Contents

GR 1689 Precision RLC Digibridge®

Form 1689-0120-03

Symbol ⚠ IEC 417 on equipment signifies that the manual contains information to prevent injury or equipment damage. Refer to Page iii and to other manuals in set.

Bolton, Massachusetts, U.S.A. 01740
March, 1983

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Specifications

Displays

Measurement results may be displayed in four ways as selected by the keyboard:
VALUE, % difference, RLC difference, and BIN NO.

The VALUE display can be one of four pairs of measured quantities L and Q, C and D, C and R, or R and Q. The primary display (L, C, or R) has five digits of resolution and the secondary display (D, Q, or R with C) has four digits of resolution.

The % difference display indicates the percent deviation of the measured L, C, or R value from a stored NOMINAL VALUE. The sign of this deviation is indicated.

The RLC difference is similar to the % difference except that the deviation is displayed in appropriate units (ohms, henries, etc.).

The BIN NO. display is the number of the bin (0 through 14) into which the component should be sorted. The testing limits for these bins are set up by the user in the ENTER mode. These test limits may be symmetrical or non-symmetrical about the NOMINAL VALUE. One bin is used for D or Q rejects and one is used for RLC rejects (outside all limits). The sum of the number of components sorted into each bin may be displayed (99999 max).

Also displayed during entry or upon interrogation are: test frequency, test voltage, number of measurements averaged, delay time, nominal value, bin limits and bin sum and codes for SPECIAL FUNCTIONS.

GO/NO-GO lights are also provided and these are active with all modes of measurement display as long as test limits have been set.

Ranges

Primary Display:
C: .00001 pF to 99999 µF
R: .00001 Ω to 99999 kΩ
L: .00001 mH to 99999 H
% difference (C, R, or L): .0001% to 99999%
RLC difference: same as R, L, or C

If any of these quantities is negative, the NEG RLC indicator light is lit.

These ranges may be extended. See SPECIAL FUNCTIONS below.

Secondary Display:
D (with C) or Q (with L or R): .0001 to 9999
D (with C) or Q (with R) in ppm: 1 ppm to 9999 ppm
R (with C): .0001 Ω to 9999 kΩ

If any of these quantities is negative, the NEG QDR indicator is lit.

Equivalent Circuit

Either the equivalent SERIES or the equivalent PARALLEL circuit representation of L, R, or C may be selected by keyboard control.

Test Frequencies

Over five hundred test frequencies between 12 Hz and 100 kHz may be selected using the keyboard. These are:

$$f = \frac{200\text{ kHz}}{n} \quad \text{where } 2 \le n \le 13$$

$$f = \frac{60\text{ kHz}}{n} \quad \text{where } 4 \le n \le 256$$

$$f = \frac{3\text{ kHz}}{n} \quad \text{where } 13 \le n \le 250$$

If the exact frequency entered is not available, the nearest available frequency will be used. Frequency tolerance is .005%.

Measurement Time

The measurement rate is selected by the keyboard, trading speed for accuracy. The test time for a complete measurement with no range change is LESS THAN the expression in the "Specification" column of the table below, if the high-speed measurement option is used, the selected display is BIN NO., the measurement mode is CONTINUOUS, and there is no data output being sent via the IEEE-488 bus. The actual measurement times for many specific test frequencies are considerably less than this expression; refer to other columns of the table for typical values for commonly-used test frequencies.

Measurement Rate	Overall Test Time Specification	Typical Measurement Time, ms, for Test Freq: .012	0.100	0.120	1	10	100 kHz
SLOW	(965 + 14/f) ms	875	905	905	945	915	915 ms
MEDIUM	(205 + 10/f) ms	670	130	185	200	190	190 ms
FAST	(80 + 10/f) ms	655	125	110	80	75	70 ms
"Max"	(45 + 17/f) ms	645	110	100	40	34	33 ms

Where f is test frequency in kHz, and "Max" is FAST measurement rate with integration time factor set to 0.25 (a special function that is normally 1.0).

For other test conditions, modify the table as follows.

1. If the high-speed measurement option is NOT used, add 25 ms for "Max" or 35 ms for SLOW, MEDIUM, or FAST measurement rates.
2. If the selected display is VALUE or delta, add 6 to 10 ms.
3. If data output is enabled via the IEEE-488 bus, add 2 to 12 ms.
4. If the measurement mode is TRIGGERED, add the programmed delay, if any (it can be 0 to 99999 ms); otherwise add the default settling time as follows. for SLOW: (12/f)ms, for MEDIUM: (10/f)ms, for FAST: (7/f)ms.

Each range change requires no more than the time for one full measurement. Automatic range changing can be inhibited (to save this time) by use of the HOLD RANGE key.

To save time in handling the DUT, test connections can be broken (handler indexing can begin) after data acquisition is complete, as indicated (somewhat later) by the ACQ signal in the handler interface. For this useage, HOLD RANGE is appropriate. Then to determine approximately the time from start of measurement to the ACQ signal, subtract 32 ms from the table for SLOW, MEDIUM, or FAST; subtract 18 ms for "Max". The resulting numbers are additive with delay (item 4 above), but NOT with the other test conditions (items 1, 2, 3 above, which have no effect on data acquisition).

Measurement Modes

Two test modes are available: CONTINUOUS and TRIGGERED.

The CONTINUOUS mode makes successive measurements continuously, updating the display after each measurement.

TRIGGERED measurements are initiated by the START button, or remotely from the IEEE bus or from the Handler Interface, and the measurement result is displayed until the next measurement is started.

Average

The AVERAGE of any number of measurements from 1 to 255 may be made as desired in either of the two MEASURE MODES. In the TRIGGERED mode, the running average is displayed and the final value held until the START button is again depressed. In the CONTINUOUS mode, only the final value is displayed.

Test Voltage

The RMS test voltage is selectable from 5 mV to 1.275 V in 5 mV steps. (Accuracy: ±[5% + 2 mV + 0.2f mV]). This voltage may be applied behind a source impedance (which depends on the range) in which case the selected voltage is the maximum that will be applied and the voltage will be less at the low impedance end of each range. The voltage may be applied also behind 25 ohms using the CONSTANT VOLTAGE function in which case the applied voltage will be constant except when low impedances are measured.

Delay

A delay of from 1 to 99999 ms may be added to allow for settling of external switches and to permit a wider selection of measurement rates.

DC Bias

An internal bias of 2 V may be applied to capacitors under test by means of the INT BIAS key.

An external bias of up to 60 VDC may be applied to capacitors under test using a panel switch. The applied current should be limited to 200 mA.

The instrument is protected from damage from charged capacitors with a stored energy up to 1 joule at 60 volts or less. Protection from higher voltages may be provided by external components.

Zeroing

Open: A simple OPEN operation removes the effects of stray capacitance and conductance of the internal test fixture or any other test fixture or cable.

Short: A similar SHORT zeroing operation removes the effects of series resistance and inductance.

DUT Connections

The instrument has a built-in test fixture that will accept radial or axial components. Four terminal (Kelvin) connections are made to the device under test. The instrument ground is guard for three-terminal measurements.

Keyboard Lock

A combination of keyboard entries makes the keyboard inactive.

Special Functions

Several special features may be selected. These include:

- Direct range setting
- Range extension
- Choice of integration time
- Blanking of lesser digits
- Signal Reversal to reduce hum pickup effects
- Selection of the median value of three measurements
- A routine that reduces transient delays when bias is applied
- Automatic parameter selection

IEEE-488 Bus/Handler Interface Card (1658-9610)

IEEE-488 Bus (J2 on rear panel with option)

All front panel functions are programmable from the bus. All RLC, DQ, and bin data are available as output to the bus.

The following functions, per IEEE-488, have been implemented:

AH1 Acceptor Handshake (Listener).
SH1 Source Handshake (Talker).
T5 Talker with normal and talk-only modes (for systems without a controller), switch selectable on rear panel.
L4 Listener.
SR1 Service Request (to request service when measurement is complete and the instrument is not addressed to talk).
RL2 Remote/Local (no local lockout, no return-to-local switch).
PP0 No parallel poll.
DC0 No device clear.
DT1 Device Trigger (to start measurement).
C0 No controller functions.

Handler Connections (J1 rear panel with option)

1. Outputs, Active low: (Open collector drivers rated at 30 V max. Each will sink 16 mA at 0.4 V. External power and pull-up resistors required).

   Bin 0 through bin 9 (10 lines) — Sorting outputs.

   ACQ OVER (1 line) — indicates end of data acquisition. Component may be removed (see TEST TIME).

   EOT (1 line) — indicates end of test. Bin No. is valid.

2. Input, Active low:

   (0 V < V_ℓ < 0.4 V, +2.5 V < Vh < +5 V)

   Start (1 line) — Initiates new measurement.

High-Speed Measurement/Interface Option (1689-9610)

Same as above option but also with high-speed capability to increase measurement rate and five more sorting bins (15 lines, open collector drives rated at 15 V max. Each will sink 24 mA at 0.5 V). See **Measurement Time** specification, above.

Environment

Operating: 0° to 50°C, 0 to 85% relative humidity.

Storage: – 40° to 74°C.

When the high-speed option is used, the operating temperature range is 0° to 40°C.

Temperature Effects (typical)

R, L or C: ± 5 ppm/°C.
Q or D: ± [2 ppm/°C + (3 ppm/° C) × (frequency in kHz)]

All specifications refer to 23°C (calibration temperature).

Power

90 to 125 V or 180 to 250 V AC, 50 to 60 Hz.

Voltage selected by rear panel switch; 50 watts maximum, 40 watts typical. When the high-speed option is used, the maximum power is 60 watts.

Mechanical

DIMENSIONS (W × H × D): 14.781 × 4.40 × 13.50 in. (375.4 × 111.8 × 342.9 mm).
WEIGHT: 13 lbs. (5.9 kg).

Description	Catalog Number
1689 Precision RLC Digibridge®	1689–9700
1689 Precision RLC Digibridge® with IEEE/Handler Interface (1658–9610)	1689–9701
1689 Precision RLC Digibridge® with High-Speed Option and IEEE/Handler Interface (1689–9610)	1689–9702
IEEE/Handler Interface Option Retrofit	1658–9610
High-Speed Measurement and IEEE/Handler Option Retrofit	1689–9610

Limit of Error (Accuracy)

Primary Readout C, R, or L

C: $.01\% \left[(1+Kcv) \text{ or } \frac{Cx}{Cmax} \text{ or } \frac{Cmin}{Cx} \right] (1+|D|) \quad (1+Ks+Kfv) + .01\%$

R: $.01\% \left[(1+Kcv) \text{ or } \frac{Rx}{Rmax} \text{ or } \frac{Rmin}{Rx} \right] (1+|Q|) \quad (1+Ks+Kfv) + .01\%$

L: $.01\% \left[(1+Kcv) \text{ or } \frac{Lx}{Lmax} \text{ or } \frac{Lmin}{Lx} \right] (1+\frac{1}{|Q|}) \quad (1+Ks+Kfv) + .01\%$

NOTES:

1. The limit of error is a percent of the reading and may be positive or negative.
2. The largest term of the first bracketed factor should be used.
3. Cx, Rx, and Lx are the values of the components being tested, and Cmax, Cmin, Rmax, etc., are range constants given in Table I below.
4. The values of Ks, Kfv, and Kcv are all zero for measurements made at 1 kHz, with the SLOW measurement rate and using a non-CONSTANT 1 V signal.

   For other test conditions, these constants may be evaluated using Tables II through V below.
5. Although L measurements on the 1689 should be capable of the accuracy stated above, calibrations by the National Bureau of Standards are specified to .02% so that this amount should be added to the 1689 specification for inductance measurements if they are to be used in any manner involving legal certification.
6. The 1689 specifications are based on the assumption that proper OPEN and SHORT zeroing procedures have been done at the default test frequency, 1 kHz. More accurate measurements can be made (particularly measurements of high or low impedance, made with another test frequency). Refer to paragraph 3.6, Accuracy.

Secondary Readout R with C

R (with C); $D \geq 1$:

$$1 \text{ count} + .01\% \left[(1+Kcv) \text{ or } \frac{Rx}{Rmax} \text{ or } \frac{Rmin}{Rx} \right] (1+\frac{1}{|D|})(1+Ks+Kfv) + .01\%$$

R (with C); $D < 1$:

$$1 \text{ count} + .01\% \left[(1+Kcv) \text{ or } \frac{Cx}{Cmax} \text{ or } \frac{Cmin}{Cx} \right] (1+\frac{1}{|D|})(1+Ks+Kfv) + .01\%$$

This is a percent of reading specification plus (or minus) 1 count because of resolution. Otherwise, the notes for the primary readout apply.

Secondary Readout D and Q

D (with C):

$$.0001 \left[(1+Kcv) \text{ or } \frac{Cx}{Cmax} \text{ or } \frac{Cmin}{Cx} \right] (1+|D|+D^2) \quad (1+Ks+Kfv) + .0001$$

Q (with R):

$$.0001 \left[(1+Kcv) \text{ or } \frac{Rx}{Rmax} \text{ or } \frac{Rmin}{Rx} \right] (1+|Q|+Q^2) \quad (1+Ks+Kfv) + .0001$$

Q (with L):

$$.0001 \left[(1+Kcv) \text{ or } \frac{Lx}{Lmax} \text{ or } \frac{Lmin}{Lx} \right] (1+|Q|+Q^2) \quad (1+Ks+Kfv) + .0001$$

NOTES:

This is not a percent error but rather the amount, positive or negative, by which the D or Q reading may be in error. Otherwise, the notes for the primary readout apply.

When using DQ in PPM the final term of .0001 should be removed.

Table I
Range Constants

	AUTO RANGE	RANGE HELD			
		RANGE 1*	RANGE 2	RANGE 3	RANGE 4
Cmax	25 μF/f	6400 pF/f	100 nF/f	1600 nF/f	25 μF/f
Cmin	400 pF/f**	400 pF/f	6.4 nF/f	100 nF/f	1.6 μF/f
Rmax	410 KΩ	410 KΩ	25.6 KΩ	1.6 KΩ	100 Ω
Rmin	6.25 Ω	25.6 KΩ	1.6 KΩ	0.1 KΩ	6.25 Ω
Lmax	65 H/f**	65 H/f	4100 mH/f	256 mH/f	16 mH/f
Lmin	1 mH/f	4.1 H/f	256 mH/f	16 mH/f	1 mH/f

Where f = test frequency in kHz.
*This range is not used above 20 kHz.
**Above 20 kHz, Cmin = 6.4 nF/f and Lmax = 4100 mH/f.

Table II
Kcv as a Function of Voltage Mode (Constant Voltage)

Voltage Mode	Non-Constant	Constant Voltage
Kcv	0	3

Table III
Ks as a Function of Measurement Rate

Measurement Rate	Slow	Medium	Fast	Maximum*
Ks	0	3	10	23

*Integration-time factor set to minimum (a special function) and measurement rate FAST.

Table IV
Kfv as a Function of Frequency and RMS Voltage for Range 1

Frequency / Voltage	12 to < 30 Hz	30 to < 100 Hz	100 to < 250 Hz	250 to < 1000 Hz	1 kHz	> 1 to 3 kHz	> 3 to 6 kHz	> 6 to 10 kHz	> 10 to 20 kHz	> 20 to 50 kHz	> 50 to 100 kHz
1 to 1.275 V	7	3	2	1	0	2	6	15	50	This range is not used above 20 kHz	
.25 to < 1 V	9	5	3	2	1	3	10	20	65		
.1 to < .25 V	12	8	6	5	4	6	15	30	100		
.03 to < .1 V	35	30	25	20	15	17	25	60	*		
.01 to < .03 V	90	80	70	60	50	50	70	*	*		

*Accuracy not specified at asterisks nor below 10 mV.

Table V
Kfv as a Function of Frequency and RMS Voltage for Ranges 2, 3, and 4*

Frequency / Voltage	12 to < 30 Hz	30 to < 100 Hz	100 to < 250 Hz	250 to < 1000 Hz	1 kHz	> 1 to 3 kHz	> 3 to 6 kHz	> 6 to 10 kHz	> 10 to 20 kHz	> 20 to 50 kHz	> 50 to 100 kHz
1 to 1.275 V	7	3	2	1	0	1	2	3	5	15	30
.25 to < 1 V	9	5	3	2	1	2	3	5	6	18	35
.1 to < .25 V	12	8	6	5	4	5	6	8	10	22	40
.03 to < .1 V	35	30	25	20	14	15	15	15	20	30	50
.01 to < .03 V	90	80	70	60	50	50	50	50	60	70	90

*Accuracy not specified below 10 mV.

GenRad

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We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with GenRad's applicable published specifications. If within one(1) year after original shipment it is found not to meet this standard, it will be repaired or at the option of GenRad, replaced at no charge when returned to a GenRad service facility.

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Introduction — Section 1

1.1 PURPOSE.

The 1689 Precision RLC Digibridge® is a microprocessor-controlled automatic programmable RLC tester and limit comparator that embodies LSI circuitry to provide high accuracy, convenience, speed, and reliability at low cost. Internal bias is provided, and both test frequency and voltage are selectable. With the interface option, this Digibridge can control other equipment and respond to remote control.

The versatile built-in test fixture, lighted keyboard, and angled display panel make this Digibridge convenient to use. Measurement results are clearly shown with decimal points and units, which are automatically presented to assure correctness. Display resolution is 5 full digits for R, L, and C (4 for D, Q, Rs — ESR — with C, and Rp with C).

The basic accuracy is 0.02%. Long-term accuracy and reliability are assured by the measurement system, which makes these accurate analog measurements over many decades of impedance without any critical internal adjustments. Calibration to account for any change of test-fixture parameters is semiautomatic; the operator needs to provide only open-circuit and short-circuit conditions in the procedure. The Digibridge normally autoranges and automatically identifies the principal measurement parameter.

The built-in test fixture, with a pair of plug-in adaptors, receives any common component part (axial-lead or radial-lead), so easily that insertion of the device under test (DUT) is a one-hand operation. True 4-terminal connections are made automatically. Extender cables are available for measurements at a moderate distance from the instrument, typically for bulky components or parts in an automatic handler. Limit comparisons facilitate sorting into 13 GO and 2 NO-GO bins.

Programmable test conditions include:
- o Test frequencies from 12 Hz to 100 kHz
- o Test voltages from 5 mV to 1.275 V; bias (2 V)
- o Delay (before data aquisition) from zero to 99999 ms
- o Measurement speeds up to 30 per second (17/s without the high-speed option)
- o Remeasurement routines with averaging and/or median taking of 2 to 765 measurements
- o Displays: measured values, percentages, differences, ratios, GO/NO-GO, binning
- o Automatic output of value, bin number, bin summary & other results via IEEE-488 bus

Bias can be applied to capacitors being measured, either by programming the selection of an internal supply (2 V) or by sliding a switch to connect an external voltage source (up to 60 V).

A choice between two interface options provides full "talker/listener" and "talker only" capabilities consistent with the standard IEEE-488 bus. (Refer to the IEEE Standard 488-1978, Standard Digital Interface for Programmable Instrumentation. See para 2.8, in Section 2.) A separate connector also interfaces with component handling and sorting equipment.

1.2 GENERAL DESCRIPTION.

1.2.1 Basic Digibridge.

Convenience is enhanced by the arrangement of test fixture and controls on the front ledge, with all controls for manual operation arranged on a lighted keyboard. Above and behind them, the display panel is inclined and recessed to enhance visibility of digital readouts and indicators. These indicators and those at the keyboard serve to inform and guide the operator in manipulating the simple controls, or to indicate that remote control is in effect.

The instrument stands on a table or bench top. The sturdy metal cabinet is durably finished, in keeping with the long-life circuitry inside. Glass-epoxy circuit boards interconnect and support high-quality components to assure years of dependable performance.

Adaptability to any common ac power line is assured by the removable power cord and the convenient line-voltage switch. Safety is enhanced by the fused, isolating power transformer and the 3-wire connection.

1.2.2 Interface Options.

Either of the two interface options adds capabilities to the instrument, enabling it to control and respond to parts handling/sorting equipment. Also (via separate connector) either option can be connected in a measurement system using the IEEE-488 Bus. Either "talker/listener" or "talker only" roles can be performed by the Digibridge, by switch selection.

One of the interface options enables the Digibridge to measure at a higher speed than it does without an option. The high-speed option provides outputs to 15 bins for sorting; the other option, to 10 bins.

1.2.3 References.

Electrical and physical characteristcs are listed in Specifications at the front of this manual. Interface connections and instrument dimensions are given in Installation, Section 2. Controls are described below in Section 1; their use, in Operation, Section 3. A functional description is given in Theory, Section 4.

1.3 CONTROLS, INDICATORS, AND CONNECTORS.

Figure 1-1 shows the controls and indicators on the front of the instrument. Table 1-1 identifies them with descriptions and functions. Similarly, Figure 1-2 shows the controls and connectors on the rear; Table 1-2 identifies them.

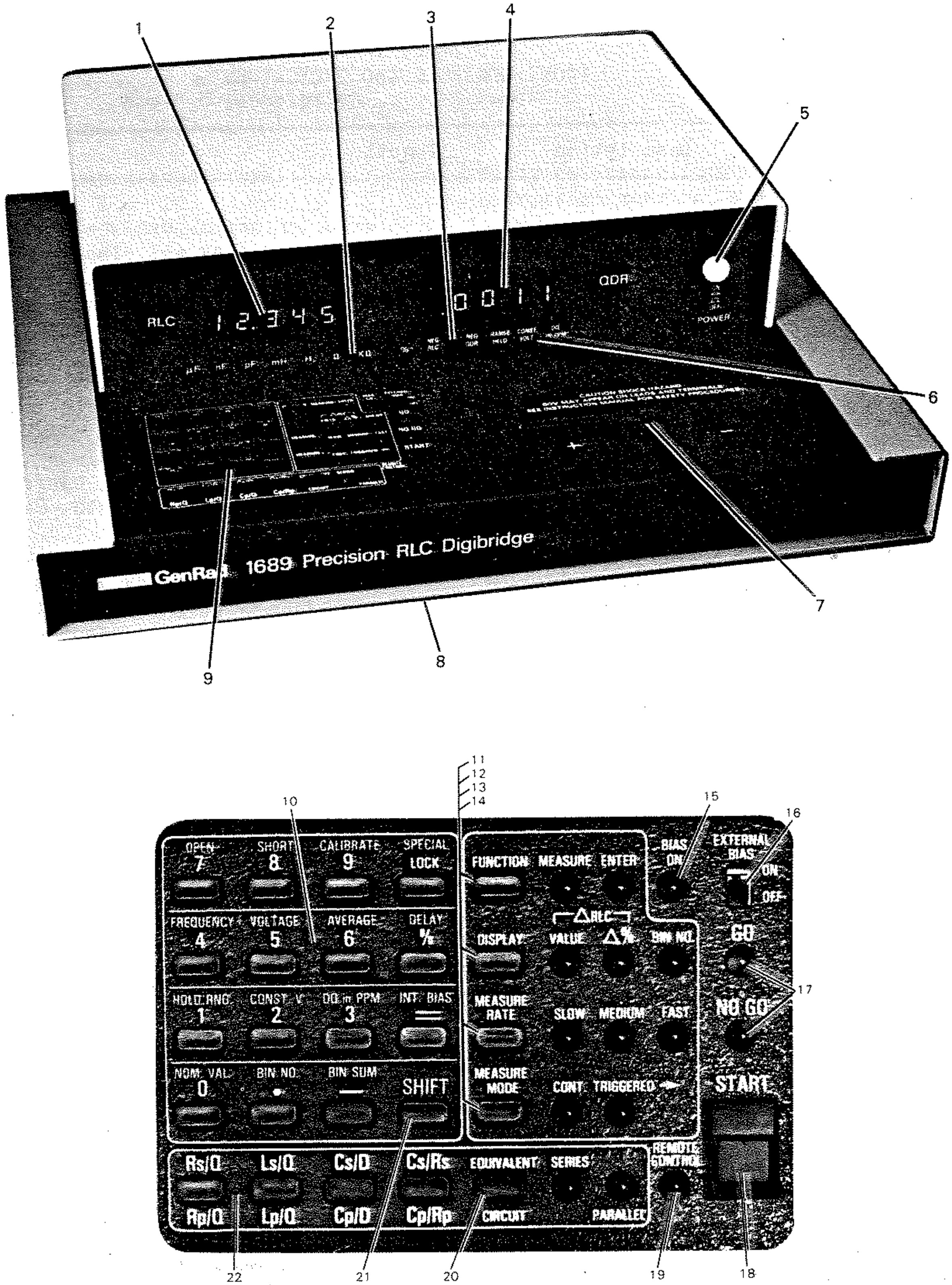

Figure 1-1. Front controls and displays. Upper illustration: Digibridge, overall. Lower illustration: keyboard detail.

Table 1-1
FRONT CONTROLS AND INDICATORS

Fig. 1-1 Ref No.	Name	Description	Function
1	RLC display	Digital display, 5 numerals with decimal points	Display of principal measured value. If function is MEASURE and display selection is VALUE, number indicates R, L, or C. If display selection is delta% or delta RLC, indicates percentage difference or value difference (respectively) of R, L, or C compared to stored nominal value. If display selection is BIN NO., indicates bin assignment of measured DUT. If function is ENTER, displays are indications of programmed entries, special functions, bin sum, status in calibration sequences, etc.
2	Units and multipliers	Light-spot (LED) indicators	Indicates measurement units associated with RLC display and secondary display if it is R. Indicates "%" if display selection is delta%. None of these indicators are lit if measurement display is "ratio".
3	"NEG" indicators	Light-spot (LED) indicators	NEG RLC and NEG QDR indicate negative signs associated with RLC and QDR displays. (For explanations see paragraph 3.3.)
4	QDR display	Digital display, 4 numerals with decimal points	If function is MEASURE, display of secondary measured value or (if display is BIN NO.) blank. If function is ENTER, RLC and QDR displays together indicate programmed entries, special functions, status in calibration sequences, etc.
5	POWER switch	Pushbutton (push again to release)	Switches the Digibridge ON (button in) and OFF (button out). OFF position breaks both sides of power circuit.
6	Other display-panel indicators	Light-spot (LED) indicators	RANGE HELD indicates that autoranging is disabled. CONST VOLT indicates that measurement source resistance is fixed at a low value. DQ in PPM indicates that the D or Q display is in parts per million.
7	Test fixture	Pair of special connectors; each makes dual contact with inserted wire	Receives radial-lead DUT, making 4-terminal connection automatically. Adaptors (supplied) make similar connection with axial-lead DUT. Extension cables (5-terminal) are available.

Table 1-1 (continued)
FRONT CONTROLS AND INDICATORS

Fig. 1-1 Ref No.	Name	Description	Function
8	Reference card	Captive pull-out card	Handy reference information for basic operation: zeroing, making measurements, programming test conditions, limit entry, and bin sorting.
9	Keyboard	Group of keys, indicators, and 2 other switches	Manual programming and control. Refer to items 10 through 22 for more detail.
10	Programming keys	Set of 16 keys, generally labeled with white and yellow	Multipurpose input of programming instructions, selections, and data. Dual purposes of keys are indicated by color: White labels apply normally. Yellow labels apply immediately after you press [SHIFT] key.
11 thru 14, 20, and 22 (See below.)		Each key has associated LED indicators	Make selection by pressing key repeatedly until the desired condition is indicated at right of the key.
11	[FUNCTION] key	Indicators MEASURE and ENTER.	Selection of function. MEASURE enables measurements and some routines that cannot be done in ENTER, such as "zero" calibrations, keyboard lock or unlock, and part of full recalibration. ENTER enables programming of all special functions, frequency, voltage averaging, delay, nominal value, and binning instructions. (Either function allows selection of hold range, constant voltage, DQ in ppm, internal bias, parameter, equivalent circuit, measure mode, measure rate, and display.)
12	[DISPLAY] key	Indicators: VALUE, delta%, BIN NO.	Selection of displays for MEASURE function; refer to items 1, 2, and 4 for description of displays. Two indicators are lit simultaneously for deltaRLC. This key has no effect on ENTER-function displays.
13	[MEASURE RATE] key	Indicators: SLOW, MED, FAST.	Selection of measurement speed as indicated. Speed is also affected by many other choices described in paragraph 3.5. Use SLOW for better accuracy; use FAST for speed.
14	[MEASURE MODE] key	Indicators: CONT, TRIGGERED	Mode selection: CONT, continuously repeating measurements; TRIGGERED, single measurement initiated by START button or input signal.

Table 1-1 (continued)
FRONT CONTROLS AND INDICATORS

Fig. 1-1 Ref No.	Name	Description	Function
15	BIAS ON indicator	LED indicator	Indicates that internal bias is on, or the EXTERNAL BIAS switch is ON.
16	EXTERNAL BIAS switch	Slide switch, 2 positions: ON, OFF	To connect and disconnect the external bias circuit (rear connector, cable supplied).
17	GO/NO-GO indicators	Pair of LED indicators	GO means measured value is acceptable, based on the limits previously stored. (See paragraph 3.8.) NO-GO means RLC or QDR value or both are unacceptable. Indicator remains lighted during next measurement.
18	START button	Pushbutton switch.	Starts measurement sequence (aborting any measurement that may be in process). Normally used in TRIGGERED measure mode.
19	REMOTE CONTROL indicator	LED indicator	Indicates when remote control is established by external command. (Functions only if an interface option is installed.)
20	EQUIVALENT CIRCUIT key	Indicators: SERIES and PARALLEL	Selection of equivalent circuit. Measured principal R, L, C and secondary R values (not D or Q) depend on this selection.
21	SHIFT key	Key labeled SHIFT	Pressing this shifts the role of any white/yellow labeled key from white to yellow.
22	Parameter keys	Set of 3 keys, labeled: R/Q, L/Q, C/D, and C/R, with subscripts s and p	Selection of principal measurement parameter — R, L, or C — and (for C only) secondary parameter D or R. Repeated pushing of any one parameter key changes range in sequence 1 2 3 4 1 ... and hence measurement units.

Table 1-2

REAR CONNECTORS AND CONTROLS

Fig. 1-2 Ref No.	Name	Description	Function
1	EXTERNAL BIAS connector	Connector, 2 pins, labeled 60 V max, 200 mA max, + - .	Receives cable (1658-2450, supplied) for external bias supply. Observe the voltage and current limits and polarity.
2	TALK switch*	Toggle switch.	Selection of mode for IEEE-488 interface: TALK/LISTEN or TALK ONLY, as labeled.
3	Air filter	Porous plastic sponge	To prevent dirt from entering inlet vent.
4	Power connector labeled 90-125 V, 180-250 V, 50-60 Hz, etc.	Shrouded 3-wire plug, conforming to International Electrotechnical Commission 320.	Ac power input. Use appropriate power cord, with Belden SPH-386 socket or equivalent. The GenRad 4200-0300 power cord (supplied) is rated for 125 V.
5	Fuse (labeled 250 V, 1/2 A, SLOW BLOW)	Fuse in extraction post holder	Short circuit protection. Use Bussman type MDL or equivalent fuse, 1/2 A, 250 V rating.
6	Line-voltage switch	Slide switch. Upper position: 90 to 125 V; lower position, 180 to 250 V.	Adapts power supply to line-voltage ranges, as indicated. To operate, use small screw-driver, not any sharp object.
7	Vent	Air passage	Ventilation
8	HANDLER INTERFACE connector*	Socket, 24-pin; receives Amphenol "Microribbon" plug P/N 57-30240 (or equiv).	Connections to component handler (outputs are bin numbers and status; input is a "start" signal).
9	Vent	Air passage	Ventilation
10	IEEE-488 INTERFACE connector*	Socket, 24-pin. Receives IEEE-488 interface cable. (See para 2.8).	Input/output connections according to IEEE Std 488-1978. Functions: complete remote control. Output of selected results, with or without controller.

* TALK switch and 24-pin connectors are supplied with the interface option only.

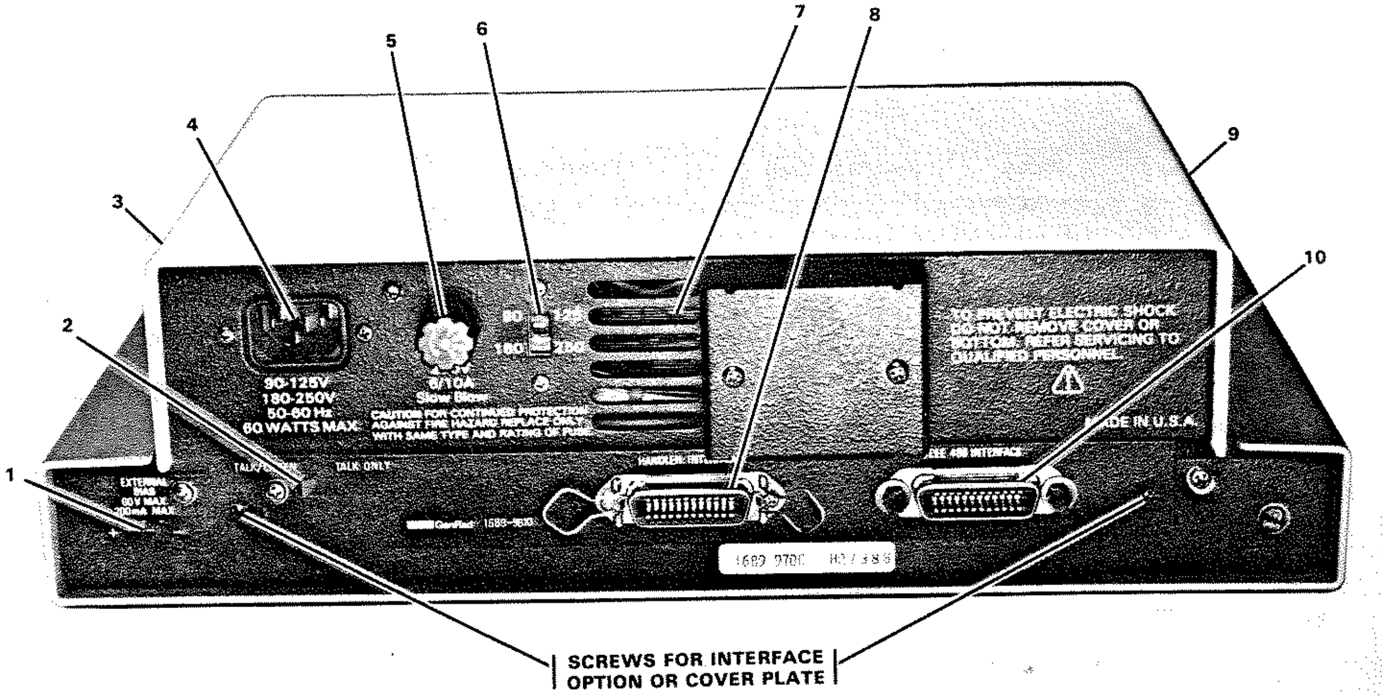

Figure 1-2. Rear controls and connectors.

1.4 ACCESSORIES.

GenRad makes several accessories that enhance the usefulness of this Digibridge. The axial-lead adaptors (provided) convert the built-in test fixture to a configuration well suited for axial-lead components. A choice of extender cables facilitates making connection to a parts handler or to any DUT that does not readily fit the built-in test fixture. Extender cables are available with your choice of banana plugs, BNC, or type 874 connectors. Each cable branches into 4 parts, for true 4-terminal connections (and guard) to the device being measured, without appreciable reduction in measurement accuracy. A remote test fixture is available to receive hand-inserted components at a distance from the Digibridge.

Other useful accessories are offered. Refer to Table 1-3 and inquire at the nearest Digibridge Technical Support Center. (Refer to the back of this manual.)

Table 1-3

ACCESSORIES AND OPTIONS

Quantity	Description	Part Number
1 supplied	Power cord, 200 cm (6.5 ft) long, 3-wire, AWG No. 18, with molded connector bodies. One end, with Belden SPH-386 socket, fits instrument. Other end conforms to ANSI standard C73.11-1966 (125 V max).	4200-0300
2 supplied	Test-fixture adaptors, for axial-lead parts. Replacements available: set of 4 adaptors	1657-5995
1 supplied	Bias cable, with built-in fuse, to connect external bias supply and switching circuit.	1658-2450
1 recommended	High-speed measurement and IEEE-488/handler interface option retrofit (plug-in).	1689-9610
1 recommended	IEEE-488/handler interface option retrofit (plug-in).	1658-9610
1 recommended	Extender cable for connection to parts handler, large or remote DUT, custom test fixture, etc. Length 100 cm (40 in.). One end fits test fixture of Digibridge; other end terminates in 5 stackable banana plugs.	1657-9600
1 recommended	Test-fixture adaptor, for BNC cable.	1689-9601
1 recommended	BNC cable assembly, 4 color coded cables with known "stray" parameters, 90 cm (36 in.) long.	1689-9602
1 recommended	Remote test fixture for radial-lead DUTs (like the fixture on the Digibridge), with BNC connectors.	1689-9600
1 available	Extender cable for connection to parts handler, large or remote DUT, custom test fixture, dielectric measurement cell, etc. Length 30 cm (12 in.). One end fits test fixture of Digibridge other end terminates in four type 874 coaxial connectors.	1688-9600
1 available	Rack mount kit (slides forward for complete access).	1657-9000
1 replacement	Battery (Note: shelf life, 10 years; life in instrument is 5 to 10 years. Refer to para 3.12.)	8410-3480*

*Use the following battery if available: Panasonic part number BR-2/3A-F1 (Matsushita Electric Corp. of America, 1 Panasonic Way, Secaucus, N.J. 07094).

Condensed Operating Instructions for GenRad 1689 Digibridge

1 GENERAL INFORMATION

The 1689 Precision RLC Digibridge® is a microprocessor-controlled, automatic RLC meter. It measures impedance of the device under test (DUT) and displays its parameters: *R, L or C* and *D, Q or R.* A front-panel keyboard is used to select and program measurement and test conditions. The test signal is programmable from 5 mV to 1.26 V and from 12 Hz to 100 kHz. (Default conditions are 1 V, 1 kHz.) Capacitors under test can be biased with 2 V (internal d.c.) or up to 60 V (external source). Consult the instruction manual for details about operation, accuracy, specifications, and service.

2 START-UP

a. Set line-voltage switch (rear panel) to power-line voltage.

b. If the Digibridge includes an optional IEEE-488 interface, set TALK switch (rear panel) to TALK ONLY (unless instructions are to be received through the IEEE-488 bus).

c. Switch EXTERNAL BIAS OFF (front panel).

d. Connect power cord to source of proper voltage.

e. Press POWER button "in". Self-check codes will show briefly.

f. Wait until keyboard lights indicate MEASURE, VALUE, SLOW, SERIES. If a fault is detected, measurements are blocked and an error code remains displayed. (See manual, paragraph 3.13.) If keyboard lights remain dark, keyboard is locked. To unlock it, see manual, paragraph 3.9. To switch power off, press POWER button and release.

3 ZEROING

Before measurement, zero the Digibridge as follows:

a. *Open Circuit.* The MEASURE keyboard light should be lit. Press [MEASURE MODE] key to select TRIGGERED mode. If any test-fixture adaptors are to be used, install and position them for use. Be sure that test fixture is open circuited. Press keys: **[Cs/D] [1] [6] [8] [9] [=] [SHIFT] [OPEN].** Keep hands and objects at least 10 cm (4 in.) from test fixture. Press **START** button. Wait for GO light.

b. *Short Circuit.* Short the fixture with a clean copper wire (AWG 18 to 30). Press **[1] [6] [8] [9] [=] [SHIFT] [SHORT].** Press **START** button. Wait for GO light.

Note: For best accuracy, repeat this procedure every day and after any change of test-fixture adaptors.

4 MEASUREMENT

a. Verify or select measurement conditions as follows (indicated by keyboard lights); press the adjacent key to change a selection.

- Function: MEASURE (**[FUNCTION]** key)
- Display: VALUE (**[DISPLAY]** key)
- Measure rate: SLOW (**[MEASURE RATE]** key)
- Measure mode: TRIGGERED (**[MEASURE MODE]** key)
- Equivalent circuit: SERIES (**[EQUIVALENT CIRCUIT]** key)

b. To measure *C and D of a Capacitor* (C Range .0001 pF to 99999 μF, D range .0001 to 9999): Press **[Cs/D].** Place capacitor in test fixture. Press **START.** The RLC display shows Cs (series capacitance) and units (μF, nF, pF); the QDR display shows D (dissipation factor). (If "NEG RLC" is lit, DUT is inductive.)

c. To measure *C and R of a Capacitor* (C Range .00001 nF to 99999 μF, R range .0001 Ω to 9999 kΩ): Press **[Cs/Rs].** Place capacitor in test fixture. Press **START.** The RLC display shows Cs (series capacitance) and units (μF, nF); the QDR display shows Rs (equivalent series resistance) and units (Ω, kΩ). (If "NEG RLC" is lit, DUT is inductive.)

d. To measure *L and Q of an Inductor* (L range .00001 mH to 99999 H, Q range .0001 to 9999): Press **[Ls/Q].** Place inductor in test fixture. Press **START.** The RLC display shows Ls (series inductance) and units (mH, H); the QDR display shows Q (quality factor). (If "NEG RLC" is lit, DUT is capacitive.)

e. To measure *R and Q of a Resistor* (R range .00001 Ω to 99999 kΩ, Q range .0001 to 9999): Press **[Rs/Q].** Place resistor in test fixture. Press **START.** The RLC display shows Rs (series resistance) and units (Ω, kΩ); the QDR display shows Q (quality factor). (If "NEG QDR" is lit, DUT is capacitive; if dark, DUT is inductive.)

f. Special Displays. When a nominal value and bin limits have been programmed (see Limit Entry below), these displays can be selected with the **[DISPLAY]** key: "Δ%" shows the difference of measured RLC from nominal in percent of nominal value. "VALUE and Δ%", both lit, shows the difference from nominal in measurement units (μF, mH, etc). "BIN NO" shows the assigned bin number.

g. Other Parameters, Rates, Modes. To measure Cp/Rp, Cp/D, Lp/Q or Rp/Q, press **[EQUIVALENT CIRCUIT]** to select PARALLEL. To measure faster, press **[MEASURE RATE]** to select MEDIUM or FAST. To measure continuously, press **[MEASURE MODE]** to select CONT.

5 PROGRAMMABLE TEST CONDITIONS

(Accessible via ENTER function.)

a. Press **[FUNCTION]** key to select ENTER function.

b. Test frequency (normally 1 kHz) can be programmed from .012 kHz to 100 kHz. For 400 Hz, press **[.] [4] [=] [SHIFT] [FREQUENCY].**

c. Test voltage (normally 1 V) can be programmed from .005 V to 1.26 V. For 15 mV, press **[.] [0] [1] [5] [=] [SHIFT] [VOLTAGE].**

d. Averaging. Results can be averages of 2 to 255 measurements. To program averaging of 25 measurements, press **[2] [5] [=] [SHIFT] [AVERAGE].** To cancel averaging, press **[1] [=] [SHIFT] [AVERAGE].**

e. Delay. A delay of 1 to 99999 ms can be added to normal test time. For 238 ms, press **[2] [3] [8] [=] [SHIFT] [DELAY].**

Note: For steps b...e, to see present conditions, press **[SHIFT] [FREQUENCY], [SHIFT] [VOLTAGE], [SHIFT] [AVERAGE], [SHIFT] [DELAY].**

f. For internal 2-volt dc bias for capacitors, press **[SHIFT] [INT BIAS].** To remove internal bias, repeat **[SHIFT] [INT BIAS].**

g. For D and Q displayed in parts per million, press **[SHIFT] [DQ in PPM].** For decimal D Q displays, repeat **[SHIFT] [DQ in PPM].**

h. To hold test voltage constant, press **[SHIFT] [CONST V].** To cancel this selection, repeat **[SHIFT] [CONST V].**

i. To hold a range: Measure a DUT in the range desired; or press one of the parameter keys (**[Rs/Q] [Ls/Q] [Cs/D] [Cs/Rs]**) repeatedly to step through the four ranges. When the desired range is indicated (by RLC unit indicator), press **[SHIFT] [HOLD RNG].** To enable autoranging, repeat **[SHIFT] [HOLD RNG].**

Note: For steps f...i, conditions are indicated by lights.

6 LIMIT ENTRY, GO/NO-GO TESTING, AND SORTING INTO BINS

a. Press **[DISPLAY]** key to select VALUE.
Press **[FUNCTION]** key to select ENTER.

b. To enter a single QDR limit (always bin 0): press parameter key (such as [Cs/D]) appropriate to DUT. To change range and unit multipliers, press same key repeatedly. Enter max limit of D or Rs or Q with R; enter min limit of Rp or Q with L, as follows. (Keyed numbers appear on left-hand display). Example, for Q limit of 85, press **[8] [5] [=] [SHIFT] [BIN NO] [0] [0].** Value now moves to right-hand display, confirming storage of limit.

Note: if you make a mistake, press parameter key again and repeat the entry.

c. To enter RLC limits for bins 1-13, three methods are given:

- *Symmetrical percentage tolerances* (nested bins). Enter nominal value of DUTs to be sorted. (The value appears on the RLC display. Units were selected in step b.) Example, for nominal value 123.40, press **[1] [2] [3] [.] [4] [=] [SHIFT] [NOM VAL].** Enter for bin 1 the narrowest percent tolerance to be sorted. Example, for a tolerance of ±0.2%: press **[.] [2] [%] [=] [SHIFT] [BIN NO] [0] [1].** The numerical limits for RLC are computed and rounded-off values displayed (upper limit at left, lower at right). For bin 2, enter the next wider tolerance, similarly; then bins 3, 4, 5,... (always 2 digits for bin no.).
- *Various nominal values* (bucket sort). Plan for non-overlapping bins, each with a nominal value and limits defined by percent tolerance. For bin 1, enter nominal value and tolerance as described above. For each successive bin, similarly enter a new nominal value, then the tolerance and bin number. (Changing the nominal value does not affect limits already stored. Any DUT that qualifies for 2 overlapping bins is assigned to the lower bin.)
- *Unsymmetrical tolerances.* To enter unsymmetrical limits, for example +2% −5% in bin 6: press **[2] [%] [−] [5] [%] [=] [SHIFT] [BIN NO] [0] [6].** Two percentages of the same sign can be entered. Always enter the more positive tolerance first.

d. You can close any bin that has been opened (steps b, c). For RLC bins, follow this example for bin 8: press **[0] [=] [SHIFT] [BIN NO] [0] [8].** To disable QDR sorting, close bin 0 thus: for D or Rs or Q with R, press **[9] [9] [9] [9] [=] [SHIFT] [BIN NO] [0] [0]**; for Rp or Q with L, press **[0] [=] [SHIFT] [BIN NO] [0] [0].**

e. To enable GO/NO-GO lights after opening at least one bin, leave "nominal value" at any non-zero value. To disable GO/NO-GO and all bin sorting, press **[0] [=] [SHIFT] [NOM VAL].**

Note: To see present numerical limits for bin 3 and nominal value, press **[SHIFT] [BIN NO] [0] [3],** and **[SHIFT] [NOM VAL].**

f. To measure DUT with bin sorting: Press **[FUNCTION]** to select MEASURE, and **[DISPLAY]** to select BIN NO. Insert DUT. Press **START.** Observe GO/NO-GO and bin-number results. NO-GO indicates either QRD failure (bin 0) or RLC failure (bin 14). See manual, paragraph 3.8.

2.1 UNPACKING AND INSPECTION

If the shipping carton is damaged, ask that the carrier's agent be present when the instrument is unpacked. Inspect the instrument for damage (scratches, dents, broken parts, etc.). If the instrument is damaged or fails to meet specifications, notify the carrier and the nearest GenRad field office. (See list at back of this manual.) Retain the shipping carton and the padding material for the carrier's inspection.

2.2 DIMENSIONS

Figure 2-1.

The instrument is supplied in a bench configuration, i.e., in a cabinet with resilient feet for placement on a table. The overall dimensions are given in the figure.

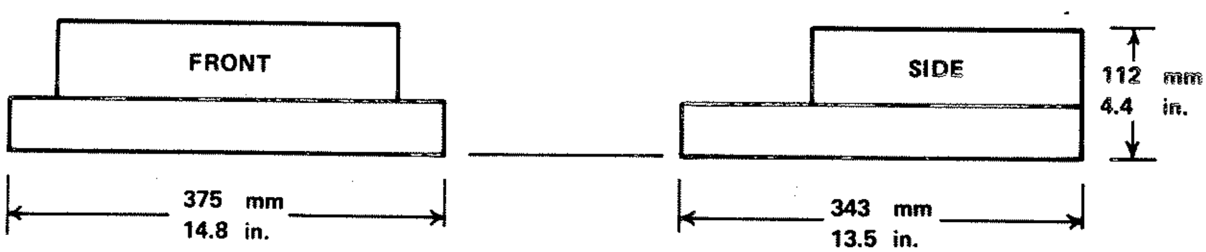

Figure 2-1. Overall dimensions.

2.3 POWER-LINE CONNECTION

Figure 2-2.

The power transformer primary windings can be switched, by means of the line voltage switch on the rear panel, to accommodate ac line voltages in either of 2 ranges, as labeled, at a frequency of 50 or 60 Hz, nominal. Making sure that the power cord is disconnected, use a small screwdriver to set this switch to match the measured voltage of your power line.

If your line voltage is in the lower range, connect the 3-wire power cable (P/N 4200-0300) to the power connector on the rear panel (Figure 1-2) and then to the power line.

The instrument is fitted with a power connector that is in conformance with the International Electrotechnical Commission publication 320. The 3 flat contacts are surrounded by a cylindrical plastic shroud that reduces the possibility of electrical shock whenever the power cord is being unplugged from the instrument. In addition, the center ground pin is longer, which means that it mates first and disconnects last, for user protection. This panel connector is a standard 3-pin grounding-type receptacle, the design of which has been accepted world wide for electronic instrumentation. The connector is rated for 250 V at 6 A. The receptacle accepts power cords fitted with the Belden type SPH-386 connector.

The associated power cord for use with that receptacle, for line voltages up to 125 V, is GenRad part no. 4200-0300. It is a 200-cm (6.5 ft), 3-wire, 18-gage cable with connector bodies molded integrally with the jacket. The connector at the power-line end conforms to the "Standard for Grounding Type Attachment Plug Caps and Receptacles", ANSI C73.11-1966, which specifies limits of 125 V and 15 A. This power cord is listed by Underwriters Laboratories, Inc., for 125 V, 10 A.

If your power line voltage is in the higher range (up to 250 V), be sure to use a power cord that is approved for 250 V. The end that connects to the Digibridge® should have a connector of the type that is on the power cord supplied; the other end, an approved connector to mate with your standard receptacle. A typical configuration for a 250-V, 15-A plug is illustrated in the accompanying figure.

If the fuse must be replaced, be sure to use a "slow blow" fuse of the current and voltage ratings shown on the rear panel, regardless of the line voltage.

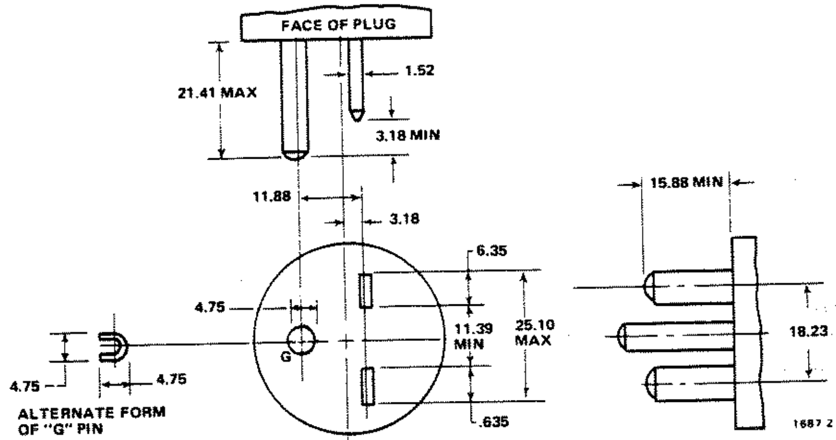

Figure 2-2. Configuration of 250-V 15-A plug. Dimensions in mm. This is listed as NEMA 6-15P. Use for example Hubbell plug number 5666.

2.4 LINE-VOLTAGE REGULATION

The accuracy of measurements accomplished with precision electronic test equipment operated from ac line sources can often be seriously degraded by fluctuations in primary input power. Line-voltage variations of +/-15% are commonly encountered, even in laboratory environments. Although most modern electronic instruments incorporate some degree of regulation, possible power-source problems should be considered for every instrumentation setup. The use of line-voltage regulators between power lines and the test equipment is recommended as the only sure way to rule out the effects on measurement data of variations in line voltage.

2.5 TEST-FIXTURE CONNECTIONS

Because an unusually versatile test fixture is provided on the front shelf of the instrument, external test-fixture connections are generally NOT required. Simply plug the device to be measured (DUT) into the test fixture, with or without its adaptors. For details, refer to para 3.2.

Accessory extender cables are available to connect to a DUT that is multiterminal, physically large, or otherwise unsuited for the built-in test fixture. Extender cables are needed, similarly, to connect from the Digibridge test fixture to the DUT socket in a mechanical parts handler. Cables and adaptors are listed in Table 1-3. Connection details are given in paragraph 3.2.

2.6 BIAS VOLTAGE FOR THE DUT

2.6.1 Internal Bias

No external connections are required for the internal 2-volt bias. The circuit is self contained.

2.6.2 External Bias

External bias can be provided by connecting a suitable current-limited, floating dc voltage source, as follows.

- o Be sure that the voltage is never more than 60 V, max.
- o A current limiting voltage supply is recommended; set the limit at 200 mA, max.
- o Be sure that the bias supply is floating; DO NOT connect either lead to ground.
- o A well-filtered supply is recommended. Bias-supply hum can affect some measurements, particularly if test frequency is the power frequency.
- o Generally the external circuit must include switching for both application of bias after each DUT is in the test fixture and discharge before it is removed.
- o Connect the external bias voltage supply and switching circuit, using the 1658-2450 cable, supplied, via the rear-panel EXTERNAL BIAS connector. Observe polarity marking on the rear panel; connect the supply accordingly.

2.7 HANDLER INTERFACE (OPTIONAL)

2.7.1 Interface via High-Speed Measurement / Interface Option (1689-9610)

If you have the 1689-9610 High-Speed Measurement / IEEE-488 Bus / Handler Interface Option, connect from the HANDLER INTERFACE on the rear panel to a handler, printer, or other suitable peripheral equipment as follows. (The presence of the 24-pin connectors shown in Figure 1-2 verifies that you have one of the interface options; see also paragraph 2.7.2.) Refer to Table 1-2 for the appropriate connector to use in making a cable. Refer to Table 2-1 for the key to signal names, functions, and pin numbers.

Connect the bin control lines to the handler. See Table 2-1. Notice that the 1689-9610 High-Speed Measurement Option provides outputs for automatic sorting into 15 bins. (Refer to paragraph 3.8.)

As indicated in the Specifications at the front of this manual, the output signals come from open-collector drivers that pull each signal line to a low voltage when that signal is active and let it float when inactive. Each external circuit must be powered by a positive voltage, up to 15 V (max), with sufficient impedance (pull-up resistors) to limit the active-signal (logic low) current to 24 mA (max).

CAUTION

Provide protection from voltage spikes over 15 V.

The cautionary note above means typically that each relay or other inductive load requires a clamping diode (rectifier) across it (cathode connected to the power-supply end of the load).

The input signal is also active low and also requires a positive-voltage external circuit, which must pull the signal line down below 0.4 V, but not less than 0.0 V, i.e., not negative. The logic-low current is 0.4 mA (max). For the inactive state (logic high), the external circuit must pull the signal line above +2.5 V, but not above +5 V.

NOTE

The "end of test" signal EOT is provided by the Digibridge only while binning is enabled, by having a non-zero "nominal value" in memory. Refer to paragraph 3.8 for details.

Table 2-1
HANDLER INTERFACE KEY

Signal Name	1689-* Pin No.	1658-* Pin No.	Function (All signals "active low")
		DC CONNECTIONS:	
-----	5, 6, 7	5, 6, 7	Ground connection.
-----	10	10	DC bus (+5 V) available; see note **
		INPUT:	
START	1	1	Initiates measurement (single or avg).
		OUTPUTS:	
EOT	18	18	"End of test"; bin signals are valid. ***
ACQ OVER	22	22	"Data acquisition over"; DUT removal OK.
BIN 0	15	15	No-go because of D or Q limit.
BIN 1	17	17	Go, bin 1.
BIN 2	19	19	Go, bin 2.
BIN 3	21	21	Go, bin 3.
BIN 4	23	23	Go, bin 4.
BIN 5	14	14	Go, bin 5.
BIN 6	16	16	Go, bin 6.
BIN 7	20	20	Go, bin 7.
BIN 8	24	-----	Go, bin 8.
BIN 9	2	-----	Go, bin 9.
BIN 10	3	-----	Go, bin 10.
BIN 11	4	-----	Go, bin 11.
BIN 12	8	-----	Go, bin 12.
BIN 13	9	-----	Go, bin 13.
BIN 14	13	-----	RLC fail, no-go by default (suits no other bin).
OTHER PASS	-----	24	Go, eighth bin, for 1689 bins 8,9,10,11,12,13.
RLC FAIL	-----	13	Ninth bin, no-go by default (1689 bin 14).

* Interface plug-in options: 1689-9610 (high-speed) and 1658-9610.
** Low-power dc bus (+5 V) available for systems use, commonly for opto-couplers. CAUTION: limit the load to 25 mA, max. To obtain this voltage, the service technician must install a wire jumper, on the interface board, at WT 2 to WT 3.
*** EOT is enabled if binning is enabled (by having a non-zero nominal value).

2.7.2 Interface via IEEE-488 Bus / Handler Interface Option (1658-9610)

If you have the 1658-9610 interface option, connect from the HANDLER INTERFACE on the rear panel to a handler, printer, or other suitable peripheral equipment as follows. (The presence of the 24-pin connectors shown in Figure 1-2 verifies that you have one of the interface options; refer to paragraph 2.7.1.) Refer to Table 1-2 for the appropriate connector to use in making a cable. Refer to Table 2-1 for the key to signal names, functions, and pin numbers.

Connect the bin control lines to the handler. See Table 2-1. Notice that the 1658-9610 IEEE-488 Bus / Handler Interface Card provides outputs for automatic sorting into 10 bins. (Refer to paragraph 3.8.)

As indicated in the Specifications at the front of this manual, the output signals come from open-collector drivers that pull each signal line to a low voltage when that signal is active and let it float when inactive. Each external circuit must be powered by a positive voltage, up to 30 V (max), with sufficient impedance (pull-up resistors) to limit the active-signal (logic low) current to 16 mA (max).

CAUTION

Provide protection from voltage spikes over 30 V.

The cautionary note above means typically that each relay or other inductive load requires a clamping diode (rectifier) across it (cathode connected to the power-supply end of the load).

The input signal is also active low and also requires a positive-voltage external circuit, which must pull the signal line down below 0.4 V, but not less than 0.0 V, i.e., not negative. The logic-low current is 0.4 mA (max). For the inactive state (logic high), the external circuit must pull the signal line above +2.5 V, but not above +5 V.

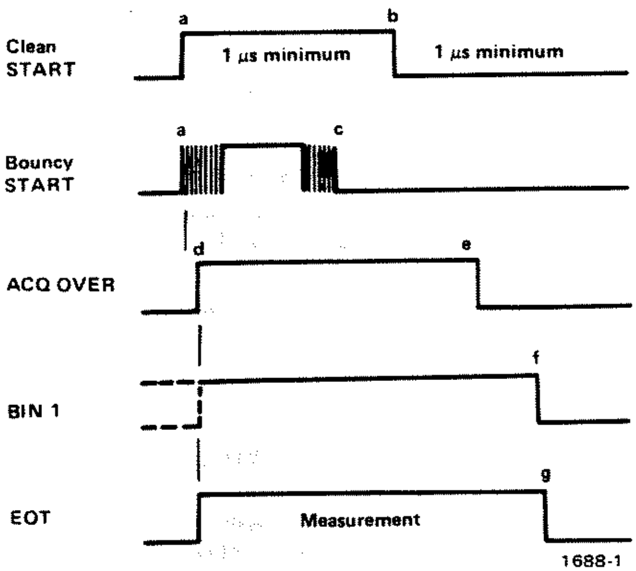

Figure 2-3. Handler interface timing diagram. External circuit must keep a-b > 1 us, and (if START is not "debounced") a-c < [the settling time or programmed delay]. For single measurements, the DUT can be disconnected after e. The selected BIN line goes low at f; the other BIN lines stay high. For MEDIAN and/or AVERAGE measurement routines, ACQ OVER goes low (e) at the end of the last measurement.

2.7.3 Timing **Figure 2-3.**

Refer to the accompanying figure for timing guidelines. Notice that START must have a duration of 1 us (minimum) in each state (high and low). If START is provided by a mechanical switch without debounce circuitry, the Digibridge will make many false starts; if START does not settle down (low) within the default settling time or the programmed delay time after the first transition to high, the measurement time may increase substantially. For an explanation of settling and delay time, refer to paragraph 3.5.3.

Measurement starts at time d, which is essentially the same as time b or c; measurement is completed at g. (The START signals are expanded for clarity.) Interval a-e, during which the DUT must remain connected for data acquisition, is considerably shorter than the total measurement time a-g. The DUT can be changed after e ("indexing on ACQ", to save time) or after g ("indexing on EOT", for a simpler test setup), as explained below.

After the calculation interval e-f, measurement results are available for sorting, i.e., one of the BIN lines goes low. A few micro-seconds later, EOT goes low (can be used to set a latch holding the bin assignment). ACQ OVER, the selected BIN line, and EOT then stay low until the next start command.

The time required for measurement depends on whether you have the high-speed measurement option, on test conditions, programmable values, and operating selections. Interval a-e can be less than 15 ms; the cycle a-g can be less than 40 ms; refer to paragraph 3.5 for details.

Set up the handler either of two ways: indexing on EOT or indexing on ACQ, as follows. The handler must supply a signal (here called "start next measurement") when it has completed connection of the DUT to the test fixture.

Indexing on EOT. Set up the handler to respond to the EOT signal from the Digibridge, which occurs at the "end of test", when the bin assignment is available for sorting. Set up the Digibridge to receive its START signal from the handler's "start next measurement" signal. This setup is simpler than the one below.

NOTE

The Digibridge requires that a non-zero value be entered for "nominal value" to enable generation of the EOT signal and indication by the GO/NO-GO lights; see paragraphs 3.8.3, 3.8.4.

Indexing on ACQ. Set up the handler to respond to the ACQ OVER signal from the Digibridge, which occurs when the "data acquisition" is complete. The handler can then remove the DUT from the test fixture and replace it with another DUT, while the Digibridge is calculating the result.

In addition, set up an interface that provides a START signal to the Digibridge by logical combination of the EOT signal from the Digibridge AND the "start next measurement" signal from the handler. Indexing on ACQ results in higher measurement rate than indexing on EOT.

Be sure the TALK switch is set to TALK ONLY, if the IEEE-488 bus is not used.

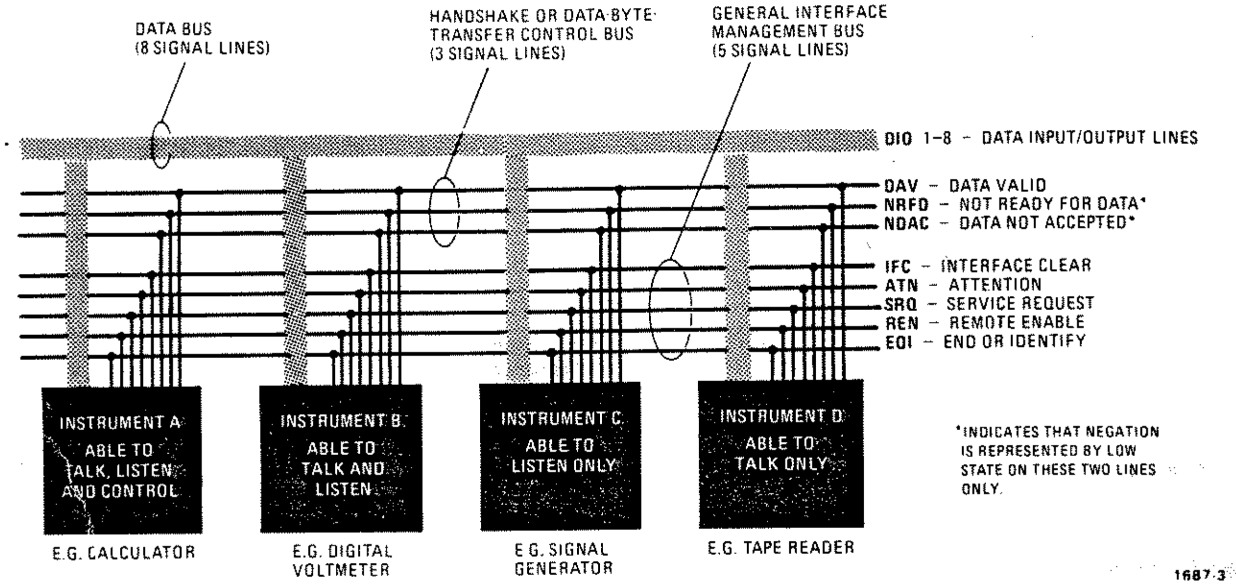

Figure 2-4. Block diagram of a generalized system interconnected by the 16-signal-line bus specified in the IEEE Standard 488. Reprinted from Electronics, November 14, 1974; copyright McGraw-Hill, Inc., 1974.

2.8 IEEE-488 INTERFACE (OPTION)

2.8.1 Purpose

Figure 2-4.

If you have either interface option, you can connect this instrument to a printer or into a system (containing a number of devices such as instruments, apparatus, peripheral devices, and generally a controller or computer) in which each component meets IEEE Standard 488-1978, Standard Digital Interface for Programmable Instrumentation. A complete understanding of this Standard (about 80 pages) is necessary to understand in detail the purposes of the signals at the IEEE-488 INTERFACE connector at the rear panel of this instrument. Commendable introductions to the Standard and its application have been published separately, for example: "Standard Instrument Interface Simplifies System Design", by Ricci and Nelson, Electronics, Vol 47, No. 23, November 14, 1974. Another article is "IEEE-488: Promise and Practice", by M. A. Gipe, Electronic Packaging and Production, Vol 18, No. 9, September, 1978.

NOTE

> For copies of the Standard, order "IEEE Std 488-1978, IEEE Standard Digital Interface for Programmable Instrumentation", from IEEE Service Center, Department PB-8, 445 Hoes Lane, Piscataway, N. J. 08854.

To make connection to a single device like a printer, use a IEEE-488 cable, which fits the rear-panel connector labeled IEEE-488 INTERFACE. For larger systems, each device is connected to a system bus, in parallel, usually by the use of several stackable cables. Refer to the figure for a diagram of a hypothetical system. A full set of connections is 24 (16 signals plus shield and ground returns), as tabulated below and also in the Standard. Suitable cables, stackable at each end, are available from Component Manufacturing Service, Inc., West Bridgewater, MA 02379, U.S.A. (Their part number 2024/1 is for a 1-meter-long cable.)

This instrument will function as either a TALK/LISTEN or a TALK ONLY device in the system, depending on the position of the TALK switch. "TALK/LISTEN" denotes full programmability and is suited for use in a system that has a controller or computer to manage the data flow. The "handshake" routine assures that the active talker proceeds slowly enough for the slowest listener that is active, but is not limited by any inactive (unaddressed) listener. TALK ONLY is suited to a simpler system -- e.g. Digibridge and printer -- with no controller and no other talker. Either mode provides measurement results to the active listeners in the system.

2.8.2 Interface Functions

Figure 2-5.

The following functions are implemented. Refer to the Standard for an explanation of the function subsets, represented by the identifications below. For example, T5 represents the most complete set of talker capabilities, whereas PP0 means the absence of a capability.

SH1, source handshake (talker)
AH1, acceptor handshake (listener)
T5, talker (full capability, serial poll)
L4, listener (but not listen-only)
SR1, request by device for service from controller
RL2, remote control (no local lockout,
 no return-to-local switch)
PP0, no parallel poll
DC0, no device clear
DT1, device trigger (typically starts measurement)
C0, no controller functions.

The handshake cycle is the process whereby digital signals effect the transfer of each data byte by means of status and control signals. The cycle assures, for example, that the data byte has settled and all listeners are ready before the talker signals "data valid". Similarly, it assures that all listeners have accepted the byte before the talker signals "data not valid" and makes the transition to another byte. Three signal lines are involved, in addition to the 8 that convey the byte itself. Refer to the accompanying figure.

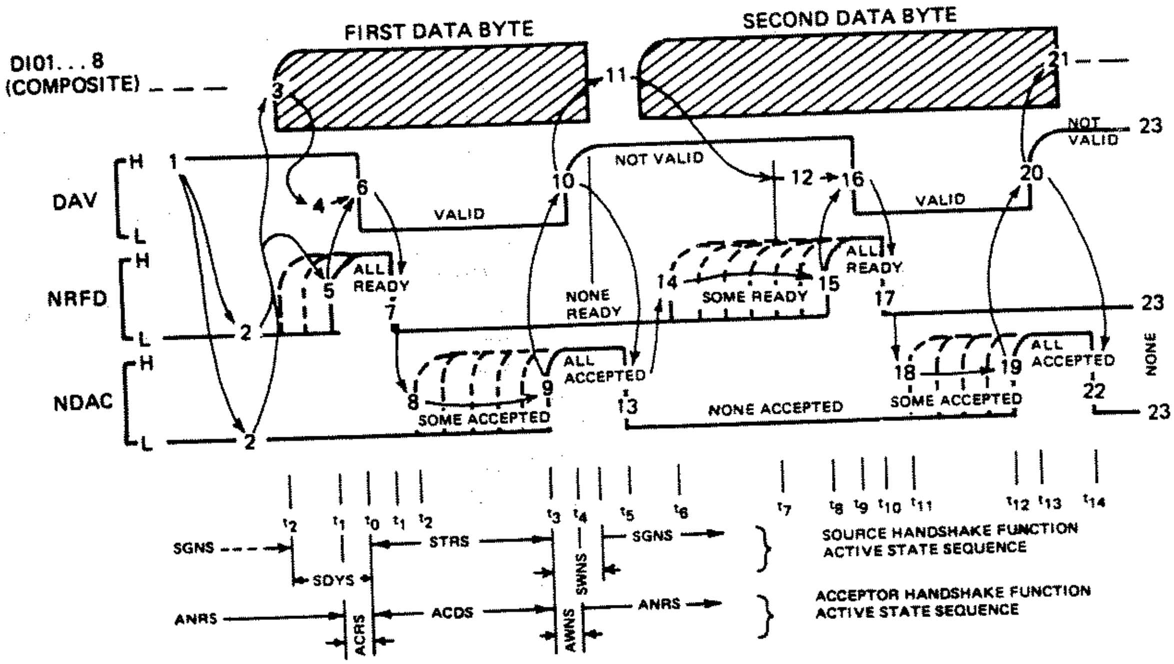

Figure 2-5. The handshake process, illustrated by timing diagrams of the pertinent signals for a system with one talker and several listeners. For details, refer to the standard.

2.8.3 Signal Identification

Refer to Table 2-2 for a key to signal names, functions, and pin numbers. Further explanation is found in the Standard. The first three signals listed take part in the "handshake" routine, used for any multiline message via the data bus; the next five are used to manage the flow of information; the last eight constitute the multiline message data bus.

Table 2-2
IEEE-488 INTERFACE KEY

Pin No.	Signal Name	Function or Significance
6	DAV	Low state: "data is available" and valid on the DI01...DI08 lines.
7	NRFD	Low state: at least 1 listener on the bus is "not ready for data."
8	NDAC	Low state: at least 1 listener on the bus is "not done accepting data."
11	ATN	"Attention", specifies 1 of 2 uses for the DI01...DI08 lines, as follows. Low state: controller command messages. High state: data bytes from the talker device.
9	IFC	"Interface clear." Low state: returns portions of interface system to a known quiescent state.
10	SRQ	"Service request." Low: a talker or listener signals (to the controller) need for attention in the midst of the current sequence of events.
17	REN	"Remote enable." Low state: enables each device to enter remote mode when addressed to listen; (Remote-control commands are conveyed while ATN is high.) High state: all devices revert to local control.
5	EOI	"End or Identify." "END" if ATN is in high state, then, low state of EOI indicates end of a multiple-byte data transfer sequence.* "IDY" if ATN is in low state; then, low state of EOI activates a parallel poll.**
1	DI01	The 8-line data bus, which conveys interface messages (ATN low state) or device-dependent messages (ATN high state), such as remote-control commands from the controller or from a talker device.
2	DI02	
3	DI03	
4	DI04	
13	DI05	
14	DI06	
15	DI07	
16	DI08	

* "END" is typically sent concurrently with the delimiter "linefeed" character that terminates the string(s) of data output from the Digibridge (1, 2, or 3 lines; see para 2.8.4).
** IDY is not implemented in this Digibridge.

2.8.4 Codes and Addresses

General. The device-dependent messages, such as instrument programming commands and measurement data (which the digital interface exists to facilitate), have to be coded in a way that is compatible between talkers and listeners. They have to use the same language. Addresses have to be assigned, except in the case of a single "talker only" with one or more "listeners" always listening. The Standard sets ground rules for these codes and addresses.

In this instrument, codes for input and output data have been chosen in accordance with the rules. The address (for both talker and listener functions) is user selectable, as explained below.

Instrument Program Commands. The set of commands used in remote programming is an input data code to which the instrument will respond as a "talker/listener", after being set to a remote code and addressed to listen to device-dependent command strings. The set includes all of the keyboard functions except switching external bias ON/OFF and full recalibration, which are not remotely programmable.

Refer to paragraph 3.12.3 for a table of the commands used in programming.

Address. The initial setting of address, provided by the factory, is binary 00011. Consequently, the talk-address command (MTA) is C in ASCII code and, similarly, the listen-address command (MLA) is #. If a different address pair is desired, set it manually using the following procedure.

WARNING

> Because of shock hazard and presence of electronic devices subject to damage by static electricity (conveyed by hands or tools), disassembly is strictly a "service" procedure.

a. Take the Digibridge to a qualified electronic technician who has the necessary equipment for minor disassembly and adjustment. Have him remove the interface option assembly, as described in his 1689 Digibridge Service instructions. (There is no need to remove the top cover first.)

b. Have him set the switches in "DIP" switch assembly S2 to the desired address, which is a 5-bit binary number. (See below.)

c. Have him replace the interface option assembly in its former place.

Notice that S2 is located at the end of the interface option board, about 3 cm (1 in.) from the TALK switch S1. If S2 is covered, lift the cover off, exposing the "DIP" switch, which has 6 tiny switches, numbered 1 thru 6. To enter logical 1's, depress the side of each switch nearest the end of the board (switch open). To enter logical 0's, depress the other side of the switch (switch closed). The address is read from 5 to 1 (not using 6). Thus, for example, to set up the address 00011, enter 0's at positions 5, 4, 3; enter 1's at positions 2, 1. (This makes the talk address "C" and the listen address "#".) Strictly speaking, the address includes more; S2 determines only the device-dependent bits of the address. You cannot choose talk and listen addresses separately, only as a pair. The list of possible pairs is shown in Table 2-3.

In the above example, the remote message codes MLA and MTA are X0100011 and X1000011, respectively. Thus the listen address and the talk address are distinguished, although they contain the same set of device-dependent bits, which you set into S2.

Table 2-3

ADDRESS PAIRS AND SETTINGS FOR SWITCH S2

Talk address Symbol	Binary	Listen address Symbol	Binary	Switch setting* 5 4 3 2 1
@	1 000 000	(space)	0 100 000	0 0 0 0 0
A	1 000 001	!	0 100 001	0 0 0 0 1
B	1 000 010	"	0 100 010	0 0 0 1 0
C	1 000 011	#	0 100 011	0 0 0 1 1
D	1 000 100	$	0 100 100	0 0 1 0 0
E	1 000 101	%	0 100 101	0 0 1 0 1
F	1 000 110	&	0 100 110	0 0 1 1 0
G	1 000 111	'	0 100 111	0 0 1 1 1
H	1 001 000	(	0 101 000	0 1 0 0 0
I	1 001 001	)	0 101 001	0 1 0 0 1
J	1 001 010	*	0 101 010	0 1 0 1 0
K	1 001 011	+	0 101 011	0 1 0 1 1
L	1 001 100	,	0 101 100	0 1 1 0 0
M	1 001 101	-	0 101 101	0 1 1 0 1
N	1 001 110	.	0 101 110	0 1 1 1 0
O	1 001 111	/	0 101 111	0 1 1 1 1
P	1 010 000	0	0 110 000	1 0 0 0 0
Q	1 010 001	1	0 110 001	1 0 0 0 1
R	1 010 010	2	0 110 010	1 0 0 1 0
S	1 010 011	3	0 110 011	1 0 0 1 1
T	1 010 100	4	0 110 100	1 0 1 0 0
U	1 010 101	5	0 110 101	1 0 1 0 1
V	1 010 110	6	0 110 110	1 0 1 1 0
W	1 010 111	7	0 110 111	1 0 1 1 1
X	1 011 000	8	0 111 000	1 1 0 0 0
Y	1 011 001	9	0 111 001	1 1 0 0 1
Z	1 011 010	:	0 111 010	1 1 0 1 0
[	1 011 011	;	0 111 011	1 1 0 1 1
\	1 011 100	<	0 111 100	1 1 1 0 0
]	1 011 101	=	0 111 101	1 1 1 0 1
^	1 011 110	>	0 111 110	1 1 1 1 0

---

* Do NOT set the switch to 11111, because a talk address of "_" would be confused with an "untalk" command, and a listen address of "?", with an "unlisten" command. (ASCII code for "_" is 1 011 111 and for "?" is 0 111 111.)

Data Output. Data (results of measurements) are provided on the DI01...DI07 lines as serial strings of characters. Each character is a byte, coded according to the 7-bit ASCII code, as explained above. The alphanumeric characters used are appropriate to the data, for convenience in reading printouts. The character strings are always provided in the same sequence as that tabulated in paragraph 3.12.3; for example: RLC value, QDR value, bin number — if all 3 were selected (by the X7 command). The carriage-return and line-feed characters at the end of each string provide a printer (for example) with the basic commands to print each string on a separate line.

For example, if the measurement was 0.54321 uF (1 kHz, range 4 held), the character string for LC value is:

U(space)C(space)uF(2 spaces)0.54321(CR)(LF).

If the Rs measurement was 23.45 ohms, the character string for QDR value is:

(2 spaces)R(3 spaces)O(3 spaces)23.45(CR)(LF).

If the measurement falls into bin 9, the character string for bin number is:

F(space)BIN(2 spaces)9(CR)(LF).

The character string for LC value has the length of 17 characters; for QDR value, 17 characters; for bin number, 10 characters — including spaces, carriage-return, and line-feed characters. Refer to the format tables in paragraph 3.12.2 for details.

2.9 ENVIRONMENT

The Digibridge can be operated in nearly any environment that is comfortable for the operator. Keep the instrument and all connections to the parts under test away from electromagnetic fields that may interfere with measurements.

Refer to the Specifications at the front of this manual for temperature and humidity tolerances. To safeguard the instrument during storage or shipment, use protective packaging. Service personnel refer to Section 5.

Operation — Section 3

3.1 BASIC PROCEDURE

3.1.1 General

For initial familiarization, follow this procedure carefully. After that, use this paragraph as a ready reference and refer to later paragraphs in this section for details.

Refer also to the Condensed Operating Instructions, found stored in a pocket under the instrument. Reach under the front edge and pull the card forward as far as it slides easily. After use, slide it back in the pocket for protection.

3.1.2 Startup

CAUTION

Set the line voltage switch properly (rear panel) before connecting the power cord.

This is the regular startup procedure.

a. After the line-voltage switch has been set to the position that corresponds to your power-line voltage (which must be in either range: 90 to 125 V or 180 to 250 V ac, nominally 50 or 60 Hz), then connect the power cord as explained below.

Temperature. If the Digibridge® has been very cold, warm it up in a dry environment, allowing time for the interior to reach 0 degrees C or above, before applying power. Otherwise, the Digibridge may be damaged by thermal shock.

Power Cord. Connect the power cord to the rear-panel connector, and then to your power receptacle.

b. If the Digibridge includes an optional IEEE-488 interface, set TALK switch (rear panel) to TALK ONLY (unless instructions are to be received through the IEEE-488 bus).

c. Switch EXTERNAL BIAS OFF (front panel).

d. Press the POWER button "in", so that it stays in the depressed position. Self-check codes will show briefly, indicating that the instrument is automatically executing a power-up routine that includes self checks.

(To turn the instrument off, push and release the POWER button and leave it in the "out" position.)

e. Wait until keyboard lights indicate MEASURE, VALUE, SLOW, CONT (or TRIGGERED), SERIES. If they do not, there are two possible explanations: self-check fault and keyboard lock. If a fault is detected in the self-check, measurements are blocked and an error code remains displayed. (See paragraph 3.13.) If the keyboard is locked, all of those keyboard indicators remain unlit except MEASURE and/or REMOTE CONTROL —— and all previously programmed test conditions, limits, etc are reestablished. To unlock it, see paragraph 3.9.

3.1.3 Zeroing

Before measurement, zero the Digibridge as follows. In this process, the Digibridge automatically measures stray parameters and retains the data, which it uses to correct measurements so that results represent parameters of the DUT alone, without (for example) test-fixture or adaptor capacitance.

NOTE: The normal procedure is given here. However, to "zero" the Digibridge for greatest accuracy at any frequency above 20 kHz, refer to paragraph 3.6.5.

a. Conditions.
SLOW measure rate, 1 V test voltage (default), RANGE HELD indicator NOT lit.

b. Open Circuit.
- Press [FUNCTION] key (if necessary) to select MEASURE function.
- Press [MEASURE MODE] key (if necessary) to select TRIGGERED mode.
- If any test-fixture adaptors are to be used, install and position them for use. (See paragraph 3.2.)
- Be sure that the test fixture is open circuited.
- If you want this "zero" process to echo a display of 00000, press the [Cs/D] key. However doing so will disable automatic parameter selection. (See paragraph 3.1.4, step b.)
- Press these keys deliberately: [1] [6] [8] [9] [=] [SHIFT] [OPEN].
- Note: the GO indicator being lit and two zeros confirm the previous step.
- Keep hands and objects at least 10 cm (4 in.) from test fixture.
- Press the START button. The GO indication disappears.
- Wait for the GO indicator to be lit again.

c. Short Circuit.

- o Short the fixture with a clean copper wire (AWG 18 to 30), length 5 to 8 cm.
- o Press these keys: [1] [6] [8] [9] [=] [SHIFT] [SHORT].
- o Note: the GO indicator being lit and two fives confirm the previous step.
- o Press the START button. The GO indication disappears.
- o Wait for the GO indicator to be lit again.
- o Remove the short circuit.

NOTE For best accuracy:
Repeat this procedure daily and after changing test-fixture adaptors or frequency.

3.1.4 Routine Measurement

a. Verify or select measurement conditions as follows (indicated by keyboard lights); press the adjacent key to change a selection.

- o Function: MEASURE ([FUNCTION] key), a necessary selection
- o Display: VALUE ([DISPLAY] key), for normal RLC/QDR results
- o Measure rate: SLOW ([MEASURE RATE] key), for best accuracy
- o Measure mode: TRIGGERED ([MEASURE MODE] key), optional
- o Equivalent circuit: SERIES ([EQUIVALENT CIRCUIT] key) -- see paragraph 3.3.

If you are in doubt about how to connect the device to be tested with the Digibridge, refer to paragraph 3.2, below.

b. To measure any passive component (without knowing whether it is essentially a resistor, inductor, or capacitor), use "automatic parameter selection". This feature is provided at power-up and remains enabled as long as you do NOT select any particular parameter. (Automatic parameter selection can be disabled by pressing the [Cs/D] key, for example. Once disabled, this feature can be enabled again by selecting the ENTER function and then pressing these keys:
[1][=][SHIFT][SPECIAL][7].)
Place DUT in test fixture. Press START.
The RLC display and units indicator show the principal measured value and the basic parameter, thus identifying the DUT.
The QDR display shows the measured Q if the principal units are ohms or henries; the measured D if they are farads.

In steps c, d, e, f, the parameters to be measured are specified by the user.

c. To measure C and D of a Capacitor (C Range .00001 pF to 99999 uF, D range .0001 to 9999): Press [Cs/D]. Place capacitor in test fixture. Press START.
The RLC display shows Cs (series capacitance) and units (uF, nF, pF);
the QDR display shows D (dissipation factor).
{If "NEG RLC" is lit, DUT is inductive.}

d. To measure C and R of a Capacitor (C Range .00001 nF to 99999 uF, R range .0001 ohm to 9999 kilohm): Press [Cs/Rs]. Place capacitor in test fixture. Press START.
The RLC display shows Cs (series capacitance) and units (uF, nF);
the QDR display shows Rs (equivalent series resistance) and units (ohms, kilohms).
{If "NEG RLC" is lit, DUT is inductive.}

e. To measure L and Q of an Inductor (L range .00001 mH to 99999 H, Q range .0001 to 9999): Press [Ls/Q]. Place inductor in test fixture. Press START. The RLC display shows Ls (series inductance) and units (mH, H); the QDR display shows Q (quality factor). {If "NEG RLC" is lit, DUT is capacitive.}

f. To measure R and Q of a Resistor (R range .00001 ohm to 99999 kilohms, Q range .0001 to 9999): Press [Rs/Q]. Place resistor in test fixture. Press START. The RLC display shows Rs (series resistance) and units (ohms, kilohms); the QDR display shows Q (quality factor). {If "NEG QDR" is lit, DUT is capacitive; if not lit, DUT is inductive.}

NOTE: This procedure is basic; there are many alternatives described later. You can select and program for other parameters, equivalent circuits, types of results displayed, test conditions, measurement rate, and bin sorting, etc.

3.2 CONNECTING THE DUT

3.2.1 General

WARNING

Charged capacitors can be dangerous, even lethal. Never handle their terminals if they have been charged to more than 60 V. Routine discharging procedures may not be perfectly dependable.

Connect the "device under test" (DUT), whose parameters are to be measured, as follows.

NOTE

Clean the leads of the DUT if they are noticeably dirty, even though the test-fixture contacts will usually bite through a film of wax to provide adequate connections.

3.2.2 Using the Integral Test Fixture for Radial-Lead DUTs **Figure 3-1.**

If the DUT is a radial-lead component or has parallel leads at one side, insert them into the Digibridge test-fixture slots as described below.

The test fixture provided on the front ledge of the Digibridge provides convenient, reliable, guarded 4-terminal connection to any common radial-lead or (with adaptors that are provided) an axial-lead component part.

The slots in the test fixture accommodate wires with diameters from 0.25 mm (.01 in., AWG 30) to 1 mm (.04 in., AWG 18), spaced from 4 to 98 mm apart (0.16 to 3.9 in.) or equivalent strip conductors. Each "radial" wire must be at least 4 mm long (0.16 in.). The divider between the test slots contains a shield, at guard potential, with its edges semi-exposed. The tapped holes (6-32 thread) at the left and right ends of the test fixture are also grounded, to connect the shields of extender cables.

Figure 3-1. A radial-lead DUT is inserted into the test fixture.

NOTE

If any adaptor(s), described below, are in place, remove them before attempting to insert a radial-lead DUT.

3.2.3 Using the Test-Fixture Adaptors for Axial-Lead DUTs   Figure 3-2.

If the DUT is an axial-lead component or has leads at opposite ends, insert the leads into the Digibridge test-fixture slots as described below.

Install the test-fixture adaptors, supplied, as shown; put one in each slot of the test fixture, by pushing vertically downward. Slide the adaptors together or apart so the body of the DUT will fit easily between them.

Notice that the contacts inside the adaptor are off center; be sure to orient the adaptors so the contacts are close to the body of the DUT, especially if it has short or fragile leads.

The adaptors accommodate wires with diameters up to 1.5 mm (.06 in., AWG 15). The body of the DUT that will fit between these adaptors can be 80 mm long and 44 mm diameter (3.1 x 1.7 in.) maximum. Each "axial" wire must be at least 3 mm long (0.12 in.). The overall length of the DUT, including the axial wires must be at least 22 mm (0.866 in.).

Insert the DUT so that one lead makes connection on the left side of the test fixture, the other lead on the right side. Insertion and removal are smooth, easy operations and connections are reliable if leads are reasonably clean and straight. Press the DUT down so that the leads enter the slots in the adaptors as far as they go easily.

Be sure to remove any obvious dirt from leads before inserting them. The test-fixture contacts will wipe through a film of wax, but can become clogged and ineffectual if dirty leads are inserted repeatedly.

Be sure to insert only one thing into each half of the test fixture, at any one time. (If any object is inserted into the same slot with a DUT lead, it will probably NOT make true "Kelvin" connections.)

NOTE

For a DUT with very short leads, it is important to orient each adaptor so that its internal contacts (which are off center) are close to the DUT. To remove each adaptor, lift with a gentle tilt left or right (never forward or back).

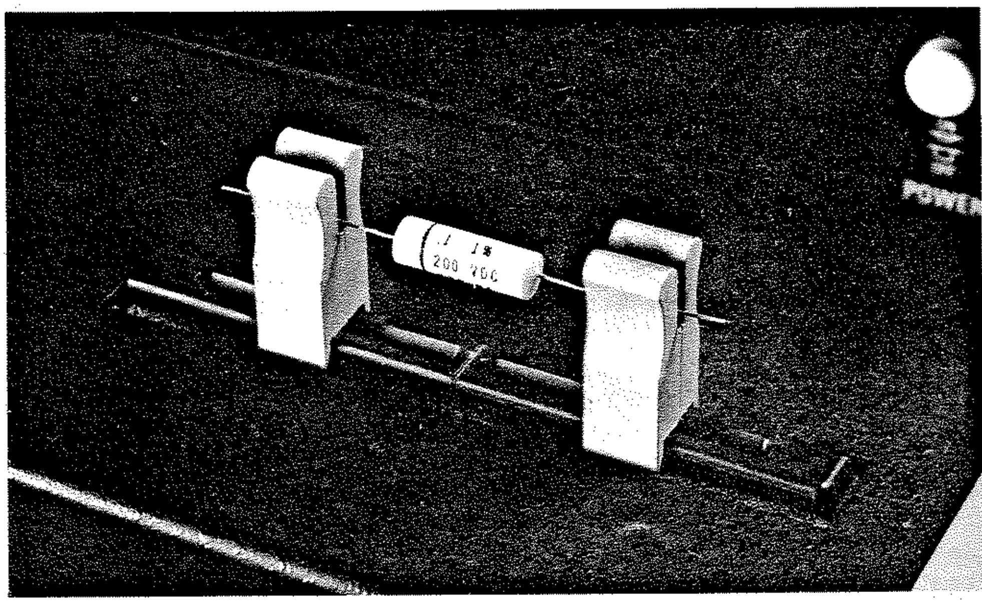

Figure 3-2. Use of the adaptors (supplied) for connection of an axial-lead DUT to the Digibridge test fixture.

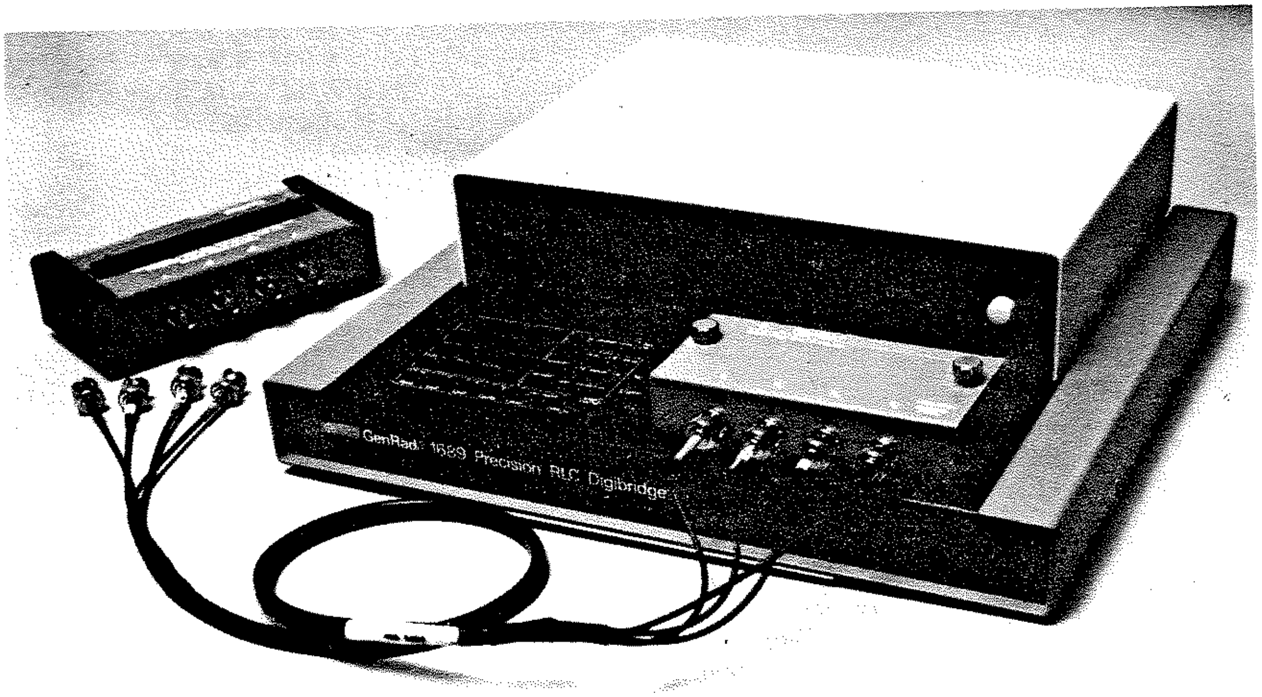

Figure 3-3. Accessory BNC test-fixture adaptor, cable, and remote test fixture.

3.2.4 Using BNC Adaptors and Cable for Remote Test Fixturing **Figure 3-3.**

Connection of the DUT at a remote test fixture requires proper adaptors and cable connections from the Digibridge. Obtain the following accessories:

- o BNC Adaptor 1689-9601
- o BNC Cable Assembly 1689-9602, or equivalent
- o Remote Test Fixture 1689-9600, or equivalent handler or special fixture.

This remote test fixture functions like the one supplied on the Digibridge. True "Kelvin" connections are made at the points of contact with the DUT leads. The recommended cable should be used (rather than any randomly chosen BNC patch cords) because the known cable parameters enable you to make corrections for best accuracy. Install the remote test fixture as follows.

a. Remove any adaptors, if present, from the test fixture.

b. Plug the BNC adaptor into the basic test fixture with the BNC connectors facing forward. Lock the connection with the 2 captive thumb screws. (The screws must be seated to complete the ground connection.)

c. Connect the cable assembly to the adaptor on the Digibridge and to the remote test fixture as indicated in Table 3-1

Table 3-1
TEST FIXTURE CONNECTIONS VIA BNC ADAPTOR 1689-9601

Test-Circuit Function	Bias Polarity	BNC Connector on 1689-9601 (at Digibridge)	Color Code in 1689-9602 Cable	Connection * at 1689-9600 Test Fixture (Remote)
IL (current, low)	+	Left	Black	I+, Left
PL (potential, low)	+	Left-center	Black/white	P+, Left-center
PH (potential, high)	-	Right-center	Red/white	P-, Right-center
IH (current, high)	-	Right	Red	I-, Right

* Left and right are defined with the fixture oriented for right reading of legend.

NOTE: User provided cables and/or remote test fixtures can be used, particularly if the DUT is to be handled automatically. (See paragraph 3.11 about handlers.) See below for comments on cable and fixture capacitance and zeroing.

c. Before making measurements, be sure to repeat the zeroing procedure (open circuit and short circuit), as described in paragraph 3.1.3.

3.2.5 The 1688-9600 Extender Cable ("Type 874" Connectors) Figure 3-4.

The accessory extender cable 1688-9600 can be used to connect a DUT that is multiterminal, physically large, or otherwise unsuited for the built-in test fixture. This low-capacitance cable is used, for example, to connect type-874 equipped impedance standards or a special test fixture. The cable tips are type 874 coaxial connectors, which mate with a broad line of components and adaptors. Make connections as follows.

a. Remove the adaptors, if present, from the test fixture.

b. Plug the single-connector end of the extender cable into the Digibridge test fixture so that its blades enter both slots and the cable lies away from the display panel. Lock the connector with the two captive thumb screws.

c. Using the branched end of the cable, connect to the DUT with careful attention to the following color code.

Notice that the 2 cables with red must connect to the same end of the DUT, through a coaxial tee if the DUT is a 2-terminal or 3-terminal device; the 2 cables labeled with black, connect to the other end, similarly. Connection of guard, via the outer portion of the coaxial connector, should be to the shield or case of the DUT, but NOT to either of the two main terminals.

EXTENDER CABLE COLOR CODE

RED AND RED: IH, current drive to "high" end of DUT.
RED AND WHITE: PH, potential connection to same.
BLACK AND BLACK: IL, current return at DUT "low".
BLACK AND WHITE: PL, potential connection to same.
OUTER CONTACTS: G, guard connection to shield or case (if isolated from the preceding terminals).

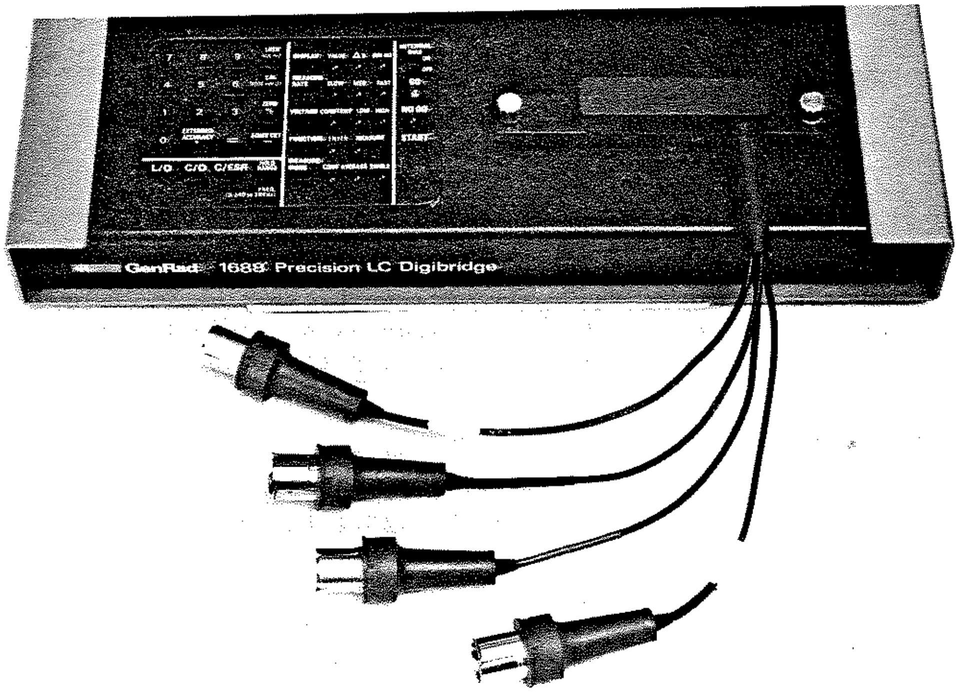

Figure 3-4. The type 874 extender cable is shown plugged into the Digibridge test fixture. Notice that the two thumb screws must be hand tightened for the guard connection (shields of cable).

3.2.6 The 1657-9600 Extender Cable (Banana Plugs)

The accessory extender cable 1657-9600 is available to connect to DUTs that are multiterminal, physically large, or otherwise unsuited for the built-in test fixture. (Refer to Table 1-3.) This cable is particularly convenient for connecting multiterminal components with binding posts that accommodate banana plugs. Use the following procedure to install the extender cable on the instrument.

a. Remove the adaptors, if present, from the test fixture.

b. Plug the single-connector end of the extender cable into the Digibridge test fixture so that its blades enter both slots and the cable lies away from the display panel. Lock the connector with the two captive thumb screws.

c. Note the color coding of the five banana plugs. Be sure that the "low" terminals (both potential and current) connect to one end of the DUT and the "high" terminals to the other end. Connect guard to a shield if any, but not to either end of the DUT.

Pl (potential, low) = Black/white Ph (potential, high) = Red/white
Il (current, low) = Black Ih (current, high) = Red
Guard = Black/green

3.2.7 The Effects of Cable and Fixture Capacitances

It is important to use very low-capacitance shielded wire for cables, not only for accuracy, but also to minimize resonance effects in the measurement of large inductance at high frequency.

The Capacitances that are Most Liable to Affect Accuracy. Any test fixture extension cable adds a bit of capacitance in parallel with the DUT (because shielding of the leads is imperfect) and more between each terminal and ground. The zero calibration process will compensate fully for the capacitances between cables in any normal test setup.

However, capacitance between ground and the "low" connections at the DUT (C from gnd to Il and C from gnd to Pl, in parallel, designated Csn) can affect measurement accuracy of very-high-impedance DUTs at high frequencies.

Zeroing. Be sure to repeat either the entire power-up procedure or at least the open-circuit and short-circuit zeroing procedure after any change in test fixtures or their cable connections.

Calculating the Capacitance Loading Error. The error due to this capacitance Csn is designated Ald ("additional error due to loading"). The magnitude of Ald can be calculated so that you know how significant it is and so that measurements can be corrected if desired. Refer to paragraph 3.6, Accuracy, subparagraph 7.

3.3 MEASUREMENT PARAMETERS, RESULTS DISPLAYS, AND OUTPUTS

3.3.1 Parameters (R/Q, L/Q, C/D, C/R)

Automatic Selection. The Digibridge as powered up provides you with automatic selection of parameters (unless keyboard has been locked with a particular parameter selected).

This feature enables you to measure any passive component (without knowing whether it is essentially a resistor, inductor, or capacitor). It is provided at power-up and remains enabled as long as you do NOT select any particular parameter.

Automatic parameter selection can be disabled by pressing any parameter key, such as the [Cs/D] key, for example. Once disabled, this feature can be enabled again by selecting the ENTER function and then pressing these keys:

[1][=][SHIFT][SPECIAL][7]

To select parameter automatically, the Digibridge calculates Q: if $|Q| < 0.125$, R is selected; otherwise, for positive Q, L is selected; and for negative Q, C is selected. (The sign of Q is the same as the sign of the reactive component of impedance.)

Manual Selection To select the parameter to be measured:

a. Press one of the 4 parameter keys: [R/Q, L/Q, C/D, C/R].

b. Use the [EQUIVALENT CIRCUIT] key to select SERIES or PARALLEL. Note: When you select SERIES equivalent ckt, the 4 keys obtain Rs/Q, Ls/Q, Cs/D and Cs/Rs. When you select PARALLEL equiv ckt, the 4 keys obtain Rp/Q, Lp/Q, Cp/D and Cp/Rp.

Note: equivalent circuits are discussed below, in paragraph 3.3.2.

For an inductor select L/Q; for a capacitor, either C/D or C/R; for a resistor, R/Q. There will be an immediate confirmation on the display panel, where appropriate units indicators will be lit. (However, do not attempt to select the unit multiplier.) The Digibridge will automatically switch to the appropriate multiplier -- from nF to pF for example --, unless RANGE is HELD, when it makes a measurement. The result will be displayed in terms of the parameters and equivalent circuit that you select, (even if the DUT has the opposite kind of reactance -- see below).

Note: Observing the results displays can be helpful in deciding whether you have made the best parameter selection. (See below.) Displays are discussed further in paragraph 3.3.3.

The NEG RLC Indicator. If the NEG RLC indicator on the main display panel is lit with an L or C value displayed, the DUT reactance is opposite to the selected parameter. As a rule, you should change parameter (usually select L instead of C or vice versa) so that a positive L or C value display can be obtained. However, the displayed negative value of L or C is mathematically correct and (without the minus sign) is in fact the value that will resonate with the DUT at the test frequency. Notice that the appearance of a device can be misleading. (For example, an inductor is capacitive if test frequency is above resonance; or a component part can be mislabeled or unlabeled.)

When the display is VALUE or BIN No., avoid incorrect choice of parameter by watching for the NEG RLC indicator on the display panel. If this indicator is lit, the principal parameter (L or C) was selected incorrectly. Try the opposite choice.

However, when the display is delta% or deltaRLC, a negative indication means that the measured value is less than the reference (stored nominal value), and the parameter is probably correct.

For more information about both the NEG RLC and the NEG QDR indicators, see paragraph 3.3.3.

3.3.2 Equivalent Circuits — Series, Parallel

The results of R, L, or C measurements of many components depend on which of two equivalent circuits is chosen to represent it — series or parallel.

The more nearly "pure" the resistance or reactance, the more nearly identical are the "series" and "parallel" values of the principal parameter. However, if D is high or Q low, Cs differs substantially from Cp and Ls differs substantially from Lp; and these values are frequency dependent. Usually several measurements at frequencies near the desired evaluation will reveal that either series measurements are less frequency dependent than parallel, or the converse. The equivalent circuit that is less frequency dependent is the better model of the actual device.

We first give general rules for selection of measurement parameters, then some of the theory.

Making the Selection. The power-up selection is "series", confirmed by the SERIES indicator being lit, on the keyboard. To change the selection, press the [EQUIVALENT CIRCUIT] key.

Specifications. The manufacturer or principal user of the DUT probably specifies how to measure it. (Usually "series" is specified.) Refer also to the applicable MIL or EIA specifications. Select "parallel" or "series" and the test frequency according to the applicable specifications. If there are none known, be sure to specify with your results whether they are "parallel" or "series" and what the measurement frequency was.

Suggested Test Conditions.

Capacitors less than 100 pF: Series or Parallel, 10 kHz.
Capacitors between 100 pF and 1 uF: Series, 1 kHz.
Capacitors greater than 1 uF: Series, 0.1 or 0.12 kHz. Unless otherwise specified or for special reasons, always select "series" for capacitors and inductors. This has traditionally been standard practice. For very small (large) capacitance, select a higher (lower) measurement frequency for best accuracy. (Refer to paragraph 3.6.)

Inductors less than 10 uH: Series, 100 kHz.
Inductors between 10 uH and 1 mH: Series, 10 kHz.
Inductors between 1 mH and 1 H: Series, 1 kHz.
Inductors greater than 1 H: Series, 0.1 kHz. Select "series" as explained above. For very small (large) inductance, select a higher (lower) measurement frequency for best accuracy.

Resistors, below about 1 kilohm: Series, 1 kHz. Usually the specifications call for dc resistance, so select a low test frequency to minimize ac effects. Select "series" because the reactive component most likely to be present in a low resistance resistor is series inductance, which has no effect on the measurement of series R.

Larger Resistors. Between 1 kilohm and 10 megohms: Parallel, 0.250 kHz.
Resistors greater than 10 megohms: Parallel, 0.030 kHz. As explained above, select a low test frequency. Select "parallel" because the reactive component most likely to be present in a high-resistance resistor is shunt capacitance, which has no effect on the measurement of parallel R. If the Q is less than 0.1, the measured Rp is probably very close to the dc resistance.

Theory — Series and Parallel Parameters. Figure 3-5.

An impedance that is neither pure reactance nor a pure resistance can be represented at any specific frequency by either a series or a parallel combination of resistance and reactance. The values of resistance and reactance used in the equivalent circuit depend on whether a series or parallel combination is used. Keeping this concept in mind will be valuable in operation of the instrument and interpreting its measurements.

The equivalent circuits are shown in the accompanying figure, together with useful equations relating them. Notice that the Digibridge measures the equivalent series components Rs, Ls, or Cs, if you select SERIES EQUIVALENT CIRCUIT. It measures the parallel equivalent components Rp, Lp, or Cp if you select PARALLEL. D and Q have the same value regardless whether series or parallel equivalent circuit is calculated.

Resistance and Inductance

$$X = \omega L$$

$$Z = R_s + j\omega L_s \qquad Z = \frac{j\omega L_p R_p}{R_p + j\omega L_p} \qquad Z = \frac{R_p + jQ^2 \omega L_p}{1 + Q^2}$$

$$Q = \frac{1}{D} \qquad Q = \frac{\omega L_s}{R_s} \qquad Q = \frac{R_p}{\omega L_p}$$

$$L_s = \frac{Q^2}{1 + Q^2} L_p \qquad L_s = \frac{1}{1 + D^2} L_p$$

$$L_p = \frac{1 + Q^2}{Q^2} L_s \qquad L_p = (1 + D^2) L_s$$

$$R_s = \frac{1}{1 + Q^2} R_p \qquad R_p = (1 + Q^2) R_s$$

$$R_s = \frac{\omega L_s}{Q} \qquad R_p = Q\omega L_p \qquad R_p = \frac{1}{G_p}$$

$$B_p = \frac{1}{X_p}$$

Resistance and Capacitance

$$X = -\frac{1}{\omega C}$$

$$Z = R_s + \frac{1}{j\omega C_s} \qquad Z = \frac{R_p}{1 + j\omega R_p C_p} \qquad Z = \frac{D^2 R_p + 1/(j\omega C_p)}{1 + D^2}$$

$$D = \frac{1}{Q} \qquad D = \omega R_s C_s \qquad D = \frac{1}{\omega R_p C_p}$$

$$C_s = (1 + D^2) C_p \qquad C_p = \frac{1}{1 + D^2} C_s$$

$$R_s = \frac{D^2}{1 + D^2} R_p \qquad R_p = \frac{1 + D^2}{D^2} R_s$$

$$R_s = \frac{D}{\omega C_s} \qquad R_p = \frac{1}{\omega C_p D} \qquad R_p = \frac{1}{G_p}$$

$$B_p = \frac{1}{X_p}$$

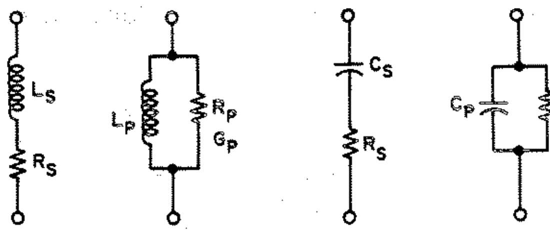

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Figure 3-5. Equivalent circuits and mathematical relationships for lossy inductors and capacitors.

ESR for Capacitors. The total loss of a capacitor can be expressed in several ways, including D and "ESR", which stands for "equivalent series resistance" and which is designated "Rs" in the preceding paragraph. To obtain ESR, be sure that the SERIES indicator is lit; if you want ESR displayed simultaneously with Cs, push the [Cs/Rs] parameter key; if you want the 5-place resolution for ESR, push the [Rs/Q] key.

"Equivalent series resistance" is typically much larger than the actual "ohmic" series resistance of the wire leads and foils that are physically in series with the heart of a capacitor, because ESR includes also the effect of dielectric loss. ESR is related to D by the formula ESR = Rs = D/wCs (where w represents "omega", 2 pi times frequency).

Parallel Equivalent Circuits for Inductors. Even though it is customary to measure series inductance of inductors, there are situations in which the parallel equivalent circuit better represents the physical device. For small "air-core" inductors, the significant loss mechanism is usually "ohmic" or "copper loss" in the wire; and the series circuit is appropriate.

However, if there is an iron core, the significant loss mechanism may be "core loss" (caused by eddy currents and hysteresis); and the parallel equivalent circuit is appropriate, being a better model of the inductor. Whether this is true at any particular frequency should be determined by an understanding of the DUT, but probably it is so if the following is true: that measurements of Lp at two frequencies near the frequency of interest differ from each other less than do measurements of Ls at the same two frequencies.

3.3.3 Results

PRINCIPAL MEASUREMENT

The principal Digibridge measurement will be presented on the left (RLC) part of the display panel in one of four ways; VALUE, deltaRLC, delta%, or BIN No., (only one way for any single measurement).

VALUE, Selected by the [DISPLAY] Key. This measurement provides two displays: the principal one is RLC (resistance, inductance, or capacitance) and the secondary one is QDR (quality factor with R or L, either dissipation factor or resistance with C). The VALUE selection is the power-up default and one of the selections of the [DISPLAY] key.

Read the measurement on the main displays. The RLC display is the principal measurement, complete with decimal point and units which are indicated by the light spot in the lower part of the display panel. The QDR display is Q if the selected parameter is R/Q or L/Q; it is D for C/D, or resistance (with units indicated) for C/R. Leading zeroes before the decimal point are automatically eliminated in most cases by positioning of the decimal point. Otherwise, such zeroes are blanked out.

The NEG RLC Indicator. If the NEG RLC indicator on the main display panel is lit with an L or C value displayed (or with parameter selection L or C and BIN NO. displayed), the DUT reactance is opposite to the selected parameter. Generally, you should change parameter (usually select L instead of C or vice versa) so that a positive L or C value display can be obtained. See paragraph 3.3.1.

However a negative indication when the display is delta% or deltaRLC means that the measured value is less than the reference (stored nominal value), and the parameter is probably correct.

Delta Percent Displays, Selected by the [DISPLAY] Key. This presents the principal measurement (RLC) in terms of a percent difference above or below the nominal value last entered (i.e., a previously stored reference). Use this procedure.

a. Select ENTER with the [FUNCTION] key.

b. Select appropriate parameter and units with [EQUIVALENT CIRCUIT] and [R/Q, L/Q, C/D, or C/R] key. (Repeat keying will change unit multipliers.)

c. Enter the reference for delta percent by keying:
(Y)[=][SHIFT][NOM VALUE]
in which Y represents 1 to 6 numerical keys and (optionally) the decimal point key, depressed in sequence. Confirmation is shown (up to 5 digits) on the RLC display.

d. Select MEASURE with the [FUNCTION] key and delta% with the [DISPLAY] key.

e. Observe that the RLC display will now be in percent, not an electrical measurement unit. It is the difference of the measured principal value from the nominal value (the stored reference), expressed as a percent of the nominal value. If the NEG RLC indicator is lit, the measured value is less than the nominal value; and conversely, if not lit, the measured value is greater.

The secondary measurement result appears in the QDR display area, just as it would if the principal display were VALUE.

NOTE: If you wish to see the delta% display simultaneously with bin sorting (data output to handler or IEEE-488 bus), enter the bin limits first, as described in paragraph 3.8. Then (unless the last setting of nominal value happens to be the desired reference for percent difference) use the above procedure for setting up delta% displays.

<u>Delta RLC Display, Selected by the [DISPLAY] Key</u>. This selection is indicated by lighting BOTH indicators together: VALUE and delta%. The deltaRLC display is a difference from the stored nominal value, measured in the indicated electrical units, such as ohms, millihenries, or picofarads. The NEG RLC indicator is lit if the measured value is less than reference. The procedure for selecting deltaRLC displays is like the delta% procedure, above, except that the [DISPLAY] key is pressed repeatedly until <u>two</u> DISPLAY indicators (together labeled deltaRLC) are lit.

The secondary measurement result appears in the QDR display area, just as it would if the principal display were VALUE.

<u>Bin No</u>. Selected by using the [DISPLAY] key. When measurement is completed, the bin assignment will be shown on the left (RLC) display only, as a one-digit or two-digit number, with the following significance:

0 = No-Go because of the secondary (QDR) limit
1 = Go, bin 1
2 = Go, bin 2
... Go, bin 3, 4, 5, ... 12, or 13, as indicated.
14 = No-go by default (suits no other bin).

<u>Ratio Displays</u>. The Digibridge can be programmed to display a ratio instead of either measured value or delta percentage. Refer to paragraph 3.3.7.

SECONDARY MEASUREMENT

The secondary Digibridge measurement will be presented on the right (QDR) display panel, for each measurement if the DISPLAY selection is VALUE, delta%, or deltaRLC. There is no secondary display if the selection is BIN NO.

The NEG QDR Indicator. The NEG QDR indicator has the following meanings.

Parameter Selection	NEG QDR not lit	NEG QDR lit
R/Q	DUT is inductive	DUT is capacitive
L/Q, C/D, or C/R	Q, D, or R is positive	Q, D, or R is negative (see below)

If the secondary measurement is negative -- Q, D, or R as calculated by the Digibridge when selected parameter is L/Q, C/D, or C/R — then there are two likely possibilities. If the Q or D value (whichever is being displayed) is very small, a small (acceptable) calibration and/or measurement error can lead to a negative result. (It should of course fall within the specified accuracy of the instrument.) Measurement error can be reduced by choice of measurement conditions, averaging, etc. Another possibility is that the DUT (as seen by the Digibridge) really does have a negative loss factor. This situation might be true of certain kinds of multiterminal network or an active device. It might be simulated (although not true) by some unusual connection of the cables normally used to provide for a remote test fixture.

DQ IN PPM, Selected by the [SHIFT][DQ in PPM] Keys. For D or Q values less than .0100, selecting DQ in PPM improves the resolution by a factor of 100. For example, if the displayed D values of two capacitors are both .0001, changing to DQ in PPM might distinguish them by providing a reading of 138 ppm for one and 87 ppm for the other.

The "DQ in PPM" selection applies to the Q or D result only, and is effective for all selections of the [DISPLAY] key except BIN NO, and for all parameter selections except C/R.

When this selection is in effect: the DQ IN PPM indicator is lit; the display is always parts per million, without decimal point; if the display is blank, the D or Q value is greater than 9999 ppm (to obtain the value, cancel "DQ in PPM").

To cancel this selection, use the same keystrokes again: [SHIFT][DQ in PPM].

GO/NO-GO

If comparison is enabled, by a non-zero entry for "nominal value", and limits in at least one bin, a GO or NO-GO indication is provided for every measurement. (The display selection can be whatever you choose.). GO means the measurement falls in bin 1 through 13; NO-GO means bin 0 or 14.

3.3.4 Units, Multipliers, and Blank Displays

Units are determined entirely by your selection of parameter. Units multipliers are fixed by parameter, range, and frequency, except that selection of delta% changes the RLC display to a percentage. See Table 3-2. Units of D and Q are dimensionless and are expressed as a decimal ratio, without multiplier — unless you select "DQ IN PPM", in which case D or Q is expressed in parts per million.

Table 3-2
UNITS AND MULTIPLIERS FOR EACH RANGE

Freq:	Up to 0.1 kHz				From 0.1 to 6 kHz				From 6+ to 20 kHz				Above 20 kHz			
Range:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Parameter																
R	K	K	ohm	ohm *	K	K	ohm	ohm	K	K	ohm	ohm	**	K	ohm	ohm
L	H	H	H	mH	H	H	mH	mH	H	mH	mH	mH	**	mH	mH	mH
C/D	nF	nF	uF	uF	pF	nF	nF	uF	pF	nF	nF	nF	**	pF	nF	nF
C/R ***	nF	nF	uF	uF	nF	nF	nF	uF	nF	nF	nF	uF	**	nF	nF	uF

* K represents "kilohms".
** Range 1 is not used if frequency is above 20 kHz.
*** For C in nF, R is in kilohms. For C in uF, R is in ohms.

Decimal Point Position. The decimal point is automatically positioned for maximum resolution (i.e., so that the first significant digit or the first zero after the decimal point is in the first position in the display) with a few exceptions, as listed below. Of course, displays on low underrange or low extension of a held range may have a number of necessary zeros to right of the decimal point (and therefore reduced number of significant digits compared to the display area) because units and multipliers are fixed on any one range. The above-mentioned exceptions are:

1. DQ IN PPM is always displayed without a decimal point, in ppm.
2. Delta% displays can resolve no less than 0.0001% (i.e., 1 ppm).
3. Hysteresis is provided to reduce flickering, as explained below.

If the first digit of the measurement is 9, the decimal point for any measured-value display is left unchanged from its previous position, provided that so doing places that 9 in either the first or second position in the display area. (Notice that a number like 09XXX has resolution almost as fine as a number like 10XXX.)

For example, if the measured value is 99.985 nF, the display is a full 5 digits if the previous measured-value display was 12.345, 99.984, or 99.999; but the display is rounded off to 099.98 nF if the previous measured-value display was 100.02 or 1234.5 nF. Hysteresis is provided on both measured-value displays (RLC and QDR).

Blanks in Measured-Value Displays. If a measurement exceeds the capability of the display (99999 for RLC display, 9999 for QDR), the display is blank. If a measurement is less than 1 right-hand digit, the display is all zeros. If any leading zero before the decimal point must occupy a position in the display, that zero is blanked out. See below for programmed selection of digit blanking.

3.3.5 D/Q in PPM

The Digibridge can easily be programmed to display the secondary test result -- when it it either D or Q — in parts per million. To choose this display, press:

[SHIFT][DQ in PPM] so that the DQ IN PPM indicator is lit.

To disable this option, repeat the same keystrokes so that the indicator is NOT lit.

3.3.6 Digit Blanking, a Special Function

If you want to truncate the measured-value displays you can deliberately blank out some of the least significant digits, using a special-function command (described in paragraph 3.10).

For example, to truncate the RLC display to 4 digits and the QDR display to 3 digits, press:
[1][.][1][=][SHIFT][SPECIAL][4]

To disable such digit blanking (return to normal), press:
[0][.][0][=][SHIFT][SPECIAL][4]

3.3.7 Ratio Displays, Virtual Range Extensions, via a Special Function

The Digibridge can easily be programmed to display the principal test result (RLC) in the form of a ratio instead of the actual measured value. The ratio is either (measured value / stored nominal value) or the reciprocal of that. By suitable choice of the nominal value, you can obtain virtual range extensions for measurement of very large values or for fine resolution in measurement of very small values.

One use of the ratio display capability is to obtain results in terms of a multiple of some reference, which can be obtained if desired by measuring a real reference DUT.

<u>For Very Large R, L, or C.</u> Another use of the ratio display is to obtain measurements of very high values (in high overrange, i.e., exceeding 99999 of the highest range). For example, consider the measurement of capacitors with values near 200 mF (i.e., 0.2 farad). Any value greater than 99999 uF (99.999 mF) normally causes a blank display. (because the unit multiplier on the highest C range is fixed (uF) and the display is limited to 5 digits).

However, if you enter a nominal value of 1000 uF, and enable calculation and display of the ratio "measurement/nominal", then measurement results can be interpreted as though they were in units of mF (although the ratio is really dimensionless and the unit indicators remain unlit). In this example, the measurement results can then be 199.99, 200.00, 200.01, etc. For much larger capacitance, the Digibridge will automatically move the decimal point, up to 99999 mF (i.e., 99.999 farads). For still larger values, you can make the nominal value larger.

<u>For Very Small R, L, or C.</u> Another use of the ratio display is to obtain better resolution of very small values (Otherwise the resolution can be no better than .00001 on the lowest range.) For example, consider the measurement of some inductors with values near 20 nH. Because the minimum measured value, and the resolution limit also, is .00001 mH, the normal measurement results can only be .00000, .00001, .00002, .00003 mH, etc, i.e., steps of 50% of the 20 nH value.

However, if you enter a nominal value of .001 mH, and enable calculation and display of the ratio "measurement/nominal", then measurement results can be interpreted as though they were in units of uH (although the ratio is really dimensionless and the unit indicators remain unlit). In this example, the measurement results can then be .01999, .02000, .02001, etc, i.e., steps of .05%, which is very fine resolution. By selecting a sufficiently small nominal value, you can obtain resolution that is better than the repeatability of measurements.

To program the Digibridge for ratio displays, enter the desired nominal value in the appropriate units of measurement, and enable the special function, as follows.

a. With the [FUNCTION] key, select ENTER.

b. If the Digibridge has just completed a measurement of a DUT, so that the principal display already indicates the appropriate units of measurement, this step can probably be skipped. Otherwise, using the appropriate parameter key, select the units of the nominal value to be stored.

c. Enter the desired nominal value. For example, if the units displayed on the panel are uF and you want to set up a ratio display that can be interpreted as mF, press:
[1][0][0][0][=][SHIFT][NOM VALUE]

d. Enable the desired special function; the pertinent commands are:
- o To display measurement/nominal -- [2][=][SHIFT][SPECIAL][6]
  (This is the correct command for the ratio-display examples, above.)
- o To display nominal/measurement -- [1][=][SHIFT][SPECIAL][6]
- o To disable ratio displays ------- [0][=][SHIFT][SPECIAL][6]

e. To enable measurements, select MEASURE with the [FUNCTION] key.

f. To display the ratio in the left-hand display area, select VALUE with the [DISPLAY] key. After measurement, the right-hand display will be QDR, as usual; however, if the parameter selection is C/R, the units for R will NOT be indicated.

NOTE

The Digibridge indicates that its principal measurement is a ratio by keeping ALL units and % indicators unlit.

If the parameter selection is C/R, the ratio display in the left-hand display area is accompanied by a resistance value in the QDR display area, without units indication. If the ambiguity in units (ohms or kilohms) must be resolved, the following method is suggested. The units can be determined for a typical DUT by temporarily disabling ratio display. While ratio is disabled, make measurements also with parameter selection C/D and observe the typical value of D. Now you are prepared to measure a batch of similar capacitors with ratio display. For any of them, a temporary change of parameter selection from C/R to C/D and another measurement will provide a quick check on whether its loss is similar to the loss of the typical DUT. If it is similar, for similar value of C at the same frequency, the R value is similar also. However if its D is much higher, the value of Rs is higher and Rp is lower, in approximate proportion to D.