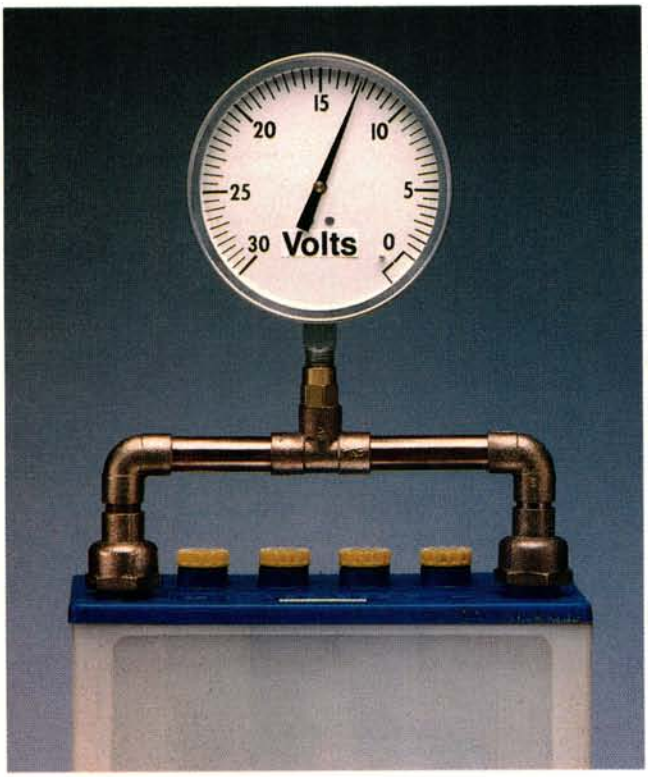
Voltmeters: Testing Electrical Pressure



Are you servicing automotive electrical systems? If you are, a voltmeter should be one of your most used instruments. A voltmeter is used to measure the amount of electrical pressure, or voltage in a circuit. Voltage is the force used to move electrical current through the circuit.

Without voltage, there can be no electrical current.

Air Pressure and Electrical Pressure

Your air compressor stores pressurized air in a tank. Without pressure in the tank, you can't inflate a flat tire or run your air tools. There just isn't enough force to move the air through the compressor hose. Most air compressor units have an air pressure gauge that indicates the amount of air pressure available to do work for you.

The automobile alternator creates electrical pressure, and stores it in a battery. Without pressure in the battery, you can't operate any of the automobile's electrical components. Your voltmeter is like that air pressure gauge on the compressor tank. But instead of checking air pressure, the voltmeter checks the amount of electrical pressure in the circuit.

Think of your voltmeter as an electrical pressure gauge. The readings you get on that electrical pressure gauge can be very useful when you troubleshoot electrical and electronic system problems.

There are analog and digital voltmeters that seem to do the same thing—namely measure voltage. They range in price from three to 300 dollars, and come with a wide range of options. So it's no wonder that selecting the right voltmeter can be a confusing matter.

Will that old analog meter still do the job for you? Or should you buy a new digital voltmeter? Is a more expensive meter necessarily a better meter? What kind of meter does the best job on the circuits you test most often?

Let's see if we can find some answers to these questions.

It Was Cheap, It Was Pretty

Unfortunately, some technicians choose a voltmeter based on price alone. That can be a big mistake.

Still others buy a voltmeter because they like its color or appearance, and never give the meter's specifications much thought. This is an equally bad mistake.

Once they've selected the wrong meter, they begin a lifetime of incorrect voltage measurement. They never realize that they've selected the wrong meter for the type of work they're doing.

If you use the right voltmeter and take the time to look up the specifications for the job at hand, you'll

find many problems that these other fellows overlook.

Let's start by looking at the differences between digital and analog voltmeters. This will help us understand *how* a voltmeter works. This will also help us to understand the advantages and disadvantages of each. That way we'll know how to choose and use the correct voltmeter for the job at hand.

Analog Voltmeters

Analog voltmeters are usually found in multimeters called Volt-Ohm-Meters or VOMs for short. Analog meters have been in use for over 50 years. They measure voltage, resistance, and electrical current. Analog voltmeters found in VOMs indicate voltage by the movement of a pointer needle across a voltage scale printed on the face of the meter.

Some people refer to analog voltmeters as "swing needle" voltmeters because the needle swings across the scale to indicate the amount of voltage in the circuit. VOMs are the lowest priced voltmeters available, and as a result are used the most.

DC Accuracy of VOMs

Voltmeters are rated with a specification known as DC ACCURACY. This specification tells us how accurately the VOM can indicate the amount of voltage actually being measured. This accuracy is measured as a percentage of the reading shown on the meter face. It is given as a plus or minus of a certain percent.

Many VOMs have a DC Accuracy of ±3.0 percent. This is not accurate enough for some precision voltage measurements, especially when working around electronic circuits.

Digital voltmeters are preferred for electronics testing since they are generally more accurate.

When DC Accuracy Is Critical

Suppose you want to measure a voltage of 12.6 volts (a fully charged battery) using a VOM with a DC Accuracy of ±3 percent. The voltmeter could read anywhere from a high of 13.0 volts to a low of 12.2 volts and still be within the meter's specified accuracy limits.

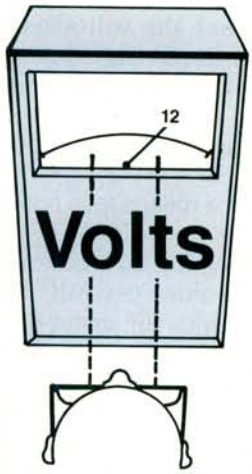
That's a spread of 0.8 volt! Not too accurate. Especially when you consider that the typical car battery reads 12.6 volts when fully charged and 12.0 volts when charged at only 25 percent and unable to start a car. That's a spread of only 0.6 volt between a working battery and one too weak to work. It becomes clear that a ±3 percent VOM is not accurate enough to measure the post voltage of a car battery to determine its state of charge.

Technicians who use this VOM to check battery post voltage to determine state of charge aren't learning anything useful. They won't find battery problems with their old VOM.

Remember, VOMs are not to be used where critically accurate voltage readings are needed.

Other Limitations of VOMs

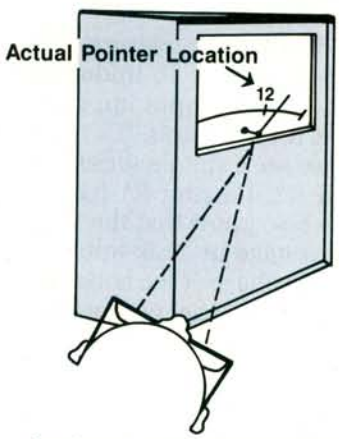
Even if the VOM's voltmeter were more accurate, there would still be problems. The technician still has to read the meter correctly. Sounds easy. But stand off to the side of the meter and take your readings. VOMs can be misread very easily, especially when the scale of the voltmeter is viewed from an angle, instead of straight on.



Look At VOM Straight-On

This optical confusion created by looking at the meter face from an angle is called *parallax*.

Notice the parallax in our illustration. Looking at the meter face from the left side causes the meter reading to seem higher than it really is.



Looks Like Pointer is Reading A Higher Voltage When Viewed From The Left Side

Furthermore, if the meter is not standing upright, or is laying on its back, the accuracy of the voltage reading can also be affected by gravity pulling on the meter movement.

One of the biggest problems with VOMs is damage

to the meter caused by connecting the meter backward. Reversing the polarity of the meter leads can permanently damage the meter when the needle moves to the left. This can bend the pointer around the end stop.

Any technician worth his salt has done this at least once in his lifetime just to be a member of the club.

VOM Low Input Impedance

Most VOMs have a low input impedance compared to digital voltmeters. In fact, many analog voltmeters have too low an input impedance. Input impedance determines how much the voltmeter loads down the circuit being tested. Input impedance may be printed on the face of the old VOM in ohms-per-volt.

Remember:

Low input impedance means more current flows through the meter.

High input impedance means less current flows through the meter.

Let's say we're testing an electronic circuit with a VOM rated at 20,000 ohms-per-volt. That's a pretty low input impedance. Since the meter doesn't impede, or slow the flow of current through itself, it becomes a big consumer in the circuit.

The circuit must now supply enough current to feed the meter as well as the circuit being tested. That extra current through the meter may cause electronic circuits to overheat and fail.

Testing An Open Circuit

A voltmeter is always connected in parallel with the circuit being tested. As a result, some circuit current flows through the voltmeter. The amount of current flowing through the voltmeter causes a voltage drop across the voltmeter.

This voltage drop is then interpreted as the amount of voltage being measured. To understand voltmeter operation, and how a low input impedance can affect a circuit, look at these figures.

In Figure A, we see a simple series circuit with two resistors, R1 and R2. Resistor R1 has a resistance of 12,000 ohms. We also know that the voltage at the top of R1 is battery voltage or 12.6 volts.

But what is our voltage at the bottom of R1? Careful, careful. Don't jump to the wrong conclusion and assume that we have a voltage drop just because we have a resistor.

We actually have 12.6 volts at the bottom of R1. Why? Because we have a series circuit that is *open* below the resistor. And we can't have current in an open circuit. With no current through R1, we have no voltage drop across R1.

If we check the bottom of the resistor using a voltmeter with a very high impedance (10 megohms), we'll find that we have 12.6 volts at the bottom of the resistor. The high impedance of the meter does not allow enough current to flow through itself to complete the circuit.

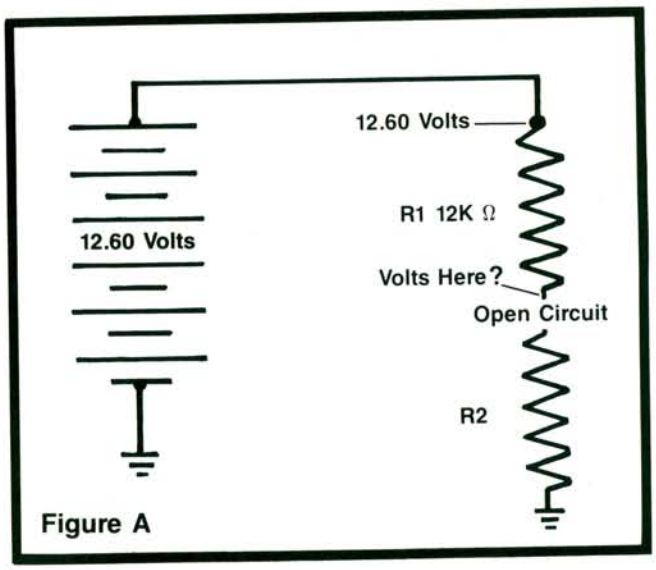


Figure A

We still have an open circuit.

We have no current flow so we have no voltage drop to measure. In addition, that 12.6 volt reading at the bottom of the resistor tells us two things:

- The resistor is not open (or we would have no voltage reading).
- The circuit is open below the resistor (or we would have a voltage drop across R1).

Sherlock Holmes couldn't do any better.

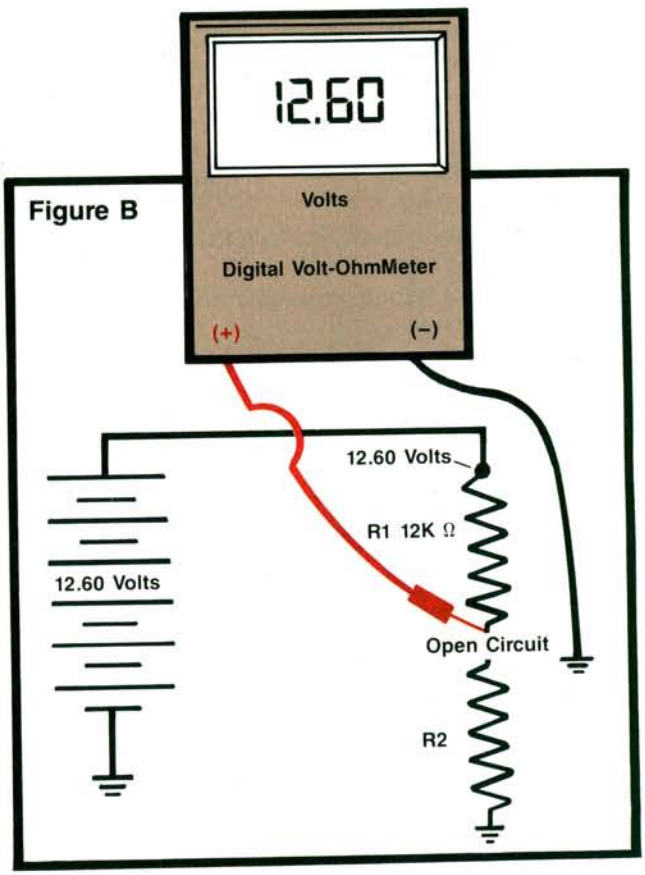


Figure B

Same Test—Different Meter

Now let's do the same test with a low impedance (100 ohms-per-volt) VOM and see what we get. This time, however, the low impedance of the meter allows a large current to flow. The meter is actually completing the open circuit.

At 1000 ohms-per-volt in a 12.6 volt circuit, the voltmeter places a total resistance of 12,600 ohms in the circuit. This is almost identical to the resistance of the 12,000 ohm resistor. Since resistor R1 and the ohmmeter have about the same resistance, they will each drop about half the voltage.

The low input impedance of the voltmeter allowed so much current to pass through R1 that a voltage drop of about 6.3 volts occurs across R1. That leaves only 6.3 volts at the bottom of the resistor for the voltmeter to read.

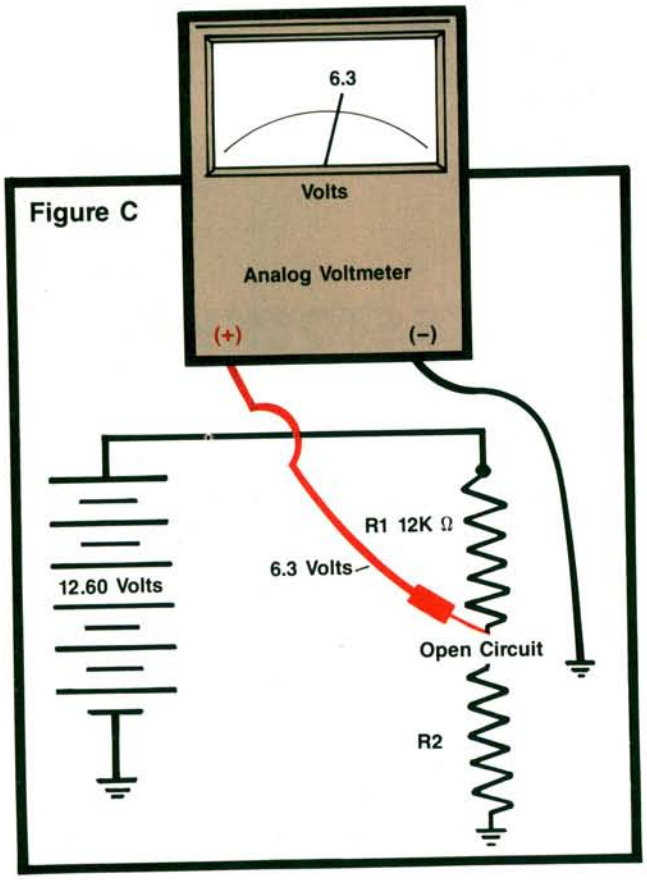


Figure C

This low input impedance of the analog voltmeter distorts the true circuit voltage at the bottom of R1, making it 6.3 volts when it should be 12.6 volts. In addition, if R1 is a sensitive electronic component, the high voltmeter current which has to pass through R1 could damage it.

The higher the input impedance of the analog meter, the better. Some cheapie models will have an input impedance of only 1000 ohms-per-volt. That's about the worst you'll see. These are a definite No-No for auto electronic circuits.

If you spend a little more money, you can get a meter with a 20,000 or even 50,000 ohm-per-volt impedance. That's better.

But to protect sensitive automotive electronic circuits, the minimum acceptable input impedance should be equal to or greater than 100,000 ohms-per-volt. Most auto manufacturers recommend a minimum voltmeter input impedance of 10 megohms (10 million ohms). This is excellent.

Recent improvements in some VOMs have raised the input impedance to 10 megohms to win auto manufacturer's approval. DC accuracy of these newer VOMs is not improved to a point where they are as accurate as digital meters.

Should I Keep My Analog Meter?

You bet you should keep your analog meter. It's not time to send the old VOM to the junkyard in the sky. Inexpensive VOMs with a low input impedance below 100,000 ohms-per-volt are still useful for voltage measurements that don't require a high accuracy. These would include lights, horns, door motors, and so forth.

VOMs are also best if you want to see the rate of change in a voltage signal from an analog sensor. As the sensor voltage rises and falls, the pointer on the VOM rises and falls to follow the voltage changes. The analog VOM actually responds to these changes faster than a digital voltmeter can. The digital voltmeter is too slow to notice small changes in analog voltages.

One last point to mention about analog voltmeters. Some have a 10 volt or a 50 volt range. Since most voltages on automotive systems are above 10 volts, you can't use the 10 volt scale. That leaves you using the 50 volt scale.

But reading 12.6 volts on the 50 volt scale means you're only using about 10 percent of a larger, less precisely calibrated scale. This makes it more difficult to make accurate readings when you try to tell the difference between 12.6 and 14.5 volts. This makes checking charging voltage a lot more difficult.

Suppose you measure a fully charged battery (12.6 volts) using a VOM with a DC Accuracy of ±3 percent. The voltmeter could read anywhere from a high of 13.0 volts to a low of 12.2 volts and still be within the meter's specified accuracy limits.

Ideally, the analog voltmeter should have a 15 or 16 volt scale. Shop around and get what you need to do the job.

Digital Voltmeters

If you don't have a digital voltmeter, get one. Never leave home without it. Digital voltmeters are included in Digital MultiMeters (DMMs), also called Digital Volt-OhmMeters (DVOMs). A stand alone digital voltmeter isn't worth the money with conventional

digital multimeters being so inexpensive.

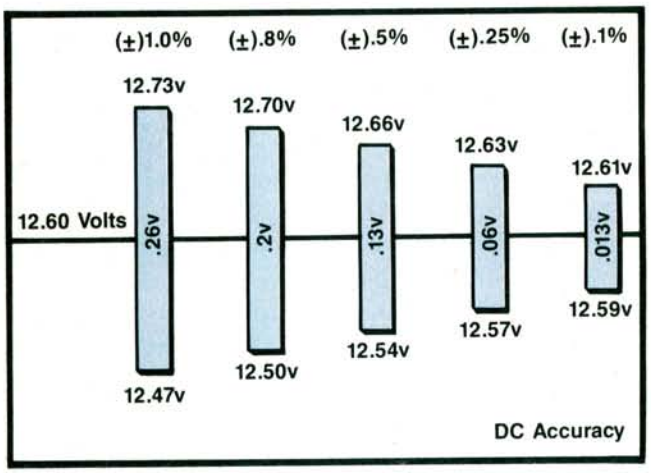
DVOMs display the voltage reading as a digital, number display, so they're easy to read. There is no chance to misread the pointer location from parallax error. The digital readout on the DVOM simply reads the voltage being measured.

DVOMs offer many advantages over the old VOM. The first advantage is improved DC Accuracy. Don't just assume that any digital meter is more accurate just because it's digital, however. Some DVOMs have a rated DC Accuracy of ±1.0 percent. That's a lot better than the VOM's ±3.0 percent, but still not accurate enough for some auto electronic circuits.

There are a wide range of DC Accuracy specifications available in DVOMs. Check our accompanying DC Accuracy chart to help you decide the DC Accuracy specification that fits your needs. The chart shows how accurate the voltage reading would be for each specification when the meter is used to measure 12.6 volts.

Notice the upper and lower limits for each specification. Also notice that as DC Accuracy improves, the bar, or "window of error" gets smaller.

As the numbers for DC Accuracy decrease, the accuracy of the readings increases. Smaller margins of error mean more accurate readings.



Let's go back to battery voltage. Only this time we'll take our DVOM along. We need to read battery post voltage to *tenths* of a volt to accurately determine state-of-charge.

If we refer to our chart, we see that ±0.5 percent is the minimum acceptable DC Accuracy that will allow us to read battery voltage to tenths of a volt. (12.6 volts x ±0.5 percent = ±0.063) That means we can be 0.063 volts above or below the actual reading. Our total range of error then becomes 0.063 x 2, or 0.126 volt.

A DC Accuracy specification of ±0.25 percent gives us a total possible error of only 0.06 volt when measuring 12.6 volts.

The best DC Accuracy is ±0.1 percent. At 12.6 volts, our maximum voltage error is a mere 0.013 volt.

As DC Accuracy improves, prices for the meter go higher. You'll have to decide how much DC Accuracy you're willing to pay for. But if DC Accuracy isn't at least ±0.5 percent, you'll simply overlook battery problems.

DVOM Ranges

Most voltage measurement in automotive applications is performed below 15.0 volts. The typical DVOM has a 2 volt range, a 20 volt range, a 200 volt range, and so on. Both 2 and 20 volt ranges are used to measure automotive voltage levels.

The 2 volt range is used to measure small voltage drops in the 0.10 to 0.30 range. Use this voltage range to check voltage drops in ground connections, wires, cables, and switches.

On the 2 volt range, there should be three places to the right of the decimal, or a maximum reading of 2.000 volts. That's measuring voltage to the thousandth of a volt. This greater accuracy allows you to detect a voltage drop as small as 0.001 volt, long before it becomes a major problem.

The 20 volt range is used for other automotive DC voltage measurements. There should be two places to the right of the decimal point on the 20 volt range, or a maximum reading of 20.00 volts. That's reading voltage to the hundredths of a volt. Two places after the decimal provides excellent accuracy between voltages of 12.50 and 12.60, for example.

With readings in the hundredths of a volt, you can tell the difference between 12.51 and 12.59 volts, to tell you just where you're at between 12.5 and 12.6 volts. This amount of accuracy can be invaluable when you test batteries and charging system voltage. It's also very important when you check regulated voltage sources from computers that are used to operate sensors.

DVOM Advantages

• High Impedance: DVOMs have a fixed input impedance of 10 megohms (10 million ohms). That's plenty safe for delicate auto electronic circuits.

• Connecting Backward: If DVOM test leads are mistakenly connected backward to measure voltage, no harm is done to the meter. The meter will simply place a minus sign in front of the voltage reading in the display.

• Selecting the Wrong Range: If the DVOM is on the 2 volt range and you try to measure 14 volts, no harm is done to the meter. It simply reads out "over voltage" to tell you you're in the wrong scale. You can smoke the old VOM by doing that.

• Autoranging: Some top of the line DVOMs will automatically select the proper range for the voltage being measured. But you pay for that convenience.

• Analog Bar Graph: This enables a digital voltmeter to indicate instant changes in the DC voltage that do not show up on the digital display.

DVOM With Analog Bar Graph

Bottom Line On Display Is Analog Bar Graph

When To Use An Analog Meter

Use an analog voltmeter when precise voltage measurement is not important. This is useful when you check lights and light circuits, horns, DC motor circuits, and other components that are not controlled by electronic components.

When To Use A DVOM

Use a DVOM for precision voltage measurement. This includes checking terminal voltage to determine battery state of charge, measuring small voltages such as a voltage drop in ground circuits (less than 0.1 volt), or any voltage measurement associated with electronic circuits when accuracy is a must.

It's Your Money

Now that you know the difference between VOMs and DVOMs and the different jobs they do, you can better decide how to spend that hard earned cash of yours. Evaluate the type of testing you do, and select the right voltmeter for the job.

If the guy trying to sell the voltmeter seems unable or unwilling to supply you with all the information about the meter's specifications, be wary. Those specifications are just as important as price and appearance when you reach for your wallet.

—By Vince Fischelli