IP2-26

INSTRUCTION MANUAL
MODEL 5110
LCR METER

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TABLE OF CONTENTS

SECTION I - GENERAL INFORMATION

SECTION II - INSTALLATION

SECTION III - OPERATION

SECTION IV - THEORY OF OPERATION

SECTION V - MAINTENANCE

SECTION VI - PARTS LIST

SECTION VII - SCHEMATICS

LIST OF ILLUSTRATIONS

LIST OF TABLES

Figure 1-1. Model 5110

SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. This instruction manual provides general information, installation and operating instructions, theory of operation, maintenance instructions, parts list, and schematics for the Model 5110 LCR Meter.

1-3. DESCRIPTION.

1-4. The Boonton Model 5110 LCR Meter is a general purpose inductance, capacitance, and resistance meter that is capable of measuring a wide range of values either locally or over the standard GPIB.

1-5. The instrument has two 3 1/2 digit LED displays. The first display indicates L, C, and R. The second display indicates the dissipation factor (D) concurrent with the capacitance indication, or the quality factor (Q) or (D) concurrent with the inductance measurement.

1-6. The Model 5110 is designed to perform measurements on components upon incoming inspection, production testing and research and development applications. The instrument has three modes of operations which are as follows:

a. Manual operation, utilizing keyboard controls.

b. Automatic operation, after L, C, or R and the test frequency is selected. The instrument selects the correct measuring range and equivalent circuit mode (series or parallel) and then displays the results of the test.

c. Fully compatible IEEE-488 programmable operation under external control with listen and talk modes.

1-7. The Model 5110 design features are as follows:

a. Measurement accuracy for L, C and R is basically ±0.3% of rdg.

b. Three test frequencies, 100 Hz, 120 Hz and 1 kHz are available for measurements from 0.1 pF to 19.99 mF, 0.1 µH to 1.999 kH, and 1 mΩ to 19.99 MΩ. Test frequency accuracy is ±0.3%. The 100 Hz and 120 Hz test frequencies allow testing of line frequency components used in power supplies.

c. Automatic range and mode selection for samples whose value is unknown, but within the optimum range.

d. The measured values C and D, L and D or Q can be displayed simultaneously. In the L measurement mode, the display can be switched from Q to D.

e. Stray capacitance offset-adjustment can be performed.

f. The measurement level, which is nominally 1 V, may be reduced to 50 mV on the low capacitance ranges where semiconductor measurements are made. DC bias may also be applied to the test via rear panel terminals.

g. Full IEEE-488 GPIB is implemented as the standard on the Model 5110. All front and rear panel controls may be programmed over the bus with the exception of power ON/OFF. Trigger and SRQ are included. Address and terminators are switch selected. The output string consists of status for each parameter followed by data in exponential form.

h. Two 4 wire test adapters are available; one for local connection of radial and coaxial leaded components, and the other for remote connection with Kelvin clips.

1-8. ACCESSORIES.

1-9. The following options are available for the instrument:

a. 5110-1 Test adapter for radial/coaxial lead components.

b. 5110-4 Kelvin clip test adapter with 1 m leads and guard for remote connection of components.

1-10. SPECIFICATIONS.

1-11. Performance specifications are listed in Table 1-1.

TABLE 1-1. Performance Specifications

Parameter	Specification
Measured parameters	Capacitance and D, Resistance, Inductance and D or Q
Test frequencies	100 Hz, 120 Hz, and 1 kHz ± 3%
Ranges:	
Capacitance	1 pF ~ 19.99 mF (8 ranges) at 100 Hz, 120 Hz 0.1 pF ~ 1999 µF (8 ranges) at 1 kHz
Inductance	1 µH ~ 1999 H (7 ranges) at 100 Hz, 120 Hz 0.1 µH ~ 199.9 H (7 ranges) at 1 kHz
Dissipation factor	D to 1.999 in one range Q to 199.9 in one range
Resistance	1 mΩ ~ 19.99 MΩ (8 ranges)
Test modes	Parallel, Series, and Auto or Manual
Test signal level	1 V or less than 50 mV
Test time	500 ms at range hold 500 ms per range change
Displays	LED type, 2 displays, 3½ digit LED annunciators for units, functions, circuit mode, frequency trigger, bias, test level range selection and GPIB
Test inputs	5 terminal configuration
Zero	Capacitance zero control with ± 5 pF range. No zero required for other parameters.
DC bias	External input at rear terminals max. 30 V DC
Dimensions	400 mm (W) x 100 mm (H) x 310 mm (D)
Weight	7.5 kg
Rear Panel	Rear panel slide switches control L D/Q, test level CP 1 V/50 mV, line frequency 50/60 Hz, trig/cont remote/local, ext. DC bias on/off
Accessories	
Test fixtures	
5110-1	Test adapter for radial/coaxial lead components
5110-4	Kelvin clip adapter with 1 m leads and guard for remote connection of components.
GPIB	IEEE-488 interface bus is standard. Implements SH1, AH1, T6, L4, SR1, RL1, DC1 and DT1.

TABLE 1-1. Performance Specifications (CONT.)

L-D/Q Measurement

Measuring Range		1	2	3	4	5	6	7
Measuring Frequency	100/120 Hz	1.999 mH	19.99 mH	199.9 mH	1.999 H	19.99 H	199.9 H	1.999 kH
	1 kHz	199.9 μH	1.999 mH	19.99 mH	199.9 mH	1.999 H	19.99 H	199.9 H
Measuring Signal		—			1 V			
		50 mA	10 mA	1 mA	100 μA	10 μA	—	
	AUTO	Same as				Same as		
Accuracy of L		—			±(0.3% + 2 count) × (1 + D)		±(0.8% + 2 count) × (1 + D)	
		±(0.8% + 2 count) × (1 + D)	±(0.3% + 2 count) × (1 + D)				—	
	AUTO	Same as				Same as		
Accuracy of D/Q		—			$\pm\left(0.5\% + (5 + \frac{Lx}{400})\ \text{count}\right)$		$\pm\left(1\% + (5 + \frac{Lx}{400})\ \text{count}\right)$	
		$\pm\left(0.5\% + (5 + \frac{1000}{Lx})\ \text{count}\right)$					—	
	AUTO	Same as				Same as		

C-D Measurement

Measuring Range		1	2	3	4	5	6	7	8
Measuring Frequency	100/120 Hz	1.999 nF	19.99 nF	199.9 nF	1.999 μF	19.99 μF	199.9 μF	1.999 mF	19.99 mF
	1 kHz	199.9 pF	1.999 nF	19.99 nF	199.9 nF	1.999 μF	19.99 μF	199.9 μF	1.999 mF
Measuring Signal		1 V or 50 mV (1 kHz only)					—		
		—			10 μA	100 μA	1 mA	10 mA	50 mA
	AUTO	Same as				Same as			
Accuracy of C		± (0.3% + 1 count) × (1 + D/2)					ϕ at 1 V		
		± (0.8% + 2 count) × (1 + D/2)	± (0.4% + 2 count) × (1 + D/2)				ϕ at 50 mV (1 kHz only)		
		—			± (0.3% + 2 count) × (1 + D/2)			± (0.5% + 3 count) × (1 + D)	± (0.8% + 3 count) × (1 + D)
	AUTO	Same as				Same as			
Accuracy of D		$\pm\left(0.3\% + (2 + \frac{1000}{Cx})\ \text{count}\right)$					ϕ at 1 V		
		$\pm\left(1\% + (10 + \frac{2000}{Cx})\ \text{count}\right)$	$\pm\left(1\% + (5 + \frac{1000}{Cx})\ \text{count}\right)$				ϕ at 50 mV (1 kHz only)		
		—			$\pm\left(0.5\% + (3 + \frac{Cx}{400})\ \text{count}\right)$				$\pm\left(1\% + (5 + \frac{Cx}{400})\ \text{count}\right)$
	AUTO	Same as				Same as			

R Measurement

Measuring Range		1	2	3	4	5	6	7	8
		1.999 Ω	19.99 Ω	199.9 Ω	1.999 kΩ	19.99 kΩ	199.9 kΩ	1.999 MΩ	19.99 MΩ
Measuring Signal		—				1 V			
		50 mA	10 mA	1 mA	100 μA	10 μA	—		
	AUTO	Same as					Same as		
Accuracy of R		—			± (0.3% + 2 count)				± (0.5% + 2 count)
		± (0.2% + 2 count)					—		
	AUTO	Same as				Same as			

Notes:

- The measuring signal level represents a typical value and varies with the value D, the number of counts, etc.
- % is in reference to an indicated value.
- Lx represents the number of counts of L.
- Cx represents the number of counts of C.
- Q = 1/D
- Accuracy is at 23°C ± 5°C.

SECTION II

INSTALLATION

2-1. INTRODUCTION.

2-2. This section contains the installation instructions for the Model 5110 LCR Meter and includes the unpacking, mounting, power requirements, cable connections, and preliminary checkout procedure.

2-3. INSTALLATION.

2-4. Unpacking. The instrument is shipped complete and is ready for use upon receipt. Unpack the instrument from it shipping container and inspect it for damage that may have occurred during shipment.

NOTE

Save the packing material and container for possible use for reshipment of the instrument.

2-5. Mounting. For bench mounting, choose a clean, sturdy, uncluttered mounting surface.

2-6. Power Requirements. The instrument has a tapped power transformer and a line voltage selector plug which permits operation from 100, 120, 220, and 240 volt ±10%. A frequency switch permits operation from either a 50 or 60 Hz, single phase AC power source. Power consumption is approximately 20 watts.

CAUTION

The line voltage selector plug must be set to the correct position most nearly corresponding to the voltage of the available AC power source and a fuse of correct rating must be installed in the fuse holder before connecting the instrument to any AC power source.

2-7. Set the rear panel line voltage selector plug to the appropriate position as indicated on the LINE VOLTAGE SELECT chart. Check that the line fuse, F1 is correct for the selected power source.

Nominal line Voltage	F1
100/120 V	1.0
220/240 V	0.5

2-8. Set the rear panel LINE FREQ switch to the power frequency to be used, either 50 Hz or 60 Hz.

2-9. Measuring Adapters and Test Leads.

a. 2 Terminal measuring method. This method is used when testing a specimen whose impedance is approximately 100 Ω ~ 10 kΩ. Refer to Figure 2-1.

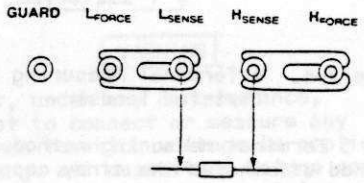

Figure 2-1. 2 Terminal Measuring Method

b. 3 Terminal measuring method. This method eliminates the effect of stray capacitance produced across test lead wires or a nearby conductor and is used to measure small capacitance values, high inductance values, and high resistance values. Refer to Figure 2-2.

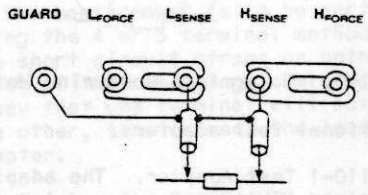

Figure 2-2. 3 Terminal Measuring Method

c. 4 Terminal measuring method. This method eliminates the resistance or residual inductance of lead wires under test or contact resistance with the specimen and is used to measure large capacitances values, low inductance values, and low resistance values. If the connecting cables are long, connect them in the following manner to eliminate measurement errors. Refer to Figure 2-3.

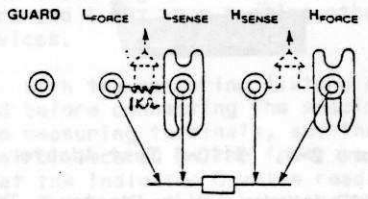

Figure 2-3. 4 Terminal Measuring Method

There is no resistance between H_{SENSE} and H_{FORCE} when the specimen is not connected; therefore, a stable reading may not be obtained. To obtain a stable reading, twist the 2 SENSE cables together and twist the 2 FORCE cables together then connect the test leads as shown. Refer to Figure 2-4.

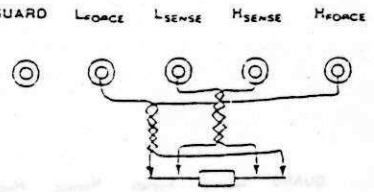

Figure 2-4. 4 Terminal Measuring Method (twisted leads)

d. 5 Terminal measuring method. This method eliminates the stray capacitance produced between test lead wires or with nearby conductors. This method also eliminates the resistance or residual inductance of test lead wires and can be used for all ranges. Refer to Figure 2-5.

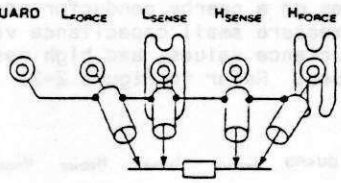

Figure 2-5. 5 Terminal Measuring Method

2-10. Optional test adapters.

a. 5110-1 Test Adapter. The adapter plugs into the instrument and is used to measure double or single lead configuration for small-sized 2 terminal tubular devices and is very convenient to use because it can be connected or disconnected in a short time. The adapter can be used for all ranges; but, should not be used for measuring micro capacitance or extremely small impedances. Refer to Figure 2-6.

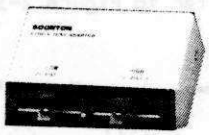

Figure 2-6. 5110-1 Test Adapter

b. 5110-4 Kelvin Clip Adapter. The adapter plugs into the instrument and is used to measure low resistance or low impedance and easily connects to short lead wires. Refer to Figure 2-7.

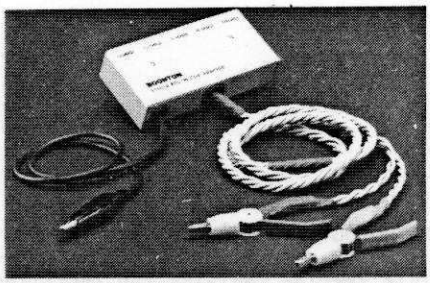

Figure 2-7. 5110-4 Kelvin Clip Adapter

2-11. Cable Connection. The only cable connection is the IEEE-488 bus connector which provides a means for connecting the standard IEEE-488 bus interface cable and is not supplied with the instrument.

2-12. PRELIMINARY CHECKOUT.

2-13. The preliminary checkout verifies that the instrument is operational and should be performed before the instrument is placed into use. Perform the preliminary checkout as follows:

a. Connect the power cord to the instrument and the desired power source. (Refer to paragraph 2-6 for proper power application.)

b. Set the TRIG/CONT switch to LOCAL.

c. Set the DC BIAS switch to OFF.

d. Set the LEVEL (C_p) switch to 1V.

e. Set the L switch to Q.

f. Securely tighten the short circuit straps found between the SENSE and FORCE terminals for the H to L sides open circuit.

g. Set the POWER ON/OFF switch to ON.

h. Both numerical displays should indicate 1888 and all the lamps should be illuminated.

i. After step h. has been performed. The instrument should automatically set the following conditions:

FUNCTION to C.

RANGE to AUTO.

CIRCUIT MODE to AUTO and PRL.

FREQUENCY to 1 kHz.

j. Decide whether the specimen is to be directly connected to the measuring terminals or the measuring adapter is to be used. If the measurement is to be performed by the 4 or 5 terminal method, tighten the short circuit straps on both H and L sides of the measuring terminals in such a way that one terminal will not touch the other. Then, connect the lead wire or adapter.

SECTION III

OPERATION

3-1. INTRODUCTION.

3-2. Section III contains the operating controls, indicators, and connectors description and functions, initial conditions, and operating instructions for the Model 5110.

3-3. OPERATING CONTROLS, INDICATORS, AND CONNECTORS.

3-4. The controls, indicators, and connectors used during operation of the instrument are listed in Table 3-1 and shown in Figures 3-1 and 3-2.

3-5. OPERATING INSTRUCTIONS.

3-6. The operating instructions for the Model 5110 are as follows:

a. Initial conditions.

b. Local operation.

c. IEEE-488 bus operation.

3-7. INITIAL CONDITIONS.

3-8. Set the initial conditions as follows:

a. Connect the power cord to the instrument and the desired power source. (Refer to paragraphs 2-6 and 2-7 for proper power application and fuse selection.)

b. Set the rear panel LINE FREQ switch to the frequency of the power to be used.

c. Set the TRIG/CONT switch to LOCAL.

d. Set the DC BIAS switch to OFF.

e. Set the LEVEL (CP) switch to 1V.

f. Set the L switch to Q.

g. Connect the short circuit straps between the ^{L}FORCE/^{L}SENSE and ^{H}FORCE/^{H}SENSE measuring terminals.

h. Set the POWER ON/OFF switch to ON.

i. Both displays should indicate 1888.

j. Verify that all the lamps illuminate.

k. The instrument will automatically be set to:

FUNCTION	C
RANGE	AUTO
CIRCUIT MODE	AUTO PRL
FREQUENCY	1 kHz

3-9. LOCAL OPERATION.

3-10. Capacitance Measurements. Capacitance measurements can be performed either automatically or manually.

WARNING

Do not, under any circumstance, attempt to connect or measure any specimen to which voltage is applied. Discharge all capacitors before connection, to prevent personal injury and damage to the instrument.

3-11. Automatic Capacitance Measurements. Perform the automatic capacitance measurement as follows:

a. Depress the C FUNCTION key. The C LED will illuminate and the instrument is ready to measure capacitance.

b. Decide whether the specimen is to be directly connected to the measuring terminals or if an adapter is to be used. If the measurement is to be performed using the 4 or 5 terminal method, tighten the short circuit straps on both H and L sides of the measuring terminals in such a way that one terminal will not touch the other, then connect the lead wire or adapter.

c. Depress the RANGE AUTO key to place the instrument in the automatic range mode.

d. Depress the CIRCUIT MODE AUTO key to place the instrument in the automatic circuit mode.

e. Set the FREQUENCY switch to 100 Hz, 120 Hz, or 1 kHz, depending on what test frequency is desired.

NOTE

Set the FREQUENCY switch to 120 Hz when measuring electrolytic capacitors and 1 kHz when testing other devices.

f. With the measuring fixture connected and before connecting the specimen to the measuring terminals, set the C ZERO control located on the front panel so that the indicated C value reads 00.0 pF. This adjustment compensates for the stray capacitance of the measuring fixture lead wire, etc.

g. After the specimen is connected the instrument will automatically select the optimum measuring range, circuit mode, and will display the capacitance value, dissipation factor (D), units, and measuring circuit mode.

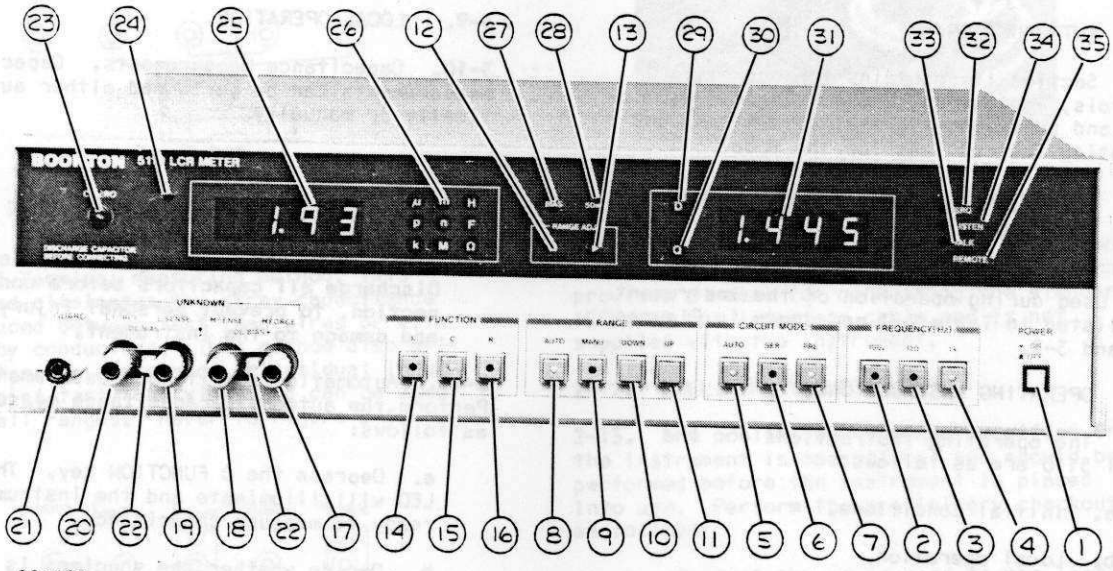

Figure 3-1. Model 5110, Front View

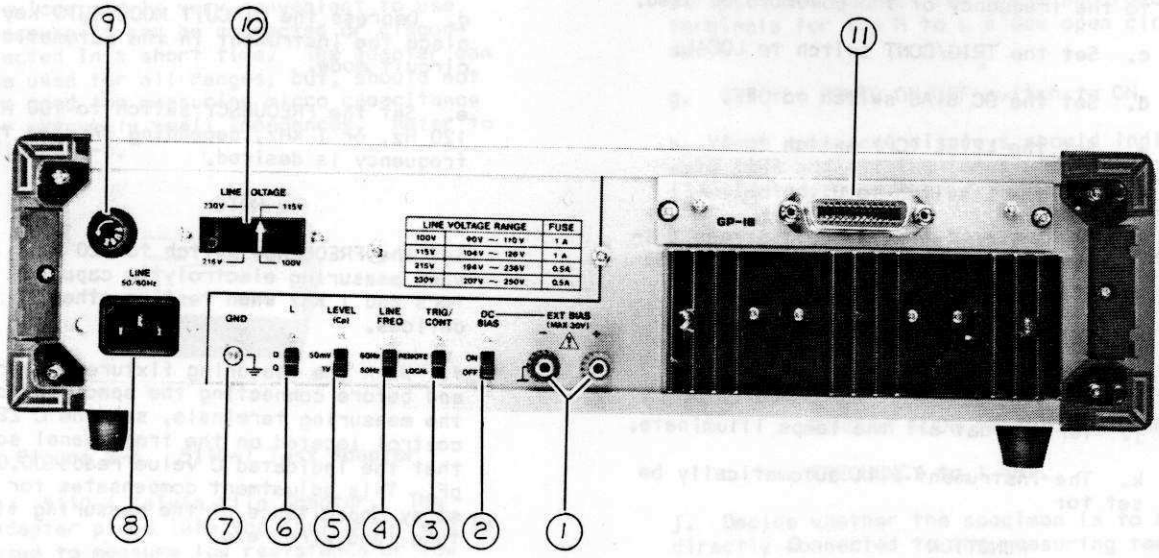

Figure 3-2. Model 5110, Rear View

TABLE 3-1. OPERATING CONTROLS, INDICATORS, AND CONNECTORS

Control, Indicator, or Connector.	Figure 3-1 Index No.	Function.
POWER switch	1	Switches the AC power ON and OFF.
FREQUENCY switches (measuring frequency)		Used to set the measuring frequency.
100 Hz	2	Selects 100 Hz measuring frequency.
120 Hz	3	Selects 120 Hz measuring frequency.
1 kHz	4	Selects 1 kHz measuring frequency.
CIRCUIT MODE switches (measuring circuit mode)		Used to select the measuring circuit mode at which the specimen is to be measured. Series equivalent circuit or parallel equivalent circuit.
AUTO switch	5	Selects the optimum mode, either SER or PRL.
SER switch	6	Selects series mode. The SER LED will flicker when the mode is not in conformity with the range.
PRL switch	7	Selects parallel mode. The PRL LED will flicker when the mode is not in conformity with the range.
RANGE switches		Selects the range at which the specimen is measured.
AUTO switch	8	Selects the automatic range selection mode whereby the optimum range is automatically selected. AUTO range switching action can be accomplished in the following manner: 2000 counts or more (up to 1999 in display) for range-up and 180 counts or less for range-down.
MANU switch	9	Selects the manual range selection mode whereby the measurement range is manually selected.
DOWN switch	10	Selects a lower measurement range.
UP switch	11	Selects a higher measurement range.
RANGE ADJ LEDs		Flickering LED indicates that the measurement range selected is too high or too low.
< Left hand LED	12	Flickering LED indicates that the measurement range selected is too high. Depress the DOWN switch.
> Right hand LED	13	Flickering LED indicates that the measurement range selected is too low. Depress the UP switch.

TABLE 3-1. OPERATING CONTROLS, INDICATORS, AND CONNECTORS (CONT.)

Control, Indicator, or Connector.	Figure 3-1 Index No.	Function.
FUNCTION Keys		Used to select either the L, C, or R function.
L Key	14	Selects the inductance function.
C Key	15	Selects the capacitance function.
R Key	16	Selects the resistance function.
MEASURING Terminals		Terminals used for connecting the specimen, (4).
H_{FORCE}	17	Connects the specimen to the signal impression HIGH side.
H_{SENSE}	18	Connects the specimen to the signal detection HIGH side.
L_{SENSE}	19	Connects the specimen to the signal detection LOW side.
L_{FORCE}	20	Connects the specimen to the signal impression LOW side.
GUARD Terminal	21	Provides a signal ground and is used to improve measuring accuracy, especially when testing a specimen of high impedance.
Short Circuit Straps	22	Used to establish a short between respective terminals on the HIGH side and LOW side.
C ZERO	23	Adjustment used to compensate for the stray capacitance in the lead wire, fixture, and across the measuring terminals when the specimen is not connected.
TRIGGER LED	24	When the LED is not flickering no measurement is being performed. Flickering LED indicates that a repeated measurement is being performed. When starting a measurement using an external trigger, the LED will flicker once for each measurement cycle.
L,C, or R Display	25	Used to display the measured values of inductance, capacitance, or resistance. Measured values will be displayed in decimal notation of $3\frac{1}{2}$ digits with numerals 000 ~ 1999 and a decimal point.

TABLE 3-1. OPERATING CONTROLS, INDICATORS, AND CONNECTORS (CONT.)

Control, Indicator, or Connector.	Figure 3-1 Index No.	Function.
FUNCTION LEDs	26	Indicates what parameter is being measured and what the multiplier is.
Ω		Indicates ohms.
F		Indicates Farads.
H		Indicates henrys.
P		Indicates pico.
n		Indicates nano.
μ		Indicates micro.
m		Indicates mili.
k		Indicates kilo.
M		Indicates mega.
BIAS LED	27	Indicates that the DC BIAS switch is set to ON and external bias will be applied.
50 mV LED	28	Indicates that the LEVEL (CP) switch located on the rear panel is set to 50 mV. The LED will go out if any mode other than the parallel capacity mode is selected.
D LED	29	Indicates that a dissipation factor is being measured and displayed.
Q LED	30	Indicates that a quality factor is being measured and displayed.
D or Q Display	31	Used to display the dissipation factor, D, or quality factor, Q. Measured values will be displayed in decimal notation of 3½ digits with numerals 000 ~ 1999 and a decimal point.
GPIB LEDs		
SRQ	32	Indicates service request enabled.
TALK	33	Indicates talker is addressed.
LISTEN	34	Indicates listener is addressed.
REMOTE	35	Indicates the IEEE-488 bus is active.

TABLE 3-1. OPERATING CONTROLS, INDICATORS, AND CONNECTORS (CONT.)

Control, Indicator, or Connector.	Figure 3-2 Index No.	Function.
EXT BIAS (MAX. 30V) terminals	1	Terminals used for inputting an external bias.
DC BIAS switch	2	Used to apply a DC bias to electrolytic capacitors.
TRIG/CONT switch	3	Selects either a triggered measurement for remote operation or continuous measurements for local operation.
LINE FREQ switch	4	Selects either 50 Hz or 60 Hz line frequency operation.
LEVEL (CP) switch	5	Selects either a 1 V or 50 mV level measuring signal to be applied to the specimen to be measured.
L switch	6	Selects either Q or D. When Q is selected while measuring inductance the Q factor will be displayed. When D is selected the D factor will be displayed.
GND terminal	7	Used as a ground connection for the LCR meter.
Power cord connector	8	Used to plug in the power cord.
Power fuse	9	Used to protect the instrument
LINE VOLTAGE switch	10	Used to select the proper operating line voltage.
GPIB connector	11	Provides a means for connecting the standard IEEE-488 bus interface cable.

3-11. (CONT.)

NOTE

If a specimen dissipation factor D reading exceeds 1.999, the value showing the dissipation factor will disappear.

3-12. Manual Capacitance Measurements. Perform the manual capacitance measurement as follows:

a. Depress the C FUNCTION key. The C LED will illuminate and the instrument is ready to measure capacitance.

b. Connect the specimen to the measuring terminals or adapter as applicable.

c. Depress the MANU key to place the instrument in the manual range mode.

d. Depress the CIRCUIT MODE AUTO key to place the instrument in the automatic circuit mode.

e. Set the FREQUENCY switch to 100 Hz, 120 Hz, or 1 kHz, depending on what test frequency is desired.

3-12. (CONT.)

f. Set the front panel C ZERO control so that the displayed C value reads 00.0 PF.

g. After the specimen is connected, observe the UP key LED and the DOWN key LED.

h. If neither the UP key LED nor the DOWN key LED is flickering, the instrument will display the capacitance value, dissipation factor (D), unit, and measuring circuit mode of the specimen.

NOTE

To accomplish one up range switching, depress the UP key once; when lowering the range, depress the DOWN key once. The optimum range will be selected at a state in which neither lamp flickers. When testing specimens of similar types continuously, depress the MANU key and fix the range to save measuring time. If the measured value exceeds the scale, 1.999, the display will disappear.

i. If the UP key LED is flickering depress the UP key to increase the range until the LED stops flickering, the instrument will display the capacitance value, dissipation factor (D), unit, and measuring circuit mode of the specimen.

j. If the DOWN key LED is flickering depress the DOWN key to decrease the range until the LED stops flickering, the instrument will display the capacitance value, dissipation factor (D), unit, and measuring circuit mode of the specimen.

3-13. Circuit Mode Manual SER or PRL dissipation (D) factor measurements.

NOTE

The instrument must be set for manual operation and the measuring range must be as specified in the Specification Table C-D Measurements.

a. Depress the SER or PRL key to select a series or parallel dissipation factors (D) measurement.

b. The LED of the mode selected will illuminate, the AUTO LED will go out, and the instrument will display the capacitance value, dissipation factor (D), unit, and measuring circuit mode of the specimen, if the instrument is set to the proper range.

c. If the measurement cannot be made the SER or PRL LED will flicker, depress the MODE key that is not flickering. If the instrument is set to the proper range, the instrument will display the capacitance value, dissipation factor (D), unit, and measuring circuit mode of the specimen.

d. If a measurement cannot be made and both MODE keys flicker when selected, the instrument is not set to the proper range; therefore, refer to the Specifications, Table C-D Measurements. Set the proper range and perform the measurement over.

3-14. Capacitance (Electrolytic) Measurements Utilizing External DC Bias. Perform the measurement as follows:

CAUTION

When applying a DC bias to a capacitor, use the external bias terminals and do not apply a voltage greater than 30 VDC. Connect the capacitor observing the proper polarity.

a. Connect the specimen to perform a 4-terminal measurement. To eliminate the effects of the measuring lead wires, use the shortest possible lead wires to connect the specimen to the instrument.

b. Set the DC BIAS switch to OFF.

c. Connect external power to the EXT BIAS (MAX 30V) terminals located on the rear panel.

d. Set the DC BIAS switch to ON.

e. Refer to paragraph 3-11 or 3-12 and perform the capacitance measurement.

3-15. Inductance Measurements. Inductance measurements can be performed either automatically or manually.

3-16. Automatic Inductance Measurements. Perform the automatic inductance measurements as follows:

a. Depress the L FUNCTION key. The L LED will illuminate and the instrument is ready to measure inductance.

b. Connect the specimen to the measuring terminals or adapter as applicable.

c. Depress the RANGE AUTO key to place the instrument in the automatic range mode.

d. Depress the CIRCUIT MODE AUTO key to place the instrument in the automatic circuit mode.

e. Set the FREQUENCY switch to 100 Hz, 120 Hz, or 1 kHz, depending on what test frequency is desired.

f. Set the L switch to Q for quality or D for dissipation of the specimen.

g. After the specimen is connected, the instrument will automatically select the optimum measuring range, circuit mode, and will display the inductance value, the Q or D value, unit, and measuring circuit mode.

NOTE

If D exceeds 1.999 or Q exceeds 199.9, the display will not indicate.

3-17. Manual Inductance Measurements. Perform the manual inductance measurements as follows:

a. Depress the L FUNCTION key. The L LED will illuminate and the instrument is ready to measure inductance.

b. Connect the specimen to the measuring terminals or adapter as applicable.

c. Depress the MANU key to place the instrument in the manual range mode.

d. Depress the CIRCUIT MODE AUTO key to place the instrument in the automatic circuit mode.

e. After the specimen is connected, observe the UP key LED and the DOWN key LED.

f. If neither the UP key LED nor the DOWN key LED is flickering, the instrument will display the inductance value, dissipation factor (D) or quality (Q), unit, and measuring circuit mode of the specimen.

g. If the UP key LED is flickering depress the UP key to increase the range until the LED stops flickering, the instrument will display the inductance value, dissipation factor (D) or quality (Q), unit, and measuring circuit mode of the specimen.

h. If the DOWN key LED is flickering depress the DOWN key to decrease the range until the LED stops flickering, the instrument will display the inductance value, dissipation factor (D) or quality (Q), unit, and measuring circuit mode of the specimen.

3-18. Circuit Mode Manual SER or PRL dissipation (D) or quality (Q) factor measurements.

a. Depress the SER or PRL key to select a series or parallel dissipation factors (D) or quality (Q) measurement.

b. The LED of the mode selected will illuminate, the AUTO LED will go out, and the instrument will display the inductance value, dissipation factor (D) or quality (Q), unit, and measuring circuit mode of the specimen, if the instrument is set to the proper range.

c. If the measurement cannot be made the SER or PRL LED will flicker, depress the MODE key that is not flickering. If the instrument is set to the proper range, the instrument will display the inductance value, dissipation factor (D) or quality (Q), unit and measuring circuit mode of the specimen.

d. If a measurement cannot be made and both MODE keys flicker when selected, the instrument is not set to the proper range, therefore, refer to the Specifications, Table C-D Measurements. Set the proper range and perform the measurement over.

3-19. Resistance Measurements. Resistance measurements can be performed either automatically or manually.

3-20. Automatic resistance measurements. Perform the automatic resistance measurements as follows:

a. Depress the R FUNCTION key. The R LED will illuminate and the instrument is ready to measure resistance.

b. Connect the specimen to the measuring terminals or adapter as applicable.

c. Depress the RANGE AUTO key to place the instrument in the automatic range mode.

d. Depress the CIRCUIT MODE AUTO key to place the instrument in the automatic circuit mode.

e. Set the FREQUENCY switch to 1 kHz.

f. After the specimen is connected, the instrument will automatically select the optimum measuring range, circuit mode, and will display the resistance value.

3-21. Manual Resistance Measurements. Perform the manual resistance measurement as follows:

a. Depress the R FUNCTION key. The R LED will illuminate and the instrument is ready to measure resistance.

b. Connect the specimen to the measuring terminals or adapter as applicable.

c. Depress the MANU key to place the instrument in the manual range mode.

d. Depress the CIRCUIT MODE AUTO key to place the instrument in the automatic circuit mode.

e. After the specimen is connected, observe the UP key LED and the DOWN key LED.

f. If neither the UP key LED nor the DOWN key LED is flickering, the instrument will display the resistance value.

g. If the UP key LED is flickering depress the UP key to increase the range until the LED stops flickering, the instrument will display the resistance value.

3-21. (CONT.)

h. If the DOWN key LED is flickering depress the DOWN key to decrease the range until the LED stops flickering, the instrument will display the resistance value.

3-22. Resistance/Inductance measurements. When the resistance of wire wound resistors is measured the inductance of the resistor must be considered, therefore; to properly measure the resistance perform the following procedure.

a. Perform the Automatic or Manual resistance measurement procedure and set the CIRCUIT MODE switch to SER.

3-23. Resistance/Capacitance measurements. When a high resistance is measured the presence of parallel capacitance must be considered, therefore; to properly measure the resistance perform the following procedure.

a. Perform the Automatic or Manual resistance measurement procedure and set the CIRCUIT MODE switch to PRL.

3-24. Series Equivalent Resistance (R_s) of a cored coil or transformer measurements. When the (R_s) of a cored coil or transformer is measured perform the following procedure.

a. Perform the Manual Inductance measurement procedure and set the CIRCUIT MODE to SER.

b. Depress the R FUNCTION key. The instrument will display the (R_s) of the cored coil or transformer.

3-25. IEEE-488 Bus Operation.

3-26. Interface Function. Refer to Table 3-2 for the GPIB Interface Functions.

3-27. IEEE-488 LED Indicators. The following four LED lamps are provided on the front panel to indicate the status of GPIB interface.

SRQ: Indicates that the SRQ (service request) signal is sent from the device to the GPIB bus line.

LISTEN: Indicates that the device is set to Listener.

TALK: Indicates that the device is set to Talker.

REMOTE: Indicates that the device is remote-controlled. The remote mode takes place when MLA is received with the GPIB bus line in the remote [REN.LLO] mode.

3-28. GPIB switch (address delimiter). The device employs a primary address method and is set to Delimiter [00] and Address [00101] at the time of shipment.

The Address Delimiter switch located on the GPIB interface board provides the means for setting the address and delimiter functions. Refer to Figures 3-3, 3-4 and Table 3-3.

3-29. Input-Output Format and Output Status Byte. The input format sent by the controller and the status byte and output format sent by the instrument are shown in Table 3-4.

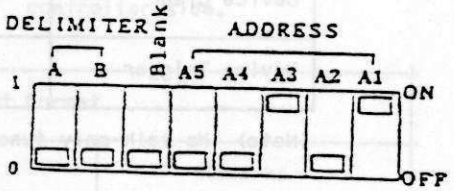

Figure 3-3. GPIB Switch (Address Delimiter)

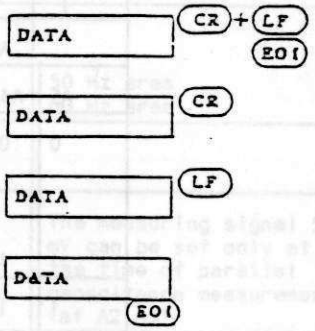

Figure 3-4. Address Delimiter Contents Chart

TABLE 3-2. Interface Functions

Name	Code	Function
Source Handshake	SH 1	Source handshake function
Acceptor Handshake	AH 1	Acceptor handshake function
Talker	T 6	Basic talker Serial poll Talker cancellation by MLA
Listener	L 4	Basic listener Listener cancellation by MTA
Service Request	SR 1	Sending of message in serial pole mode
Remote/Local	RL 1	Remote/Local changeover function (without local switch)
Device Clear	DC 1	Function for initializing the device
Device Trigger	DT 1	Function for trigger-controlling the device

(Note) No talk-only function is provided.

TABLE 3-3. Address Delimiter Functions

DELIMITER A	DELIMITER B	CONTENTS	OUTPUT CODE
0	0	CR+LF (EOI is output to LF)	CR+LF
0	1	CR Only	CR
1	0	LF Only	LF
1	1	EOI output to final byte of data	-

ADDRESS A5	A4	A3	A2	A1	10 decimal	NOTE
0	0	0	0	0	0 0	
				∫	∫	Arbitrary setting
1	1	1	1	0	3 0	
1	1	1	1	1	3 1	Prohibited to use

3-30. Input format. Measuring conditions are set by sending the following program codes.

```
(Example of input format)
PRINT @5; "F1 R0 M0 A2 B0 S1 E1"
    F1:  FUNCTION C
    R0:  AUTO RANGE
    M0:  AUTO MODE
    A2:  FREQUENCY 1kHz
    B0:  BIAS OFF
    S1:  SRQ ON
    E1:  GET START
```

3-31. Output status byte of service request. The service request function can be used by setting the program code to "S1" after turning the power ON. The device status byte is arranged as shown in Table 3-5.

3-32. Output format. The numerical data is output in an exponential form (fixed-point part + exponent part). The output format for Inductance and Capacitance measurements and Resistance measurements is shown in Table 3-6. Refer to Table 3-7 for a complete output format statement.

3-33. IEEE-488 Measurement Precautions.

a. Program precautions.

1. All switches found on the front panel and rear panel can be software-controlled by program codes.

2. The controller assigns the device to Listener and sends the program code of necessary setting conditions.

3. By setting "E1" in the program code, measurements can be started with a GET message.

4. The controller assigns the device to Talker and reads the data.

5. When making service request (SRQ) in serial poll, be sure to read the status byte corresponding to that request on the controller side.

TABLE 3-4. Input-Output Format

Functions	Program codes	Contents	Remarks
Measuring function	F 0 F 1 F 2	Inductance measurement Capacitance measurement Resistance measurement	L-D, L-Q C-D R
Measuring range	R 0 R 1 R 2 R 3 R 4 R 5 R 6 R 7 R 8	Auto range setting Range 1 Range 2 Range 3 Range 4 Range 5 Range 6 Range 7 Range 8	 There is no Range 8 for L measurement.
Measuring mode	M 0 M 1 M 2	Auto mode setting Series mode setting Parallel mode setting	AUTO SER PAR
Measuring frequency	A 0 A 1 A 2 A 3	100 Hz 120 Hz 1 kHz 1.02 kHz	 50 Hz area 60 Hz area
External bias ON/OFF	B 0 B 1	Bias OFF Bias ON	
Measuring signal voltage	L 0 L 1	50 mV rms 1.0 V rms	The measuring signal 50 mV can be set only at the time of parallel capacitance measurement. (at A2 A3)
Display of dissipation in inductance measurement	Q 0 Q 1	Display D Display Q	Display "D" (dissipation) in inductance measurement Display "Q" (quality of coil) in inductance measurement

TABLE 3-4. Input-Output Format (CONT.)			
Service request SRQ	S 0 S 1	Service request OFF Service request ON	
Measurement starting (trigger)	E 0 E 1	Internal trigger External trigger	Address command GET START

TABLE 3-5. Output Status Bytes

Bit	7	6	5	4	3	2	1	0
	0	RQS	0	0	0	COMMAND ERROR	PROGRAM ERROR	DATA READY
(DIO	8)	†(7)	(6)	(5)	(4)	†(3)	†(2)	†(1)

Set to 1 when service request occurs with the program code at S1, then the SRQ line is set to True.

Set to 1 when handshake error, unrecognized command, etc. occur.

Set to 1 when erroneous remote program code or numerical data is received.

Set to 1 when preparation of data to be sent is complete.

TABLE 3-6. L, C, and R Measurement Output Format

Inductance and Capacitance measurement:

4 letters	5 letters	4 letters	1 letter	2 letters	5 letters	
NCPC	DATA 1	E ± X X	,	ND	DATA 2	CRLF (EOI)
Data item	Fixed-point part	Exponent part	Marking off	Data item	Fixed-point part	Delimiter

Resistance measurement:

4 letters	5 letters	4 letters	
NRSC	DATA 1	E ± X X	CRLF (EOI)
Data item	Fixed-point part	Exponent part	Delimiter

TABLE 3-7. Output Format Statement

Example output format statement:

```
N C P C 1.999  E-06  , N D 1.999  CRLF
↑↑ ↑ ↑  ↑      ↑     ↑ ↑ ↑  ↑     ↑
1 2 3 4  5     6     7 8 9  10    11
```

No.	Output code	Contents
1 8	N O	Measurement data normal Over-range
2	L C R	Inductance measurement Capacitance measurement Resistance measurement
3	S P	Series mode measurement Parallel mode measurement
4	A B C D	100 Hz 120 Hz 1 kHz 1.02 kHz
5 10	5 10	LCR data D, Q data
6	E - 12 E - 09 E - 06 E - 03 E + 00 E + 03 E + 06	µH mH H kH PF nF µF mF Ω kΩ MΩ
7	,	Marking-off of data
9	D Q	Dissipation factor Quality of coil
11	Delimiter	Refer to delimiter output format

3-34. Example Programs.

The following are examples of IEEE-488 controller programs:

```
10  REM*****GP-IB TEST PROGRAM (1)*****
20  REM*****NEC-PC8001 N BASIC    *****
30  DEF USR0=&H6000
40  A=USR0(1)
50  ISET IFC                          'INTERFACE CLEAR
60  ISET REN                          'REMOTE ENABLE
70  CMD DELIM=0                       'DELIMITER ASSIGNMENT
80  CMD TIMEOUT=2                     'TIME-OUT PARAMETER
90  '
100 ON SRQ GOSUB 200                  'SRQ SUBROUTINE
110 FOR I=0 TO 500:NEXT I             'SETUP DELAY
120 PRINT @5;"F1R0M0A2B0L1Q1S1E1"     'DATA IS SENT AS ASC II CHARACTERS
130 A$="START"
140 WBYTE &H25,&H8;                   'GET START
150 IF A$<>"END" THEN 150
160 GOTO 130
170 '
200 POLL 5,B                          'SERIAL POLL
210 IF IEEE(4) <> &H41 THEN 300       'DEVICE STATUS
220 INPUT @5;C$,D$                    'DATA RECEPTION
230 PRINT C$,D$
240 A$="END"
250 SRQ ENABLE                        'SRQ RECEPTION IS PERMITTED
260 RETURN
270 '
300 PRINT "ERROR"                     'PROCESSING OF ERROR
310 END
```

```
10  ! ******** HPIB TEST PROGRAM(2) ********
20  !      HP-9000 SERIES 200 COMPUTERS
30  !           MODEL 216
40  ! ***************************************
50  !
60  ABORT 7                           ! INTERFACE CLEAR
70  REMOTE 7                          ! REMOTE ENABLE
80  OUTPUT 705;"F1R0M0A2B0L1Q1S0E1"   ! UNL+MLA+DATA
90  TRIGGER 705                       ! GROUP EXCUTE TRIGGER
100 ENTER 705;A$,B$                   ! UNT+MTA+STRING$
110 PRINT A$'B$                       ! DISP DATA LCR;DQ
120 GOTO 90
130 END
```