KEITHLEY

Model 3330 LCZ Meter

Operator's Manual

A GREATER MEASURE OF CONFIDENCE

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

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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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KEITHLEY 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 Installation Category I and Installation Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Installation Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Installation 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 **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.

Table of Contents

SECTION 1 — General Information

SECTION 2 — Getting Started

SECTION 3 — Operation

SECTION 4 — GPIB Interface

APPENDICES

List of Illustrations

SECTION 2 — Getting Started

SECTION 3 — Operation

SECTION 4 — GPIB Interface

List of Tables

SECTION 3 — Operation

SECTION 4 — GPIB Interface

SECTION 1
General Information

1.1 INTRODUCTION

This section contains general information about the Model 3330.

1.2 PRODUCT DESCRIPTION

The Model 3330 LCZ Meter is a high-accuracy (0.1% basic accuracy), full-function LCZ meter. The instrument includes comparator functions and a material handler interface for parts sorting (binning), memory for test configurations, and a GPIB (IEEE-488) interface for computer control.

The Model 3330 drives the device under test (DUT) with a sine wave signal (201 frequencies available). Impedance is determined by applying a known voltage, precisely measuring the resulting current that flows through the DUT, and then computing the impedance magnitude and phase. Displayed parameters such as inductance, capacitance, and resistance are calculated from the magnitude and phase of the computed impedance.

1.2.1 Condensed Specifications

The following condensed specifications summarize the capabilities of the Model 3330. For complete and detailed instrument specifications, refer to Appendix A.

- **Measurement Functions:** L, C, R, |Z|, Q, D, ESR, G, X, θ, V, I. Most functions can be automatically selected, and deviation (or % deviation) can be displayed.
- **Basic Accuracy:** 0.1% (at 1kHz)
- **Measurement Ranges (Display):**
  |Z|: 0.1mΩ to 19.999MΩ
  C: 0.001pF to 199.99mF
  L: 0.1nH to 19.999kH
  G: 0.001µS to 199.99S
  Q, D: 0.0001 to 19999
  θ: −180.00° to +179.99°
  V: 0.0mVrms to 1.999Vrms
  I: 0.00µA rms to 19.99mA rms
- **Measurement Frequency:** 40Hz to 100kHz (201 measurement frequencies available)
- **Measurement Signal Level:** 10mVrms to 1.1Vrms
- **Equivalent Circuit:** Series, parallel, and automatic
- **DC Bias:** Internal: 2V; External: 0 to ±35V
- **Zero Correction:** Automatic (OPEN, SHORT).
- **Measuring Time:** FAST (60msec), MED (150msec), SLOW (480msec)
- **Comparator Function:** 20 categories (bins)
- **Memory for Test Setups:** 10 test configurations can be saved in battery backed-up memory

1.2.2 Features

- High Accuracy — Basic accuracy of 0.1% with a display resolution of 0.0001 at 4 1/2-digits.
- Wide Frequency Range — 201 frequency selections in the range from 40Hz to 100kHz are available.

- Programmable Measurement Signal Levels — Sine wave signal levels from 10mVrms to 1.1Vrms can be applied to the DUT. Also, the DUT can be biased by selecting the 2V internal DC bias voltage, or by applying an external DC bias voltage of up to ±35V.
- Variety of Measurement Functions — In addition to the conventional functions including L, C, R, D and Q, you can also display the equivalent series resistance (ESR), parallel conductance (G), series reactance (X) and impedance magnitude and phase angle (| Z | and θ). Additional display functions include V (voltage across DUT), I (current through DUT), and deviation from standard value.
- Automatic Function and Range Selection — In addition to the conventional auto-range feature, display function and equivalent circuits can also be selected automatically.
- Built-in DC Bias Power Supply — The built-in 2V DC bias power supply can be used to bias devices such as electrolytic capacitors and semiconductors during measurement.
- Built-in Comparator Functions — Twenty-bin comparator function simplifies parts sorting.
- Built-in Handler Interface — Operates in conjunction with the built-in comparator to control a user-supplied material handler for automatic binning capabilities.
- Battery Backed-up Memory — Up to 10 unique setup configurations can be saved. Battery back-up prevents these setup configurations from being lost when instrument power is turned off.
- GPIB (IEEE-488) Interface — Allows the instrument to be controlled by a computer.

1.3 WARRANTY INFORMATION

Warranty information is located on the inside front cover of this manual. Should your Model 3330 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual in order to provide the repair facility with the necessary information.

1.4 MANUAL ADDENDA

Any improvements or changes concerning the instrument or manual will be explained in an addendum included with the manual. Be sure to note these changes and incorporate them into the manual before using your unit.

1.5 SAFETY SYMBOLS AND TERMS

The following symbols and terms may be found on an instrument or used in this manual.

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

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 LCZ meter. Such damage may invalidate the warranty.

1.6 INSPECTION

The Model 3330 was carefully inspected, both 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 reshipment. The following items are included with every Model 3330 order:

- Model 3330 LCZ Meter
- Model 3330 Operator's Manual.
- Additional accessories as ordered.

If an additional manual is required, order the manual package, Keithley part number 3330-900-00. The manual package includes a manual and any pertinent addenda.

1.7 OPTIONAL ACCESSORIES

1.7.1 Test Leads and Cables

The following optional accessory test fixtures and test leads are available from Keithley for use with the Model 3330:

Model 3323 Direct Test Fixture: Allows parts with leads to be directly connected to the instrument for measurement without using test leads. This fixture is especially convenient for parts sorting.

Model 3324 4-Terminal Alligator Clip Test Leads: Designed for four-terminal components where current-sourcing terminals and voltage-measurement terminals are separate.

Model 3325 Kelvin Clip Test Leads: Uses two clips for four-terminal connections. Used to measure large or irregularly shaped components that cannot be inserted into the Model 3323 test fixture.

Model 3326 Chip Component Test Leads: This tweezer-type test lead set permits easy connection to surface-mounted chip components.

The cables for all the above test leads are shielded to minimize stray capacitance.

1.7.2 GPIB Cables

Model 7007 Shielded IEEE-488 (GPIB) Cables: Connect the Model 3330 to the GPIB. Available as the Model 7007-1 (1m; 3.3 ft.) and Model 7007-2 (2m; 6.6 ft.).

1.7.3 Handler Interface Connector

The following 36-pin connector is recommended for use with the HANDLER INTERFACE connector: Cinch Connector part number 57-30360.

1.8 SPECIFICATIONS

Detailed Model 3330 specifications are located in Appendix A at the back of this manual.

SECTION 2
Getting Started

2.1 INTRODUCTION

This section will guide you though some basic front panel operations, and it is intended to acquaint you with basic instrument operation. Detailed operating instructions are covered in Section 3.

Basic operations covered in this section include:

- Basic L, C, R, and Z measurements.
- Deviation measurements.
- Comparator operation.

Figure 2-1 shows the front panel of the Model 3330 with the optional Model 3323 test fixture connected.

2.2 POWER-UP

The instrument is designed to operate from 90-132V or 198-250V line power voltages at a frequency from 48 to 62Hz. Perform the following steps to connect the instrument to line power:

1. Make sure that the rear panel LINE SUPPLY selector switch setting agrees with the line power available in your area. If not, set the switch to the correct voltage range. (Keep in mind that changing the line voltage setting may require a fuse change; see Section 3.)

CAUTION
Operating the unit on a line voltage outside the voltage setting range may result in instrument damage.

2. Connect the female end of the supplied power cord to the AC receptacle on the rear panel, and connect the other end of the power cord to a grounded AC outlet.

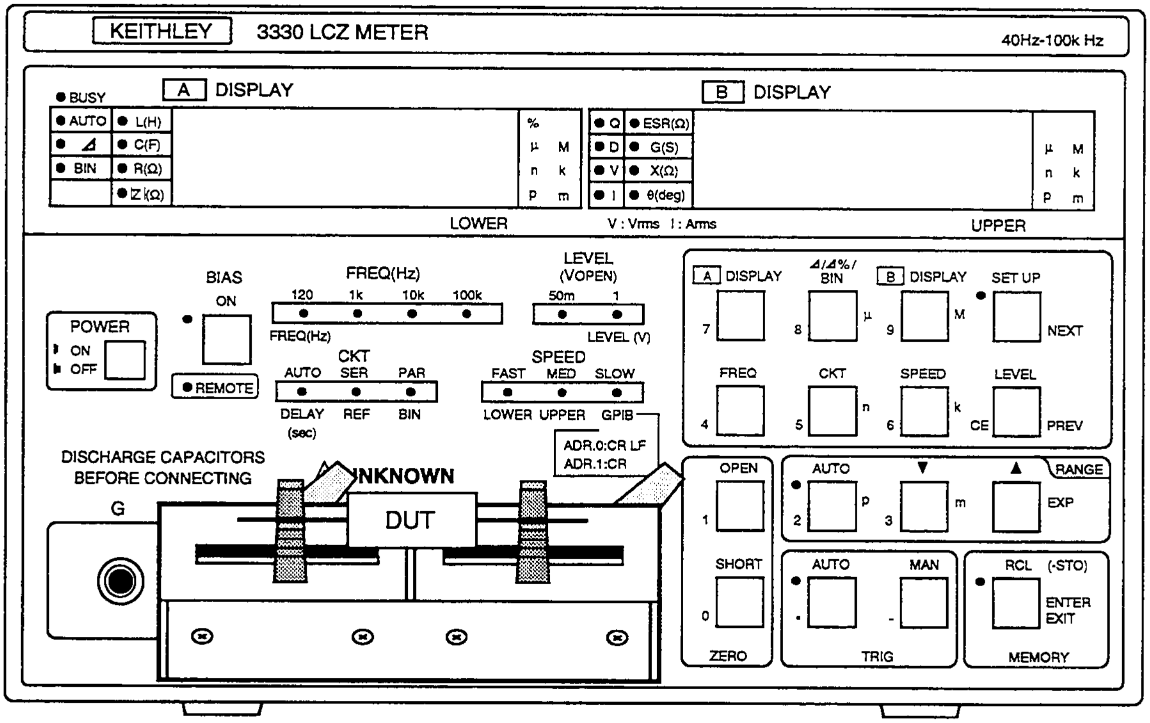


Figure 2-1. Model 3330 Front Panel with Optional Test Fixture Connected

WARNING
The instrument is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with grounded outlets. When proper connections are made, instrument chassis is connected to the power line ground. If the AC outlet is not grounded, the rear panel safety earth ground terminal must be connected to a known safety earth ground using #18 AWG (or larger) wire. Failure to properly ground the instrument may result in personal injury or death caused by electric shock.

3. Turn on the instrument by pressing the POWER switch in to the ON position. The instrument will perform its power-up sequence (see paragraph 3.3). After successfully completing the power-up tests, the instrument will assume default conditions that configure the instrument for immediate measurements.

NOTE
The instrument is ready for immediate use. However, the instrument must be allowed to warm up for at least 1/2 hour to achieve rated accuracy.

2.3 BASIC MEASUREMENTS

The Model 3330 determines impedance by applying a known rms voltage at a specific frequency to the DUT and then measuring the current through the DUT. Impedance magnitude and phase are calculated from the voltage and current, and displayed parameters such as inductance, capacitance, and resistance are calculated from the impedance.

2.3.1 Measurement Procedure

The procedure below outlines the steps for making basic measurements. This procedure assumes that the instrument is configured to its power-up default conditions. If you are not sure about the setup configuration, simply turn the power off for about three seconds, and then turn the power back on again.

NOTE

The following procedure assumes that you will be using the Model 3323 Test Fixture to connect DUTs to the instrument. If you are using test cables, be sure to use 4-terminal connections, as explained in paragraph 3.4.

Perform the following steps to make basic L, C, R, or Z measurements:

1. Connect the Model 3323 test fixture to the instrument (see Figure 2-1). This test fixture allows easy DUT connection to the instrument, and it provides accurate measurements by eliminating the stray capacitance of test cables.
2. Note that automatic function is selected as denoted by the AUTO indicator LED to the left of the [A] DISPLAY. In AUTO function, the instrument will automatically select the appropriate function (L, C, R, or Z) for the device being measured.
3. Connect the DUT (device under test) to the test fixture terminal. The appropriate function for the DUT will be selected, and the measurements will be displayed as follows:

   - For inductors (L), the [A] DISPLAY indicates the reading in henries (H), and the [B] DISPLAY shows the quality factor (Q).
   - For capacitors (C), the [A] DISPLAY shows the reading in farads (F), and the [B] DISPLAY indicates the dissipation factor (D).
   - For resistors (R), the [A] DISPLAY indicates the reading in ohms (Ω), and the [B] DISPLAY shows the quality factor (Q).

NOTE

The exponent symbol indicators (p, n, µ, m, k and M) for readings are located to the right of each display.

2.3.2 Setting Level and Frequency

The procedure outlined in paragraph 2.3.1 required no changes in instrument settings to test components. The test was completely automated simply by using the power-up default setup configuration. Of course, this setup configuration may not be appropriate for all measurements, and may require changes to appropriate operating parameters. For example, you may wish to change the signal level or test frequency, as discussed below.

Signal Level

Upon power-up, the test signal level is set to 1Vrms, as indicated by the corresponding front panel LEVEL LED. To toggle the signal level between 50mV rms and 1V rms, simply press the LEVEL key on the front panel.

You can also set the signal level to a value from 10mVrms to 1.1V rms in 1mV increments by using the SET UP key. More information on level programming may be found in paragraph 3.8 in Section 3.

Signal Frequency

Upon power-up, the test frequency is set to 1kHz, as indicated by the FREQ LED. To select one of the other fixed frequencies (10kHz, 100kHz or 120Hz), repeatedly press and release the FREQ key until the corresponding frequency indicator turns on.

You can also program 201 separate frequencies by using the SET UP key. Refer to paragraph 3.8 in Section 3 for more information on programming the frequency.

2.4 DEVIATION MEASUREMENTS

The Model 3330 can be configured to measure and display the deviation (Δ) or percent deviation (Δ%) between the measured value of a DUT and a defined reference value. The deviation and percent deviation are defined as follows:

Δ = Measured Value – Reference Value

Δ% = (Δ / Reference Value) × 100

In order to use the deviation feature, you must key in a reference value and place the instrument in the deviation display mode.

Example: Assume that you wish to display the deviation and percent deviation of the value of a nominal 1kΩ resistor from a 1kΩ reference value. The steps below describe the process of setting up the instrument and displaying deviation values.

Step 1: Configure the Instrument for Measurement

1. Return the instrument to default operating modes by turning the power off for three seconds and then turning the instrument back on. Allow the instrument to go through its power-up self-test before proceeding.
2. Since deviation cannot be measured while the automatic function is enabled (AUTO display indicator lamp on), disable the AUTO function by repeatedly pressing the [A] DISPLAY key until only the R function is selected (R indicator lamp on, AUTO indicator lamp off).

Step 2: Define the Reference Value

1. Repeatedly press and release the SET UP key until the REF indicator (labelled in blue) blinks. The current reference value will appear on the [B] DISPLAY.
2. Using the data entry keys, enter the reference value of 1k in one of the following two ways:
   A. Using the numeric entry keys (labelled in blue), press 1, 0, 0, 0 in that order, then press the ENTER key.
   B. Press the 1 key, then press the EXP key (labelled in green). Notice that all the exponent symbols turn on. To select the 10^3 (kilo) exponent, press the k key (labelled in green). Only the k exponent symbol will remain on. With 1k displayed, press ENTER.
3. Exit from the setup mode by pressing the EXIT key.

Step 3: Measure the DUT

1. Connect the 1kΩ resistor to the instrument.
2. Note the measured value of the resistor on the [A] DISPLAY.

Step 4: Display Deviation

1. To display the deviation (Δ) between the measured value of the 1kΩ resistor and the 1kΩ reference value, use the Δ/Δ%/BIN key to select the following indicator LED combination:

   Δ display indicator on
   BIN display indicator off
   % display indicator off

   Note: The % indicator is located to the right of the [A] DISPLAY above the exponent symbol indicators.

   Example: If the measured resistor value is 1.0059kΩ, the deviation (Δ) reading will be 0.0059kΩ (1.0059 – 1000).

2. To display the percent deviation (Δ%) between the measured value and the reference value, use the Δ/Δ%/BIN key to select the following indicator LED combination:

   Δ display indicator on
   % display indicator on
   BIN display indicator off

   Example: If the measured reading of the resistor is 1.0059kΩ, the deviation reading in percent (Δ%) will be 0.59% ([0.0059 / 1] × 100).

3. When you are finished measuring deviation, repeatedly press the Δ/Δ%/BIN key until the Δ, % and BIN indicators are all off.

2.5 COMPARATOR OPERATION

The comparator allows DUTs to be compared to defined reading limits and classified into one of up to 20 categories (bins). Upper and lower limits can be set for each of the 20 bins. (The comparator can also be used in conjunction with the material handler interface and external equipment to sort parts automatically; see paragraph 3.17 in Section 3 for details.)

Example:

Comparator operation can be demonstrated by configuring the instrument to accomplish the following task: Assume that you have a mixed batch of 1kΩ, 2kΩ and 3kΩ resistors. A resistor is considered "good" if its measured value is within a tolerance of ±1%. A resistor is "bad" if it is not within ±1% tolerance. It is your job to sort the resistors as follows:

1. Place "good" 1kΩ resistors in Bin 1.
2. Place "good" 2kΩ resistors in Bin 2.
3. Place "good" 3kΩ resistors in Bin 3.
4. Place all "bad" (out-of-tolerance) resistors in Bin 0.

Procedure:

Step 1: Configure the Instrument for Measurement

1. Briefly turn the instrument power off and then back on again. Allow the instrument to complete its power-up sequence before proceeding.
2. Since the comparator (BIN) cannot be used while the automatic function is enabled (AUTO display indicator lamp on), disable the AUTO function by repeatedly pressing and releasing the [A] DISPLAY key until only the R function is selected (R indicator lamp on, AUTO indicator lamp off).

Step 2: Define Comparator Limits

1. Repeatedly press and release the SET UP key until the BIN indicator (labelled in blue) blinks. A zero (Bin 0) will appear on the [B] DISPLAY.

NOTE

On power-up, the upper and lower limits for all bins are set to zero. Since these Bin 0 upper and lower limits are satisfactory for this example, it is not necessary to set limits for Bin 0 in this case. All "bad" resistors are to be assigned to Bin 0, so Bin 0 limits need not be defined for this example.

2. Select Bin 1 by pressing the 1 and ENTER keys in that order.
3. Press the NEXT key to select LOWER; the LOWER indicator will blink. At this point, the present lower and upper limits for Bin 1 will be displayed. Verify that both limits are .0000.

NOTE

The following steps require data entry. Use the CE key to clear any invalid entries.

4. Since Bin 1 is to be used for "good" 1kΩ resistors, the lower limit for this bin is 990 (99% of 1000). Using the number keys, key in 9, 9, 0 in that order, then press the ENTER key. UPPER will then be selected as indicated by the blinking UPPER indicator.
5. Since the upper limit for Bin 1 is 1010 (101% of 1000), key in 1, 0, 1, 0, then press ENTER. Note that the instrument will convert units to kΩ and display the k exponent symbol.
6. Press the NEXT key. BIN will again be selected, and Bin 2 will be displayed.
7. Press the NEXT key to select LOWER.
8. Bin 2 is used for "good" 2kΩ resistors, so the lower limit for Bin 2 is 1980 (99% of 2000). Key in 1, 9, 8, 0, then press ENTER. UPPER will then be selected, as indicated by the flashing UPPER LED.
9. Since the upper limit for Bin 2 is 2020 (101% of 2000), key in 2, 0, 2, 0, and then press ENTER.
10. Select Bin 3 by pressing NEXT.
11. Press NEXT to select LOWER.
12. Since Bin 3 is used for "good" 3kΩ resistors, the lower limit for Bin 3 is 2970 (99% of 3000). Key in 2, 9, 7, 0, then press ENTER. UPPER will then be selected.
13. The upper limit for Bin 3 is 3030 (101% of 3000), so key in 3, 0, 3, 0, and press ENTER.

NOTE

Bins 4 through 19 are not used for this example. Since the limits for Bin 4 are set to zero, Bins 4 through 19 are considered closed and are effectively removed from the test system. As explained in paragraph 3.7, Bin 0 is a special-case bin used to identify those parts that are not within the limits of active bins.

14. Press EXIT to return the instrument to the normal measurement state.

Step 3: Enable Comparator (BIN)

To enable the comparator, use the Δ/Δ%/BIN key to select the following combination:

BIN display indicator on
Δ display indicator off
% display indicator off

Step 4: Connect DUTs for Sorting

1. Connect the first DUT to the instrument.
2. The [A] DISPLAY will show the bin number that the resistor is assigned to based on its value and the programmed limits for Bins 1 through 3 (1kΩ, ±1%; 2kΩ, ±1%; 3kΩ, ±1%). Any resistor that is not within the 1% tolerance limits for Bins 1 through 3 is assigned to Bin 0 and is considered to be "bad".
3. Repeat steps 1 and 2 for all DUTs to be sorted.
4. To cancel the comparator mode, press Δ/Δ%/BIN repeatedly until the Δ, % and BIN indicator lamps are all off.

NOTE
The comparator can also be used with deviation to compare deviation readings. See Section 3 for details.

SECTION 3
Operation

3.1 INTRODUCTION

This section describes Model 3330 front panel operation in detail. For information on operating the instrument over the GPIB (IEEE-488) bus, refer to Section 4.

3.2 FRONT AND REAR PANEL FAMILIARIZATION

The following paragraphs describe the controls, indicators, and connectors on the front and rear panels of the instrument, which are shown in Figures 3-1 and 3-2.

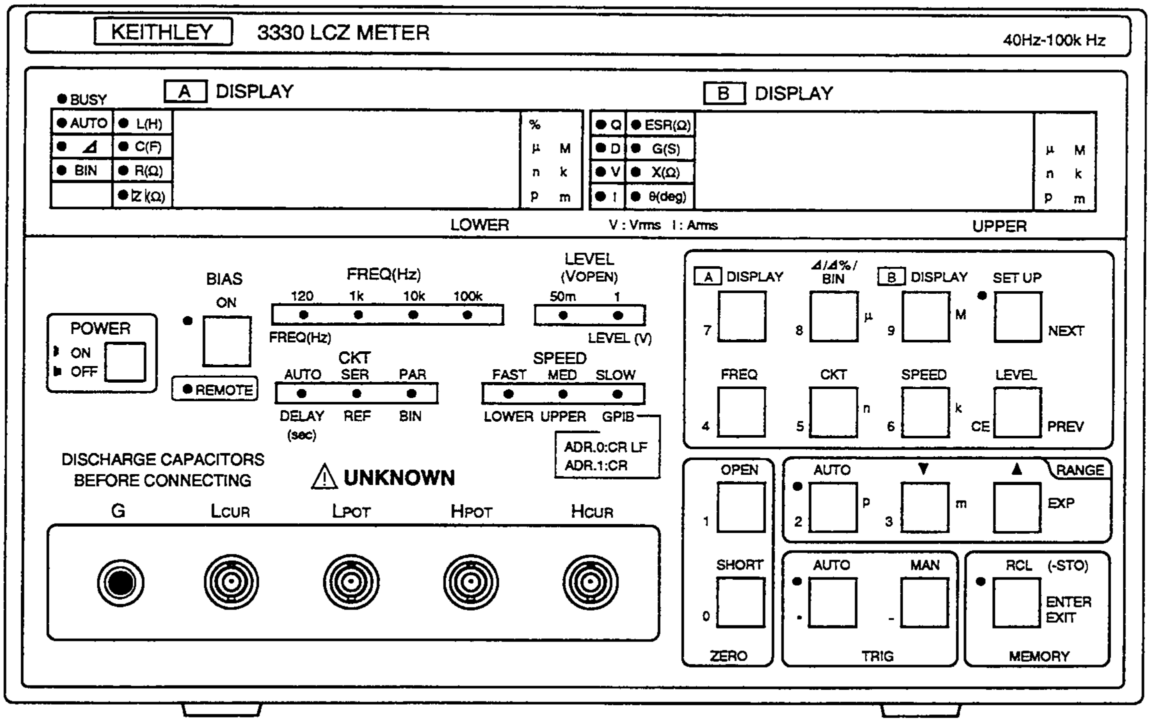


Figure 3-1. Model 3330 Front Panel

3.2.1 Front Panel Description

[A] DISPLAY / [B] DISPLAY — These two 4 1/2-digit displays are used primarily to display the measurement for the selected function and function parameter. The selected function and function parameter are indicated by LEDs to the left of the two displays. The LEDs to the right of the displays indicate the magnitude of the reading using exponent symbols (μ, n, p, M, etc.).

[A] DISPLAY Function Indicators — These indicators denote the selected function:

AUTO — The Model 3330 selects [A] DISPLAY, [B] DISPLAY, and equivalent circuit parameters automatically.

L — Self inductance (H)

C — Electrostatic capacity (F)

R — Resistance (Ω)

|Z| — Impedance (Ω)

Δ — Deviation or % deviation; % deviation is denoted by the % indicator located to the right of the displayed reading.

BIN — Comparator (for parts sorting) enabled.

NOTE: The values of L, C, and R change according to whether the equivalent circuit is in series or parallel mode.

[B] DISPLAY Function Parameter Indicators — These indicators denote the selected function parameter:

Q — Quality factor

D — Dissipation factor (D = 1/Q)

V — Voltage across DUT (rms)

I — Current through DUT (rms)

ESR — Equivalent series resistance

G — Parallel conductance

X — Series reactance

θ — Phase angle of impedance

Exponent Indicators (both displays) — The following exponent indicators are used to denote the magnitude of the reading:

M = mega = 10^6	m = milli = 10^{-3}	n = nano = 10^{-9}
k = kilo = 10^3	μ = micro = 10^{-6}	p = pico = 10^{-12}

Front Panel Indicators:

BUSY — Measurement Indicator Lamp. This lamp indicates that a measurement is being made. This lamp is off while OPEN or SHORT correction is being performed.

BIAS ON — Bias on Indicator Lamp. This indicator turns on when the internal or external voltage bias source is turned on with the BIAS ON key. Note that the bias can be turned on only when the unit is not in the AUTO function while measuring capacitance.

REMOTE — Remote Indicator Lamp. This lamp is on when the GPIB interface is in the remote state. While the unit is in remote, the front panel controls are disabled (except for clearing error messages).

FREQ (Hz) — Measurement Frequency Indicator Lamps. Denotes the frequency (120Hz, 1kHz, 10kHz or 100kHz) that was selected using the FREQ key. If all these lamps are off, an alternate frequency is selected. To check the frequency selection, press the SET UP key. The frequency will be displayed on the [B] DISPLAY. To return to the normal measurement state, press the EXIT key.

CKT — Equivalent Circuit Indicator Lamps. Denote the equivalent circuit that was selected using the CKT key.

AUTO Automatic selection mode; SER or PAR automatically selected.

SER Series equivalent circuit.

PAR Parallel equivalent circuit.

NOTE: CKT selections affect only readings on the [A] DISPLAY.

SPEED — Measurement Speed Indicator Lamps. Denote the measurement speed that was selected by the SPEED key.

FAST High speed (about 60 to 80msec). Basic accuracy is reduced when using this speed.

MED Medium speed (about 150 to 245msec). Standard speed.

SLOW Slow speed (about 480 to 600msec). Use this speed when measured values are erratic (noisy).

LEVEL — Measurement Signal Level Indicator Lamps. Denotes the level of the measurement signal that was selected using the LEVEL key.

50m 50mV rms signal level. Basic accuracy is lower when using this level.

1 Standard 1V rms signal level.

In addition to these two fixed levels, you can also program a level between 10mV rms and 1.1V rms by using the SET UP key. Refer to paragraph 3.8 for details.

NOTE: The indicated signal level is the rms voltage applied at the output under open-circuit (no-load) conditions. The output resistance of the signal source is approximately 100Ω. Device loading can cause the signal level to drop below the indicated voltage level. You can monitor the voltage across the DUT by selecting the V mode on the [B] DISPLAY.

Front Panel Controls:

POWER ON-OFF — Power Switch. The "in" position indicates power on and the "out" position indicates power off. After turning power off, wait at least three seconds before turning it back on.

BIAS ON — Bias On/Off Key. Pressing this key enables the internal 2V bias power supply. Pressing the key a second time disables the bias supply. With the rear panel BIAS INT/EXT switch set to the EXT position, the BIAS ON key will instead control the externally applied bias voltage. See paragraph 3.14 for more details.

NOTE

The bias supply can be enabled only with the C (capacitance) function selected and the AUTO function ([A] DISPLAY) disabled.

[A] DISPLAY — Function Selection Key. Use this key to select the desired function (AUTO, L, C, R or Z). The function indicators to the left of the [A] DISPLAY denote the selected function. While in the AUTO function, the unit automatically determines the type of device connected to the instrument and selects the appropriate function accordingly.

While in AUTO, the following conditions apply:

1. The [B] DISPLAY function parameter is automatically selected. Pressing the [B] DISPLAY key while in AUTO will result in an "Err 13" display.
2. AUTO CKT is enabled, and the appropriate equivalent circuit is selected. Pressing the CKT key will result in "Err 13".
3. Δ (deviation) and BIN cannot be selected. Pressing the Δ/Δ%/ BIN key will result in "Err 13". If Δ or BIN is enabled, selecting AUTO will disable Δ and BIN.

[B] DISPLAY — Function Parameter Selection Key. Use this key to select the desired function parameter (Q, D, ESR, G, X, θ, V, or I). The indicator lights denoting the selected function parameter are located to the left of the [B] DISPLAY. If the AUTO function is selected (AUTO indicator for [A] DISPLAY turned on), pressing the [B] DISPLAY will result in "Err 13".

Δ/Δ%/ BIN — Deviation (Δ and Δ%) and BIN Selection Key. This key is used to enable one or more of these operations. The selected operation(s) are denoted by the [A] DISPLAY indicator lamps. Operations that can be selected include:

Δ   Δ%   BIN   Δ BIN   Δ% BIN

Pressing the Δ/Δ%/BIN key with Δ% and BIN selected will disable all these functions. Paragraphs 3.6 and 3.7 cover deviation and comparator (bin) operations in more detail.

NOTE: Pressing the Δ/Δ%/BIN key while in the AUTO function (AUTO indicator lamp for [A] DISPLAY turned on) will result in "Err 13".

CKT — Equivalent Circuit Selection Key. This key is used to select the equivalent circuit. The selected circuit is denoted by the CKT indicator lamps. Equivalent circuit selections include:

AUTO   SER   PAR

In the AUTO mode, SER (series) or PAR (parallel) is automatically selected.

NOTE: Pressing the CKT key while in AUTO function (AUTO indicator lamp for [A] DISPLAY turned on) will result in "Err 13".

See paragraph 3.5 for details on equivalent circuits.

FREQ — Measurement Frequency Selection Key. This key is used to select the frequency of the measurement signal. The selected frequency is denoted by the FREQ indicator lamps. Frequency selections include:

120Hz   1kHz   10kHz   100kHz

Refer to paragraph 3.8 for information on setting alternate frequencies.

SPEED — Measurement Speed Selection Key. This key is used to select instrument measurement speed. The selected speed is denoted by the SPEED indicator lamps. Speed selections include:

FAST (60msec/reading)
MED (150msec/reading)
SLOW (480msec/reading)

Refer to paragraph 3.11 for more information on measurement speed.

LEVEL — Measurement Signal Level Selection Key. This key is used to select the level of the measurement signal. The selected level is denoted by the LEVEL indicator lamps. Level selections include:

50mV rms   1V rms

NOTE: The indicated signal level is the rms voltage applied at the output under open-circuit (no-load) conditions. The output resistance of the signal source is approximately 100Ω. Device loading can cause the signal level to drop below the indicated voltage level.

You can also set the level to values from 10mV rms to 1.1V rms by using the SET UP key. See paragraph 3.8 for more information.

SET UP — Auxiliary SET UP Key. This key is used to enable the auxiliary SET UP mode. In this mode, parameter values can be checked or changed to alternate values. While the unit is in the SET UP mode, front panel keys assume functions indicated by blue and green labeling.

When SET UP is pressed, the SET UP mode is enabled and the indicator lamp adjacent to the key turns on. The parameter to be checked or changed is denoted by the blinking indicator lamp. The current value of the selected parameter is displayed on the [A] DISPLAY or the [B] DISPLAY.

The following keys are associated with SET UP operation:

NEXT — Each press of this key enables the next SET UP parameter. In general, parameter selections move from left-to-right (as indicated by the blinking lamp) on the front panel with each key press. The eight SET UP parameters that can be selected are as follows:

FREQ DELAY REF BIN LOWER UPPER GPIB LEVEL

PREV — Each press of this key selects the previous parameter. This key operates similarly to the NEXT key, except that, in general, selections move from right-to-left.

Data Entry Keys — These keys are used to enter new parameter values while in the SET UP mode. The keys associated with numeric entry include:

0 to 9	—	Number keys
"."	—	Decimal point key
"–"	—	Sign key. Toggles between plus and minus polarity. Plus is implied by the absence of the "–" sign.

If an exponent (see EXP) is not required to input a parameter value, simply input a valid numeric value, and press ENTER (see ENTER).

EXP — Exponent Input Key. Use this key to enter the exponent part of a parameter value. When this key is first pressed, all the exponent indicator lamps for the [A] or [B] DISPLAY turn on. To select an exponent, press the desired exponent key (μ, M, n, k, p, m). Only the indicator for the selected exponent will remain lit. The pending parameter value can be entered by pressing ENTER (see ENTER key) or cancelled by pressing CE (see CE key).

CE — Cancel Entry Key. Use this key to cancel a pending parameter value. A blinking least significant digit identifies a pending value. Pressing the CE key will cancel the displayed pending value and default to the previously entered value.

ENTER/EXIT — Enter and Exit Key. Use this key to enter a pending parameter value, or to exit SET UP without changing the previous parameter value. If the displayed value is pending (least significant digit blinking), this key functions as an ENTER key. Otherwise, pressing EXIT cancels the SET UP mode.

Trying to enter an invalid parameter value will result in "Err 12". Pressing any front panel key will display the previously entered value.

ZERO — Zero Correction Keys. Performing zero correction measures residual impedance and stray admittance, and then automatically corrects the displayed reading for these errors. The following keys are used to perform zero correction:

OPEN — Open the input terminals, and press OPEN to perform zero correction.

SHORT — Short the input terminals, and press SHORT to perform zero correction.

See paragraph 3.15 for additional zero correction information.

TRIG — Trigger Control Keys. The following two keys are used to control triggering:

AUTO — Auto Trigger Key. This key toggles between automatic triggering and manual triggering. In AUTO trigger, measurements are made continuously at an interval determined by the selected SPEED. AUTO trigger is denoted by the indicator lamp adjacent to the key.

MAN — Manual Trigger Key. In MAN trigger, each press of the MAN key triggers a single measurement. Prior to each actual measurement, the instrument waits for the specified DELAY period.

RCL (–STO) — Memory Key. This key is used to store the current instrument setup in memory, or to recall one of ten setups previously stored in memory. To store the current setup in memory, first press the (–STO) key, then press the sign (–) key. Assign a memory location by pressing a number key (1 to 9), then press ENTER.

To configure the instrument with a setup previously stored in memory, first press the RCL key, press a number key (0 to 9) that corresponds to the memory location where the setup is stored, and then press ENTER.

When the instrument is turned off, the current instrument setup is automatically stored in memory location 0.

RANGE — Measurement Range Selection Keys. The following keys are used to select the measurement range of the instrument:

AUTO — Auto Range Selection Key. This key toggles between auto ranging and manual ranging. Selecting AUTO range turns on the AUTO indicator lamp and automatically selects the most optimum range to make the measurement. Use AUTO range for most measuring situations except as noted below.

▼ (Down-range) — Each press of this key selects the next lower measurement range.

▲ (Up-range) — Each press of this key selects the next higher measurement range.

Note that manually selecting an invalid range will result in an error message. See paragraph 3.16 for a description of error messages.

NOTES:

1. Manual ranging should be used when measuring small changes in component values or when comparing parts with essentially the same values.
2. When using AUTO range, the effects of noise could cause inadvertent range changes. Use manual ranging in this situation.

Measurement Terminals:

UNKNOWN — The following front panel connectors are used to connect the DUT to the instrument:

G — Ground terminal that is connected to the chassis of the instrument. G is generally used for shielding.

L CUR — Detects the current through the DUT

L POT — Voltage detection terminal (Low)

H POT — Voltage detection terminal (High)

H CUR — Applies the drive signal to the DUT

L CUR and L POT are connected to one DUT terminal, and H CUR and H POT are connected to the other DUT terminal. Thus, the bias voltage and the drive signal can be monitored between the H and L terminals.

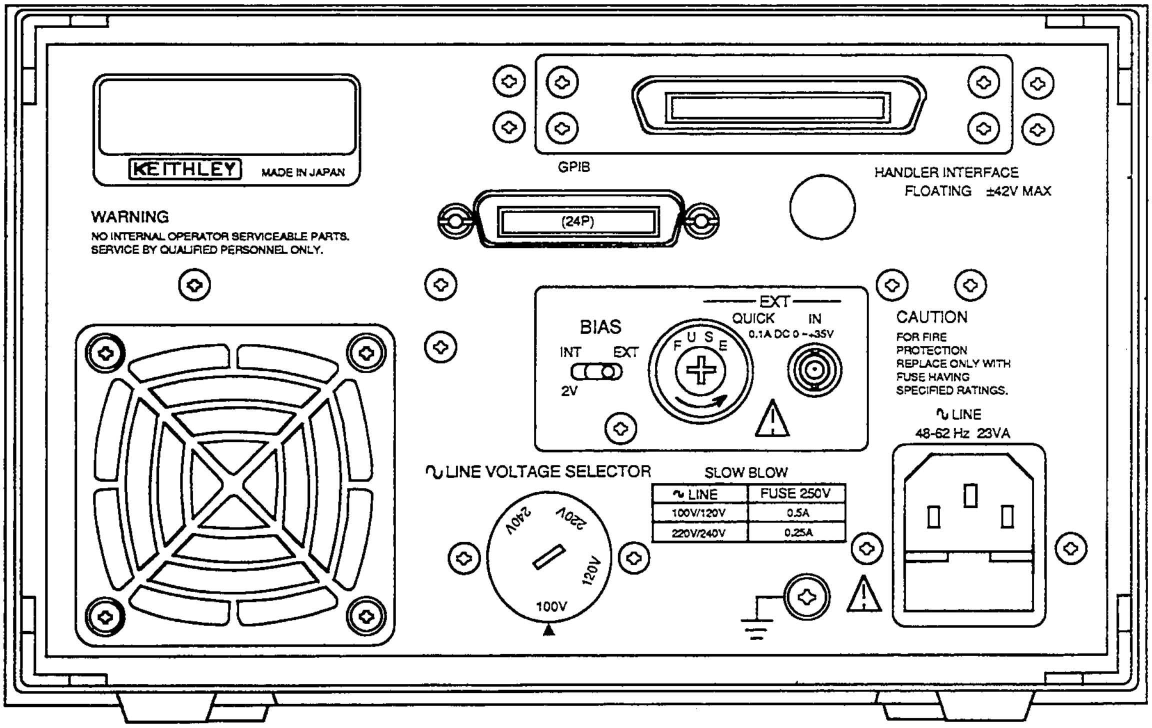


Figure 3-2. Model 3330 Rear Panel

3.2.2 Rear Panel

Figure 3-2 shows the rear panel of the Model 3330.

HANDLER INTERFACE — This 36-pin connector is used to connect a user-supplied material handler to the instrument. The material handler can be used in conjunction with the comparator to sort parts automatically. Refer to paragraph 3.17 for details on the handler interface. Paragraph 3.7 describes comparator operation.

WARNING
Maximum voltage between HANDLER INTERFACE connector ground terminals and chassis ground is ±42V. Exceeding this level may create a shock hazard.

GPIB — GPIB Connector. This connector is used to connect the GPIB (IEEE-488) interface of the instrument to GPIB interface of a computer. See Section 4 for details.

BIAS — The switch, fuse, and input connector described below pertain to the use of an external bias supply:

INT/EXT Switch — This toggle switch is used to switch between the built-in (INT) bias power supply (2VDC) and the externally applied (EXT) bias supply (0 to ±35VDC).

Fuse — External bias fuse, which protects the external bias input (0.1A quick acting type, 250V, 5mm x 20mm).

CAUTION
Replace the fuse only with the recommended type. Using the wrong fuse may result in instrument damage.

IN Connector — BNC connector used to connect the external bias supply to the instrument. Use a 0 to ±35V supply with low ripple and noise.

CAUTION
The maximum voltage that can be applied to the BIAS IN connector is ±35VDC. Voltages

outside this range may blow the fuse and cause damage to the instrument.

Ventilation Fan — The fan is used to cool internal parts. The fan pulls cool air into the instrument and exhausts warm air out the vents in the top cover. For proper ventilation:

1. Maintain at least four inches between the rear panel and a wall.
2. Do not block the air vents in the top cover.
3. Clean the air filter periodically to prevent clogging. Figure 3-3 shows how to remove the filter for cleaning. Soak the filter in a solution of mild detergent and water to clean it. Rinse the filter element then allow it to dry thoroughly before installation.

WARNING
Be sure to turn off the power and remove the power cord before removing or installing the filter.

LINE VOLTAGE SELECTOR — Line Voltage Selection Switch. Set this switch to the available line voltage. Changing the line voltage setting will require a fuse change. See paragraph 3.3.2 for details.

CAUTION
To prevent damage to the instrument that may not be covered by the warranty, be sure to turn off power and disconnect the line cord before changing the line voltage setting. Do not use a fuse other the one specified for the line voltage setting.

Safety Ground Terminal ⏚ — If the instrument is not connected to a safety earth ground through the supplied 3-wire line cord, connect this terminal to a known safety earth ground using #18 AWG (or larger) wire.

LINE — Power Receptacle and Fuse. Use the supplied line cord to connect the instrument to the line power. Fuse replacement is covered in paragraph 3.3.2.

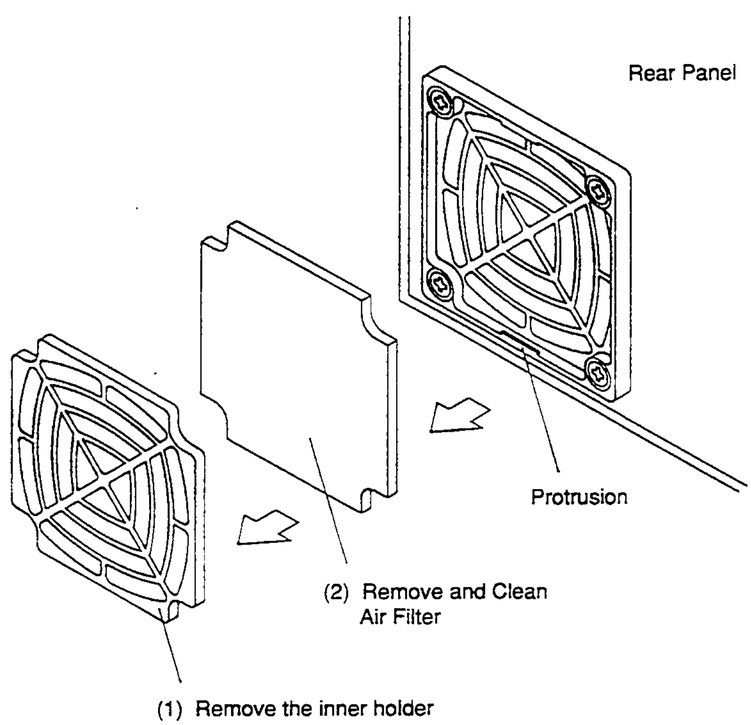


Figure 3-3. Cleaning Air Filter

3.3 POWER-UP PROCEDURE

3.3.1 Line Voltage Setting

The Model 3330 is designed to operate from 90-132V or 198-250V line power ranges at 48 to 62Hz. Perform the following procedure to set the line voltage:

WARNING
Disconnect the instrument from the power line and all other equipment before changing the LINE VOLTAGE SELECTOR switch setting.

1. Check the setting of the LINE VOLTAGE SELECTOR switch on the rear panel. To change the setting, use a flat-blade screw driver to set the rotary switch to the setting that best matches the available line power.

CAUTION
Operating the instrument on an incorrect line voltage may result in damage not covered by the warranty.

2. If the switch setting was changed, install a fuse consistent with the operating voltage as described in the next paragraph.

3.3.2 Fuse Replacement

A rear panel fuse located inside the LINE receptacle is used to protect the power line input of the instrument. If the fuse must be replaced (line voltage switch setting changed or blown fuse), perform the following steps:

WARNING
Make sure the instrument is disconnected from the power line and other equipment before replacing the fuse.

1. Using a flat-blade screwdriver, pry open the fuse drawer as shown in Figure 3-4.
2. Remove the fuse from the fuse clip. Notice that there is a spare fuse in the holder.
3. Replace the fuse with the following type:

Line Voltage Setting	Fuse Type
100V, 120V	0.5A, 250V, 5 × 20mm, Slow Blow
220V, 240V	0.25A, 250V, 5 × 20mm, Slow Blow

CAUTION
Do not install a fuse with a higher current rating than specified, or instrument damage may occur.

4. Push the fuse drawer back into the receptacle.

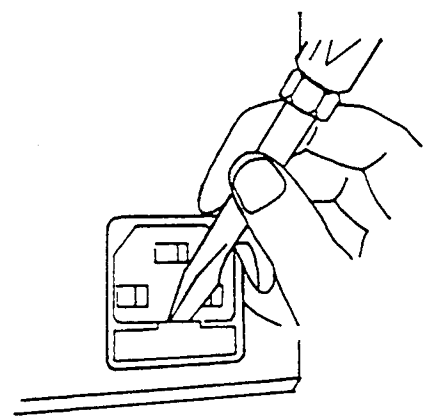


Figure 3-4. Fuse Replacement

3.3.3 Power Cord

Connect the female end of the power cord to the AC receptacle on the rear panel of the instrument. Connect the male end of the cord to a grounded AC outlet.

WARNING
The instrument is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with grounded outlets. When proper connections are made, instrument chassis is connected to the power line ground. If the AC outlet is not grounded, the rear panel safety earth ground terminal must be connected to a known safety earth ground using #18 AWG (or larger) wire.

CAUTION

Be sure that the power line voltage agrees with the indicated voltage of the LINE SUPPLY switch. Failure to observe this precaution may result in instrument damage not covered by the warranty.

3.3.4 Power Up Sequence

To turn on the instrument, press the POWER button. During the power up cycle, the unit will perform the following:

1. All indicator lamps and display segments will turn on for a few seconds. This display allows you to check for defective LEDs or display digits.
2. The revision level of the firmware is displayed briefly on the [A] DISPLAY. For example:

   – 1.10 –

   (Note that the firmware revision level of your unit may be different.)
3. The self-check on memory elements and self-calibration of internal circuits are performed. During this period, the "CAL" message will be displayed on the [A] DISPLAY, and a countdown from 18 to 0 will take place on the [B] DISPLAY. Any errors that occur are indicated by error messages on the display. Paragraph 3.16 explains error messages.
4. The unit will begin normal operation with the power-up defaults discussed in the next paragraph. The displays will remain blank until the first readings are available.

3.3.5 Default Conditions

Default conditions are the setup conditions that the instrument will assume when the instrument is powered up (or when a DCL or SDC command is sent over the GPIB). The default conditions for the instrument are summarized in Table 3-1.

Table 3-1. Power-up Defaults

Parameter	Setting	Comment
[A] DISPLAY	AUTO	
[B] DISPLAY	(AUTO)	
Δ, Δ%, BIN	Disabled	
CKT	AUTO	
FREQ	1kHz	
DELAY	0.00	
REF	.0000	
Bin no.	0	1,3
UPPER	.0000 (all bins)	
LOWER	.0000 (all bins)	
LEVEL	1Vrms	
SPEED	MED	
TRIG	AUTO	
RANGE	AUTO	
Zero correction	No correction	1,4
BIAS	Off	1
Header output	Inhibit (GPIB "HD 0")	1
SRQ output	Inhibit (GPIB "RQ 0")	1
Primary address	2	1,2
Delimiter	<CR><LF>	1,2
Talk only	Cancelled	1,4

Comments:

1. The setting for this parameter cannot be saved in one of the 10 battery backed-up memories. The settings for all other parameters can be returned to power-up defaults by recalling memory location 0 (RCL 0).
2. The settings for these parameters are stored in battery backup-up memory, and they automatically return to the last programmed value on power-up.
3. Whenever a setup configuration is recalled, the current bin location resets to 0.
4. If the power is turned on when the LOCK signal of the handler interface is active (low level), memory 0 is recalled and the unit returns to the state prior to power down. At this time, previous zero correction values are recalled, and talk-only operation is placed into effect.

3.3.6 Backup Battery Check

An internal battery backs up calibration data and setup memories. Memory is automatically tested upon power-up.

Calibration Data

Calibration data is stored in battery backed up memory. If calibration constants are corrupted, an "EEEEE 22222" message is displayed, and the unit must be calibrated before it can be used.

Memory Failure During Power-up

If a memory error is detected during power-up, an "Err 21" message will be displayed. The primary address will default to 2, and the delimiter will default to <CR> <LF>.

Setup Memory

The unit checks the contents of the 10 setting memories. If an error is detected, default settings are used, and the unit displays an error which cannot be cancelled.

3.4 TEST CONNECTIONS

In general, 4-wire measurements are made on the device under test using the front panel UNKNOWN BNC terminals. A test fixture (such as the Model 3323 which connects directly to the front panel) or test cables can be used to make connections to the DUT.

3.4.1 UNKNOWN Terminals

The UNKNOWN terminals include:

G — Ground terminal for guard that should be used to shield the DUT.

L CUR — Current detection terminal that senses the current through the DUT.

L POT — Voltage detection terminal (Low).

H POT — Voltage detection terminal (High).

H CUR — Drive signal output terminal that delivers the DC bias and the sine wave test signal to the DUT.

3.4.2 Cable Connections

Refer to Figure 3-5 and Figure 3-6, and use the following rules to connect cables:

- Maintain 4-wire connections through to the device under test.
- Use coaxial cables, and bundle the cables as shown in Figure 3-6(a). Twist the two voltage cables together, then twist the two current cables together. Finally, twist the two separate cable pairs together to form one twisted cable assembly.
- Connect the voltage detection terminals (H POT and L POT) to the inner position on the DUT leads as shown in the illustration.
- Keep cables as short as possible.
- At the DUT, connect the shields of the BNC cables together.

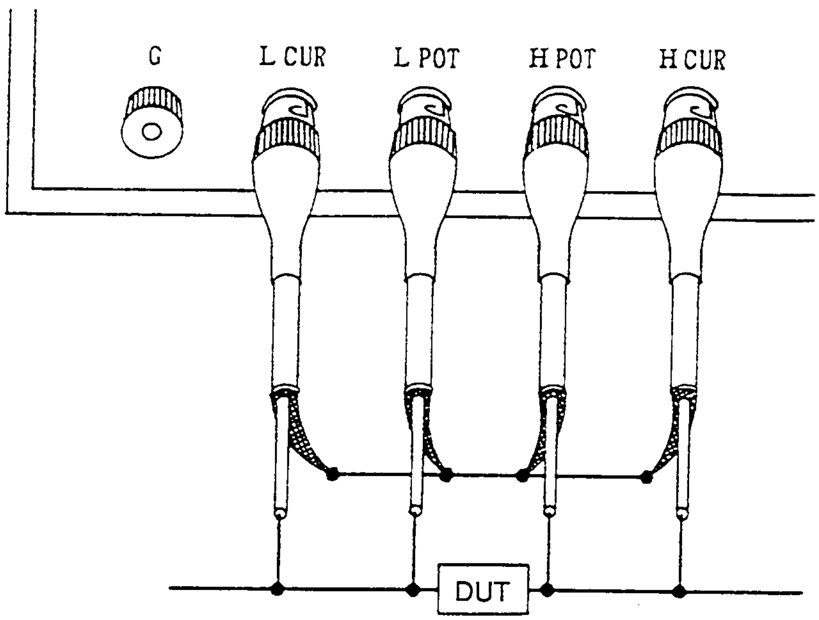


Figure 3-5. Connection to Device Under Test

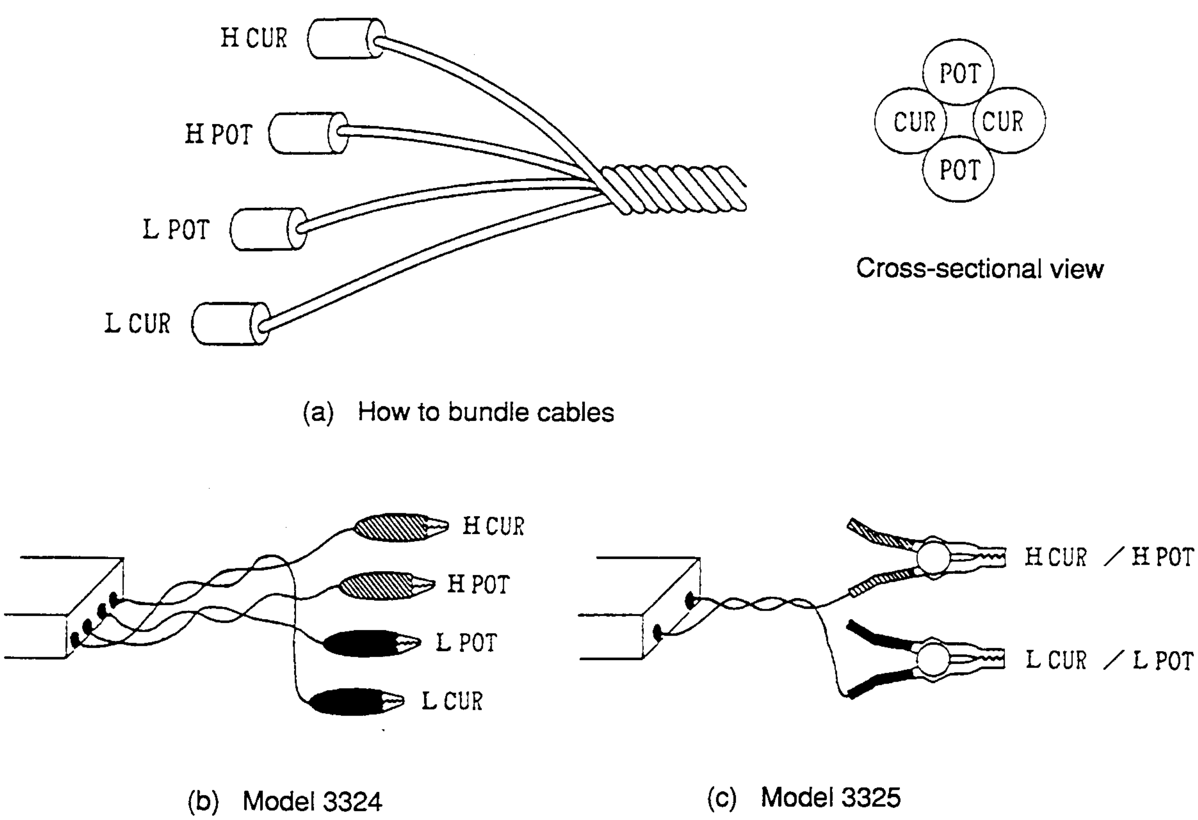


Figure 3-6. Test Cables and Leads

3.4.3 Using Test Leads

Low Impedance Measurements

Model 3324 4-Terminal Alligator Clip Test Leads: If possible, twist the two current leads and the two voltage leads separately as shown in Figure 3-6(b).

Model 3325 Kelvin Clip Test Leads: If possible twist the two leads together as shown in Figure 3-6(c).

High Impedance Measurements

When measuring high impedances, use cables that are shielded all the way to the test clips. Doing so will minimize stray capacitance between the H and L terminals. The Models 3324 and 3325 test leads are properly shielded for this application.

3.4.4 Minimizing Cable and Test Lead Errors

To minimize errors caused by cables or test leads, perform OPEN and SHORT zero correction procedures under conditions that are similar to the actual measurement condition. Leave the cables connected to the instrument, and the open or short the ends of the cables or test leads as appropriate. (When performing the ZERO OPEN procedure, the two L terminals should be connected together, and the two H terminals should be connected together. When performing ZERO SHORT, all four terminals should be connected together.) See paragraph 3.16 for more information on zero correction.

3.4.5 Additional Cable and Test Lead Errors

Accuracy specifications are based on making measurements without using cables or test leads (for example, when using the Model 3323 Direct Test Fixture). If you are using cables or test leads to connect the DUT to the instrument, additional error caused by stray capacitance and voltage drop is introduced into measurements.

High-impedance Errors

The additional errors caused by test cable capacitance when making high-impedance measurements are summarized in Table 3-2.

Table 3-2. Additional Error in |Z| Caused by Test Cables

	Additional Percent Error at Given Frequency				
Impedance	5kHz	10kHz	20kHz	50kHz	100kHz
1kΩ	–	–	–	0.05%	0.2%
10kΩ	–	0.02%	0.08%	0.5%	2%
50kΩ	0.05%	0.1%	–	–	–

Low-impedance Errors

Test cables add the following additional error to |Z| measurements of <2Ω:

- 100 to 5kHz: 0.2mΩ
- 10kHz: 0.3mΩ
- 20kHz: 0.4mΩ
- 50kHz: 0.7mΩ
- 100kHz: 1.5mΩ

3.5 BASIC MEASUREMENTS

3.5.1 Measurement Function Selection

Select basic measurement functions with the [A] DISPLAY key. The selected function is indicated by the LEDs located to the left of the [A] DISPLAY. The measured value for the selected function is shown on the [A] DISPLAY, and the exponent indicators for the measured reading are located to the right of the [A] DISPLAY.

Available functions include:

AUTO – Automatic function selection. With AUTO function selected, the instrument will determine the type of device connected to the input and automatically select the appropriate measurement function.

L (H) — Inductance

C (F) — Capacitance

R (Ω) — Resistance

|Z| (Ω) — Magnitude of impedance

To select the desired function, simply press and release the [A] DISPLAY key repeatedly until the desired function indicator turns on.

Automatic Function Selection — When AUTO is enabled, the instrument selects the function, function parameter, and equivalent circuit automatically (see paragraph 3.5.3 for a description of equivalent circuit). It does so by measuring the phase angle (θ) of the DUT connected to the UNKNOWN terminals. Table 3-3 defines the selected function and function parameter based on the internally measured (not displayed) phase angle (θ).

Table 3-3. AUTO Function Selections

Measured Phase Angle (θ)	Function ([A] DISPLAY)	Function Parameter ([B] DISPLAY)
+60° to +90°	L	Q
0°±30°	R	Q
–60° to –90°	C	D
Other than the above	|Z|	θ

While in the AUTO function:

1. Function parameters are automatically selected. Pressing the [B] DISPLAY key will result in "Err 13".
2. The equivalent circuit (CKT) is automatically (AUTO) selected (SER or PAR).
3. Δ, Δ% and BIN are inoperative. Pressing the Δ/Δ%/BIN key will result in "Err 13".

3.5.2 Measurement Function Parameter Selection

The measurement parameter for the selected function is selected using the [B] DISPLAY key. Note however, that if AUTO function is enabled, this key is inoperative (Err 13). In the AUTO function, the measurement parameter is automatically selected.

The selected function parameter is identified by the indicator lamp located to the left of the [B] DISPLAY. The [B] DISPLAY provides the reading of the selected parameter, and the exponent part of the reading is located to the right of the display. The available function parameters include:

Q — Quality factor
D — Dissipation factor (D = 1/Q)
ESR (Ω) — Equivalent series resistance
G (S) — Parallel conductance
X (Ω) — Series reactance
θ (deg.) — Phase angle of impedance
V (volts) — the rms voltage applied to the DUT
I (amps) — the rms current through the DUT

To select the desired function parameter, simply press and release the [B] DISPLAY key repeatedly until the appropriate function parameter indicator lamp turns on. When ESR, X or G is selected, the equivalent series resistance, series reactance or parallel conductance are displayed, respectively. The readings for Q, D, θ, V, and I are not related to the equivalent circuit.

3.5.3 Equivalent Circuit Selection

The equivalent circuit (series or parallel) is selected using the CKT key. Note that if AUTO function is enabled, the CKT key is inoperative (Err 13), and the unit is placed in the AUTO equivalent circuit mode.

The CKT indicator lamps on the front panel denote the selected equivalent circuit. The equivalent circuit (series or parallel as shown in Figure 3-7) affects the measured values of L, C and R on the [A] DISPLAY. The equivalent circuit selections include:

AUTO – Automatic equivalent circuit selection
SER – Series circuit
PAR – Parallel circuit

To select the equivalent circuit (assuming AUTO function is disabled), simply press and release the CKT key repeatedly until the desired indicators turn on.

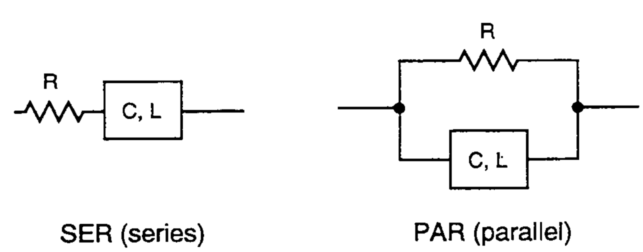


Figure 3-7. Equivalent Circuits of Device Under Test

Table 3-4. Auto Equivalent Circuit Selections

Conditions for selection of series mode (SER)		Conditions for selection of parallel mode (PAR)	
Function	**Function Parameter**	**Function**	**Function Parameter**
L, C, R, |Z|	ESR, X	L, C, R, |Z|	G
L, C (|Z| ≤1kΩ)	Q, D, θ	L, C, (|Z| >1kΩ)	Q, D, θ
R (θ≥0)	Q, D, θ	R (θ<0)	Q, D, θ
|Z|	Q, D, θ		

AUTO Equivalent Circuit

With AUTO CKT enabled, the instrument selects an equivalent circuit automatically, and the selected circuit is determined according to the combination of selected function, function parameter, and phase angle. Table 3-4 summarizes the combinations that determine the equivalent circuit while AUTO CKT is enabled.

Series and Parallel Equivalent Circuits

The circuit model for the SER CKT (series circuit) mode is shown in Figure 3-8(a). The impedance of the circuit is defined as follows:

$$Z = R + jX$$

Here, Z is the impedance, R is the resistance, and X is the capacitive or inductive reactance.

The circuit model for the PAR CKT (parallel circuit) mode is shown in Figure 3-8(b). The admittance of the circuit is:

$$Y = \frac{1}{Z} = G + jB$$

Y is the admittance, G is the conductance, and B is the susceptance.

The net impedance of equivalent series and parallel circuits at a given frequency are identical, but the values of the individual components are not. We can demonstrate this relationship mathematically as follows:

$$G + jB = \frac{1}{R + jX}$$

To eliminate the imaginary term in the denominator of the right-hand term, we can multiply the both the denominator and numerator by the complex conjugate of the denominator as follows:

$$G + jB = \frac{1}{R + jX} \times \frac{R - jX}{R - jX}$$

Performing the multiplication and combining terms, we have:

$$G + jB = \frac{R - jX}{R^2 + X^2}$$

If we assume the reactance is capacitive, we can substitute $-1/\omega C_S$ for the reactance and ωC_P for the susceptance (C_S is the equivalent series capacitance, and C_P is the equivalent parallel capacitance). The above equation then becomes:

$$G + j\omega C_P = \frac{R + j\frac{1}{\omega C_S}}{R^2 + \frac{1}{\omega^2 C_S^2}}$$

In a lossless circuit (R=0, G=∞), C_P and C_S would be equal (as would L_S and L_P, the series and parallel inductance). A practical circuit, however, does have loss because of the finite values of R or G. Thus, C_P and C_S (L_P and L_S) are not equal, and the greater the circuit loss, the large the disparity between the series and parallel values.

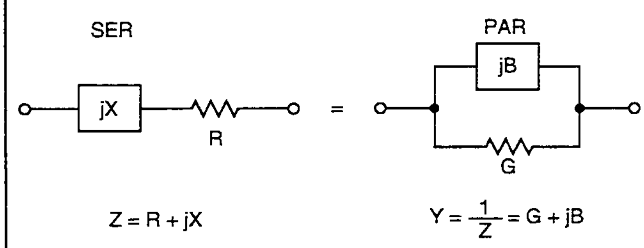


Figure 3-8. Series and Parallel Equivalent Circuits

Series and parallel capacitance and inductance values can be converted to their equivalent forms by taking into account a dissipation factor, D. (D is simply the reciprocal of the circuit Q.) Table 3-5 summarizes dissipation factors and conversion formulas for both capacitive and inductive circuits with parallel and series models.

Table 3-5. Series and Parallel Conversion Factors

Model		Dissipation Factor	Conversion Formulas
C	PAR	$D = \frac{G}{\omega Cp} = \frac{1}{Q}$	$Cs = (1+D^2)\, Cp,\ R = \frac{D^2}{1+D^2} \bullet \frac{1}{G}$
	SER	$D = \omega CsR = \frac{1}{Q}$	$Cp = \frac{1}{1+D^2}\ Cs,\ G = \frac{D^2}{1+D^2} \bullet \frac{1}{R}$
L	PAR	$D = \omega LpG = \frac{1}{Q}$	$Ls = \frac{1}{1+D^2}\ Lp,\ R = \frac{D^2}{1+D^2} \bullet \frac{1}{G}$
	SER	$D = \frac{R}{\omega Ls} = \frac{1}{Q}$	$Lp = (1+D^2)\, Ls,\ G = \frac{D^2}{1+D^2} \bullet \frac{1}{R}$

Optimizing Circuit Selection

For best results, test the DUT using the equivalent circuit specified by the manufacturer. If the equivalent circuit is unknown, use the AUTO mode.

Auto Mode Operation

In auto mode, the rules for selecting SER or PAR with $|Z|$ less than 1kΩ are as follows:

1. Capacitance Measurements
   - When the capacitive reactance is small (capacitance large, frequency high), R_P and R_S affect the measurement, as shown in Figure 3-9(a), and the unit measures in SER mode.
   - When the capacitive reactance is large (capacitance small, frequency low), R_P and R_S affect the measurement as shown in Figure 3-9(b), and the unit measures in PAR mode.
2. Inductance Measurements
   - When the inductive reactance is small (small inductance, low frequency), R_P and R_S affect the measurement as shown in Figure 3-10(a), and the unit measures in SER mode.
   - When the inductive reactance is large (large inductance, high frequency), R_P and R_S affect the measurement as shown in Figure 3-10(b), and the unit measures in PAR mode.

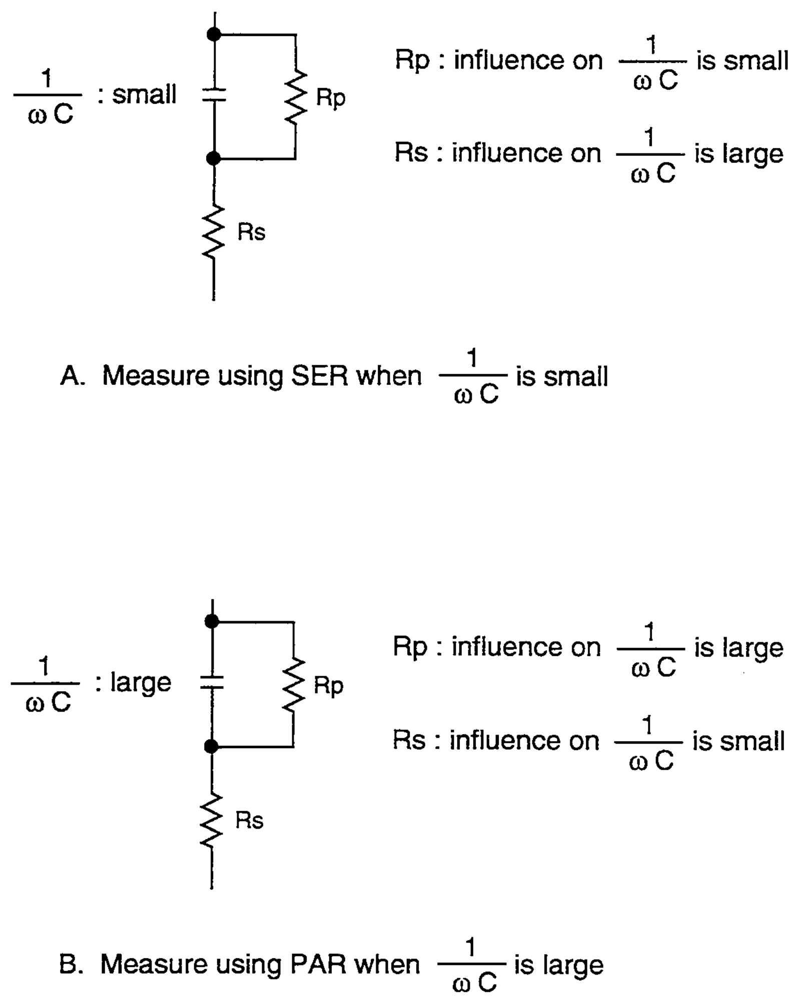
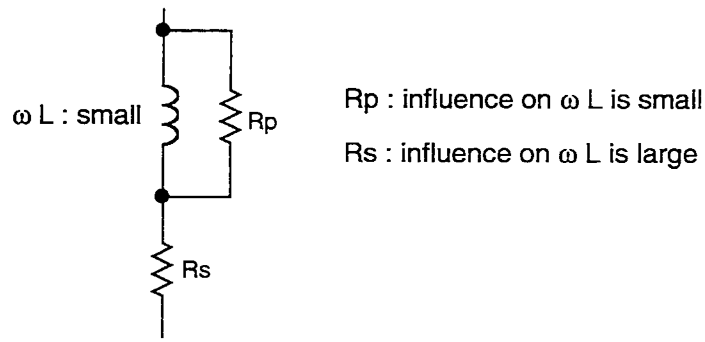
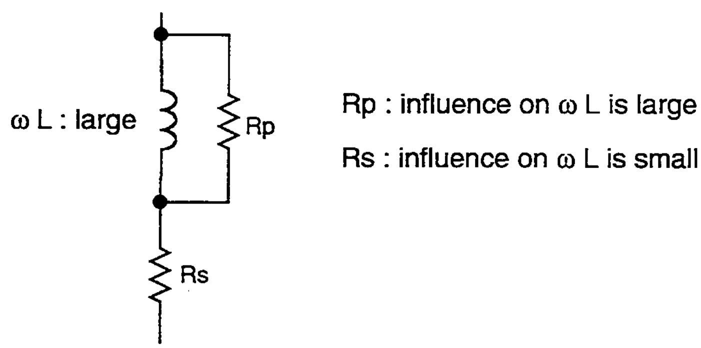


Figure 3-9. Auto Circuit Modes for Capacitance Measurements



A. Measure using SER when ω L is small



B. Measure using PAR when ω L is large

Figure 3-10. Auto Circuit Modes for Inductance Measurements

3.5.4 Measurement Range Selection

The instrument can be set up to select the measurement range for the selected function (A DISPLAY) either automatically or manually. Reading range for the function parameter (B DISPLAY) is always selected automatically.

The following front panel keys are used for range selection:

AUTO — Each press of this key toggles between auto-range (AUTO RANGE indicator lamp on) and manual range.

▼ — Pressing this key disables AUTO range (if enabled) and selects the next lower range.

▲ — Pressing this key disables AUTO range (if enabled) and selects the next higher range.

Selecting AUTO Range

In AUTO range, the instrument will go to the optimum (most accurate) range to make the measurement. To enable auto-range, simply press the AUTO key. The indicator lamp located adjacent to the AUTO key will turn on. To disable auto-range, press AUTO a second time, or press one of the manual range keys (▼ or ▲). The ▼ key down ranges while the ▲ key up ranges.

Impedance Ranges

Table 3-6 lists the impedance ranges for the instrument. Note that the valid measurement range is frequency dependent. The reading limits for each range are defined by the Lower Limit Extension and the Upper Limit Extension. The instrument will not display readings that are outside these limits. For example, trying to measure 100kΩ on Range 2 will cause the "OF" message to be displayed because the largest allowable reading for Range 2 is 11kΩ.

Table 3-6. Impedance Ranges

Frequency	Range	Reference Resistance (Ω)	Measurement Range (Ω) Lower Limit Extension	Lower Limit**	Upper Limit ***	Upper Limit Extension
40Hz	*1	100	—	0	5	11
:	2	100	0.9	5	2k	11k
:	3	1k	980	2k	20k	110k
10kHz	4	10k	9.8k	20k	200k	1.1M
	5	50k	49k	200k	2M	5.5M
	*6	50k	450k	2M	20M	∞
11kHz	*1	100	—	0	5	11
:	2	100	0.9	5	2k	11k
:	3	1k	980	2k	20k	110k
100kHz	4	10k	9.8k	20k	200k	1.1M
	*5	10k	90k	200k	2M	∞
	*6	10k	90k	200k	2M	∞

* Extension range
** Lower Limit values are inclusive
*** Upper Limit values are not inclusive

NOTES:
1. The measurement ranges include DUT impedance, residual impedance, and floating admittance.
2. Ranges 5 and 6 are the same at frequencies above 11kHz.

Display messages that result from exceeding range limits include:

OF (Overflow) – The measured value is greater than the Upper Limit Extension value.

UF (Underflow) – The measured value is less than the Lower Limit Extension value.

OU – The measured value is out of the operating range of measurement circuitry, and the instrument cannot detect an overflow or underflow.

An optimum measurement is performed on the range that is bounded by the Lower Limit and Upper Limit values (see Table 3-6). For example, with a 10kΩ measurement, the most accurate reading will occur on Range 3. While in AUTO range, the instrument will automatically make the measurement utilizing the Lower Limit and Upper Limit range.

When in AUTO range, sufficient noise may prevent the instrument from staying on the optimum range. In this situation, disable AUTO range while on the optimum range. Range changes will not occur when in manual ranging.

AUTO Range Hysteresis

For AUTO ranging, a hysteresis of approximately 10% is used to keep the instrument from changing ranges for a reading that varies along the borderline of two ranges. When a reading is increasing, the instrument will up range immediately after 19,999 counts. For example, on Range 2, assume a reading of 1.9999kΩ. If the reading increases by one count, the instrument up ranges and reads 2.000kΩ on Range 3. When the reading is decreasing, the instrument will down range after 1800 counts. Continuing with the same example, a decreasing reading will read 1.800kΩ on Range 3. When the reading decreases one more count, the instrument will down range to Range 2 and read 1.7999kΩ. Thus, a window of 200 counts is provided for reading variances.

3.5.5 Measurement Capabilities

The measurement capability of each function and function parameter is summarized as follows:

|Z|, R, ESR, X

Type:	Exponential display
Resolution:	4 1/2 digits (19999 digits max); Mininum reading = 0.1mΩ
Range:	0.0mΩ, ±(0.1mΩ to 19.999MΩ)

C

Type:	Exponential display
Resolution:	4 1/2 digits (19999 maximum)
Range:	0.000pF, ±(0.001pF to 199.99mF) The range of |C| changes according to frequency: 40Hz to 130Hz : 0.000nF to 199.99mF 160Hz to 1.5kHz : 0.0pF to 19.999mF 1.6kHz to 15kHz : 0.00pF to 1.999mF 16kHz to 100kHz : 0.000pF to 199.99µF

L

Type:	Exponential display
Resolution:	4 1/2 digits (19999 maximum)
Range:	0.0nH, ±(0.1nH to 19.999kH) The range of |L| changes according to frequency: 40Hz to 130Hz : 0.0µH to 19.999kH 160Hz to 1.5kHz : 0.00µH to 1.9999kH 1.6kHz to 15kHz : 0.000µH to 199.99H 16kHz to 100kHz : 0.0nH to 19.999H

G

Type:	Exponential display
Resolution:	4 1/2 digits (19999 maximum)
Range:	0.000µS, ±(0.001µS to 199.99S); Equivalent to 1GΩ to 5mΩ

Q, D

Type:	Floating-point display
Resolution:	4 1/2 digits (19999 maximum)
Range:	0.0000, ±(0.0001 to 19999)

θ

Type:	Fixed decimal point display
Resolution:	0.01°
Range:	–180.00° to +179.99°

V

Type:	Exponential display
Resolution:	3 1/2 digits (1999 maximum)
Range:	0.0mVrms to 1.100V rms

I

Type:	Exponential display
Resolution:	3 1/2 digits (1999 maximum)
Range:	0.00µA rms to 11.00mA rms
	Resolution is limited by impedance range:
	1µA (100Ω reference resistance)
	0.1µA (1kΩ reference resistance)
	0.1µA (10kΩ, 50kΩ reference resistance)

Deviation

Range information for deviation is covered in paragraph 3.6.3.

Display with Fixed Ranges

The display range is limited by the measurement range (see Table 3-6). However, Q, D, and θ displays operate in basically the same manner in both manual and auto-range modes.

- When the reading is within the Upper Limit or Lower Limit stated in Table 3-6, the display operates the same as when auto-range is used.
- In the Upper Extension or Lower Extension areas, display range and resolution are limited, but measurements can still be observed as long as the display value does not exceed 19999.
- If the Extension Limits are exceeded, or if the display value exceeds 19999, the "OF", "UF", or "OU" message will be displayed as appropriate (see paragraph 3.5.4 for a description of these messages).

Additional Display Notes

- The display exponent and measurable range are subject to limitations, and they are displayed in the form of <mantissa> (see below) + <exponent> (k, m, etc.). The ranges for the mantissa are as follows:

  *999.9 – *200.0 (* indicates blank)
  199.99 – *20.00
  19.999 – *2.000
  1.999 – 1.0000

- For R, ESR, and G readings, measurement range and resolution are reduced as the phase angle (θ) deviates farther from 0° or –180° (+180°).
- For L, C, and X measurements, measurement range and resolution are reduced as the phase angle (θ) deviates farther from –90° or +90°.
- The "OF" message will be displayed if the display range is exceeded.
- The "+" symbol is not displayed, and positive values are indicated by the absence of the minus ("–") sign.

3.5.6 Voltage and Current Monitoring

The rms voltage and current values shown on the B DISPLAY are calculated using the following equations, which compensate for the effects of residual impedance:

$$V_M = E_X \, | Z_X / (Z_X + Z_{SS}) |$$

$$I_M = I_X \, | Y_X / (Y_X + Y_{PP}) |$$

Where: V_M = Displayed rms voltage across DUT.
I_M = Displayed rms current through DUT.
E_X = Voltage measured between H POT and L POT terminals (compensated by data taken during instrument calibration).
Z_X = Impedance of DUT (measured impedance).
Z_{SS} = Residual impedance (measured during SHORT correction).
I_X = Current measured flowing into terminal L CUR (compensated by data taken during calibration).

Y_X = Admittance of DUT (measured admittance).
Y_{PP} = Floating admittance (measured during OPEN correction).

3.5.7 Calculating Admittance and Susceptance

Admittance Y ($|Y|$ and θy) and susceptance (B) are not displayed by the instrument, but these parameters can be calculated as follows:

$$|Y| = 1/|Z|$$
$$\theta_Y = -\theta$$
$$B = |Y| \cdot \sin\ \theta_Y = -X/(R_S^2 + X^2)$$

where: R_S is the value of R (=ESR) for the series equivalent circuit (SER).

3.6 DEVIATION (Δ, %Δ)

The Model 3330 can display the deviation (Δ) and percent deviation (Δ%) of a function with respect to a reference value. (Note that deviation of a function parameter cannot be displayed.) The deviation and percent deviation are defined as follows:

Δ = Measured value – Reference value
Δ% = (Δ/Reference value) × 100

Paragraph 3.6.1 explains how to set a reference value, and paragraph 3.6.2 explains how to display deviation and percent deviation.

3.6.1 Setting a Reference Value

SET UP REF is used to set a reference value for deviation measurements. The range of the reference value is defined as follows:

Reference Range: ±(0.0001p to 19999.M)

Perform the following steps to set a reference value for deviation measurements:

1. Press the SET UP key. The [A] DISPLAY will blank, and the FREQ (Hz) indicator (labeled in blue) will blink.
2. Press and release the NEXT key twice so that the REF (blue label) indicator lamp blinks. The current reference value will be displayed on the [B] DISPLAY. If the current reference value is to be retained, exit from this mode by pressing ENTER/EXIT twice. Otherwise, proceed to the next step.
3. Key in the desired reference value using the numeric entry keys and exponent keys (if necessary). For example, you can key in a 1kΩ reference value either by pressing the "1", "0", "0", "0" keys in order, or by pressing the "1", "EXP", "k" keys in order.
4. With the desired reference value displayed, press ENTER.
   Note: The instrument is still in the REFerence SET UP mode. If you entered an incorrect reference value, simply key in the correct value, and press ENTER.
5. With the desired reference value displayed, press EXIT. The instrument will return to the normal measurement state.

3.6.2 Displaying Deviation

With an appropriate reference value established (see previous paragraph), deviation (Δ or Δ%) can be displayed. The procedures in this paragraph assume that the instrument is appropriately configured to measure a DUT.

In general, deviation (Δ or Δ%) is displayed using the Δ/Δ%/BIN key. This key simply selects Δ, Δ%, BIN or a deviation/BIN combination (Δ/BIN or Δ%/BIN).

Perform the following steps to display deviation and percent deviation:

1. Since deviation cannot be displayed with the instrument in the AUTO function, use the [A] DISPLAY key to disable the AUTO function if it is presently enabled, and to select the appropriate function.
2. To display Δ (deviation), press and release the Δ/Δ%/BIN key until the Δ indicator lamp turns on, and the % and BIN indicator lamps turn off. Deviation (Δ) is displayed on the [A] DISPLAY.
3. To display Δ% (percent deviation), press and release the Δ/Δ%/BIN key until the Δ and % indicators turn on, and the BIN indicator turns off. Percent deviation (Δ%) is displayed on the [A] DISPLAY.

Note: Deviation can be used with the Comparator (BIN) and is explained in paragraph 3.7.6.

3.6.3 Deviation Measurement Range

The measurement capabilities for deviation and percent deviation are summarized as follows:

Δ (Deviation)

Format:	Exponent representation Displayed using the same decimal point position and exponent as the reference value, similar to the measured value. Displayed by automatic range switching.
Display Range:	±19999 counts (decimal point is omitted) Normally, the reference value, ±100% or more can be displayed. "OF" is displayed if range is exceeded.

Notes:

1. When the reference value is zero, the Δ value is the same as the measured value.
2. If the displayed measured value is "OF", "UF" or "OU", the Δ reading is also "OF, "UF, or "OU".

Δ% (Percent Deviation)

Format:	Fixed point representation
Display Range:	–199.99% to +199.99%; Resolution: 0.01% (When exceeding this range, "OF" is displayed)

Notes:

1. When the reference value is zero, the displayed Δ% value is "OF".
2. If the displayed measured value is "OF", "UF" or "OU", the Δ% reading is also "OF, "UF, or "OU".

3.7 COMPARATOR (BIN)

The Comparator allows DUTs to be compared to defined reading limits and classified into one of up to 20 categories (bins). Upper and lower limits can be set for the 20 bins that are designated as Bins 0 through 19.

NOTE
The comparator can be used in conjunction with the material handler interface. See paragraph 3.17 for handler interface details.

3.7.1 Measurement Function Comparisons

Bins 1 though 19 are used for comparing and categorizing the readings of measurement functions (L, C, R or Z). For example, if a resistor measures 900Ω, it will be assigned to the first bin (starting with bin 1) whose limits will accommodate the value 900. If there are no bins that are defined to accommodate the 900Ω reading, the resistor will be assigned to Bin 0.

3.7.2 Function Parameter Comparisons

When enabled with valid limits, Bin 0 becomes a special case bin that first compares the reading of the function parameter (Q, D, ESR, G, X, θ, V, or I). If the reading of the function parameter is not within the defined limits, it is considered a failed part and is assigned to Bin 0. If, however, the reading of the function parameter passes, then the reading of the basic measurement function is compared, and the part is assigned to the appropriate bin as explained in paragraph 3.7.1.

3.7.3 Defining Comparator Limits

The following procedure explains how to define limits for the 20 bins. The values of the limits that you choose will depend on the type of comparison that is to be performed. Basic measurement readings can be compared, or deviation measurement readings can be compared. Details for comparing deviation readings are contained in paragraph 3.7.6.

Perform the following steps to define comparator limits:

1. Select BIN.
   Press and release the SET UP key repeatedly until the BIN indicator (labeled in blue) blinks. The last defined bin will be displayed on the **B** DISPLAY. (Upon power-up, Bin 0 will be displayed when BIN is selected, and upper and lower limits of all bins will also be set to zero.)
2. Select Bin 0.
   Press the 0 key ("0" will blink on and off), and press ENTER.
3. Define limits for Bin 0.
   If you do not wish to evaluate the function parameter measurement, the lower limit of Bin 0 must be equal to or greater than the upper limit (Lower Limit ≥ Upper Limit). For example, to disable evaluation of the function parameter, simply set both upper and lower limits to zero.

A. With Bin 0 displayed, press the NEXT key. The LOWER indicator lamp will blink on and off, and the current lower and upper limits of Bin 0 will be displayed (lower limit on the [A] DISPLAY and upper limit on the [B] DISPLAY).
B. To change the lower limit, perform step a. To retain the displayed lower limit, perform step b.
   a. Change Limit — Key in the new value using the data entry keys (see paragraph 3.8), and press ENTER. The UPPER indicator lamp will blink on and off.
   b. Retain Limit — Press the NEXT key. The UPPER indicator lamp will blink on and off.
C. To change the upper limit, key in the new value, and press ENTER.
   Note: If no further changes to other bins already defined are to be made, press EXIT to return to the normal measurement state.

4. Define limits for Bins 1 through 19
   A. With the limits for Bin 0 still displayed, press NEXT. The BIN indicator lamp will blink on, and off and Bin 1 will be displayed on the [B] DISPLAY.
   B. Press NEXT. The LOWER indicator lamp will blink on and off, and the upper and lower limits for Bin 1 will be displayed.
   C. To change the lower limit, perform step a. To retain the displayed lower limit, perform step b.
      a. Change Limit — Key in the new value using the data entry keys (see paragraph 3.8), and press ENTER. The UPPER indicator lamp will blink on and off.
      b. Retain Limit — Press the NEXT key. The UPPER indicator lamp will blink on and off.
   D. To change the upper limit, key in the new value, and press ENTER.
   E. Press NEXT to proceed to the next bin and define the limits as explained in steps B, C and D.
   F. Repeat the basic procedure in steps B through E for as many bins (up to Bin 19) as needed.
   G. After defining the last bin, press EXIT to return to the normal measurement state.
      Note: When a bin is closed (Lower Limit ≥ Upper Limit), that bin and all subsequent bins are effectively removed from the test system. For example, for a 5 bin test system, Bins 1 through 5 are defined with valid limits (Lower Limit < Upper Limit). Bin 6 is closed by making the lower limit equal to or greater than the upper limit. For this test system, bins 6 through 19 are not used. All parts will be sorted to bins 0 through 5.
5. Check Bin Limits
   After defining limits for all the needed bins, it is a good idea to scan through the bins to check for mistakes and make necessary corrections.

   To check limits, press and release SET UP until the front panel BIN indicator lamp blinks on and off. The last defined bin will be displayed. To start at Bin 0, key in 0, and press ENTER. At this point, simply press and release the NEXT key to scroll through the bins. The PREV key can also be used to scroll through the bins in reverse order. Note that after scrolling past Bin 19 (using NEXT) or past Bin 0 (using PREV), the instrument will automatically return to the normal measurement state. You can return to the normal measurement state at any time by pressing EXIT.

   A displayed lower limit can be changed by keying in a new lower limit while the LOWER indicator lamp is blinking on and off, and pressing ENTER. Similarly, a new upper limit can be entered with the UPPER indicator lamp blinking.

3.7.4 Limit Overlapping

If device parameters fall within the limits of two or more bins, the device will always be assigned to the lowest-numbered bin. Thus, you should program unique limits to avoid erroneous results.

3.7.5 Basic Comparator Operation

1. Configure instrument for DUT measurement.
   Configure the instrument to measure the device type that you wish to compare and assign to bins. The Compare (BIN) feature cannot be used with AUTO function enabled. If the AUTO function is enabled, use the [A] DISPLAY key to disable it, and manually select the appropriate measurement function.
2. Define comparator limits.
   Define the limits of the comparator bins as explained in paragraph 3.7.1.
3. Select the BIN function.
   Press and release the Δ/Δ%/BIN key until the BIN display indicator lamp turns on. Note that this key also controls the deviation selections (Δ and Δ%), so unless you are comparing deviation readings make sure they are not enabled.

   If comparing deviation readings, use the Δ/Δ%/BIN key to select either Δ/BIN or Δ/Δ%/BIN. See paragraph 3.7.6 for information on comparing deviation readings.
4. Test DUT.
   Connect the DUT to the input of the instrument. Instead of displaying the measured reading of the DUT, the bin number that the device is assigned to is displayed on the [A] DISPLAY.

If Bin 0 is open (Lower Limit < Upper Limit), the function parameter (Q, D, ESR, G, X, θ, V or I) will first be tested. If the part is not within the defined limits of Bin 0, it will be assigned to Bin 0. If the part is within the limits, then the function measurement (L, C, R or Z) is compared and assigned to the appropriate bin. If there are no bins that will accommodate the measured reading, then the part will be assigned to Bin 0.

When the displayed value for any part is "OF", "UF" or "OU", that part is assigned to Bin 0.

3.7.6 Comparing Deviation Readings

The instrument can be configured to use Bins 1 through 19 to compare deviation (Δ or Δ%) readings. In general, deviation readings are the result of subtracting the measured value from a defined reference value. The difference (Δ) or the percentage of the difference (Δ%) becomes the deviation value. Detailed information on deviation is contained in paragraph 3.6.

When comparing deviation values, make sure the limits for the bins reflect the appropriate deviation readings. For example, assume that you wish to compare devices that have a nominal value of 1kΩ. For this comparison, a reference value of 1kΩ would be established. If you wish to to assign devices that are within ±1% (±10Ω) tolerance to Bin 1, you would set the Lower Limit of Bin 1 to –1.000 (for Δ%) or –10.00 (for Δ), and the Upper Limit to 1.000 (for Δ%) or 10.00 (for Δ).

Comparisons begin at the lowest numbered bin. The tested device will be assigned to the first bin whose limits will accommodate the deviation reading. For this reason, deviation limits must be in an ascending order starting with the lowest bin. For example, assume that you wish to sort devices into one of the following three categories; ±1% tolerance, ±10% tolerance and ±25% tolerance. The correct way to do so is to define Bin 1 for the 1% limits, Bin 2 for the 10% limits, and Bin 3 for the 25% limits. If instead, you defined Bin 1 for the 10% limits and Bin 2 for the 1% limits, devices that have ±1% tolerance would be assigned to Bin 1 since it is within the defined limits.

After defining comparator limits and a deviation reference value, deviation comparisons are performed by selecting ΔBIN for deviation or BINΔ% for percent deviation.

3.8 SET UP

This section explains how use SET UP to select and set up auxiliary parameters (labeled in blue). The SET UP parameter selections include:

FREQ — Use to select an auxiliary measurement frequency.

DELAY — Use to program a trigger delay.

REF — Use to define a reference value for deviation measurements.

BIN, LOWER, UPPER — Use to define the upper and lower limits of bins for the comparator.

GPIB — Use to set the primary address and delimiter of the GPIB.

LEVEL — Use to program the test signal level.

To enable SET UP, press the SET UP key. The indicator lamp next to the key will turn on. The blinking indicator lamp denotes which SET UP parameter is enabled, and the current value of the selected parameter is displayed. Each press of the NEXT key enables the next SET UP parameter and displays its value. In general, selections using the NEXT key move from left-to-right. The PREV key operates in a similar manner except that selections move from right-to-left.

The SET UP mode can be canceled by pressing the EXIT key. The instrument will return to the normal measurement state.

Data Entry

When using the SET UP mode, numeric values for the selected operation are entered using the data entry keys. The data entry keys include the number keys ("0" – "9", ".", "–" and "CE"), which are labeled in blue, and exponent keys ("EXP", "μ", "M", "n", "k", "p" and "m"), which are labeled in green.

Use the following general rules to enter data for SET UP:

1. Once SET UP is enabled (SET UP indicator lamp on), the data entry keys (labeled in blue) become functional.
2. Each display has a value range from .0001 to 19999. A value in this range can be keyed in using the number keys (0 – 9), decimal point (.) and polarity sign (–). The – key toggles between minus (–) polarity and

plus (+) polarity, which is implied by the absence of the minus sign (–).

3. The exponent part of the value is selected with the EXP key. When the EXP key is pressed, all the exponent indicator lamps turn on to denote that the green exponent keys (μ, M, n, k, p and m) are functional. Exponent is selected simply by pressing the desired exponent key. The indicator lamp that corresponds to the selected exponent will remain lit. All others will turn off. Exponent symbols are defined as follows:

p = pico = 10^{-12}	m = milli = 10^{-3}
n = nano = 10^{-9}	k = kilo = 10^{3}
μ = micro = 10^{-6}	M = Mega = 10^{6}

Note: The instrument will automatically adjust the exponent in order to allow the largest possible mantissa to be displayed. For example, if you enter 0.001M, the instrument will display 1.0000 k.

4. Once a number is keyed in, the blinking digit will denote that the displayed value is pending until it is entered. A pending value can be cancelled by pressing the CE key. This cancel entry key will cancel the pending value and display the previously defined value.
5. A pending value is entered by pressing the ENTER key.

3.8.1 FREQ (Hz)

The four most used measurement frequencies (120Hz, 1kHz, 10kHz and 100kHz) are selected using the FREQ key, as explained in paragraph 3.10. SET UP FREQ allows any of the additional measurement frequencies to be selected. 201 frequencies can be programmed as follows:

- 40Hz to 130Hz: 10Hz increments
- 160Hz, 200Hz, 250Hz
- 300Hz to 9.9kHz: 100Hz increments
- 10kHz to 100kHz: 1kHz increments

Perform the following steps to select one of the above frequencies:

1. Use the SET UP key to enable FREQ (Hz). The currently selected frequency will be displayed on the [B] DISPLAY. To retain this setting, simply press EXIT to return to the normal measurement state.
2. To select an alternate frequency, key in the frequency using the data entry keys (see paragraph 3.8 for details), and press ENTER.
3. To exit from SETUP, press EXIT.

Notes:

1. Entering an invalid frequency will result in "Err 12". To clear the error message, press any front panel key.
2. When one of the auxiliary frequencies is selected, all the FREQ indicator lamps will be off when the instrument is in the normal measurement state.
3. If you enter a value that is not exactly at one of the allowed frequency increments, the instrument will round up or round down the value as appropriate. For example, the instrument will round up an entered value of 240Hz to 250Hz.

3.8.2 DELAY

Trigger Delay Time is the time period between a manual trigger and the time when the measurement starts. An appropriate delay period allows the instrument and the device to stabilize before a measurement is taken. A defined delay period is used only when the unit is in manual trigger (MAN TRIG). For continuous trigger (AUTO TRIG), the delay is disabled (0 sec).

Range: 0.00sec to 199.99sec; Resolution: 0.01sec

Perform the following steps to set a trigger delay time:

1. Press the SET UP/NEXT key twice to enable DELAY programming. The currently selected delay period will be displayed on the [B] DISPLAY. To retain this setting, simply press EXIT to return to the normal measurement state.
2. To set a different delay period, key in the delay using the data entry keys (see paragraph 3.8 for details), and press ENTER.
3. To exit from SET UP, press EXIT.

3.8.3 REF

A reference value from ±(0.0001p to 19999M) can be established for deviation measurements. In general, a reference value is established by selecting REF with the SET UP key, and then entering a valid reference value. Details for establishing a reference value are located in paragraph 3.6.1.

3.8.4 BIN, LOWER, UPPER

BIN, LOWER and UPPER are used to set the upper and lower limits for the bins of the comparator. In general, BIN is used to select the bin number, LOWER is used to enter the lower limit value, and UPPER is used to enter the upper limit value. Complete details on using the comparator are contained in paragraph 3.7.

3.8.5 GPIB

GPIB is used to set the GPIB primary address and the delimiter (terminator). The GPIB address can be set from 0 to 30. The delimiter can be set to 0, which is carriage return, line feed (<CR> <LF>) or to 1, which is carriage return (<CR>) only.

NOTE
A programmed address of 31 enables the talk-only mode. See paragraph 4.10 for details.

The displayed address and delimiter values are separated by a decimal point on the B DISPLAY. The integer part of the parameter is the primary address, and the fractional part of the parameter sets the delimiter. For example, a GPIB address of 2 and a <CR> <LF> delimiter is displayed as follows:

2.0

Perform the following steps to set the GPIB address and delimiter:

1. Press the SET UP key, then press the PREV key twice to enable GPIB programming. The GPIB LED will blink, and the currently selected GPIB address and delimiter value will be shown on the B DISPLAY. To retain these settings, simply press EXIT to return to the normal measurement state.
2. To set a different address and/or delimiter, key in the valid values using the data entry keys, and press ENTER. Make sure to separate the two parts of the parameter with a decimal point. If only the GPIB address is entered, the delimiter will automatically default to 0 (<CR> <LF>).
3. To exit from SET UP, press EXIT.

   Note: The GPIB address and delimiter are stored in battery backed-up memory and are not lost when power is cycled.

3.8.6 Level

The SET UP LEVEL selection allows you to program the test signal level to any value from 10mV rms to 1.1V rms in 1mV increments. Program the level as follows:

1. From normal display, press SET UP then PREV, and note that the LEVEL (V) LED blinks, indicating that level programming is enabled.
2. To return to normal display at this point without changing the level, press EXIT.
3. Key in the desired level using the data entry keys, then press ENTER.
4. Press EXIT to return to normal display.

Notes:

1. Entering an invalid level value will result in "Err 12". Press any front panel key to cancel an error.
2. Both front panel LEVEL LEDs will be off when a programmed level value is in effect.
3. To cancel a programmed level setting, simply press the LEVEL key. Doing so will return the level to 1V rms.

3.9 CONFIGURATION MEMORY

Up to 10 measurement configurations can be stored in internal memory. The memory is battery backed-up so that setup data is not lost when power is cycled.

The ten memories are designated as Memories 0 through 9. Setup configurations can be stored in and recalled from Memories 1 through 9 at the user's discretion. Memory 0 is a special case where configuration storage is not controlled by the user. Upon power-down, the current instrument configuration is automatically stored in Memory 0. When the unit is again turned on, the instrument goes to the power-up default conditions (see Table 3-1). However, the last setup configuration (upon power-down) can be restored by selecting Memory 0. Of course, any other configurations stored in Memories 1 through 9 can be restored instead.

3.9.1 Stored Operating States

The following operating states are stored in memory:

A DISPLAY: Function (L, C, R, Z)

B DISPLAY: Function parameter (Q, D, ESR, G, X, θ, V, I)

Δ/Δ%/BIN: Deviation and comparator (BIN) bin assignment

FREQ: Measurement frequency

CKT: Equivalent circuit mode

SPEED: Measurement speed

LEVEL: Measurement signal level

RANGE: Range

TRIG: Trigger mode

DELAY: Trigger delay time

REF: Reference value for deviation

LOWER/UPPER: Lower and upper limits for comparator (BIN)

The GPIB address and delimiter are also backed-up by battery and not lost after power-down. However, these values are not stored in any of the 10 sets of memory. They are controlled by SETUP GPIB (see paragraph 3.8.5).

Note that DC bias on state, OPEN and SHORT correction values, and talk-only mode are not backed up by battery. If necessary, these operations can be performed after memory recall.

3.9.2 Storing a Setup Configuration

Perform the following steps to store the current setup configuration in one of the nine available memories:

1. Press the (–STO) key. The indicator lamp next to that key will turn on, and "0" will be displayed on the [B] DISPLAY.
2. Press the – (sign) key. The "0" will blink on and off.
3. Key in the number (1 through 9) of the memory in which you wish to store the configuration, and press ENTER.

After you press ENTER, the setup configuration will be stored in the selected memory designation, and the instrument will return to the normal measurement state.

3.9.3 Recalling a Setup Configuration

Perform the following steps to recall a setup configuration from one of the 10 available memories:

1. Press the RCL key. The indicator lamp next to that key will turn on, and "0" will be displayed on the [B] DISPLAY.
2. Key in the number (0 through 9) of the memory that contains the setup configuration that you wish to recall, and press ENTER.

After pressing ENTER, the instrument will return to the configuration that is defined by the selected memory location.

Notes:

1. With a memory designation number displayed, the polarity sign can be changed as needed. With plus (– sign not displayed), the setup will be recalled. Conversely, with minus (–), the setup will be stored.
2. An incorrect value can be cleared with the CE key.
3. The recall operation will not be performed if you press ENTER while a non-blinking "0" is displayed.

3.10 FREQUENCY SELECTION

3.10.1 Selecting the Optimum Frequency

The impedance of an inductor or capacitor changes with frequency. Therefore, these devices should normally be measured at their operating frequencies. Measurement with the highest precision is normally possible at 1kHz, but L or C impedance may be too small at 1kHz.

Use the following general guidelines to select a measurement frequency:

- 40Hz, 50Hz, 60Hz: Measurement of transformers, coils, etc.
- 100Hz and 120Hz: Use to measure electrolytic capacitors.
- 1kHz: Use to measure intermediate values of L and C and all values of R.
- 10kHz to 100kHz: Use to measure smaller values of L and C.

Note: When the frequency is changed, the displays remain blank until the next reading is available.

3.10.2 Using FREQ

To select one of the four measurement frequencies labeled on the front panel (120Hz, 1kHz, 10kHz, 100kHz), repeatedly press and release the FREQ key until the desired frequency is selected. The selected frequency is denoted by the enabled indicator lamp.

3.10.3 Alternate Frequencies

You can also program alternate frequencies by using SETUP FREQ. Alternate frequencies include:

- 40Hz to 130Hz: 10Hz increments
- 160Hz, 200Hz, 250Hz
- 300Hz to 9.9kHz: 100Hz increments
- 10kHz to 100kHz: 1kHz increments

To program the frequency, press SET UP, then key in the desired frequency. Frequency values within the range of the instrument (40Hz-100kHz) that are not at specified increments will be rounded up or rounded down to the closest available frequency. An "Err 12" will be displayed if you attempt to program a frequency outside the range of the instrument.

If all the FREQ indicator lamps are off, an alternate frequency is selected. Using the FREQ key to select a frequency will cancel any alternate frequency previously programmed using SET UP FREQ.

For more information on using SETUP FREQ, refer to paragraph 3.8.1.

3.11 SPEED SELECTION

3.11.1 Selecting a Measurement Speed

Measurement speed is the time that it takes the instrument to process a single measurement. There are three measurement speeds that can be selected: FAST, MED, or SLOW. To select a measurement speed, simply press the SPEED key repeatedly until the corresponding SPEED indicator turns on.

Use the MED speed for most measurement situations. If a faster reading rate is required, use the FAST speed. At the FAST speed, however, measurement accuracy is reduced. Use the SLOW speed when the measured reading is noisy and difficult to read.

3.11.2 Typical Measurement Times

Table 3-7 lists typical measurement times for various frequencies.

Table 3-7. Typical Measurement Times

Speed	1V, 1kHz, 1kΩ Resistance	100Hz	40Hz
FAST	60msec	55-95msec	90-120msec
MED	150msec	135-300msec	290-490msec
SLOW	480msec	440-740msec	1.0-1.3sec

- Add 14msec to above times for V or I display.
- Add 1msec to above times for Δ or Δ% display.
- When bins 0–n of comparator are used, add the following: .05msec + [(n+1) x 0.25msec].

3.12 SIGNAL LEVEL SELECTION

The instrument measures devices by applying an rms signal (at the selected frequency) and then measuring the subsequent current. The level of the test signal can be set using LEVEL, or by programming specific level values using the SET UP key, as discussed in the following paragraphs.

3.12.1 Using LEVEL

Signal levels that can be selected with the LEVEL key are 50mV rms and 1V rms. The front panel LEVEL indicator lamp denotes the current signal level. To select the alternate level, simple press the LEVEL key once.

The 1V signal level can be used for most measurements. For semiconductors with non-linear characteristics that are affected by signal magnitude, use the 50mV level, or program the level as discussed in the following paragraph.

Note: After the signal level is changed, the displays will blank until the next measurement is completed.

3.12.2 Programming the Level

You can also set the level to a value from 10mV rms to 1.1V rms with 1mV rms resolution by using SET UP LEVEL. To do so, press SET UP then PREV, and program the desired level. If you attempt to program a level outside the allowed range, an "Err 12" will be displayed.

While the programmed level is in effect, both front panel LEVEL indicators will be off. You can cancel the programmed level and return to a fixed 1V rms level by pressing the LEVEL key.

Refer to paragraph 3.8.6 for details on programming the level.

3.12.3 Level Loading Considerations

The specified signal levels are for open-circuit (no-load) conditions (no DUT connected to the UNKNOWN terminals). Since the output resistance of the instrument is approximately 100Ω, the loading effects of lower impedances will reduce the actual level from its indicated open-circuit value.

For example, measuring a 1kΩ resistor will result in a level reduction of about 10%; a 1V rms indicated level will actually be about 900mV rms in this example. Note that you can display the actual voltage across the DUT by placing the [B] DISPLAY in the V display mode.

3.13 TRIGGER

A trigger is a stimulus that will start a measurement conversion. The instrument can be set for automatic triggering (AUTO TRIG) or manual triggering (MAN TRIG). Also, a delay time between triggers can be set.

3.13.1 Trigger Selection

In the automatic (AUTO) trigger mode, readings are triggered and displayed continuously. The display is constantly refreshed with readings at a rate that is determined by the selected measurement speed (SPEED).

In the manual (MAN) trigger mode, a trigger will only occur when the front panel MAN TRIG key is pressed. Each press of this key will cause one reading to be measured and displayed after the trigger delay period elapses (see paragraph 3.13.2). The advantages of using manual trigger are as follows:

- The measured value can be retained on the display
- After connecting a device for sorting (Comparator), manual triggering allows the test system time to stabilize before a reading is triggered.

On power-up, AUTO trigger is enabled, as denoted by the indicator lamp next to the AUTO TRIG key. Note that the BUSY indicator lamp is also enabled, and it blinks at the measurement conversion rate. The AUTO TRIG key toggles the instrument between automatic triggering and manual triggering. When AUTO TRIG is disabled, the BUSY indicator lamp turns off, and the last processed readings are retained on the display.

Automatic triggering can also be disabled by pressing the MAN TRIG key. The first press of this key disables AUTO TRIG and triggers a reading after allowing the trigger delay period to elapse. Each subsequent press of this key will trigger one reading after waiting the trigger delay period.

3.13.2 Trigger Delay

In the manual (MAN) trigger mode, a trigger delay period from 0 to 199.99 seconds with 10msec resolution can be set. When the MAN TRIG key is pressed, the trigger delay period will elapse before the reading occurs. A delay period is useful for allowing a device to stabilize before measurement, and it is especially useful when sorting parts using the comparator. A proper delay period will also allow an applied bias voltage to settle before the comparison is performed.

In AUTO TRIG, the trigger delay is disabled (0sec).

The delay period is set using SET UP, as explained in detail in paragraph 3.8.2. In general, you can set the trigger delay by repeatedly pressing SET UP until the DELAY indicator blinks, keying in the time period, and pressing ENTER.

Note: When a manual trigger occurs, the BUSY indicator lamp will turn on and remain on until the measurement is completed. When the BUSY indicator lamp turns off, it indicates that the test on the device is completed, and the DUT can be removed.

3.14 DC BIAS

A DC bias voltage can be applied to the DUT when the unit is in the capacitance measurement mode. This voltage can be used to bias such devices as semiconductors and polarized electrolytic capacitors to determine capacitance under actual operating conditions. DC bias cannot be used when measuring L, R, or Z. Pressing the BIAS key while in one of these functions will result in "Err 14".

3.14.1 Internal 2V Bias

The instrument has a built in 2V bias source that can be used to bias the DUT. You can turn the bias voltage on or off simply by pressing the front panel BIAS key; the bias on state is indicated by the associated LED.

3.14.2 External Bias

An external bias voltage from 0 to ±35VDC can be applied via a BNC connector on the rear panel. Like the internal bias source, the external bias voltage can be toggled on/off with the BIAS key.

3.14.3 Bias Stabilization Time

When bias is abruptly changed by turning BIAS on to its peak value, a certain amount of time is required for the bias voltage to stabilize before an accurate capacitance measurement can be made. Use the following equation to determine the time required to achieve stability:

Stabilization time = (4 + 0.015C)sec

where C is the capacitance in µF.

3.14.4 Using DC Bias

Perform the following steps to use DC bias:

1. If you are using an external supply, connect it to the BIAS EXT IN BNC connector on the rear panel. Before making connections, make sure the supply is in standby and is set for 0V.

   CAUTION

   To prevent damage to the instrument, do not apply voltage that is outside the 0V to ±35V range. Also, observe the precautions and considerations explained in paragraph 3.14.5 below.

2. Set the rear panel BIAS switch to INT or EXT as appropriate. If you are using the internal supply, set the toggle switch to the INT 2V position. If you are using an external bias supply, set the toggle switch to the EXT position.
3. Using the [A] DISPLAY key, select the C function. Note that AUTO function must be disabled; DC bias cannot be enabled in AUTO function.
4. Connect the device to be measured.

   CAUTION

   When measuring a polarized device, be sure to observe polarity (H is positive with respect to L). Also, make sure to discharge capacitors before connecting them to the UNKNOWN terminals.

5. Enable DC bias by pressing the BIAS key. When BIAS is enabled, its indicator lamp will turn on. Note that if a different function is selected, BIAS will be turned off.
6. If you are using an external bias source, increase the bias source gradually from 0V to the desired level.
7. The capacitance reading using DC bias will be displayed.
8. If you are using an external bias source, gradually decrease the level to 0V.
9. Turn off the bias by pressing the BIAS key.
10. Disconnect the device.

3.14.5 External Bias Supply Precautions and Considerations

Ripple and Noise

The external power supply must have low ripple and noise (<1mVrms). A switching type power supply should not be used because of its relatively high noise level. If ripple and noise are large, measurement accuracy will be reduced.

Measuring Large Capacitors with External Bias

When measuring capacitors larger than 100µF using a bias of more than 10V, connect the capacitor to the UNKNOWN terminals with the external bias supply set to 0V. After connecting the capacitor, increase the voltage gradually to the desired value. After completing the measurement, decrease the voltage gradually to 0V, and then disconnect the device.

Maximum Rate of Change

When using a bias voltage of 10V or more, the voltage level must be changed at at rate of <10V/sec. Otherwise, the EXT 0.1A protection fuse (accessed from the rear panel) will blow.

3.15 ZERO CORRECTION

Zero correction should be performed whenever test connections are changed to cancel the effects of residual impedance and stray admittance caused by test fixtures and test cables.

NOTE

Zero correction constants are not backed up by the battery (except in case of memory location 0 readout by the handler interface LOCK signal).

Zero correction must be performed when power is first turned on or if test connections are changed.

3.15.1 Zero Correction Procedures

OPEN — Stray Admittance Measurement

Perform the following steps to perform the OPEN correction procedure:

1. Open the measurement terminals as shown in Figure 3-11.

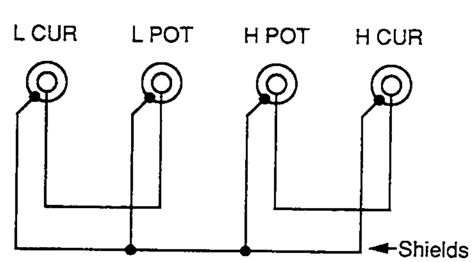


Figure 3-11. OPEN Measurement for Connections

NOTE

For OPEN correction, make sure L CUR is connected to L POT, and H POT is connected to H CUR as shown in Figure 3-9. If cables or leads are being used, short the appropriate terminals at the test cable end. Be sure all four cable shields are connected together.

2. Press the OPEN key. The instrument measures the stray admittances for frequencies listed in paragraph 3.15.2 (below), and it stores the values in memory. At the start of the correction process, the message "OP 31" will be shown on the [A] DISPLAY. While correction proceeds, the display will count down to "OP 0", which signals the end of the correction procedure. The instrument will then return to the normal measurement state using the corrected values to calculate readings. Note that during the execution of the correction procedure, stray capacitance readings will be displayed on the [B] DISPLAY.

SHORT — Residual Impedance Measurement

Perform the following steps to perform the SHORT correction procedure:

1. Short the measurement terminals as shown in Figure 3-12.

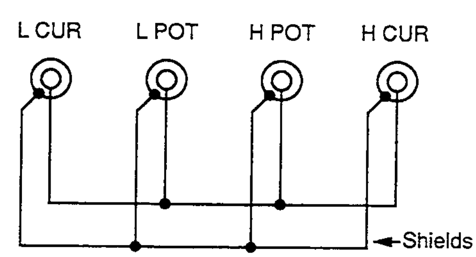


Figure 3-12. SHORT Measurement Connections

NOTE

For the SHORT correction, make sure L CUR, L POT, H POT and H CUR are all connected together as shown in Figure 3-10. If cables or test leads are being used, short the terminals at the test cable ends. Be sure all four cable shields are connected together.

2. Press the SHORT key. During the SHORT correction process, the instrument measures the residual impedance for all frequencies listed in paragraph 3.15.2, and it stores the values in memory. At the start of the process, the message "SH 31" will be shown on the [A] DISPLAY. During correction, the display will count down to "SH 0", which signals the end of the correction process. The instrument will then return to the normal measurement state using the corrected values to calculate readings. Note that during the execution of the correction procedure, residual impedance readings will be displayed on the [B] DISPLAY.

3.15.2 Zero Correction Frequencies

During the correction process, the instrument measures the residual impedance and stray admittance at the following frequencies: 40Hz, 100Hz, 120Hz, 200Hz, 500Hz, 1kHz, 10kHz, 16kHz, 20kHz, 32kHz, 50kHz, 75kHz, and 100kHz. Correction factors are stored in memory, and those factors at the closest frequency to the frequency being used for the measurement are interpolated for correction during a normal measurement.

3.15.3 Aborting Correction

To abort a SHORT or OPEN correction, press the SHORT or OPEN key. If correction is aborted, previous correction constants will be used.

3.15.4 Equivalent Measurement System Circuits

Normal Measurement Mode

Figure 3-13(a) shows the equivalent circuit of the normal measurement mode.

Elements of the model include:

Z_X = Impedance of DUT being measured
Z_{SS} = Residual series impedance
R_{SS} = Residual resistance (part of Z_{SS})
L_{SS} = Residual inductance (part of Z_{SS})
Y_{PP} = Stray parallel admittance
G_{PP} = Stray conductance (part of Y_{PP})
C_{PP} = Stray capacitance (part of Y_{PP})
Y_M = Virtual admittance

Note that Z_{SS} and Y_{PP} are error terms that are determined by the SHORT and OPEN zero correction process, as discussed below.

OPEN Measurement Mode

The equivalent circuit during OPEN correction is shown in Figure 3-13(b). During OPEN correction, the UNKNOWN terminals are open circuited, and Z_X and Z_{SS} are effectively removed from the circuit. The instrument measures the stray admittance Y_{PP}, which is made of the stray conductance G_{PP} and the stray capacitance C_{PP}.

SHORT Measurement Mode

The equivalent circuit during SHORT correction is shown in Figure 3-13(c). During SHORT correction, the UNKNOWN terminals are short circuited. Since the value of $1/Y_{PP}$ is much higher than Z_{SS}, the value of Y_{PP} can be ignored for all practical purposes, and the instrument measures Z_{SS} (made up of R_{SS} and L_{SS}) during the SHORT zero correction process.

Calculating Corrected Impedance

During a normal measurement, the true impedance of the DUT is calculated from the measured virtual admittance and the stored OPEN and SHORT corrections factors as follows:

$$Z_X = 1/(Y_M - Y_{PP}) - Z_{SS}$$

Where: Z_X = True impedance of DUT
Y_M = Virtual admittance
Y_{PP} = Stray admittance (determined during OPEN correction)
Z_{SS} = Residual impedance (determined during SHORT correction)

3.15.5 Correctable Ranges

The correctable ranges for Z_{SS} and Y_{PP} are as follows:

Z_{SS} < approx. 3Ω (R_{SS} < approx. 3Ω, L_{SS} < approx. 5µH at 100kHz.

Y_{PP} < approx. 10µS ($R_{PP} = 1/G_{PP}$ > approx. 100kΩ, C_{PP} < approx. 16pF at 100kHz)

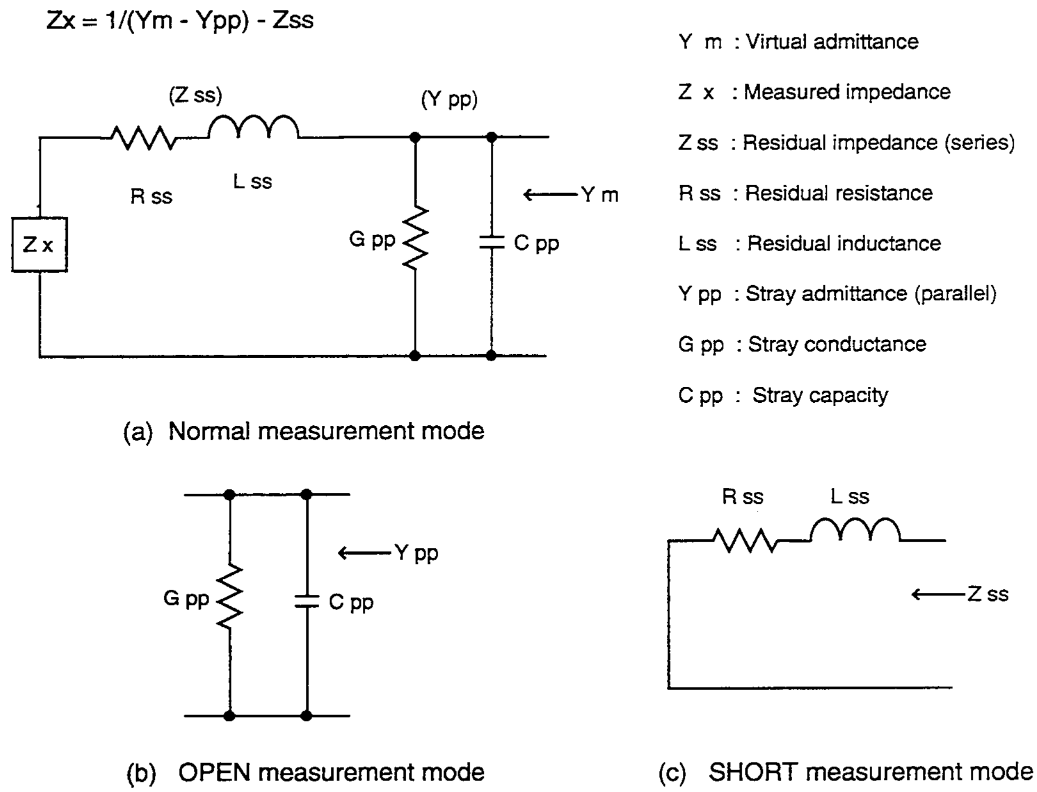


Figure 3-13. Equivalent Circuits of Measurement System

If a residual impedance or stray admittance value exceeds the correctable range, an error results, and the present OPEN or SHORT correction factor does not change. The instrument measures the overall impedance including residual impedance and stray admittance and then corrects for residual impedance and stray admittance by calculation. Therefore, if the magnitude of the residual impedance or stray admittance is a large percentage of the magnitude of the measured impedance, or if the magnitude of the stray admittance or residual impedance is larger than the magnitude of the measurement impedance, the measuring accuracy is reduced. In this case, calibrate the instrument using an external standard.

3.16 ERROR MESSAGES

3.16.1 Types of Errors

Errors may result from the following:

1. Self-check (power-up test or zero measurement during OPEN or SHORT correction).
2. Invalid front panel setting.
3. Programming error over the GPIB bus.

Error messages are listed and explained in Table 3-8.

It is possible to get the following messages on the [A] and [B] DISPLAYS if the instrument is exposed to excessive noise fields:

[A] DISPLAY: FFFFF   [B] DISPLAY: 66666

To clear this error, turn off power, and turn power back on after three seconds. If this error occurs frequently, the instrument may be defective. Contact your sales representative or the factory.

Table 3-8. Error Messages

[A] DISPLAY	[B] DISPLAY	Description	Clear Error?
		(1) Memory Abnormal	No
EEEEE	nnnnn		
	n = 2	Cal constants error	
	n = 4-7	RAM error	
	n = 9	ROM error	
		(2) Mode or Parameter Entry errors	Yes
	Err 12	Entered value exceeds measurement range.	
	Err 13	Attempted to select a function parameter ([B] DISPLAY key), or enable deviation or BIN (Δ/Δ%/BIN key) while AUTO function is enabled.	
	Err 14	Attempted to enable BIAS while AUTO, L, R, or Z is selected. BIAS can be used only for capacitance (C) measurements.	
	Err 19	Attempted to select a range past the upper or lower limit.	
		(3) Errors That Occur During Execution of Instrument Operation	Yes
	Err 21	Battery backed-up memory failure detected during power-up. Primary address defaults to 2, and delimiter defaults to <CR> <LF>.	
	Err 22	Zero correction value exceeds tolerance.	
		(4) GPIB Errors Caused by Programming or Inquiry Error	Yes
	Err 31	Attempted to send command string with too many characters. All commands in string are ignored.	
	Err 32	Illegal header; received header that was not defined.	
	Err 33	Illegal header; inquiry requested when unit programmed to perform operation, or operation requested when unit programmed to perform inquiry.	
	Err 34	Illegal parameter; parameter expected but not sent.	
	Err 35	Illegal parameter; comma (,) which defines parameters missing.	
	Err 36	Talk-only cancelled from handler interface. Returns to address before talk-only.	
	Err 37	No listener detected during talk-only output.	
	Err 50-79	(5) Hardware Errors. Power-down unit and see if error clears. Repair unit if error persists (contact factory).	No

3.16.2 Clearing Error Messages

Once an error message is displayed, it will remain displayed until it is cleared by the operator. The instrument is effectively inoperable while the error message is displayed.

Clearing Errors from the Front Panel

An error message can be cleared by pressing any front panel key. In this case, the operation inherent to the key does function.

Clearing Errors Over the GPIB

An error can be reset by sending the device clear command (DCL, SDC) over the bus.

Errors that Cannot Be Cleared

Note: If "EEEEE" or "FFFFF" is displayed on the [A] DISPLAY or when an error number exceeds 50, the instrument is not functioning properly. Turn off power, and then turn power on again after three seconds. If the error message does not clear, the instrument is defective. Contact your sales representative or the factory.

3.17 HANDLER INTERFACE

3.17.1 Overview

The handler interface operates in conjunction with the comparator and a user-supplied material handler to provide up to 12 classifications of comparator judgments for automatic binning of devices. The handler interface includes a panel lock input and trigger input, and an internal beeper can be sounded according to comparator judgment when a measurement is completed. All interface inputs and outputs are isolated from chassis ground to allow floating interface connections.

3.17.2 Input/Output Connections

Connector

The handler interface uses a 36-pin connector with the terminal arrangement shown in Figure 3-14. Table 3-9 summarizes terminal assignments for the interface connector. Use only an appropriate 36-pin connector when making handler interface connections. See paragraph 1.7.3 for connector recommendations.

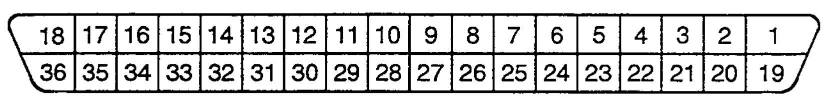


Figure 3-14. Handler Interface Connector

Table 3-9. Handler Interface Signals

Pin	Signal	Type	Description
1	BIN 0	OUT	Bin 0 judgement
2	BIN 1	OUT	Bin 1 judgement
3	BIN 2	OUT	Bin 2 judgement
4	BIN 3	OUT	Bin 3 judgement
5	BIN 4	OUT	Bin 4 judgement
6	BIN 5	OUT	Bin 5 judgement
7	BIN 6	OUT	Bin 6 judgement
8	BIN 7	OUT	Bin 7 judgement
9	BIN 8	OUT	Bin 8 judgement
10	BIN 9	OUT	Bin 9 judgement
11	BIN 10	OUT	Bin 10 judgement
12	BIN 11	OUT	Bin 11 judgement
13	A_NG	OUT	Main parameter failure
14	B_NG	OUT	Sub parameter failure
15	STROBE	OUT	Judgement complete
16	BUSY	OUT	Measurement in progress
17	TRIG	IN	Trigger
18	LOCK	IN	Panel lock

Pins 19-36 are signal ground pins.

Cables

In order to avoid possible interference, use cabling with shielded, twisted pairs, and keep the cable as short as possible. Signal and corresponding ground lines are arranged opposite one another on the connector. For example, pin 19 is the signal ground connection for pin 1 (BIN 0).

When long cables are used, or if noise is a problem, observe the following measures to minimize the possibility of improper operation:

- Increase the signal voltage to about 15V to raise the noise margin.
- Add 200μsec time constant low-pass RC filters to input circuits.
- Change the orientation of the connecting cable, or reroute the cable away from noise sources to minimize spurious noise pickup.

Grounding

The handler interface is DC isolated from the LCZ meter chassis to allow for floating operation. The maximum voltage between any handler interface terminal and chassis ground is 42V.

CAUTION

Do not exceed 42V between any handler interface terminal and chassis ground, or instrument damage may occur.

In some cases, better noise performance may be obtained by connecting the cable shield at both ends. Normally, however, cable shields should be connected either at the LCZ meter end, or at the handler end (but not at both ends). Use the following general rules for connecting cable shields:

- If the material handler uses TTL or CMOS interfacing, connect the cable shield to handler ground.
- If the material handler uses photocoupler interfacing (to enhance voltage isolation), connect the cable shield to LCZ meter chassis ground.

Note that the shell of the handler interface connector is insulated from LCZ meter chassis ground and is connected to signal ground of the handler interface.

CAUTION

If the handler interface and GPIB interface are used simultaneously, the shells of the two connectors may touch one another. To avoid shorting the two shells together, install suitable insulating material between the two connectors.

3.17.3 Panel Lock

To automatically lock out the front panel controls and restore memory location 0 settings when the instrument is first turned on, set the interface LOCK signal to a low logic level (≈0V) before turning on Model 3330 power. When the LOCK signal is low, the instrument automatically performs the following at power on:

- Recalls memory location 0 settings.
- Locks out front panel controls (except for clearing errors).
- Recalls previous OPEN and SHORT zero correction constants.
- Enables the GPIB talk-only mode.

NOTE

Since zero correction values may change over a period of time, measurement errors may increase if OPEN and SHORT correction procedures are not performed for a considerable length of time. Zero correction should be performed at least once a week, or more often when the ambient temperature varies widely.

3.17.4 Beeper Settings

An internal beeper can be set to sound under go or no-go conditions for bin comparisons. As shipped from the factory, the beeper is disabled, but it can be enabled, as explained in Appendix E.

3.17.5 Start-up

Turning on the Power

When the Model 3330 is connected to a material handler, always use the following procedure for start-up. This procedure should be followed because the handler interface outputs do not become stable until a certain amount of time has elapsed after power is turned on.

1. With the material handler deactivated, turn on Model 3330 power.
2. Allow the Model 3330 to complete its self-calibration cycle and enter the normal measurement state.
3. Activate the handler.

Handler Interface Activation

The handler interface output operates when the Model 3330 is set to bin display. To enable bin display, press the Δ/Δ%/BIN key repeatedly until the BIN indicator turns on. When the unit is not in the bin display mode, all handler interface output signals are inactive (high level), and the beeper is disabled.

Note that the TRIG and LOCK input signals are always valid whether or not the instrument is in the bin display mode.

3.17.6 Setting Up Operating Modes for Handler Operation

Front Panel Operation

When the LOCK signal line is low, all front panel controls are locked out (except for error cancellation), including such important modes as manual trigger (MAN key), and zero correction (ZERO OPEN and SHORT keys). Consequently, you should select all front panel operating modes before setting the LOCK signal low. After setting the desired operating states, setting LOCK low will prevent inadvertent setting changes during handler operation.

GPIB Operation

The status of the LOCK signal has no effect on GPIB programming. Thus, you can program the instrument over the GPIB whether or not the LOCK signal is low.

3.17.7 Output Signals

Signal Types

- BIN 0-11: Bin Judgment

  Only the signals of bins classified according to measurement value judgment results are active (low level). For example, if the comparator assigns a device to Bin 2, the BIN 2 line will go low. If the results of the comparator judgment classifies the DUT in bins 12-19, the signal levels of BIN 0-11 are all placed inactive (high).

- A_NG: Main Parameter Failure

  This signal is active (low) when the main ([A] DISPLAY) parameter does not fall within the range of any bin. However, if the lower limit of bin 1 is greater than or equal to the upper limit, this signal does not become active.

- B_NG: Sub Parameter Failure

  This signal is active (low) when the sub ([B] DISPLAY) parameter is out of range. However, when the lower limit for bin 0 is greater than or equal to the lower limit, this signal does not become active.

- STROBE: Judgment Complete Pulse

  This signal becomes active (low) when the measurement and comparator judgment are completed, and all handler interface outputs are stable (BIN 0-11, A_NG, and B_NG). The pulse width of this signal is approximately 2msec.

- BUSY: Measurement in Progress Flag

  This signal is active (low) while the device is being measured, and it operates basically the same as the front panel BUSY indicator. The device should be connected for measurement when BUSY is low; the next device can be connected when BUSY goes high.

Signal Levels

- Output type:

  Open collector output, TTL level, negative logic.

- Drive capability:

  Drives TTL or CMOS type logic, or a relay up to 24V

- Maximum ratings:

  Pull-up voltage: 30V
  Sink current: 48mA

- Fanout:

  10 standard TTL maximum

- High-level output voltage under load:

  ≥3.6V (load ≥100kΩ)

Output Circuit

Figure 3-15 shows the output circuit for each handler interface output signal line.

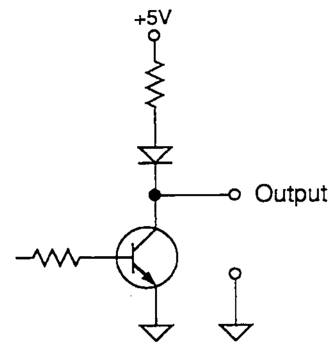


Figure 3-15. Output Circuit

Typical Handler Input Circuits

Figure 3-16 shows typical material handler input circuits. Typical circuits include TTL, CMOS, relay, and photocoupler circuits. Refer to the material handler documentation to determine the type of interface circuits in your particular equipment.

CAUTION

When using relays, be sure to connect a protection diode in parallel with each relay coil to avoid possible instrument damage. Without a protection diode, a high voltage is generated when the relay is de-energized; this voltage may damage the handler interface drive circuits. Be sure to connect the protection diode with proper polarity, or instrument damage may result. (See Figure 3-16(d).)

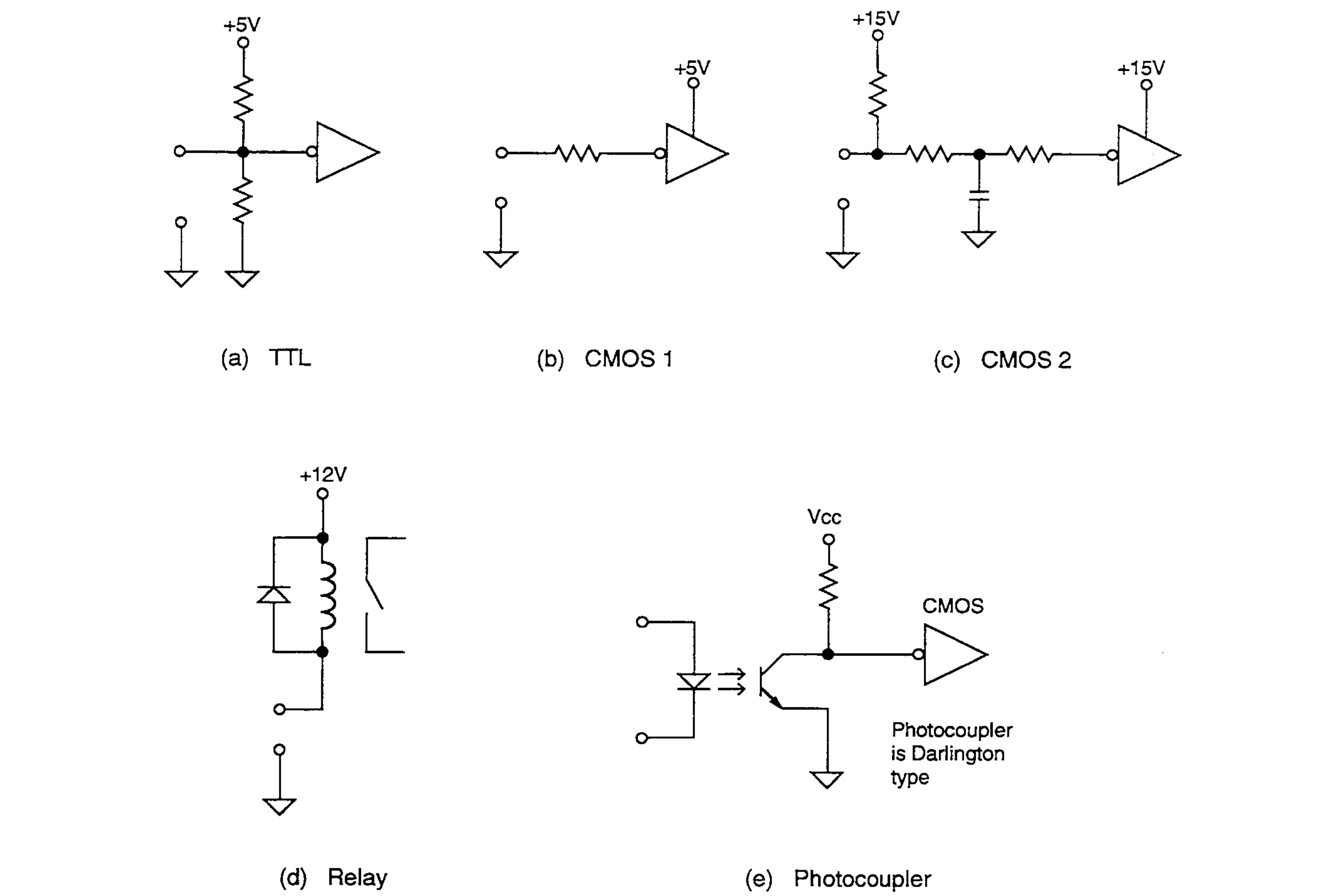


Figure 3-16. Typical Handler Input Circuits

3.17.8 Input Signals

Signal Types

- TRIG: Trigger

  This signal is the measurement start signal. To start a measurement, set TRIG low for a minimum of 100µsec. Since the trigger signal is ignored during a measurement, wait until after the STROBE signal is asserted before applying the next trigger signal.

- LOCK: Panel Lock

  When set low, LOCK disables all front panel controls (except for error cancellation). Note that GPIB programming is not inhibited by LOCK.

  If LOCK is held low when the Model 3330 power is turned on, the settings from memory location 0 are automatically recalled, previous OPEN and SHORT zero correction values are recalled, and the unit is placed in the GPIB talk-only mode.

Signal Levels

- TRIG

  TTL level, negative logic (low level triggers measurement)
  Low level input voltage: –1.5V to +0.8V
  High level input voltage: +2.4V to +30V (2mA maximum current flows into terminal when voltage exceeds +5V)

Low level input current: –0.33mA (negative sign indicates current flows out of terminal)

- LOCK

Negative logic (locked with low logic level)
Low level input voltage: –1.5V to +0.8V
High level input voltage: +3.5V to +30V
Low level input current: approx. –3mA (when input voltage = 0V)

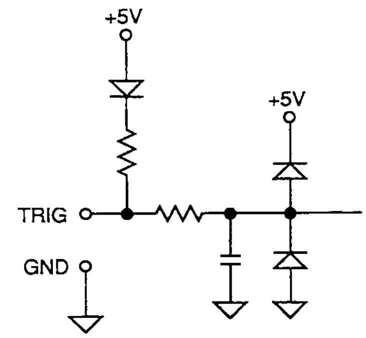
NOTE
Since both inputs are pulled up to +5V by internal resistance, an open input assumes a high logic level. Thus, the inputs can be driven by TTL or open-collector circuits, or by using mechanical contacts such as switches or relays.

Input Circuits

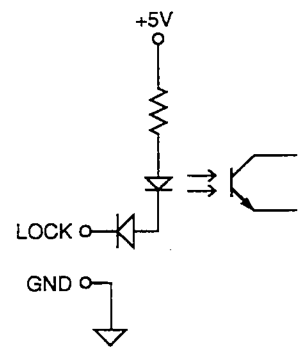
Figure 3-17 shows the equivalent circuits for the TRIG and LOCK input circuits.

Typical Handler Drive Circuits

Figure 3-18 shows typical handler drive circuits.



(a) TRIG



(b) LOCK

Figure 3-17. Input Circuits

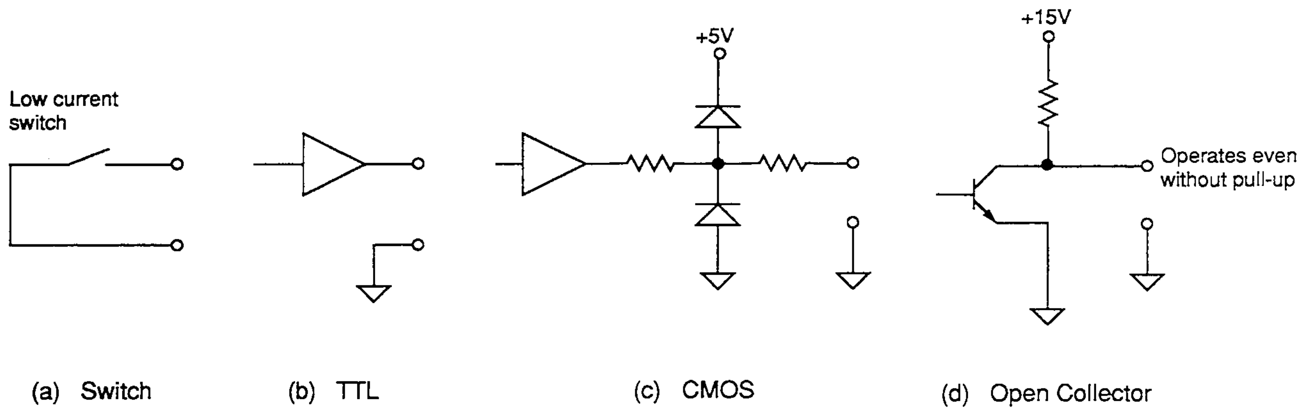


Figure 3-18. Typical Handler Drive Circuits

3.17.9 Triggers

Overview

The manual trigger used to start a measurement can be any of the following signals:

- Front panel MAN key
- GPIB trigger commands (GET, "TG")
- Handler interface TRIG input

Note that these signals are valid only when the instrument is in the manual trigger mode. In the continuous trigger mode, measurements are taken continuously regardless of the applied trigger signals.

MAN Key

The MAN key can be used to trigger a measurement in the manual trigger mode only when the instrument is in the local mode, and when the LOCK signal is inactive (high).

GPIB Trigger Commands

The GPIB GET and "TG" commands can be used to trigger the instrument only when it is in the remote mode. Note that GPIB operation is not affected by the LOCK signal, so these commands are valid even if the LOCK signal is low.

TRIG Input

The TRIG signal is valid only when the instrument is in the local mode. If TRIG is held low, measurements will be taken continuously.

3.17.10 Operating Sequence

Figure 3-19 shows a standard timing diagram for handler interface operation. The following points should be noted when using the interface:

- Once a TRIG signal is received, and the instrument begins a measurement, the instrument will ignore any further triggers until the measurement is completed, and the judgment signal is output. Wait until after the STROBE signal occurs before applying the next trigger.
- If an A/D overflow occurs during measurement, the BUSY period will be considerably shorter than normal, and the judgment result will become available almost immediately after the trigger is applied. If the TRIG pulse duration is long, the first trigger may be seen by the instrument as the next trigger, and the measurement may be restarted. To avoid continuous retriggering in this situation, keep the TRIG pulse duration to 2msec or less.

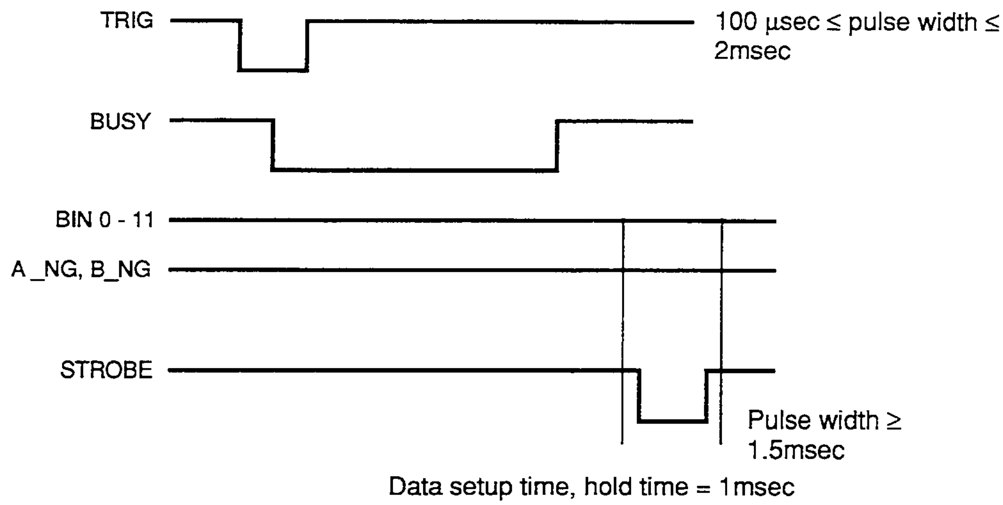


Figure 3-19. Handler Interface Timing

SECTION 4
GPIB Interface

4.1 INTRODUCTION

This section contains detailed information on using the Model 3330 over the GPIB (IEEE-488) interface bus. Information includes:

- Device-dependent command programming.
- Setting the primary address and delimiter.
- Making measurements over the GPIB.
- Example computer programs.
- Talk-only mode.

4.2 DEVICE-DEPENDENT COMMANDS

A command used to control the instrument over the GPIB or to read the operating mode or measured data is called a device-dependent command. Device-dependent commands are classified as follows.

- Operating mode command: Sets operating modes such as measurement function.
- Inquiry command: Reads operating mode settings or measured data.

The following paragraphs give an overview of device-dependent commands and describe each command in detail.

4.2.1 Device-dependent Command Summary

Table 4-1 summarizes device-dependent commands. The table includes both operating mode and inquiry commands. Entries under the Output Format heading indicate the instrument responses to corresponding inquiries where applicable.

Table 4-1. Device-dependent Command Summary

Name or Function of Parameter	Operating Mode Command		Inquiry Command	Output Format		
	Header	Parameter	Header	Header	Parameter	Para.
BIN	BN	m1,m2,m3 (No, Lower, Upper)	?BN	BN	m1,m2,m3 (repeat 20)	4.3.1
BIAS ON/OFF	BO (NR1)	0 : OFF, 1 : ON	?BO	BO (NR1)	0 to 1	4.3.2
CIRCUIT	CK (NR1)	0 : AUTO, 1: SER, 2 : PAR	?CK	CK (NR1)	1, 2 (MAN) 3, 4 (AUTO)	4.3.3
[A] DISPLAY	DA (NR1)	0 to 4 (to 8) (0 : AUTO)	?DA	DA (NR1)	1 to 8 (5 : AUTO L)	4.3.4
[B] DISPLAY	DB (NR1)	0 to 7 (0 : Q)	?DB	DB (NR1)	0 to 7 (4 : X)	4.3.5
Δ/BIN	DE (NR1)	0 to 5 (0 : NORM)	?DE	DE (NR1)	0 to 5	4.3.6
DELAY	DL (NR2)	0.00 to 199.99	?DL	DL (NR2)	0.00 to 199.99	4.3.7
MEASURED DATA	—	—	?DT	DT	n1,n2 (DISPLAY–A, B)	4.3.8
FREQUENCY	FR (NR3)	40 to 100E+3 Various	?FR	FR (NR3)	40 to 100E+3	4.3.9
HEADER	HD (NR1)	0 : DISABLE 1 : ENABLE	?HD	HD (NR1)	0 to 1	4.3.10
LEVEL	LV (NR3)	10E–3 to 1.1	?LV	LV (NR3)	10.E–03 to 1.100E+00	4.3.11
ZERO OPEN	OP	—	—	—	—	4.3.12
RECALL	RC (NR1)	0 to 9	—	—	—	4.3.13
REFERENCE	RF (NR3)	0 to +/–19999.E+6	?RF	RF (NR3)	0 to +/–19999.E+6	4.3.14
RANGE	RN (NR1)	0 to 6 (to 12) 0 : AUTO	?RN	RN (NR1)	1 to 12 (8 : AUTO 2)	4.3.15
SERVICE REQUEST	RQ (NR1)	0 : DISABLE 1 : ENABLE	?RQ	RQ (NR1)	0 to 1	4.3.16
ZERO SHORT	SH	—	—	—	—	4.3.17

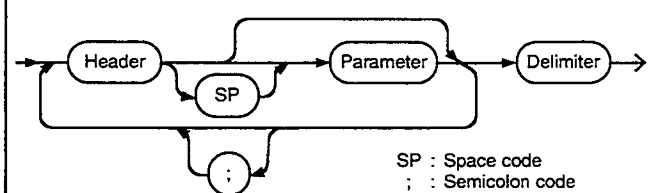
Device-dependent Command Summary (Cont.)

Name or Function of Parameter	Operating Mode Command Header	Operating Mode Command Parameter	Inquiry Command Header	Output Format Header	Output Format Parameter	Para.
SPEED	SP (NR1)	0:FAST, 1:MED 2:SLOW	?SP	SP (NR1)	0 to 2	4.3.18
STORE	SR (NR1)	1 to 9	—	—	—	4.3.19
STATUS	—	—	?ST —	ST (NR1)	0 to 127	4.3.20
MAN TRIG	TG	—	—	—	—	4.3.21
TRIG MODE	TR (NR1)	0:AUTO, 1:MAN	?TR	TR (NR1)	0 to 1	4.3.22

4.2.2 Operating Mode Commands

Command Summary

Table 4-2 summarizes device-dependent commands that control instrument operating modes. Each command listing includes the header, parameter type and range, and whether or not that command has a corresponding inquiry.



Header : Programs a major category such as functions.
Parameter : Values to be set.
Delimiter : Indicates the end of a command.

Figure 4-1. Operating Mode Command Syntax

Table 4-2. Operating Mode Commands

Parameter Name or Function	Command		Operation and Setting Range	Inquiry
	Header	Parameter		
BIN	BN	NR1 (Integer) and NR3 (Exponent Type)	<Comparator> Format: m1, m2, m3 m1: Bin No. (BIN) m2: Lower Limit (LOWER) m3: Upper Limit (UPPER) Range: m1 = 0 to 19 m2, m3 = 0, and ±(0.0001E–12 to 19999E+6)	Yes
BIAS ON/OFF	BO	NR1 (Integer)	<Bias> Range: 0 = Off 1 = On	Yes
CIRCUIT	CK	NR1 (Integer)	<Equivalent circuit> Range: 0 = AUTO 1 = SER 2 = PAR 3 to 4 = AUTO	Yes
[A] DISPLAY	DA	NR1 (Integer)	<Function> Range: 0 = AUTO 1 = L 2 = C 3 = R 4 = |Z| 5 to 8 = AUTO	Yes
[B] DISPLAY	DB	NR1 (Integer)	<Function Parameter> Range: 0 = Q 1 = D 2 = ESR 3 = G 4 = X 5 = θ 6 = V 7 = I	Yes
Δ/BIN	DE	NR1 (Integer)	<Deviation and bin display> Range: 0 = Normal 1 = Δ 2 = Δ% 3 = BIN 4 = ΔBIN 5 = Δ%BIN	Yes
DELAY	DL	NR2 (Floating-point)	<Delay Time> Time from the application of trigger to the start of measurement Range: 0.00 to 199.99[s] Resolution: 0.01[s]	Yes

Parameter Name or Function	Command		Operation and Setting Range	Inquiry
	Header	**Parameter**		
FREQUENCY	FR	NR3 (Exponent Type)	<Frequency> Range: 40 to 100E+3 [Hz] Selections: 40 to 130Hz: 10Hz increments 160, 200, 250Hz 300Hz-9.9kHz: 100Hz increments 10kHz-100kHz: 1kHz increments	Yes
HEADER	HD	NR1 (Integer)	<Header Output> Range: 0 = Disable 1 = Enable	Yes
LEVEL	LV	NR3 (Exponent Type)	<Measuring signal level> Range: 10E–3 to 1.100[Vrms] Resolution: 1E–3[Vrms]	Yes
ZERO OPEN	OP	—	<Stray admittance correction> Starts OPEN correction.	No
RECALL	RC	NR1 (Integer)	<Memory Recall> Range: 0 to 9	No
REFERENCE	RF	NR3 (Exponent Type)	<Reference value of deviation display> Range: 0 and ±(0.0001E–12 to 19999E+6) Resolution: Max. 4 1/2 digits	Yes
RANGE	RN	NR1 (Integer)	<Range> Range: 0 = AUTO 1 = MAN Range 1 : : 6 = MAN Range 6 7 to 12 = AUTO	Yes
SERVICE REQUEST	RQ	NR1 (Integer)	<Service Request> Programs whether or not to assert SRQ. Range: 0 = Disable 1 = Enable	Yes
ZERO SHORT	SH	—	<Residual impedance correction> Starts SHORT correction.	No
SPEED	SP	NR1 (Integer)	<Measuring Speed> Range: 0 = FAST 1 = MED 2 = SLOW	Yes
STORE	SR	NR1 (Integer)	<Memory Store> Range: 1 to 9	No
MAN TRIG	TG	—	<Manual Trigger> Establishes manual trigger mode and triggers measurement.	No
TRIG MODE	TR	NR1 (Integer)	<Trigger Mode> Range: 0 = AUTO 1 = MAN	Yes

Examples of operating commands include:

"FR 10E3" — Sets frequency to 10kHz.

"DA 0" — [A] DISPLAY, [B] DISPLAY and CKT are placed in the automatic selection mode.

"RC 2" — Setup Memory 2 is recalled.

NOTE
Zero correction OPEN and SHORT operation and the measurement in the manual trigger mode are held up while the instrument is executing subsequent commands.

Command Execution

A command is stored in the receive buffer, interpreted when its delimiter is received, and then executed. When execution is completed, the receive buffer is cleared, and the instrument is ready for the next command.

Receive Buffer

The receive buffer can store a maximum of 256 characters. Space, semicolon, <CR>, and <LF> characters are not stored in the receive buffer.

When the instrument receives a command string longer than the capacity of the receive buffer, the buffer overflows, and an error results. All commands are ignored, and the receive buffer is cleared when the buffer overflows.

Character Codes

7-bit ASCII codes are used for all commands. The MSB (parity bit) of 8-bit data is ignored. Uppercase letters and lowercase letters are treated the same.

Allowable characters include:

! " # $ % & ' ( ) * + , - . /

0 1 2 3 4 5 6 7 8 9 : < = > ? @

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

\ ^ _ '

a b c d e f g h i j k l m n o p q r s t u v w x y z

{ | } ~

The characters other than the above (including space, semicolon, and tab) are ignored. <CR> (carriage return) and <LF> (line feed) are used only as delimiters indicating the end of a command string.

Command String Delimiters

Command string delimiters include: <CR>, <LF>, or END message (EOI line set true in data transfer mode). Any combination of these delimiters may be used to terminate a command string.

NOTE
The instrument will not execute a command string until it receives a delimiter.

Basic Command Syntax

The basic syntax of an operating mode device-dependent command is shown Figure 4-1. The syntax of a command is as follows.

<Header> < Parameter> < Delimiter>

- Header: Defines command objectives.
- Parameter: Indicates selections or values. There are three types: NR1 (integer), NR2 (floating-point) and NR3 (exponent).
- Delimiter: <CR>, <LF>, etc. which indicates the end of a command.

Using Multiple Commands

A number of commands can be grouped together and sent as one command string as long as the string length is within the capacity of the receive buffer. Spaces or semicolon characters can be used to separate multiple commands to improve readability.

Command Parameters

There are three numeric formats for command parameters. Any one of the three formats can be used if the value is within the allowed range for that particular parameter. However, each command has a standard parameter format, and if a different format is used, the parameter is converted to the standard format. When the number of significant digits is too large, the value is rounded to the specified resolution.

Standard parameter formats include:

- NR1 (Integer format)
  Examples: 99 056 –1234 +24
- NR2 (Floating-point format)
  Examples: 1.2 .001 –160.5 +003.82
- NR3 (Exponent format)
  Examples: 12E3 9.8E+02 +04.5E–6 –.007E+09

4.2.3 Inquiry Commands

A command to read an instrument setting or measured data is called an inquiry command. Each command consists of the inquiry header that is preceded by the "?" character. Inquiry commands are listed in Table 4-3. The response to an inquiry command is in the format of "header" + "parameter" + "delimiter". Seven-bit ASCII codes are used without parity (MSB of 8-bit data = 0). Alpha characters are transmitted using only uppercase letters.

Headers

The output of a header is optional. The header output is inhibited when power is turned on or when the device clear command is received. The header can be turned on or off with the "HD" command.

Parameters

The following formats are used for parameters. The type of output and the number of digits (number of letters) vary depending on the inquiry messages.

- NR1: Integer
  Examples: 0, 1.
- NR2: Floating-point representation (no exponent)
  Example: 12.345.

  With this format, the position of the decimal point may be fixed or variable.
- NR3: Exponent representation (includes exponent)
  Example: 15.75E+03.

  With this format, the exponent assumes a value in multiples of 3 in the range of E–12 (10^{-12}) to E+06 (10^{6}). This convention is consistent with front panel display of exponents.
  Generally, a zero NR3 value is expressed by setting both the mantissa and exponent to all zeros (0.0000E+00). However, for a measured value, only the mantissa becomes zero.

Notes:

1. Leading zeros are omitted (except for one zero before a decimal point), and data is right-justified.
2. The plus sign (+) for positive numbers is omitted (+ is assumed). However, the plus sign (+) for the exponent is included. The exponent always has two digits.

Delimiters

The instrument terminates each output response with one or two delimiter characters. The following two delimiters can be selected from the front panel by using the SET UP key (see paragraph 4.5):

- <CR> <LF> (Carriage return and line feed)
- <CR> (Carriage return only)

The END message is sent with the last character of an inquiry response (EOI line set low).

Notes on Using Inquiry Commands

1. When the instrument is addressed to talk without sending an inquiry command, a single space character and a delimiter are sent except immediately after a measurement is performed in the manual trigger mode.
2. When more than one inquiry command is sent, only the last inquiry is valid. Other inquiries are ignored.
3. The response to an inquiry is canceled by sending a "TG" or GET command before requesting the response after sending an inquiry command.

Example Inquiry Responses

"?FR" (Frequency) — "1E+03" or "FR 1E+03"

"?DT" (Measured value) — "123.45E–03, 0.0012" or "DT 123.45E–03, 0.0012"

The example responses are shown with and without the header.

Table 4-3. Inquiry Commands

Parameter Name or Function	Inquiry Command Header	Output Format and Content of Inquiry		Operating Mode Command
		Header	Parameter*	
BIN	?BN	BN	<Comparator> Format: m1, m2, m3 m1: Bin No. (BIN) m2: Lower Limit (LOWER) m3: Upper Limit (UPPER) Delimited by delimiters for each bin setting in the sequence of BIN 0 to 19 and output in succession from BIN 0 to 19. Type: m1: NR1 (Integer) m2, m3: NR3 (Exponent type) Range: m1 = 0 to 19 m2, m3 = 0.0000E+00 and ±(0.0001E–12 to 19999.E+6) No. of char: 27 (29) per bin up to 620 with delimiters included.	Yes
BIAS ON/OFF	?BO	BO	<Bias> Type: NR1 (Integer) Range: 0 = Off 1 = On No. of char: 2 (4)	Yes
CIRCUIT	?CK	CK	<Equivalent circuit> Type: NR1 (Integer) Range: 1 = SER 2 = PAR 3 = AUTO SER 4 = AUTO PAR No. of char: 2 (4)	Yes
A DISPLAY	?DA	DA	<Function> Type: NR1 (Integer) Range: 1 = L 2 = C 3 = R 4 = |Z| 5 = AUTO L 6 = AUTO C 7 = AUTO R 8 = AUTO |Z| No. of char: 2 (4)	Yes

*Number of characters shown in parentheses are with header.

Inquiry Commands (Cont.)

Parameter Name or Function	Inquiry Command Header	Output Format and Content of Inquiry		Operating Mode Command
		Header	Parameter*	
[B] DISPLAY	?DB	DB	<Function Parameter> Type: NR1 (Integer) Range: 0 = Q 1 = D 2 = ESR 3 = G 4 = X 5 = θ 6 = V 7 = I No. of char: 2 (4)	Yes
Δ/BIN	?DE	DE	<Deviation and bin display> Type: NR1 (Integer) Range: 0 = Normal 1 = Δ 2 = Δ% 3 = BIN 4 = ΔBIN 5 = Δ%BIN No. of char: 2 (4)	Yes
DELAY	?DL	DL	<Delay time> Type: NR2 (Floating-point) Range: 0.00 to 199.99 [s] Resolution: 0.01 [s] Fixed point No. of letters: 7 (9)	Yes
MEASURED DATA	?DT	DT	<Measuring signal level> Format: Only bin No. for [A] DISPLAY and [B] DISPLAY. Type & Range: Different from parameter to parameter. No. of char: 23 (25) max.	No
FREQUENCY	?FR	FR	<Frequency> Type: NR3 (Exponent type) Range: 40E+00 to 100E+03 [Hz] Selections: 40 to 130Hz: 10Hz increments 160, 200, 250Hz 300 to 9.9kHz: 100Hz increments 10kHz to 100kHz: 1kHz increments	Yes
HEADER	?HD	HD	<Header output> Type: NR1 (Integer) Range: 0 = Inhibit (Not output) 1 = Admit (Ouptut) No. of char: 2 (4)	Yes

*Number of characters shown in parentheses are with header.

Inquiry Commands (Cont.)

Parameter Name or Function	Inquiry Command Header	Output Format and Content of Inquiry: Header	Output Format and Content of Inquiry: Parameter*	Mode Command
LEVEL	?LV	LV	<Measuring signal level> Type: NR3 (Exponent type) Range: 10.E–03 to 1.100E+00 [Vrms] No. of char: 2 (4)	Yes
REFERENCE	?RF	RF	<Reference value of deviation display> Type: NR3 (Exponent type) Range: 0.0000E+00 and ±(0.0001E–12 to 19999.E+06) Resolution: Max. 4 1/2 digits, when not restricted by exponent No. of char: 11 (13)	Yes
RANGE	?RN	RN	<Range> Type: NR1 (Integer) Range: 1 = Range 1 : : 6 = range 6 7 = AUTO range 1 : : 12 = AUTO range 6 No. of char: 3 (5)	Yes
SERVICE REQUEST	?RQ	RQ	<Service request output> Type: NR1 (Integer) Range: 0 = Inhibit (Not output) 1 = Admit (Output) No. of char: 2 (4)	Yes
SPEED	?SP	SP	<Measuring speed> Type: NR1 (Integer) Range: 0 = FAST 1 = MED 2 = SLO No. of char: 2 (4)	Yes
STATUS BYTE	?ST	ST	<Status byte> Type: NR1 (Integer) Range: 0 to 127 Converted to decimal notation from binary. See Table 4-5. No. of char: 4 (6)	No
TRIG MODE	?TR	TR	<Trigger mode> Type: NR1 (Integer) Range: 0 = AUTO 1 = MAN No. of char: 2 (4)	Yes

*Number of characters shown in parentheses are with header.

4.3 COMMAND REFERENCE

Detailed descriptions for each of the commands summarized in Table 4-1 through Table 4-3 are included on the following pages. Programming examples are written in Hewlett-Packard BASIC 5.0 for HP9000 series 200 and 300 computers.

4.3.1 BN, ?BN — Comparator

Purpose

To program comparator bin lower and upper limits, and to request comparator parameters.

Format

BN <Bin #>,<Lower Limit>,<Upper Limit>

Parameters

Bin #: (0-19)
Lower Limit: (0, ±[0.0001E–12 to 19999E+6])
Upper Limit: (0, ±[0.0001E–12 to 19999E+6])

Inquiry Command

?BN

Inquiry Response

[BN] <Bin 0>,<Lower Limit>,<Upper Limit> <Delimiter>...
<Bin n>,<Lower Limit>,<Upper Limit> <Delimiter>...
<Bin 19>,<Lower Limit>,<Upper Limit> <Delimiter + END>
(See parameter limits listed above.)

Default

Upon power-up the bin number, lower limit, and upper limit are all set to 0 ("BN 0, 0.0000E+00,0.0000E+00").

Description

The "BN" command programs the lower limit and upper limit values to be used for comparisons for all 20 comparator bins (bins 0-19), and it combines the functions of the front panel SET UP BIN, SET UP LOWER, and SET UP UPPER modes. Bins 1-19 are used for comparing measurement functions (L, C, R, or Z), and Bin 0 can be used to compare function parameter readings (Q, D, ESR, G, X, θ, V, or I). Generally, failed parts are assigned to Bin 0.

The "?BN" inquiry allows you to read back the lower and upper limit information for each of the 20 bins. The data for each of the bins is separated by delimiters, and the END message is sent with the delimiter following Bin 19 data.

Refer to paragraph 3.7 for complete details on comparator operation.

Programming Notes

1. The comparator can also be used in conjunction with the handler interface to sort parts automatically. See paragraph 3.17.
2. Refer to paragraph 4.6.4 for more information on reading bin, lower, and upper information over the bus.

Programming Examples

```
100 OUTPUT 702; "BN 1,990,1010"   ! Program Bin 1 limits.
110 OUTPUT 702; "BN 2,400,600"    ! Program Bin 2 limits.
120 DIM A$[100]                   ! Dimension input string.
130 OUTPUT 702; "?BN?             ! Send bin inquiry.
140 ENTER 702; A$                 ! Get inquiry response.
150 PRINT A$                      ! Print response.
```

4.3.2 BO, ?BO — Bias On/Off

Purpose

To turn the DC bias source on or off, and to read back the on/off status of the DC bias source.

Format

BO <n>

Parameters

BO 0 Bias off
BO 1 Bias on

Inquiry Command

?BO

Inquiry Response

[BO] 0 Bias off
[BO] 1 Bias on

Default

Upon power-up, DC bias is turned off ("BO 0")

Description

The "BO" command turns the internal or external DC bias source on or off, and it performs the same function as the front panel BIAS key. (The bias source is selected with the rear panel EXT switch.) The internal bias is fixed at 2VDC, and the maximum external bias that can be applied is ±35VDC.

The "?BO" inquiry returns the bias source status. A returned value of 0 indicates that bias is off, and a returned value of 1 shows that bias is on.

Refer to paragraph 3.14 for more details on using bias.

Programming Note

DC bias can be used only for the C (capacitance) measurement function. It cannot be used for AUTO, L, R, or Z functions. An "Err 14" message will be displayed on the front panel if you attempt to turn on the bias with one of these functions selected.

Programming Examples

```
100 OUTPUT 702; "DA 2"        ! Select C function.
110 OUTPUT 702; "BO 1"        ! Turn on bias.
120 OUTPUT 702; "?BO"         ! Request bias status.
130 ENTER 702; A$             ! Input bias status.
140 PRINT A$                  ! Display bias status.
```

4.3.3 CK, ?CK — Equivalent Circuit

Purpose

To set the equivalent circuit mode to series or parallel, and to request equivalent circuit status.

Format

CK <n>

Parameters

CK 0 AUTO
CK 1 SER (series)
CK 2 PAR (parallel)
CK 3 AUTO
CK 4 AUTO

Inquiry Command

?CK

Inquiry Response

[CK] 0 AUTO
[CK] 1 SER (series)
[CK] 2 PAR (parallel)
[CK] 3 AUTO SER
[CK] 4 AUTO PAR

Default

Upon power-up, the instrument is in the AUTO equivalent circuit mode ("CK 0").

Description

The "CK" command programs the equivalent circuit mode, and it performs the same operation as the front panel CKT key. The "?CK" inquiry requests the status of the equivalent circuit.

While the AUTO mode, the instrument automatically sends back measured data using series or parallel circuit equivalent based on the selected function and function parameter as follows:

Conditions for SER Mode		Conditions for PAR Mode	
Function	Function Parameter	Function	Function Parameter
L,C,R, |Z|	ESR,X	L,C,R, |Z|	G
L,C,(|Z|≤1kΩ)	Q,D,θ,V,I	L,C,R, |Z|>1kΩ	Q,D,θ,V,I
R (θ≥0)	Q,D,θ,V,I	R (θ<0)	Q,D,θ,V,I
|Z|	Q,D,θ,V,I		

Refer to paragraph 3.5.3 for additional information on equivalent circuits.

Programming Note

Only the AUTO equivalent circuit mode can be programmed when the unit is in the AUTO function mode ("DA 0"). An "Err 13" will be displayed if you attempt to program the series or parallel equivalent circuit mode while the unit is in the AUTO function. See paragraph 4.3.4 for more information on programming the measurement function.

Programming Examples

```
100 OUTPUT 702; "DA 3"      ! Turn off AUTO function.
110 OUTPUT 702; "CK 2"      ! Select parallel circuit.
130 OUTPUT 702; "?CK"       ! Send circuit inquiry.
140 ENTER 702; A$           ! Input response.
150 PRINT A$                ! Display response.
```

4.3.4 DA, ?DA — Measurement Function

Purpose

To program the measurement function, and to request status on the presently selected measurement function.

Format

DA <n>

Parameters

DA 0	AUTO
DA 1	L (H) – Inductance
DA 2	C (F) – Capacitance
DA 3	R (Ω) – Resistance
DA 4	|Z| (Ω) – Impedance
DA 5	AUTO
DA 6	AUTO
DA 7	AUTO
DA 8	AUTO

Inquiry Command

?DA

Inquiry Response

[DA] 0	AUTO
[DA] 1	L
[DA] 2	C
[DA] 3	R
[DA] 4	|Z|
[DA] 5	AUTO L
[DA] 6	AUTO C
[DA] 7	AUTO R
[DA] 8	AUTO |Z|

Default

Upon power-up, the AUTO measurement function is selected ("DA 0").

Description

The "DA" command programs the measurement function (AUTO, L, C, R, or |Z|) in a manner similar to the front panel [A] DISPLAY key. The "?DA" inquiry allows you to request measurement function status from the instrument. When the AUTO function is selected, the instrument automatically chooses the function and function parameter (paragraph 4.3.5) based on an internally measured phase parameter as follows:

Internal Phase Angle	Function	Function Parameter
+90° ±30°	L	Q
0° ±30°	R	Q
–90° ±30°	C	D
Other than the above	|Z|	θ

See paragraph 3.5.1 for more information on measurement functions.

Programming Notes

1. Function parameters are automatically selected when the unit is in the AUTO function mode. See paragraph 4.3.5 for more information on programming function parameters using the "DB" command. Attempting to program function parameters while in the AUTO function mode will result in "Err 13".
2. The equivalent circuit ("CK" command, paragraph 4.3.3) is automatically selected (AUTO) when the unit is in the AUTO function. Attempting to program the parallel or series circuit mode when the AUTO function is enabled will result in "Err 13".
3. The deviation and BIN modes (paragraph 4.3.6) are inoperative when the instrument is in the AUTO function. Attempting to enable deviation or BIN modes when AUTO function is enabled will result in "Err 13".
4. Refer to paragraph 4.6.3 for details on data formats for the various functions.

Programming Examples

```
100 OUTPUT 702; "DA 2"        ! Select C function.
110 OUTPUT 702; "?DA"         ! Send function inquiry.
120 ENTER 702; A$             ! Input response.
130 PRINT A$                  ! Display response.
```

4.3.5 DB, ?DB — Function Parameter

Purpose

To program the measurement function parameter, and to request status on the presently selected measurement function parameter.

Format

DB <n>

Parameters

- DB 0 Q – Quality factor
- DB 1 D – Dissipation factor (D = 1/Q)
- DB 2 ESR (Ω) – Equivalent series resistance
- DB 3 G (S) – Parallel conductance
- DB 4 X (Ω) – Series reactance
- DB 5 θ (deg.) – Phase angle
- DB 6 V (rms) – Voltage across DUT
- DB 7 I (rms) – Current through DUT

Inquiry Command

?DB

Inquiry Response

[DB] 0 Q
[DB] 1 D
[DB] 2 ESR (Ω)
[DB] 3 G (S)
[DB] 4 X (Ω)
[DB] 5 θ (deg.)
[DB] 6 V (rms)
[DB] 7 I (rms)

Default

Since the AUTO measurement function is selected upon power-up, the function parameter will depend on the device being measured (see below.)

Description

The "DB" command programs the function parameter (Q, D, ESR, G, X, θ, V, or I) in a manner similar to the front panel [B] DISPLAY key. The "?DB" inquiry allows you to request function parameter status from the instrument.

When the AUTO function is selected (see paragraph 4.3.4), the instrument automatically chooses the function and function parameter based on an internally measured phase parameter as follows:

Internal Phase Angle	Function	Function Parameter
+90° ±30°	L	Q
0° ±30°	R	Q
–90° ±30°	C	D
Other than the above	|Z|	θ

See paragraph 3.5.2 for more information on function parameters.

Programming Notes

1. Attempting to program function parameters while in the AUTO function mode will result in "Err 13".
2. Refer to paragraph 4.6.3 for details on data formats for the various function parameters.

Programming Examples

```
100 OUTPUT 702; "DB 5"        ! Select θ parameter.
110 OUTPUT 702; "?DB"         ! Send parameter inquiry.
120 ENTER 702; A$             ! Input response.
130 PRINT A$                  ! Display response.
```

4.3.6 DE, ?DE — Deviation and Bin Display

Purpose

To program the unit to display and send back deviation and/or bin readings, and to request status on the presently selected deviation and bin reading mode.

Format

DE <n>

Parameters

DE 0	Normal readings
DE 1	Deviation (Δ)
DE 2	Percent deviation (Δ%)
DE 3	Bin
DE 4	Bin and deviation (Δ/BIN)
DE 5	Bin and percent deviation (Δ%/BIN)

Inquiry Command

?DE

Inquiry Response

[DE] 0	Normal
[DE] 1	Δ
[DE] 2	Δ%
[DE] 3	BIN
[DE] 4	Δ/BIN
[DE] 5	Δ%/BIN

Default

Upon power-up, the normal reading mode is selected ("DE 0").

Description

The "DE" command controls whether or not bin and deviation readings are sent and displayed, and it operates in essentially the same way as the Δ/Δ%ΔBIN key. The "?DE" inquiry allows you to request information on the type of reading (normal, bin, or deviation) from the instrument.

See paragraphs 3.6 and 3.7 for more information on deviation and comparator (bin) operation.

Programming Note

1. The unit cannot be programmed to display or send back bin or deviation readings while it is in the AUTO function mode ("DA 0"). Attempting to program the unit for deviation or bin readings ("DE 1" to "DE 5") while in the AUTO function mode will result in "Err 13".
2. Refer to paragraph 4.6.3 for details on deviation and bin data formats.

Programming Examples

```
100 OUTPUT 702; "DE 1"        ! Select deviation
110 OUTPUT 702; "DE 3"        ! Select bin.
120 OUTPUT 702; "?DE"         ! Send deviation/bin inquiry.
130 ENTER 702; A$             ! Input response.
140 PRINT A$                  ! Display response.
```

4.3.7 DL, ?DL — Delay Time

Purpose

To program the delay time the unit uses in the manual trigger mode, and to read back delay time information.

Format

DL <n>

Parameters

Delay Time = 0.00 to 199.99 [s]; 0.01s resolution

Inquiry Command

?DL

Inquiry Response

[DL] <Delay Time>
Delay Time = 0.00 to 199.99 [s]; 0.01s resolution

Default

Upon power-up, the delay time is set to 0s ("DL 0").

Description

The "DL" command programs the delay time that the instrument uses in the manual trigger mode and performs essentially the same operation as SET UP DELAY. The "?DL" inquiry allows you to read back the programmed delay period.

The delay time is defined as the time from when the unit is triggered until it begins a measurement. Delay time can be used to allow device parameters to settle before measurement, and it is particularly useful when using the comparator or when applying a DC bias to the DUT.

Refer to paragraph 4.3.22 for information on programming the unit for the manual trigger mode. Paragraph 4.3.21 discusses triggering instrument readings in detail.

Programming Note

The delay time is disabled (0s) when the unit is in the automatic (AUTO) trigger mode regardless of the programmed delay time. You can, however, program the delay time while the unit is in the AUTO trigger mode, and it will use that delay time after switching to the manual trigger mode (MAN).

Programming Examples

```
100 OUTPUT 702; "DL 3"     ! Program three second delay.
110 OUTPUT 702; "?DL"      ! Send delay time inquiry.
120 ENTER 702; A$          ! Input response.
130 PRINT A$               ! Display response.
```

4.3.8 ?DT — Measured Data

Purpose

To request a reading from the instrument.

Response

[DT] <[A] DISPLAY data>, <[B] DISPLAY data>

Description

The "?DT" inquiry places the last measured reading in the transmit buffer. The instrument will then send that reading the next time it is addressed to talk.

Reading data consists of [A] DISPLAY data and [B] DISPLAY data separated by a comma. Normally, this data will consist of the measurement function and function parameter information. If deviation or bin readings are enabled, however, ("DE" command, paragraph 4.3.6), deviation or bin information will be sent instead.

Programming Notes

1. A reading can also be triggered and obtained by using the "TG" command, as described in paragraph 4.3.21.
2. Refer to paragraph 4.6 for more information on making measurements over the GPIB.

Programming Examples

```
100 OUTPUT 702; "?DT"        ! Send data inquiry.
110 ENTER 702; A$            ! Input data.
120 PRINT A$                 ! Display data.
```

4.3.9 FR, ?FR — Frequency

Purpose

To program the frequency of the test signal, and to request frequency information from the instrument.

Format

FR <Frequency>

Parameter

Frequency: 40 to 100E3 [Hz]
40 to 130Hz: 10Hz increments
160, 200, 250Hz
300Hz to 9.9kHz: 100Hz increments
10kHz to 100kHz: 1kHz increments

Inquiry Command

?FR

Inquiry Response

[FR] <Frequency>
Frequency = 40.0E+00 to 100.E03 [Hz]
(See Parameter description above for frequencies.)

Default

Upon power-up, the frequency is set to 1kHz ("FR 1000").

Description

The "FR" command sets the frequency of the test signal applied to the DUT, combining the functions of the front panel FREQ key and the SET UP FREQ auxiliary setup mode. The "?FR" inquiry allows you to request the selected frequency from the unit.

The frequency can be set to certain, discrete values in the range of 40Hz to 100kHz, as outlined above. If you send a frequency value within the allowed range that is not at one of the exact frequency increments, the instrument will round up or round down frequency to the closest value. For example, a frequency of 220Hz will be rounded down to 200Hz, while a frequency of 230Hz will be rounded up to 250Hz.

Since the impedance of an inductor or capacitor changes with frequency, these devices should normally be measured at their operating frequencies. Use the following general guidelines to select a measurement frequency:

- 40Hz, 50Hz, 60Hz: Use to test coils, transformers, etc.
- 100Hz and 120Hz: Use to measure electrolytic capacitors..
- 1kHz: Use to measure intermediate values of L and C and all values of R.
- 10kHz to 100kHz: Use to measure smaller values of L and C.

Programming Note

Sending a frequency value outside the allowed range will result in an "Err 13". However, since the unit rounds off frequencies to the nearest value, the actual programmable range is from slightly below 40Hz to slightly above 100kHz. For example, a frequency of 35Hz will be rounded up to 40Hz — the lowest valid frequency setting.

Programming Examples

```
100 OUTPUT 702; "FR 250"        ! Program 250Hz frequency.
110 OUTPUT 702; "?FR"           ! Request frequency setting.
120 ENTER 702; A$               ! Input frequency setting.
130 PRINT A$                    ! Display frequency.
```

4.3.10 HD, ?HD — Header

Purpose

To enable and disable the header sent with inquiry responses, and to request header status.

Format

HD <n>

Parameters

HD 0 Disable header
HD 1 Enable header

Inquiry Command

?HD

Inquiry Response

[HD] 0 Header disabled
[HD] 1 Header enabled

Default

Upon power-up, the header is disabled ("HD 0").

Description

The "HD" command enables or disables the two-character header the instrument sends back at the beginning of inquiry responses. (The header is useful for identifying the type of information in an inquiry response.) The "?HD" inquiry allows you to determine whether or not the header is enabled.

Note that each header is made up of the same two letters used for the corresponding inquiry command. For example, "FR" is the header for the "?FR" inquiry response.

Programming Note

Although both lower- and upper-case letters can be used for commands, inquiry headers use only upper-case letters.

Programming Examples

```
100 OUTPUT 702; "HD 1"     ! Enable header.
110 OUTPUT 702; "?HD"      ! Send header inquiry.
120 ENTER 702; A$          ! Input inquiry response.
130 PRINT A$               ! Display response.
```

4.3.11 LV, ?LV — Level

Purpose

To set the test signal voltage level, and to request the current level.

Format

LV <Level>

Parameter

Level = 10E–3 to 1.1 [Vrms]; 1E–3 (1mVrms) resolution

Inquiry Command

?LV

Inquiry Response

[LV] <Level>
Level = 10.E–03 to 1.100E+00 [Vrms]; 1E–03 resolution

Default

Upon power-up, the level will be set to 1V rms ("LV 1.000E+00").

Description

The "LV" command sets the voltage of the test signal applied to the DUT, thus combining the functions of the LEVEL key and SET UP LEVEL. The "?LV" inquiry allows you to read back the current level setting from the instrument.

The 1V rms level can be used to test most devices. A lower level may be required to test non-linear devices such as semiconductors whose characteristics depend on the signal level.

Programming Notes

1. Level values are for no-load (open-circuit) conditions. Since the output resistance is about 100Ω, DUTs with lower impedance values will reduce the actual test signal level from its programmed value. For example, the signal level across a 1kΩ resistor will be reduced by about 10% from the indicated value.
2. The actual voltage across the DUT can be requested by sending the "DB 6" command to place the [B] DISPLAY in the Vrms mode (paragraph 4.3.5), and then using the "?DT" inquiry to read back the level from the instrument (paragraph 4.3.8).

Programming Examples

```
100 OUTPUT 702; "LV 650E-3"     ! Program 650mV level.
110 OUTPUT 702; "?LV"           ! Send level inquiry.
120 ENTER 702; A$               ! Input inquiry response.
130 PRINT A$                    ! Display level setting.
```

4.3.12 OP — Zero Open

Purpose

To perform open zero correction

Format

OP

Parameters

None

Inquiry Command

None

Default

Upon power-up, open zero correction will be disabled (no open correction).

Description

The "OP" command performs open zero correction in the same manner as pressing the front panel ZERO OPEN key. During the open correction process, the instrument measures the stray admittance at a number of frequencies, and it then applies a correction factor during actual DUT measurements to null out any residual errors.

To perform open zero correction, first disconnect the DUT from the test fixture or test leads, then send the "OP" command over the bus. Wait until the correction process has been completed before sending any further commands.

See paragraph 3.15 for more information on open zero correction.

Programming Notes

1. Sending commands to the instrument during open correction will abort the process. Previous correction constants will remain in effect if open correction is aborted. (You can determine when correction is completed over the bus by programming the instrument to generate an SRQ when correction has been completed; see paragraph 4.3.16.)
2. Connect L CUR to L POT, and connect H CUR and L CUR before performing open correction. See paragraph 3.15 for details.
3. Short zero correction should also be performed to compensate for residual impedance. See paragraph 4.3.17 for more information.

Programming Example

```
100 OUTPUT 702; "OP"          ! Perform open correction.
```

4.3.13 RC — Recall

Purpose

To recall instrument configurations from setup memory.

Format

RC <n>

Parameters

n = memory location (0-9)

Inquiry Command

None

Description

The RC command recalls instrument configurations from memory in a manner similar to the front panel RCL key. (Memory configuration is battery backed up so that setup data is not lost when power is turned off.) Locations 1 through 9 are user-defined configurations stored with the "SR" (store) command, as described in paragraph 4.3.19.

Memory location 0 stores the instrument configuration from the last time the power was turned off. This configuration will not be automatically restored at power-on, but you can recall this configuration by sending "RC 0".The following configurations are stored in memory for recall:

Function (L, C, R, Z): "DA"
Function parameter (Q, D, ESR, G, X, θ, V, I): "DB"
Deviation and comparator bin assignment: "DE"
Measurement frequency: "FR"
Equivalent circuit mode: "CK"
Measurement speed: "SP"
Measurement signal level: "LV"
Range: "RN"
Trigger mode: "TR"
Trigger delay time: "DL"
Reference value for deviation: "RF"
Lower and upper limits for comparator: "BN"

Programming Notes

1. The GPIB primary address and delimiter are also stored in battery backed-up memory, but these parameters are not recalled by the "RC" command. The GPIB address and delimiter can be programmed by using SET UP GPIB, as discussed in paragraph 3.8.5.
2. DC bias on state, OPEN and SHORT correction values, and the GPIB talk-only state are not stored in memory for recall by the "RC" command.

Programming Example

```
100 OUTPUT 702; "RC 1"        ! Recall memory location 1.
```

4.3.14 RF, ?RF — Reference

Purpose

To program the reference value used for deviation and percent deviation, and to read back the reference value from the instrument.

Format

RF <Reference>

Parameter

Reference = 0, ±(0.0001E–12 to 19999E+6)

Inquiry Command

?RF

Inquiry Response

[RF] <Reference>
Reference = 0.0000E+00, ±(0.0001E–12 to 19999E+06)

Default

Upon power-up, the reference value will be set to 0 ("RF 0.0000E+00").

Description

The "RF" command programs the reference value in the same manner as the front panel auxiliary SET UP REF function. The "?RF" inquiry reads back reference information from the instrument.

Once the reference value is programmed, you can enable deviation or percent deviation using the "DE" command (paragraph 4.3.6). Deviation computations are as follows:

- Deviation (Δ) = Measured value – Reference value
- Percent deviation (Δ%) = (Δ/Reference value) × 100

Programming Note

Deviation and percent deviation can also be used with the comparator. See paragraphs 3.6 and 3.7 for details.

Programming Examples

```
100 OUTPUT 702; "RF 1.3E3"     ! Program 1.3E3 reference.
110 OUTPUT 702; "?RF"          ! Send reference inquiry.
120 ENTER 702; A$              ! Input response.
130 PRINT A$                   ! Display response.
```

4.3.15 RN, ?RN — Range

Purpose

To program the measurement range, and to request measurement range information from the instrument.

Format

RN <n>

Parameters

RN 0	AUTO
RN 1	Range 1
RN 2	Range 2
RN 3	Range 3
RN 4	Range 4
RN 5	Range 5
RN 6	Range 6
RN 7	AUTO
RN 8	AUTO
RN 9	AUTO
RN 10	AUTO
RN 11	AUTO
RN 12	AUTO

Inquiry Command

?RN

Inquiry Response

[RN] 1	Manual range 1.
[RN] 2	Manual range 2.
[RN] 3	Manual range 3.
[RN] 4	Manual range 4.
[RN] 5	Manual range 5.
[RN] 6	Manual range 6.
[RN] 7	AUTO range 1.
[RN] 8	AUTO range 2.
[RN] 9	AUTO range 3.
[RN] 10	AUTO range 4.
[RN] 11	AUTO range 5.
[RN] 12	AUTO range 6.

Default

Upon power-up, the instrument is in the AUTO range mode ("RN 0").

Description

The "RN" command sets the measurement range of the instrument in a way similar to using the front panel RANGE keys. The "?RN" inquiry requests range information.

In most cases, the instrument can be left in the AUTO mode, in which case it will automatically select the best range for the measurement. In some cases, excessive noise may prevent the instrument from staying on the optimum range. In this situation, program the appropriate manual range using the "RN" command.

For more details on range selection, refer to paragraph 3.5.4.

Programming Note

Improperly programming a manual range may result in an "OF", "UF", or "OU" error (see paragraph 3.5.4). These error conditions are identified by the type of data the unit sends back, as discussed in paragraph 4.6.3.

Programming Examples

```
100 OUTPUT 702; "RN 3"      ! Program manual range 3.
110 OUTPUT 702; "?RN"       ! Send range inquiry.
120 ENTER 702; A$           ! Input response.
130 PRINT A$                ! Display response.
```

4.3.16 RQ, ?RQ — Service Request

Purpose

To enable and disable SRQ (service request), and to request service request status.

Format

RQ <n>

Parameters

RQ 0 Disable SRQ
RQ 1 Enable SRQ

Inquiry Command

?RQ

Inquiry Response

[RQ] 0 SRQ disabled
[RQ] 1 SRQ enabled

Default

Upon power-up, SRQ is disabled ("RQ 0").

Description

The "RQ" command allows you to program whether or not the instrument will generate an SRQ (service request) under certain conditions, and the "?RQ" inquiry requests information on whether or not SRQ is enabled.

When SRQ is enabled ("RQ 1"), the instrument will generate an SRQ under the following conditions:

- When one measurement is completed in the manual trigger mode.
- After open or short zero correction is completed.
-

Once asserted, SRQ can be reset (cleared) as follows:

- By reading the status byte with the serial polling sequence.
- By requesting status information using the "?ST" inquiry.
- By sending a device clear command (DCL or SDC).

Programming Notes

1. SRQ will be asserted (when enabled) only in the manual trigger mode. It will not be generated when the instrument is in the AUTO trigger mode (see paragraph 4.3.22).
2. The exact cause of the SRQ can be determined by using the "?ST" (status) inquiry, as explained in paragraph 4.3.20.

Programming Examples

```
100 OUTPUT 702; "RQ 1"        ! Enable SRQ.
110 OUTPUT 702; "?RQ"         ! Send SRQ inquiry.
120 ENTER 702; A$             ! Input response.
130 PRINT A$                  ! Display response.
```

4.3.17 SH — Short Zero Correction

Purpose

To perform short zero correction

Format

SH

Parameters

None

Inquiry Command

None

Default

Upon power-up, short zero correction will be disabled (no short correction).

Description

The "SH" command performs short zero correction in the same manner as pressing the front panel ZERO SHORT key. During the short correction process, the instrument measures the residual impedance at a number of frequencies, and it then applies a correction factor during actual DUT measurements to null out any residual errors.

To perform short zero correction, first short all four UNKNOWN terminal together, then send the "SH" command over the bus. Wait until the correction process has been completed before sending any further commands.

See paragraph 3.15 for more information on short zero correction.

Programming Note

1. Sending commands to the instrument during short correction will abort the process. Previous correction constants will remain in effect if short correction is aborted. (You can determine when correction is completed over the bus by programming the instrument to generate an SRQ when correction has been completed; see paragraph 4.3.16.)
2. Connect L CUR, L POT, H CUR, and H POT together before performing short correction. See paragraph 3.15 for details.
3. Open zero correction should also be performed to compensate for stray admittance. See paragraph 4.3.12 for more information.

Programming Example

```
100 OUTPUT 702; "SH"          ! Perform short correction.
```

4.3.18 SP, ?SP — Speed

Purpose

To program the measurement speed, and to request information on the present measurement speed.

Format

SP <n>

Parameters

SP 0 FAST
SP 1 MED
SP 2 SLOW

Inquiry Command

?SP

Inquiry Response

[SP] 0 FAST
[SP] 1 MED
[SP] 2 SLOW

Default

Upon power-up, the MED (medium) speed is selected ("SP 1").

Description

The "SP" command programs the measurement speed and performs the same function as the front panel SPEED key. The "?SP" inquiry reads back the present measurement speed setting.

Use the MED speed for most measurement situations. If a faster reading rate is required, use the FAST speed. At the FAST speed, however, measurement accuracy is reduced. Use the SLOW speed when measurement data is noisy and difficult to read.

Typical time per measurement for the three speeds is shown below.

Speed	1V, 1kHz 1kΩ Resistance	100Hz	40Hz
FAST	60msec	55-95msec	90-120msec
MED	150msec	135-300msec	290-490msec
SLOW	480msec	440-740msec	1.0-1.3sec

Programming Notes

1. Add 14msec to above times for V or I display.
2. Add 1msec to above times for deviation display (Δ or Δ%).
3. When using bins 0-n, add the following to above times:
   +0.05msec +[(n+1) × 0.25msec]

Programming Examples

```
100 OUTPUT 702; "SP 2"        ! Select SLOW speed.
110 OUTPUT 702; "?SP"         ! Send speed inquiry.
120 ENTER 702; A$             ! Input response.
130 PRINT A$                  ! Display response.
```

4.3.19 SR — Store

Purpose

To store instrument configurations into setup memory.

Format

SR <n>

Parameter

n = memory location (1–9)

Inquiry Command

None

Description

The "SR" command stores instrument configurations into memory in a manner similar to the front panel –STO key. (Memory configuration is battery backed up so that setup data is not lost when power is turned off.) Note that you can store configurations in locations 1 through 9, but you cannot use the "SR" command for location 0. Memory location 0 stores the instrument configuration from before the last time the power was turned off. This configuration will not be automatically restored at power-on, but you can recall this configuration by sending "RC 0".

The following configurations are stored in memory for recall:

Function (L, C, R, Z): "DA"
Function parameter (Q, D, ESR, G, X, θ, V, I): "DB"
Deviation and comparator bin assignment: "DE"
Measurement frequency: "FR"
Equivalent circuit mode: "CK"
Measurement speed: "SP
Measurement signal level: "LV"
Range: "RN"
Trigger mode: "TR"
Trigger delay time: "DL"
Reference value for deviation: "RF"
Lower and upper limits for comparator: "BN"

Programming Notes

1. Use the "RC" command (paragraph 4.3.13) to recall stored instrument configurations.
2. The GPIB primary address and delimiter are also stored in battery backed-up memory, but these parameters are not stored by the "SR" command. The GPIB address and delimiter can be programmed by using SET UP GPIB, as discussed in paragraph 3.8.5.
3. Bias on state, zero correction constants, and GPIB talk-only mode are not stored in memory by the "SR" command.

Programming Example

```
100 OUTPUT 702; "SR 1"          ! Store in memory location 1.
```

4.3.20 ?ST — Status

Purpose

To request status information from the instrument.

Format

?ST

Response

[ST] <n>
n = decimal number (0-127) representing bits (see below).

Default

Upon power-up, all status bits are set to zero.

Description

The "?ST" inquiry allows you to request status byte information from the instrument. Information returned by sending "?ST" is in the form of a decimal number with values summarized below:

Bit	Decimal Value	Content	Condition to be set (1)	Condition to be cleared (0)
7 (MSB)	—	Always 0		
6	64	RQS	SRQ asserted	By sending device clear or by reading status byte.
5	32	ERR	Zero correction error (value too large).	By sending device clear or by reading status byte.
4	16	BUSY	While measuring (including zero correction)	While not measuring.
3	8	ZERO	End of open or short correction (including abnormal end)	By sending device clear, reading status, or by starting zero correction.
2	—	Always 0		
1	—	Always 0		
0	—	Always 0		

Programming Notes

1. Device clear: DCL or SDC.
2. The status byte can be read either by sending "?ST" or by using the serial polling sequence. Status byte bits are always cleared with "?ST", but these bits are not cleared by serial polling when SRQ is disabled.
3. If multiple bits are set, add up the decimal values above to determine the returned value. For example, a value of 40 will be returned when an unsuccessful zero correction process is completed: Bit 5 (ERR) = 32; Bit 3 (ZERO) = 8.

4.3.21 TG — Manual Trigger

Purpose

To trigger a measurement in the manual trigger mode.

Format

TG

Parameters

None

Inquiry Command

None

Description

The "TG" command can be used to trigger a reading when the instrument is in the manual trigger mode, and it operates in a similar manner as the front panel MAN key (see paragraph 4.3.22 for an explanation of trigger modes). When the "TG" command is sent, a reading is taken, and the data is placed in the transmit buffer. The reading is then transmitted the next time the instrument is addressed to talk.

Programming Notes

1. Sending the "TG" command will automatically place the instrument in the manual (MAN) trigger mode.
2. The "DL" command can be used to program a trigger delay (the time from the trigger until the time the measurement is taken). See paragraph 4.3.7 for information on programming the trigger delay.
3. The GET command can also be used to trigger the instrument in the manual trigger mode.

Programming Examples

```
100 OUTPUT 702; "TG"        ! Trigger reading.
110 DIM A$[50]              ! Dimension reading string.
120 ENTER 702; A$           ! Input reading.
130 PRINT A$                ! Display reading.
```

4.3.22 TR, ?TR — Trigger Mode

Purpose

To program the trigger mode, and to request the current trigger mode setting.

Format

TR <n>

Parameters

TR 0 Automatic (AUTO)
TR 1 Manual (MAN)

Inquiry Command

?TR

Inquiry Response

[TR] 0 Automatic (AUTO)
[TR] 1 Manual (MAN)

Default

Upon power-up, the AUTO trigger mode is selected ("TR 0").

Description

The "TR" command programs the trigger mode, and it operates in a manner similar to the front panel AUTO TRIG key. "?TR" allows you to request trigger mode status from the instrument.

In the automatic (AUTO) trigger mode, readings are triggered and measured continuously. You can request a reading at any time by using the "?DT" inquiry, as discussed in paragraph 4.3.8.

In the manual (MAN) trigger mode, however, the unit must be triggered by using the "TG" command (paragraph 4.3.21). You can obtain a triggered reading by addressing the unit to talk after sending each "TG" command. The manual trigger mode is useful in situations requiring a delay time before measurement, or when measurements must be synchronized to external events.

Programming Notes

1. The "DL" command can be used to program a trigger delay (the time between the trigger and the measurement). See paragraph 4.3.7.
2. The GET command can also be used to trigger the instrument in the manual trigger mode.

Programming Examples

```
100 DIM A$[50]          ! Dimension input string.
110 OUTPUT 702; "TR 1"  ! Select manual mode.
120 OUTPUT 702; "?TR"   ! Send mode inquiry.
130 ENTER 702; A$       ! Input response.
140 PRINT A$            ! Display response.
150 OUTPUT 702; "TG"    ! Trigger using "TG".
160 ENTER 702; A$       ! Input reading.
170 PRINT A$            ! Display reading.
180 TRIGGER 702         ! Trigger using GET.
190 ENTER 702; A$       ! Input reading.
200 PRINT A$            ! Display reading.
```

4.4 GENERAL BUS OPERATION

4.4.1 Responses to Interface Messages

Instrument responses to interface messages are summarized in Table 4-4.

Notes:

1. Display parameters and frequency are not affected by the IFC command. The IFC command affects all devices connected to the bus.
2. DCL and SDC commands are valid in the local mode, but the GET command is valid only when the unit is in remote.
3. Since SDC, GTL, and GET are addressed commands (see Appendix B), the instrument will respond to these commands only after it has been addressed to listen. The DCL command, however, is in the universal command group, and it is always valid for all devices equipped with the device clear function. No addressing is required for DCL.

4.4.2 Remote/Local Operation

Remote

When the instrument is addressed to listen with the REN line true, the unit goes into the remote mode, and the REMOTE indicator on the front panel turns on. While in remote, the instrument can be programmed by sending commands over the GPIB, but the front panel keys are disabled (except for error reset). During the transition from local to remote, the auxiliary set up mode (SET UP key) is canceled (if enabled), but the current measurement cycle is not interrupted.

Local

When REN is set false (REN line set high), or when the instrument receives the GTL command, the instrument goes into the local mode, and the REMOTE indicator turns off. In the local mode, front panel keys are enabled, but GPIB device-dependent commands are ignored, and the GET command is also invalid. A measurement is not interrupted by the transition from remote to local.

Table 4-4. Response to Interface Messages

IFC (Interface Clear)	Initializes the GPIB Interface. (Cancels Listener or Talker)	
DCL (Device Clear) or SDC (Selective Device Clear)	Resets an error. Clears the transmit and receive buffers of the GPIB. Clears SRQ. Disables SRQ. Disables header. Resets the wait state for end of measurement in manual trigger mode.	 (Status byte is reset.) (Equivalent to "RQ 0") (Equivalent to "HD 0")
GTL (Go To Local)	Establishes the local mode.	
GET (Group Execute Trig)	Starts measurement in manual trigger mode (Same as trigger by "TG") Once triggered by the GET command, the next GET command is ignored until the end of measurement.	

4.4.3 Service Request (SRQ)

The Model 3330 can be programmed to issue an SRQ by sending "RQ 1" over the bus. When enabled, SRQ is asserted and reset under the conditions described

Assert SRQ

When enabled, SRQ is asserted under the following conditions:

- After one measurement is completed in the manual trigger mode. Note: an SRQ will not be generated in the continuous trigger mode.
- After OPEN or SHORT zero correction is completed.

Reset SRQ

An SRQ can be reset (cleared) by performing the following:

- By reading the status byte with a serial polling sequence.
- By sending the "?ST" inquiry command to request status.
- By sending the DCL or SDC command over the bus.

4.4.4 Status Byte

The status byte sent in response to serial polling and the "?ST" inquiry message is defined in Table 4-5. Note that single byte is returned by the serial polling sequence (SPE, SPD), while the decimal value of the status byte is returned by the ?ST inquiry.

Table 4-5. Status Byte

Bit	Description	Condition to be set (1)	Condition to be reset (0)
7 MSB	Always zero		
6	RQS	When issuing the SRQ command	After receiving the device clear command* After reading the status byte.**
5	ERR	Zero correction error (Correction value is too large.)	After receiving the device clear command* After reading the status byte When the zero correction is normally performed.
4	BUSY	During measurement (Zero correction included)	During non-measurement
3	Zero	End of zero correction of OPEN or SHORT (Abnormal end included)	After receiving the device clear command After reading the status byte When starting zero correction
2	Always zero		
1	Always zero		
0 LSB	Always zero		

*Device clear: DCL or SDC command
**Status byte read: Reading of the status byte by the inquiry message "?ST" or serial poll performed when issuing the SRQ command. (Reset is not performed by the serial poll when the SRQ command is not issued.)

4.4.5 Process Time

The data transfer rate depends both on the speed of the controller and the process time of the instrument. The process time of the instrument is slower when making measurements. Table 4-6 lists process times for standard commands during non-measurement phases of operation. The process time differs slightly from parameter to parameter.

Table 4-6. Typical Process Times of Commands

Setting Message		Inquiry Message	
Header	Processing Time (Approx.)	Header	Processing Time (Approx.)
DA	5msec	?DA	6msec
DB	5msec	?DB	6msec
DE	5msec	?DE	6msec
CK	5msec	?CK	6msec
RF	8msec	?RF	10msec
BN	14msec	?BN	300msec*
—		?DT	15msec**
FR	100msec***	?FR	9msec
LV	8msec	?LV	9msec
RN	5msec	?RN	6msec
SP	5msec	?SP	6msec
DL	6msec	?DL	8msec
BO	5msec	?BO	6msec
TR	5msec	?TR	6msec
TG	3msec	—	
OP	3msec	—	
SH	3msec	—	
SR	6msec	—	
RC	100msec***	—	
HD	4msec	?HD	6msec
RQ	4msec	?RQ	6msec
—		?ST	6msec

*When all data of 20 bins are transmitted
**Approximately 5msec for bin display.
*** Actual time may range from 60 to 140msec.
NOTE: Times determined using HP9000 Series 200 computer

The process times shown in Table 4-6 includes the following data transfer times:

Receive (transfer to the instrument): about 250μsec/byte.

Transmit (transfer from the instrument): about 120μsec/byte.

The process time for inquiry commands includes the time from the start of command reception to the completion of response transmission. When the inquiry response header is enabled, add about 0.5msec to the process time.

4.5 SETTING GPIB ADDRESS AND DELIMITER

The GPIB address and delimiter of the instrument can be set from the front panel using the following format:

aa.d

where: Address aa = 0 to 30
Delimiter d = 0 or 1;
0 = <CR><LF> (carriage return, line feed)
1 = <CR> (carriage return)

Follow the procedure below to check or change the GPIB address and delimiter:

1. Press the SET UP key, then press PREV twice to enable the GPIB set up mode (GPIB indicator blinking). The currently selected address and delimiter will be displayed on the [B] DISPLAY. For example, if the current address is 2 and the delimiter is <CR> <LF>, the following will be displayed:

   2.0

   To retain the current address and delimiter, press EXIT. Otherwise, proceed to the next step.
2. Using the number keys (labeled in blue), key in the value of the address and delimiter. Make sure to separate the two values using the decimal point (.) key.
3. With the desired address and delimiter values displayed, press the ENTER key.
4. Press the EXIT key to return to the normal display state.

NOTES:

1. The entered address and delimiter are retained when power is turned off. However, if the values are lost due to a memory error when power is turned on, the address and delimiter are set to default values (address = 2, delimiter = 0; <CR><LF>).
2. The delimiter value defaults to 0 (<CR> <LF>) if no delimiter parameter is entered.
3. Programming a primary address of 31 enables the talk-only mode (see paragraph 4.10).

4.6 GPIB MEASUREMENTS

Using the GPIB to make measurements is similar to making measurements from the front panel. Before using the GPIB, be sure to review the front panel operation information in Section 3.

4.6.1 Preparation

1. Input/output connections — Connect a test fixture or test leads to the instrument, and perform zero correction.
2. Initial GPIB Settings:
   - Interface clear (IFC) — Initialize the GPIB system by sending the interface clear command from the controller.
   - Remote enable (REN) — Send the REN message from the controller to enable the instrument to respond to GPIB commands. The REN command must be true (REN line low). REN must remain true unless the front panel keys must be enabled for some reason.
   - Device clear (DCL, SDC) — Initialize instrument by sending a device clear command (DCL or SDC) from the controller. The transmit and receive buffers will be cleared, and any previous error will be reset. SRQ will be disabled, and the inquiry response header will be disabled.

NOTE

With some computers, the bus may hang up if a GPIB command is executed immediately after a device clear command has been sent. After sending a device clear, provide an appropriate delay loop to allow the instrument to return to normal operation before sending any further commands.

4.6.2 Measurement and Reading of Data

This paragraph describes how to make a measurement and send the reading (data) over the GPIB bus to the controller.

1. Set Measurement Conditions
   Example: "FR 2E3;SP 1;LV 1;RN0"

   FR 2E3: Frequency = 2kHz
   SP 1: Measuring speed = MED
   LV 1: Measuring signal level = 1Vrms (no load)
   RN 0: Range = Auto

2. Set Display
   Example: "DA 2; DB 1;DE 0;CK 1"

   DA 2: C is displayed on [A] DISPLAY (capacitance)
   DB 1: D is displayed on [B] DISPLAY (dissipation)
   DE 0: Deviation and BIN are not displayed (NORMAL)
   CK 1: Equivalent circuit (CKT) is series (SER).

   When using the Comparator and Deviation functions for sorting, additional settings are required.

   Example: "RF 100E–12;DE 5; BN 0,–.0005,.004;BN 1,–2,2;BN 2,–5,5;BN 3,0,0"

   RF 100E–12: Reference = 100pF
   DE 5: % BIN (sorts the devices by %.)
   BN 0 ...: BIN 0 = –.0005 to .004; Acceptance range of D
   BN 1 ...: BIN 1 = –2 to +2 (%)
   BN 2 ...: BIN 2 = –5 to +5 (%)
   BN 3,0,0: Closes BINs 3 to 19.

   With the above commands, a device in the range of 100pF ±2%, is assigned to Bin 1, and a device in the range of ±2% to ±5% is assigned to Bin 2. Devices out of these ranges are assigned to Bin 0.

3. Perform Measurement

   Send the following command string to select the manual trigger mode and make a single measurement:

   "TR 1; TG"
   TR 1: Selects the manual trigger mode.
   TG: Applies a trigger and performs one measurement. The GET command can also be used to trigger the unit.

4. Read Data

   Once the measurement has been made, the reading (data) is sent to the computer by programming the instrument to talk.

   SRQ can be used to ensure that the measurement is completed before sending the reading by programming the instrument to talk. To enable SRQ, send the following command before making the measurement:

   "RQ 1"

When an SRQ occurs, serial poll the instrument to confirm that the RQS bit is set, and then address it to talk.

Another way to verify the completion of a measurement is to read the status byte using the "?ST" inquiry command and wait until the BUSY bit (Bit 4) is reset.

4.6.3 Reading Measured Data

Requesting Measured Data

Measured data can be read by using either of the following two methods:

- Request data by sending the inquiry command "?DT"
- Trigger the instrument to measure data by sending "TG" or the GET command.

1. "?DT"
   This command programs the instrument to place the last measured reading in the transmit buffer. That reading will be sent the next time the instrument is addressed to talk. Note that data output by using "?DT" is canceled when any other inquiry message or the command "TG" is sent after the unit receives the "?DT" command.

2. "TG" or GET Command
   When the manual trigger mode (MAN) is enabled ("TR1" command), and the unit is triggered with the "TG" or the GET command, the instrument aborts the present measurement and starts a new measurement. When the new measurement has been completed, the reading is placed in the transmit buffer. If the instrument is addressed to talk immediately after being triggered, the reading is sent as soon as that measurement is completed (the listener will normally wait until the measurement is completed). Note that data output triggered by "TG" is canceled if another command is sent after the "TG" command.

If SRQ is enabled ("RQ 1"), SRQ is asserted when the measurement is completed. (SRQ will also be asserted by triggering the unit from the front panel with the MAN key.) When the next trigger is applied without reading data, the transmit buffer is cleared, but SRQ is not reset. (SRQ is cleared only by reading the status byte, or by sending DCL or SDC.)

Data Format

Instrument data is transmitted as a string of ASCII characters with data corresponding to the [A] DISPLAY and the [B] DISPLAY readings separated (delimited) by a comma (,) as follows:

"<Header> <[A] DISPLAY data>, <[B] DISPLAY data> <Delimiter>"

When transmitting bin data (Comparator operation), only the bin number is sent:

"<HEADER> <Bin number> <Delimiter>"

The header is enabled and disabled by the commands "HD 0" and "HD 1" respectively. A delimiter (<CR> <LF> or <CR>) is selected from the front panel using SET UP GPIB. The END message (EOI line set low) is asserted with the last byte of the delimiter.

Each measured value is output in the same format as it is displayed on the front panel, and is summarized as follows:

L, C, R, |Z|, ESR, G, X

Type:	NR3 (Exponent representation)
Resolution:	Exponent part is a multiple of 3. 4 1/2 digits (19999 max. typically 2000 to 19999)
Range:	0.0000E–12, ±(0.0001E–12 to 19999.E+06) The display range is determined by the types of parameters, ranges and phase angles. The exponent and a decimal point are always sent.
"OF":	"99999.E+06"
"UF":	"–99999.E+06"
"OU":	"88888.E+06" (L, C, R, |Z|); 0.0000E+00")ESR, G, X)
Blank:	"77777.E+06"
No. of char:	11

Q, D

Type:	NR2 (Floating-point representation)
Resolution:	4 1/2 digits (19999 max.)
Range:	0.0000, ±(0.0001 to 19999.)
"OF":	"99999."
"UF":	"–99999."
"OU":	"0.0000"
Blank:	"77777."
No. of char:	7

θ

Type:	NR2 (Floating-point representation)
Resolution:	0.01°
Range:	–180.00° to +179.99°
"OU":	"0.00"
Blank:	"777.77"
No. of char.:	7

Δ

Type:	NR3 (Exponent representation) Exponent part is a multiple of 3
Resolution:	4 1/2 digits (19999 max.)
Range:	0.0000E–12, ±(0.0001E–12 to 19999.E+06)
"OF":	"99999.E+06"
"UF":	"–99999.E+06"
"OU":	"88888.E+06"
Blank:	"77777.E+06"
No. of char:	11

Δ%

Type:	NR2 (Fixed point representation)
Resolution:	0.01
Range:	±199.99
"OF":	"999.99"
"UF":	"–999.99"
"OU":	"888.88"
Blank:	"777.77"
No. of char:	7

BIN

Type:	NR1 (Integer)
Range:	0 to 19 ("OF", "UF", "OU", blank means 0)
No. of char:	3

V

Type:	NR3 (Exponent representation) Exponent part is a multiple of 3
Resolution:	3 1/2 digits (1999 max.), 0.1mV
Range:	0.0E–03 to 1.999E+00
"OF":	"9999.E+06"
"OU":	"0.0000E+00"
Blank:	"7777.E+06"
No. of char:	10

I

Type:	NR3 (Exponent representation) Exponent part is a multiple of 3
Resolution:	3 1/2 digits (1999 max.), 1μA resolution
Range:	0.00E–06 to 19.99E–03
"OF":	"9999.E+06"
"OU":	"0.000E+00"
Blank:	"7777.E+06"
No. of char:	10

Notes:

1. The plus sign (+) for the mantissa is omitted and a positive value is implied by its absence. However, the plus sign is always included in the exponent for positive exponent values.
2. The major differences between the data displayed at the front panel and the GPIB output are as follows:

Front Panel Display	Equivalent GPIB Data String
K, μ, etc.	E+03, E–06, etc.
.1234	0.1234
OF, UF, OU	Numeric such as "99999.E+06"
Blank; measured value not displayed	Numeric such as "77777."

4.6.4 Reading Bin Parameters

When the bin parameters of the comparator are requested with the "?BN" inquiry, the parameters for all 20 bins are sent in sequence beginning with Bin 0. The output format for each bin parameter is as follows:

> "<Header> <Bin No.>, <Lower limit>, <Upper limit> <Delimiter>"

Note that the bin number, lower limit, and upper limit are arranged in this order and are delimited by commas (,). The header is optional and is enabled and disabled by the "HD 0" and "HD 1" commands, respectively.

The delimiter (<CR> <LF> or <CR>; selected from the front panel using SET UP GPIB) separates the group of parameters associated with each bin. The END message (EOI line set low) is asserted only with the last byte of the delimiter for Bin 19 parameters. The END message is not asserted with other bin parameters.

The format of each parameter is as follows:

Bin Number

Type:	NR1 (Integer)
Range:	0 to 19
No. of char:	3

Lower and Upper Limits

Type:	NR3 (Exponent representation) Exponent is a multiple of 3
Resolution:	4 1/2 digits
Range:	0.0000E+00, ±(0.0001E–12 to 19999.E+06)
No. of char:	11

4.7 GPIB OPERATING CONSIDERATIONS

- Before connecting or disconnecting GPIB cables, be sure to turn off the instrument and other equipment connected to the bus.
- When using the GPIB, make sure all equipment connected to the bus is turned on.
- Be sure to use the correct delimiters; improper delimiters may cause the bus to hang up.
- A maximum of 15 devices (including the controller) can be connected to the GPIB at one time.
- Cable length restriction:
  Total transmission path length = 2m × (no. of units) or 20m (whichever is shorter).
  Maximum length of one cable = 4m.
- The GPIB is intended to be used in an environment that is not subjected to excessive electrical noise.

4.8 GPIB ERRORS

When an error occurs during GPIB operation, an error message is displayed on the front panel (see Table 4-7), and the command string is ignored. After the GPIB error is analyzed, it can be cleared by pressing any front panel key or by sending a device clear command (DCL or SDC) over the bus.

Operation When Errors Occur

Err 21: This error occurs during the OPEN or SHORT correction process if the correction values are not out of range. This error will not occur at the time the "OP" or "SH" command is sent.

Err 31: The entire command string is invalid.

Other Errors: Only commands after the error are invalid. Commands prior to the error in the command string will be executed.

Table 4-7. GPIB Error Messages

Err12	The entered parameter value exceeds the rated range
Err13	Display assignment error While [A] DISPLAY in AUTO, an item of [B] DISPLAY is assigned, CKT is assigned, or deviation display is assigned.
Err14	Illegal request for DC bias While [A] DISPLAY in AUTO, L, R or |Z|, you attempted to turn on DC bias.
Err22	Zero correction abnormal Zero correction value exceeds the tolerable range.
Err31	Receive buffer overflow A program code is too long for the receive buffer. Command string is ignored.
Err32	Illegal header Receives a header that is not assigned.
Err33	Illegal header Though only a setting can be made, an inquiry is made, or though only an inquiry can be made, a setting is made.
Err34	Illegal parameter Required parameter missing.
Err35	Illegal parameter Comma ",", which delimits a parameter, is missing.

4.9 EXAMPLE PROGRAMS

This section provides some example programs used to control the instrument over the GPIB. All programs are intended to run on HP 9000 Series 200 computers (HP9816, 9826, etc.) using HP BASIC version 2.0 or later. See Appendix C for similar example programs for the IBM PC and compatible computers running under Quick BASIC.

4.9.1 GPIB Initialization

The following program will initialize the GPIB:

Sample program to initialize GPIB:

```
100     ABORT 7
110     CLEAR 702
```

Program Analysis:

Line No.	Operation
100	Send the IFC (Interface Clear) command.
110	Send the SDC (Selective Device Clear) command.

Normally REN is enabled, unless otherwise programmed, and the delimiter is <CR> <LF> unless otherwise programmed by the OUTPUT statement.

4.9.2 Display Mode

The following example program will set the display mode to measure R and X continuously at 1kHz. Make sure the GPIB was previously initialized (see paragraph 4.9.1) before using this program.

Sample program to set display mode:

```
100     OUTPUT 702; "FR 1E3;DA 3;DB 4;DE 0;
        CK 1;TR 0"
```

4.9.3 Inquiry

The following sample program will inquire and display the currently selected frequency and the bin settings for the comparator. Make sure the GPIB was previously initialized (see paragraph 4.9.1) before using this program.

Sample program to inquire instrument settings:

```
100     OUTPUT 702;"HD 0"
200     OUTPUT 702;"?FR"
210     ENTER 702;Fr
220     PRINT "FREQ = ";Fr
230     PRINT
300     OUTPUT 702; "?BN"
310     PRINT "BIN,   LOWER  ,   UPPER"
320     DIM A$[64]
330     FOR I=0 TO 19
340     ENTER 702;A$
350     PRINT A$
360     NEXT I
```

Program Analysis:

Line No.	Comment
100	Disables response header.
200 to 220	Inquires and displays the frequency.
300	Inquires the bin settings (bin No., upper limit, and lower limit).
320	Dimensions string.
330 to 360	Reads and prints all 20 bin settings in sequence.

4.9.4 SRQ and Serial Poll

The following sample program will acquire measured data using SRQ. Measurements are performed at a frequency of 1kHz and are displayed on the computer CRT. Make sure the GPIB was previously initialized (see paragraph 4.9.1) before using this program.

Sample program to SRQ and serial poll:

```
100     DIM A$[64]
110     OUTPUT 702;"FR 1E3;DA 2;DB 1;DE 0;CK2;
        TR 1;SP 1"
120     ON INTR 7 GOSUB 200
130     OUTPUT 702; "RQ 1"
140     OUTPUT 702; "TG"
150     ENABLE INTR 7;2
160     GOTO 160
170     !
180     !
200     S=SPOLL (702)
210     IF BINAND(S,64)=0 THEN 260
220     OUTPUT 702; "?DT"
230     ENTER 702;A$
240     PRINT A$
250     TRIGGER 702
260     ENABLE INTR 7
270     RETURN
```

Program Analysis:

Line No.	Comment
100	Dimensions string.
110	Sets measurement conditions. Frequency = 1kHz, [A] DISPLAY = C, [B] DISPLAY = D, no deviation and no bin display, parallel equivalent circuit, manual trigger mode, speed = MED.
120	When SRQ is received, branches to the subroutines starting from line 200.
130	Enables instrument SRQ.
140	Triggers unit to make measurement.
150	Enables interrupt on SRQ.
200	Performs serial poll.
210	Confirms that the RQS bit of a status byte is set, waits for the completion of zero correction.
220 to 2400	Inputs and displays measured values.
250	Triggers unit with GET command to start the next measurement.
260	Enables SRQ interrupt.

4.9.5 Measurements

The following sample program measures an electrolytic capacitor.

Sample program to measure electrolytic capacitor:

```
100   DIM A$[64]
110   ABORT 7
120   CLEAR 702
130   OUTPUT 702; "LV 1;RN 0;SP 1;DA 2;DB 2;
      DE 0;CK 1;TR 1;DL 1"
140   OUTPUT 702;"BO 1"
150   Wtm=15
160   T=TIMEDATE+Wtm
170   WHILE TIMEDATE<T
180   END WHILE
200   RESTORE Flist
210   PRINT "FREQ(Hz)   C(F)   ESR(ohm)"
220   READ F$
230   WHILE F$<>"*"
240   OUTPUT 702; "FR"&F$
250   Wtm=2
260   T=TIMEDATE+Wtm
270   WHILE TIMEDATE<T
280   END WHILE
290   OUTPUT 702;"TG"
300   PRINT " "&F$&" ";
310   ENTER 702;A$
320   PRINT A$
330   READ F$
340   END WHILE
350   OUTPUT 702; "BO 0"
360   PRINT
370   PRINT "End of measurement"
380   STOP
390   !
400   Flist: !
410   ! Frequency list
420   DATA " 100"," 200"," 500"," 1E3"," 2E3",
      " 5E3"," 10E3"
430   DATA " 20E3"," 50E3","100E3","*"
440   END
```

Program Analysis:

Line No.	Comment
100	Dimensions string.
110 to 120	Initializes GPIB.
130	Sets measuring conditions: Signal level =1V, measurement range = automatic, speed = MED. [A] DISPLAY = C, [B] DISPLAY = ESR, no deviation and no bin display, series equivalent circuit, manual trigger mode, trigger delay time 1s.
140 to 180	Turns on the DC bias and allows capacitor time to charge.
200	Assigns a frequency table.
210	Displays a header.
220 to 340	Reads and displays the frequency.
220, 330	Deletes a frequency from a frequency table.
230	"*" is displayed at the end of the table.
240 to 280	Sets a frequency and allows reading to settle.
290	Triggers unit to make a single measurement.
300	Displays a measured frequency.
310 to 320	Reads and displays the measured value.
350 to 380	Turns off the bias and ends measurement.
400 to 430	Frequency table.

4.10 TALK-ONLY MODE

The Model 3330 can be used in the talk-only mode to directly output data to a listen-only device such as a printer without requiring a bus controller. The following paragraphs discuss talk-only operation in detail.

4.10.1 Talk-only Operation

The standard procedure for using the talk-only mode is outlined below:

1. Turn off the power to the Model 3330 and the listen-only device (for example, a printer).
2. Connect the Model 3330 to the listen-only device using a shielded GPIB cable.
3. Turn on the power to the listen-only device.
4. Turn on the Model 3330; note that the instrument will be in the addressable mode at the previously programmed primary address.
5. Set the desired Model 3330 operating modes using the front panel controls. Typically, you would use the manual trigger mode so that you can control when readings are sent to the printer.
6. Set the Model 3330 to the talk only mode as follows:
   A. Press SET UP, then press PREV twice until the GPIB indicator blinks.
   B. Using the numeric entry keys, key in a primary address of 31, then press ENTER.
   C. Press ENTER to begin talk-only operation. The instrument will send readings to the listen-only device as they become available. (If the instrument is in the manual trigger mode, you must trigger each reading.)

CAUTION

To avoid possible instrument damage, do not connect the instrument to a controller while the LCZ meter is in the talk-only mode. Also, do not connect more than one talk-only device to the bus at any given time.

4.10.2 Cancelling Talk-only Operation

Cancel the talk-only mode as follows:

1. Press SET UP, then press PREV twice until the GPIB indicator blinks.
2. Using the numeric entry keys, key in the desired primary address, in the range of 0 to 30, then press ENTER.
3. Press EXIT to return to normal operation.

The talk-only mode will also be cancelled when Model 3330 power is turned off, or if any of the conditions listed below occur. An "Err37" error message will be displayed, and the instrument will return to the previously programmed primary address.

- The GPIB cable is disconnected while power is turned on.
- The power of the listen-only device is turned off.
- The instrument is connected to a system using a bus controller.

4.10.3 Using Talk-only with the Handler Interface

If the handler interface LOCK line is held low when Model 3330 power is turned on, the instrument will automatically enter the talk-only mode. It will also lock out front panel controls, recall settings stored in memory location 0, and restore previous zero correction constants. See paragraph 3.17 in Section 3 for details.

4.10.4 Talk-only Data Formats

All Formats Except Bin Display

In the talk-only mode, the Model 3330 sends data as follows:

<Header>< [A] DISPLAY data><units>,< [B] DISPLAY data><units><Delimiter>

Table 4-8 summarizes [A] DISPLAY headers and units, and Table 4-9 summarizes [B] DISPLAY headers and units. Note that "s" or "p" is added to the header for L, C, and R readings only. Figure 4-2 shows an example print out.

Table 4-8. Talk-only Mode [A] DISPLAY Format

[A] DISPLAY		
Type	**Header***	**Units**
L	"L"	"H"
C	"C"	"F"
R	"R"	"ohm"
|Z|	"Z"	"ohm"
ΔL	"DLTL"	"H"
ΔC	"DLTC"	"F"
ΔR	"DLTR"	"ohm"
Δ|Z|	"DLTZ"	"ohm"
Δ%L	"DLTL"	"%"
Δ%C	"DLTC"	"%"
Δ%R	"DLTR"	"%"
Δ%Z	"DLTZ"	"%"

*Equivalent circuit follows header for L, C, and R:
Serial (SER): "s"
Parallel (PAR): "p"

Table 4-9. Talk-only Mode [B] DISPLAY Format

[B] DISPLAY		
Type	**Header***	**Units**
Q	"Q"	None
D	"D"	None
ESR	"R"	"ohm"
G	"G"	"S"
X	"X"	"ohm"
θ	"P"	"deg"
V	"V"	"V"
I	"I"	"A"

Cp	4.755E-09	F	,	D	0.0134
Cp	4.755E-09	F	,	D	0.0132
Cp	4.753E-09	F	,	D	0.0134
Cp	4.756E-09	F	,	D	0.0135
Cp	4.754E-09	F	,	D	0.0133
Cp	4.753E-09	F	,	D	0.0135
Cp	4.753E-09	F	,	D	0.0136
Cp	4.755E-09	F	,	D	0.0135

Figure 4-2. Example Talk-only Print Out

Bin Output Format

The bin output format for the talk-only mode is as follows:

BIN <bin number> <Delimiter>

Measurement Value Formats

The formats of measured values and bin information formats are the same as those for the addressable mode discussed in paragraph 4.6.3. The numeric values that indicate "OF", "UF", and "OU" conditions are also the same as the addressable mode.

Supplemental Parameters

Note that supplemental parameters such as frequency, level, and range are not output by the instrument when it is in the talk-only mode.

APPENDIX A
Model 3330 Specifications

A.1 MEASUREMENT PARAMETERS

Main Parameters (Display A) and Range

L: Inductance, 0.1nH to 19.999kH

C: Capacitance, 0.001pF to 199.99mF

R: Resistance, 0.1mΩ to 19.999MΩ

|Z|: Magnitude of impedance, 0.1mΩ to 19.999MΩ

AUTO: Automatically selects main parameters, sub-parameters, and equivalent circuit.

Sub-parameters (Display B) and Range

Q: Quality factor, 0.0001 to 19999

D: Dissipation factor, 0.0001 to 19999

ESR: Equivalent series resistance, 0.1mΩ to 19.999MΩ

G: Parallel conductance, 0.001μS to 199.99S

X: Series reactance, 0.1mΩ to 19.999MΩ

θ: Phase angle of impedance, –180.00° to +179.99°

V: Voltage monitor (RMS voltage across device) 0.0mV to 1.999Vrms

I: Current monitor (RMS current through device), 0.00μArms to 19.99mArms

Measurement resolution will vary depending on frequency, measurement range, and impedance phase angle.

Automatic Parameter Selection

Phase	Display A	Display B
+120° to +60°	L	Q
+30° to -30°	R	Q
-120° to -60°	C	D
others	|Z|	θ

Deviation Measurement

Δ: Deviation of main parameter (range of deviation is at least ±100% of the measurement range)

Δ%: % deviation display of main parameter (display range ±199.99%)

Note: Deviation and % deviation of sub-parameters cannot be displayed.

Execution Times

Measurement Time (IEEE-488)

FAST: 65msec (typ)

MED: 155msec (typ)

SLOW: 485msec (typ)

Note: 1kΩ impedance, 1kHz frequency and one shot trigger.

Specifications subject to change without notice.

Autoranging Time: Approximately equal to measurement time

Stabilization Time After Range Change: 0.2 - 4.0s

Stabilization Time After Frequency Change: 0.15 - 4.0s

Bias Stabilization Time: (4 + 0.015C)s

where: C = capacitance of DUT (in μF)

Equivalent Circuits

AUTO: Automatic selection

SER: Series

PAR: Parallel

Automatic Equivalent Circuit Selection

Display A	Display B	Equivalent Circuit
L, C, R or |Z|	ESR or X	Series
L or C (|Z| ≤1kΩ)	Q, D, θ, V or I	Series
R (θ ≥ 0)	Q, D, θ, V or I	Series
|Z|	Q, D, θ, V or I	Series
L, C, R, or |Z|	G	Parallel
L or C (|Z| > 1kΩ)	Q, D, θ, V or I	Parallel
R (θ < 0)	Q, D, θ, V or I	Parallel

Displayed Resolution

4-1/2 digits (19999 max counts)

D, Q maximum resolution: 0.0001

θ resolution: 0.01°

V resolution: 0.1mV

I resolution: 1μA (when reference resistance is 100Ω)
0.1μA (when reference resistance is 1kΩ)
0.01μA (when reference resistance is 10kΩ or 50kΩ)

Note: Reference resistance is measurement range dependent.

Accuracy of V, I

Accuracy of V, I: ±(2% + |Z| accuracy)

Accuracy of |Z| and θ (1 year 18°-28°C)*

For 0.2Ω ≤ |Z| ≤ 20MΩ and 0.9-1.1V test level, see Table A-1.

For 0.2Ω ≤ |Z| ≤ 20MΩ and 50mV test level, see Table A-2.

For |Z| < 0.2Ω and 1V test level, see Table A-3.

For |Z| >20MΩ and 1V test level, see Table A-4.

*when properly zero corrected and using Model 3323A test fixture.

Table A-1. Impedance Magnitude Accuracy (%) and Phase Accuracy (°)
Test Level= 0.9-1.1Vrms, Speed = Med or Slow

|Z| (Ω)	Frequency (Hz) 40 ~ 90	100 ~ 130	160 ~ 900	1k	1.1k ~ 5.0k	5.1k ~ 10k	11k ~ 20k	21k ~ 50k	51k ~ 100k
10M ≤ |Z| < 20M	4.5% 2.25°	3.0% 1.5°	2.0% 1.0°	1.0% 0.80°	2.0% 1.5°	3.5% 2.0°	4.0% 3.0°	14% 8.0°	20% 12°
5M ≤ |Z| < 10M	2.2% 1.3°	1.5% 0.90°	1.0% 0.60°	0.5% 0.40°	1.0% 0.60°	1.8% 1.1°	2.0% 1.3°	7.0% 4.0°	10% 6.0°
2M ≤ |Z| < 5M	1.10% 0.68°	0.75% 0.45°	0.5% 0.30°	0.3% 0.20°	0.5% 0.30°	0.9% 0.60°	1.0% 0.60°	3.5% 2.0°	5.0% 3.0°
1M ≤ |Z| < 2M	0.54% 0.33°	0.36% 0.22°	0.30% 0.15°	0.20% 0.10°	0.30% 0.15°	0.40% 0.20°	0.50% 0.30°	1.6% 1.0°	3.0% 2.0°
200k ≤ |Z| < 1M	0.37% 0.22°	0.25% 0.15°	0.20% 0.12°	0.15% 0.09°	0.20% 0.12°	0.27% 0.16°	0.35% 0.20°	1.0% 0.60°	2.0% 1.2°
20k ≤ |Z| < 200k	0.22% 0.15°	0.15% 0.10°	0.12% 0.06°	0.10% 0.04°	0.18% 0.08°	0.25% 0.15°	0.30% 0.20°	0.60% 0.40°	1.2% 0.8°
2k ≤ |Z| < 20k	0.21% 0.13°	0.14% 0.09°	0.12% 0.05°	0.10% 0.03°	0.12% 0.06°	0.15% 0.08°	0.20% 0.12°	0.40% 0.30°	0.80% 0.60°
10 ≤ |Z| < 2k	0.20% 0.12°	0.13% 0.08°	0.11% 0.05°	0.10% 0.03°	0.11% 0.08°	0.13% 0.10°	0.17% 0.15°	0.40% 0.25°	0.70% 0.50°
2 ≤ |Z| < 10	0.37% 0.22°	0.25% 0.15°	0.20% 0.10°	0.15% 0.07°	0.20% 0.12°	0.32% 0.20°	0.50% 0.30°	0.80% 0.40°	1.5% 0.80°
1 ≤ |Z| < 2	0.52% 0.33°	0.35% 0.22°	0.30% 0.20°	0.20% 0.12°	0.25% 0.15°	0.50% 0.30°	0.70% 0.40°	1.0% 0.60°	2.0% 1.2°
0.5 ≤ |Z| < 1	1.0% 0.68°	0.70% 0.45°	0.60% 0.40°	0.40% 0.25°	0.50% 0.30°	0.80% 0.50°	1.2% 0.70°	1.7% 1.0°	3.3% 2.0°
0.2 ≤ |Z| < 0.5	2.1% 1.3°	1.4% 0.90°	1.1% 0.70°	0.80% 0.50°	1.1% 0.70°	1.2% 0.80°	1.8% 1.1°	2.7% 1.6°	5.5% 3.0°

Notes:

1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| accuracy by 1.4, and the phase accuracy by 1.8.
2. When measurement speed is FAST, multiply the accuracies by 2.0.
3. For test levels other than 0.9-1.1Vrms or 50mVrms see Accuracy Notes.

Table A-2. Impedance Magnitude Accuracy (%) and Phase Accuracy (°)
Level = 50mVrms, Speed = Med or Slow

|Z| (Ω)	Frequency (Hz)								
	40 ~ 90	100 ~ 130	160 ~ 900	1k	1.1k ~ 5.0k	5.1k ~ 10k	11k ~ 20k	21k ~ 50k	51k ~ 100k
10M ≤ |Z| < 20M	10.5% 6.0°	7.0% 4.0°	4.5% 2.5°	3.5% 2.0°	6.0% 3.5°	8.5% 5.0°	17% 10.0°	100% 60°	120% 70°
5M ≤ |Z| < 10M	5.25% 3.0°	3.5% 2.0°	2.2% 1.3°	1.7% 1.0°	2.7% 1.6°	3.5% 2.0°	7.0% 4.0°	50% 30°	60% 35°
2M ≤ |Z| < 5M	3.0% 1.8°	2.0% 1.2°	1.2% 0.80°	0.90% 0.60°	1.2% 0.8°	1.6% 1.0°	3.5% 2.0°	25% 15°	30% 18°
1M ≤ |Z| < 2M	1.5% 0.90°	1.0% 0.60°	0.60% 0.35°	0.40% 0.25°	0.60% 0.35°	0.80% 0.50°	1.6% 0.90°	12% 7.0°	14% 8.0°
200k ≤ |Z| < 1M	0.75% 0.45°	0.50% 0.30°	0.40% 0.25°	0.30% 0.18°	0.35% 0.20°	0.40% 0.25°	0.70% 0.40°	6.0% 3.6°	7.0% 4.0°
20k ≤ |Z| < 200k	0.45% 0.27°	0.30% 0.18°	0.20% 0.12°	0.16% 0.08°	0.24% 0.14°	0.32% 0.18°	0.40% 0.23°	1.8% 1.0°	3.0% 1.5°
2k ≤ |Z| < 20k	0.37% 0.23°	0.25% 0.15°	0.18% 0.09°	0.16% 0.06°	0.20% 0.12°	0.24% 0.14°	0.35% 0.20°	1.4% 0.80°	2.0% 1.2°
10 ≤ |Z| < 2k	0.30% 0.18°	0.20% 0.12°	0.18% 0.09°	0.15% 0.06°	0.20% 0.12°	0.23% 0.13°	0.32% 0.18°	1.2% 0.70°	1.6% 1.0°
2 ≤ |Z| < 10	0.75% 0.45°	0.50% 0.30°	0.35% 0.20°	0.25% 0.14°	0.35% 0.20°	0.50% 0.30°	0.70% 0.40°	3.4% 2.0°	4.0% 2.3°
1 ≤ |Z| < 2	1.5% 0.9°	1.0% 0.60°	0.60% 0.40°	0.50% 0.30°	0.60% 0.40°	0.80% 0.50°	1.1% 0.70°	6.0% 3.6°	8.0% 5.0°
0.5 ≤ |Z| < 1	2.7% 1.65°	1.8% 1.1°	1.2% 0.70°	1.0% 0.60°	1.2% 0.70°	1.5% 0.90°	1.8% 1.1°	10% 6.0°	14% 8.5°
0.2 ≤ |Z| < 0.5	5.55% 3.3°	3.7% 2.2°	2.6% 1.5°	2.0% 1.2°	2.6% 1.5°	2.9% 1.7°	3.4% 2.0°	21% 13°	28% 16°

Notes:

1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| by 2.0, and the phase accuracy by 2.0.
2. When measurement speed is fast, multiply the accuracies by 2.0.
3. Accuracy is not guaranteed in the following ranges: |Z| > 20MΩ, |Z| < 0.2Ω.
4. For test levels other than 0.9-1.1Vrms or 50mVrms see Accuracy Notes.

Table A-3. Accuracy of |Z| and θ for |Z| <0.2Ω

|Z| (Ω)	LEVEL =1V rms, SPEED = MED or SLOW Frequency, (Hz)							
	100 120	200 500	1k	2k 5k	10k	20k	50k	100k
0≤|Z|<0.2	1.7% +0.2mΩ	1.5% +0.2mΩ	1.0% +0.2mΩ	1.3% +0.2mΩ	1.4% +0.3mΩ	2.0% +0.6mΩ	3.0% +1.5mΩ	6.0% +3mΩ

|Z| Accuracy: ±(% reading + R) shown.
θ Accuracy: (θ Accuracy for 0.2≤|Z|<0.5 in Table A-1) × (0.2Ω/|Z|)
When SPEED=FAST, multiply accuracy by 2.
For 5°-18°C or 28°-40°C, multiply accuracy by 2.

Table A-4. Accuracy of |Z| and θ for |Z|≥20MΩ

|Y| (S)	LEVEL =1V rms, SPEED = MED or SLOW Frequency, (Hz)							
	100 120	200 500	1k	2k 5k	10k	20k	50k	100k
0≤|Y|≤50nS	1.8nS	1.2nS	0.6nS	1.2nS	2.1nS	2.4nS	7.5nS	12nS

|Z| Accuracy: Specified by the ± deviation (S) of admittance |Y| shown.
θ Accuracy: (θ Accuracy for 10M≤|Z|<20M in Table A-1 × (|Z|/20MΩ).
When SPEED=FAST, multiply accuracy by 2.
For 5°-18°C or 28°-40°C, multiply accuracy by 2.

Accuracy Notes

1. When a measurement is made at line frequency or at twice line frequency, the measured value may deviate beyond the accuracy range due to interaction with line frequency. In this case, use 50Hz or 100Hz for a 60Hz line and 60Hz or 120Hz for a 50Hz line.
2. Tables A-1 through A-4 show the worst case value in each impedance range. A more precise value for accuracy may be obtained by interpolation.
3. In order to determine the impedance magnitude accuracy (A_Z) and impedance phase accuracy (A_θ) at measurement signal levels (LV) other than 50mV or 0.9V - 1.1V, use one of the following equations:

Measurement Signal Level (LV) From	To	Measured Impedance Magnitude |Z|	Impedance Magnitude Accuracy [%] (A_Z)	Impedance Phase Accuracy [°] (A_θ)
10mV	49mV	<20MΩ and ≥0.2Ω	$A_{Z2}\left(\frac{50mV}{LV}\right)$	$A_{\theta 2}\left(\frac{50mV}{LV}\right)$
51mV	899mV	≥20MΩ	$A_{Z4}\left(\frac{1V}{LV}\right)$	$A_{\theta 4}\left(\frac{1V}{LV}\right)$
51mV	899mV	<20MΩ and ≥0.2Ω	$A_{Z1}+\left[(A_{Z2}-A_{Z1})\left(\frac{50mV}{LV}\right)\right]$	$A_{\theta 1}+\left[(A_{\theta 2}-A_{\theta 1})\left(\frac{50mV}{LV}\right)\right]$
51mV	899mV	<0.2Ω	$A_{Z3}\left[1+\left(\frac{100mV}{LV}\right)\right]\left(\frac{0.2\Omega}{\lvert Z\rvert}\right)[\%]+B_{Z3}\,[m\Omega]$	$A_{Z5}\,[\%]\times 0.6°$

where:

LV = Test level voltage

A_{Z1} = Impedance Magnitude Accuracy (%) from Table A-1

$A_{\theta 1}$ = Impedance Phase Accuracy (°) from Table A-1

A_{Z2} = Impedance Magnitude Accuracy (%) from Table A-2

$A_{\theta 2}$ = Impedance Phase Accuracy (°) from Table A-2

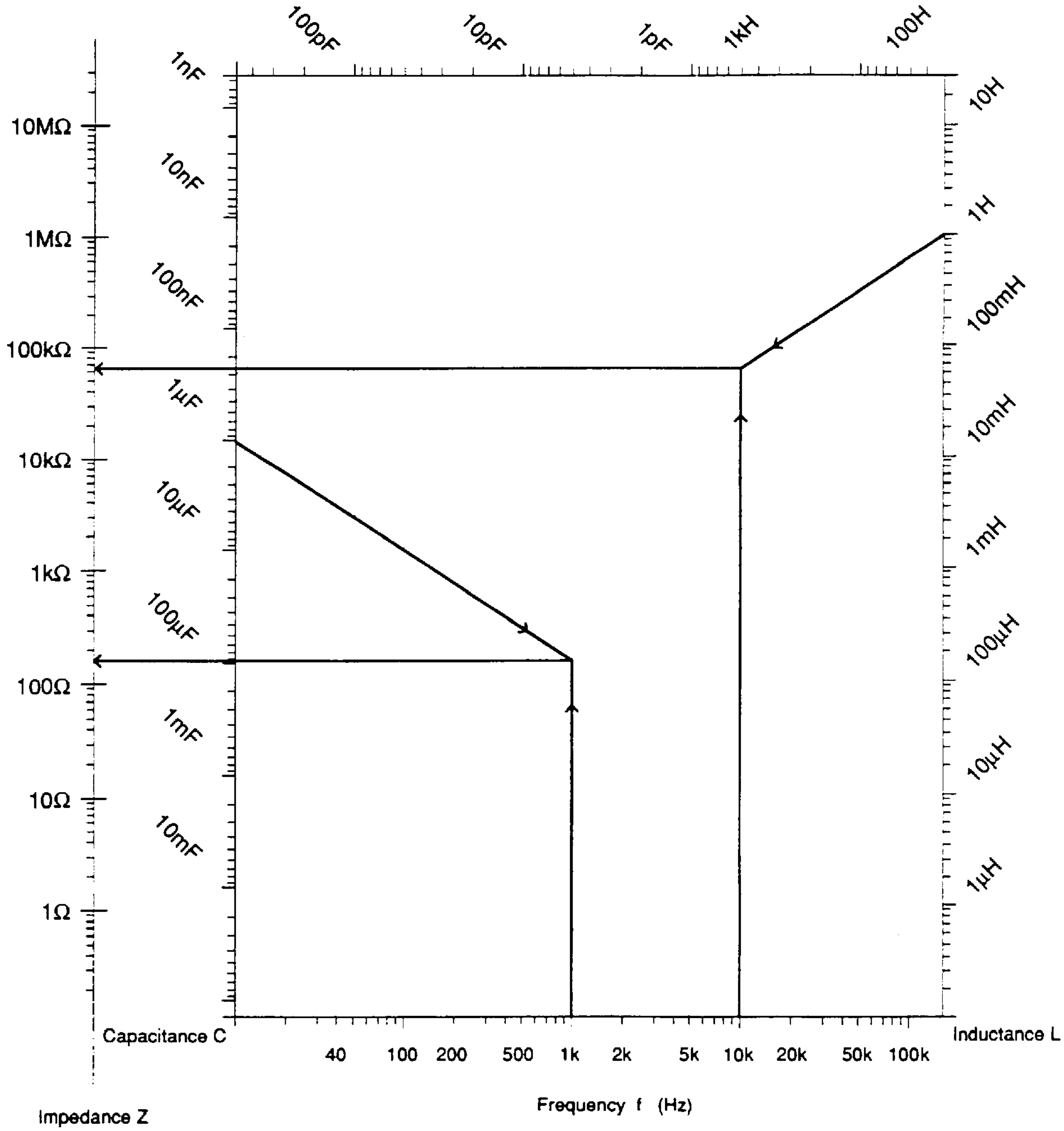
A_{Z3} = Impedance Magnitude Accuracy (%) from Table A-3

B_{Z3} = Impedance Magnitude offset (mΩ) from Table A-3

A_{Z4} = Impedance Magnitude Accuracy (%) from Table A-4

$A_{\theta 4}$ = Impedance Phase Accuracy (°) from Table A-4

A_{Z5} = Impedance Magnitude Accuracy for $51mV \le LV \le 899mV$ and $\lvert Z\rvert < 0.2\Omega$



Notes: Use this chart to determine the impedance magnitude of an inductor or capacitor at a particular frequency. For example, a 1H inductor at 10kHz and a 1μF capacitor at 1kHz are shown on the diagram.

1H @ 10kHz = 63kΩ
1μF @ 1kHz = 160Ω

Figure A-1. Conversion Diagram

Examples of Determining Accuracy

Example 1: Component = 33kΩ resistor
Test Frequency = 10kHz
Test Level = 1V rms
Temperature = 18°-28°C
Speed = Med or Slow

1. Find the accuracy values corresponding to 33kΩ and 10kHz on Table A-1. Record the impedance magnitude accuracy (0.25%) and impedance phase accuracy (0.15°).
2. If the ambient temperature is 5°C - 18°C or 28°C - 40°C, multiply the impedance magnitude accuracy by 1.4 and the impedance phase accuracy by 1.8.
3. If measurement speed is set to FAST, multiply the impedance magnitude accuracy by 2.0 and the impedance phase accuracy by 2.0.
4. Resistance accuracy is approximately equal to the impedance magnitude accuracy if $Q \le 0.1$.
5. If $Q > 0.1$, see example 4.

Example 2: Component = 10μF capacitor
Test Frequency = 1kHz
Test Level = 50mV
Temperature = 18°-28°C
Speed = Med or Slow

1. Determine the impedance of the 10μF capacitor at 1kHz by referring to Figure A-1 or by solving the following equation:

$$|Z| = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 1\text{kHz} \times 10\mu\text{F}} = 16\Omega$$

2. Find the accuracy values corresponding to 16Ω at 1kHz on Table A-2. Record the impedance magnitude accuracy (0.15%) and impedance phase accuracy (0.06°).
3. If the ambient temperature is 5°C - 18°C or 28°C - 40°C, multiply the impedance magnitude accuracy by 1.4 and the impedance phase accuracy by 1.8.
4. If measurement speed is set to FAST, multiply the impedance magnitude accuracy by 2.0 and the impedance phase accuracy by 2.0.
5. If $D \le 0.1$, the accuracy of the capacitance measurement accuracy (C_{acc}) is related to the impedance magnitude accuracy (Z_{acc}) by the following equation:

$$C_{acc} = \frac{Z_{acc}}{1 - Z_{acc}}$$

In this example $Z_{acc} = 0.1\%$ and $C_{acc} = 0.1001\%$.

6. If $D > 0.1$, see example 4.

Example 3: Component = 680μH
Test Frequency = 100kHz
Test Level = 1V rms
Temperature = 18°-28°C
Speed = Med or Slow

1. Determine the impedance magnitude accuracy of the 680μH inductor at 100kHz by referring to Figure A-1 or by solving the following equation:

$$|Z| = 2\pi fL = 2\pi \times 100\text{kHz} \times 680\mu\text{H} = 427\Omega$$

2. Find the accuracy values corresponding to 427Ω at 100kHz on Table A-1. Record the impedance magnitude accuracy (0.7%) and impedance phase accuracy (0.5°).
3. If the ambient temperature is 5°C - 18°C or 28°C - 40°C, multiply the impedance magnitude accuracy by 1.4 and the impedance phase accuracy by 1.8.
4. If measurement speed is set to FAST, multiply the impedance magnitude accuracy by 2.0 and the impedance phase accuracy by 2.0.
5. If $Q > 10$ the inductance measurement accuracy is approximately equal to the impedance magnitude accuracy.
6. If $Q < 10$, see example 4.

Example 4: Determine precision of parameters other than $|Z|$ and θ at any frequency.

1. First, measure $|Z|$ and θ. Or, calculate them from other measured parameters by applying the following equations:

$$\theta_{meas} = \arctan Q \qquad Q = 1/D$$
$$|Z|_{meas} = 2\pi fL_S/\sin\theta = 2\pi fL_S/ESR$$
$$= 1/(2\pi fC_S \sin\theta) = 1/(2\pi fC_S\, ESR)$$
$$= 2\pi fL_P \sin\theta = (2\pi fC_P)/G$$
$$= \sin\theta/(2\pi fC_P) = 1/(2\pi fL_P\, G)$$

where:
f = frequency (Hz).
C_S, L_S = series equivalent circuit variables.
C_P, L_P = parallel equivalent circuit variables.

2. Determine the impedance magnitude accuracy (A_Z) and impedance phase accuracy (A_θ) of $|Z_{meas}|$ and θ_{meas} by referring to the appropriate table (Table A-1, A-2, A-3 or A-4).
3. Determine the maximum and minimum value by using the following equations:

$$Z_{max} = |Z|_{meas} \times (1 + A_Z)$$
$$Z_{min} = |Z|_{meas} \times (1 - A_Z)$$
$$\theta_{max} = \theta_{meas} + A_\theta$$
$$\theta_{min} = \theta_{meas} - A_\theta$$

4. Determine the maximum and minimum value of the parameter of interest by substituting the values found in step 3 into one of the following equations. There will be four combinations:

$$R_S = |Z|\cos\theta \qquad R_P = |Z|/\cos\theta$$
$$ESR = |Z|\cos\theta \qquad G = \cos\theta/|Z|$$
$$X = |Z|\sin\theta \qquad B = \sin\theta/|Z|$$
$$L_S = X/2\pi f \qquad L_P = -1/2\pi fB$$
$$C_S = -1/2\pi fX \qquad C_P = B/2\pi f$$
$$Q = |\tan\theta| \qquad D = 1/|\tan\theta|$$

5. Accuracy is found by determining the largest deviation from the measured values.

A.2 MEASUREMENT SIGNAL

Frequency

Range:
40Hz-130Hz: 10Hz steps
160, 200, 250Hz
300Hz-9.9kHz: 100Hz steps
10kHz-100kHz: 1kHz steps
Accuracy: ±0.005%

Output Impedance: 100Ω (typ)

Signal Level (voltage when drive terminal HCUR is open)
Range: 10mVrms-1.100Vrms: 1mV steps
Accuracy:
±(3% + 1mV) for 1kHz
±(4% + 1mV) for 40Hz-20kHz
±(5% + 1mV) for 21kHz-100kHz)

Bias Voltage

Internal: 0 or +2VDC (±5%)
External: 0 to ±35VDC

A.3 COMPARATOR/BINNING FUNCTIONS

Number of bins: 20.

The comparator function can sort on the main parameters (R, L, C, or Z) into bins 1-19. Also, the comparator function can sort on the sub-parameter into bin 0 (Q, D, ESR, G or X).

A.4 FRONT PANEL SET-UP MEMORY

Number of front panel set-ups: 10.
Front panel set-up contents: All front panel parameters except bias control.
Battery life: At least 3 years if storage temperture is less than 40°C.

A.5 HANDLER INTERFACE

Connector: 36-pin Centronix type (Cinch 57-30360)
Output signals:
BIN 0-11: Bin judgment signals
A_NG: Main parameter failure
B_NG: Sub-parameter failure
STROBE: Judgment completion pulse (pulse width ≥1.5ms)
BUSY: Measurement in progress flag

Output characteristics:
Type: TTL negative logic
Maximum TTL load: 10 standard TTL
Maximum output current: 48mA (sink, output voltage ≤1V)
Input signals:
TRIG: Measurement start trigger (pulse width ≥100μs)
LOCK: Panel operation prohibited
Input characteristics:
Low level input voltage: -1.5 to +0.8V
High level input voltage: +2.4V to 30V (TRIG), +3.5V to 30V (LOCK)
Low level input current (Approximation)
TRIG: -0.33mA
LOCK: -3mA
Handler Interface Ground: isolated from chassis ground. Max voltage from chassis ±42VDC.
Beeper (two functions, dip switch selectable):
Beeper on/off: Enables beeper function.
Beeper Mode:
1. Beep only for NO GO
2. 4KHz beep for GO and 2kHz beep for NO GO.

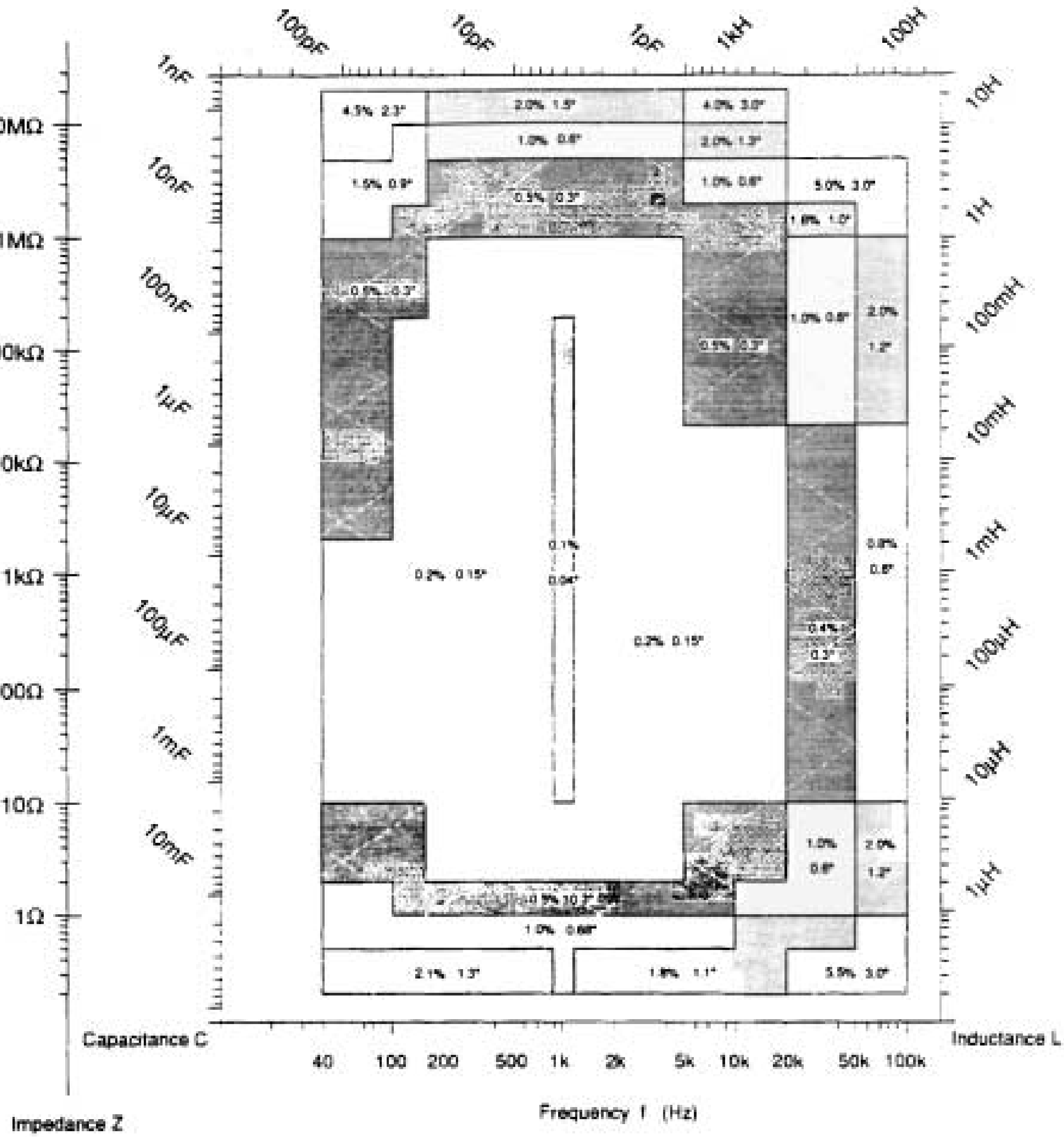
Note: GO refers to comparator bins 1-19, and NO GO refers to comparator bin 0.

A.6 IEEE-488 BUS IMPLEMENTATION

Multiline Commands: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD
Uniline Commands: IFC, REN, EOI, SRQ, ATN
Interface Functions: SH1, AH1, T5, L4, SR1, RL2, PP0, DC1, DT1, C0.

A.7 GENERAL

Line Voltage: 100, 120, 220 or 240 ±10% VAC (external switch selectable)
Environment Operating: 0°~40°C, 10~90% RH (non-condensing)
Storage: -10°~50°C, 10~80% RH (non-condensing)
Dimensions, Weight: 132.5mm high × 216mm wide × 350mm deep (5 1/4 in. × 8 1/2 in. × 13 3/4 in.) Net weigth 3.7kg (8.1 lbs.) (instrument only, excluding accessories).
Warm-up: 30 minutes.
Front Panel Connectors: 4 BNC connectors and a five way binding post.
Rear Panel Connectors:
Handler Interface
External Bias: BNC
IEEE Connector: Floating
Display: Two 4 1/2 digit displays for main and sub-parameters.
Trigger Mode: Automatic (continuous) and manual.
Trigger Delay Time: 0-199.99s
Calibration Cycle: 1 year

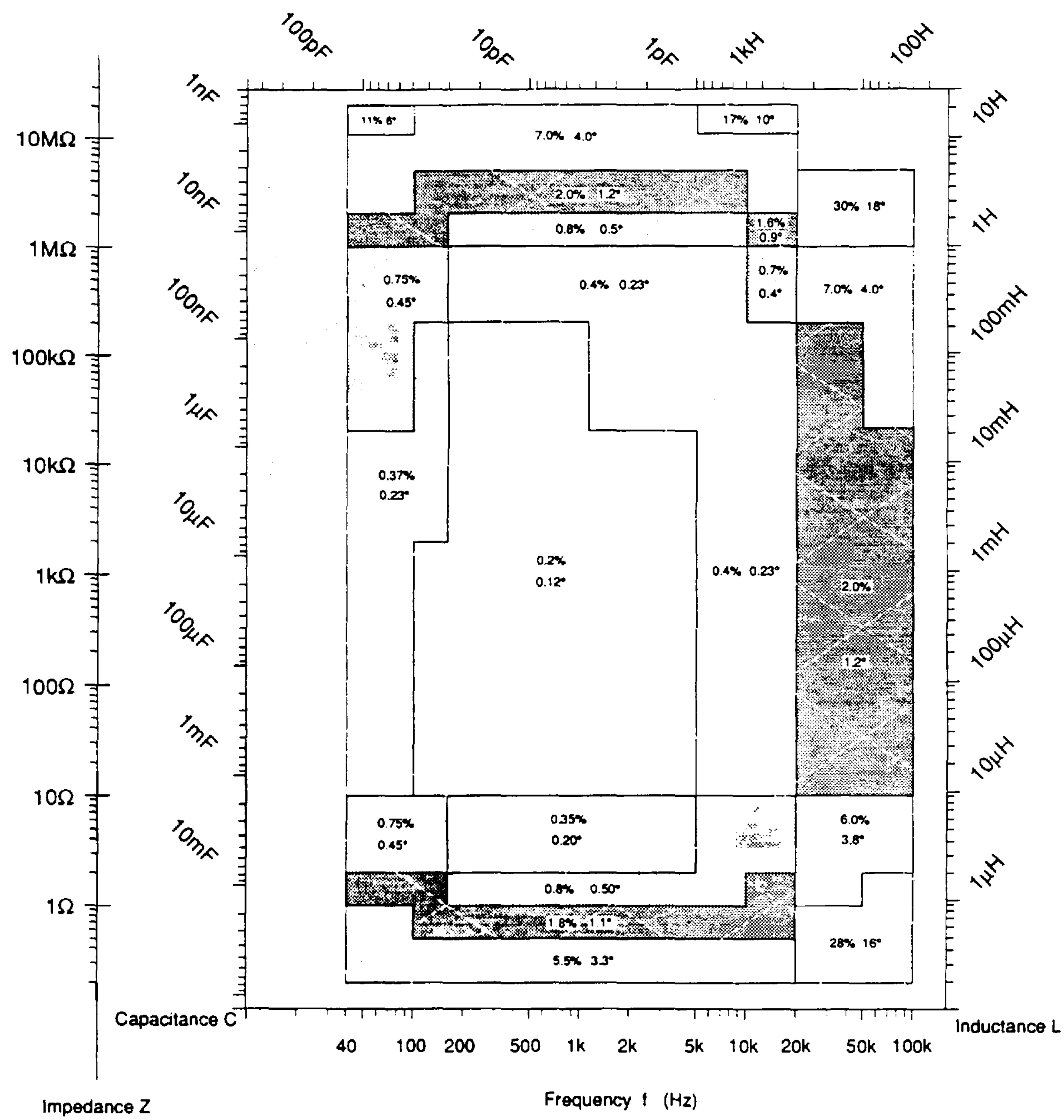


Note : 1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| accuracy by 1.4, and the phase accuracy by 1.8.

2. When measurement speed is FAST, double the accuracy.

Level = 0.9V-1.1V rms   Speed = Medium or Slow

Figure A-2. Accuracy Diagram



Note : 1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| accuracy by 2.0, and the phase accuracy by 2.0.
2. When measurement speed is FAST, double the accuracy.
3. Accuracy is not guaranteed in the following ranges : |Z|>20MΩ, |Z|<.2Ω.

Level = 50mV rms Speed = Medium or Slow

Figure A-3. Accuracy Diagram

APPENDIX B
General GPIB Information

B.1 INTRODUCTION

This appendix contains general information on the GPIB as well certain Model 3330 bus specifications. For details on GPIB operation, refer to Section 4.

B.2 GPIB OVERVIEW

The GPIB Interface is a general-purpose interface bus system recognized by the IEEE (Institute of Electrical and Electronics Engineers) in 1975 in the U.S and is a method of standardizing the data input/output transfer between measuring instruments and peripherals including remote control functions.

By designing each controller and peripheral device into an interface conforming to this standard, it is possible to establish complete hardware compatibility between each device.

Up to 15 devices may be connected to a single interface bus with data transfer performed by three handshake lines. These handshake lines ensure reliable data transfer between data senders and receivers even though they may have different transfer rates.

Various names have been applied to the GPIB, including IEEE-488 bus. The official name, however, is the "IEEE-Std 488-1978: IEEE Standard Digital Interface for Programmable Instrumentation."

B.2.1 Major GPIB Specifications

- Overall cable length: 20m max.
- Cable lengths between device: 4m max.
- Number of devices on bus
  (including controller): 15 max.
- Transfer method: 3 Handshake Lines
- Transfer rate: 1M bytes/s (max.)
- Data transfer: 8 Bits parallel
- Signal lines:
  Data bus: 8 Lines
  Control bus: 8 Lines
  Handshake lines: DAV, NRFD and NDAC
  Control lines: ATN, REN, IFC, SRQ and EOI
  Signal/system grounds: 8 Lines
- Signal logic: Negative
  True (low-level): 0.8V max.
  False (high-level): 2.0V min.
- Interface Connector: See Figure B-1

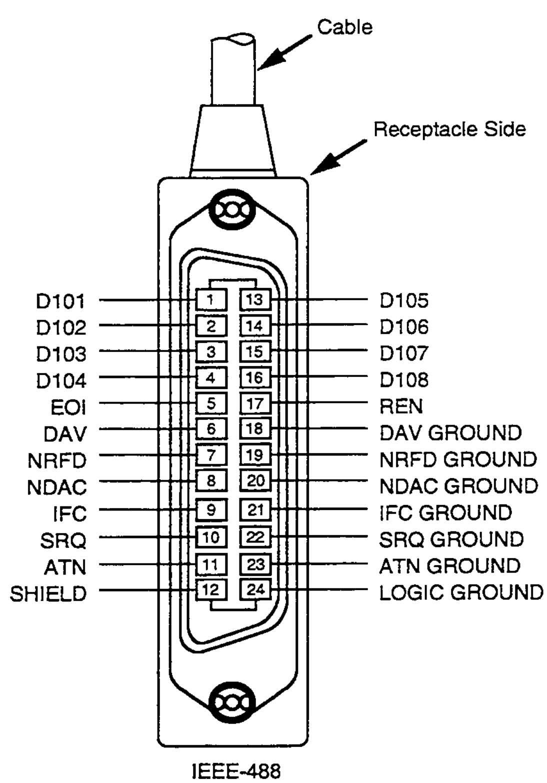


Figure B-1. Interface Connector

B.2.2 Bus Line Signals and Operations

The GPIB bus line consists of 24 lines, including 8 data lines, 8 control lines and 8 signal/system ground lines.

Data Bus (DIO1 to DIO8) — These are the data input/output lines which are also used to input and output both address and command information. The type of data present on these lines are identified by means of the ATN line. DIO1 is the least significant bit (LSB).

Handshake Bus (DAV, NRFD, NDAC) — These three lines are handshake lines used to ensure reliable data transfer.

- DAV (DAta Valid) — This line indicates that the data on the DIO lines sent from a talker or the controller is valid.
- NRFD (Not Ready For Data) — This line indicates the condition of readiness of listeners to accept data on the DIO lines.
- NDAC (Not Data ACcepted) — This line indicates the condition of acceptance of data by listeners.

Control Bus (ATN, REN, IFC, SRQ, EOI):

- ATN (ATteNtion) — This line is an output line from the controller which indicates whether the signals on the DIO bus are data signals or commands.
- REN (Remote ENable) — This output line from the controller switches devices between remote control and local control.
- IFC (InterFace Clear) — The output line from the controller clears the interface of devices.
- SRQ (Service ReQuest) — This control line is used to call the controller from a talker or a listener. The controller detects this signal and executes a serial or parallel poll operation.
- EOI (End Or Identify) — This line is used to indicate the end of a multiple byte transfer sequence or, in conjunction with ATN, to execute a parallel poll.

B.2.3 GPIB Handshaking

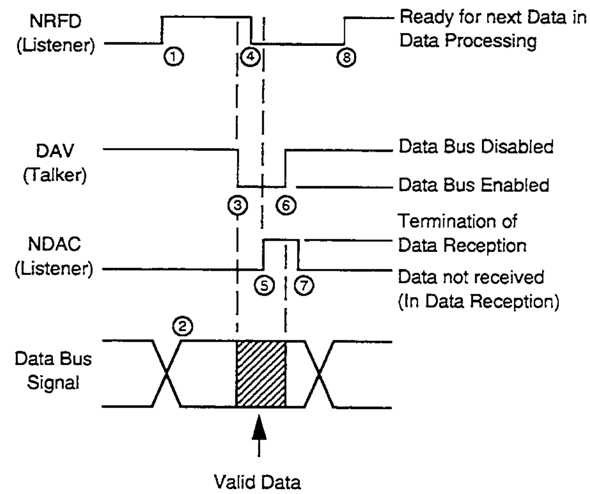
GPIB handshaking is performed by checking the status of all the listeners and inhibiting the next data transfer until all listeners have received the data. Handshaking allows the slowest device on the bus to perform data transfer reliably. The handshaking operations are executed by the following status signals:

NRFD = High level. All listeners are ready for accepting data.
DAV = Low level. A talker is outputting valid data to the data bus.
NDAC = High level. All listeners have completed data reception.

The handshaking timing diagram is shown in Figure B-2.

B.2.4 Data Transfer Example

Figure B-3 provides a data transfer example using the three-line handshake process. In this example, the data "ABC" is sent, followed by the delimiter "CR/LF".



① Indicates that all listeners are waiting for data.
② The talker outputs data to be sent to the data lines.
③ The talker checks NRFD and if high, DAV is set low to indicate to the listener that data is valid.
④ When the DAV goes low, the listener reads data and NRFD is set low, indicating to the talker that data processing is in progress. Each listener sets NDAC high at the completion of data input. The NDAC of the bus is the OR function of the NDACs from each listener.
⑤ When all listeners have completed receiving data, NDAC goes high (result of the OR output) indicating to the talker that data reception has been completed.
⑥ The talker sets DAV high indicating to the listener that the data on bus is not valid.
⑦ The listener checks whether DAV is high and sets NDAC low, completing the handshake.
⑧ Indicates that all listeners have completed data processing and is waiting for next data.

Figure B-2. Handshake Timing Diagram

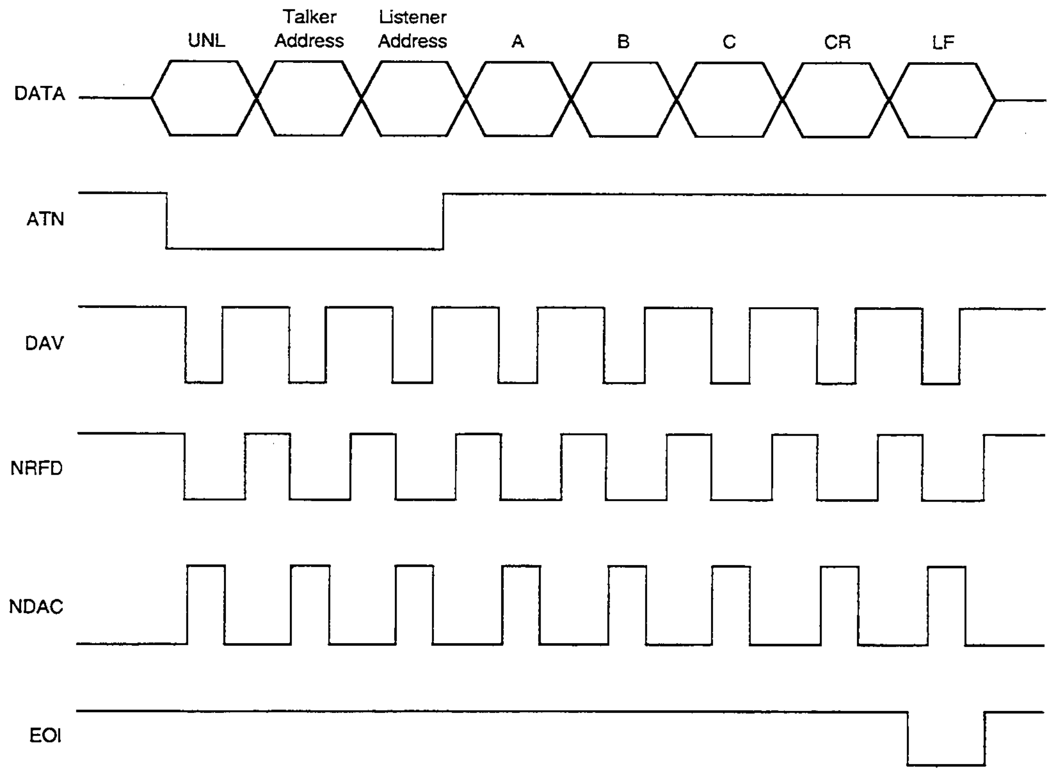


Figure B-3. Data Transfer Example

B.2.5 Basic Talker Functions

- Only one talker may exist on the GPIB at any time.
- When the controller ATN signal is high, data is sent to the listeners.
- Source handshaking is performed automatically.
- A service request (SRQ) is sent to the controller.
- The talker function is enabled for both the local and remote modes.
- The talker function is canceled by any of the following:

  Whenever the talker address of another device is received.
  Whenever the device is specified as a listener.
  Whenever untalk (UNT) is received. Whenever IFC is received.

B.2.6 Basic Listener Functions

- Two or more listeners may exist on the GPIB at any time.
- When the controller ATN signal is high, data is received from a talker.
- Acceptor handshake is performed.
- The listener function is canceled by any of the following:

  Whenever the device is specified as a talker.
  Whenever unlisten (UNL) is received.
  Whenever IFC is received.

B.2.7 Major Specifications of Controller Functions

- Only one controller can be active on GPIB.
- Sets the ATN signal low to control the listener and talker, and transmission of commands such as device clear.
- Outputs IFC and REN signals.

B.2.8 Multi-line Interface Message

Multi-line interface messages are sent by the controller when the ATN signal is low (true). Multi-line interface messages are summarized in Table B-1.

B.3 MODEL 3330 GPIB SPECIFICATIONS

B.3.1 Interface Functions

The interface functions of the instrument are listed in Table B-2.

B.3.2 Bus Drivers

The specifications of the bus drivers of the instrument are listed in Table B-3.

B.3.3 Primary Address

The address of the instrument can be set within the following range:

0 to 30 (Decimal)

Use the SET UP key to set the primary address, as described in Section 4.

Table B-1. Multi-line Interface Messages

b7 b6 b5					0 0 0	MSG	0 0 1	MSG	0 1 0	MSG	0 1 1	MSG	1 0 0	MSG	1 0 1	MSG	1 1 0	MSG	1 1 1	MSG
b4	b3	b2	b1	COLUMN / ROW	0		1		2		3		4		5		6		7	
0	0	0	0	0	NUL		DLE		SP	LISTENER ADDRESSES ASSIGNED TO DEVICES	0	LISTENER ADDRESSES ASSIGNED TO DEVICES	@	TALKER ADDRESSES ASSIGNED TO DEVICES	P	TALKER ADDRESSES ASSIGNED TO DEVICES		MEANING DEFINED BY PCG	p	MEANING DEFINED BY PCG
0	0	0	1	1	SOH	GTL	DC1	LLO	!		1		A		Q		a		q	
0	0	1	0	2	STX		DC2		"		2		B		R		b		r	
0	0	1	1	3	ETX		DC3		#		3		C		S		c		s	
0	1	0	0	4	EOT	SDC	DC4	DCL	$		4		D		T		d		t	
0	1	0	1	5	ENQ	PPC[3]	NAK	PPU	%		5		E		U		e		u	
0	1	1	0	6	ACK		SYN		&		6		F		V		f		v	
0	1	1	1	7	BEL		ETB		'		7		G		W		g		w	
1	0	0	0	8	BS	GET	CAN	SPE	(		8		H		X		h		x	
1	0	0	1	9	HT	TCT	EM	SPD	)		9		I		Y		i		y	
1	0	1	0	10	LF		SUB		*		:		J		Z		j		z	
1	0	1	1	11	VT		ESC		+		;		K		[		k		{	
1	1	0	0	12	FF		FS		,		<		L		\		l		¦	
1	1	0	1	13	CR		GS		-		=		M		]		m		}	
1	1	1	0	14	SO		RS		.		>		N		^		n		~	
1	1	1	1	15	SI		US		/		?	UNL	O		_	UNT	o		DEL	

Columns 0 and MSG: ADDRESSED COMMAND GROUP (ACG)
Columns 1 and MSG: UNIVERSAL COMMAND GROUP (UCG)
Columns 2–3 and MSG: LISTEN ADDRESS GROUP (LAG)
Columns 4–5 and MSG: TALK ADDRESS GROUP (TAG)
Columns 0–5: PRIMARY COMMAND GROUP (PCG)
Columns 6–7: SECONDARY COMMAND GROUP (SCG)

NOTES
1 MSG IS THE INTERFACE MESSAGE
2 b1 = DIO8 . . . b2 = DIO7
DIO8 IS NOT USED
3 HAS SECONDARY COMMAND

Table B-2. Interface Functions

SH1	All functions of transmit handshake
AH1	All functions of receive handshake
T5	Has basic talker function, serial poll, talker canceled by MLA function, talk-only function.
L4	Has basic listener function, listener canceled by MTA function, no listen only function
SR1	All functions of service request
RL2	Has remote/local switching function, no lock-out function.
PP0	No parallel poll function
DC1	All functions of device clear
DT1	All functions of device trigger
C0	No controller function

Table B-3. Bus Drivers

Data Bus	DIO1 to DIO8	Open Collector
Handshake bus	NRFD, NDAC DAV	Open collector
Control bus	SRQ EOI	Open collector Tri-state

APPENDIX C
Example Programs for IBM PC and Compatible Computers

C.1 INTRODUCTION

This appendix includes several example programs intended to run under Microsoft QuickBASIC on IBM PC, AT, or compatible computers. Refer to Section 4, paragraph 4.9 for HP 9000 Series 200 computer examples.

Computer Hardware Requirements

The following computer hardware is necessary to use the example programs:

- IBM PC, AT, or compatible computer.
- Keithley Instruments PC-488-CEC, IOtech Personal488, CEC PC-488, or National Instruments PC-II or PC-IIA IEEE-488 interface for the computer.

Computer Software Requirements

The following software is required to use the example programs:

- MS-DOS or PC-DOS version 3.30 or later.
- Microsoft QuickBASIC compiler, version 4.0 or later.
- IOtech Driver488 (IEEE-488 bus driver), Rev. 2.3 or later. NOTE: Later versions of Driver488 may not support other manufacturers' interface cards.

Hardware/Software Installation

Make sure the IEEE-488 interface and Driver488 software are installed per the manufacturer's instructions. Board settings for such items as base I/O address, DMA, and interrupt status must be the same as the corresponding driver software settings.

C.2 EXAMPLE PROGRAMS

The five programs that follow demonstrate various techniques for programming the Model 3330 over the GPIB. Follow the instructions below for all test programs.

1. Make certain the Model 3330 primary address is set to 2, and that the delimiter is <CR> <LF>. (Use SET UP GPIB to set both address and delimiter.)
2. Enter the QuickBASIC editor by typing the following while in the QuickBASIC directory:

   QB <Enter>

3. Enter the program lines from the desired program, then check for errors.
4. Run the program by pressing Shift + F5, and follow the prompts on the screen.

Electrolytic Capacitor Test Program

Program C-1 tests electrolytic capacitors and is similar to the HP 9000 Series 200 computer version in Section 4. The program will apply a test bias voltage to the DUT and then measure the capacitance and ESR at various frequencies. A listing of frequencies, capacitance, and ESR values will be displayed on the computer screen.

Program C-1. Electrolytic Capacitor Test

```
' This program tests electrolytic capacitors.
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1     ' Open IEEE-488 output path.
OPEN "\DEV\IEEEIN" FOR INPUT AS #2       ' Open IEEE-488 input path.
IOCTL #1, "BREAK"                        ' Reset interface.
PRINT #1, "RESET"                        ' Warm start interface
PRINT #1, "CLEAR"                        ' Send device clear.
PRINT #1, "ABORT"                        ' Send interface clear.
PRINT #1, "REMOTE 02"                    ' Put unit in remote.
PRINT #1, "OUTPUT 02;LV 1 RN 0"          ' 1V level, autorange.
PRINT #1, "OUTPUT 02;SP 1 DA 2"          ' Medium speed, C function.
PRINT #1, "OUTPUT 02;DB 2 DE 0"          ' ESR, normal readings.
PRINT #1, "OUTPUT 02;CK 1 TR 1"          ' Series circuit, manual trig.
CLS
PRINT "Connect capacitor, press any key to continue."
DO WHILE INKEY$ = "": LOOP               ' Wait for key press.
PRINT #1, "OUTPUT 02;DL 1 BO 1"          ' 1 sec delay, turn on bias.
Wtm = 15                                 ' Charging time (s).
T = TIMER                                ' Wait for cap to charge.
PRINT "Waiting"; Wtm; "seconds for capacitor to charge."
WHILE (TIMER - T) < Wtm: WEND
RESTORE Flist                            ' Point to frequency list.
PRINT
PRINT "FREQ(Hz)    C(F)    ESR(ohms)"    ' Print header.
READ F$                                  ' Read frequency parameter.
WHILE F$ <> "*"                          ' Loop for all frequencies.
PRINT #1, "OUTPUT 02;FR"; F$             ' Program frequency.
Wtm = 2                                  ' 2 sec delay for settling.
T = TIMER
WHILE (TIMER - T) < Wtm: WEND            ' Delay loop.
PRINT #1, "OUTPUT 02;TG"                 ' Trigger reading.
PRINT "  "; F$; " ";
PRINT #1, "ENTER 02"                     ' Address meter to talk.
LINE INPUT #2, A$                        ' Input reading.
PRINT A$                                 ' Display reading.
READ F$                                  ' Read next frequency.
WEND                                     ' Loop back for next test.
PRINT #1, "OUTPUT 02;BO 0"               ' Turn off bias.
PRINT #1, "LOCAL 02"                     ' Restore local operation.
PRINT
PRINT "End of measurement."
CLOSE 1: CLOSE 2
END                                      ' Close I/O.
Flist:
' Frequency list
DATA "   40","  100","  250","  500","  1E3","  2E3","  5E3"," 10E3"
DATA " 20E3"," 50E3","100E3","*"
```

Bin Test Program

Program C-2 demonstrates using the bin feature to sort 1kΩ resistors according to tolerance. The bin limits used by the program are as follows:

- Out-of-tolerance resistors: Bin 0.
- Resistors within ±1% tolerance: Bin 1
- Resistors within ±5% tolerance: Bin 2.
- Resistors within ±10% tolerance: Bin 3.
- Resistors within ±20% tolerance: Bin 4.

When the program is run, you will be prompted to connect resistors to test. The bin assignment for each resistor will be displayed on the computer CRT. The program will then continue for as many resistors as you wish to test.

Program C-2. Resistor Test Using BIN

```
' This program tests 1kohm resistors for
' +/-1%, +/-5%,, +/-10%, and +/-20% tolerance using BIN.
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1     ' Open IEEE-488 output path.
OPEN "\DEV\IEEEIN" FOR INPUT AS #2       ' Open IEEE-488 input path.
IOCTL #1, "BREAK"                        ' Reset interface.
PRINT #1, "RESET"                        ' Warm start interface
PRINT #1, "CLEAR"                        ' Send device clear.
PRINT #1, "ABORT"                        ' Send interface clear.
PRINT #1, "REMOTE 02"                    ' Put unit in remote.
PRINT #1, "OUTPUT 02;LV 1 RN 0"          ' 1V level, autorange.
PRINT #1, "OUTPUT 02;SP 1 DA 3"          ' Medium speed, resistance.
PRINT #1, "OUTPUT 02;DE 3 HD 0"          ' Bin readings, header off.
PRINT #1, "OUTPUT 02;CK 0 TR 1"          ' Auto circuit, manual trig.
PRINT #1, "OUTPUT 02;FR 1000 DL 1"       ' 1kHz frequency, 1s delay.
PRINT #1, "OUTPUT 02;BN 0,0,0"           ' Disable bin 0.
PRINT #1, "OUTPUT 02;BN 1,990,1010"      ' Define bin 1 limits.
PRINT #1, "OUTPUT 02;BN 2,950,1050"      ' Define bin 2 limits.
PRINT #1, "OUTPUT 02;BN 3,900,1100"      ' Define bin 3 limits.
PRINT #1, "OUTPUT 02;BN 4,800,1200"      ' Define bin 4 limits.
PRINT #1, "OUTPUT 02;BN 5,0,0"           ' Close bin 5.
CLS
Start:
PRINT "Connect resistor, press any key to continue ('Q' to quit)."
Lp: A$ = INKEY$: IF A$ = "" THEN GOTO Lp' Wait for key press.
IF A$ = "Q" OR A$ = "q" THEN GOTO Quit
PRINT #1, "OUTPUT 02;TG"                 ' Trigger reading.
PRINT #1, "ENTER 02"                     ' Address meter to talk.
INPUT #2, A                              ' Input bin number.
PRINT "Put resistor in bin"; A; "."      ' Display bin number.
PRINT
GOTO Start
Quit:
PRINT #1, "LOCAL 02"                     ' Restore local operation.
CLOSE 1: CLOSE 2                         ' Close I/O.
END
```

Optimizing Measurement Speed

Program C-3 demonstrates how to optimize measurement speed using the following operating modes:

- Manual ranging.
- Fast measurement speed.

Manual ranging speeds up the reading rate because automatic range changes take a certain amount of time. The fast measurement speed, of course, minimizes the amount of time per reading.

At the start of the program, you will be prompted to select a manual range. (Refer to the information in paragraph 3.5 for information on selecting the appropriate range based on DUT impedance.) Readings will then be continuously taken and displayed on the computer screen.

Program C-3. Optimizing Measurement Speed

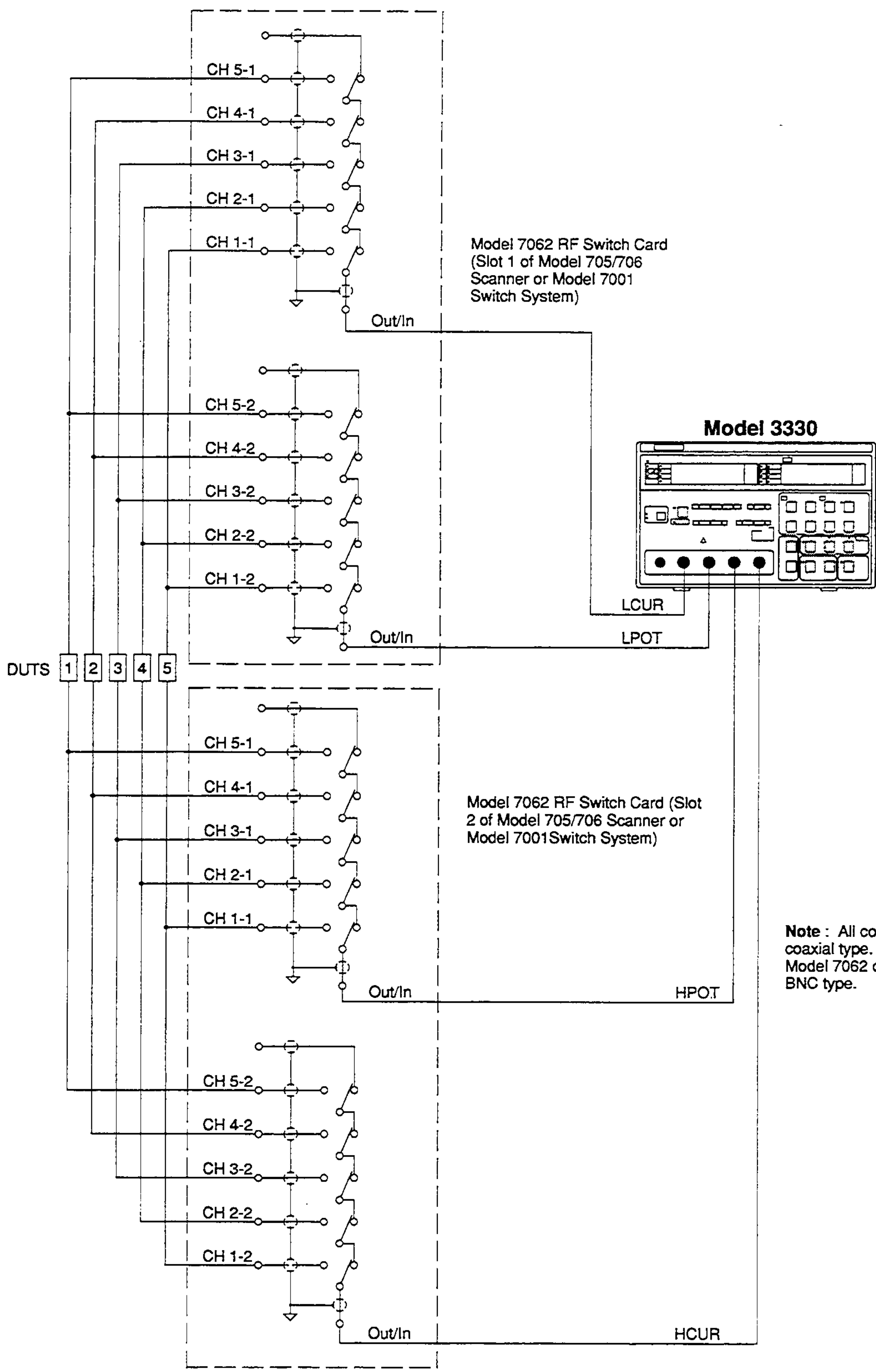
```
' This program demonstrates how to maximize measurement speed.
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1    ' Open IEEE-488 output path.
OPEN "\DEV\IEEEIN" FOR INPUT AS #2      ' Open IEEE-488 input path.
IOCTL #1, "BREAK"                       ' Reset interface.
PRINT #1, "RESET"                       ' Warm start interface
PRINT #1, "CLEAR"                       ' Send device clear.
PRINT #1, "ABORT"                       ' Send interface clear.
PRINT #1, "REMOTE 02"                   ' Put unit in remote.
PRINT #1, "OUTPUT 02;LV 1 FR 1E3"       ' 1V level, 1kHz frequency
PRINT #1, "OUTPUT 02;DA 2 DB 1"         ' Capacitance, dissipation.
PRINT #1, "OUTPUT 02;DE 0 HD 0"         ' Normal data, header off.
PRINT #1, "OUTPUT 02;CK 1 TR 1"         ' Series circuit, man. trig.
PRINT #1, "OUTPUT 02;SP0 DL 0"          ' Fast speed, 0s delay.
CLS
INPUT "Range (1-6)"; R                  ' Input measurement range.
PRINT #1, "OUTPUT 02;RN"; R             ' Program range.
PRINT "Connect DUT, press key to continue."
PRINT "Press any key while measuring to end program."
DO WHILE INKEY$ = "": LOOP              ' Wait for key press.
WHILE INKEY$ = ""                       ' Loop until stopped.
PRINT #1, "OUTPUT 02;TG"                ' Trigger reading.
PRINT #1, "ENTER 02"                    ' Address meter to talk.
LINE INPUT #2, A$                       ' Input reading.
PRINT A$                                ' Display reading.
WEND                                    ' End of loop.
PRINT #1, "LOCAL 02"                    ' Restore local operation.
CLOSE 1: CLOSE 2                        ' Close I/O.
END
```

Using the LCZ Meter with Switching Systems

The Model 3330 LCZ Meter can be used with a switching system to test a number of DUTs automatically. Figure C-4 shows a typical switching test system using two Model 7062 RF Scanner cards to switch connections to five DUTs. The Model 7062 Cards can be installed in either a Model 705 or Model 706 Scanner mainframe, or in a Model 7001 Switch System mainframe. The Models 705 and 7001 each hold two cards, allowing up to five DUTs per mainframe to be tested, while the Model 706 holds a maximum of 10 cards and can be used to test a maximum of 25 DUTs per mainframe.

Program C-4 demonstrates using the scanning system to test five DUTs automatically using a Model 705 or 706 Scanner. Program C-5 is a similar program written to control a Model 7001 Switch System. At the start of each program, you will be prompted to enter the test frequency and to open DUT #1 connections so that zero open correction can be performed. Next, you will be prompted to short DUT #1 connections so that zero short correction can be performed. If an error is detected during either zero correction process, an error message will be displayed, and the program will halt. Note that zero correction is particularly important when using switching cards because the residual impedance and stray admittance are generally much higher than when using test fixtures without switching.

During the main part of the test, the program will cycle through scanner or switch channels and measure each DUT. Data for each device will be displayed on the computer screen and written to a disk file called "LCZ.DAT" along with the DUT number. After the test is completed, use the DOS TYPE or PRINT command to view or print out this file as desired.



Note : All connecting cables are coaxial type. Model 3330 and Model 7062 card connectors are BNC type.

Figure C-1. Connections for Typical LCZ Meter Switching Test System

Program C-4. Using the LCZ Meter with a Model 705/706 Scanner

```
' This program tests five DUTs using a Model 705 Scanner
' equipped with two Model 7062 RF Scanner Cards.
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1     ' Open IEEE-488 output path.
OPEN "\DEV\IEEEIN" FOR INPUT AS #2       ' Open IEEE-488 input path.
IOCTL #1, "BREAK"                        ' Reset interface.
PRINT #1, "RESET"                        ' Warm start interface
PRINT #1, "CLEAR"                        ' Send device clear.
PRINT #1, "ABORT"                        ' Send interface clear.
PRINT #1, "REMOTE 02"                    ' Put unit in remote.
PRINT #1, "OUTPUT 02;LV 1 RN 0"          ' 1V level, autorange.
PRINT #1, "OUTPUT 02;SP 1 DA 0"          ' Medium speed, AUTO function.
PRINT #1, "OUTPUT 02;DE 0 HD 0"          ' Normal data, header off.
PRINT #1, "OUTPUT 02;TR 1 DL 2"          ' Manual trig., 2s delay.
CLS
INPUT "Test frequency (40 to 100E3)"; F
PRINT #1, "OUTPUT 02;FR"; F              ' Program frequency.
PRINT #1, "REMOTE 17"                    ' Put scanner in remote.
PRINT #1, "OUTPUT 17;R0X"                ' Reset scanner.
PRINT #1, "OUTPUT 17;A2X"                ' Select 2-pole mode.
PRINT "Disconnect DUT #1, then press any key."
DO WHILE INKEY$ = "": LOOP               ' Wait for key press.
PRINT #1, "OUTPUT 17;C1C6C11C16X"        ' Close DUT #1 channels.
PRINT #1, "OUTPUT 02;OP"                 ' Do open zero correction.
PRINT "Performing OPEN correction."
GOSUB Busy                               ' Wait until done.
PRINT "Short DUT #1 connections, then press any key."
DO WHILE INKEY$ = "": LOOP               ' Wait for key press.
PRINT #1, "OUTPUT 02;SH"                 ' Do short correction.
PRINT "Performing SHORT correction."
GOSUB Busy
PRINT #1, "OUTPUT 17;R0X"                ' Open channels.
PRINT "Connect DUTs, then press any key."
DO WHILE INKEY$ = "": LOOP               ' Wait for key press.
OPEN "LCZ.DAT" FOR OUTPUT AS #3          ' Open disk file.
FOR I = 1 TO 5                           ' Loop for all 5 DUTs.
PRINT #1, "OUTPUT 17;C"; I; "C"; I + 5; "C"; I + 10; "C"; I + 15; "X"
PRINT #1, "OUTPUT 02;TG"                 ' Trigger reading.
PRINT #1, "ENTER 02"                     ' Address meter to talk.
LINE INPUT #2, A$                        ' Input reading.
PRINT #3, I; A$                          ' Store reading on disk.
PRINT "DUT#"; I; " reading:"; A$         ' Display reading.
PRINT #1, "OUTPUT 17;R0X"                ' Open channels.
NEXT I                                   ' Measure next DUT.
PRINT "Measurements completed."
Quit:
PRINT #1, "LOCAL 02"                     ' Restore local operation.
CLOSE 1: CLOSE 2: CLOSE 3                ' Close I/O.
END
Busy:                                    ' Wait during zero routine.
PRINT #1, "SPOLL 02"                     ' Serial poll instrument.
INPUT #2, S                              ' Input status byte.
IF S = 0 THEN GOTO Busy                  ' Wait if still busy.
IF (S AND 32) = 32 THEN                  ' Check for error.
        BEEP
        PRINT "Zero correction error."
        GOTO Quit
END IF
RETURN
```

Program C-5. Using the LCZ Meter with a Model 7001 Switch System

```
' This program tests five DUTs using a Model 7001 Switch System
' equipped with two Model 7062 RF Scanner Cards.
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1     ' Open IEEE-488 output path.
OPEN "\DEV\IEEEIN" FOR INPUT AS #2       ' Open IEEE-488 input path.
IOCTL #1, "BREAK"                        ' Reset interface.
PRINT #1, "RESET"                        ' Warm start interface
PRINT #1, "CLEAR"                        ' Send device clear.
PRINT #1, "ABORT"                        ' Send interface clear.
PRINT #1, "REMOTE 02"                    ' Put unit in remote.
PRINT #1, "OUTPUT 02;LV 1 RN 0"          ' 1V level, autorange.
PRINT #1, "OUTPUT 02;SP 1 DA 0"          ' Medium speed, AUTO function.
PRINT #1, "OUTPUT 02;DE 0 HD 0"          ' Normal data, header off.
PRINT #1, "OUTPUT 02;TR 1 DL 2"          ' Manual trig., 2s delay.
CLS
INPUT "Test frequency (40 to 100E3)"; F
PRINT #1, "OUTPUT 02;FR"; F              ' Program frequency.
PRINT #1, "REMOTE 17"                    ' Put 7001 in remote.
PRINT #1, "OUTPUT 17;*RST"               ' Reset 7001 switch system.
PRINT #1, "OUTPUT 17;:ROUT:CONF:SLOT1:CTYPE C7062" ' Slot 1 = 7062.
PRINT #1, "OUTPUT 17;:ROUT:CONF:SLOT2:CTYPE C7062" ' Slot 2 = 7062.
PRINT #1, "OUTPUT 17;:ROUT:OPEN ALL"     ' Open all channels.
PRINT "Disconnect DUT #1, then press any key."
DO WHILE INKEY$ = "": LOOP               ' Wait for key press.
PRINT #1, "OUTPUT 17;:ROUT:CLOS (@1!1,1!6,2!1,2!6)" ' Close channels.
PRINT #1, "OUTPUT 02;OP"                 ' Do open zero correction.
PRINT "Performing OPEN correction."
GOSUB Busy                               ' Wait until done.
PRINT "Short DUT #1 connections, then press any key."
DO WHILE INKEY$ = "": LOOP               ' Wait for key press.
PRINT #1, "OUTPUT 02;SH"                 ' Do short correction.
PRINT "Performing SHORT correction."
GOSUB Busy
PRINT #1, "OUTPUT 17;:ROUT:OPEN ALL"     ' Open channels.
PRINT "Connect DUTs, then press any key."
DO WHILE INKEY$ = "": LOOP               ' Wait for key press.
OPEN "LCZ.DAT" FOR OUTPUT AS #3          ' Open disk file.
FOR I = 1 TO 5                           ' Loop for all 5 DUTs.
PRINT #1, "OUTPUT 17;:ROUT:CLOS (@1!"; I; ",1!"; I + 5; ")"
PRINT #1, "OUTPUT 17;:ROUT:CLOS (@2!"; I; ",2!"; I + 5; ")"
PRINT #1, "OUTPUT 02;TG"                 ' Trigger reading.
PRINT #1, "ENTER 02"                     ' Address meter to talk.
LINE INPUT #2, A$                        ' Input reading.
PRINT #3, I; A$                          ' Store reading on disk.
PRINT "DUT#"; I; " reading:"; A$         ' Display reading.
PRINT #1, "OUTPUT 17;:ROUT:OPEN ALL"     ' Open channels.
NEXT I                                   ' Measure next DUT.
PRINT "Measurements completed."
Quit:
PRINT #1, "LOCAL 02"                     ' Restore local operation.
CLOSE 1: CLOSE 2: CLOSE 3                ' Close I/O.
END
Busy:                                    ' Wait during zero routine.
PRINT #1, "SPOLL 02"                     ' Serial poll instrument.
INPUT #2, S                              ' Input status byte.
IF S = 0 THEN GOTO Busy                  ' Wait if still busy.
IF (S AND 32) = 32 THEN                  ' Check for error.
        BEEP
        PRINT "Zero correction error."
        GOTO Quit
END IF
RETURN
```

Interrupt-driven SRQ

Program C-6 demonstrates using interrupt-driven SRQ (service request) to determine when readings are done. The program triggers a Model 3330 reading and then waits in a do-nothing loop until the SRQ occurs. When the SRQ does occur, the program branches to a service routine and then reads and displays the reading. The next reading is then triggered, and the program returns to the main loop to wait until the next reading is completed.

Program C-6. Interrupt-driven SRQ

```
' This program demonstrates interrupt-driven SRQ.
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1     ' Open IEEE-488 output path.
OPEN "\DEV\IEEEIN" FOR INPUT AS #2       ' Open IEEE-488 input path.
IOCTL #1, "BREAK"                        ' Reset interface.
PRINT #1, "RESET"                        ' Warm start interface
PRINT #1, "CLEAR"                        ' Send device clear.
PRINT #1, "ABORT"                        ' Send interface clear..
PRINT #1, "REMOTE 02"                    ' Put unit in remote.
PRINT #1, "OUTPUT 02;FR 1E3 LV 1"        ' 1kHz frequency, 1V level.
PRINT #1, "OUTPUT 02; DA 0 DE 0"         ' Auto, normal data.
PRINT #1, "OUTPUT 02;TR 1 SP 1"          ' Manual trig., med. speed.
PRINT #1, "OUTPUT 02;RQ 1 DL 1"          ' Enable SRQ, 1s delay.
PRINT #1, "ARM SRQ"                      ' Arm interface SRQ.
ON PEN GOSUB SRQ.Event                   ' Define interrupt vector.
PEN ON                                   ' Enable interrupt.
PRINT #1, "OUTPUT 02;TG"                 ' Trigger reading.
DO WHILE INKEY$ = "": LOOP               ' Do nothing loop.
CLOSE 1: CLOSE 2                         ' Close I/O.
END
SRQ.Event:                               ' Interrupt service routine.
PRINT #1, "SPOLL 02"                     ' Serial poll meter.
INPUT #2, S                              ' Input status byte.
IF (S AND 64) = 0 THEN RETURN            ' Check status byte.
PRINT #1, "OUTPUT 02;?DT"                ' Request reading.
PRINT #1, "ENTER 02"                     ' Address unit to talk.
LINE INPUT #2, A$                        ' Input reading.
PRINT A$                                 ' Display reading.
PRINT #1, "TRIGGER 02"                   ' Trigger next reading.
RETURN
```

APPENDIX D
Typical Performance Data

D.1 INTRODUCTION

This appendix provides information on typical perform of the Model 3330 LCZ Meter

The instrument was thoroughly tested and inspected, and certified as meeting its published specifications when it was shipped from the factory. However, the typical performance data represents mean values of measurement for each Model 3330. Thus, measured performance of your Model 3330 may be different than indicated by the typical performance curves shown in this appendix.

D.2 TYPICAL DATA

Figure D-1 shows typical impedance accuracy for various frequencies and ranges at a signal level of 1V rms (trends for lower signal levels are similar). Measuring errors tend to increase as the DUT impedance varies from the reference resistance for each range. Also, the calibration accuracy of the instrument for DUT impedances close to the reference resistance is restricted by temperature and long-term drift.

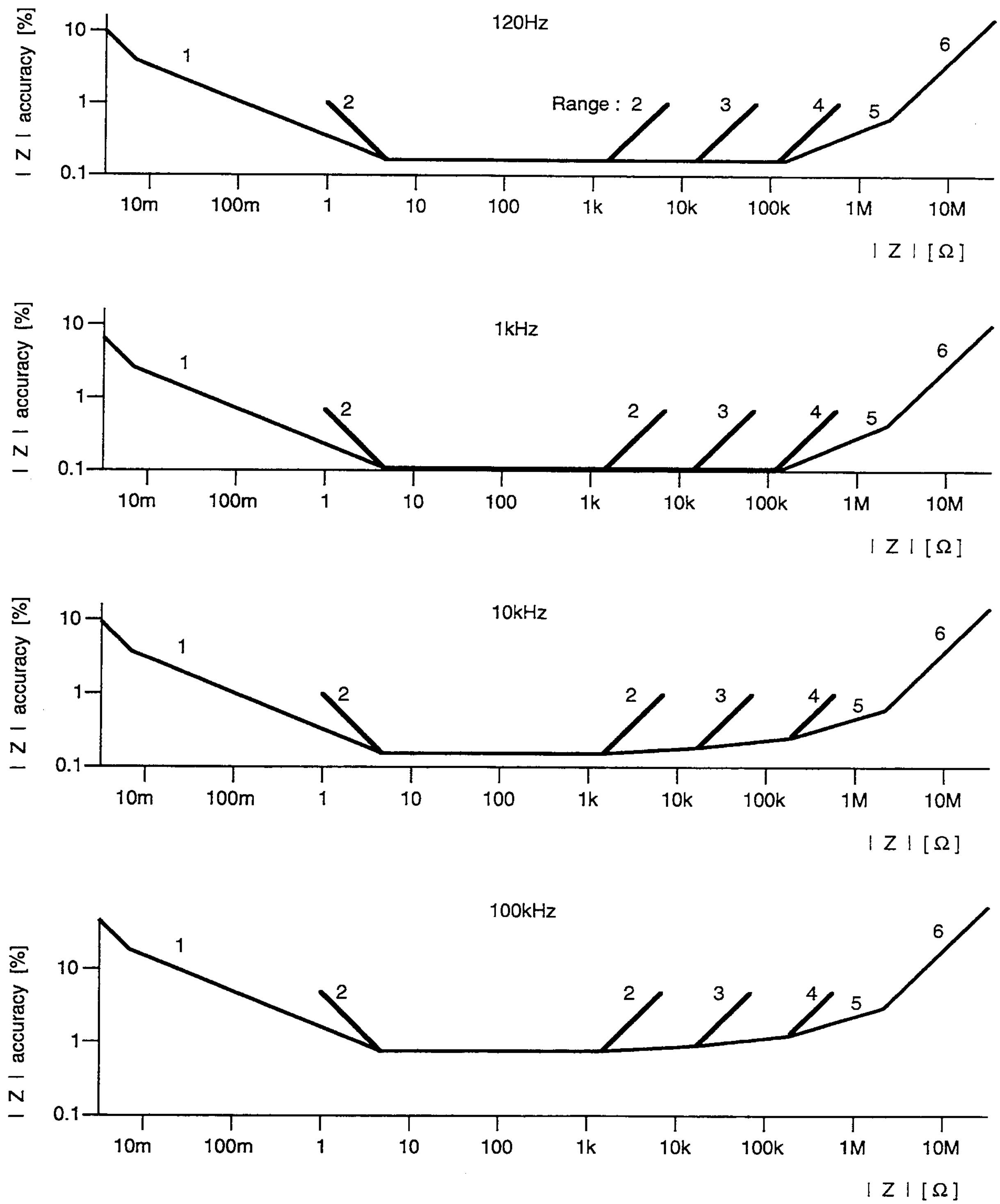


Figure D-1. *Typical Data*

APPENDIX E
Beeper Setting

INTRODUCTION

An internal beeper can be set to sound for go or no-go comparator conditions. As shipped, the beeper is disabled, but internal switches can be changed to enable the beeper, as outlined below.

WARNING
The information in this appendix is intended only for qualified service personnel who recognize potentially hazardous conditions. Do not attempt to perform this procedure unless you are qualified to do so.

Procedure

Refer to Figure E-1 and the steps below to change the beeper setting.

1. Disconnect the power cord and all other equipment from the Model 3330.

WARNING
Disconnect the power line cord and all equipment before removing covers.

2. Remove the four screws that secure the bottom cover, then remove the top and bottom covers.
3. Set the DIP switches on the handler interface board based on the type of beeper operation desired (see Table E-1).
4. Replace the top and bottom covers, and replace the four screws removed earlier. Be careful not to pinch internal cables when replacing the covers.

Table E-1. Beeper Operation Switch Positions

Switch		
1	2	Operation
OFF	–	Beep disabled (factory default)
ON	ON	Beep sounded only for NG
ON	OFF	High beep for GO (bins 1-19) Low beep for NG (bin 0)

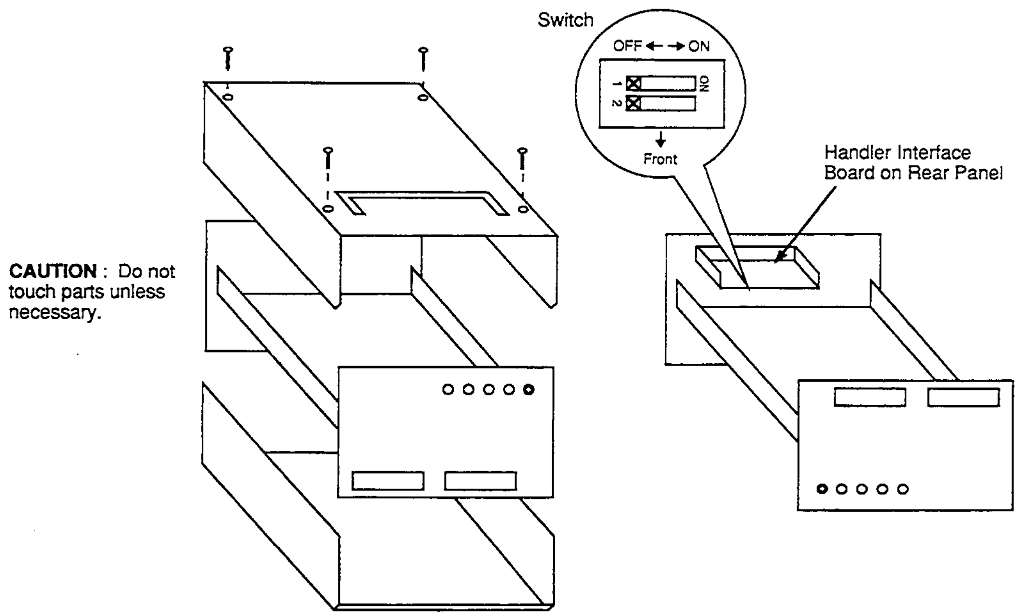


Figure E-1. Beeper Switch Setting

Index

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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
- ❑ Will not read applied input
- ❑ Overload

- ❑ Calibration only
- ❑ Certificate of calibration required
- ❑ Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system 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 phone number on this service form.

KEITHLEY

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ITALY:	Viale San Gimignano, 38 • 20146 Milano • 02-48 39 16 01 • Fax: 02-48 30 22 74
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