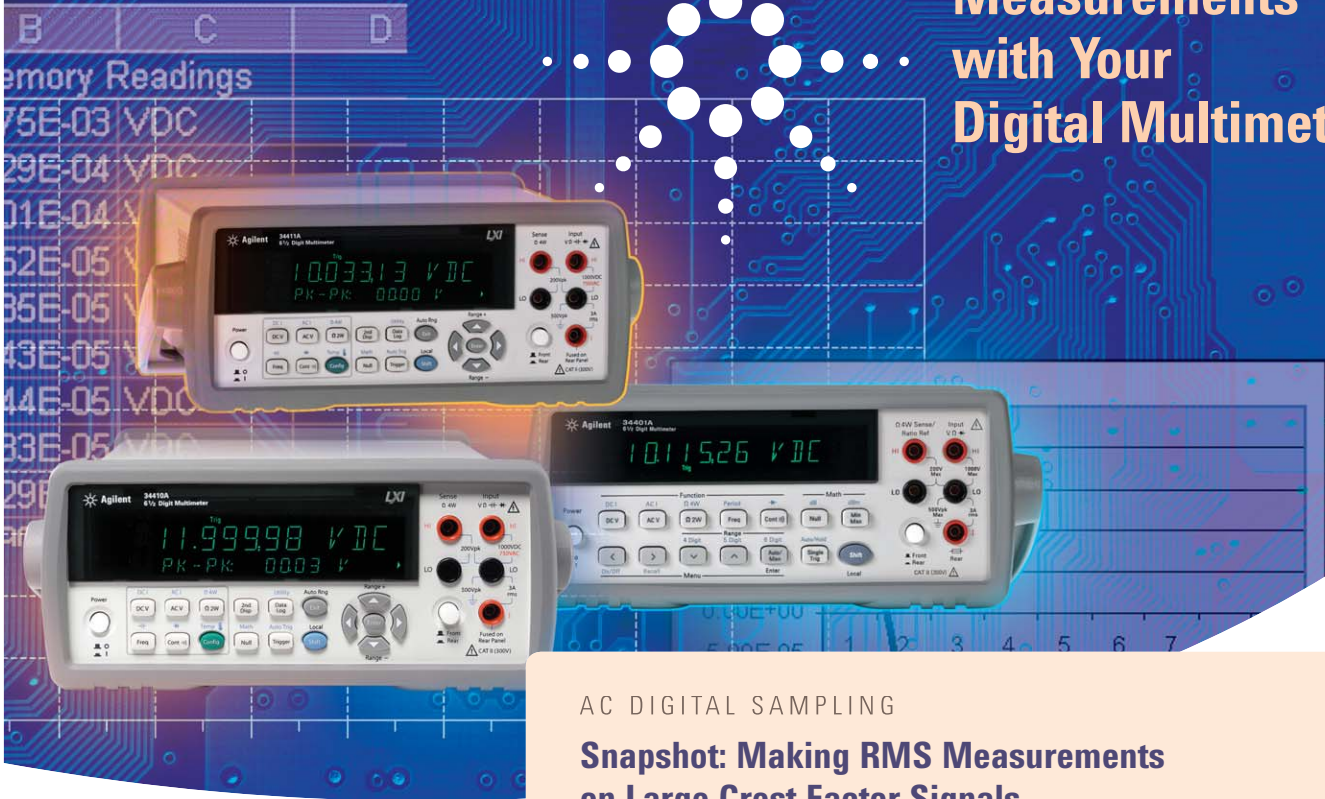


MEASUREMENT TIPS

Volume 5, Number 2

Make Better AC Measurements with Your Digital Multimeter



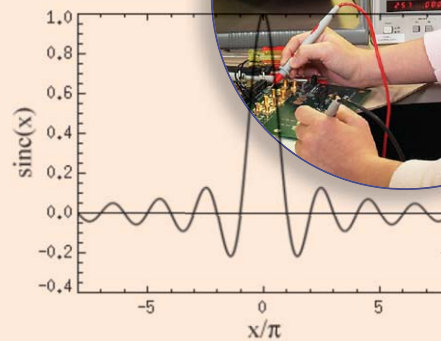
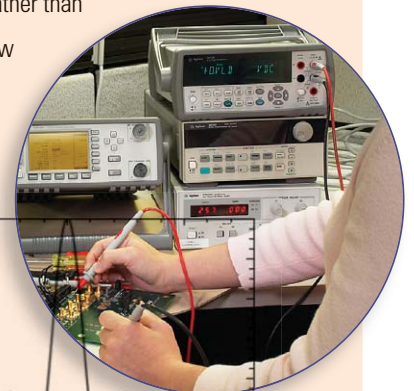
When you use a digital multimeter to measure AC voltages, it is important to know how your DMM makes the measurements and understand your instrument's limitations.

A True RMS (root-mean-square) AC measurement is often described as a measure of the equivalent heating value of the signal, with a relationship to the power dissipated by a resistive load driven by the equivalent DC value. Over the years, true RMS responding multimeters have used a number of techniques to measure this "heating" potential of an applied AC voltage. These techniques have included applying the AC signal to a thermopile and monitoring the resultant temperature, using hardware to generate the root, mean and square functions in an AC-to-DC converter, and employing digital sampling techniques to measure AC. This measurement tip will discuss the advantages and drawbacks of these techniques, as well as describe good practices and cautions regarding making AC measurements.

AC DIGITAL SAMPLING

Snapshot: Making RMS Measurements on Large Crest Factor Signals

An engineer was attempting to measure the RMS value of a 16 kHz repetition rate SINC waveform with a positive peak voltage of 1.0 volts and a negative peak voltage of -0.2 volts. She expected to get an RMS reading of 281 mV RMS. Instead, her DMM was reading 263 mV RMS, nearly 7% low. By using a different DMM that used a *digital sampling* technique rather than an *analog* technique for measuring RMS, the new reading was 280.6 mV RMS. The duty cycle of the SINC pulse was creating an error in the analog circuitry that resulted in the lower than expected result.



Agilent Technologies

AC-to-DC Converter Effects on RMS measurements

One of the considerations in making RMS measurements with a DMM is the type of AC-to-DC converter used to make the measurement. The thermal technique mentioned earlier is rarely used today. Instead, two techniques are employed, one being analog and the other being digital.

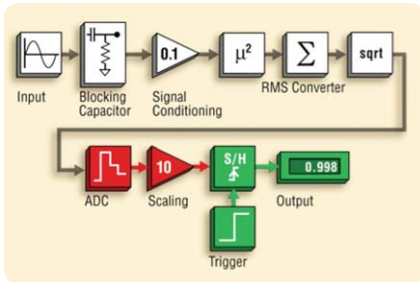


Figure 1. Block diagram of an analog AC converter

Analog AC converter

Many mid-range and high-end DMMs use a chain of analog circuits to compute the RMS value of the AC signal. The converter circuitry first squares the input signal. Next, it runs through a circuit that averages the signal. Finally, it passes through circuitry that generates the square root of the signal. The result is an RMS value, independent of the wave shape being applied. This method is fast, accurate and relatively inexpensive to implement. The required analog converters can fit onto a single chip and provide good performance/cost. There are, however, limitations regarding bandwidth, accuracy, crest factor, etc. Be sure to consult your digital multimeter's data sheet to understand these potential limitations for your particular application.

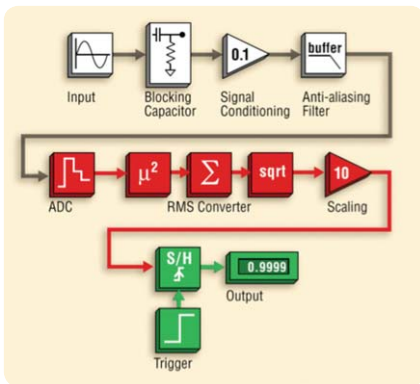


Figure 2. Block diagram of a digital sampling AC converter

Digital sampling AC converter

A second AC-to-DC converter technique uses direct digital sampling, which is similar to the technique used in modern oscilloscopes. An anti-aliasing filter is placed after the input signal conditioning, and the resultant output is applied directly to the A/D converter. The A/D converter digitizes the input signal at a high sample rate and then calculates the RMS value of the digitized waveform. This digital sampling technique has some advantages over the analog converter just described. For example, you can make faster measurements of AC, and better measurements of pulse trains and other low-duty-cycle signals. However, because of the anti-aliasing filter, high-frequency content such as harmonics will be lost above the bandwidth of the filter.

MEASUREMENT TIP

Some modern meters, such as the Agilent 34410A and 34411A DMMs use digital sampling techniques to measure RMS values. The front end samples the input signal at a 1.4 MHz rate and digitizes the input waveform. This sampling is running at all times, even when the meter is making DC voltage measurements. As a result, it is possible to make a DC voltage measurement and see the peak-to-peak AC measurements simultaneously in a second display.



Figure 3. An example of a DMM that can display both DC and AC voltage measurements simultaneously

Crest Factor Effects


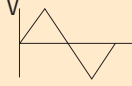
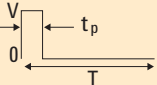
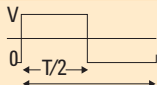
Waveform shape	Crest factor	AC RMS
	$\sqrt{2}$	$\frac{V}{\sqrt{2}}$
	$\sqrt{3}$	$\frac{V}{\sqrt{3}}$
	$\sqrt{\frac{T}{t_p}}$	$\frac{V}{CF} \times \sqrt{1 - \frac{1}{CF^2}}$
	1	V

Table 1: Crest factors (CF) for a variety of typical waveform shapes

MEASUREMENT TIP

Crest factor can affect the accuracy of your AC measurement. Traditionally, DMMs include a crest factor derating table that will show the errors introduced at higher crest factors. Often crest factors greater than 3 will begin to cause significant errors. In the case of the digital sampling RMS converter technique used in the Agilent 34410A and 34411A DMM, no additional errors are introduced for crest factors <10. Be sure to consult the data sheet for the DMM you use.

Crest factor is defined as the ratio of the peak value to the RMS value of a waveform. Some common crest factors are shown in Table 1. For a pulse train, the crest factor is approximately equal to square root of the inverse of the duty cycle. Notice however that for a pulse train, crest factor is a composite parameter, dependent on the pulse width and the repetition frequency. One of the advantages of using the digital sampling technique for AC converters described previously is that it is not inherently sensitive to crest factor.

Avoiding Common Measurement Traps

When you make AC measurements with a DMM, pay attention to the traps listed below.

- 1. Measurements below full scale:** Most meters specify AC inputs down to 5 or 10 percent of full scale, some even lower. For maximum accuracy, measure as close to full scale as you can. You might need to override auto scaling in some cases. Be careful with high-crest-factor signals not to overload and saturate the meter's input circuitry.
- 2. Settling time:** By definition, RMS measurements require time-averaging over multiple periods of the lowest frequency being measured. Be sure to select your DMMs appropriate low-frequency filter to allow for the fundamental to be captured. The lower the AC filter frequency is, the longer the settling time and hence the longer it will take to make the measurement.
- 3. First reading accuracy:** Many DMMs have a large-value DC-blocking capacitor in the input path. You need to allot sufficient time to allow this capacitor to charge, especially when you are measuring low-frequency signals or when you are switching between measurement points that have a large DC offset.
- 4. Low-level measurement errors:** When you measure AC voltages less than 100 mV, be aware that these measurements are especially susceptible to errors introduced by extraneous noise sources. An exposed test lead will serve as an antenna and the DMM will measure these unwanted signals as well. Reduce the area of the "antenna," use good shielding techniques, and make sure the AC source and the DMM are connected to the same electrical outlet to minimize ground loops.
- 5. AC loading errors:** The input impedance of a DMM is often in the region of 10 M Ω in parallel with 100 pF. The cabling you use to connect signals to the multimeter adds additional capacitance and loading. As frequency increases, loading will change. For example, at 1 kHz, the input resistance will now be closer to 850 k Ω , and at 100 kHz it will be closer to 16 k Ω .
- 6. Harmonic content:** Signals that are rich in harmonics can produce low reading measurements if the more significant of these components are not included in the measurement. Conversely, it is also possible to measure a higher-than-actual value if only the fundamental is measured. It is important to check the DMMs data sheet to see how much bandwidth you have to work with.

Summary

Making accurate true RMS AC measurements with modern DMMs is simple and straightforward and results in consistent and accurate measurements. However, you need to avoid common traps and pay attention to details. Know your meter and its limitations and use good measurement techniques and you should get accurate results.



Agilent Email Updates

www.agilent.com/find/emailupdates

Get the latest information on the products and applications you select.



www.lxistandard.org

LXI is the LAN-based successor to GPIB, providing faster, more efficient connectivity. Agilent is a founding member of the LXI consortium.

Agilent Channel Partners

www.agilent.com/find/channelpartners

Get the best of both worlds: Agilent's measurement expertise and product breadth, combined with channel partner convenience.



Learn more about Agilent's digital multimeter family at

www.agilent.com/find/dmm

Remove all doubt

Our repair and calibration services will get your equipment back to you, performing like new, when promised. You will get full value out of your Agilent equipment through-out its lifetime. Your equipment will be serviced by Agilent-trained technicians using the latest factory calibration procedures, automated repair diagnostics and genuine parts. You will always have the utmost confidence in your measurements. For information regarding self maintenance of this product, please contact your Agilent office.

Agilent offers a wide range of additional expert test and measurement services for your equipment, including initial start-up assistance, onsite education and training, as well as design, system integration, and project management.

For more information on repair and calibration services, go to:

www.agilent.com/find/removealldoubt

www.agilent.com

For more information on Agilent Technologies' products, applications or services, please contact your local Agilent office. The complete list is available at:

www.agilent.com/find/contactus

Americas

Canada	(877) 894 4414
United States	(800) 829 4444

Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Thailand	1 800 226 008

Europe & Middle East

Austria	43 (0) 1 360 277 1571
Belgium	32 (0) 2 404 93 40
Denmark	45 70 13 15 15
Finland	358 (0) 10 855 2100
France	0825 010 700* *0.125 €/minute
Germany	49 (0) 7031 464 6333
Ireland	1890 924 204
Israel	972-3-9288-504/544
Italy	39 02 92 60 8484
Netherlands	31 (0) 20 547 2111
Spain	34 (91) 631 3300
Sweden	0200-88 22 55
Switzerland	0800 80 53 53
United Kingdom	44 (0) 118 9276201

Other European Countries:

www.agilent.com/find/contactus

Revised: April 28, 2010

Product specifications and descriptions in this document subject to change without notice.

© Agilent Technologies, Inc. 2010

Printed in USA, June 24, 2010

5990-3219EN



Agilent Technologies