

Model DMM7510 7½ Digit Multimeter

Application Manual

DMM7510-904-01 Rev. D March 2021



DMM7510-904-01D

Model DMM7510
7½ Digit Multimeter
Application Manual

© 2021, Keithley Instruments, LLC

Cleveland, Ohio, U.S.A.

All rights reserved.

Any unauthorized reproduction, photocopy, or use of the information herein, in whole or in part, without the prior written approval of Keithley Instruments, LLC, is strictly prohibited.

These are the original instructions in English.

TSP®, TSP-Link®, and TSP-Net® are trademarks of Keithley Instruments, LLC. All Keithley Instruments product names are trademarks or registered trademarks of Keithley Instruments, LLC.

Other brand names are trademarks or registered trademarks of their respective holders.

The Lua 5.0 software and associated documentation files are copyright © 1994 - 2015, Lua.org, PUC-Rio. You can access terms of license for the Lua software and associated documentation at the Lua licensing site (<https://www.lua.org/license.html>).

Microsoft, Visual C++, Excel, and Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

Document number: DMM7510-904-01 Rev. D March 2021

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with nonhazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the user documentation for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product warranty may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the user documentation. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, perform safe installations, and repair products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are measurement, control, and data I/O connections, with low transient overvoltages, and must not be directly connected to mains voltage or to voltage sources with high transient overvoltages. Measurement Category II (as referenced in IEC 60664) connections require protection for high transient overvoltages often associated with local AC mains connections. Certain Keithley measuring instruments may be connected to mains. These instruments will be marked as category II or higher.

Unless explicitly allowed in the specifications, operating manual, and instrument labels, do not connect any instrument to mains.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30 V RMS, 42.4 V peak, or 60 VDC are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 V, no conductive part of the circuit may be exposed.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance-limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, ensure that the line cord is connected to a properly-grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.


For safety, instruments and accessories must be used in accordance with the operating instructions. If the instruments or accessories are used in a manner not specified in the operating instructions, the protection provided by the equipment may be impaired.


Do not exceed the maximum signal levels of the instruments and accessories. Maximum signal levels are defined in the specifications and operating information and shown on the instrument panels, test fixture panels, and switching cards.

When fuses are used in a product, replace with the same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as protective earth (safety ground) connections.


If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.


If a  screw is present, connect it to protective earth (safety ground) using the wire recommended in the user documentation.

The  symbol on an instrument means caution, risk of hazard. The user must refer to the operating instructions located in the user documentation in all cases where the symbol is marked on the instrument.

The  symbol on an instrument means warning, risk of electric shock. Use standard safety precautions to avoid personal contact with these voltages.


The  symbol on an instrument shows that the surface may be hot. Avoid personal contact to prevent burns.

The  symbol indicates a connection terminal to the equipment frame.

If this  symbol is on a product, it indicates that mercury is present in the display lamp. Please note that the lamp must be properly disposed of according to federal, state, and local laws.

The **WARNING** heading in the user documentation explains hazards that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in the user documentation explains hazards that could damage the instrument. Such damage may invalidate the warranty.

The **CAUTION** heading with the  symbol in the user documentation explains hazards that could result in moderate or minor injury or damage the instrument. Always read the associated information very carefully before performing the indicated procedure. Damage to the instrument may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits — including the power transformer, test leads, and input jacks — must be purchased from Keithley. Standard fuses with applicable national safety approvals may be used if the rating and type are the same. The detachable mains power cord provided with the instrument may only be replaced with a similarly rated power cord. Other components that are not safety-related may be purchased from other suppliers as long as they are equivalent to the original component (note that selected parts should be purchased only through Keithley to maintain accuracy and functionality of the product). If you are unsure about the applicability of a replacement component, call a Keithley office for information.

Unless otherwise noted in product-specific literature, Keithley instruments are designed to operate indoors only, in the following environment: Altitude at or below 2,000 m (6,562 ft); temperature 0 °C to 50 °C (32 °F to 122 °F); and pollution degree 1 or 2.

To clean an instrument, use a cloth dampened with deionized water or mild, water-based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., a data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

Safety precaution revision as of June 2017.

Table of contents

Introduction	1-1
Welcome	1-1
Introduction to this manual	1-1
Extended warranty	1-2
Contact information	1-2
Measuring dc voltage with high accuracy	2-1
Introduction	2-1
Equipment required	2-1
Device connections	2-1
High-accuracy dc voltage measurements	2-3
Using the front panel	2-4
Using SCPI commands	2-5
Using TSP commands	2-5
Test results	2-6
Measuring 4-wire resistance with offset compensation	3-1
Introduction	3-1
Equipment required	3-1
Device connections	3-2
Measuring 4-wire resistance with offset compensation	3-4
Using the front panel	3-4
Using SCPI commands	3-5
Using TSP commands	3-5
Test results	3-6
Sampling temperature at a set time interval	4-1
Introduction	4-1
Equipment required	4-1
Device connections	4-1
Sample temperatures at a specific time interval	4-3
Using SCPI commands	4-4
Using TSP	4-5
Test results	4-7
Grading and binning resistors	5-1
Introduction	5-1
Instrument connections	5-2
Resistor grading and binning test	5-2
Trigger-model template: GradeBinning	5-3

Overview of the application	5-4
Using SCPI commands	5-5
Using TSP commands	5-6
Integrating with a Model 3706A-S using TSP-Link.....	6-1
Introduction	6-1
Equipment required.....	6-1
Device connections	6-2
Integrating with a Model 3706A-S test setup	6-4
Set up TSP nodes on the DMM7510 and Model 3706A-S	6-5
Using SCPI.....	6-5
Using TSP	6-5
Capturing and analyzing waveforms	7-1
Introduction	7-1
Equipment required.....	7-1
Device connections	7-2
Testing a buck converter.....	7-3
Ripple noise on the output voltage	7-4
Duty cycle from switch node voltage	7-7
Inductor current linearity with varying load	7-11
Power-up behavior	7-16
Next steps.....	8-1
Additional information.....	8-1

Introduction

In this section:

Welcome	1-1
Introduction to this manual	1-1
Extended warranty	1-2
Contact information	1-2

Welcome

Thank you for choosing a Keithley Instruments product. The Keithley Instruments Model DMM7510 is a 7½ digit graphical sampling multimeter that expands standard DMM functions with high-speed digitizing and large graphical color touchscreen display. This DMM offers a broad range of measurement capabilities, including 17 measurement functions. In addition to industry-leading dc accuracies, functions such as capacitance, 10 A current, and 18-bit current and voltage digitizing are included. Tying all these features together is a large 5-inch color touchscreen display that brings users an unprecedented combination of data visualization and interaction, enabling users to gain deeper insight into their measurements.

The DMM7510 provides superior measurement accuracy and the speed necessary for a broad range of applications, from system applications and production testing to benchtop applications. The DMM7510 meets application requirements for production engineers, research and development engineers, test engineers, and scientists.

Introduction to this manual

This manual provides application examples that demonstrate how to use the DMM7510 in some typical situations.

For installation and basic instrument information, refer to the *Model DMM7510 User's Manual*.

For detailed information on the DMM7510, including descriptions of the SCPI and TSP commands, refer to the *Model DMM7510 Reference Manual*.

These manuals are available at tek.com/keithley.

Extended warranty

Additional years of warranty coverage are available on many products. These valuable contracts protect you from unbudgeted service expenses and provide additional years of protection at a fraction of the price of a repair. Extended warranties are available on new and existing products. Contact your local Keithley Instruments office, sales partner, or distributor for details.

Contact information

If you have any questions after you review the information in this documentation, please contact your local Keithley Instruments office, sales partner, or distributor. You can also call the Tektronix corporate headquarters (toll-free inside the U.S. and Canada only) at 1-800-833-9200. For worldwide contact numbers, visit [tek.com/contact-us](https://www.tek.com/contact-us).

Measuring dc voltage with high accuracy

In this section:

Introduction	2-1
Equipment required	2-1
Device connections	2-1
High-accuracy dc voltage measurements	2-3

Introduction

This example application demonstrates how to use a DMM7510 to make a high-accuracy dc voltage measurement.

This type of test is often done in metrology laboratories, where high accuracy is required for calibration and verification.

Equipment required

- One DMM7510
- One computer set up for communication with the DMM7510
- Two insulated cables with banana plugs
- One device to be tested

Device connections

You can use either the front or rear input terminals for this test. Both front-panel and rear-panel connections are safety banana jacks. Note that you must use either the front terminals or the rear terminals. You cannot mix front and rear connections.

Make sure that the front-panel TERMINALS switch is set to the terminals you are using. When **F** is displayed next to the switch, the instrument is reading the front-panel terminals. **R** indicates that the instrument is reading the rear-panel terminals.

Make sure power to the instrument is off and make the following connections:

- Connect the test leads to the INPUT HI and LO terminals.
- Connect the INPUT HI connection to one of the DUT leads.
- Connect the INPUT LO connection to the other DUT lead.

The physical connections for the front and rear panels are shown in the following figures.

Figure 1: Front-panel connections for high-accuracy dc voltage measurements

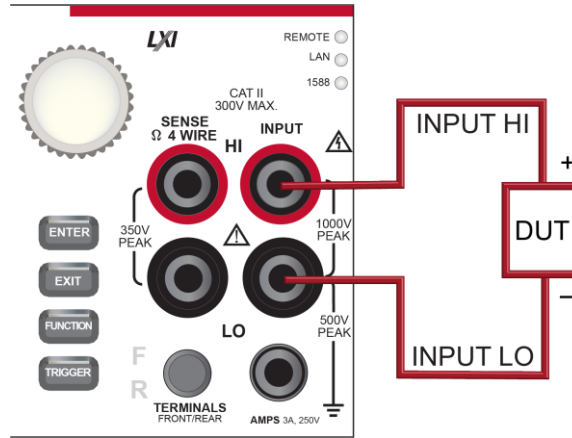
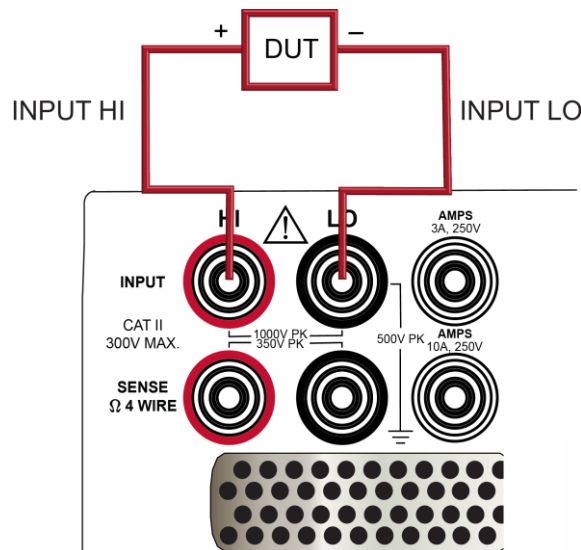


Figure 2: Rear-panel connections for high-accuracy dc voltage measurements



⚠ 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 power before connecting DUTs. 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 DMM7510. 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. Failure to recognize and observe normal safety precautions could result in personal injury or death.

High-accuracy dc voltage measurements

This application demonstrates how to use the DMM7510 to make a high-accuracy dc voltage measurement. You can make the measurement from the front panel or over the remote interface using SCPI code or TSP code. For information about setting up remote communications, see "Remote communications interfaces" in the *Model DMM7510 User's Manual*.

For this application, you will:

- Restart the instrument.
- Select the dc voltage function.
- Set the integration rate to 10 power line cycles (PLCs). At 60 Hz line frequency, 10 PLCs provide an aperture of 166.7 ms.
- Set the input impedance to Auto.
- Turn on autozero. This enables the instrument to optimize the accuracy of readings by checking reference measurements.
- Enable a repeating filter with a count of 100. This reduces noise error because the results are more stable when the measurements are averaged.
- Generate readings from the front panel or the remote interface.

Using the front panel

Restart the instrument and select the function, integration rate, auto zero, and filter settings:

1. Press the **POWER** button on the front panel to turn on the instrument.
2. On the FUNCTIONS swipe screen, select **DCV**.
3. On the top half of the home screen, select **Range**.
4. Select **10V**.
5. Swipe to the **SETTINGS** swipe screen.
6. Set the Rate to **10**.
7. Select **OK**.
8. Set Input Z to **Auto**.
9. Verify that Auto Zero is selected.
10. Press the **MENU** key.
11. Under Measure, select **Calculations**.
12. Set Filter to **On**.
13. Select **Settings**.
14. Set the Type to **Repeat**.
15. Set the Count to **100**.
16. Select **OK**.
17. Press the **HOME** key.

NOTE

If measurements are not updating, press the **TRIGGER** key for a few seconds. Verify that the trigger mode is set to **Continuous Measurement**.

The measurement is displayed in the top area of the home screen.

With a repeating filter count of 100 and NPLC of 10, the measurement cycle time is slow but accurate. By reducing the values of these settings, you can get faster but less accurate readings. The balance between speed and accuracy depends on the needs of your specific application.

Using SCPI commands

This sequence of SCPI commands sets up and runs a single high-accuracy dc voltage measurement when a device under test is connected to the DMM7510 and controlled remotely.

You may need to make changes so that this code will run in your programming environment.

Send the commands in the following table for this example application.

Command	Description
<pre>*RST :SENS:FUNC "VOLT:DC" :SENS:VOLT:RANG 10 :SENS:VOLT:INP AUTO :SENS:VOLT:NPLC 10 :SENS:VOLT:AZER ON :SENS:VOLT:AVER:TCON REP :SENS:VOLT:AVER:COUN 100 :SENS:VOLT:AVER ON :READ?</pre>	<ul style="list-style-type: none"> ▪ Reset the DMM7510. ▪ Set the instrument to measure dc voltage. ▪ Set the measure range to 10 V. ▪ Set the input impedance to automatic so the instrument selects 10 GΩ for the 10 V range. ▪ Set the integration rate (NPLCs) to 10. ▪ Enable autozero. ▪ Set the averaging filter type to repeating. ▪ Set the filter count to 100. ▪ Enable the filter. ▪ Read the voltage value; wait a few seconds for the reading.

Using TSP commands

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 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 *Model DMM7510 Reference Manual*.

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

By default, the DMM7510 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. Set the Command Set to **TSP**.
4. At the prompt to reboot, select **Yes**.

This sequence of TSP commands makes a single high-accuracy dc voltage measurement when a device under test is connected to the DMM7510.

After the code executes, the reading is displayed in the Instrument Console of Test Script Builder.

Send the following commands for this example application:

```
-- Reset the instrument to the default settings.
reset()
-- Set the measure function to dc voltage.
dmm.measure.func = dmm.FUNC_DC_VOLTAGE
-- Set the measurement range to 10 V.
dmm.measure.range = 10
-- Set the number of power line cycles to 10.
dmm.measure.nplc = 10
-- Set the input impedance to auto so it selects 10 Gohm for the 10V range.
dmm.measure.inputimpedance = dmm.IMPEDANCE_AUTO
-- Enable autozero.
dmm.measure.autozero.enable = dmm.ON
-- Set the averaging filter type to repeating.
dmm.measure.filter.type = dmm.FILTER_REPEAT_AVG
-- Set filter count to 100.
dmm.measure.filter.count = 100
-- Enable the filter.
dmm.measure.filter.enable = dmm.ON
-- Read the voltage value.
print(dmm.measure.read())
```

Test results

The following table shows the tradeoff between accuracy and speed of measurements based on the integration rate (NPLC), averaging filter, and autozero settings. The first row of data is from the setup documented in this example. The other rows show the results if the integration rate, filter, and auto zero settings are changed.

DC voltage	Measurement time (seconds)	Integration rate (NPLC)	Filter	Auto zero
5.0700528516	50.702501353	10	ON	ON
5.0701004092	0.510109919	10	OFF	ON
5.0700203296	0.017853353	1	OFF	ON
5.070064163	0.019507031	1	OFF	OFF



Measuring 4-wire resistance with offset compensation

In this section:

Introduction	3-1
Equipment required	3-1
Device connections	3-2
Measuring 4-wire resistance with offset compensation	3-4

Introduction

This application example demonstrates how to use the DMM7510 to accurately measure a resistance device.

To provide the best resistance measurement accuracy, the four-wire (Kelvin) measurement and the offset compensation methods are used for this test. Offset compensation is a measuring technique that reduces or eliminates thermoelectric electromotive forces (EMFs) in low-level resistance measurements. The voltage offsets that occur because of the presence of thermoelectric electromotive force (V_{EMF}) can adversely affect resistance measurement accuracy.

To overcome these offset voltages, you can use offset-compensated ohms.

Equipment required

- One DMM7510
- One computer setup for communication with the DMM7510
- Four insulated cables with banana plugs
- One device to be tested; the application shown here uses a 20 Ω resistor (actual resistance value can vary with availability and user discretion)

Device connections

You can use either the front-panel or the rear-panel terminals for this application. The following figures show the physical connections for the front and rear panels. Note that you must use either the front terminals or the rear terminals. You cannot mix front and rear connections.

Make sure that the front-panel TERMINALS switch is set to the terminals you are using. When **F** is displayed next to the switch, the instrument is reading the front-panel terminals. **R** indicates that the instrument is reading the rear-panel terminals.

The front-panel and rear-panel connections are both safety banana jacks.

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.
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 power before connecting DUTs. 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 DMM7510. 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. Failure to recognize and observe normal safety precautions could result in personal injury or death.

Figure 3: Front-panel connections for 4-wire resistance measurements

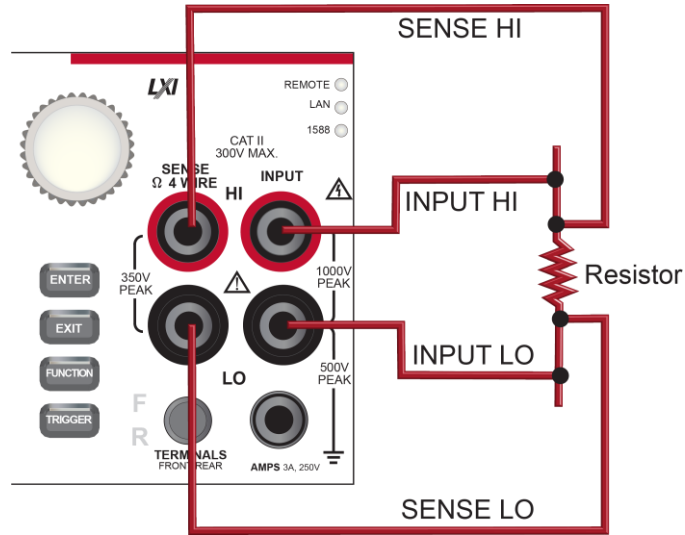
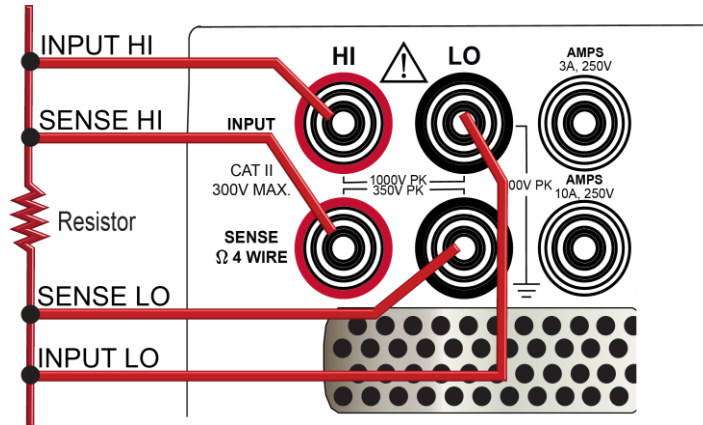


Figure 4: Rear-panel connections for 4-wire resistance measurements



Measuring 4-wire resistance with offset compensation

This application demonstrates how to use the DMM7510 to measure the resistance of a device or component. You can make this measurement from the DMM7510 front panel or over the remote interface using SCPI code or TSP code. For information about setting up remote communications, see "Remote communications interfaces" in the *Model DMM7510 User's Manual*.

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

To set up the application from the front panel:

1. Press the **POWER** button 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. Set Offset Compensation to **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. The device under test is connected to the DMM7510 and controlled remotely.

You may need to make changes so that this code will run in your programming environment.

Send the commands in the following table to set up and run this example application.

Command	Description
*RST :SENS:FUNC "FRES" :SENS:FRES:RANG: AUTO ON :SENS:FRES:OCOM ON :SENS:FRES:AZER ON :SENS:FRES:NPLC 1 :READ?	<ul style="list-style-type: none"> ■ Reset the DMM7510. ■ Set to measure four-wire resistance. ■ Enable autorange. ■ Enable offset compensation. ■ Enable autozero . ■ Set NPLC to 1. ■ Read the resistance value.

Using TSP commands

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 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 *Model DMM7510 Reference Manual*.

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

By default, the DMM7510 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. Set the Command Set to **TSP**.
4. At the prompt to reboot, select **Yes**.

In this example, the DMM7510 makes 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 DMM7510 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 percent and a temperature coefficient of ± 15 ppm per $^{\circ}\text{C}$, a compliant resistor measures between 19.97 Ω and 20.03 Ω .

Offset compensation	Resistance
OFF	0.020035852875 k Ω
ON	0.019991329184 k Ω

Sampling temperature at a set time interval

In this section:

Introduction	4-1
Equipment required.....	4-1
Device connections	4-1
Sample temperatures at a specific time interval.....	4-3

Introduction

This application example demonstrates how to use the DMM7510 to log temperature measurement data every minute over a 24-hour period.

It can be important for product quality during production or storage to know the ambient temperature of the testing environment. You can use the DMM7510 to set up a temperature monitoring system that samples temperatures at a fixed time interval for an extended period.

Equipment required

- One DMM7510
- 100 Ω RTD temperature probe (such as Tektronix TP750)
- One computer set up for remote communication with the DMM7510

Device connections

Use of a four-wire resistance temperature detector (RTD) reduces the effects of lead resistance on accuracy and provides high stability.

You can use either the front or rear input terminals for this test. Both front-panel and rear-panel connections are safety banana jacks. You must use either the front terminals or the rear terminals. You cannot mix front and rear connections.

Make sure that the front-panel TERMINALS switch is set to the terminals you are using. When **F** is displayed next to the switch, the instrument is reading the front-panel terminals. **R** indicates that the instrument is reading the rear-panel terminals.

Make the following connections:

- Connect the red test leads to the SENSE HI and INPUT HI terminals.
- Connect the black test leads to the SENSE LO and INPUT LO terminals.

The physical connections for the front and rear panels are shown in the following figures.

Figure 5: 4-wire RTD probe front-panel connections

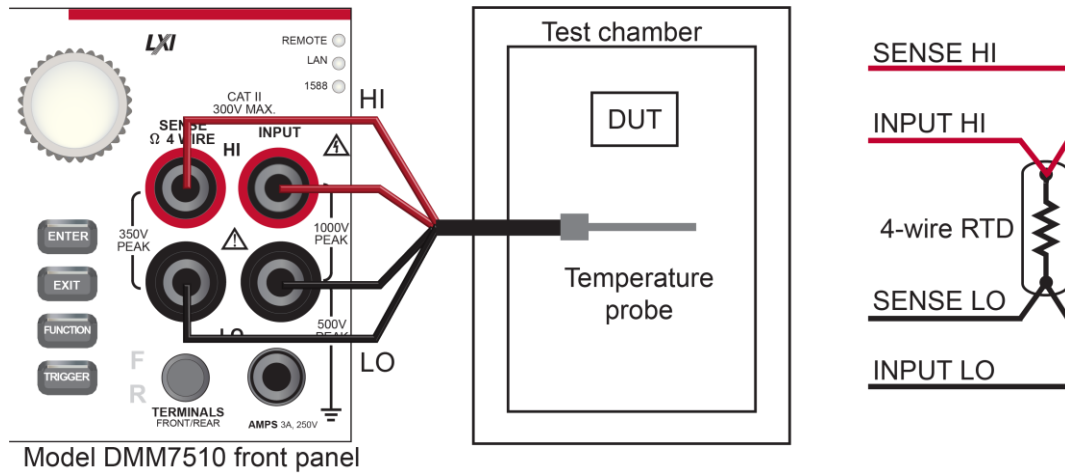
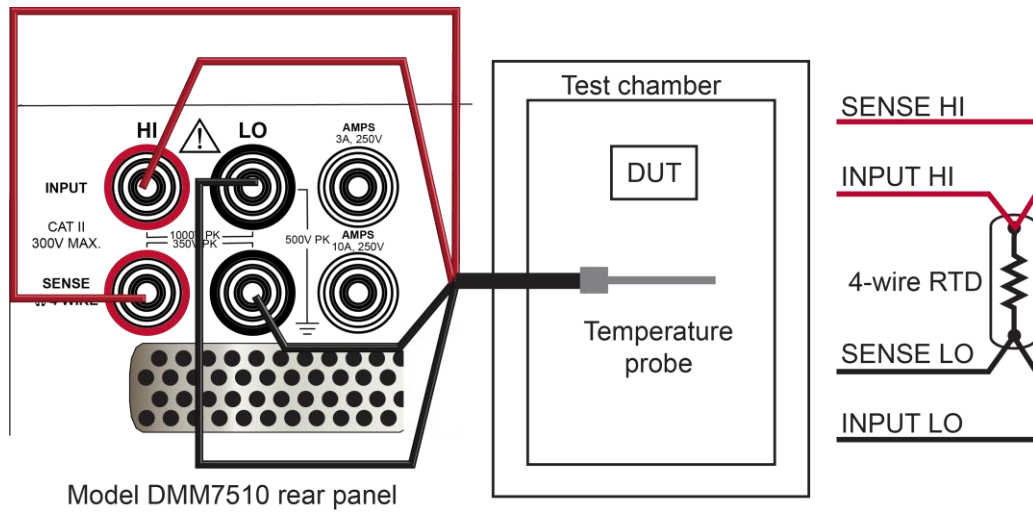


Figure 6: 4-wire RTD probe rear-panel connections



⚠ 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 power before connecting DUTs. 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 DMM7510. 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. Failure to recognize and observe normal safety precautions could result in personal injury or death.

Sample temperatures at a specific time interval

This application demonstrates how to use the DMM7510 to measure temperature at fixed time intervals using commands sent over a remote interface. You can make the measurement using SCPI code or TSP code. For information about setting up remote communications, see "Remote communications interfaces" in the *Model DMM7510 User's Manual*.

For this application, you will:

- Reset the instrument.
- Configure the instrument to measure a temperature using an RTD type PT100.
- Enable detection of open leads and offset compensation for more accurate readings.
- Set up a timer to make a temperature measurement every 60 seconds for 1440 times (24 hours) using a trigger model.

Using SCPI commands

This sequence of SCPI commands makes temperature readings every minute for 24 hours.

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. The light-brown shaded code represents pseudocode that will vary depending on the programming environment you use.

Ensure that the TERMINALS switch is set to REAR.

Send the commands in the following table to set up and run this example application.

Command	Description
*RST	<ul style="list-style-type: none"> Reset the DMM7510.
MeasCount = 1440 MeasInterval = 60	<ul style="list-style-type: none"> Define variables to make a measurement every 60 seconds for 24 hours (1440 times).
<pre> :SENSe:FUNCTion "TEMPerature" :SENSe:TEMPerature:TRANsducer FRTD :SENSe:TEMPerature:RTD:FOUR PT100 :SENSe:TEMPerature:ODETector ON :SENSe:TEMPerature:NPLCycles 1 :SENSe:TEMPerature:OCOMpensated ON :DISPlay:SCReen GRAPh :TRIGger:TIMer1:DELay MeasInterval :TRIGger:TIMer1:STARt:STIMulus NOTify1 :TRIGger:TIMer1:STARt:GENerate OFF :TRIGger:TIMer1:STATe ON :TRIGger:BLOCK:WAIT 1, DISPlay :TRIGger:BLOCK:NOTify 2, 1 :TRIGger:BLOCK:MDIGitize 3, "defbuffer1" :TRIGger:BLOCK:WAIT 4, TIMer1 :TRIGger:BLOCK:BRANch:COUNter 5, MeasCount, 2 :INIT </pre>	<ul style="list-style-type: none"> Set the instrument to measure temperature. Set the transducer type to 4-wire RTD. Set the RTD to type PT100. Enable the detection of open leads. Set NPLC to 1. Enable offset compensation. Switch to the GRAPH swipe screen. Set up timer 1 with delay time of MeasInterval. Set the notify 1 event to trigger the start of the timer. Generate a timer event once when the timer delay elapses. Enable the timer. Set trigger model block 1 to wait for front-panel TRIGGER key press. Set block 2 to send NOTIFY1 to start the timer. Set block 3 to make a measurement and store it in defbuffer1. Set block 4 to wait for the timer 1 event after the delay elapses. Set block 5 to go to block 2 MeasCount times. Initiate the trigger model.

Using TSP

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 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 *Model DMM7510 Reference Manual*.

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

By default, the DMM7510 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. Set the Command Set to **TSP**.
4. At the prompt to reboot, select **Yes**.

This sequence of TSP commands makes a series of temperature measurements. After the code executes, the data is displayed in the Instrument Console of Test Script Builder.

Ensure that the TERMINALS switch is set to REAR.

Send the following commands for this example application:

```
-- Reset the instrument to the default settings.
reset()
-- Establish variables to make a measurement every 60 seconds 1440 times (24 hours).
MeasCount = 1440
MeasInterval = 60
-- Set to measure temperature.
dmm.measure.func = dmm.FUNC_TEMPERATURE
-- Configure to measure 4-wire RTD.
dmm.measure.transducer = dmm.TRANS_FOURRTD
-- Enable the detection of open leads.
dmm.measure.opendetector = dmm.ON
-- Select 4-wire RTD type to be a PT100 sensor.
dmm.measure.fourrtd = dmm.RTD_PT100
-- Set the number of power line cycles to 1.
dmm.measure.nplc = 1
-- Enable offset compensation for more accurate readings.
dmm.measure.offsetcompensation.enable = dmm.ON
-- Display the GRAPH swipe screen.
display.changescreen(display.SCREEN_GRAPH_SWIPE)
```

```
-- Set up timer 1.
trigger.timer[1].reset()
-- Timer delays each time the timer is triggered.
trigger.timer[1].delay = MeasInterval
-- Set the notify 1 event to trigger the start of timer.
trigger.timer[1].start.stimulus = trigger.EVENT_NOTIFY1
-- Generate the timer event once when the timer delay elapses.
trigger.timer[1].start.generate = trigger.OFF
-- Enable the timer to perform delay operation.
trigger.timer[1].enable = trigger.ON

-- Wait for TRIGGER key press from front panel to start trigger model.
trigger.model.setblock(1, trigger.BLOCK_WAIT, trigger.EVENT_DISPLAY)
-- Send notify to start the timer.
trigger.model.setblock(2, trigger.BLOCK_NOTIFY, trigger.EVENT_NOTIFY1)
-- Make a measurement and store the reading in default buffer.
trigger.model.setblock(3, trigger.BLOCK_MEASURE_DIGITIZE, defbuffer1)
-- Wait for timer delay to elapse.
trigger.model.setblock(4, trigger.BLOCK_WAIT, trigger.EVENT_TIMER1)
-- Go to block 2 for the number of times set by MeasCount.
trigger.model.setblock(5, trigger.BLOCK_BRANCH_COUNTER, MeasCount, 2)

-- Initiate trigger model and wait until finished.
trigger.model.initiate()
display.changescreen(display.SCREEN_USER_SWIPE)
display.clear()
-- Display a message on the USER swipe screen to indicate test in progress.
display.settext(display.TEXT1, "Test in progress...")
waitcomplete()
-- Display a message on the user swipe screen to indicate test completion.
display.clear()
display.settext(display.TEXT1, "Test complete.")
-- Print the temperature readings and the corresponding timestamps.
printbuffer(1, defbuffer1.n, defbuffer1)
printbuffer(1, defbuffer1.n, defbuffer1.relativetimestamps)
```

Test results

The following figures show a sample graph and final test measurement for this application.

Figure 7: Model DMM7510 graph of temperature measurements

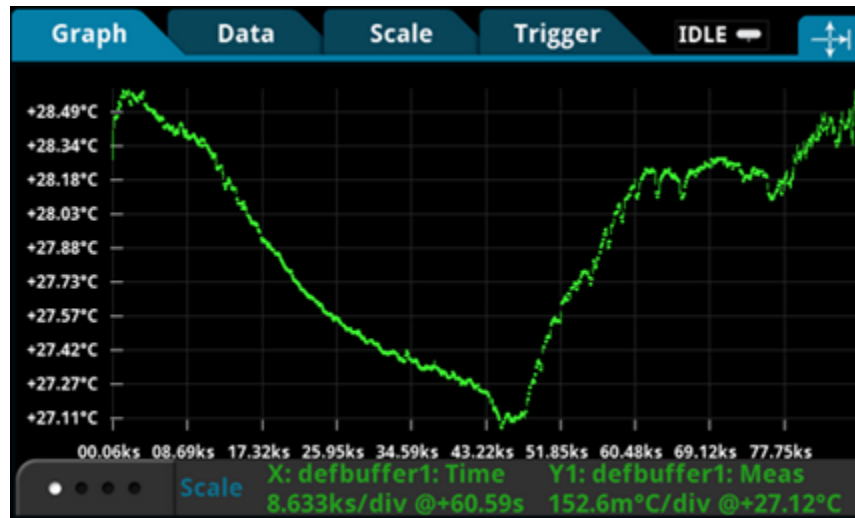


Figure 8: Model DMM7510 final temperature measurement



Grading and binning resistors

In this section:

Introduction.....	5-1
Instrument connections	5-2
Resistor grading and binning test	5-2

Introduction

This application example demonstrates how to use the DMM7510 to perform benchtop binning operations. It uses the trigger model and digital I/O to control external component-handling devices.

The DMM7510 can do simple pass-or-fail testing and grading and sorting. Grading resistors is a common application that is done by monitoring multiple limits until the first failure is received. Binning resistors is also common but unlike grading, involves monitoring limits until the first pass is received.

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 power before connecting DUTs. Safe installation requires proper shields, barriers, and grounding to prevent contact with test leads.

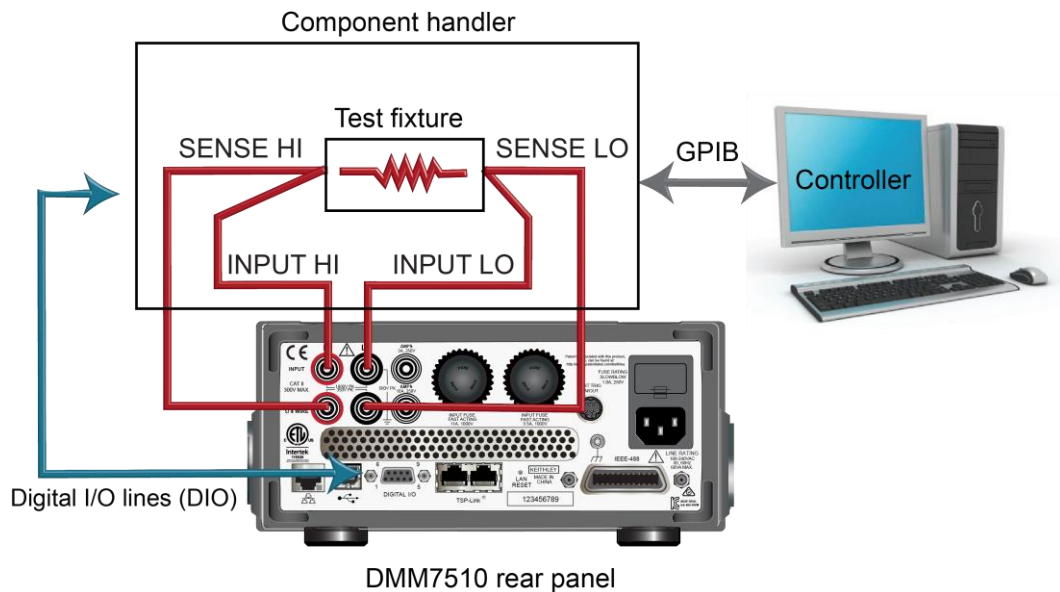
There is no internal connection between protective earth (safety ground) and the LO terminals of the DMM7510. Therefore, hazardous voltages (more than 30 V_{RMS}) can appear on LO terminals. This can occur when the instrument is operating in any mode. To prevent hazardous voltage from appearing on the 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. Failure to recognize and observe normal safety precautions could result in personal injury or death.

Instrument connections

In this example, the output signals that represent the grading results are sent from the DMM7510. The signals are sent to the component handler, which bins the devices.

The figure below shows the rear-panel connections from the DMM7510 to the test fixture and the digital lines to the component handler. In addition, there is GPIB communication between the controller and the component handler.

Figure 9: Device connections for component binning



Resistor grading and binning test

This resistance grading application uses limit tests to inspect a single resistor under test against multiple limits until the first failure occurs. When the resistor fails, it is placed into a designated resistance tolerance bin as defined by the limits.

Resistors are placed into bins based on the bit patterns that are assigned to the limits. In this example, the DMM7510 GradeBinning trigger-model template is used to simplify the application. This trigger-model template grades components into four tolerance levels (for example, 20%, 10%, 5%, and 1%) as defined by limits 1 to 4. A single spot measurement is inspected against multiple limits, which tighten progressively around the same nominal value. When the appropriate tolerance level for a resistor under test is determined, limit checking stops and the application immediately bins the tested resistors.

Limits are inspected in ascending numeric order. The measured resistance is checked first against limit 1, which is the 20% limit. If the resistor fails this limit inspection, its resistance value is outside of the 20% tolerance band and the trigger model outputs the limit 1 fail pattern, which causes the component handler to place the resistor in the limit 1 fail bin (20% fail bin).

If a resistor passes the 20% limit test, the resistance value is checked against limit 2, which is the 10% limit value. If the resistor fails this limit inspection, the resistance is outside of the 10% tolerance band. The trigger model outputs the limit 2 fail pattern, which causes the component handler to place the resistor in the limit 2 fail bin (10% fail bin).

If a resistor passes the 10% limit test, the resistance value is checked against limit 3, which is the 5% limit value, and so on. If a resistor passes all the limit tests, the trigger model outputs the overall pass bit pattern, which causes the component handler to place the resistor in the all pass bin.

For this example, the same fail pattern is assigned to both the lower and upper bounds of the limits. Therefore, a fail bin contains resistance values in the range (Resistance – Percentage to Resistance + Percentage). The percentage is 20, 10, 5, or 1. You can assign different bit patterns for different limit values.

Trigger-model template: GradeBinning

The GradeBinning trigger-model template contains the settings for the number of components, digital I/O, and limits. The command parameters for the template are described in the following commands and table.

SCPI command usage:

```
:TRIGger:LOAD "GradeBinning", <components>, <startInLine>, <startDelay>, <endDelay>,
<limit1High>, <limit1Low>, <limit1Pattern>, <allPattern>, <limit2High>,
<limit2Low>, <limit2Pattern>, <limit3High>, <limit3Low>, <limit3Pattern>,
<limit4High>, <limit4Low>, <limit4Pattern>, "<bufferName>"
```

TSP command usage:

```
trigger.model.load("GradeBinning", components, startInLine, startDelay, endDelay,
limit1High, limit1Low, limit1Pattern, allPattern, limit2High, limit2Low,
limit2Pattern, limit3High, limit3Low, limit3Pattern, limit4High, limit4Low,
limit4Pattern, bufferName)
```

Parameter list

<i>components</i>	100
<i>startInLine</i>	Digital I/O line 5
<i>startDelay</i>	100 ms
<i>endDelay</i>	100 ms
<i>limit1High</i>	Resistance = 100 Ω, Percentage = 20%, 100 + 20% = 120 Ω
<i>limit1Low</i>	Resistance = 100 Ω, Percentage = 20%, 100 – 20% = 80 Ω
<i>limit1Pattern</i>	Bin 1 fail pattern 15: Drive all digital I/O lines high (1111)
<i>allPattern</i>	All pass pattern 4: Drive line 3 high (0100)

<i>limit2High</i>	Resistance = 100 Ω, Percentage = 10%, 100 + 10% = 110 Ω
<i>limit2Low</i>	Resistance = 100 Ω, Percentage = 10%, 100 – 10% = 90 Ω
<i>limit2Pattern</i>	Bin 2 fail pattern 1: Drive line 1 high (0001)
<i>limit3High</i>	Resistance = 100 Ω, Percentage = 5%, 100 + 5% = 105 Ω
<i>limit3Low</i>	Resistance = 100 Ω, Percentage = 5%, 100 – 5% = 95 Ω
<i>limit3Pattern</i>	Bin 3 fail pattern 2: Drive line 2 high (0010)
<i>limit4High</i>	Resistance = 100 Ω, Percentage = 1%, 100 + 1% = 101 Ω
<i>limit4Low</i>	Resistance = 100 Ω, Percentage = 1%, 100 – 1% = 99 Ω
<i>limit4Pattern</i>	Bin 4 fail pattern 3: Drive line 1 and 2 high (0011)
<i>bufferName</i>	The reading buffer is set to <i>bufferVar</i>

Overview of the application

For this application, you:

- Reset the instrument.
- Select the four-wire resistance function.
- Enable offset compensation.
- Set autozero to Once.
- Set up digital I/O lines 1 to 4 as outputs to component handler.
- Set up digital I/O line 5 for trigger-model control, detecting the trigger as the start-of-test input.
- Set up digital I/O line 6 as the end-of-test output notification.
- Initiate the GradeBinning trigger-model template.
- Display "Test Completed" message on the front panel.

Using SCPI commands

This sequence of SCPI commands grades resistors into bins based on the measured accuracy.

You may need to make changes so that this code will run in your programming environment.

Send the commands in the following tables to setup and run this example application.

Command	Description
<pre>*RST :TRAC:MAKE "bufferVar", 1000000 :SENS:FUNC "FRES" :SENS:FRES:NPLC 1 :SENS:AZER:ONCE :SENS:FRES:OCOM ON :DIGital:LINE1:MODE DIG, OUT :DIG:LINE2:MODE DIG, OUT :DIG:LINE3:MODE DIG, OUT :DIG:LINE4:MODE DIG, OUT :DIG:LINE1:STAT 0 :DIG:LINE2:STAT 0 :DIG:LINE3:STAT 0 :DIG:LINE4:STAT 0 :DIG:LINE5:MODE TRIG, IN :TRIGger:DIG5:IN:EDGE FALL :DIG:LINE6:MODE TRIG, OUT :TRIGger:DIGital6:OUT:LOGic NEG :TRIG:DIG6:OUT:PULSewidth 10e-6 :TRIG:DIG6:OUT:STIMulus NOT1 :TRIGger:LOAD "GradeBinning", 100, 5, 0.1, 0.1, 120, 80, 15, 4, 110, 90, 1, 105, 95, 2, 101, 99, 3, "bufferVar" INIT *WAI :DISP:SCR SWIPE_USER :DISP:USER1:TEXT "Test Completed"</pre>	<ul style="list-style-type: none"> ■ Reset the DMM7510 to default settings ■ Make a buffer named <code>bufferVar</code> with a capacity of 1,000,000 readings ■ Set instrument to measure 4-wire resistance ■ Set the number of power line cycles (NPLC) to 1 ■ Enable autozero once ■ Enable offset compensation for more accurate resistance readings ■ Configure digital I/O lines 1 through 4 as digital outputs; these are used to output binning code to the component handler ■ Set the states of digital I/O lines 1 through 4 to bit low ■ Configure digital I/O line 5 as trigger input to detect start-of-test trigger ■ Set trigger detector to detect falling edge on digital I/O line 5 ■ Configure digital I/O line 6 as a trigger output used to send end-of-test trigger with negative logic and output pulse width of 10 µs ■ The trigger pulse occurs when the notify block generates an event ■ Define the GradeBinning trigger-model template ■ Initiate the trigger model ■ Set the front-panel display to the USER swipe screen ■ Display "Test Completed" when the binning test is complete

Using TSP commands

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 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 *Model DMM7510 Reference Manual*.

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

By default, the DMM7510 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. Set the Command Set to **TSP**.
4. At the prompt to reboot, select **Yes**.

This sequence of TSP commands grades resistors into established bins of accuracy. After the code executes, the data is displayed in the Instrument Console of Test Script Builder.

Send the following commands for this example application:

```
-- Reset the instrument to default settings.
reset()
-- Create a user-defined reading buffer that can store up to 1 million readings.
bufferVar = buffer.make(1000000)
bufferVar.clear()
-- Set the measure function to 4-wire resistance.
dmm.measure.func = dmm.FUNC_4W_RESISTANCE
-- Set the number of power line cycles 1 PLC.
dmm.measure.nplc = 1
-- Immediately update autozero reference measurements and
-- then disable the autozero function.
dmm.measure.autozero.once()
-- Enable offset compensation for more accurate resistance reading.
dmm.measure.offsetcompensation.enable = dmm.ON
-- Configure digital I/O lines 1 through 4 as digital outputs.
-- These I/O lines are used to output binning code to component handler.
digio.line[1].mode = digio.MODE_DIGITAL_OUT
digio.line[2].mode = digio.MODE_DIGITAL_OUT
digio.line[3].mode = digio.MODE_DIGITAL_OUT
digio.line[4].mode = digio.MODE_DIGITAL_OUT
-- Clear digital I/O lines to 0.
digio.line[1].state = digio.STATE_LOW
digio.line[2].state = digio.STATE_LOW
digio.line[3].state = digio.STATE_LOW
digio.line[4].state = digio.STATE_LOW
-- Configure digital I/O line 5 as a trigger input used to detect
-- the start-of-test trigger from the component handler.
digio.line[5].mode = digio.MODE_TRIGGER_IN
-- Set trigger detector to detect falling edge.
trigger.digin[5].edge = trigger.EDGE_FALLING
-- Configure digital I/O line 6 as a trigger output used to send
-- an end-of-test trigger to the component handler.
digio.line[6].mode = digio.MODE_TRIGGER_OUT
-- Output a falling edge trigger.
trigger.digout[6].logic = trigger.LOGIC_NEGATIVE
-- Set width of output trigger pulse to 10 us.
trigger.digout[6].pulsewidth = 10E-6
-- Trigger pulse is output when the notify block generates an event.
trigger.digout[6].stimulus = trigger.EVENT_NOTIFY2
-- Load the GradeBinning trigger-model template.
trigger.model.load("GradeBinning", 100, 5, 0.1, 0.1, 120, 80, 15, 4, 110, 90, 1, 105,
  95, 2, 101, 99, 3, bufferVar)
-- Initiate trigger model and wait until finished.
trigger.model.initiate()
waitcomplete()
-- Display on front-panel USER swipe screen after binning test completes.
display.changescreen(display.SCREEN_USER_SWIPE)
display.settext(display.TEXT1, "Test Completed")
```

Integrating with a Model 3706A-S using TSP-Link

In this section:

Introduction	6-1
Equipment required	6-1
Device connections	6-2
Integrating with a Model 3706A-S test setup	6-4

Introduction

This application example demonstrates how to configure the DMM7510 and Model 3706A-S System Switch to interact through TSP-Link®. The application measures different types of signals on multiple channels in multiple slots of a Model 3706A-S.

This is a common production test setup that monitors a variety of signals. These signals are typically routed through a switch that can accommodate the performance and throughput of the test requirement.

The example includes:

- 30 channels that measure dc voltage in slot 1 at two different ranges
- 10 channels that measure ac voltage in slot 1
- 20 channels that measure 4-wire resistance in slot 4

Equipment required

This application requires the following equipment:

- One DMM7510
- One Model 3706A-S Six-Slot System Switch
- One Model 3721 Dual 1 × 20 Channel Multiplexer Card and Model 3721-ST Screw Terminal Block
- One Model 3724 Dual 1 × FET Multiplexer Card and Model 3724-ST Screw Terminal Block
- Multiple devices or components to be tested
- Several insulated cables with banana plugs
- One computer set up for communication with the DMM7510

Device connections

The Model 3706A-S used in this test includes two multiplexer cards and screw terminal blocks:

- Model 3721 Dual 1 × 20 Channel Multiplexer Card and Model 3721-ST Screw Terminal Block (slot 1)
- Model 3724 Dual 1 × 30 FET Multiplexer Card and Model 3724-ST Screw Terminal Block (slot 4)

The signal lines are connected through the Model 3721 and Model 3724 multiplexer cards in the 3706A-S. The entire application is performed over the remote interface using Test Script Processor (TSP®) code. For information about setting up remote communications, see "Remote communications interfaces" in the *Model DMM7510 User's Manual*.

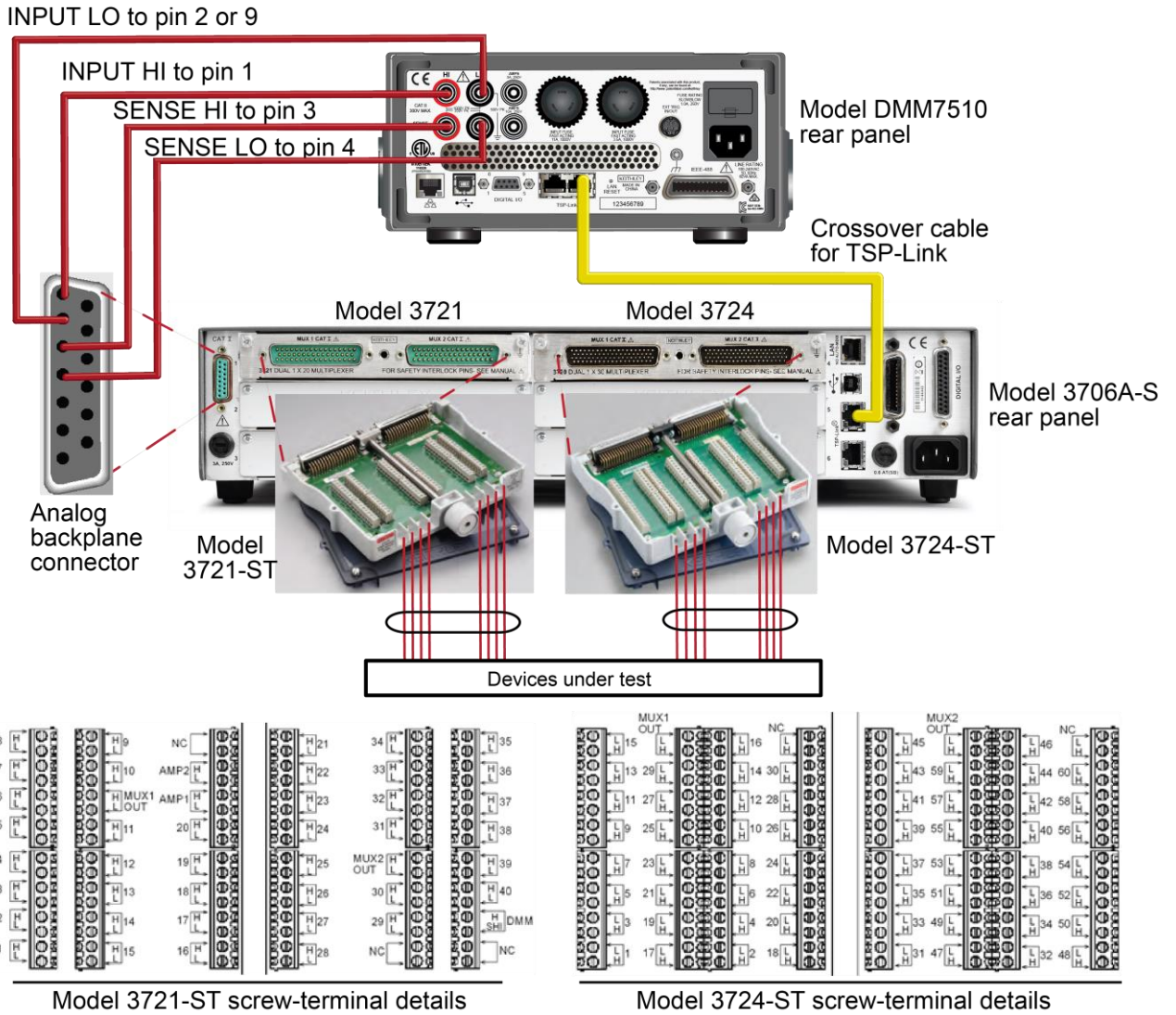
Keithley Instruments TSP-Link® is a high-speed trigger synchronization and communication bus that test system builders can use to connect multiple instruments in a master and subordinate configuration. Once connected, all the instruments that are equipped with TSP-Link in a system can be programmed and operated under the control of the master instrument or instruments. This allows the instruments to run tests more quickly because they can be decoupled from frequent computer interaction. The test system can have multiple master and subordinate groups, which can be used to handle multi-device testing in parallel. Combining TSP-Link with a flexible programmable trigger model ensures speed.

Using TSP-Link, multiple instruments are connected and can be used as if they are part of the same physical unit for simultaneous multichannel testing. The test system can be expanded to include up to 32 TSP-Link enabled instruments.

TSP-Link functionality is only available when using the instrument front panel or the TSP commands to control the instrument. It is not available if you are using SCPI commands.

Refer to the following figure for connections between the DMM7510 and the Model 3706A-S.

Figure 10: Connections for the Model 3706A-S integration application



⚠ 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 power before connecting DUTs. 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 DMM7510. 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. Failure to recognize and observe normal safety precautions could result in personal injury or death.

Integrating with a Model 3706A-S test setup

For this application, you will:

- Make sure that the TSP-Link node for the 3706A-S is set to 1.
- Connect the computer to the DMM7510.
- Reset the instruments.
- Initialize TSP-Link.
- Configure the DMM7510 input and output TSP-Link triggers.
- Create a configuration list in the DMM7510 that contains measure settings for dc voltage, ac voltage, and 4-wire resistance.
- Configure the 3706A-S input and output TSP-Link triggers.
- Create a scan list on the 3706A-S.
- Create a trigger model on the DMM7510 that interacts with the 3706A-S trigger model through the predefined measure functions for the number of channels.
- Initiate scanning and measurement on the DMM7510 and 3706A-S.

Set up TSP nodes on the DMM7510 and Model 3706A-S

Before executing the TSP code, you must set up the nodes on the instruments and configure the TSP-Link network.

To set up TSP-Link on the DMM7510:

1. Press the **MENU** key.
2. Under System, select **Communication**.
3. Select the **TSP-Link** tab.
4. Set the Node to **2**.
5. Select **Initialize**.

To set up TSP-Link on the 3706A-S:

1. Press the **MENU** key.
2. Use the navigation control to select **TSPLINK**.
3. Use the navigation control to select **NODE**.
4. Use the navigation control to enter **1**.
5. Press the **ENTER** key.
6. Press the **EXIT** key as many time as needed return to the main display.

NOTE

The communication from the computer is made directly to the DMM7510 in the following TSP code. This makes the DMM7510 the master in this TSP-Link network, with the 3706A-S as the subordinate. You can change the master to be the 3706A-S. However, you must modify the code `tsplink.initialize()` and change it to `tsplink.reset()`.

The master node does not require the `node[x].` prefix. If you need to improve program execution speed, remove all the master node prefixes in the TSP code in the following example.

Using SCPI

This example cannot be replicated in SCPI code because TSP-Link events and commands are only available through the TSP command language.

However, you can use other instrument trigger interfaces, such as digital I/O or external trigger I/O, to replace TSP-Link and achieve similar operation.

Using TSP

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 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 *Model DMM7510 Reference Manual*.

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

By default, the DMM7510 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. Set the Command Set to **TSP**.
4. At the prompt to reboot, select **Yes**.

Send the following commands for this example application:

```
-- Initialize the TSP-Link network, where node 1 is 3706A-S and node 2 is DMM7510.
tsplink.initialize()
-- If the TSP-Link state is not online, print an error message and quit.
state = tsplink.state
print(state)
if state ~= "online" then
    print("Error:\n-Check that all instruments have a different node number")
    print("-Check that all instruments are connected correctly\n")
return
end
-- Reset both instruments to the default settings.
node[1].reset()
-- Node 1 is 3706A-S.
node[2].reset()
-- Node 2 is DMM7510.
--[
Create a configuration list on DMM7510 named "myScanConfigList".
Index 1 is DCV 100 mV range, 10 channel.
Index 2 is DCV 10 V range, 20 channel.
Index 3 is ACV 1 V range, 9 channel.
Index 4 is Resistance 4W, 20 channel.
]
node[2].dmm.measure.configlist.create("myScanConfigList")
node[2].dmm.measure.func = node[2].dmm.FUNC_DC_VOLTAGE
node[2].dmm.measure.range = 10
node[2].dmm.measure.nplc = 1
-- Index 1.
node[2].dmm.measure.configlist.store("myScanConfigList")
node[2].dmm.measure.func = node[2].dmm.FUNC_DC_VOLTAGE
node[2].dmm.measure.range = 1000
node[2].dmm.measure.autozero.enable = node[2].dmm.OFF
-- Index 2.
node[2].dmm.measure.configlist.store("myScanConfigList")
node[2].dmm.measure.func = node[2].dmm.FUNC_AC_VOLTAGE
node[2].dmm.measure.range = 10
node[2].dmm.measure.autozero.enable = node[2].dmm.OFF
-- Index 3.
node[2].dmm.measure.configlist.store("myScanConfigList")
node[2].dmm.measure.func = node[2].dmm.FUNC_4W_RESISTANCE
node[2].dmm.measure.autorange = dmm.ON
node[2].dmm.measure.autozero.enable = node[2].dmm.OFF
```

```

-- Index 4.
node[2].dmm.measure.configlist.store("myScanConfigList")
-- Handshaking between the DMM7510 and 3706A-S.
-- Configure DMM7510 TSP-Link line 1 to input the trigger from 3706A-S.
-- Input from 3706A-S.
node[2].tsplink.line[1].mode = node[2].tsplink.MODE_TRIGGER_OPEN_DRAIN
-- Configure DMM7510 TSP-Link line 2 to output trigger to 3706A-S.
node[2].tsplink.line[2].mode = node[2].tsplink.MODE_TRIGGER_OPEN_DRAIN
-- Clear DMM7510 TSP-Link event detectors.
node[2].trigger.tsplinkin[1].clear()
node[2].trigger.tsplinkin[2].clear()
-- Configure the DMM7510 TSP-Link line 1 input trigger to detect falling edge triggers.
node[2].trigger.tsplinkin[1].edge = node[2].trigger.EDGE_FALLING
-- Configure DMM7510 TSP-Link line 1 output trigger to output negative pulses at 10 us
-- pulse width when NOTIFY1 event is detected.
node[2].trigger.tsplinkout[2].logic = node[2].trigger.LOGIC_NEGATIVE
node[2].trigger.tsplinkout[2].pulsewidth = 10e-6
node[2].trigger.tsplinkout[2].stimulus = node[2].trigger.EVENT_NOTIFY1
-- Configure 3706A-S TSP-Link line 1 to output trigger to DMM7510.
node[1].tsplink.trigger[1].mode = node[1].tsplink.TRIG_FALLING
-- Configure 3706A-S TSP-Link line 2 to input trigger from DMM7510.
node[1].tsplink.trigger[2].mode = node[1].tsplink.TRIG_FALLING
-- Input from DMM7510.
-- Clear 3706A-S TSP-Link event detectors.
node[1].tsplink.trigger[1].clear()
node[1].tsplink.trigger[2].clear()
-- Configure scan start stimulus to and input trigger on TSP-Link line 2.
node[1].scan.trigger.arm.stimulus = 0
node[1].scan.trigger.channel.stimulus = node[1].tsplink.trigger[2].EVENT_ID
node[1].tsplink.trigger[1].stimulus = node[1].scan.trigger.EVENT_CHANNEL_READY
-- Create a scan list.
node[1].scan.create("")
muxChannels = {}
-- DCV 1.
muxChannels[1] = "1001:1020"
-- DCV 2.
muxChannels[2] = "1021:1030"
-- ACV.
muxChannels[3] = "1031:1040"
-- 4W RES.
muxChannels[4] = "4001:4020"
muxChannelsCount = {}
lastcount = 0
node[1].channel.setpole("4001:4020", 4)
node[1].channel.setbackplane("1001:1020", "1911")
node[1].channel.setbackplane("1021:1030", "1921")
node[1].channel.setbackplane("1031:1040", "1921")
node[1].channel.setbackplane("slot4", "4911, 4922")
-- Get channel count for each measurement configuration.
for i = 1, table.getn(muxChannels) do
    node[1].scan.add(muxChannels[i])
    muxChannelsCount[i] = node[1].scan.stepcount - lastcount
    lastcount = node[1].scan.stepcount
end

```

```

-- Define the number of times the scan will run.
node[1].scan.scancount = 1
node[1].scan.bypass = node[1].scan.ON
node[1].scan.mode = node[1].scan.MODE_FIXED_ABR
--[[
Create a DMM7510 trigger model that will wait for an input trigger from 3760A-S indicating
a channel is closed before making a measurement. An output trigger will be sent to
the 3706A-S from the DMM7510 upon completing the measurement before closing another
the channel.
]]
node[2].defbuffer1.capacity = node[1].scan.stepcount

node[2].trigger.model.setblock(1, node[2].trigger.BLOCK_CONFIG_RECALL,
    "myScanConfigList", 1)
node[2].trigger.model.setblock(2, node[2].trigger.BLOCK_WAIT,
    node[2].trigger.EVENT_TSPLINK1)
node[2].trigger.model.setblock(3, node[2].trigger.BLOCK_MEASURE_DIGITIZE)
node[2].trigger.model.setblock(4, node[2].trigger.BLOCK_NOTIFY,
    node[2].trigger.EVENT_NOTIFY1)
node[2].trigger.model.setblock(5, node[2].trigger.BLOCK_BRANCH_COUNTER,
    muxChannelsCount[1], 2)
node[2].trigger.model.setblock(6, node[2].trigger.BLOCK_CONFIG_NEXT,
    "myScanConfigList")
node[2].trigger.model.setblock(7, node[2].trigger.BLOCK_WAIT,
    node[2].trigger.EVENT_TSPLINK1)
node[2].trigger.model.setblock(8, node[2].trigger.BLOCK_MEASURE_DIGITIZE)
node[2].trigger.model.setblock(9, node[2].trigger.BLOCK_NOTIFY,
    node[2].trigger.EVENT_NOTIFY1)
node[2].trigger.model.setblock(10, node[2].trigger.BLOCK_BRANCH_COUNTER,
    muxChannelsCount[2], 7)
node[2].trigger.model.setblock(11, node[2].trigger.BLOCK_CONFIG_NEXT,
    "myScanConfigList")
node[2].trigger.model.setblock(12, node[2].trigger.BLOCK_WAIT,
    node[2].trigger.EVENT_TSPLINK1)
node[2].trigger.model.setblock(13, node[2].trigger.BLOCK_MEASURE_DIGITIZE)
node[2].trigger.model.setblock(14, node[2].trigger.BLOCK_NOTIFY,
    node[2].trigger.EVENT_NOTIFY1)
node[2].trigger.model.setblock(15, node[2].trigger.BLOCK_BRANCH_COUNTER,
    muxChannelsCount[3], 12)
node[2].trigger.model.setblock(16, node[2].trigger.BLOCK_CONFIG_NEXT,
    "myScanConfigList")
node[2].trigger.model.setblock(17, node[2].trigger.BLOCK_WAIT,
    node[2].trigger.EVENT_TSPLINK1)
node[2].trigger.model.setblock(18, node[2].trigger.BLOCK_MEASURE_DIGITIZE)
node[2].trigger.model.setblock(19, node[2].trigger.BLOCK_NOTIFY,
    node[2].trigger.EVENT_NOTIFY1)
node[2].trigger.model.setblock(20, node[2].trigger.BLOCK_BRANCH_COUNTER,
    muxChannelsCount[4], 17)
-- Initiate trigger models on both 3706A-S and DMM7510 and wait until finished.
node[2].trigger.model.initiate()
-- To guarantee that the DMM7510 trigger model is at WAIT block (block 2).
delay(2)
node[1].scan.background()

waitcomplete()
-- Open all channels on slots 1 and 4.
node[1].channel.open("slot1, slot4")

```

Capturing and analyzing waveforms

In this section:

Introduction	7-1
Equipment required	7-1
Device connections	7-2
Testing a buck converter	7-3

Introduction

This example application demonstrates how to use the DMM7510 to capture voltage and current waveforms. In this application, you use both the digitize voltage and digitize current functions to directly interact with the waveforms. The waveforms are acquired from a 5 V dc-to-dc voltage step-down converter, or buck converter, through the front-panel touchscreen interface.

The touchscreen can be helpful in a variety of applications that involve transient signal analysis at a 1 megasample per second sampling rate. You can analyze signals from a microvolt to 1000 V up to 350 kHz, or a microamp to 10 A up to 100 kHz.

Equipment required

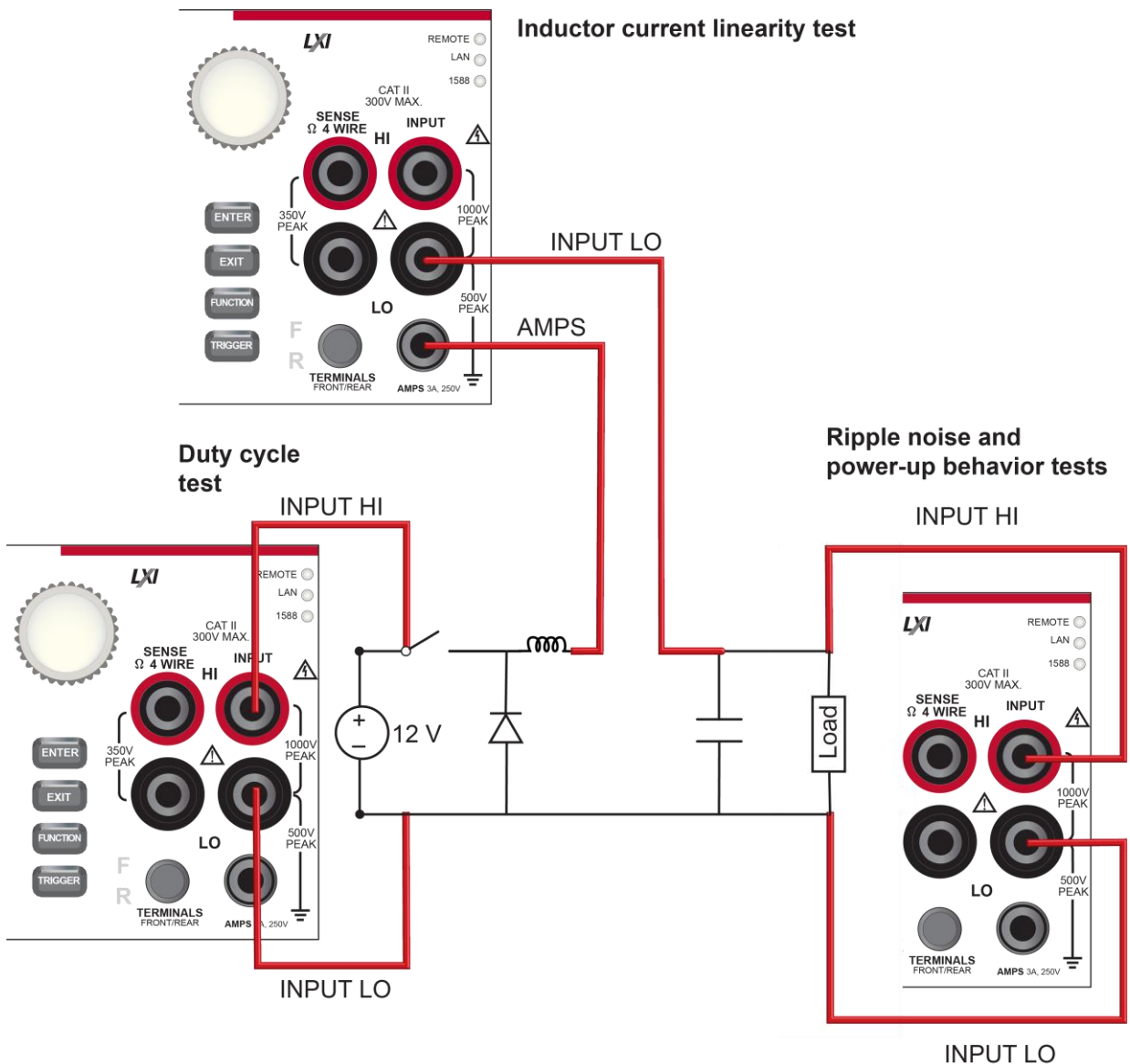
- One DMM7510
- A power supply
- Buck controller evaluation board, such as the Texas Instruments LM25088MH-1/NOPB Current Mode Non-Synchronous Buck Controller evaluation board
- Four insulated cables with banana plugs
- Resistors for a varying load application; the application shown here uses resistors from 3 Ω to 8 Ω
- One computer set up for remote communication with the DMM7510

Device connections

This application example consists of four tests with different connections. An overview of the connections is shown in the figure below.

You can use either the front-panel or rear-panel connections for these tests. Make sure that the front-panel TERMINALS switch is set to the terminals you are using. When **F** is displayed next to the switch, the instrument is reading the front-panel terminals. **R** indicates that the instrument is reading the rear-panel terminals. You must use either the front terminals or rear terminals. You cannot mix connections.

Figure 11: Buck converter evaluation board connections overview



⚠ 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 power before connecting DUTs. 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 DMM7510. 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. Failure to recognize and observe normal safety precautions could result in personal injury or death.

Testing a buck converter

A buck converter is a highly efficient switch mode dc-to-dc voltage step-down converter. It stores energy in the form of a magnetic field on an inductor. In the on state, the switch is closed and the input voltage charges the inductor. In the off state, the switch is open and the inductor discharges the stored energy as current flow through the load. Some of the key measurements involved in testing a buck converter are:

- Ripple noise on the output voltage
- Duty cycle from switch node voltage
- Inductor current linearity with varying load
- Power-up behavior

The following test uses the Texas Instruments LM25088MH-1/NOPB evaluation board to demonstrate the digitizing capabilities of the DMM7510. Modifications were made to the evaluation board to generate a 50 kHz switching frequency. An input voltage of 12 V is used on all subsequent tests.

Since the maximum output current of the evaluation board is 3 A, different resistive loads can be used to achieve a variety of loading effects, as shown in the following tests.

Ripple noise on the output voltage

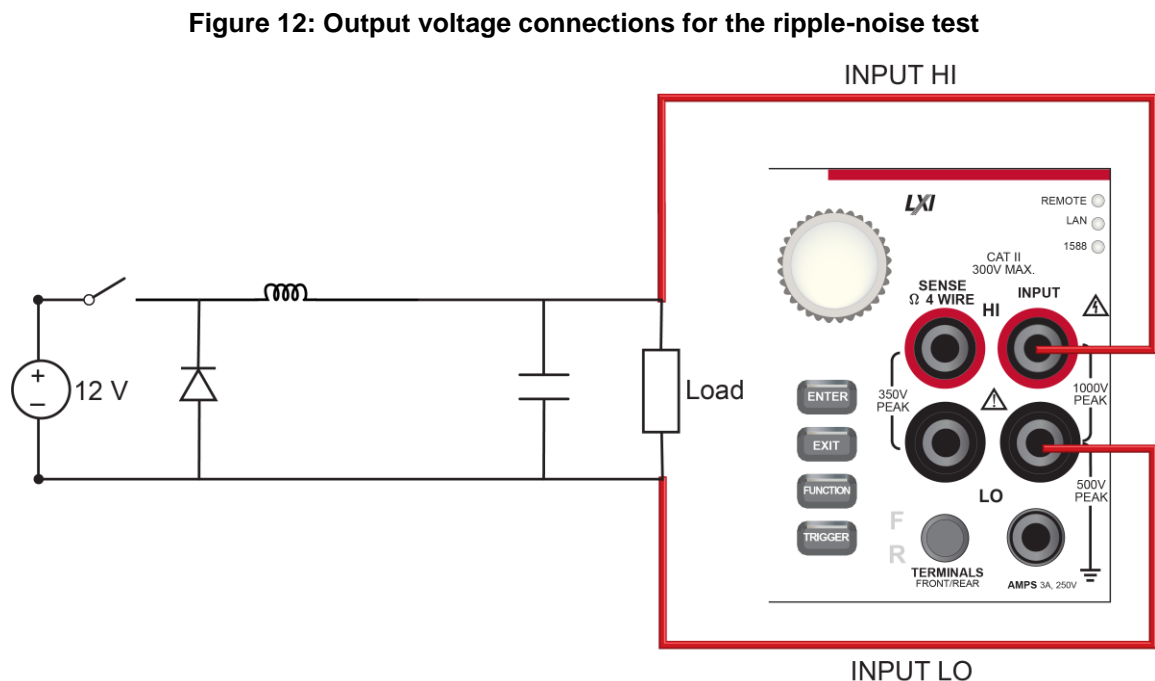
This test measures the ripple voltage captured on the output terminal of the buck converter evaluation board.

For this test, you will:

- Connect the 3 Ω load resistor to the output terminals of the buck converter
- Connect test leads to the output terminals of the buck converter
- Supply 12 V to the input terminals of the buck converter
- Reset the instrument
- Select the digitize voltage function and set sample rate to 1 megasamples per second with a sample count of 100
- View the data on the graph screen
- Turn on horizontal cursors to measure the magnitude of the voltage ripple

Device connections

The connections for the ripple-noise test are shown in the figure below.

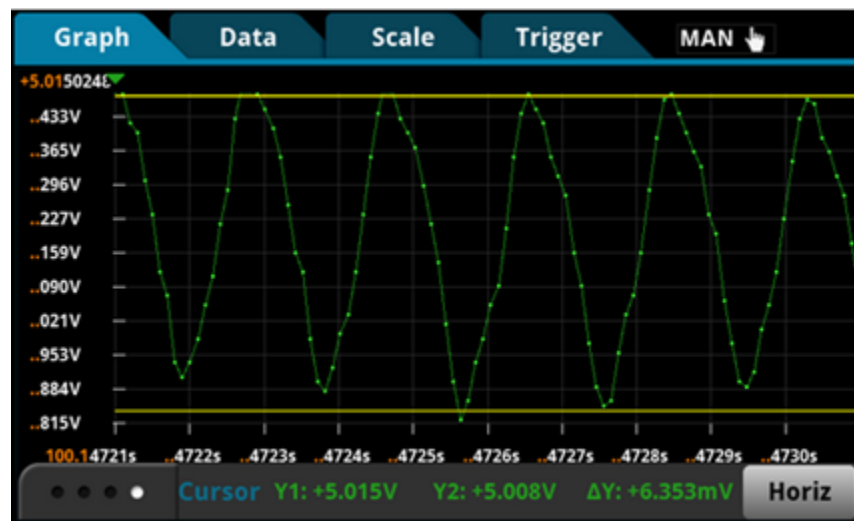


Run the test using the front panel

To run the test using the front panel:

1. Press the **POWER** button on the front panel to turn on the instrument.
2. On the FUNCTIONS swipe screen, select **Digi V** to select the Digitize Voltage measure function.
3. Swipe to display the **SETTINGS** swipe screen.
4. Set the Sample Rate to **1,000,000**.
5. Set the Count to **100**.
6. Swipe to display the **GRAPH** swipe screen.
7. Select the graph icon on the upper right of the swipe screen to open the Graph screen.
8. To analyze the voltage ripple peak-to-peak value, swipe the bottom of the graph screen until the Cursor Enable button is displayed.
9. Select the **Cursor Enable** button until Horiz is displayed. The horizontal cursors are displayed.
10. Touch the yellow horizontal cursor lines on the graph and move them to measure the peak-to-peak ripple amplitude.
11. The ΔY value is shown on the graph swipe bar.

Figure 13: Results of the ripple noise test



Using SCPI commands

You may need to make changes so that this code will run in your programming environment.

Send the commands following in the following table to set up and run the test.

Command	Description
<pre>*RST :SENS:DIG:FUNC "VOLT" :SENS:DIG:VOLT:RANG 10 :SENS:DIG:VOLT:INP AUTO :SENS:DIG:VOLT:SRATE 1000000 :SENS:DIG:VOLT:APER AUTO :SENS:DIG:COUN 100 :TRAC:POIN 100 :TRAC:CLE :TRAC:TRIG:DIG :TRAC:DATA? 1, 100, "defbuffer1", READ :TRAC:DATA? 1, 100, "defbuffer1", REL</pre>	<ul style="list-style-type: none"> ■ Reset the DMM7510. ■ Set the instrument to measure digitize voltage. ■ Set range to 10 V. ■ Set the input impedance to automatic, which selects 10 GΩ for the 10 V range. ■ Set the sample rate to 1,000,000. ■ Enable automatic aperture. ■ Set the sample count to 100. ■ Set <code>defbuffer1</code> to store 100 points. ■ Clear <code>defbuffer1</code>. ■ Digitize the signal. ■ Read the first 100 measurement and relative timestamp values from <code>defbuffer1</code>.

Using TSP commands

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 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 *Model DMM7510 Reference Manual*.

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

By default, the DMM7510 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. Set the Command Set to **TSP**.
4. At the prompt to reboot, select **Yes**.

Send the following commands:

```

-- Reset the instrument to default settings.
reset()
-- Create a local variable to store the number of samples.
numofsamples = 100
-- Set the measure function to digitize voltage to capture the ripple waveform.
dmm.digitize.func = dmm.FUNC_DIGITIZE_VOLTAGE
-- Voltage range must be fixed when using digitize voltage.
dmm.digitize.range = 10
-- Set sample rate to 1 megasample per second to sample a
-- 50 kHz voltage ripple.
dmm.digitize.samplerate = 1e6
-- Set aperture to automatic to get the highest accuracy measurement
-- for the configured sampling rate.
dmm.digitize.aperture = dmm.APERTURE_AUTO
-- Set sample count to the number of samples to capture about 5 ripples.
dmm.digitize.count = numofsamples
-- Set the input impedance to automatic so it selects 10 G for the 10 V range.
dmm.digitize.inputimpedance = dmm.IMPEDANCE_AUTO
-- Set the buffer to align with the number of samples (optional).
defbuffer1.capacity = numofsamples
-- Clear buffer.
defbuffer1.clear()
-- Make sure your signal is connected to the DMM and digitize.
dmm.digitize.read()

-- Print the digitized readings.
if defbuffer1.n > 0 then
  print("Ripple Voltage:")
  print("Total Count:", defbuffer1.n)
  printbuffer(1, defbuffer1.n, defbuffer1)
  print("Timestamps:")
  printbuffer(1, defbuffer1.n, defbuffer1.relativetimestamps)
else
  print("No data collected")
end
print("Test Ended")

```

Duty cycle from switch node voltage

The switching duty cycle determines the voltage at the output compared to the input voltage, as shown in the following equation:

$$\text{Duty Cycle Percentage} = \frac{V_{\text{OUT}}}{V_{\text{IN}}} \times 100\%$$

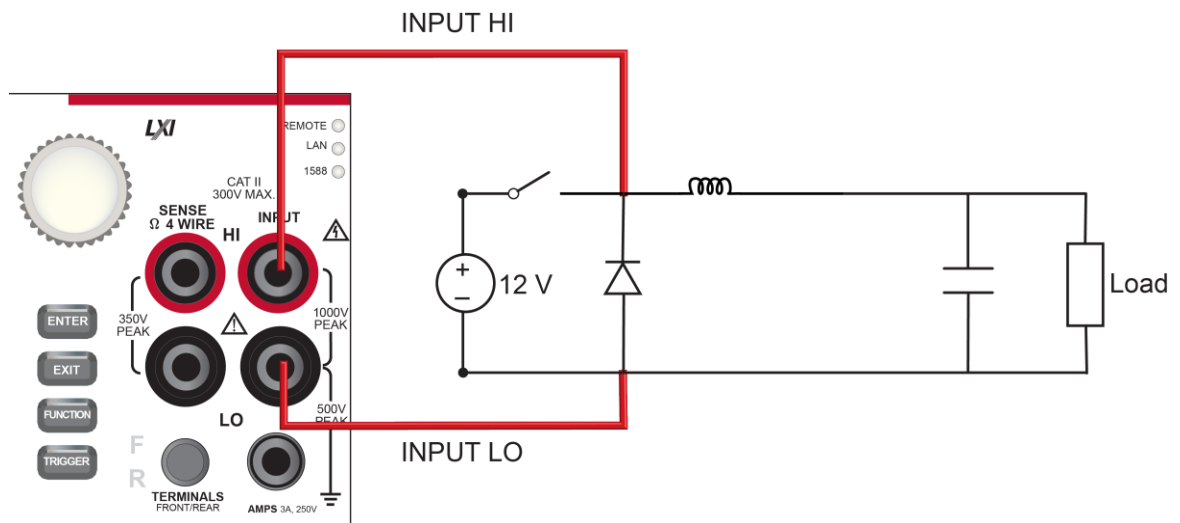
For this test, you will:

- Connect the 3 Ω load resistor to the output terminals of the buck converter
- Connect one test lead to the switch node voltage of the buck converter
- Connect another test lead to the ground of the buck converter
- Supply 12 V of input voltage to the input terminals of the buck converter
- Reset the instrument
- Select the digitize voltage function and set sample rate to 1 megasample per second with a sample count of 100
- View the data on the Graph screen
- Turn on vertical horizontal cursors to calculate the duty cycle percentage

Device connections

The connections for the duty cycle test are shown in the figure below.

Figure 14: Duty cycle device connections



Run the test using the front panel

To run the duty-cycle test from the front panel:

1. Press the **POWER** button on the front panel to turn on the instrument.
2. On the FUNCTIONS swipe screen, select **Digi V** to select the digitize voltage function.
3. Swipe to display the SETTINGS swipe screen.
4. Set the Sample Rate to 1,000,000.
5. Set the Count to 100.
6. Swipe to the **GRAPH** swipe screen.
7. Select the graph icon in the upper right of the swipe bar to view the graph in the full screen.
8. Swipe the bottom of the graph screen until the Cursor swipe bar is displayed.
9. Select the button on the Cursor swipe bar until **Vert** is displayed. Vertical cursors are displayed on the graph.
10. Swipe the vertical cursor lines to move them to the changes in time of a single cycle. The change is displayed as ΔX in the Cursor swipe bar.

Test results

The front-panel graph shows results that are similar to the following.

Figure 15: Duty cycle 1

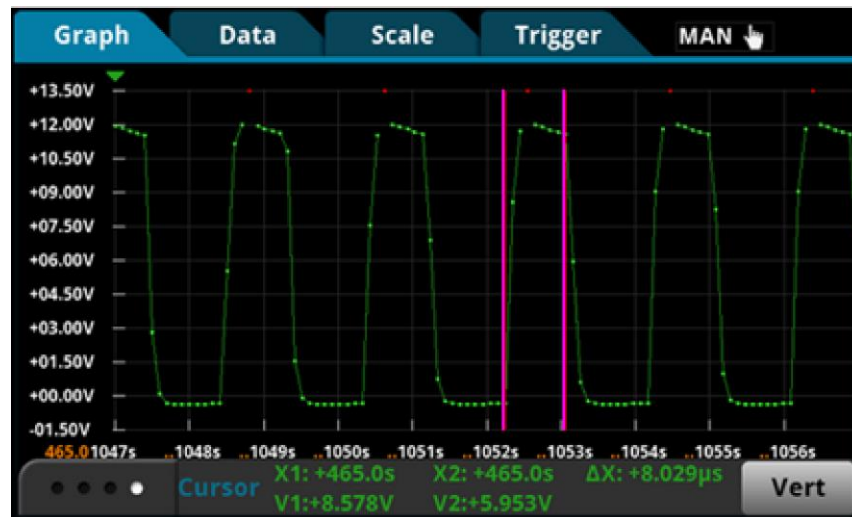
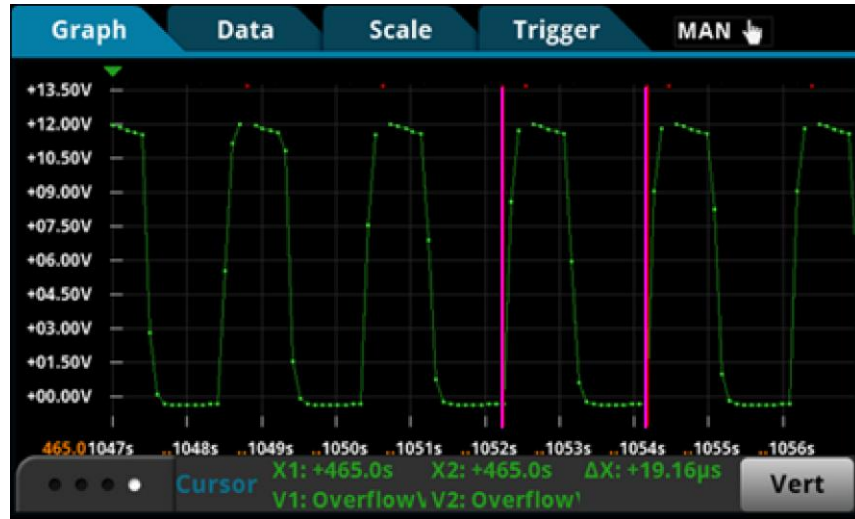


Figure 16: Duty cycle 2



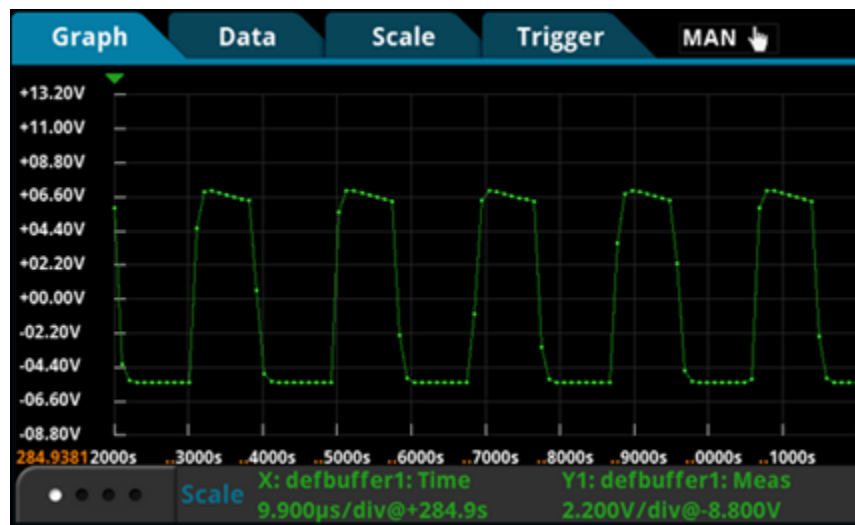
- $\Delta_{high} = 8.029 \mu s$
- $\Delta_{period} = 19.16 \mu s$
- Duty cycle = $8.029 \mu s / 19.16 \mu s = 40\%$

Expected output = duty cycle x input = $40\% \times 12 V = 5 V$

NOTE

The red dots at the top of the cycles indicate an overflow condition, which occurs because the 12 V measurement is over the 10 V measurement range. Instead of increasing the range to 100 V, which reduces the analog bandwidth to 6 kHz, you can change the signal coupling to ac to maintain the bandwidth integrity. Refer to the following screen capture of the ac coupled waveform.

Figure 17: Graph with ac signal coupling



Using SCPI or TSP commands

Use the command sequence for the ripple noise on the output voltage test to acquire the switching voltage waveform. Refer to [Ripple noise on the output voltage](#) (on page 7-4).

Inductor current linearity with varying load

The inductor current is expected to be a linear triangular waveform with varying amplitude, depending on the loading at the output terminals. The current increases linearly when energy is stored into the inductor and decreases when energy discharges from the inductor. Any nonlinearity in the slope of the triangle waveform indicates inductor saturation, which is likely caused by overloading the output.

For this test, you:

- Connect the 3 Ω load resistor to the output terminals of the buck converter
- Connect test leads to the output terminals of the buck converter
- Supply 12 V to the input terminals of the buck converter
- Reset the instrument
- Select the digitize current function and set sample rate to 500 kilosamples per second
- Set sample count to 50
- Display the graph
- Repeat these steps with 4 Ω and 8 Ω resistive loads to see the change in the inductor current

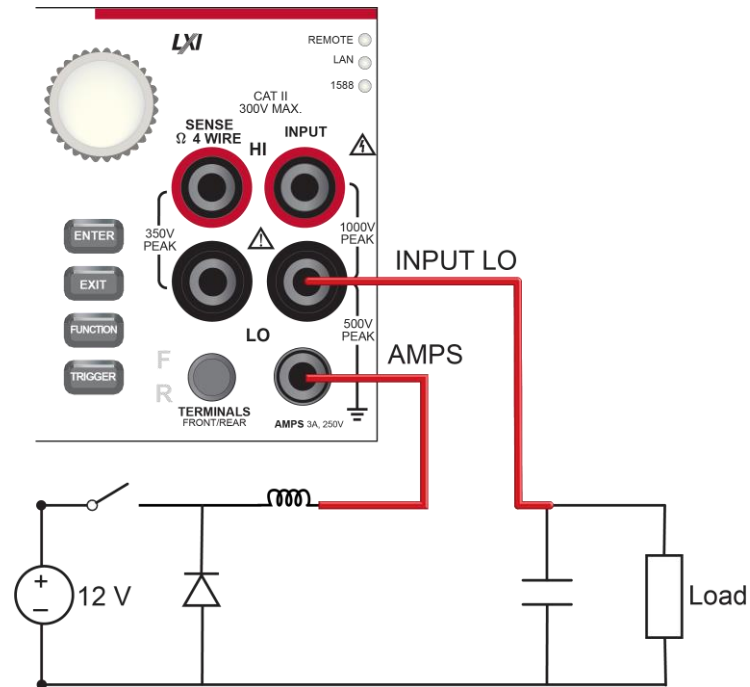
Inductor current measurement device connections

You can use either the front or rear inputs. Ensure that the front-panel TERMINALS switch is set correctly (**F** displayed for front; **R** displayed for rear). You must use either the front terminals or rear terminals. You cannot mix connections.

Both front-panel and rear-panel connections are safety banana jacks. You can make these connections with two insulated cables with banana plugs.

Connect the test leads as shown in the following figure.

Figure 18: Inductor current linearity test connections



Run the test using the front panel

Running the inductor current linearity test from the front panel:

1. Press the **POWER** button on the front panel to turn on the instrument.
2. On the FUNCTIONS swipe screen, select **Digi I** to select the digitize current function.
3. Swipe to the SETTINGS swipe screen.
4. Set the Sample Rate to **500,000**.
5. Set the Count to **50**.
6. Press the **MENU** key.
7. Select **Graph** to view the graph.

Inductor current linearity results

The front-panel graph shows results that are similar to the following.

Figure 19: Inductor current linearity results at 3 Ω

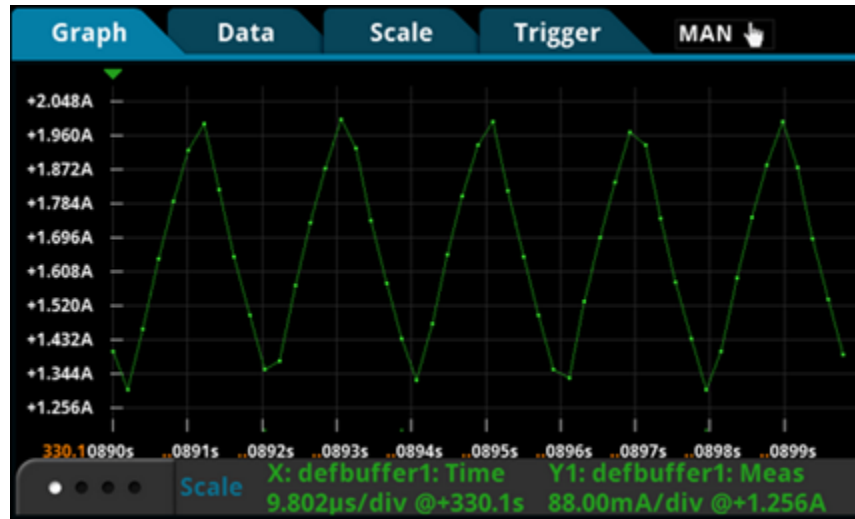


Figure 20: Inductor current linearity results at 4 Ω

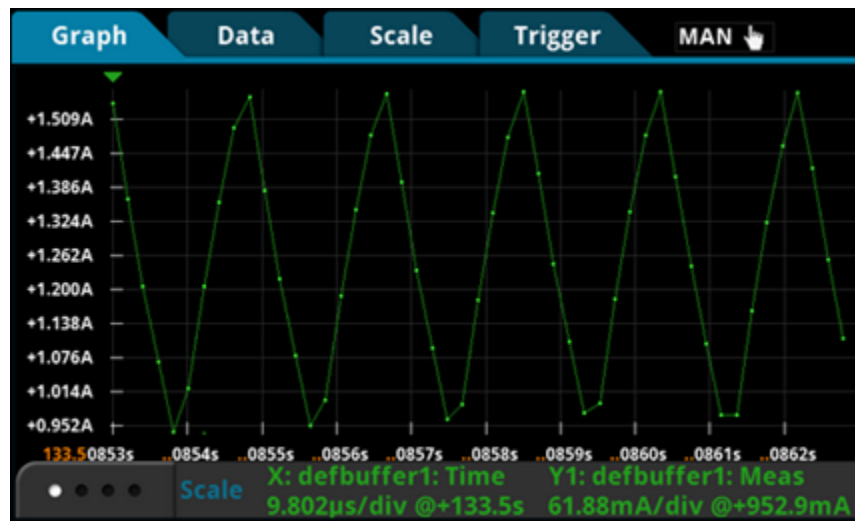
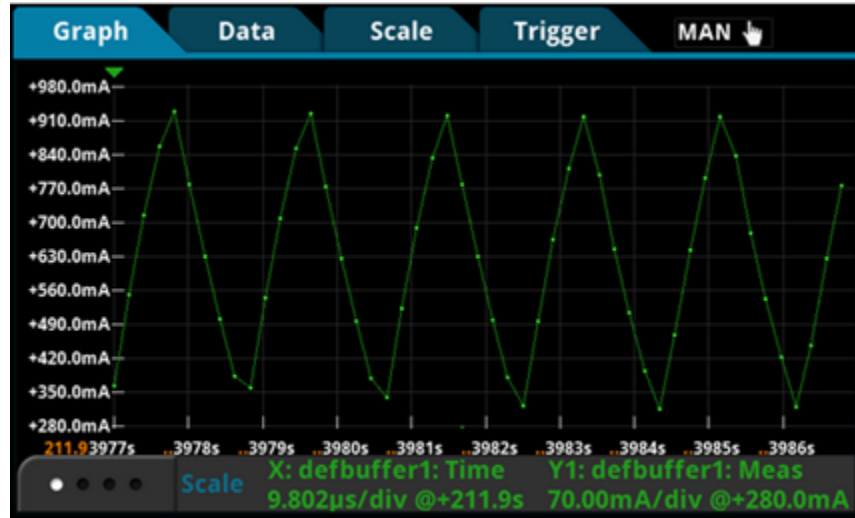


Figure 21: Inductor current linearity results at 8 Ω



Using SCPI commands

You may need to make changes so that this code will run in your programming environment.

Send the following commands:

Command	Description
<pre>*RST :SENS:DIG:FUNC "CURR" :SENS:DIG:VOLT:RANG 1 :SENS:DIG:VOLT:SRAT 500e3 :SENS:DIG:VOLT:APER AUTO :SENS:DIG:COUN 50 :TRAC:POIN 50 :TRAC:CLE :TRAC:TRIG:DIG :TRAC:DATA? 1, 50, "defbuffer1", READ :TRAC:DATA? 1, 50, "defbuffer1", REL</pre>	<ul style="list-style-type: none"> ■ Reset the DMM7510. ■ Set the instrument to measure digitize current. ■ Set range to 1 A. ■ Set the sample rate to 500,000. ■ Enable automatic aperture. ■ Set the sample count to 50. ■ Set defbuffer1 to store 50 points. ■ Clear defbuffer1. ■ Make digitize measurements. ■ Retrieve the readings from the buffer. ■ Retrieve the relative timestamps from the buffer.

Using TSP commands

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 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 *Model DMM7510 Reference Manual*.

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

By default, the DMM7510 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. Set the Command Set to **TSP**.
4. At the prompt to reboot, select **Yes**.

Send the following commands:

```
-- Reset the instrument to default settings.
reset()
-- Create a local variable to store the number of samples.
numofsamples=50
-- Set the DMM function to digitize current to capture the inductor current.
dmm.digitize.func = dmm.FUNC_DIGITIZE_CURRENT
-- Current range must be fixed when using digitize current.
dmm.digitize.range = 1
-- Set the sample rate to 500 kilosamples per second to sample a 50 kHz current waveform.
dmm.digitize.samplerate = 500e3
-- Set the aperture to automatic to get the highest accuracy measurement
-- for the configured sampling rate.
dmm.digitize.aperture = dmm.APERTURE_AUTO
-- Set the sample count to the number of samples to capture about 5 ripples.
dmm.digitize.count = numofsamples
-- Clear buffer.
defbuffer1.clear()
-- Make sure your signal is connected to the DMM and digitize.
dmm.digitize.read()

if defbuffer1.n > 0 then
    print("Digitize Current:")
    print("Total Number of readings:", defbuffer1.n)
    printbuffer(1, defbuffer1.n, defbuffer1)
    print("Timestamps:")
    printbuffer(1, defbuffer1.n, defbuffer1.relativetimestamps)
else
    print("No data collected")
end
print("Test Ended")
```

Power-up behavior

You can use the DMM7510 to capture the start-up behavior of the buck converter. The start-up inspection can ensure that the device turns on in a reasonable amount of time without any unexpected glitches or pulses. You can capture the asynchronous power-up event by using the analog trigger feature on the DMM7510.

For this test, you:

- Connect the 4 Ω load resistor to the output terminals of the buck converter
- Connect test leads to the output terminals of the buck converter
- Reset the instrument
- Select the digitize voltage function and set the sample rate to 1 megasample per second
- Set sample count to 10,000 to monitor the power-up event for 10 ms
- On the front panel of the instrument, open the Graph screen and set the graph scale option X-Axis Method to All
- Set up the edge trigger level and position
- Run the trigger model to capture the voltage waveform
- Turn on 12 V of input voltage to the input terminals of the buck converter

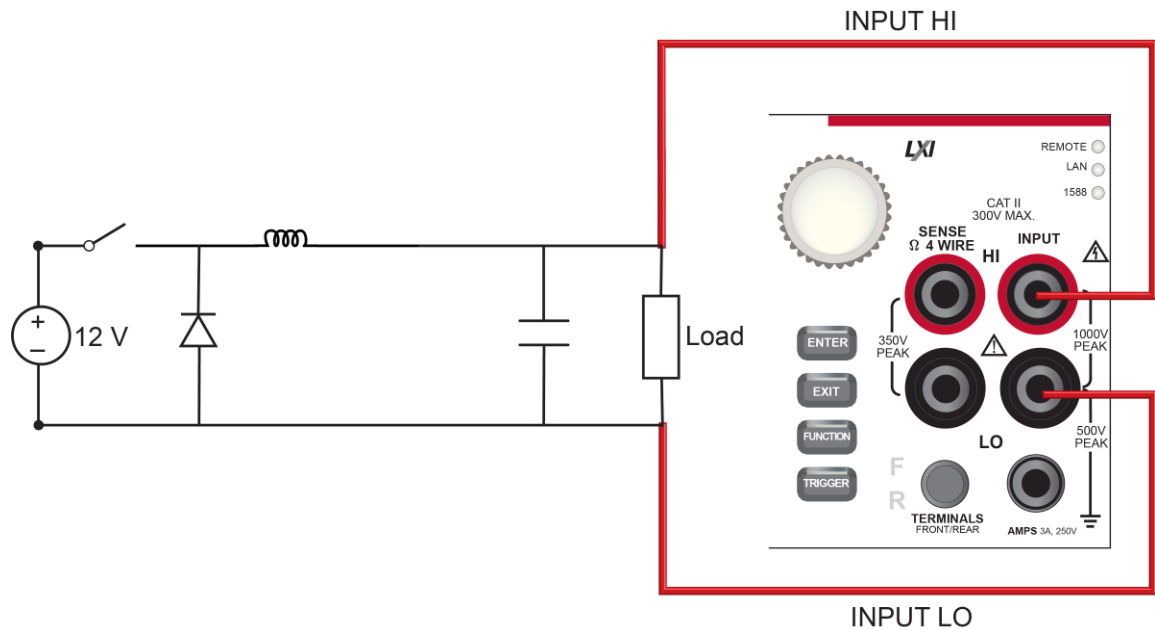
Device connections

You can use either the front or rear inputs. Ensure that the front-panel TERMINALS switch is set correctly (**F** displayed for front; **R** displayed for rear). Note that you must use either the front terminals or rear terminals. You cannot mix connections.

Both front-panel and rear-panel connections are safety banana jacks. You can make these connections with two insulated cables with banana plugs.

Connect the test leads as shown in the following figure.

Figure 22: Power-up behavior test connections



Run the test using the front panel

Set up the digitize function:

1. Press the **POWER** button on the front panel to turn on the instrument.
2. On the **FUNCTIONS** swipe screen, select **Digi V** to select the digitize voltage function.
3. Swipe to display the **SETTINGS** swipe screen.
4. Set the Sample Rate to **1,000,000**.
5. Set the Count to **1**.
6. Press the **MENU** key.
7. Select **Reading Buffers**.
8. Set the Capacity to **10,000**.

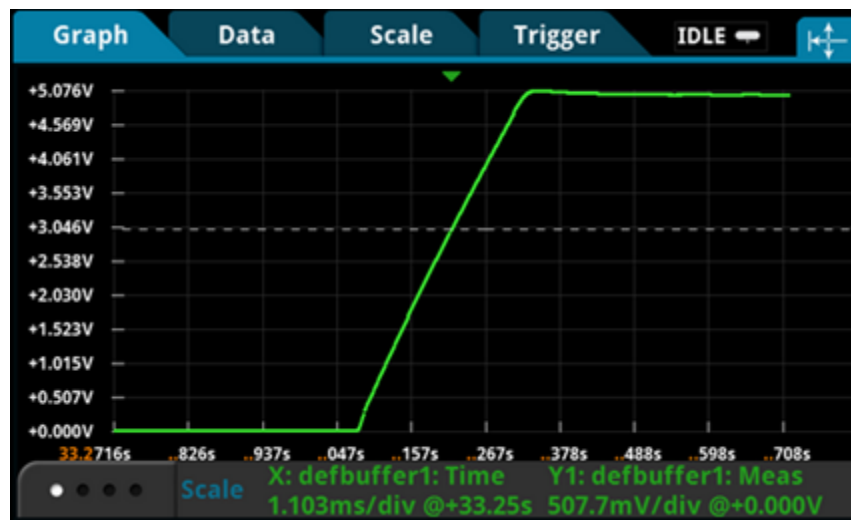
Set up triggering:

1. Press the **MENU** key.
2. Select **Graph**.
3. Select the **Scale** tab.
4. Set the X-Axis Method to **Show All Readings**.
5. Select the **Trigger** tab.
6. Set Source Event to **Waveform**.
7. Select **Analog Edge**.
8. Set Level to **3V**.
9. Set Position to **50%** for the pretrigger position.
10. Select the **Graph** tab to view the graph.
11. To start capturing the buck converter power-up behavior, press the **TRIGGER** key on the front panel. The pretrigger data is shown on the graph.
12. Turn on the 12 V output from the power supply.

Test results

The front-panel graph shows results that are similar to the following.

Figure 23: Power-up test results



Using SCPI commands

You may need to make changes so that this code will run in your programming environment.

Send the following commands:

Command	Description
<pre>*RST :SENS:DIG:FUNC "VOLT" :SENS:DIG:VOLT:RANG 10 :SENS:DIG:VOLT:INP AUTO :SENS:DIG:VOLT:SRAT 1e6 :SENS:DIG:VOLT:APER AUTO :SENS:DIG:COUN 1 :TRAC:POIN 10000 :TRAC:CLE :SENS:DIG:VOLT:ATR:MODE EDGE :SENS:DIG:VOLT:ATR:EDGE:SLOPe RIS :SENS:DIG:VOLT:ATR:EDGE:LEV 3 :TRIG:BLOC:DIG 1, "defbuffer1", INF :TRIG:BLOC:WAIT 2, ATR :TRIG:BLOC:DIG 3, "defbuffer1", 5000 INIT *WAI :TRAC:DATA? 1, 100, "defbuffer1", READ :TRAC:DATA? 1, 100, "defbuffer1", REL</pre>	<ul style="list-style-type: none"> ■ Reset the DMM7510. ■ Set the instrument to measure digitized voltage. ■ Set range to 10 V. ■ Set the input impedance to automatic, which selects 10 GΩ for the 10 V range. ■ Set the sample rate to 1,000,000. ■ Enable automatic aperture. ■ Set the sample count to 1 (optional). ■ Set <code>defbuffer1</code> to store 10,000 points. ■ Clear <code>defbuffer1</code>. ■ Enable analog edge trigger. ■ Set the edge trigger to rising slope. ■ Set the edge trigger level to 3 V. ■ Set up a trigger model that digitizes voltage indefinitely while waiting for the edge trigger event and digitizes 50% post trigger readings. ■ Start the trigger model. ■ Wait for the trigger model to complete. ■ Retrieve the readings from the buffer. ■ Retrieve the relative timestamps from the buffer.

Using TSP commands

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 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 *Model DMM7510 Reference Manual*.

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

By default, the DMM7510 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. Set the Command Set to **TSP**.
4. At the prompt to reboot, select **Yes**.

Send the following commands:

```
-- Reset the instrument to default settings.
reset()
-- Create a local variable to store the number of samples.
numofsamples = 10000
-- Set the measure function to digitize voltage to capture the power-up behavior.
dmm.digitize.func = dmm.FUNC_DIGITIZE_VOLTAGE
-- Voltage range must be fixed when using digitize voltage.
dmm.digitize.range = 10
-- Set the sample rate to 1 megasample per second to capture any small glitch.
dmm.digitize.samplerate = 1e6
-- Set aperture to automatic to get the highest accuracy measurement
-- for the configured sampling rate.
dmm.digitize.aperture = dmm.APERTURE_AUTO
-- Changing count is optional. The reading buffer capacity determines the actual count.
dmm.digitize.count = 1
-- Set the input impedance to automatic to select 10 gigaohms for the 10 V range.
dmm.digitize.inputimpedance = dmm.IMPEDANCE_AUTO
-- Set the buffer size to the number of samples to capture both
-- pre- and post-triggered data.
defbuffer1.capacity = numofsamples
-- Clear buffer.
defbuffer1.clear()
-- Select analog edge trigger to capture the power-up behavior.
dmm.digitize.analogtrigger.mode = dmm.MODE_EDGE
-- Set edge slope to detect a rising edge.
dmm.digitize.analogtrigger.edge.slope = dmm.SLOPE_RISING
-- Set edge level trigger to 3 V for the 5 V steady-state output.
dmm.digitize.analogtrigger.edge.level = 3

-- Define a trigger model that will capture 50% pre- and 50% post-triggered data.
trigger.model.setblock(1, trigger.BLOCK_MEASURE_DIGITIZE, defbuffer1,
    trigger.COUNT_INFINITE)
trigger.model.setblock(2, trigger.BLOCK_WAIT, trigger.EVENT_ANALOGTRIGGER)
trigger.model.setblock(3, trigger.BLOCK_MEASURE_DIGITIZE, defbuffer1,
    numofsamples/2)
trigger.model.initiate()
-- Waits for the trigger model to finish collecting data before proceeding.
waitcomplete()
print("test ended")
```

In this section:

[Additional information.....](#) 8-1

Additional information

This manual has prepared you to start using your new DMM7510 7½ Digit Multimeter for your application.

For detailed information on all features of the DMM7510, refer to the Keithley Instruments *Model DMM7510 Reference Manual*, part number DMM7510-901-01.

Also see tek.com/keithley for support and additional information about the instrument. From the website, you can access:

- The Knowledge Center, which contains the following handbooks:
 - *The Low Level Measurements Handbook: Precision DC Current, Voltage, and Resistance Measurements*
 - *Switching Handbook: A Guide to Signal Switching in Automated Test Systems*
- Application notes
- Updated drivers
- Information about related products

Your local Field Applications Engineer can help you with product selection, configuration, and usage. Check the website for contact information.

Specifications are subject to change without notice.
All Keithley trademarks and trade names are the property of Keithley Instruments.
All other trademarks and trade names are the property of their respective companies.

Keithley Instruments
Corporate Headquarters • 28775 Aurora Road • Cleveland, Ohio 44139 • 1-800-833-9200 • tek.com/keithley

