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## NOTE


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## GR 1689-9751 Precision RLC Digibridge<sup>®</sup>

Form 1689-0126-00

Symbol  ICE417 on equipment signifies that the manual contains information to prevent injury or equipment damage. Refer to page 5-1.

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# Specifications

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## Displays

Measurement results may be displayed in four ways as selected by the keyboard:

1. The VALUE display can be one of eight pairs of measured quantities L and Q, C and D, C and R, R and Q, R and X, G and B, Z and Ang, or Y and Ang. The primary display (L, C, R, G, Z, or Y) has five digits of resolution. The secondary display D, Q, R, X, B, or Ang has four digits of resolution.
2. The % difference display indicates the percent deviation of the measured L, C, R, G, Z, or Y value from a stored NOMINAL VALUE. The sign of this deviation is indicated.
3. The RLC difference is similar to the % difference except that the deviation is displayed in appropriate units (ohms, henries, etc.)
4. 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 uF               |
| R: | .00001 $\Omega$ to 99999 k $\Omega$ |
| L: | .00001 mH to 99999 H                |
| G: | .00001 uS to 99999 S                |
| Z: | .00001 $\Omega$ to 99999 k $\Omega$ |
| Y: | .00001 uS to 99999 S                |

% difference (C, R, or L): .0001% to 99999%; RLC difference: same as R, L, or C. If any of these quantities is negative, the "-" indicator light is lit.

\*These ranges may be extended by a factor of more than 10,000 larger or smaller by using the special ratio mode:

*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  $\Omega$  to 9999 k $\Omega$   
X .0001  $\Omega$  to 9999 k $\Omega$   
B .0001 uS to 9999 S  
Ang .0001 degree to 9999 degrees 1 ppm to 9999 ppm

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 200 kHz may be selected using the keyboard. These are:

$$f = \frac{200kHz}{n} \text{ where } 1 \leq n \leq 13$$

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

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

If the exact frequency entered is not available, the nearest available frequency will be used. Frequency tolerance is .01%.

**Measurement Time**

Measurement rate is selected via the keyboard. The time required for a complete measurement is typically less than indicated in Table A.

The measurement times are obtained with use of the continuous measurement mode, bin number display/handler output, and without IEEE-Bus data output. For other conditions, refer to the table notes.

If the measurement mode is triggered, programmed delay (settling time), if any, should be added. Normal power up conditions included a programmed delay of 7/f to 12/f ms depending upon measurement rate. This delay can be programmed to zero or to any value up to 100 sec.

Test connections can be broken (handler indexing can begin) as soon as data acquisition is complete (ACQ line low on handler interface). See Note 4 in tables.

## 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.

TABLE A  
GR1689-9751 MEASUREMENT RATE

| RATE    | TEST FREQUENCY |        |       |       |        |         |
|---------|----------------|--------|-------|-------|--------|---------|
|         | 12 Hz          | 100 Hz | 120Hz | 1 kHz | 10 kHz | 100 kHz |
| SLOW    | 899            | 944    | 944   | 974   | 944    | 944     |
| MEDIUM  | 694            | 144    | 194   | 204   | 194    | 194     |
| FAST    | 694            | 129    | 114   | 89    | 79     | 79      |
| MAXIMUM | 672            | 113    | 98    | 44    | 34     | 34      |

- Notes: 1. If the high-speed option is used, subtract 12 ms for MAXIMUM, or 24 ms for SLOW, MEDIUM or FAST measurement.  
2. If the display is value,  $\Delta\%$  or  $\Delta RLC$ , add 3 to 5 ms.  
3. If data is output via the IEEE Bus, add 3 to 6 ms.  
4. For ACQ, subtract 11 ms for SLOW, MEDIUM or FAST and 6 ms for MAXIMUM.

\* These times can be shortened by 14 ms with reduced accuracy using the quick acquisition routine.

## Test Voltage

The RMS test voltage is selectable from 5 mV to 1.275 V in 5 mV steps. The accuracy is:  $(5\% + 2 \text{ mV}) (1 + .001 f)$  where  $f$  = frequency in kHz.

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 1689-9751 has BNC connectors for attachment to a wide variety of measurement accessories. 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
- 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
- Quick acquisition routine

## IEEE-488 Bus/Handler Interface Card (1658-9620)

*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. Output data format: ASCII or Binary.

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.
- DC1 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:

$$(0 \text{ V} \leq V_l \leq 0.4 \text{ V}, +2.5 \text{ V} \leq V_h \leq +5 \text{ V})$$

Start (1 line)-initiates new measurement.

**High-Speed Measurement/Interface Option 1689-9620)**

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 Rate 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) x (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 x H x D):

17.25 x 5.625 x 15.160 in. (438.15 x 142.87 x 385.06 mm)

WEIGHT: 17 lbs. (7.71 kg.)

### Limit of Error (Accuracy)

Primary Readout C, R, L, G, |Z|, or |Y|

$$C: .01\% \left[ (1 + K_{cv}) \text{ or } \frac{C_x}{C_{max}} \text{ or } \frac{C_{min}}{C_x} \right] / (1 + |D|) (1 + K_s + K_{fv}) + .01\%$$

$$R: .01\% \left[ (1 + K_{cv}) \text{ or } \frac{R_x}{R_{max}} \text{ or } \frac{R_{min}}{R_x} \right] / (1 + |Q|) (1 + K_s + K_{fv}) + .01\%$$

$$L: .01\% \left[ (1 + K_{cv}) \text{ or } \frac{L_x}{L_{max}} \text{ or } \frac{L_{min}}{L_x} \right] / \left( 1 + \frac{1}{|Q|} \right) (1 + K_s + K_{fv}) + .01\%$$

$$G: .01\% \left[ (1 + K_{cv}) \text{ or } G_x R_{min} \text{ or } \frac{1}{G_x R_{max}} \right] / (1 + |Q|) (1 + K_s + K_{fv}) + .01\%$$

$$|Z|: .01\% \left[ (1 + K_{cv}) \text{ or } \frac{Z_x}{R_{max}} \text{ or } \frac{R_{min}}{Z_x} \right] / (1 + K_s + K_{fv}) + .01\%$$

$$|Y|: .01\% \left[ (1 + K_{cv}) \text{ or } Y_x R_{min} \text{ or } \frac{1}{Y_x R_{max}} \right] / (1 + K_s + K_{fv}) + .01\%$$

### 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.  $C_x$ ,  $R_x$ , and  $L_x$  are the values of the components being tested, and  $C_{max}$ ,  $C_{min}$ ,  $R_{max}$ , etc., are range constants given in Table B.
4. The values of  $K_s$ ,  $K_{fv}$ , and  $K_{cv}$  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 C through F.
5. These specifications assume proper OPEN and SHORT zeroing calibrations made at 1 kHz. Much better accuracy is possible at extreme impedance values if these zeroing calibrations are recent and made at the test frequency to be used. For example, the SLOW MEASUREMENT rate typically will give 1% accuracy when measuring 100 M $\Omega$  at 30 Hz, 0.1F at 120 Hz, 0.1 pF at 10 kHz, or 0.1 uH at 100 kHz. Even better accuracy is possible if several measurements are averaged.
6. 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%; this amount should be added to the 1689 specification for inductance measurements if they are to be used in any manner involving legal certification.



Secondary Readout R with C, X, or B

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

$$1 \text{ count} + .01\% [(1 + K_{cv}) \text{ or } \frac{R_x}{R_{max}} \text{ or } \frac{R_{min}}{R_x}] / (1 + \frac{1}{|D|}) (1 + K_s + K_{fv}) + .01\%$$

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

$$1 \text{ count} + .01\% [(1 + K_{cv}) \text{ or } \frac{C_x}{C_{max}} \text{ or } \frac{C_{min}}{C_x}] / (1 + \frac{1}{|D|}) (1 + K_s + K_{fv}) + .01\%$$

X:

$$1 \text{ count} + .01\% [(1 + K_{cv}) \text{ or } \frac{X_x}{R_{max}} \text{ or } \frac{R_{min}}{X_x}] / (1 + |\frac{1}{Q}|) (1 + K_s + K_{fv}) + .01\%$$

B:

$$1 \text{ count} + .01\% [(1 + K_{cv}) \text{ or } B_x R_{min} \text{ or } \frac{1}{B_x} R_{max}] / (1 + |D|) (1 + K_s + K_{fv}) + .01\%$$

NOTES:

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, Q, or Ang

D (with C):

$$.0001 [(1 + K_{cv}) \text{ or } \frac{C_x}{C_{max}} \text{ or } \frac{C_{min}}{C_x}] / (1 + |D| + D^2) (1 + K_s + K_{fv}) + .0001$$

Q (with R):

$$.0001 [(1 + K_{cv}) \text{ or } \frac{R_x}{R_{max}} \text{ or } \frac{R_{min}}{R_x}] / (1 + |Q| + Q^2) (1 + K_s + K_{fv}) + .0001$$

Q (with L):

$$.0001 [(1 + K_{cv}) \text{ or } \frac{L_x}{L_{max}} \text{ or } \frac{L_{min}}{L_x}] / (1 + |Q| + Q^2) (1 + K_s + K_{fv}) + .0001$$

Ang (with Z):

$$.01 \text{ degree } [(1 + K_{cv}) \text{ or } \frac{Z_x}{R_{max}} \text{ or } \frac{R_{min}}{Z_x}] / (1 + K_s + K_{fv})$$

Ang (with Y):

$$.01 \text{ degree } [(1 + K_{cv}) \text{ or } Y_x R_{min} \text{ or } \frac{1}{Y_x R_{max}}] / (1 + K_s + K_{fv})$$

NOTES:

This is not a percent error but rather the amount, positive or negative, by which the D, Q, or Ang 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 B**  
**Range Constants**

| AUTO RANGE | RANGE HELD |           |           |           |          |
|------------|------------|-----------|-----------|-----------|----------|
|            | RANGE 1*   | RANGE 2   | RANGE 3   | RANGE 4   |          |
| Cmax       | 25 uF/f    | 6400 pF/f | 100 nF/f  | 1600 nF/f | 25 uF/f  |
| Cmin       | 400 pF/f** | 400 pF/f  | 6.4 nF/f  | 100 nF/f  | 1.6 uF/f |
| Rmax       | 410 KΩ     | 410 KΩ    | 25.6 KΩ   | 1.6 KΩ    | 100 Ω    |
| Rmin       | 6.25Ω      | 25.6 KΩ   | 1.6 KΩ    | 0.1 KΩ    | 6.25Ω    |
| 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 C**  
**Kcv as a Function of Voltage Mode (Constant Voltage)**

| Voltage Mode | Non-Constant | Constant Voltage |
|--------------|--------------|------------------|
| Kcv          | 0            | 2                |

**Table D**  
**Ks as a Function of Measurement Rate**

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

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

| Frequency Voltage | 12to <30Hz | 30to <100Hz | 100to <250Hz | 250to <1kHz | 1kHz | >1to 3kHz | >3to 6kHz | >6to 10kHz | >10to 20kHz | >20to 50kHz                         | >50to 100kHz |
|-------------------|------------|-------------|--------------|-------------|------|-----------|-----------|------------|-------------|-------------------------------------|--------------|
| 1 to 1.26V        | 7          | 3           | 2            | 1           | 0    | 2         | 6         | 15         | 50          |                                     |              |
| 0.25 to <1V       | 10         | 6           | 4            | 2           | 1    | 3         | 10        | 20         | 65          | This range is not used above 20kHz. |              |
| 0.1 to <.25V      | 20         | 13          | 9            | 6           | 4    | 6         | 15        | 30         | 100         |                                     |              |
| 0.03 to <.1V      | 70         | 50          | 35           | 25          | 15   | 17        | 25        | 60         | *           |                                     |              |
| 0.01 to <.03V     | *          | *           | 100          | 70          | 50   | 50        | 70        | *          | *           |                                     |              |

\* Not specified

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

| Frequency<br>Voltage | 12to<br><30Hz | 30to<br><100Hz | 100to<br><250Hz | 250to<br><1kHz | 1kHz | >1to<br>3kHz | >3to<br>6kHz | >6to<br>10kHz | >10to<br>20kHz | >20to<br>50kHz | >50to<br>100kHz | 200<br>kHz |
|----------------------|---------------|----------------|-----------------|----------------|------|--------------|--------------|---------------|----------------|----------------|-----------------|------------|
| 1 to 1.26V           | 7             | 3              | 2               | 1              | 0    | 1            | 2            | 3             | 5              | 15             | 30              | 30         |
| 0.25 to <1V          | 9             | 5              | 3               | 2              | 1    | 2            | 3            | 5             | 6              | 18             | 35              | 200        |
| 0.1 to <.25          | 12            | 8              | 6               | 5              | 4    | 5            | 6            | 8             | 10             | 22             | 40              | 300        |
| 0.03 to <.1V         | 35            | 30             | 25              | 20             | 14   | 15           | 15           | 15            | 20             | 30             | 50              | *          |
| 0.01 to <.03V        | 90            | 80             | 70              | 60             | 50   | 50           | 50           | 50            | 60             | 70             | 90              | *          |

\* Not specified.

IN ADDITION TO THE PREVIOUS ACCURACY SPECIFICATIONS, THE 1689-9751 WILL ALSO MEET THE FOLLOWING SPECIFICATIONS:

CONDITIONS (unless stated otherwise): 1 volt, 1 kHz, Slow, Open and Short circuit zero performed at frequency to be used.

**CAPACITANCE ACCURACY:**

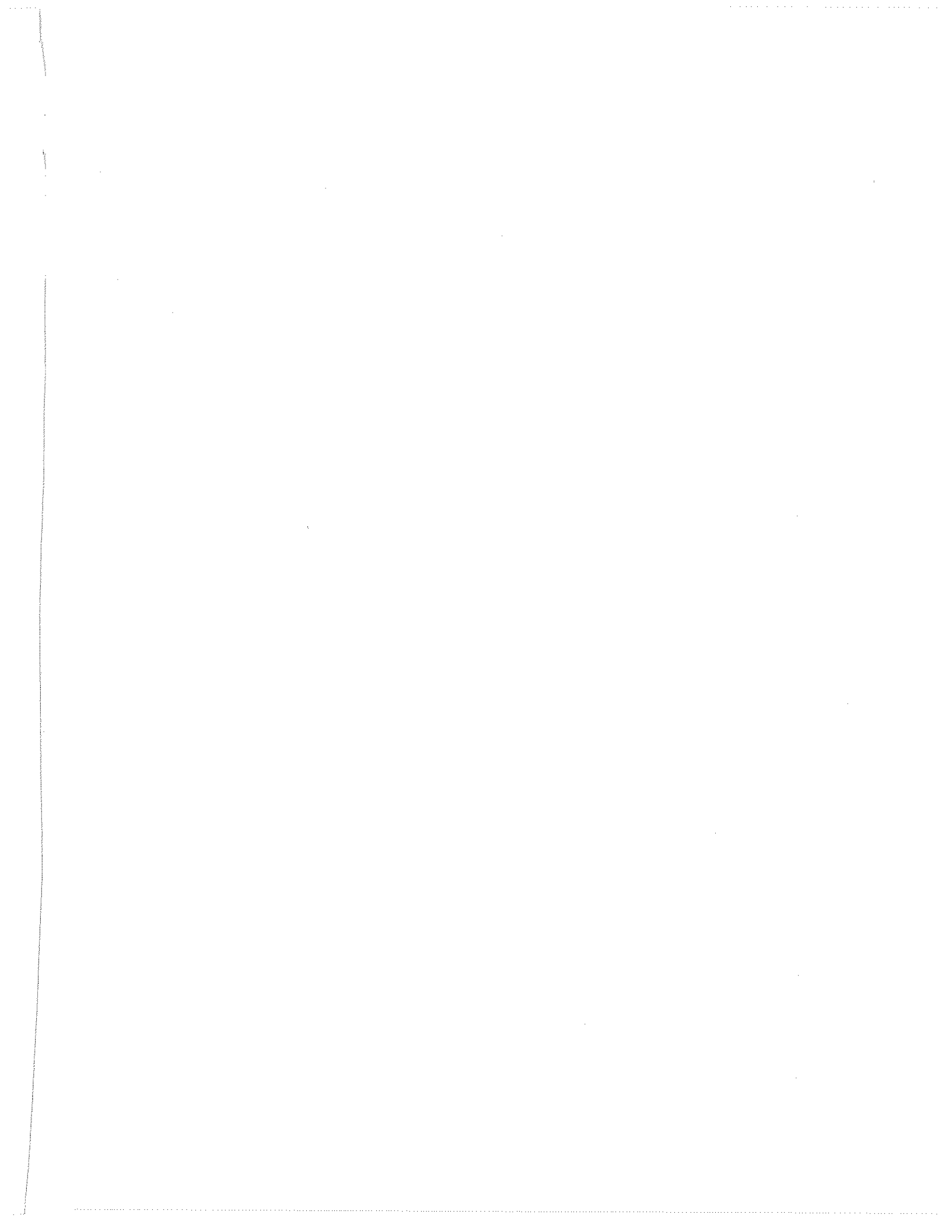
|                                |       |
|--------------------------------|-------|
| 10 nF - 10 uF:                 | .02%  |
| 10 nF - 10 uF, 100 Hz - 5 kHz: | .05%  |
| 1 nF - 1 uF, 1 kHz - 10 kHz:   | .05%  |
| 10 nF - 1 mF, 100 Hz:          | .1 %  |
| 10 pF - 100 uF:                | .5 %  |
| 1 mF - 10 mF:                  | 1.0 % |
| 1 nF - 1 uF, 10 kHz - 100 kHz: | 1.0 % |
| 1 nF - 100 nF, 200 kHz:        | 2.0 % |
| 10 mF - 1 F, 50 Hz:            | 3.0 % |
| 1 pF - 10 pF, 10 kHz:          | 3.5 % |

**INDUCTANCE ACCURACY:**

|                                   |       |
|-----------------------------------|-------|
| 10 mH - 1 H, 100 Hz - 5 kHz:      | .05%  |
| 100 mH - 10 H, 100 Hz - 1 kHz:    | .05%  |
| 10 H - 100 H:                     | .1 %  |
| 100 H - 1000H:                    | .3 %  |
| 100 uH - 10 mH, 100 Hz - 100 kHz: | 1.0 % |
| 1 uH - 100 uH:                    | 5.0 % |

**RESISTANCE ACCURACY:**

|                       |       |
|-----------------------|-------|
| 10 ohms - 100 kohms:  | .02%  |
| 1 ohm - 10 ohms:      | .1 %  |
| 100 kohms - 1 Mohms:  | .11%  |
| 1 Mohm - 10 Mohms:    | .35%  |
| 10 mohms - 1 ohm:     | 1.5 % |
| 10 Mohms - 100 Mohms: | 3.5 % |



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# Warranty

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**GenRad**

## WARRANTY

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.

CHANGES IN THE PRODUCT NOT APPROVED BY GENRAD SHALL VOID THIS WARRANTY.

GENRAD SHALL NOT BE LIABLE FOR ANY INDIRECT, SPECIAL, OR CONSEQUENTIAL DAMAGES, EVEN IF NOTICE HAS BEEN GIVEN OF THE POSSIBILITY OF SUCH DAMAGES.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

## SERVICE POLICY

Your local GenRad office or representative will assist you in all matters relating to product maintenance, such as calibration, repair, replacement parts and service contracts.

GenRad policy is to maintain product repair capability for a period of five (5) years after the unit goes out of production and to make this capability available at the then prevailing schedule of charges.



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# Introduction – Section 1

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## 1.1 PURPOSE

The Digibridge™ precision RLC tester, 1689-9751, is a microprocessor- controlled, automatic, programmable RLC measuring instrument that provides high accuracy, convenience, speed, and reliability at low cost. Limit comparison, binning, and internal bias are provided; both test frequency and voltage are selectable. With an interface option, the Digibridge tester can communicate with other equipment and respond to remote control.

The versatile, adaptable test fixture, lighted keyboard, and informative display panel makes the Digibridge tester 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, C, G, Z, and Y (4 full digits for D, Q, R, X, B, and ANG. Notice that R is also known as ESR (equivalent series resistance).

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 tester normally autoranges and automatically identifies the principal measurement parameter.

The optional 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.

Limit comparisons facilitate sorting into 13 GO and 2 NO-GO bins.

- Test frequencies from 12 Hz to 200 kHz
- Test voltages from 5 mV to 1.275 V; bias (2 V)
- Delay (before data acquisition) from zero to 99999 ms
- Measurement speeds up to 45 per second.
- Multi-measurement routines with automatic averaging and/or median taking of 2 to 765 measurements.
- Displays: measured values, percentages, differences, ratios, GO/NO-GO, binning
- Automatic output of value, bin number, bin summary and 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 The 1689-9751 Digibridge**

The basic features of the 1689-9751 are provided on the vertical front panel. These include the keypad, display, and the power ON/OFF button. The set of four BNC connectors for connection to the test fixture is supplied on the front panel, but can be relocated to the rear if that is preferred. The display-panel and keyboard indicators serve to inform and guide the operator in manipulating the simple controls, or to indicate that remote control is in effect.

The 1689-9751 instrument also stands on a table or bench, where the bail provided under its front edge can be used to tilt it back for operator convenience. This model goes particularly well in a rack, with its vertical front panel and cable connection (from either front or rear) to a suitable test fixture. 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 References**

Electrical and physical characteristics 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 1689-9751 instrument. Figure 1-2 shows the front controls and displays. Table 1-1 identifies them with descriptions and functions.

Similarly, Figure 1-3 shows the controls and connectors on the rear of the 1689-9751. Table 1-2 identifies them.





Figure 1-1. The 1689-9751 RLC DigiBridge tester, front view.

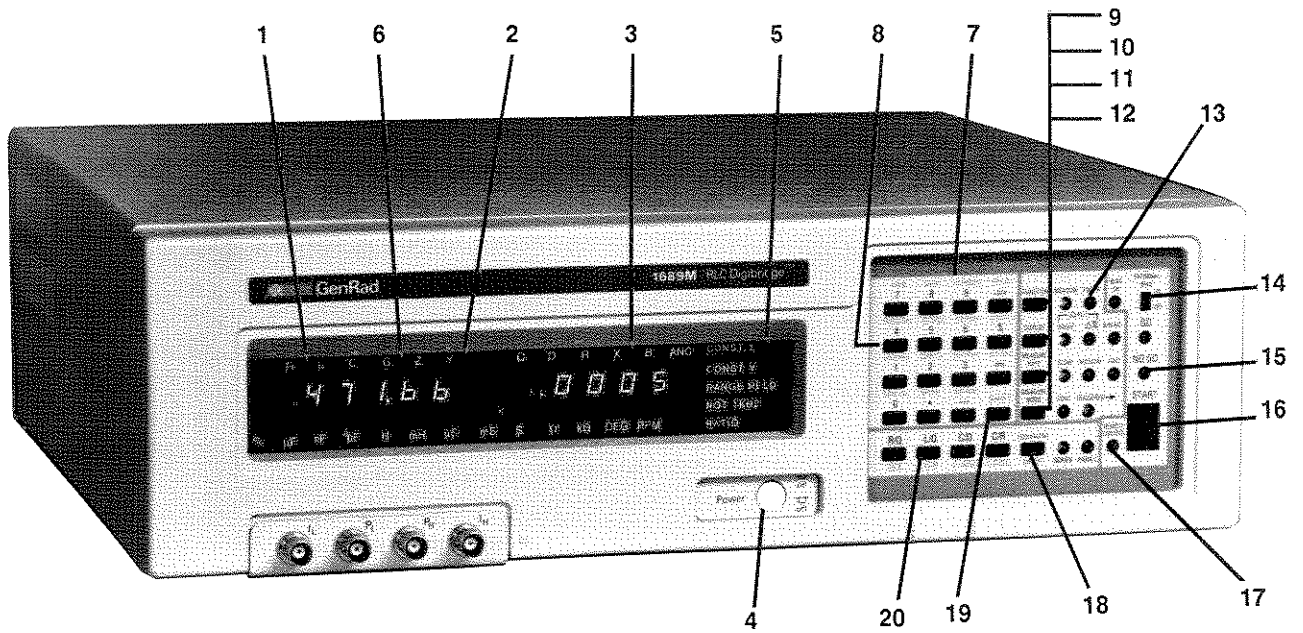


Figure 1-2. Front controls and displays: 1689-9751 DigiBridge.

Table 1-1  
FRONT CONTROLS AND INDICATORS

Fig. 1-2

| Ref No. | Name                           | Description   | Function   |
|---------|--------------------------------|---|--|
| 1       | RLOGZY display                 | Digital display, 5 numerals with decimal points and negative sign (-) when applicable | Display of principal measured value. If function is MEASURE and display selection is VALUE, number indicates R, L, C, G, Z, or Y. If display selection is delta% or delta RLC, indicates percentage difference or value difference (respectively) of R, L, C, G, Z, Y compared to stored nominal value. If display selection is BIN NO., indicates bin assignment is 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 the primary and secondary display. Indicates "%" if display selection is delta%. Indicates "PPM" if Q or D display selection is parts per million.   |
| 3       | QDRXBang Display               | Digital display, 4 numerals with decimal points and negative sign (-) when applicable | 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.  |
| 4       | 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.  |
| 5       | Other display-panel indicators | Light-spot (LED) indicators   | CONST I indicates that a fixed current has been selected. CONST V indicates that measurement source resistance is fixed at a low value. RANGE HELD indicates that autoranging is disabled. NOT 1KHZ indicates that a frequency other than 1 kHz has been selected. RATIO indicates that the ratio mode has been selected.  |

Table 1-1 (continued)  
FRONT CONTROLS AND INDICATORS

Fig. 1-2

| Ref No.                            | Name               | Description   | Function  |
|------------------------------------|--------------------|---|---|
| 6                                  | Selected Parameter | Light-Spot Indicators                                 | Indicated parameter selected for primary (RLOGZY) and secondary display (QDRXBANG).   |
| 7                                  | Keyboard           | Group of keys, indicators, and 2 other switches       | Manual programming and control. Refer to items 8 through 20 for more detail.  |
| 8                                  | Programming keys   | Set of 16 keys, generally labeled with black and gray | Multipurpose input of programming instructions, selections, and data. Dual purposes of keys are indicated by color: Black labels apply normally. Gray labels apply immediately after you press and release the [SHIFT] key.   |
| 9 thru 12, 18, and 20 (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.   |
| 9                                  | [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, current, 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.) |
| 10                                 | [DISPLAY] key      | Indicators: VALUE, delta%, BIN NO.                    | Selection of displays for MEASURE function; refer to items 1, 2, and 3 for description of displays. Two indicators are lit simultaneously for deltaRLC. This key has no effect on ENTER-function displays.  |
| 11                                 | [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.   |

Table 1-1 (continued)  
FRONT CONTROLS AND INDICATORS

Fig. 1-2

| Ref No. | Name                     | Description   | Function   |
|---------|--------------------------|---|--|
| 12      | [MEASURE MODE] key       | Indicators: CONT, TRIGGERED   | Mode selection: CONT, continuously repeating measurements; TRIGGERED, single measurement initiated by START button or input signal.  |
| 13      | BIAS ON indicator        | LED indicator   | Indicates that internal bias is on, or the EXTERNAL BIAS switch is ON.   |
| 14      | EXTERNAL BIAS switch     | Slide switch, 2 positions: ON, OFF                                  | To connect and disconnect the external bias circuit (rear connector, cable supplied).  |
| 15      | 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. |
| 16      | START button             | Pushbutton switch.  | Starts measurement sequence (aborting any measurement that may be in process). Normally used in TRIGGERED measure mode.  |
| 17      | REMOTE CONTROL indicator | LED indicator   | Indicates when remote control is established by external command. (Functions only if an interface option is installed.)  |
| 18      | EQUIVALENT CIRCUIT key   | Indicators: SERIES and PARALLEL                                     | Selection of equivalent circuit. Selection of EQUIVALENT CIRCUIT for R/Q, C/D, L/Q, or C/R, R/X is always SERIES, G/B is always PARALLEL, Z/ANG and Y/ANG are MAGNITUDE.                                     |
| 19      | SHIFT key                | Key labeled SHIFT   | Pressing this shifts the role of any key labeled with both black and gray FROM the white TO the gray label. Do NOT hold the [SHIFT] key down; press it first, then the other key.                            |
| 20      | Parameter keys           | Set of 4 keys, labeled: R/Q, L/Q, C/D, C/R, R/X, G/B, Z/Ang, Y/Ang. | Selection of principal and secondary measurement parameters. In the ENTER mode, repeated pushing of any one parameter key changes the range in sequence 4 3 2 1 4 . . . and hence measurement values.        |

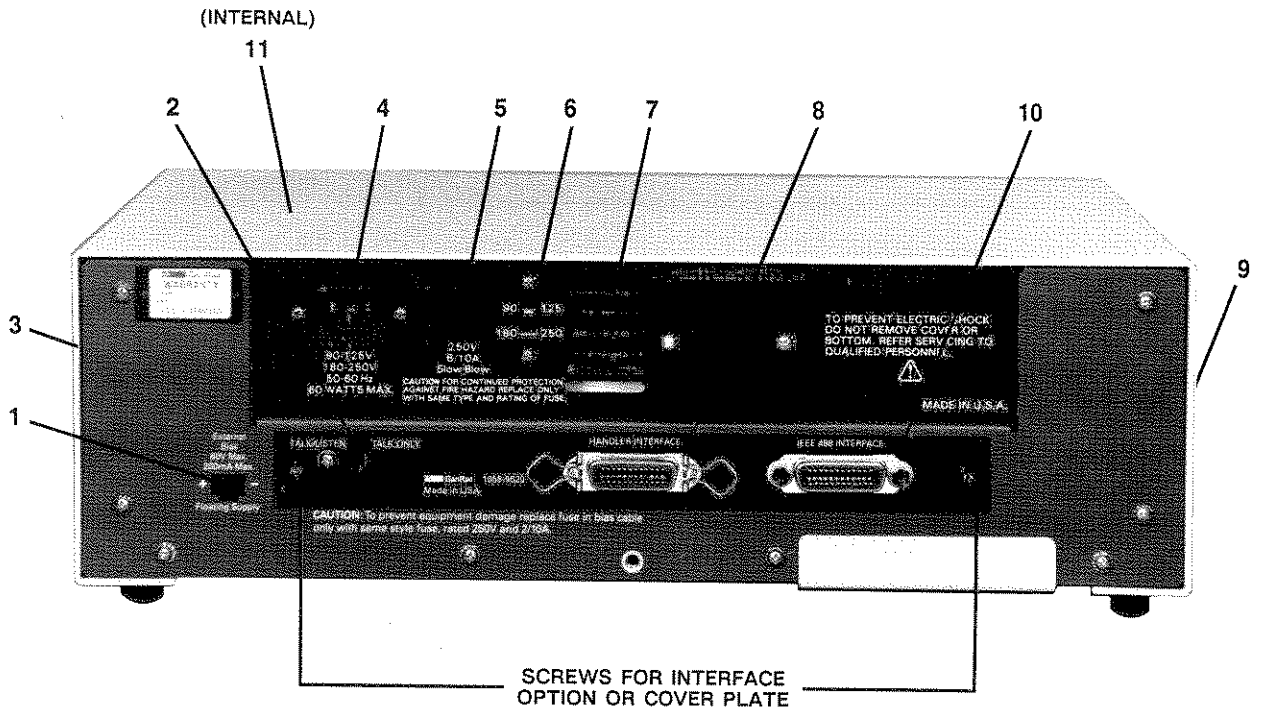


Figure 1-3. Rear controls and connectors, 1689-9751 Digibridge.

Table 1-2  
REAR CONNECTORS AND CONTROLS

Fig. 1-3

| 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 a small screw driver, not a 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. |

Table 1-2 (continued)  
REAR CONNECTORS AND CONTROLS

Fig. 1-3

| Ref.No. | Name         | Description  | Function   |
|---------|--------------|--|--|
| 11      | Fuse (1/4 A) | Plug-in type, sub-miniature, quick acting. Manufacturers Part No. 273.250 by LITTLEFUSE, Inc., 800 E. Northwest Hwy., Des Plains, IL 60016 | Protects instrument circuitry from damage by charged capacitors. |

#### 1.4 ACCESSORIES

GenRad makes several accessories that enhance the usefulness of each Digibridge. A choice of extender cables facilitates making connection to a parts handler or to any DUT that does not readily fit the 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 GenRad Sales Office. (Refer to the back of this manual.)

#### NOTE

The GenRad line of Digibridge test fixtures, adaptors, and other accessories does continue to be improved and expanded. Inquire periodically at your local GenRad sales office for the latest information.

Table 1-3  
ACCESSORIES AND OPTIONS FOR 1689-9751 DIGIBRIDGE

| 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   |
| 1 supplied    | Bias cable, with built-in fuse, to connect external bias supply and switching circuit.  | 1658-2450   |
| 1 supplied    | BNC cable assembly, 4 color coded cables with known "stray" parameters, 90 cm (36 in.) long. (Supplied with BNC-to-banana-plug adaptors.)   | 1689-9602   |
| 1 supplied    | IEEE-488/handler interface option retrofit (plug-in).   | 1658-9620   |
| 1 recommended | Tweezers, for handling and measuring chip components with terminals on opposite faces. BNC connectors; 127-cm (50-inch) cable. (No adaptor needed.)   | 1689-9603   |
| 1 available   | High-speed measurement and IEEE-488/handler interface option retrofit (plug-in) can be used in place of the 1658-9620 above.  | 1689-9620   |
| 1 recommended | Rack mount kit. (Digibridge front panel is always accessible; the BNC connectors for cable to test fixture can be mounted on either front or rear panel.)   | 1689-9611   |
| 1 recommended | Remote test fixture for radial-lead DUTs (like test fixture on 1689 Digibridge), with BNC connectors. Use 1689-9602 cable (supplied with 1689-9751). Use axial-lead adaptors (supplied) if appropriate. Accepts other accessories, like extender cables 1657-9600, 1688-9600. | 1689-9600   |
|               | OR  |             |
|               | Remote test fixture (like the 1689-9600); also has START bar, GO/NO-GO lights, which functions only if Digibridge has an interface option (1689-9620 or 1658-9620). Use cables 1689-9602 (supplied with 1689-9751) and 1689-2400 (included with this fixture).                | 1689-9605   |



Table 1-3 (continued)  
ACCESSORIES AND OPTIONS FOR 1689-9751 DIGIBRIDGE

| Quantity      | Description  | Part Number |
|---------------|--|-------------|
| 1 recommended | Test-fixture adaptors (set of 4) for axial-lead parts. For use with 1689-9600 or 9605 above.   | 1657-5995   |
| 1 recommended | Calibration kit, contains six Kelvin-connected references (four precision resistances, open, and short), that plug into the 1689-9605 or the 1689-9600 test fixture.   | 1689-9604   |
| 1 recommended | Kelvin Clip Cable, for measuring large, low impedance components.  | 1689-9606   |
| 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 remote test fixture of Digibridge; other end terminates in 5 stackable banana plugs. For use with 1689-9600 or 9605 above.                                 | 1657-9600   |
| 1 recommended | Extender cable for connection to standards, large or remote DUT, custom test fixture, dielectric measurement cell, etc. Length 30 cm (12 in.). One end fits remote test fixture of Digibridge; other end terminates in four type 874 coaxial connectors. For use with 1689-9600 or 9605 above. | 1688-9600   |

# Condensed Operating Instructions For 1689-9751 Digibridge

## 1 GENERAL INFORMATION

The 1689-9751 RLC Digibridge® is a microprocessor-controlled, automatic RLC meter. It measures impedance of the device under test (DUT) and displays its parameters: *R, L, C, G, Z* or *Yand D, Q, R, X, B*, or *Angle*. A front-panel keyboard is used to select and program measurement and test conditions. The test signal is programmable from 5 mV to 1.275 and from 12 Hz to 200 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

- Set line-voltage switch (rear panel) to power-line voltage.
- 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).
- Switch EXTERNAL BIAS OFF (front panel).
- Connect power cord to source of proper voltage.
- Press POWER button "in". Self-check codes will show briefly.
- 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 3.14.) 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:
- Connect a test fixture to the instrument and position for use.
  - Open Circuit.* The MEASURE keyboard light should be lit. Press [MEASURE MODE] key to select TRIGGERED mode. Be sure that test fixture is open circuited. Press keys: [C/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.
  - 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

- 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)
- To measure *C* and *D* of a Capacitor (C Range .00001 pF to 99999  $\mu$ F, D range .0001  $\Omega$  to 9999): Press [C/D]. Place capacitor in test fixture. Press START. The RLCGZY display shows C (series capacitance) and units ( $\mu$ F, nF, pF); the QDRXB Angle display shows D (dissipation factor). If RLCGZY is negative, DUT is inductive.)
- To measure *C* and *R* of a Capacitor (C Range .00001 nF to 99999  $\mu$ F, R range .0001  $\Omega$  to 9999 k $\Omega$ ): Press [C/R]. Place capacitor in test fixture. Press START. The RLCGZY display shows C (series capacitance) and units ( $\mu$ F, nF); the QDRXB Angle display shows R (equivalent series resistance) and units ( $\Omega$ , k $\Omega$ ). (If RLCGZY is negative, DUT is inductive.)
- To measure *L* and *Q* of an Inductor (L range .00001 mH to 99999 H, Q range .0001 to 9999): Press [L/Q]. Place inductor in test fixture. Press START. The RLCGZY display shows L (series inductance) and units (mH, H); the QDRXB Angle display shows Q (quality factor). (If RLCGZY is negative, DUT is capacitive.)
- To measure *R* and *Q* of a Resistor (R range .00001  $\Omega$  to 99999 k $\Omega$ , Q range .0001 to 9999): Press [R/Q]. Place resistor in test fixture. Press START. The RLCGZY display shows R (series resistance) and units ( $\Omega$ , k $\Omega$ ); the QDRXB Angle display shows Q (quality factor). (If QDRXB Angle is negative, DUT is capacitive; if not, DUT is inductive.)
- To measure *R* and *X* or a component (R range .00001  $\Omega$  to 99999 k $\Omega$ , X range .0001  $\Omega$  to 9999 k $\Omega$ ): Press [SHIFT] [R/X]. Place component in test fixture. Press START. The RLCGZY display shows R (series resistance) and units ( $\Omega$ , k $\Omega$ ); the QDRXB Angle display shows X (series reactance) and units ( $\Omega$ , k $\Omega$ ). (If QDRXB Angle is negative, DUT is capacitive.)
- To measure *G* and *B* of a component (G range .00001  $\mu$ S to 99999 S, B range .0001  $\mu$ S to 9999 S): Press [SHIFT] [G/B]. Place component in test fixture. Press START. The RLCGZY display shows G (parallel conductance) and units ( $\mu$ S, mS, S); the QDRXB Angle display shows B (parallel susceptance) and units ( $\mu$ S, mS, S). (If QDRXB Angle is negative, DUT is inductive.)
- To measure *Z* and Angle of a component (Z range .00001  $\Omega$  to 99999 k $\Omega$ , Angle range .0001° to 180°): Press [SHIFT] [Z/ANG]. Place component in test fixture. Press START. The RLCGZY display shows Z (impedance) and units ( $\Omega$ , k $\Omega$ ); the QDRXB Angle display shows Angle and units (degrees). (If QDRXB Angle is negative, DUT is capacitive.)
- To measure *Y* and Angle of a component (Y range .00001  $\mu$ S to 99999 S, Angle range .0001° to 180°): Press [SHIFT] [Y/ANG]. Place component in test fixture. Press START. The RLCGZY display shows Y (Admittance) and units ( $\mu$ S, mS, S); the QDRXB Angle display shows Angle and units (degrees). (If QDRXB Angle is negative, DUT is inductive.)

- 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: "% $\Delta$ " shows the difference of measured RLC from nominal in percent of nominal value. "VALUE and  $\Delta$ %", both lit, shows the difference from nominal in measurement units ( $\mu$ F, mH, etc). "BIN NO" shows the assigned bin number.
- Other Parameters, Rates, Modes. To measure C/R, C/D, L/Q or R/Q parallel, 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.)
- Press [FUNCTION] key to select ENTER function.
  - Test frequency (normally 1 kHz) can be programmed from .012 kHz to 200 kHz. For 400 Hz, press [.] [4] [=] [SHIFT] [FREQUENCY].
  - Test voltage (normally 1 V) can be programmed from .005 V to 1.275 V. For 15 mV, press [.] [0] [1] [5] [=] [SHIFT] [VOLTAGE].
  - 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].
  - Delay. A delay of 1 to 99999 ms can be added to normal test time. For 238 ms, press [2] [3] [8] [=] [SHIFT] [SPECIAL] [4].  
Note: For steps b...e, to see present conditions, press [SHIFT] [FREQUENCY], [SHIFT] [VOLTAGE], [SHIFT] [AVERAGE], [SHIFT] [SPECIAL] [4].
  - For internal 2-volt dc bias for capacitors, press [SHIFT] [INT BIAS]. To remove internal bias, repeat [SHIFT] [INT BIAS].
  - For D and Q displayed in parts per million, press [SHIFT] [DQ in PPM]. For decimal D Q displays, repeat [SHIFT] [DQ in PPM].
  - To hold test voltage constant, press [SHIFT] [CONST V]. To cancel this selection, repeat [SHIFT] [CONST V].
  - To hold a range: Measure a DUT in the range desired; or press one of the parameter keys ([R/Q] [L/Q] [C/D] [C/R] or [SHIFT] [R/X] [G/B] [Z/ANG] [Y/ANG]) repeatedly to step through the four ranges. When the desired range is indicated (by RLCGZY 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

- Press [DISPLAY] key to select VALUE. Press [FUNCTION] key to select ENTER.
- To enter a single QDRXB Angle limit (always bin 0): press parameter key (such as [C/D]) appropriate to DUT. To change range and unit multipliers, press same key repeatedly. Enter max limit of D, R (series), X, B, Angle or Q with R; enter min limit of R (parallel) 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.
- To enter RLCGZY 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 RLCGZY 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  $\pm 0.2\%$ : press [.] [2] [%] [=] [SHIFT] [BIN NO] [0] [1]. The numerical limits for RLCGZY 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.
- You can close any bin that has been opened (steps b, c). For RLCGZY bins, follow this example for bin 8: press [0] [=] [SHIFT] [BIN NO] [0] [8]. To disable QDRXB Angle sorting, close bin 0 thus: D, R (series), X, B, Angle or Q with R; press [9] [9] [9] [=] [SHIFT] [BIN NO] [0] [0]; for R (parallel) or Q with L, press [0] [=] [SHIFT] [BIN NO] [0] [0].
- 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].
- 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 QDRXB Angle failure (bin 0) or RLCGZY failure (bin 14). See manual, paragraph 3.8.

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# Installation – Section 2

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|  |      |
|--|------|
| 2.1 UNPACKING AND INSPECTION . . . . . | 2-1  |
| 2.2 DIMENSIONS . . . . .               | 2-1  |
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## 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.

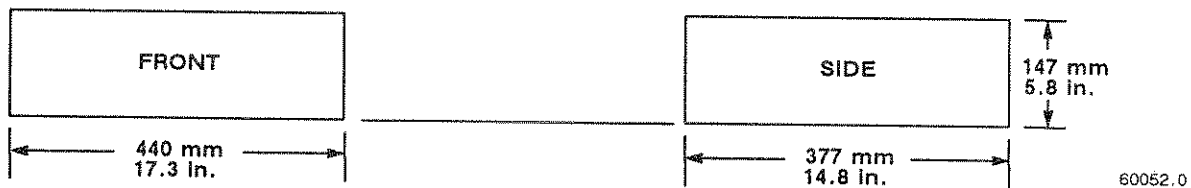


Figure 2-1. Overall dimensions of the Digibridge tester.

### 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.

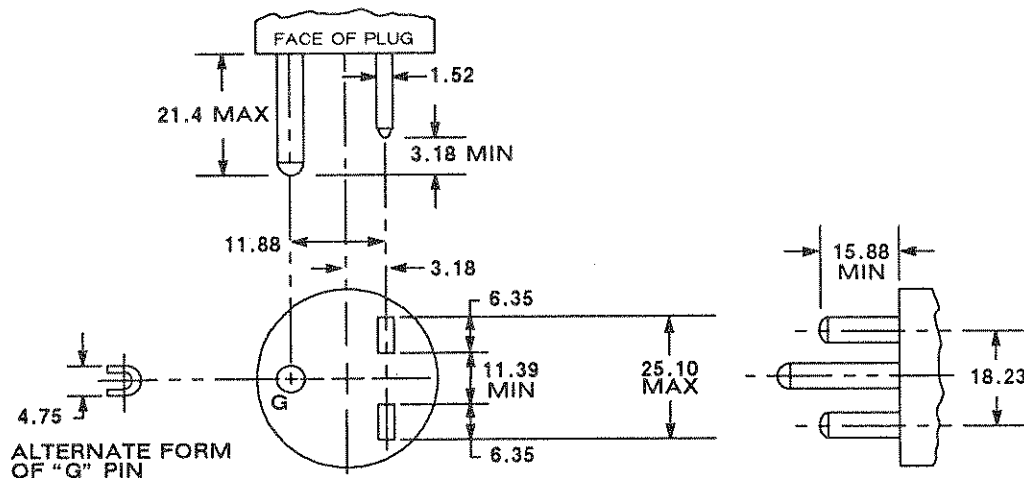
If your line voltage is in the lower range, connect the 3-wire power cable (P/N 4200-0300) to the power connector on the rear panel (Figure 1-2) and then to the power line.

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™ tester 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 Figure 2-2.

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.



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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  $\pm 15\%$  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

An external test fixture is always required, because connection from the 1689-9751 Digibridge to the DUT is provided via BNC cables (from connectors that can be positioned at either front or rear of the instrument, as described in Section 5). For general purposes, the recommended test fixture, cable, and their connections are as follows. Refer to paragraphs 1.4 and 3.2 for more information about accessories.

| On 1689-9751 | Cable 1689-9602 | On 1689-9600 or -9605 Test Fixture |
|--------------|-----------------|------------------------------------|
| IL           | black band      | I+                                 |
| PL           | black & white   | P+                                 |
| PH           | red & white     | P-                                 |
| IH           | red band        | I-                                 |

COMMENT: It is important that the IL and PL leads connect to the same end of the DUT (and that PH and IH connect to the other end). Also, connecting IL/PL to the test-fixture connectors labeled "+" (and IH/PH to "-") assures that the test fixture's "+" and "-" labels agree with the bias polarity.

NOTE: In the cable's color code, RED is associated with "hot" leads, which have dc voltage, negative with respect to ground, when bias is used.

## 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.

- Be sure that the voltage is never more than 60 V, max.
- A current limiting voltage supply is recommended; set the limit at 200 mA, max.
- Be sure that the bias supply is floating; DO NOT connect either lead to ground.
- A well-filtered supply is recommended. Bias-supply hum can affect some measurements, particularly if test frequency is the power frequency.
- 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.

- 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

Refer to Table 2-1 for the key to Handler Interface signal names, functions, and pin numbers.

### 2.7.1 Interface via IEEE-488 Bus / Handler Interface Option (1658-9620) (Supplied with 1689-9751).

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 1-3 verifies that you have one of the interface options). 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 1658-9620 IEEE-488 Bus / Handler Interface Option 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.

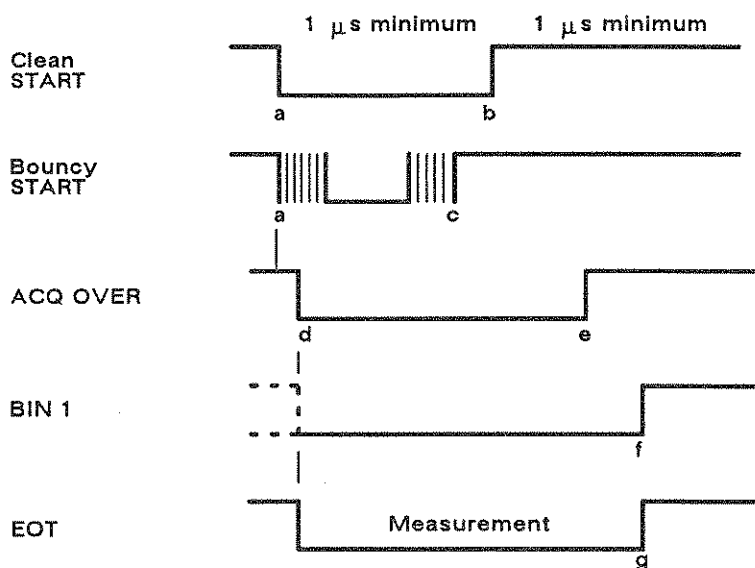
The cautionary note above means typically that each relay or other inductive load requires a clamping diode (rectifier) across it (cathode connected to the power-supply end of the load).

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.

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 option: 1689-9620 (high-speed).
  - \*\* Interface plug-in option: 1658-9620 (supplied with 1689-9751).
  - \*\*\* Low-power dc bus (+5 V) available for systems use, commonly for opto-couplers. CAUTION: Limit the load to 25 mA, max.
  - \*\*\*\* EOT is enabled if binning is enabled (by having a non-zero nominal value).



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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.

### 2.7.2 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 stays 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.

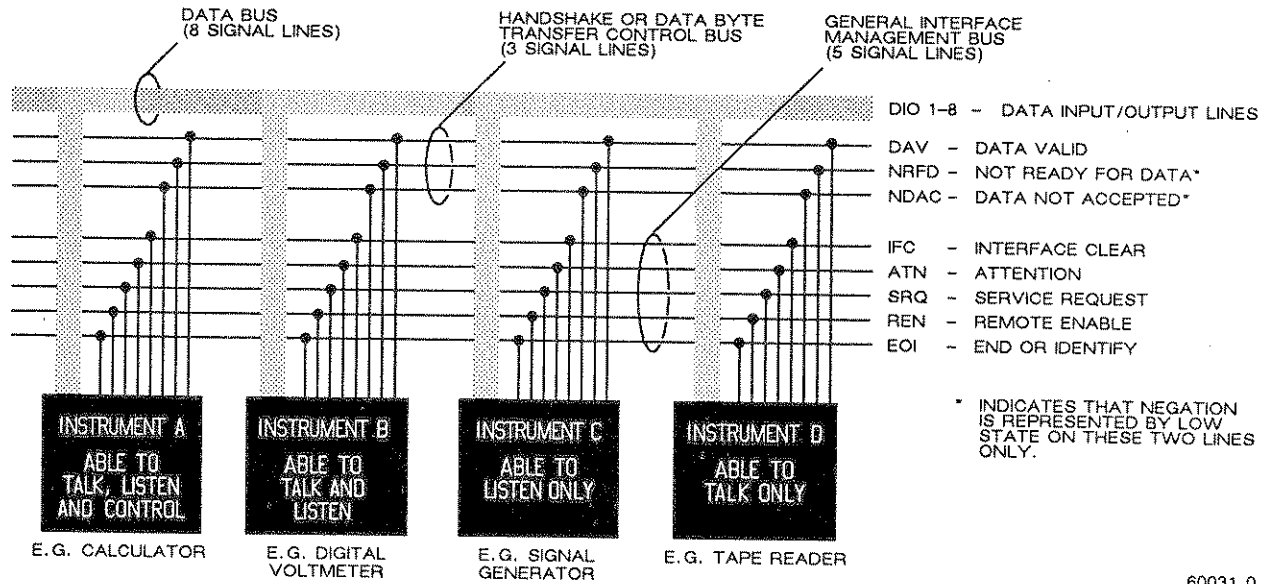


Figure 2-4. Block diagram of a generalized system interconnected by the 16-signal line bus specified in the IEEE Standard 488. Reprinted from *Electronics*, November 14, 1974; copyright McGraw-Hill, Inc., 1974.

## 2.8 IEEE-488 INTERFACE (SUPPLIED)

### 2.8.1 Purpose

### Figure 2-4.

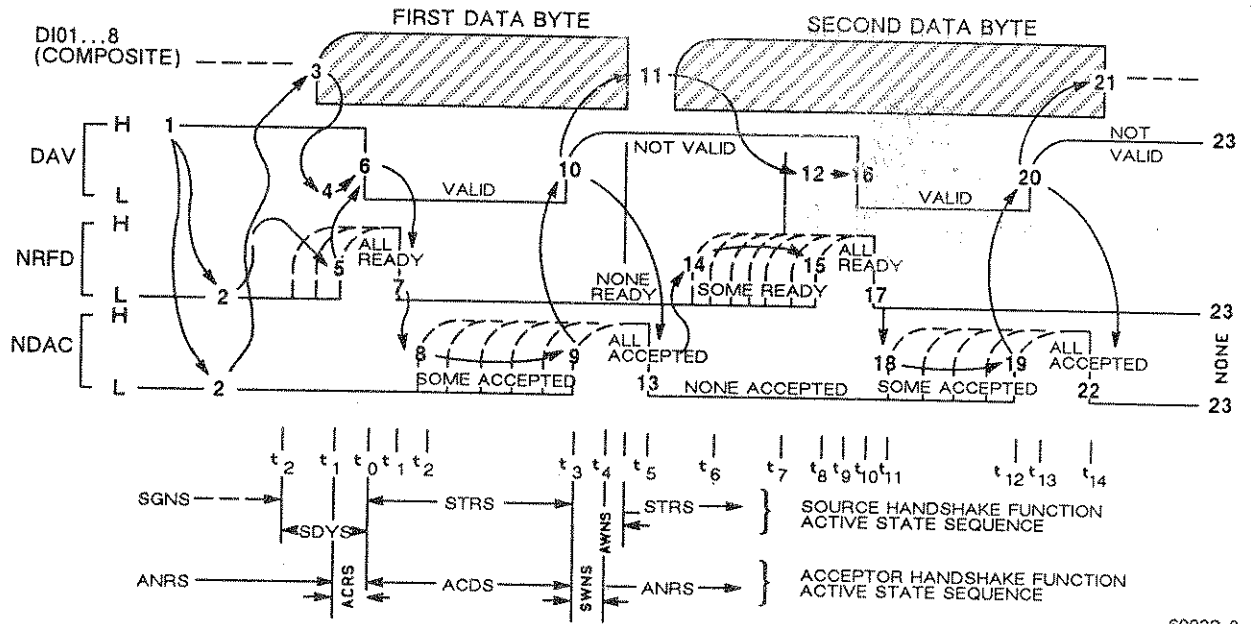
If you have either interface option, you can connect this instrument to a printer or into a system (containing a number of devices such as instruments, apparatus, peripheral devices, and generally a controller or computer) in which each component meets IEEE Standard 488-1978, Standard Digital Interface 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 on the rear panel of this instrument.

#### 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.



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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.

## 2.8.2 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
- DC1, 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.

### 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.

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

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       | NRFED       | 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 portion 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.*<br>"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.

Table 2-3  
ADDRESS PAIRS AND SETTINGS FOR SWITCH S2

| Talk address |           | Listen address |           | Switch setting* |
|--------------|-----------|----------------|-----------|-----------------|
| Symbol       | Binary    | Symbol         | Binary    | 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.)

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.

*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 RLC value is:

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

If the D measurement was .001, the character string for QDR value is:

(2 spaces)D(5 spaces)00.0010(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 RLC 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.

When the Digibridge is mounted in a rack or other enclosed location, make sure that the ambient temperature **inside the rack** does not exceed the limits specified under "Environment" in the Specifications at the front of this manual, and that air can circulate freely past all air inlet and outlet vents.

## 2.10 RACK MOUNTING

Use the following procedure for rack mounting the 1689-9751 Digibridge with the 1689-9611 Rack Mount Kit.

a. If the location of the four BNC connectors (for test-fixture cables) is satisfactory, go on to the next step. Otherwise, the BNC connector location can be moved from front to rear (or vice versa); this is a SERVICE procedure, described in Section 5, paragraph 5.5.

b. Preassemble the instrument with the shelf of the 1689-9611 Rack Mount Kit, as follows. Place the instrument on the shelf so that its feet drop through the large holes. Lift the shelf up snugly under the instrument and secure them together with a No. 10-32 screw through the small hole centered at the rear of the shelf, into the corresponding tapped hole in the instrument's rear panel.

### NOTE

This screw is important for electrical grounding, as well as for mechanical security.

c. Position this assembly in the rack as desired and fasten the shelf at front of the rack, using the four dress screws, supplied. If the rack's mounting holes are tapped with number 10-32 threads, the nuts supplied for these screws can be omitted.



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# Operation – Section 3

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## 3.1 BASIC PROCEDURE

### 3.1.1 General

For initial familiarization with the Digibridge™ RLC tester, follow this procedure carefully. After that, use this paragraph as a ready reference and refer to later paragraphs in this section for details. Condensed operating instructions are provided near the front of this manual.

### 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 tester 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 instrument 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 tester 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. Under some conditions, the block to operation can be bypassed. (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 instrument 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.

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.
- Connect the remote test fixture or at least the BNC cables and adaptors that will contact the DUT.
- Be sure that the test fixture is open circuited.
- If you want this "zero" process to echo a display of 00000, press the [C/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.  
Watch the GO indicator on the keyboard; not one on any remote test fixture.
- 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.

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

- Function: MEASURE ([FUNCTION] key), a necessary selection
- Display: VALUE ([DISPLAY] key), for normal RLC/QDR results
- Measure rate: SLOW ([MEASURE RATE] key), for best accuracy
- Measure mode: TRIGGERED ([MEASURE MODE] key), optional
- 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 [C/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. (See note below.)

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.

#### NOTE

Use either the Digibridge START button or the start bar on the 1689-9605 test fixture (if properly connected).

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 [C/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 "--" 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 [C/R]. 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 "--" 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 [L/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 "--" 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 [R/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 "--" 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.



Figure 3-1. Remote test fixture (1689-9605), connected to 1689-9751 Digibridge tester.

### 3.2.2 The 1689-9600 or -9605 Remote Test Fixture (with -9602 BNC Cable) Figure 3-1.

Connection of the DUT at a remote test fixture normally requires:

- Remote Test Fixture 1689-9600, 1689-9605, or equivalent special fixture.
- BNC Cable Assembly 1689-9602 -- *supplied with 1689-9751 Digibridge*

This remote test fixture provides that 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, cables, etc, if present, from the DUT port of the instrument.

b. Connect the BNC cable assembly to the Digibridge and to the remote test fixture as indicated in Table 3-1. Note that red designates leads that may be "hot". (When bias is applied, they carry dc negative voltage with respect to ground.)

Table 3-1  
REMOTE TEST FIXTURE CONNECTIONS VIA BNC CABLE

| Test-Circuit Function | Bias Polarity | BNC Connector at Digibridge | Color Code on 1689-9602 Cable | Connection at 1689-9600/-9605 Test Fixture* |
|-----------------------|---------------|-----------------------------|-------------------------------|---|
| 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 reading the legend.

c. For the 1689-9605 remote test fixture --- in order to activate the "Start" bar and the GO/NO-GO lights --- connect the 1689-2400 Remote Tester Cable (supplied with the fixture) as follows. Connect one end to the HANDLER INTERFACE connector behind the instrument. Connect the other end to a similar connector behind the fixture.

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

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.) For notes on cable and fixture capacitance and zeroing, see paragraph 3.2.7, below.

### 3.2.3 Using the Remote Test Fixture for Radial-Lead DUTs

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

The test fixture provides convenient, reliable, guarded 4-terminal connection to any common radial-lead or an axial-lead component part (using adaptor, 1657-5995). 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.

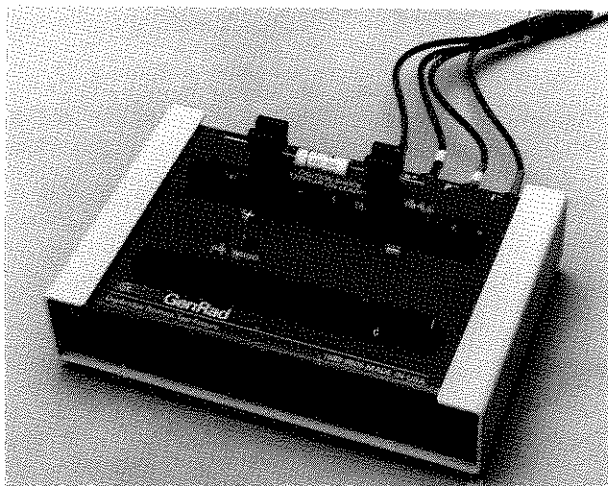


Figure 3-2. Use of the adaptors for connection of an axial-lead DUT to the Digibridge Remote Test Fixture.

### 3.2.4 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 test-fixture adaptor's slots as shown in Figure 3-2 and described below.

Install the test-fixture adaptors as shown in Figure 3-2; put one in each slot of the test fixture, by pushing vertically downward. Slice 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).

### 3.2.5 The 1688-9600 Extender Cable ("Type 874" Connectors)

The accessory extender cable 1688-9600 can be used to connect a DUT that is multiterminal, physically large, or otherwise unsuited for the test fixtures. 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 (remote test fixture type 1689-9600 or 1689-9605 used with the 1689-9751).
- b. Plug the single-connector end of the extender cable into the test fixture so that its blades enter both slots and the cable lies away from the display panel (or away from the BNC connectors of the remote test fixture). Lock the connector with the two captive thumb screws.
- c. Using the type 874 connectors, connect to the DUT with careful attention to the following color code.

|                       |                |   |
|-----------------------|----------------|---|
| IL (current, low)     | Black/black    | Connect to first (+) main terminal of DUT.                                      |
| PL (potential, low)   | Black/white    | Connect to first main terminal of DUT.  |
| PH (potential, high)  | Red/white      | Connect to second (-) main terminal of DUT.                                     |
| IH (current, high)    | Red/red        | Connect to second main terminal of DUT.   |
| Guard (shield or gnd) | Outer contacts | Connect to shield or case of DUT, if any, only if isolated from main terminals. |

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.*

### 3.2.6 The 1657-9600 Extender Cable (Banana Plugs) and BNC Cable with Banana Plug Adaptors

#### *1657-9600 Extender Cable*

The accessory extender cable 1657-9600 is available to connect to DUTs that are multiterminal, physically large, or otherwise unsuited for the remote test fixtures. (Refer to Table 1-3.) This cable is particularly convenient for connecting multiterminal components with binding posts that accommodate banana plugs.

- a. Remove the adaptors, if present, from the test fixture.
- b. Plug the single-connector end of the extender cable into the remote 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. Refer to the following tabulation.



|                       |             |   |
|-----------------------|-------------|---|
| IL (current, low)     | Black       | Connect to first (+) main terminal of DUT.                                |
| PL (potential, low)   | Black/white | Connect to first main terminal of DUT.                                    |
| PH (potential, high)  | Red/white   | Connect to second (-) main terminal of DUT.                               |
| IH (current, high)    | Red         | Connect to second main terminal of DUT.                                   |
| Guard (shield or gnd) | Black/green | Connect to shield of DUT, if any, but <i>not</i> to either main terminal. |

NOTE: The Kelvin junctions (IL & PL) and (PH & IH) can be made by using stackable banana plugs, for convenience --- so that only one connection is sufficient at each main terminal of the DUT. Then, to obtain best results, it is very important to locate the banana-plug hardware in final position while zeroing (paragraph 3.1.3).

#### *BNC Cable with Adaptors to Banana Plugs*

This arrangement is used for the same applications as described above.

- a. Connect 1689-9602 BNC cable to 1689-9751 Digibridge as specified in Table 3-1.
- b. Connect the set of four BNC-to-banana-plug adaptors to the free end of this cable. (One of these adaptors, supplied with 1689-9751, has a pigtail for connecting "guard", which may not be identified with the colors that the table indicates.)
- c. Connect the banana plugs (and guard, if appropriate) to the DUT as described above.

#### NOTE

Avoid contact between outer conductors of BNC-to-banana adaptors. Otherwise, measurements with high test frequency are liable to have errors that result from the changing mutual inductances between shields of cable conductors.

### 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 zeroing process (paragraph 3.1.3) 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 ground to IL and  $C$  from ground to PL, in parallel, designated  $C_{sn}$ ) 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  $C_{sn}$  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.

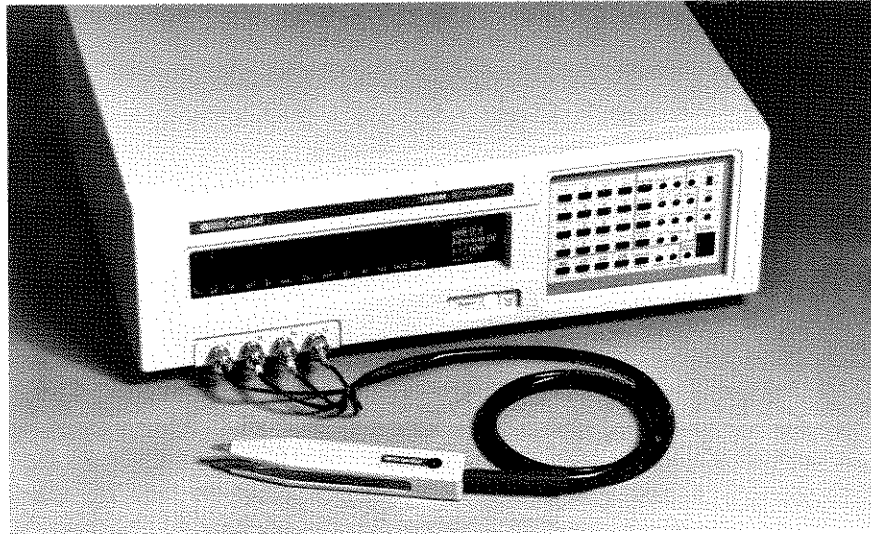


Figure 3-3. 1689-9603 tweezers connected to the 1689-9751 Digibridge

### 3.2.8 The 1689-9603 Tweezers

Figure 3-3.

The 1689-9603 tweezers combine the two functions:

1. Tweezers for handling chip components, up to 0.5 in. (12 mm) thick.
2. Test fixture for measuring these components, if their terminals are on opposite faces.

With these tweezers, you can conveniently pick up a tiny chip component, measure it, and put it in a bin (or decide what else to do with it), all in one operation.

- a. Remove any adaptors, cables, etc, if present, from the DUT port of the instrument.
- b. Connect the BNC cables of the tweezer assembly to the Digibridge as indicated in Table 3-1. Note that red designates leads that may be "hot". (When bias is applied, they carry dc negative voltage with respect to ground.)
- c. If dc bias is used (see paragraph 3.7), notice that the faces of the tweezers are labeled "+" and "-" to indicate bias polarity.

### 3.2.9 The 1689-9606 Kelvin Clip Cable

The 1689-9606 Kelvin Clip Cable provides a means for easily making four terminal (Kelvin) connections to passive components. This cable is especially useful for testing low impedance devices or devices that have large non-standard terminations, such as electrolytic capacitors or inductors.

Installations on the 1689-9751 Digibridge requires the 1689-9601 BNC Adaptor. Install Kelvin Clips as follows:

- a. Remove any adaptors, cables, etc, if present, from the DUT port of the instrument.
- b. Connect the BNC cables of the kelvin clips to the Digibridge as indicated in Table 3-1. Note that red designates leads that may be "hot". (When bias is applied, they carry dc negative voltage with respect to ground.)
- c. If dc bias is used (see paragraph 3.7), notice that the kelvin clips are color-coded "+" (black) and "-" (red) to indicate bias polarity.

NOTE: Instructions supplied with the 1689-9606 may differ from Table 3-1. It is important to be aware that if DC BIAS is used, that it is a negative voltage and that it is applied to the IH lead from the instrument.

### 3.3 MEASUREMENT PARAMETERS, RESULTS DISPLAYS, AND OUTPUTS

#### 3.3.1 Parameters (R/Q, L/Q, C/D, C/R, R/X, G/B, Z/ANG, Y/ANG)

*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 [C/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].

or

[SHIFT][R/X, G/B, Z/ANG, Y/ANG]

The LEDs above the display will indicate which parameter is selected.

- b. Use the [EQUIVALENT CIRCUIT] key to select SERIES or PARALLEL. Table 3-2 indicates the displayed results.

Table 3-2  
EQUIVALENT CIRCUIT MANUAL SELECTION DISPLAYED RESULTS

| KEY   | SERIES    | PARALLEL  | PARAMETER MEASURED      | UNITS           |
|-------|-----------|-----------|-------------------------|-----------------|
| R/Q   | $R_s/Q$   | $R_p/Q$   | Resistance/Quality      | Ohms/none       |
| L/Q   | $L_s/Q$   | $L_p/Q$   | Inductance/Quality      | Henries/none    |
| C/D   | $C_s/D$   | $C_p/D$   | Capacitance/Dissipation | Farads/none     |
| C/R   | $C_s/R_s$ | $C_p/R_p$ | Capacitance/Resistance  | Farads/Ohms     |
| R/X   | $R_s/X_s$ | *         | Resistance/Reactance    | Ohms/Ohms       |
| G/B   | *         | $G_p/B_p$ | Conductance/Susceptance | Siemens/Siemens |
| Z/ANG | *         | *         | Impedance/Angle         | Ohms/Degrees    |
| Y/ANG | *         | *         | Admittance/Angle        | Siemens/Degrees |

-----  
\* Not Applicable

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 parameter and unit indicators will be lit. (However, do not attempt to select the unit multiplier.) The Digibridge will automatically switch to the appropriate multiplier -- from  $\mu\text{F}$  to  $\text{pF}$  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.

*Negative RLC.* If RLC is negative 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.)

For more information about both the -- RLC and the -- 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,  $C_s$  differs substantially from  $C_p$  and  $L_s$  differs substantially from  $L_p$ ; 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 10 pF: Parallel, 10 kHz.
- Capacitors from 10 to 400 pF: Series or Parallel, 10 kHz.
- Capacitors from 400 pF to 1  $\mu$ F: Series, 1 kHz.
- Capacitors greater than 1  $\mu$ F: 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 capacitance, select a higher measurement frequency for best accuracy. (Refer to paragraph 3.6.) Conversely, for very large capacitance, select a lower measurement frequency for best accuracy.

- Inductors less than 10  $\mu$ H: Series, 100 kHz.
- Inductors from 10  $\mu$ H to 1 mH: Series, 10 kHz.
- Inductors from 1 mH to 1 H: Series, 1 kHz.
- Inductors greater than 1 H: Series, 0.1 kHz.

Select "series" as explained above. For very small inductance, select a higher measurement frequency for best accuracy. Conversely, for very large inductance, select a 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  $R_p$  is probably very close to the dc resistance.

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 Figure 3-4, together with useful equations relating them. Notice that the Digibridge measures the equivalent series components  $R_s$ ,  $L_s$ , or  $C_s$ , if you select SERIES EQUIVALENT CIRCUIT. It measures the parallel equivalent components  $R_p$ ,  $L_p$ , or  $C_p$  if you select PARALLEL.  $D$  and  $Q$  have the same value regardless whether series or parallel equivalent circuit is calculated.

**Resistance and Inductance**

$$X = \omega L$$

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

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

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

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

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

$$B_p = -\frac{1}{\omega L_p} \quad y = G_p - j\frac{1}{\omega C_p}$$

**Resistance and Capacitance**

$$X_s = -\frac{1}{\omega C_s}$$

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

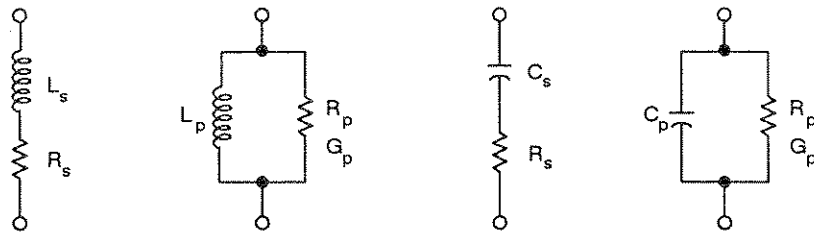
$$D = \frac{1}{Q} \quad D = \omega R_s C_s \quad D = \frac{1}{\omega R_p C_p}$$

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

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

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

$$B_p = \omega C_p \quad y = G_p + j\omega C_p$$



60046.0

Figure 3-4. Equivalent circuits and mathematical relationships for lossy inductors and capacitors.

*Polar Form: Magnitude and Phase.* A complex number may be expressed in polar form as well as in the Cartesian form used so far. For impedance and admittance the relationships are:

$$Z = R_s + jX_s = |Z|e^{j\theta} \text{ and } Y = G_p + jB_p = |Y|e^{j\phi}$$

where  $|Z|$  and  $|Y|$  are the magnitudes and  $\theta$  (theta) and  $\phi$  (phi) are the phase angle in radians (see Figure 3-5).

The magnitude of a complex number is the square root of the sum of the squares of the two parts so that

$$|Z| = \sqrt{R_s^2 + X_s^2} \text{ and } |Y| = \sqrt{G_p^2 + B_p^2}$$

Note that  $|Z| = 1/|Y|$ .

The phase angle of an impedance or an admittance is the angle whose tangent is the ratio of the imaginary part to the real part so that

$$\theta = \arctan (X/R) = \arctan Q, \text{ or } \tan \theta = Q$$

and

$$\phi = \arctan (G/B) = \arctan Q, \text{ or } \tan \phi = Q$$

The size of the phase angle of an admittance is the same as that of the corresponding impedance, but if we use the convention that a positive angle is one in the counterclockwise direction then the angle of an admittance is the negative of that of the corresponding impedance, as one can see from the equation

$$Y = \frac{1}{Z} = \frac{1}{|Z|e^{j\theta}} = \frac{Y}{e^{j\theta}} = |Y|e^{-j\theta} = |Y|e^{j\phi}$$

Euler's formula,

$$e^{jX} = \cos X + j \sin X,$$

is useful when dealing with imaginary exponents and can be used to show that

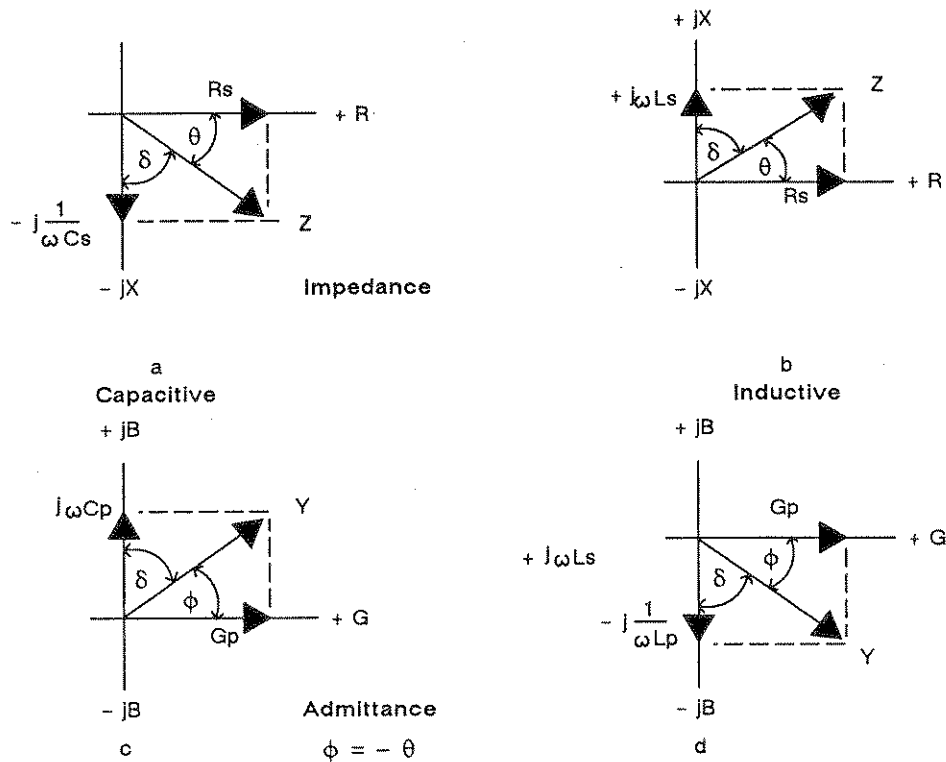
$$R_s = |Z| \cos \theta, \text{ and that } X_s = |Z| \sin \theta$$

These phase relationships can be understood better using the diagrams of Figure 3-5 which show both inductive and capacitive impedance phasors (or planar vectors) on both the Z and Y planes. Here the angle is measured from the positive real axis (+r or +G) and the angle

$\delta$  (delta) is defined as the complement of  $\theta$  and  $\phi$

so one can see that:

$$\text{tangent } \delta = \text{cotangent } \theta = \frac{R_s}{X_s} = \frac{G_p}{B_p} = D.$$



60047.0

Figure 3-5. Phasor diagrams of capacitive and inductive Impedances and admittances.

**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 " $R_s$ " in the preceding paragraph. To obtain ESR, be sure that the SERIES indicator is lit; if you want ESR displayed simultaneously with  $C_s$ , push the  $[C_s/R_s]$  parameter key; if you want the 5-place resolution for ESR, push the  $[R_s/Q]$  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:  $ESR = R_s = D/\omega C_s$  (where  $\omega$  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  $L_p$  at two frequencies near the frequency of interest differ from each other less than do measurements of  $L_s$  at the same two frequencies.



### 3.3.3 Results Displayed

#### PRINCIPAL MEASUREMENT RESULTS

The principal Digibridge measurement will be presented on the left (RLCGZY) 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 R, L, C, G, Z or Y and the secondary one is Q, D, R, X, B or DEG. The VALUE selection is the power-up default and one of the selections of the [DISPLAY] key. For purposes of simplicity, the left display will be called the RLC and the right display called the QDR.

Read the measurement on the main displays. The RLC display is the principal measurement, complete with decimal point parameter and units which are indicated by the light spot in the upper and lower part of the display panel. The QDR display is the secondary measurement, complete with decimal point parameter and units indicator. Leading zeroes before the decimal point are automatically eliminated in most cases by positioning of the decimal point. Otherwise, such zeroes are blanked out.

*Negative RLC.* If the RLC is negative with an L or C value 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.

*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, C/R or [SHIFT] R/X, G/B, Z/ANG, Y/ANG] key. (Repeat keying will change unit multipliers.)
- c. Enter the reference for delta percent by keying:  
(N)[=][SHIFT][NOM VALUE]  
in which N represents 1 to 6 numerical keys and (optionally) the decimal point key (in the units selected), 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.

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.

*DELTA RLC DISPLAY, Selected by the [DISPLAY] Key.* 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. This display is negative, 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 *two* 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.

*Bin No.* 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).

*Ratio Displays.* 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 RESULTS

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.

*Negative QDR.* The sign for QDR has the following meanings.

| Parameter Selection | + QDR                  | - QDR                              |
|---------------------|------------------------|------------------------------------|
| R/Q, R/X, Z/ANG     | 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) |
| G/B, Y/ANG          | DUT is capacitive      | DUT is inductive                   |

If the secondary measurement is Q, D, or R and is negative -- 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 occur when you are measuring certain kinds of multiterminal networks or active devices.

#### NOTE

Improper connection of extender cables can cause a false indication of negative QDR.

*D, Q or ANG IN PPM, Selected by the [SHIFT]/[DQ in PPM] Keys.* For D, Q or ANG 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, D or ANG result only, and is effective for all selections of the [DISPLAY] key except BIN NO, and for all parameter selections except C/R, R/X, and G/B.

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 INDICATORS

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 at the keyboard, for every measurement. If you are using the 1689-9605 remote test fixture, a GO/NO-GO indication appears there also. (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 of R, L, C, G, Z, and Y 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 (see below). To obtain D or Q in percent, from the regular display, move the decimal point two places to the right. For example, a regular display of D = .0045 is equivalent to 0.45%

Table 3-3  
UNITS AND MULTIPLIERS FOR EACH RANGE

| Parameter | Freq: Up to 0.1kHz |    |     |      | From 0.1 to 6kHz |    |     |     | From 6+ to 20kHz |    |     |     | Above 20kHz |    |     |     |
|-----------|--------------------|----|-----|------|------------------|----|-----|-----|------------------|----|-----|-----|-------------|----|-----|-----|
|           | 1                  | 2  | 3   | 4    | 1                | 2  | 3   | 4   | 1                | 2  | 3   | 4   | 1           | 2  | 3   | 4   |
| R, Z      | 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  | nF  |
| G, Y      | uS                 | mS | mS  | S    | uS               | mS | mS  | S   | uS               | mS | mS  | S   | **          | mS | mS  | S   |

\* K represents "kilohms".

\*\* Range 1 is not used if frequency is above 20kHz.

\*\*\* 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.

### 3.3.5 D, Q, ANG in PPM

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

[SHIFT][DQ in PPM]

so that the PPM indicator is lit. To disable this option, repeat the same keystrokes so that the indicator is NOT lit. Units of D and Q in PPM are dimensionless and are expressed as a decimal ratio, with the multiplier of 1,000,000 understood. To obtain D or Q in percent, from the DQ in PPM display, place a decimal point four places to the left of its "understood" position at the right-hand end of the display. For example, a "DQ in PPM" display of  $D = 120$  ppm is equivalent to 0.012%.

### 3.3.6 Ratio Displays, Virtual Range Extensions, and Conductance Measurements, via a Special Function

The Digibridge can easily be programmed to display the principal test result (R, L, C, G, Z, Y) 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.

*For Very Large R, L, or C.* 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 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.

*For Very Small R, L, or C.* 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.

*Procedure.* To program the Digibridge for ratio displays: enter desired nominal value in appropriate units of measurement; 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:

- To display measurement/nominal -- [2][=][SHIFT][SPECIAL][6]
- To display nominal/measurement -- [1][=][SHIFT][SPECIAL][6]
- To disable ratio displays -- [0][=][SHIFT][SPECIAL][6]
- If ratio is selected, the "RATIO" indicator will light on the display window.

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.

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.

### 3.4 PRINCIPAL TEST CONDITIONS

#### 3.4.1 Test Frequency

Power-up frequency is 1 kHz, unless the keyboard has been locked with some other choice. There are 504 available frequencies, as detailed below. If a frequency other than 1 kHz is selected, the "NOT 1 KHZ" indicator will light on the display window.

*Selection.* To select the test frequency, simply key in the desired frequency as follows, and the Digibridge will automatically obtain the nearest available one.

a. Select ENTER with the [FUNCTION] key.

b. Enter the desired frequency *in kilohertz* and press [=][SHIFT][FREQUENCY] in sequence, as follows. For example, to select 500 Hz, press:

[.][5][=][SHIFT][FREQUENCY]

Up to 6 digits and decimal point are valid in entry of desired frequency. For another example, if the desired frequency is 2300 Hz, key in:

[2][.][3][=][SHIFT][FREQUENCY]

The actual frequency obtained appears immediately in the left (RLC) display area. In the example of desired frequency 2300 Hz, the display is 2.3077. The actual frequency obtained is always the closest one of the 504 available frequencies, which can be calculated from the following formulas, where n is always an integer in the range indicated:

|                |  |
|----------------|--|
| (3 kHz)(C/n)   | where n range is: 13...250 (freq .012000 to 0.23077 kHz) |
| (60 kHz)(C/n)  | where n range is: 4...256 (freq 0.23438 to 15.000 kHz)   |
| (200 kHz)(C/n) | where n range is: 1...13 (freq 15.385 to 200.00 kHz)     |

and where  $C = 1 + c$ , where c is a very small number between -.000099 and +.000099

The "nominal value" of an available frequency can be calculated from the appropriate one of the three formulas, the appropriate value of integer n, and by assuming that  $c = 0$ . The "corrected value" is more accurate, and is calculated in the same way except for using the true value of c.

The value of c is determined individually for each Digibridge as part of its factory calibration. If you want to find out what c is for your instrument, do the following. (The value will be in the range: -99 to 99 ppm.)

Select ENTER with the [FUNCTION] key. Then press:  
[SHIFT][SPECIAL][0]

*Indication.* Frequency display is the nominal value, to 5-digit resolution. This display is shown when frequency is selected (as described above) or by interrogation as follows: select ENTER function and then press:

[SHIFT][FREQUENCY]

### 3.4.2 Test Voltage

The power-up test voltage is 1.0 volt rms, unless the keyboard has been locked with some other choice. There are a total of 255 choices: .005 to 1.275 V in increments of .005 V. To program the test voltage:

a. Select ENTER with the [FUNCTION] key.

b. Enter the desired voltage in volts and press [=][SHIFT][VOLTAGE], in sequence as follows. For example, to select 750 mV rms, press:

[.][7][5][=][SHIFT][VOLTAGE]

The accuracy of the programmed source voltage is:

$$\pm [(5\% + 2 \text{ mV}) (1 + 0.001 f^2)],$$

where  $f$  = value of test frequency in kHz.

The actual voltage across the DUT is never more than the source voltage, and depends on the DUT impedance and the source resistance of the Digibridge, for the range in use. The DUT voltage is close to the source voltage at the high-impedance end of each measurement range and lower at the low-impedance end. Normally, the smallest voltage across the DUT (if its impedance is 6.25 ohms or more) will be 20% of the source voltage; this is the case for resistors measured at the low end of each range. Refer to Table 3-4 for details. (This table is similar to the table of range constants in the specifications. However, the extreme limits are given here, on ranges 1 and 4.)

For example, what is the voltage across the DUT if it is a 1-uF capacitor. Assume the test frequency is 1 kHz, the test voltage is 1.0 V, the CONSTANT VOLTAGE indicator is NOT lit and the RANGE HELD indicator is NOT lit. The Digibridge will measure on range 3, with 1.0 V behind source resistance of 400 ohms. The DUT reactance is 159 ohms and the voltage across it is 370 mV.

For comparison, what is the voltage across the same DUT if you select CONSTANT VOLTAGE (see paragraph 3.4.3) or if range 4 is held. In either case, the source, 1.0 V, is behind 25 ohms. The voltage across the DUT is 988 mV.

Table 3-4  
AUTORANGING MEASUREMENT RANGES AND SOURCE RESISTANCES

| Range | Source Resistance | Principal Measured Parameter |               |               |
|-------|-------------------|------------------------------|---------------|---------------|
|       |                   | Resistance                   | Capacitance   | Inductance    |
| 1     | 97.4 kohms        | max 99999 K                  | min .00001 pF | max 99999 H * |
|       |                   | mid 102 K                    | mid 1600 pF/f | mid 16 H/f    |
|       |                   | min 25.6 K                   | max 6400 pF/f | min 4.1 H/f   |
| 2     | 6.4 kohms         | max 25.6 K                   | min 6.4 nF/f  | max 4100 mH/f |
|       |                   | mid 6.4 K                    | mid 25.3 nF/f | mid 1025 mH/f |
|       |                   | min 1.6 K                    | max 100. nF/f | min 256 mH/f  |
| 3     | 400 ohms          | max 1600 ohms                | min 100 nF/f  | max 256 mH/f  |
|       |                   | mid 400 ohms                 | mid 400 nF/f  | mid 64 mH/f   |
|       |                   | min 100 ohms                 | max 1600 nF/f | min 16 mH/f   |
| 4     | 25 ohms           | max 100 ohms                 | min 1.6 uF/f  | max 16 mH/f   |
|       |                   | mid 25 ohms                  | mid 6.4 uF/f  | mid 4 mH/f    |
|       |                   | min .00001 ohm               | max 99999 uF  | min .00001 mH |

-----  
\* "K" is kilohms; "f" is equal to the test frequency in kHz.

### 3.4.3 Constant-Voltage Source

If it is important to measure the DUT at a particular test voltage, then select the constant-voltage feature as follows. Press:

[SHIFT][CONSTANT VOLTAGE]

so that the CONSTANT VOLTAGE indicator is lit. The Digibridge now retains a source resistance of 25 ohms for all ranges. The voltage is constant for any DUT impedance significantly larger than 25 ohms. An example is given in the preceding paragraph. Choosing this feature causes a reduction in measurement accuracy by a factor of three, as accounted for by Kcv in the accuracy specifications. (To disable the constant-voltage feature, press the same keys again.)

### 3.4.4 Constant-Current Source

If it is important to measure the DUT with a particular test current applied, then select the constant-current feature as follows.

- a. Select ENTER with the [FUNCTION] key.
- b. Enter the desired current in milliamps.
- c. Press [=][SHIFT][CONST I] for example to enter .2 mA, press [.] [2] [=][SHIFT][CONST I]



Note that the CONST I and RANGE HELD LEDs come on. The Digibridge will now hold the proper range and adjust the test voltage to apply the selected current into a short circuit. The current applied through the DUT will always be less than the selected current (except for a short circuit). If Constant Voltage or Hold Range is selected after Constant Current, Constant Current will be disabled.

To disable Const. I, press: [0][=][SHIFT][CONST. I]. Refer to Table 3-5 for a listing of constant-current source values.

Table 3-5  
CURRENT RANGE AND SOURCE RESISTANCE

|                 |                |                 |                  |               |
|-----------------|----------------|-----------------|------------------|---------------|
| CURRENT RANGE   | 51 nA- 13.1 uA | 13.2 uA- 198 uA | 200 uA- 3.195 mA | 3.2 mA- 51 mA |
| SOURCE RESISTOR | 97.4K          | 5.6K            | 400 ohms         | 25 ohms       |
| RANGE           | 1              | 2               | 3                | 4             |

When Const. I is enabled, the following procedure can be used to determine the current, voltage, and range set.

- Select ENTER with the [FUNCTION] key.
- For current, press: [SHIFT][CONST I], current will be displayed in ma.
- For voltage, press: [SHIFT][VOLTAGE], voltage will be displayed in v.
- For range, press: [SHIFT][SPECIAL][1], the range will be displayed.

To calculate the actual current through the DUT, use:  $I = V / (R_s + Z_{dut})$ .

### 3.4.5 Other Conditions

Other test conditions are described in other parts of this manual.

Delay (programmable settling time before acquisition of data) --- paragraph 3.5.3.

Averaging (selection of number of measurements to be averaged) --- paragraph 3.6.3.

Bias applied to the DUT (if it is a capacitor) --- refer to paragraph 3.7.

Special functions --- refer to paragraph 3.10.

## 3.5 MEASUREMENT TIME AND MEASUREMENT RANGES

### 3.5.1 General

Selection of MEASURE RATE (SLOW, MEDIUM, and FAST) obviously relates to measurement time, providing the user with an easily made choice. (The slower rates provide greater accuracy.) Programming a DELAY (typically because the normal settling time is insufficient for a particular handler or biasing routine) also obviously affects measurement time.

In this paragraph, the many items that affect measurement time are explained. The measurement time (required to complete a measurement and display the results) depends not only on the selected measure rate, and programmed delay, but also on the presence or absence of the high-speed measurement option, test conditions, choice of display, whether data is being sent out to other devices, etc. The best combination of conditions for any particular job should be selected recognizing their effects on speed and accuracy. The following examples are representative; some of the numbers are approximate.

#### NOTE

Except where stated otherwise (as in paragraph 3.5.9), measurement time is given for the condition that the **"quick acquisition" special function is NOT selected**. So accuracy is as specified. (See front of manual.)

*1689-9751 Digibridge.* The minimum measurement time is about 34 ms (30 meas/sec). The corresponding conditions are: measure rate = fast, IT factor set to 0.25 (integration time factor -- paragraph 3.5.5), test frequency = 10 to 100 kHz, display selection = bin no., measure mode = continuous (which eliminates the settling time that is normal with triggered mode), 1689-9751 Digibridge without high-speed measurement option, no data output via IEEE-488 bus. For test frequency = 1 kHz, the minimum is about 44 ms (23 measurements per second). In general, without the high-speed option, each measurement cycle is about 12 to 24 ms longer than it would be WITH the high-speed option.

*Surprisingly Long Times.* Please be aware of the long time periods that *can* be required by this very fast measuring instrument.

#### NOTE

Under some conditions, testing can consume so much time that the operator might wonder whether the Digibridge is really operating. See below.

The longest single measurement cycle (including programmable delay set to 99999 ms and the special-function selection of "median value") is about 5 minutes. The Digibridge will execute up to 255 full-length cycles if you select maximum averaging, for a total of about 22 hours from START to display of measured result.

### 3.5.2 Measure Rate Selection at Keyboard

Choose one of 3 basic measurement rates with the [MEASURE RATE] key: SLOW, MEDIUM, or FAST. The continuous-mode rates are respectively about 1, 4, and 8 measurements per second, if the other test conditions and programmable selections are left at normal power-up defaults.

The tradeoff is speed vs. accuracy. The Digibridge will make a more precise and accurate measurement at a slower rate. For the above conditions, in very simplified terms, the basic accuracy is 0.02%, and the tradeoff is as follows:

SLOW rate, 1 measurement per second, 0.02% accuracy (or better);  
MEDIUM rate, 4 measurements per second, 0.05% accuracy (or better);  
FAST rate, 8 measurements per second, 0.12% accuracy (or better).

For details on accuracy, refer to the specifications. In the accuracy formulas, the effect of measure rate selection appears as the term "Ks".

### 3.5.3 Settling Time or Programmed Delay, in Triggered Measure Mode

For accurate measurements, it is often helpful to have a time delay between the START signal and the beginning of the first voltage measurement within the process of data conversion. Because such a delay allows time for switching transients to settle, and because more time is required for low test frequencies, the Digibridge normally incorporates "settling time" as follows.

If measure mode is CONTINUOUS, settling time = zero, programmed delay is disabled.  
If measure mode is TRIGGERED, with measure rate FAST, settling time = 7 ms/f  
If measure mode is TRIGGERED, with measure rate MEDIUM, settling time = 10 ms/f  
If measure mode is TRIGGERED, with measure rate SLOW, settling time = 12 ms/f,

where f is equal to the test frequency in kHz. NOTE: the three times given above are verifiable in the ENTER function by pressing [SHIFT][SPECIAL][4].

If measure mode is TRIGGERED, you can program any desired delay (from 0 to 99999 milliseconds) for transient voltages to settle, for mechanical handling to be completed and contacts to settle, etc. The Digibridge will pause for this much time after each START signal, before actually starting to take data.

Any programmed delay *replaces* the default "settling time"; and affects measurements only in TRIGGERED measure mode.

As an example, you can set delay to 25 ms, as follows.

Select ENTER with the [FUNCTION] key and press:  
[2][5][=][SHIFT][SPECIAL][4]

Programmed delay is typically required for measurement of capacitors with bias, if the measure mode is TRIGGERED. Refer to paragraph 3.7.

NOTE: In the CONTINUOUS measurement mode, there will be no settling time or programmed delay; the speed of the Digibridge makes it reasonable to disregard the first displayed result (which is liable to be in error for several reasons), and observe subsequent displays for consistency, which indicates that any transients have settled.

### 3.5.4 Measure Mode and Display Selection, Effects on Measurement Time

*Measure Mode TRIGGERED.* Selection of TRIGGERED mode introduces a settling time or delay between the START signal (which is necessary in this mode) and the beginning of data acquisition. Refer to paragraph 3.5.3, above.

*Measure Mode CONTINUOUS.* Selection of CONTINUOUS measure mode eliminates the delay described above. Notice that in continuous mode, the measurement being made when the DUT is connected to the Digibridge is erroneous. Subsequent measurements have the benefit of any effective "delay" furnished by the preceding ones.

*Display Selection.* The selection of BIN NO. display cuts 6 to 10 ms from the measurement time, compared to any other choice of display. Therefore, the BIN NO. choice is recommended for use with an automatic parts handler, if maximum throughput is desired and there is no need for the operator to observe values or percent differences.

More information about operation with a parts handler is given in paragraph 3.11.

### 3.5.5 Integration-Time Factor (a Special Function)

The length of time that the Digibridge spends integrating analog voltages in the process of data acquisition can be varied by programming a number called the "integration-time factor", if the measure rate is selected to be FAST or MEDIUM. In general, programming the I-T factor to a larger value allows the Digibridge to integrate over more cycles of the test signal, thus increasing the measurement time and enhancing the accuracy. (If the measure rate is SLOW, integration time is automatically fixed at a relatively large value, so that any programmed I-T factor has no effect on measurement time.)

The I-T factor is normally 1. You can program it to values in the range from 0.25 to 6. For I-T factor = 0.25, if measurement rate is FAST, the integration time is set to 1 ms if the test frequency is above 1 kHz, or to one period of the test signal if test frequency is less than 1 kHz. The following tabulation indicates the integration time for several combinations of I-T factor and measurement rate, for test frequency of 1 kHz.

|        | I-T FACTOR = 0.25 | 1      | 6      |                              |
|--------|-------------------|--------|--------|------------------------------|
| FAST   | 1 ms              | 4 ms   | 24 ms  |                              |
| MEDIUM | 4 ms              | 17 ms  | 100 ms |                              |
| SLOW   | 100 ms            | 100 ms | 100 ms | (not affected by I-T factor) |

Programming the I-T factor is a special function, which is under keyboard control only if you have selected ENTER function. Then, for example, press these keys:

[.] [2] [5] [=] [SHIFT] [SPECIAL] [5] (to make the IT factor 0.25)

#### NOTE

"Max" rate is defined as the combination of FAST measure rate with I-T factor programmed to be 0.25. (The quick-acquisition special function is NOT used. See paragraph 3.10. With it, the measure rate would be even higher.)

The accuracy of measurement is affected by the value of I-T factor (in combination with measure rate and other conditions). The tradeoff is illustrated as follows, for 1-kHz test frequency, display = BIN NO., measurement mode = CONTINUOUS.

- I-T factor = any value, SLOW rate, 0.02% accuracy, 1 measurement per second;
- I-T factor = 1, MEDIUM rate, 0.05% accuracy, 4 measurements per second;
- I-T factor = 1, FAST rate, 0.12% accuracy, 8 measurements per second.
- I-T factor = 0.25, FAST rate ("Max"), 0.25% accuracy, 23 measurements/second.

For details about accuracy, refer to the specifications, where the effect of programming I-T factor to be 0.25 and selecting FAST rate is designated as "maximum measurement rate" in the table of values for the term "Ks".

### 3.5.6 Ranges, Range Changing, and Holding a Range to Save Time

#### RANGES and RANGE CHANGING

Descriptions of ranges, range extensions, and decimal point control are explained below.

*Basic Ranges.* The 4 basic ranges are numbered 1, 2, 3, 4, in order of decreasing impedance. Each basic range is approximately a factor of 16 wide. Refer to paragraph 3.4.2 for a table of ranges.

The word "upper" as used below refers to increasing measured value (which is the direction of increasing range number only if the principal measured parameter is capacitance). Similarly, the word "lower" as used below refers to decreasing measured value (which is the direction of decreasing range number only if the principal measured parameter is capacitance).

*Extensions.* Each of the 4 ranges goes beyond its basic range, with both upper and lower range extensions (also called overrange and underrange). Most of these extensions are seldom used because they overlap basic portions of other ranges and the Digibridge will automatically select the basic range unless you have selected "hold range" (see RANGE HELD indicator). Measurement units and multipliers in any range extension are the same as in the basic range. The fact that range definition depends on frequency causes a considerable variation in the width of range extensions. The lower limit is generally .00001, with all-zeros next; the upper limit is 99999, with all blanks next. Blanks in the measurement display are discussed below. In general, for any measurement within the specifications of the Digibridge, if a measurement can be displayed, it will be.

The only range extensions that are valid with autoranging are low underrange and high overrange, explained below.

*Low Underrange.* The "low" extension of the low range goes down to 1 count, with reduced accuracy. The smallest "1-count" increment in the display is the minimum measured value, given in the specifications in the front of this manual. Any measurement smaller than 1 count is displayed as all zeros.

NOTE: If the measured value is very small (even below one count) or very large (even over 99999), high-resolution measurements are possible using the ratio display. Refer to paragraph 3.3.7 or 3.10.

*High Overage.* The "high" extension of the high range goes up to the maximum display (all 9's, with the decimal point at the right), and finally to blank, with reduced accuracy. The high overrange is used for the very large values of RLC that exceed the basic high range.

*Autoranging.* Autoranging is normal; it is inhibited only if you select RANGE HELD. There is a slight hysteresis in the changeover from range to range to eliminate a possible cause of display flickering.

*Time Required to Change Range.* The Digibridge must almost complete a measurement cycle in the previously established range before starting measurement in the range to which it changes. The Digibridge completes the data acquisition and a large part of the calculation process before "deciding" whether the present range is best for the measured value. (If you have selected "median value", a special function, the Digibridge will go through basically three measurement cycles so that it has the median value for making the decision whether to change ranges.) Thus, measuring a lot of components that straddle a range boundary requires almost double the regular measurement time for every DUT that is on the opposite side of the boundary from its predecessor. (Note: if the Digibridge starts in range 1 to measure in range 4, four almost complete measurement cycles are required before the desired result appears.)

Therefore (at least in some measurement situations), maximum measurement speed requires range holding.

## RANGE HOLDING

*Why Hold a Range?* If you have many components to measure that are similar, and spread across the boundary between two ranges, you may prefer to hold one or other of the ranges. The advantages to holding range include consistency of unit multiplier in the results, and time saved.

For example, if many parts are being measured in values that fall in one basic range, one might hold that range. Some accuracy of measurement would be sacrificed for values in either range extension. (Refer to accuracy formulas; notice the fractional terms such as  $C_x/C_{max}$ .) But the system would save time that would be required to change range and remeasure, as could happen if range were not held. For details of the time required to make typical measurements, refer to all of paragraph 3.5 (Measurement Time), summarized with typical numbers in paragraph 3.5.10.

To inhibit autoranging, select the "range held" mode (RANGE HELD indicator lit) as described below -- four methods.

*To Hold Present Range.* If the present range (as indicated by the measurement display) is the desired one, press:

[SHIFT][HOLD RANGE] to light the RANGE HELD indicator.

(To return to the normal autoranging feature, press the same two keys again, making the RANGE HELD indicator unlit.)

*To Hold the Range of a Sample DUT.* One way to get into the desired range is to measure a DUT known to be in that range, thus:

Measure the DUT as usual.

Verify that the desired range is confirmed by the measurement display.

Press: [SHIFT][HOLD RANGE] to light the RANGE HELD indicator.

(To return to the normal autoranging feature, press the same two keys again, making the RANGE HELD indicator unlit.)

*To Hold the Range selected by Use of a Parameter Key.* Another way to get into the desired range is to use a parameter key, thus:

Select ENTER function with the [FUNCTION] key.

Press the appropriate parameter key (such as  $C_s/D$ ) repeatedly, watching the units indicators. The range advances with each repetition, enabling you to determine the present range by the pattern of changes. Notice that there is *not* always a change of unit multiplier with each range change.

(Refer to the table in paragraph 3.3.4.)

Press: [SHIFT][HOLD RANGE] to light the RANGE HELD indicator.

(To return to the normal autoranging feature, press the same two keys again, making the RANGE HELD indicator unlit.)

*To Hold Range by Number.* If you know the desired range number (see table in paragraph 3.4.2), use the special function key as follows:

Select ENTER with the [FUNCTION] key. Then:

For range 1, press: [1][=][SHIFT][SPECIAL][1]

For range 2, press: [2][=][SHIFT][SPECIAL][1]

For range 3, press: [3][=][SHIFT][SPECIAL][1]

For range 4, press: [4][=][SHIFT][SPECIAL][1]

(Note: for autoranging, press: [0][=][SHIFT][SPECIAL][1].)

### 3.5.7 Time Required for Obtaining Median Values and Averaging

Accuracy can be enhanced, at the cost of increased measurement time, by either or both of these methods. The time considerations and a brief instruction for selecting each method (while in the ENTER FUNCTION) are given here.

*Median Value.* This measurement time is somewhat less than triple the single measurement time, because three nearly complete measurements are made, from which the Digibridge selects the median for final results. To be more specific, each median-value measurement requires approximately as much time as three single measurements MINUS two of the three settling or delay time intervals and also MINUS about half of the calculation time. (The relative magnitudes of settling time, delay time, and calculation time in the single measurement cycle are illustrated in paragraph 3.5.10.)

Enabling and disabling median-value selection is a special function (paragraph 3.10). The enabling command is:

[1][=][SHIFT][SPECIAL][8] (See paragraph 3.6.4.)

*Averaging.* The measurement time is multiplied by the number of measurements (2 to 255), specified when averaging was programmed. To program the Digibridge to average, for example, 8 measurements, press:

[8][=][SHIFT][AVERAGE] (See paragraph 3.6.3.)

*Both.* If both median value and averaging are enabled together, the measurement time is multiplied by almost three times the number specified when averaging was programmed. (The Digibridge finds the medians of groups of three measurements and then calculates the average of the medians.)

### 3.5.8 Time Required if IEEE-488 Output is Enabled

If data output is enabled, via IEEE-488 bus, additional time --- about 2 ms to 12 ms --- is required per measurement. This time requirement depends on the selected display and what data is being sent out, approximately as follows. (Refer to explanation of operation with the IEEE-488 interface, paragraph 3.12.)

|                   | Regular Output Data Format |     |     |         |         |         |             | CBF *  |
|-------------------|----------------------------|-----|-----|---------|---------|---------|-------------|--------|
| Output data:      | BIN                        | RLC | QDR | RLC,QDR | BIN,RLC | BIN,QDR | BIN,RLC,QDR | (any)  |
| Display = BIN NO. | 2                          | 6   | 8   | 10      | 10      | 10      | 12          | < 2 ms |
| Display = other   | 2                          | 2   | 2   | 4       | 4       | 4       | 6           | < 2 ms |

\* Compacted Binary Format. If the compacted binary format is selected, data output requires less than 2 ms.

### 3.8.2 Accuracy for Some Typical Conditions

Figure 3-7.

For convenience in comparing the tradeoffs between speed and accuracy, the accuracy is tabulated in Table 3-7 for the same frequencies, and the results tabulated in the same arrangement, as the measurement-time tables. The data also appear as a graph of speed vs accuracy for several frequencies, in the accompanying figure.

Table 3-7  
ACCURACY FOR A SET OF CONDITIONS COMPARABLE TO THOSE IN PREVIOUS TABLE \*

| Range 1 (Basic Range) ** |                 |     |     |          | Ranges 2, 3, 4 (Basic) *** |                 |     |               |  |
|--------------------------|-----------------|-----|-----|----------|----------------------------|-----------------|-----|---------------|--|
| Meas Rate                | Test Freq (kHz) | 0.1 | 1   | 10 100   | Meas Rate                  | Test Freq (kHz) | 0.1 | 1 10 100      |  |
| "Max"                    |                 | .27 | .25 | .40 xx % | "Max"                      |                 | .27 | .25 .28 .55 % |  |
| FAST                     |                 | .14 | .12 | .27 xx % | FAST                       |                 | .14 | .12 .15 .43 % |  |
| MED                      |                 | .07 | .05 | .20 xx % | MED                        |                 | .07 | .05 .08 .35 % |  |
| SLOW                     |                 | .04 | .02 | .17 xx % | SLOW                       |                 | .04 | .02 .05 .32 % |  |

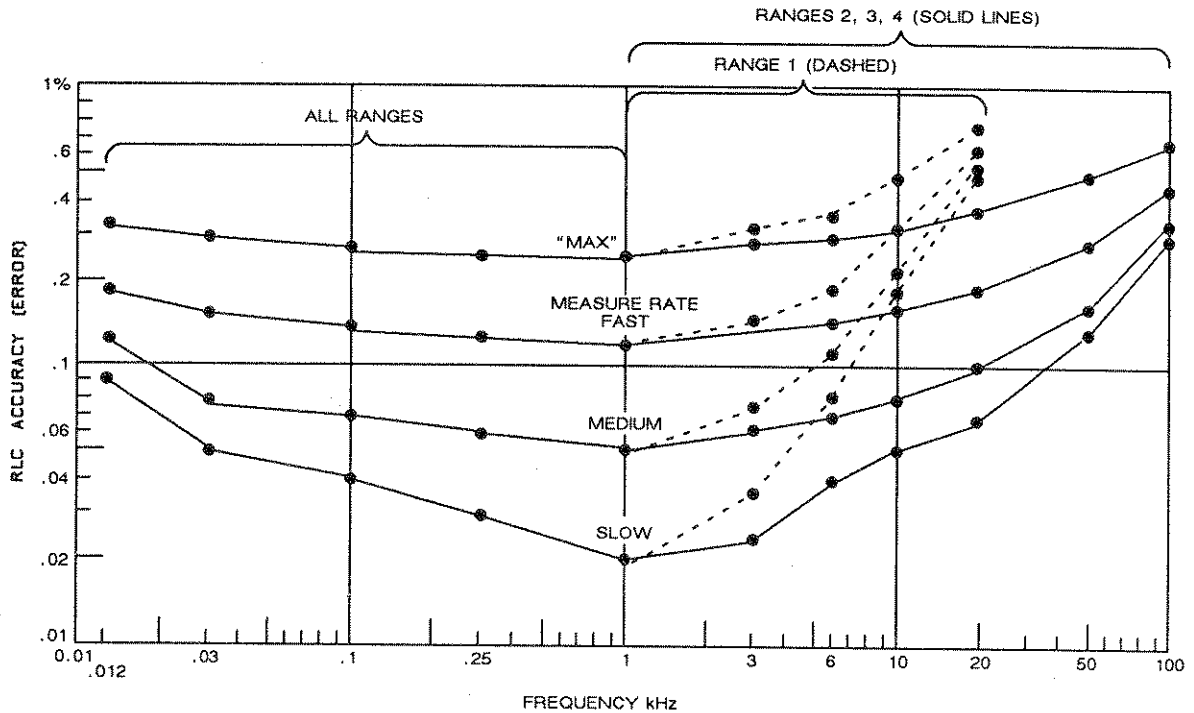
\* With test voltage = 1 to 1.275 V, CONSTANT VOLTAGE indicator NOT lit, autoranging RLC value within basic ranges (see below), and  $Q \ll 1$  with R,  $Q \gg 1$  with L,  $D \ll 1$  with C.

\*\* (R) 25.6 to 410 kilohm  
 (L)  $4.1/f$  to  $65/f$  H  
 (C)  $400/f$  to  $6400/f$  pF  
 (G) 39 to 2.44 uS  
 (Z) 25.6 to 410 kilohm  
 (Y) 39 to 2.44 uS

\*\*\* (R) 6.25 ohms to 25.6 kilohm  
 (L)  $1/f$  mH to  $4100/f$  mH  
 (C)  $6.4/f$  nF to  $25/f$  uF  
 (G) 0.39 mS to .16 S  
 (Z) 6.25 ohms to 25.6 kilohm  
 (Y) .039 mS to .16 S

Each curve shows the tradeoff for one test frequency. Operating points are labeled according to the selected measure rate (FAST, MEDIUM, SLOW). All of these curves apply to the following conditions: R, L, or C within basic ranges,  $D \ll 1$  or  $Q > 1$ , display is BIN NO., test voltage  $\geq 1.0$  V, constant voltage NOT selected, delay NOT programmed, measure mode is CONTINUOUS, and the high-speed option is not used (except for the dashed curve, which shows approximately the difference that this option makes). NOTE: for display of VALUE, add 6 to 10 ms to the time.





60050.0

Figure 3-8. Approximate RLC accuracy vs test frequency for these test conditions: R, L, and C within basic ranges,  $D \ll 1$  or  $Q \gg 1$ , test voltage  $\approx 1$  V, constant voltage NOT selected. The curves are labeled according to measure rate, SLOW, MEDIUM, and FAST; "Max" is FAST with integration-time factor set to 0.25 (a special function).

### 3.6.3 Averaging to Improve Accuracy

Figure 3-8.

The accuracy of measuring each DUT can be enhanced automatically by the Digibridge if you program it to make several measurements and average them before reporting the final result. Thus, errors due to electrical noise and other effects that are just as likely to make the measurement too high as too low are largely canceled. (This is true regardless of the display selection, VALUE, BIN NO., etc.) Of course, the time required to complete a measurement with averaging set to 10 (for example) is 10 times as long as the time for a single measurement.

Averaging can be set to any integer up to 255. To select 8 for example, select ENTER with the [FUNCTION] key, then press:

[8][=][SHIFT][AVERAGE]

Similarly, to inhibit averaging, select ENTER function and press:

[1][=][SHIFT][AVERAGE]

This is the default situation (no averaging).

Displays of averaged measurements depend on the measure mode.

1. If the measure mode is TRIGGERED, the display is repeatedly updated to be the running average, until the programmed number of measurements have been made; then the final average remains displayed until the next START command.
2. If the measure mode is CONTINUOUS, averaging proceeds without any change of display until the programmed number of measurements have been made; then the final average is displayed and remains until replaced by another final average.

#### 3.6.4 Selection of Median Value for Better Accuracy

The Digibridge can be programmed to make measurements in one or more groups of three and take for results the median value in each group. If you also select averaging (of 5 for example), the median values of (5) groups will be averaged. Examples of uses for the median-value capability are given below.

If the "median-value" capability is enabled, the Digibridge makes three measurements, discards the highest and lowest results, and uses the median result for further calculations (if any), such as averaging. This capability is a special function. To enable it, press the following keys:

[1][=][SHIFT][SPECIAL][8]

To disable "median value", press: [0][=][SHIFT][SPECIAL][8]

An example of a use for the median value capability is to greatly reduce the likelihood of displaying an erroneous "transitory" measurement in CONTINUOUS measure mode. This erroneous measurement is typically caused by insertion or switching of the DUT at some indeterminate time during a measurement cycle. Typically, this erroneous measurement is preceded and followed by valid ones. (The next several measurements are correct until the DUT is changed again). If median value capability is enabled, the Digibridge displays the median of three measurements, only one of which is liable to be erroneous. Because the erroneous one is commonly quite different from the other two, the median is very likely to be one of the correct ones. Consequently, you see only one change in the value displayed, from "before" to "after" the DUT change.

Another example of a use for the median value capability is for measuring in the presence of occasional noise that pollutes some measurements --- particularly noise spikes or bursts that can occasionally be coupled from electrical equipment (through power line to Digibridge circuits or via inductive or capacitive coupling to the DUT itself). Such noise pollutes a measurement now and then, among a majority of measurements that are correct. This noise is non-random, i.e., not "white" noise, but it may be repetitive. Obviously you would prefer to have only the correct results displayed and/or output via the interfaces to other devices. If the duration of the noise spike is typically small compared to the length of a measurement cycle and the noise repetition rate is small compared to the Digibridge measurement rate, then it is likely that any polluted measurement will be one of three measurements in the median taking, the other two being valid and practically identical. The median of any three consecutive measurements is therefore very likely to be correct.

#### 3.6.5 Accuracy Enhancement for Large or Small Impedances at Particular Frequencies

*Regular Zeroing at Test Frequency.* When measuring very large or small values of impedance, the Digibridge will provide much better accuracy than the specifications, *if* the OPEN and SHORT zeroing procedure has been recently repeated with test frequency set to the actual test condition.

Examples of the accuracy that is typically obtained with measure rate = SLOW, after using the actual test frequency when zeroing:

At 30 Hz,  $R = 100$  megohms  $\pm 1\%$  (range-1 extension, a factor of 240 over  $R_{max}$ )

At 120 Hz,  $C = 0.1$  farad  $\pm 1\%$  (range-4 extension, a factor of 480 over  $C_{max}$ )

At 10 kHz,  $C = 0.1$  pF  $\pm 1\%$  (range-1 extension, a factor of 400 below  $C_{min}$ )

At 100 kHz,  $L = 0.1$  uH  $\pm 1\%$  (range-4 extension, a factor of 100 below  $L_{min}$ ).

NOTES. Even better accuracy is possible if several measurements are averaged. See paragraph 3.6.3, above. Use of the "ratio display" special function is recommended when you measure very large values (which otherwise cannot be displayed) or very small values (for which ratio display can provide greatly improved resolution). See paragraph 3.3.7.

### 3.6.6 Accuracy Enhancement by Special Attention to Short-Circuit Inductance

The ratio display (paragraph 3.3.7) enables very high-resolution measurements of low inductance and high capacitance -- even beyond the limits of normal RLC displays. If such measurements are planned, especially if the test frequency is high, the inductance of the "short circuit" used in the normal zeroing procedure should be considered.

The short circuit provided by a wire inserted into the Digibridge test fixture (paragraph 3.1.3) has an effective inductance in series with its very low resistance. This inductance typically has a magnitude of several nanohenries.

To enhance accuracy of measurements in which a few nanohenries of inductance are significant, use a properly chosen shape, size, and orientation of wire for the short circuit. For greatest accuracy, particularly for axial-lead DUTs, also correct the measured value by suitable calculation.

*Accuracy Enhancement Procedures.* Three methods are described. See Figure 3-9.

If measurements are to be made without any adaptors (radial-lead DUT), use a piece of no. 18 (AWG) wire, 2.2 cm long (7/8 in.), bent into a hair-pin shape as shown in "A". Press this wire fully down into the Digibridge test fixture, keeping the straight sides of the wire vertical. Measurement results now depend on the geometry of the DUT leads, but will typically contain a related error less than 10 nH. For even smaller error, correct inductance measurements by adding 5 nH to the displayed value.

If measurements are to be made with adaptors (axial-lead DUT), for most situations, make the short-circuit calibration WITHOUT the adaptors. Use a piece of no. 18 (AWG) wire, 5 cm long (2 in.), bent into a rectangular shape as shown in "B". Press this wire fully down into the Digibridge test fixture, keeping the center of the wire above the center of the fixture and the straight sides of the wire vertical. Measurement results (with adaptors) will typically contain a related error of less than 5 nH, which can be verified by measuring a DUT consisting of a straight wire of known inductance -- refer to one of the accompanying tables of inductances. (Wire length is measured between points of contact in the adaptors.)

If measurements are to be made with adaptors (axial-lead DUT), for greatest accuracy (requiring a manual calculation for every measurement), make the short-circuit calibration WITH adaptors spaced exactly as they will be for the DUT. Use any piece of straight wire having a known self inductance  $L_0$  -- refer to Table 3-8. Measure the DUT using the series equivalent circuit. Then make the following calculation for each measurement.

For an inductor:  $L_s = L_m + L_0$

### 3.7 BIAS FOR THE DUT

#### NOTE

Keep the EXTERNAL BIAS switch OFF and the BIAS ON indicator unlit, for all measurements of inductors and resistors, and also for capacitors unless they are to be measured with dc bias applied.

#### 3.7.1 Internal Bias

To measure capacitors with the internally available 2-volt dc bias voltage applied, use the following procedure. (The FUNCTION can be either MEASURE or ENTER.)

a. Press [SHIFT][INT BIAS] keys so that the BIAS ON indicator is lit. NOTE: This indication, for internal bias, is somewhat dimmer than the other keyboard indicators.

b. The special shorting routine is recommended (see para 3.7.3); enable it as follows. Select ENTER function and then press:

[2][=][SHIFT][SPECIAL][3]      Select MEASURE function.

c. Wait at least 1 second before initiating measurement, to allow for settling of internal circuits. (In the CONTINUOUS mode, disregard displays for this interval.) This delay is associated with enabling the internal bias; it applies to each DUT only if internal bias is disabled for each change of DUT.

d. Observe correct polarity when inserting DUT into test fixture. Bias POSITIVE polarity is at the LEFT ("low" terminals) of the remote test fixtures 1689-9600 and 1689-9605. Bias NEGATIVE polarity is at the RIGHT.

e. For each DUT, in the CONTINUOUS measure mode, disregard the first displayed result and read the second. Notice enough of the subsequent results to verify that the DUT has stabilized. Use the stable result.

f. In the TRIGGERED measure mode, each measurement cycle includes the normal settling time (7 to 12 ms for 1-kHz measurements), or a programmed delay. See paragraph 3.5.3. Remeasure enough DUTs to be sure that they are stabilized in the first measurement so that any subsequent differences are well within the error permitted by your needs. If not, program in a longer delay.

NOTE: There are two effects to be aware of in watching for stabilization of the DUT: voltage and capacitance. Besides charging to a "final" voltage, there is also the stabilization of capacitance value itself. For example, some aluminum electrolytic capacitors respond slowly to a change in applied voltage, therefore the DUT capacitance can be settling long after the voltage is essentially stable.

Normally, the delay for internal bias measurements should be about:

$$\text{Delay} = 10 \text{ Rstd Cx} \quad \text{seconds}$$

(If the internal bias is being switched off during each change of DUT -- by remote control perhaps -- this delay should be 1 second larger:  $1 + 10 \text{ Rstd Cx}$ .)

NOTE: Rstd is 102400 for range 1, 6400 for range 2, 400 for range 3, 25 for range 4. (See table in paragraph 3.4.2.) Cx is the capacitance of the DUT in farads.

For example, measuring 2000 pF at 1 kHz (range 1), this delay time should be about  $(10)(102\ 400)(.000\ 000\ 002) = \text{approx } .002 \text{ seconds}$ . (Normal settling time is adequate.)

g. After biased measurements are completed, remember to disable the shorting routine, by selecting the ENTER function and pressing:

[0][=][SHIFT][SPECIAL][3]

h. Remove internal bias by pressing the [SHIFT][INT BIAS] keys, so that the BIAS ON indicator is NOT lit.

#### NOTE

The BIAS ON indicator serves to indicate whether internal bias is connected or disconnected *only if the EXTERNAL BIAS is switched OFF*. (See below for external bias.)

Notice that repeating the same keyboard sequence will cyclically enable and disable internal bias. For best results, after removing bias and before making further measurements, allow least 2 seconds for internal circuit discharge and settling.

### 3.7.2 External Bias

If bias is required at some other voltage than the 2-V internal bias, use external bias as described below. Also:

- Be sure that the voltage is never more than 60 V, max.
- A current limiting voltage supply is recommended; set the limit at 200 mA, max.
- Be sure that the bias supply is floating; DO NOT connect either lead to ground.
- 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.
- A well-filtered supply is recommended. Bias-supply hum can affect some measurements, particularly if test frequency is the power frequency.

#### Setup Procedure.

- a. 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.
- b. Set the external supply to limit current ( $< 200 \text{ mA}$ ).
- c. Set the external bias supply to the desired voltage ( $< 60 \text{ V}$ ).
- d. If the Digibridge power is off, switch its POWER ON and wait for completion of the self-check routine before the next step.
- e. Switch the EXTERNAL BIAS ON (switch is at right of keyboard) and verify that the BIAS ON indicator is lit -- see below. (If polarity is inverted, the indicator will not be lit as brightly as normal.)

If the bias cable fuse must be replaced, use a 200 mA fast-acting fuse.

f. Switch the bias off using an external switch, so that the DUT can be inserted before bias is applied to it. Refer to the Operating Procedure below.

#### NOTE

The BIAS ON indicator serves to indicate *that the EXTERNAL BIAS is switched ON, NOT NECESSARILY the presence of external bias.* See below. Also: whenever the EXTERNAL BIAS switch is ON, the Digibridge automatically selects CONSTANT VOLTAGE.

*Indicator.* When the EXTERNAL BIAS switch is ON, the BIAS ON indicator shines as long as the Digibridge POWER is ON. (The indicator brightness depends somewhat on the external bias voltage.) Also, when the EXTERNAL BIAS switch is ON, but the POWER is switched OFF, this indicator is lit by external bias voltages above about 3 V.

*Effect on Power-Up.* Be sure that the EXTERNAL BIAS switch is OFF before you switch the Digibridge POWER ON. This is generally necessary to permit the power-up self checks to pass.

*Protection.* The Digibridge is internally protected from damage from charged capacitors with stored energy up to 1 joule at any voltage up to 60 V.

#### CAUTION

If your test procedure includes charging capacitors to higher energy or higher voltage before or during connection to the Digibridge, EXTERNAL PRECAUTIONS MUST BE TAKEN TO PROTECT THE INSTRUMENT.

#### *Operating Procedure.*

a. If TRIGGERED measure mode is to be used, calculate the delay that is suitable for the largest value capacitor in the group to be measured with external bias, thus:

$$\text{Delay} = (C_x V_{\text{bias}}) / I_{\text{max}} + 10 R_{\text{std}} C_x \quad \text{seconds}$$

NOTE:  $C_x$  is the capacitance of the DUT in farads.  $V_{\text{bias}}$  is the external bias voltage in volts.  $I_{\text{max}}$  is the maximum current from the external supply (usually 0.2) amperes.  $R_{\text{std}}$  is 102400 for range 1, 6400 for range 2, 400 for range 3, 25 for range 4. (See table in paragraph 3.4.2.)

If the calculated delay is greater than the normal settling time (7 to 12 ms for 1-kHz measurements), then program the Digibridge to use this delay. See paragraph 3.5.3.

b. The special shorting routine is recommended (see para 3.7.3); enable it as follows. Select ENTER function and press:

[2][=][SHIFT][SPECIAL][3]      Select MEASURE function.

c. Observe correct polarity when inserting DUT into test fixture. Bias POSITIVE polarity is at the LEFT ("low" terminals) of the remote test fixtures 1689-9600 and 1689-9605. Bias NEGATIVE polarity is at the RIGHT.

d. Use the external switches (user supplied) to remove bias from the test fixture, apply bias after the DUT is in place, remove bias after measurement, and short the DUT before its removal. A routine like this is generally recommended.

However, for occasional (non-production) measurements, if the capacitances being measured are less than 200 uF and the bias voltage less than 30 V, an optional procedure is to leave the external bias circuitry "on" during measurements and to use the Digibridge EXTERNAL BIAS switch to apply bias to the DUT (ON) and to remove it and discharge the DUT (OFF).

e. For each DUT, in the CONTINUOUS measure mode, disregard the first displayed result and read the second. Notice enough of the subsequent results to verify that the DUT has stabilized. Use the stable result.

f. In the TRIGGERED measure mode, each measurement cycle includes the normal settling time (7 to 12 ms for 1-kHz measurements), or a programmed delay. Remeasure enough DUTs to be sure that they are stabilized in the first measurement so that any subsequent differences are well within the error permitted by your needs. If not, program in a longer delay.

NOTE: There are two effects to be aware of in watching for stabilization of the DUT: voltage and capacitance. Besides charging to a "final" voltage, there is also the stabilization of capacitance value itself. For example, some aluminum electrolytic capacitors respond slowly to a change in applied voltage, therefore the DUT capacitance can be settling long after the voltage is essentially stable.

g. After biased measurements are completed, remove all bias by sliding the EXTERNAL BIAS switch OFF and if necessary pressing the [SHIFT][INT BIAS] keys, so that the BIAS ON indicator is NOT lit. Disable the shorting routine. (See below.)

### 3.7.3 Suppression of Transients

When measuring biased capacitors, the time required for settling of transients in the measuring circuitry can usually be reduced by selecting the automatic shorting routine (a special function), as follows. Select ENTER function and press:

[2][=][SHIFT][SPECIAL][3]

However, if there is no bias, the normal routine is faster. To obtain it, select ENTER function and press:

[0][=][SHIFT][SPECIAL][3]

#### NOTE

This automatic shorting routine DOES NOT discharge the capacitor DUT. It does short a capacitance in the measurement circuit to help terminate the transient that results from connecting a DUT with bias.

[8][5][=][SHIFT][BIN NO][0][0].

The value now moves to the right-hand display, confirming storage of the limit. Note: if you make a mistake, press the parameter key again and repeat the entry.

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

1. *Symmetrical percentage tolerances* (nested bins). Enter the nominal value of DUTs to be sorted. (The value appears on the RLC display. Units were selected in step b.) For example, to enter 123.40 as the nominal value, press

[1][2][3][.][4][=][SHIFT][NOM VAL].

Enter for bin 1 the narrowest percent tolerance to be sorted. As an example, for a tolerance of +/-0.2%: press

[.][2][%][=][SHIFT][BIN NO][0][1].

The numerical limits for RLC are automatically computed and rounded-off values appear on the Digibridge displays (upper limit at the left, lower at the right).

For bin 2, enter the next wider tolerance, similarly. (Be sure to use 2 digits for the bin number.) Repeat the procedure for bins 3, 4, 5, ... up to a maximum of 13 bins.

2. *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 will automatically be assigned to the lower bin.)

3. *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 (as in 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 (using two digits for the bin number, as noted before); thus: for D or Rs or Q with R, press

[9][9][9][9][=][SHIFT][BIN NO][0][0];

however, 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 the present numerical limits for bin 3 (for example), press

[SHIFT][BIN NO][0][3]

and similarly, to see the nominal value, press

[SHIFT][NOM VAL].

limits, and (when function is changed to MEASURE and measurements are made) for calculation of delta %, delta RLC, etc.

f. To measure a DUT with bin sorting:

- Press the [FUNCTION] key to select MEASURE
- Press the [DISPLAY] key to select BIN NO.
- Insert the DUT.
- If the measure mode is TRIGGERED, press the START button.
- Observe GO/NO-GO and bin-number results. NO-GO indicates either QDR failure (bin 0) or RLC failure (bin 14).  
See also paragraph 3.1.4.

For continued operation of the Digibridge, in MEASURE function, using the limits entered as above, you can select any desired display, such as VALUE, or BIN No., with the [DISPLAY] key. (If you have the interface option, the available output data are not limited to the display selection.) The GO/NO-GO lights will operate unless you inhibit comparisons. (See below.)

### 3.8.4 Verification of Nominal and Limit Values

While the function is ENTER, the exact values entered into the Digibridge can be seen by either of 2 methods, as follows.

*During the Entry Process.* A confirming display is automatically provided immediately after the final keystroke of each entry step. For example, after the [NOM VALUE] keystroke, the entered value appears on the RLC display. After the [BIN NO] and number keystrokes, the actual limits of RLC value (not percentages) appear across the full display area: upper limit on the regular RLC display, lower limit (4 most significant digits) in the regular QDR display area. For bin 0, the QDR limit appears in the QDR area.

*Upon Demand.* To see the current "nominal value", depress the [NOM VALUE] key (while the ENTER indicator is lit). To see the limits in any particular bin (or to verify that it has been closed), depress [SHIFT][BIN NO] and the desired number, similarly. Displays selected in this way are limited by the units that are shown on the panel. For example, if the bin-3 limits are 162 and 198 nF, but the display units are pF, when you press [BIN No.] [0] [3], the display will go blank. Select either nF or uF (instead of pF) to obtain a display of these limits.

However, any "nominal values" previous to the current one are lost and cannot be displayed (unless entered again). Bin limits are not lost until replaced by new entries in the particular bin; but they are normally lost when POWER is switched OFF. To prevent loss, lock the keyboard; see paragraph 3.9.

For comments on how bin sorting information is displayed, see paragraph 3.3.3.

### 3.8.5 Examples of Limit Entry

*Nested Limits.* To enter a set of nested limits, operate the keyboard as described below for the example of inductors having  $Q > 21$ ,  $L_s = 33 \text{ mH} \pm 0.35\%$ ,  $\pm 1\%$ ,  $\pm 5\%$ ,  $+7 -9\%$ .

- a. With [FUNCTION] key, select ENTER.
- b. With [EQUIVALENT CIRCUIT] key, select SERIES.
- c. With parameter key [Ls/Q], select RLC units: mH.
- d. Enter Q limit thus: [2][1][=][SHIFT][BIN No.][0][0].
- e. Enter nominal RLC value: [3][3][=][SHIFT][NOM VALUE].
- f. Set bin 1 limits: [.] [3] [5] [%] [=] [SHIFT] [BIN No.] [0] [1].
- g. Set bin 2 limits: [1] [%] [=] [SHIFT] [BIN No.] [0] [2].
- h. Set bin 3 limits: [5] [%] [=] [SHIFT] [BIN No.] [0] [3].
- i. Set bin 4 limits: [7] [%] [-] [9] [%] [=] [SHIFT] [BIN No.] [0] [4].
- j. Close bin 5 (if open): [0] [%] [=] [SHIFT] [BIN No.] [0] [5].
- k. Close bins 6 through 13, similarly, if used before.

*Sequential Limits.* Sequential limits can be entered by either of the following methods; use the method that fits your application.

**Method 1**, changing the nominal value for each bin.

Advantage: Straightforward definition of each bin in terms of percentages of the bin's nominal value.

Disadvantage: overlaps or gaps in coverage among several bins are not obvious.

(Remember that overlaps default to the lower-numbered bin; gaps default to bin 14.)

Example: For sorting capacitors into part of the standard 5% series, setting  $D < .005$ , and nominal values for the bins at  $C_s = 0.91, 1.0, 1.1, 1.2, 1.3 \text{ uF}$ .

- a. With [FUNCTION] key, select ENTER.
- b. With [EQUIVALENT CIRCUIT] key, select SERIES.
- c. With parameter key [Cs/D], select units: uF.
- d. Enter D limit: [.] [0] [0] [5] [=] [SHIFT] [BIN No.] [0] [0].
- e. Enter nominal C value: [.] [9] [1] [=] [SHIFT] [NOM VALUE].
- f. Set bin 1 limits: [5] [%] [=] [SHIFT] [BIN No.] [0] [1].
- g. Redefine nominal: [1] [=] [SHIFT] [NOM VALUE].
- h. Set bin 2 limits: [5] [%] [=] [SHIFT] [BIN No.] [0] [2].
- i. Redefine nominal: [1] [.] [1] [=] [SHIFT] [NOM VALUE].
- j. Set bin 3 limits: [5] [%] [=] [SHIFT] [BIN No.] [0] [3].
- k. Redefine nominal: [1] [.] [2] [=] [SHIFT] [NOM VALUE].
- l. Set bin 4 limits: [5] [%] [=] [SHIFT] [BIN No.] [0] [4].
- m. Redefine nominal: [1] [.] [3] [=] [SHIFT] [NOM VALUE].
- n. Set bin 5 limits: [5] [%] [=] [SHIFT] [BIN No.] [0] [5].
- o. Close bin 6 (if open): [0] [%] [=] [SHIFT] [BIN No.] [0] [6].
- p. Close bins 7 through 13, similarly (if used before).

NOTE: Because there are overlaps, bin numbers affect the binning (if a DUT satisfies two bins, it goes into "the lower-numbered bin"); for example, 1.046 uF will go into the 1.0-uF bin (No. 2) because it is numbered lower than the 1.1-uF bin (No. 3).

**Method 2**, using one nominal value for the set of bins.

Advantage: All bin limits are related to the same nominal value, making it easy to define bins exactly adjacent to each other without overlaps or gaps.

Disadvantage: Each bin is not readily defined in terms of its own nominal value.

Example: For sorting capacitors into six adjacent "1%" bins from -3% to +3%, setting  $D < .005$ , and nominal value of the six bins at  $C_s = 1.0 \mu\text{F}$ .

- a. With [FUNCTION] key, select ENTER.
- b. With [EQUIVALENT CIRCUIT] key, select SERIES.
- c. With parameter key [Cs/D], select units:  $\mu\text{F}$ .
- d. Enter D limit: [.] [0] [0] [5] [=] [SHIFT] [BIN No.] [0] [0].
- e. Enter nominal C value: [1] [=] [SHIFT] [NOM VALUE].
- f. Set bin 1 limits: [-] [2] [%] [-] [3] [%] [=] [SHIFT] [BIN No.] [0] [1].
- g. Set bin 2 limits: [-] [1] [%] [-] [2] [%] [=] [SHIFT] [BIN No.] [0] [2].
- h. Set bin 3 limits: [0] [%] [-] [1] [%] [=] [SHIFT] [BIN No.] [0] [3].
- i. Set bin 4 limits: [1] [%] [0] [%] [=] [SHIFT] [BIN No.] [0] [4].
- j. Set bin 5 limits: [2] [%] [1] [%] [=] [SHIFT] [BIN No.] [0] [5].
- k. Set bin 6 limits: [3] [%] [2] [%] [=] [SHIFT] [BIN No.] [0] [6].
- l. Close bin 7 (if open): [0] [%] [=] [SHIFT] [BIN No.] [0] [7].
- m. Close bins 8 through 13, similarly (if used before).

NOTE: For any bin the less negative or more positive percentage **must** be entered first as shown clearly in steps f and k. Because there are no overlaps, there will be no "default assignment to the lower-numbered bin". Bin-number sequence is immaterial.

### 3.8.6 Notes on Limit Entries in General

For additional detail, refer to the condensed instructions on the reference card under the Digibridge, and to the following notes.

*Frequency.* It is NOT necessary to select the test frequency first. Comparison results are valid even if the test frequency is changed later in the entry/measurement procedure.

*Bin 0.* The limit entered in bin 0 is always QDR. It is an upper or lower limit on the *secondary* measured value, depending on the parameter selection, as tabulated:

|              |              |              |               |
|--------------|--------------|--------------|---------------|
| Rs/Q (upper) | Ls/Q (lower) | Cs/D (upper) | Cs/Rs (upper) |
| Rp/Q (upper) | Lp/Q (lower) | Cp/D (upper) | Cp/Rp (lower) |

*Unsymmetrical Limit Pairs.* Enter 2 percentages for the bin. One or both may be + (unspecified sign) or -. Enter first the one that yields the larger absolute value of RLC.

*Unused Bins.* Initially, at power-up, bins 1 through 13 are closed so that unused ones can be ignored. Every unused bin that has previously been used (except 14) must be closed by entering 0%, as in the above examples. Once closed, it will stay closed until non-zero percent limits are inserted.

*Allowable Limits.* A maximum of 6 significant figures for nominal value and percent up to 99999.9.

*Bin Order.* Optional except for nested bins; be sure the narrower limit pairs go into lower numbered bins (because all overlap goes to the lower numbered bin).

*Inhibiting Comparisons.* To inhibit all comparisons, set nominal value to zero. (Then GO/NO-GO indicators stay off.) Subsequent setting of nominal value to any number except zero enables all comparisons as previously set up. To inhibit QDR comparisons, set bin 0 to the "all-pass" extreme, i.e., to 0000 for Rp, or Q with L; to 9999 for D or Rs or Q with R.

### 3.9.2 Function Map

Figure 3-12.

The figure shows graphically (like a map of the keyboard) which programming keys are enabled in the MEASURE function and which ones in the ENTER function. Notice that one row of keys inside the square 16-key area and all of the keys outside of that square are enabled *regardless* of any selection by the [FUNCTION] key.

### 3.9.3 Summary of Interrogations

Certain status (and results) information is indicated automatically on the display panels. For example:

Indicators above and below RLC display --- parameter and/or units of measurement.  
RANGE HELD --- autoranging is disabled.  
CONST VOLT --- source resistance held to 25 ohms (accuracy compromised).  
PPM --- units of D, Q, or ANG (not R or X) are parts per million.  
CONST I --- short circuit current set.  
NOT 1KHZ --- frequency is other than 1 kHz.  
RATIO --- ratio mode is enabled.  
Hardly any keyboard indicators lit --- keyboard is locked.  
Left display "0", right also "0", GO --- open-circuit zeroing enabled.  
Left display "5", right also "5", GO --- short-circuit zeroing enabled.  
Left display "6", right also "6", GO --- calibration enabled.  
Left display "0 14", right "blank" --- measurement signal overload.  
Left display "22222", right "1111" --- convertor/detector malfunction.  
Left display "22222", right "2222" --- convertor/detector malfunction.

The preceding three lines are explained in paragraph 3.14. Indicators on the keyboard provide important information, NOT summarized here.

The following interrogations will work only if you select the ENTER function:

[SHIFT] [NOM VAL] --- stored nominal value (appears displayed at left).  
[SHIFT] [BIN NO] [0] [1] --- limits for bin 1 (both displayed, left and right).  
[SHIFT] [BIN NO] [1] [2] --- limits for bin 12 (both displayed).  
[SHIFT] [BIN SUM] [0] [3] --- count in bin (left); bin number (right).  
[SHIFT] [FREQUENCY] --- test frequency, kHz (displayed at left).  
[SHIFT] [CONST I] --- short circuit current if selected.  
[SHIFT] [VOLTAGE] --- test voltage that is applied behind source resistance.  
[SHIFT] [AVERAGE] --- number of measurements (or medians) averaged per result.

The following special functions are explained more fully in paragraph 3.10. Each response display is: detail code at left and special-function number at right.

|               |           |     |     |   |
|---------------|-----------|-----|-----|---|
| Interrogation |           |     | --- | Detail Code   |
| [SHIFT]       | [SPECIAL] | [1] | --- | present range number.                                       |
| [SHIFT]       | [SPECIAL] | [2] | --- | code for data output via IEEE-488 bus (see paragraph 3.10). |
| [SHIFT]       | [SPECIAL] | [3] | --- | measurement routine (see paragraph 3.10).                   |
| [SHIFT]       | [SPECIAL] | [4] | --- | milliseconds of delay after start before data is acquired.  |
| [SHIFT]       | [SPECIAL] | [5] | --- | integration time factor (normal: 1).                        |
| [SHIFT]       | [SPECIAL] | [6] | --- | displays -- meas/nom: 2, nom/meas: 1, normal: 0.            |
| [SHIFT]       | [SPECIAL] | [7] | --- | parameter selection -- auto: 1, normal: 0.                  |
| [SHIFT]       | [SPECIAL] | [8] | --- | if median of 3 meas taken: 1, normal: 0.                    |
| [SHIFT]       | [SPECIAL] | [9] | --- | version number of Digibridge internal software.             |
| [SHIFT]       | [SPECIAL] | [0] | --- | ppm offset of source frequency from nominal.                |
| [SHIFT]       | [SPECIAL] | [.] | --- | IEEE-488 address (2 digits).                                |

The following interrogation will work only if you select MEASURE function:

[SHIFT][SPECIAL] (hold key down) --- all special functions

except 0, 1, 4 and 9 (see above) that are NOT set to "0". For example, under default (power-up) conditions, the display is \*\*\*\* \*7\* (where \* represents "blank").

NOTE: special function 7 is initially set to 1; see Table 3-11. If you set special functions 2 through 8 each to 1, this display will be 2315 678. If you set these special functions each to 0, this display will be \*\*\*\* \*\*\* (blank).

### 3.10 SPECIAL FUNCTIONS

Most of the special functions are described in more detail in other parts of the manual. Refer to Table 3-11 for a brief summary of the special functions and how to operate the [SPECIAL] key. Programming of special functions can be done only in ENTER function.

Table 3-11  
SPECIAL FUNCTIONS

| Purpose                            | Specific Selection   | Keystrokes                    | Re Para |
|------------------------------------|--|-------------------------------|---------|
| 1. Setting the Range               | Autorange (normal)   | [0] [=] [SHIFT] [SPECIAL] [1] | 3.5.6   |
|                                    | Hold range 1   | [1] [=] [SHIFT] [SPECIAL] [1] |         |
|                                    | Hold range 2   | [2] [=] [SHIFT] [SPECIAL] [1] |         |
|                                    | Hold range 3   | [3] [=] [SHIFT] [SPECIAL] [1] |         |
|                                    | Hold range 4   | [4] [=] [SHIFT] [SPECIAL] [1] |         |
| 2. Output via IEEE-488 Bus         | No output (max meas speed)   | [0] [=] [SHIFT] [SPECIAL] [2] | 3.5.8   |
|                                    | Bin numbers only   | [1] [=] [SHIFT] [SPECIAL] [2] |         |
|                                    | QDR results only   | [2] [=] [SHIFT] [SPECIAL] [2] |         |
|                                    | QDR and bin numbers  | [3] [=] [SHIFT] [SPECIAL] [2] |         |
|                                    | RLC results only   | [4] [=] [SHIFT] [SPECIAL] [2] |         |
|                                    | RLC and bin numbers  | [5] [=] [SHIFT] [SPECIAL] [2] |         |
|                                    | RLC and QDR results  | [6] [=] [SHIFT] [SPECIAL] [2] |         |
|                                    | RLC, QDR, & bin numbers = full data  | [7] [=] [SHIFT] [SPECIAL] [2] |         |
|                                    | No data on PASS, full data on FAIL   | [8] [=] [SHIFT] [SPECIAL] [2] |         |
| BIN no. on PASS, full data on FAIL | [9] [=] [SHIFT] [SPECIAL] [2]  |                               |         |
| 3. Special Measurement Routines    | Normal   | [0] [=] [SHIFT] [SPECIAL] [3] | 3.6.8   |
|                                    | Signal reversing (useful when test frequency coincides with power frequency)   | [1] [=] [SHIFT] [SPECIAL] [3] |         |
|                                    | Shorting in measurement circuit (useful when measuring biased capacitors)  | [2] [=] [SHIFT] [SPECIAL] [3] | 3.7.3   |
|                                    | Both reversing and shorting  | [3] [=] [SHIFT] [SPECIAL] [3] | 4.2.4   |
|                                    | Quick acquisition meas routine (MED and FAST only; useful at low frequencies)  | [4] [=] [SHIFT] [SPECIAL] [3] |         |
|                                    | Quick acquisition <i>and</i> shorting (MED and FAST only; useful at low frequencies)   | [5] [=] [SHIFT] [SPECIAL] [3] |         |
| 4. Delay                           | Milliseconds of delay after start before data is acquired. "d"=msec  | [d] [=] [SHIFT] [SPECIAL] [4] | 3.5.3   |
| 5. Integration-Time Factor         | Multiplies integration time by factor f (0.25 to 6), normally 1. Reducing f decreases accuracy and reduces measurement time. Increasing f does the converse. | [f] [=] [SHIFT] [SPECIAL] [5] | 3.5.5   |

Table 3-11 (continued)  
SPECIAL FUNCTIONS

| Purpose                         | Specific Selection                                       | Keystrokes                    | Re Para |
|---------------------------------|--|-------------------------------|---------|
| 6. Ratio Displays (RLC only)    | Normal displays  | [0] [=] [SHIFT] [SPECIAL] [6] | 3.3.6   |
|                                 | Ratio displayed:   | [1] [=] [SHIFT] [SPECIAL] [6] |         |
|                                 | nominal/meas value<br>meas value/nominal                 | [2] [=] [SHIFT] [SPECIAL] [6] |         |
| 7. Man/auto Parameter Selection | Manual selection of parameter                            | [0] [=] [SHIFT] [SPECIAL] [7] | 3.3.1   |
|                                 | Automatic selection of parameter, default.               | [1] [=] [SHIFT] [SPECIAL] [7] |         |
| Reset                           | Reset all selections to default (power-up) conditions.   | [2] [=] [SHIFT] [SPECIAL] [7] | Note*   |
| 8. Median Result                | Normal, no median found                                  | [0] [=] [SHIFT] [SPECIAL] [8] | 3.6.4   |
|                                 | Display is median of 3 meas                              | [1] [=] [SHIFT] [SPECIAL] [8] |         |
| 9. Version                      | Displays the software version                            | [SHIFT] [SPECIAL] [9]         |         |
| 10. Frequency Correction        | Displays the correction "c"<br>Refer to paragraph 3.4.1. | [SHIFT] [SPECIAL] [0]         | 3.4.1   |
| 11. IEEE Address                | Displays the listen address of the 1658-9620 interface.  | [SHIFT] [SPECIAL] [.]         | 5.10.1  |

NOTE

Resetting all choices to power-up (default) selections quickly establishes known operating conditions suitable for routine operation (paragraph 3.1.4) or for making any further selections. Refer to a note about command P2, near the end of paragraph 3.12.3.

### 3.11 OPERATION WITH A HANDLER

If you have the interface option and have made the system connections to a handler (paragraph 2.7), the Digibridge operating procedure is as follows.

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

*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.

*Indexing on ACQ.* Set up the handler to respond to the ACQ signal from the Digibridge, which occurs after 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.

b. Program the Digibridge for binning, as described in paragraph 3.8. The 1689-9620 High-Speed Measurement Option includes the capability to sort automatically into all of the bins. However, with the 1658-9620 IEEE-488 Bus / Handler Interface Card (supplied with 1689-9751), leave bins 9 through 13 closed because this handler interface lumps all five of them with bin 8, as explained in paragraph 3.8.1.

NOTE: Be sure to leave a non-zero number as "nominal value" in the Digibridge memory, to enable the GO/NO-GO indicators and the EOT signal.

c. If measured values are not needed, select BIN NO. with the [DISPLAY] key. This selection saves 6 to 10 ms for each measurement, compared to other displays.

However, if measured values are to be monitored visually, select VALUE with the [DISPLAY] key, or select the desired "delta" display. If the secondary measurement is D or Q, select DQ IN PPM or normal DQ. The displays are useful for incidental monitoring of measurements while the handler automatically sorts the parts being processed.

d. If the normal settling time is insufficient for transients (or if a shorter delay is appropriate), program the desired delay, as explained in paragraph 3.5.3.

e. Select MEASURE function and TRIGGERED mode. This mode (together with suitable settling time or delay) minimizes the time between insertion of the DUT into the test fixture and beginning of a valid measurement. Measurement starts when the Digibridge receives the START signal from the handler (or when the START button is pressed).

f. Select other measurement conditions as desired: EQUIVALENT CIRCUIT, RANGE HELD or autorange, MEASURE RATE, test FREQUENCY, test VOLTAGE, CONSTANT VOLTAGE or normal voltage, AVERAGE or regular, etc.

g. Select any desired special function (output of results via IEEE-488 bus, special routines, median result, etc -- refer to paragraph 3.10). Enabling IEEE-488 output adds several milliseconds of calculation time to each measurement cycle: about 2 to 12 ms depending on the type of data. The presence of the high-speed measurement interface option subtracts about 35 ms from the same calculation time. Median calculation requires somewhat less than three times as long as normal measurements. For measurement time considerations, refer to paragraph 3.5.



### 3.12 DATA OUTPUT AND/OR PROGRAMMING VIA IEEE-488 BUS

These considerations apply only if you have an interface option. (If you do, there will be interface connectors at the rear. See Figure 1-3.) The two interface options are interchangeable in the basic IEEE-488-bus function. However, the 1689-9620 high-speed option is faster in making measurements than the 1658-9620 (supplied with 1689-9751); and the 1689-9620 provides handler-interface outputs for 15 bins, whereas the 1658-9620 provides them for 10 bins.

#### 3.12.1 IEEE-488 Interface Unused

If there is no system connection to the IEEE-488 INTERFACE connector, be sure to keep the TALK switch set to TALK ONLY.

#### 3.12.2 Talk-Only Use, for Data Output

This pertains to a relatively simple system, with the Digibridge outputting data to one or more "listen-only" (IEEE-488 compatible) devices such as a printer.

- a. Set the TALK switch to TALK ONLY.
- b. Program the Digibridge to send out results automatically after each measurement. (Refer to paragraph 3.10.) The "special" commands for this purpose can be executed only in ENTER function, as follows.

|                           |  |
|---------------------------|--|
| [1][=][SHIFT][SPECIAL][2] | (for bin numbers)                          |
| [2][=][SHIFT][SPECIAL][2] | (for QDR)                                  |
| [3][=][SHIFT][SPECIAL][2] | (for QDR and bin numbers)                  |
| [4][=][SHIFT][SPECIAL][2] | (for RLC)                                  |
| [5][=][SHIFT][SPECIAL][2] | (for RLC and bin numbers)                  |
| [6][=][SHIFT][SPECIAL][2] | (for RLC and QDR)                          |
| [7][=][SHIFT][SPECIAL][2] | (for RLC, QDR, and bin numbers)            |
| [8][=][SHIFT][SPECIAL][2] | (no output on PASS, full data set on FAIL) |
| [9][=][SHIFT][SPECIAL][2] | (BIN data on PASS, full data set on FAIL)  |
| [0][=][SHIFT][SPECIAL][2] | (for no data output via IEEE-488 bus)      |

Operate the Digibridge in the usual way (manually). The system may constrain operation in some way. For example, a slow printer will limit the measurement rate because it requires a certain time to print one value before it can accept the next.

Refer to Table 3-12 for examples of the interface message code for data transfer. This table shows typical codes, but does not repeat the entire ASCII code. (There is a more complete table, in paragraph 2.8.)

*Output Formats for RLC, QDR, and BIN NO. Results.* Refer to Tables 3-13 through 3-15 for the formats of the output data: RLC, QDR, bin number (for the most recent measurement). If output of results has been enabled, by special function 2 as described above (or X1 ... X9 command; see paragraph 3.12.3, Table 3-19), the Digibridge sends data to the IEEE bus at the completion of each measurement sequence. The character string for RLC 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.

NOTE

For a description of the compacted binary data output format (which saves time), refer to paragraph 3.12.4.

Table 3-12  
ABBREVIATED INTERFACE MESSAGE CODE FOR "TALK-ONLY" DATA TRANSFER

| Character<br>(ASCII) | Decimal<br>Equiv | DI08 | DI07 | DI06  | DI05 | DI04 | DI03 | DI02 | DI01 |
|----------------------|------------------|------|------|-------|------|------|------|------|------|
| A                    | 65               | 0    | 1    | 0     | 0    | 0    | 0    | 0    | 1    |
| B                    | 66               | 0    | 1    | 0     | 0    | 0    | 0    | 1    | 0    |
| C                    | 67               | 0    | 1    | 0     | 0    | 0    | 0    | 1    | 1    |
| -----                |                  | etc  |      | ----- |      |      |      |      |      |
| 1                    | 49               | 0    | 0    | 1     | 1    | 0    | 0    | 0    | 1    |
| 2                    | 50               | 0    | 0    | 1     | 1    | 0    | 0    | 1    | 0    |
| 3                    | 51               | 0    | 0    | 1     | 1    | 0    | 0    | 1    | 1    |
| -----                |                  | etc  |      | ----- |      |      |      |      |      |

Table 3-13  
DATA OUTPUT FORMAT FOR RLC VALUE, delta%, deltaRLC, OR RATIO

| Character<br>Sequence | Purpose                           | Allowed<br>Characters | Meaning  |
|-----------------------|-----------------------------------|-----------------------|--|
| 1                     | Status                            | (space)               | Normal operation, measurement on a basic range     |
|                       |                                   | U                     | Underrange held (reduced accuracy)*                |
|                       |                                   | O                     | Overrange held (reduced accuracy)*                 |
|                       |                                   | E                     | End extension of range 1 or 4 (reduced accuracy)** |
|                       |                                   | I                     | Invalid measurement due to signal overload         |
| 2                     | Value or<br>delta RLC or<br>ratio | (space)               | Normal display                                     |
|                       |                                   | ^                     | Δ RLC Mode   |
|                       |                                   | /                     | Ratio Mode: Nominal Value/RLC Value                |

Table 3-13 (continued)  
 DATA OUTPUT FORMAT FOR RLC VALUE, delta%, deltaRLC, OR RATIO

| Character Sequence | Purpose              | Allowed Characters   | Meaning  |
|--------------------|----------------------|--|--|
| 3                  | Parameter            | L<br>C<br>R<br>G<br>Z<br>Y   | Inductance<br>Capacitance<br>Resistance<br>Conductance<br>Impedance<br>Admittance  |
| 4                  | Normal or ratio mode | (space)<br>/   | Normal mode (one of 3 described above)<br>Ratio Mode: RLC Value/Nominal Value  |
| 5,6                | Units                | (space)H<br>mH<br>uF<br>nF<br>pF<br>(space)S<br>mS<br>uS<br>(space)%<br>(space)O<br>kO | Henries<br>Millihenries<br>Microfarads<br>Nanofarads<br>Picofarads<br>Siemens<br>Millisiemens<br>Microsiemens<br>Percent difference from nominal value<br>Ohms<br>Kilohms                      |
| 7                  | Format               | (space)  |  |
| 8                  | Sign                 | (space)<br>-   | Positive R, L, C, G, Z, Y or $\Delta$ , or $\Delta$ RLCGZY<br>Negative R, L, C, G, Z, Y or $\Delta$ , or $\Delta$ RLCGZY   |
| 9...15             | Number               | 012345<br>6789.<br>(space)   | Measured number, right justified in format field; like the RLC display except the zero before the decimal point is explicitly provided and this number can be as long as seven characters. *** |
| 16<br>17           | Delimiter            | (CR)<br>(LF)   | The standard "carriage return" and "line feed" characters; end of string.  |

--- FOOTNOTES FOR TABLE 3-13 ---

\* Underrange generally occurs when the measured impedance is lower than the normal low limit (for automatic range change) and there is a lower-impedance range. Overrange generally occurs when the measured impedance is higher than the normal high limit (for automatic range change) and there is a higher-impedance range. In either case, an appropriate range change will improve accuracy. If there is no appropriate range to change to, the status is "range end extension"; see below. Range limits are different if CONSTANT VOLTAGE OR CONSTANT CURRENT has been selected; see paragraph 3.5.6.

\*\* Range 1 end extension if DUT impedance exceeds that of the largest R or L (smallest C) in basic range 1. Range 4 end extension if DUT impedance is less than that of the smallest R or L (largest C) in basic range 4. No possibility of changing range to improve accuracy.

\*\*\* If the measurement is outside of the display range (display goes blank), 9999999 is output in this numeric field.

Table 3-14  
QDR-VALUE DATA OUTPUT FORMAT

| Character Sequence | Purpose   | Allowed Characters  | Meaning   |
|--------------------|-----------|---|---|
| 1                  | Status    | (space)<br>0<br>I   | Normal operation<br>Overrange of QDR display<br>Invalid measurement due to signal overload  |
| 2                  | Format    | (space)   |   |
| 3                  | Parameter | Q<br>D<br>R<br>X<br>B<br>A  | Quality factor<br>Dissipation factor<br>Resistance<br>Reactance<br>Susceptance<br>Angle   |
| 4                  | Format    | (space)   |   |
| 5...7              | Units     | (2 spaces)0<br>(space)kO<br>(2 spaces)S<br>(space)mS<br>(space)uS<br>deg<br>ppm<br>(3 spaces) | Ohms<br>Kilohms<br>Siemens<br>Millisiemens<br>Microsiemens<br>Degrees<br>Parts per million (for D, Q or Angle)<br>Dimensionless (for Q or D)  |
| 8                  | Sign      | (space)<br>-  | Positive QDRXBAngle value<br>Negative QDRXBAngle value  |
| 9 ...15            | Number    | 012345<br>6789.<br>(space)<br>**  | Measured number, right justified in format field; like the QDR display except the zero before the decimal point is explicitly provided and this number can be as long as six characters plus decimal point. * |
| 16                 | Delimiter | (CR)  | The standard "carriage return" and "line feed" characters; end of string.   |
| 17                 |           | (LF)  |   |

\* If measurement is overrange (display goes blank), 999999 is output in this field.

\*\* 2 leading zeroes will precede the decimal point on values less than 1.

2 spaces will precede the value on values greater than 1.

Table 3-15  
BIN-NUMBER DATA OUTPUT FORMAT

| Character Sequence | Purpose    | Allowed Characters | Meaning  |
|--------------------|------------|--------------------|--|
| 1                  | Pass/fail  | (space)<br>F       | Go (bins 01 through 13)<br>No-Go (bins 00 or 14)                             |
| 2                  | Format     | (space)            |  |
| 3                  | Label      | B                  | The word "BIN".  |
| 4                  |            | I                  |  |
| 5                  |            | N                  |  |
| 6                  | Format     | (space)            |  |
| 7,8                | Bin number | 01234<br>56789     | Bin number assignment, 00 to 14.   |
| 9                  | Delimiter  | (CR)               | The standard "carriage return" and<br>"line feed" characters; end of string. |
| 10                 |            | (LF)               |  |

Table 3-16  
BIN SUMMARY DATA OUTPUT FORMAT

| Character Sequence | Purpose     | Allowed Characters | Meaning  |
|--------------------|-------------|--------------------|--|
| 1                  | Pass/fail   | (space)<br>F       | Go (bins 01 through 13)<br>No-Go (bins 00 or 14)                             |
| 2                  | Format      | (space)            |  |
| 3                  | Label       | B                  | The word "BINSUM".   |
| 4                  |             | I                  |  |
| 5                  |             | N                  |  |
| 6                  |             | S                  |  |
| 7                  |             | U                  |  |
| 8                  |             | M                  |  |
| 9                  | Format      | (space)            |  |
| 10, 11             | Bin number  | 01234<br>56789     | Bin Summary Number, 00 to 14.  |
| 12                 | Equivalence | =                  | Equals   |
| 13-17              | Sum         | 01234<br>56789     | Total number counted in this bin,<br>the bin-summary number.                 |
| 18                 | Delimiter   | (CR)               | The standard "carriage return" and<br>"line feed" characters; end of string. |
| 19                 |             | (LF)               |  |

*Bin Summary Output Format, Table 3-16.* The bin summary output can be enabled by the [SHIFT][BIN SUM][LOCK] sequence from the keyboard. (It can also be enabled by the E1 command from the bus. See paragraph 3.12.3.) The bin summary output consists of 15 lines, one apiece for the 15 bins (00 through 14). Each line has the format shown in the table.

### 3.12.3 Talk/Listen Use, for Remote Programming and Data Transfers

Observe the REMOTE CONTROL indicator light. If it is lit, there is no opportunity for manual operation (except switching EXTERNAL BIAS ON and OFF and use of the START button if manual start is enabled.) The displays may be observed then, but their content is controlled by the system controller, via the IEEE-488 bus.

Details of test program preparation are beyond the scope of this manual. Refer to Table 3-20 for an example of message activity during a control sequence in which the controller says "start" and the Digibridge (after a measurement) says "C uF 1.2345".

*Programming Guidelines.* If the Digibridge is to be programmed (TALK switch set to TALK/LISTEN), keep the following suggestions in mind.

1. An "unlisten" command is required before measurement is possible.
2. If not addressed to talk, the Digibridge sends a service request (SRQ low) when it has data ready to send.
3. Then SRQ will not go false (high) until the Digibridge has been addressed to talk or has been serially polled. A typical program might include these features:
  - \* Initial Setup: with ATN true, "untalk unlisten, my listen address (of Digibridge), my talk address (of CPU)"; then with ATN false, measurement conditions.
  - \* Measurement Enabling Sequence, for example: untalk the Digibridge, send a GET, unlisten the Digibridge.
  - \* After the CPU receives the SRQ, necessary enabling of data transfer: with ATN true, "untalk, unlisten, my listen address (of CPU), my talk address (of Digibridge)"; then ATN false.

*Serial Poll -- Status Byte -- Table 3-18.* When the bus is in the serial poll mode and the Digibridge is addressed to talk, the Digibridge responds with a status byte, which is encoded as shown in the table and sent on the data lines DI01 through DI08.



Table 3-17  
INTERFACE MESSAGE CODE FOR REMOTE CONTROL

| Message code* | Note ** | ASCII Equiv | Decimal Equiv*** | Sent concurrently with ATN line true: |      |      |                            |      |      |      |      |
|---------------|---------|-------------|------------------|---------------------------------------|------|------|----------------------------|------|------|------|------|
|               |         |             |                  | DI08                                  | DI07 | DI06 | DI05                       | DI04 | DI03 | DI02 | DI01 |
| MLA           | Set     | #           | 35               | X                                     | 0    | 1    | 0                          | 0    | 0    | 1    | 1    |
|               | Tot     | (SP) to >   | 32 to 62         | X                                     | 0    | 1    | <MSB--device-address--LSB> |      |      |      |      |
| MTA           | Set     | C           | 67               | X                                     | 1    | 0    | 0                          | 0    | 0    | 1    | 1    |
|               | Tot     | @ to ^      | 64 to 94         | X                                     | 1    | 0    | <MSB--device-address--LSB> |      |      |      |      |
| SPD           | --      | (EM)        | 25               | X                                     | 0    | 0    | 1                          | 1    | 0    | 0    | 1    |
| SPE           | --      | (CAN)       | 24               | X                                     | 0    | 0    | 1                          | 1    | 0    | 0    | 0    |
| UNL           | --      | ?           | 63               | X                                     | 0    | 1    | 1                          | 1    | 1    | 1    | 1    |
| UNT           | --      | ---         | 95               | X                                     | 1    | 0    | 1                          | 1    | 1    | 1    | 1    |

Because the following messages are addressed commands, they will affect the Digibridge operation only while it is addressed to listen.\*\*\*\*

|     |    |       |   |   |   |   |   |   |   |   |   |
|-----|----|-------|---|---|---|---|---|---|---|---|---|
| GET | -- | (BS)  | 8 | X | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| GTL | -- | (SOH) | 1 | X | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

-----  
\*Mnemonic key to codes: MLA = my listen address; MTA = my talk address; SPD = serial poll disable; SPE = serial poll enable; UNL = unlisten; UNT = untalk; GET = group execute trigger; GTL = go to local.  
\*\* Set = address setting as supplied by factory. Tot = total range of choice. See paragraph 2.8 for address changing procedure.

\*\*\* Decimal equivalent makes DI08 (which is immaterial) a zero. Logical 1 is low state (true), logical 0 is high state.

\*\*\*\* Digibridge is addressed to listen by MLA message containing its device address (see para. 2.8). It terminates this condition when it receives UNL command, which is necessary before it can make measurements or recognize its own keyboard.

Table 3-18  
STATUS CODE

| Line | Significance of a "1" (Low)                              | Significance of a "0" (High)                  |
|------|--|---|
| DI08 | Remote.  | Local.  |
| DI07 | Request for service, RQS.<br>(This device asserted SRQ.) | No request by this Digibridge<br>for service. |
| DI06 | Recalibration required.                                  | Normal operation.                             |
| DI05 | Busy, measurement in process.                            | Measurement completed.                        |
| DI04 | Limits were tested.                                      | Limits were not tested.                       |
| DI03 | RLC measured value is available.                         | RLC value is not available.                   |
| DI02 | QDR measured value is available.                         | QDR value is not available.                   |
| DI01 | Bin No. assignment is available.                         | Bin No. assignment is not available.          |

*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 put into a remote-control mode via the bus (see Table 3-17) and addressed to listen to device-dependent command strings.

Refer to Table 3-19. The programming command set includes all of the keyboard functions except switching external bias ON/OFF and full recalibration, which are not remotely programmable. Keyboard functions are explained above, particularly in paragraphs 3.3, 3.4, 3.8, 3.9, 3.10; and most of these commands are related to them in an obvious way.

Zero calibration by remote control is similar to the manual procedure. The "Z1" command is equivalent to manually keying

[1][6][8][9][=][SHIFT][OPEN]

It is necessary to allow the Digibridge to reach range 1. (It must not be held on another range.) The test fixture must be physically open-circuited. Zero calibration is initiated by a "G0" command (equivalent to pressing START), which should not be followed by other commands until the Digibridge responds with "SRQ". (The purpose of the "Z0" command is to defeat the preceding "Z1" command, as you might wish to do if the "Z1" was sent by mistake.)

Limit entry commands are interpreted in relation to the previously established parameter; send the "M" command first. Use the limit entry commands in the tabulated sequence, except that nominal value need not be repeated after once being entered.

Notice that f, n, h, and l in the table are "E-notation" numbers, containing any number of digits, with optional use of decimal point and optional use of power-of-ten multiplier. Do NOT omit the semicolon after each of these. (Refer to the table.) The letter n in the table is nominal value in base units (ohms, farads, or henries). For example, nominal value can be set to 543.21 pF by the command:

N543.21E-12;

Limits for bins 1 thru 13 are entered using percentages, referred to the current nominal value. For example, Bin No. 1 (designated 01) is set to +1.5%, -.05% by the command sequence:

B01H1.5;L-5E-2;

However, the limit for Bin Zero (the desired upper limit for D or Rs or Q with R, lower limit for Rp or Q with L) is entered as a value (dimensionless for D or Q, ohms for R). For example, Bin Zero is set to 250 ppm (with parameter selection C/D) by the command:

B00H250E-6;

Frequency is entered in kilohertz. If the desired frequency is (for example) 3.25 kHz, the following command will select the nearest available frequency, which is 3.3333 kHz:

F3.25;

There are three types of commands: two-byte, three-byte, and floating-point, as described below. Each byte is coded according to the 7-bit ASCII code, using the DI01...DI07 lines. The most significant bit is DI07, as recommended by the Standard. (The eighth bit -- DI08 -- is ignored.) Thus, for example, the command for "MEASURE FUNCTION" is P0, having octal code 120 followed by 060. The two 7-bit binary bytes are therefore: 1 010 000 and 0 110 000.

Note: The ASCII code -- "X3.4-1968, Code for Information Interchange" -- is available from American National Standards Institute, 1430 Broadway, New York, N.Y. 10018. This code can be written out as follows. For the numerals 0, 1, 2 ... 9, write the series of octal numbers 060, 061, 062 ... 071; for the alphabet A, B, C ... Z, write the series 101, 102, 103 ... 132. (Refer also to the table in the paragraph about "Address", in 2.8.4.) The ASCII code conforms to the 7-bit code ISO 646 used internationally.

*Two Byte and Three Byte Entries.* These command entries, as shown in Table 3-19, are simple ASCII character sequences of two or three characters. The first character is a letter which designates the category of the entry. The following ASCII character -- or two characters if this is a three-byte entry -- are decimal digits (0 to 9) which convey information about the selection within the category. For example, the ASCII sequence *D2* means "in DISPLAY category, select VALUE." The command is like pressing the [DISPLAY] key to select VALUE.

*Floating Point Entries.* These entries (also shown in the table) are ASCII character sequences of arbitrary length, always terminated with a semicolon (;). The first character is a letter which designates the category of the entry. The following ASCII characters -- before the semicolon -- define a floating-point number including at least one decimal digit (0 to 9) and optional characters (+ - . e E). Any space character is ignored. The character e or E is recognized as "exponent" in E-format notation. For example, any of the following three entries will set the test frequency to 100 Hz:

F0.1;      F1e-1;      F100.0E-3;

#### NOTE

The 2-byte command **P2** is recommended as the first command in a remote programming sequence because it resets all selections to their power-up (default) conditions.

Table 3-19  
 COMMANDS USED IN PROGRAMMING VIA IEEE-488 BUS

| Program Category    | Program Selection                           | Command Type   | Command Entry |
|---------------------|---|----------------|---------------|
| Display             | Bin #                                       | 2 byte         | D0            |
|                     | Delta %                                     | 2 byte         | D1            |
|                     | Value                                       | 2 byte         | D2            |
|                     | Delta RLC                                   | 2 byte         | D3            |
|                     | Ratio: nominal value/RLC value              | 2 byte         | D4            |
|                     | Ratio: RLC value/nominal value              | 2 byte         | D5            |
|                     | Bin on ratio: nominal value/RLC value       | 2 byte         | D6            |
|                     | Bin on ratio: RLC value/nominal value       | 2 byte         | D7            |
|                     | Measurement Rate                            | Fast           | 2 byte        |
| Medium              |   | 2 byte         | S1            |
| Slow                |   | 2 byte         | S2            |
| Measurement Voltage | Constant, off                               | 2 byte         | Y0            |
|                     | Constant, on                                | 2 byte         | Y1            |
|                     | Value (in volts) = v                        | Floating Point | Vv;           |
| Function or Reset   | Measure function                            | 2 byte         | P0            |
|                     | Enter function                              | 2 byte         | P1            |
|                     | Reset all selections to power-up conditions | 2 byte         | P2            |
| Measurement Mode    | Triggered                                   | 2 byte         | T0            |
|                     | Continuous                                  | 2 byte         | T1            |
|                     | Triggered median value                      | 2 byte         | T2            |
|                     | Continuous median value                     | 2 byte         | T3            |
| Parameter           | Inductance (L/Q)                            | 2 byte         | M0            |
|                     | Capacitance (C/D)                           | 2 byte         | M1            |
|                     | Capacitance (C/R)                           | 2 byte         | M2            |
|                     | Resistance (R/Q)                            | 2 byte         | M3            |
|                     | Inductance (L/Q) ppm                        | 2 byte         | M4            |
|                     | Capacitance (C/D) ppm                       | 2 byte         | M5            |
|                     | Capacitance (C/R)                           | 2 byte         | M6            |
|                     | Resistance (R/Q) ppm                        | 2 byte         | M7            |
|                     | Automatic selection of RLC                  | 2 byte         | M8            |
|                     | Resistance (R/X)                            | 2 byte         | K2            |
|                     | Conductance (G/B)                           | 2 byte         | K3            |
|                     | Impedance (Z/ANG)                           | 2 byte         | K4            |

Table 3-19 (Continued)  
 COMMANDS USED IN PROGRAMMING VIA IEEE-488 BUS

| Program Category                 | Program Selection                       | Command Type   | Command Entry      |
|----------------------------------|---|----------------|--------------------|
|                                  | Admittance (Y/ANG)                      | 2 byte         | K5                 |
|                                  | Impedance (Z/ANG) PPM                   | 2 byte         | K6                 |
|                                  | Admittance (Y/ANG) PPM                  | 2 byte         | K7                 |
| Equivalent Circuit Range Control | Parallel                                | 2 byte         | C0                 |
|                                  | Series                                  | 2 byte         | C1                 |
|                                  | Hold range                              | 2 byte         | RO                 |
|                                  | Hold range 1                            | 2 byte         | R1                 |
|                                  | Hold range 2                            | 2 byte         | R2                 |
|                                  | Hold range 3                            | 2 byte         | R3                 |
|                                  | Hold range 4                            | 2 byte         | R4                 |
|                                  | Autorange                               | 2 byte         | R5                 |
| Frequency                        | Value (in kHz) = f                      | Floating point | Ff;                |
| Zero Calibration                 | Disable                                 | 2 byte         | Z0                 |
|                                  | Enable open                             | 2 byte         | Z1                 |
|                                  | Enable short                            | 2 byte         | Z2                 |
| Output Format                    | Normal (not compacted)                  | 2 byte         | x0 (Lower-case x.) |
|                                  | Compacted binary format                 | 2 byte         | x1 (Lower-case x.) |
| Data Output                      | None                                    | 2 byte         | X0                 |
|                                  | Bin #                                   | 2 byte         | X1                 |
|                                  | QDR                                     | 2 byte         | X2                 |
|                                  | QDR, Bin #                              | 2 byte         | X3                 |
|                                  | RLC                                     | 2 byte         | X4                 |
|                                  | RLC, Bin #                              | 2 byte         | X5                 |
|                                  | RLC, QDR                                | 2 byte         | X6                 |
|                                  | RLC, QDR, Bin #                         | 2 byte         | X7                 |
|                                  | RLC, QDR, Bin # on FAIL only            | 2 byte         | X8                 |
| Same on FAIL; Bin # on PASS      | 2 byte                                  | X9             |                    |
| Nominal Value                    | Value (in ohms henries, farads) = n     | Floating point | Nn;                |
| Limit Entry                      | Bin #                                   | 3 byte         | Bbb                |
|                                  | High limit (in %) = h                   | Floating point | Hh;                |
|                                  | Low limit (in %) = l                    | Floating point | Ll;                |
| Initiation                       | Start a measurement (like start switch) | 2 byte         | G0                 |
| Manual Start                     | Enable switch                           | 2 byte         | W0                 |
|                                  | Disable switch                          | 2 byte         | W1                 |

Table 3-19 (Continued)  
 COMMANDS USED IN PROGRAMMING VIA IEEE-488 BUS

| Program Category                    | Program Selection  | Command Type   | Command Entry     |
|-------------------------------------|--|----------------|-------------------|
| Keyboard Lock                       | Unlock   | 2 byte         | K0                |
|                                     | Lock   | 2 byte         | K1                |
| Average                             | # of measurements = a  | Floating point | Aa;               |
| Internal Bias                       | Off  | 2 byte         | U0                |
|                                     | On   | 2 byte         | U1                |
| Bin Summary                         | Disable output   | 2 byte         | E0                |
|                                     | Enable output  | 2 byte         | E1                |
|                                     | Reset bin summary to 0   | 2 byte         | E2                |
| Measurement Routines                | Normal routine (highest speed)   | 2 byte         | Q0                |
|                                     | Signal reversal (use for low frequency hum rejection)  | 2 byte         | Q1                |
|                                     | Shorting between measurements (used for reducing transient-recovery time within measuring circuit, when measuring with bias; NOT FOR DISCHARGING THE DUT). | 2 byte         | Q2                |
|                                     | Signal reversal <i>and</i> shorting between measurements   | 2 byte         | Q3                |
|                                     | Quick-acquisition feature  | 2 byte         | Q4                |
|                                     | Quick acquisition & shorting   | 2 byte         | Q5                |
| Display Digit Blanking              | Eliminate (a) digits from RLC, (b) digits from QDR   | 3 byte         | Oab               |
| Integration-Time Multiplying Factor | Value (i) multiplies MEDIUM and FAST integration times   | Floating point | Ii;               |
| Delay                               | Value (in ms) = j  | Floating point | Jj; *             |
| Constant Current                    | Value (in mA) = #  | Floating point | i#;(lower-case i) |

\* Delay command must be entered after frequency command. (Inverting this sequence will cause delay to revert to its default value.)

Table 3-20  
MESSAGE ACTIVITY ON IEEE-488 BUS DURING A SIMPLE EXAMPLE OF REMOTE CONTROL

| Byte<br>order | Message* | ATN<br>line | Comment   |
|---------------|----------|-------------|---|
| 1             | (UNT)    | true        | Untalk all devices.   |
| 2             | (UNL)    | true        | Unlisten all devices.   |
| 3**           | (MLA 3)  | true        | Set Digibridge (address 3) to listen.                                     |
| 4             | (MTA n)  | true        | Set controller (address n) to talk.                                       |
| 5             | G        | false       | Typical device-dependent message: START. (See                             |
| 6             | 0        | false       | Table 3-17 for "program commands".)                                       |
| 7             | (UNL)    | true        | Unlisten Digibridge (must for measurement).                               |
| --            | --       | --          | Digibridge makes measurement, asserts SRQ<br>line to indicate completion. |
| 8             | (MLA n)  | true        | Set controller to listen.   |
| 9**           | (MTA 3)  | true        | Set Digibridge to talk.   |
| 10            | (space)  |             | Typical data stream from Digibridge in                                    |
| 11            | (space)  |             | the format of Tables 3-13, 3-14, 3-15 sent to                             |
| 12            | C        |             | controller, which will execute  |
| 13            | (space)  |             | some kind of read command   |
| 14            | u        |             | (specified by programmer) according to                                    |
| 15            | F        |             | destination (such as a printer).  |
| 16            | (space)  |             |   |
| 17            | (space)  |             |   |
| 18            | (space)  |             |   |
| 19            | 1        |             |   |
| 20            | .        |             |   |
| 21            | 2        |             |   |
| 22            | 3        |             |   |
| 23            | 4        |             |   |
| 24            | 5        |             |   |
| 25            | (CR)     |             |   |
| 26            | (LF)     |             |   |

-----  
\*Message on DI01...DI08 lines is coded and interpreted differently depending on simultaneous state of ATN line (true = asserted = low, false = high). See Table 2-2.

\*\*Bytes 3 and 4 can be programmed in a single command to controller; bytes 8 and 9 similarly. Notice that we refer to factory-set address as "3" by reading a 5-bit binary number (lines DI05...DI01).

### 3.12.4 Data Output in Compacted Binary Format

The compacted binary format for data output can be selected to save time. Selection must be made via IEEE-488 bus, not via the keyboard. The time saving is indicated by the fact that this format conveys a full set of test results in 8 binary bytes, compared to 44 binary bytes required by the regular format. Fewer characters are sent if you select less than complete results (such as bin number only, output only for FAIL, etc).

The data stream for one measurement consists of two to eight 8-bit bytes, depending on what output is programmed. The format is explained partly in truth Table 3-21, and partly in the text that follows.

#### NOTE

The 8 bits in each byte are 76543210, where 0 is LSB (least significant bit). The vertical line or space between bytes is for clarity only, not present in data.

The full eight bytes are sent only if RLC, QDR, and Bin information is needed (i.e., only if "status" bits 2,1,0 are logic 111. Otherwise, the data word is shortened, as follows.

If QDR data are NOT needed, the data format uses 5 bytes as follows.

If both QDR and BIN data are not needed, the "OTHER" byte is omitted.

|               |        |        |               |        |       |
|---------------|--------|--------|---------------|--------|-------|
| Name :        | STATUS | RLC, e | RLC, mantissa | OTHER  |       |
| Byte Number : | byte 1 | byte 2 | byte 3 byte 4 | byte 5 |       |
| -----         | -----  | -----  | -----         | -----  | ----- |

If RLC data are NOT needed, the data format uses 5 bytes as follows.

If both RLC and BIN data are not needed, the "OTHER" byte is omitted.

|               |        |        |               |        |       |
|---------------|--------|--------|---------------|--------|-------|
| Name :        | STATUS | QDR, e | QDR, mantissa | OTHER  |       |
| Byte Number : | byte 1 | byte 2 | byte 3 byte 4 | byte 5 |       |
| -----         | -----  | -----  | -----         | -----  | ----- |

If only BIN data are needed, the data format uses only 2 bytes, as follows.

If RLC, QDR, and BIN data are all NOT needed, no data output occurs.

|               |        |        |       |
|---------------|--------|--------|-------|
| Name :        | STATUS | OTHER  |       |
| Byte Number : | byte 1 | byte 2 |       |
| -----         | -----  | -----  | ----- |

The *RLC,e* byte (except for bit 7) conveys the RLC exponent (2s complement).

The *RLC,mantissa* bytes (all 16 bits) convey the RLC mantissa (base 2).

The *QDR,e* byte (except for bit 7) conveys the QDR exponent (2s complement).

The *QDR,mantissa* bytes (all 16 bits) convey the QDR mantissa (base 2).

The binary exponent and mantissa define a binary floating-point number, as follows:

$$(\text{Sign}) ( 2^{(\text{exponent})} ) * (\text{mantissa})$$



Table 3-21  
TRUTH TABLE OF COMPACTED BINARY FORMAT FOR OUTPUT DATA

| Name:                                     | STATUS   | RLC, e | RLC, mantissa | QDR, e | QDR, mantissa | OTHER    |
|---|----------|--------|---------------|--------|---------------|----------|
| Byte Number:                              | byte 1   | byte 2 | byte 3 byte 4 | byte 5 | byte 6 byte 7 | byte 8   |
|   | 76543210 | 7      |               | 7      |               | 76543210 |
| Normal meas'mt                            | 00 *     |        |               |        |               |          |
| Overrange                                 | 01       |        |               |        |               |          |
| Underrange                                | 10       |        |               |        |               |          |
| Invalid meas                              | 11       |        |               |        |               |          |
| Range 1                                   | 00       |        |               |        |               |          |
| Range 2                                   | 01       |        |               |        |               |          |
| Range 3                                   | 10       |        |               |        |               |          |
| Range 4                                   | 11       |        |               |        |               |          |
| Bin number                                | 001      |        |               |        |               |          |
| QDR                                       | 010      |        |               |        |               |          |
| QDR & bin no.                             | 011      |        |               |        |               |          |
| RLC                                       | 100      |        |               |        |               |          |
| RLC & bin no.                             | 101      |        |               |        |               |          |
| RLC, QDR, bin #                           | 111      |        |               |        |               |          |
| RLC value is +                            |          | 0      |               |        |               |          |
| RLC value is -                            |          | 1      |               |        |               |          |
| QDR value is +                            |          |        |               | 0      |               |          |
| QDR value is -                            |          |        |               | 1      |               |          |
| Parameter L/Q                             |          |        |               |        |               | 00       |
| Parameter C/D                             |          |        |               |        |               | 01       |
| Parameter C/R                             |          |        |               |        |               | 10       |
| Parameter R/Q,<br>R/X,G/B,Y/ANG,<br>Z/ANG |          |        |               |        |               | 11       |
| Ratio (either)                            |          |        |               |        |               | 00       |
| Delta percent                             |          |        |               |        |               | 01       |
| Value (default)                           |          |        |               |        |               | 10       |
| Delta RLC                                 |          |        |               |        |               | 11       |
| BIN 0                                     |          |        |               |        |               | 0000     |
| BIN 1                                     |          |        |               |        |               | 0001     |
| BIN 2                                     |          |        |               |        |               | 0010     |
| BIN 3                                     |          |        |               |        |               | 0011     |
| BIN 4                                     |          |        |               |        |               | 0100     |
| (etc)                                     |          |        |               |        |               |          |
| (etc)                                     |          |        |               |        |               |          |
| BIN 13                                    |          |        |               |        |               | 1101     |
| BIN 14                                    |          |        |               |        |               | 1110     |

\* Bit 3 of STATUS byte does not convey data.

The following examples illustrate how to obtain ordinary (base-10) numbers from the compacted binary data.

**EXAMPLE 1.** (Bytes are shown separated by spaces.)

| STATUS   | RLC, e   | RLC, mantissa |          | QDR, e   | QDR, mantissa |          | OTHER    |
|----------|----------|---------------|----------|----------|---------------|----------|----------|
| byte 1   | byte 2   | byte 3        | byte 4   | byte 5   | byte 6        | byte 7   | byte 8   |
| 76543210 | 76543210 | 76543210      | 76543210 | 76543210 | 76543210      | 76543210 | 76543210 |
| 0001x111 | 01100101 | 11100001      | 00001001 | 01110101 | 10100000      | 00000000 | 01100111 |

The example-1 interpretation is as follows:

Byte 1: Normal measurement. Range 2. RLC, QDR, and bin number data are needed.

Byte 2, bit 7: Sign of C value is +.

Byte 2, other bits: C exponent is 1100101 in 2s complement notation, which is the same as a negative exponent of 011011 (i.e., -27, base 10).

NOTE 1: bit 6 is always 1 for a negative exponent, 0 for a positive exponent. Bytes 3, 4: C mantissa is .879044 (directly from the 16-bit binary number).

NOTE 2: In the mantissa, the first bit has the weight of 0.5, the next bit 0.25, the next bit 0.125, and each other bit half of the one before it, to the 16th bit.

Therefore, the C value is  $+(2 \text{ to the } -27\text{th power}) * (.879044) = (7.45058) * (10 \text{ to the } -9 \text{ power}) * (.879044) = 6.54939 * 10^{-9} \text{ farads} = 6.5494 \text{ nF}$ . Bytes 5, 6, and 7 (by the same method as bytes 2, 3, and 4):  $D = .0003$   
 Byte 8: Parameters are C/D. Data numbers are values (normal). Bin 7 assignment.

**EXAMPLE 2.** (Bytes are shown separated by spaces.)

| STATUS   | RLC, e   | RLC, mantissa |          |
|----------|----------|---------------|----------|
| byte 1   | byte 2   | byte 3        | byte 4   |
| 76543210 | 76543210 | 76543210      | 76543210 |
| 0010x010 | 00001010 | 10100011      | 00011100 |

The example-2 interpretation is as follows:

Byte 1: Normal measurement. Range 3. RLC data are needed.

Byte 2, bit 7: Sign of R value is +.

Byte 2, other bits: R exponent is 0001010 in 2s complement notation, which is the same as a positive exponent of 001010 (i.e., +10, base 10). (See NOTE 1, above.) Bytes 3, 4: R mantissa is .637146 (from the 16-bit binary number; see NOTE 2, above).

Therefore, the R value is  $+(2 \text{ to the } +10\text{th power}) * (.637146) = (1024) * (.637146) = 652.44 \text{ ohms}$ .

### 3.13 SAMPLE IEEE PROGRAMS

Below are three sample IEEE-488 programs using three different IEEE controllers. These programs are intentionally very short and are intended as aids to demonstrate to the programmer how to operate a digibridge using a typical controller. It is assumed that the digibridge address is set to 3.

#### 3.13.1 Programming Hints

- a. The initiation (start) command is "G0". That is the number 0, not the letter O.
- b. It is good practice to begin a new program with a "P2" command. This will reset all parameters to the known turn-on state. If "P2" is used later in the program, it will reset everything, including Nominal Value and any Bin Limits that may be set.
- c. An "X" command must be sent to enable data output.
- d. The string "P2A10;M3X4Z2G0" should be sent for the Short Circuit Zero. A frequency other than 1 kHz can be sent if needed.
- e. The string "P2A10;M1X4Z1G0" should be sent for the Open Circuit Zero. A frequency other than 1 kHz can be sent if needed.
- f. All commands sent to the digibridge must be followed by an UNL (unlisten) and then ATN (attention) must be unasserted. If the instrument is set to TALK, this should happen automatically.

#### 3.13.2 Hewlett Packard HP85

```
100 REMOTE 703
110 OUTPUT 703; "P2X4G0"
120 ENTER 703; C$
130 DISP C$
140 LOCAL 703
150 SEND 7; UNL @ RESUME 7
160 END
```

#### 3.13.3 Capital Equipment Corp. PC-488 Card With the IBM-PC

```
100 DEFINT A-Z
110 DEF SEG=&HC000
120 INIT=0 : TRANSMIT=3 : ENTER=21
130 MY.ADDR=21 : SYSTEM.CONTROL=0
140 DIGIBRIDGE=3
150 CALL INIT (MY.ADDR, SYSTEM.CONTROL)
160 REN$="REN"
170 CALL TRANSMIT (REN$, STATUS)
180 M$="P2X4G0"
190 ST$="LISTEN 3 MFA DATA '+M$+' UNL"
200 CALL TRANSMIT (ST$, STATUS)
210 R$=SPACE$(17)
220 CALL ENTER (R$, LENGTH, DIGIBRIDGE, STATUS)
230 PRINT " MEASUREMENT IS: ";R$
240 END
Ok
```

' PC-488 memory address  
' PC-488 commands  
' Initialize IEEE-488  
' Address of Digibridge  
' Enable remote control first  
' Command for Digibridge  
' Receive data  
' Print result

### 3.13.4 National Instruments GPIB-PCII Card With the IBM-PC

```
100 *****INITIALIZE BRIDGE*****
110 ADAP$="GPIB0" : DIGI$="DIGI":V%=1
120 CALL IBFIND (ADAP$,GPIB0%):CALL IBSIC (GPIB0%)
130 IF IBSTA% < 0 THEN GOTO 120
140 CALL IBGTS (GPIB0%,V%)
150 CALL IBFIND (DIGI$,DIGI%)
160 CLS *****MEASURE AND DISPLAY DATA*****
170 C$=SPACE$(20):D$=SPACE$(20)
180 SET$="P2X6G0" ' bridge setup string
190 CALL IBWRT (DIGI%,SET$) ' send string to bridge
200 CALL IBRD (DIGI%,C%): CALL IBRD (DIGI%,D$) ' read measurement results
210 PRINT C$;D$ ' display results
220 CALL IBLOC (DIGI%) : CALL IBGTS (GPIB0%,V%) ' return to local control
230 END
Ok
```

### 3.14 SELF CHECKS AND FAILURE DISPLAYS (ERROR CODES)

#### 3.14.1 Power-Up Self Check

Every time the instrument is switched ON or the line voltage reappears after an interruption, the Digibridge keeps itself busy for a short time going through an automatic self-check routine. The RLC and QDR displays indicate in code which check is being performed. It is possible to halt the diagnostic routine and hold the displayed code by pressing and holding the [SHIFT] key or other key. Normally these displays follow one another rapidly. However, if one of them persists, there has been a failure in the self check. The nature of the failure and the proper remedy for each are indicated below. Normal operation is inhibited in each of these cases.

#### NOTE

Operation can usually be enabled (in spite of failure messages other than 88888 or 33333) by pressing START button. This action is useful to enable measurements using a test fixture with very large capacitance or for certain transfer impedance measurements. But, it IS NOT RECOMMENDED unless you are well aware of what caused the self-check failure.

*88888 8888*. The random-access-memory read/write exercise was imperfect. Try power-up again; otherwise the remedy is beyond the operator's control; repair service is required.

*77777 XXXX*. The detector test was not completed satisfactorily. Be sure that the EXTERNAL BIAS switch is OFF; try power-up again. Otherwise the remedy is beyond the operator's control; repair service is required. (The QDR display provides some service information indicating in code which of 4 important digital signals is stuck, and whether high or low.)

**66666 XXXX.** The detector scale test failed. CPU will loop on failure. Switch POWER OFF and ON again. If these remedies are ineffective, repair service is required.

**555 D XXXX.** A signal-strength check failed. When D is 1...4, it indicates the range being checked (with voltage = 1.275 V). When D is 5, the range is 4, with voltage = .075 V. CPU will loop on failure. Be sure that the EXTERNAL BIAS switch is OFF and check to make sure that the charged capacitor protective fuse has not blown (Item 11, Figure 1-3). Recycle power OFF and ON to exit from loop.

**444 E XXXX.** A check on test frequency and waveform failed. For E of 1, 2, 3, 4, 5, 6, the frequency being checked is 6.06, 6.0, 1.2, 0.48, .0968, .0118 kHz, respectively. CPU will loop on failure; recycle power OFF and ON to exit from loop.

**33333 XXXX.** PROM data checksum test. XXXX = checksum, which must be zero to pass the test.

**222 F XXXX.** Calibration constants test. XXXX = normalized value of constant, which must be within the limits of 1.00000 +/- 0.78125 to pass the test. For F = 0, the constant is frequency correction factor. For F = 1, 2, 3, or 4, it is the conductance of range 1, 2, 3, or 4, respectively.

You can proceed from this power-up self-check failure (222 F XXXX) and operate the Digibridge. To do so, press the [C/D] key. Of course, the measured results are liable to be erroneous; you should then proceed to obtain service to repair the fault and/or recalibrate.

**11111 1111.** Failure of the high-speed math chip on the 1689-9620 high-speed measurement and IEEE/handler interface option. (This check is performed only if that option is present.)

You can proceed from this power-up self-check failure (11111 1111) and operate the Digibridge. To do so, press the [C/D] key. Interface functions can be expected to work properly. However, the Digibridge will operate at its regular speed (as though the high-speed option were absent) if it has this failure.

### **3.14.2 Failure Display due to Signal Overload**

**"0 14"** (*right display blank*) Occurrence of an unrecoverable signal overload during the last measurement. This means that a signal overload occurred during RANGE HELD or while measuring on Range 4. Otherwise (if a signal overload occurs on range 1, 2, or 3 and range is NOT held), this failure display is not shown; instead, the Digibridge will change to the next higher-numbered range and try again.

Signal overload can result from any of five causes:

1. RANGE HELD and CONSTANT VOLTAGE with impedance value too low for the range.
2. Transient voltage from charged capacitor.
3. Transient due to application of bias voltage.
4. Hardware failure.
5. LC resonance effect (measuring inductance).

### 3.14.3 Failure Display due to Abnormal Measurement Cycle

22222 xxxx. The Digibridge will abort the measurement and provide this display if there is (even once during a measurement) a converter/detector malfunction such that the integrator's conversion cannot be completed. There are two versions of this failure:

22222 2222. The cycle is "too long". Integrator voltage does not return to zero in reasonable time.

22222 1111. The cycle is "too short". Integrator voltage was already zero (or wrong polarity) when conversion began.

### 3.14.4 Failure Display due to LC Resonance

A display of "0 14 " or 22222 1111 can occur, in place of the expected L and Q, because the inductor being measured resonates with measuring circuit capacitance. (Resonance can cause an overload of the converter/detector.) The Digibridge thus presents an easily noticed failure display rather than an invalid measurement result.

*When Expected.* This resonance effect can be expected when large values of inductance are being measured at high frequency. In particular, if the Digibridge is autoranging, this effect can be expected in range 1 under any of the following 4 equivalent conditions. (A representative value of L that will cause selection of range 1 is indicated in parentheses beside each condition.)

1. Without extender cable,  $f > 3.8 \text{ kHz}$  ( $L > 1 \text{ H}$  at 4 kHz).
2. With 1688-9600 cable (874 connectors),  $f > 2.8 \text{ kHz}$  ( $L > 1.3 \text{ H}$  at 3 kHz).
3. With 1657-9600 cable (banana plugs),  $f > 1.1 \text{ kHz}$  ( $L > 3 \text{ H}$  at 1.2 kHz).
4. With 1689-9602 cable (BNC/BNC),  $f > 2 \text{ kHz}$  ( $L > 2 \text{ H}$  at 2 kHz).
5. With any other cable and remote test fixture, use the following formula:  
$$f > 770 / (200 + C).$$

where  $f$  is in kHz,  $C$  is stray capacitance outside of the Digibridge, from the high (Ih, Ph) terminal to ground (guard), expressed in pF. (Measurement will be on range 1 if  $L > 4/f$ .)

This resonance effect can also be expected under some conditions of high-frequency measurement with range 1 held but the inductance of the DUT appropriate for range 2. The effect is NOT expected with autoranging in ranges 2, 3, 4, unless stray capacitance is considerably larger than that of the 1657-9600 extender cable.

It is possible for valid measurement, with a slight reduction in accuracy, to be made under conditions very close to those that will trigger the LC resonance failure display. Such a measurement can be expected to meet accuracy specifications if it is displayed at all.

*Recommended Procedure.* If this LC-resonance failure display appears, in the course of otherwise normal measurements, the instrument is functioning normally. Valid measurements can usually be made by taking one or more of the following steps.

a. Select low source impedance, by pressing [SHIFT][CONST VOLTAGE] so that the CONSTANT VOLTAGE indicator lights up.

b. Select a low-impedance range. For example, if measurement is normally in range 1, try holding range 2; or if range 1 has been held, select autorange.

c. Reduce the measurement frequency.

d. If cable and test fixture capacitance can be reduced, do so.

e. If this resonance effect is not easily avoided, consider that the DUT may be self-resonant. If so, unqualified measurements of apparent inductance are misleading. Try a set of measurements of apparent inductance at several frequencies sufficiently low (or high) to avoid the resonance failure display.

NOTE: If RLC is negative, with indicated units of mH or H, the measured reactance is capacitive, although the RLC display is a number of millihenries or henries.





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# Theory – Section 4

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|                              |     |
|------------------------------|-----|
| 4.1 INTRODUCTION.....        | 4-1 |
| 4.2 PRINCIPAL FUNCTIONS..... | 4-4 |

## 4.1 INTRODUCTION.

### 4.1.1 General.

This instrument uses an unusual method of measurement, which is quite different from those used in most previous impedance meters or bridges. A thorough understanding of this method will be helpful in unusual applications of the instrument. The following paragraph gives a brief overall description outlining the measurement technique to one familiar with impedance measurement methods. A more detailed description of operation, specific circuitry, and control signals is given later.

### 4.1.2 Brief Description of the 1689-9751 Digibridge.

This Digibridge™ RLC tester uses a patented measurement technique, in which a microprocessor calculates the desired impedance parameters from a series of 6 or 8 voltage measurements (6 for FAST, 6 for MED, and 8 for SLOW measurement rates). These measurements include quadrature (90 degree) and inverse (180 degree) vector components of the voltages across the device under test  $Z_x$  (the DUT), and across a standard resistor  $R_s$  carrying the same current as the DUT. Each of these voltage measurements is meaningless by itself, because the reference signals have no particular phase relationship to the measured analog signals, and because the current through  $Z_x$  is not controlled. Each set of voltage measurements is made in rapid sequence with the same phase-sensitive detector and analog-to-digital converter. Therefore properly chosen differences between these measurements subtract out fixed offset errors, and ratios between them cancel out the value of the common current, the scale factor of the detector-converter, and the effect of the relative reference-to-signal phase angle.

The phase-sensitive detector uses 4 reference signals, precisely 90 degrees apart, that have exactly the same frequency as the test signal, but whose phase relationship to any of the analog voltages or currents (such as the current through  $Z_x$  and  $R_s$ ) is incidental. Therefore, no precise analog phase shifter or waveform squaring circuit is required. Correct phase relationships are maintained by generating test signal and reference signals from the same high-frequency source.

Because of the measurement technique and circuitry, the only calibration adjustment in the Digibridge is the factory setting of the test-voltage-level reference. The only precision components in this instrument are four standard resistors and a quartz-crystal stabilized oscillator. There is no reactance standard. For example, C and D are calculated by the microprocessor from the set of voltage measurements, the predetermined frequency, and the calibrated R and Q of the applicable standard resistor.

In these calculations, the microprocessor automatically removes from the measured result the parameters of the test connection ("stray" capacitance and conductance and series resistance and inductance), if simple open-circuit and short-circuit "ZERO" calibration measurements have been performed by the operator. The values obtained during "ZERO" calibration are stored in Digibridge memory and retained during power-down and power-up.

The impedance of each internal standard resistor is similarly stored in memory for use by the microprocessor in the calculation of parameters being measured. (For this purpose, the Digibridge measures its own internal standard resistors against an external standard during factory calibration -- and recalibration, if any.) Therefore, the impedances of the internal resistance standards are known at the calibration frequency (usually 1 kHz), and are computed by the microprocessor for other test frequencies.

The Digibridge also stores the frequency error of its crystal-referenced oscillator (actual vs nominal frequency, expressed in parts per million) so that the microprocessor uses a corrected frequency value in each calculation of capacitance or inductance from measured impedance. This frequency correction is programmed into the Digibridge during factory calibration -- and recalibration, if any.

The microprocessor controls the measurement sequence, according to programs in the read-only memory, using stored operator selections that are made available through keyboard control or (if you have the interface option) by remote-control command. Selections include for example -- parameters: R and Q, L and Q, C and D, or C and R; test voltage: .005 to 1.275 V; equivalent circuit: series or parallel; test rate: SLOW, MEDIUM, or FAST; frequency: programmable from 12 Hz to 200 kHz in 504 steps; delay: up to 99999 ms; and averaging: 2 to 255 measurements; etc.

The instrument normally autoranges to find the correct range; but operation can be restricted to any of the four ranges (1, 2, 3, 4), under keyboard control. Each range is 4 octaves wide (16:1), with reduced-accuracy extensions both above and below.

Leading zeroes before the decimal point are blanked out of the RLC and QDR displays.

#### 4.1.3 Block Diagram.

Figure 4-1.

The block diagram shows the microprocessor in the upper center connected by data and address buses to digital circuitry including memories (RAM and ROM) and peripheral interface adaptors (PIAs).

Analog circuitry is shown in the lower part of the diagram, where  $Z_x$  is supplied with a test signal at frequency  $f$  from a sine-wave generator, driven by a crystal-controlled digital frequency divider circuit. The P/I signal selector and instrumentation amplifier supply an analog signal that represents 2 impedances alternately: the appropriate internal resistance standard,  $R_s$ , and the DUT,  $Z_x$ .

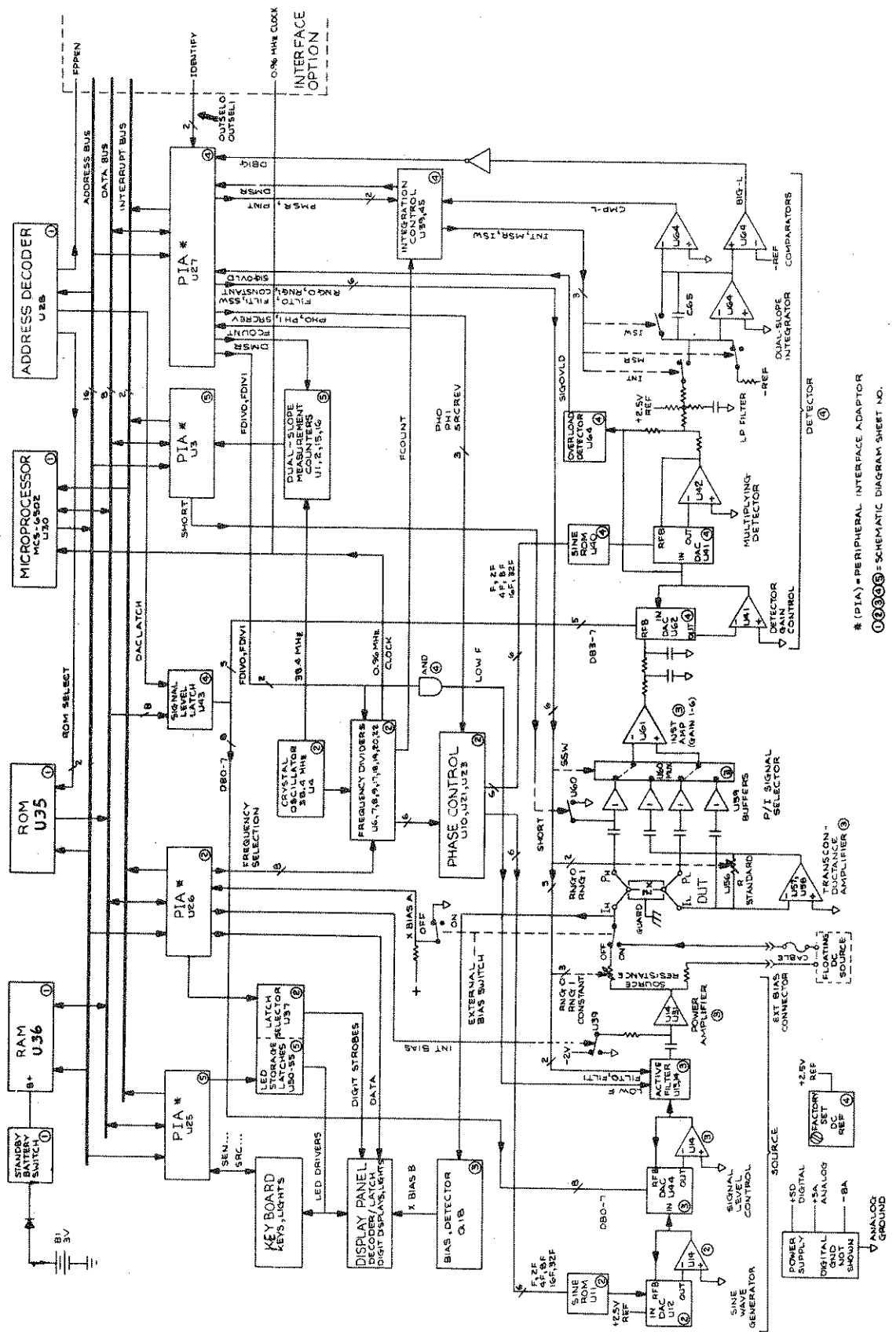
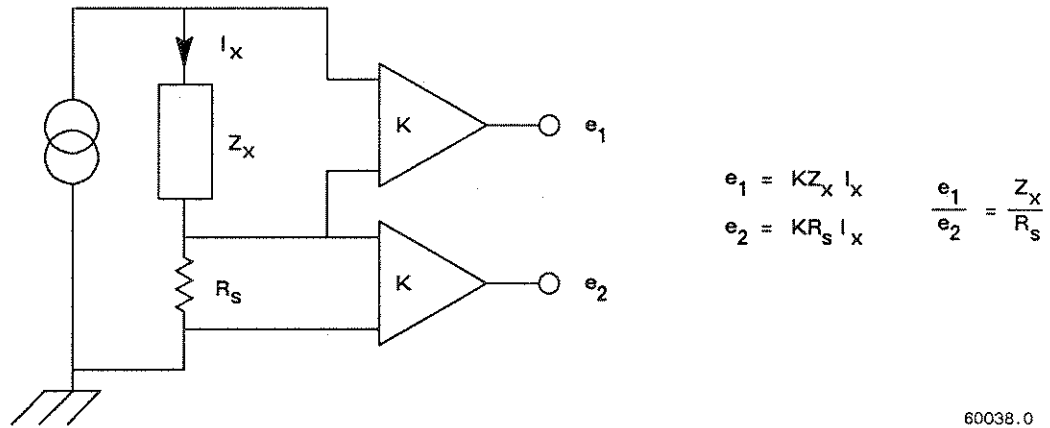


Figure 4-1. Block diagram of the 1689-9751 Precision RLC DigiBridge.

The phase-sensitive (dual-slope) detector and measurement counters convert this analog signal into digital form. See circuit descriptions below.

From this information and criteria selected by the keyboard (or remote control), the microprocessor calculates the RLC and QDR values for display, averaging, bin assignments, etc.



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Figure 4-2. Elementary measurement circuit.

## 4.2 PRINCIPAL FUNCTIONS.

### 4.2.1 Elementary Measurement Circuit.

Figure 4-2.

The measurement technique is illustrated by the accompanying simplified diagram, which can be correlated with the previous (block) diagram. A sine-wave generator drives current  $I_x$  through the DUT  $Z_x$  and standard resistor  $R_s$  in series. Two differential amplifiers with the same gain  $K$  produce voltages  $e_1$  and  $e_2$ . Simple algebra, some of which is shown in the figure, leads to the expression for the "unknown" impedance:

$$Z_x = R_s [e(1)/e(2)]$$

Notice that this ratio is complex. Two values (such as C and D or L and Q) are automatically calculated by the microprocessor from  $Z_x$ , frequency, and other information.

The return (deintegration) time depends on the dc voltage being converted and whether "BIG-L" has been triggered (see above); therefore, this time requirement varies in a complex manner.

Data acquisition includes several complete dual-slope conversion cycles, with the reference sine wave at 3 or 4 different phases, exactly 90 degrees apart, as follows:

For FAST and MEDIUM rates, 6 cycles (2 each with reference phases of 0, 90, and 180).

For FAST and MEDIUM rates if "quick acquisition" special function is enabled, 5 cycles.

For SLOW measurement rate, 8 cycles (2 each with ref phases of 0, 90, 180, and 270).

Therefore, data acquisition time is a complex, discontinuous function of test frequency, the selected measurement rate, programmed integration-time factor, enabling or disabling of "quick acquisition", and pauses for synchronization.



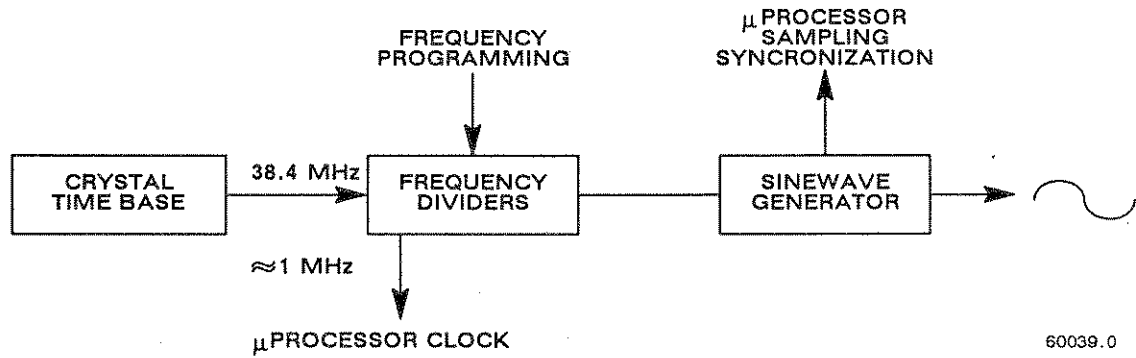


Figure 4-3. Frequency and timing source. Several clocks and synchronizing pulses as well as the measurement signal  $f$  are derived from the accurate time-base signal.

#### 4.2.2 Frequency and Time Source.

Figure 4-3.

A necessary standard for accuracy is the frequency of the test signal; and equally important are the generation of multi-phase references for detection and clocks for the microprocessor. Frequency and timing requirements are implemented by derivation from a single very accurate oscillator, operating at 38.4 MHz. Digital dividers and logic circuitry provide the many clocks and triggers, as well as driving the sine-wave generator described below.

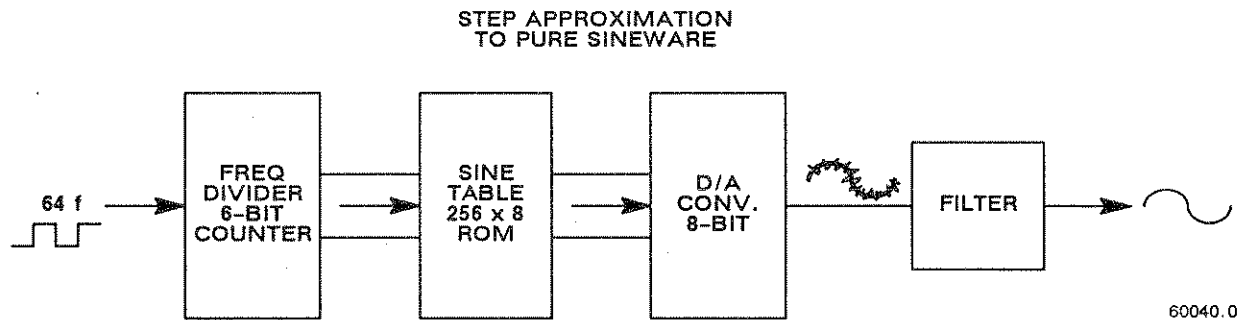


Figure 4-4. Sine wave generator. Given square waves at frequencies of  $64 f$ ,  $32 f$ ,  $16 f$ ,  $8 f$ ,  $4 f$ ,  $2 f$ , and  $f$ , a ROM containing the mathematical sine function drives a D/A converter to form a finely stepped approximation to a sine wave at frequency  $f$ . The filter provides smoothing of the test signal.

### 4.2.3 Sine-Wave Generation.

Figure 4-4.

*Source of the Test Signal.* Starting with a digital signal at 64 times the selected test frequency, the sine-wave generator provides the test signal that drives a small but essential current through the DUT. The sine wave is generated as follows.

Binary dividers count down from 64 f, providing signals at 32 f, 16 f, ... 2f, f. This set of signals is used to address a read-only memory which contains a 64-step approximation to a sine function. The ROM output (as an 8-bit binary number) is converted by a D/A converter to a stepped approximation of a sine-wave, which is then smoothed by filtering before its use in the measurement of a DUT. The filter is switched appropriately, according to the selected test frequency.

*Source of the Reference Sine Wave for the Multiplying Detector.* Another sine-function ROM is addressed by the same digital signals (64 f through f) to produce another stepped approximation of a sine wave at 0 degrees. Suitable inversions of signals 2f and/or f serve to shift the phase of the output sine wave, under microprocessor control, by 90, 180, or 270 degrees.

### 4.2.4 The Dual-Slope Integrating Detector and Converter (See Figure 4-1.)

*Circuitry.* The phase-sensitive detector/converter circuit consists of a multiplier whose dc output is measured by a dual-slope converter, providing the measurement in digital form. The multiplier is a multiplying D/A converter whose "reference" input is the test signal and whose digital controls are signals representing a stepwise approximation of a reference sine wave at the test frequency. The dc value of the multiplier output is proportional to the product of signal magnitude multiplied by the cosine of the phase angle between the test signal and the reference sine wave.

The dual-slope converter includes these three stages: dual-slope integrator, comparator, and counter (all controlled by the microprocessor through PIAs). In the dual-slope integrator, a capacitor is charged for a controlled integration time interval (sampling) at a rate proportional to the multiplier output voltage. This capacitor is then discharged at a fixed rate (the deintegration slope) to zero voltage, a condition that is sensed by a comparator. (See signal name "CMP-L" on the block diagram.) Thus, the integrator and comparator transform the sampled dc output from the multiplier into a precise interval of time. The dual-slope measurement counter is gated by this time interval, thus converting it into a digital number, which is a principal data input to the microprocessor.

If the integration time is relatively long, so that the integration capacitor voltage reaches a certain reference level, another comparator triggers the beginning of the return (deintegration) slope before sampling has been completed. (See signal name "BIG-L" on block diagram.) The detector is then sampling and converting simultaneously for a portion of the dual-slope conversion cycle.

*Data Acquisition Time.* Data acquisition time includes pauses for synchronization, and several integration/deintegration cycles.

A pause for synchronization varies depending on timing relationships among the START signal, length of settling time or programmed delay, length of the previous integration/deintegration cycle, and the Digibridge clocks (particularly FCOUNT, shown on block diagram). This pause can be as much as one test-frequency period for high frequencies or up to 1/32 of the test-frequency period for low frequencies.

The integration (sampling, gate, or capacitor charging) time of the dual-slope integrator is the number of full periods of the test frequency whose sum is closest to (4 ms)x(integration-time factor) for FAST, closest to but not over (16.7 ms)x(integration-time factor) for MEDIUM, or closest to but not over 100 ms for SLOW measurement rate. (The integration-time factor is normally 1.0 but can be programmed between 0.25 and 6.)