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Two-Wire vs. Four-Wire Resistance Measurements: Which Configuration Makes Sense for Your Application?

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MOST precision digital multimeters (DMMs) and many Source Measurement Units (SMUs) offer both two-wire and four-wire resistance measurement capabilities. However, these two techniques are not equally well suited for all resistance measurement applications. This article offers a quick overview of how to determine the most appropriate technique for a specific application.

DMMs typically employ the constant-current method to measure resistance, which sources a constant current (I_{SOUR}) to the device under test (DUT) and measures the voltage (V_{MEAS}). Resistance (R_{DUT}) is then calculated and displayed using the known current and measured voltage ($R_{DUT} = V_{MEAS}/I_{SOUR}$). ***Figure 1*** shows a simple diagram of the constant-current test.

The test current sourced to the DUT depends on the selected measurement range (***Table 1***). For example, for the 100Ω range, the test current is 1mA. Because the voltmeter of a typical DMM has very high input impedance, virtually all the test current (1mA) flows through the DUT.

Table 1. Typical DMM ranges and test currents

Measurement Range	Test Current
100 Ω	1 mA
1 kΩ	1 mA
10 kΩ	100 µA
100 kΩ	10 µA
1 MΩ	1 µA
10 MΩ	0.1 µA
100 MΩ	0.1 µA

(Source Keithley Model 2110)

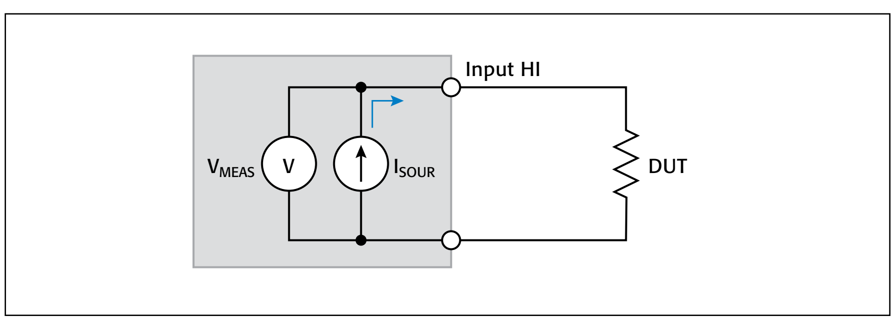

Figure 1. The constant-current method of resistance measurement, in a two-wire test configuration.

Two-Wire Resistance Measurements

Figure 2 represents a two-wire resistance test configuration employing the constant current method.

The main measurement issue with the two-wire method, as applied to low resistance measurements, is that the total lead resistance (R_{LEAD}) is added to the measurement. Because the test current (I) causes a small but significant voltage drop across the lead resistances, the voltage (V_M) measured by the meter won't be exactly the same as the voltage (V_R) directly across the test resistance (R), and considerable error can result. Typical lead resistances range from 10mΩ to 1Ω, so it's very difficult to obtain accurate two-wire resistance measurements when the resistance under test is lower than 100Ω because the resistance of interest will be completely swamped by the lead resistance. In fact, lead resistance will be the dominant source of error. For example, using test leads with a 100mΩ combined resistance to perform a two-wire resistance measurement on a 500mΩ resistor will result in a 20% measurement error in addition to that of the instrument.

Four-Wire (Kelvin) Resistance Measurements

Due to the limitations of the two-wire method, a different approach is used for low resistance measurements that reduce the effect of test lead resistance. For measuring DUTs with resistances equal to or less than 1kΩ, test engineers may use the four-wire (Kelvin) connection shown in ***Figure 3***. Because the voltage is measured at the DUT, voltage drop in the test leads is eliminated (this voltage could be significant when measuring low-resistance devices).

With this configuration, the test current (I) is forced through the test resistance (R)

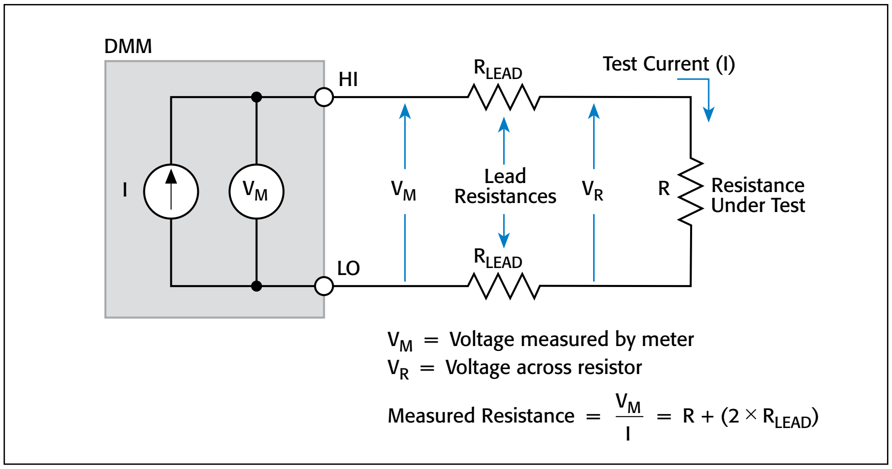

Figure 2. Two-wire resistance measurement schematic.

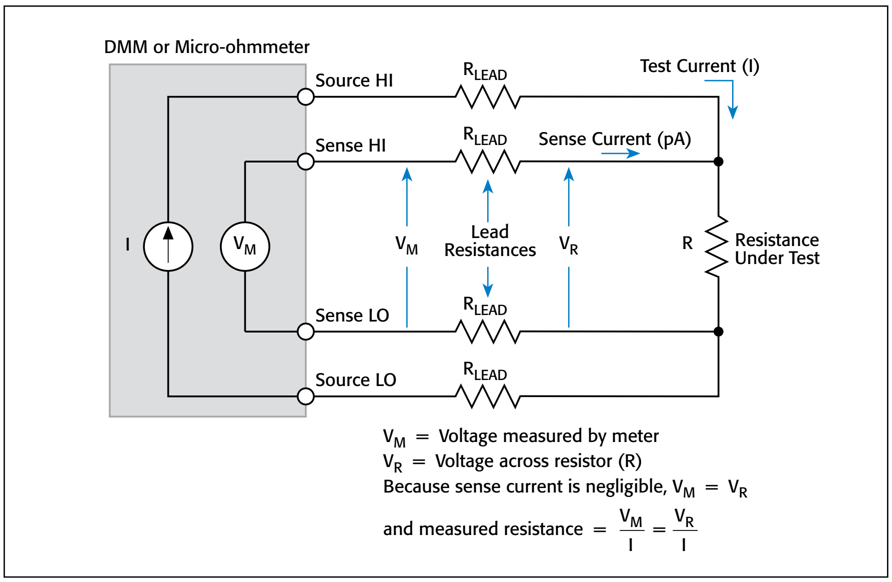

Figure 3. Four-wire resistance measurement configuration.

Figure 4. Keithley's 5½-digit Model 2110 DMM supports both two-wire and four-wire configurations for resistance measurement ranges of 100Ω, 1kΩ, 10kΩ, 100kΩ, 1MΩ, 10MΩ, and 100MΩ.

via one set of test leads, while the voltage (V_M) across the DUT is measured through a second set of leads (sense leads).

Although some small current (typically less than 100pA) may flow through the sense leads, it is usually negligible and can generally be ignored for all practical purposes. Therefore the voltage measured by the meter (V_M) is essentially the same as the voltage (V_R) across the resistance (R). As a result, the resistance value can be determined much more accurately than with the two-wire method. Note that the voltage-sensing leads should be connected as close to the resistor under test as possible to avoid including part of the resistance of the test leads in the measurement. ■

About the Author

Jerry Janesch is a senior market development manager at Keithley Instruments, Inc., headquartered in Cleveland, Ohio, which is part of the Tektronix test and measurement portfolio. He earned a bachelor's degree in electrical engineering from Fenn College of Engineering and a master's of business administration from John Carroll University. He has been with Keithley since 2000.

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