Series 3500 Portable RF PowerMeter®

User's Manual

3500S-900-01 Rev. B / October 2006

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

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Portable RF PowerMeter®
User's Manual

Cleveland, Ohio, U.S.A.
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Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

Revision A (Document Number 3500S-900-01).....September 2006
Revision B (Document Number 3500S-900-01).....October 2006

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Safety Precautions

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 non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified 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 manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product 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 manual. 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, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are rated Measurement Category I and Measurement Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Measurement Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Measurement Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

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 30V RMS, 42.4V peak, or 60VDC 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 volts, 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, make sure 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.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

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

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

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth 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 safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The  symbol indicates a connection terminal to the equipment frame.

The WARNING heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The CAUTION heading in a manual explains hazards that could damage the instrument. Such damage 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 Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. 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 Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth 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., 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.

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Section 1
Introduction

In this section:

Introduction

This section contains general information about the Keithley Instruments Model 3500 Portable RF PowerMeter®. The information is organized as follows:

If you have any questions after reviewing this information, please contact your local Keithley Instruments representative or call one of our Applications Engineers at 1-800-KEITHLEY. You can also contact us through our website at www.keithley.com.

Feature overview

Keithley Instruments' Model 3500 Portable RF PowerMeter is a compact, handheld instrument designed for making RF power measurements in both the field as well as research and development laboratory environments. In the laboratory, the Model 3500 can be used as an RF power datalogger by transferring data through its built-in USB interface to a computer, allowing for trend or drift analysis. For use in the field, the compact size of the Model 3500 allows it to be placed in a toolkit. Users do not have to carry both an instrument and a separate sensor module (the Model 3500 has a built-in sensor). Key features and benefits include:

- Easy to use interface with LCD display
- Economical single-function unit
- Wideband (10MHz – 6GHz) average RF power measurements
- Both sensor and display are housed in the same compact handheld package
- USB (Universal Serial Bus) control interface
- Flexibility of drawing operating power from an on-board battery, an optional external power supply, or a computer via the USB interface

Figure 1-1
Model 3500 Portable RF PowerMeter

Manual addenda

Any improvements or changes concerning the Model 3500 or manual will be explained in an addendum included with the manual. Be sure to note these changes and incorporate them into the manual.

Safety symbols and terms

The following symbols and terms may be found on the Model 3500 or used in this manual.

The ⚠ symbol indicates that the user should refer to the operating instructions located in the manual.

The ⚠ symbol shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the unit. Such damage may invalidate the warranty.

Specifications

Full Model 3500 specifications are included in Appendix A. Check the Keithley Instruments website at www.keithley.com for the latest updates to the specifications.

Unpacking and inspection

Inspection for damage

The Model 3500 was carefully inspected electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. Report any damage to the shipping agent immediately. Save the original packing carton for possible future shipment.

Shipment contents

The following items are included with every Model 3500 order:

- Model 3500 Portable RF PowerMeter
- Model USB-MINI-1 USB Cable, Type A to Mini Type B, 1m (3.3ft.) in length
- CD containing required software and manuals

Instruction manual

A CD-ROM containing this User's Manual and required software is included with each Series 3500 order. If a hardcopy of the Series 3500 User's Manual is required, you can order the Manual Package (Keithley Instruments Part Number 3500S-900-01). The Manual Package includes an instruction manual and any pertinent addenda.

Always check the Keithley Instruments website at www.keithley.com for the latest revision of the manual. The latest manual can be downloaded (in PDF format) from the website.

Repacking for shipment

Should it become necessary to return the Model 3500 for repair, carefully pack the unit in its original packing carton or the equivalent, and follow these instructions:

- Call the Repair Department at 1-800-552-1115 for a Return Material Authorization (RMA) number.
- Advise as to the warranty status of the Model 3500.
- Write ATTENTION REPAIR DEPARTMENT and the RMA number on the shipping label.
- Complete and include the Service Form located at the back of this manual.

Available accessories

NOTE *Check the Keithley Instruments website (www.keithley.com) for additional accessories that may have been added to the Keithley Instruments product line for the Model 3500.*

Keithley Instruments part numbers are contained in parenthesis (unless otherwise specified).

- **Model 3500-PWR External Power Supply** (optional) includes:
  - Line Cord
  - Power Supply
- **Model USB-MINI-3**: USB Cable Type A to Mini Type B, 3m (9.8ft.) in length

Connections

Available Model 3500 connections:

- RF: Type N male RF connector (50Ω characteristic impedance)
- USB: Miniature "B" USB connector
- External Power: Power receptacle (connect optional External Power Supply Model 3500-PWR)

NOTE *Refer to* Section 2 *for detailed connection information.*

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Section 2
Connections

In this section:

Introduction

This section contains information about handling the Keithley Instruments Model 3500 Portable RF PowerMeter® and making connections:

- Handling precautions
- RF connector
- USB port
- External power connector
- Battery power

Handling precautions

To maintain high-impedance isolation, use care when handling the Model 3500 to avoid contamination from foreign materials such as body oils. Such contamination can reduce isolation resistance. To avoid possible contamination:

- Do not touch connector insulators.
- If the unit becomes contaminated, it should be thoroughly cleaned. Refer to "Handling and cleaning precautions" in Section 4 for more information.

RF connector

Make RF signal connections to the Type N male RF connector (50Ω characteristic impedance—refer to Figure 2-1). When making connections, be sure to follow the guidelines contained below.

Figure 2-1
Signal connection

Maximum input power limitations

Do not connect or apply power outside of the Model 3500 specifications. Complete specifications are contained in Appendix A.

Connection for a power measurement

NOTE *When connecting the Type N connector of the Model 3500 to a Type N female connector for a power measurement, observe the following proper practice for tightening the connection.*

While holding the body of the PowerMeter in one hand, turn the Type N Male Connector Nut to tighten the connection (do not turn the body of the Model 3500). Continue to do so until the connection is hand-tight. It is important to turn the nut of the connector rather than the body of the PowerMeter when tightening the connection.

USB port

NOTE *The term USB (Universal Serial Bus) is used in this manual. USB is simply another term for the Universal Serial Bus.*

The PowerMeter has a USB 2.0 interface with a USB Type Mini-B port (refer to USB Type Mini-B port in Figure 2-2). The Model 3500 can be remotely programmed over this USB interface. In addition to programming, the Model 3500 can be powered by the USB. With the USB connected and providing power, and the optional external power disconnected, the Model 3500 will be powered from USB regardless of whether batteries are present.

NOTE *The interface is USB 2.0 compatible, but with an interface speed of 12 Mbps.*

Figure 2-2
USB and power connector

External power connector

A power connector provides a connection for the optional external power supply (refer to Figure 2-2). If the external power supply is connected, the Model 3500 will be powered by the external supply, regardless of whether USB power or batteries are present.

CAUTION **Only connect the optional external power supply (Model 3500-PWR) to this connector. Instrument damage may result if improper power is applied.**

Battery power

The Model 3500 can also be powered by two AA batteries. If installed, the batteries will power the Model 3500 only if the external power supply and USB are not connected. Refer to "Battery replacement" in Section 4 for more information.

Section 3
Operation

In this section:

Topic	Page

Introduction

This section contains the following operating information for the Keithley Instruments Model 3500 Portable RF PowerMeter®:

Environmental requirements

Make sure environmental requirements are maintained. The operating environment requirements are listed in this section and in the complete specification, which can be found in Appendix A.

Operating environment

The Model 3500 will not perform within the instrument's specifications if operated outside of the following environmental conditions:

- Operating temperature: 0°C to 50°C (32°F to 122°F)
- Operating humidity: <80% RH at 35°C (95°F), non-condensing

Storage

Storage conditions: -20°C to 70°C (-4°F to 158°F).

Maximum signal considerations

CAUTION **To prevent damage to the Model 3500, do not exceed the following maximum signal level specifications:**

+20 dBm, 5VDC

Front panel operation

Throughout this section, the following manual convention applies:

- Bold-face type style represents Model 3500 keys. For example, **MENU** key refers to the front panel key labeled MENU.
- Menus are quoted. For example, "Averaging" menu refers to the Model 3500 menu of the same name.
- Menu items appear bracketed in <>. For example, <Off> refers to the default Model 3500 menu item on the "Averaging" menu.

Keys

Figure 3-1 shows the location of the front panel keys. Refer to Table 3-1 for front panel key descriptions and use.

Figure 3-1
Front panel

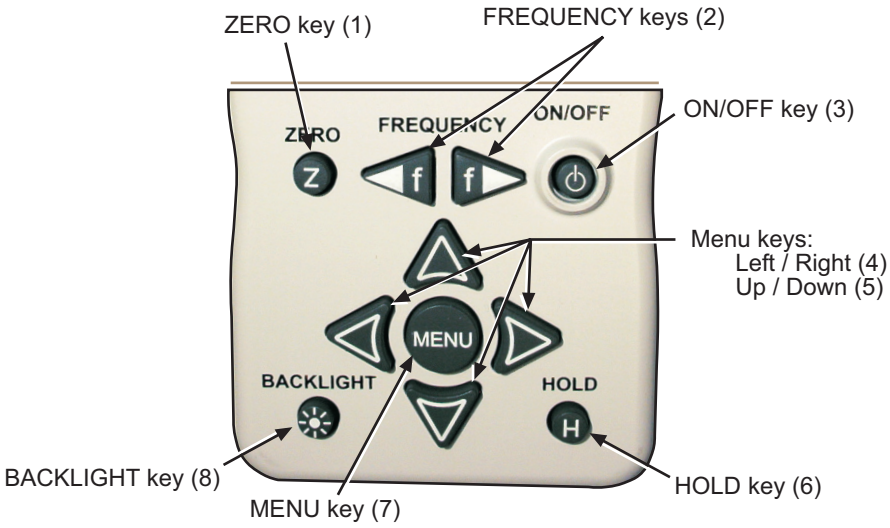


Table 3-1
Front panel keys

Key	Description
ZERO key (1)	Use to zero the Model 3500. When pressed, the PowerMeter measures the offset voltages in the signal path and zeroes the Model 3500. This allows a more accurate measurement at low power levels. The PowerMeter's RF input may be left disconnected when it is zeroed, or it may be connected to other hardware, but make sure that no signals are present on the RF input (inaccurate readings will result). For example, if the PowerMeter is connected to a signal generator, turn the signal generator's output off before pressing the zero key. When the PowerMeter is zeroed, the display will show "ZEROING." The entire operation takes approximately 30 seconds.
FREQUENCY keys (2)	Use to set the Model 3500 to the frequency of the input signal. There are two keys for adjusting the frequency. The **left arrow** key decrements the present frequency in 10MHz steps. Likewise, the **right arrow** key increments the present frequency in 50MHz steps. The present frequency is displayed on the second line of the display. Pressing and holding one of the **frequency** keys down will change the frequency setting rapidly.
ON/OFF key (3)	Use to turn the PowerMeter on and off.
Up / Down menu keys (4) and **Left / Right menu** keys (5)	The four arrow keys are active in menu mode only. Enter menu mode by pressing the **MENU** key. When the PowerMeter is in normal mode, the four arrow keys are inactive.
	(4) Up/Down Menu keys: The **Up** and **Down menu** keys select different menus. For example, these keys can be used to change from the "Averaging" menu to "Units" menu.
	(5) Left/Right Menu keys: In a given menu, these keys allow the user to adjust the settings. For example, in the "Averaging" menu, these keys are used to select the number of averages performed by the Model 3500.
HOLD key (6)	Normally, the Model 3500 power reading is continuously updated. In some cases, this may be undesirable. For example, the PowerMeter might be connected to a signal source in a location that makes it difficult to read the display. When the **Hold** key is pressed, the most recent reading is frozen on the display and is no longer updated. This allows the user to disconnect the PowerMeter from the source and then read the display. Pressing the **Hold** key again will disable the hold function and the display will once again be continuously updated. When the hold function is enabled, an "**H**" is displayed in the upper-right corner of the display.
MENU key (7)	Use to access functions that are not available to the user directly from a front panel key. Pressing this key allows the user to enter or exit the PowerMeter menus. Pressing this key once will cause the power display to be replaced with the menu display. The menu can be navigated with the menu navigation keys. Pressing the **MENU** key again will exit the menu mode and the display will return to normal mode.
BACKLIGHT key (8)	The PowerMeter's display and keys are backlit to ensure visibility in dark locations. The backlight is turned on and off by pressing the **Backlight** key. In order to conserve battery power, when the backlight is turned on it will automatically turn off after a certain delay. By default, this delay is set to one minute. Change this delay setting using the Model 3500's menus.

Navigating the menu system

NOTE *There is no "enter" key to activate a particular menu selection. Once the **Left** or **Right menu** keys are used to select one of the choices in a menu, that choice is automatically activated.*

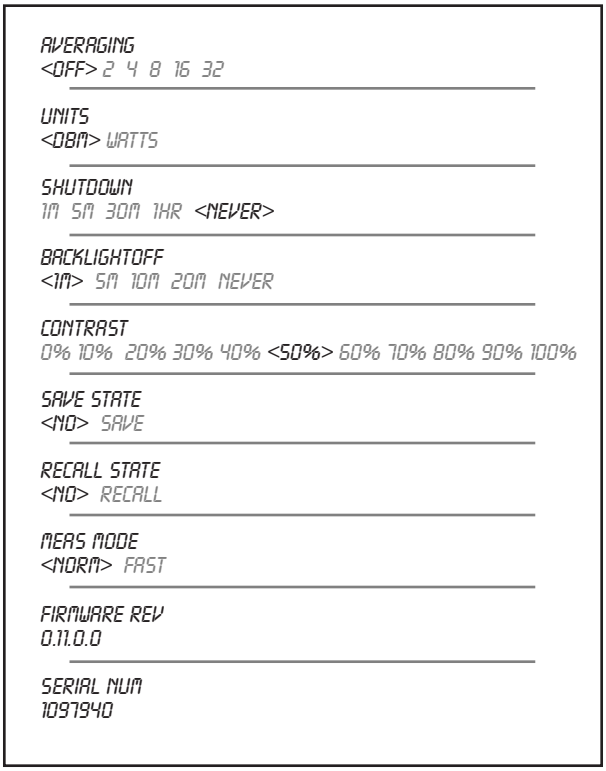
Pressing the **MENU** key toggles the display between normal mode and menu mode. Use the four arrow keys surrounding the **MENU** key to navigate and make selections while in menu mode. Use the **Up** and **Down menu** keys to select the available function menus.

For example, press the **MENU** key to change the display from normal mode to menu mode. Press the **Down menu** key to change the active menu from the "Averaging" menu to the "Units" menu. Use the up and **Down menu** keys in this fashion to scroll through the various menus available.

While in a menu, use the **Left** and **Right menu** arrow keys to select the available choices. All menu commands are executed immediately when the choice is selected.

For example: In the "Averaging" menu, the **Left** and **Right menu** keys can turn averaging "Off' or select 2, 4, 8, 16, or 32 averages. If the present selection is <2>, and the **Right menu** key is pressed, the selection of <4> will immediately become the active selection. Refer to Figure 3-2 for a map of the menu structure. In Figure 3-2, menu items bracketed in <> are the default menu values.

Figure 3-2
Menu map



Turning the Model 3500 on and off

Use the **ON/OFF** key to turn the Model 3500 on or off. While operating on battery power, the Model 3500 has a power auto-shutoff feature to preserve battery life. This feature automatically turns the unit off after a certain delay. The default auto-shutoff feature time is disabled.

NOTE *Change the length of time for the power auto-shutoff feature in the "Shutdown" menu.*

Setting the power auto-shutoff interval

NOTE *The "Shutdown" menu returns to the default value of <Never> when the unit is turned off.*

Step 1: Press the **MENU** key to enter menu mode.

Step 2: Display the "Shutdown" menu:

- Scroll using the **down arrow** key until "Shutdown" is displayed.

Step 3: Select the desired timeout interval:

- Use the **Left** or **Right menu** keys to select the desired timeout interval.

NOTE *Select timeout interval of **<Never>** to disable auto-shutoff.*

Front panel procedures

The Model 3500 can be operated and programmed using the front panel. All commands and functions accessible over USB can also be accessed from the front panel.

Measure power

To measure the power of a signal with the most accuracy, use the following procedure:

Step 1: Set frequency reading:

NOTE *The unit returns to the default frequency value setting of 500MHz when the unit is turned off.*

- Press the **Left** or **Right FREQUENCY** keys as needed to set appropriate frequency. The Model 3500 can be set from 0MHz to 6000MHz in 50MHz increments.

Step 2: Zero the Model 3500. Refer to "Zero PowerMeter" later in this section for more information.

Step 3: Connect the Model 3500 RF input to the signal to be measured. Refer to "RF connector" in Section 2 for more information.

The top line of the display shows the measured power of the signal. The Model 3500 will continuously measure power and update the display appropriately.

In the upper right-hand corner of the display, an at sign (**@**) is displayed whenever a new measurement is completed and the results have been displayed. If this character changes to an H, the Model 3500 will hold the present reading (the unit is in hold mode). Press the **HOLD** key to return to normal operation.

Zero PowerMeter

Zeroing the PowerMeter improves the measurement accuracy of the Model 3500 significantly, especially at low power levels. After the Model 3500 is turned on, it should always be zeroed

before making any measurements. The Model 3500 should be zeroed when it warms up, and periodically when the ambient temperature changes.

Step 1: Prior to zeroing the Model 3500, make sure all RF power is removed from the Model 3500's RF input. This can be done by disconnecting the RF input, or by disabling the output of any signal sources connected to the Model 3500.

Step 2: Once all RF power is removed from the Model 3500's RF input, press the **ZERO** key (refer to Table 3-1). The Model 3500 will display the message "Zeroing..." during the zeroing process. When the display returns to normal mode, zeroing is complete and measurements can be made.

Set input frequency

NOTE *The unit returns to the default frequency value setting of 500MHz when the unit is turned off.*

The Model 3500 has internal calibration tables that correct for frequency response variations of its circuitry. For best accuracy, correctly set the input signal frequency.

Set input frequency with the **FREQUENCY** keys (refer to Table 3-1). The left arrow decreases the frequency, and the right arrow increases it. The present frequency setting is displayed on the second line of the display when the display is in normal mode.

Holding either key down will cause the frequency to increase or decrease rapidly, allowing the user to quickly set the frequency to the desired value.

Set measurement speed

In normal operation speed, the Model 3500 will complete a power measurement in about 1 second (+/- 0.5 second depending on the power level of the input signal). Lower level signals take longer to measure than higher level signals. This is due to the fact that more filtering is required to get a good signal-to-noise ratio when measuring low-level signals.

If faster measurements are required, set the Model 3500 to high-speed mode. In this mode (for measurements greater than -40dBm) the Model 3500 can make approximately three measurements per second.

In most cases, the normal measurement speed is the best choice. Measurement data filtering is greatly reduced in high-speed mode, resulting in significantly higher measurement noise than in normal mode.

Enabling and disabling high-speed mode

NOTE *The unit returns to the default "Meas mode" setting of <Norm> when the unit is turned off.*

Step 1: Press the **MENU** key to enter menu mode.

Step 2: Select the "Meas mode" menu:

- Scroll using the **Down menu** key until "Meas mode" is displayed.

Step 3: Set desired measurement speed mode:

- Press the **Left** or **Right menu** keys to select either the <Norm> or <Fast> option. <Norm> will select normal measurement speed; <Fast> will select high-speed mode.

Saving the instrument state

NOTE *The default "Save State" menu item is <No>. Saving the instrument's state places all menu values in the unit's memory so that it can be recalled after cycling power. Frequency settings are not saved or recalled.*

Step 1: Press the **MENU** key to enter menu mode.

Step 2: Select the "Save State" menu:

- Scroll using the **Down menu** key until "Save State" is displayed.

NOTE *Menu commands are executed immediately when the menu item is selected. Therefore, the Save State command is implemented as soon as the <Save> menu item is highlighted. There is no undo — as soon as the <Save> menu item is selected, the current menu settings write over previously saved settings.*

Step 3: Use the **Right menu** key to select <Save>. This will save the instrument state in the PowerMeter's non-volatile memory.

Recalling the instrument state

NOTE *The default "Recall State" menu item is <No>. Recalling the instrument's state restores all stored menu values in the PowerMeter's non-volatile memory. Frequency settings are not recalled.*

Step 1: Press the **MENU** key to enter menu mode.

Step 2: Select the "Recall State" menu:

- Scroll using the **Down menu** key until "Recall State" is displayed.

NOTE *Menu commands are executed immediately when the menu item is selected. Therefore, the command Recall State is implemented as soon as the <Recall> menu item is highlighted. There is no undo — as soon as the <Recall> menu item is selected, saved menu settings write over the present settings.*

Step 3: Use the **Right menu** key to select <Recall>. This will recall the instrument state from the PowerMeter's non-volatile memory.

Setting units: dBm or watts

NOTE *When operating the Model 3500 using the front panel, and while in watts mode, the front panel will display nW, µW, mW or W as appropriate.*

The unit returns to the default "Unit" menu setting of <dBm> when the unit is turned off. Refer to Appendix B for information on dBm and watts.

Step 1: Press the **MENU** key to enter menu mode.

Step 2: Select the "Units" menu:

- Scroll using the **Down menu** key until "Units" is displayed.

Step 3: Using the **Left** or **Right menu** keys, select desired units: <dBm> or <watts>.

Controlling the backlight

The PowerMeter's display and keys are backlit to allow operation in dark environments. The backlight can be turned on and off with the **BACKLIGHT** key (refer to Table 3-1). The backlight will automatically turn off after a certain length of time to preserve battery life (the default time is one minute). Change the time interval in the "BacklightOff" Menu.

Setting the backlight auto-shutoff interval

NOTE *The unit returns to the default "BacklightOff" menu setting of <1m> when the unit is turned off.*

Step 1: Press the **MENU** key to enter menu mode.

Step 2: Select the "BacklightOff" menu:

- Scroll using the **Down menu** key until "BacklightOff" is displayed.

Step 3: Press the **Left** or **Right menu** keys to select the desired timeout interval. Select <Never> to disable the backlight's auto-shutoff.

Remote USB operation

Introduction

The Model 3500 is USB programmable. Commands and functions accessible from the front panel are also available over USB, except the following:

- On and off
- Save state
- Recall state
- Shutdown time setting
- Backlight off time setting

The driver for the Model 3500 is uncomplicated—few commands are necessary to initiate a connection and read and write from the instrument. Device programming is accomplished by sending and receiving strings over the USB. This programming model is very similar to GPIB programming.

Bus connections

Before using the Model 3500 remotely, after installing the required drivers (refer to "Driver installation" for more information), connect the USB connector on the side of the Model 3500 to the USB connector of the controller (refer to "USB port" in Section 2 for more information).

Driver installation

The Model 3500 drivers support the following Microsoft operating systems:

- Windows XP
- Windows 2000

Installing the drivers for the Model 3500 is a three-step process: Check (or install) the Microsoft .NET Framework; Install the Model 3500 USB driver (this step installs the low-level drivers that set up the physical communication link between the Model 3500 and the PC); Install the programming drivers, which allow you to program the Model 3500 (this step installs the high-level drivers that manage the USB interface and facilitate programming the Model 3500). Use the following installation procedure as a guide:

Step 1. Install Microsoft .NET Framework

1. Verify that Microsoft .NET Framework is installed. An executable that installs the framework is supplied on the Model 3500's product information CD. To install:
- Execute the file named "**dotnetfx.exe**" located on the Model 3500's product information CD.
- To complete the installation, select default values or agree when prompted.

Step 2. Install USB driver (Windows XP shown, others similar)

1. Install Model 3500 driver software:
   - Execute the file named "setup.exe" located on the Model 3500's product information CD.
   - To complete the installation, select default values or agree when prompted.
2. Connect the Model 3500 to the PC's USB port with the supplied USB cable.

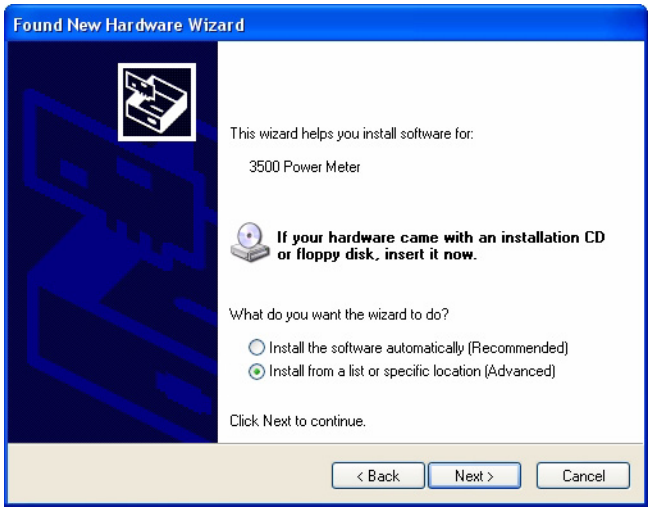
NOTE *The Model 3500 should automatically turn on when connected to the PC's USB port. Turn unit on manually if it does not.*

If the "Welcome to the Found New Hardware Wizard" dialog box does not appear (refer to Figure 3-3), cycle power on the Model 3500.

Figure 3-3
Welcome to the Found New Hardware Wizard dialog box

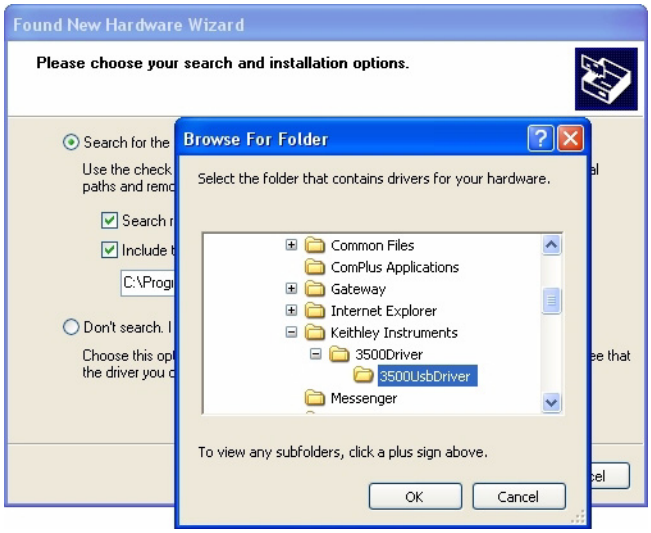
3. When the "Welcome to the Found New Hardware Wizard" installation screen (refer to Figure 3-3) appears:
   - Select "**No, not this time**."
   - Click **Next**.
4. When the "Found New Hardware Wizard" installation screen appears (refer to Figure 3-4):
   - Select "**Install from a list or specific location (Advanced)**."
   - Click **Next**.

Figure 3-4
Found New Hardware Wizard



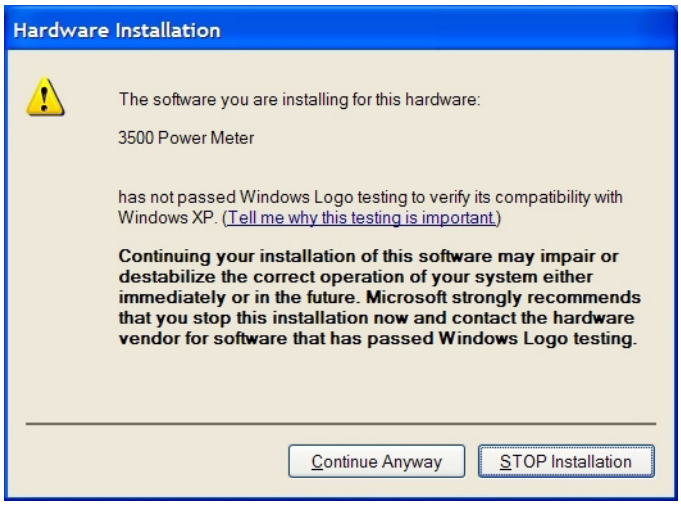
5. Select location:
   - Click **Browse** and select the following location on your hard drive (refer to Figure 3-5): C:\Program Files\Keithley Instruments\3500Driver\3500UsbDriver (this is the default location for the Model 3500's USB drivers installed by **setup.exe**).
   - Click **OK**.
   - Click **Next**.

Figure 3-5
Browse for Folder window



6. The Hardware Installation screen (Figure 3-6) will appear. To complete the USB driver installation:
   - Click **Continue anyway**.

Figure 3-6
Hardware Installation Screen



7. When the wizard has completed installing the software, click **Finish** to close the wizard.

Step 3. Install programming driver

In order for your program to be able to communicate with the programming driver, it must be able to find the appropriate DLL. The method used to find the appropriate DLL is dependent on the software used to create your programs. Refer to the paragraphs titled "When using Microsoft Visual Studio .NET," or "When using Microsoft Visual Studio 6.0," as applicable.

When using Microsoft Visual Studio .NET

NOTE *The default setup places the Keithely3500.dll file in the following folder:* ***C:\Program Files\Keithley Instruments\Keithley 3500 Driver****.*

In the installation directory, find the file named **Keithley3500.dll** and add a reference to this file in your project. Refer to "Adding a reference (Microsoft Visual Studio .NET)" for more information.

NOTE *An alternative method would be to place a local copy of* ***Keithley3500.dll*** *in your project directory and add a reference to this copy. If this alternative method is used, and an updated driver for the Model 3500 is later installed, the local copy in the project directory will not be updated (it will remain the earlier version of the driver).*

Advantage: when updating the Model 3500 driver, this method removes the risk that updating the Model 3500 driver will break your software.

Disadvantage: when updating the Model 3500 driver, this method requires manual placement of a copy of the new ***Keithley3500.dll*** *in your project directory and also rebuilding code to take advantage of the new driver.*

Adding a reference (Microsoft Visual Studio .NET)

The following procedure outlines how to add a reference while using Microsoft Visual Studio .NET. Adding a reference in other programming languages is similar.

1. While in Microsoft Visual Studio .NET, select the desired project.
2. Under the **View** menu, select **Solution Explorer** (alternatively, press **Ctrl**-**Alt-L**).
3. In the **Solution Explorer**, expand the project (if needed):
   - Click the (+) sign next to the project.
4. Add the Reference:
   - Right click **References**.
   - Click **Add Reference...**
5. In the **Add Reference** window that opens, **Browse** to the directory where the PowerMeter programming driver **Keithley3500.dll** is stored.
6. Double-click the **Keithley3500.dll** component.
7. Click on **OK** in the **Add Reference** window. **Keithley3500** should now appear under **References** in the **Solution Explorer** window.

When using Microsoft Visual Studio 6.0

NOTE *In Microsoft Visual Studio 6.0, the Keithley3500.tlb file must referenced in its install location — a reference to a local copy placed in your project directory cannot be used.*

The procedures for referencing the DLL differ for Visual Basic 6.0 and Visual C++ 6.0.

Adding a reference (Visual Basic 6.0)

1. With your Visual Basic 6.0 project open, from the **Project** menu, select the **Reference** menu item. The **References** dialog box will open.

NOTE *The default setup places the Keithley3500.tlb file in the following folder:* ***C:\Program Files\Keithley Instruments\Keithley 3500 Driver.***

2. **Browse** to the installation directory.
3. Select **Keithley3500.tlb**.
4. Click **Open**.
5. Verify that the **Keithley 3500 RF Powermeter Driver** has been added (is checked).
6. Click **OK**.

Adding a reference (Microsoft Visual C++ 6.0)

To add the reference In Visual C++ 6.0, make sure the program contains the following line (no other special steps are required to add the reference):

```
#import "C:\Program Files\Keithley Instruments\Keithley 3500 Driver\Keithley3500.tlb"
    no_namespace named_guids
```

NOTE *The above line is correct for an installation in the default directory. If installed in a different directory, modify the statement accordingly.*

Addressing

When programming the Model 3500 remotely, the Model 3500 serial number is used as the instrument's unique address. Find the serial number on the Model 3500's back label. Look for an integer number in the range of 1 to 99,999,999. If desired, this number can also be found on the menu (refer to "Navigating the menu system") or retrieved from the firmware using the **SerialNumber** driver command.

Remote USB commands

Perform the following two steps prior to communicating with the Model 3500:

1. Set the serial number in the user's software. The Model 3500 serial number is used as the instrument's unique address for communication and can be found underneath the barcode on the Model 3500's back panel or displayed using the menu (refer to Navigating the menu system).
2. Initialize the Model 3500.

NOTE *Refer to "Examples" later in this section for more information.*

Basic driver commands

In each driver command's **Usage** section, *myPM* is an instance of a power meter class that has been created. Refer to "Examples" later in this section for language-specific sample applications.

SerialNumber

Description **SerialNumber** is a property used to control which specific Model 3500 is accessed. **SerialNumber** is a 32-bit signed integer (1 to 99,999,999).

Usage

C# .NET

```
int SN = 1097330;
myPM.SerialNumber=SN;
```

Visual Basic .NET

```
Dim SN As Integer
SN=1097330
myPM.SerialNumber=SN
```

Visual C++ .NET

```
int SN=1097330;
myPM->SerialNumber=SN;
```

Visual Basic 6.0

```
Dim SN As Long
SN=1097330
myPM.SerialNumber=SN
```

Visual C++ 6.0

```
int SN=1097330;
myPM->SerialNumber=SN;
```

Parameters *myPM* refers to the created Model 3500 object.
SN is the serial number (32-bit signed integer) of the Model 3500 being checked.

IsDeviceAvailable()

Description This **int** function checks the status of the device pointed to by **SerialNumber**.

Usage

C# .NET

```
int SN=1097330;
int MeterAvailable=myPM.IsDeviceAvailable(SN);
```

Visual Basic .NET

```
Dim SN As Integer
SN=1097330
Dim MeterAvailable As Integer
MeterAvailable = myPM.IsDeviceAvailable(SN)
```

Visual C++ .NET

```
int SN=1097330;
int MeterAvailable=myPM->IsDeviceAvailable(SN);
```

Visual Basic 6.0

```
Dim SN As Long
SN=1097330
Dim MeterAvailable As Integer
MeterAvailable=myPM.IsDeviceAvailable(SN)
```

Visual C++ 6.0

```
int SN = 1097330;
int MeterAvailable=myPM.IsDeviceAvailable(SN);
```

Parameters *myPM* refers to the created Model 3500 object.
SN is the serial number (32-bit integer) of the Model 3500 being checked.
MeterAvailable is the integer variable created containing the device status.

Return Value Returns a 32-bit integer with one of the following values:

0: Unavailable—the device may have been opened by another program.

1: Available.

-1: Absent—the device was not found.

Initialize()

Description This void function opens the link between the Model 3500 and the PC. The **Serial-Number** property must be set prior to executing.

Usage

C# .NET

```
myPM.SerialNumber=1097330;
myPM.Initialize();
```

Visual Basic .NET

```
myPM.SerialNumber=1097330
myPM.Initialize()
```

Visual C++ .NET

```
myPM->SerialNumber=1097330;
myPM->Initialize();
```

Visual Basic 6.0

```
myPM.SerialNumber=1097330
myPM.Initialize
```

Visual C++ 6.0

```
myPM.SerialNumber=1097330;
myPM->Initialize();
```

Parameters *myPM* refers to the created Model 3500 object.

SendString

Description Use this command to send and receive string messages from the Model 3500—all communication with the Model 3500 is accomplished using this command.

Usage

C# .NET

```
string Reply=myPM.SendString("*RST\n");
```

Visual Basic .NET

```
Dim Reply As String
Reply=myPM.SendString("*RST" & vbLf)
```

Visual C++ .NET

```
String * Reply;
Reply=myPM->SendString("*RST\n");
```

Visual Basic 6.0

```
Dim Reply As String
Reply = myPM.SendString("*RST" & vbCrLf)
```

Visual C++ 6.0

```
BSTR Reply;
Reply=myPM->SendString("*RST\n");
```

Parameters *myPM* refers to the created Model 3500 object.

Close()

Description This command closes and releases the program's connection to the Model 3500. After the connection is released, the Model 3500 is available for use with other programs.

Usage

C# .NET

```
myPM.Close();
```

Visual Basic .NET

```
myPM.Close()
```

Visual C++ .NET

```
myPM->Close();
```

Visual Basic 6.0

```
myPM.Close
```

Visual C++ 6.0

```
myPM->Close();
```

Parameters *myPM* refers to the created Model 3500 object.

FindUninitializedDevices()

Description Use this command to return a string containing a listing of serial numbers of all un-initialized Model 3500 PowerMeters (comma-delimited). If no un-initialized Model 3500 PowerMeters are present, the string is empty.

NOTE *The statement "un-initialized Model 3500 PowerMeters" refers to those power meters which are connected to the user's computer, but have not had the **Initialize()** function called on them. Also, when **Close()** is called on initialized devices, they return to the un-initialized state and are visible to the **FindUninitializedDevices()** command.*

Usage

C# .NET

```
string List;
List=myPM.FindUninitializedDevices();
```

Visual Basic .NET

```
Dim List As String
List = myPM.FindUninitializedDevices()
```

Visual C++ .NET

```
String * List;
List = myPM->FindUninitializedDevices();
```

Visual Basic 6.0

```
Dim List As String
List=myPM.FindUninitializedDevices()
```

Visual C++ 6.0

```
BSTR List;
List=myPM->FindUninitializedDevices();
```

Parameters *myPM* refers to the created Model 3500 object.
List is the string variable containing the returned serial number(s).

Basic Model 3500 commands

Reset

Description This command resets the PowerMeter to its factory power-on state.

Syntax *RST<LF>

Response OK

Triggered power read

Description This is the basic measurement command for the PowerMeter.

Syntax *TRG<LF>

Response <Value>

Return Value Returns the present PowerMeter reading.

Comments The PowerMeter's present read cycle is interrupted, and a new one is started. The measurement from the new cycle is returned.

Non-triggered power read

Description This command returns the present PowerMeter reading.

Syntax PWR? <LF>

Response <Value>

Comments This is a non-triggered measurement. If the input power has changed during the present measurement cycle, the measured power may be unpredictable.

Zero command

Description This command zeroes the PowerMeter.

Syntax ZERO<LF>

Response OK

Comments This internal correction routine removes offset errors in the measurement. This is necessary to preserve accuracy when measuring low-level signals.

Set frequency

Description This command sets the PowerMeter's operating frequency.

Syntax FREQ<Value><LF>

Response OK

Comments The units of measurement are Megahertz.

Averaging control commands

Set averaging factor

Description This command sets how many averages are taken before returning a power measurement.

Syntax SETAVG<Value><LF>

Response OK

Parameters The valid range of <Value> is 0 through 5 (refer to Table 3-2).

Table 3-2
SETAVG command values

<Value>	Number of averages taken
0	1*
1	2
2	4
3	8
4	16
5	32
* Equivalent to disabling averaging	

Comments Sending a value using this command results in taking averages of 2^x measurements (where *x* = <Value>). For example: sending a "SETAVG<1><LF>" causes the average factor to take 2^1 or 2 measurements; sending a "SETAVG<2><LF>" causes the average factor to take 2^2 or 4 measurements; sending a "SETAVG<3><LF>" causes the average factor to take 2^3 or 8 measurements. When <Value> = 0, (sending a "SETAVG 0"), the number of measurements is set to 1, and is equivalent to disabling averaging.

Get averaging factor

Description This command reads and returns the averaging factor, which is equal to $\log_2$ (number of measurements per average).

Syntax AVG?<LF>

Response <Value>

Comments A value of 0 is equivalent to having averaging turned off.

Measurement speed control commands

Set normal speed mode

Description This command sets the Model 3500 to **Normal Speed Mode**.

Syntax NMODE<LF>

Response OK

Comments **Normal speed mode** is the default mode of operation.
Model 3500 accuracy specifications apply in normal mode. Measurement speed is level-dependent.

Set high speed mode

Description This command sets the Model 3500 to **High Speed Mode**.

Syntax HSMODE<LF>

Response OK

Comments **High Speed Mode** turns off all internal averaging and filtering. Measurement noise is higher (especially at low signal levels), but the measurement speed is much faster.

Unit of measurement commands

dBm mode

Description This command sets the PowerMeter to **dBm mode**.

Syntax UDBM<LF>

Response OK

Comments Send this command to express remote and front panel measurements in dBm.

watts mode

Description This command sets the PowerMeter to **watts Mode**.

Syntax UMW<LF>

Response OK

Comments Send this command to express **remote** measurements in units of **watts**, regardless of the units displayed on the front panel. The front panel display will express measurements in units of watts, milliwatts, or microwatts, as appropriate.

Miscellaneous commands

Backlight on

Description This command turns on the display and keyboard backlight.

Syntax BLON<LF>

Response OK

Comments The backlight will remain on for the length of time specified by the backlight timer. The timer is controllable from the front panel using the menu (refer to Table 3-1).

Backlight off

Description This command turns off the display and keyboard backlight.

Syntax BLOFF<LF>

Response OK

Get serial number

Description This command returns the numeric serial number of the unit.

Syntax Syntax: SN?<LF>

Response <Value>

Examples

This subsection provides example programs that initialize the Model 3500, take a reading, and then close the Model 3500. Examples are provided for:

- Microsoft Visual Studio .NET
- Microsoft Visual Basic 6.0
- Microsoft Visual C++ 6.0

Microsoft Visual Studio .NET

The following examples are console applications. To run in Microsoft Visual Studio .NET:

1. Create a new .NET console application project.
2. Delete the contents of the source file.
3. Copy the desired applicable example code into the source code file.
   - Example code: Microsoft C# .NET (refer to Table 3-3)
   - Example code: Microsoft Visual Basic .NET (refer to Table 3-4)
   - Example code: Microsoft Visual C++ .NET (refer to Table 3-5)
4. Add a reference to the DLL — refer to Adding a reference (Microsoft Visual Studio .NET).

Table 3-3
Example code: Microsoft C# .NET

```
// This sample program shows how to program the Keithley 3500 PowerMeter
// using Microsoft C# .NET 2003


using System;

namespace Example3500
{
   class Class1
   {
      [STAThread]
      static void Main(string[] args)
      {
         string Reply;
         double MeasuredPower;

         //The namespace for the 3500 driver is Keithley3500_NS
         //First, create the PowerMeter object
         Keithley3500_NS.Keithley3500 myPM =new Keithley3500_NS.Keithley3500();


         //Set the serial number and check that the meter is available
         int SN=1097330;//Set this to the serial number of your 3500
         int MeterAvailable=myPM.IsDeviceAvailable(SN);
         //A return value of 1 means the PowerMeter is available.
         // A value of -1 means it is absent, and a value of 0 means it
         // it is unavailable (for example, it may be in use by another program).
         if (MeterAvailable != 1)
         {
            Console.WriteLine("PowerMeter not available; status={0}",MeterAvailable);
            return;
         }
         Console.WriteLine("3500 serial number {0} is available", SN);
         myPM.SerialNumber=SN;
```

Table 3-3 (continued)
Example code: Microsoft C# .NET

```
            //Initialize the PowerMeter
            try
            {
                myPM.Initialize();
            }
            //If initialization fails:
            catch(Exception e)
            {
                Console.WriteLine("Error initializing PowerMeter: "+e.Message);
                return;
            }
            Console.WriteLine("3500 initialized");


            //Now we can communicate with the PowerMeter.
            //Configure the PowerMeter for a measurement:
            try
            {
                Reply=myPM.SendString("*RST\n");//Reset the power meter
                CheckForOK(Reply);
                Reply=myPM.SendString("FREQ1000\n");//Set the frequency to 1000 MHz
                CheckForOK(Reply);
            }
                //If an error occurred:
            catch(Exception e2)
            {
                Console.WriteLine("Error communicating with PowerMeter: "+e2.Message);
                return;
            }
            Console.WriteLine("3500 configured");

            //Take a reading:
            try
            {
                Reply=myPM.SendString("*TRG\n");
                MeasuredPower=Convert.ToDouble(Reply);
            }
            //If an error occurred:
            catch(Exception e3)
            {
                Console.WriteLine("Error reading power from the PowerMeter: "+e3.Message);
                return;
            }
            Console.WriteLine("Measured power was {0:F2} dBm",MeasuredPower);
        }


        static void CheckForOK(string Message)
        {
            if (Message.Equals("OK"))
                return;
            else
            {
                Console.WriteLine("Expected an 'OK' from the 3500; received: "+Message);
            }
        }
    }
}
```

Table 3-4
Example code: Microsoft Visual Basic .NET

```
' This sample program shows how to program the Keithley 3500 PowerMeter
' using Microsoft Visual Basic .NET 2003
Module Module1

    Sub Main()
        Dim MeasuredPower As Double
        Dim Reply As String
        Dim SN As Integer
        Dim MeterAvailable As Integer

        'The namespace for the 3500 driver is Keithley3500_NS
        'First, create the PowerMeter object
        Dim myPM As Keithley3500_NS.Keithley3500
        myPM = New Keithley3500_NS.Keithley3500

        'Set the serial number and check that the meter is available
        SN = 1097330            'Set this to the serial number of your 3500
        MeterAvailable = myPM.IsDeviceAvailable(SN)
        'A return value of 1 means the PowerMeter is available.
        'A value of -1 means it is absent, and a value of 0 means it
        'is unavailable (for example, it may be in use by another program).
        If (MeterAvailable <> 1) Then
            Dim Message As String
            Message = "PowerMeter is not available; status=" + MeterAvailable.ToString()
            Console.WriteLine(Message)
            Exit Sub
        End If
        Console.WriteLine("3500 serial number {0} is available", SN)
        myPM.SerialNumber = SN

        'Initialize the PowerMeter
        Try
            myPM.Initialize()
            'If initialization fails:
        Catch e As Exception
            Console.WriteLine("Error opening 3500: " & e.Message)
            Exit Sub
        End Try
        Console.WriteLine("3500 initialized")

        'Now we can communicate with the PowerMeter.
        'Configure the PowerMeter for a measurement:
        Try
            Reply = myPM.SendString("*RST" & vbLf)      'Reset the PowerMeter
            CheckForOK(Reply)
            Reply = myPM.SendString("FREQ1000" & vbLf)  'Set the frequency to 1000 MHz
            CheckForOK(Reply)
            'If an error occurred:
        Catch e2 As Exception
            Console.WriteLine("Error sending to 3500: " & e2.Message)
            Exit Sub
        End Try
        Console.WriteLine("3500 configured")
```

Table 3-4 (continued)
Example code: Microsoft Visual Basic .NET

```
        'Take a reading:
        Try
            Reply = myPM.SendString("*TRG" & vbLf) 'Trigger a power measurement
            MeasuredPower = Convert.ToDouble(Reply)
        Catch e3 As Exception
            Console.WriteLine("Error reading power from 3500: " & e3.Message)
            Exit Sub
        End Try
        Console.WriteLine("The measured power was " & MeasuredPower.ToString())

        'Now that we're done, close the 3500, making available for other users
        myPM.Close()
    End Sub
    Private Sub CheckForOK(ByVal Message As String)
        If (Message.Equals("OK")) Then
            Exit Sub
        End If
        Console.WriteLine("Expected an 'OK' from the 3500, received: " & Message)
    End Sub
End Module
```

Table 3-5
Example code: Microsoft Visual C++ .NET

```
// This sample program shows how to program the Keithley 3500 PowerMeter
// using Microsoft Visual C++ .NET 2003

#include "stdafx.h"

#using <mscorlib.dll>

using namespace System;
using namespace Keithley3500_NS;

int _tmain()
{
   String * Reply;
   double MeasuredPower;
   void CheckForOK(String * Msg);

   //The namespace for the 3500 driver is Keithley3500_NS
   //First, create the PowerMeter object
   Keithley3500_NS::Keithley3500 *myPM =new Keithley3500();


   //Set the serial number and check that the meter is available
   int SN=1097330;//Set this to the serial number of your 3500
   int MeterAvailable=myPM->IsDeviceAvailable(SN);
   //A return value of 1 means the PowerMeter is available.
   // A value of -1 means it is absent, and a value of 0 means it
   // it is unavailable (for example, it may be in use by another program).
   if (MeterAvailable != 1)
   {
      Console::WriteLine(S"PowerMeter not available; status={0}",__box(MeterAvailable));
      return 0;
   }
   Console::WriteLine("3500 serial number {0} is available", __box(SN));
   myPM->SerialNumber=SN;
```

Table 3-5 (continued)
Example code: Microsoft Visual C++ .NET

```
    //Initialize the PowerMeter
    try
    {
        myPM->Initialize();
    }
    //If initialization fails:
    catch(Exception *e)
    {
        Console::Write(S"Error initializing PowerMeter: ");
        Console::WriteLine(e->Message);
        return 0;
    }
    Console::WriteLine(S"3500 initialized");

    //Now we can communicate with the PowerMeter.
    //Configure the PowerMeter for a measurement:
    try
    {
        Reply=myPM->SendString("*RST\n");//Reset the power meter
        CheckForOK(Reply);
        Reply=myPM->SendString("FREQ1000\n");//Set the frequency to 1000 MHz
        CheckForOK(Reply);
    }

    //If an error occurred:
    catch(Exception *e2)
    {
        Console::Write(S"Error communicating with PowerMeter: ");
        Console::WriteLine(e2->Message);
        return 0;
    }
    Console::WriteLine(S"3500 configured for power measurement");

    //Take a reading:
    try
    {
        Reply=myPM->SendString("*TRG\n");
        MeasuredPower=Convert::ToDouble(Reply);
    }
    //If an error occurred:
    catch(Exception *e3)
    {
        Console::Write(S"Error reading power from the PowerMeter: ");
        Console::WriteLine(e3->Message);
        return 0;
    }
    Console::WriteLine(S"Measured power was {0:F2} dBm",__box(MeasuredPower));

    return 1;
}


void CheckForOK(String * Message)
{
    if (Message->Equals("OK"))
        return;
    else
    {
        Console::Write(S"Expected an 'OK' from the 3500; received: ");
        Console::WriteLine(Message);
    }
}
```

Microsoft Visual Basic 6.0

This example section contains a **Windows Forms** application. To use the code, in Microsoft Visual Basic 6.0:

1. Create a new **Windows Forms** project.
2. Delete the source code of the newly created **Windows Forms** project.
3. Copy the following code into the source code file.
4. Create three controls on the form:
   - A button named **btnReadPower**
   - A button named **btnExit**
   - A text box named **txtMessages**
5. Add a reference to the DLL — refer to Adding a reference (Visual Basic 6.0).

Table 3-6
Example code: Microsoft Visual Basic 6.0

```
' This sample program shows how to program the Keithley 3500 PowerMeter
' using Microsoft Visual Basic 6.0

Dim myPM As New Keithley3500.Keithley3500
Dim Message As String

Private Sub btnExit_Click()
    myPM.Close
    End
End Sub

Private Sub btnReadPower_Click()
    Dim MeasuredPower As Double
    Dim Reply As String

    'Now we can communicate with the PowerMeter.
    'Configure the PowerMeter for a measurement:
    On Error GoTo Err_Failed_Setup
    Reply = myPM.SendString("*RST" & vbCrLf)      'Reset the PowerMeter
    CheckForOK(Reply)
    Reply = myPM.SendString("FREQ1000" & vbCrLf)  'Set the frequency to 1000 MHz
    CheckForOK(Reply)
    Message = Message & "3500 configured." & vbCrLf
    txtMessages.Text = Message

    'Take a reading:
    On Error GoTo Err_Failed_Read
    Reply = myPM.SendString("*TRG" & vbCrLf)
    Message = Message & "Measured power: " & Reply & " dBm." & vbCrLf
    txtMessages.Text = Message
    Exit Sub

Err_Failed_Setup:
    Message = Message & "Error configuring 3500 for measurement: " & Err.Description & vbCrLf
    txtMessages.Text = Message
    Exit Sub

Err_Failed_Read:
    Message = Message & "Error reading power from 3500: " & Err.Description & vbCrLf
    txtMessages.Text = Message
    Exit Sub

Err_Failed_Send:
    MsgBox("Error during send " & Err.Description)
End Sub
```

Table 3-6 (continued)
Example code: Microsoft Visual Basic 6.0

```
Private Sub CheckForOK(ByVal Msg As String)
    Dim StringCompare As Integer
    StringComp = StrComp(Msg, "OK")
    If (StringCompare = 0) Then
        Exit Sub
    Else
        Message = Message & "Expected an 'OK' from the 3500; received: " & Msg & vbCrLf
        txtMessages.Text = Message
    End If
End Sub


Private Sub Form_Load()
    Dim SN As Long
    Dim MeterAvailable As Integer
    Message = ""

    'Attempt to register the Keithley 3500 DLL
    On Error GoTo Err_DLL_Not_Registered
    Message = Message & "Successfully created 3500 object." & vbCrLf
    txtMessages.Text = Message


    'Set the serial number and check that the meter is available
    SN = 1097330            'Set this to the serial number of your 3500
    MeterAvailable = myPM.IsDeviceAvailable(SN)
    'A return value of 1 means the PowerMeter is available.
    ' A value of -1 means it is absent, and a value of 0 means it
    ' it is unavailable (for example, it may be in use by another program).
    If (MeterAvailable <> 1) Then
        Message = Message & "PowerMeter is not available; status=" & MeterAvailable & vbCrLf
        txtMessages.Text = Message
        Exit Sub
    End If
    Message = Message & "3500 serial number " & SN & " is available." & vbCrLf
    txtMessages.Text = Message
    myPM.SerialNumber = SN


    'Initialize the 3500
    On Error GoTo Err_Failed_Initialize
    myPm.Initialize
    Message = Message & "3500 successfully initialized." & vbCrLf
    txtMessages.Text = Message

    Exit Sub


Err_DLL_Not_Registered:
    ' Check to see if error 429 occurs
    If Err.Number = 429 Then
        Message = Message & "Failed To Register 3500 DLL" & vbCrLf
    Else
        Message = Message & "Error creating 3500 object: " & Err.Description & vbCrLf
    End If
    txtMessages.Text = Message
    Exit Sub

Err_Failed_Initialize:
    Message = Message & "Error initializing 3500: " & Err.Description & vbCrLf
    txtMessages.Text = Message
    Exit Sub

End Sub
```

Microsoft Visual C++ 6.0

This example is a console application. To run in Visual C++ 6.0:

1. Create a new **Win32 Console Application**.
2. Delete the source code of the newly created **console application project**.
3. Copy the following code into the source code file.

NOTE *Although Visual C++ 6.0 does not need any special steps to reference the DLL, make sure the code refers to the correct installation directory — refer to Adding a reference (Microsoft Visual C++ 6.0). In Table 3-7, the specific program statement regarding the driver file installation is in bold-face type style.*

Table 3-7
Example code: Microsoft Visual C++ 6.0

```
// This sample program shows how to program the Keithley 3500 PowerMeter
// using Microsoft Visual C++ 6.0

#include "stdafx.h"
#include <atlbase.h>
#include <atlconv.h>
#include <iostream.h>
#include <windows.h>
#include <stdio.h>

#pragma warning (disable: 4278)

#import "C:\Program Files\Keithley Instruments\Keithley 3500 Driver\Keithley3500.tlb" \
no_namespace named_guids

void dump_com_error(_com_error &e);
void CheckForOK(BSTR Message);

int main(int argc, char* argv[])
{
    PMInterface *myPM = NULL;
    BSTR Reply=NULL;
    int MeterAvailable=0;
    int SN;
    USES_CONVERSION;//Enables use of ATL string conversion macros
    CoInitialize(NULL);//Initializes the COM library on the current thread
    //Create an instance of the 3500 driver:
    HRESULT hr = CoCreateInstance(CLSID_Keithley3500,NULL, CLSCTX_INPROC_SERVER,
        IID_PMInterface, reinterpret_cast<void**>(&myPM));
    if (FAILED(hr))
    {
        printf("Couldn't create an instance of the 3500 driver!... 0x%x\n", hr);
        return 0;
    }


    //Set the serial number and check that the meter is available
    SN=1097330;
    try
    {
        MeterAvailable=myPM->IsDeviceAvailable(SN);
    }
    catch (_com_error& e)
    {
        cout << "COM error on IsDeviceAvailable"<<endl;
        dump_com_error(e);
        return 0;
    }
```

Table 3-7 (continued)
Example code: Microsoft Visual C++ 6.0

```
//A return value of 1 from IsDeviceAvailable() means the PowerMeter is available.
// A value of -1 means it is absent, and a value of 0 means it
// it is unavailable (for example, it may be in use by another program).
if (MeterAvailable != 1)
{
    cout << "3500 PowerMeter is not available; status= "<<MeterAvailable<<endl;
    return 0;
}
cout<<"3500 serial number "<< SN << " is available"<<endl;
myPM->SerialNumber=SN;

//Initialize the PowerMeter
try
{
    myPM->Initialize();
}
//This catches errors with COM:
catch (_com_error& e)
{
    cout << "COM error initializing 3500:"<<endl;
    dump_com_error(e);
}
//This catches all other errors.
catch (...)
{
    cout << "Error initializing" << endl;
    return 0;
}
cout << "3500 initialized" << endl;
//Setup the PowerMeter for a measurement:
try
{
    Reply=myPM->SendString("*RST\n");//Reset the power meter
    CheckForOK(Reply);
    Reply=myPM->SendString("FREQ1000\n");//Set the frequency to 1000 MHz
    CheckForOK(Reply);
}
//This catches errors with COM:
catch (_com_error& e)
{
    cout << "COM error while programming 3500:"<<endl;
    dump_com_error(e);
}
//This catches all other errors.
catch (...)
{
    cout << "Error programming 3500" << endl;
}
cout << "3500 configured for power measurement" << endl;
```

Table 3-7 (continued)
Example code: Microsoft Visual C++ 6.0

```
//Take a reading:
    try
    {
        Reply=myPM->SendString("*TRG\n");
        cout << "Measured power: " << W2A(Reply) << endl;
    }
    catch (_com_error& e)
    {
        cout << "COM error while making a power measurement with 3500"<<endl;
        dump_com_error(e);
    }
    catch (...)
    {
        cout << "Error reading power from 3500" << endl;
    }

    myPM->Release();
    myPM=NULL;
    CoUninitialize();
    return 1;
}

void dump_com_error(_com_error &e)
{
     _tprintf(_T("COM Error Information:\n"));
     _tprintf(_T("Code = %08lx\n"), e.Error());
     _tprintf(_T("Code meaning = %s\n"), e.ErrorMessage());
     _bstr_t bstrSource(e.Source());
     _bstr_t bstrDescription(e.Description());
     _tprintf(_T("Source = %s\n"), (LPCTSTR) bstrSource);
     _tprintf(_T("Description = %s\n"), (LPCTSTR) bstrDescription);

}
void CheckForOK(BSTR Message)
{
    USES_CONVERSION;//Enables use of ATL string conversion macros
    char ExpectedReturn[]="OK";
    char *ActualReturn=W2A(Message);
    int Result=strcmp(ActualReturn,ExpectedReturn);
    if (Result)
    {
        cout << "Expected an 'OK' from the 3500, received " << W2A(Message) << endl;
    }
}
```

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Section 4
Service Information

In this section:

Introduction

This section contains information about overall PowerMeter® configuration and connections and is organized as follows:

- Handling and cleaning precautions
- RF connector care
- Battery replacement
- Performance verification

CAUTION ***Other than removing the battery door as described in Battery replacement, do not open the Model 3500. Opening the Model 3500 will void it's calibration, produce incorrect readings, and possibly damage the PowerMeter.***

Handling and cleaning precautions

Use the same care when handling or cleaning the Model 3500 as you would during normal Model 3500 operation.

RF connector care

RF coaxial connectors are precision mechanical devices. Their mechanical performance has a direct impact on their electrical performance. It is particularly important for precision instruments like PowerMeters that the connectors be in good mechanical condition.

Inspection and cleaning

Inspect the Model 3500 RF connector prior to making a connection:

Step 1: Examine the connector interior for debris or metal particles.

- If any are found, clean them out using compressed air. Pay particular attention to the connector's center conductor and mating surfaces.

Step 2: Examine the connector for dirt or tarnish.

- If these are present, gently clean the connector surfaces using isopropyl alcohol and a foam swab.

Battery replacement

Use two 1.5V alkaline AA batteries for the Model 3500. Do not use nickel-cadmium (NiCad) or nickel-metal hydride (NiMH) rechargeable batteries.

NOTE *The output voltage for NiCad and NiMH is lower than that of alkaline batteries, and is insufficient for the Model 3500.*

Changing the batteries

To change the Model 3500 batteries:

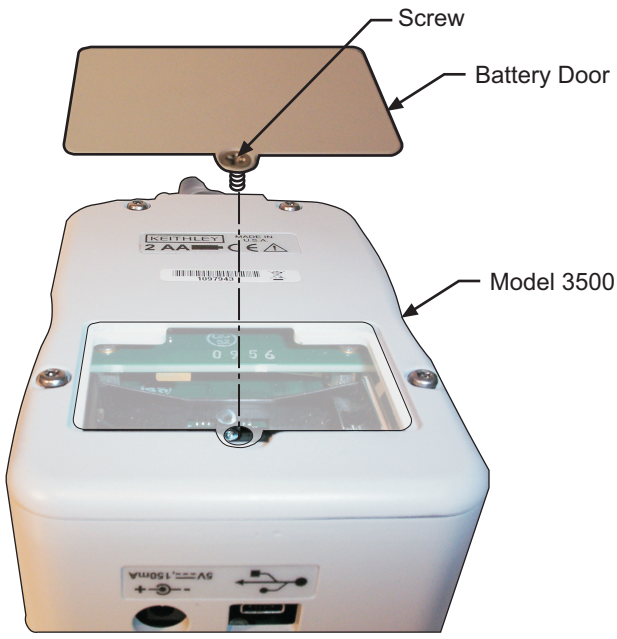
Step 1: Use a Phillips screwdriver to loosen the battery door **Screw**, then remove the **Battery Door** (refer to Figure 4-1).

Step 2: Remove and properly dispose of the old batteries.

Step 3: Replace the batteries with two new AA alkaline cells. Proper orientation for the batteries is shown on the black battery holder (visible when the door is removed).

Step 4: After replacing the batteries, replace the **Battery Door** and tighten the battery door **Screw**.

Figure 4-1
Battery door removal



Performance verification

The accuracy of the Model 3500 can be verified by comparing its performance to that of a known-good PowerMeter. Table 4-1 describes the required equipment:

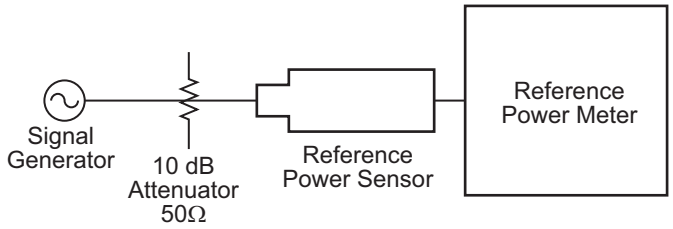
Table 4-1
Performance verification equipment

Equipment	Specification
RF signal generator	Covering the frequency and power range of interest.
10 dB attenuator	A high-quality attenuator with a return loss of better than 20 dB over the frequency range of interest.
Power meter and Power sensor	Known-good equipment covering the frequency and power range of interest.

Verification procedure

Step 1: Connect the signal generator, the attenuator, and the reference power meter and sensor together as shown in Figure 4-2. For best accuracy, connect the equipment directly together without using cables.

Figure 4-2
Reference power meter setup



Step 2: Turn off the signal generator's RF output.

Step 3: Zero the reference power meter.

Step 4: Turn the signal generator's output **on**. Turn **off** any modulation on the signal generator.

Step 5: Set the signal generator's frequency to a known setting, and set its power output to a known level.

Step 6: Record the reference power meter's reading at the given frequency and power setting. A sample form is shown in Table 4-2.

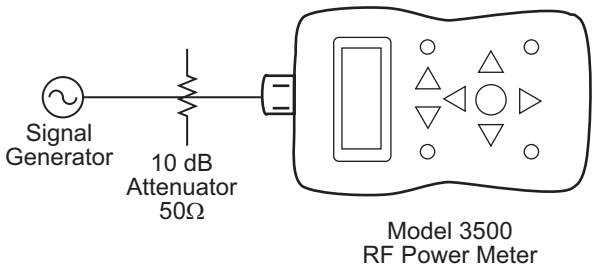
Table 4-2
Sample frequency and power verification form

Signal Generator Frequency	Signal Generator Power	Reference Power Meter Reading	Model 3500 Reading	Difference in Readings

Step 7: Repeat Steps 5 and 6 for each different combination of frequency and power level as desired.

Step 8: Disconnect the reference power meter and connect the Model 3500 in its place as shown in Figure 4-3.

Figure 4-3
Model 3500 verification setup



Step 9: Repeat Steps 2 through 7 with the Model 3500. Calculate values for difference in readings column on the form.

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Appendix A
Specifications

KEITHLEY

Model 3500

Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139
(440) 248-0400
www.keithley.com

Portable RF Power Meter Specifications

Specifications

Specifications Category	Specifications
Frequency range	10MHz to 6GHz
Power range	+20dBm to -63dBm
Max power	+23dBm, 5VDC
Power accuracy[1]	(at 23°C +/- 5°C) +20dBm to +6dBm +/- 0.24dB 10MHz to 3GHz (characteristic)[2] +/- 0.16dB 3GHz to 5GHz (characteristic) +/- 0.22dB 5GHz to 6GHz (characteristic) +6dBm to -9dBm +/- 0.26dB 10MHz to 3.75GHz +/- 0.07dB typical[3] +/- 0.40dB 3.75GHz to 6GHz +/- 0.07dB typical[3] -10dBm to -29dBm +/- 0.26dB 10MHz to 3.75GHz +/- 0.05dB typical[3] +/- 0.37dB 3.75GHz to 6GHz +/- 0.05dB typical[3] -30dBm to -40dBm +/- 0.21dB 10MHz to 3.75GHz +/- 0.12dB typical[3] +/- 0.27dB 3.75GHz to 6GHz +/- 0.13dB typical[3]
Linearity	(at 23°C +/- 5°C) +/- 0.10dB +6dBm to -40dBm
Noise floor	-63 dBm

[1] Customer Spec = $\overline{X}(x,f) + K(=2)^* \delta(x,f) + \Delta_E(x,f,(18°C\text{-}28°C)) + \mu$

Where:

$\overline{X}$ = Mean of the data taken in the frequency range stated (x,f)
δ = Standard deviation of the data taken in the frequency range stated (x,f)
x = Measured value at test frequencies
f = Frequency range over which data was taken for specification
μ = Measurement uncertainty
Δ_E = Change associated temperature variation
18-28 = Statistics generated separately at these temperatures and larger statistical value used in setting spec.

[2] Characteristic (or expected value); "characteristic" indicates performance that a unit would be expected to exhibit under the following conditions:

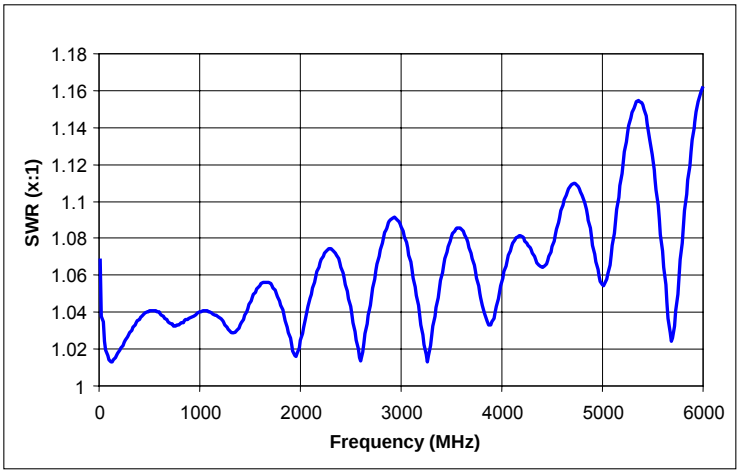
- Ambient operating temperature of 18°C to 28°C, unless otherwise noted.
- After specified warm up time of 30 minutes.
- Does not include measurement uncertainty.
- This performance is not warranted.

Specifications are subject to change without notice.

Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139
(440) 248-0400
www.keithley.com

Portable RF Power Meter Specifications

SWR (typical)[3]



Specifications Category	Specifications
SWR	1. 12:1 10MHz to 3.75GHz 1. 20:1 3.75GHz to 6GHz
Display	4 digits, backlight, auto-shutoff, hold—the most recent reading is shown on the display and is no longer updated
Units	dBm, Watts
Unit power (*Equipped with auto-shutoff)	Unit can be powered from any of these methods: • Two 1.5V alkaline AA batteries (not included) - Typical battery life: 17.5 hours;[4] low battery indicator • USB[5] • Optional DC power supply[6] (3500-PWR)
Speed	• Normal: ~2 readings per second > -30dBm approximately ~1 readings per second ≤ -30dBm approximately • High-speed: >34 readings per second > -30dBm approximately >11 readings per second ≤ -30dBm approximately

[3] Typical (mean + 3 standard deviations); "typical" indicates performance that all units will meet under the following conditions:
- Ambient operating temperature of 23°C, unless otherwise noted.
- After specified warm up time of 30 minutes.
- Does not include measurement uncertainty.
- This performance is not warranted.

[4] Typical battery life was measured in default conditions at 500MHz with backlight off and no USB communications. With backlight on, typical battery life is 2.5 hours.

[5] With the USB connected and providing power and the optional external power disconnected, the Model 3500 will be powered from USB—regardless of whether batteries are present.

[6] If the external power supply is connected, the Model 3500 will be powered by the external supply—regardless of whether USB power or batteries are present.

Specifications are subject to change without notice.

Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139
(440) 248-0400
www.keithley.com

Portable RF Power Meter Specifications

Specifications Category	Specifications
Host interface	USB 2.0 interface with a miniature "B" USB connector[7]
Averaging	1, 2, 4, 8, 16, and 32 averages

Connectors

RF	Type N male RF connector (50Ω characteristic impedance)
USB	Miniature "B" USB connector
External power	Power receptacle (connect optional External Power Supply: 3500-PWR)

Operating Conditions

Operating temperature	0°C to 50°C (32°F to 122°F)
Operating humidity	<80% RH at 35°C (95°F), non-condensing
Air quality	Compatible for use in a Class 10 cleanroom

General

Storage conditions	0°C to 70°C (32°F to 158°F), 5% to 70% RH, non-condensing
Dimensions	3.125 inches x 5.260 inches x 1.925 inches, not including N connector
Weight	0.5kg (1.1 lb).
Warranty	1 year; 1 year suggested calibration cycle
EMC	Conforms to European Union Directive 89/336/EEC, EN 61326-1
Safety	Conforms to European Union Directive 73/23/EEC, EN 61010-1

[7] The interface is USB 2.0 compliant, but with an interface speed of 12Mbps.

Appendix B
RF Measurement Basics

In this appendix:

Power defined

In electrical circuits, power delivered to an electrical load can be defined as:

$$P = \frac{V^2}{R}$$

Where:

P is the delivered power

V is the voltage applied to the load

R is the resistance of the load

When the power is in the form of an AC waveform, a more complex definition is needed. The cyclic power from the AC waveform varies with time. Although the power of an AC waveform delivered at a specific time can still be defined using the above formula, this does not adequately describe AC waveform power delivered to a load. Power of an AC waveform delivered to an electrical load is equal to the mean power delivered over the course of one cycle of the sinusoidal waveform defined by:

$$P = \int_0^T (V_{peak}\cos(2\Pi t / T))^2 / R dt$$

Where:

T is the period of the AC waveform.

Evaluating the integral, we can reduce this expression to:

$$P = \frac{V_0^2}{R}$$

Where:

$$V_0 = \frac{V_{peak}}{\sqrt{2}}$$

V_0 is known as the rms (root mean square) voltage of the sinusoid.

Units of measurement

RF power measurements can be expressed in either watts or dBm. The Model 3500 can display results in either Watts or dBm.

Watts

Watts are the standard SI unit for power measurements. In electrical terms, one volt applied across a one-ohm resistor dissipates one watt of power.

Decibels

Decibels (abbreviated dB), are a logarithmic scale used to express power. Decibels are inherently a ratio measurement providing the relative magnitude of two different numbers.

For power measurements, the difference between two signals in decibels is:

$$10 \times \log_{10}\left(\frac{P_1}{P_0}\right)$$

Where:

P_1 and P_0 are the two power levels to be compared.

Absolute measurement can be made on the decibel scale by using a standard power level in place of P_0. If P_0 is defined to be 1 milliwatt, the resulting units are called "dBm." Power expressed in dBm is calculated with the formula:

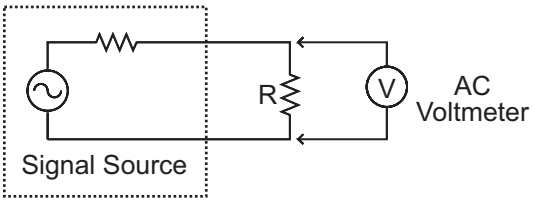
$$P_{dBm} = 10 \times \log_{10}\left(\frac{P_1}{1mW}\right)$$

RF power measurement

Low frequency method

At low frequencies, power delivered from an AC source to a load can be measured with an AC voltmeter connected across the load terminals (refer to Figure B-1). The voltmeter provides a high enough input resistance that at low frequencies, the effective value of load resistance is not changed.

Figure B-1
Low frequency power measurement



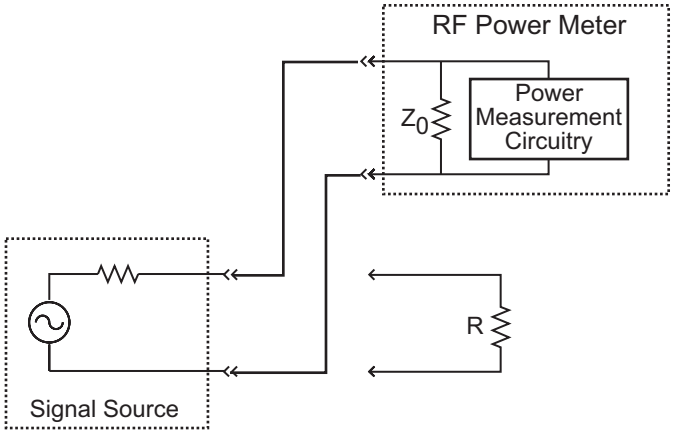
High frequency method

At high frequencies, the low frequency measurement technique produces inaccurate readings. To produce reliable results, a different method is required.

Parasitic capacitance is one of the main sources of the low frequency method's inaccurate readings. Parasitic capacitance causes the impedance of the shunt voltmeter to decrease, thereby behaving unpredictably with frequency.

The high frequency method replaces the AC Voltmeter (as described in the "Low frequency method," above) with an RF power meter (the RF power meter has an internal, known load resistance). This effectively replaces the circuit's load resistor (**R**) with the characteristic impedance ($\mathbf{Z_0}$) built-in to the RF power meter (refer to Figure B-2).

Figure B-2
High frequency power measurement



RF circuits and systems are usually designed to work with a standard impedance value called the characteristic impedance (refer to $\mathbf{Z_0}$ in Figure B-2). Typical signal sources are designed to work with a load of the same impedance ($\mathbf{Z_0}$). Generally, the $\mathbf{Z_0}$ value for RF circuits is 50Ω or 75Ω, with 50Ω being the most common. The power meter's internal load resistance is designed to equal $\mathbf{Z_0}$.

Power of various types of signals

CW signals

CW (continuous-wave) signals are the simplest form of RF signal. CW signals consist of a constant sine wave. Power measurements on this type of wave result in a single numerical value.

Modulated signals

Modulated signals are sinusoids whose amplitude, phase, or frequency change with respect to time. Changes in either the phase or frequency do not change the power of the signal, but changes in amplitude do.

Two approaches can be taken to characterizing the power of modulated signals:

- Peak power meters
- Average power meters (the Model 3500 takes this approach)

Peak power meters

A peak power meter measures the power of the signal very rapidly (faster than the rate at which the modulation changes). The results can then be displayed in a graph of power versus time similar to an oscilloscope display. This approach has the advantage of displaying a great deal of information. One disadvantage is that the results can be hard to interpret—especially for the complex modulation schemes in use today.

Averaging power meters

An averaging power meter measures the power versus time of the signal, but then averages the result—condensing the measurement to a single number. The
Model 3500 is an averaging power meter. In effect, the power meter performs the following calculation:

$$P_{avg} = \frac{1}{T}\int_{0}^{T} P(t)dt$$

Where:

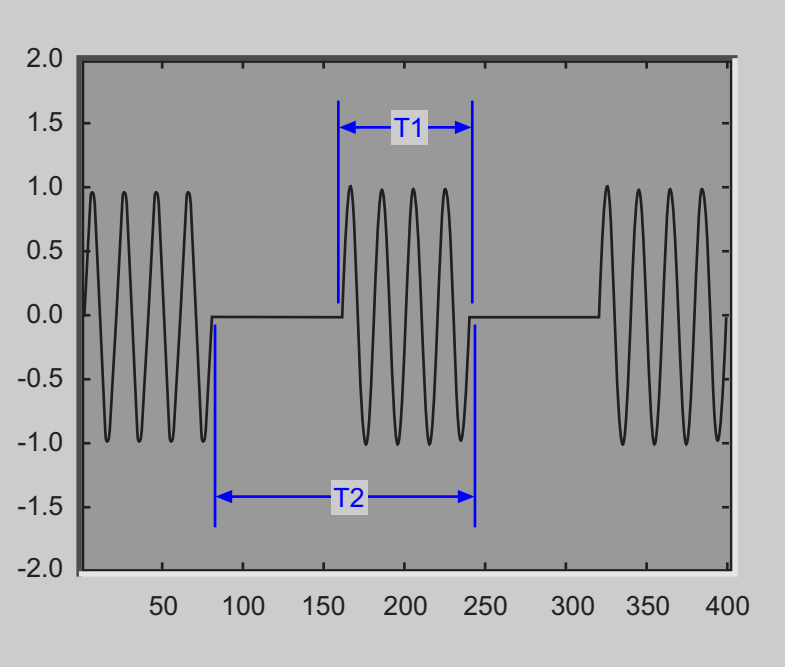
P(t) is the power of the modulated signal as a function of time.

In cases where the modulation format is known, the peak instantaneous power can be calculated from the average power.

Pulse modulated signals

As an example, consider the pulse-modulated signal shown in Figure B-3.

Figure B-3
Example pulse-modulated signal



T1 is the pulse width of the signal—the time duration of the pulsed signal's on state.

T2 is the period of the waveform—how often the pulses occur.

Since the power is constant over the interval **T1**, and since the power is zero over the remainder of the interval **T2**, the average and peak power of pulse modulated signals are related by the equation:

$$P_{peak} = \frac{T_2}{T_1} P_{avg}$$

Where:

T_1 is the pulse width of the signal.

T_2 is the period of the waveform.

In decibels, this would be expressed as:

$$P_{peak,\ dB} = 10 \times \log_{10}(T_2 / T_1) + P_{avg,\ dB}$$

Measurement accuracy

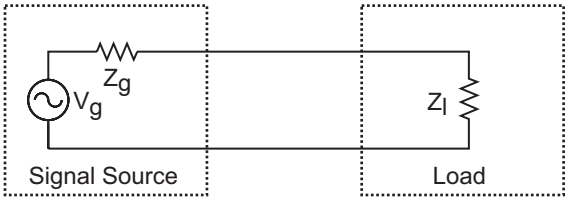
Mismatch error

Mismatch error is one of the primary factors affecting power measurement accuracy. Simply put, the goal is to measure the power that a source will deliver into a load of impedance $\mathbf{Z_0}$. The power meter is designed to have an impedance as close as possible to $\mathbf{Z_0}$. Because its impedance is not exactly $\mathbf{Z_0}$, the power delivered to the meter is not exactly equal to the power delivered to a perfect load.

Deriving the equations to calculate mismatch error is beyond the scope of this manual, but the results are easily understood.

Consider the setup in Figure B-4. A source of output impedance $\mathbf{Z_g}$ is connected to a load of impedance $\mathbf{Z_l}$.

Figure B-4
Mismatch in power measurements



The reflection coefficient of a device (Γ_g) is a measure of its impedance relative to $\mathbf{Z_0}$ ($\mathbf{Z_0}$ is the characteristic impedance of the system).

The reflection coefficient of the source (Γ_g) is defined as:

$$\Gamma_g = \frac{Z_g - Z_0}{Z_g + Z_0}$$

Similarly, the reflection coefficient (Γ_l) of the load is defined as:

$$\Gamma_l = \frac{Z_l - Z_0}{Z_l + Z_0}$$

If the source or load impedance is exactly equal to $\mathbf{Z_0}$, the corresponding reflection coefficient is zero. For simplicity, let's assume $\mathbf{V_g}$ is defined as:

$$V_g = \frac{Z_g + Z_0}{Z_0}\sqrt{Z_0}$$

With $\mathbf{V_g}$ defined as in the above equation—the source will deliver 1 watt to a load of impedance $\mathbf{Z_0}$. The power delivered to the actual load is then defined by:

$$P_{load} = \frac{1 - |\Gamma_l|^2}{|1 - \Gamma_g \Gamma_l|^2}$$

Into a perfect load of impedance $\mathbf{Z_0}$, the power delivered to the load is:

$$P_{load,\ Z_0} = 1$$

The mismatch error in the power measurement, then, is the ratio between $P_{load,\ Z_0}$, and the power delivered to the actual load presented by the power meter is defined by:

$$\frac{P_{load,\ meter}}{P_{load,\ Z_0}} = \frac{1 - |\Gamma_{meter}|^2}{|1 - \Gamma_g \Gamma_{meter}|^2}$$

If the magnitude and phase of the source and load reflection coefficient are known, this mismatch error can be calculated and compensated for—completely eliminating mismatch uncertainty and an error term.

Alternatively, if just the magnitude of the power meter's reflection coefficient is known, we can then exactly calculate the term in the numerator of the previous equation and remove its effect on measurement uncertainty. In that case, the equation becomes:

$$P_{load,\ Z_0} = |1 - \Gamma_g \Gamma_{meter}|^2 \times \frac{P_{load,\ meter}}{1 - |\Gamma_{meter}|^2}$$

The error term $|1 - \Gamma_g \Gamma_{meter}|^2$ depends on both the magnitude and phase of the source and load reflection coefficients. Frequently, the magnitude of the reflection coefficient is known or specified, but the phase is unknown. The error term will reach its maximum value when both reflection coefficients are real and 180° out of phase. This Maximum Error Ratio is described by the equation:

$$MaximumErrorRatio = (1 + |\Gamma_g||\Gamma_{meter}|)^2$$

The error term will reach its minimum when both reflection coefficients are real and in-phase. This Minimum Error Ratio is described by the equation:

$$MinimumErrorRatio = (1 - |\Gamma_g||\Gamma_{meter}|)^2$$

With this information — and knowing or estimating the reflection coefficient of the device under test — estimation of the mismatch measurement uncertainty is possible.

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KEITHLEY

Service Form

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

❒ Intermittent ❒ Analog output follows display ❒ Particular range or function bad; specify

_____

❒ IEEE failure ❒ Obvious problem on power-up ❒ Batteries and fuses are OK

❒ Front panel operational ❒ All ranges or functions are bad ❒ Checked all cables

Display or output (check one)

❒ Drifts ❒ Unable to zero ❒ Unstable

❒ Overload ❒ Will not read applied input

❒ Calibration only ❒ Certificate of calibration required ❒ Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.) _____

_____

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and telephone number on this service form.

KEITHLEY

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