MANUAL VOL 1

Protek Z9216

High Accuracy, Wide Range LCR Meter

High Accuracy, Wide Range LCR Meter

Protek

Chapter

1

Introduction

Important Background Information

The Model Z9216 LCR Meter is a high quality instrument that will provide you with many years of reliable service. Please read the information in this chapter before using or applying power to the meter. Information for operating the Model 2600 LCR meter is provided in the following chapters.

Warranty

PROTEK warrants that this product will be free from defects in materials and workmanship for a period of two (2) years from the date of shipment. If any product proves defective during this warranty period, PROTEK, at its option, either will repair the defective product without charge for parts and labor, or will provide a replacement in exchange for the defective product.

In order to obtain service under this warranty, the customer must notify PROTEK of the defect before the expiration of the warranty period and make suitable arrangements for the performance of service. The customer shall be responsible for packaging and shipping the defective product to the service center designated by PROTEK, with shipping charges prepaid. PROTEK shall pay for the return of the product to Customer if the shipment is to a location within the country in which the PROTEK service center is located. The customer shall be responsible or paying all shipping charges, duties, taxes, and any other charges for products returned to any other locations.

This warranty shall not apply to any defect, failure or damage caused by improper use or improper or inadequate maintenance and care. PROTEK shall not be obligated to furnish service under this warranty:

- to repair damage resulting from attempts by personnel other than PROTEK representatives to install, repair or service the product;
- to repair damage resulting from improper use or connection to incompatible equipment; or
- to service a product that has been modified or integrated with other products when the effect of such modification or integration increases the time or difficulty of servicing the product.

This warranty is given by PROTEK with respect to this product in lieu of any other warranties, expressed or implied. PROTEK and its vendors disclaim any implied warranties of merchantability or fitness for a particular purpose.

PROTEK's responsibility to repair or replace defective products is the sole and exclusive remedy provided to the customer for breach of this warranty. PROTEK and its vendors will not be liable for any indirect, special, incidental, or consequential damages irrespective of whether PROTEK or the vendor has advance notice of the possibility of such damages.

General Safety Summary

Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it.

NOTE: Only qualified personnel should perform service procedures.

Preventing Injury

Use Proper Power Cord. To avoid fire hazard, use only the power cord specified for this product.

Avoid Electrical Overload. To avoid electric shock or fire hazard, do not apply a voltage to a terminal exceeding the rating specified for that terminal.

Ground the Product. This product is grounded through the grounding conductor of the power cord. To avoid electric shock, the grounding conductor must be connected to earth ground. Before making connections to the input or output terminal of the product, ensure that the product is properly connected.

Do Not Operate Without Cover. To avoid electric shock or fire hazard, do not operate this product with covers or panels removed.

Use Proper Fuse. To avoid fire hazard, use only the fuse type and rating specified for this product.

Do Not Operate in Wet/Damp Conditions. To avoid electric shock, do not operate this product in damp or wet conditions.

Do Not Operate in an explosive atmosphere. To avoid injury or fire hazard, do not operate this product in an explosive atmosphere.

Keep Probe Surface clean. To avoid electric shock and erroneous readings, keep the probe and/or test fixture surfaces clean.

Preventing Instrument Damage

Maintenance, Repair, and Storage

This equipment contains precision components, which are sensitive to environmental conditions. Care must be taken when handling or storing this product.

Occasionally, if the surface of the instrument becomes dirty, rub the affected area lightly with a soft cloth soaked in a mild detergent or alcohol. Never use highly volatile material such as benzene or paint thinner.

The ideal ambient temperature range for storing this equipment is −10°C to +60°C (14°F to 140°F).

To avoid personal injury, do not remove the product covers. Do not operate the product without the covers properly installed.

Two spare fuses are shipped with this equipment.

In order to maintain this equipment in a stable and efficient operating condition, calibrate the equipment after every 1,000 hours operating time or every 6 months, whichever comes first.

Product Damage Prevention

Use Proper Power Source. Do not operate this product from a power source that applies more than the specified voltage.

Provide Proper Ventilation. To prevent overheating, provide adequate clearance around the instruments air vents.

Do Not Operate With Suspected Failures. If you suspect there is damage to this product, have it inspected by qualified service personnel.

Do not immerse in Liquids. Clean the probe using only a damp cloth. Refer to the cleaning instructions.

Line Voltage Requirements

Refer to the following table for the correct operating voltage ranges for this LCR meter. Check the line voltage prior to connecting to the power source, and verify that it is within a voltage range listed below.

Rating	Operating Voltage Range
115 VAC	AC 98 V–132 V
230 VAC	AC 196–253 V

This instrument comes from the factory with the power supply set to 115VAC. If the LCR meter is to be used at 230VAC, the operating voltage may be changed by the following procedure ·

- Remove the power cable from the AC input.
- Insert a flat-bladed screwdriver into the slot located on right side of the fuse holder cap; remove the cap by pressing and then pulling up the screwdriver.
- Rotate the cap on the fuse holder to set the voltage to the desired level.
- Change the fuse to the proper rating as specified below.
- Connect power cable to the AC input.

If a voltage, lower than 115 VAC, is required, the power cable and fuse may need to be changed. In such case, contact your nearest dealer for appropriate service.

After use, disconnect the equipment from the AC outlet.

Fuse Requirements

In order to prevent circuit damage resulting from over current, use the correct fuse value. The fuse ratings are as follows.

Circuit No.	Shape (diameter × length) mm	Rating	Remarks
F1101	5.2 × 20	250 V T500 mA	For I15 VAC
		250 V T250 mA	For 230 VAC
F601	5.2 × 20	250 V F250 mA	

The internal fuse rating is as follows:

Circuit No.	Shape (diameter × length) mm	Rating	Remarks
F602	5.2 × 20	250 V F250 mA	

Note: Refer to the section on troubleshooting in Volume 2 of the User's Manual, for instructions on replacing the internal fuse.

Conventions Used in This Manual

- In this manual, you will find various procedures, which contain steps of instructions for you to perform. To keep these instructions clear and consistent, this manual uses the following conventions:
- Operating procedures and names of front panel controls are in uppercase and **BOLDFACE** print.
- The case of each name used in the manual is the same (Initial Capitals or UPPERCASE) as that used on the instrument itself.
- Instruction steps are numbered (1, 2, 3, ...), unless there is only one step.
- When steps require that you make a sequence of selections using front panel controls and keys, an arrow (→) is used in the text to indicate an LED result when a front panel entry is made. Also, whether a name is a key or LED display reading is clearly indicated:

  Example: Press DISP → (Entry) → ENTER

Safety Terms

The following terms are also used in this manual:

- **WARNING** identifies conditions or practices that could result in injury.
- **CAUTION** identifies conditions or practices that could result in damage to this product or other property.
- **NOTICE** identifies conditions or practices that could result in incorrect test data.

Chapter

2

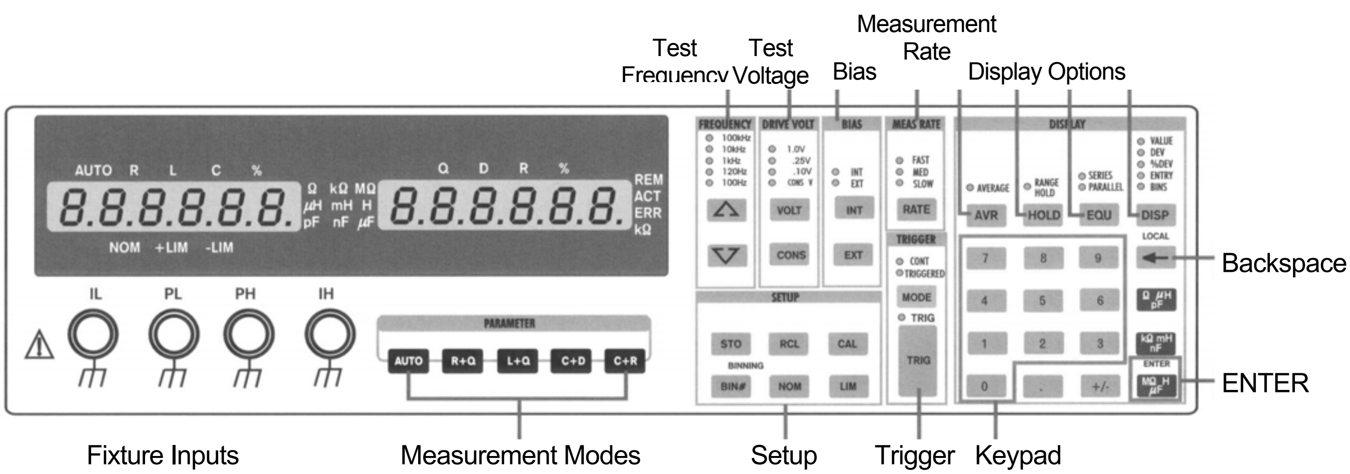
Product Familiarization

Description of the LCR Meter and Its Features

In this chapter, the controls and connections of the LCR Meter are described, and its basic operation is summarized in terms of the meter's specifications, features, options and operating modes.

Front Panel Controls

The front panel and its displays, controls and connections are shown in the following illustration:



In this section, the displays, controls, and connections on the left side of the front panel shall be explained first, then the keys located on the right side of the front panel, will be explained.

Fixture Inputs

The input terminals labeled IL, PL, PH, and IH connect the test fixture or adapter to the instrument, as discussed in the section in Chapter 3 on "Connecting a Component." Two of the terminals, IL & IH provide a test current to the component under test, and the other two terminals, PL & PH provide a high impedance connection to measure the voltage across the device. This four-wire or "Kelvin" type of measurement setup is designed to increase accuracy by reducing the amount of error due to voltage drop in the current sourcing wires.

Warning: Do not connect any active voltage source to these terminals, especially high voltages.

Measurement Modes and the Mode Selection Keys

These keys select the measurement to be made on the component under test. One of five measurement modes may be selected: Auto, R+Q, L+Q, C+D or C+R. The selected mode is indicated by LEDs above the alphanumeric displays. The operation of each mode is described as follows:

- **AUTO** - In this mode, the meter automatically selects the most appropriate measurement on the device. The selection is made according to the following criteria:
  - If $|Q| < 0.125$, the meter selects the R+Q measurement mode.
  - If $Q > +0.125$, the meter selects the L+Q measurement mode.
  - If $Q < -0.125$ and the meter is in the series equivalent circuit mode, the C+R measurement mode is selected.
  - If $Q < -0.125$ and the meter is in the parallel equivalent circuit mode, the C+D measurement mode is selected.
- **R+Q** - In this mode, resistance is displayed on the main parameter display and the Q (quality factor) is displayed on the secondary parameter display. The R-value is either the series or parallel equivalent resistance of the component under test. The unit for R is Ω, kΩ, or MΩ. The Q value is the dimensionless ratio of the imaginary part of the component's impedance to its real part. If Q has a positive (+) value, the reactive component of the device under test is inductive. If Q has a negative (–) value, it is capacitive.
- **L+Q** - In this mode, the series or parallel equivalent inductance value of a component under test is displayed on the main parameter display units in units of µH, mH, or H, and its dimensionless Q value is displayed on the secondary parameter display.
- **C+D** - In this mode, the series or parallel equivalent capacitance value of a component under test is displayed on the main parameter display in units of pF, nF, or µF. On the secondary parameter display, the dimensionless ratio $D = 1/Q$ is given. D is normally a small value for a good capacitor.
- **C+R** - In this mode, the capacitance is displayed on the main parameter display and the equivalent resistance is displayed on the secondary parameter display. The unit for resistance is Ω unless the kΩ indicator LED is lit.

Alphanumeric Displays and Parameter Indicators

The two, 5-digit (plus sign) LED[1], segmented alphanumeric displays provide measurement results, entered parameter values, and status messages. The left display gives the value of the main parameter of the component under test (L, R, C) and the right display gives the value of its secondary parameter (Q, D, R, %). Above and next to these two alphanumeric displays are various annunciators that, when lit, indicate characteristics of the measurement:

- **AUTO, R, L, C, %** LEDs that indicate the measurement type for the main parameter
- **Q, D, R, %** LEDs that indicate the measurement type for the secondary parameter
- **Ω, kΩ, MΩ**
  μH, mH, H
  pF, nF, μF LEDs indicating the units of the value being displayed on the left
- **kΩ** The right-side display is dimensionless or has units of ohms unless this LED is on.

- **REM, ACT, ERR** These LEDs provide information on the status of the remote control (computer) interface operations.
  - **REM**: Indicates that the display is being controlled remotely via the interface connector on the rear panel.
  - **ACT**: Indicates that the remote control interface is active.
  - **ERR**: Indicates that a remote command contained an error.
- **NOM, +LIM, −LIM** Indicate which Binning[2] parameter is being entered

Programming and Operator Interface Keys

On the right side of the front panel of the LCR meter, there are many buttons and keys for programming test conditions and for general operator interface. These keys are grouped according to function, and some groups have LED indicators associated with them show which option has been selected.

- **Frequency** The MODEL 2600 has five selectable fixed frequencies with accuracy to 100ppm (0.01%). 100Hz, 120Hz, 1kHz, 10kHz or 100 kHz may be selected by pressing the ▲▼ up/down keys on the front panel keypad until its corresponding LED is illuminated.
- **Drive Voltage**
  - **VOLT** Pressing the VOLT key allows you to select one of three fixed output drive voltages (0.1V, 0.25V, 1.0V). An LED indicates the selected drive voltage. If NO LED is lit, then the output drive voltage is in the vernier mode.
  - **CONS** This key sets the meter to the constant voltage mode.
- **BIAS** The bias mode is used only for capacitance measurements. Pressing these keys for any other measurement will generate the "bias for c" error message.

[1] LED = light-emitting diode
[2] Binning is explained later.

- **INT** Selects a 2.0 VDC internal bias.
- **EXT** Selects a voltage from an external source, 0 – 40 VDC, to be applied to the capacitor under test.

- **MEAS RATE** Selects the measurement rate. At frequencies of 1kHz or greater, slow (2 measurements per second), medium (10 measurements per second and fast measurements (20 measurements per seconds) may be selected.
- **DISPLAY**
  - **Average** The average of 2 to 20 measurement readings may be displayed. The number of measurements in the average is selected from the keypad.
  - **HOLD** This key holds the meter in its current measurement range. Pressing the hold key a second time returns the meter to the Auto-Range mode. A specific range may also be entered from the numeric keys on the keypad.
  - **EQU** This key toggles the equivalent circuit for the component under test between a series or parallel circuit.
  - **DISP** The DISP key cycles through the display parameters that may be selected. The display parameters that may be selected are:
    - **VALUE** The measured value of the device under test is displayed.
    - **DEV** The deviation from a value previously entered is displayed.
    - **% DEV** The percent deviation from a previously entered value is displayed.
    - **ENTRY** Used for entering parameter values.
    - **BINS** Selects the bin number when Binning is enabled.

Note: Certain displays are not available unless data has been entered. For example, DEV and % DEV are not available unless a nominal value has already been entered. Also, BINS is not available unless binning data has previously been entered.

- ← Backspace key used for correcting mistakes when entering numeric data. This key also serves as the "Local" function.
- [0]...[9] These keys are used to enter parameters and are only active when the meter is in the ENTRY mode.
- **ENTER** [Ω, μH, pF], [kΩ, mH, n F], [MΩ, H, μF]. These three keys are used for entering numeric parameters in the entry mode (e.g. R, L, C values). The bottom-most key (MΩ, H, μF) may be used as a general entry key for entering parameters not listed on the keypad, such as percent %.

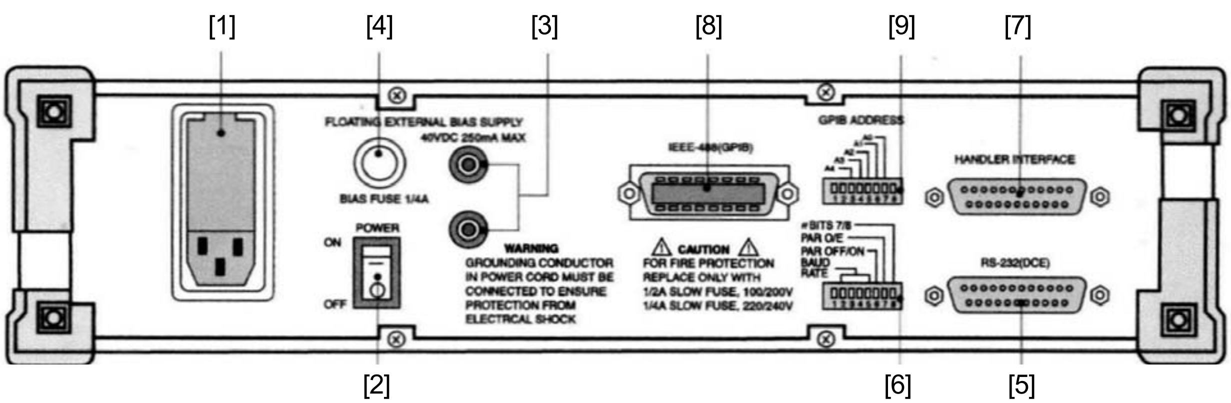
- **SETUP**
  - **STO**, **RCL** The MODEL 2600 can store up to nine setups in the memory. To store the present configuration in memory location #*n*, press **STO** [n] → **ENTER**. To recall a setup, press **RCL** → [n] → **CAL ENTER**.
  - **CAL** Enables a series of internal calibration routines, including open/short and settling time calibration, output amplitude drive, and internal self-tests. Each time the CAL button is pressed, the left-hand display will scroll through the available calibration modes.

- **BIN#**, **NOM**, **LIM** These keys are used to enter Binning parameters. The **BINNING** LED, located in the SETUP section, is on when Binning is enabled and the optional handler is active.

- **TRIGGER**
  - **MODE** This key toggles between continuous (**CONT**) or **TRIGGERED** measurements.
  - **TRIG** When **TRIGGER** mode is selected, measurements are initiated when this key is pressed or by the handler or computer interfaces. The **TRIG** LED will flash when this mode is enabled.

Rear Panel Components

The rear panel and its controls and connections are shown in the following illustration:



[1] AC POWER CONNECTOR The AC power cord is inserted into this connector. The fuse and line voltage selector are located in the connector housing.

[2] POWER SWITCH Turns the meter on and off.

[3] EXTERNAL BIAS INPUT Two banana plugs are used to input an external bias voltage. The bias supply voltage must be floating and well filtered. Neither input connector can be referenced to ground.

[4] EXTERNAL BIAS FUSE Protects external bias circuit from currents greater than 250 mA.

[5] RS232 DB25 This connector allows the meter to communicate as a DCE (data communications equipment, e. g. a modem) to a DTE (data terminal equipment, e.g., a computer) using the RS-232C protocol. For further information, refer to the material on remote programming in the Reference Manual.

[6] SW1 The switches set the RS232C protocol parameters. The Baud rate, word length and parity may be set.

[7] HANDLER INTERFACE This DB-25 male connector provides control lines to a component handler for sorting components. The interface supplies input trigger lines, output lines indicating the bin data available, ten bins, and a busy signal.

[8] GPIB IEEE INTERFACE This connector allows a computer to control the meter over a GPIB (General Purpose Interface Bus) IEEE-488 interface. Refer to the material on remote programming for more information.

[9] SW2 These switches set the device address for the GPIB interface. Refer to the material on remote programming for more information.

Specifications

Display

- Measurement Modes: Auto, R+Q, L+Q, C+D, C+R
- Equivalent Circuit: Series or Parallel
- Parameters Displayed: Value, Deviation, % Deviation or Bin Number. Deviation and % deviation are calculated from a stored relative value
- Averaging: 2–10 Measurements
- Measurement Range:

Measurement Range:	R+Q:	R: 0.0001Ω–2000 MΩ
		Q: 0.00001–50
	L+Q:	L: 0.0001 μH–99999 H
		Q: 0.00001–50
	C+D:	C: 0.0001 pF–99999 μF
		D: 0.00001–10
	C+R:	C: 0.0001 pF–99999 μF
		R: 0.00001Ω–99999 kΩ

Test Conditions

Test Frequency:	100 Hz, 120 Hz, 1 kHz, 10 kHz, 100 kHz Frequency accuracy: ±100ppm.
Drive Voltage:	Preset Levels: 0.10, 0.25, and 1.0 Vrms. Vernier: 0.1 to 1.0 Vrms with 50 mV resolution.
Drive level accuracy:	±2%.
Measurement Rates:	(a) Slow (2 meas./sec.), Medium (10 meas./sec.), or Fast (20 meas./sec.) for test frequencies of 1 kHz and above. (b) Approx. 0.6, 2.4, or 6 measurements per second at 100 Hz and 120 Hz.
Ranging	Auto or Manual

- Triggering — Continuous, Manual, or Remote over RS232, GPIB or Handler Interface
- Bias Voltage — Internal: 2.0 VDC ±2%
  External: 0 to +40 VDC (fused @ 0.25 A)

Accuracy

- Conditions: Allow 30 minutes of warm-up before measurements; all accuracies are at 23° C (73°F) ±5°C (±9°F)
- Basic accuracy 0.20%: Refer to the accuracy section in the Reference Manual for detailed specifications.
- The following summarizes typical accuracy specifications:

Accuracy Value

Better than 1% for:	R > 0.125 Ω and R < 16 MΩ
	L > 2.5 μH and L < 25 kH
	C > 1.25 pF and C < 12.8 mF
Better than 5 % for:	R > 21 mΩ and R < 96 MΩ
	L > 420 nH and L < I50 kH
	C > 0.21 pF and C < 77 mF
at the following conditions:	
	1.0V, 0.5V, or 0.25V output voltage
	Slow or medium measurement speed
	Q and D < 0.1 for R and C
	Q > 10 for L
	100Hz, 120Hz or 1 KHz test frequency for R
	100 Hz test frequency for L_{max} and C_{max}
	10 KHz test frequency for L_{min} and C_{min}

Features and Options

General Features

Feature	Specification
Fixture	4-wire Kelvin fixture for parts with radial and axial leads
Protection	Protected up to 1 Joule of stored energy, 200 V DC for charged capacitors; fused at 0.25 A output current for biased measurement
Zeroing	Open and short circuit compensation. Compensation Limits: short circuit: R<20Ω, Z<50Ω, open circuit: Z>10kΩ
Binning	Up to 8 Pass Bins, QDR and General Fail Bins, all defined by the front panel or computer interface. Binning setups may be stored in nonvolatile memory
Self Test	Tests the ROM, CPU, nonvolatile RAM, clock generator, A/D converter, internal bias, multiplier, output drive circuitry, gain circuitry, and source resistances.
Store and Recall memory	Stores and recalls nine complete instrument setups. Recall 0 recalls the default setup.
RS232 Interface	All instrument functions can be controlled or read over the interface.
Operating Conditions	0 to 50°C (32°F to 122°F) at a relative humidity of 0 to 80%
Power	20 Watts, 115/230 VAC, 50/60 Hz
Dimensions	4 ¼" H × 14 ¼" W × 15" D (108H X 362W X 381D mm)
Weight:	12 ¾ lbs (5.78kg)
Warranty	Two year parts and labor on materials and workmanship

Options

Feature	Part # & Description
IEE-488 interface Handler/sorter interface	Model Z9216 - Instrument functions can be controlled and read over this interface DB male connector provides the signal lines for binning, instrument status and input trigger. **Note: option consists of both interfaces**
Kelvin Clips	KC-2600 - Provides connection to devices that are not easily accommodated by the test fixture. Polarity is indicated for biased measurements.
SMD Tweezers	TW-2600 - Provides connection to surface mount components
BNC fixture adapter	Connects remote fixtures or devices to the MODEL 2600

Chapter

3

Basic Operation

How the Model 2600 Operates and its Capabilities

The Model 2600 LCR meter is very versatile in that the user can customize the measurement and operating modes to obtain the best results in a particular situation. In this chapter, the basics of the meter's operation are summarized.

Operation of the LCR Meter For the First Time

Before using Model 2600 LCR Meter, ensure that it is properly installed, and powered on.

To get the maximum accuracy for your measurements you should be familiar with how to choose the various settings of the Model Z9216 and how to properly use the test fixtures.

Unpacking and Inspection

After unpacking the Model 2600 LCR Meter, verify that all parts are included and have not been damaged during transportation. Retain the packing materials for future shipment .

Packing Contents:

- Model 2600 LCR Meter
- Radial Fixture
- Power Cord
- User Manuals

Installation

To properly install and power on the meter, perform the following steps:

- Be sure the instrument will be used in the appropriate operating environment.
- Leave a space of at least 5.1 cm (2 in) on each side of the meter for proper ventilation.
- Check the fuse for proper type and rating for the selected operating voltage.
- Check for proper electrical connections.
- Connect the power cord to the power connector on the rear panel.

Startup Procedures

When turned on, the meter will enter the self-test mode and perform the following procedure: It will display the program version “0X” and the Model number “XXXX” for about three seconds. Next, the meter will display “test” and “…..” while it performs the self-test. If all tests are successful, “test pass” will be displayed as a result. In order for the self-test to operate correctly, it is important to follow the startup procedures.

Before Applying Power

Prior to turning the unit on, verify that there are no components in the input fixture. Components in the fixture will cause the self-test to fail and display an error code.

Before Using the Test Fixture

When the self-test is completed, “over range” will be displayed, and the user can proceed to set up the test conditions and to make measurements. For maximum accuracy, however, a “null calibration” of the test fixtures needs to be performed before taking any measurements and is described on page 15 of this manual.

Fixture Options

On the front panel of the instrument there are four BNC connectors designated IL, PL, PH, and IH. In what is known as a “4-wire Kelvin connection,” two of these terminals, IL & IH, provide current to and from the device under test, and two of the terminals, PL & PH, sense the potential (voltage) across the device. Separate wires are used for sensing the voltage in order to minimize stray impedance that can cause measurement errors.

There are several fixtures available for special measurements: RF-2600 Radial fixture (standard), KC-2600 Kelvin clips, TW-2600 SMD tweezers, and BNC adapter.

The standard Model 2600 test fixture attaches to the four input terminals on the front panel of the meter and provides two polarized, spring-loaded connection slots to secure radial-leaded components under test while they are being measured. The fixture also accommodates axial-leaded components whose leads are bent to enable insertion into the fixture. Most components will plug into this test fixture, thereby eliminating the need for special fixtures.

RF-2600
Radial Test Fixture

KC-2600
Radial Test Fixture

TW-2600
Radial Test Fixture

Null Calibration Procedure

Whenever the test configuration is changed, including a change of the fixture, open and short circuit "null" calibrations should be made prior to taking measurements to compensate for stray impedances, such as component lead impedance, and fixture, cable and other stray capacitance. Null calibration should be performed after any change in fixture configuration or for changes in the drive amplitude. This calibration corrects for all frequencies and all ranges-it is not necessary to re-calibrate for changes in frequency. For critical measurements, null calibration should be performed frequently at some interval during the course of measurements.

Open and short circuit calibration data is stored in the Model Z9216s nonvolatile memory. These data values are stored with the **STO** key and recalled using the **RCL** key, allowing null calibration constants to be saved for different fixtures.

The null calibration procedure is on the menu that is invoked by pressing the **CAL** (Calibrate) key in the **SETUP** group of keys on the front panel of the meter. To perform a null calibration, press the **CAL** key until the message "nuLL cAL" appears on the alphanumeric display. Pressing the **ENTER** key while this message is being displayed causes the message to change to "Short cAL."

A short-circuit null calibration is performed by placing a wire in the fixture (thereby shorting the fixture's terminals) that is between 26 to 16 AWG (0.016" to 0.05" or 0.41 to 1.27 mm dia.). The calibration proceeds automatically after the user presses the **ENTER** key. Special care should be taken to assure that the users hands or any other outside elements are kept away form the test fixture. This is due to the effect that these objects can have on the test fixtures's impedance. When the short circuit calibration is finished, the meter prompts the user for the next operation by displaying the message "oPEn cAL."

To perform the open-circuit null calibration, remove the shorting wire, press **ENTER**. When the unit has finished, it displays the message "cAL donE." To dismiss this message and return to a normal display mode, press the **DISP** (Display) key.

Changing Test Setup Parameter Settings

When first powered, the Model 2600 LCR Meter defaults to the automatic (**AUTO**) measurement mode, and the result of the measurement is displayed on the alphanumeric readout. For most measurements, the test conditions in the automatic mode are sufficient. However, by pressing the parameter keys on the front panel, the user may enter customized test setup parameter selections, and by pressing the keypad keys, enter the desired values of test parameters. Test parameters that are not associated with dedicated keys on the front panel or keypad, such as the number of measurements being averaged, deviation measurements, etc., may be entered by pressing the **DISP** key to enter the **ENTRY** mode. Table 3-1 below shows appropriate settings for typical component values.

Table 3-1 Test Setup Parameter Settings for Typical Component Values.

Component	Value	Meas. Mode	Equiv. Circuit	Frequency
Unknown	Any	AUTO	Series	1 kHz
Resistor	< 1 kΩ > 1 kΩ	R+Q	Series	1 kHz 100 or 120 Hz
Inductor	< 10 µH 10 µH–1 mH 1 mH–1H > 1H	L+Q	Series	100 kHz 10 kHz 1 kHz 100 or 120 Hz
Capacitor	< 10 pF 10 pF–400 pF 400 pF–1 µF > 1 µF	C+D C+D C+D C+R or C+D	Parallel Series or parallel Series Series	10 kHz 10 kHz 1 kHz 100 or 120 Hz

Default Setup

Holding down the backspace key (←) key while turning on the power causes the meter to set to the default settings as listed in the table below.

Note: All user calibration settings and values will be lost.

In order to prevent the user calibration settings from being destroyed, turn the meter on without pressing the backspace key, press **RCL** → [0] → **ENTER**. This key sequence will reset the meter to the default settings listed in the table below without affecting user-entered calibration values. See the sections that follow for more details on the settings listed in the table below.

Table 3-2 Model Z9216 Default Settings

Setting	Value
Parameter	AUTO
Frequency	1 kHz
Drive Voltage	1.0 V_{rms}
Bias	OFF
Measurement Rate	SLOW
Averaging	OFF
Range Hold	OFF
Equivalent Circuit	SERIES
Display Setting	VALUE
Trigger Mode	CONTINUOUS
Binning	OFF

Changing, Storing, and Recalling Custom Setups

Measurement Mode

The measurement mode is selected by pressing one of the five keys in the **PARAMETER** group of keys on the front panel.

AUTO In this mode, the meter automatically selects the most appropriate measurement on the device. The selection is made according to the following criteria:

If $|Q| < 0.125$, the meter selects the R+Q measurement mode.

If $Q > +0.125$, the meter selects the L+Q measurement mode.

If $Q < -0.125$ and the meter is in the series equivalent circuit mode, the C+R measurement mode is selected.

If $Q < -0.125$ and the meter is in the parallel equivalent circuit mode, the C+D measurement mode is selected.

R+Q In this mode, resistance is displayed on the main parameter display and the Q (quality factor) is displayed on the secondary, or right-hand, parameter display. The R-value is either the series or parallel equivalent resistance of the component under test depending upon what mode the meter is in. The unit for R is Ω, kΩ, or MΩ. The Q value is the dimensionless ratio of the imaginary part of the component's impedance to its real part. If Q has a positive (+) value, the reactive component of the device under test is inductive. If Q has a negative (–) value, it is capacitive.

L+Q In this mode, the series or parallel equivalent inductance value of a component under test is displayed on the main parameter display units in units of μH, mH, or H, and its dimensionless Q value is displayed on the secondary parameter display.

C+D In this mode, the series or parallel equivalent capacitance value of a component under test is displayed on the main parameter display in units of pF, nF, or µF. On the secondary parameter display, the dimensionless ratio D = 1/Q is given. D is normally a small value for a good capacitor.

C+R In this mode, the capacitance is displayed on the main parameter display and the equivalent resistance is displayed on the secondary parameter display. The unit for resistance is Ω unless the kΩ indicator LED is lit.

Frequency

The output frequency is accurate to 100ppm, (0.01%). The output frequency is set by pressing the up/down keys, ▲▼, on the front panel keypad until the LED corresponding to the desired frequency is illuminated. If the meter is in range hold mode, setting the meter on Range 0 will disable the 100 kHz frequency selection. Attempting to set the frequency to 100kHz, while in Range 0 will cause the meter to beep and an "r-f error", (range frequency error), will appear on the alphanumeric display. For more details, see the section on Range.

Drive Voltage

The Model 2600 meter has three fixed output rms voltages, 0.1 V, 0.25 V and 1.0 V. These voltages are selectable from the front panel. A variable, (vernier), rms voltage is also available, which is adjustable from 0.1 V to 1.0 V in 50 mV steps. The basic accuracy of the voltage levels is 2%.

To select a fixed voltage, press and release the **VOLT** key located in the **DRIVE VOLT** section on front panel keypad until the LED indicates the desired voltage.

To set the variable output voltage:

1. Press the **CAL** keypad button. The DISP LED will indicate the ENTRY mode. On the alphanumeric display, "vtest" and the present test voltage will be shown.

2. Enter the desired output voltage from the numeric keypad (0.1 to 0.9 may be entered) and press **ENTER** (MΩ H µF key).

3. The output voltage may be set in 50mV steps.

   NOTE: If the drive voltage is a value other than one of the three fixed voltages the CONS LED will light .

The output voltage is applied to the device under test through a source impedance. Thus, the voltage across the device is always less than or equal to the output drive voltage. The available source impedances for the four auto ranging selections made by the meter are 25 Ω (Range 3), 400 Ω (Range2), 6.4 kΩ (Range 1) and 100 kΩ (Range 0), all of which are accurate to 2%. The source impedance is automatically selected as a function of the measurement range, unless the unit is in the constant voltage mode. In the constant voltage mode, the source impedance is always 25 Ω. See the section on Range for determining which measurement range the meter is using.

Figure 3-1 shows the voltage across the Device Under Test (DUT) vs. the DUT impedance for the different measurement ranges. The values are normalized to a 1.0-V output drive setting for different applied voltages; that is, the Figure plots the normalized voltage across the DUT, given by

$$(V_{DUT}/V_{source}) = R_{DUT}/(R_{source} + R_{DUT})$$

Note that the voltage applied to the DUT is nearly equal to the output voltage at the upper end of each range and decreases due to lower impedance toward the lower end of the range. This is because of the impedance of the voltage source. If the meter is in the constant voltage (CV) mode, the source impedance is always set to 25 Ω. For any DUT with impedance significantly larger than 25Ω, the voltage across the part is essentially equal to the output drive voltage.

For most devices, including resistors and capacitors, and for many inductors, the 1.0 Vrms setting is the most appropriate setting. For some inductors and for semiconductor or active devices, such as diodes and transistors, the 0.25 or 0.1 Vrms setting should be used. Certain devices require a specific test voltage, such as Z5U ceramic disk capacitors (test voltage = 0.5 Vrms). In these cases, use a variable voltage setting to obtain the exact voltage required. In general, use the largest voltage possible for the best signal-to-noise ratio and accuracy.

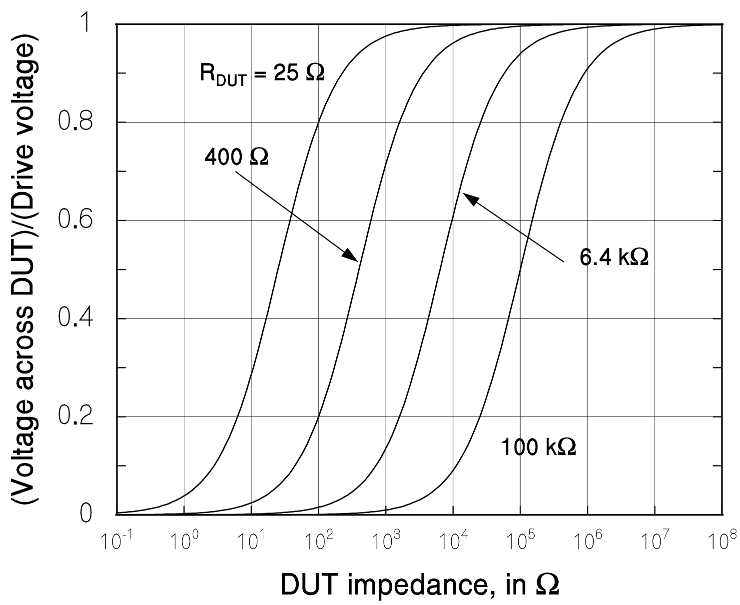


Figure 3-1. Normalized Voltage Across DUT vs. DUT Impedance

Bias

Internal or external DC bias voltages can be applied to capacitors. Electrolytic and tantalum capacitors need a positive bias for accurate measurements, although the meter bipolar test voltage will not typically be enough to damage them. The 2 VDC internal or up to 40 VDC external bias voltage allows measurements to be made while approximating actual operating conditions. The external bias capability also allows CV measurements to be made on semiconductor devices.

Notice: Always be certain that the capacitor being tested is inserted with the correct polarity. The bias voltage is always positive to the right and is marked on the meter. Failing to observe the correct polarity can result in the destruction of the component under test and possibility injury. Beware that capacitors can hold their charge for a long time if removed from the fixture without discharging the DC bias voltage.

Warning: Care must be taken to discharge the capacitor after making measurements, especially when using a high external bias voltage. Failing to discharge the device can result in damage to the device, damage to the meter, or possible injury. The meter is protected internally against discharging capacitors with up to 1 joule of stored energy (C*V^2).

The internal and external bias circuitry will only work if the unit is in the C+D or C+R mode. Bias voltage cannot be applied if the meter is in the R+Q, L+Q or AUTO mode.

The error message “bias for c” will appear if the bias button is pressed in an inappropriate mode. Whenever the bias circuitry is active, the meter is in the constant voltage mode, so that the voltage across the capacitor under test will stabilize in a reasonable amount of time. See the section on the constant voltage mode for effects on ranges and accuracy.

It will take a short while for the internal circuitry and the DUT to stabilize after applying the bias voltage. The time is primarily determined by the RC time constant of the source resistance and the capacitor under test, plus the internal AC coupling capacitor of 0.47 μF. During this time, the reading on the meter may change if it is continuously triggered. In this case, the initial readings should be disregarded. If this is a problem, use the triggered mode (simply wait a short time before triggering) or increase the settling time. See the section on measurement rate for information on how to set the settling time. In addition, the capacitance of some capacitors will slowly drift after a change in DC voltage.

Internal Bias

To apply the 2.0 VDC internal bias voltage to the capacitor under test, first verify that the capacitor is connected to the test fixture with correct polarity (positive to the right). Press the **INT** key to apply the bias voltage. After a second or two, the reading should be stable. Before removing it from the fixture, press the **INT** key a second time to switch off the bias in order to discharge the capacitor.

External Bias

The meter has rear panel connectors to allow an external bias voltage of up to +40 VDC to be applied across the capacitor under test. This supply must be floating (neither side connected to ground) and must be current limited to less than 250mA. A linear supply is recommended (instead of a switching supply). The supply should be well filtered, to remove ripple from the bias voltage. Connections to the bias supply are made on the rear panel with two banana jacks. The red jack is the positive side of the supply and the black, the negative. There is an internal diode within the unit to prevent a negative voltage from being applied. The bias supply lines are fused with a 250mA fuse on the rear panel, next to the banana jacks. If the meter does not yield stable readings when the external bias switched is on, check this fuse. If the bias supply is connected backwards, there is a good chance that the bias supply fuse will blow. Provisions are needed to discharge the bias voltage from the capacitor under test before removing it from the fixture. In general, external switches or discharging resistors should be provided along with the bias supply to ensure safe operation.

To apply an external bias voltage, ensure that the bias supply is connected correctly. Verify that the capacitor is installed with the correct polarity in the test fixture (positive to the right). Next press **EXT** button to apply the bias voltage. After a second or two, the reading should be stable. After the measurement is complete, discharge the capacitor under test before removing it from the fixture.

For occasional nonrepetitive use with small capacitors (<500 μF) and low bias voltages (<20 VDC), the meter can discharge the capacitor internally. Press the **EXT** button to switch off the bias. The capacitor will then discharge through the meter in the same manner as the internal bias.

Another solution for somewhat larger bias voltages and/or capacitors is to connect a resistor across the terminals of the bias supply. Switch off the bias supply and allow the capacitor to discharge through the resistor before removing it from the fixture. Make certain the discharge resistor is rated to handle the steady state current that the bias voltage will generate through it and that the supply can provide this additional current. For larger capacitors or higher supply voltages it will be necessary to provide external switches to remove the bias voltage and discharge the capacitor.

Measurement Rate

The Model 2600 has three measurement rates, which are selected by pressing the Rate button. Slow, medium or fast rate may be selected. Table 3-3 lists the maximum measurement rates attainable when the meter is not in the auto-range mode, binning is disabled, and neither the GPIB nor the RS232 interface is active. The measurement affects the accuracy with slow and medium being the most accurate and fast being the least accurate.

The actual measurement time can be calculated from the following equation:

$$T_{meas} = T_s + (N_i/f + T_{di} + T_{rs} + T_d)\,N_m + T_{calc}$$

where T_s = settling time, N_i = number of test frequency cycles used in the measurement, f = test frequency, T_{di} = deintegration time, T_{rs} = resynchronization time, T_d = delay time, N_m = number of sub measurements per read, and T_{calc} = calculation time. T_{di}, T_d and T_{calc} are constants, while T_{rs} and f are set by the measurement frequency. N_i and N_m are determined by the measurement rate and T_s can be set by the user. See Table 3-4 for the appropriate values.

In addition to these factors, the measurement time is increased when using auto ranging, binning or GPIB or RS232 interface. Binning adds about 2.5 ms to the total measurement time. Auto ranging adds n*(T_{meas} – 1 ms) where n = number of range changes required and T_{meas} is calculated according the equation given above.

It is difficult to determine the exact amount of time added when using the GPIB or RS-232 interfaces, since it is dependent on baud rate, the speed of the computer, and the software. It takes about 5 ms for the meter to respond with a reading to send back over the interface. In general, simple commands and responses like setting the frequency or checking what range the meter is on, can be returned in about l0 ms. Longer responses, like XALL?, can take as long as 2 seconds over the RS-232. If communications speed is critical, the binary data format, which reduces the number of bytes transferred, can be used.

Table 3-3 Measurement Rates (Number of Measurements/Sec)

Frequency	Slow	Medium	Fast
100 kHz	2.8	14	28
10 kHz	2.8	14	27
1 kHz	0.7	13	24
120 Hz	0.7	2.8	7
100 Hz	0.6	2.4	6

Table 3-4: Table for Appropriate Values

Variables	Appropriate Values for Variables				
N_m	Slow	8			
	Medium	8			
	Fast	5			
N_i		100/120 Hz	1 kHz	10 kHz	100 kHz
	Slow	20	40	400	4000
	Medium	4	4	40	400
	Fast	2	2	20	200
T_{xx}	T_{rs}	T_{di}	T_d	T_{calc}	T_s
	1/f	2 mS	2 mS	3 mS	2 – 99 mS

Settling Time

Occasionally it is advantageous to delay making a measurement after the meter is triggered. This allows bias voltages on capacitors to stabilize or contacts on a handler to debounce. The settling time is set in 1ms intervals from 2 to 99 ms.

To set the settling time,

1. Press the **CAL** key until the "settle" message appears in the left alphanumeric display and the present settling time, in the right display.
2. Enter the new settling time value, from 2 to 99.
3. Press the **ENTER** key.

If an illegal value is entered, the meter will beep and display "range error."

Triggering

The Model 2600 can make measurements continuously or in response to a trigger. To change the trigger mode:

1. Press the **MODE** key in the **TRIGGER** group of front panel keys until the desired mode LED is on; either CONT or TRIGGERED may be selected.
2. In the continuous mode, the meter will trigger itself at its maximum measurement rate. In the trigger mode, the trigger can be from the TRIG button or from the RS232, GPIB or Handler interface.

The TRIG LED will flash whenever the **TRIG** key is depressed and the meter will make a single measurement.

Note: When making a measurement, the meter will ignore any triggers it receives until the current measurement is complete.

Store and Recall

The STO and RCL buttons allow nine complete instrument setups to be saved in nonvolatile memory. All the test conditions, including binning, configuration and open short circuit compensation, are saved.

To store a setup,

1. Press the **STO** button, which will display the “store” message.
2. Press the number where the setting is to be stored ([1]–[9]), then press the **ENTER** button.

To recall a stored setting,

1. Press the **RCL** button, which will display “rcl”.
2. Press the number where the setting is stored ([1]–[9]), and then press the **ENTER** button

Notes: 1. **STO**→ 0→ **ENTER** will give an error since the factory default setting is stored in location 0.

2. **RCL**→ 0→ **ENTER** returns the default setup, including null calibration values.
3. If a “cal error 4” appears during the self-test, or a “rcl error” message appears when recalling a setup, the stored setup was lost and must be re-entered.

Range

The meter has four measurement ranges, designated by the numbers 0 to 3. The range may be selected manually or the meter can auto range. Table 3-5 specifies the impedance ranges for each of the measurement ranges. Each of the four ranges has a source impedance of approximately the mid-scale impedance. Note that the measurement ranges determine an impedance range (not a parameter value range), so the ranges of inductance and capacitance depend upon the test frequency. The parameter f is the test frequency. In addition, the impedance of a capacitor is inversely proportional to its capacitance, so larger capacitors are measured in the lower impedance ranges.

Table 3-5: Measurement Range and Impedance Range

Range	Source Resistance	Resistance	Inductance	Capacitance
3	25.0 Ω	10 µΩ – 100.0 Ω	0.0001 µH – (15.9/f) H	99999 µF – (1.59/f) mF
2	400 Ω	100.0 Ω – 1.6 kΩ	(15.9/f) H – (255/f) H	(1.59/f) mF – (99.5/f) µF
1	6.4 Ω	1.6 kΩ – 25.6 kΩ	(255/f) H – (4074/f) H	(99.5/f) µF – (6.22/f) µF
0	100 kΩ	25.6 kΩ – 2000 MΩ	(4074/f) H – 99999 H	(6.22/f) µF – 0.0001pF

*** f = test frequency**

Auto Ranging Mode

During normal operations, the meter automatically changes to the most accurate range for the device under test. When the meter measures an impedance that is out of its current range, it goes up or down one range, and makes another measurement. If this measurement is within the current range, it displays a reading. If not, it changes ranges (if available), and repeats this process. There is built-in hysteresis to avoid repeated range changes when a component is on a range boundary. Up-range changes occur when the impedance measured exceeds 450% of the mid-scale impedance (i.e, the source impedance), or 12.5% over the nominal range limit. Down-range changes occur when the measured impedance drops below 22% of the mid-scale impedance, or 12.5% below the nominal range. See Table 3-6 for the actual values where the range changes occur.

Table 3-6 Range Change Points When Auto Ranging

Ranging to Lower Impedances		Ranging to Higher Impedances	
Range Change	Impedance	Range Change	Impedance
2 to 3	Z < 88Ω	3 to 2	Z > 115Ω
1 to 2	Z < 1.4 kΩ	2 to 1	Z > 1.8 kΩ
0 to 1	Z < 22.4 kΩ	1 to 0	Z > 29.9 kΩ

RANGE HOLD Mode

It is sometimes desirable to disable auto ranging since it takes nearly a complete measurement cycle each time a range changes occurs. This can be annoying if there are no parts in the fixture and the meter is continuously triggering, due to the nearly infinite impedance of the test fixture. The meter will auto range to range 0 (range 1 for 100 kHz) and then auto range back to the appropriate range when a part is inserted in the fixture. Range holding is helpful if measurement speed is a concern or if a number of parts with similar values are being measured.

There are two ways to implement a RANGE HOLD mode:

1. The present measurement range can be held simply by pressing the **HOLD** key. The LED above the **HOLD** key indicates that the meter is in the RANGE HOLD mode.

2. A measurement range can also be entered from the ENTRY display. Select the ENTRY display using the **DISP** key, then press **HOLD**. The message “range” will appear in the left display, and the present range, 0–3, will appear in the right display. Enter the desired range and press the **ENTER** button.

Use the **DISP** key to return to the desired display. The RANGE HOLD LED will be on. If an invalid range is entered, the meter will beep and display the message “range error” and not accept the range entry. Range 0 cannot be entered when the frequency is set to 100kHz. If this is attempted, the meter will beep and display an “r-f error” (range-frequency error). To return the meter to the auto ranging mode, simply press the **HOLD** button.

Constant Voltage (CONS) Mode

Occasionally, a test will require using a specific drive voltage that is not possible using the normal source resistance for that measurement range. In these cases, press the **CONS** key and thereby set the source impedance to a fixed 25 Ω. The voltage across the component under test will be almost constant for all devices with impedance substantially larger than 25Ω. When the meter is in constant voltage mode, the measurement range changes to avoid overloading the meter. However, it also reduces the accuracy of the measurement by a factor of 2. See the accuracy section in the Reference Manual for more detail. Table 3-7 lists the measurement and impedance ranges when using the constant voltage mode. Table 3-8 shows the range change points when auto ranging in the constant voltage mode.

Under certain conditions, the “over load” message will be displayed. This normally occurs when the unit is in the constant voltage mode with the range hold on. To correct this, simply change to a higher impedance range, or use auto ranging.

Table 3-7 Measurement and Impedance Ranges for Constant Voltage Mode

Range	Source Resistance	Resistance	Inductance	Capacitance
3	25.0Ω	10 μΩ – 360 Ω	.0001 μH – (57/f) H	99999 μF – (442/f) mF
2	25.0Ω	360 Ω – 5.76 kΩ	(57/f) H – (917/f) H	(442/f) mF – (27.7/f) μF
1	25.0Ω	5.76 kΩ – 90.0 kΩ	(917/f) H – (1432/f) H	(27.7/f) μF – (1.77/f) μF
0	25.0Ω	90.0 kΩ – 2000 MΩ	(1432/f) H – 99999 H	(1.77/f) μF – 0.0001 pF

Table 3-8: Range Change Points when Auto-Ranging in Constant Voltage Mode

Range Change	Impedance	Range Change	Impedance
2 to 3	Z < 315 Ω	3 to 2	Z > 400 Ω
1 to 2	Z < 5.04 kΩ	2 to 1	Z > 6.4 kΩ
0 to 1	Z < 78.8 kΩ	1 to 0	Z > 100 kΩ

Series and Parallel Equivalent Circuits

Generally, as illustrated in Figure 3-2, any non-ideal component has a different value for a series or parallel equivalent circuit due to the characteristics of the component. The “quality” of an inductor is expressed by Q, the ratio of the reactive (inductive) part of its impedance to its resistive part. The “quality” of a capacitor is similarly defined, as summarized in Table 3-9. Often it is more useful to calculate a capacitor’s “dissipative factor,” which is the inverse of its Q[3]. As Q for inductors decreases towards 10 and Q for resistors or D for capacitors increase towards 0. 1, the series and parallel circuit values begin to diverge. Most components have an approximate value for the series equivalent circuit. Manufacturers often specify which representation should be used when testing their devices.

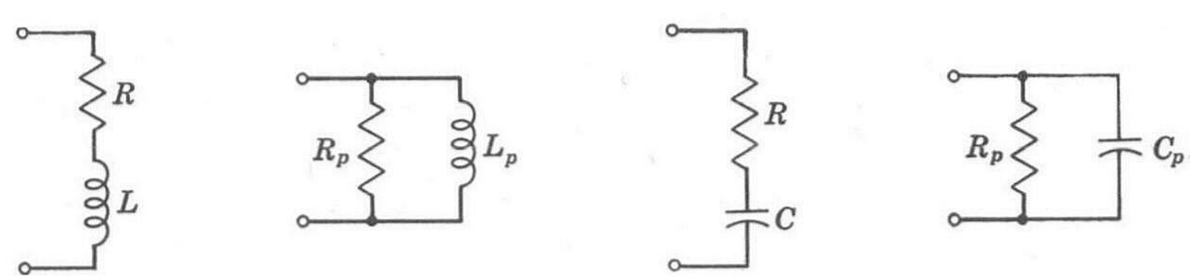


Figure 3-2 Series and Parallel Equivalent Circuits.

[3] W. L. Everett and G. E. Anner, *Communication Engineering* (3rd edition), McGraw-Hill, 1956.

Table 3-9 Quality Factors for Equivalent Circuits

Component	Equivalent Circuit	Q
Inductor	Series	ωL/R
	Parallel	Rp/ωLp
Capacitor	Series	1/ωCR
	Parallel	ωCpRp

Display Types

The **DISP** key can select one of five different types of displays. A display is selected by repeatedly pressing the **DISP** key until till the LED indicates the desired display option. These options are described as follows:

VALUE: This is the default display mode when the meter is turned on.

DEV: In the Deviation display mode, the difference between the currently measured component value and a previously entered value is displayed. The Deviation display is selected by repeatedly pressing the **DISP** key until the DEV LED is lit. The Deviation display is not available in the AUTO mode and if no nominal value has been previously entered.

To Enter a Nominal Value,

1. Press and release the **DISP** key until the ENTRY LED is lit.
2. Select the measurement mode by pressing one of the keys in the PARAMETER group of keys on the front panel.
3. The left alphanumeric display shows the currently stored nominal value.
4. Enter a new nominal value using the numeric keypad.
5. Press the appropriate enter key (Q, μH, pF, Ω), (kΩ, mH, nF) or (MΩ, H, μF).

% DEV In this mode, the meter displays the difference between the currently measured component value and a previously entered value as a percentage. % DEV is not available in the AUTO mode or if a nominal value has not yet been entered.

ENTRY In the ENTRY display mode, the user is permitted to enter nominal values, measurement conditions and calibration data. If an out of range or incorrect value is entered, the meter will beep and display a “range error” message.

NOTES: