## 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 503 available frequencies, as detailed below.

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 503 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: 2...13 (freq 15.385 to 100.00 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: +/- [5% + 2 mV + 0.2 f mV], where f is equal to the 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 3-3 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 3-3
AUTORANGING MEASUREMENT RANGES AND SOURCE RESISTANCES

| Range | Source Resistance | ------- Principal Measured Parameter ------- Resistance | Capacitance | Inductance |
|---|---|---|---|---|
| | | max 99999 K | min .00001 pF | max 99999 H * |
| 1 | 102.4 kohms | mid 102 K | mid 1600 pF/f | mid 16 H/f |
| | | min 25.6 K | max 6400 pF/f | min 4.1 H/f |
| | | max 25.6 K | min 6.4 nF/f | max 4100 mH/f |
| 2 | 6.4 kohms | 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 |
| | | max 1600 ohms | min 100 nF/f | max 256 mH/f |
| 3 | 400 ohms | mid 400 ohms | mid 400 nF/f | mid 64 mH/f |
| | | min 100 ohms | max 1600 nF/f | min 16 mH/f |
| | | max 100 ohms | min 1.6 uF/f | max 16 mH/f |
| 4 | 25 ohms | 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 four, 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

To provide a constant-current source for any measurement, select and hold a range such that the source resistance is much larger than the DUT impedance. (See table of ranges, above.) Thus:

a. Select ENTER function with the [FUNCTION] key.

b. Select and hold a range as follows: (See also paragraph 3.10.)
For source resistance = 102.4 kilohms (range 1): press [1][=][SHIFT][SPECIAL][1]
For source resistance = 6.4 kilohms (range 2): press [2][=][SHIFT][SPECIAL][1]
For source resistance = 400 ohms (range 3): press [3][=][SHIFT][SPECIAL][1]
Source resistance is 25 ohms for range 4, which could be held similarly, if desired. However, if the DUT impedance is small compared to 25 ohms, the Digibridge will autorange to range 4 anyway.

c. Program the source voltage to be the product of the desired source current times the source resistance of the selected range. (Refer to paragraph 3.4.2 above, for programming the voltage.)

For example, if the DUT is a capacitor of nominal value near 0.4 uF, measured at about 1 kHz, its reactance is about 400 ohms. To measure it with constant-current source, select and hold range 2 (source resistance 6.4 kilohms). If the desired test current is 0.1 mA, program the source voltage too be 0.1 mA times 6.4 kilohms = 0.64 V. (Note that range 1 would provide still higher source resistance, but measurements would be less accurate, as shown by the factor Cx/Cmax in the accuracy formula; see specifications in the front of the manual.)

### 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.

## 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.

The minimum measurement time is about 33 ms (about 30 measurements per second). The corresponding conditions are: measure rate = fast, IT factor set to 0.25 (integration time factor -- paragraph 3.5.5), test frequency = 100 kHz, display selection = bin no., measure mode = continuous (which eliminates the settling time that is normal with triggered mode), Digibridge with high-speed measurement option, no data output via IEEE-488 bus.

For test frequency = 1 kHz, the minimum is about 40 ms (25 meas per second). For best accuracy (power-up conditions), the time is about 1000 ms (1 meas/second).

If you do NOT have the high-speed option: minimum is about 58 ms (17 meas/second); for test frequency = 1 kHz, the minimum is about 65 ms (15 measurements per second). In general, without the high-speed option, each measurement cycle is about 21 to 38 ms longer than it would be WITH the high-speed option.

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, 4.8, and 11 measurements per second, if the other test conditions and programmable selections are left at normal power-up defaults, for the Digibridge with high-speed option.

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;
MEDIUM rate, 4.8 measurements per second, 0.05% accuracy;
FAST rate, 11 measurements per second, 0.12% accuracy.

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 = 6 ms/f
If measure mode is TRIGGERED, with measure rate MEDIUM, settling time = 9 ms/f
If measure mode is TRIGGERED, with measure rate SLOW, settling time = 11 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][DELAY]; however, the actual system settling times are longer, approximately 6.9, 9.9, and 11.9 ms/f (respectively).

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][DELAY]

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 roughly the additional measurement time for several combinations of I-T factor and measurement rate:

| | ITF = 0.25 | ITF = 1 | ITF = 6 | |
|---|---|---|---|---|
| FAST | 1 ms | 27 ms | 208 ms | |
| MEDIUM | 27 ms | 170 ms | 730 ms | |
| SLOW | 960 ms | 960 ms | 960 ms | (not affected by ITF) |

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 the following 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 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, with the high-speed option:

I-T factor = any value, SLOW rate, 0.02% accuracy, 1 measurement per second;
I-T factor = 1, MEDIUM rate, 0.05% accuracy, 5 measurements per second;
I-T factor = 1, FAST rate, 0.12% accuracy, 12 measurements per second.
I-T factor = 0.25, FAST rate ("Max"), 0.25% accuracy, 25 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 Overrange. 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

Range Holding, to Save Time. To inhibit autoranging, select this mode (RANGE HELD indicator lit) as described below — three methods.

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 Cx/Cmax.) 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, below.

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 Cs/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 the IEEE-488 bus, an additional interval --- 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:

| Output data: | BIN | RLC | QDR | RLC,QDR | BIN,RLC | BIN,QDR | BIN,RLC,QDR |
|---|---|---|---|---|---|---|---|
| Display = BIN NO. | 2 | 6 | 8 | 10 | 10 | 10 | 12 ms |
| Display = other | 2 | 2 | 2 | 4 | 4 | 4 | 6 ms |

(Refer to explanation of operation with the IEEE-488 interface, paragraph 3.12.)

### 3.5.9 Effect of Selecting a Low Test Frequency on Measurement Time

Selection of a test frequency near or below 0.1 kHz affects measurement time in two ways: both settling time and data acquisition time depend on the period of the test signal. (Selection of test frequency near and above 1 kHz has little effect on measurement time, particularly if the integration time factor is left at default or set to a larger value.)

In general, measurement time includes the following two terms, which are additive. (Note: f is equal to the test frequency in kHz.)

- o Settling time (if measure mode is TRIGGERED and you have not programmed any DELAY) is [6 to 11 ms][1/f]. In other words, approximately 10 periods.
- o Data-acquisition time is generally more than 9 periods (15 periods at SLOW measure rate), although the relationship is not linear. (Refer to the summary below and to theory, Section 4.)

START SIGNAL — ACQ — EOT

| DELAY | DATA ACQUISITION | CALCULATION | DISPLAY | OUTPUT VIA IEEE-488 BUS |
|---|---|---|---|---|
| CONTINUOUS MODE: 0 ms | (IRREGULAR, GENERALLY LESS THAN:) | | | NO OUTPUT: 0 ms |
| TRIGGERED MODE:<br>DEFAULT SETTLING TIME<br>FAST: (1/f) 6 ms<br>MEDIUM: (1/f) 9 ms<br>SLOW: (1/f) 11 ms | FAST:<br>[9/f + 36 (ITF)] ms<br><br>MEDIUM:<br>[9/f + 160 (ITF)] ms | WITH HI-SPEED OPT<br>(ITF < 1): 25 ms<br>(ITF ≥ 1): 34 ms | BIN NO.: 0 ms | IF DISPLAY IS BIN NO,<br>ONE { BIN: 2 ms, RLC: 6 ms, QDR: 8 ms }<br>ANY TWO: 10 ms<br>ALL THREE: 12 ms |
| PROGRAMMED DELAY<br>0 TO 99999 ms | SLOW:<br>[950 + 15/f] ms | WITHOUT HI-SPEED OPT<br>(ITF < 1): 50 ms<br>(ITF ≥ 1): 69 ms | VALUE OR DELTA:<br>6 TO 10 ms | IF DISPLAY IS VALUE OR DELTA,<br>ANY ONE: 2 ms<br>ANY TWO: 4 ms<br>ALL THREE: 6 ms |

Figure 3-6. Summary of the components of measurement time used by the Digibridge and an indication of how the time per measurement depends on measurement conditions and system selections. The START signal can be received via START button, IEEE-488 bus, or handler interface. The ACQ (otherwise known as ACQ OVER) and EOT signals are sent via the handler interface. Symbol "f" is test frequency in kHz and "ITF" is integration time factor.

## 3.5.10 Measurement Time Summary

**Figure 3-6.**

To summarize the relationships of measurement time to a representative set of the many possible test conditions and operating selections, refer to Table 3-4 and the accompanying figure.

Table 3-4
TYPICAL MEASUREMENT TIMES VS FREQUENCY AND MEASURE RATE

FOR DIGIBRIDGE WITH HIGH-SPEED MEASUREMENT OPTION

| | Measure Mode = Continuous * | | | | | | | | | | Measure Mode = Triggered ** | | | | Note *** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Display = BIN Test Freq (kHz) | | | | Display = VALUE Test Freq (kHz) | | | | | | Display = BIN Test Freq (kHz) | | | | Display = VALUE Test Freq (kHz) | | | | |
| Meas Rate | 0.1 | 1 | 10 | 100 | 0.1 | 1 | 10 | 100 | | kHz: | 0.1 | 1 | 10 | 100 | 0.1 | 1 | 10 | 100 | |
| "Max" | 115 | 42 | 36 | 35 | 123 | 50 | 44 | 43 | ms | "Max" | 185 | 49 | 37 | 35 | 193 | 57 | 45 | 43 | ms |
| FAST | 124 | 79 | 72 | 71 | 132 | 87 | 80 | 79 | ms | FAST | 194 | 86 | 73 | 71 | 202 | 94 | 81 | 79 | ms |
| MED | 133 | 205 | 189 | 185 | 141 | 213 | 197 | 193 | ms | MED | 233 | 215 | 190 | 185 | 241 | 223 | 198 | 193 | ms |
| SLOW | 958 | 960 | 950 | 915 | 966 | 968 | 958 | 923 | ms | SLOW | 1078 | 972 | 951 | 915 | 1086 | 980 | 959 | 923 | ms |

FOR DIGIBRIDGE WITHOUT HIGH-SPEED MEASUREMENT OPTION ****

| | Measure Mode = Continuous * | | | | | | | | | | Measure Mode = Triggered ** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Display = BIN Test Freq (kHz) | | | | Display = VALUE Test Freq (kHz) | | | | | | Display = BIN Test Freq (kHz) | | | | Display = VALUE Test Freq (kHz) | | | | |
| Meas Rate | 0.1 | 1 | 10 | 100 | 0.1 | 1 | 10 | 100 | | kHz: | 0.1 | 1 | 10 | 100 | 0.1 | 1 | 10 | 100 | |
| "Max" | 140 | 67 | 61 | 60 | 148 | 75 | 69 | 68 | ms | "Max" | 210 | 74 | 62 | 60 | 218 | 82 | 70 | 68 | ms |
| FAST | 159 | 114 | 107 | 106 | 167 | 122 | 115 | 114 | ms | FAST | 229 | 121 | 108 | 106 | 237 | 129 | 116 | 114 | ms |
| MED | 168 | 240 | 224 | 220 | 176 | 248 | 232 | 228 | ms | MED | 268 | 250 | 225 | 220 | 276 | 258 | 233 | 228 | ms |
| SLOW | 993 | 995 | 985 | 950 | 1001 | 1003 | 993 | 958 | ms | SLO | 1113 | 1007 | 986 | 950 | 1121 | 1015 | 994 | 958 | ms |

* No entry for delay. When measure mode is CONTINUOUS, settling time is zero.
** No entry for delay. When measure mode is TRIGGERED, settling time is 6, 9, 11 ms/f defaults for measure rate = FAST, MED, SLOW, respectively; where f = test freq in kHz. Any programmed delay (can be 0 to 99999 ms) would replace the default settling time.
*** Display of VALUE, delta% or deltaRLC requires 6 to 10 ms more than display of BIN.
**** Omitting the high-speed measurement option adds about 37 ms normally, about 27 ms for "Max" rate (or any other condition in which IT factor is $< 1$).
"Max" is defined as FAST rate with IT factor set to 0.25 (a special function).

NOTE: Table 3-4 differs slightly from the table of typical measurement times given in the Specifications at the front of this manual (and data in paragraphs 3.5.1, 3.5.2, 3.5.5), although the tables are reasonably accurate. The differences underscore that these "typical" numbers are not specifications and that several test conditions and selections in addition to those stated for the tables affect measurement time. For example, selections of parameter and equivalent circuit affect calculation time.

## 3.6 ACCURACY, THE LIMITS OF ERRORS

### 3.6.1 General

Refer to the Specifications, at the front of this manual. The specifications apply at an ambient temperature of 23 degrees C (unless recalibration has been done at some other temperature), in low humidity, and if the OPEN and SHORT zeroing procedures have been executed properly (paragraph 3.1).

Typical accuracy is described below, for convenience in obtaining a birds-eye view of the way it relates to the principal test conditions, instrument programming, averaging, and median-value selection.

Refinement of the zeroing procedure to enhance accuracy for certain kinds of measurements is described in paragraphs 3.6.5 and 3.6.6. Cable-related errors and their correction are described in paragraph 3.6.7. Paragraph 3.6.8 describes the use of signal reversing (a special function) to enhance accuracy whenever test frequency is the same as power-line frequency.

### 3.6.2 Accuracy for Some Typical Conditions

**Figure 3-7.**

For convenience in comparing the tradeoffs between speed and accuracy, the accuracy is tabulated in Table 3-5 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 3-5
ACCURACY FOR A SET OF CONDITIONS COMPARABLE TO THOSE IN PREVIOUS TABLE *

---- Range 1 (Basic Range) ** ----

| Meas Rate | Test Freq (kHz) 0.1 | 1 | 10 | 100 | |
|---|---|---|---|---|---|
| "Max" | .27 | .25 | .40 | xx | % |
| FAST | .14 | .12 | .27 | xx | % |
| MED | .07 | .05 | .20 | xx | % |
| SLOW | .04 | .02 | .17 | xx | % |

----- Ranges 2, 3, 4 (Basic) *** ----

| Meas Rate | Test Freq (kHz) 0.1 | 1 | 10 | 100 | |
|---|---|---|---|---|---|
| "Max" | .27 | .25 | .28 | .55 | % |
| FAST | .14 | .12 | .15 | .43 | % |
| MED | .07 | .05 | .08 | .35 | % |
| 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<<1 with R, Q>>1 with L, D<<1 with C.

** (R) 25.6 to 410 kilohm
(L) 4.1/f to 65/f H
(C) 400/f to 6400/f pF

*** (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

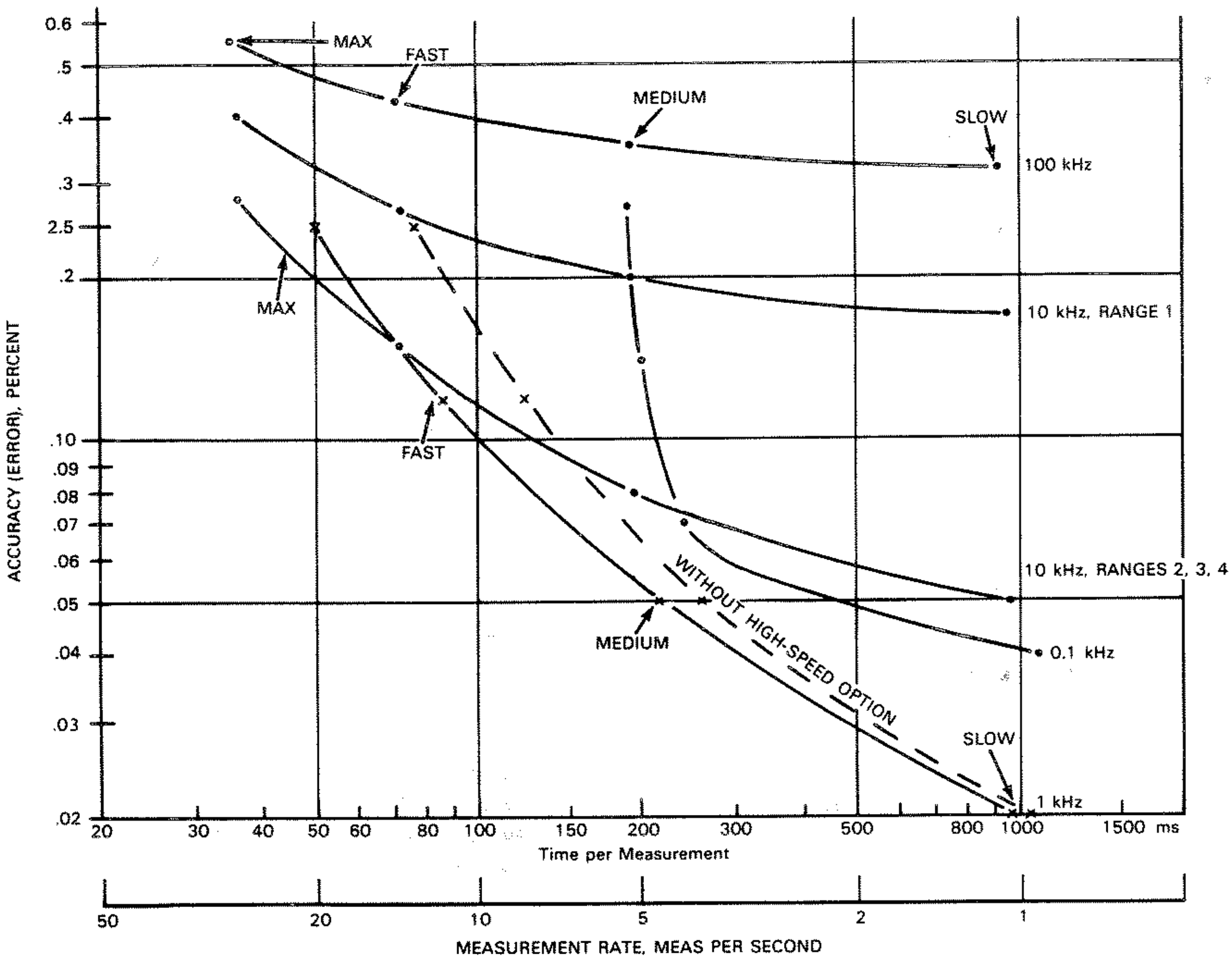


Figure 3-7. General view of the tradeoffs between measurement time and accuracy. Each curve shows the tradeoff for one test frequency. Operating points are labeled according to the selected measure rate (FAST, MEDIUM, SLOW). All of these curves apply to the following conditions: R, L, or C within basic ranges, D<<1 or Q>>1, display is BIN NO., test voltage => 1.0 V, constant voltage NOT selected, delay NOT programmed, measure mode is TRIGGERED, and the high-speed option is 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.

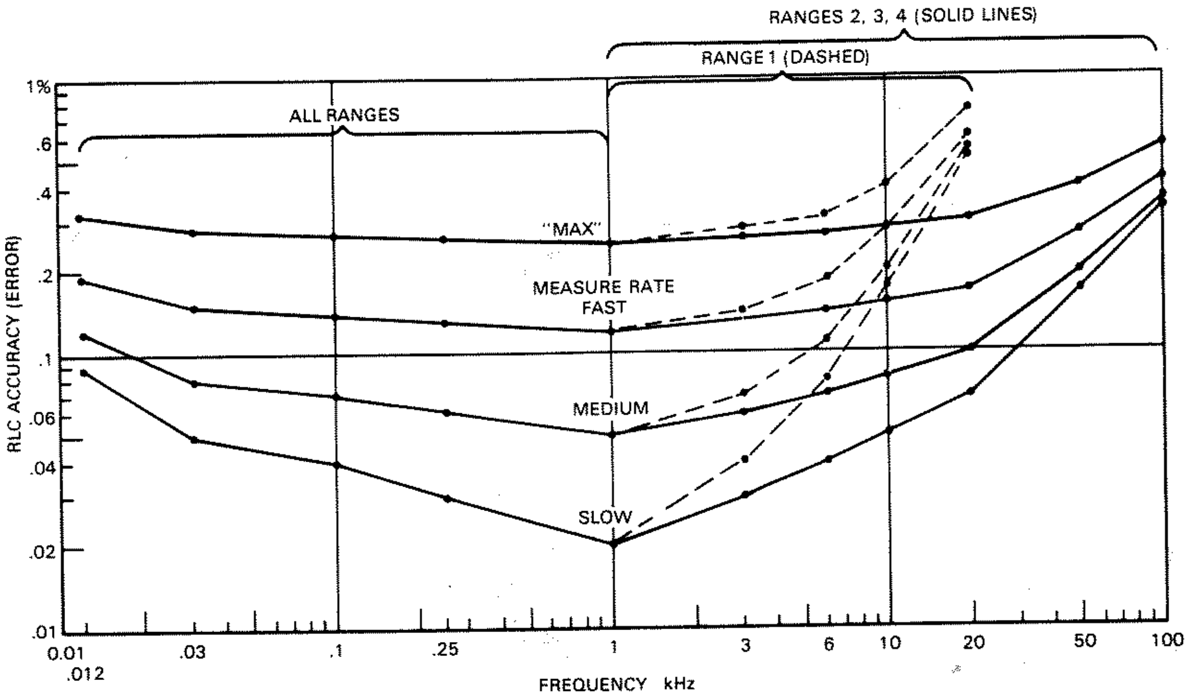


Figure 3-8. Approximate RLC accuracy vs test frequency for these test conditions: R, L, and C within basic ranges, D<<1 or Q>>1, test voltage => 1 V, constant voltage NOT selected. The curves are labeled according to measure rate, SLOW, MEDIUM, and FAST; "Max" is FAST with integration-time factor set 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, up to 20 kHz. For frequencies above this, see below.

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 +/- 1% (range-1 extension, a factor of 240 over Rmax)

At 120 Hz, C = 0.1 farad +/- 1% (range-4 extension, a factor of 480 over Cmax)

At 10 kHz, C = 0.1 pF +/- 1% (range-1 extension, a factor of 400 below Cmin)

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.

Special Zeroing Procedure for Frequencies above 20 kHz.

a. Set the frequency to 20 kHz and complete the open-circuit portion of the zeroing procedure (paragraph 3.1.3, step a).

b. Set the frequency to the desired value (above 20 kHz) and complete the short-circuit zeroing procedure (paragraph 3.1.3, step b).

Example of the accuracy typically obtained with measure rate = SLOW, after zeroing with this procedure.

At 100 kHz, L = 0.1 uH +/- 1% (range-4 extension, a factor of 100 below Lmin).

### 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 Lo — refer to Table 3-6. Measure the DUT using the series equivalent circuit. Then make the following calculation for each measurement.

For an inductor: Ls = Lm + Lo

For a capacitor: Cs = Cm / (1 - wwLoCm) = approx Cm (1 + wwLoCm)

where Ls and Cs are the corrected series values, Lm and Cm are the measured series values, w represents omega = 2 pi times frequency, and Lo is defined above. (Refer to the specification: MIL C-39010.)

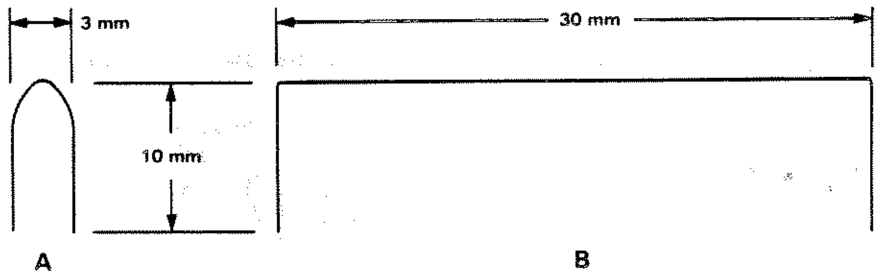


Figure 3-9. Shapes of wire recommended for short-circuit zeroing procedures before critical low-impedance measurements. Use "A" for radial-lead or miscellaneous DUTs. Use "B" before installing adaptors for axial-lead DUTs.

Table 3-6
INDUCTANCE OF STRAIGHT ROUND WIRES
(Body of Table = Inductance in nH)*

| Wire Size | For frequency = 100 kHz, Wire Length in Centimeters: 2 | 3 | 4 | 5 | 6 | 7 | 8 | Delta | For low frequency, Wire Length in Centimeters: 2 | 3 | 4 | 5 | 6 | 7 | 8 | Delta |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 13.0 | 22.0 | 31.6 | 41.7 | 52.3 | 63.1 | 74.3 | .13 | 13.5 | 22.7 | 32.6 | 42.9 | 53.7 | 64.8 | 76.2 | .25 |
| 18 | 14.1 | 23.5 | 33.7 | 44.3 | 55.4 | 67.3 | 78.5 | .16 | 14.4 | 24.1 | 34.4 | 45.2 | 56.4 | 68.1 | 79.9 | .25 |
| 20 | 15.1 | 25.1 | 35.8 | 47.0 | 58.5 | 70.5 | 82.7 | .19 | 15.4 | 25.5 | 36.3 | 47.6 | 59.3 | 71.3 | 83.6 | .25 |
| 22 | 16.2 | 26.7 | 37.9 | 49.6 | 61.7 | 74.1 | 86.9 | .22 | 16.3 | 26.9 | 38.1 | 49.9 | 62.1 | 74.6 | 87.3 | .25 |

*From the formula L = 2l[logn(2l/rho) - 1 + delta] nanohenries, where l = length (cm), rho = radius (cm), logn = natural logarithm, delta = skin-effect correction (tabulated). Reference: R. E. Terman, Radio Engineers' Handbook, McGraw Hill.

### 3.6.7 Cable-Related Errors and How to Correct for them

Test-fixture extension can introduce measurement error so that specified accuracy may not be met. In other words, some of the series impedances and ground capacitances associated with connecting a remote DUT can be large enough to introduce terms that add significantly to the error permitted by the accuracy specifications. In this paragraph, we discuss the cable-related sources of error, how to estimate it, and how to correct for it.

The Digibridge automatically compensates for capacitance between "high" terminals and "low" in the zero calibration. Also the 5-terminal "Kelvin" circuitry is designed to minimize the effect of other cable and test-fixture impedances on measurement accuracy. However, the following terms can be significant under some circumstances, particularly if a long extender cable is used.

1. Acm, common-mode accuracy term, most significant on range 4.
2. Ald, capacitive-loading accuracy term, most significant on range 1, at high frequency.

Formulas and typical constants are given below for obtaining useful approximations to these terms.

Acm = +/- [(.05) (r + jx) / Z] % of measured impedance

where (r + jx) is the series impedance in the Il lead including the cable, and Z is the DUT impedance. However, if you have selected SERIES EQUIV CKT, it is more useful to split Acm into the following 2 components, for treating Ls and Cs errors separately from Rs error:

Acmx = +/- [(.05) (x) / (DUT reactance)] % of measured series L or C

Acmr = +/- [(.05) (r) / (Rs)] % of measured Rs.

If either of these is significant, one can calculate and use it to correct each corresponding measured value. However, first make careful measurements with a known low-impedance DUT, to determine whether each correction should be positive or negative for your particular test fixture.

Ald = [(.003) (Krange) (ff) (Csn / 1000 pF)] % of principal measured value

where Krange is: for range 1, 1; for range 2, .0625; for range 3, .0040; for range 4, .00024. Factor f is frequency in kilohertz. Csn is total capacitance from the low (Il and Pl) terminals to ground (in Digibridge, cable, and test fixture).

If Ald is significant, one can calculate and use it to correct each measured C, L, or (if the DUT is a resistor) R. The effect on D or Q is negligible. For C, the Digibridge reads high; use a negative correction -- for L or R, the converse.

Refer to Table 3-7 for typical values to be used in the preceding formulas. Refer to Table 3-8 for some representative examples of accuracy (error) terms related to cables, for certain range and frequency selections. Notice that the addition of any remote test fixture will effectively increase each of these parameters and error terms. Also, cable and test fixture capacitance can aggravate a resonance problem in measurement of large values of inductance at high frequency; refer to para 3.12.

Table 3-7
TYPICAL PARAMETERS FOR DIGIBRIDGE WITH EXTENDER CABLE

| Cable | r (ohm) | Lc (uH)* | Csn (pF) |
|---|---|---|---|
| 1688-9600 | .019 | 0.45 | 155 |
| 1657-9600 | .036 | 1.10 | 475 |
| 1689-9602 | .335 | 1.10 | 210** |

* The formulas for Acm and Acmx contain x, which is 2(pi)fLc, where pi is 3.1416, f is expressed in Hz, and inductance Lc is tabulated above.
** Includes BNC adaptor 1689-9601 and remote fixture 1689-9600.

Table 3-8
TYPICAL CABLE-RELATED ACCURACY (ERROR) TERMS

| Cable | Range | Frequency | Accuracy term* |
|---|---|---|---|
| 1688-9600 | -- | 1 kHz | Acmx = +/- [.00014/(DUTX)] % of Ls, Cs |
| | -- | 20 | Acmx = +/- [.0028/(DUTX)] % of series Ls, Cs |
| | -- | -- | Acmr = +/- [.001/(Rs)] % of measured Rs |
| | 1 | 1 | Ald = +/- .00046 % of measured value |
| | 1 | 20 | Ald = +/- 0.19 % of measured value |
| | 2 | 20 | Ald = +/- 0.012 % of measured value |
| | 3 | 20 | Ald = +/- 0.0007 % of measured value |
| 1657-9600 | -- | 1 kHz | Acmx = +/- [.00034/(DUTX)] % of series Ls, Cs |
| | -- | 20 | Acmx = +/- [.0069/(DUTX)] % of series Ls, Cs |
| | -- | -- | Acmr = +/- [.0018/(Rs)] % of measured Rs |
| | 1 | 1 | Ald = +/- .0014 % of measured value |
| | 1 | 20 | Ald = +/- .0.57 % of measured value |
| | 2 | 20 | Ald = +/- 0.036 % of measured value |
| | 3 | 20 | Ald = +/- 0.0022 % of measured value |

*(DUTX) represents the reactance of the DUT.

### 3.6.8 Use of Signal Reversing (Special Function) for Tests at Power Frequencies

The special "signal reversing" function is primarily for use whenever the test frequency is 60 or 120 Hz (if your power frequency is 60 Hz) or whenever it is 50 or 100 Hz (if your power frequency is 50 Hz). However, it is also useful whenever the test frequency is equal to or very close to the frequency of any constant external signal that can be coupled to the low terminal(s) of the DUT (Il and Pl).

If this disturbance is strong enough, it can degrade the accuracy of normal measurements. However, if the disturbance is not so very strong that the Digibridge sensing circuits are overdriven, then "signal reversing" will typically restore specified accuracy. This special function enables a test routine in which the phase of the test signal is periodically reversed and the Digibridge senses both phases additively. However, the constant-phase disturbance component of the sensed signal is canceled by subtraction. This capability is a special function. To enable it, press the following keys:

[1][=][SHIFT][SPECIAL][3]

To disable "signal reversing", for fastest measurements, press:

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

## 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 built-in test fixture. 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 (6 to 11 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:

Delay = 10 Rstd Cx 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 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) = approx .002 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:

- o Be sure that the voltage is never more than 60 V, max.
- o A current limiting voltage supply is recommended; set the limit at 200 mA, max.
- o Be sure that the bias supply is floating; DO NOT connect either lead to ground.
- o Generally the external circuit must include switching for both application of bias after each DUT is in the test fixture and discharge before it is removed.
- o 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 mA).

c. Set the external bias supply to the desired voltage (< 60 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:

Delay = (Cx Vbias) / Imax + 10 Rstd Cx seconds

NOTE: Cx is the capacitance of the DUT in farads. Vbias is the external bias voltage in volts. Imax is the maximum current from the external supply (usually 0.2) amperes. 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.)

If the calculated delay is greater than the normal settling time (6 to 11 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 built-in test fixture. 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. That 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 (6 to 11 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.

## 3.8 BIN SORTING AND GO/NO-GO RESULTS

### 3.8.1 Introduction to Binning (Sorting Based on Limit Comparisons)

If a group of similar DUTs are to be measured, it is often convenient to use the limit-comparison capability of the Digibridge to categorize the parts. This can be done in lieu of or in addition to recording the measured value of each part. For example, the instrument can be used to sort a group of nominally 2.2-uF capacitors into bins of 2%, 5%, 10%, 20%, lossy rejects, and other rejects. Or it can assign DUTs to bins of (for example) a 5% series such as 1.8, 2.0, 2.2, 2.4, 2.7 uF, etc. The bin assignments can be displayed, for guidance in hand sorting, or (with an interface option) output automatically to a handler for mechanized sorting.

Up to 13 regular bins are provided for categories of the principal measurement (RLC), in addition to a bin for rejects in the secondary measurement (QDR), and a bin for all other rejects; total = 15 bins.

NOTE: The 1689-9610 high-speed measurement and IEEE/handler interface option provides a separate output signal line for each bin, suitable for connection to automatic handlers. However, the 1658-9610 IEEE/handler interface option provides only eight "go" bin output signal lines. Thus, an automatic handler can sort into bins 1 through 8. However, any assignments by the Digibridge into bins 9 through 13 are lumped with bin 14 (no-go), so far as the 1658-9610 handler interface is concerned.

Manually entered limits are normally entered in pairs (defining the upper and lower limits of a bin), in the form of "nominal value" and "percent" above and below that nominal. If only one "percent" value is entered for a bin, the limit pair is symmetrical (such as +/- 2%). To set up a non-symmetrical pair of limits, two "percent" values must be entered, the higher one first. Any overlapping portion of 2 bins is automatically assigned to the lower-numbered bin.

For simple GO/NO-GO testing, set up a QDR limit and one regular bin. Entry of limits in additional bins will define additional GO conditions. Be sure the unused bins are closed. (Bins 0 thru 13 are initially zero, at power-up. This means that the default QDR limit is "all fail" for D, Rs, and Q with R; it is "all pass" for Rp or Q with L; and that bins 1 through 13 are initially closed.)

The test frequency can be selected after limits are entered, before any particular measurement.

## 3.8.2 Sorting Methods

**Figures 3-10, 3-11.**

The figures illustrate 2 basic methods of sorting: nested and sequential. Nested limits are the natural choice for sorting by tolerance around a single nominal value. The lower numbered bins must be narrower than the higher numbered ones. Symmetrical limit pairs are shown; but unsymmetrical ones are possible. (For example, range AB could be assigned to bin 3 and range FG to bin 4 by use of unsymmetrical limit pairs in these bins.)

Sequential limits, on the other hand, are the natural choice for sorting by nominal value. Any overlap is assigned to the lower numbered bin; any gap between bins defaults to bin 14. The usual method of entry uses a redefined nominal value for each bin, with a symmetrical pair of limits. If it is necessary to define bins without overlap or gaps, use a single nominal value and unsymmetrical limit pairs. It is possible to set up one or more tighter-tolerance bins within each member of a sequence.

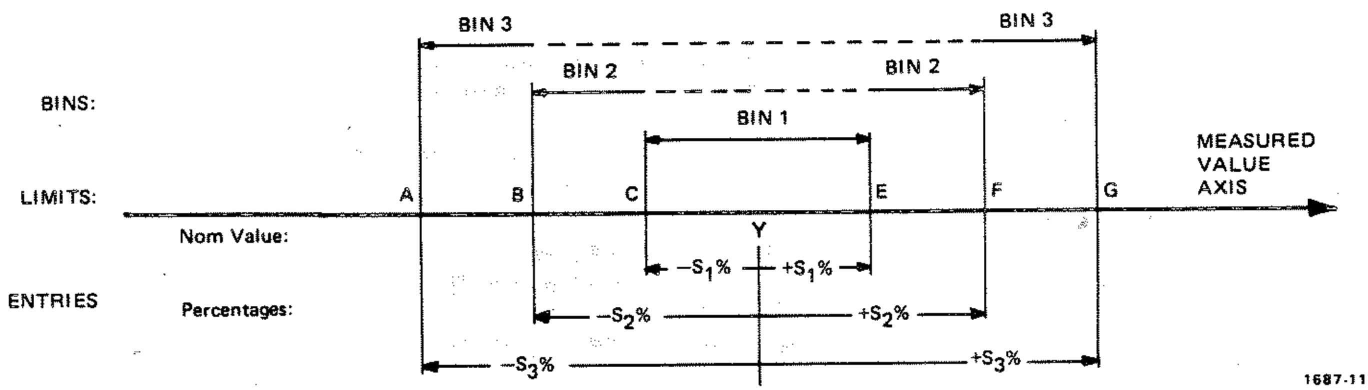


Figure 3-10. Nested limits. A single nominal value Y is used and all limit pairs are symmetrical in this basic plan.

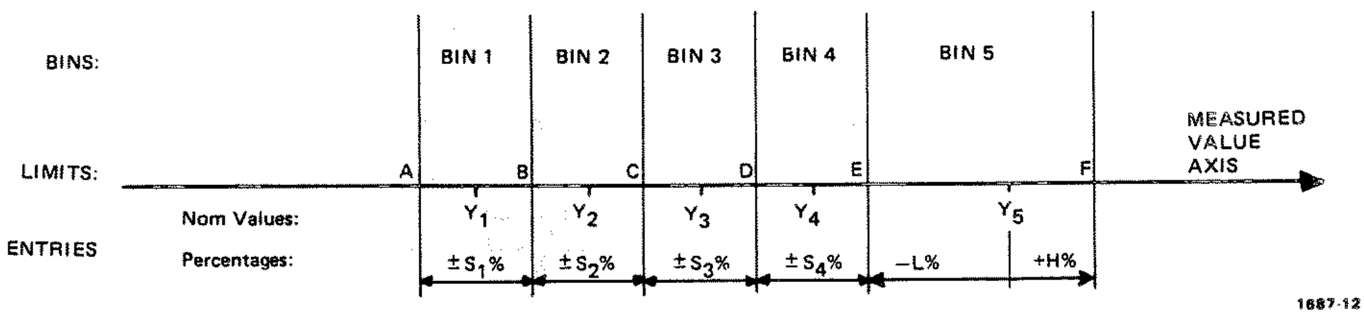


Figure 3-11. Sequential limits. A different nominal value is entered for each bin and all limit pairs are symmetrical except for the unsymmetrical pair shown for example in bin 5.

Bucket sorting means sorting into bins that are not nested. The usual method is that mentioned above, sequential limits. However, there is no requirement that the bins be adjacent. Any of them can be defined with its own specific limits, which may be overlapping, adjacent, or isolated from any other bin.

### 3.8.3 Limit Entry Procedure

To enable comparisons (unless the keyboard is locked), first enter limits as follows. This procedure makes use of limit entry keys, (at the left of the [SHIFT] key), with yellow labels that apply only when the selected FUNCTION is ENTER.

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

b. To enter a single QDR limit (always bin 0): press the parameter key (such as [Cs/D]) appropriate to DUT. To change range and unit multipliers, press the same key repeatedly. (Refer to paragraph 3.3.4 for a table of units and multipliers, which indicates the sequence of multipliers that will appear.) Enter the maximum limit of D or Rs or Q with R; enter the minimum limit of Rp or Q with L, as follows. (Keyed numbers appear on the left-hand display). For example, to enter a Q limit of 85, press

[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:

o <u>Symmetrical</u> <u>percentage</u> <u>tolerances</u> (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.

o <u>Various</u> <u>nominal</u> <u>values</u> (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.)

o <u>Unsymmetrical</u> <u>tolerances</u>. 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].
This is the value that the Digibridge will use for a subsequent entry of bin 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:
- o Press the [FUNCTION] key to select MEASURE
- o Press the [DISPLAY] key to select BIN NO.
- o Insert the DUT.
- o If the measure mode is TRIGGERED, press the START button.
- o 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.

<u>During the Entry Process</u>. 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.

<u>Upon Demand</u>. 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, Ls = 33 mH +/- 0.35%, +/- 1%, +/- 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. To enter a set of sequential limits, operate the keyboard as described below for the following capacitor sorting example: D < .005, Cp = 0.91, 1.0, 1.1, 1.2, 1.3 uF (the standard 5% series).

a. With [FUNCTION] key, select ENTER.
b. With [EQUIVALENT CIRCUIT] key, select PARALLEL.
c. With parameter key [Cp/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).

### 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. Maximum of 6 significant figures (for example: 38.6719% or 999999%).

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.

NOTE

When POWER is switched ON — if the keyboard is not locked -- nominal value is initialized at zero. Therefore, all bin sorting is initially inhibited.

Changing Entries. Enter new value(s) — or a zero — to delete obsolete or erroneous nominal value or bin limits. Do not attempt to change or enter a single separate limit in a bin; any single percentage entered for a bin will be interpreted as a symmetrical pair of limits. Changing nominal value does not change any limits, but does determine the base for subsequent limit entries for specific bins. (After function is changed to MEASURE, this nominal value will also serve as reference for delta percent measurements.)

RLC Unit Selection. In limit entry procedures, it is NOT necessary to select the range that the Digibridge will use in measuring. Just be sure that the number you enter for nominal value is suited to the units and unit multiplier indicated on the display panel. For example, nominal values of .033 H, and 33 mH are equivalent.

### 3.8.7 Go/No-Go and Bin Assignment Results

If comparison (binning) is enabled, the GO/NO-GO indicators will provide the following information after each measurement:

GO --- The DUT passed, in bin 1, 2, 3, ... 13
NO-GO --- The DUT failed, in bin 0 (QDR failure) or bin 14 (RLC failure).

If the display selection is BIN NO., the bin assignment will be shown in the left display area.

### 3.8.8 Bin Sum Information

If comparison (binning) is enabled, the Digibridge automatically keeps totals of the number of measurements assigned to each bin since power-up (or reset of the count to zero). The sums can be called up onto the display or sent out over the IEEE-488 bus. To make use of the bin-sum feature use these keystroke sequences:

```
[SHIFT][BIN SUM][0][0]      --- requests the sum for bin 0
[SHIFT][BIN SUM][0][1]      --- requests the sum for bin 1
[SHIFT][BIN SUM][0][2]      --- requests the sum for bin 2
    (etc)                   Note: sum appears at left, bin number at right.
[SHIFT][BIN SUM][LOCK]      --- sends the sums out via the IEEE-488 bus
[=][SHIFT][BIN SUM][0][0][1][4]    --- resets all sums to zero
```

### 3.8.9 Binning and Ratio Measurement Simultaneously

In order to bin-sort component parts whose values lie beyond the normal measurement range of the Digibridge, you must combine ratio measurement (paragraph 3.3.7) with limit comparisons and binning (paragraph 3.8). You should first become familiar with both ratio measurement and binning procedures because the combined procedure (as follows) can be somewhat tricky. Just as the display is a dimensionless number in ratio measurement, so the limit comparisons are made on dimensionless ratios in this combined procedure.

Plan ahead so that you have in mind what the ratio display will be like for any given measurement. For entering bin limits, each nominal ratio is the ratio display that would be expected if a corresponding nominal-valued DUT were measured.

General Procedure.

a. Select units appropriate for the component you plan to measure and a range that uses the largest unit multiplier. (This is necessary even if the measured value of the DUT is very small.) Select ENTER function.

b. Enter the nominal ratio (see above) as the bin-limit "nominal value". Ignore units and multiplier (although those selected in step a will still be displayed); the number entered will be used by the Digibridge as a ratio reference.

c. Enter (as usual) the desired set of tolerances for bin sorting. (If sequential limits are desired, also enter another nominal ratio, limits for other bins, etc.)

d. If you plan to measure large-value components, make no change in range. (However, if you plan to measure small-valued components select a range that uses a small unit multiplier.)

e. Enter the nominal value to be used by the Digibridge in the ratio calculations. Notice that units and multiplier are displayed. You can calculate what to enter as follows:

$$\frac{\text{expected typical measurement}}{\text{corresponding ratio to be displayed}} = \text{nominal value to be entered.}$$

f. Enable ratio measurement (measured value / nominal) as usual. [NOTE: if you want the other ratio (nominal / measured value) instead, then the calculation in step e has to be the product (expected meas)X(corresponding ratio).]

g. Select MEASURE function and proceed with measurements. Display selections VALUE, delta%, and deltaRLC will all display the ratio; BIN NO. will display the bin assignment. With a few strokes of the [DISPLAY] key, it is easy to obtain both ratio and bin number for each DUT (even without using the handler or IEEE-488 interfaces).

Example 1. To sort 200-mF capacitors in bins of +/-5%, 10%, and 20%. Displays to be ratios that can be interpreted as Cp values in mF and dissipation factor D.

a. Select PARALLEL equivalent circuit and ENTER function. Press [Cp/D]. Hold range 4 as follows:
[4][=][SHIFT][SPECIAL][1]

b. Set up nominal ratio to look like 200 mF:
[2][0][0][=][SHIFT][NOM VAL]

c. Set up symmetrical bins as stated above:
[5][%][=][SHIFT][BIN NO][0][1]
[1][0][%][=][SHIFT][BIN NO][0][2]
[2][0][%][=][SHIFT][BIN NO][0][3]

d. No action is required; range is correct.

e. Calculate (200 000 uF) / (200) = 1000 and press:
[1][0][0][0][=][SHIFT][NOM VAL]

f. Enable the ratio mode (measurement/nominal) by pressing:
[2][=][SHIFT][SPECIAL][6]

g. Select MEASURE function and make measurements as usual. If you enable VALUE display, the ratio shown can be interpreted as value in mF, and the measured D is also displayed. If you enable BIN NO. display, the bin number only will be shown.

Example 2. To sort 1-milliohm resistors in bins of +/-1%, 5%, and 10%. Displays to be ratios that can be interpreted as Rs values in milliohms (with better resolution than displays in ohms) and Q. NOTE: If the display resolution were not important, normal binning procedures would be sufficient; ratio measurement is not necessary for this binning.

a. Select SERIES equivalent circuit and ENTER function. Press [Rs/Q]. Hold range 1 as follows:
[1][=][SHIFT][SPECIAL][1]

b. Set up nominal ratio to look like 1 milliohm:
[1][=][SHIFT][NOM VAL]

c. Set up symmetrical bins as stated above:
[1][%][=][SHIFT][BIN NO][0][1]
[5][%][=][SHIFT][BIN NO][0][2]
[1][0][%][=][SHIFT][BIN NO][0][3]

d. Change from largest-value range to smallest-value range by pressing:
[4][=][SHIFT][SPECIAL][1]

e. Calculate (.001 ohm) / (1) = .001 and press:
[.][0][0][1][=][SHIFT][NOM VAL]

f. Enable the ratio mode (measurement/nominal) by pressing:
[2][=][SHIFT][SPECIAL][6]

g. Select MEASURE function and make measurements as usual. If you enable VALUE display, the ratio shown can be interpreted as value in milliohms, and the measured Q is also displayed. If you enable BIN NO. display, the bin number only will be shown.

## 3.9 KEYBOARD LOCK, FUNCTION MAP, AND SUMMARY OF INTERROGATIONS

### 3.9.1 Keyboard Lock

Locking the keyboard provides security against unintentional or unauthorized change in the keyboard-selectable test conditions, as well as preserving them during the time that POWER is switched OFF.

Indications of the unlocked or locked state are as follows:
Unlocked -- several keyboard indicators lit.
Locked -- NO keyboard indicators lit, except possibly MEASURE, BIAS ON and/or REMOTE CONTROL.

To lock the keyboard, first select MEASURE function. Then, press the following keys <u>deliberately</u>. The command sequence is the same to lock and to unlock:

[1][6][8][9][=][LOCK]

NOTE

If the REMOTE CONTROL indicator is lit, the keyboard may have been deactivated by remote command, in which case the way to reactivate it is by remote command. Refer to paragraph 3.12.

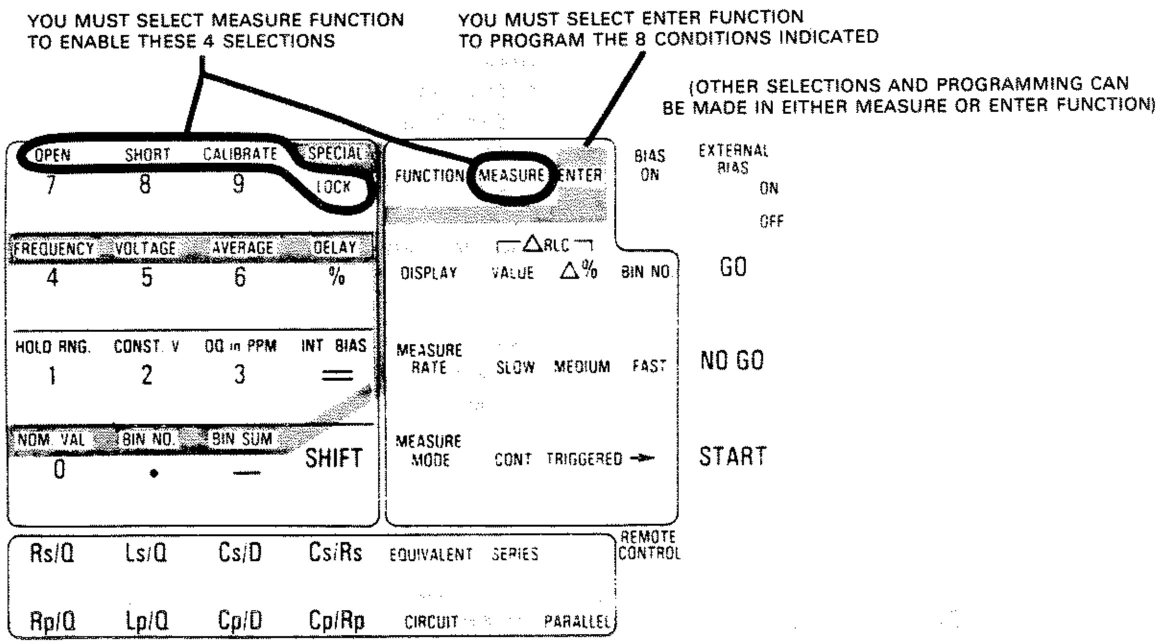


Figure 3-12. Map of keyboard, showing which programming entries can be made in MEASURE function and which ones in ENTER function.

### 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 <u>regardless</u> 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 below RLC display —— parameter and/or units of measurement.
All units and % indicators unlit —— display is either bin no. or ratio.
NEG RLC —— "negative" L or C; or (for displays of delta% or deltaRLC) measured value less than stored nominal.
NEG QDR —— capacitive resistor; or apparently negative loss factor.
RANGE HELD —— autoranging is disabled.
CONST VOLT —— source resistance held to 25 ohms (accuracy compromised).
DQ IN PPM —— units of D or Q (not R) are parts per million.
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 3.13. Indicators on the keyboard provide important information, NOT summarized here.

The following interrogations will work only if you select 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][VOLTAGE] —— test voltage that is applied behind source resistance.
[SHIFT][AVERAGE] —— number of measurements (or medians) averaged per result.
[SHIFT][DELAY] —— milliseconds of delay after START before data is acquired.

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] —— held range number (display of "0" if autoranging).
[SHIFT][SPECIAL][2] —— code for data output via IEEE-488 bus (para 3.10).
[SHIFT][SPECIAL][3] —— measurement routine (see paragraph 3.10).
[SHIFT][SPECIAL][4] —— number of digits blanked from left & right displays.
[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.

## 3.10 SPECIAL FUNCTIONS

Most of the special functions are described in more detail in other parts of the manual. Refer to Table 3-9 for a brief summary of the special functions and how to operate the [SPECIAL] key. Programming and interrogation of special functions can be done only in ENTER function.

Table 3-9
SPECIAL FUNCTIONS

| Purpose | Specific Selection | Keystrokes | Re Para |
|---|---|---|---|
| 1. Setting 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, and bin numbers | [7][=][SHIFT][SPECIAL][2] | |
| 3. Special Measurement Routines | Normal (fastest measurements) | [0][=][SHIFT][SPECIAL][3] | |
| | Signal reversing (useful when test frequency coincides with power frequency) | [1][=][SHIFT][SPECIAL][3] | 3.6.8 |
| | 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. Digit Blanking | Elimination of "a" digits from RLC display and "b" digits from QDR display | [a][.][b][=][SHIFT][SPECIAL][4] | |
| 5. Integration-Time Factor | Multiplies integration time by factor f (0.25 to 6). Normal is 1. Smaller factor decreases accuracy and measurement time. | [f][=][SHIFT][SPECIAL][5] | 3.5.5 |
| 6. Ratio Displays (RLC only) | Normal displays | [0][=][SHIFT][SPECIAL][6] | 3.3.7 |
| | Ratio displayed: nominal/meas value | [1][=][SHIFT][SPECIAL][6] | |
| | meas value/nominal | [2][=][SHIFT][SPECIAL][6] | |
| 7. Automatic Parameter Selection | Normal, manual selection | [0][=][SHIFT][SPECIAL][7] | 3.3.1 |
| | Automatic selection of parameter (R/Q, L/Q, or C/D) | [1][=][SHIFT][SPECIAL][7] | |
| 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] | |
| 0. Frequency Correction | Displays the correction "c" Refer to paragraph 3.4.1 | [SHIFT][SPECIAL][0] | 3.4.1 |

### 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 1689-9610 High-Speed Measurement Option includes the capability to sort automatically into all of the bins. However, with the 1658-9610 IEEE-488 Bus / Handler Interface Card, leave bins 9 through 13 closed because this handler interface lumps all five of them with bin 14, 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 1-2.) The two interface options are interchangeable in the basic IEEE-488-bus function. However, the 1689-9610 high-speed option is faster in making measurements than the 1658-9610; and the 1689-9610 provides handler-interface outputs for 15 bins, whereas the 1658-9610 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) |
| [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 3-10 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 3-11 through 3-13 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 ... X7 command; see paragraph 3.12.3), 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.

Table 3-10
ABBREVIATED INTERFACE MESSAGE CODE FOR "TALK-ONLY" DATA TRANSFER

| Character (ASCII) | Decimal 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 | ———— | | | | | |

---- FOOTNOTES FOR TABLE 3-11 ----

* For range-held measurements with "non constant voltage", underrange (overrange) occurs if DUT impedance is equal to that of an R, L or C too small (large) for the basic portion of the range being held, and if a range change is possible to improve accuracy. Similarly, for measurements with CONSTANT VOLTAGE, underrange (overrange) occurs if one quarter of the DUT impedance is outside the basic portion of the range being held. (In other words, this applies if the DUT impedance less than that at the midpoint of the basic range or greater than four times its high impedance end). Refer to para 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 overrange (display goes blank), 9999999 is output in this numeric field.

Table 3-11
DATA OUTPUT FORMAT FOR RLC VALUE, delta%, deltaRLC, OR RATIO

| Character Sequence | Purpose | Allowed 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 delta RLC or ratio | (space) | Normal display |
| | | ^ | /\RLC Mode |
| | | / | Ratio Mode: Nominal Value/RLC Value |
| 3 | Parameter | L | Inductance |
| | | C | Capacitance |
| | | R | Resistance |
| 4 | Normal or ratio mode | (space) | Normal mode (one of 3 described above) |
| | | / | Ratio Mode: RLC Value/Nominal Value |
| 5,6 | Units | (space)H | Henries |
| | | mH | Millihenries |
| | | uF | Microfarads |
| | | nF | Nanofarads |
| | | pF | Picofarads |
| | | (space)% | Percent difference from nominal value |
| | | (space)O | Ohms |
| | | KO | Kilohms |
| 7 | Format | (space) | |
| 8 | Sign | (space) | Positive R,L,C, /\%, or /\RLC |
| | | - | Negative R,L,C, /\%, or /\RLC |
| 9...15 | Number | 012345 6789. (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 | | (CR) | The standard "carriage return" and |
| 17 | Delimiter | (LF) | "line feed" characters; end of string. |

* ** *** Footnotes: see preceding page.

Table 3-12
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 | Quality factor<br>Dissipation factor<br>Resistance |
| 4 | Format | (space) | |
| 5...7 | Units | (2 spaces)0<br>(space)k0<br>ppm<br>(3 spaces) | Ohms<br>Kilohms<br>Parts per million (for D or Q)<br>Dimensionless (for Q or D) |
| 8 | Format | (space) | |
| 9 | Sign | (space)<br>- | Positive QDR value<br>Negative QDR value |
| 10...15 | Number | 012345<br>6789.<br>(space) | 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. * |
| 16<br>17 | Delimiter | (CR)<br>(LF) | The standard "carriage return" and "line feed" characters; end of string. |

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

Table 3-13
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<br>4<br>5 | Label | B<br>I<br>N | The word "BIN". |
| 6 | Format | (space) | |
| 7,8 | Bin number | 01234<br>56789 | Bin number assignment, 00 to 14. |
| 9<br>10 | Delimiter | (CR)<br>(LF) | The standard "carriage return" and "line feed" characters; end of string. |

Table 3-14
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<br>4<br>5<br>6<br>7<br>8 | Label | B<br>I<br>N<br>S<br>U<br>M | The word "BINSUM". |
| 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, the bin-summary number. |
| 18<br>19 | Delimiter | (CR)<br>(LF) | The standard "carriage return" and "line feed" characters; end of string. |

Bin Summary Output Format, Table 3-14. 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 3-18 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 3-16. 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 3-15
INTERFACE MESSAGE CODE FOR REMOTE CONTROL

| Message code* | Note ** | ASCII Equiv | Decimal Equiv*** | Sent concurrently with ATN line true: DIO8 | DIO7 | DIO6 | DIO5 | DIO4 | DIO3 | DIO2 | DIO1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 DIO8 (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 3-16
STATUS CODE

| Line | Significance of a "1" (Low) | Significance of a "0" (High) |
|---|---|---|
| DIO8 | Remote. | Local. |
| DIO7 | Request for service, RQS. (This device asserted SRQ.) | No request by this Digibridge for service. |
| DIO6 | Recalibration required. | Normal operation. |
| DIO5 | Busy, measurement in process. | Measurement completed. |
| DIO4 | Limits were tested. | Limits were not tested. |
| DIO3 | RLC measured value is available. | RLC value is not available. |
| DIO2 | QDR measured value is available. | QDR value is not available. |
| DIO1 | 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 3-15) and addressed to listen to device-dependent command strings.

Refer to Table 3-17. 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 "GO" 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 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 3-17, are simple ASCII character sequences of two or three characters. The first character is a CAPITAL 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 CAPITAL 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;

Table 3-17
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 | S0 |
| | 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 | Measure | 2 byte | P0 |
| | Enter | 2 byte | P1 |
| 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 R/Q, C/D, L/Q | 2 byte | M8 |
| Equivalent Circuit | Parallel | 2 byte | C0 |
| | Series | 2 byte | C1 |

Table 3-17 (Continued)
COMMANDS USED IN PROGRAMMING VIA IEEE-488 BUS

| Program Category | Program Selection | Command Type | Command Entry |
|---|---|---|---|
| Range Control | Hold range | 2 byte | R0 |
| | 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 |
| 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 |
| 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 |
| 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 |

Table 3-17 (Continued)
COMMANDS USED IN PROGRAMMING VIA IEEE-488 BUS

| Program Category | Program Selection | Command Type | Command Entry |
|---|---|---|---|
| Measurement Routines | Normal routine (highest speed) | 2 byte | Q0 |
| | Signal reversal (use for low frequency hum rej.) | 2 byte | Q1 |
| | Shorting between measurements (for Bias, charged cap.) | 2 byte | Q2 |
| | Signal reversal and shorting between measurements | 2 byte | Q3 |
| Display Digit Blanking | Eliminate (a) digits from RLC, (b) digits from QDR | 3 byte | Oab |
| Integration-Time Mult. Factor | Value (i) multiplies MEDIUM and FAST integr. times | Floating Point | Ii; |
| Delay | Value (in ms) = j | Floating Point | Jj; * |

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

Table 3-18
MESSAGE ACTIVITY ON IEEE-488 BUS DURING A SIMPLE EXAMPLE OF REMOTE CONTROL

| Byte order | Message* | ATN 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 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 3-11, 3-12, 3-13 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).

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

### 3.13.1 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.

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. 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 15.4, 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 1689-9610 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.

### 3.13.2 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).

### 3.13.3 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.

### 3.13.4 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 kHz (L > 1 H at 4 kHz).
2. With 1688-9600 cable, f > 2.8 kHz (L > 1.3 H at 3 kHz).
3. With 1657-9600 cable, f > 1.1 kHz (L > 3 H at 1.2 kHz).
4. 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.

f. 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 the NEG RLC indicator is lit, with indicated units of mH or H, the measured reactance is capacitive, although the RLC display is a number of millihenries or henries.