The Modern Digital Multimeter, and How to use it.

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To start of with, just what can these meters measure? And what do these terms mean, anyhow? Well, the basic items for electricity are "Volts", "Ohms" and "Amps". That's it. Volts, ohms and amps. And, just about any digital multimeter can measure these three items. Turns out that Volts, Ohms, and Amps are directly related to each other. If you know two of them, you can calculate the third, as follows.

Volts = Amps multiplied by Ohms.
Amps = Volts divided by Ohms
Ohms = Volts divided by Amps

Not directly measured by any Multimeter is a term identified as "Watts". Watts is a rate of energy performance, and is directly equivalent to Horsepower. In fact, it takes exactly 746 Watts output power on your motor shaft to equal one horsepower. So,

Horsepower = Watts Divided by 746

So, just what are these three items? They are described below:

Volts: Volts or voltage is the electrical "Pressure" behind any electric supply, be it a 1.5 Volt penlite battery, a 3.6 Volt A123 cell, a 12 Volt auto lead acid battery and similar. Note that these batteries are all DC, or Direct Current. Volts is similar to the water pressure in your house, measured in Pounds per Square Inch. Most everything in your house is AC or Alternating Current.

Amperes: Amps or Amperes is the RATE of electric flow, similar to water coming out of a garden hose in gallons per minute. Note that current flow in Amperes can also be DC or AC current. If you look at the name plate of just about any electrical appliance, such as a toaster, or electric motor, the product will list its current requirements in AC Amperes. (Note, the term milli-amperes is also often used, where a battery can be rated as 2300 Milliampere hours or 2.3 Ampere Hours. Typical abbreviations are MaHrs, and AmpHrs. Depending on what part of the world you live in, other abbreviations may be used for MaHrs and AmpHrs.) Typical currents pulled by an average RC receiver runs about 10 to 50 Milliamperes, depending on brand. Servo's add to this by a small amount. But, Servos can easily pull 1000 Milliamperes, or one ampere or more when you go from "Full Up to Full Down" very rapidly. The Servo motor has to stop turning one direction, and instantly reverse direction. That can pull a LOT of current for a very short period of time.

If you've got a 1/4 scale model full of servos, the total current pulled out of the battery can easily peak at 4 amperes or higher. You'd better be using sub C NiHyd cells in these type models to handle the higher currents. (Or a high capacity Battery Elimination Circuit with a switching converter, such as the Castle Creations 10 Amp uBEC.) Smaller capacity cells can have a voltage drop due to the high loads, which has been known to cause radio receivers such as the Spektrum 2.4 Ghz to "Drop out" for a short time. (If you've got an older Spektrum radio, they will update your receivers to the latest software to reduce or eliminate this problem at no charge. All related information is available on the Spektrum web page.)

Ohms: Ohms is the RESISTANCE of current flow similar to the diameter of the garden hose carrying the water per above. Resistance is a term that defines how many amperes will through a device such as a light bulb, electric heater and so on. (Something to note here, the resistance of a device can vary widely, such as the resistance of a light bulb when cold, and when it is powered up. That light bulb resistance can change by a factor of 10 from cold to hot.)

Watts: Not many meters can measure Watts directly. One that can is the Astroflight Whattmeter. Watts is the product of the Voltage times the Amperes of the unit under test. (This is NOT always true on AC,

but that is far beyond the scope of this series of articles.) It takes 746 watts to make one horsepower.

A few of Denny's Multimeters ranging from $3.00 to $375.00

Back in the early 1960's I was repairing several of our circuit breaker controls that were having calibration problems. They could not meet our plus/minus 5 percent tolerance. I had to obtain a precision 0-30 Volt DC voltmeter that was rated at plus/minus one percent to measure the voltage of a one percent voltage reference device that was in question.

That 30 Volt DC meter was about 16 inches square, and was about 5 inches deep! It had a moving needle type meter scale that had a mirror under it so you were not reading the needle "off to one side" for parallax issues. The scale of that meter was hand calibrated against the National Bureau of Standards, and cost the equivalent of one years house payments! And, it only had one range, 0-30 Volts DC. If you wanted another meter with a 0-5 Volt range accurate to one percent, that was another years house payments. Same for measuring current, same for measuring resistance, watts and everything else.

And, if you accidentally connected 120 Volts AC to the 30 Volt DC meter, you instantly burned it up. We quickly developed the habit of double or triple checking the meter to make certain we had the proper meter for what we wanted to measure.

We also had something called a "MultiMeter" that combined the functions of Voltage, Current and Resistance. These meters used analog moving needle scales with multiple ranges, allowing you to measure a 1.5 Volt battery, or a 277/480 Volt AC three phase bus bar. Typical accuracy was something on the order of plus/minus 5 percent.

These analog type Multimeters served us well for many years. But, they also had the annoying habit of burning up if you accidentally connected 120 VAC to a 3 volt DC range. And, these meters loaded down sensitive circuits which really complicated measurements.

Now days, everything is digital in nature, as shown in some of Denny's assortment of Digital Multimeters shown on this page. The little red meter shown on the left is from Harbor Freight, and on sale, cost $3.99. That is not a misprint, it's under four dollars when it's on sale. And, it is more accurate than that 30 Volt DC meter I used in the 1960s. You can connect 120 VAC to a 2 Volt DC range on this meter and not hurt anything. Oh yeah, if you connect 120 VAC to a **current range** on this meter, you need to go to Harbor Freight to buy another meter! But, even if you should damage it, you are only out four bucks!

The two center Radio Shack meters are in the $50-$75 range, and are no longer made. Radio Shack has similar meters now days such as their model # 22-817. (Some of the cheaper meters may use **EX-**

PENSIVE batteries. Word to the wise.)

That Fluke meter is the Rolls Royce of the multimeters, worth about $375. This meter is just about idiot and damn fool proof, but its interesting to note that the internal fuses ALONE for this Fluke meter cost more than the $3.99 Harbor Freight meter! I've dropped one of these meters from 10 feet high to a concrete pad, with absolutely no damage or effect to these meters. This meter has something called auto ranging, where the meter itself automatically selects the proper voltage or current range on either AC or DC.

This meter can also measure frequency, pulse width, peak values (maximum and minimum) of voltage, current, and a lot of other stuff, far beyond what's needed for the average modeler. And, I would not have a problem measuring the voltage on a 480 Volt Three Phase bus with this Fluke meter. That would **NOT** be the case with the Harbor Freight or Radio Shack meters!

The top meter is what is called a "Clamp On Ammeter" that was purchased at Sears Roebuck. This is a $60 meter that primarily is used to measure current values, without having to cut into the wires. You simply clamp the meter around the conductor, and measure current. This meter has ranges 0-40 amperes, and 0-400 Amperes, and can measure ***both AC and DC currents***. (Most Clamp On Ammeters are AC current only.) It also can measure voltage, resistance, frequency and so on. This Sears Roebuck (Model #82369) allows the user to quickly measure the DC current flowing into an Electric models brushless motor, without having to use connector adaptors and such. Just simply clamp the meter around one of the battery leads. It can also be used to measure battery charging current from your cars alternator and a lot of other stuff.

If you want to start out with a cheap meter, consider the Harbor Freight $3.99 (or $4.99 when not on sale) meter. If you want the next step, consider the Sears Roebuck #82369 meter. Note that the Sears meter can NOT measure currents such as those pulled by your receiver and servos. But the Harbor Freight plus the Sears meter would be a good combination.

So far in this series, we've talked about volts, amps, resistance, watts and a few other things. And photos were shown of the types of electronic meters that can be used to measure these electrical characteristics.

What we will need is a standard MultiMeter for the following pages in this article. Everyone sells them, from Radio Shack, to Farm and Fleet, to Menards, even Wal-Mart!

These meters are very similar in operation, and have most of the same dials or something similar.

I picked up a good basic MultiMeter from Wal-Mart today to use as an example for this series. It's a Etrex # 10709, and sells for just under $20, tax included. It runs on standard AAA batteries, so cost to run it will be reasonable.

Take a look at it:

Caution!

Look at the "Yellow" areas of the rotary switch on this meter. This is a caution flag that these ranges require proper connections to your meter. Example, trying to measure voltage on a 5 cell NiCad pack when the meter is set to the "10 A" range will damage the meter. We will cover this next issue.

DC VOLTAGE MEASUREMENTS

Lets start by first plugging in the meter test leads, then turn the meter on. Turn the rotary switch to about "10:00 AM" where it shows "2" in the area where the meter range shows –V with a funny little wave under it. Note the pushbutton "AC" and "DC" at the lower left side of the meters display. This pushbutton should be "out" setting the

meter to measure DC voltage. Next, touch the multimeters leads to a 1.5 volt penlight alkaline battery cell. The meter shows 1.602 volts DC which is a good value for a new alkaline battery cell. (Previous page)

Note that the meters red wire should connect to the "+" connection of the battery and the meters black wire should connect to the "-" connection of the meter.

Now, reverse the connections to the battery. You will find that the meter measures the same exact voltage, only it has a "-" in front of the voltage, indicating you've got the wires backwards. No, it won't burn anything up. It's showing the "minus" to let you know you've got the red/black wires backwards.

FYI, these alkaline batteries pretty much follow a curve, where the lower the battery voltage, the less capacity it has left. 0.8 VDC for an alkaline battery is pretty much dead.

Now, connect this same MultiMeter to a 9 volt battery. If it shows just the number "1", it indicates you've over ranged the meter, that's still set on its 2 volt range. Simply set the meter to its 20 DCV (Direct Current Voltage) range, and retest. Again, a new 9 volt battery will show over 9.0 VDC. That's a quick check on your battery operated fire alarm's that you should have in your house. This reading of 8.40 Volts DC on an alkaline 9 volt battery came from a fire alarm that has been in service for about one year, and the reading of 8.40 Volts DC shows it should be replaced.

If you've got a A123 pack, these batteries will measure about 3.6 VDC per cell, so a two cell battery pack will measure 7.2 Volts DC. Incidentally, if you should accidentally connect a battery to the meter when its set to an AC voltage range, it won't work. On this meter, it just shows zero volts when connected to a battery.

A good lead acid battery will measure about 12.5 VDC fully charged, and that voltage drops off linearly to about 12 VDC when the battery is complete discharged. Note that this battery voltage will increase while the battery is being charged. Typical battery voltages in your automobile will be about 13.7 to 14.5 Volts DC while the engine is running.

That voltage will vary, because the alternator charges at different voltages depending on the temperature outside. If you ever wonder if your alternator is working in your car, this is a quick check.

Now, lets move on to this meters AC Voltage ranges. Just what is "AC Voltage"? Kind of hard to explain, but AC Voltage stands for Alternating Voltage. Which is why you may be familiar with the term "Alternator" in your car, or a stand by generator that puts out Alternating voltage.

Why use AC Voltage??? Turns out it's a fundamental property of electricity, where it is very difficult to change the voltage of a DC supply to another voltage, especially if you need any real amounts of power. A transformer will not work!

On the other hand, changing voltage in an Alternating Voltage system requires just a transformer, something you see in your back yard that changes the powerline 13,000 volts or so to the 120/240 VAC power to your home.

Now, if you push the "AC" "DC" button, when its depressed, the meter is now set to measure AC voltage.

If any readers ever do any wiring changes in your house, it's nice to know that when you've turned off the breaker,

that the wires you are playing with are actually dead.

Now, be aware that you are playing with 120 VAC, and getting your self across it can stand your hair on end. Or worse.

But, if you set your meter to its 200 VAC range, and touch one lead to a mechanical ground, such as the conduit box, and touch the other lead to the black wire, it will measure 120 VAC if the circuit is live, and zero if its dead. You will also measure 120 VAC between the black and white wire, if it's "hot".

If your breaker is off, note that the meter might measure 5 or 10 volts or some strange value. This is "stray voltage". Its being picked up by your meter. This meter is sensitive enough to detect it.

This meter has an interesting feature, as shown below:

The electronics field has had something called a "Thermal Couple" that has been around for probably 100 years. These thermal couples were used to measure temperature over a rather wide range of well below zero, to 1800 degrees F. This is a little thing that consists of two dissimilar pieces of wire, that's welded together at its tip. Now, with modern day electronics, you can use one of these thermocouples to measure temperature. The thermocouple included with the Etek meter is rated to a maximum temperature of 785 degrees F. Its accurate to about 3% or so, quite sufficient for our needs.

This thermocouple unit can be used to check temperatures of batteries, or anything else desired. Just note that this thermocouple is made of wire, so use care to not short out a battery with it.

FYI, any 120 Volt AC power line in your house does radiate ***very*** small amounts of energy directly from the wires. It's pretty minor, so you'd never notice. But, this Etek meter has a "Non Contact Voltage" function where you push the "Non Contact Voltage" grey button under the display, and hold the top of the meter nearby any 120 Volt AC supply, like an extension cord plugged into an outlet. If the extension cord has voltage on it, this meter will "Beep" and the orange display will lite up.

It also works for Romex wiring in your house, but will NOT sense voltage inside a steel conduit or BX armored wire. This could be used for that desk light, just hold this meter near its lamp cord, if the meter shows power in the cord, you know your outlet is "Hot".

Next, we will cover the meters "resistance" and 'current" ranges.

Speaking of resistance, that is a fundamental characteristic of electricity, where just about every electric conductor, such as copper, aluminum or even iron has "resistance" to the flow of electricity.

This also applies to your NiCad or NiMh battery packs you use for your radios. These four or five cell battery packs have something called internal resistance, which determines just how good this battery is under load conditions. Some of these penlight sized rechargeable batteries have ratings as high as 2700 Milliampere Hours, or even higher. They get these high capacity Milliampere Hour ratings by making their internal battery plates extremely thin, causing an increase in internal resistance. That will result in problems with voltage regulation in the larger models with the big servos.

But, this meter, and any similar digital MultiMeter also has resistance ranges identified by the "Little Horseshoe" symbol. That symbol is the electronic symbol for resistance.

So, just what do we have here? Well, resistance is part of the general electronics world. Just about everything that carries electricity has some resistance to that electricity. This resistance can be good, as in a incandescent light bulb, or bad in an electric motor or receiver battery pack. This Etek meter can be used to quickly check to see if an incandescent light bulb is burned out. Just remove the bulb from the socket, set your Etek meter to the "200" ohm range per the photo. Note that this meter will

immediately show "1 ." That is telling you that the meter has found an open circuit. Next, short the two meter leads together. You will read something like 0.02 ohms, which is the resistance of the meter lead wires themselves.

Next, find an incandescent light bulb, and connect the meters probes to the shell and terminal of the light bulb. A typical 40 watt bulb will measure something around 25 ohms. This same meter can be used to check switch contacts of your RC radio, by connecting it to the red wires on both sides of the switch. If the switch is open, the meter will show the "1 ." And if the switch is closed, the meter should show pretty close to the 0.02 ohms previously described.

This meter also has the "2K, 20K, 200K, 2M and 20M resistance ranges. These are much higher values of resistance, and would not likely be found in typical stuff around your house.

Note that these "Resistance Ranges" are meant to be used ONLY on DE-ENERGIZED Circuits! These newer meters will not be damaged if you should accidentally measure resistance of a Nicad battery. But, it will not read the resistance of the Nicad battery!

If you want to measure the internal resistance of a battery, that resistance value needs to be calculated, based on reading the battery voltage at two different test current values. The battery resistance is related to the difference in voltage drop against the difference in test current value. I've done this hundreds of times. .

And, if you want to measure the resistance of the windings of that brushless motor you've got, none of these "Multimeters" will not be able to do it. (I used an instrument called a "MicroOhmeter" at work before retiring. These meters can easily measure motor winding resistance. But, then these MicroOhmeters cost about $3000.00. I've got another thread in Wattflyer, showing how to use two multimeters to calculate the DC resistance of a motor winding.

So far, we've covered these meters and their voltage ranges, and resistance ranges. Last, but not least is their **CURRENT** range.

Here is where you need to be a little careful, since using the wrong meter range, or wrong meter probe connections can burn up or damage the meter. (Or on the 20 & 200 Ma range blow a fuse.)

And, no, none of these digital Multimeters can be used to measure the current pulled by one of those electric motors. The typical MultiMeter has a maximum current range on the order of 10 Amperes, whereas the typical electric model's motor will pull five times that value. The result is, you will burn up the 10 Amp range on that meter with one of these electric motors. (This range is not fused on this meter.)

So, just what good is the current range anyhow? Well, they can be very useful when setting up the servo's in your model airplane. Especially when you have several servo's operating in parallel on those larger models.

These servos pull very little power when they are just sitting there with no load on its output arm. This will change very rapidly when you call on the servo to move something. Now, after the servo has moved "something" the current pulled by the servo should drop down to a very low level again, close to that value when the servo is in its "neutral" point. If that servo hits a wall, like going past the mechanical

travel of an aileron, elevator or similar, it's going to pull more current. Same thing with a retractable landing gear, or a throttle servo that hits the mechanical stop of your engines carburetor. This extra current pulled by your servo does two things. The servo electronics is going to get hot. Not good. And the servo is going to place added loads to your receiver battery. Again not good.

Here comes the Digital MultiMeter to the rescue!

What you need is a little adaptor that allows connecting your MultiMeter into your radio battery system. It takes a servo extension cord, and two banana plugs from Radio Shack. Total cost, not including the meter is about 5 bucks.

This photo shows the modified servo extension cable with the brown wire cut, and two Radio Shack banana plugs connected to the two cut brown wires. This photo shows that the receive is pulling 0.03 Amps on the meters 10 Amp range. (Or 30 Milliamps)

Meter on 10 Amp Range

This meter has a 10 Amp range, and a "20" and "200" current ranges. So, that 10 Amp range is also a 10,000 Milliampere range. (To match up with the 20 and 200 Milliamp ranges.) This meter has a protective fuse on the 20 and 200 Milliamp range, that will blow if you try to connect it across a battery on the current range. But, as usual on these Multimeters, the 10 Amp range is NOT FUSED. (For that you've got to spend $375 for a Fluke or similar meter!)

When measuring on the 20 and 200 Ma ranges, take a look at the photo below, and note the change in the red banana plug that's plugged into your meter. Its moved from the left to the right side. The black plug stays where it is. Its hard to see, but the meter is showing negative 33.9 Milliamperes, which is the same as the negative 0.03 Amps on the first photo of this meter. Yep, 0.03 amps equals 30 Milliamperes.

Meter on 200 Ma Range

And, now if you plug in a servo, you need to be on the meters 10 Amp range. (Note that this meter also has a AC and DC push button switch. (If you try to measure DC when the switch is on AC, it will read zero.)

OK, now you've got a big model, with multiple servos on the ailerons or elevator, or what ever. And, you are worried if these servo's track each other. Fix up a modified servo extension cord, perhaps one you don't trust after a "Crash". (***Make damned certain your servo extension cable doesn't have reversed red and black wires, if you made both connectors on the extension cable yourself***. Won't be a problem with a commercial cable.)

Plug your battery into the battery end of this custom cable, the other to the receiver. Turn on your transmitter and receiver.

After it's powered up, place a few pounds of pressure on one of the servo arms. You will see the MultiMeter current reading jump, as the servo tries to keep its position. And, if you've got multiple servos, and they don't track each other, it will show up with this test as you move the transmitter stick back and forth.

You can quickly repeat this test on all remaining servos to make certain none are pulling to much current. If you find binding, you just paid for your meter, and it's now your job to adjust the linkage and throws to fix it.

This article is a basic instruction set on what you can do with your digital multimeter. And, these meters can be used for far more detailed investigations, troubleshooting and so on, but that would be another series of articles.

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