Keysight Technologies
Overcome Your Test Challenges with True*volt* Series Digital Multimeters
34465A and 34470A

Application Compendium

A compendium of six 34465A and 34470A test challenge application briefs

KEYSIGHT
TECHNOLOGIES

Unlocking Measurement Insights

Introduction

In a rack or on a bench real-world signals are never flat. They have some level of AC signal riding on top from power line noise, other environmental noise, or injected current from the meter itself. How well your meter deals with these extraneous factors and eliminates them from the true measurement makes a big difference to your accuracy. Behind the scenes, Keysight's Truevolt Series digital multimeters (DMMs) account for measurement errors created by these real-world factors so you can be confident in your measurements.

Truevolt DMMs utilizes an analog-to-digital converter that enables a patented metrology-grade architecture. Using this architecture, Keysight delivers a good balance of measurement resolution, linearity, accuracy, and speed at a value price, all derived and guaranteed per ISO/IEC 17025 industry standards.

Some of the key test challenges for which the Truevolt Series DMMs are especially well suited are included in the following application briefs:

Achieving Enhanced Digital Multimeter Accuracy in the Presence of Temperature Variation

Overview

Accurate measurements with a benchtop or system Digital Multimeter (DMM) are very important. However, an often overlooked specification adder is the Temperature Coefficient (TC). The basic premise of a TC specification is that if you are using your DMM at a temperature that is not the same temperature at which you calibrated the instrument, then you need to add an error to account for the TC specification. Most DMMs are calibrated in a temperature controlled environment, nominally at 23 °C. However, often times DMM's are used in real-life environments where the temperature is not the same as the calibration lab. See how the latest True*volt* Series DMMs can help minimize this TC specification adder.

Making highly sensitive, accurate measurements in a lab with variable temperature

You need to make highly sensitive measurements with your DMM, while maximizing accuracy. However, the temperature of your lab can vary by a few degrees over the course of a day. This temperature variation has a direct impact on the accuracy of your measurements and can affect the quality of your data; especially if your lab's working temperature is not the same as the temperature at which the DMM was calibrated.

The True*volt* Series DMMs for Keysight Technologies features built-in autocalibration designed to help minimize errors due to temperature drift. Using these instruments allows you to make your measurements with the added assurance that autocalibration will help adjust for any errors.

Making DMM rack measurements when the internal system temperature is higher than ambient

You have mounted your DMM into a rack. Like a good system designer, you have controlled air flow and temperature monitoring. Even with these precautions, the internal temperature of your system is 15 °C higher than ambient due to the other instruments in your system. With a 15 degree rise, your DMM reading specifications are now higher than design tolerances with the TC specification adders. Since you designed in a True*volt* Series DMM with autocalibration, you can reduce the TC adders up to 5x and still stay within your specification budget for your DMM measurements.

Achieving Enhanced Digital Multimeter Accuracy in the Presence of Temperature Variation *(continued)*

DMM specifications

If you look at a DMM datasheet you will normally find 90-day and 1-year specification columns. These columns are populated with percentage of reading and of range, and are based on the measurement that you are taking. Table 1 shows the datasheet for the new 34465A 6.5 digit DMM. The inclusion of 24 hour, 90 day, 1 year, and TC columns are common for high-end DMMs.

To calculate your accuracy specification, consider an example when the DCV 10-V range is used to measure 9 V. In this case, your 1-year specification (based on Table 1) would be calculated as 0.0035% reading+0.0005% range, or: 9 V * 0.003%+10 V * 0.0004% = 0.00027 + 0.00004 = 0.00031 V

Consequently, the accuracy you would expect is 9 V ± 0.31 mV

If your measurement environment—the ambient temperature where the DMM is operating—is not the same as the temperature of the DMM calibration, then you need to consider the TC error adder. For example, a unit was calibrated at 22 °C, but is operating at 40 °C inside of a test system. Such a rise in temperature is common in test sets inside of a system rack. We need to add in error due to TC specifications. From Table 1, the right most column contains the TC specification. For each degree C, the specification adder is: 9 V * 0.0005%+10 V * 0.0001% = 0.000045 V+0.00001 V = 0.000055 V (0.055 mV)

For the True*volt* 34465A DMM, the 1-year specification applies for temperatures ± 2 °C of the calibration temperature. If you are outside of the 2 °C range, in our example the threshold is 24 °C, then you need to add in the TC specification for each degree. In the example cited here that would mean adding in 16 °C of TC adder.

The total specification for this example would be: 9 V ± (0.00032 + 16 * 0.000055) = 9 V ± 0.00119 V (1.19 mV), which represents a 385 percent increase in your potential measurement error!

Specification ± (% of reading + % of range)

Range	24 hours $T_{ACAL} \pm 1$ °C	90 days $T_{ACAL} \pm 2$ °C	1 year $T_{ACAL} \pm 2$ °C	2 years $T_{ACAL} \pm 2$ °C	Non ACAL temperature coefficient/°C	With ACAL temperature coefficient/°C
DC voltage: 34465						
100 mV	0.0030 + 0.0030	0.0040 + 0.0035	0.0050 + 0.0035	0.0065+ 0.0035	0.0005 + 0.0005	0.0002 + 0.0005
1 V	0.0015 + 0.0004	0.0025 + 0.0004	0.0035 + 0.0004	0.0050 + 0.0004	0.0005 + 0.0001	0.0002 + 0.0001
10 V	0.0010 + 0.0003	0.0020 + 0.0004	0.0030 + 0.0004	0.0045 + 0.0004	0.0005 + 0.0001	0.0002 + 0.0001
100 V	0.0020 + 0.0006	0.0035 + 0.0006	0.0040 + 0.0006	0.0055 + 0.0006	0.0005 + 0.0001	0.0002 + 0.0001
1000 V	0.0020 + 0.0006	0.0035 + 0.0006	0.0040 + 0.0006	0.0055 + 0.0006	0.0005 + 0.0001	0.0002 + 0.0001

Figure 1. Shown here are the 34465A DCV specifications.
Please refer to the True*volt* Series DMM data sheet, publication number 5991-1983EN, for additional specification details.

Achieving Enhanced Digital Multimeter Accuracy in the Presence of Temperature Variation *(continued)*

Truevolt autocalibration

The new 34465A and 34470A Truevolt Series DMMs feature autocalibration (ACAL), which greatly reduces temperature drift error. ACAL is the built-in ability of the DMM to compensate for temperature drift and internal errors. This is also known as self calibration. The only other Keysight DMM with ACAL is the high-end 3458A with its high-end price;
a bestselling 8.5-digit DMM. The new 34465A and 34470A Truevolt DMMs at 6.5 digits and 7.5 digits, respectively, are lower performance and with prices at a fraction of the cost of the 3458A.

The 34465A and 34470A Truevolt DMMs feature ACAL circuitry that adjusts the calibration for DCV, OHM and the internal Analog-to-Digital Converter (ADC) circuitry. Keysight designers were able to optimize the calibration for cost, accuracy and speed. The ACAL operation is a short 15 to 20 seconds; greatly improved over the 3458A ACAL DMM operations, which could take 12 minutes to complete.

With this improved ACAL, Keysight is able to optimize the circuit design to offer a high-end DMM that is price competitive with non-ACAL DMMs. This economical solution is ideal for high accuracy needs in DCV and Ohms functions, both of which are often the most challenging measurements for engineers needing the most accuracy.

In a higher accuracy DMM, temperature stability is a larger factor. Temperature variations affect voltage and ADC accuracy. With the 34465 and 34470A, the base specifications are applicable for TCAL ± 2 °C. This means that the specification would apply for a range of 21 °C to 25 °C if the unit was calibrated at 23 °C. While this range is tighter than most 6.5-digit DMMs, it is also wider than the 3458A, which is specified at TCAL ± 1 °C.

Because the 34465A and 34470A DMMs have a built-in temperature reference, it is easier to track the temperature at which your instrument was calibrated. The calibration menu shows what the current temperature is, the calibration temperature and the temperature change. Figure 1 illustrates the new information available in the calibration screen.
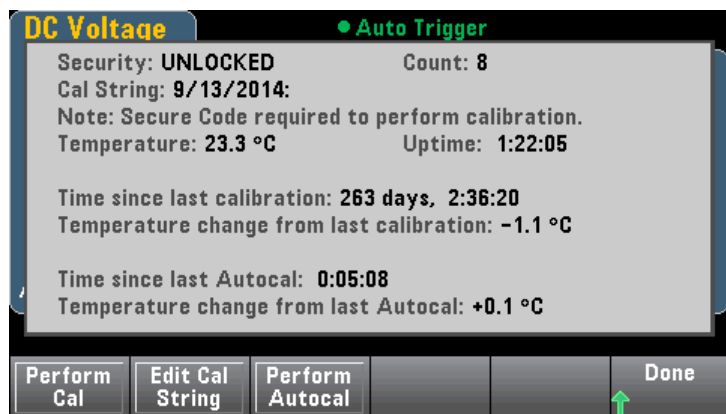

Figure 1. Shown here is the new 34465A and 34470A DMM calibration screen.

Achieving Enhanced Digital Multimeter Accuracy in the Presence of Temperature Variation *(continued)*

Better accuracy with ACAL

Now let's take a look at the specifications for the 34470A and see how the accuracy limits change if you perform ACAL. Using the same scenario previously presented (9-V DC reading, 10-V range, 22 °C cal temperature, and a 40 °C operating temperature), we can calculate the specifications using the table in Table 2;

1-year base accuracy = 9 * 0.0016% + 10 * 0.0002% = 0.000144 + 0.00002 = 0.000164 V (0.164 mV)

The base 1-year accuracy using a 34470A will be 9 V ± 0.164 mV.

There are two options for you here, depending on whether you choose to do an ACAL or not. If you skip the ACAL step, you would use the TC adder for the non-ACAL column. For each degree Celsius outside of the T_{CAL} ± 2 °C, you would add in the following:

9 V * 0.0005% + 10 V * 0.0001% = 0.000045 V + 0.00001 V = 0.000055 V (0.055 mV)

In this example, the base specification is applicable for 22 °C + 2 °C = 24 °C. Since we are operating at 40 °C, we need to multiply our TC adder by 16 degrees (40 °C-24 °C = 16 °C). Consequently, the final calculation is:

9 V ± (0.000164 + 16 * 0.000055) = 9 V ± 0.00104V (1.04 mV)

The TC adder increases the error potential to 1.04 mV. This is over 600 percent of the original specification!

However, since we can use the ACAL, we can greatly reduce the TC error. By performing an ACAL shortly before our most accurate measurements, we can usually assume that the temperature will not change by more than 2 °C.

Accuracy specification: DC voltage and resistance, automatic calibration (ACAL) capable, Specification ± (% of reading + % of range)

Range	24 hours T_{ACAL} ± 1 °C	90 days T_{ACAL} ± 2 °C	1 year T_{ACAL} ± 2 °C	2 years T_{ACAL} ± 2 °C	Non ACAL temperature coefficient/°C	With ACAL temperature coefficient/°C
DC voltage: 34470						
100 mV	0.0030 + 0.0030	0.0040 + 0.0035	0.0040 + 0.0035	0.0045 + 0.0035	0.0005 + 0.0005	0.0001 + 0.0005
1 V	0.0010 + 0.0004	0.0015 + 0.0004	0.0020 + 0.0004	0.0025 + 0.0004	0.0005 + 0.0001	0.0001 + 0.0001
10 V	0.0008 + 0.0002	0.0013 + 0.0002	0.0016 + 0.0004	0.0020 + 0.0002	0.0005 + 0.0001	0.0001 + 0.0001
100 V	0.0020 + 0.0006	0.0032 + 0.0006	0.0038 + 0.0006	0.0040 + 0.0006	0.0005 + 0.0001	0.0001 + 0.0001
1000 V	0.0020 + 0.0006	0.0032 + 0.0006	0.0038 + 0.0006	0.0040 + 0.0006	0.0005 + 0.0001	0.0001 + 0.0001

Table 2. Shown here are the 34470A DCV specifications.
Please refer to the True*volt* Series DMM data sheet, publication number 5991-1983EN, for additional specification details.

Achieving Enhanced Digital Multimeter Accuracy in the Presence of Temperature Variation *(continued)*

Using the new TC column with ACAL specifications, the TC adder is now:

9 V * 0.0001% + 10 V * 0.0001% = 0.000009 V + 0.00001 V = 0.000019 V (0.019 mV)
Multiplying by sixteen degrees we get:

9 V ± (0.000164 + 16 * 0.000019) = 9 V ± 0.000468 V (0.468 mV)

While the TC adder is still a large effect over the base specifications, the overall accuracy with ACAL is much better than the specifications without ACAL. The accuracy is widened by 285 percent and is more accurate than a non-ACAL DMM's specifications.

Table 3 compares the accuracy specifications for the 34465A and 34470A DMMs when used with the following scenario: 9 V, tested on a 10-V range, calibrated at 22 °C, used at 40 °C.

Model	Input voltage/range	Base spec at 22 °C	Specs w/TC at 40 °C	Specs w/TC and ACAL @ 40 °C
34465A	9 V/10 V range	± 310 µV	± 640 µV	± 424 µV
34470A	9 V/10 V range	± 164 µV	± 494 µV	± 278 µV

Table 3. 9-V input on a 10-V range, with calibration temperature at 22 °C and operating temperature at 40 °C.

For reference, Tables 4 and 5 are provided to allow you to compare the performance of the two DMMs.

Model	Input voltage/range	Base spec at 22 °C	Specs w/TC at 40 °C	Specs w/TC and ACAL @ 40 °C
34465A	50 V/100 V range	± 2.6 mV	± 8.2 mV	± 5.8 mV
34470A	50 V/100 V range	± 2.5 mV	± 8.1 mV	± 4.9 mV

Table 4. 50-V input on a 100-V range, with calibration temperature at 22 °C and operating temperature at 40 °C.

Model	Input voltage/range	Base spec at 22 °C	Specs w/TC at 40 °C	Specs w/TC and ACAL @ 40 °C
34465A/34470A	10 KΩ/10 KΩ range	± 0.45 Ω	± 1.57 Ω	± 0.93 Ω

Table 5. 10-KΩ input on a 10-KΩ range, with calibration temperature at 22 °C and operating temperature at 40 °C.

Summary

The operating temperature of your DMM can affect the accuracy of your readings. A DMM with ACAL capabilities can greatly minimize your TC errors. With an operation time of less than 20 seconds, ACAL is a task that you can run often to ensure optimal accuracy, as shown in the tables. The new 34465A and 34470A True*volt* Series DMMs can help ensure that your readings are accurate, even with temperature errors.

Measuring Difficult AC Signals with a Digital Multimeter

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.

Measuring Difficult AC Signals with a Digital Multimeter *(continued)*

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

Measuring Difficult AC Signals with a Digital Multimeter *(continued)*

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)

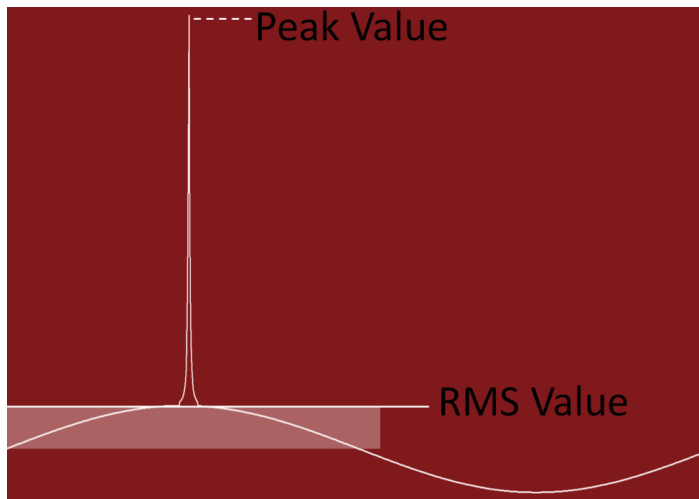Figure 1 depicts an extreme case where the peak value is much higher than the RMS value.

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.

Measuring Difficult AC Signals with a Digital Multimeter *(continued)*

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.
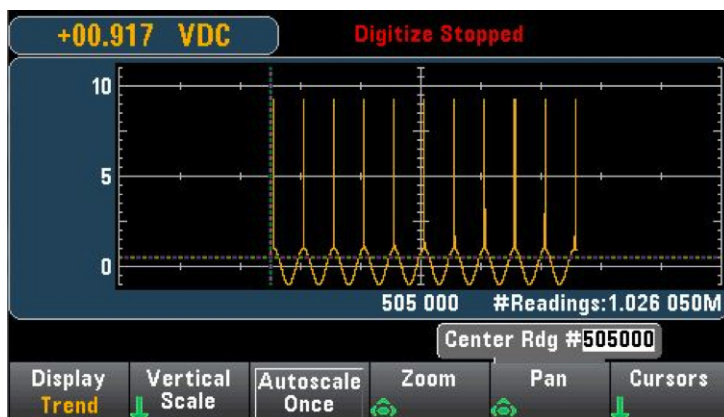

Figure 2. Shown here is digitized AC voltage with large crest factor.

Measuring Difficult AC Signals with a Digital Multimeter (continued)

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.

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.
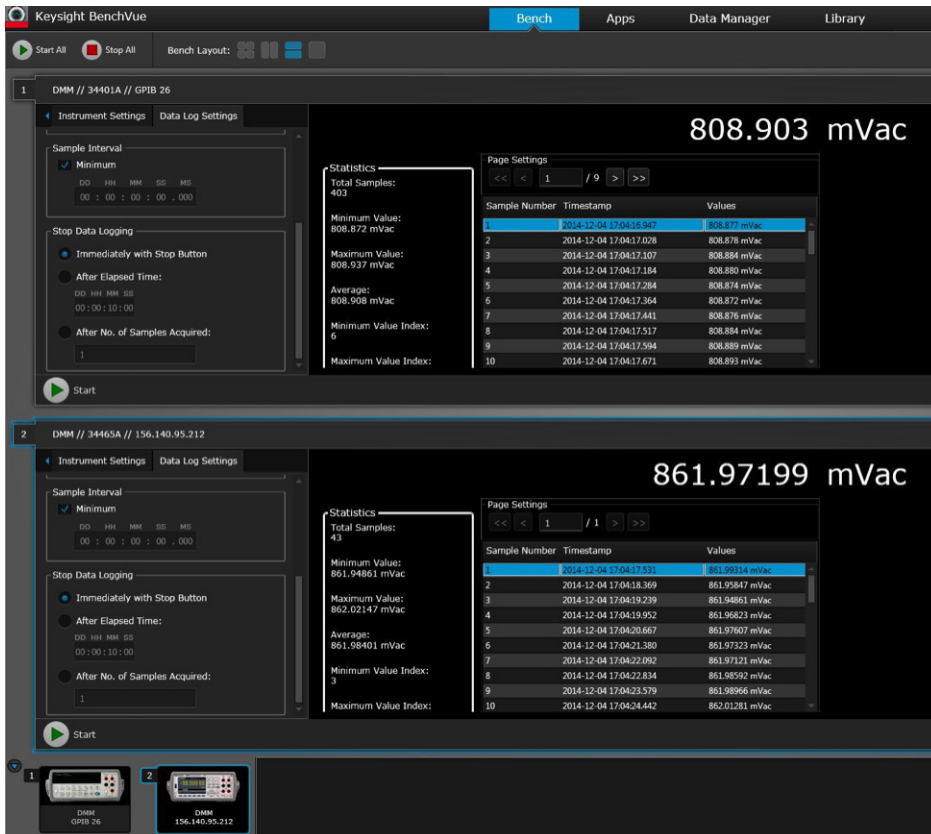

Figure 3. This display compares two parallel DMM readings. The reading taken with the 34465A DMM, at the bottom, measures the complete AC signal and hence, explains the higher reading value.

Measuring Difficult AC Signals with a Digital Multimeter (continued)

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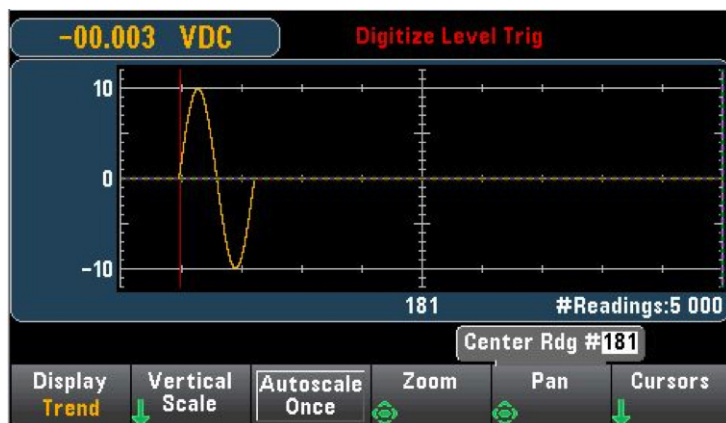
Figure 4. Shown here is an example of a digitized waveform.

Measuring Difficult AC Signals with a Digital Multimeter *(continued)*

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).

Measuring Difficult AC Signals with a Digital Multimeter *(continued)*

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.
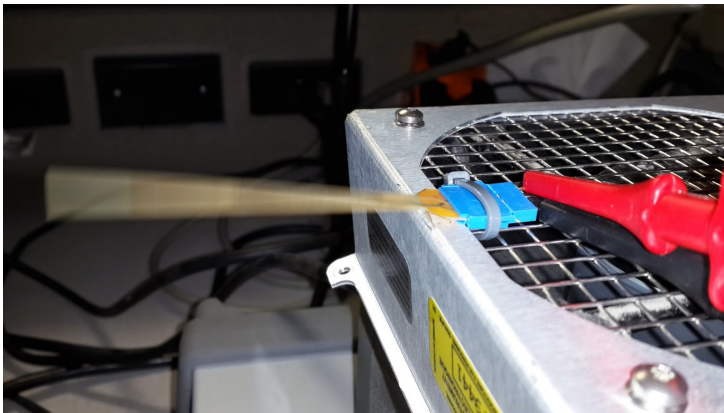

Figure 6. In this image a piezoelectric generator is attached to a vibration source — in this case, a fan.

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.
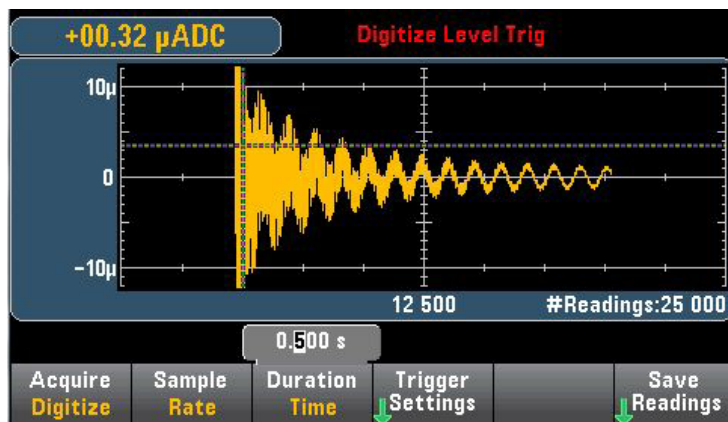

Figure 7. The digitized current from a piezoelectric generator device.

Measuring Difficult AC Signals with a Digital Multimeter *(continued)*

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.
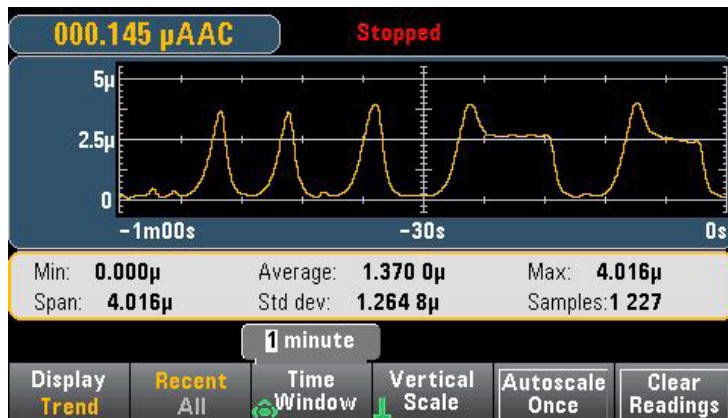

Figure 8. Shown here is the characterization of a piezoelectric generator connected to a vibration source.

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.

Measuring Low Current Consumption with a Digital Multimeter

Overview

DMMs measure current. It's one of the basic functions of a digital multimeter (DMM). These instruments are the go-to tool for most engineers and technicians when they need to make current or voltage measurements. Keysight has added additional current ranges to the True*volt* DMM series that allow you to measure a wider range of currents than other 6.5 digit DMMs. Learn some of the details on how expanded current ranges can help your measurements.

Characterizing the power consumption of a battery powered device

You are tasked with characterizing the power consumption of a battery powered device. Designers have optimized the device's current draw, but need complete measurements of the current from sleep mode to full operating load. To fully characterize the device's different current cycles, you decide to use a 34465A DMM. Its' 1-µA DC current range provides the pico-amp resolution needed to accurately characterize the sleep mode. It also has a high range, 10 A, which allows you to measure a wide range of currents for your battery powered device when operating in full load conditions.

Testing the current draw of a low leakage diode

You are testing the current draw of a low leakage diode. To do so, you need pico-amp resolution, but with the ability to measure forward currents with dozens of mA's. While you can perform these measurements with a more expensive electrometer, you might also be able to make them using a stable DC power supply and a new True*volt* DMM. The 34465A/34470A True*volt* DMMs feature a low DC current range of 1 µA, which allows for pico-amp resolution with less than 100 pA accuracy (1 year specs, depending on current reading) to accurately characterize leakage current. With a no-open circuit range change up to 3 A, you can characterize your device's backward and forward current without breaking the circuit.

Measuring Low Current Consumption with a Digital Multimeter
(continued)

DMM current readings

Many 6½ digit DMMs are limited to a 1-mA low current range when measuring DC. This offers a best case resolution of 1 nA. Other DMMs offer a 100-µA or 200-µA range, which in turn offers 100-pA resolution.

The new 34465A and 34470A True*volt* Series of DMMs feature a low current range of 1 µA, which in turn offers an exceptional 1-pA resolution. The new True*volt* DMMs also offer extended current ranges that are simply not available with other DMMs in this class. The new current ranges include 10 µA, 1 µA on the low end, and a 10-A range on the higher end (Figure 1). With pA resolution on the 1-µA range, the potential current measurements range from 1 pA to 10 A, resulting in 13 orders of magnitude to be measured by these DMMs.

Measurement tip

When measuring very small currents be sure to null your readings before your crucial measurement. Doing so removes any system related offsets, allowing the measurement to be more accurate.

Accuracy specifications: DC current and other DC functions
Specification ± (% of reading + % of range)

Range/frequency	24 hours T_{CAL} ± 1 °C	90 days T_{CAL} ± 5 °C	1 year T_{CAL} ± 5 °C	2 years T_{CAL} ± 5 °C	Temperature coefficient/°C
DC current					
1 µA	0.007 + 0.005	0.030 + 0.005	0.050 + 0.005	0.060 + 0.005	0.020 + 0.010
10 µA	0.007 + 0.002	0.030 + 0.002	0.050 + 0.002	0.060 + 0.002	0.015 + 0.006
100 µA	0.007 + 0.001	0.030 + 0.001	0.050 + 0.001	0.060 + 0.001	0.015 + 0.004
1 mA	0.007 + 0.003	0.030 + 0.005	0.050 + 0.005	0.060 + 0.005	0.015 + 0.005
10 mA	0.007 + 0.020	0.030 + 0.020	0.050 + 0.020	0.060 + 0.020	0.020 + 0.020
100 mA	0.010 + 0.004	0.030 + 0.005	0.050 + 0.005	0.060 + 0.005	0.020 + 0.005
1 A	0.050 + 0.006	0.070 + 0.010	0.080 + 0.010	0.100 + 0.010	0.050 + 0.010
3 A	0.180 + 0.0020	0.200 + 0.020	0.200 + 0.020	0.230 + 0.020	0.050 + 0.020
10 A	0.050 + 0.0010	0.120 + 0.010	0.120 + 0.010	0.150 + 0.010	0.050 + 0.010

Figure 1. Shown here are all of the new current ranges available with the 34465A and 34470A True*volt* Series of DMMs.
Please refer to the True*volt* Series DMM data sheet, publication number 5991-1983EN, for additional specification details.

Measuring Low Current Consumption with a Digital Multimeter
(continued)

Burden voltage

When measuring low levels of current, burden voltage can be a concern. Burden voltage is the change in potential created when current flows through the shunt resistor of a DMM. While this is not normally a concern, very sensitive components must be aware of the voltage, especially if the DMM is placed in series in the return path as shown in Figure 2. By adding a small voltage above the low of the power supply, the low of your device might well be above your design tolerance.

If the burden voltage gets sufficiently large, the offset voltage on the return path might cause a problem; depending on your device. The burden voltages of the 34465A and 34470A DMMs are shown in Figure 3.

Measurement tip

Consider moving the DMM in series to the positive side of your power supply. If you can increase the voltage to accommodate for the burden voltage, you can still supply the correct voltage to your device and measure current.
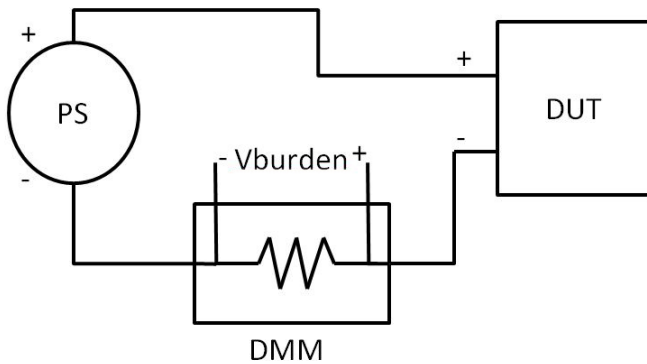

Figure 2. Shown here is the DMM in series on the return path.

DC and AC current burden voltage at full scale

DC current range	Burden voltage
1 µA	< 0.0011 V
10 µA	< 0.011 V
100 µA	< 0.11 V
1 mA	< 0.11 V
10 mA	< 0.027 V
100 mA	< 0.27 V
1 A	< 0.7 V/0.05 V[1]
3 A	< 2.0 V/0.15 V[1]
10 A	< 0.5 V

1. The second burden voltage can be obtained by using the 10 A range input.

Table 2. This table represents the burden voltages of the different current ranges of the 34465A and 34470A.

Measuring Low Current Consumption with a Digital Multimeter
(continued)

Dynamic current measurements

Dynamic current measurements can be quite complex due to the DMM range change based on the level of current you are measuring. Keysight offers specialized instruments (e.g., the Keysight N6782A SMU) that can digitize power, voltage and current without ranging issues. While this may be a great solution for current characterization, the solution is a bit more expensive than using a True*volt* DMM. In situations where budget or flexibility is a concern, the True*volt* DMM allows you to accomplish many of the same measurements.

Whether you are measuring the reverse and forward bias current of an LED or the sleep/operating mode current of a battery powered device, you will have a very large difference between the two modes of operation.

Figure 4 illustrates a simple block diagram for battery drain analysis. You can effectively monitor the power drain from your battery powered device using one DMM to monitor the voltage and another DMM to monitor the current. On the True*volt* DMMs, the 10-A input is separate from the low current input. This setup uses the low current input.
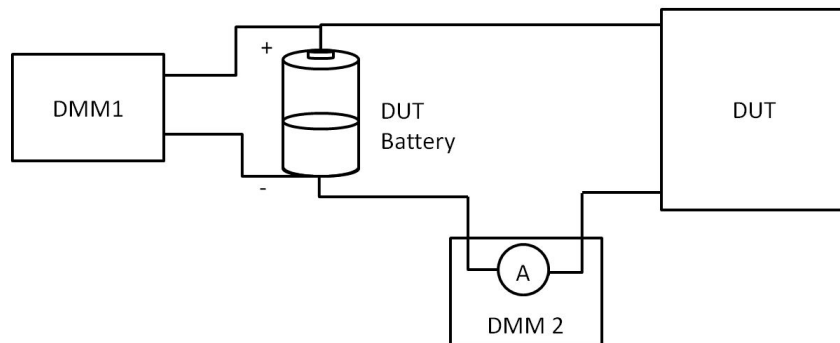
Measurement tip

Using the True*volt* DMM digitizing capability and High Speed (HS) option, you can measure fast changing characteristics while measuring with a time resolution with a time resolution of 20 µs. To effectively digitize with accurate timing, ensure that auto zero and auto ranging is turned off. This eliminates the timing variation that occurs when the DMM makes additional readings for the auto zero or switching to a different range.

Figure 4. This block diagram depicts a battery drain analysis using two DMMs.

Measuring Low Current Consumption with a Digital Multimeter
(continued)

Figure 5 shows a typical current profile of a portable radio transceiver. As you can see, the current draw is complicated with a wide range of sleep, standby and active modes. The dynamic range of the current is large because the operating currents are drawing approximately 30 to 40 mA, while the standby currents are only 1 to 10 µA.

In order to get accurate readings for both ranges with a DMM, you need to take multiple reading sweeps with different ranges. One method for capturing the current profile would be to run the Device-Under-Test (DUT) multiple times to capture the sleep and standby modes separately and then the operating mode currents. In the first capture, set the DMM to the 100-mA range and 0.001 plc (20 µS per sample). This will capture the complete current signal, including the active mode values between 30 to 40 mA, but provides less resolution on the lower current measurements.
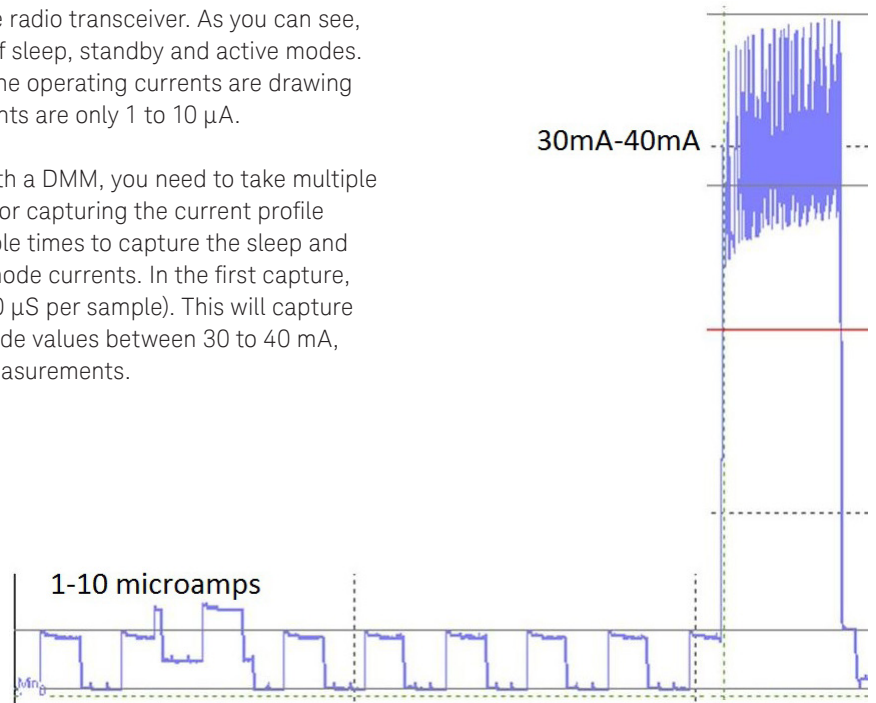

Figure 5. Shown here is a current profile from a portable radio.

Figure 6 shows a trend chart view of the currents read using a 34465A DMM. Notice that the lower current measurements seem to be very uniform, which is due a loss of resolution. To measure the low current values, you need to take another measurement at a lower current range. Once you have captured the readings, the data can be saved to memory and analyzed on a PC.

Measurement tip

You can use Keysight's BenchVue software to control and trigger both DMMs simultaneously. Use the digitizing mode of the DMM to ensure 20 µS/sample timing. Note that the datalogging mode in BenchVue includes PC overhead that can interfere when precise timing is required.
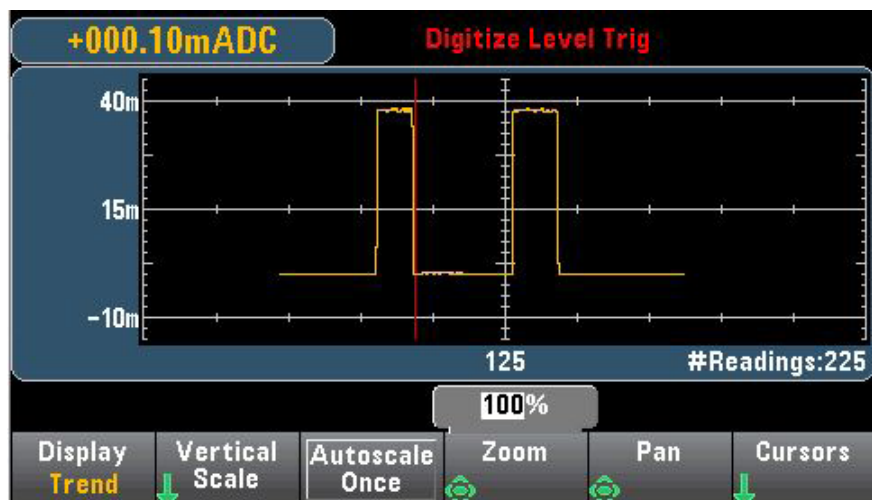

Figure 6. This operating current was captured with the 34465A DMM. Shown here is the DMM front panel.

Measuring Low Current Consumption with a Digital Multimeter
(continued)

Next, you can set the DMM to a lower current range for the standby and/or sleep currents. Figure 7 shows a graphical data capture, using BenchVue, of the standby currents measured by the top graph. The bottom graph shows the DCV readings. Figure 8 shows the statistics and actual readings from the data set. The currents captured range from approximately 2 to 10 µA. They were captured with the DUT in standby mode, thus allowing for a single range current capture. Anything above 120 percent of the range will result in an overload condition.

Figure 7. These two graphs illustrate the digitized DCI (top image) and DCV (bottom image) consumption.

Figure 8. Shown here are the statistics and actual readings from the data set captured in Figure 7.

Summary

With extended current ranges and digitizing capabilities, the 34465A and 34470A True*volt* DMMs can effectively characterize dynamic currents. Whether your DUT is drawing high current at 10 A or you need to measure lower current in the pico-amp region, the new True*volt* DMMs have the features and measurement capabilities to be a workhorse instrument on your bench.

Faster Data Analysis with Graphical Digital Multimeter Measurements

Overview

New modern DMMs allow you to analyze your setup and data using only the front panel. The True*volt* Series of DMMs—the 34460A, 34461A, 34465A, and 34470—offer other methods for gaining insight into measurement data, without having to first transfer that data to a PC. True*volt* DMMs feature a large graphical display and built-in math functions that show measurement trends, statistics, and histograms all in a single, compact unit. With advanced analysis and data collection methods on the 34465A and 34470A, it may even be possible to run an entire analysis using only the DMM. See how the True*volt* Series DMMs can help you more quickly analyze your data.

Analyzing changes with time

You need to characterize the drift of a precision resistor in your design. Rather than setting up a program or using your PC, you decide to use your True*volt* DMM's trend chart feature to gather the data. After allowing the design to heat up for 20 minutes, you start to see nonlinear behavior in the resistor. With the pan, zoom and cursor capability of the new 34465A/34470A DMM's, you identify the instant the measurement goes nonlinear. As a result of this discovery, you decide that the resistor is not performing to specification and that you need to evaluate other parts.

Identifying noise in your design

You are troubleshooting a switching DC power supply that appears to work well. However, there is some behavior that drops the voltage out of tolerance. Using your True*volt* DMM you characterize the power supply's output. By switching between trend chart and histogram mode you identify that the power supply's noise is not Gaussian and is skewed toward the lower end of
regulation. Your analysis only takes 10 minutes and was accomplished without a computer.

Faster Data Analysis with Graphical Digital Multimeter Measurements
(continued)

Trend charts show direction

If you expect a measurement to remain constant, only measure it once. That's because in the real world values drift with time, track other parameters, or vary in complex ways with outside influences. You can set the trend chart display on the 34461A, 34465A, and 34470A DMMs to display the most recent data over the last minute, or to display all of the data collected since the last time the readings were cleared (Figure 1).

An example of a common secondary measurement would be the ability to measure the frequency of an AC signal, as shown in Figure 1.

Histograms tell all about the data

When the lowest digits of a reading are changing constantly and sometimes too quickly to visually track, it is important to know the nature of that variation. The histogram provides insight by showing the distribution of the measured values (Figure 2). The average, distribution shape, and standard deviation are all critical information for understanding the variation phenomena.
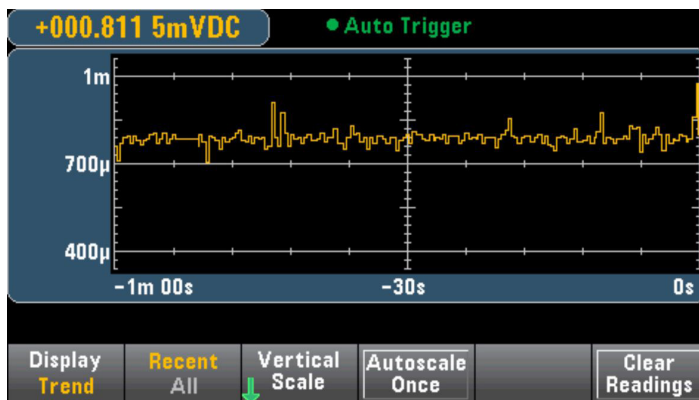

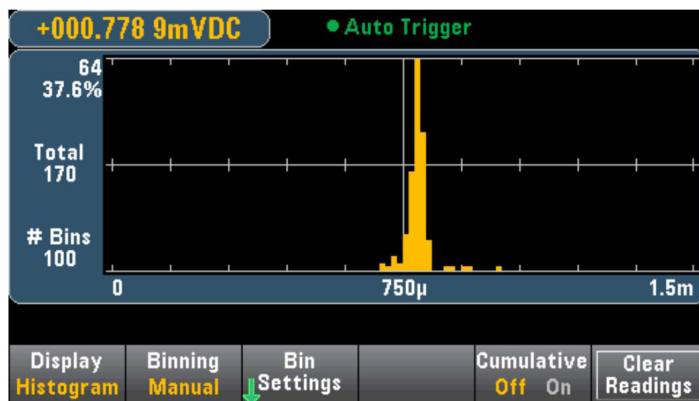Figure 1. The trend chart display shows direction and reading anomalies.

Figure 2. The histogram show data distribution.

Faster Data Analysis with Graphical Digital Multimeter Measurements
(continued)

Secondary measurements

With the ability to have secondary measurements run concurrently with your primary measurement, you can gather two types of information at a glance; for example, a thermistor temperature measurement (primary) and the resistance measurement made on the thermistor (Figure 3). For further information on secondary measurements, see the Keysight Technologies application brief "Simultaneous Measurements with a Digital Multimeter" publication number 5992-0419EN or the True*volt* DMM datasheet, publication number 5991-1983EN.
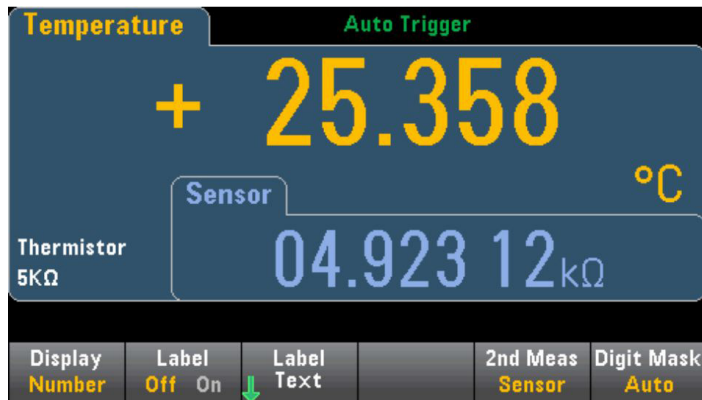

Figure 3. The True*volt* DMMs allow secondary measurements to run concurrently with a primary measurement.

Advanced DMM triggering

If the traditional DMM triggering model was insufficient for your testing needs, then the new True*volt* DMMs may have just the solution for you. Traditional DMMs either make measurements right after you configure the measurement (immediate trigger), do a single measurement, or trigger from an external source via the External Trigger port. Higher-end DMMs like the 34465A and 34470A have additional modes wherein a combination of trigger settings, delay times, number of samples per trigger, and pre-trigger settings can be used to provide concise data (Figure 4).

Using the DMM's advanced trigger modes you can set a level trigger that will start making measurements when the desired level is reached (Figure 5). You can also set a trigger delay to wait a defined time after the trigger event. Another useful setting is the ability to define the number of samples after a trigger is received, which helps to ensure a number of continuous measurements after the trigger event, rather than just a single reading per trigger.

Figure 4. The 34465A/34470A DMMs feature advanced trigger modes.

Figure 5. The True*volt* DMMs' advanced trigger modes allow designers to set a level trigger.

Faster Data Analysis with Graphical Digital Multimeter Measurements
(continued)

New acquisition modes

In addition to the traditional continuous measurement mode, the 34465A and 34470A DMMs provide data logging and digitizing modes from the front panel. These new modes are accessible from the Acquire menu located on the front panel. To start the acquisition, you simply press the Run/Stop button.

Data logging

The 34465A and 34470A DMMS feature a new data logging mode for front panel usage. Found under the Acquire menu, the mode allows you to get readings at a constant sample interval to effectively log your data over time. You can easily set your sample interval (e.g., how often you want to make a measurement) and your total duration (e.g., how long or how many readings you want to make). You can also choose your start time by defining either a delay time from when you press RUN or a start time in terms of Hour/Min/Sec. Data logging allows you to stream directly to a .csv file on either the DMM's internal memory or a USB thumb drive connected to the front panel of the DMM. You may log up to 100 hours or 360 million readings, whichever is less (Figure 6). In data logging mode, you may sample as fast as 1000 samples/second. Because the data logging feature is optimized for precision timing in its readings, some features are not available, such as the level trigger and external trigger.

Exporting to a .csv file allows you to analyze your data on a computer (Figure 7). The .csv file includes the start time and measurement interval (in seconds); allowing you to extract the time that your measurement was taken.
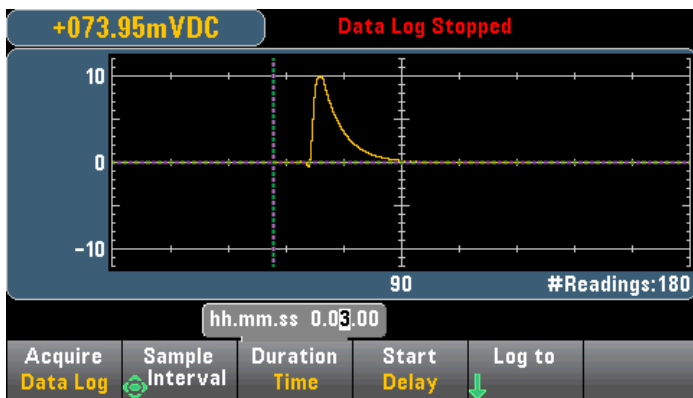
	A	B	C	D
1	Start date	11/1/2014	Start time	18:27.3
2	Sample in	100		
3	Reading #	Reading		
4	1	8.05E-02		
5	2	7.98E-02		
6	3	7.98E-02		
7	4	7.98E-02		
8	5	7.98E-02		
9	6	7.98E-02		
10	7	7.98E-02		
11	8	7.98E-02		
12	9	7.98E-02		
13	10	7.98E-02		
14	11	7.98E-02		
15	12	7.98E-02		
16	13	7.92E-02		
17	14	9.05E-02		
18	15	8.98E-02		
19	16	8.98E-02		
20	17	8.98E-02		
21	18	8.98E-02		
22	19	8.98E-02		
23	20	8.98E-02		
24	21	8.98E-02		
25	22	8.98E-02		
26	23	8.98E-02		
27	24	8.98E-02		
28	25	8.98E-02		

Figure 7. CSV data file from True*volt* DMM.

Figure 6. Data logging allows you to log up to 100 hours or 360 million readings.

Figure 8. A True*volt* DMM shows up like a drive on your PC.

Measurement tip

You can set the DMM's real-time clock to your local time. True*volt* DMM's ship from the factory with Greenwich Mean Time (GMT) standard. Setting the clock to your local time allows for start times to be more intuitive for analysis.

Measurement tip

With a USB connection to your PC, True*volt* DMMs show up like a drive on your PC (Figure 8) Using the Easy File Access, you can drag and drop files from or to your DMM without additional software. This is an easy method to get readings from your DMM to your PC for analysis.
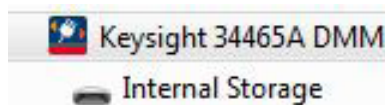
Faster Data Analysis with Graphical Digital Multimeter Measurements
(continued)

Digitizing mode

The True*volt* DMM digitizing mode allows you to sample at the maximum rate and analyze your data from the front panel. With a 50-kHz sampling rate, you can take a measurement every 20 µs (Figure 9). The slowest rate for digitizing is 100 ms. The digitizing mode sends data to the DMM's measurement memory, which can keep up to 2 million readings with the optional memory (50,000 readings standard). After the readings have completed, you can store the readings to a .csv file.

In addition to the fast sampling, the digitizing mode allows you to setup a level trigger to start your readings. You can set the level and polarity at which you want to start the triggering of the measurement. You can also select the number of pre-trigger readings to digitize. This allows you to keep measurements that happen before your trigger level has been reached.
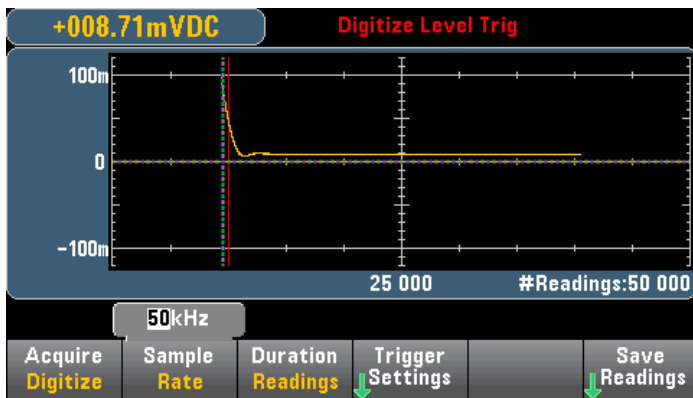

Figure 9. A 50-KHz sampling rate allows you capture fast changes in your signal.

Faster Data Analysis with Graphical Digital Multimeter Measurements
(continued)

Pan/zoom/cursors

If you are using the histogram or trend chart display modes, you have additional features for analysis. For readings in measurement memory, you can pan or zoom into your data. With zooming, you can enlarge portions of your data for viewing. Panning allows you to move the display screen to the measurement sample number that you want to view. Figure 10 shows a digitized reading that looks similar to the Keysight logo. In Figure 11, the DMM has zoomed into a number of readings to show how individual sine waves actually make up the total logo.
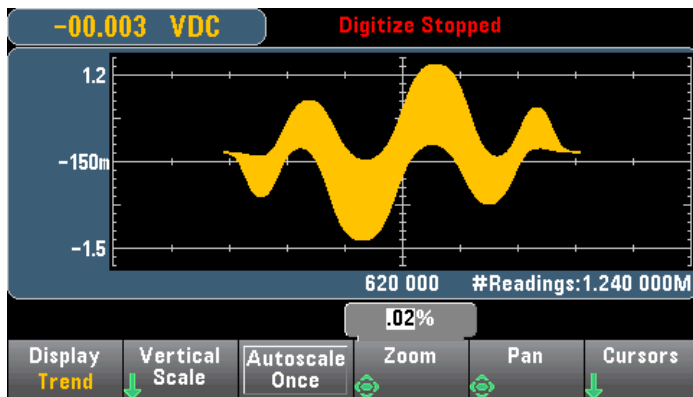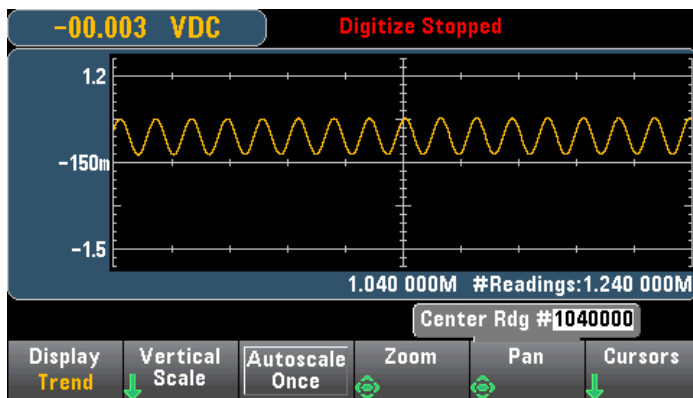

Figure 10. Digitized data of 1.2 million readings.

Figure 11. Zoomed/panned in data that shows individual sine waves.

Faster Data Analysis with Graphical Digital Multimeter Measurements
(continued)

The new cursor functionality in the trend chart allows you to place two X and Y cursors on your data (Figure 12). Each cursor shows the time (from a start time of 0 seconds) and the measurement value for where the cursor is placed. While this feature has been commonly used in oscilloscopes for years, it is new to DMMs and only available on True*volt* DMMs.

Histograms include cursor functionality as well (Figure 13). Histogram cursors allow you to select which bin to view and show the number of occurrences and percentage of total readings that the bin has accumulated. The span feature includes between the cursor information about the range of the readings, the number of readings, and the percentage of readings between the cursors compared to the total readings.

Figure 12. The True*volt* DMMs allows you to place X and Y cursors on your data.

Figure 13. Histogram cursors.

Measurement tip

If you need to control multiple DMMs or a mix of instruments, and analyze their data, use Keysight's BenchVue software for your PC. BenchVue supports all True*volt* DMMs, along with more than 200 other Keysight instruments.
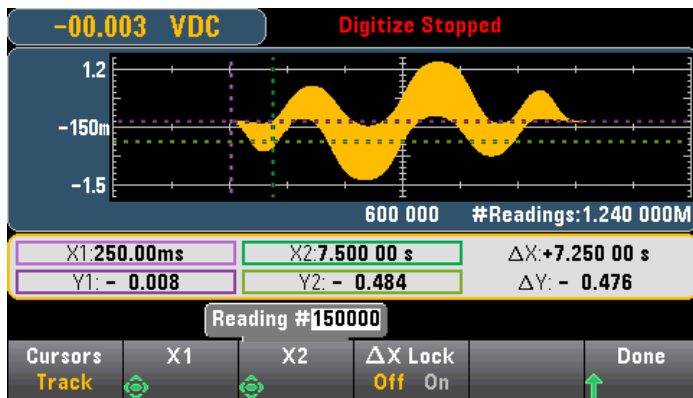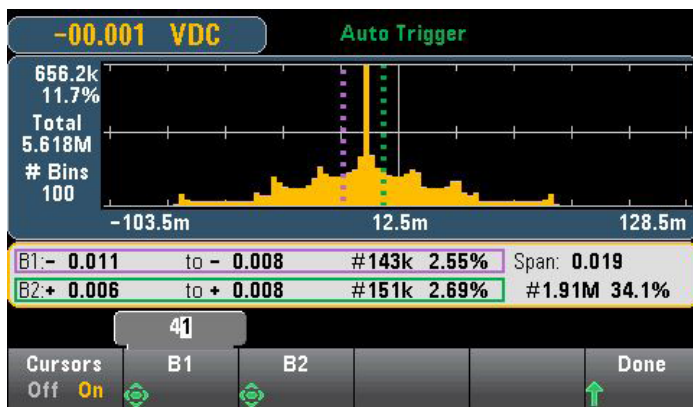
Conclusion

Setting up a computer connection for data collection and analysis can take too much time, especially if you are measuring a single parameter. It is clear that a single value does not provide much insight into the performance of your DUT over time or in response to outside interference. A picture, on the other hand, can offer much richer insight with just a single glance. Now, with the True*volt* Series DMMs' new graphical display, advanced analysis modes, and built-in math functions, the ability to turn lots of data into results that can be quickly analyzed is at your fingertips—all this with just simple front-panel menu entries. Using the True*volt* DMMs you can now meet your testing goals faster than ever before.

Simultaneous Measurements with a Digital Multimeter

Overview

Traditionally, digital multimeters (DMMs) have been single-measurement instruments. In some cases; however, system designers want the ability to track more than one parameter on their signal. Doing so often provides complementary data that can make measurements significantly easier to understand. With the right architecture and design, DMMs can now make secondary measurements. See how the True*volt* Series DMMs helps designers make secondary measurements without ever having to change the instrument's configuration. The advanced functionality on the 34465A and 34470A (e.g., expanded math functions) also means that designers can now analyze their data faster.

Making more confident measurements

A test engineer wants to monitor the temperature inside of an environmental chamber and needs a high level of confidence that the measurements are accurate. A 34465A DMM is selected due to its ability to log data and provide simple trend charts. A 5-KΩ NTC thermistor is used to spot check for accuracy.

The engineer notices that the thermistor has a temperature error of a few degrees. To understand the error, the secondary display on the True*volt* DMM is turned on and temperature and resistor readings are read at the same time. According to the datasheet for the thermistor, it should read 25 ºC at 5 KΩ. The engineer's probe is put inside of a calibrated chamber set to 27 ºC, but the probe reads 25 ºC with a 5-KΩ resistance reading, a two degree error. After a bit of characterization, the engineer decides that he can simply add an offset value to adjust for the offset of his thermistor.

Making dual measurements in less time

A system designed to apply a linear force to a small structure has the ability to provide an oscillating force with an AC signal and a constant force with a DC signal. The system designer wants to keep track of both signals concurrently in order to characterize how much force is being applied. Using a True*volt* DMM with its ability to make secondary measurements, he is able to read both the DC and AC components of his control signal at the same time.

Simultaneous Measurements with a Digital Multimeter *(continued)*

Two measurements one screen

Secondary measurements are defined as auxiliary measurements that augment information provided by a main primary measurement function. Depending on the function, you can measure complementary data that traditionally would have taken two different operations and function changes to acquire. The table illustrates all secondary measurement capabilities of the True*volt* DMMs.

Primary measurement function	34460A secondary measurement function	34465A/70A secondary measurement function
DCV	ACV	ACV, peak, pre-math
ACV	Frequency	DCV, frequency, pre-math
2-wire, 4-wire resistance		Pre-math
DCI	ACI	ACI, peak, pre-math
ACI	Frequency	DCI, frequency, pre-math
Frequency	Period	Period, ACV, pre-math
Period	Frequency	Frequency, ACV, pre-math
Temperature	Sensor	Sensor, pre-math
Ratio	Input/Ref	Input/ref, pre-math
Capacitance		Pre-math
Continuity		None
Diode		None

Table 1. Secondary measurement capabilities supported by the True*volt* DMMs.

An example of a common secondary measurement would be the ability to measure the frequency of an AC signal, as shown in Figure 1.
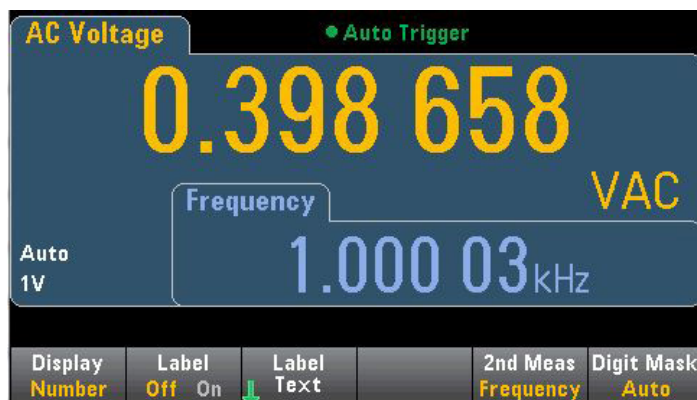

Figure 1. AC voltage with frequency.

Simultaneous Measurements with a Digital Multimeter *(continued)*

With the advanced secondary features of the 34465A and 34470A DMMs, the secondary measurements provide more information than is possible with other DMMs. As an example, Figure 2 shows the primary measurement of DC voltage (DCV) with a secondary measurement of AC voltage (ACV). This is an especially important measurement if your signal has both an AC and DC component.

In DCV mode, there are two additional secondary measurements that can be made to provide insight into your signal: Peak and Pre-Math. The Peak measurement, as shown in Figure 3, keeps track of the minimum and maximum DCV readings read by the DMM. This is similar to the information that is available from the statistics display.
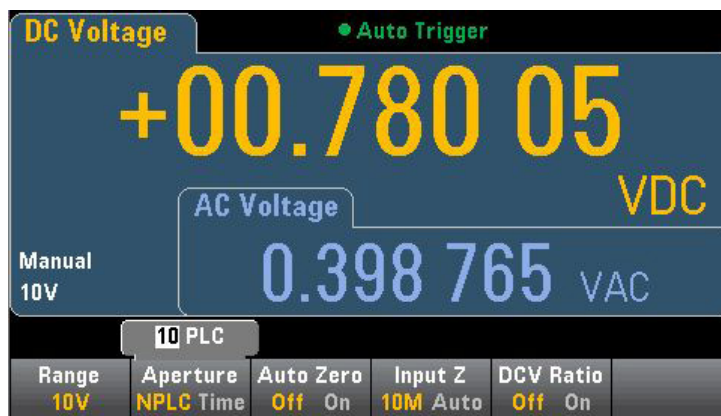

Figure 2. DC voltage (primary) and AC voltage (secondary) measurements.

Figure 3. Peak measurement of DCV.

Simultaneous Measurements with a Digital Multimeter *(continued)*

Pre-Math is also a very valuable measurement because it allows you to see modified readings and raw readings in one screen (Figure 4). You can even modify your primary display by applying useful math functions to your data (e.g., a null value or scaling) or filtering your data (Figure 5). See Adding Math Enables Faster Analysis section for more information on applying math function.

Once you have applied the desired math function, the secondary display will display the raw reading without the math. This is useful for determining if the applied math is correct, and if the readings are within the expected range.

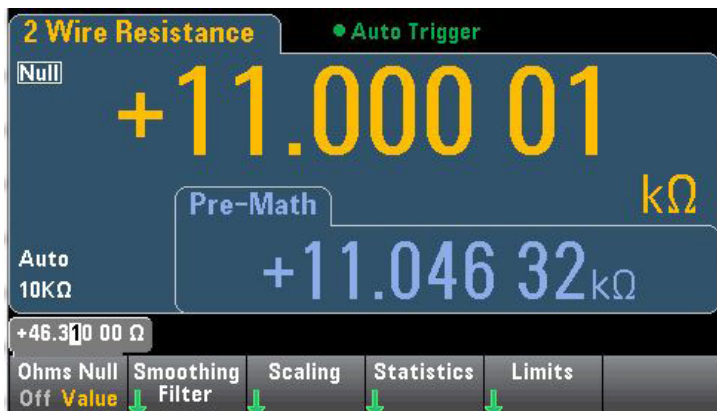Figure 4. A DCV signal with dB scaling with the Pre-Math measurement.

Figure 5. A with the null value applied with the raw measurement on the secondary display.

Simultaneous Measurements with a Digital Multimeter *(continued)*

With the temperature measurement capabilities included on True*volt* DMMs, you might also want to see what the sensor readings are in volts or ohms, depending on your sensor (Figure 6). All four True*volt* DMM models provide this capability on the secondary display.
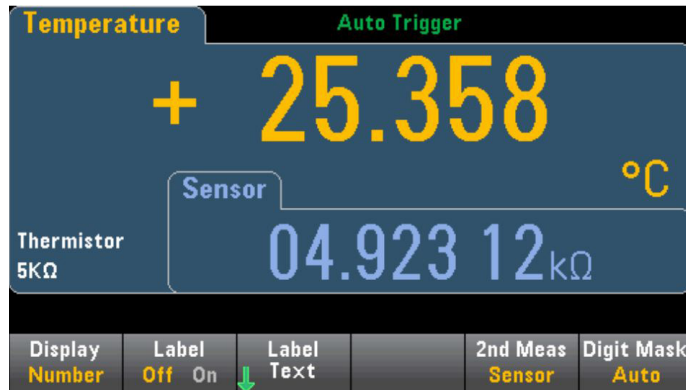

Figure 6. Sensor readings displayed on the secondary display for a given temperature measurement.

Another useful feature of the dual display is the ability to provide raw measurements when you are using the DCV ratio function. With the addition of the second display, you can read the ratio, the input voltage, and the reference voltage in one glance (Figure 7). The DCV ratio is a function measured by comparing the voltage on the Input terminals divided by the reference voltage. The reference voltage is the difference of two separate measurements. These measurements are the DC voltages from the HI Sense terminal to the LO Input terminal and from the LO Sense terminal to the LO Input terminal. Figure 8 shows a simple DCV ratio diagram.

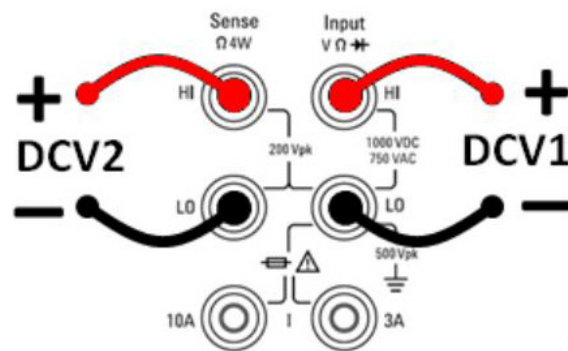Figure 7. With the True*volt* DMM dual display, you can view 2 voltage measurements when using the DCV ratio function.

Figure 8. Basic DCV ratio diagram.

Simultaneous Measurements with a Digital Multimeter *(continued)*

Additional information

Adding math enables faster analysis

A key advantage of the 34465A/34470A True*volt* Series DMMs is that they feature additional Math functions as compared to their predecessors, the 34460A and 34461A. These earlier True*volt* DMMs allow you to Null readings to zero out your measurement offsets, set Limits for your readings, and show statistics. The newer 34465A/34470A DMMs provide the same capabilities, but they also include a Smoothing filter and Scaling (Figure 9).

The Smoothing filter is useful if you want to average out statistical outliers. Applying the smoothing filter means the DMM uses a moving average (boxcar) filter to reduce random noise. You may change the filter response by choosing Fast/Medium/Slow (Figure 10). The slower the filter gets, the more readings are used in the filter.

Additional Scaling features are available on the new DMMs as well. You can now change the readings on your front panel by scaling the readings with either a dB, dBm, %, or Mx-B scaling (Figure 11). For dB scaling, the result is the difference between the input signal and the stored dB-relative value reference. The dBm Scaling is a result based on the calculation of power delivered to a reference resistance (Ref R), relative to 1 milliWatt. The % scaling shows a percent change from a reference value, while the Mx-B allows for linear scaling with an offset operation.

Figure 9. Math functions available in the 34465A/34470A DMMs.

Figure 10. Smoothing filter options.

Figure 11. Options for scaling.

Summary

Advanced dual-screen measurements not only allow you to get more information concurrently, they also allow you to check your raw data compared to your adjusted measurements. Using the True*volt* Series DMMs to make dual measurements, you not only save time and but also gain more information than is possible with other similar instruments.

Making Simpler DC Power Measurements with a Digital Multimeter

Overview

Many applications need to measure power. In fact, it can be the more intuitive parameter for your specific test. For many years, the DMM has served as the "go to" solution for measuring power. While DMMs can measure both current and voltage, their internal architecture inhibits their ability to measure both at exactly the same time. Using a few different techniques; however, you might be able to get a good V/I measurement from your benchtop DMM. Those measurements can then be used to calculate DC power. This brief describes several methods that can aid you in making simple DC power measurements using a single True*volt* Series DMM.

Measuring DC voltage and current with a single digital multimeter

You are tasked with measuring the power consumption of a *Bluetooth*® speaker, which is normally powered from a battery. The operating voltage of the speaker is 19.2 V and the current consumption ranges from a few hundred micro-amps to a few amps. You would like to keep the voltage stable and monitor the current to understand the power consumption in terms of watts. Using a True*volt* Series DMM and internal math scaling of the current measurement, you can use a simple math function to multiply a known voltage with the measured current signal. This will provide you a reading in watts. With the display capabilities and low current ranges of the True*volt* Series DMMs, you can do make your power measurements with just a single DMM.

Measuring watts with a digital multimeter

You have a lower power DC-to-DC converter and need to monitor the voltage and current consumption at the same time to understand its efficiency. This typically takes one DMM to measure the voltage, and one to monitor the current. With the help of a stable external shunt resistor and a True*volt* Series DMM, you can accurately measure lower power voltage and current at intervals very close to each other. With knowledge of the limitations of this method, you can get an accurate and precise measurement of your DC power characteristics.

Making Simpler DC Power Measurements with a Digital Multimeter
(continued)

Measuring Power with a DMM

The most basic equation in DC power is an extension to Ohm's law, given by:

$$P = V * I$$

The typical configuration used to monitor power with DMMs is to have one DMM monitor voltage, while another one measures the current. The power is then calculated on a PC. Figure 1 shows a typical DC power measurement configuration.
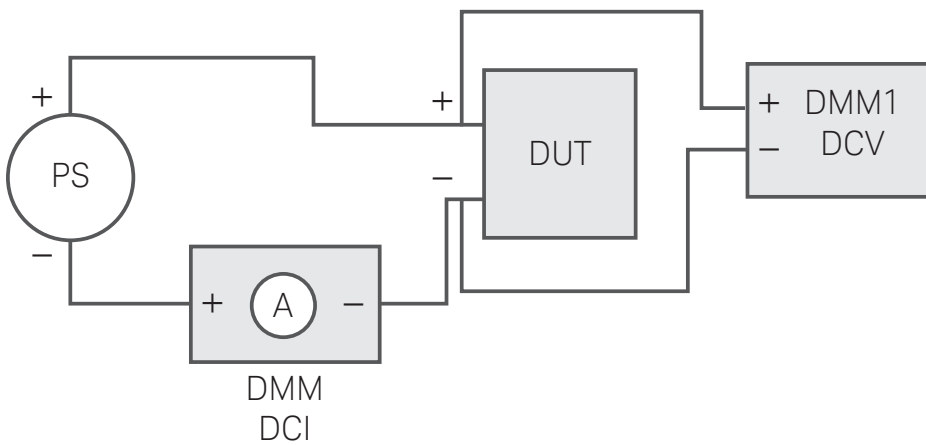

Figure 1. This diagram represents a typical DCV and DCI measurement configuration using two DMMs.

A dual DMM configuration is needed to monitor voltage and current at the same, or very nearly the same time. This approach is highly flexible, allowing you to measure a wider variety of voltage and current levels. However, it does add complexity because you need to monitor two DMMs. Also, if you want to control the timing of the readings such that they are close to each other, you will likely need some sort of PC program to control the multimeters. Often, you might not have the resources for this type of approach or even the time to create and debug the program.

Some engineers assume they can use a single DMM to measure voltage and current at the same time since there are two different ports, one for voltage and one for current. There are a couple of issues with this approach. The first is that most DMMs do not support both readings without an internal configuration change. Internal relays will change state, ranges change, and circuits might be disrupted. Thus, the timing of the voltage and current readings is often unpredictable. Another issue is that the ports share the same common LO terminal. Unless you are very careful with how you wire your test, you might actually damage your DMM or Device Under Test (DUT) by applying a dangerous floating voltage on either the current or voltage terminals. Because of this, many DMM manufacturers do not allow for simultaneous voltage and current measurements.

Measurement tip

Instruments that are dedicated to measuring power include Keysight's N6705B and N6715B DC power analyzers. For AC power analysis, Keysight offers the new PA2200 IntegraVision power analyzers. Go to www.keysight.com for more information.

Making Simpler DC Power Measurements with a Digital Multimeter
(continued)

Using scaling to get readings in watts

Often in power measurements, you might have a constant voltage or current source and the other factor varies. For example, if you have a constant voltage, the power varies because the current is changing. Many times you would like to see your DMM readings in terms of watts, as this makes the readings more intuitive. If you have a constant param-eter, such as a constant voltage, you can make a single voltage reading and then use the same DMM to measure current. Finally, you can convert your current measurements to watts in real time with a simple scaling operation on either the True*volt* 34465A or 34470A DMM.

For this example, a DC voltage reading was taken at the DUT inputs as shown in Figure 2. The DMM was then moved in series with the DUT on the return path. This is done to measure current as shown in Figure 3. After enabling mathematical scaling on the DC current reading, a gain was applied to the readings.
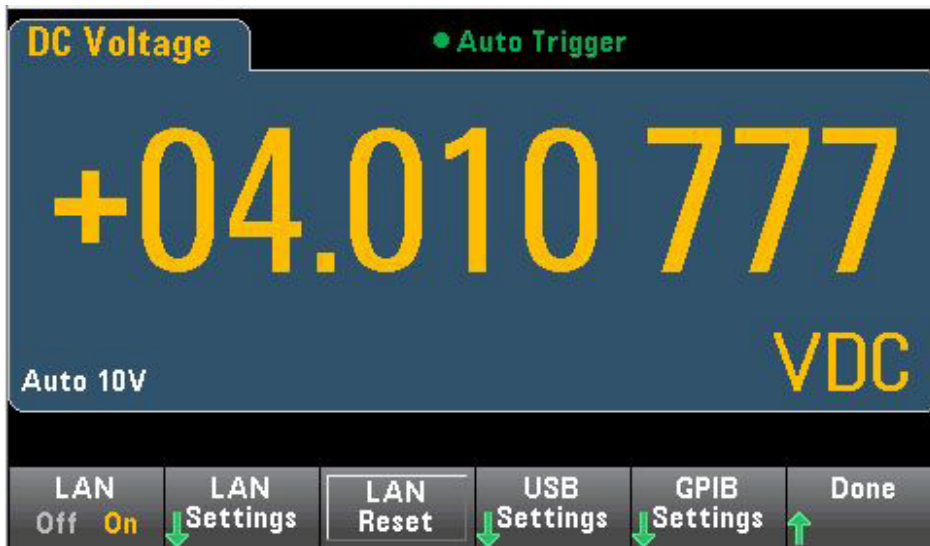

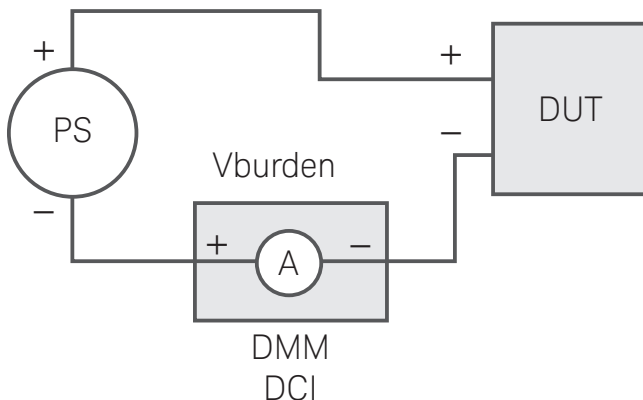Figure 2. Shown here is a DCV reading at the inputs to the DUT.

Figure 3. The DCI current can be measured using the configuration shown here.

Making Simpler DC Power Measurements with a Digital Multimeter
(continued)

In Figure 4, you can see that the gain applied was the same DC voltage reading taken in Figure 1. The reading in yellow is the total watts that are measured (V*I) and is updated constantly as the DCI measurement changes. Also, note the raw DC current reading in the secondary measurement in blue. You may enable or disable the secondary measurement as needed. In the math menu, you may also enter in a user defined unit (max 4 characters) that allows the displayed measurement to be shown in watts.
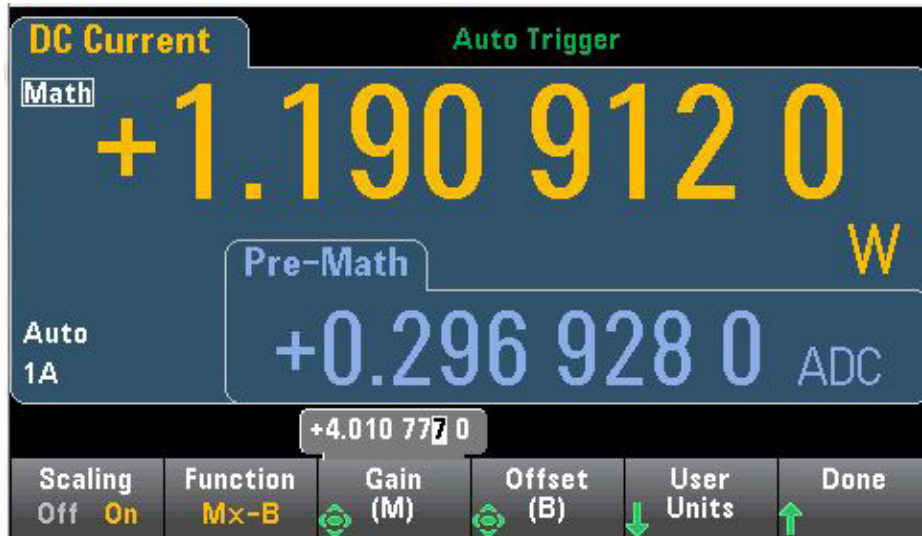

Figure 4. This screen displays the watt reading given the gain and raw current readings shown.

Measure voltage and current at nearly the same time

If your voltage or current is not constant, the method previously outlined might not be right for you. Fortunately, there is another method available on the True*volt* Series DMMs that measures both voltage and current at close intervals to one another. This method involves the use of an external resistor to convert a DC voltage measurement to current, again utilizing Ohm's law.

The True*volt* Series DMMs have a DC voltage ratio measurement that normally takes two DCV measurements and reports the ratio between them. The connection diagram for the measurements is shown in Figure 5. The ratio is the voltage on the Input terminals divided by the reference voltage. The reference voltage is the difference between two separate measurements, the DC voltages from the HI Sense terminal to the LO Input terminal and from the LO Sense terminal to the LO Input terminal. For the purposes of this discussion, the LO input terminal and LO Sense terminal are shorted together. This reduces measurement errors caused from floating DCV1 and DCV2.

Measurement tip

If you need to measure currents higher than the 10-A range available on the True*volt* Series DMMs, consider using external shunts on the DC volts terminal or current transformers. You can still use the math scaling functions to convert the measurements to the units that you expect.

Measurement tip

Burden voltage is the change in potential created when current flows through the shunt resistor of a DMM. Be aware of the burden voltage and the effect it can have on the accuracy of your power measurements.

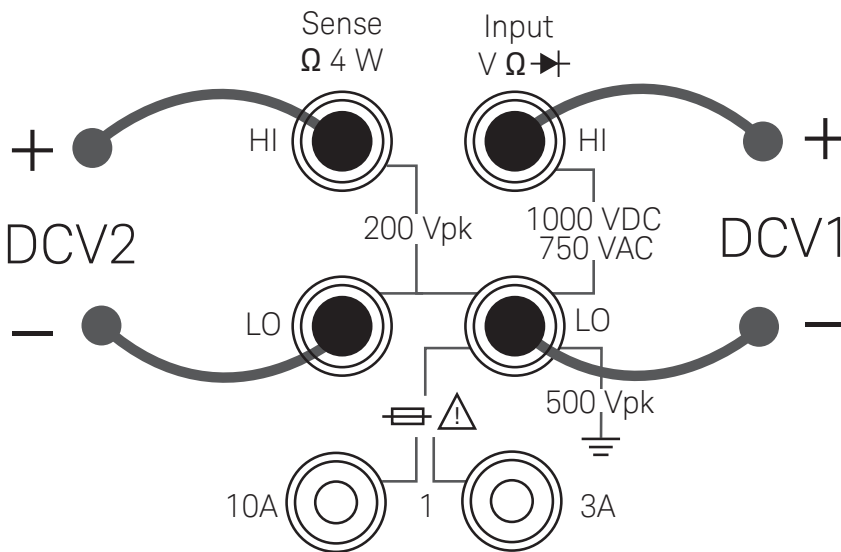# Making Simpler DC Power Measurements with a Digital Multimeter
(continued)

Figure 5. Shown here is the ratio diagram for the two DCV measurements.

Note that the reference measurements must be within the range of ±12 VDC. Also, the reference voltage is always autoranged.

Utilizing the DCV ratio, we can put an external resistor on one side of the ratio measurement. Normally, the DCV ratio measurement reports the ratio; however, Keysight offers a secondary measurement that reports both DCV1 and DCV2. Using this feature, located in the DMM's display menu, we can see the two voltage measurements independently of the ratio measurement (Figure 6).

Figure 6. Here, the Input/Ref measurements are displayed independent of the ratio measurement.

Making Simpler DC Power Measurements with a Digital Multimeter
(continued)

To make a current measurement, a shunt resistor can be placed on either side of the ratio measurement. Figure 7 shows an example configuration for using the DCV1 and DCV2 measurements to make separate DC voltage and current measurements.
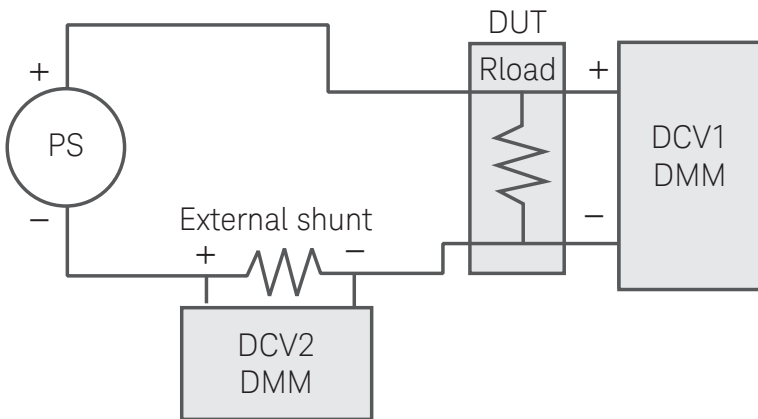

Figure 7. This configuration can be used to make seperate DCV and DCI measurements.

We can convert the DCV2 reading into current by dividing the reading by the value of the shunt resistor using Ohm's law (I=V/R). In this case, the 34330A current shunt was used and has a value of 0.001 ohms. The current reading would then be:

-000.165 mV/.001 Ohm = 165 mA

To get more resolution on the current readings, a larger shunt resistor can be used.

Other DCV ratio measurement considerations

The LO sides of the two voltage measurements (DCV1 and DCV2) require some consideration. The difference in potential between Sense LO and Input LO cannot exceed 12 V. Doing so might damage the DMM or cause either reading to be in error. Keep in mind that any difference between the LO Sense and Input LO will add error to the reference reading because this voltage is directly related to the reference voltage (see the DCV ratio above). As a recommendation, if you cannot put the current sense resistor in series with the low side of your circuit, then put the current sense on the high side. Make sure; however, that the LO connections are shorted together and expect a negative DCV1 reading.

Figure 8 shows a recommended block diagram for the case where you cannot separate the grounds to insert a current measurement. Look closely at the DCV1 polarity. It is reversed so that the LO input is connected to the LO Sense input of DCV2.
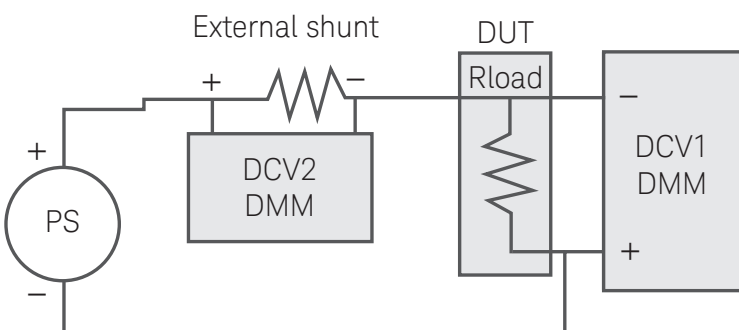

Figure 8. This DCV1 and DCV2 configuration is used for an earth grounded circuit.

Measurement tip

If you do choose an external shunt, make sure it is stable enough and large enough to handle the current that will be passing through. Keysight offers the 34330A current shunt, which can handle 15 A of continuous current with very low drift. It is a precision 0.001-ohm resistor housed in a plastic case surrounded by epoxy, and is designed for minimal drift under power.

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