WHITE PAPER

# Autocalibration Improves DMM Measurement Stability and Accuracy

KEYSIGHT

# What Is Autocalibration for a Digital Multimeter?

Autocalibration (ACAL) refers to the ability of a device or system to self-calibrate automatically. For example, every time you power up a printer, the printer typically performs a self-calibration. This calibration involves many internal sensors and a physical reference for the printhead location for the printer to print accurately over time.

Similarly, electronic test and measurement instruments, such as a digital multimeter (DMM), require self-calibration to ensure its measurements are consistently accurate over time including the ambient temperature changes.

Accurate measurements using a benchtop or a system DMM are critical to most applications. However, a point often overlooked is the specification adder for 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 undergo calibration in a temperature-controlled environment, nominally at 23 °C. However, DMMs in real-life environments encounter temperatures that are different from the calibration lab. Learn how modern DMMs can help you minimize the TC specification adder.

## Benefits of autocalibration in a DMM:

- Reduces DC current, DC voltage, and resistance measurement errors due to ambient temperature changes.
- Reduces measurement drifts over time and provides overall stability and accuracy.

# How Does ACAL Improve Measurement Stability and Accuracy?

The purpose of the autocalibration function in a DMM is to reduce temperature drift error and internal drift error. For example, in a DMM with an autocalibration function, the built-in temperature reference tracks the DMM calibration temperature. It knows automatically the current temperature, calibration, and the temperature change. Figure 1 is an example of a DMM's autocalibration and a detailed information screen.

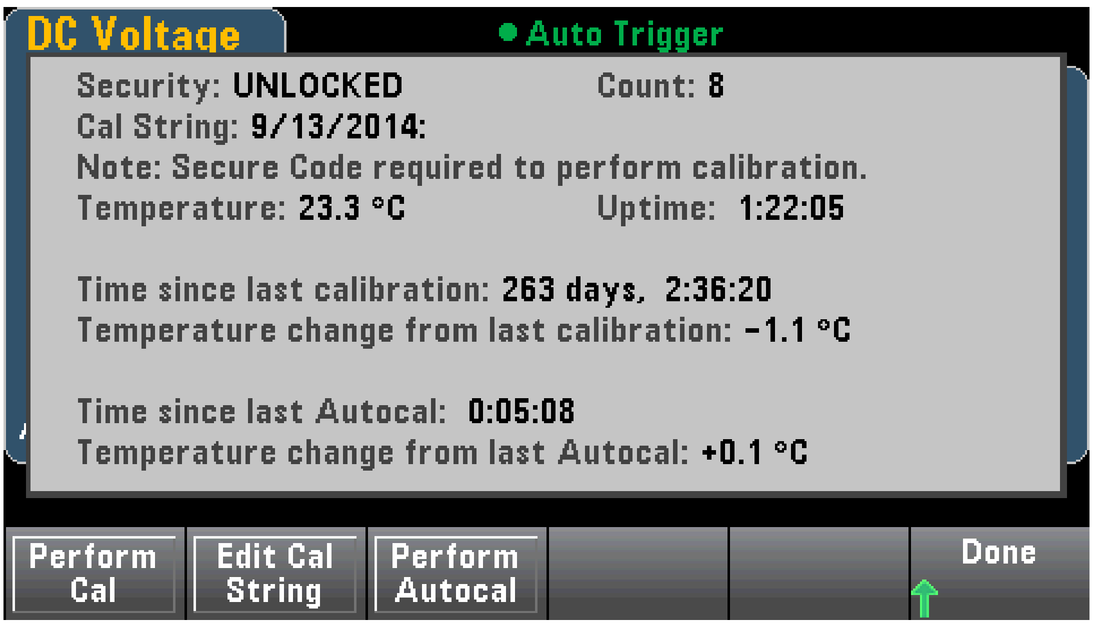


**Figure 1.** Autocalibration screen from a DMM

Use autocalibration on an ad hoc basis via a button on the front panel or through SCPI programming commands. You can perform autocalibration at regular intervals to suit your test environment using SCPI programming commands. It is good practice to perform autocalibration at least every 24 hours to minimize errors due to temperature drifts. Ideally, perform the autocalibration just before your production test shift begins.

Figure 2 shows an example of a DC voltage specification table with and without autocalibration (ACAL) from a 7.5-digit DMM. Accuracy specification is in ± (% of reading + % of range).

# Column key

**Column A** – Displays the multiple DC voltage ranges of the DMM.

**Column B** – Displays the DC voltage accuracy specifications with timeframes relative to calibration standards.

**Column C** – Displays the added errors for each °C outside the last ACAL ± 2 °C. Use this column if you do not use autocalibration.

**Column D** – Shows added errors for each °C outside ACAL ± 2 °C. Use this column if you use autocalibration.

| A | B | | | | C | D |
|---|---|---|---|---|---|---|
| Range | 24 Hours $T_{ACAL}$ ± 1 °C | 90 Days $T_{ACAL}$ ± 5 °C | 1 Year $T_{ACAL}$ ± 5 °C | 2 Years $T_{ACAL}$ ± 5 °C | Non ACAL Temperature coefficient/°C | With ACAL Temperature coefficient/°C |
| DC voltage | | | | | | |
| 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 + 0.0002 | 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 |

**Figure 2.** Example DC voltage specification table from a 7.5-digit DMM

If you want to measure 9 V on a 10 V range with your 7.5-digit DMM, these two scenarios with reference to your DC voltage accuracy as shown in the specification table in Figure 2.

# Scenario 1: Not using ACAL with your DMM

Your guaranteed accuracy is from the 10 V range and 1-year specification. The calculations are from the errors from column B (blue), plus errors for each °C outside the last ACAL ± 2 °C from column C (orange).

# Scenario 2: Using ACAL with your DMM

Your guaranteed accuracy is from the 10 V range and 1-year specification. The calculations are from the errors from column B (blue), plus errors for each °C outside ACAL ± 2 °C from column D (green).

For example, let us calculate the 1-year base accuracy for the 7.5-digit DMM from Figure 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 uses the 7.5-digit DMM from Figure 2 — 9 V ± 0.164 mV**

If you choose to skip the ACAL step like scenario 1, you would use the TC adder for the non-ACAL column. For each degree Celsius outside of the TCAL ± 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)**

The base specification is applicable for 22 ˚C + 2 ˚C = 24 ˚C. Since we are operating at 40 ˚C, you would multiply the TC adder by 16 ˚C (40 ˚C-24 ˚C = 16 ˚C).

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 600% of the original specification.

If you choose scenario 2, you can greatly reduce the TC error by using the ACAL. By performing an ACAL shortly before our most accurate measurements, you can usually assume that the temperature will not change by more than 2 ˚C.

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 16 degrees:

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

The overall accuracy with ACAL is much better than the specifications without ACAL. The accuracy is widened by 285% and is more accurate than a non-ACAL DMM's specifications.

Figure 3 is a summary of the 7.5-digit DMM, and the levels of accuracy with and without ACAL turned on. The example is measuring 9 V on a 10 V range with calibration temperature at 22 ˚C and operating temperature at 40 ˚C.

| Model | Input voltage / range | Base spec at 22 °C | Spec with TC at 40 °C | Spec with TC and ACAL at 40 °C |
|---|---|---|---|---|
| 7.5-digit DMM | 9 V/10 V range | ± 164 µV | ± 1044 µV | ± 468 µV |

**Figure 3.** Comparisons of DMM accuracies with and without autocalibration

The temperature coefficient is sometimes an overlooked specification adder. At 40 ˚C, the error increased by 637% when compared to the base specification at room temperature. However, if you use ACAL, the error increased by 285% when compared to the base specification at room temperature.

Accuracy is often considered a critical specification of products. The ACAL feature enables you to characterize your products with better accuracy.

# When do I need to use the autocalibration function?

1. Use autocalibration while making highly sensitive, accurate measurements in a lab with variable temperature.

   You want 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. This is especially true if your lab's working temperature is different from the temperature at which the DMM underwent calibration.

2. How to make DMM rack measurements when the internal system temperature is higher than ambient.

   You have positioned your DMM in a rack and have controlled the air flow and temperature monitoring (Figure 4). Even with these precautions, the internal temperature of your system is 15 °C higher than ambient because of 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. ACAL can reduce your TC errors and help you meet the specification budget for your DMM measurements.

**Figure 4.** Test rack with equipment

# Conclusion

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.

The Keysight Truevolt Series DMMs and Keysight's 3458A 8.5-digit DMM with built-in ACAL can help ensure that your readings are accurate — even with temperature errors.

For more information about Keysight's Truevolt Series DMMs, visit www.keysight.com/find/Truevolt and Keysight's 8.5-digit high performance DMM, visit www.keysight.com/find/3458A


**Figure 5.** Keysight's Truevolt Series DMMs


**Figure 6.** Keysight's high performance 3458A DMM

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