Section 6

# Measuring 4-wire resistance with offset compensation

**In this section:**



## Introduction

This application example demonstrates how to use the DMM6500 to accurately measure resistance.

Typical resistance measurements made using the 2-wire method source current through the test leads and the device under test (DUT). The voltage is measured and the resistance is calculated.

It is very difficult to obtain accurate 2-wire resistance measurements when the DUT is lower than 100 Ω. Typical lead resistances lie in the range of 1 mΩ to 10 mΩ. When the 2-wire method is applied to low-resistance measurements, there is a small but significant voltage drop across the resistance of each test lead. The voltage measured by the instrument is not the same as the voltage directly across the DUT.

The 4-wire method is preferred for low-resistance measurements. With this configuration, the test current is sourced through the DUT using one set of test leads, while a second set of SENSE leads measures the voltage across the DUT. The voltage-sensing leads should be connected as close to the device under test as possible to avoid including the resistance of the test leads in the measurement.

Thermoelectric voltages (EMFs) can seriously affect low-resistance measurement accuracy. The DMM6500 can apply the offset-compensated ohms method (OCOMP), which makes one normal resistance measurement and one using the lowest current source setting to eliminate EMFs.

For this example, you will use a 20 Ω resistor. Fixed measurement ranges are applied in order to optimize scanning speed and OCOMP is applied to correct for any EMF effects.

NOTE

**For comprehensive information on 4W resistance measurements, thermoelectric EMFs, and offset compensation methods, see the "Low Level Measurements Handbook," which is available on the Keithley Instruments website.**

# Equipment required

- One DMM6500
- One computer setup for communication with the instrument
- Four insulated banana cables, such as the Model 1757 Standard Test Lead Kit. (you will need two kits)
- One device to be tested (the application shown uses a 20 Ω resistor)

# Device connections

This example application uses the DMM6500 to perform a 4-wire resistance-device measurement using offset compensation. Both the front and rear-panel connections are safety banana jacks. You can use either the front or the rear input terminals.

**NOTE**

**You must use either the front or the rear terminals. You cannot mix the front and rear connections.**

Make sure that the front-panel **TERMINALS** switch is set to the terminals you are using. An illuminated green LED next to the switch indicates that the instrument is reading the front-panel terminals. An illuminated yellow LED indicates that the instrument is reading the rear-panel terminals.

***To use the 4-wire connection method:***

1. Connect one set of test leads to the INPUT HI and INPUT LO terminals.
2. Connect the other set of test leads to the SENSE HI and SENSE LO terminals.

**Figure 33: Font-panel connections for 4-wire resistance measurements**

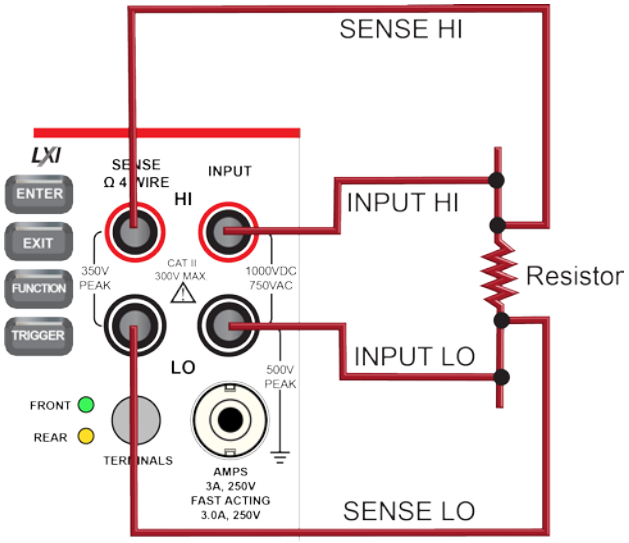
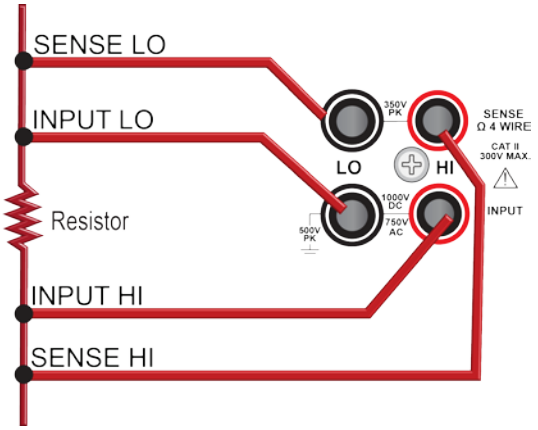



**Figure 34: Rear-panel connections for 4-wire resistance measurements**



3. Connect the INPUT HI and SENSE HI connections to one of the device-under-test (DUT) leads. Connect the sense connection as close to the DUT as possible.
4. Connect the INPUT LO and SENSE LO to the other DUT lead. Connect the sense connection as close to the DUT as possible.

**⚠ WARNING**

**To prevent electric shock, test connections must be configured such that the user cannot come in contact with test leads or any device under test (DUT) that is in contact with the conductors. It is good practice to disconnect DUTs from the instrument before powering the instrument. Safe installation requires proper shields, barriers, and grounding to prevent contact with test leads.**

**There is no internal connection between protective earth (safety ground) and the LO terminals of the DMM6500. Therefore, hazardous voltages (more than 30 $V_{rms}$) can appear on LO terminals. This can occur when the instrument is operating in any mode. To prevent hazardous voltage from appearing on the LO terminals, connect the LO terminal to protective earth (safety ground) if your application allows it. You can connect the LO terminal to the chassis ground terminal on the front panel or the chassis ground screw terminal on the rear panel. Note that the front-panel terminals are isolated from the rear-panel terminals. Therefore, if you are using the front-panel terminals, ground to the front-panel LO terminal. If using the rear-panel terminals, ground to the rear panel LO terminal. Failure to follow these guidelines can result in injury, death, or instrument damage.**

# Measuring 4-wire resistance with offset compensation

This application demonstrates how to use the DMM6500 to measure the resistance of a device or component. You can make this measurement from the front panel or over the remote interface using SCPI or TSP code. For information about setting up remote communications, see Remote communications interfaces (on page 3-1).

***For this application, you will:***

- Reset the instrument.
- Select the 4-wire resistance function. This method eliminates the effect of the lead resistance on measurement accuracy.
- Enable offset compensation.
- Make measurements from the front panel or the remote interface.

## Using the front panel

**NOTE**

**Range is automatically set to auto, autozero is automatically set to On, and NPLC is automatically set to 1.**

***To set up the application from the front panel:***

1. Press the **POWER** switch on the front panel to turn on the instrument.
2. On the FUNCTIONS swipe screen, select **4W Ω** to select the 4-wire resistance measure function.
3. Press the **MENU** key.
4. Under Measure, select **Settings**.
5. Select Offset Compensation and select **On.**
6. Press the **HOME** key.

The measurement readings are displayed in the top area of the Home screen.

## Using SCPI commands

This sequence of SCPI commands measures the resistance of a device or component.

You may need to make changes so that this code will run in your programming environment. In the table, the SCPI commands have a light gray background.

***Send the following commands for this example application:***

| Commands | Descriptions |
|---|---|
| `*RST` | • Reset the DMM6500 |
| `:SENS:FUNC "FRES"` | • Set function to 4-wire measurement |
| `:SENS:FRES:RANG: AUTO ON` | • Enable auto range |
| `:SENS:FRES:OCOM ON` | • Enable offset compensation |
| `:SENS:FRES:AZER ON` | • Enable auto zero |
| `:SENS:FRES:NPLC 1` | • Set NPLC to 1 |
| `:READ?` | • Read the resistance value |

## Using TSP commands

**NOTE**

**The following TSP code is designed to be run from Keithley Instruments Test Script Builder (TSB). TSB is a software tool that is available from the Keithley webpage on the Tektronix website (tek.com/keithley). You can install and use TSB to write code and develop scripts for TSP-enabled instruments. Information about how to use TSB is in the online help for TSB and in the "Introduction to TSP operation" section of the *DMM6500 Reference Manual*.**

**To use other programming environments, you may need to make changes to the example TSP code.**

By default, the DMM6500 uses the SCPI command set. You must select the TSP command set before sending TSP commands to the instrument.

***To enable TSP commands:***

1. Press the **MENU** key.
2. Under System, select **Settings**.
3. For Command Set, select **TSP**.
4. At the prompt to reboot, select **Yes**.

This sequence of TSP commands initiates one resistance reading. After the code is executed, the data is displayed in the Instrument Console of Test Script Builder.

***Send the following commands for this example application:***

```
--Reset the Model DMM6500 to the default settings.
reset()
--Set the measure function to 4-wire resistance.
dmm.measure.func = dmm.FUNC_4W_RESISTANCE
--Enable autorange.
dmm.measure.autorange = dmm.ON
--Enable autozero.
dmm.measure.autozero.enable = dmm.ON
--Enable offset compensation.
dmm.measure.offsetcompensation.enable = dmm.ON
--Set the number of power line cycles to 1.
dmm.measure.nplc = 1
--Read the resistance value.
print(dmm.measure.read())
```

## Test results

The results of a low-resistance measurement test using a 20 Ω resistor are shown in the table below.

For example, if the resistor specification has a tolerance of ±0.1% and a temperature coefficient of ±15 ppm/°C, a compliant resistor measures between 19.97 Ω and 20.03 Ω.

| Offset compensation | Resistance |
|---|---|
| Off | 19.992460878 |
| On | 19.991394395 |

**Figure 35: 4-wire resistance test results**