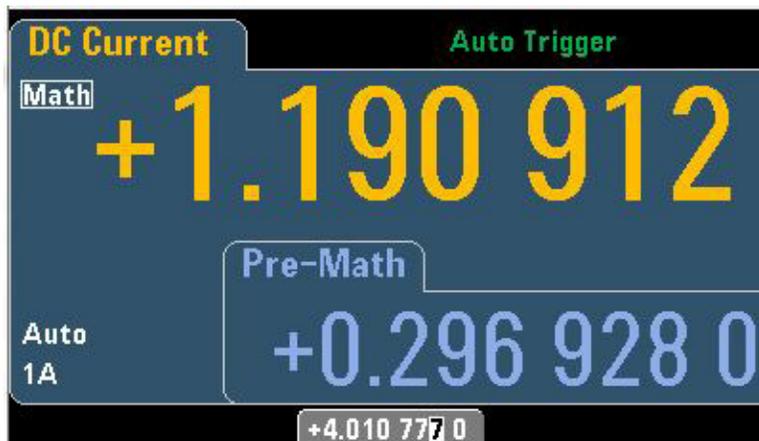


Keysight Technologies

Making Simpler DC Power Measurements with a Digital Multimeter

Application Brief



Test Challenges:

- Measuring DC voltage and current with a single digital multimeter
- Measuring watts with a digital multimeter

Overview

Most engineers need to measure power. In fact, power measurements can often tell you the most about what you're testing. 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 precisely the same time. However, if you use a few different techniques and the right equipment you can 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 help you make simple DC power measurements.

Your Challenge: 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 Truevolt 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 Truevolt Series DMMs, you can do make your power measurements with just a single DMM.

Your Challenge: 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 Truevolt 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.

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.

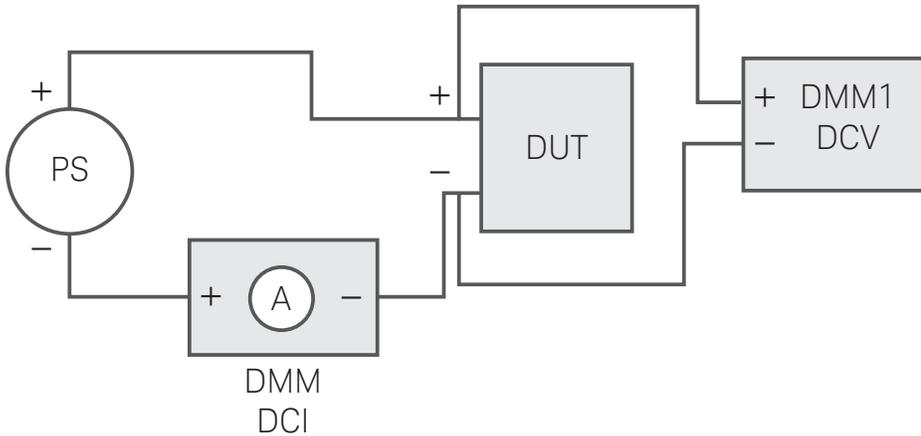


Figure 1. This diagram represents a typical DCV and DCI measurement configuration using two DMMs.

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.

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 parameter, 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 Truevolt 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.

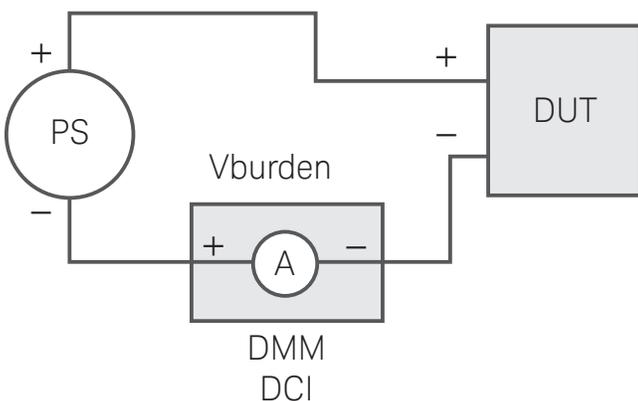


Figure 3. The DCI current can be measured using the configuration shown here.

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 ($V \cdot I$) 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.

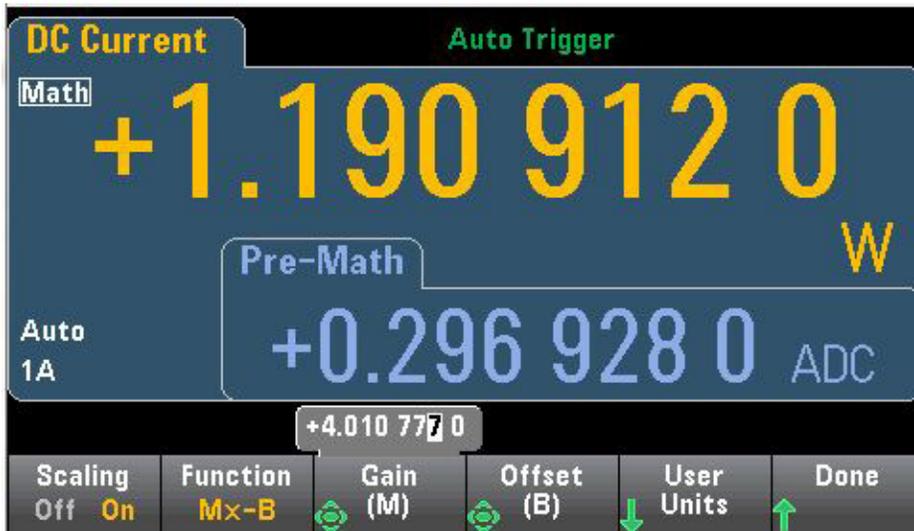


Figure 4. This screen displays the watt reading given the gain and raw current readings shown.

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 Truevolt 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 Truevolt 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 Truevolt 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.

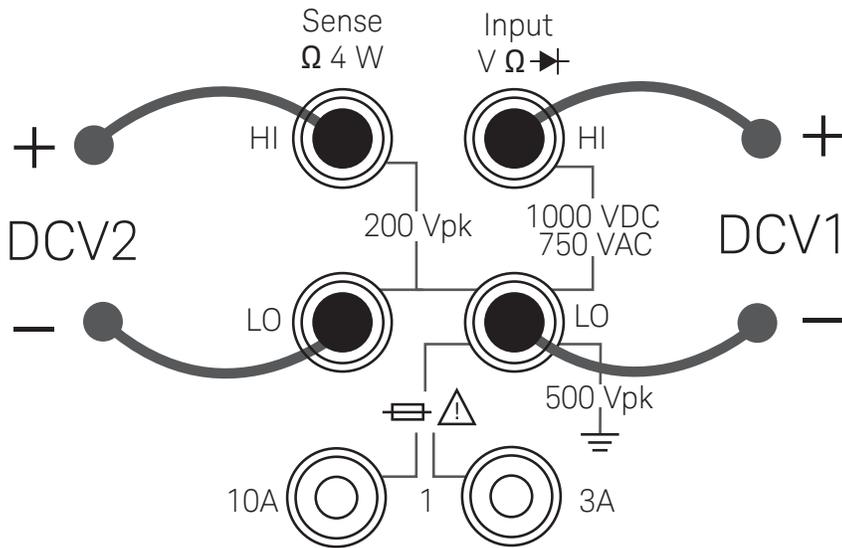


Figure 5. Shown here is the ratio diagram for the two DCV measurements.

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.

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.

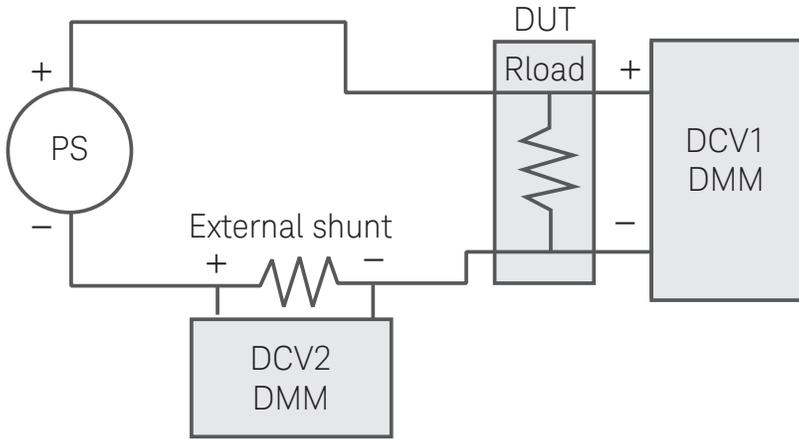


Figure 7. This configuration can be used to make separate DCV and DCI measurements.

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:

$$-000.165 \text{ mV} / 0.001 \text{ Ohm} = 165 \text{ mA}$$

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.

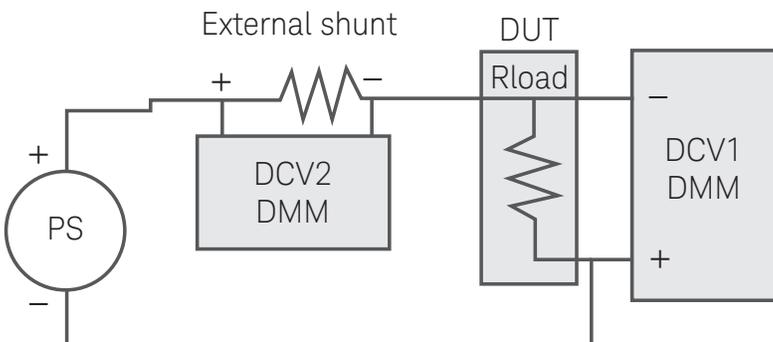


Figure 8. This DCV1 and DCV2 configuration is used for an earth grounded circuit.

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.

It is important to note that the readings between DCV1 and DCV2 are not made at the same time. Two separate DMM measurements are made to get the two readings. In addition, each of the readings has an autozero reading applied to correct for internal offsets. Autozero cannot be disabled for DCV ratio measurements. Since the exact timing of the readings are not controllable by a user, this method is not recommended for fast moving power measurements. However, it is recommended if you have a relatively static power measurement. It allows you to report both voltage and current at the same time, and then convert the measurements to power.

For the best tradeoff between noise rejection and reading rate, you will want to use a 1 plc measurement. If faster reading correlation is desired, turn off the autorange and set an explicit range. As a general rule, after the first reading, the DCV1 and DCV2 readings should be no more than two integration cycles apart. This means that if the integration setting is set for 1 NPLC (e.g., 16.6 ms for a 60-Hz line and 20 ms for a 50-Hz line), the timing of the readings normally will not be more than 2 NPLC apart (e.g., 33.3 ms at 60 Hz and 40 ms at 50 Hz).

Summary

Various methods can be used for measuring power with a single DMM. If you have constant voltage or current, you can use scaling to read the varying parameter and modify the reading to report watts. Or, if you have a relatively slow change in both parameters, you can use an external shunt and the secondary display capabilities of the Truevolt Series DMMs to display both DCV and DCI readings at the same time. If neither of these methods are feasible for your application, you can always just use two DMMs to measure the current and voltage and then sync the measurements together using external software.

For more information about the Keysight Digital Multimeters, go to www.keysight.com/find/dmm

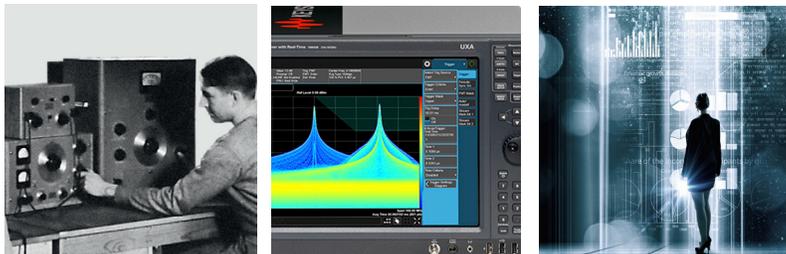
Measurement tip

Using the Input and Reference voltage secondary measurements disables the Truevolt Series DMMs' math scaling capability. You cannot scale or put user units on the secondary measurements.

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Published in the USA November 7, 2017
5992-0749EN
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