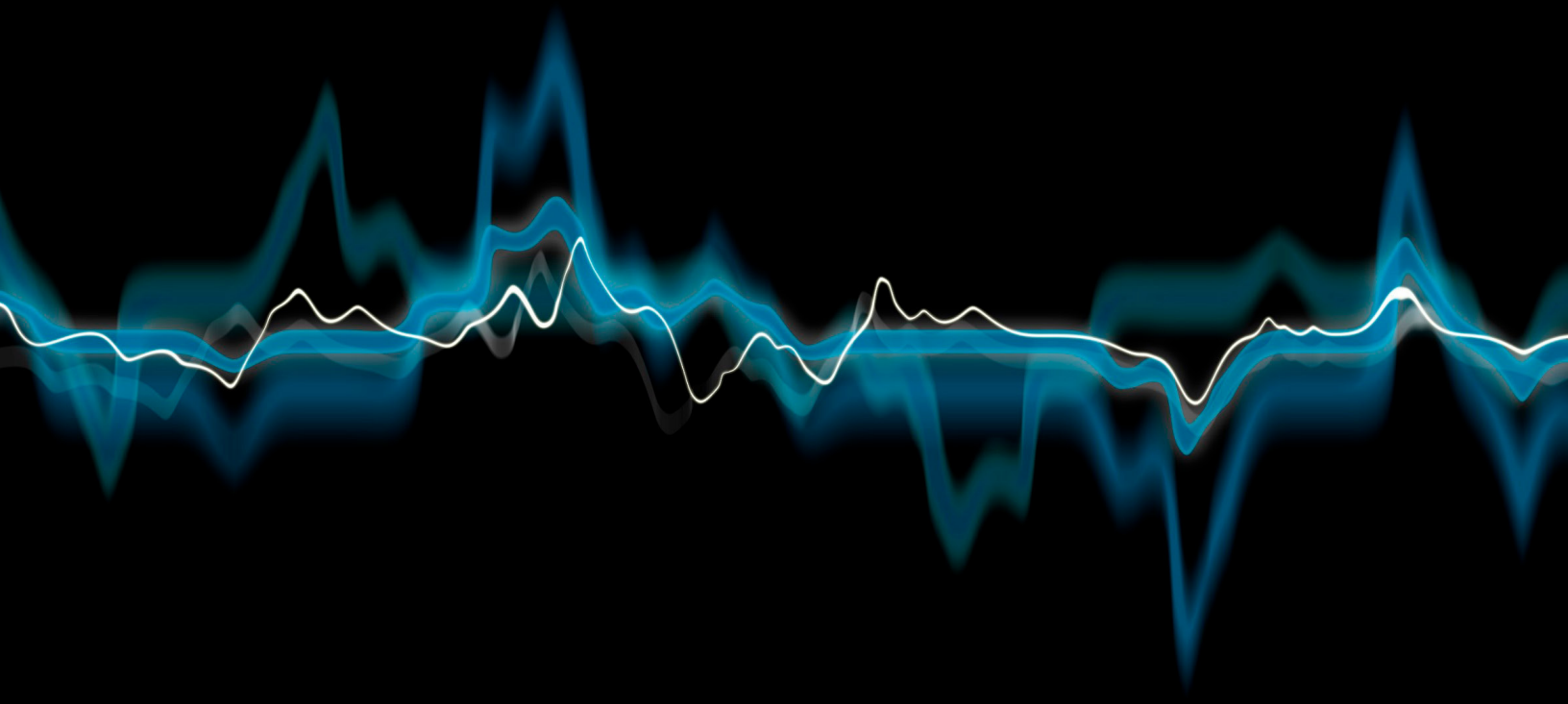
WHITE PAPER



Remove Resistance, Current, and Frequency Measurement Errors in DMMs

KEYSIGHT

Introduction

When you make measurements with a digital multimeter (DMM), common errors will occur. This white paper covers the types of measurement errors for resistance, DC and AC currents, including frequency and period. You will learn how to eliminate potential measurement errors to achieve the highest accuracy with a DMM.

Key factors causing resistance measurement errors with a DMM:

- Long leads create a voltage drop across the leads.
- Lower DMM resistance range generates higher test current, which may affect sensitive DUT with a large temperature coefficient.
- Large resistance range changes require proper measurement settling delays.
- Current leakages on test leads and fixtures affect high resistance measurements.

Resistance Measurement Errors

Many modern benchtop DMMs offer two methods for measuring resistance — two-wire and four-wire resistance measurements. For both methods, the test current flows from the input HI terminal and then through the resistor being measured. For two-wire resistance measurements, the voltage drop across the resistor being measured is sensed internal to the multimeter. Therefore, this method also measures the test lead resistance. For four-wire resistance measurements, separate "sense" connections are necessary. Figure 1 is the four-wire resistance measurement process, while using a current source along with a remote sensing digital voltmeter to eliminate measuring the additional lead resistance in your measurement. Since no current flows through the voltage sense leads, there is no voltage drop in the leads and, thus, no lead resistance error in the measurement.

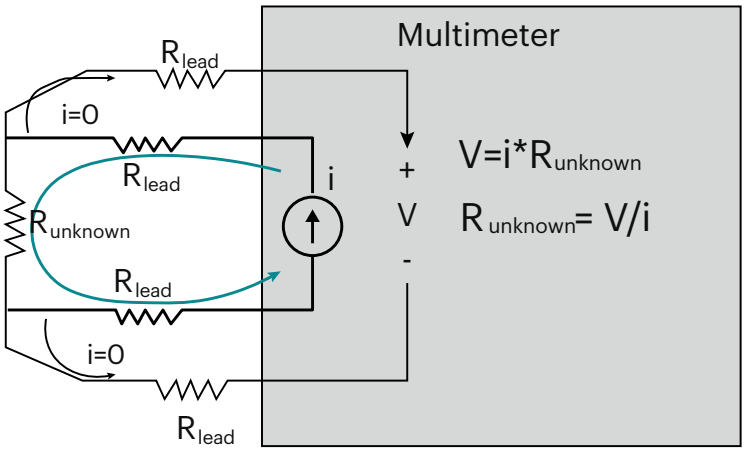


Figure 1. A 4-wire resistance measurement process

Errors for DC voltage measurements also apply to resistance measurements. However, additional error sources that are unique to resistance measurements exist.

Power dissipation effects

When measuring resistors designed for temperature measurements or other resistive devices with large temperature coefficients, the multimeter will dissipate some power in the device under test (DUT). If power dissipation is a problem, select the multimeter's next higher measurement range to reduce the errors to acceptable levels. See Figure 2 for examples of DMM ranges with corresponding test currents.

Range	Test current	DUT power at full-scale
100 Ω	1 mA	100 µW
1 kΩ	1 mA	1 mW
10 kΩ	100 µA	100 µW
100 kΩ	10 µA	10 µW
1 MΩ	5 µA	25 µW
10 MΩ	500 nA	2.5 µW

Figure 2. Examples of various DMM ranges and its corresponding test current and DUT power at full scale

Settling time effects

A modern DMM can insert automatic measurement settling delays. These delays are adequate for resistance measurements with less than 200 pF of combined cable and device capacitance. This settling delay time setting is particularly important when measuring resistances above 100 kΩ. Settling due to RC time constant effects can be lengthy. Some precision resistors and multifunction calibrators use large parallel capacitors — 1000 pF to 0.1 µF — with high resistor values to filter out noise currents injected by their internal circuitry. Non-ideal capacitances in cables and other devices may have lengthy settling times because of RC time constants due to dielectric absorption (soak) effects. Measurement errors occur during the settling period after the initial connection or after a range change.

High resistance measurement errors

When you measure high resistances, significant errors can occur because of insulation resistance and surface cleanliness. You should take the necessary precautions to maintain a clean high-resistance system. Test leads and fixtures are susceptible to leakage because of the moisture absorption in insulating materials and dirty surface films. Nylon and PVC (polyvinyl chloride) are relatively poor insulators (109 Ω) compared to PTFE (polytetrafluoroethylene) insulators (1013 Ω). Leakage from nylon or PVC insulators can easily contribute a 0.1% error when measuring a 1 MΩ resistance in humid conditions.

DC Current Measurement Errors

When you connect the multimeter in a series with a test circuit to measure current, it introduces a measurement error due to the multimeter's burden voltage. Figure 3 shows how the voltage develops across the wiring resistance and current shunt resistance of the multimeter.

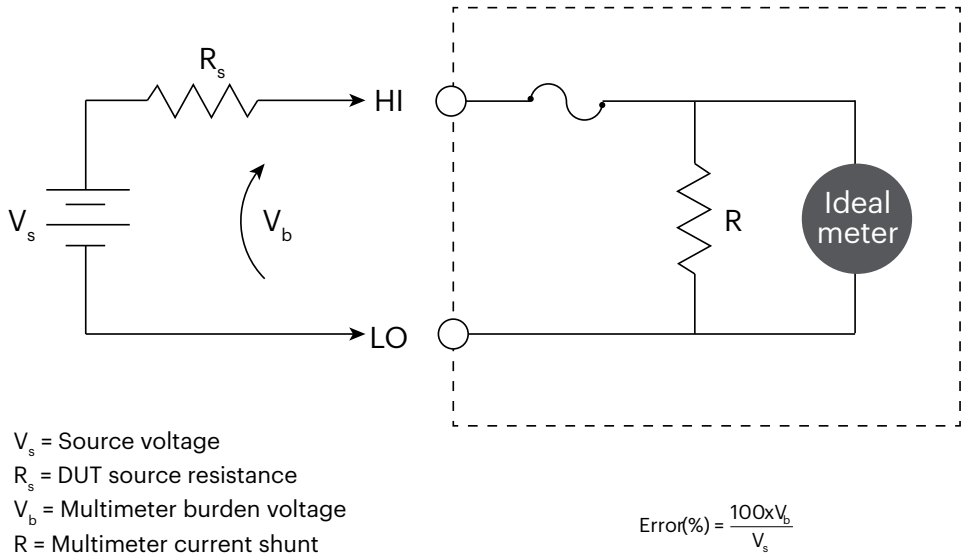


Figure 3. A DMM's burden voltage is introduced to the measurement circuit when connected to the DUT in series

AC Current Measurement Errors

Burden voltage errors, which apply to DC current, also apply to AC current measurements. However, the burden voltage for AC current is larger because of the multimeter's series inductance and the measurement connections.

The burden voltage increases as the input frequency increases — some circuits may oscillate when performing current measurements due to the multimeter's series inductance and the specific measurement connections.

Frequency and Period Measurement Errors

Many modern DMMs are quite versatile — frequency and period measurements are additional features built into the DMMs. Some DMMs use a reciprocal counting technique to measure frequency and period to generate constant measurement resolution for any input frequency. In general, all frequency counters are susceptible to errors when measuring low-voltage, low-frequency signals. The effects of both internal noise and external noise pickup are critical when measuring slow signals — the error is inversely proportional to frequency. Measurement errors will also occur when you attempt to measure the frequency or period of an input following a DC offset voltage change. To avoid this, allow the multimeter's input DC blocking capacitor to fully settle before making frequency measurements.

Conclusion

When measuring small resistance or low current, it is important to take extra precautions to make quality measurements. Once the system settling times are determined, the reading delay times can be set to optimize measurement time and increase system throughput.

The Keysight Truevolt DMMs enable you to measure with confidence. With a Truevolt DMM, you can measure real-world signals and not instrument errors. The Truevolt DMM generates the least noise and injected current compared to benchtop DMM alternatives in the marketplace with models to fit your measurement requirements (Figure 4).



Figure 4. Keysight Truevolt DMMs — 34460A, 34461A, 34465A, and 34470A

To learn more, go to www.keysight.com/find/Truevolt.

For more information on Keysight Technologies' products, applications, or services, please visit: www.keysight.com

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