Keysight Technologies
Measuring Difficult AC Signals with a Digital Multimeter

Application Brief

Test Challenges:

- Measuring high peaking AC signals
- Characterizing an energy harvesting device

KEYSIGHT TECHNOLOGIES

Overview

Ideal AC signals used in electronics and power supplies are considered to be sinusoidal waveforms. In the real world; however, AC voltages and currents are anything but ideal. Instead, they can take on widely varying shapes and values. See how the Keysight True*volt* Series of digital multimeters (DMMs) can help you more quickly and easily characterize, analyze and understand your AC waveforms.

Measuring high peaking AC signals

You are designing a switching power supply and need to characterize the apparent power factor when the supply is loaded. With a capacitive load, the input current is not a pure sinusoid. Often times, it is a signal that has large peaks compared to its Root-Mean-Square (RMS) level. This can lead to measurement errors when using a DMM. Using the True*volt* Series of DMMs from Keysight Technologies you can obtain accurate AC current measurements, even if the peak value is 10 times greater than the RMS value.

Characterizing an energy harvesting device

With new technology comes new measurement challenges. In the energy harvesting industry, for example, the signal levels are low and often non-repetitive. Devices like piezoelectric generators create AC signals from intermittent or continuous mechanical stress. Characterizing these types of signals requires excellent measurement resolution and the ability to discern non-continuous waveforms. The True*volt* Series of DMMs not only measures these types of low-level signals, but can also help you visualize ugly AC signals with its, digitizing capability.

Understanding your AC waveform

Not every signal is going to be ideal—that's a fact. It's also a fact that as humans, it is easier to understand things if we can visualize them. This is especially true for waveforms.

Using the digitizing capability of the 34465A and 34470A True*volt* DMMs, you can visualize and characterize your AC waveforms to help you better understand their shape. Traditionally this has been accomplished using an oscilloscope, but these instruments are often limited to two digits of amplitude resolution. With a True*volt* Series DMM, you can digitize your waveforms with a minimum of 4½ digits and up to 7½ digits of resolution.

The 34465A and 34470A DMMs have deterministic sampling intervals and sampling modes that allow you to digitize your signal. Other digitizing capabilities available in the DMMs include the ability to digitize directly from the front panel using the graphical display and advanced trigger configurations (e.g. level-based triggering and logging measurements to memory for post analysis).

For those who prefer using a PC for digitizing, Keysight's BenchVue software can be used to set up the measurement. Both BenchVue and the True*volt* DMM front panel allow you to visualize your signal with more resolution than you would typically get from an oscilloscope. Furthermore, using a DMM for digitizing has the added benefit of allowing you to digitize current or voltage without the complexity of external current shunts, clamps or voltage dividers.

Measurement tip

With the True*volt* Series of DMMs you can analyze your AC measurements using the built-in statistics, trend chart or histogram displays. You can also save your readings to an internal storage, a USB thumb drive, or use BenchVue software to easily transfer your reading to a PC.

www.keysight.com/find/BenchVue

Higher crest factor helps you get the whole signal

While digitizing waveforms might allow you to see a few cycles of the waveforms, if you are interested in the RMS amplitude or frequency of your AC waveform over time you'll need to make AC measurements. The True*volt* Series of DMMs use a proprietary digital AC circuit that enables faster AC measurements and higher accuracy when compared to older DMM architectures.

One AC component that is often overlooked is the crest factor. The True*volt* Series of DMMs not only have one of the highest crest factor measurement capabilities in their class, but also are able to measure double that possible with previous generation DMMs.

The crest factor is defined as the ratio of peak value to RMS value in a waveform. Mathematically it can be expressed as:

Crest Factor (peak-to-RMS ratio) = (peak value)/(RMS value).

Remove period

Figure 1 depicts an extreme case where the peak value is much higher than the RMS value.

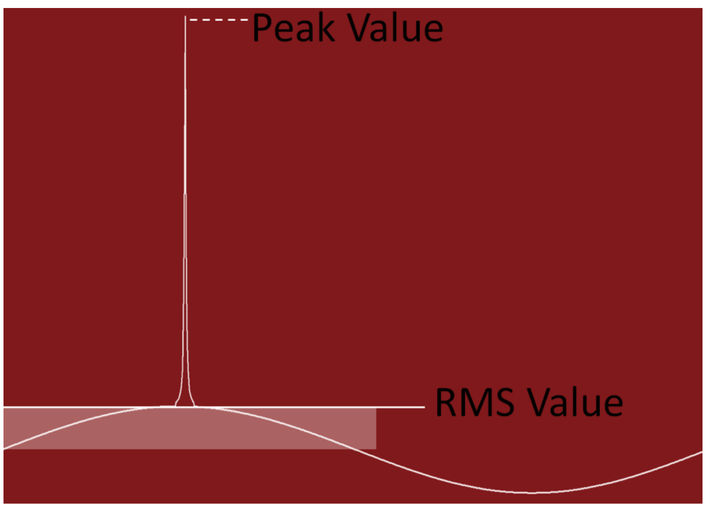

Figure 1. This image illustrates an AC signal with a large peak to RMS value.

Measurement tip

The True*volt* Series of DMMs connected to your PC via a USB cable can be accessed like a USB drive. Your DMM shows up as a drive. You can access your saved readings by simply dragging and dropping to your PC.

A DMM's crest factor represents how much of the total energy from the peak value will be included in an AC measurement. Ideally, you would like to include as much of the total energy in the waveform as possible to get an accurate measurement. For a measuring instrument, the crest factor expresses the size of the dynamic range for an input signal. We define the crest factor as the size of the dynamic range based on rated range value (RMS value). Since the True*volt* Series of DMMs have a crest factor rating of 10, it is possible to measure an input signal whose peak value is ten times larger than that of the rated range value.

Consider, for example, the readings of a 34401A DMM that uses an older analog AC circuit design compared to the measurements of a 34465A DMM with the improved digital AC. Note that many DMMs out on the market today still use older analog AC circuit designs. Figure 2 shows the digitized input signal using the built-in digitizing capability of the 34465A DMM. Notice that the majority of the energy is around 1-V RMS, but the signal has a very high peak, close to 10 V. It is in this area where the measurement accuracy of the 34465A DMM makes a difference.

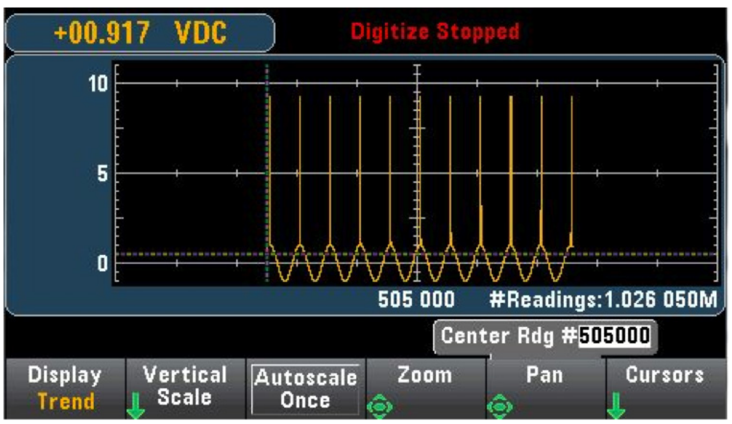

Figure 2. Shown here is digitized AC voltage with large crest factor.

Figure 3 shows the AC readings that were obtained from two DMMs employing BenchVue software. The 34465A DMM readings are on the bottom panel, while the older 34401A DMM readings are on the top. Notice that the readings on the 34465A DMM are higher than that of the 34401A DMM's readings. The difference is 52 mV, which equates to a 6 percent amount error. This error is significant compared to a normal AC specification of less than 0.2 percent.

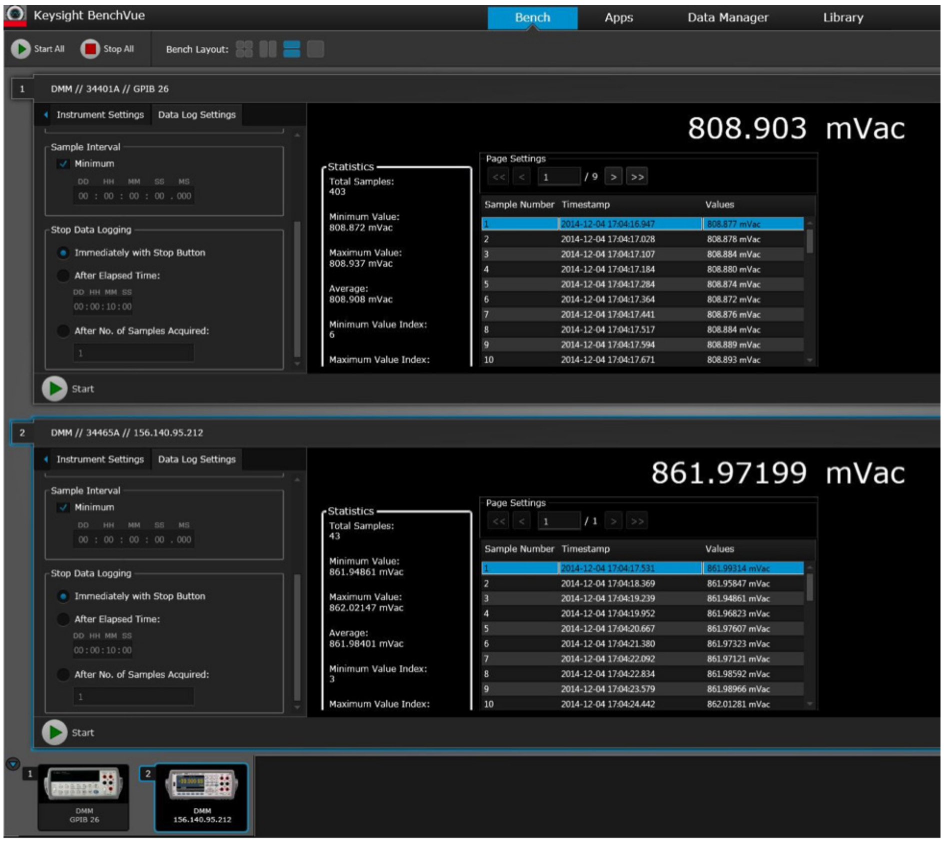

Figure 3. This display compares two parallel DMM readings. The reading taken with the 34465A DMM, at the bottom, measures the complete AC signal and hence, explains the higher reading value.

Measurement tip

You can use the dual display features of the 34465A/34470A DMMs to measure frequency concurrently with your AC signals. See more dual display modes with the following Keysight application brief "Faster Data Analysis with Graphical Digital Multimeter Measurements" publication number 5992-0421EN.

Another area where crest factor is important is when measuring pulsed signals. That's because for many DMMs it can be challenging to accurately read the RMS voltage/current when a signal level that has an "on" period is followed by a period where no activity occurs. With the larger crest factor of the True*volt* Series of DMMs; however, you can achieve better accuracy—even when the pulse ratio changes.

As an example, consider a 7-V RMS sine wave running at 10 KHz, which translates to a period of 10 ms. Any 6.5-digit DMM will measure this type of signal with minimal issues. Where the True*volt* Series of DMMs standout; however, is when the number of sine pulses in the input signal is reduced. Figure 4 shows a digitized pulsed waveform with a single sine pulse of 0.1 ms, followed by a quiet period of 9.9 ms. The total period is still the same at 10 ms. The new signal represents a drop in power of 100:1, while the RMS voltage drops 10:1, when compared to the original.

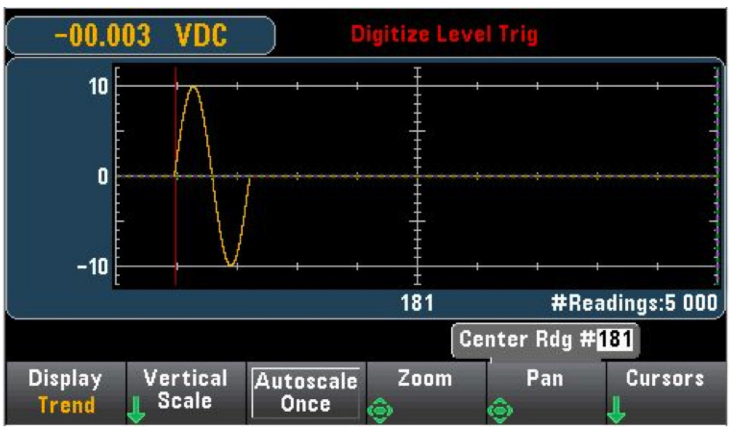

Figure 4. Shown here is an example of a digitized waveform.

Given these results, we would expect that the voltage would be one tenth of our original signal's 7 V. The expected result should be 0.7-Vac. However, as can be seen in Figure 5, only the True*volt* Series DMM gives an accurate reading of 0.69987 V. The older analog AC measurement produces a 0.4677 V reading! The old DMM now has an error of 0.23 V or 35 percent from nominal! Again, it is the True*volt* Series DMM's superior handling of crest factor that enables a more accurate measurement on this challenging signal.

Figure 5. In this graphic, 1/10th of the V_{RMS} is measured accurately by the 34465A (bottom measurement).

Green energy example

Energy harvesting is the industry term for scavenging and accumulating ambient energy that has historically been deemed unusable, and converting it to a usable power source. Examples of ambient energy sources include solar, wind, vibrations from a motor, or even RF energy from ambient radio transmitters. Today there are a number of devices on the market to harvest these sources, and electronics manufacturers are continuing to investigate methods for making them more efficient.

One such device that is used to convert mechanical vibrations to usable power is a piezoelectric generator (Figure 6). This device is designed to harvest the otherwise wasted vibration energy and convert it to power that can be used directly or saved to a battery. However, the power generated by this type of device is understandably small — often times, its maximum power output is less than 1 mW and this depends on the magnitude of the vibration source.

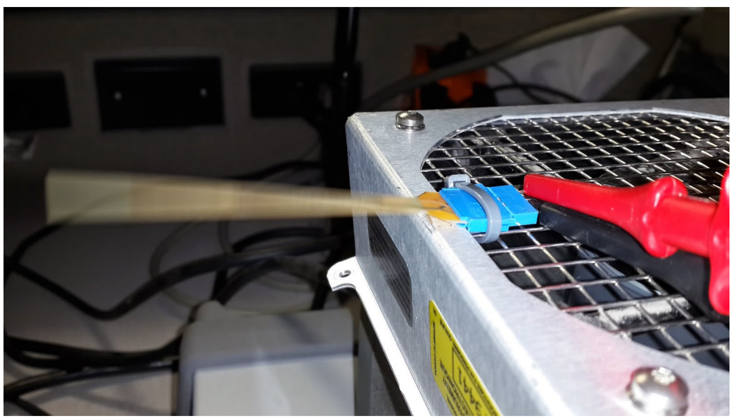

Figure 6. In this image a piezoelectric generator is attached to a vibration source — in this case, a fan.

The AC performance of the True*volt* Series of DMMs can be useful for characterizing energy harvesting devices such as piezoelectric generators. These generators are typically mounted on mechanical devices with very irregular vibration cycles. As such, the current output of these generators can vary from a very large signal to a small signal. With a True*volt* Series DMM, you can visualize the current and then measure the AC signals accurately. Figure 7 shows a digitized current that starts with a large magnitude (when the device is vibrating) and decays rapidly. The digitized picture also shows the AC nature of piezoelectric devices.

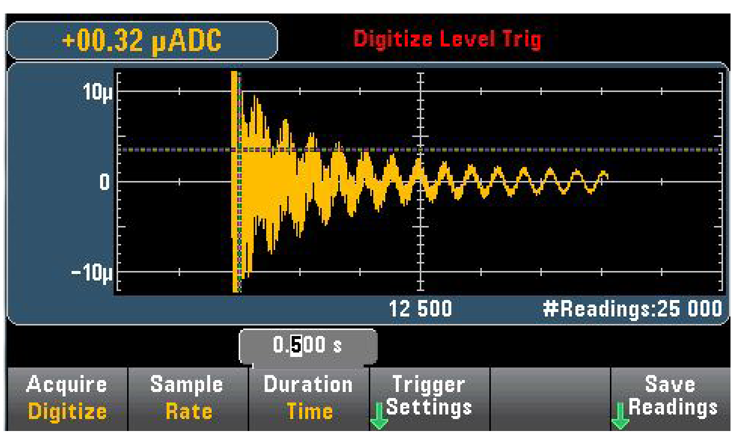

Figure 7. The digitized current from a piezoelectric generator device.

Since we now know that our device outputs an AC signal, we can measure the AC current of the device and characterize this over time and different conditions. In Figure 8, you can easily see that the vibration source has varying "on" periods and quiet periods. By using an AC measurement, we can measure the total RMS current generated. We can then use the in-box statistics to understand the value of our average output current. We also can save and transfer the readings to a PC for further analysis. With the improved AC techniques of the True*volt* Series of DMMs, you can trust these results to be accurate.

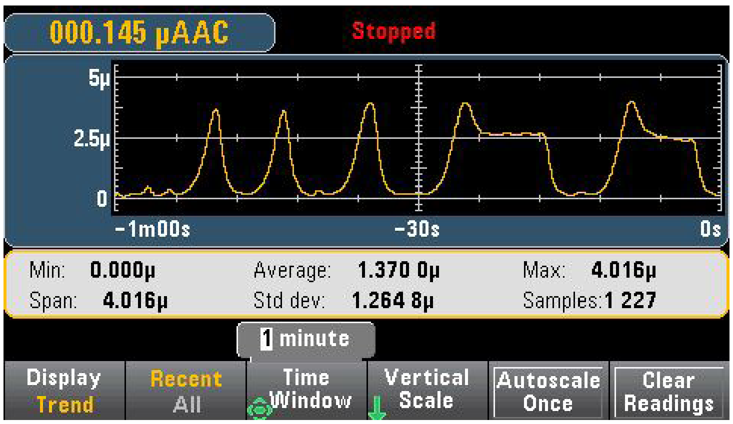

Figure 8. Shown here is the characterization of a piezoelectric generator connected to a vibration source.

Summary

The True*volt* Series of DMMs can accurately measure your AC signals. Whether you have a typical AC signal or a signal that is more challenging, you can use its digitizing feature to help you visualize and better understand your signal. You can then use its AC measurements to characterize your signals.

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