

DMM Specifications - What do they mean?

The Problem

Do you need to make accurate measurements of electrical quantities like volts, amps, or ohms? Are you a quality assurance engineer that must verify the operation of some electrical device, such as a power supply? As a technician or electrician have you been sent to make a measurement in a circuit and told that the reading should be, for example, between 27.5V and 28.5V? If this has happened to you you're not alone. In order to perform these tests you need to know how accurate your digital multimeter is.

Fluke is often asked "How do I determine the accuracy of a measurement based on your specification tables". The purpose here is to help you understand how the different functions of a meter are specified how to calculate measurement limits for a particular meter reading, and to help you visualize how the specifications will affect the accuracy of your measurement.

A Brief Look at Meter Specification History

We're not going to go back to the beginning here but we will start with a brief look at meter antiquity – the analog meter. The analog meter generally consists of a needle on a shaft with coils attached and a magnet or electromagnet. When a current flows through the coils the needle will be deflected based on the amount of field produced by the current. Since calibration of the movement was at full needle swing (full scale) the specifications are stated as " \pm percent of full scale". A typical specification is " $\pm 2\%$ of full scale" so that a 250V range will have a ± 5 V error for any voltage on the range.

With the advent of digital multimeters measurement methods improved and so did specifications. Over the years several different methodologies have been applied to writing digital meter specifications. Here we will discuss those that relate to general purpose digital multimeters not those relating to very high precision DMM's. Typically you will see a meter specification written in one of two forms. They both mean the same thing so once you understand one the other will make sense. You may see the accuracy stated in the following ways: $\pm ([\% \text{ of reading}] + [\text{counts}])$ or $\pm ([\% \text{ of reading}] + [\text{number of least significant digits}])$. In the distant past you might have even seen the "[counts]" or "[number of least significant digits]" replaced by a measurement value for the specific measurement function, i.e. 0.001 volts, 0.01 ohms, etc.

Calculating the Measurement Error

Let's break down the accuracy statement and see how it relates to our measurements. First, what does "[% of reading]" mean? This one is pretty straight forward, it means that we take the percent in the specification table, convert it to a decimal, and then multiply the value in the meter display by that decimal number. The result is a measurement quantity, for example 0.001 volts, 0.2 ohms, etc.

“Counts” or “number of least significant digits” is a little more complicated. Generally the best way to view this part of the specification is that it is the smallest error for any measurement. It is *always* added to the percent of reading error calculated when determining final accuracy of a measurement. You will sometimes find this referred to as the measurement “floor”. So, what do we do with the numbers in this part of the specification? Suppose that the specification indicated that the error would be 20 “counts” or “least significant digits”. The first thing we need to do is determine the resolution of the instrument for the voltage being measured. We find that in one of two ways; (1) the specification table indicates the resolution for each range, for example 0.001, or (2) the table shows the range with all of the measurement resolution, for example 4.000V. In our example of 20 counts with a resolution of 0.001 the error is 0.020V or 20 mV.

Putting it All Together

For a real life example let’s use the Fluke 189 dmm. Below is the dc volts specification table for the meter.

Accuracy	Accuracy specifications are given as \pm ([% of reading] + [number of least significant digits])		
Function	Range	Resolution	DC
DC mV	50.000 mV	0.001 mV	0.1% + 20
	500.00 mV	0.01 mV	0.03% + 2
	3000.0 mV	0.1 mV	0.025% + 5
DC V	5.0000V	0.0001V	0.025% + 10
	50.000V	0.001V	0.03% + 3
	500.00V	0.01V	0.1% + 2
	1000.0V	0.1V	0.1% + 2

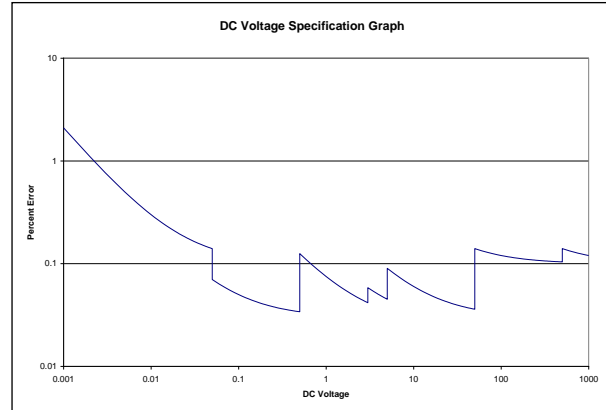
Let’s say that our meter reading is 1750.0mV. Notice that this is in the 3000.0mV range so the specification for the measurement is \pm (0.025% of reading + 5 least significant digits). To obtain the reading error for the “% of reading” part of the specification multiply (1750.0mV X 0.00025) yielding 0.4375mV. And, five (5) least significant digits equals 0.5mV based on a range of 3000.0mV or from multiplying 5 times 0.1mV (the resolution specified in the accuracy table). Since the measurement resolution is only 1 decimal place we’ll round 0.4375mV to 0.4mV and add 0.4mV to 0.5mV to obtain the total measurement error, \pm 0.9mV. This means that the measurement at 1750.0mV is accurate to \pm 0.9mV. When the error is included the actual voltage will be between 1749.1mV and 1750.9mV.

So, let’s write the formula: $(1750.0\text{mV} \times (0.025/100)) + (5 \times 0.1\text{mV}) = 0.9375\text{mV}$ which we round to 0.9mV to match the resolution of the instrument.

A Typical Specification Graph

Probably the best way to see the effect of meter specifications on a measurement is to examine a graph of instrument specifications covering the entire measurement range. Here is a graph of the Fluke 189 specifications shown above. The graph plots the voltage

along the “X” axis and the error as a percentage of reading along the “Y” axis. Each abrupt change is a range change point for the instrument, i.e. 50mV, 500mV, 3000mV, 5V, 50V, 500V. The graph shows you the effect the “number of least significant digits” or “floor” specification has on measurement accuracy as the input voltage decreases to the range change point. Again, as stated earlier, this occurs because the floor specification is a fixed value that is always added into the error calculation. From a measurement perspective it is obvious that your most accurate measurements are always made as high up on a voltage scale as possible.



What’s the Point

As multimeter specifications are examined it is important to determine your measurement requirements, voltage and accuracy, before you consider which digital multimeter to use. One of the biggest mistakes made when considering measurement accuracy in selecting a multimeter is that resolution is equal to accuracy. This is never true! Complete specifications will include a “floor” which is a fixed error that must be added to the error calculated using the “percent of reading” part of the specification. Your best measurement accuracy or least measurement error comes from an instrument that has the lowest “percent of reading” and “number of least significant digits” (“counts”) specification.

Understanding digital multimeter specifications isn’t difficult when you realize that they consist of two independent variables that must be taken into account. Once you have calculated the errors associated with each variable and summed them you have the possible measurement error in volts, ohms, or whatever function you have selected. The calculations are simple and once you’ve performed them you will know what to expect when you make your measurements.