of the stated value. In order to get exactly 1.25 Ohms, there needs to be some form of "Fine Tuning Adjustment" designed into the circuit. This adjustment can be achieved by using a potentiometer.

A potentiometer is a variable resistor that you can change the value of by turning a knob. The volume control on your stereo is potentiometer, it varies the resistance to change the volume. In our case we need the potentiometer (or Pot for short) to adjust the output current.

To adjust the current, and have a range of adjustment from say 0.95 amps to 1.05 amps, we need to create a resistance that is adjustable from about 1.20 Ohms to 1.30 Ohms. To create this I put a 1.5 Ohm resistor in parallel with a 10 Ohm resistor to give me a 1.304 Ohm resistor. To make the adjustment I then added a 50 Ohm Pot in parallel with the other 2 resistors. However, this by itself will not work, since you could turn the Pot all the way to zero Ohms and short everything out. I needed to put another resistor in series with the Pot to limit the minimum value of the Pot resistance. After crunching a few numbers, I came up with putting another 10 Ohm resistor in series with the Pot so I ended up with a variable resistor that could be adjusted from 10 Ohms (10 + 0) to 60 Ohms (10 + 50).

When I put all that together I ended up with a resistor that could be adjusted from 1.15 Ohms to 1.277 Ohms, which should give me an operating range of 0.979 Amps to 1.087 Amps.

With that settled, I could move on to the rest of the circuit, which is the easy part! To make the Test Fixture self powered, I decided to create a simple DC power Supply inside with a transformer, a couple diodes and some capacitors to smooth out the AC and convert it to DC voltage. Since the LM317T regulator needs about 2.5 volts across it to properly regulate, I don't need much voltage. I decided to use a 12.6 volt transformer rated for 1.2 amps, and run it in the center-tapped mode to get a 6.3 volt output at 2.4 amps. By running this transformer through a couple diodes and capacitors, I will get a power supply that will put out around 7-8 volts DC.

Since the 1.25 Ohm current setting resistor will drop 1.25 volts, and the LM317T needs about 2.5 volts across it to regulate properly, this will leave 3-4 volts that has to go somewhere. This voltage can be dropped across the regulator, but his just makes it get hot, so I added a 3 ohm resistor in the output to absorb 3 volts at 1 amp, and this pushes the regulator up to about 3.5 volts of drop to insure real good regulation.

This basically completes the design of the circuit and we are ready to start turning theory into parts, and parts into a test fixture. Here is a reduced version of the complete schematic as described here thus far.

Starting from the left and working through the circuit we begin at the AC plug. This provides 120 Volts AC (or 240 if you are on the other side of the pond) to the transformer that converts it to 12.6 volts AC with a center tap. Next we have the 2 diodes which filter out only the positive peaks of the AC input and send that to the capacitors. The capacitors store the AC energy and filter out the ripple to provide stable DC current to the regulator.

With the bias resistors that were described earlier the regulator puts out exactly 1.00 amps of current when VR1, the 50 Ohm Pot, is properly adjusted. This current is directed to a couple pairs of terminal posts that enable the user to hook up a motor and volt meter, and finally the 3 Ohm resistor at the end eats up the excess voltage to take some of the load off the regulator. That , in a nutshell, is how the entire circuit works. In actuality, it is pretty simple, and works great. A full size version of the schematic is attached at the bottom of this article which can be downloaded and printed if you care to build your own Test Fixture.

So now that you know how I came up with the design, let's build this puppy!

Here is a photo of all the parts I purchased at Radio Shack, plus the power resistors that were purchased at Fry's Electronics.

In the photo you can see the plastic box to mount everything in, the transformer, a little circuit board, the LM317T voltage regulator, a couple diodes, some binding posts and a few resistors. The Pot, switches and other small pieces I had laying around in my parts bins. The one thing that I forgot to to put in the photo is the capacitors.

I went to my scrap bin looking for the capacitors, and I was out of the size I needed, bummer! What was I going to do now? It looked like it was time for a little electronic transplant surgery!

I am a computer geek, and have boxes and boxes of excess computer parts lying around the garage. In case you never realized it, old computer power supplies contain an absolute wealth of parts that can be harvested and re-used in other projects. I knew that I had a box with about a dozen old power supplies inside it down in the garage. In the box I found a 145 watt ATX power supply that was never going to be used in a computer again, so I figured it was time to cash in it's "Donor Card" and pull out what I needed. After I took off the cover, this is what I found inside.

Up in the top right corner you can see a half dozen nice capacitors that I will be using in the build. There are also a bunch of nice resistors, diodes, voltage regulators, a power switch, torroid coils and a fan in addition to a whole bunch of really nice wire! I wanted to have around 3,000 to 4,000 uF of total capacitance in the power supply section of my design, As it turns out there were three 2200 uF 10 volt capacitors and three 1000 uF 16 Volt capacitors inside. Since the open circuit voltage of the transformer would be a little over 8 Volts, the 10 volt caps were cutting it a little too close, so I put the three 16 volt Caps together to form a 3,000 uF 16 volt capacitor.

Next I wanted to lay out the major components ans see how they would fit inside my project box. The box came with both a plastic bottom and an aluminum bottom. I decided to use the aluminum bottom, since I could attach the voltage regulator to it and use the bottom plate as a built-in heatsink. Here is the transformer and PC board being laid out on the metal bottom plate.

Next I soldered all the resistors, capacitors and diodes onto the PC board. When I did the original calculations for the component values, I figured the voltage drop across the voltage regulator, but forgot about the voltage drop across the 1.25 Ohms current sense resistor. Because of this, I figured that I needed about 4.5 ohms of load resistors and used two 2.2 Ohm resistors in series to get 4.4 Ohms. So in the next photo you can see two 2.2 Ohm 10 Watt resistors, two 10 Ohm 5 watt resistors, a 1.5 Ohm 5 Watt resistor, a 50 Ohm Potentiometer, the three 1000 uF 16 Volt Capacitors, two 1N5400 diodes and the LM 317T voltage regulator. You can see that the regulator has been mounted on the back side of the PC board, so it can be bolted to the metal bottom plate of the box.

Now that I had all the parts solderd together it was time to test the circuit. I soldered the transformer leads to the board and added a couple wires to bring out the output terminals. I also bolted a small temporary heatsink to the voltage regulator to keep it from overheating. Here is what the board looked like at that point. You will notice an extra resistor piggy-backed on top of the 2.2 Ohm resistors, I will explain that in a moment.

I connected my Amp Meter to the outputs of the circuit and then I hooked up the power to the transformer and turned on the switch. The initial reading on the meter was 0.86 amps. According to my calculations, the minimum current should be around 0.97 amps. What was wrong? Then it dawned on me. In my design, I had forgotten to take into account the 1.25 volt drop across the 1.25 Ohm current sense resistor, and there was not enough voltage left fot the voltage regulator to work properly. I needed a load resistor that would drop at least 1.25 volts less than my 4.4 ohm resistor would. I need to lower the load resistor from 4.4 ohms to about 3.1 Ohms.

Well, it just so happened that I had an extra 1.5 Ohm resistor left over, since they came in packs of two. After doing some quick calculations, I determined that if I put this 1.5 Ohm resistor in parallel with one of the 2.2 Ohms resistors, it would make it into a 0.89 Ohm resistor, and when I added this to the other 2.2 Ohm resistor, I would end up with a 3.09 Ohm resistor, which is exactly what I needed! Woo-Hoo, Good Save!

I soldered the 1.5 Ohm resistor in place and powered up the circuit with the Pot turned all the way to the minimum current position. Here is what I got.

The current meter showed 0.97 Amps, which is exactly what I had calculated. You gotta love it when a plan comes together!

Next I needed to test the circuit with the current adjustment pot set to maximum current position. Here is what that looked like.

I got 1.05 Amps, a little less than the calculated 1.08 amps, but still good enough, since I need to set it to exactly 1.00 amps for the test. Now that I knew that the circuit actually worked, I set the pot back to the minimum value, and slowly turned up the current until the meter flickered from 0.99 amps to 1.00 amps. Here is photo of the meter showing exactly 1.00 amps.

Great! Now that I knew everything was working properly, it was time to box it up. I set the parts back onto the metal bottom plate, and used a Sharpie pen to mark the location of 7 holes, 2 for mounting the transformer, 4 for mounting the little PC board, and 1 for the bolt to hold the voltage regulator to the bottom plate. After I drilled the holes, I bolted everything in place. I used some 1/4" long stand-offs under the PC board to keep the solder traces on the bottom from shorting out on the metal bottom plate.

A Word Of Caution! The metal tab on a LM317T regulator is electrically connected to the output pin, so you cannot bolt the regulator directly to the metal plate. You MUST use a non-conductive heat transfer pad and a plastic spacer washer through the hole in the tab of the regulator to keep it electrically insulated from the metal plate. You just want to pull the heat out of the device without having it actually touch the metal plate. If the metal tab on the regulator comes in direct contact with the metal plate, it could short out the regulator. The LM317T has internal short circuit protection, so it should not be damaged if you accidentally short it out, but it will not function properly unless it is insulated from the metal plate.

Now it was time to put everything into the box. I drilled four 5/16" holes in the top of the box to mount the binding post terminals, and a 3/8" hole to mount the adjustment pot. I drilled a 1/4" hole in one side of the box for the AC power cord, and a 1/2" x 3/4" rectangular hole in the other side to mount the power switch. Instead of using the big switch that I showed in the first parts photo, I used the switch that I salvaged from the computer power supply. It was smaller and looked neater than the big toggle switch. Here is a shot of everything wired up, just before I closed up the box.

And finally, here is the finished Motor Resistance Test Fixture. The knob adjusts the potentiometer inside to fine tune the current to exactly 1.00 amps. The pair of terminals on the left side is where you hook up the volt meter, and the pair of the terminals on the left is where you hook the current meter to calibrate the test fixture, and where you attach the motor being tested. You can also see the AC power cord coming out the left side of the tester.

Here is another view that shows the location of the power switch on the side of the tester.

To use the Motor Resistance Tester, you first need to make sure it is calibrated. Put your DVM in the Amp mode and connect the leads to the right pair of terminals. On most DVM's you need to plug the red lead into a different hole to use the meter in the Amp mode. Turn on the tester and adjust the pot until the meter just changes from 0.99 amps to 1.00 amps as shown in the next photo. Now the current source inside is calibrated and ready to use. Turn the tester back off now for the next step.

To test the motor, first remove the DVM and switch it from the Amp mode into the Voltage mode. Again, this may require moving the red lead to a different hole. Set the meter to the 200mv scale and attach it to the left set of terminals as shown in the photo below. Once the meter has been attached, connect 2 of the leads on the motor you wish to test to the pair of binding posts on the right side of the tester. Once everything is set, switch the power switch on the tester back on, and the voltmeter will read out the resistance of the motor in Milli-Ohms. For my test I used a BM3520-7 motor that I had laying on my workbench, and as you can see in the display of the DVM, the DC resistance of thei motor (Rm) is 36.7 milli-Ohms which is equal to 0.0367 Ohms.

You can check all 3 pairs of lead combinations and take the average if their are any variations. I first checked the Red-Yellow phase, then I checked the Red-Black phase, and finally I checked the Yellow-Black phase. Two of the phases measured 36.7 milli-ohms and the other phase measured 36.6 milli-ohms, so I got very consistent values.

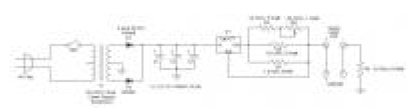
With no motor attached to the output terminals, there is an open circuit voltage of about 8 volts present at the terminals when the power is turned on. To prevent damage to the DVM, turn off the power on the tester after the measurements are complete. Then remove the voltmeter from the tester first, and finally, remove the motor from the tester.

So there you have it, a totally self contained, simple and accurate way of measuring Rm on any brushless motor, that you can build yourself for less than $40.00 in parts. Now how cool is that! 😎 You can also use the tester to measure Rm of a brushed motor as well. You just have to hold the shaft to keep the motor from turning during the test.

Any comments or suggestions for improvement are welcome. One thing that I thought of after I finished it was that it would be cool to have an indicator light to let me know when it is powered on. That would be very easy to do, and I might go back and retro-fit one in. You simply need to hook up an LED, with a 470 Ohm resistor in series to limit the current, across the power supply section of the circuit. You would attach a wire from the negative lead to ground, and run the positive lead to the 470 Ohm resistor, and then run a wire from the other side of the resistor to the positive side of the capacitors.

That wraps up this How-To article. Hopefully you all will learn something, and some of you will actually build one of these for testing your motors. Good luck and have fun!

Lucien



Last edited by LBMiller5; May 28, 2019 at 10:54 AM.
