Facts about true-rms measurement

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By Chuck Newcombe

A while back I was asked by a young acquaintance, "How did you measure ac accurately before there were true-rms DMMs?" My answer was, "Very carefully," and it's true!

In 1961, when I first began work in a measurement standards laboratory, there were three kinds of precision rms meters available to me. The available types were all analog; the electrodynamic, the iron vane, and the thermocouple. They were all fragile, requiring careful handling to achieve accurate measurements and avoid damage. They were also slow to respond, and presented a significant load to the measured circuit.

How different it is today, with many digital multimeters featuring true-rms ac measurement capability. Today's meters are rugged, respond quickly, are more sensitive, and present the results with easy to read, digital clarity. But there are some subtle points you should be aware of when making rms measurements.

Most DMMs today measure the ac-coupled true-rms signal, rejecting the dc component, if any is present. A few models, such as the Fluke 189, offer the additional option of measuring ac+dc true-rms, calculating the total rms value with the dc component present. Why the difference? When should you use one versus the other?

In a properly operating power distribution system supplied through transformers, only ac should be present, so the ac-coupled measurement offered by most DMMs is appropriate. And, when a diode fails in a motor drive rectifier circuit, it's usually more effective to detect the failure by observing a reading in the dc voltage function which rejects the ac component.

Then, there's the case where you would like to trace an audio signal through an amplifier circuit. That signal might exist on the collector of a transistor where a dc bias current is also present. Here again, when you want to separate the ac and dc components, the ac-coupled mode of the DMM is the correct one to use.

One case for measuring ac+dc occurs in the output of an unfiltered dc power supply where a significant ac ripple voltage is present on the dc signal. Since a resistive heater or incandescent lamp connected to such a supply will respond to the total energy available, an ac+dc measurement will more accurately indicate how the load might react.

What can you do if you have only the ac-coupled rms measurement capability in your DMM and you want to measure the combined ac and dc energy? Bring on the calculator.

You can first measure the ac voltage and then the dc, recording both values. Next, you square both terms and add these squared values together. Finally, you take the square root of the sum and you have the ac+dc true-rms value of the signal.

A variation of this technique may be used to investigate the ac output of an electronic motor drive by using the low pass filter function available on the Fluke 87V.

The primary signal of interest on the output of such a drive is the low frequency signal that drives the motor. The low pass filter of the 87V isolates this signal so you can make accurate measurements of its frequency and true-rms voltage.

When you don't use the filter, you get a much higher reading, because the measured signal now includes all the switching voltages used to create the motor drive voltage.

To determine the rms value of this difference, you can do the following:

- Measure the total voltage and record the value.

- Measure the voltage with the low pass filter on and record that value.

- Now, square both terms and subtract the second squared value from the first.

- Finally, take the square root of the result and you will have the true-rms value of all the excess energy that was not filtered, within the bandwidth of the meter's input.

For you mathematicians, here are the equations used in the above examples:

$$V_{AC+DC} = \sqrt{V_{AC}^2 + V_{DC}^2}$$
$$V_{High\ Frequency} = \sqrt{V_{Total}^2 - V_{Low\ Pass}^2}$$

If you try either of these methods, you will discover that the results are much different than you might get by

simply adding or subtracting the original readings. That's because the signals you are working with are not coherent, meaning that they are not of the same frequency and phase.

One case where rms results may be added or subtracted directly is at your household panel, where the sum of the two 120V legs is indeed 240V. Those two signals are coherent.

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