BETTER TRUCKING

The Automotive Guide to the Multimeter

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Introduction

If you get a check engine light and read the codes, do you know what to do with it? Do you replace the sensor or is there may be a problem with the wiring?

The driver's report claims a light has burned out. You replace the light and the new one doesn't work. What now?
The test light is a go to for most mechanics. Test lights are great tools for quick readings but test lights are not perfect and can lead to bad diagnostics. One example is a trailer stop light problem I once had. In order to save time (and use my 15$ tool rather than my 300$+ tool), I take out my test light to check my power and ground. The tractor is off and 53 feet away I'm reading 12.2 volts. Great. So, I plug in a new light and tell the driver to push on the brakes. Nothing happens. So, I check my new light with a known power/ground (two test leads on a battery) and it works. Something doesn't add up. I grab my voltmeter and I have a good ground and voltage at the back of the tractor, the front of the trailer, and back of the trailer. I check the amperage, there isn't enough to light a single incandescent light.

Long story short a circuit breaker in the tractor fuse box is half burned but there is just enough life left in it to let a tiny bit of voltage through. Just enough for a LED test light, but not enough for a set of incandescent lights. The part of the story I left out is that another mechanic who only owned a test light had spent two hours not understanding the problem, replacing lights and pigtails, searching high and low but using the wrong tool for the job.

Now a 5-10$ light isn't a big deal. Engine sensors and electric motors are big deals. Diagnosing by replacing parts can be very expensive. But not everyone has had good multi-meter training. Many who have been trained can forget, it's definitely a perishable skill.

So, whether it's for the first time or just a refresher, what follows in the coming days is a primer on everything you need to know all in the name of being a better mechanic. We`ll be covering all the basics of voltmeters, ammeters, and ohmmeters as well as practical things like the voltage drop test and how to use an amp clamp to make testing easier.

What follows is intended to give a general understanding of the value and use of a multimeter capable of measuring volts, amps, and ohms. There is no replacement of having someone experienced and qualified to show you the ropes. Generally, the worse thing you can do with a voltmeter is blow a fuse, but measuring something incorrectly or wiring something incorrectly can lead to damaged parts, including a battery blowing up and even someone getting hurt. Luckily when working on vehicles with 12-volt systems the ability to get someone hurt is minimal, the problem still exists with 12-volt systems, and is amplified by hybrid and full electric vehicles and even 12-volt/24-volt systems. So be careful, always look for appropriate warning labels, and if you're unqualified, then find someone to guide you.

Chapter 1 - Meter Overview

Today multimeters can do a whole lot. We're also lucky that with that versatility, multimeters have become safer, easier to operate and much more accurate and consistent. Unfortunately, a lot of mechanics and technicians, young and old, aren't as confident as they could be with a multimeter. And it's my experience that quite a few technicians use lesser tools like the test light for the wrong sort of jobs.
As the first installment of the multi-meter series, we'll look at the different, practical, uses of today's multimeter and how and why one should be used on a nearly daily basis.

When to use a multimeter

For a lot of day-to-day stuff like verifying marker lamps and checking fuses, a test light is more than enough. But the moment that what you're seeing with your test light (power and ground) doesn't make sense, then you should go get your multimeter. The reason for this is simple. As I mentioned, a LED test light especially takes very little voltage to light up. A wire meant to deliver 12V to a light can be 99.9% frayed, cut or burned and it will still light up most test lights. A test light is meant to show a presence of power and a ground but tells you absolutely nothing else. Some new, more expensive test leads may give you a direction and voltage, but you are always getting a better reading from a proper multimeter to be sure.

How to make sure a multimeter is reliable

The majority of people who use multimeters are guilty (myself included) of doing very little to make sure a multimer is up to the job. Usually, we'll make sure there are some zeroes on the screen. Nothing more. We may put the meter to ohms to hear the buzzer, and that's about it. There are a few more things that take very little time and no talent to make sure we are getting the most out of our multimeters.

One of the most important things we can do has nothing to do with turning on a multimeter but turning it off. First of all, we should turn them off. Pretty much every multimeter today has a screen saver type function that will turn off automatically after a certain amount of time. Leaving it to do so, however, wears on the battery, and a weak battery gives weak results. Consider this to be maintenance.

Check the screen when you turn on your multimeter for either BAT or a battery symbol. Both mean the same thing. It means the battery is weak and needs to be replaced. It's a good idea to take apart your multimeter once or twice a year and test or simply replace the battery. They are usually about 2-3$ and are worth every cent in reliable readings.

The test leads and overall functioning of the multimeter are the other things anyone can do to make sure the multimeter is working well. Again, when putting the multimeter away, make sure you either disconnect the leads and store separately. If you chose not to, at least make sure there is no tension anywhere on the leads or its tips when stored.

Now, to make sure the multimeter and leads are functioning there are a few short and simple tests that can be done. First, turn on the multimeter and put it to volts, at any range or on auto-range. Hold the tips together. The meter should read o.1 or less. If the reading is higher, you have a problem. The problem is either with the meter or the leads. To figure this out take a short jumper or even a pin and jump the red and black jacks. If the reading is still high, the meter is at fault and you should find a dealer to repair and adjust the multimeter properly.

If the reading goes to 0.1 or lower, then one or both the leads is at fault. Plug in the red lead, and put the other end in the black jack. If the reading is high, it is a faulty lead and needs to be replaced. If it reads low, the lead is fine. To check the black lead install it in its jack and put the other end in the red jack. The same rule applies. If the reading is high, replace the lead, if not it is fine.

Conclusion

That sums up the basics of using the multimeter in a garage. Of course, there are a ton of uses for a multimeter. For the average and even the advanced mechanic, there are a few basics that we'll go into later in other parts of the series. We'll also look at specific tests that we use in garages all the time. For now, we now know when and why to use a multimeter and how to get the most out of yours.

Chapter 2 - The Practical Differences Between A/C and D/C Voltage

Just about the entire world runs on alternating current (A/C) voltage. Cars and trucks or anything else that runs off a battery will run on direct current (D/C) voltage. Many don't know what the difference really is, or what it means for technicians and the diagnostics they have to perform. There is only one difference between the two types of current but that can create many problems for techs. In this article, we'll look at what that difference is, how it affects us, and how new technology is changing the way trucks run, and the way we diagnose them.

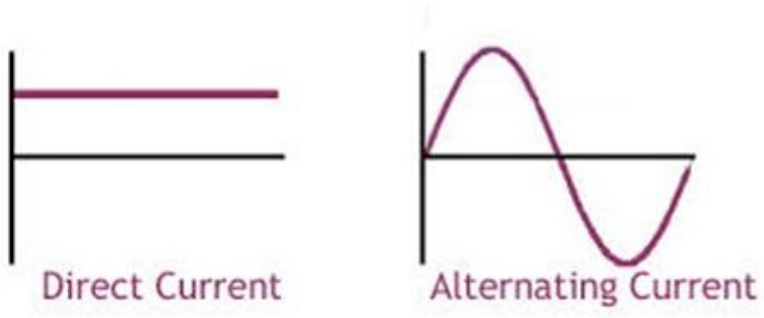
A/C voltage and why it runs our world

Long story short, A/C is cheaper and more efficient over long distances. This is important when you look at where power is generated and where that power is used (homes and businesses). Also, it takes a lot more amperage to create the same heat (and damage) that high voltage will create in a wire or cable carrying D/C voltage. What this means is that a voltage spike or a short circuit will do less damage in an A/C system.

If you've had the unfortunate experience of shorting a cable for a fraction of a second, then you know how fast a wire will burn up. Although you would want to avoid ever causing a short, it is a little less aggressive in an A/C circuit. If you want to learn more about the intense battle between Edison and Tesla (not the car guy Elon Musk, but the inventor guy Nikola Tesla) there are a ton of great articles, books, and documentaries on the topic. For that reason, I'll let that lie, suffice to say that our power grids are A/C by our choice, batteries are D/C their nature.

As you can see in the graph below the name A/C or Alternating Currents alternates. It literally goes back and forth the way a cylinder moves up and

down as it cycles in an engine.



D/C voltage and why every truck is all about it

Our vehicles being run on D/C has a lot less to do with a choice having been made than by the reality that batteries supply a steady and direct current like you see in the graph above. Now, while D/C is simply the way it is by its nature that doesn't mean that A/C cannot be used on a vehicle. And it certainly doesn't mean that A/C can't be used on a truck. A simple transformer can turn a D/C line to an A/C one.

With modern vehicles, you always have to check before you assume a component is broken. There is even a truck model with a throttle position sensor that takes A/C and sends out D/C as a signal to the ECM (electronic control module). The point I'm trying to make is this: Before assuming that there is a fault 'upstream' (closer to the power source) always make sure that you are looking for the right sort of voltage. There are even models of transmission that use a 'doubler'. A doubler does exactly what it sounds like, it turns 12V to 24V. So, you can spend days looking at 12.6V DC when you should have somewhere around 24-26V DC. And don't forget, an ABS sensor output is A/C.

One obvious takeaway is that, more than ever, a test light will not help you in many diagnostic tests.

Conclusion

The reason that not looking for the right current is a problem is that with A/C being a wave for a signal, and D/C being a straight line for a signal, the multi-meter will look for the wrong sort of information. Like anyone or anything looking for one signal but receiving another, it will misunderstand. This means taking longer to find the real problem and possibly replacing electronic parts (that can't be returned).

A common complaint is that it is very hard to come across electrical plans if you don't work for a manufacturer or a licensed dealer. Information is usually available, but it sure isn't cheap. One solution is to, when what you're reading doesn't make sense, simply try different ranges and functions on your multi-meter to make sure you aren't missing anything. In the same way that if you aren't confident with the ground you are using you try different points.

Chapter 3 - Troubleshooting with a Multi-Meter

By now we've covered some important fundamentals. We looked at basic functions and how to get the most out of your meter. As well as the differences between different types of current and how they are read by a multi-meter. Unfortunately, many techs choose not to use a multi-meter to troubleshoot because they don't know how. More often, however, they don't have confidence in their ability to troubleshoot effectively with a multi-meter. I think this is a shame and I also think it's a problem a lot of people can overcome.

Not so scary schematics

A lot of people look at electrical plans, if they're lucky enough to have them, and are totally overwhelmed with what they see. What makes this a little crazy is that the same person who is looking at a schematic with 100 wires in it and finds it intimidating, but wouldn't think twice about taking part a component that has as many mechanical parts and needs to be taken apart, inspect, repaired, rebuilt and timed.

The reality is that for every schematic that seems intimidating there is always a simple shortcut to cut through a lot of noise. Most schematics will have quite a few components on it. Let's take a schematic that might represent the entire cabin electrical system. Chances are, if you're troubleshooting the HVAC blower fan there is a very simple circuit mapped inside of that larger schematic. Now you don't want to muck up expensive troubleshoot guides but often you can make a photocopy. Often you can print out a page. Simply highlight the component you want to troubleshoot and all the wires associated with it. What this does is elevate the circuit you need to focus on. The rest becomes background noise. And this will help make the job easier every time.

Not so available schematics

The reality is that manufacturers do a fantastic job keeping their information far away from the mechanics. Unless you work in a dealership you probably don't have the wiring diagrams and troubleshooting guides. This doesn't mean that you cannot troubleshoot electrical problems. It just means it will be a little more difficult. But as they say, if it was easy, everybody would do it.

Let's go back to the previous example of the fan. Most mechanics with a bit of experience will know that the ingredients needed for the fan to work are as follow: A battery, a fuse, a switch (normally variable in this case) a resistance block, and the fan. Any one of these things or the wires and cables that connect them all can cause a failure. Finding out which part of any given recipe is causing the problem is what we are using the multi-meter and, if possible, the schematics to find out. This doesn't mean you need schematics. As a matter of fact, in relatively simple cases like this, you wouldn't really care for schematics.

Despite the fact that in the schematics the wires seem to follow natural routes, they do not in any way. They will give clues such as which wire or harness passes through the firewall or floor. Follow the plans like they are a real map, however, and you will do more to harm the troubleshoot than help. So, while the schematics are great for helping you see which harness passes where, if there are connectors along the way, etc. a proper troubleshoot can be done without. It may just take a little more time, and more thought.

Conclusion

We will look at measuring voltage and learn how to measure a voltage drop in the next article. I hope this article has given you a little more confidence to take on more electrical problems, knowing that it can be done. It is a lot of work, but it does lean towards working with your head and less your back. This is usually a good thing. The results of fixing a

lighting problem are no less that the results of replacing brake linings. Learning to troubleshoot electrical problems will also differentiate one tech from another.

Chapter 4 - Using the Voltmeter and the Voltage Drop Test

We've covered some basics by now such as how a multimeter works, and how to get the most reliable results from a multi-meter. We also looked at the functional differences between Alternating Current (AC) and Direct Current (DC). Please feel free to go back for a little refresher if you feel the need.

It's probably safe to say that the average person willing to use a multi-meter at all knows how to check for voltage and a ground. An easy example would be a burned-out light that may need replacing. Remove the light from the connector, put your voltmeter to 20V or whichever setting is closest to, but over, 12 volts (since we're talking about automotive) and put one test lead end to each pin. If you read a number around 12.00V then your power and ground are likely okay. If the multi-meter reads -12.00V or something of the sort, it simply means you have your negative lead on the positive pin and your positive lead on the negative. For our purposes the reading still is 12V and your circuit is likely okay.

It's my experience that everyone instinctively knows this to be true. One problem, however, can be that a wire is mostly burned or frayed such that while there are 12 volts getting from one end to the other, the wire is damaged such that it can't carry enough amperage to do the work of lighting bulb. The problem could also be a loose connection somewhere. A loose wire connection and a frayed or otherwise damaged wire has essentially the same effect. Not enough amperage getting through. This is exactly why the voltmeter is so important and the test light so useless. While the test light takes so little amperage to light up, it could be misleading in that you one may believe the whole circuit must be in working order.

Beyond the test light

So, let's take a look at what the voltmeter can do that the test light cannot. Let's use the simple example we took earlier: the light that we think is burned out. The rear marker light isn't working. We've removed the light, and checked for a solid ground and a positive 12 volts. With the test leads firmly placed on either pin we read 12.6 volts. IT seems to be a perfect circuit. The light must be defective. We replace the light. It still doesn't work. How is this possible? We saw 12.6 volts and if we use a test light, it lights up. In my experience, this could be anything from a frayed or burned wire, to a faulty switch or even a melted fuse. You wouldn't think a fuse could melt, but apparently, they can.

One important thing to note is that you can't put too much faith in new parts. Many mechanics have made the mistake of going through an entire diagnostic, finding the problem, replacing the suspected part, and then assuming that the entire diagnostic was wrong because the results aren't what we expect. Despite how good the majority of manufacturers are, no company is perfect and your new part could be defective as well. Be it a light, an air valve, or any other component, when this happens, check the new component with known inputs before dismissing your diagnostic. What I mean by known inputs is replace a light (for example) that is working, for the new one to see if it is the circuit or the new light.

How to test wires making up a circuit

Many people would simply take out their multi-meter and set it to ohms. More generally speaking, the ohms' function that will beep when a circuit is complete. This is not the way to test a circuit for the same reason that a test light is no good. It takes next to nothing for the meter to read the circuit to be 'complete'. This doesn't mean that enough power can pass through a wire to power a light or electric motor.

Wire or cable testing

Now, to test a cable or wire, placement of the test leads is essential. One lead should be at the battery, or as close as possible to it. The other lead should be at the load (light, electrical motor, etc.), or as close as possible to it. The multi-meter should be set to whatever is above 12 volts and it should be set to DC. Also, the circuit should be complete. If the light, motor, etc. is removed the circuit cannot be complete and the test will not give accurate results. Once all of this is done, the circuit should then be turned on. The reading should be between .00 volts and 0.30 volts. This is where most people get confused. Common sense, or logic, usually tells us that the circuit should read 12 volts. The reason it doesn't, or shouldn't read 12 volts is that we are measuring the load, and so we aren't measuring voltage compared to the ground. If the meter did, in this example, read 12 volts, it means that the wire is broken or damaged and needs to be fixed or replaced.

As far as voltage readings go, the following is essentially what they represent:

0.00-0.30 volts DC = Wire/cable is in good condition.
0.30-11.00 volts DC = Wire/cable damaged, frayed, burned or loose connections.
11.00-+ volts DC = Wire/cable cut, otherwise disconnected.

Now we've seen how to measure a positive wire for any possible problems it may have, it's worth noting that you can't forget the ground wire or ground connection. The ground is measured the same way as the positive, just on the other side of the load. On lead going to the other side of the load, the other to the ground terminal on the battery.

More and more components are being controlled by the ground. Even starter motors. Some would argue, and I tend to agree, that the ground should be checked first. One reason why I would disagree is that if you take the example of a trailer lighting system, the one ground serves all six other functions. So, if the brake lights aren't working but everything else is, then it likely isn't the main ground.

How to do a voltage drop test on a starter motor

Step one: Secure the vehicle (wheel chocks) and make sure the vehicle is in neutral.

Step two: Put one test lead on the positive post of the starter, and the other test lead on a known ground such as the chassis. This is often easier done with alligator clips.

Step three: Have someone turn the key to the 'Start' position, or use a remote starter.

Step four: read the results on your multi-meter.

Results: Again, same as with the wires, the lower the reading the better. Over 1.00 volt could mean a faulty starter motor. Over 2-3.00 volts definitely means a faulty starter motor.

Conclusion

With trucks and trailers getting more and more complex electronics knowing how to test and verify circuits is more important than ever. Also, some manufacturers will do anything they can to not pay a warranty. Approaching them with circuit information like that that you learned here today will help. Also, diagnostic by replacing components is expensive. Add to that the fact that the vast majority of electrical components will not be accepted back from your suppliers and all the more reason to learn how to diagnose more effectively.

Chapter 5 - What is amperage and how do you measure it?

What is amperage? For most people, it's little more than a rating on a fuse. We know it takes very little to hurt someone and we know a battery system should offer a starter around 700 of them.

Amperage is the strength of electric current through a wire, a cable or anything else that can conduct electricity. Like the frame of a tractor or trailer often used as a ground for lights and other accessories. Amperage can be defined as 'flow rate'. Any mechanic will know that their air tools take different CFM (air flow) just like any electric tool will take different amperage (current flow).

This is why Amperage is important. Restrict the air flow to an air tool, and the tool's performance will suffer. Restrict amperage to an electrical motor, or light or anything else, and performance suffers. Therefore, in diagnosing the performance of, say, an electric starter motor, measuring amperage is important. Here is how.

How to read amperage

Measuring amperage is actually pretty straight forward, and with today's tools, easier than ever. This is why it's a shame, not more mechanics use amperage readings more often when going about their work. To be clear, however, it isn't shameful that any given mechanic doesn't know, or is uncomfortable with measuring amperage. It's a shame that measuring amperage, and using those measurements has been made so complicated.

The main way, and the oldest way, of measuring amperage is by taking the multi-meter and making the meter a part of the series. It must be said that if ever there is a doubt of what you are doing, you are best to see a trained technician for help. If ever there is a risk of injury, which is often the case

with electricity, you are best to see a trained technician for help. If ever you are working on something that can be damaged, you are best to see a trained technician for help. Especially if ruining any part of your test would be financially difficult. That being said, here are the basic, rough steps to measuring amperage with a multi-meter.

1- Choose the current type, alternating (A/C) or direct (D/C). IT almost always is D/C with vehicles, but A/c does happen at times. Either inform yourself of the sort of amperage that could be in the system or make the best estimate possible. For example, a light bulb will not take 50 amps. And choose the right setting on your multi-meter dial, as well as the plug you will use for your red (positive) test lead.

2- Once your meter is set, take apart, or cut one part of the circuit. An example would be to take the positive wire, cut it (this can lead to problems so be careful when and where you choose to do this) and use the test leads to complete the circuit.

3- Turn on the circuit and take a reading from your multi-meter. The higher the amperage, the quicker you should try to be about taking the reading and turning off the circuit. For your meters sake.

In short: setup your multi-meter. Make the meter, with the leads, a part of the circuit you want to measure. Turn on the circuit and read the meter.

What's worse is that it has gotten even easier with today's tools. You can easily, and with decent reliability, measure the amperage in a system without compromising the integrity of the system. The tool I'm referring to is the amp clamp. There are essentially two sorts of amp clamps. Both are pretty great.

First is the amp clamp you buy for maybe one or two hundred dollars and you have a great accessory for your multi-meter that you plug in like any other test lead. You push a button, the 'mouth' opens, and you put the

clamp over the cable you are trying to measure. No taking the circuit apart. And no passing hundreds of amps through a thin wire and a sensitive electronic measuring device. This may not be as accurate as the old method. But for most purposes, it's more than enough to give a clear image of what is happening with an electrical system.

The other is a standalone amp clamp meter. All they typically do is read amperage through the clamp. They are also much more expensive that the accessory type. So that's the trade off with those two options. Often a safe middle ground for the majority of truck mechanics is a quality accessory type. There is no lack of great options as well from Fluke, to the Mac, and the Snap-On, there are many to choose from.

The amp clamp really doesn't take much explaining. Find the wire or cable you want to measure. Put the clamp around it with the meter set to the closest expected range. And turn on the circuit.

When in doubt of which amperage setting to use on your meter: Use the highest, and work your way down until you get a proper reading. This will severely lessen your chances of damaging your equipment

Conclusion

That is almost all you need to know about amperage and how to measure it. Of course, there is the question of what you are reading versus what you should be reading. You should guess as little as possible and when in doubt do the necessary research to find how much amperage a healthy circuit should be using. Be it a starter motor or a LED light, being armed with the right information is always the biggest advantage a mechanic can have.

Conclusion and Wrap-Up

The improper diagnosis of a circuit or component can lead to a waste of time, parts, and money. Improper diagnostic technique can lead to damaged components, electrical fires, batteries shorting, and all this can cause someone to get hurt or worse. I hope that this E-Book has given a foundation to build on but it is always best to find someone to guide you through the learning process. Serious problems are rare, but mostly because people learn proper techniques.

I hope that this E-Book has been helpful, and I hope this warning doesn't dissuade you from learning more. Learning now will take the form of getting your hands on a vehicle and trying things for yourself. Multimeters are fantastic tools and in the new era of electronic everything, it has never been more necessary. Just because almost everything is operated by some form of computer doesn't mean you can't fix anything. The computers themselves hardly fail, but they can be diagnosed too. For everything else, we're still looking at nothing more than a sensor of a component that uses electricity to "speak" or function.

Good Luck,
Kevin Gauthier