# GenRad

1689 $\$$4,950.00

# GR 1658 RLC Digibridge®

$\$$3,350.00 ?

Form 1658-0120-D

# Instruction Manual

10-8-82

# Contents



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# GR 1658
# RLC Digibridge®

Form 1658-0120-D


Concord, Massachusetts, U.S.A. 01742
May, 1980

# Specifications

**Measurement Parameters and Modes:** Series or parallel R and Q, series or parallel L and Q, series or parallel C and D. Continuous-repetitive, single, or averaged (set of 10) measurements; start button initiates single or averaged measurements. Keyboard selection of these and all measurement conditions.

**Main Displays:** (3 selections): Value display is LED-type numerical readout with automatically positioned decimal points and illumination of units; five digits for RLC (99999) and simultaneously four digits for DQ (9999). Limits display shows comparator bin limits and nominal values. Bin No. display shows the bin assignment of the measured device.

**Measurement Rates:** Approximately 2, 3, and 7 measurements/second. Keyboard selections are: "slow, medium, fast."

**Test Frequencies:** Keyboard selection between 2. Accuracy re panel legends is +2%, −.01%. Actual frequencies: for 1658-9700, 120.00 Hz ± .01% and 1020.0 Hz ± .01% (panel legend "1 kHz"); for 1658-9800, 100.00 and 1000.0 Hz ± .01%.

**Applied Voltage:** 0.3 V rms, maximum.

**Ranges:** Automatic ranging for best accuracy; autorange can be inhibited by keyboard selection. Three basic ranges (best accuracy, see table) of 2 decades each, for each parameter. Automatic extensions to min and max, as tabulated.

| Parameter | Minimum | Basic ranges | Maximum |
|---|---|---|---|
| R; 1 kHz | 0.0001 Ω | 2 Ω to 2 MΩ | 9.9999 MΩ |
| R; 120 Hz* | 0.0001 Ω | 2 Ω to 2 MΩ | 99.999 MΩ |
| L; 1 kHz | .00001 mH | 0.2 mH to 200 H | 999.99 H |
| L; 120 Hz* | 0.0001 mH | 2 mH to 2000 H | 9999.9 H |
| C; 1 kHz | .00001 nF | 0.2 nF to 200 μF | 999.99 μF |
| C; 120 Hz* | 0.0001 nF | 2 nF to 2000 μF | 99999 μF |
| Q (with R) | .0001 | (fully automatic) | 9.999 |
| Q (with L) | 00.01 | (fully automatic) | 999.9 |
| D (with C) | .0001 | (fully automatic) | 9.999 |

*120 Hz or 100 Hz, depending on the instrument.

**Accuracy:** For R, L, and C: ± 0.1% of reading in basic ranges, if quadrature component is small (< 10% of principal measurement), for slow measurement rate. More details given in table. Accuracy of Q (with R): ± .001; of Q (with L): ± .01; of D (with C): ± .0005; in basic ranges, for D or Q << 1; (otherwise, see table).

| Parameter | Basic accuracy: F* Low extens | Basic accuracy: Basic ranges | Basic accuracy: High extensions | Cross-term factor |
|---|---|---|---|---|
| R; either freq | ± M [2 mΩ, | 0.1% of rdg, | (R/20 MΩ) % of rdg] | (1+Q) |
| L; 1 kHz | ± M [0.2 μH, | 0.1% of rdg, | (L/2000 H) % of rdg] | (1+1/Q) |
| L; 120 Hz** | ± M [2 μH, | 0.1% of rdg, | (L/20 kH) % of rdg] | (1+1/Q) |
| C; 1 kHz | ± M [0.2 pF†, | 0.1% of rdg, | (C/2000 μF) % of rdg] | (1+D) |
| C; 120 Hz** | ±M [2 pF†, | 0.1% of rdg, | (C/.02 F) % of rdg] | (1+D) |
| Q (with R) | ±KM [ .001 | + .001 | Q (1+Q) ] | |
| Q (with L) | ±K [ .01 | + .001 | MQ(1+Q) ] | |
| D (with C) | ±KM [ .0005 | + .001 | D (1+D) ] | |

*Factors: M is 1, 2, or 5 for SLOW, MEDIUM, or FAST measurement rate, respectively. K is the quotient (RLC basic accuracy) / (RLC basic accuracy in basic range). Therefore, K = 1 in basic ranges. **120 Hz or 100 Hz. † Fixed offset "zero" capacitance is < 2.0 pF.

**Bias:** Connector for external voltage source, on-off switch, and indicator light. Limit, 60 V (max). External source requirements: ripple < 1 mV pk-pk, dynamic Z << 1 Ω with currents of ± 50 mA pk (source and sink); external discharge circuit recommended.

**Supplementary displays:** Parameters, modes, overrange and underrange conditions, range held, bias on, and remote control.

**Sorting:** Limit comparator sorts vs a DQ limit and up to 8 pairs of RLC limits into 10 bins, conveniently defined by keyboard entries. GO/NO-GO is indicated, whether bin number or measured value is selected as main display.

**Interface option:** 2 ports (1 with choice of 2 modes); a 24-pin connector for each port. IEEE-488 INTERFACE PORT: Functions are SH1, AH1, T5, L4, SR1, RL2, PP0, DC0, DT1, C0. Refer to IEEE Standard 488-1978. Switch selection between 2 modes as follows. TALKER-LISTENER MODE: Input commands from system controller can disable keyboard and program all functions (except setting limits for sorting); any or all measurement results are available as outputs. TALKER-ONLY MODE: Measured results are always output, for use in systems without controllers. HANDLER INTERFACE PORT: 1 input (start signal), 2 output (status signals), and set of 10 output lines (sorting data); active-low logic; for input, logic low is 0.0 to +0.4 V (current is 0.4 mA max) and logic high is +2.4 to +5.0 V; for outputs, open-collector drivers rated at +30 V max, 40 mA max (sink), each, this port only. (External power supply and pullup resistors are required.)

**Environment:** TEMPERATURE: 0 to 40°C operating, −40 to +75°C storage. HUMIDITY: 0 to 85% R.H., operating.

**Supplied:** Power cord, axial-lead adaptors, bias cable, instruction manual.

**Line Voltage and Power:** 90 to 125 V or 180 to 250 V, 50 to 60 Hz. Either of these ranges selected by rear-panel switch. 30 W max.

**Mechanical:** Bench mounting. DIMENSIONS: (wxhxd): 375x112x343 mm (14.8x4.4x13.5 in.). WEIGHT: 6 kg (13.5 lb) net, 10 kg (22 lb) shipping.

| Description | Catalog Number |
|---|---|
| **1658 RLC Digibridge TM** | |
| 120 Hz and 1 kHz Test Frequencies | **1658-9700** |
| Same with Interface Option | **1658-9701** |
| 100 Hz and 1 kHz Test Frequencies | **1658-9800** |
| Same with Interface Option | **1658-9801** |
| **Extender Cable** (for remote measurements) | **1657-9600** |

Patent applied for.

# Table of Contents

**Condensed Operating Instructions are on page 1-6.**

# Warranty

GenRad

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable GenRad specifications. If within one year after original shipment it is found not to meet this standard, it will be repaired or, at the option of GenRad, replaced at no charge when returned to a GenRad service facility. Changes in the product not approved by GenRad shall void this warranty. GenRad shall not be liable for any indirect, special, or consequential damages, even if notice has been given of the possibility of such damages.

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

GenRad policy is to maintain product repair capability for a period of ten years after original shipment and to make this capability available at the then prevailing schedule of charges.

# Introduction—Section 1



## 1.1 PURPOSE.

The 1658 Digibridge (TM) is a digital impedance meter and limit comparator embodying use of a microprocessor and other LSI circuitry to provide convenience, speed, accuracy, and reliability at low cost. With the interface option, this Digibridge can control other equipment and respond to remote control.

The versatile built-in test fixture, lighted keyboard, and angled display panel make this Digibridge convenient to use. Measurement results are clearly shown with decimal points and units, which are automatically presented to assure correctness. Display resolution is 5 digits for R, C, and L (4 for D or Q) and the basic accuracy is 0.1%.

Long-term accuracy and reliability are assured by the measurement system. It makes these accurate analog measurements over many decades of impedance without a single calibration or "trimming" adjustment (not even in original manufacture).

The built-in test fixture, with a pair of plug-in adaptors, receives any common component part (axial-lead or radial-lead), so easily that insertion of the device under test (DUT) is a one-hand operation. Four-terminal (Kelvin) connections are made automatically, ungrounded, with guard at ground potential. An extender cable is available for measurements at a distance from the instrument, typically for bulky components.

Bias can be applied to capacitors being measured, by connection of an external voltage source and sliding a switch. Bias levels from 0 to 60 V are suitable.

The interface option provides full "talker/listener" and "talker only" capabilities consistent with the standard IEEE-488 Bus. [1] A separate connector also interfaces with component handling and sorting equipment.

## 1.2 GENERAL DESCRIPTION.

### 1.2.1 Basic Digibridge.

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

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

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

### 1.2.2 Interface Option.

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

### 1.2.3 References.

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

## 1.3 CONTROLS, INDICATORS, AND CONNECTORS.

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

## 1.4 ACCESSORIES.

GenRad makes several accessories that enhance the usefulness of this Digibridge. The extender cable facilitates making connection to those devices and impedance standards that do not readily fit the built-in test fixture. The cable branches into 5 parts, each with a stackable banana plug, for true 4-terminal connections (and guard) to the device being measured, without appreciable reduction in measurement accuracy. Other useful accessories are offered, such

[1] IEEE Standard 488-1975, Standard Digital Interface for Programmable Instrumentation. (See para 2.8, below.)

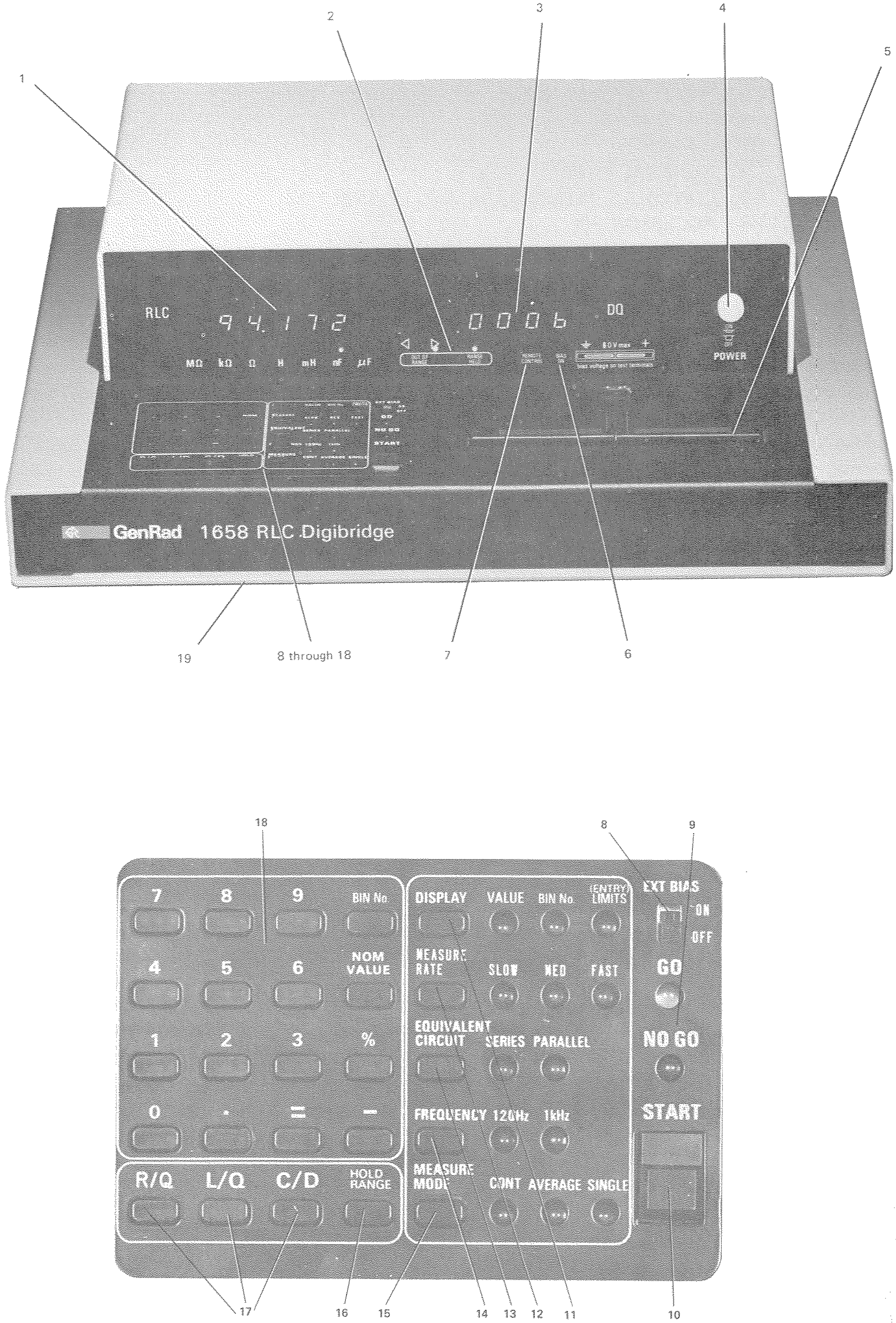



Figure 1-1. Front controls and displays. Upper, whole instrument. Lower, keyboard, detail.

Table 1-1

FRONT CONTROLS AND INDICATORS

| Figure 1-1 Item | Name | Description | Function |
|---|---|---|---|
| 1 | RLC display | Digital display, 5 numerals with decimal points. Unit labels MΩ, kΩ, Ω, H, mH, nF, μF, with 7 lights. | Display of principal measured value. Light spot indicates units. |
| 2 | OUT OF RANGE and RANGE HELD lights. | Legend with arrows and 3 lights. | Indicates when measurement is OUT OF basic RANGE: underrange (left arrow), overrange (right arrow), or DUT not compatible with selected parameter (both arrows). For low underrange, neither arrow is lit. (However, if RLC display has less than 4 digits, the measurement was made on low underrange.) When RANGE HELD indicator is out, the range is automatically optimized. |
| 3 | DQ display | Digital display, 4 numerals with decimal points. | Display of secondary measured value, D if you select C/D, Q if you select L/Q or R/Q with item 17. |
| 4 | POWER switch | Pushbutton (push again to release). | Turns instrument ON when in, OFF when out. OFF position breaks both sides of power circuit. |
| 5 | Test fixture | Pair of special connectors; each makes dual contact with inserted wire lead of DUT. | Receives radial-lead part, making 4-terminal connection automatically. Adaptors are supplied to make similar connection with axial-lead part. |
| 6 | BIAS light | Legend with light. | Light shines when bias is applied (via EXT BIAS switch, item 8). |
| 7 | REMOTE CONTROL light | Legend with light. | Light shines when remote control is established by external command. Functions only if you have the interface option. |
| 8 | EXT BIAS switch | Slide switch, 2 positions: ON, OFF. | To connect and disconnect the external bias circuit. See item 6. Use an external switch routinely to apply bias and to discharge capacitors. Always leave OFF when bias circuit is not in use. |
| 9 | GO/NO-GO lights | LED indicator lights | GO means measured value is acceptable, based on the limits stored by item 18. NO-GO means unacceptability of basic parameter, loss factor, or both. |
| 10 | START button | Pushbutton switch. | Starts measurement sequence. (Normally used when measurement mode is either SINGLE or AVERAGE.) |
| 11 : 15 | (see below) | Each key has associated LED indicators at right. | Selection of indicated function, accomplished by pressing key repeatedly (causing corresponding indicators to cycle through the alternatives) until desired choice is lit. |
| 11 | DISPLAY key | Indicators: VALUE, BIN NO., ENTER LIMITS. | Two choices enable measurement, with display senses as follows: VALUE = measured parameters, BIN NO. = limit category into which value fits. When ENTER LIMITS is selected, measurements are inhibited, limit-entry keys are enabled, and display is limits or nominal value, depending on use of item 18. |
| 12 | MEASURE RATE key | Indicators: SLOW, MED, FAST | Selection of measurement speed as indicated. (Accuracy is best with SLOW.) |
| 13 | EQUIVALENT CIRCUIT key | Indicators: SERIES, PARALLEL. | Selection of equivalent circuit assumed for the DUT. |
| 14 | FREQUENCY key | Indicators: 120 Hz and 1 kHz (or 100 Hz, 1 kHz). | Selection of test-signal frequency. |
| 15 | MEASURE MODE key | Indicators: CONT, AVERAGE, SINGLE. | Mode selection: continuously repeating measurements; running average of 10 measurements and display held after the 10th; single measurement (display held). Continuous mode does not require "start." |

Table 1-1 (Cont.)

FRONT CONTROLS AND INDICATORS

| Figure 1-1 Item | Name | Description | Function |
|---|---|---|---|
| 16 | HOLD RANGE key | Key associated with RANGE HELD light. (See item 2.) | Key action alternates state between "autorange" (indicator off) and RANGE HELD (indicator on), which holds the present range for subsequent measurements. |
| 17 | Parameter keys | Set of 3 keys, labeled: R/Q, L/Q, C/D. | Selection of basic parameter to be measured: R, L, or C. Also, during "limit entry", (see item 11), repeated pushing of any one key selects measurement units (for limits), as displayed in item 1. |
| 18 | Limit-entry keys | Group of 16 keys with numbers and other labels. | Manual entry of limits that define go/no-go categories and 10 bin assignments, and selection of limit displays on items 1 and 3. Functional only if ENTER LIMITS has been selected by item 11. |
| 19 | Reference card | Captive pull-out card. | Handy reference information for basic operation, limit entry, and programming. |

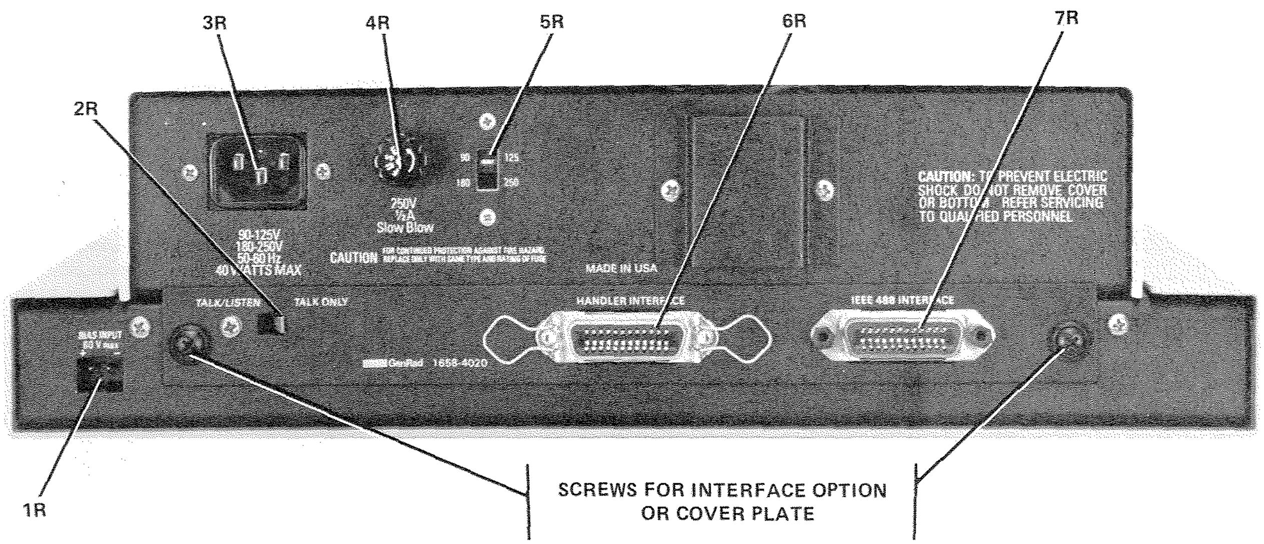



Figure 1-2. Rear controls and connectors.

as standards for checking the performance of the Digibridge. Refer to Table 1-3 in this manual and the brochure of Impedance Standards and Precision Bridges, available from GenRad upon request.

Table 1-2

REAR CONNECTIONS AND CONTROLS

| Figure 1-2 Ref. No. | Name | Description | Function |
|---|---|---|---|
| 1R | BIAS INPUT connector | Recessed plug, 2-pin, Labeled: 60 V max, +, −, (rear view). | Connection of external voltage source for biasing capacitors via test fixture. Observe instructions in para 2.6. |
| 2R | TALK switch* | Toggle switch. | Selection of mode for IEEE-488 interface: TALK/LISTEN or TALK ONLY, as labeled. |
| 3R | Power connector (labeled 50-60 Hz) | Safety shrouded 3-wire plug, conforming to International Electrotechnical Commission 320. | Ac power input. Use appropriate power cord, with Belden SPH-386 socket or equivalent. The GenRad 4200-9625 power cord (supplied) is rated for 125 V. |
| 4R | Fuse (labeled 250 V, 0.5 A, SLOW BLOW) | Fuse in extraction post holder. | Short circuit protection. Use Bussman type MDL or equivalent fuse, 1/2 A, 250 V rating. |
| 5R | Line-voltage switch | Slide switch. Upper position, 90 to 125 V; lower position, 180 to 250 V. | Adapts power supply to line-voltage ranges, as indicated. To operate, use small screwdriver, not any sharp object. |
| 6R | HANDLER INTERFACE connector* | Socket, 24-pin; receives Amphenol "Microribbon" plug P/N 57-30240 (or equiv). | Connections to component handler (bin numbers and status, out; "start", in). |
| 7R | IEEE-488 INTERFACE connector* | Socket, 24-pin. Receives IEEE-488 interface cable (see para 2.8). | Input/output connections according to IEEE Std 488-1978. Functions: complete remote control, output of all display values. |

*TALK switch and 24-pin connectors are supplied with the Interface Option only.

Table 1-3

ACCESSORIES

| Quantity | Description | Part Number |
|---|---|---|
| 1 supplied | Power cord, 210 cm (7 ft) long, 3-wire, AWG No. 18, with molded connector bodies. One end, with Belden SPH-386 socket, fits instrument. Other end is stackable (hammer-head) conforming to ANSI standard C73.11-1966 (125 V max). | 4200-9625 |
| 2 supplied | Test-fixture adaptors, for axial-lead parts. | 1686-1910 |
| 1 supplied | Bias cable, 120 cm (4 ft) long, 2-wire. One end fits BIAS INPUT connector. Other end has stackable banana plugs (black, red). | 1658-2450 |
| 1 supplied | Keyboard cover. | 1687-2210 |
| 1 recommended | Extender cable for connection to multi-terminal standards and large or remote DUT's. Length 100 cm (40 in.). | 1657-9600 |
| 1 available | Rack mount kit (slides forward for complete access) | 1657-9000 |

CONDENSED OPERATING INSTRUCTIONS

GenRad 1658 Digibridge®

## 1. GENERAL INFORMATION

Refer to instruction manual for details of specification, installation, operation, and service.

MEASUREMENT RANGES

| Parameter; Frequency | Minimum (Reduced Acc) | Basic Ranges, Full Accuracy | Maximum (Reduced Acc) |
|---|---|---|---|
| R; 120 Hz* | Ø.0001 Ω | 2 Ω to 2 MΩ | 99.999 MΩ |
| R; 1 kHz | Ø.0001 Ω | 2 Ω to 2 MΩ | 9.9999 MΩ |
| Q (with R) | .0001 | ----- | 9.999 |
| L; 1 kHz | .00001 mH | 0.2 mH to 200 H | 999.99 H |
| L; 120 Hz* | Ø.0001 mH | 2 mH to 2000 H | 9999.9 H |
| Q (with L) | ØØ.01 | ----- | 999.9 |
| C; 1 kHz | .00001 nF | 0.2 nF to 200 μF | 999.99 μF |
| C; 120 Hz* | Ø.0001 nF | 2 nF to 2000 μF | 99999 μF |
| D (with C) | .0001 | ----- | 9.999 |

*120 Hz or 100 Hz, depending on model.

## 2. EXTENDER CABLE

Available from GenRad (P/N 1657-9600).

COLOR CODE OF EXTENDER CABLE

| Colors | Signal | DUT | Digibridge |
|---|---|---|---|
| Red | I+ | "High" end | Signal source (hi) |
| Red and white | P+ | "High" end | Potential sense (hi) |
| Black | I– | "Low" end | Current sense (lo) |
| Black and white | P– | "Low" end | Potential sense (lo) |
| Black and green | GND | Shield only | Guard |

## 3. EXT BIAS SWITCH

Keep this switch OFF (regardless of whether any bias source is connected) for all measurements except when applying dc bias to capacitors. (Refer to manual, para 3.7.)

## 4. OPERATION

a. Select VALUE mode with [DISPLAY] key.

b. Select measurement conditions with keys at right. Repeat keying advances selection as indicated nearby.

c. With [HOLD RANGE] key, select autorange (no indication) or RANGE HELD (indicator on panel).

d. Select parameter with R/Q, L/Q, or C/D key; note confirmation by type of unit, on panel. (Repeat keying has no effect except in entry mode; see para 6.)

e. Refer to manual for details of test fixture connections. Keep EXT BIAS switch generally OFF (see above).

f. Use START button for AVERAGE or SINGLE MEASURE MODE.

g. Read RLC and DQ displays. Observe range lights:

| Underrange: better accuracy is available on a lower range.* | ◁ OUT OF RANGE ▷ (both arrows lighted) WRONG PARAMETER R/Q, L/Q, or C/D. | Overrange; RLC value is too large for basic range of the currently used range.* |
|---|---|---|

*Select autorange (avoid RANGE HELD) to obtain best available accuracy and minimize the number of under- and over-range measurements.

h. If limits have been entered and enabled (para 6), observe GO/NO-GO lights.

i. If limits have been entered and enabled (para 6), to see display of bin number instead of measured values, use [DISPLAY] key to select BIN No. and remeasure the DUT.

## 5. INTERFACE OPTION, USE OF IEEE–488 BUS

Set the TALK switch (rear panel) as follows:

TALK ONLY – whenever bus is not in use and while communicating only with "listen-only" devices.

TALK/LISTEN – to enable use in a system with a controller device, e.g., calculator. Refer to table below for device-dependent messages to control Digibridge.

PROGRAMMING COMMANDS

| Command | Code | Command | Code | Command | Code |
|---|---|---|---|---|---|
| Display | | Measure mode | | Data output** | |
| Entry* | DØ | Single | LØ | None | XØ |
| Bin | D1 | Average | L1 | Bin number | X1 |
| Value | D2 | Continuous | L2 | DQ | X2 |
| Measurement rate | | Parameter | | DQ, bin no. | X3 |
| Fast | SØ | L/Q | MØ | RLC | X4 |
| Medium | S1 | C/D | M1 | RLC, bin no. | X5 |
| Slow | S2 | R/Q | M2 | RLC, DQ | X6 |
| Equivalent circuit | | Range control | | RLC, DQ, bin | X7 |
| Parallel | CØ | Hold range | RØ | Initiation | |
| Series | C1 | Hold rng 1 | R1 | Start*** | GØ |
| Frequency | | Hold rng 2 | R2 | Manual start | |
| 120 Hz (100) | FØ | Hold rng 3 | R3 | Enable switch | EØ |
| 1 kHz | F1 | Autorange | R4 | Disable sw | E1 |

*Enables entry of bin limits, which must be entered via keyboard.
**Must be specified before initiation of measurement.
***An alternative command is given in manual.

## 6. ENTRY MODE

Entry-mode keys (left rear block of 16 keys) are effective only when selected DISPLAY is ENTER LIMITS.

| LIMIT ENTRY PROCEDURE | DISPLAY |
|---|---|
| With [FREQUENCY] select: | 120 Hz (100 Hz) or 1 kHz. |
| With [DISPLAY] select: | ENTER LIMITS. |
| Use [R/Q] [L/Q] or [C/D] to select units by repeat keying | MΩ, kΩ, Ω, H, mH, nF, or μF. |
| (X) [=] [BIN No.] [0] (X is the desired DQ limit)* | (X) in DQ display area; max 4 digits and dec pt. |
| (Y) [=] [NOM VALUE] (Y = number; above units)* | (Y) in RLC display area; max 5 digits and dec pt. |
| (S) [%] [=] [BIN No.] (Z) (for symmetrical limit pair) (S is number up to 100.00)* (Z is 1, 2, 3, ... 8). | Upper limit in RLC area, lower limit in DQ area, (values, not percents). |
| (H) [%] [–] (L) [%] [=] [BIN No.] (Z) (for unsymmetrical limit pair) (H is number up to 10000)* (L is number up to 100.00.)* | Upper limit in RLC area, lower limit in DQ area, (values, not percents.) |
| To change nom val, reenter.** | (Y) in RLC display area. |
| To change bin limits, reenter. | Both limit values. |
| To close a bin, use zero for S. | Identical limit values. |
| To see, press [NOM VALUE] | (Y) in RLC display area. |
| To see, key in [BIN No.] (Z) | Limit values (as above). |
| Inhibit: [0] [=] [NOM VALUE] | 0 in RLC display area. |
| Enable: (Y) [=] [NOM VALUE] | (Y) in RLC display area. |

| BIN No. | GENERAL ASSIGNMENT |
|---|---|
| Bin Ø | DQ failure |
| Bin 1 | RLC pass, tightest tolerance |
| Bin 2 | RLC pass, next looser tolerance |
| -- | (progressively looser tolerances) |
| Bin 8 | RLC pass, last available bin |
| Bin 9 | RLC fail (default bin) |

*Use numerical and decimal-point keys in sequence to enter number; max of 5 digits and decimal pt valid, even if display is limited to 4.
**New nominal value does not affect bins already set up.

To resume operation using limits entered as above, press [DISPLAY] key (see para 4); do not change frequency.

# Installation–Section 2



## 2.1 UNPACKING AND INSPECTION.

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

## 2.2 DIMENSIONS. Figure 2-1.

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

## 2.3 POWER-LINE CONNECTION.

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

If your line voltage is in the lower range, connect the 3-wire power cable (P/N 4200-9625) to the power connector on the rear panel (Figure 1-2) and then to the power line.

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

The associated power cord for use with that receptacle, for line voltages up to 125 V, is GenRad part no. 4200-9625. It is a 210-cm (7 ft), 3-wire, 18-gage cable with connector bodies molded integrally with the jacket. The connector at the power-line end is a stackable hammerhead design that conforms to the "Standard for Grounding Type Attachment Plug Caps and Receptacles," ANSI C73.11-1966, which specifies limits of 125 V and 15 A. This power cord is listed by Underwriters Laboratories, Inc., for 125 V, 10 A.

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

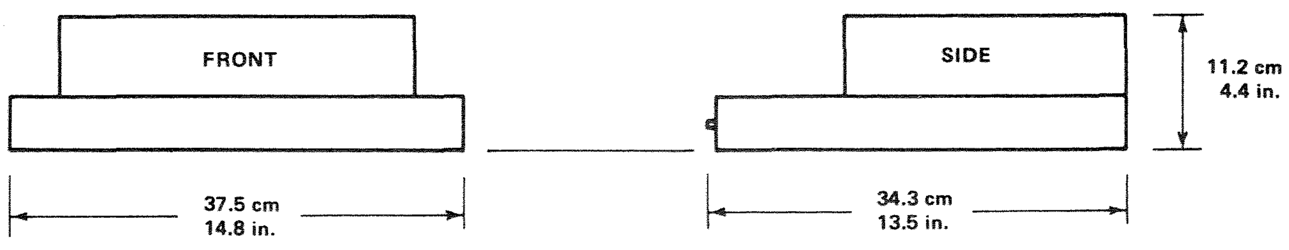



Figure 2-1. Overall dimensions

If your line voltage is in the higher range selectable by the line voltage switch, use a power cord of the proper rating (250 V, 15 A) that mates with both instrument and your receptacle. It is possible to replace the "hammerhead" connector on the power cord that is supplied with a suitable connector. Be sure to use one that is approved for 250 V, 15 A. A typical configuration is shown in Figure 2-2.

## 2.4 LINE-VOLTAGE REGULATION.

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

## 2.5 TEST-FIXTURE CONNECTIONS.

Because an unusually versatile test fixture is provided on the front shelf of the instrument, no test-fixture connection is generally required. Simply plug the device to be measured (DUT) into the test fixture, with or without its adaptors. For details, refer to para 3.2.

The accessory extender cable 1657-9600 is needed to connect to a DUT that is multiterminal, physically large, or otherwise unsuited for the built-in test fixture. (Refer to Table 1-3.) This cable is needed also to connect impedance standards for accuracy checks. Use the following procedure to install the extender cable on the instrument.

a. Remove the adaptors, if present, from the test fixture. (See para 3.1.)

b. Plug the single-connector end of the extender cable into the test fixture, so that its blades enter both slots. Then lock the connector with the 2 captive thumb screws (which also provide a ground connection).

c. Notice the color coding of the 5 banana plugs. (I+ is "current source"; I– is "current sense"; both P are "potential sense".)

I+ = RED P+ = RED/WHITE Guard = BLACK/GREEN
I– = BLACK P– = BLACK/WHITE.

## 2.6 EXTERNAL BIAS

**WARNING**

- **Maximum bias voltage is 60 V. Do NOT exceed.**
- **Bias voltage is present at connectors, test fixtures, and on capacitors under test.**
- **Capacitors remain charged after measurement.**
- **Do not leave instrument unattended with bias applied.**

Full bias voltage appears on test leads, bias-voltage-source terminals, and on the leads of the DUT. Capacitors that have been measured with bias applied can be dangerous until properly discharged, if several of them become connected in series by chance contact. For safety, all personnel operating the instrument with bias must be aware of the hazards, follow safe procedures, and remove bias before leaving the equipment unattended. Refer to para 3.7.

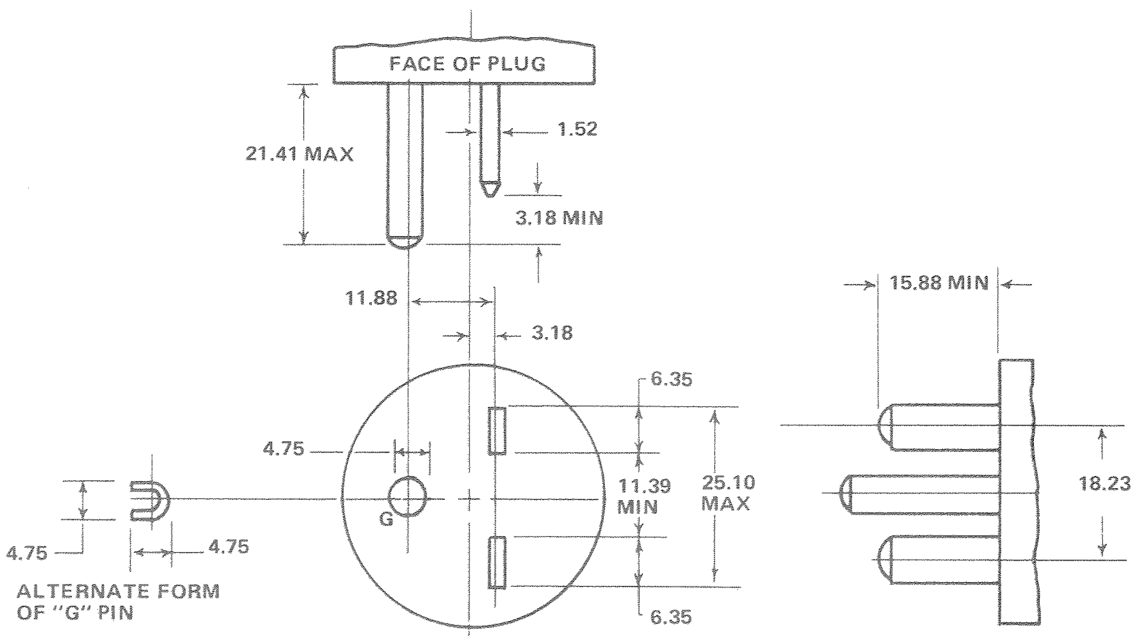



**Figure 2-2 Configuration of 250-V 15-A plug. Dimensions in mm. This is listed as NEMA 6-15P. Use for example Hubbell plug number 5666.**

In order to measure a capacitor with dc bias voltage applied, connect an external voltage source as follows.

a. Plug the bias cable, supplied, into the BIAS connector, at the rear. Be sure to orient the plug so that the red-tipped wire connects to the + pin. (Refer to the label at the BIAS connector.)

b. Connect the black and red tips to the external bias supply – and + terminals, respectively. The bias voltage source must satisfy several criteria:

1. Supply the desired terminal voltage (dc).
2. Serve as source for charging current; but have current limiting, set to 200 mA.
3. Serve as source and sink for the measuring current (ac), which is 50 mA peak.
4. Present a low, linear terminal impedance ($<< 10\ \Omega$) at measuring frequency.

If the bias voltage source is a regulated power supply with the usual characteristic that it functions properly only as a source, not a sink, then the following test setup is recommended. Connect across the power supply a bleeder resistor that draws dc current at least as great as the peak measuring current (50 mA). In parallel with the bleeder, connect a 100-$\mu$F capacitor. (If the power supply has exceptionally good transient response, the capacitor is not necessary.)

No single bleeder resistor will suffice for all bias conditions; so it may be necessary to switch among several. Each resistance must be small enough to keep the power supply regulator current unidirectional (as mentioned above) for the smallest bias voltage in its range of usefulness. Also, the resistance and dissipation capacity must be large enough so that neither the power supply is overloaded nor the resistor itself damaged, for the highest bias voltage in its range of application.

NOTE

For convenience, a suitable active current sink can be used in lieu of bleeder resistors.

A discharge circuit is also required. (Do not depend on the switch on the Digibridge, nor on the above-mentioned bleeder resistor.) If more than 30 V is sometimes used, a dual discharge circuit is recommended, as follows. One (to be used first) should have a 10-$\Omega$ resistor in series; the other (as a backup) should make a direct connection across the bias circuit.

If the measurement program warrants the expense of a remote test fixture (perhaps in conjunction with a handler), for biased capacitor measurements, it should be provided with the kind of circuit described above. It should have convenient switching to remove the bias source, to discharge through 10 $\Omega$, and finally to short out the capacitor after measurement. For automated test setups, it is also feasible to precharge the capacitors before attachment to the test fixture and to discharge them after they have been removed. The equipment should be designed to safeguard personnel from electrical shock and adjusted to avoid the passage of large transient currents through the test fixture.

## 2.7 HANDLER INTERFACE (OPTION).

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

As indicated in the Specifications at the front of this manual, the output signals come from open-collector drivers that pull each signal line to a low voltage when that signal is active and let it float when inactive. Each external circuit must be powered by a positive voltage, up to 30 V (max), with sufficient impedance to limit the active-signal (logic low) current to 40 mA (max).

CAUTION

Provide protection from voltage spikes over 30 V.

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

The input signal is also active low and also requires a positive-voltage external circuit, which must pull the signal line down below +0.4 V, but not less than 0.0 V (i.e., not negative). The logic-low current is 0.4 mA (max). For the inactive state (logic high), the external circuit must pull the signal line above +2.4 V but not above +5.0 V.

Table 2-1

HANDLER INTERFACE KEY

| Signal Name | Pin No. | Function (All signals "active low") |
|---|---|---|
| -------- | 5, 6, 7 | Ground connection. |
| -------- | 10 | Plus 5 V, if internal jumper in place. (Limit current to 250 mA.) |
| | | INPUT: |
| START | 1 | Initiates measurement (single or avg). |
| | | OUTPUTS: |
| EOT | 18 | "End of test"; bin signals are valid. |
| ACQ OVER | 22 | "Data acquisition over"; DUT removal OK. |
| BIN 0 | 15 | No-go because of D or Q limit. |
| BIN 1 | 17 | Go, bin 1. |
| BIN 2 | 19 | Go, bin 2. |
| BIN 3 | 21 | Go, bin 3. |
| BIN 4 | 23 | Go, bin 4. |
| BIN 5 | 14 | Go, bin 5. |
| BIN 6 | 16 | Go, bin 6. |
| BIN 7 | 20 | Go, bin 7. |
| BIN 8 | 24 | Go, bin 8. |
| BIN 9 | 13 | No-go by default (suits no other bin). |

Refer to Figure 2-2A for timing guidelines. Notice that START must have a duration of 1 μs (minimum) in each state (high and low). If START is provided by a mechanical switch without debounce circuitry, the Digibridge will make many false starts; but these will not cause extraneous test-result signals if START is made to settle down (low) within 20 ms (maximum) of the first transition to high. After completion of the measurement, ACQ OVER goes low, indicating that the DUT can be changed. Then after 10 to 50 ms, measurement results are available for sorting, i.e., one of the BIN lines goes low. A few microseconds later, EOT goes low (can be used to set a latch holding the bin assignment). ACQ OVER, the selected BIN line, and EOT then stay low until the next start command.

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

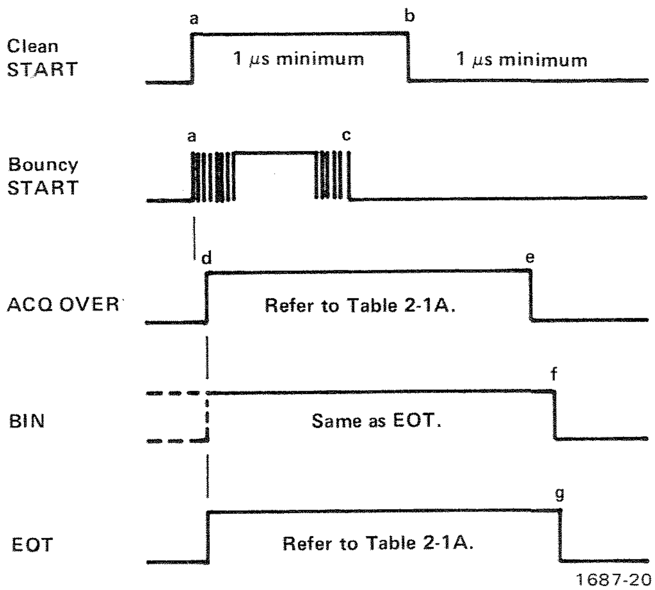



Figure 2-2A. Handler interface timing diagram. External circuitry must keep a-b > 1 μs, b-a > 1 μs, and (if START is not "debounced") a-c < 20 ms. The DUT can be disconnected after "e." The selected "BIN" line goes low at "f"; the others stay high. Refer to Table 2-1A for the values of ACQ OVER and EOT.

## 2.8 IEEE-488 INTERFACE (OPTION).

### 2.8.1 Purpose.

Figure 2-3.

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

NOTE

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

Table 2-1A
HANDLER INTERFACE TIMING DATA

| Test Frequency | Line Frequency | Measurement Speed | Time from START signal to ACQ OVER | EOT |
|---|---|---|---|---|
| 1 kHz | 50 Hz | FAST | 160 ms | 185 ms |
| | | MEDIUM | 335 | 370 |
| | | SLOW | 635 | 660 |
| 1 kHz | 60 Hz | FAST | 145 ms | 170 ms |
| | | MEDIUM | 310 | 335 |
| | | SLOW | 585 | 610 |
| 120 Hz | 60 Hz | FAST | 240 ms | 265 ms |
| | | MEDIUM | 400 | 425 |
| | | SLOW | 660 | 685 |
| 100 Hz | 50 Hz | FAST | 255 ms | 280 ms |
| | | MEDIUM | 425 | 450 |
| | | SLOW | 710 | 735 |

Each device is connected to a system bus, in parallel, usually by the use of several stackable cables. Refer to the figure for a hypothetical system. A full set of connections is 24 (16 signals plus shield and ground returns), as tabulated below and also in the Standard. Suitable cables, stackable at each end, are available from Component Manufacturing Service, Inc., West Bridgewater, MA 02379; U.S.A. (Their part number 2024/1 is for a 1-meter-long cable.)

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

### 2.8.2 Interface Functions.

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

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

The handshake cycle is the process whereby digital signals effect the transfer of each data byte by means of status and control signals. The cycle assures, for example, that the data byte has settled and all listeners are ready before the talker signals "data valid". Similarly, it assures that all listeners have accepted the byte before the talker signals "data not valid" and makes the transition to another byte. Three signal lines are involved, in addition to the 8 that convey the byte itself. Refer to Figure 2-4.

### 2.8.3 Signal Identification.

Refer to Table 2-2 for a key to signal names, functions, and pin numbers. Further explanation is found in the Standard. The first 3 signals listed take part in the "handshake" routine, used for any multiline message via the data bus; the next 5 are used to manage the flow of information; the last 8 constitute the multiline message data bus.

### 2.8.4 Codes and Addresses.

The device-dependent messages, such as instrument programming commands and measurement data (which the digital interface exists to facilitate), have to be coded in a way that

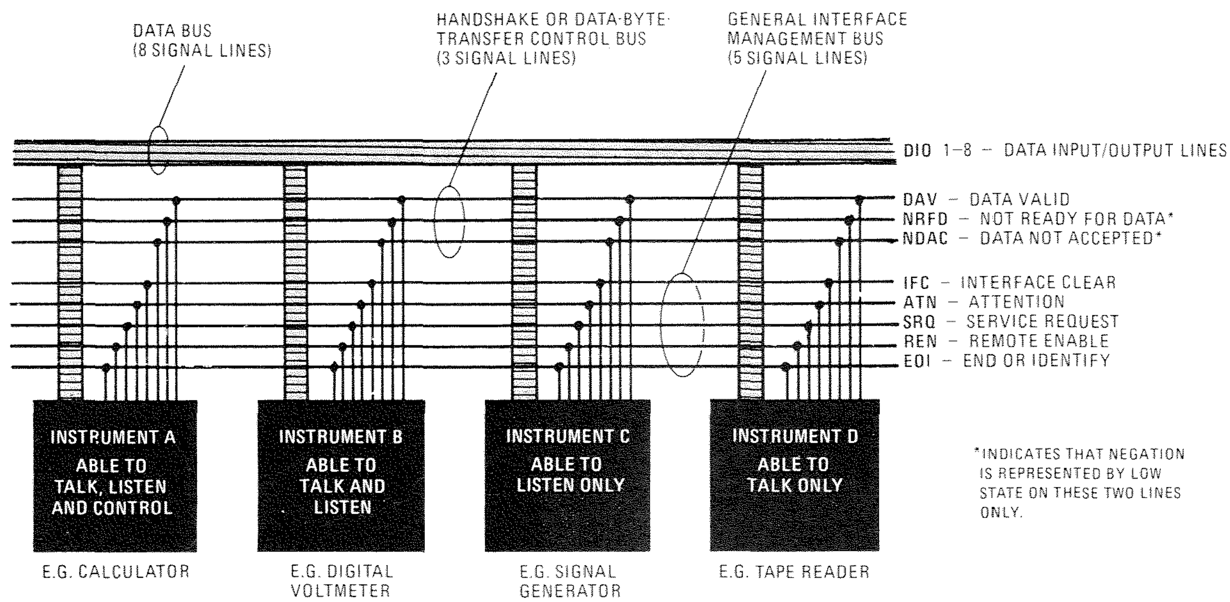



**Figure 2-3. Block diagram of a generalized system interconnected by the 16-signal-line bus specified in the IEEE Standard 488. Reprinted from *Electronics,* November 14, 1974; copyright McGraw-Hill, Inc., 1974.**

Table 2-2

IEEE-488 INTERFACE KEY

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

* "END" is typically sent concurrently with the delimiter "linefeed" character that terminates the string(s) of data output from the Digibridge (1, 2, or 3 lines; see para 2.4.8). ** IDY is not implemented in the 1658 Digibridge.

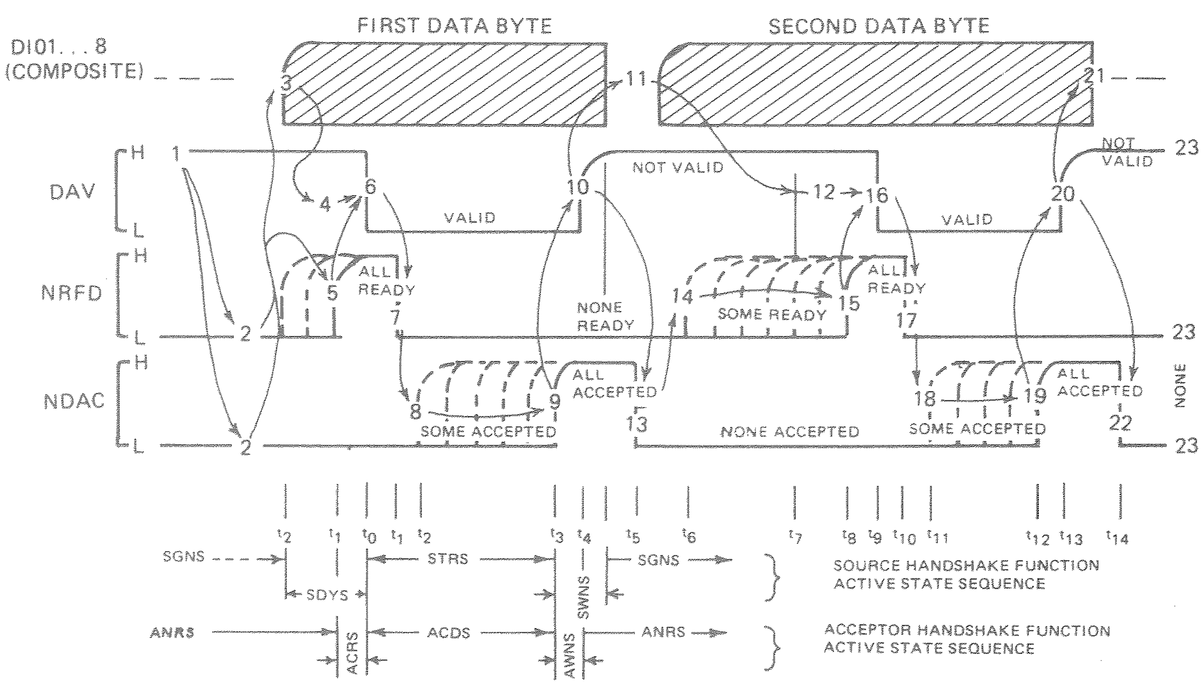



**Figure 2-4. The handshake process, illustrated by timing diagrams of the pertinent signals for a system with one talker and several listeners. For details, refer to the Standard.**

Table 2-3

INSTRUMENT PROGRAM COMMANDS

| Category | Selection | Command |
|---|---|---|
| Display | Enter limits* | D0 |
| | Bin | D1 |
| | Value | D2 |
| Measurement rate | Fast | S0 |
| | Medium | S1 |
| | Slow | S2 |
| Equivalent circuit | Parallel | C0 |
| | Series | C1 |
| Frequency | 120 (100) Hz | F0 |
| | 1 kHz | F1 |
| Measurement mode | Single | L0 |
| | Average | L1 |
| | Continuous | L2 |
| Range control | Hold range | R0 |
| | Hold range 1 | R1 |
| | Hold range 2 | R2 |
| | Hold range 3 | R3 |
| | Auto-range | R4 |
| Parameter | Inductance (L/Q) | M0 |
| | Capacitance (C/D) | M1 |
| | Resistance (R/Q) | M2 |
| Data output** | None | X0 |
| | Bin number | X1 |
| | DQ | X2 |
| | DQ, bin number | X3 |
| | RLC | X4 |
| | RLC, bin number | X5 |
| | RLC, DQ | X6 |
| | RLC, DQ, bin no. | X7 |
| Initiation*** | Start | G0 |
| START switch | Enable | E0 |
| | Disable | E1 |

*Enables entry of limits, which must be entered manually (para 3.6).
**Must be specified before initiation of measurement.
***An alternative "start" command is GET (group execute trigger), which is binary 0 001 000 in conjunction with ATN in the low state.

is compatible between talkers and listeners. They have to use the same language. Addresses have to be assigned, except in the case of a single "talker only" with one or more "listeners" always listening. The Standard sets ground rules for these codes and addresses.

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

*Instrument Program Commands.* Refer to Table 2-3. This input data code is a set of commands to which the instrument will respond as a "talker/listener", after being set to a remote code and addressed to listen to device-dependent command strings.

Notice that the set includes all the keyboard functions except entry of limits, which are not remotely programmable. Also, some of the remote-control commands have no manual-control equivalents. Range control includes the option of selecting specific ranges. Data output commands enable selection of specific classes of measurement results, independently from the actual displays.

Each command is 2 bytes; each byte is coded according to the 7-bit ASCII code, [1] using the DI01 . . . DI07 lines. The most significant bit is DI07, as recommended by the Standard. Thus, for example, the command for "1-kHz test frequency" is F1, having octal code 106 061. The 7-bit binary bytes are therefore: 1 000 110 and 0 110 001. (The ASCII 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", below. The ASCII code conforms to the 7-bit code ISO 646 used internationally.) Notice that the 8th bit (DI08) is ignored.

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

WARNING

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

a. Take the instrument to a qualified electronic technician who has the necessary equipment; refer to para 5.6. Have him remove the interface option assembly, as described in that paragraph. (There is no need to remove the top cover first.)

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

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

Notice that S2 is located at the end of the interface option board, about 3 cm (1 in.) from the TALK switch S1. If S2 is covered, lift the cover off, exposing the "DIP" switch, which has 2 rows of 6 tiny square pads with numbers 1 . . . 6 between the rows. To enter logical 1's, depress pads nearest the end of the board. To enter logical 0's, depress pads on the other side of the "DIP" switch, the side marked with a + sign. The address is read from 5 to 1 (not using 6). Thus,

[1] "X3.4 - 1968, Code for Information Interchange", available from American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

Table 2-4

ADDRESS PAIRS AND SETTINGS FOR SWITCH S2

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

* Do NOT set the switch to 11111, because a listen address of "?" would be confused with an "attention" command. (ASC11 code for "underline" is 1 011 111, and for "?" is 0 111 111.)

for example, to set up the address 00011, enter 0's at positions 5, 4, 3; enter 1's at positions 2, 1. (This makes the talk address "C" and the listen address "#".) Strictly speaking, the address includes more; S2 determines only the device-dependent bits of the address. You cannot choose talk and listen addresses separately, only as a pair. The list of possible pairs is shown in Table 2-4.

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

*Data Output.* Data (results of measurements) are provided on the DI01 . . . DI07 lines as serial strings of characters. Each character is a byte, coded according to the 7-bit ASCII code, as explained above. The alphanumeric characters used are appropriate to the data, for convenience in reading printouts. The character strings are always provided in the same sequence as that shown in Table 2-3; for example: RLC value, DQ value, bin number – if all 3 were selected (by the X7 command). The carriage-return and line-feed characters at the end of each string provide a printer (for example) with the basic commands to print each string on a separate line.

For example, if the measurement was .00325 kΩ (range 2), the character string for RLC value is:

U(space)R(space)kO(space)(space)0.00325(CR)(LF).

If a dissipation-factor measurement was .2345, the character string for DQ value is:

(space)(space)D(6 spaces)0.2345(CR)(LF).

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

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

The character string for RLC value has the length of 17 characters; for DQ value, 17 characters; for bin number, 10 characters – including spaces, carriage-return, and line-feed characters. Refer to Tables 2-5, 2-6, and 2-7 for details.

*Status.* The Digibridge responds with a status byte when the bus is in the serial poll mode and the Digibridge is addressed to talk. The status is encoded as shown in Table 2-8 and sent on the data lines DI01 . . . DI08.

### 2.8.5 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 (Table 2-3).
- Measurement-enabling sequence, for example: untalk the Digibridge, send a GET, unlisten the Digibridge.
- After 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.

## 2.9 ENVIRONMENT.

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

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

**Table 2-5**

RLC-VALUE DATA OUTPUT FORMAT

| Character sequence | Purpose | Allowed characters | Meaning |
|---|---|---|---|
| 1 | Status | (space)<br>U<br>O<br>W | Normal operation<br>Underrange<br>Overrange<br>Wrong parameter or other invalidity |
| 2 | Format | (space) | ——— |
| 3 | Parameter | R<br>L<br>C | Resistance<br>Inductance<br>Capacitance |
| 4 | Format | (space) | ——— |
| 5, 6 | Units | (space) O<br>kO<br>MO<br>(space) H<br>mH<br>uF<br>nF | Ohms<br>Kilohms<br>Megohms<br>Henries<br>Millihenries<br>Microfarads<br>Nanofarads |
| 7, 8 | Format | (space) | ——— |
| 9 . . . 15 | Number | 012345<br>6789.<br>(space) | Measured number, right justified in format field; like the RLC display except the zero before the decimal point is explicitly provided and this number can be as long as 7 characters. |
| 16<br>17 | ———<br>Delimiter | (CR)<br>(LF) | The customary "carriage-return" and "line-feed" characters, end of string. |

**Table 2-6**

DQ-VALUE DATA OUTPUT FORMAT

| Character sequence | Purpose | Allowed characters | Meaning |
|---|---|---|---|
| 1, 2 | Format | (space) | ——— |
| 3 | Parameter | D<br>Q | Dissipation factor<br>Quality factor |
| 4 . . . 9 | Format | (space) | ——— |
| 10 . . . 15 | Number | 012345<br>6789.<br>(space) | Measured number, right justified in format field, like the DQ display except the zero before the decimal point is explicitly provided and this number can be as long as 6 characters. |
| 16<br>17 | ———<br>Delimiter | (CR)<br>(LF) | The customary "carriage-return" and "line-feed" characters, end of string. |

Table 2-7

BIN-NUMBER DATA OUTPUT FORMAT

| Character sequence | Purpose | Allowed characters | Meaning |
|---|---|---|---|
| 1 | Pass/fail | (space)<br>F | GO (bins 1 . . . 8)<br>NO-GO (bin 0 or 9) |
| 2 | Format | (space) | --- |
| 3<br>4<br>5 | Label | B<br>I<br>N | The word "BIN". |
| 6, 7 | Format | (space) | --- |
| 8 | Category | 01234<br>56789 | Bin number assignment. |
| 9<br>10 | ---<br>Delimiter | (CR)<br>(LF) | The customary "carriage-return" and "line-feed" characters, end of string. |

Table 2-8

STATUS CODE

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

# Operation–Section 3



## 3.1 BASIC PROCEDURE.

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

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

CAUTION

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

a. Before connecting the power cord, slide the line-voltage switch (rear panel) to the position that corresponds to your power-line voltage. Power must be nominally 50 or 60 Hz ac, in either range: 90 to 125 V or 180 to 250 V. Connect the power cord to the rear-panel connector, and then to your power line.

*Power.* Depress the POWER button so that it stays in the depressed position. (To turn the instrument off, push and release this button so that it remains in the released position.)

b. Connect a typical device, whose impedance is to be measured, as follows. (This device under test is denoted DUT.)

NOTE

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

*Radial-lead DUT.* Insert the leads into the test-fixture slots as shown in Figure 1-1. For details of wire size and spacing limits, refer to para 3.2.

*Axial-lead DUT.* Figure 3-1A.

Install the test-fixture adaptors, supplied, one in each slot of the test fixture, as shown in the accompanying figure. Slide the adaptors together or apart so the body of the DUT will fit easily between them. Press the DUT down so that the leads enter the slots in the adaptors as far as they go easily. For details of wire size and DUT size limits, refer to para 3.2.

NOTE

To remove each adaptor, lift with a gentle tilt left or right. For a DUT with very short leads, it is important to orient each adaptor so its internal contacts (which are off center) are close to the DUT.

*Any other DUT or test fixture.* Use the accessory extender cable. Refer to para 3.2.

c. Choose the conditions of measurement. For the first 6 selections, below, the recommended choice is automatically provided when you switch the POWER ON. (To obtain another choice, press the corresponding key in the keyboard as many times as necessary, watching the indicator lights.)

*Display:* VALUE
*Measurement Rate:* MEDIUM
*Equivalent Circuit:* SERIES
*Frequency:* 1 kHz
*Measurement Mode:* CONTINUOUS
*Hold Range:* NOT selected; autorange is indicated by having the RANGE HELD light out
*External Bias switch:* OFF
*Talk switch:* TALK ONLY (rear panel). [1]

*Parameter.* For resistance, press R/Q; for inductance, press L/Q; for capacitance, press C/D. The choice is confirmed by illumination of appropriate unit label in the RLC display.

d. Read the measurement on the main displays. The RLC display is the principal measurement, complete with decimal point and units which are indicated by the light spot behind MΩ, kΩ, Ω, H, mH, nF, or F. [2] The DQ display is D if the selected parameter is C/D; it is Q if the selected parameter is L/Q or R/Q.

[1] This switch is provided only if you have the Interface Option.
[2] If the extender cable is used, it may be necessary to correct for its capacitance.

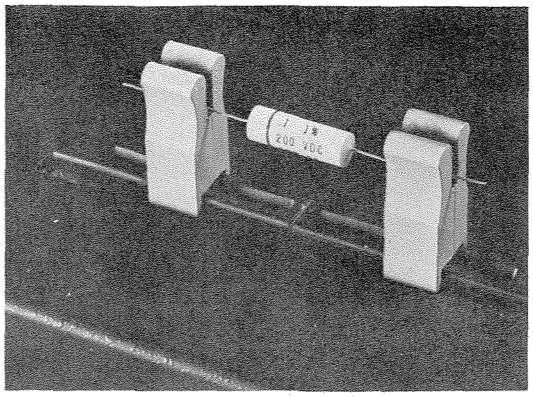


Figure 3-1A. Use of the test fixture adaptors.

NOTE

The following actions or conditions will abort measurements in progress or prevent measurement.

1. Pressing any key listed in step c above *except HOLD RANGE,* will abort the current measurement.

2. If there is no proper IEEE-488 system connection and the TALK switch on the rear panel is switched to TALK/ LISTEN, continuous measurement is inhibited. (If you have the Interface Option, generally keep this switch set to TALK ONLY.)

## 3.2 CONNECTION OF THE DUT.

### 3.2.1 The Integral Test Fixture.

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

The slots in the test fixture accommodate wires of any diameter from 0.25 mm (.01 in., AWG 30) to 1 mm (.04 in., AWG 18), spaced from 6 to 98 mm apart (0.23 to 3.9 in.) or equivalent strip conductors. Each "radial" wire must be at least 1 cm long (0.4 in.). The divider between the test slots contains a shield, at guard potential, with its edges exposed. The adaptors accommodate wires of any diameter up to 1.5 mm (.06 in., AWG 15). The body of the DUT that will fit between these adaptors can be 80 mm long and 44 mm diameter (3.1 x 1.7 in.) maximum. Each "axial" wire must be at least 3 mm long (0.12 in.).

For radial-lead parts, remove each adaptor from the test fixture by a gentle pull upward, made easier by tilting the adaptor left or right (never forward or back). For axial-lead parts, insert the adaptors, one in the left slot and the other in the right slot of the test fixture, by pushing vertically downward. Each adaptor can be slid left and right to match the length of DUT to be measured. Notice that the contacts inside the adaptor are off center; be sure to orient the adaptors so the contacts are close to the body of the DUT, especially if it has short or fragile leads.

Insert the DUT so one lead makes connection on the left side of the test fixture, the other lead on the right side. Insertion and removal are smooth, easy operations and connections are reliable if leads are reasonably clean and straight.

Be sure to remove any obvious dirt from leads before inserting them. The test-fixture contacts will wipe through a film of wax, but will become clogged and ineffectual if you are careless about cleanliness. Be sure the contact pair inside each half of the test fixture is held open by a single item ONLY, whether that is one lead of an axial-lead DUT or one adaptor. (Otherwise you will not obtain true "Kelvin" connections to the DUT.)

### 3.2.2 The Extender Cable. Figure 3-1B.

The accessory extender cable described in Table 1-3 is needed to connect any DUT that is multiterminal, physically large, or otherwise unsuited for the built-in test fixture. This cable is needed, for example, to connect impedance standards or a remote test fixture. Make connections as follows.

a. Remove the adaptors from the test fixture. Plug the extender cable into the basic test fixture and lock the connection with the 2 captive thumb screws.

b. Using the branched end of the cable, connect to the DUT with careful attention to the following color code. The cable tips are stackable banana plugs (adaptable with slip-on alligator clips, supplied). Notice that the 2 red tips must connect to the same end of the DUT. Connect both black and black/white tips to the other end.

EXTENDER CABLE COLOR CODE

RED: I+, current connection to "high" end of DUT.
RED & WHITE: P+, potential connection to same.
BLACK: I–, current connection to "low" end of DUT.
BLACK & WHITE: P–, potential connection to same.
BLACK & GREEN: G, guard connection to shield or case (if isolated from the preceding terminals). Do not connect G to the case of a capacitor if the case serves as (or is connected to) one of its 2 main terminals.

### 3.2.3 Correction for Cable Capacitance.

The extender cable adds capacitance in parallel with the DUT (because shielding of the leads is imperfect). The 1657-9600 cable adds about 0.5 pF. Because the physical arrangement and spacing of the cable branches and connectors is significant, a correction should be determined for each measurement setup. The following procedure applies to connection with a precision 3-terminal capacitor, GR 1404 or 1413, for example.

a. Install an adaptor, GR 874-Q2, on each of the two coaxial connectors, L and H, of the capacitor.

b. Connect cable branch G to the ground post of the "low" terminal adaptor. With a clip lead or plain wire, connect this point to the ground post of the "high" adaptor.

c. Connect cable branch P– to the main post of the "low" adaptor and stack I– on top of P–.


Figure 3-1B. Extender cable, attached to test fixture.

d. Similarly, connect P+, with I+ stacked on top of it, to the main post of the "high" adaptor.

e. Measure this total capacitance, the sum of the desired measurement and the cable capacitance, Cx + Cc.

f. Carefully lift the stacked pair of cable tips, I+/P+, from the "high" adaptor and hold them about 0.5 cm (1/4 in.) above the binding post where they were connected. DO NOT rearrange the cable branches or change their spacing more than is absolutely necessary to follow these directions. Hold the plastic tips (not the wires) and touch the guard (G) circuit firmly with a couple of fingers, to minimize the effect of capacitance in your body.

g. Measure the cable capacitance, Cc.

h. Subtract the result of step g from that of step e, to obtain the desired measurement, Cx.

## 3.3 ACCURACY AND SPEED.

The basic accuracy of this Digibridge is 0.1% of reading R, L, or C, over wide ranges of values, for suitable measurement conditions. Outside of these ranges and conditions, accuracy drops off in known ways, which should be understood by the operator. For example, selection of a faster measurement rate leads to less accurate measurements. To facilitate choice of conditions (if optional) and determination of accuracy for any particular results, refer to the accuracy statement in the specifications at the front of this manual, as well as the following graphs.

### 3.3.1 RLC Basic Accuracy. Figure 3-2.

This graph shows that the basic accuracy extends for 6 decades (for example 2 Ω to 2 MΩ), over the 3 basic ranges. In high overrange and low underrange, the best available accuracy rises a factor of 10 for each decade of impedance (45° lines on graph). If a range is "held", the basic accuracy is valid for only 2 decades, beyond which there are similar overrange conditions.

*Measurement Rate.* The same graph shows the effects of choosing rate. To obtain 0.1% accuracy, select SLOW MEASUREMENT RATE. Lower accuracies (higher percentage) are obtained at higher rates, as shown by the alternative scales at the left.

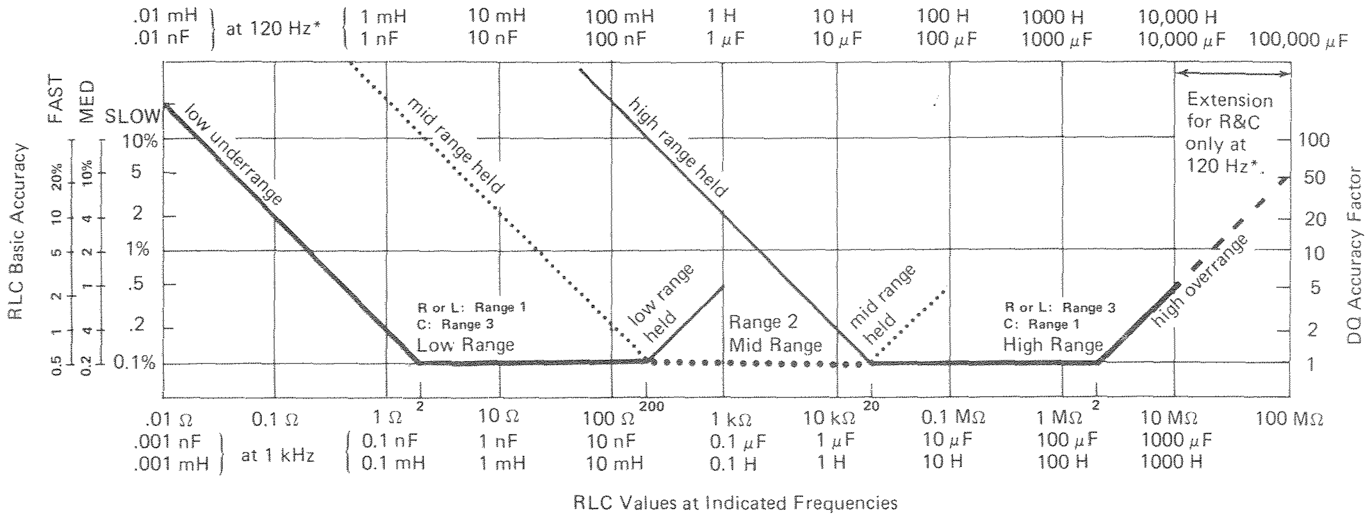



**Figure 3-2. RLC basic accuracy as a percent of reading. Heavy lines (solid and dotted) represent auto-ranging (range not held). Lighter lines represent reduced-accuracy operation due to a range being held. Range 2 is dotted. Notice that L and C scales above graph are for 120 Hz (*equally valid for 100 Hz) and the 2 below graph are for 1 kHz. The DQ accuracy factor (right-hand scale) is the multiplier that, applied to the DQ basic accuracy, yields complete DQ accuracy, for range extensions as well as the basic ranges. (Range extensions are all represented by slanted lines.)**

This basic RLC accuracy is valid only for "pure" R, L, or C. For the effect of quadrature impedance, multiply each basic accuracy value by the RLC accuracy factor; see below.

### 3.3.2 RLC Accuracy Factor. Figure 3-3.

This graph shows the effect of D (or Q) on the accuracy of R, L, and C measurements. Multiply the RLC basic accuracy by this factor. For example, suppose a resistor is measured at SLOW MEASUREMENT RATE to be 1.0 Ω, with Q = 0.5. The RLC basic accuracy is 0.2% and the RLC accuracy factor is 1.5; so the accuracy of the R measurement is 0.3%.

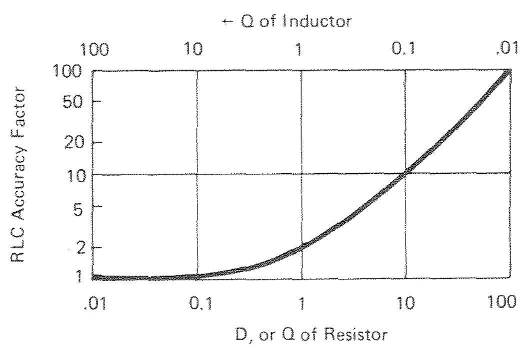



**Figure 3-3. RLC accuracy factor (or cross term), as a function of D or Q. Multiply the RLC basic accuracy by this factor to obtain complete RLC accuracy. Notice that for nearly "pure" resistance or reactance, this factor is unity.**

### 3.3.3 D and Q Accuracy. Figures 3-4, 3-5.

These graphs show the basic accuracy of each D and Q measurement directly for impedances in the basic ranges (the main, horizontal line in the RLC basic accuracy graph). For the above-mentioned example (Q = 0.5) the graph shows a basic accuracy of 0.25%. However, for any overrange or underrange measurement (45° lines on RLC basic accuracy graph), use the following correction factor.

*DQ Accuracy Factor.* This factor is directly proportional to the RLC basic accuracy; refer to the scale at the right of that graph (above). For the above-mentioned example, the DQ accuracy factor is 2; therefore, the Q measurement accuracy is 0.5%.

### 3.3.4 Convenience of Logarithmic Scales.

The logarithmic scales on these figures make it very easy to apply the accuracy factors *visually*. For example, suppose a capacitor is being measured on one of the basic ranges, with the SLOW measurement rate; and the D display is about 1. Figure 3-3 shows that the C accuracy factor is about 1/3 of a decade on the logarithmic scale. On Figure 3-2, find the heavy horizontal line and point to the basic C accuracy (0.1%) at the left. Now apply the C accuracy factor by moving the pointer up about 1/3 of a decade. The pointer now shows the corrected C accuracy, 0.2%.

### 3.3.5 Insignificant Digits.

One or more of the digits at the right end of the RLC and/or DQ displays may be insignificant. This is particularly

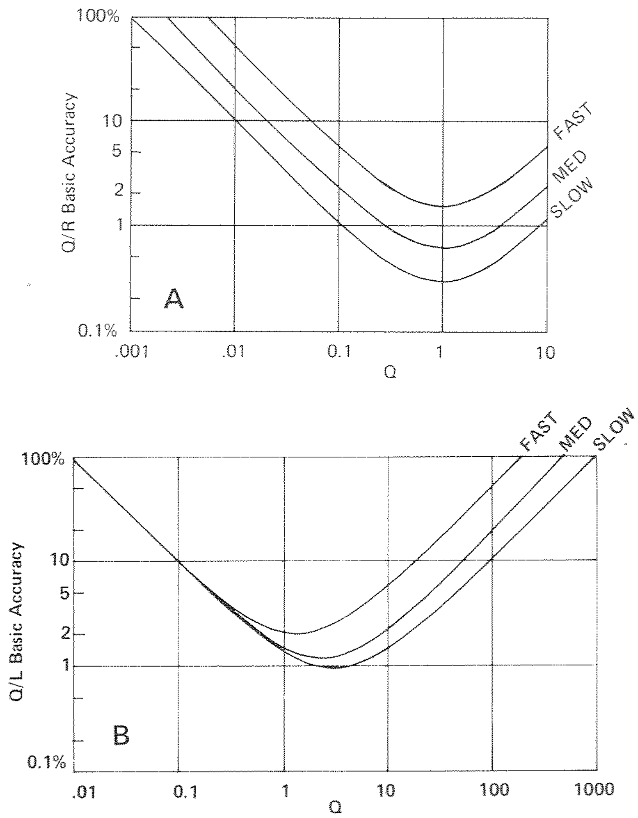



**Figure 3-4. Q basic accuracy as a percent of reading. Each curve applies for one measurement rate, as labeled. For measurements on any of the range extensions, multiply by the DQ accuracy factor, shown in Figure 3-2. A. Q of resistors. B. Q of inductors.**

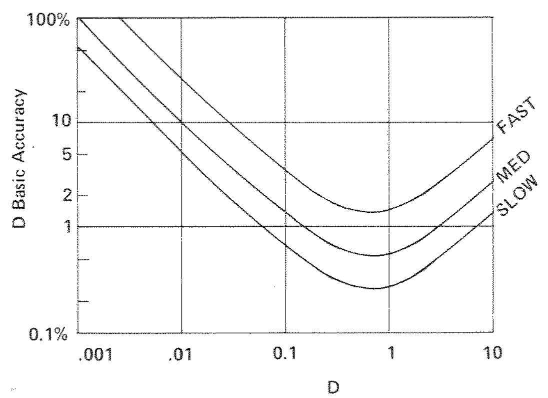



**Figure 3-5. D basic accuracy as a percent of reading (for capacitors). Each curve applies to one measurement rate, as labeled. For measurements on any of the range extensions, multiply by the DQ accuracy factor, shown in Figure 3-2.**

true at the upper extension of a range. If there are more than one insignificant digits in a display, the least significant is typically noisy. That is, it will appear to flicker at random over a range of values and should be ignored.

For example, if you measure a 4-MΩ resistor, the display might ideally be 4.1234 MΩ; but the one or two final digits might be changing at random. This flickering is entirely normal. The specified accuracy (± 0.4%) is the key to expected performance; in this example, the last 2 digits are insignificant and the last digit is quite unnecessary. Typically, one would record this measurement as 4.12 MΩ ± .02 MΩ.

### 3.3.6 Measurement Rate.

Choose one of 3 rates with the MEASURE RATE key: SLOW, MEDIUM, or FAST. The continuous-mode rates are respectively about 2, 3, and 7 measurements per second. Range changes introduce some delays. For details, refer to the following specifics.

For CONTINUOUS measurement mode, steady state, each measurement requires a *base period* of about 570, 310, or 145 ms, depending on whether the measurement rate is SLOW, MEDIUM, or FAST, respectively. To that base period, add approximately 25 ms (for test frequency 1 kHz) or 100 ms (for 120 or 100 Hz) for *startup* following each press of the START button. If the Digibridge is autoranging and a given measurement is out of range, the next measurement requires as much time as *startup plus base period* (the same total as for SINGLE measurement initiated by START). In AVERAGE measurement mode, the time required for an entire measurement sequence, initiated by START, is *startup plus 10 base periods.*

## 3.4 TEST FREQUENCY AND EQUIVALENT CIRCUIT.

### 3.4.1 General.

Except for very large values of the principal measurement, you can select either measurement frequency: 1 kHz or 120 (100) Hz. The lower frequency is required to measure above 10 MΩ, 1000 μF, or 1000 H. There is no such restriction on the choice of equivalent circuit, although there are rules to follow, as explained below.

The value of the principal measurement (R, L, or C) of a certain DUT depends on which of 2 equivalent circuits is chosen to represent it. (Many impedance measuring instruments provide no choice in the matter, but this one allows selection). The more nearly "pure" the resistance or reactance, the more nearly identical are the "series" and "parallel" values. However, for D or Q near unity, the difference is substantial. Also, the principal measurement often depends on measurement frequency. The more nearly "pure" the resistance or reactance, the less is this dependence. However, for D or Q near unity and/or for measuring frequency near the self-resonant frequency of the DUT, this dependence is quite substantial. We first give general rules for selection of measurement parameters, then some of the theory.

### 3.4.2 Rules.

*Specifications.* The manufacturer or principal user of the DUT probably specifies how to measure it. (Usually "series" is specified for C, L, and low values of R.) Select "parallel" or "series" and 1 kHz or 120 Hz (100 Hz) according to the applicable specifications. If there are none known, be sure to specify with your results whether they are "parallel" or "series" and what the measurement frequency was.

*Resistors, below about 1 kΩ: Series, 120 Hz (100 Hz).* Usually the specifications call for dc resistance, so select a low test frequency to minimize ac losses. Select "series" because the reactive component most likely to be present in a low resistance resistor is series inductance, which has no effect on the measurement of series R. If the Q is less than 0.1, the measured Rs is probably very close to the dc resistance.

*Resistors, above about 1 kΩ: Parallel, 120 Hz (100 Hz).* As explained above, select a low test frequency. Select "parallel" because the reactive component most likely to be present in a high-resistance resistor is shunt capacitance, which has no effect on the measurement of parallel R. If the Q is less than 0.1, the measured Rp is probably very close to the dc resistance.

*Capacitors below 2 nF: Series, 1 kHz.* Unless otherwise specified or for special reasons, always select "series" for capacitors and inductors. This has traditionally been standard practice. Select a high measurement frequency for best accuracy.

*Capacitors above 200 µF: Series, 120 Hz (100 Hz).* Select "series" for the reasons given above. Select a low measurement frequency for best accuracy and to enable measurement of capacitors larger than 1000 F.

*Inductors below 2 mH: Series, 1 kHz.* Select "series" as explained above. Select a high measurement frequency for best accuracy.

*Inductors above 200 H: Series, 120 Hz (100 Hz).* Select "series" as explained before. Select a low measurement frequency for best accuracy and to enable measurement of inductors larger than 1000 H.

### 3.4.3 Series and Parallel Parameters. **Figure 3-6.**

An impedance that is neither pure reactance nor a pure resistance can be represented at any specific frequency by either a series or a parallel combination of resistance and reactance. Keeping this concept in mind will be valuable in operation of the instrument and interpreting its measurements. The values of resistance and reactance used in the equivalent circuit depend on whether a series or parallel combination is used. The equivalent circuits are shown in the accompanying figure, together with useful equations relating them. Notice that the Digibridge measures only Rs, Ls, or Cs, if you select SERIES EQUIVALENT CIRCUIT. It measures only Rp, Lp, or Cp if you select PARALLEL.

### 3.4.4 Equivalent Series R for Capacitors.

The total loss of a capacitor can be expressed in several ways, including D and "ESR", which stands for "equivalent series resistance". To obtain ESR, one can measure directly; push the R/Q parameter key and select SERIES EQUIVALENT CIRCUIT.

Both C and ESR should be measured on the same range. If D is below 1, depress the C/D key and measure Cs first,

Resistance and Inductance

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

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

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

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

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

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

Resistance and Capacitance

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

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

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

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

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

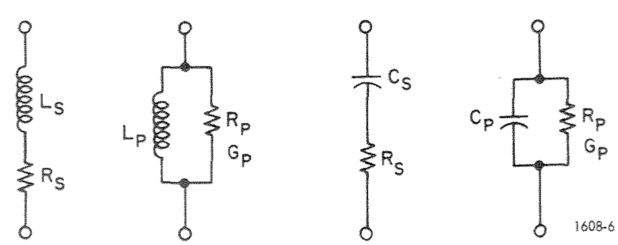



**Figure 3-6. Equivalent circuits and mathematical relationships for lossy inductors and capacitors.**

select HOLD RANGE, depress the R/Q key, and measure Rs. On the other hand, if D is above 1, measure Rs first, select HOLD RANGE, and then measure Cs.

"Equivalent series resistance" is larger than the actual resistance of the wire leads and foils that are physically in series with the heart of a capacitor. ESR includes also the effect of dielectric loss. Generally, measured ESR is closer to actual series resistance for capacitors with lower reactance (larger capacitance and/or higher test frequency).

### 3.4.5 Parallel Equivalent Circuits for Inductors.

Even though it is customary to measure series inductance of inductors, there are situations in which the parallel equivalent circuit better represents the physical device. At low frequencies, the significant loss mechanism is usually "ohmic" or "copper loss" in the wire; and the series circuit is appropriate If there is an iron core, at higher frequencies the significant loss mechanism may be "core loss" (related to eddy currents and hysteresis); and the parallel equivalent circuit is appropriate. Whether this is true at 1 kHz should be determined by an understanding of the DUT, but probably it is so if the following is true: that measurements of Lp at 1 kHz and at 120 Hz (100 Hz) are more nearly in agreement than measurements of Ls at the same 2 frequencies.

## 3.5 PARAMETER, RANGE HOLDING, AND MODE.

### 3.5.1 Parameter – R, L, or C.

The selection of the parameter to be measured is almost self-explanatory. Depress the appropriate button: R/Q, L/Q, or C/D to measure resistance, inductance, or capacitance. The instrument will tolerate, to some degree, a poor choice of parameter, but accuracy is thereby reduced. The readout will indicate a completely wrong choice, as explained below. Notice that the appearance of a device can be misleading. (For example, a faulty inductor can be essentially capacitive or resistive; a component part can be mislabeled or unlabeled.)

Incorrect choice of parameter, for the measured DUT, is best avoided by watching for indications such a simultaneous lighting of both OUT OF RANGE arrows or an extreme DQ display. Refer to Table 3-1, which shows conditions of poor choice of parameter (sometimes useful) as well a wrong choice (measurement generally useless). Another possible indication of wrong choice of parameter is repeated autoranging between 2 ranges, with meaningless measurements being made in each (with or without a display). It is also possible to have a zero RLC display that results from trying to measure a very large L or small C, but erroneously selecting C/D or L/Q respectively.

### 3.5.2 Ranges and Range Holding.

Descriptions of ranges, extensions, and subranges are explained below. Refer to the RLC basic accuracy graph (Figure 3-2) for illustration.

*Basic Ranges.* The 3 basic ranges together cover the 6 decades of basic accuracy (such as 2 Ω to 2 MΩ). The 3 are distinguished as low, mid, high, in order of increasing parameter value or 1, 2, 3, in order of increasing impedance. Mid range is the same as range 2.

Each basic range is slightly more than 2 decades wide, from an RLC display of Ø1900, with an automatic decimal-point change between the decades, to 19999. (The symbol Ø represents a blanked zero. Initial zeroes to the left of the decimal point are always blanked out of the RLC display.)

*Extensions.* Each of the 3 ranges goes beyond its basic range, with both upper and lower range extensions (shown by lighter lines in the RLC basic accuracy graph). Most of these extensions are seldom used because they overlap basic portions of other ranges.

*Underrange.* The "low" extension of each range goes from Ø1999 down to Ø0000, with reduced accuracy. The low extension of each high and mid range has the decimal point unchanged from its position in the lower decade of the

**Table 3-1**
INDICATIONS OF PARAMETER MISMATCH TO DUT

| Parameter selected* | Indication | Significance | Correct parameter |
|---|---|---|---|
| R/Q | OUT OF RANGE, both arrows | Wrong parameter | C/D or L/Q |
| L/Q | OUT OF RANGE, both arrows | Wrong parameter | C/D or R/Q |
| C/D | OUT OF RANGE, both arrows | Wrong parameter | L/Q or R/Q |
| R/Q | Q = 1.001 to 9.999 | R accuracy reduced | (L/Q or C/D) |
| | Q = blank | Wrong parameter | L/Q or C/D |
| L/Q | Q = 00.01 to 00.99 | L accuracy reduced | (R) |
| | Q = 00.00 | Wrong parameter | R |
| C/D | D = 1.001 to 9.999 | C accuracy reduced | (R) |
| | D = blank | Wrong parameter | R |
| R/Q | R = blank, units changing | Wrong parameter | C/D or L/Q |

*The unit designation (MΩ . . . μF) under the RLC display indicates which parameter has been selected.

basic range. However, the low extension of the low range is displayed with the decimal one place farther left than the basic low range, thus providing fine resolution for small values of RLC. If the measured value is small enough to reduce accuracy by a factor of 20, the operator is alerted by the reduced number of digits displayed. (For example, an RLC display of Ø.0999, having only 3 significant digits, is recognizable in this way.)

*Overrange.* The "high" extension of each range is a factor of 5 (with 2 exceptions), going from 19999 up to 99999, and finally to blank, without any change in decimal point, but with reduced accuracy. The high overrange (above 2 MΩ for example) is always used for the very large values of RLC that exceed the basic high range. The operator is alerted to the accuracy reduction by seeing the right-hand OUT OF RANGE arrow lighted, the "overrange indication."

The high overrange for R and C only, at 120 Hz (100 Hz) only, is a factor of 50, going from 19999, with an automatic decimal-point change, up to 99999, and finally to blank, with reduced accuracy. For high overrange, there is an overrange indication, as described above.

*Subranges.* Each range includes 2 or 3 subranges, distinguished by the automatic decimal-point shift. The operator can NOT control them. Subranges are detailed in Table 3-2. Notice, for example, on C, 1 kHz, RANGE 1, there are 2 subranges: 19-μF and 999-μF. If a series of measurements is made with C increasing slowly above 19 μF, the automatic subrange change takes place at 21. But with C decreasing, the change takes place at 20. This hysteresis eliminates a possible cause of flickering of the display.

*Autoranging.* Autoranging is normal; it is inhibited only if you select RANGE HELD. There is a slight hysteresis in the changeover (at 20 as the value increases, at 19 as it decreases) to eliminate a possible cause of display flickering.

*Range Holding.* To inhibit autoranging, select this mode with the HOLD RANGE button, and verify that the RANGE HELD light is on. Whatever range the instrument is using for current or previous measurements will be held. For example, if a 100-Ω resistor is being measured when you select HOLD range, then the operation of the instrument is locked to the low range, Range 1, including the regularly unused overrange portion (labeled "low range held" on the RLC basic accuracy graph).

An advantage of holding a range is time saved. For example, if a large number of resistors are being measured in values below 900 Ω, one might "hold" range 1. Some accuracy of measurement would be sacrificed for values above 200 Ω. But the system would save the time that would be required to change to range 2 and perhaps (for open-circuited parts) to range 3. For details of the time required to make typical measurements, refer to para 3.3.6.

The OUT OF RANGE arrows will indicate whenever a measurement is made on a range extension (except for the low underrange). Thus:

- Neither arrow = all basic ranges and low underrange
- Left arrow = underrange (except low underrange)
- Right arrow = overrange
- Both arrows = wrong parameter selected.

NOTE

The OUT OF RANGE and RANGE HELD indicators alert the operator to unusual measurement conditions that could be selected by mistake. Be watchful for these indicators.

### 3.5.3 Measurement Modes

*Continuous.* Select CONT for automatically repeating measurements, at one of 3 rates (approx. 2, 3, or 7 per second

Table 3-2
FULL SCALE READOUTS ON EACH SUBRANGE

| Range | Automatic subrange | R 1 kHz | R 120 (100) Hz | L 1 kHz | L 120 (100) Hz | C 1 kHz | C 120 (100) Hz |
|---|---|---|---|---|---|---|---|
| | 1A† | 1.9999 Ω | 1.9999 Ω | .19999 mH | 1.9999 mH | ------ | ----- |
| 1 | 1B | 19.999 Ω | 19.999 Ω | 1.9999 mH | 19.999 mH | 19.999 μF | 199.99 μF |
| ($Z_o$ = 10 Ω) | 1C* | 999.99 Ω | 999.99 Ω | 99.999 mH | 999.99 mH | 999.99 μF | 9999.9 μF |
| | 1D** | ------ | ----- | ----- | ----- | ----- | 99999. μF |
| 2 | 2B | 1.9999 kΩ | 1.9999 kΩ | .19999 H | 1.9999 H | .19999 μF | 1.9999 μF |
| ($Z_o$ = 1 kΩ) | 2C* | 99.999 kΩ | 99.999 kΩ | 9.9999 H | 99.999 H | 9.9999 μF | 99.999 μF |
| | 3A† | ------ | ----- | ----- | ----- | .19999 nF | 1.9999 nF |
| 3 | 3B | .19999 MΩ | .19999 MΩ | 19.999 H | 199.99 H | 1.9999 nF | 19.999 nF |
| ($Z_o$ = 100 kΩ) | 3C* | 9.9999 MΩ | 9.9999 MΩ | 999.99 H | 9999.9 H | 99.999 nF | 999.99 nF |
| | 3D** | ------ | 99.999 MΩ | ----- | ----- | ----- | ----- |

† Each "A" subrange is the low extension of the lowest range (example 0.0001 to 2 Ω).
* Each "C" subrange covers a full decade (example, 20 to 200 Ω) in the basic range and an upper range extension (example 200 to 999+ Ω), in which accuracy is reduced and the overrange light is on (the right-hand OUT OF RANGE indicator).
** Each "D" subrange is a further extension of the highest range (example 10 to 99.9+ MΩ).

as you choose SLOW, MED, or FAST. The displays will NOT be held after the DUT is removed or changed. Although there may be some annoyance due to changeability of the least significant digits in the displays, this mode provides a rapidly updated "current" measurement automatically. So it is the normal mode.

*Single.* Select SINGLE for a measurement to be made with each depression of the START button. The resulting RLC and DQ displays are held until a subsequent measurement is made, regardless of changing the DUT. This mode is suitable for many kinds of "production" testing programs.

*Average.* Select AVERAGE for a string of 10 measurements to be made after each depression of the START button. A running average is displayed, that is, each time a measurement is completed, the RLC and DQ displays are updated to be the average of all measurements made since "start". After the 10th measurement (6 or 7 s after "start", if selected RATE is SLOW), the displays are held, as described above. This mode provides smoothing of any possible "noise" or slight variation from one measurement to another theoretically identical measurement, in a particularly convenient way.

## 3.6 LIMIT-COMPARISON BINS.

### 3.6.1 Introduction.

If a group of similar DUT's 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-$\mu$F capacitors into bins of 2%, 5%, 10%, 20%, lossy rejects, and other rejects. Or it can assign DUT's to bins of (for example) a 5% series such as 1.8, 2.0, 2.2, 2.4, 2.7 $\mu$F, etc. The bin assignments can be displayed, for guidance in hand sorting, or (with the interface option) output automatically to a handler for mechanized sorting.

Up to 8 regular bins are provided for, in addition to a bin for DQ rejects and a bin for all other rejects; total = 10 bins. To set up the desired categories, use the 16 limit-entry keys in the left corner of the keyboard, as described below.

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%). Two "percent" values must be entered, the higher one first, to set up a non-symmetrial pair of limits. Any overlapping portion of 2 bins is automatically assigned to the lower-numbered bin.

For simple GO/NO-GO testing, set up a DQ limit and 1 regular bin. Entry of limits in additional bins will define additional GO conditions. Be sure the unused bins are closed. (Bins 1 . . . 8 are initially closed, at power-up.)

### 3.6.2 Limit Entry Methods — Figures 3-7, 3-8.

The figures illustrate 2 basic methods of limit entry: 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 for 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 9. 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. USE BIN 0

### 3.6.3 Limit Entry Procedure.

a. With FREQUENCY key, select test frequency.

b. With DISPLAY key, select ENTER LIMITS.

c. With parameter key R/Q, L/Q, C/D, (by repeat keying) select convenient units as shown in the RLC display.

d. Enter the desired DQ limit by keying:

[X] [=] [BIN No.] [0],

in which X represents 1 to 5 numerical keys and (optionally) the decimal-point key, depressed in sequence. Confirmation is shown on the DQ display, up to 4 significant digits.

e. Enter a nominal value for limits by keying:

[Y] [=] [NOM VALUE],

in which Y represents 1 to 5 numerical keys and (optionally) the decimal-point key, depressed in sequence. Confirmation is shown on the RLC display.

f. For a symmetrical pair of limits (centered on the nominal value just entered), enter one percentage, by keying:

[S] [%] [=] [BIN No.] [Z];

in which S represents 1 to 5 numerical keys and (optionally) the decimal-point key, depressed in sequence, forming a number not exceeding 100.00; and Z represents one key for the chosen bin: 1, 2, 3, 4, 5, 6, 7, or 8. Confirmation is shown, upper limit on the RLC display, lower limit (4 significant digits) on the DQ display. Notice that these displays are actual R, L, or C values, not percentages.

g. For an unsymmetrical pair of limits, similarly, key in:

[H] [%] [–] [L] [%] [=] [BIN No.] [Z];

in which H represents a number not exceeding 10000 and L a number not exceeding 100.00. Both H and L (or neither) may have a negative-sign prefix; but H must always yield a higher limit (absolute value) than L.

h. To enter another pair of limits based on the established nominal value, repeat step f or g, choosing another bin number.

–10 +50

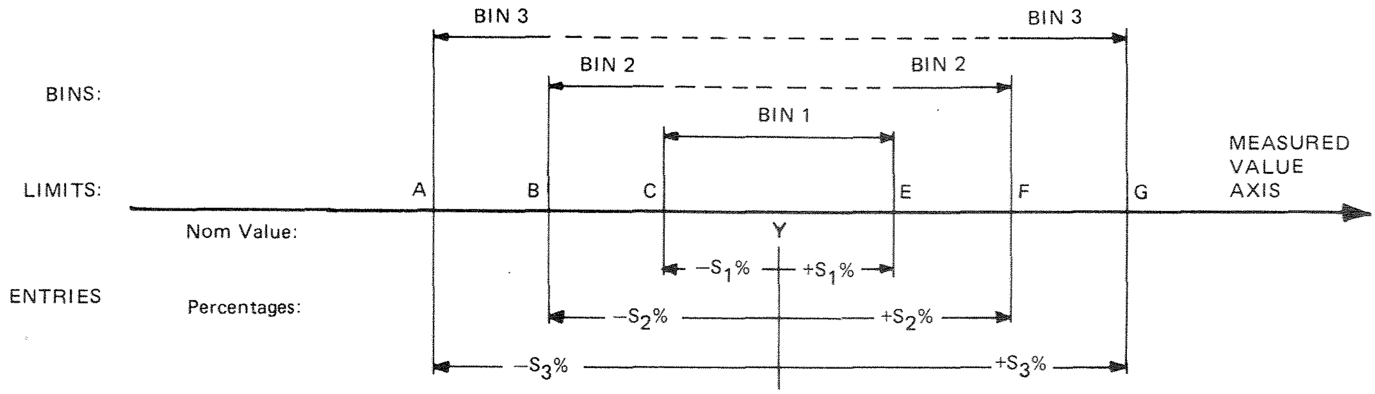



**Figure 3-7. Nested limits. A single nominal value Y is used and all limit pairs are symmetrical in this basic plan.**

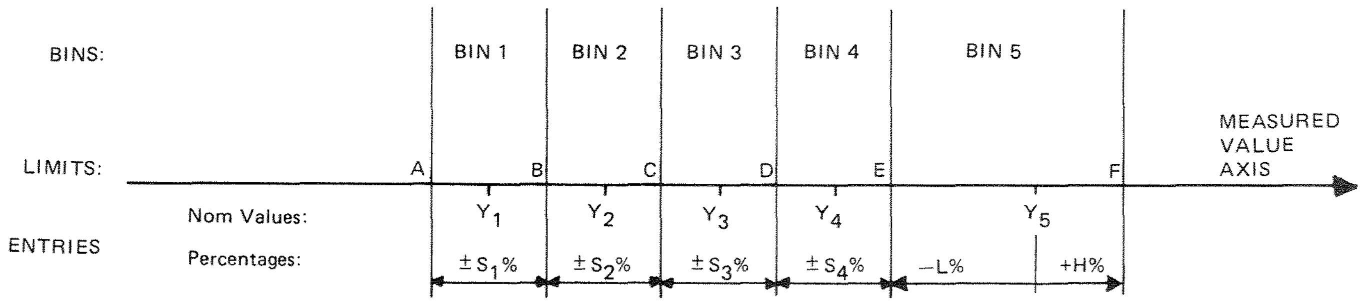



**Figure 3-8. Sequential limits. A different nominal value is entered for each bin and all limit pairs are symmetrical except for the unsymmetrical pair shown for example in bin 5.**

i. To enter another pair of limits based on a different nominal value, repeat step e and then step f or g, similarly.

j. To change the limits in any of the 8 bins, reenter the pair, as above.

k. To close a bin that has limits entered in it, repeat step f with zero for S. Confirmation is shown by 2 identical numbers appearing in the RLC and DQ displays.

l. To resume operation of the Digibridge, using the limits entered as above, press the DISPLAY key. The display will be either measured VALUE, or BIN No., whichever you select. In either case, if you have the Interface Option, the available output data are not limited to the display selection.

### 3.6.4 Examples of Limit Entry.

*Nested Limits.* To enter a set of nested limits, operate the keyboard as described below for the example of resistors having Q < .001, R = 33 kΩ ± 0.35%, ± 1%, ± 5%, +7 −9%.

a. With FREQUENCY key, select the desired test frequency.

b. With DISPLAY key, select ENTER LIMITS.

c. With parameter key R/Q, select RLC units: MΩ.

d. Enter Q limit thus: [.] [0] [0] [1] [=] [BIN No.] [0].

e. Enter nominal RLC value: [.] [0] [3] [3] [=] [NOM VALUE].

f. Set bin 1 limits: [.] [3] [5] [%] [=] [BIN No.] [1].

g. Set bin 2 limits: [1] [%] [=] [BIN No.] [2].

h. Set bin 3 limits: [5] [%] [=] [BIN No.] [3].

i. Set bin 4 limits: [7] [%] [−] [9] [%] [=] [BIN No.] [4].

j. Close bin 5, by keying: [0] [%] [=] [BIN No.] [5].

k. Close bins 6, 7, and 8, 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, C = 0.91, 1.0, 1.1, 1.2, 1.3 μF (the standard 5% series).

a. With FREQUENCY key, select the desired test frequency.

b. With DISPLAY key, select ENTER LIMITS.

c. With parameter key C/D, select RLC units: μF.

d. Enter D limit: [.] [0] [0] [5] [=] [BIN No.] [0].

e. Enter nominal RLC value: [.] [9] [1] [=] [NOM VALUE].

f. Set bin 1 limits: [5] [%] [=] [BIN No.] [1].

g. Redefine nominal: [1] [=] [NOM VALUE].

h. Set bin 2 limits: [5] [%] [=] [BIN No.] [2].

i. Redefine nominal: [1] [.] [1] [=] [NOM VALUE].

j. Set bin 3 limits: [5] [%] [=] [BIN No.] [3];

k. Redefine nominal: [1] [.] [2] [=] [NOM VALUE].

l. Set bin 4 limits: [5] [%] [=] [BIN No.] [4].

m. Redefine nominal: [1] [.] [3] [=] [NOM VALUE].

n. Set bin 5 limits: [5] [%] [=] [BIN No.] [5].

o. Close bin 6: [0] [%] [=] [BIN No.] [6].

p. Close bins 7 and 8, similarly, if used before.

### 3.6.5 Entries in General.

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

*Frequency.* Select the test frequency first. Comparison results are liable to error if the test frequency is changed later in the entry/measurement procedure.

*Bin 0.* The limit entered in bin 0 is always DQ. For R it is Q; for C it is D, both upper limits. For L it is Q, a lower limit.

*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. (Examples are shown above.)

*Unused Bins.* Initially, at power-up, bins 1 . . . . 8 are closed so that unused ones can be ignored. Every unused bin that has previously been used (except 9) 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.* Positive limits up to 10 000%, negative limits down to −100%, maximum of 5 significant figures (for example: 38.671%).

*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 bin).

*Inhibiting Comparisons.* To inhibit DQ comparisons, set bin 0 to the "all pass" extreme, i.e., to 0000 for Q or 9999 for D. To inhibit all comparisons, set NOM VALUE to zero. (Then GO/NO-GO indicators stay off.) Subsequent setting of NOM VALUE to any number except zero enables all comparisons as previously set up.

When POWER is switched ON, "nominal value" is initialized at zero. (Comparisons are 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.

*RLC Unit Selection.* No distinction is made between the 2 ranges that display in units of H or between the 2 ranges that display in units of $\mu$F, in limits entry procedures. It is NOT necessary to select (for limit entry) the range that the Digibridge will use in measuring. For example (see para 3.6.4), it is equally valid to enter a nominal value of .033 MΩ, 33 kΩ, or 33000 Ω.

### 3.6.6 Verification of Nominal and Limit Values.

While the DISPLAY selection is ENTER LIMITS, the exact values entered into the Digibridge can be seen by either of 2 methods, as follows:

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

*Upon Demand.* To see the current "nominal value", depress the [NOM VALUE] key (while ENTER LIMITS is lit. To see the limits in any particular bin (or to verify that it has been closed), depress [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 kΩ, but the display units are Ω, when you press the [BIN No.] [3] keys, the display will go blank. Select either kΩ or MΩ (instead of Ω) 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* lost when POWER is switched OFF.

### 3.6.7 Value, Bin, and Go/No-Go Displays.

The Digibridge measurement will be presented either of 2 ways; VALUE or BIN, but not both ways for a single measurement. This distinction is unimportant for most measurements, in the continuous mode. But for single or average-mode operation, select the desired display before pushing START.

*Value.* Select VALUE with the DISPLAY button. When measurement is completed, the value will be shown on the RLC and DQ displays.

*Bin.* Alternatively, select BIN with the DISPLAY button. When measurement is completed, the bin assignment will be shown on the RLC display (a single digit), with the following significance:

0 = No-Go because of D or Q limit
1 = Go, bin 1
2 = Go, bin 2
. . . Go, bin 3, 4, 5, 6, 7 or 8, as indicated.
9 = No-go by default (suits no other bin).

*GO/NO-GO.* If comparison is enabled, by a non-zero entry for "nominal value" (see para 3.6.5), this indication is provided. The DISPLAY selection can be either VALUE or BIN. GO means the measurement falls in bin 1 . . . 8; NO-GO means bin 0 or 9.

## 3.7 BIAS.

**WARNING**

- **Maximum bias voltage is 60 V. Do NOT exceed.**
- **Bias voltage is present at connectors, test fixtures and on capacitors under test.**
- **Capacitors remain charged after measurement.**
- **Do not leave instrument unattended with bias "on".**

NOTE

Keep the EXT BIAS switch OFF (regardless of whether any external bias source is connected) for all measurements made WITHOUT dc bias applied to the DUT. (Switch ON, without a low-impedance bias source causes errors in measurement.)

To measure capacitors with dc bias voltage applied:

### 3.7.1 Bias Less Than 30 V and C Less Than 1000 $\mu$F.

a. Connect a bias supply via rear-panel connector, observing polarity, as described in para 2.6. Be sure the bias supply meets the requirements (such as current sinking and limiting to 200 mA) given in that paragraph. Generally, the external circuit must include switching for both application of bias and discharge of the DUT.

b. For capacitors less than 1000 $\mu$F only, with bias less than 30 V, use the EXT BIAS switch on the keyboard to apply bias (ON) and to discharge the DUT (OFF).

Notice that this switch should NOT be used for this purpose above 30 V, or 1000 $\mu$F, or for production quantity measurements. In such cases, leave the EXT BIAS switch ON and use switches in the external circuit.

c. Be sure to orient the DUT correctly, positive terminal to the right.

d. Operate the bridge in the usual way. Disregard any measurements that may be made by the Digibridge in continuous measurement mode during the charge or discharge transients. Notice that the BIAS ON light indicates the presence of bias voltage; it goes off when the voltage drops to zero even though the EXT BIAS switch may be ON. It will not light if the bias power supply polarity is inverted.

### 3.7.2 Bias Up to 60 V.

a. Observe the warning above.

b. Connect bias power supply and external switching circuit as described above.

c. Keep the EXT BIAS switch ON (toward the rear) regularly, unless you want to use it as an extra safety device. As a safety device, be sure to turn it ON before the external switch and OFF a second or more after the external switch is off.

To protect the operator and to avoid damaging the instrument, define a safe procedure like the one that follows and use it regularly:

a. Set the bias voltage to zero.
b. Attach the DUT, with correct polarity.
c. Raise the bias voltage to the specified value.
d. Allow a specified charging and soaking time.
e. Observe and record measurements (usually Cs and D).
f. Set the bias voltage source to zero.
g. Connect the 10-$\Omega$ discharging circuit.
h. After about 2 s, connect the safety short circuit.
i. Remove the DUT.

## 3.8 OPERATION WITH A HANDLER

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

a. Enter the bin limits as described above.

b. Select the measurement conditions as desired: MEASUREMENT RATE, EQUIVALENT CIRCUIT, MEASUREMENT MODE (SINGLE), RANGE HOLD (or autorange). (Do NOT change FREQUENCY or parameter – R, L, C – after limits have been entered.)

c. Select either BIN or VALUE DISPLAY for incidental monitoring of measurements while the handler automatically sorts the parts being processed.

## 3.9 SYSTEM CONSIDERATIONS

These considerations apply only if you have the interface option. (If you do, there will be interface connectors at the rear. See Figure 1-2.)

### 3.9.1 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.

### 3.9.2 Talk-Only Use.

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

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 needs time to print one value before it can accept the next.

### 3.9.3 Talk/Listen Use.

Observe the REMOTE CONTROL indicator light. If it is lighted, there is no opportunity for manual operation (except entry of limits). The displays may be observed then, but their content is controlled by the system controller, via the IEEE-488 bus.

**Entry of Limits.** Any remotely controlled systems use involving limit comparisons must be designed for manual entry of limits, as follows:

a. Be sure the REMOTE CONTROL light is out.

b. Enter the limits as described in para 3.6.

c. Enable the controller to proceed. (This step may require attention to controls on some other device.)

## 3.10 CARE OF DISPLAY PANEL.

Use caution when cleaning the display window, not to scratch it nor to get cleaning substances into the instrument. Use soft cloth or a ball of absorbent cotton, moistened with a mild glass cleaner, such as "Windex" (Drackett Products Co., Cincinnati, Ohio). Do NOT use a paper towel; do NOT use enough liquid to drip or run.

If it should be necessary to place marks on the window, use paper-based masking tape (NOT any kind of marking pen, which could be abrasive or react chemically with the plastic). To minimize retention of any gummy residue, remove the tape within a few weeks.

# Theory—Section 4



## 4.1 INTRODUCTION.

### 4.1.1 General.

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

### 4.1.2 Brief Description of the 1658 Digibridge.

This Digibridge™ uses a new measurement technique in which a microprocessor calculates the desired impedance parameters from a series of 5, 8, or 16 voltage measurements (for FAST, MED, and SLOW measurement rates, respectively).* These measurements include quadrature (90°) and inverse (180°) vector components of the voltage across a standard resistor Rx carrying the same current as Zx.** Each of these measurements is meaningless by itself, because the current through Zx is not controlled. But each set of voltage measurements is made in rapid sequence with the same phase-sensitive detector and analog-to-digital converter. Therefore properly chosen differences between these measurements subtract out fixed offset errors, and ratios between the differences cancel out the value of the common current and the scale factor of the detector-converter.

The phase-sensitive detector uses eight reference signals, precisely 45° apart, that have exactly the same frequency as the test signal, but whose phase relationship to any of the analog voltages or currents (such as the current through Zx and Rx) is incidental. Therefore, no precise analog phase shifter or waveform squaring circuit is required. Correct phase relationships are maintained by generating test signal and reference signals from the same high-frequency source.

There are no calibration adjustments in the Digibridge, thanks to the measurement technique. The only precision components in this instrument are three standard resistors and a quartz-crystal stabilized oscillator. There is no reactance standard. For example, C and D are calculated by the microprocessor from the set of voltage measurements and predetermined values of frequency and the applicable standard resistance.

The microprocessor also controls the measurement sequence, using programs in the ROM memory and stored keyboard selections. The desired parameters, C and D, L and Q, or R and Q; equivalent circuit, series or parallel; test rate, slow, medium or fast; and frequency, either 120 Hz (100 Hz) or 1 kHz, are selected by keyboard control. The instrument normally autoranges to find the correct range; but operation can be restricted to any of the three ranges (1, 2, 3), under keyboard control.

Each range is 2 decades wide, with reduced-accuracy extensions both above and below. For example, consider resistance measurement on Range 1 (Figure 3-2). The 2 decades extend from Ø2.000 Ω, with an automatic decimal-point shift at 21.000 going up (at Ø20.00, going down) to 200.00 Ω. The range extensions generally go as far as can be displayed without further decimal-point shifting. In our example, the low-range-held overrange extension goes up to 999.99 Ω.

However, the low underrange is different from the low extensions (range held) of mid and high ranges, in that there is an additional decimal-point shift to provide excellent resolution in small-value measurements. Continuing with the example, the shift takes place a 2.1000 Ω going up and at Ø2.000 Ω going down. Consequently, this low underrange goes down to Ø.0001 Ω. Similarly, for L/Q, the smallest measurement is .00001 mH; for C/D, it is .00001 nF.

There is a decimal-point shift without hysteresis in the high overrange for R and C only, at 120 Hz (100 Hz) only. This shift takes place between 9.9999 and 10.000 MΩ for R, between 9999.9 and 10000 μF for C.

Leading zeroes before the decimal point are blanked out of the RLC display. Such blanked zeroes are designated with the symbol Ø in some parts of this manual.

*Patent applied for.

**If the measurement rate is SLOW, vector components are sampled 45° apart, in order to reject odd harmonics (3, 5, 11, 13), for greater accuracy.

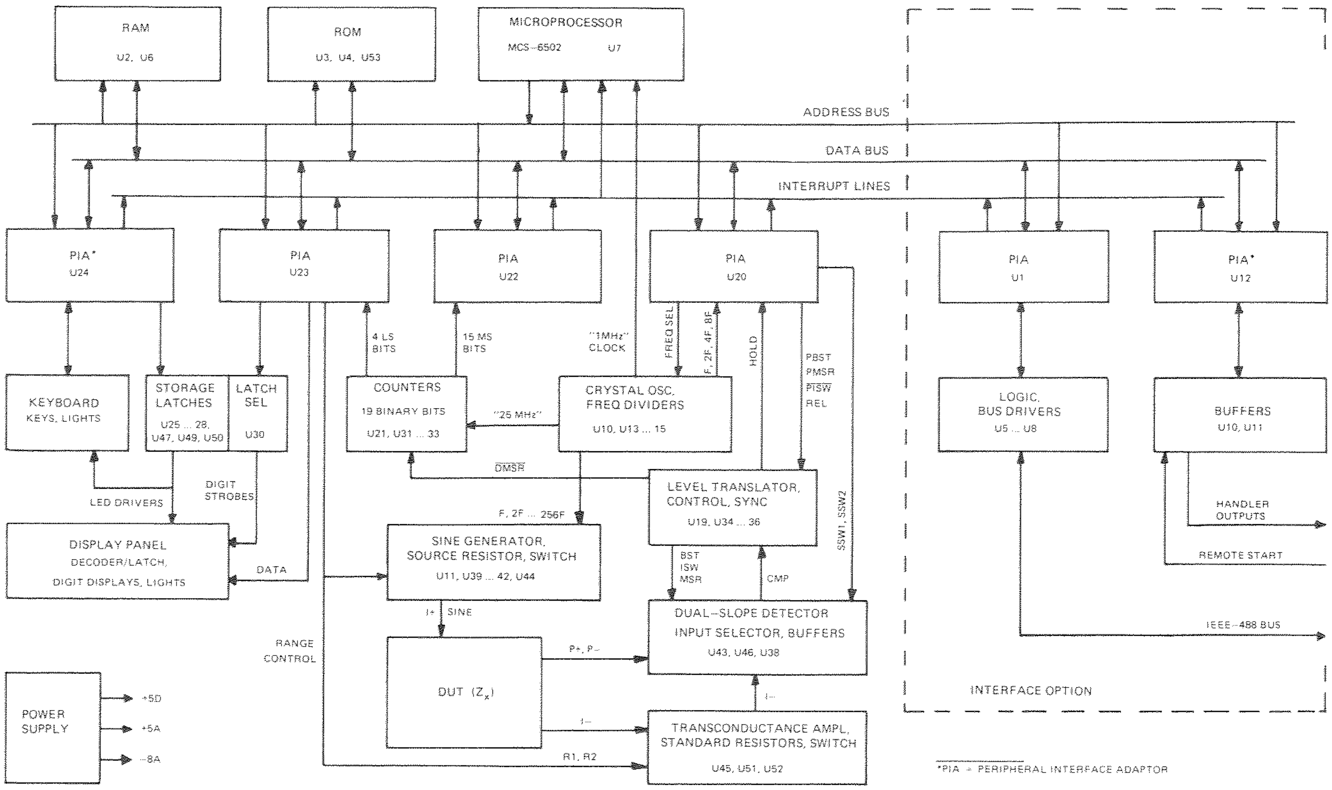



**Figure 4-1. Functional block diagram.**

Test frequences are within 2% of the front-panel indication. However, for reasons related to rejection of power-line-frequency stray signals that could be picked up by the DUT, thereby causing measurement errors; the actual frequencies are as follows – accurate to ±0.01%:

catalog number 1658-9700: 1020.0 Hz, 120.00 Hz
catalog number 1658-9800: 1000.0 Hz, 100.00 Hz.

### 4.1.3 Block Diagram. Figure 4-1.

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

Analog circuitry is shown in the lower part of the diagram, where Zx is supplied with a test signal at frequency f from a sine-wave generator, driven by a crystal-controlled digital frequency divider circuit. The front-end amplifier circuit supplies an analog signal that represents two impedances alternately: the internal standard, Rx, and the DUT, Zx.

The detector control block provides sampling commands (in eight phases). The detector is a dual-slope converter, including an integrator and comparator, which converts each phase component of the analog signal proportionally into a period of time. The dual-slope measurement is converted into a digital number by a counter that is gated by this period.

From this information and criteria selected by the keyboard (or remote control), the microprocessor calculates the RLC and DQ values subsequently displayed.

## 4.2 PRINCIPAL FUNCTIONS.

### 4.2.1 Elementary Measurement Circuit. Figure 4-2.

The measurement technique is shown diagrammatically. A sine-wave generator drives current Ix through the DUT Zx and standard resistor Rs in series. Two differential amplifiers with the same gain K produce voltages $e_1$ and $e_2$ Simple algebra, some of which is shown in the figure, leads to the expression for the "unknown" impedance:

$$Zx = Rs\,[e_1/e_2]$$

Notice that this ratio is complex. Both a magnitude and a loss (or quality) value are automatically calculated from Zx and frequency.

### 4.2.2 Frequency and Time Source Figure 4-3.

A necessary standard for accuracy is the frequency of the test signal; and equally important are the generation of eight-phase references for detection and clocks for the microprocessor. Frequency and timing requirements are implemented by derivation from a single very accurate oscillator, operating near 25 MHz. Digital dividers and logic circuitry provide the many clocks and triggers, as well as driving the sine-wave generator described below.

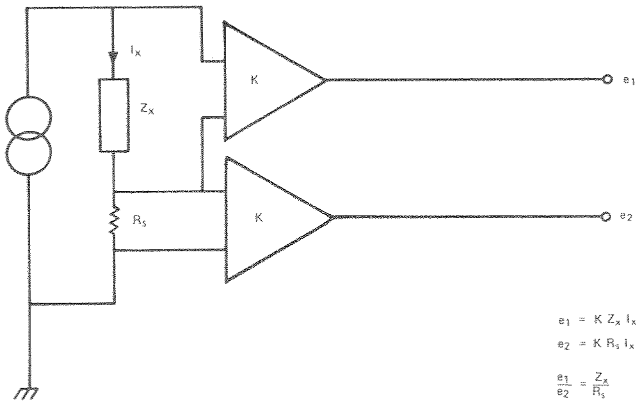



Figure 4-2. Elementary measurement circuit.

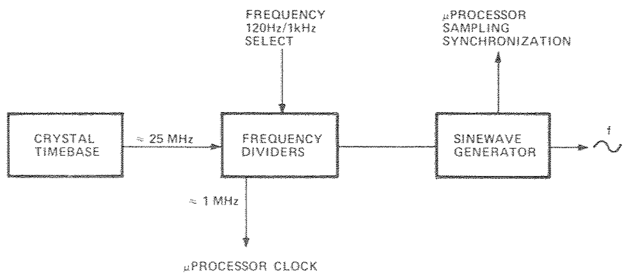



Figure 4-3. Frequency and timing source. A push-button determines the frequency select function. Several clocks and synchronizing pulses as well as the measurement signal f are derived from the accurate time-base signal.

### 4.2.3 Sine-Wave Generation

Figure 4-4.

Starting with a digital signal at 256 times the selected test frequency, the sine-wave generator provides the test signal that drives a small but essential current through the DUT.

Binary dividers count down from 256 F, providing 128 F, 64 F, 32 F, . . . 2F, F. This set of signals is used to address a read-only memory which contains a 256-step approximation to a sine function. The ROM output (as an eight-bit binary number) is converted by a D/A converter to a somewhat "noisy" sine-wave, which is then smoothed by filtering before its use in the measurement of a DUT. The filter is switched appropriately, according to the selected test frequency.

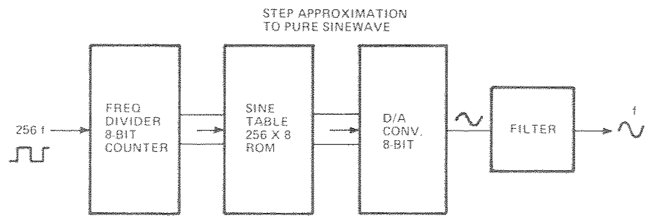



Figure 4-4. Sine wave generator. Given a square wave at 256 f, from preceding dividers, this generator uses a ROM containing the mathematical sine function to form a finely stepped approximation to a sine wave at frequency f. A filter provides smoothing.

# Service and Maintenance—Section 5



## WARNING

These servicing instructions are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing, other than that contained in the operating instructions, unless you are qualified to do so.

CAUTIONS

For continued protection against fire hazard, replace fuse only with same type and ratings as shown on rear panel and in parts list.

Service personnel, observe the following precautions whenever you handle a circuit board or integrated circuit in this instrument.

HANDLING PRECAUTIONS
FOR ELECTRONIC DEVICES
SUBJECT TO DAMAGE BY STATIC ELECTRICITY

Place instrument or system component to be serviced, spare parts in conductive (anti-static) envelopes or carriers, hand tools, etc. on a work surface defined as follows. The work surface, typically a bench top, must be conductive and reliably connected to earth ground through a safety resistance of approximately 250 kilohms to 500 kilohms. Also, for personnel safety, the surface must NOT be metal. (A resistivity of 30 to 300 kilohms per square is suggested.) Avoid placing tools or electrical parts on insulators, such as books, paper, rubber pads, plastic bags, or trays.

Ground the frame of any line-powered equipment, test instruments, lamps, drills, soldering irons, etc., directly to earth ground. Accordingly, (to avoid shorting out the safety resistance) be sure that grounded equipment has rubber feet or other means of insulation from the work surface. The instrument or system component being serviced should be similarly insulated while grounded through the power-cord ground wire, but must be connected to the work surface before, during, and after any disassembly or other procedure in which the line cord is disconnected. (Use a clip lead.)

Exclude any hand tools and other items that can generate a static charge. (Examples of forbidden items are non-conductive plunger-type solder suckers and rolls of electrical tape.)

Ground yourself reliably, through a resistance, to the work surface; use, for example, a conductive strap or cable with a wrist cuff. The cuff must make electrical contact directly with your skin; do NOT wear it over clothing. (Resistance between skin contact and work surface through a commercially available personnel grounding device is typically in the range of 250 kilohms to 1 megohm.)

If any circuit boards or IC packages are to be stored or transported, enclose them in conductive envelopes and/or carriers. Remove the items from such envelopes only with the above precautions; handle IC packages without touching the contact pins.

Avoid circumstances that are likely to produce static charges, such as wearing clothes of synthetic material, sitting on a plastic-covered or rubber-footed stool (particularly while wearing wool), combing your hair, or making extensive erasures. These circumstances are most significant when the air is dry.

When testing static-sensitive devices, be sure dc power is on before, during, and after application of test signals. Be sure all pertinent voltages have been switched off while boards or components are removed or inserted, whether hard-wired or plug-in.

## 5.1 CUSTOMER SERVICE.

Our warranty (at the front of this manual) attests the quality of materials and workmanship in our products. If malfunction does occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone the nearest GenRad service facility (see back page), giving full information of the trouble and of steps taken to remedy it. Describe the instrument by name, catalog number, serial number, and ID (lot) number if any. (Refer to front and rear panels.)

## 5.2 INSTRUMENT RETURN.

### 5.2.1 Returned Material Number.

Before returning an instrument to GenRad for service, please ask our nearest office for a "Returned Material" number. Use of this number in correspondence and on a tag tied to the instrument will ensure proper handling and identification. After the initial warranty period, please avoid unnecessary delay by indicating how payment will be made, i.e., send a purchase-order number.

### 5.2.2 Packaging.

To safeguard your instrument during storage and shipment, please use packaging that is adequate to protect it from damage, i.e., equivalent to the original packaging. Any GenRad field office can advise or provide packing material for this purpose. Contract packaging companies in many cities can provide dependable custom packaging on short notice. Here are two recommended packaging methods.

*Rubberized Hair.* Cover painted surfaces of instrument with protective wrapping paper. Pack instrument securely in strong protective corrugated container (350 lb/sq in. bursting test), with 2-in. rubberized hair pads placed along all surfaces of the instrument. Insert fillers between pads and container to ensure a snug fit. Mark the box "Delicate Instrument" and seal with strong tape or metal bands.

*Excelsior.* Cover painted surfaces of instrument with protective wrapping paper. Pack instrument in strong corrugated container (350 lb/sq in. bursting test), with a layer of excelsior about 6 in. thick packed firmly against all surfaces of the instrument. Mark and seal the box as described above.

## 5.3 REPAIR AND REPLACEMENT OF CIRCUIT BOARDS.

This instruction manual contains sufficient information to guide an experienced and skillful electronic technician in fault analysis and the repair of some circuits in this instrument. If a malfunction is localized to one board (or more) that is not readily repairable, it can be returned to GenRad for repair. To save time, we recommend that you obtain a replacement first, as described below, before returning the faulty board.

*Exchanges.* For economical, prompt replacement of any etched-circuit board, order an exchange board. Its price is considerably less than that of a new one. Place the order through your nearest GenRad repair facility. (Refer to the last page of this manual.) Be sure to request an exchange board and supply the following information:

1. Instrument description: name and catalog and serial numbers. Refer to front and rear panels.
2. Part number of board. Refer to the parts lists in this manual. (The number etched in the foil is generally NOT the part number.)
3. Your purchase order number. This number facilitates billing if the unit is out of warranty and serves to iden tify the shipment.

To prevent damage to the board, return the defective board in the packing supplied with the replacement (or equivalent protection). Please identify the return with the

Return Material number on the tag supplied with the replacement and ship to the address indicated on the tag.

*New Boards.* For equally prompt replacement of any etched-circuit board, and for maximum life expectancy, order a new one. Use the same procedure as described above, but request a new board. Please return the defective one to GenRad.

## 5.4 PERFORMANCE VERIFICATION.

This procedure is recommended for verification that the instrument is performing normally. No other check is generally necessary because this procedure checks operation of nearly all the circuitry. There are no calibrations or adjustments that could require resetting; and the internal standards are very stable. (However, for a rigorous performance and accuracy check, refer to para 5.5.) The necessary resistors, capacitors, and inductors are inexpensive and readily obtained. The most accurate ones available should be used; tolerances listed are the "best" commonly catalogued. Refer to Table 5-1.

CAUTION

Be sure the line voltage switch, rear panel, is correctly set for your power line voltage.

Table 5-1

RESISTORS, CAPACITORS, AND INDUCTORS

| Name | Type* | Nominal Value | Tolerance (%) |
|---|---|---|---|
| Resistors, metal film | MIL-R-10509C Style RN60 | 49.9 Ω | 0.1 |
| | | 499 Ω | 0.1 |
| | | 4.99 kΩ | 0.1 |
| | | 49.9 kΩ | 0.1 |
| | | 499 kΩ | 0.1 |
| Capacitors, polystyrene | Arco: 1PJ-332J | 0.0033 μF | 0.5 |
| | 1PJ-333J | 0.033 μF | 0.5 |
| | 1PJ-334J | 0.33 μF | 0.5 |
| | 1PJ-504J | 0.5 μF | 0.5 |
| . . . metalized polyester | GE: BA-14A105C | 1.0 μF | 5 |
| | BA-19A106C | 10 μF | 5 |
| Inductors, | J.W. Miller: | | |
| nonferrous | 9220-28 | 1000 μH | 5 |
| ferrite core | 9250-107 | 100 mH | 10 |

*Equivalents may be substituted.

Verify performance as follows:

a. Set the line voltage switch, connect the power cord, and depress the POWER button.

b. Press the MEASURE RATE button as many times as necessary to select SLOW. For DISPLAY, verify that the VALUE light is on; for EQUIVALENT CIRCUIT, the SERIES light. (If necessary, operate the corresponding buttons.)

c. Press the FREQUENCY button as many times as necessary to select 120 Hz (100 Hz). For MEASURE MODE, verify that the CONT light is on; for HOLD RANGE, that the RANGE HELD light (on display panel) is NOT on. (If necessary operate the corresponding buttons.)

d. Press parameter button R/Q and verify that any one of the corresponding units is indicated on the display panel (MΩ, kΩ, or Ω).

e. Set the EXT BIAS slide switch to OFF. Set the TALK switch (rear panel, provided only with the Interface Option) to TALK ONLY.

f. Install the test fixture adaptors, as described in para 3.2. Insert the 49.9-Ω resistor as the device under test or "unknown" component (DUT).

g. Verify that the displays are within the extremes shown in "check number 1" in Table 5-2, if the resistor value is within the tolerance listed above.

h. Similarly make the other checks indicated in this table. In check number 12, verify that the 5th digit is reasonably stable, as follows. (Notice that the 4th digit is the least significant one in the readout, for 0.2% accuracy.)

i. In check number 12, the flickering of the 5th digit should stay typically within a range of ±3 counts. For example, if the display is 1.051X μF, the "X" might flicker between 2 and 8 (or a smaller range). If, for example, "X" is flickering between 7 and 13, it will of course cause a flickering of the preceding digit (1.0517 to 1.0523). In such a case, the correct readout is the larger 4-digit number (1.052) and the 5th digit is acceptably stable.

*Tolerances.* Acceptable performance of the instrument is bracketed by the set of display "extremes" in Table 5-2. These are defined as the nominal (ideal) measurements plus-or-minus the sum of the instrument accuracy tolerance and the DUT accuracy tolerance (or slightly more). If the accuracy of your DUT is different from the recommendation, revise the acceptable "extremes" accordingly. Notice that this performance verification is NOT intended to prove the accuracy of the instrument.

*Insignificant Figures.* The right-hand digit(s) of the display normally flicker and change if they are not significant for the specified accuracy of the instrument. Refer to para 3.3.

## 5.5 MINIMUM PERFORMANCE STANDARDS.

### 5.5.1 General.

This procedure is a more rigorous alternative to the performance verification described above. Precision standards of impedance are required for this procedure, which checks the accuracy as well as the overall performance of the instrument. It will be controlled from the front panel, without disassembly. Table 5-3 lists the recommended standards and associated equipment.

Table 5-2

PERFORMANCE VERIFICATION

| Check Number | Parameter; Frequency | DUT | RLC Display Extremes | DQ Display Extremes |
|---|---|---|---|---|
| 1 | R/Q; 120 Hz* | 49.9 Ω | Ø49.80 to Ø50.00 Ω | |
| 2 | | 499 Ω | Ø.4980 to Ø.5000 kΩ | |
| 3 | | 4.99 kΩ | Ø4.980 to Ø5.000 kΩ | |
| 4 | | 49.9 kΩ | .04980 to .05000 MΩ | |
| 5 | | 499 kΩ | Ø.4980 to Ø.5000 MΩ | |
| 6 | C/D; 1 kHz | .0033 μF | Ø3.280 to Ø3.320 nF | (.0000 to .0100) |
| 7 | 120 Hz* | .0033 μF | Ø3.280 to Ø3.320 nf | |
| 8 | 1 kHz | .033 μF | .03280 to .03320 μF | |
| 9 | 120 Hz* | .033 μF | Ø32.80 to Ø.3320 nF | (.0000 to .0100) |
| 10 | both freq | 0.33 μF | Ø.3280 to Ø.3320 μF | |
| 11 | both freq | 0.5 μF | Ø.4970 to Ø.5030 μF | |
| 12 | both freq | 1.0 μF | Ø.9480 to 1.0520 μF | (.0000 to .0300) |
| 13 | 1 kHz | 10 μF | Ø9.480 to 10.520 μF | |
| 14 | 120 Hz* | 10 μF | Ø9.480 to 10.520 μF | |
| 15 | L/Q; 1 kHz | 1000 μH | Ø.9480 to 1.0520 mH | (03.00 to 300.0) |
| 16 | | 100 mH | .08980 to .11020 H | (03.00 to 300.0) |

*120 or 100 Hz.
**Refer to paragraphs headed "Tolerances" and "Insignificant figures," in the accompanying text.

Table 5-3

EQUIPMENT FOR ACCURACY VERIFICATION AND TROUBLE ANALYSIS

| Name | Requirements | Recommended Type* |
|---|---|---|
| Extender cable | Adapts text fixture to standards with binding posts and banana plugs. | GR 1657-9600 |
| Resistors | Four-terminal, 1 Ω, 0.02% | GR 1440-9601 |
| | 10 Ω, 0.01% | GR 1440-9611 |
| | Decade, 100 to 11 111 000 Ω, 0.01% | GR 1433-9719 (-Y) |
| Capacitors | Three-terminal, 100 pF, 0.02% | GR 1403-9704 (-D) |
| | 1000 pF, 0.02% | GR 1403-9701 (-A) |
| | Decade, 3-terminal, 1 pF to 1 (+) μF, 0.05% ± 0.5 pF. | GR 1413-9700 |
| | Four-terminal, ratio type, 1 μF to 10 mF, 0.25% (ratios, 0.02%). | GR 1417-9700 |
| | Dc blocking, 500 μF, 10 V. | GE 69F2214G2 |
| Inductors | Fixed, 2-terminal, 100 mH, 0.1%. | GR 1482-9712 (-L) |
| Adaptors | GR874® (for 1413 capacitor) and binding-post pair (two required). | GR 0874-9870 (-Q2) |
| Shorting link | Ground jumper connection. | GR 0938-9712 (-L) |
| Scope** | General purpose, 100 MHz, dual trace. | Tektronix 465 |
| Scope probe** | Capacitance less than 10 pF, X10. | Tektronix P6053B |
| Voltmeter** | Digital, general purpose, with probe. | Data Precision 3400 |
| Counter** | Dc to 35 MHz, 10 V rms. | Tektronix DC504 |
| Pulse generator** | General purpose. | Tektronix PG501 |
| Resistor** | 200 ohm, 1/4 watt. | — |

*Equivalents may be substituted.
**Required for trouble analysis (Paragraph 5.8); not required for Paragraph 5.5.

Verify that the instrument meets performance specifications as follows.

*Calibration of Standard.* The acceptable RLC readout (min to max range) may have to be modified if the actual (calibrated) value of your standard — Zx — or its accuracy — Zx accuracy — (either or both) is different from the tabulated value(s).

For example, if your 10-Ω standard is known to be 10.006 ± .002 Ω, then add .005 Ω to the lower acceptable extreme and add .007 Ω to the upper one. (In Table 5-4, 2nd line, substitute the numbers 09.994 to 10.018.)

*Insignificant Digits.* The right-hand digit(s) of the display normally may flicker and change if they are not significant for the specified accuracy of the instrument. Refer to para 3.3.

*Cable Capacitance.* Because the cable adds capacitance in parallel with the DUT, it is sometimes necessary to obtain a "corrected readout" from the numerical display on the instrument. Do this for all checks involving small capacitance (less than about 1000 pF). The equivalent correction for large inductance (above 30 H at 1 kHz or 3000 H at 120 Hz) is not applicable in the recommended inductance check procedure. For capacitance measurement, obtain the corrected readout by subtracting the cable capacitance from the visible readout, as described in para 3.2. Because C is large compared to cable capacitance and D is small, the simple calculation (subtraction) is applicable whether the measurement is "parallel" or "series."

CAUTION

Be sure the line voltage switch, rear panel, is correctly set for your power line voltage.

### 5.5.2 Resistance Measurement Accuracy.

Make the test setup and verify instrument performance as follows.

a. Set the line voltage switch, connect the power cord, and depress the POWER button, as described in para 3.1.

b. Connect the extender cable to the Digibridge test fixture, as described in para 3.2.

c. Connect a standard resistor (1-Ω initially) to the extender cable, as follows:

RED, I+: left front terminal of resistor
RED & WHITE; P+: left rear terminal
BLACK, I−: right front terminal
BLACK & WHITE, P−: right rear terminal
BLACK & GREEN, G: no connection.

**Table 5-4**
RESISTANCE ACCURACY CHECKS

| Standard as DUT* | Test Frequency | Equivalent Circuit | Measure Rate | Typical Standard Accuracy* (%) | Digibridge Accuracy (%) | RLC Display Acceptable Extremes* |
|---|---|---|---|---|---|---|
| 1.000 Ω | 1 kHz | SERIES | SLOW | .02 | 0.2 | Ø.9978 to 1.0022 Ω |
| 10.00 Ω | 1 kHz | SERIES | SLOW | .01 | 0.1 | Ø9.989 to 10.011 Ω |
| 10.00 Ω | 1 kHz | SERIES | MEDIUM | .01 | 0.2 | Ø9.979 to 10.021 Ω |
| 10.00 Ω | 1 kHz | SERIES | FAST | .01 | 0.5 | Ø9.949 to 10.051 Ω |
| 100.0 Ω | 1 kHz | SERIES | SLOW | -.01, +.02 | 0.1 | Ø99.89 to 100.12 Ω |
| 100.0 Ω | 1 kHz | SERIES | MEDIUM | -.01, +.02 | 0.2 | Ø99.79 to 100.22 Ω |
| 100.0 Ω | 1 kHz | SERIES | FAST | -.01, +.02 | 0.5 | Ø99.49 to 100.52 Ω |
| 1.000 kΩ | 1 kHz | SERIES | SLOW | .01 | 0.1 | Ø.9989 to 1.0011 kΩ |
| 1.000 kΩ | 1 kHz | SERIES | MEDIUM | .01 | 0.2 | Ø.9979 to 1.0021 kΩ |
| 1.000 kΩ | 1 kHz | SERIES | FAST | .01 | 0.5 | Ø.9949 to 1.0051 kΩ |
| 10.00 kΩ | 1 kHz | PARALLEL | SLOW | .01 | 0.1 | Ø9.989 to 10.011 kΩ |
| 10.00 kΩ | 1 kHz | PARALLEL | MEDIUM | .01 | 0.2 | Ø9.979 to 10.021 kΩ |
| 10.00 kΩ | 1 kHz | PARALLEL | FAST | .01 | 0.5 | Ø9.949 to 10.051 kΩ |
| 100.0 kΩ | 1 kHz | PARALLEL | SLOW | .01 | 0.1 | .09989 to .10011 MΩ |
| 100.0 kΩ | 1 kHz | PARALLEL | MEDIUM | .01 | 0.2 | .09979 to .10021 MΩ |
| 100.0 kΩ | 1 kHz | PARALLEL | FAST | .01 | 0.5 | .09949 to .10051 MΩ |
| 1.000 MΩ | 1 kHz | PARALLEL | SLOW | .01 | 0.1 | Ø.9989 to 1.0011 MΩ |
| 1.000 MΩ | 120 Hz† | PARALLEL | SLOW | .01 | 0.1 | Ø.9989 to 1.0011 MΩ |
| 1.000 MΩ | 1 kHz | PARALLEL | MEDIUM | .01 | 0.2 | Ø.9979 to 1.0021 MΩ |
| 1.000 MΩ | 120 Hz† | PARALLEL | MEDIUM | .01 | 0.2 | Ø.9979 to 1.0021 MΩ |
| 1.000 MΩ | 120 Hz† | PARALLEL | FAST | .01 | 0.5 | Ø.9949 to 1.0051 MΩ |
| 1.000 MΩ | 1 kHz | PARALLEL | FAST | .01 | 0.5 | Ø.9949 to 1.0051 MΩ |

*If the calibrated value of your resistance standard is slightly different from the nominal value or if the standard's accuracy is different from the typical accuracy, correct the "acceptable extremes" accordingly.
†120 Hz or 100 Hz, depending on model of Digibridge.

d. Set up the measurement conditions on the Digibridge as tabulated below. (See para 3.1.)

DISPLAY – VALUE
MEASURE RATE – SLOW (initially)
EQUIVALENT CIRCUIT – SERIES (initially)
FREQUENCY – 1 kHz (initially)
MEASURE MODE – CONT
HOLD RANGE – autorange (RANGE HELD light off)
Parameter – R/Q (resistance units light on)
EXT BIAS – OFF
TALK (on Interface Option only) – TALK ONLY.

e. Refer to Table 5-4. Verify that the RLC display is between the extremes (inclusively) shown in the 1st row. Proceed down the table, changing the resistance standard and verifying the RLC readout as shown; refer to the next step.

f. For larger values of resistance standard, use the decade resistor, making connection as follows.

RED, I+: stack on P+
RED & WHITE, P+: resistor H
BLACK, I–: stack on P–
BLACK & WHITE, P–: resistor L
BLACK & GREEN, G: resistor G.

### 5.5.3 Single and Average Modes.

Retain the conditions of the last row in Table 5-4 except as follows. Set the Digibridge to:

MEASURE MODE – SINGLE

a. Press START.

b. Verify that the subsequent RLC display is acceptable, as before. (Repeated starts will yield different display values but they should be within the acceptable extremes, inclusively.)

c. Set the Digibridge to:

MEASURE MODE – AVERAGE.

d. Press START.

e. Verify that the RLC display is acceptable, as before, after allowing 5 s (time for the instrument to complete 10 measurements). Repeated starts will yield different display values, but the "final" averages should be less variable than the measurements in step b.

### 5.5.4 Capacitance Measurement Accuracy (Small C).

Make the test setup and verify Digibridge performance as a continuation of the previous procedure, except as follows:

a. Remove the resistance standard and connect the test-fixture extender cable tips to the pair of 874 adaptors thus:

RED, I+: stack on P+
RED & WHITE, P+: center post of 1st adaptor
BLACK, I–; stack on P–
BLACK & WHITE, P–: center post of 2nd adaptor
BLACK & GREEN, G: side post of 2nd adaptor

When the standard is the 1403 type of capacitor, connect each adaptor to one of the coaxial ports. When it is the 1413 (decade box) capacitor, connect the 1st adaptor to the port labeled H, connect 2nd adaptor to port L, and be sure to link the side (ground) posts together, using the recommended link or a short piece of bus wire.

b. Confirm or select measurement conditions on the Digibridge thus:

DISPLAY – VALUE
MEASURE RATE – SLOW
EQUIVALENT CIRCUIT – PARALLEL
FREQUENCY – 1 kHz
MEASURE MODE – CONT
HOLD RANGE – autorange (RANGE HELD light off)
Parameter – C/D (capacitance units light on)
EXT BIAS – OFF
TALK (on Interface Option only) – TALK ONLY.

c. Refer to Table 5-5, 1st row. Connect the capacitance standard and arrange the cable as desired for the complete measurement. Determine Co, the "zero capacitance" of extender cable and associated connections, as follows.

Carefully lift the red stacked pair of cable tips free from the post in the 1st adaptor. Hold them about 0.5 cm (1/4 in.) above the binding post where they belong. DO NOT re-arrange the cable branches or change their spacing more than is absolutely necessary to follow these directions. Hold the plastic tips (not the wires or conductors) and firmly touch a finger to the guard (G) circuit, to minimize the effect of capacitance in your body.

Read the capacitance Co on the RLC display. Then plug the stacked pair of cable tips into the 1st adaptor as described before.

d. Read the RLC display, with the capacitance standard connected. Correct the reading by subtracting "zero" capacitance, shown in the table as Co." Verify that this result is within the specifications.

e. Proceed down the table, changing capacitance standard if necessary and determining Co again with each such change. For each row in the table, also select frequency and measurement rate as tabulated; then verify that the RLC display (corrected) meets the specifications.

Notice that different values of Co are to be expected with each change in the capacitance standard (Co" with 100 pF, Co' with 1000 pF, and Co with the decade capacitor are shown in the table). When the decade capacitor is connected, determine Co with the decade switches all set to zero and the extender cable connected. (In this case, do NOT hold any extender-cable tips in the lifted position.)

### 5.5.5 Limit Comparison Bins.

Verify the Digibridge performance with regard to limit comparison and bin assignments as follows. The test setup is unchanged from the previous one.

a. Confirm or select measurement conditions on the Digibridge as listed:

DISPLAY – ENTER LIMITS (new condition)
MEASURE RATE – SLOW
EQUIVALENT CIRCUIT – PARALLEL

Table 5-5

CAPACITANCE ACCURACY CHECKS

| Standard as DUT* | Test Frequency | Measure Rate | Typical Standard Accuracy* (%) | Digibridge Accuracy* (%) | Correction | Corrected Display* Acceptable Extremes | DQ Display Maximum |
|---|---|---|---|---|---|---|---|
| 100.0 pF | 1 kHz | SLOW | .03 | 0.2 | –Co″ | .09977 to 1.0023 nF | – |
| 1000. pF | 1 kHz | SLOW | .02 | 0.1 | –Co′ | Ø.9988 to 1.0012 nF | .0010 |
| 1000. pF | 120 Hz† | SLOW | .02 | 0.2 | –Co′ | Ø.9978 to 1.0022 nF | .0010 |
| 1000. pF | 120 Hz† | MEDIUM | .02 | 0.4 | –Co′ | Ø.9958 to 1.0042 nF | – |
| 1000. pF | 1 kHz | MEDIUM | .02 | 0.2 | –Co′ | Ø.9978 to 1.0022 nF | – |
| 1000. pF | 1 kHz | FAST | .02 | 0.5 | –Co′ | Ø.9948 to 1.0052 nF | – |
| 1000. pF | 120 Hz† | FAST | .02 | 1.0 | –Co′ | Ø.9898 to 1.0102 nF | – |
| 10000 pF | Both | FAST | .05 | 0.5 | –Co | Ø9.945 to 10.055 nF | – |
| 10000 pF | Both | MEDIUM | .05 | 0.2 | –Co | Ø9.975 to 10.025 nF | – |
| 10000 pF | Both | SLOW | .05 | 0.1 | –Co | Ø9.985 to 10.015 nF | .0010 |
| 0.100 μF | 1 kHz | SLOW | .05 | 0.1 | –Co | .09985 to .10015 μF | – |
| 0.100 μF | 120 Hz† | SLOW | .05 | 0.1 | –Co | Ø99.85 to 100.15 nF | – |
| 0.100 μF | 120 Hz† | MEDIUM | .05 | 0.2 | –Co | Ø99.75 to 100.25 nF | – |
| 0.100 μF | 1 kHz | MEDIUM | .05 | 0.2 | –Co | .09975 to .10025 μF | – |
| 0.100 μF | 1 kHz | FAST | .05 | 0.5 | –Co | .09945 to .10055 μF | – |
| 0.100 μF | 120 Hz† | FAST | .05 | 0.5 | –Co | Ø99.45 to 100.55 nF | – |
| 1.000 μF | Both | FAST | .05 | 0.5 | –Co | Ø.9945 to 1.0055 μF | – |
| 1.000 μF | Both | MEDIUM | .05 | 0.2 | –Co | Ø.9975 to 1.0025 μF | – |
| 1.000 μF | Both | SLOW | .05 | 0.1 | –Co | Ø.9985 to 1.0015 μF | .0010 |
| 0.500 μF | 1 kHz | SLOW | .05 | 0.1 | –Co | Ø.4992 to Ø.5008 μF | .0010 |

* If the calibrated value of your capacitance standard is slightly different from the nominal value or if the standard's accuracy is different from the typical accuracy, correct the "acceptable extremes" accordingly.
†120 Hz to 100 Hz, depending on model of Digibridge.

FREQUENCY – 1 kHz
MEASURE MODE – CONT
HOLD RANGE – autorange
Parameter – C/D
Units selected – μF
EXT BIAS – OFF.

b. Refer to Table 5-6. After making the sequence of keystrokes (using the appropriate limit entry keys) shown under "Entry," verify that the Digibridge numerical displays are like the numbers tabulated in the same row of the table under "Displays." Make all entries as tabulated; this is part of the setup for later procedures.

Table 5-6

ENTRY OF LIMITS

| Entry | RLC Display | DQ Display |
|---|---|---|
| (none) | (blank) | (blank) |
| [.] [5] [=] [NOM VALUE] | .49999 | (blank) |
| [.] [0] [0] [1] [=] [BIN No.] [0] | (blank) | .0010 |
| [1] [%] [=] [BIN No.] [1] | .50499 | .4949 |
| [2] [%] [=] [BIN No.] [2] | .50999 | .4899 |
| [3] [%] [=] [BIN No.] [3] | .51499 | .4849 |
| [4] [%] [=] [BIN No.] [4] | .51999 | .4799 |
| [5] [%] [=] [BIN No.] [5] | .52499 | .4749 |
| [6] [%] [=] [BIN No.] [6] | .52999 | .4699 |
| [7] [%] [=] [BIN No.] [7] | .53499 | .4649 |
| [8] [%] [=] [BIN No.] [8] | .53999 | .4599 |

c. Select on the Digibridge:
DISPLAY – VALUE.

Verify that the GO light is on. (The RLC and DQ displays should be within the extremes given in Table 5-5, as checked previously.)

d. Select on the Digibridge:
DISPLAY – BIN No.

e. Refer to Table 5-7. For each setting of the capacitance standard, verify that the DQ display is blank, the bin (RLC) display is a single digit as tabulated, and the GO/NO-GO lights work as tabulated.

f. Select on the Digibridge:
DISPLAY – ENTER LIMITS.

g. Make the following entry (as in step b):
[=] [NOM VALUE].

Verify that the RLC display is five zeroes.

h. Select on the Digibridge:
DISPLAY – VALUE

Notice that the RLC and DQ displays are normal (last entry in Table 5-5). Verify that both of the GO/NO-GO lights are off.

i. Select on the Digibridge:
DISPLAY – BIN NO.

Verify that both RLC and DQ displays are blank.

j. Select on the Digibridge:
DISPLAY – ENTER LIMITS.

Table 5-7
BIN ASSIGNMENT CHECK

| DUT ($\mu$F) | GO/NO-GO | Bin Display |
|---|---|---|
| 0.5000 | GO | 1 |
| 0.5057 | GO | 2 |
| 0.5107 | GO | 3 |
| 0.5157 | GO | 4 |
| 0.5207 | GO | 5 |
| 0.5257 | GO | 6 |
| 0.5307 | GO | 7 |
| 0.5357 | GO | 8 |
| 0.5407 | NO-GO | 9 |
| 0.0000 | NO-GO | 0 |
| 0.5000 | GO | 1 |

Check that each of the 7 unit indicator lights is functioning, in the RLC display area, as follows. Repeatedly depress the R/Q key for the 3 resistance units, the L/Q key for the 2 inductance units, and then the C/D key for the 2 capacitance units. Be sure the last parameter key to be used is C/D.

**5.5.6 Capacitance Measurement Accuracy (Large C).**

Continue the procedure as follows:

a. Confirm or select measurement conditions as listed:
DISPLAY – VALUE (new condition)
MEASURE RATE – SLOW
EQUIVALENT CIRCUIT – SERIES (new condition)
FREQUENCY – 1 kHz
MEASURE MODE – CONT
HOLD RANGE – autorange
Parameter – C/D
EXT BIAS – OFF.

b. Remove the decade capacitor and connect the 4-terminal 1-$\mu$F capacitance standard (GR 1409-Y) as follows. This standard should be certified to an accuracy of ±.03%, including aging effects.
RED, I+: capacitor H binding post
RED & WHITE, P+: capacitor H banana plug
BLACK, I–: capacitor L binding post
BLACK & WHITE, P–: capacitor L banana plug
BLACK & GREEN, G: capacitor G.

c. Verify that the RLC display agrees with the certified value of the standard (corrected for temperature if appropriate) within ±.0013 $\mu$F i.e., within the sum of .03% for the standard and 0.1% for the Digibridge. See Table 5-8, line 1. Calculate the difference D1 = (displayed measurement) – (value of standard), for future use. Units of D1 are $\mu$F.

d. Remove the 1-$\mu$F standard and connect the 4-terminal ratio-type capacitance standard (GR 1417) as follows. Be sure the dc blocking capacitor is fully discharged before connecting it. Notice that only the left-hand terminals of the standard are used.
RED, I+: + end of blocking capacitor (500 $\mu$F); other end to capacitance standard, CURRENT H
RED & WHITE, P+: standard, POTENTIAL H
BLACK, I–: standard, CURRENT L
BLACK & WHITE, P–: standard, POTENTIAL L
BLACK & GREEN, G: standard, uninsulated terminal.

e. Set the dials on the capacitance standard thus:
TEST FREQUENCY – 1 kHz
CAPACITANCE – 1 $\mu$F.

NOTE
For detailed information on the GR 1417 4-Terminal Capacitance Standard, refer to its instruction manual.

f. Read the RLC display, which should be close to 1 $\mu$F. Calculate the difference D2 = (1.0000 $\mu$F) – displayed measurement. Units of D2 are $\mu$F. The DQ display should show D = .0085 to .0115.

g. Calculate the calibration factor K as follows:
K = D1 + D2.

Example. In step c, the display is 1.0012, the standard is 1.0006; then D1 = +.0006 $\mu$F. In step f, the nominal is 1.0000, the display is 1.0024; then D2 = –.0024 $\mu$F. The factor K is therefore –.0018 (no units required).

h. Reset the capacitance-standard dial to:
CAPACITANCE – 10 $\mu$F.

Read the RLC display and correct it by adding 10K. (For example, if display is 10.023 $\mu$F, corrected measurement [for K = –.0018] is 10.005 $\mu$F.) Verify that the corrected measurement is within the acceptable extremes of Table 5-8, line 2.

i. Resetting the capacitance standard and Digibridge frequency, as indicated, continue to line 3 in the table. Verify results as above.

j. Set the Digibridge frequency thus:
FREQUENCY – 120 Hz (or 100 Hz).

Repeat steps b and c. (See line 4 of table.) Also determine a new value of D1 for this frequency.

k. Repeat step d and set the capacitance-standard dials as follows. (Choose frequency to agree with Digibridge.)
TEST FREQUENCY – 120 Hz or 100 Hz
CAPACITANCE – 1 $\mu$F.

l. Repeat steps f and g, determining a new value of K for this frequency. (Call it K′.)

m. Continue down Table 5-8, making the settings, calculations, and verifications indicated there.

**5.5.7 D-Measurement Accuracy.** **Figure 5-1.**

Verify D-measurement accuracy with the following procedure. Dissipation-factor checks will be made using both series and parallel equivalent circuits, with corresponding connections of resistance and capacitance standards.

a. Using the extender cable and plain bus wire, connect the decade R and C standards in series, as DUT to the Digibridge, as shown in the diagram and tabulated below. (Use adaptors on the coaxial connectors, as before.)
RED, I+: stack on P+
RED & WHITE, P+: resistor H

Table 5-8

CAPACITANCE ACCURACY CHECKS

| Standard as DUT* | Test Frequency | Typical Standard Accuracy (%) | Digibridge Accuracy (%) | Correction | Corrected C Display Acceptable Extremes | DQ Display Acceptable |
|---|---|---|---|---|---|---|
| 1.000 µF | 1 kHz | .03 | 0.1 | – | ±.0013 µF* | – |
| 10.00 µF | 1 kHz | .07 | 0.1 | +10 K | Ø9.983 to 10.017 µF | .0085 to .0115 |
| 100.0 µF | 1 kHz | .07 | 0.1 | +100 K' | Ø99.83 to 100.17 µF | .0085 to .0015 |
| 1.000 µF | 120 Hz† | .03 | 0.1 | – | ±.0013 µF* | – |
| 10.00 µF | 120 Hz† | .05 | 0.1 | +10 K' | Ø9.985 to 10.015 µF | .0085 to .0115 |
| 100.0 µF | 120 Hz† | .05 | 0.1 | +100 K' | Ø99.85 to 100.15 µF | .0085 to .0115 |
| 1.000 mF | 120 Hz† | .05 | 0.1 | +1000 K' | Ø998.5 to 1001.5 µF | .0085 to .0115 |
| 10.00 mF | 120 Hz† | .06 | 0.5 | 10000 K' | 9944.0 to 10056 µF | .0065 to .0135 |

*Acceptable display is certified value of standard, plus or minus the tolerance given.
†120 Hz or 100 Hz, depending on model of Digibridge.

BLACK, I–: stack on P–
BLACK & WHITE, P–: capacitor L, center
BLACK & GREEN, G: resistor G, capacitor H side post, and capacitor L side post (suitably connected together with a link and/or bus wire).

Also connect with a short jumper from resistor L to capacitor H, center post.

b. Confirm or select measurement conditions on the Digibridge thus:

DISPLAY – VALUE
MEASURE RATE – SLOW
EQUIVALENT CIRCUIT – SERIES
FREQUENCY – 120 Hz (100 Hz)
MEASURE MODE – CONT
HOLD RANGE – autorange
Parameter – C/D
EXT BIAS – OFF.

c. Set the resistance and capacitance standards to the values given in line 1 of Table 5-9. Verify that the DQ display is within the range given, inclusive. (Notice that the C-standard value depends on the test frequency of your particular model.)

d. Continue down the table, verifying each line. Because the capacitance in the series equivalent circuit is different from the decade capacitor setting when the series resistance is large, use the RLC readout to indicate capacitance in those lines of the table.

e. Reconnect the standards in parallel as shown in the diagram and change the Digibridge measurement conditions as follows:

EQUIVALENT CIRCUIT – PARALLEL
FREQUENCY – 1 kHz.

f. Verify the D accuracy, as before, by following Table 5-10. Notice that the 1658-9700 (which has 120 Hz for its lower test frequency) actually tests at 1020 Hz, whereas the 1658-9800 tests at 1000 Hz; hence the different requirements for capacitance in the table.

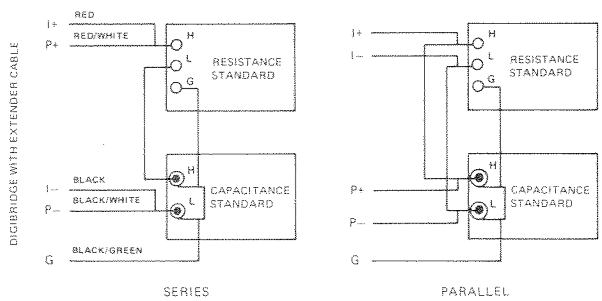



Figure 5-1. Series and parallel connections of standards for D accuracy checks.

Table 5-9

SERIES-CIRCUIT D-ACCURACY CHECK

| Resistance Standard | Capacitance Standard (120 Hz) | (100 Hz) | DQ Display (Min to Max) |
|---|---|---|---|
| 50 Ω | 0.1326 µF | 0.1592 µF | .0045 to .0055 |
| 100 Ω | same | same | .0095 to .0105 |
| 500 Ω | same | same | .0494 to .0506 |
| 1 kΩ | same | same | .0994 to .1006 |
| 5 kΩ | same | same | .4987 to .5013 |
| 10 kΩ | same | same | .9975 to 1.003 |
| 50 kΩ | reset* | reset* | 4.969 to 5.031 |
| 90 kΩ | reset* | reset* | 8.909 to 9.091 |

*Reset the capacitance standard to obtain, on the RLC readout, the tabulated capacitance.

Table 5-10

PARALLEL-CIRCUIT D-ACCURACY CHECKS

| Resistance Standard | Capacitance Standard (-9700) | (-9800) | DQ Display (Min to Max) |
|---|---|---|---|
| 1 MΩ | 31.22 nF | 31.84 nF | .0045 to .0055 |
| 500 kΩ | same | same | .0095 to .0105 |
| 100 kΩ | same | same | .0494 to .0506 |
| 50 kΩ | same | same | .0994 to .1006 |
| 10 kΩ | same | same | .4987 to .5013 |
| 5 kΩ | same | same | .9975 to 1.003 |
| 1 kΩ | same | same | 4.969 to 5.031 |
| 500 Ω | same | same | 9.889 to 10.11 |

### 5.5.8 Inductance Measurement Accuracy.

Verify the accuracy of inductance measurements, as follows.

a. Using the extender cable, connect the 100-mH inductance standard as DUT, thus:

RED, I+: stack on P+
RED & WHITE, P+: inductor HIGH
BLACK, I–: stack on P–
BLACK & WHITE, P–: inductor LOW
BLACK & GREEN, G: inductor case (ground).

b. Confirm or select measurement conditions on the Digibridge as follows.

DISPLAY – VALUE
MEASURE RATE – SLOW
EQUIVALENT CIRCUIT – SERIES
FREQUENCY – 120 Hz (100 Hz)
MEASURE MODE – CONT
HOLD RANGE – autorange
Parameter – L/Q.

c. Verify that the RLC display is within ±0.10 mH of the certified effective 100-Hz series inductance of the standard.

d. Calculate the low-frequency Q of the standard inductor as follows:

$$Q = 6.2832\ f\ L/R$$

where f is the measurement frequency, L is the certified series inductance, and R is the dc resistance, also given on the certificate. (Notice that the 100-Hz Q is given on the certificate; but not the 120-Hz Q.)

e. Verify that the DQ display is within ±.0114 of the calculated low-frequency Q.

f. Change test frequency as follows:

FREQUENCY – 1 kHz.

g. Verify that the RLC display is within 0.10 mH of the certified effective 1000-Hz series inductance of the standard.

h. Calculate the high-frequency Q of the standard inductor using the above formula and the present test frequency.

i. Verify that the DQ display is within ±.078 of the calculated high-frequency Q.

### 5.5.9 Zero Capacitance.

Check the "zero" or residual capacitance in the Digibridge and its test fixture as follows.

a. Remove the extender cable from the Digibridge.

b. Confirm or select the measurement conditions thus:

DISPLAY – VALUE
MEASURE RATE – SLOW
EQUIVALENT CIRCUIT – SERIES
FREQUENCY – 1 kHz
MEASURE MODE – CONT
HOLD RANGE – autorange
Parameter – C/D (new condition).

c. Verify that the RLC display is less than .002 nF (i.e., 2 pF).

## 5.6 DISASSEMBLY AND ACCESS.

WARNING

**If disassembly or servicing is necessary, it should be performed only by qualified personnel familiar with the electrical shock hazards inherent to the high-voltage circuits inside the cabinet.**

CAUTION

Observe the following precautions whenever you handle a circuit board or integrated circuit in this instrument.

HANDLING PRECAUTIONS
FOR ELECTRONIC DEVICES
SUBJECT TO DAMAGE BY STATIC ELECTRICITY

Refer to page 5-0 for details. The following integrated circuits are known to require these precautions.

1658-4700: MB-U2, -U3, -U4, -U6, -U8, -U19 through -U24, -34 through -U37, -U41, -U42, -U45, -U46, -U52, -U53. 1658-4715: DB-U47 through -U55.

Notice that it is safe to assume that all circuits in this instrument are subject to damage by static electricity, and observe the precautions always.

### 5.6.1 Disassembly.

Use the following procedure for access to replaceable parts and contact points used in trouble analysis.

a. Disconnect the power cord.

b. Remove the top-cover screws from the rear panel of the main chassis. See Figure 1-2. Slide the top cover forward about 6 mm so that its front corners are unhooked. Lift it directly upward (Figure 5-2). Reassembly note: 2 screws, 13 mm long.

The next step, removal of display board, is recommended (though not absolutely necessary) before removal of the main circuit board.

c. Remove the 2 support screws, at left and right, that hold the display board to its brackets. (See Figure 5-2.) Pull the board directly out of its socket in the main board. Keep the display board in its original (inclined) plane until

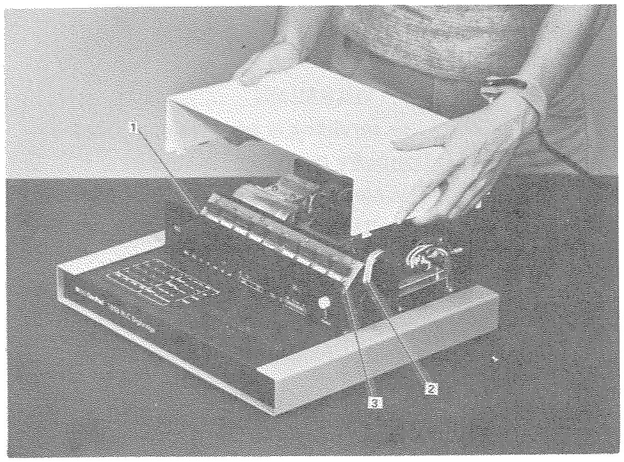



Figure 5-2. Removal of top cover. Items 1 and 3 are screws that hold the display board. Item 2 is ribbon cable 1657-0200 that connects power supply to main board.

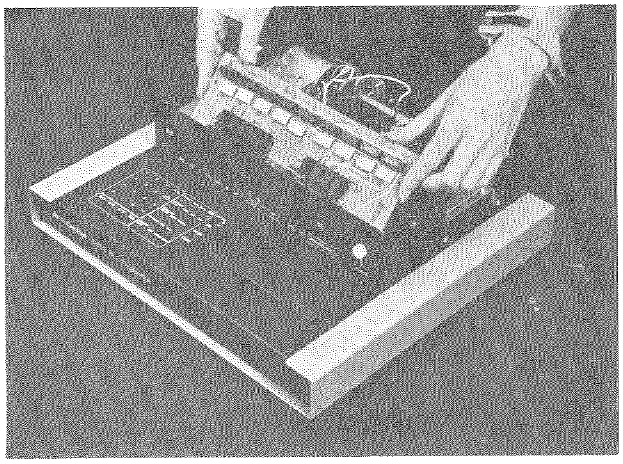


Figure 5-3. Removal of the display board.

it is completely free (Figure 5-3). Reassembly note: 2 screws, 6 mm long with washers.

d. Remove the ribbon cable (1657-0200) from power supply (at V-J1) and main board (at MB-J5). Notice that the connectors are symmetrical and reversible; and the cable is extra long, for convenience in servicing.

The next step, removal of the power supply, is NOT related to the removal of the main board. Either can be left in place while the other is removed.

e. Remove the 4 screws that pass vertically through the 4 corners of the power supply into the main chassis. Lift the power supply slightly and move it back carefully while disengaging the POWER pushbutton extension from its hole in the front panel (Figure 5-4). Reassembly note: 4 screws, 8 mm long.

f. Remove the interface option, if you have one, after removing the 2 large screws with resilient washers in the rear panel. (If the panel held by these screws is blank, leave it in place.) Reassembly note: align board edges carefully with connector and guide that are inside of instrument, while pushing interface option into position.

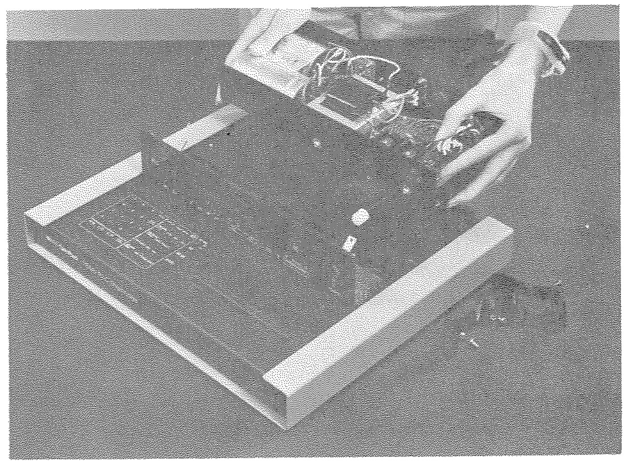


Figure 5-4. Removal of the power supply. The ribbon cable must be disconnected first. The display board can be left in place, but has been removed in this picture.

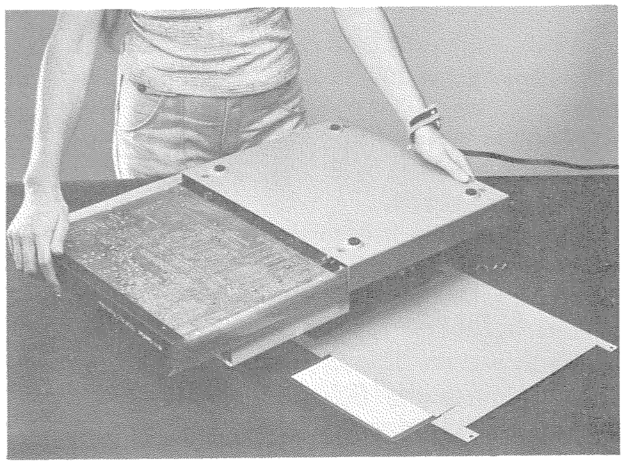


Figure 5-5. Removal of the bottom shell. The top cover has been temporarily installed as a support.

g. Provide a convenient "upsidedown" support by reinstalling the top cover, temporarily. Turn the instrument, bottom up.

h. Remove 4 screws from the bottom shell, one near each rubber foot. Lift the instruction card and its retaining pan free. Slide the bottom shell back (or forward), free of the main chassis (Figure 5-5). Reassembly notes: Be sure to enfold the pliable dirt seals at left and right sides of main chassis as you start to slide bottom shell onto main chassis; use 4 screws, 8 mm long.

i. Remove 11 screws from positions shown in Figure 5-6 as A and B, to free the main board. Slide it forward so the bias connector can be lifted past the lip of the chassis. Figure 5-7 shows how to tilt and rotate the main board to the best position for removal. Reassembly note: return washers (if any) to original positions; screws at A are 6 mm, B are 8 mm long.

j. To remove the keyboard module, remove the 4 screws at D and carefully pull the module directly away from the main board. Reassembly note: be very careful not to bend

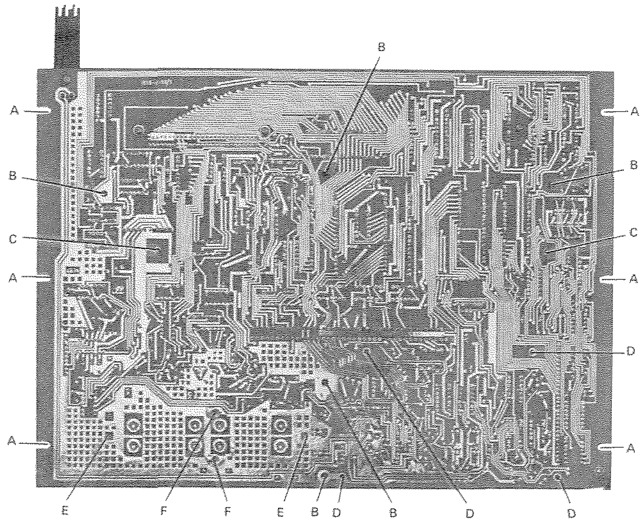



Figure 5-6. Locations of screws on the main board, bottom view. Screws at A and B hold the board to the chassis. Screws at C hold brackets for display board; D, the keyboard module; E and F, the test fixture guide block. All except F are accessed from this side.

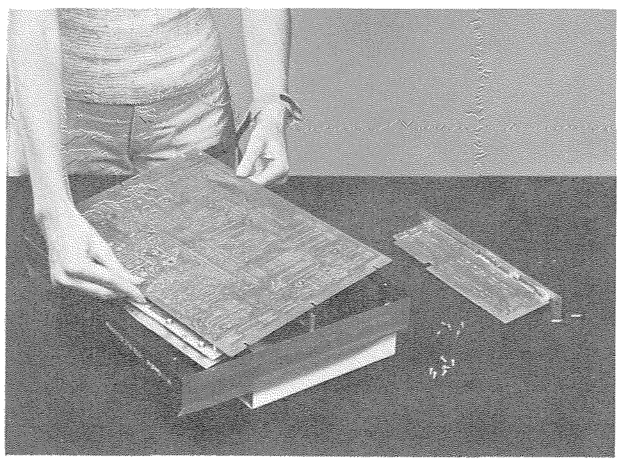


Figure 5-7. Removal of the MB board. The ribbon cable must be disconnected first. Prior removal of the display board also is highly recommended. Because the board is partially enclosed by the main chassis, some motions are necessary: toward front, disengaging bias connector, tilting, turning as shown, and toward the rear.

pins when plugging the keyboard-module connectors into their main-board sockets.

k. Remove dross shield assembly separately if desired (or as part of guide block; see below). The shield can be removed by spreading the mid parts of the long sides slightly and lifting it off.

l. For access to the test-fixture contacts, remove the guide block 1657-2200 (includes dross shield) by removing 2 screws E and 2 hex-socket screws F (.094-inch wrench) from opposite sides of the main board (Figure 5-6). Reassembly note: see para 5.7.1.

### 5.6.2 Access. Figures 5-8, 5-9, and 5-10.

Locations of principal interior parts and points of interest for trouble analysis are shown in the accompanying pictures. On the main board, the crystal oscillator U14 and DIP switch S900 are identified, being the key components in alteration of the test frequencies. (By changing U14 and depressing the correct switch tabs, you can convert a 1658-9700 functionally to a 1658-9800, and vice versa. Details are tabulated on the schematic diagram. Also, refer to Table 5-13.)

Also on the main board, notice that the analog circuitry is placed along the front (forward of the display-board connector) and along the front half of the right-hand edge. Most of this board supports digital circuitry.

For a more complete guide to parts location, refer to Table 5-11. This lists the principal parts of the main (MB–) board and indicates where each one is shown on both board layout and schematic diagrams. The alphanumerics such as B4 or C6 are coordinates on the indicated figures in Section 6. The vertical coordinates are A to E (top to bottom); the horizontal coordinates are 1 to 8 (left to right).

### 5.6.3 Reference Designations.

Refer to Section 6 for an explanation of these designations. For example, V-T1 designates transformer number one in the power supply (V) assembly. MB-U3 is integrated circuit number 3 on the MB board, which is the analog and control board, often called the main board.

### 5.6.4 Removal of Multiple-Pin Packages.

Use caution when removing a plug-in integrated-circuit or other multiple-pin part, not to bend pins nor stress the circuit board. Withdraw the part straight away from the board. Unless an IC is known NOT to be a MOS type, place it immediately on a conductive pad (pins in the pad) or into a conductive envelope.

DO NOT attempt to remove a soldered-in IC package unless you have the proper equipment and skills to do so without damage. If in doubt, return the board to GenRad.

## 5.7 PERIODIC MAINTENANCE.

### 5.7.1 Care of the Test Fixture.

About once a year (more or less depending on usage) the test fixture and its axial-lead adaptors should be inspected and cleaned as follows:

a. Clean the contact surfaces and blades of the axial-lead adaptors with isopropyl alcohol. Rub with a cotton swab (Q-tip). Remove any remaining liquid alcohol by blowing with the breath and remove any remaining cotton fibers, with tweezers.

b. Remove the MB board and expose the text-fixture contacts by removing its guide block (part number 1657-2200), as described above. See Figure 5-6.

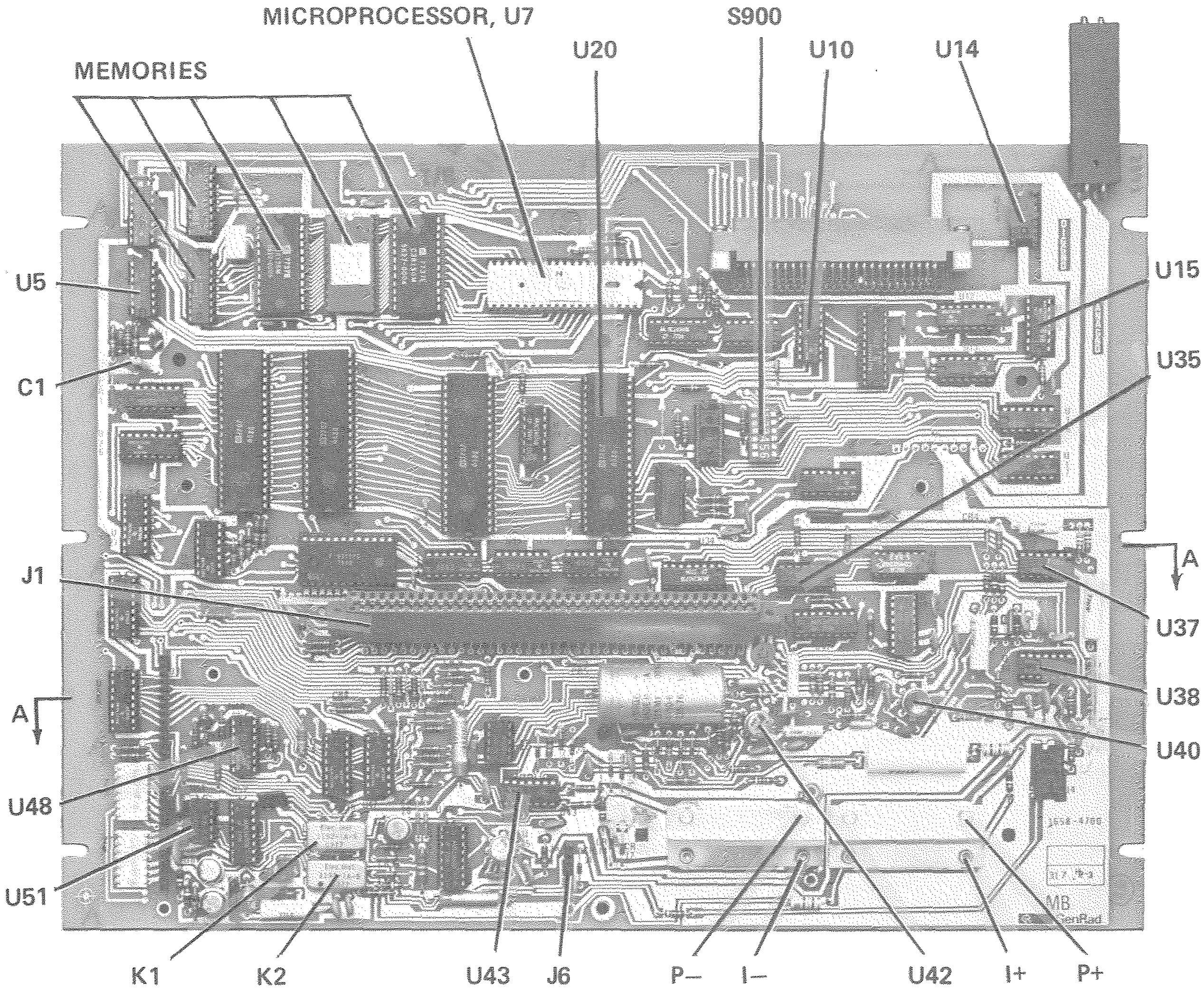



Figure 5-8. Main or MB board, top view. Functional conversion between 1658-9700 and 1658-9800 involves replacement of precision oscillator and depressing switch tabs; locations indicated. Arrows A–A indicate approximately the area of analog circuitry.

c. Clean and check the 4 contact strips. Use a card wet with isopropyl alcohol for cleaning. Hold the board at an angle so that any drip falls away from the circuits.

d. If necessary, the contact strips (part number 1686-1940) can be removed (2 screws apiece). In reassembly, observe the following. Align them, so both contact gaps are the same distance from the front edge of the board. The contact strips are supposed to press against each other, with tiny dielectric spacers preventing contact. Except at the ends of the gap (where the spacers are) the gap should be .05 to 0.2 mm (.002 to .008 in.) all along the gap.

When tightening the 8 screws that hold the 4 contact strips, use 12 inch-pounds of torque. When replacing the guide block, be sure the slots are aligned with the gaps between contact strips, as verified by eye, looking directly down on the board. Guide-block screws are 8 mm long, with washers.

For best results and minimum maintenance effort, the operator must remove any obvious dirt from leads of DUT's before inserting them into the test fixture. Its contacts will wipe through a film of wax, but they can become clogged and ineffectual if the operator is careless about cleanliness.

### 5.7.2 Care of the Display Panel.

Use caution when cleaning the display window, not to scratch it nor to get cleaning substances into the instrument. Use soft cloth or a ball of absorbent cotton, moistened with

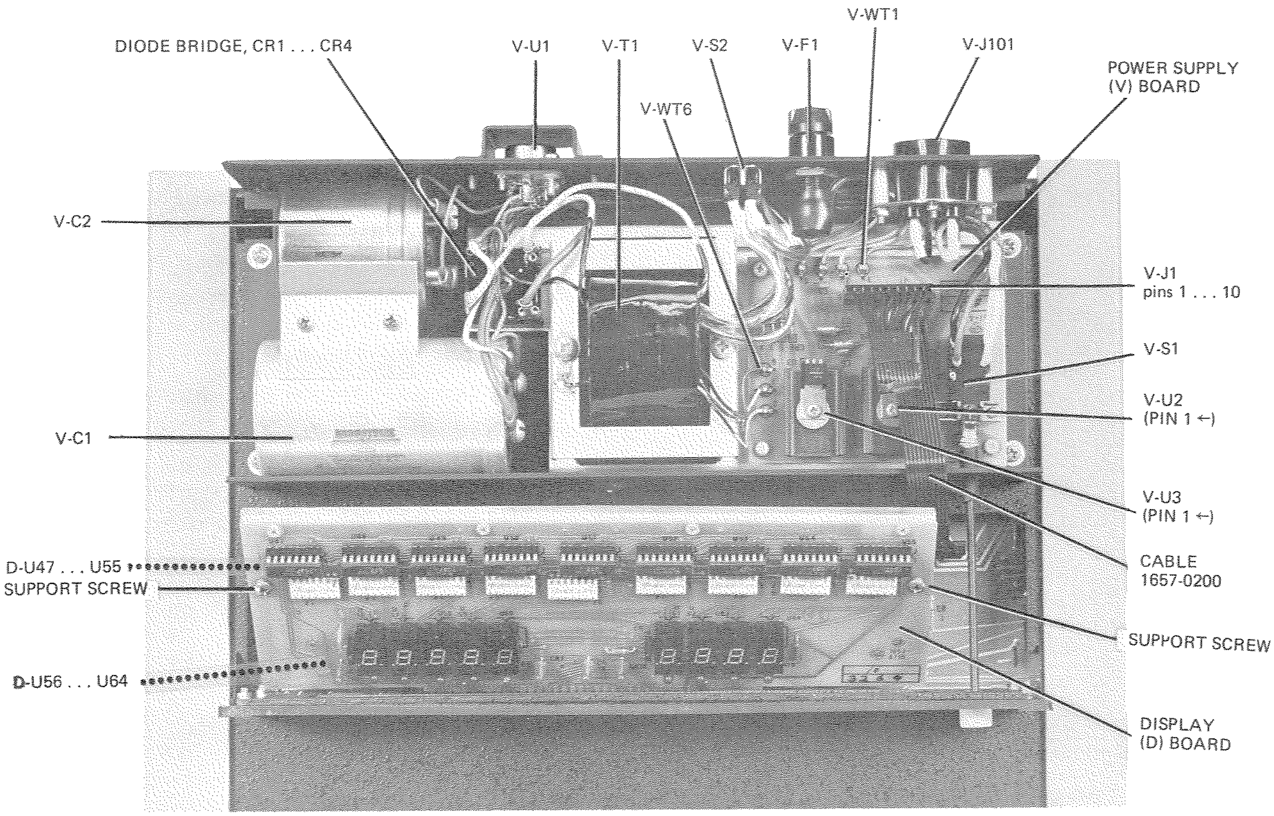



Figure 5-9. Power supply (V assembly) and display or DB board, shown in the instrument, with top cover off.

a mild glass cleaner, such as "Windex" (Drackett Products Co., Cincinnati, Ohio). DO NOT use a paper towel; do NOT use enough liquid to drip or run.

If it should be necessary to place marks on the window, use paper-based masking tape (NOT any kind of marking pen, which could be abrasive or react chemically with the plastic). To minimize retention of any gummy residue, remove the tape within a few weeks.

## 5.8 TROUBLE ANALYSIS.

### 5.8.1 General.

CAUTION

> Only well qualified personnel should attempt trouble analysis. Be sure power is OFF during disassembly and setting up for tests. Carefully observe the HANDLING PRECAUTIONS given in para 5.6.

*Resources.* Refer to Section 4 for a good understanding of the theory of operation. The block diagrams and discussion there provide necessary background, which can generally save time in trouble analysis. Refer to Section 6 for hardware details: circuit layouts, schematic diagrams, and parts lists.

*Abnormal digital signal levels.* Most digital signal levels in this instrument are normally near zero (logic low), about +3.5 to +5 V (logic high), or rapidly switching between these states. Failure of a digital source often produces a dc voltage of about +2 V on a signal line. Use high-impedance probes in measuring. Use a scope as well as a voltmeter, because an average of 2 V may be normal for a digital signal that has a duty cycle near 50%.

*Duplicated circuits.* Some circuits, as in the display board for example, are duplicated several times. The IC's can usually be exchanged between a faulty circuit and a functional one, to identify a "bad" IC. Notice, also, that the resistor networks DB-Z2 . . . DB-Z10 are simply compact packages of 220-Ω resistors. If one resistor is open, it is not necessary to replace the entire package. Use a 5% resistor.

*Circuit board replacement.* Refer to para 5.3 for recommended procedures to obtain replacements.

*Telltale symptoms.* Scan the following group of symptoms for a preliminary analysis of trouble and suggestions for more detailed procedures if applicable.

Display. A perpetually blank digit or decimal point may be caused by a fault in the directly associated circuit on the display board. (Refer to comments above.)

D Error. A large D error may be caused by faulty "protection" diodes in the analog front end. Check MB-CR15 . . . MB-CR26 (a total of 12 diodes).

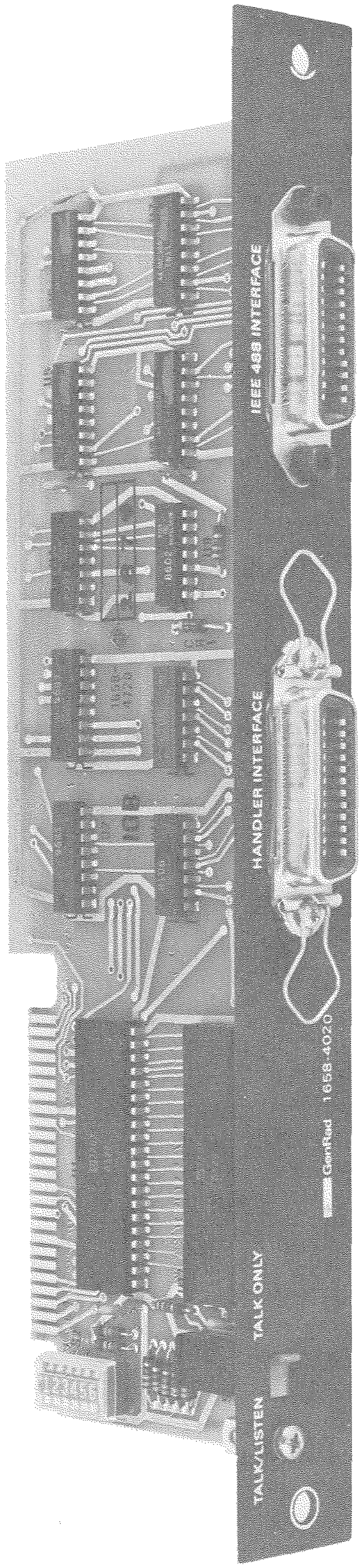



Figure 5-10. Interface option assembly 1658-4020, including the interface option board (IOB) 1658-4720.

Table 5-11

MB– BOARD PARTS LOCATIONS

| Part | Layout* | Schematic** | |
|---|---|---|---|
| J1 | D4 | 6-8 | D5 |
| — | — | 6-9 | E— |
| J2 | A5 | 6-7 | C1 |
| J3 | D1 | 6-9 | C7 |
| — | — | 6-9 | E— |
| J4 | D7 | 6-5 | 3,5 |
| J5 | B6 | 6-5 | E1 |
| J6 | E4 | 6-5 | B1 |
| J7 | A7 | 6-5 | B1 |
| K1 | E2 | 6-5 | B2 |
| K2 | E2 | 6-5 | C2 |
| Q1 | B1 | 6-7 | B2 |
| Q2 | D2 | 6-5 | D3 |
| Q3 | D2 | 6-5 | D3 |
| Q4 | E3 | 6-5 | A2 |
| Q5 | E2 | 6-5 | D3 |
| Q6 | E2 | 6-5 | C3 |
| S900 | B5 | 6-3 | B7 |
| S901† | B5 | 6-3 | B5 |
| U1 | A1 | 6-7 | A4 |
| U2 | A2 | 6-7 | B7 |
| U3 | A2 | 6-7 | B5 |
| U4 | A3 | 6-7 | B4 |
| U5 | A1 | 6-7 | A3 |
| U6 | B2 | 6-7 | E7 |
| U7 | A4 | 6-7 | B3 |
| U8 | B4 | 6-3 | C4 |
| — | — | 6-3 | D1 |
| U9 | B5 | 6-3 | C5 |
| U10 | B5 | 6-3 | D3 |
| U11 | B6 | 6-3 | D3 |
| U12 | B6 | 6-3 | B5 |
| U13 | B6 | 6-3 | B3 |
| U14 | A6 | 6-3 | B1 |
| U15 | B7 | 6-3 | B3 |
| U16 | B7 | 6-9 | B5 |
| — | — | 6-3 | C6 |
| U17 | C7 | 6-3 | B5 |
| U18 | C5 | 6-3 | E3 |
| U19 | C4 | 6-5 | B6 |
| — | — | 6-5 | D2 |
| U20 | B4 | 6-7 | E6 |
| — | — | 6-5 | A6 |
| U21 | B4 | 6-8 | C6 |
| U22 | B3 | 6-8 | B5 |
| — | — | 6-7 | E4 |
| U23 | B2 | 6-8 | B3 |
| — | — | 6-7 | E3 |
| U24 | B2 | 6-7 | E2 |
| — | — | 6-9 | A6 |
| U25 | B1 | 6-9 | B6 |
| U26 | B1 | 6-9 | C6 |
| U27 | C1 | 6-9 | C5 |
| U28 | C1 | 6-9 | C3 |
| U29 | C2 | 6-9 | B6 |
| U30 | C2 | 6-8 | D2 |
| U31 | C3 | 6-8 | C3 |
| U32 | C3 | 6-8 | C4 |
| U33 | C4 | 6-8 | C5 |
| U34 | C5 | 6-5 | C6 |
| U35 | C5 | 6-5 | B7 |
| U36 | C6 | 6-5 | C7 |
| U37 | C7 | 6-5 | D7 |
| U38 | D7 | 6-5 | D5 |
| — | — | — | D7 |
| U39 | C6 | 6-3 | D4 |
| U40 | D6 | 6-3 | D5 |
| U41 | C5 | 6-3 | E5 |
| U42 | D5 | 6-3 | D6 |
| U43 | D4 | 6-5 | D4 |
| U44 | D3 | 6-3 | D7 |
| U45 | E3 | 6-5 | E2 |
| U46 | E3 | 6-5 | D5 |
| U47 | D3 | 6-9 | C4 |
| U48 | D2 | 6-5 | C1 |
| U49 | D2 | 6-9 | C2 |
| U50 | D1 | 6-9 | C1 |
| U51 | E1 | 6-5 | E3 |
| U52 | E2 | 6-5 | D2 |
| U53 | A2 | 6-7 | C5 |

*See Figure 6-4 for physical location.
**See indicated figure, 6-3, 6-5, 6-7, 6-8, or 6-9, for location on schematic diagram.
†Not present on standard models. (Used on special models with non-standard test frequencies.)

Reactance Error. If R measurements are accurate but C (and L) measurements are not, the test signal source may be at fault. In checking it, as in the following paragraph, verify that the frequency is within ±0.01% of the specified "actual" frequency. (See front of manual.)

*Test Signal.* To check performance of the test-signal source, use a scope to look at the open-circuit signal at the I+ terminal of the test fixture (right front contact – be sure there is no DUT). The signal should be an undistorted sine wave at the selected frequency, amplitude about 0.65 V pk-pk (±15%) on each range. If this is correct, skip over para 5.8.3.

*Analog Front End.* To check the entire analog front end, verify that the signal at MB-U3 pin 12 has the characteristic staircase/sawtooth waveform illustrated in para 5.8.4, while the instrument is measuring a DUT. If this is true for all modes (EQUIVALENT CIRCUIT, FREQUENCY, parameter R/Q, L/Q, and C/D), skip to para 5.8.6. Otherwise, check the test signal at the test fixture as outlined above.

*Introduction to Detailed Analysis.* The following trouble analysis procedures will serve as a guide for localizing a fault to a circuit area. In some cases, a specific component part can be isolated for replacement. In other cases, the problem can be narrowed down only to a circuit board.

Except for the short-cuts indicated above, follow the procedure strictly in the order given, doing the principal steps (a, b, c, d, . . . ) until a failure is found. If so, follow the secondary steps, if any are given at the point of failure (aa, ab, ac . . . ).

### 5.8.2 Power Supply.

Check the power supply (V assembly) if there is a massive failure (nothing works) or as a starting procedure in any thorough analysis. Refer to Figure 5-9.

NOTE

If a voltage regulator (U1, U2, or U3) must be replaced, be sure to spread silicone grease (like Dow Corning compound no. 5) on the surface toward the heat sink. For U1, coat both sides of the insulating washer.

a. Check the output voltages, using a digital voltmeter, with ground reference at V-J1, pin 9 (ribbon cable unplugged), as follows:

Pin 1 = +5 V.
Pin 3 = +5 V.
Pin 4 = –8 V.

*aa. If trouble is found at step a, check "+5 V" circuit:*
*At outputs of U1 and U2: +5 V dc (regulated).*
*At WT1 (inputs of U1 and U2): +10.8 V dc.*
*Across input to diode bridge (yellow-to-yellow): 10 V rms.*
*ab. Check "–8 V" circuit:*
*At output of U3: -8 V dc (regulated).*
*At input (center terminal) of U3: -13.8 V dc.*
*Across WT7 to WT8: 11.3 V rms.*
*ac. Check power-line circuit to primary of transformer V-T1.*

b. Make a check similar to step a, with ribbon cable connected, ground reference at right edge of MB board, probing MB-J5 from below the board. (This checks for overload outside the power supply.)

### 5.8.3 Sinewave Generator.

Check the MB-board circuits that supply the test signal to the DUT, as follows: (We proceed backward, to the precision oscillator, then forward through dividers and sinewave generator.)

a. Make the following test setup and keyboard selections:

DUT: 0.1 $\mu$F and 3 k$\Omega$, connected in series.
MEASURE RATE – SLOW
EQUIVALENT CIRCUIT – SERIES
FREQUENCY – 1 kHz
Parameter – C/D.

b. Verify that the signal at test fixture, + side (right hand), is a 1-kHz sine wave, 490 mV pk-pk. Use an oscilloscope.

*ba. If this signal is distorted or missing on all ranges, but present at MB-U42 pin 2 or J4 pin 5, check diode network MB-CR19 . . . -CR23. To change range, select ENTER as FUNCTION and press the Cs/D key one or more times.*

c. If no fault appears in steps a, b, skip to para 5.8.4.

NOTE

The prefix "MB-" is omitted in the following text, where it is not necessary for clarity.

d. Verify that "1.4 V RMS TEST SIGNAL" found at U42 pin 2 is a 1-kHz sine wave, approx 4.0 V pk-pk (±10%).

e. Check at U42 pin 6 for a 1-kHz sine wave, 4.0 V pk-pk.

*ea. Check at U42 pin 3 for a 1-kHz sine wave, 3.4 V pk-pk. If this is verified but step e is not, isolate the fault to U42 or to U44.*

f. Verify that the output of U40, found at J4 pin 10 is a 1-kHz sine wave, 4.0 V pk-pk. (A "noisy" waveform is normal.)

g. Remove U40. Connect a 200-Ω resistor across its socket between pins 2 and 3. (Note: if the resistor leads are about 0.5 mm [0.02 in.] in diameter, they will fit the socket directly.) Check at U39 pin 4 for a 1-kHz sine wave, 0.4 V pk-pk. If this is verified but step f is not, fault is in U40. If neither is verified, reinstall U40 and continue.

h. Check that each input to the D/A converter U39 (pins 5 . . . 12), is a digital signal, about 4 V pk-pk. Each of these 8 signals should repeat with a period of 1 ms.

*ha. If these inputs are verified but step g is not, fault is in U39 circuit. Check at the end of R46 closer to the test fixture for +3 V dc; if that is correct, replace U39. Otherwise, fault is in associated circuit.*

If these digital signals are NOT correct, continue the analysis by checking the crystal oscillator and divider chain, as follows.

NOTE

Dual specifications of frequency appear below. The first frequency is correct for 1658-9700 (the 120-Hz version). The second is correct for 1658-9800 (the 100-Hz version). Frequency tolerance is ±0.01%.

i. Make the following test setup. Connect from the scope vertical-channel output to a counter. Be sure to use a low-capacitance probe at the scope input, so as not to load the high-impedance circuits being analyzed.

j. Oscillator. Check at U15 pin 14 for a fast digital waveform (see schematic diagram) of the following frequency: 25.067 or 24.576 ± 0.003 MHz. If correct, skip to step k. If oscillator signal is not verified, U14 is faulty.

k. Check at U15 pin 8 for a noisy square wave, 4 V pk-pk, 2.0889 or 2.0480 MHz. Otherwise, U15 is faulty.

l. Check at U13, pins 1 and 8 for pulses (essentially rectangular), with frequencies as follows:

Pin 1, 1.0445 or 1.0240 MHz.
Pin 8, 261.12 or 256.00 kHz.

Otherwise, U13 is faulty.

m. Check at U12 for similar pulses, with frequencies as follows:

Pin 12, 522.24 or 512.00 kHz.
Pin 9, 276.00 or 216.12 kHz.
Pin 8, 122.80 or 156.00 kHz.
Pin 11, 61.44 or 78.00 kHz.

n. Check at U17 pin 9 for a 5 V pk-pk rectangular wave, with frequency of 30.72 or 26.11 kHz. Otherwise, U17 is faulty.

o. Check at U9 pin 8 for a square wave, 5 V pk-pk, at 261.12 or 256.00 kHz.

NOTE

Servicing the digital circuitry, such as that "behind" FREQ SEL, is beyond the scope of this manual. Swapping identical PIA's may be informative; refer to para 5.8.1.

p. While monitoring U9 pin 8, press the FREQUENCY key and select 120 Hz, (or 100 Hz). Check that the monitored signal (which should always be 256 times the test frequency) is now 30720 Hz or 25600 Hz. Again press the FREQUENCY key and select "1 kHz."

q. Check that the outputs of U18 are square waves, 5 V pk-pk, with frequencies as follows (for 1658-9700 or 1658-9800 respectively). Otherwise, U18 is faulty.

Pin 12, 130.56 or 128.00 kHz.
Pin 9, 65.28 or 64.00 kHz.
Pin 8, 32.64 or 32.00 kHz.
Pin 11, 16.32 or 16.00 kHz.

r. Check U10 similarly. (Otherwise U10 is faulty.)

Pin 12, 8.160 or 8.000 kHz.
Pin 9, 4.080 or 4.000 kHz.
Pin 8, 2.040 or 2.000 kHz.
Pin 11, 1.0200 or 1.0000 kHz.

s. If inputs to the sine rom U11 are valid (steps i . . . r) but its output is not (steps a . . . h), U11 is faulty; or possibly (because step h does not check the output code from U11) U39 may be faulty. They can be checked against their manufacturer's data sheets.

### 5.8.4 Front End Amplifiers and Switches. Figure 5-11.

Check the MB-board analog circuits that process the measurement signals from the test fixture to the point of A/D conversion, as follows.

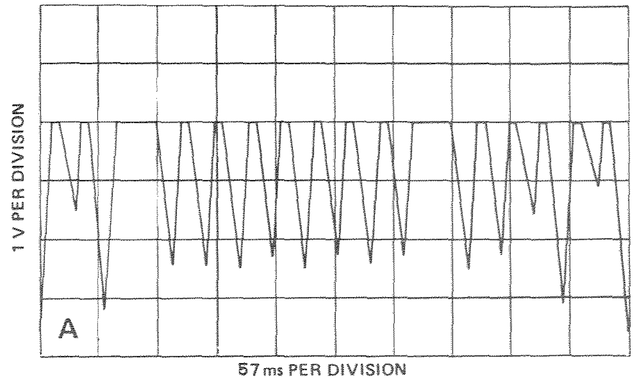
NOTE

When it is necessary to access parts under the keyboard, select the desired measurement conditions (usually including CONT MEASURE MODE), and then remove the keyboard module as described above. Connect temporarily from the right end of R68 to the front end of C21 or plug in a temporary jumper of AWG No. 20 wire between pins 5 and 6 of MB-J6. Carefully plug the module into its connectors again whenever the procedure requires keyboard operation.

a. Verify that there is a normal test signal at the test fixture. (See para 5.8.1 or para 5.8.3 step b.)

*oa. If step o is not confirmed, be sure you have selected 1 kHz on the front panel. Check that FREQ SEL (U9 pin 1) is logic high. (Otherwise check back to U20 pin 39.)*

*ob. If those checks are confirmed, fault is in the gates, U9.*



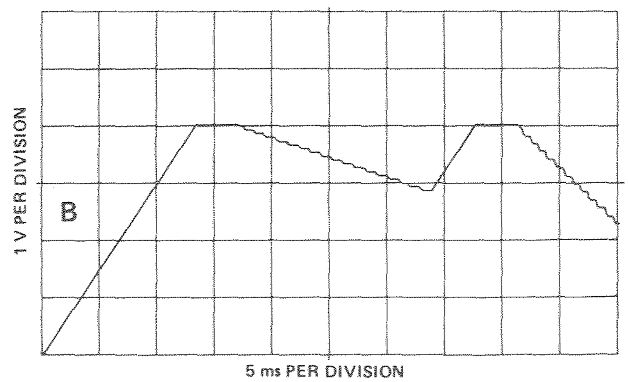




Figure 5-11. Integrator output waveform for the conditions of para 5.8.4: VALUE, SLOW, SERIES, 1 kHz, CONT, R/Q, autorange; DUT is 1 Ω. The waveform repeats every 570 ms, including 16 staircases, for a complete measurement cycle. The expansion, B, shows typical detail in the first 2 staircases. Each staircase has 17 or 20 steps. For details, refer to Table 5-13.

b. Check the range switching circuitry as follows. Insert as DUT each of the following resistors; and check for a 1-kHz sine wave with a scope connected to the + (right) end of each DUT in turn:

1 Ω; test signal should be 60 mV pk-pk
1 kΩ; 330 mV pk-pk
1 MΩ; 580 mV pk-pk.

*ba. If discrepancy is found in step b, check for continuity through relays K1, K2 (pin 1 to pin 4) and for their control signals, as shown in Table 5-12.*

c. Install a 1 k-Ω resistor in the test fixture. Check the P+ circuit at U43 pin 1, for a 1-kHz sine wave, 350 mV pk-pk.

*ca. If there is a discrepancy in step c, but U43 pin 3 has a 330-mV pk-pk sine wave, then U43 is faulty.*

d. Check part of the I− circuit at U43 pin 10, for a 1-kHz sine wave, 330 mV pk-pk.

*da. If discrepancy in step d, check at U52 pin 14 for a 1-kHz sine wave, 330 mV pk-pk; and at pin 10 for a logic high (+5V).*

*db. Check U52 pins 12, 15 for presence of signal. If the signal is correct at pin 15 but missing at 12, check Q5, Q6, and associated circuit, or U52.*

*dc. Conversely, if the signal is correct at pin 12 but missing at pin 15, replace U52.*

*dd. If both signals at U52 are correct, check at U51 pin 3 for a 1-kHz sine wave, 360 mV pk-pk. If discrepant, check U45 pin 6; replace U45.*

Table 5-12
SOURCE-RESISTOR RANGE SWITCHING CHECKS

| DUT | K1,(1-4) | K2,(1-4) | U48 Pin 10 | U48 Pin 8 |
|---|---|---|---|---|
| 1 Ω | open | closed | high | low |
| 1 kΩ | closed | open | low | high |
| 1 MΩ | open | open | high | high |

e. Check at U43 pin 8 for a 1-kHz sine wave, 330 mV pk-pk. Otherwise U43 is faulty.

f. Exchange the DUT for a 1-Ω resistor. Check the output of the signal selector, U46 pin 13 for a 1-kHz switched sine wave, 580 and 60 mV pk-pk levels.

g. Check at output of differential amplifier U38 pin 1 for a 1-kHz switched sine wave, 4 V and 0.4 V pk-pk, or somewhat larger. The ratio should be 10 to 1.

h. Check the integrator output at U38 pin 12 (or the front end of C38) for the staircase waveform shown in the accompanying figure. Notice that there are 17 steps for the 1658-9700, but 20 steps for the 1658-9800, *if* the test frequency is "1 kHz." The amplitudes of the staircases depend on the range as well as the impedance components of the DUT. For details, refer to Table 5-13.

The waveform is more easily stopped on the scope if the chosen conditions make one staircase taller than the others. Careful setting of scope trigger adjustment is usually required, preferably on the positive slope, at a low voltage, near the negative peak.

Table 5-13
FREQUENCY SELECTION AND VARIOUS CHARACTERISTICS OF STANDARD MODELS

| Characteristic | -9700 | -9800 |
|---|---|---|
| Hi-f "1 kHz" | 1020 Hz | 1000 Hz |
| Lo-f "120 Hz" | 120 Hz | 100 Hz |
| Crystal f (MHz) | 25.0675 | 24.576 |
| Rejected freq | 60 Hz | 50 Hz |
| DIP switch, set: | | |
| S900, 1 | – | – |
| S900, 2 | ON | OFF |
| S900, 3 | OFF | ON |
| S900, 4 | OFF | OFF |
| S900, 5 | ON | ON |
| S900, 6 | OFF | ON |
| Steps* for Hi-f: | 17/17/8 | 20/20/10 |
| for Lo-f: | 2/2/1 | 2/2/1 |
| Staircases** | 16/8/5 | 16/8/5 |

*Steps per staircase (pulses/burst, BST; Figure 5-12) slow/med/fast rates.
**Staircases (BST bursts; Figure 5-13) per measurement, for slow/med/fast rates, either frequency.

### 5.8.5 Control Signal Checks. Figures 5-12, 5-13.

If there is no staircase waveform at the integrator output, in the phase-sensitive detector, as described above, use the following procedure to determine whether the fault is in the digital control circuitry.

*de. Check at U51 pin 8 for a 1-kHz sine wave, 360 mV pk-pk. If discrepant, fault is in U51.*

*df. Check at U52 pin 13 for a 1-kHz sine wave, 330 mV pk-pk. If discrepant, check C50, U43, and U52 for loading or an open circuit.*

*fa. If discrepancy in step f, check the digital signal SSW1 at U46 pin 10 (or J1 pin 57, display-board connector). It should be a slow rectangular wave, switching between 0 and +4 V. Refer to timing diagram, below.*

*ga. Otherwise, using a X10 scope probe with a short connection to ground, check at U38 pin 2 for a switched sine wave, 30 and 10 mV pk-pk. Check pin 3 similarly. If these verified but not step g, U38 is faulty.*

*ha. If step h is not verified, check at detector-switch control terminals U37 pins 5, 6, 12, 13 for the presence of digital signals with logic high and low levels of +5 V and -8 V. If all of these signals are present, either U37 or U38 is faulty; replace both of them. Otherwise, check the quad flip-flop U34. Also, refer to para 5.8.5.*

a. Examine the frequency synchronizing signals, which should all be similar except for frequency (differing by factors of 2): F, 2F, 4F, 8F at U20 pins 2, 3, 4, 5. If there is a fault, check the circuit of U10.

b. Look at the following control signals with a scope and compare them with the timing diagram:

PBST, at U20 pin 12,

PMSR, at U20 pin 20.

If they are normal, skip to step c. If they are inactive, perhaps they can be stimulated by applying pulses to the power-on reset circuit; see step ba.

*ba. Provide reset pulses in either of 2 ways. Preferably, set up a pulse generator as follows:*

*Source resistance: 50 Ω.*

*Repetition rate (period): 1 s.*

*Pulse polarity and duration: positive, 0.5 s.*

*Dc levels: high = 4.5 V; low = 0 V.*

*Connect from ground to U5 pin 11.*

*bb. The alternative method is to short across C1 momentarily (and repeatedly) with a clip lead. Watch the scope carefully for activation, perhaps for only 1 cycle, of PBST and/or PMSR, after each application of the short circuit. Notice that this short must be only momentary and that it must not be applied while the pulse generator is connected. Find C1 between Q1 and U25.*

*bc. If PBST and PMSR remain inactive in spite of the preceding stimulation, the digital control circuitry is at fault: go to para 5.8.6. Otherwise, proceed to step b, continuing to use the reset pulses.*

c. Examine each of the following digital feedback signals and compare it with the timing diagram. If any one is questionable, check the circuit from which it is derived:

MSR, at U34 pin 10 and its converse $\overline{\text{DMSR}}$, at U20 pin 40 (from PMSR).

$\overline{\text{DONE}}$; at U36 pin 6 (comment follows).

Notice that $\overline{\text{DONE}}$ is normally a negative pulse that starts with the rising edge of CMP and very quickly terminates, when $\overline{\text{REL}}$ drops to "low." (CMP stays high for a variable length of time.) However, if reset pulses are being provided as in step aa, and CMP is low, then $\overline{\text{DONE}}$ is triggered by $\overline{\text{RES}}$.

d. If the digital feedback signals are present, look at each of the following control signals and compare it with the timing diagram: (The first 5 signals have logic low and high levels of 0 and +5 V; the last 6 signals, −8 and +5 V.)

PBST, at U19 pin 6;

$\overline{\text{PISW}}$, at U19 pin 4;

PMSR, at U19 pin 2;

$\overline{\text{RES}}$, at U35 pin 8 (reset, normally only at power-up);

SSW1, at U20 pin 14;

Clock at U34 pin 9 (from 8F, at U35 pin 6);

$\overline{\text{DONE}}$, at U34 pin 1;

BST, at U37 pin 12 (clocked by 8F, enabled by PBST);

$\overline{\text{BST}}$, at U37 pin 13 (clocked by 8F, enabled by PBST);

MSR at U37 pin 6 (clocked by 8F, enabled by PMSR);

ISW, at U37 pin 5 (clocked by 8F, enabled by $\overline{\text{PISW}}$).

If any is abnormal, trace back to the source of the signal, with the help of the schematic diagram (to check for poor connections or other interface problems). If the source is faulty, go to para 5.8.6. If these control signals are all valid, the digital control circuitry is functional; the fault is probably in the integrator U38 or associated circuits.

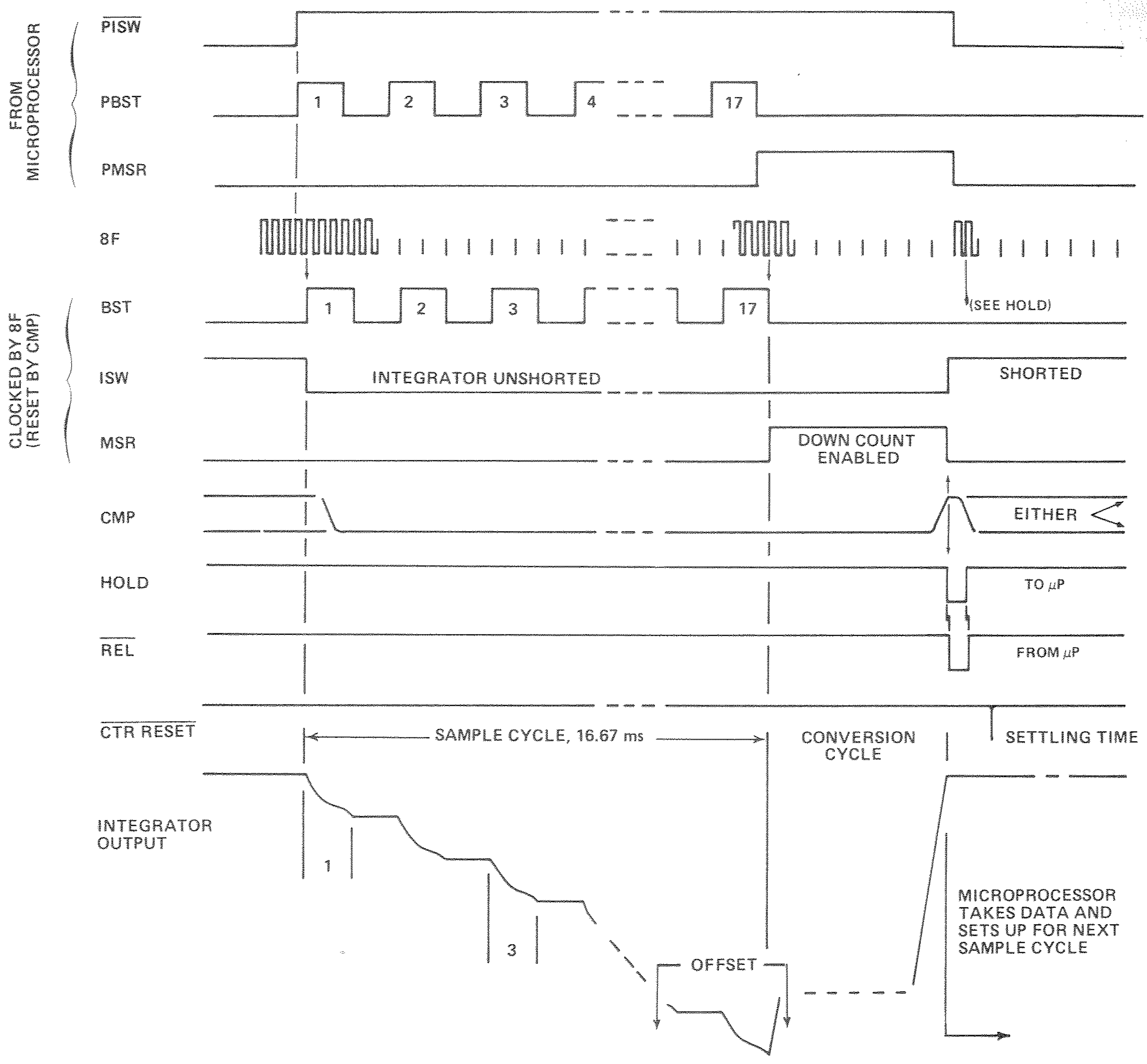



Figure 5-12. Timing diagram. One complete staircase cycle for a typical SLOW- or MEDIUM-rate 1-kHz measurement on a 1658-9700. The 3 main divisions are: sample cycle (stair steps down), conversion cycle (smooth ramp up, during which a counter arrives at digital value of signal being sampled), and data-taking cycle (microprocessor takes data and sets up for next staircase). In this example, there are 17 samples taken.

### 5.8.6 Digital Circuitry.

*Display Board.* A faulty integrated-circuit package can usually be identified by interchanging plug-in component parts of the same type between display channels. Notice that a resistor network need NOT be replaced as a unit; use ordinary resistors. (See para 5.8.1.)

*Recommended Procedure.* If careful analysis of a faulty instrument, using the preceding information, indicates that the trouble is in the digital circuitry (whether in control, computation, or display decoding), further analysis is beyond the scope of this manual. Return the faulty board (the MB board, if the fault is digital, and not in the display board) or return the instrument for service. Refer to para 5.2 and 5.3.

*Special Testing.* Because of the very high speed and considerable complexity of the digital circuitry in the MB Board and IOB (Interface Board), it is impossible to analyze trouble there with ordinary test equipment. GenRad production and in-factory service departments make use of fast, versatile automatic test systems (GenRad products). Their efficiency and accuracy are important factors in our recommendation that digital circuit problems be solved by exchanging boards.

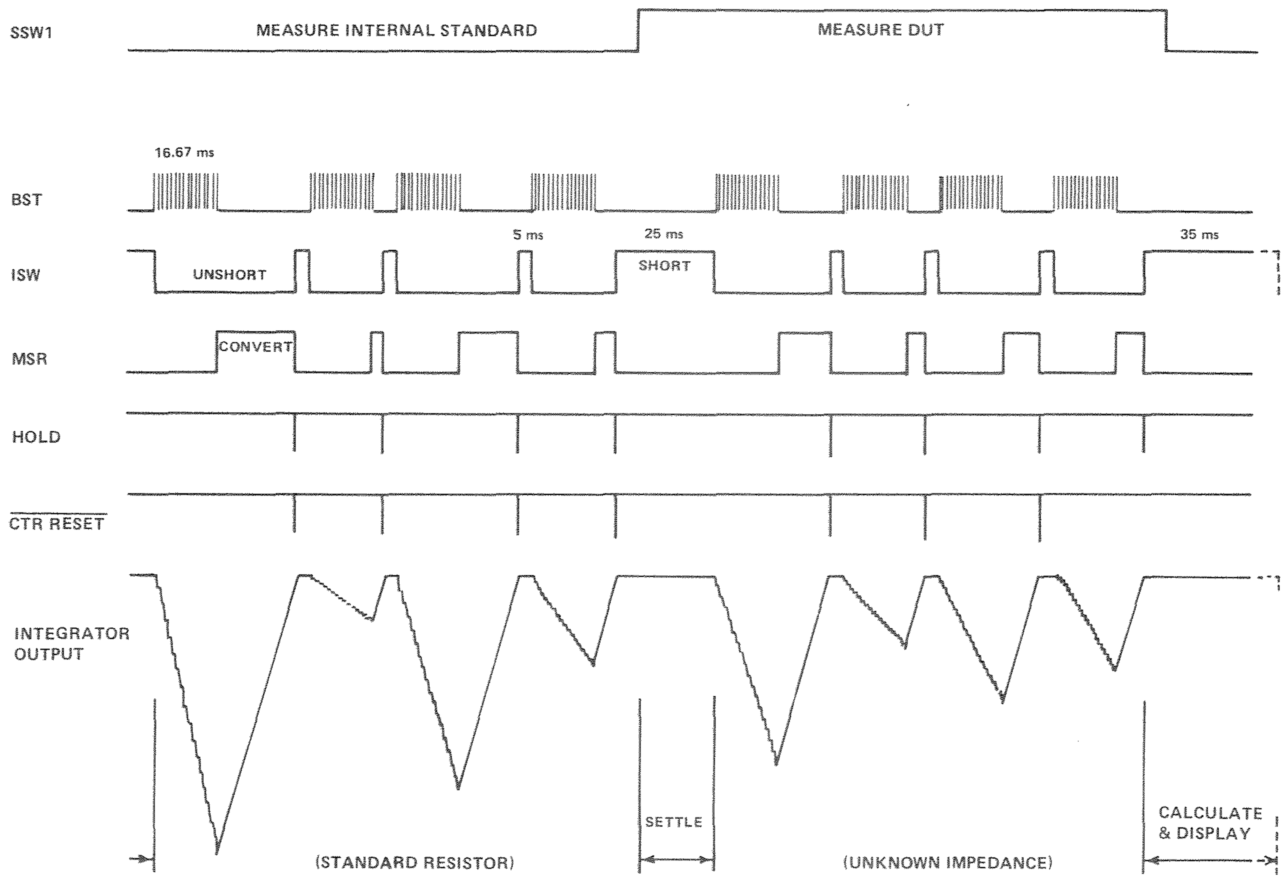



Figure 5-13. Timing diagram. One complete measurement cycle for a typical MEDIUM-rate 1-kHz measurement on a 1658-9700. There are 8 staircase cycles, one with each phase of BST for the signal from the standard and one with each phase of BST for the signal from the DUT.

# Parts Lists and Diagrams – Section 6



## 6.1 GENERAL.

This section contains the parts lists, circuit-board layout drawings and schematic diagrams for the instrument. (Section 4 contains functional block diagrams. Section 5 contains photographs of the instrument, identifying various parts.) The heavy lines on schematic diagrams denote the major signal flow.

Reference designation usage is described below.

## 6.2 REFERENCE DESIGNATIONS.

Each electrical component part on an assembly is identified on equipment and drawings by means of a reference designator comprised of numbers and letters. Component types on an assembly are numbered sequentially, the numbers being preceeded by a letter designation that identifies the component (R for resistor, C for capacitor, etc.). Some of the less obvious designators are: DS, lamp; Q, transistor; U, integrated circuit; WT, wire tie point; X, J, P, or SO, connector; Y, crystal resonator; Z, network.

Each assembly (typically a circuit board) has its own sequence of designators which can be identified by using prefixes, such as A- for the main frame and V- for power supply. Examples: B-R8 designates B board, resistor 8; D-WT2 = D board, wire-tie point 2; CR6 on the V schematic is a shortened form of designator V-CR6 = V board, diode 6. The instrument may contain A-R1, B-R1, C-R1, and D-R1.

## 6.3 DIAGRAMS.

Generally, each schematic diagram is located on a right-hand fold-out page for convenience. The associated layout drawing and parts list are located on the same page, the facing page, or otherwise nearby.


Figure 6-1. Front view, showing replaceable mechanical parts.

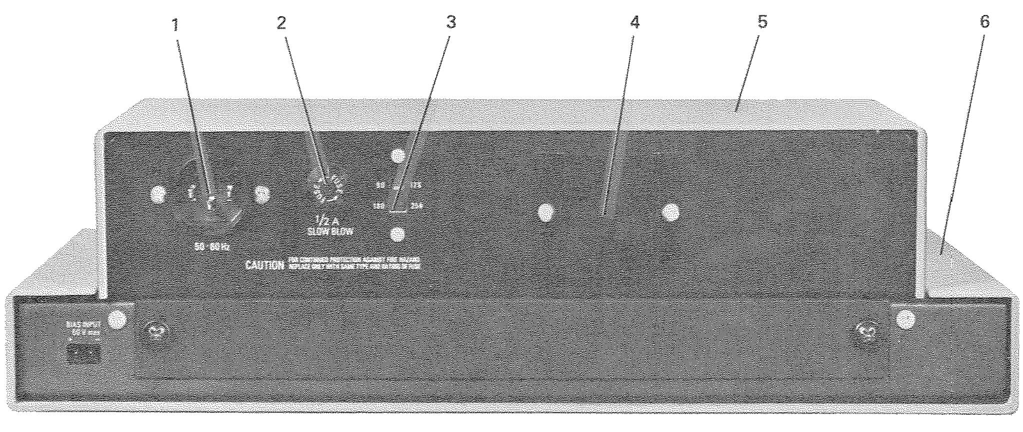



Figure 6-2. Rear view, showing replaceable mechanical parts. Notice that item 1 is slightly different from the picture (more rectangular than round).

## MECHANICAL PARTS LIST

FRONT

| Figure 6-1 | Quantity | Description | GenRad Part No. | FMC | Mfgr Part No. |
|---|---|---|---|---|---|
| 1 | 4 | Foot | 5260-2051 | 24655 | 5260-2051 |
| 2 | 1 | Display panel (plastic) | 1658-7032 | 24655 | 1658-7032 |
| 3 | 1 | Actuator (push rod) | 1657-2810 | 24655 | 1657-2810 |
| 4 | 1 | Guide block assembly | 1657-2200 | 24655 | 1657-2200 |
| 5 | 1 | Card pan | 1658-8200 | 24655 | 1658-8200 |
| 6 | 1 | Instruction card | 1658-0110 | 24655 | 1658-0110 |
| 7 | 1 | Keyboard plate (120 Hz) | 1658-8045 | 24655 | 1658-8045 |
| | or | Keyboard plate (100 Hz) | 1658-8046 | 24655 | 1658-8046 |

REAR

| Figure 6-2 | Quantity | Description | GenRad Part No. | FMC | Mfgr Part No. |
|---|---|---|---|---|---|
| 1 | 1 | Power connector J101 | 4240-0250 | 82389 | EAC-302 |
| 2 | 1 | Fuse extractor post F1 | 5650-0100 | 75915 | 342-004 |
| 3 | 1 | Slide switch S2 | 7910-0832 | 82389 | 11A-1266 |
| 4 | 1 | Cover (safety) | 1657-8120 | 24655 | 1657-8120 |
| 5 | 1 | Top cover | 1657-8060 | 24655 | 1657-8060 |
| 6 | 1 | Bottom shell | 1657-8000 | 24655 | 1657-8000 |

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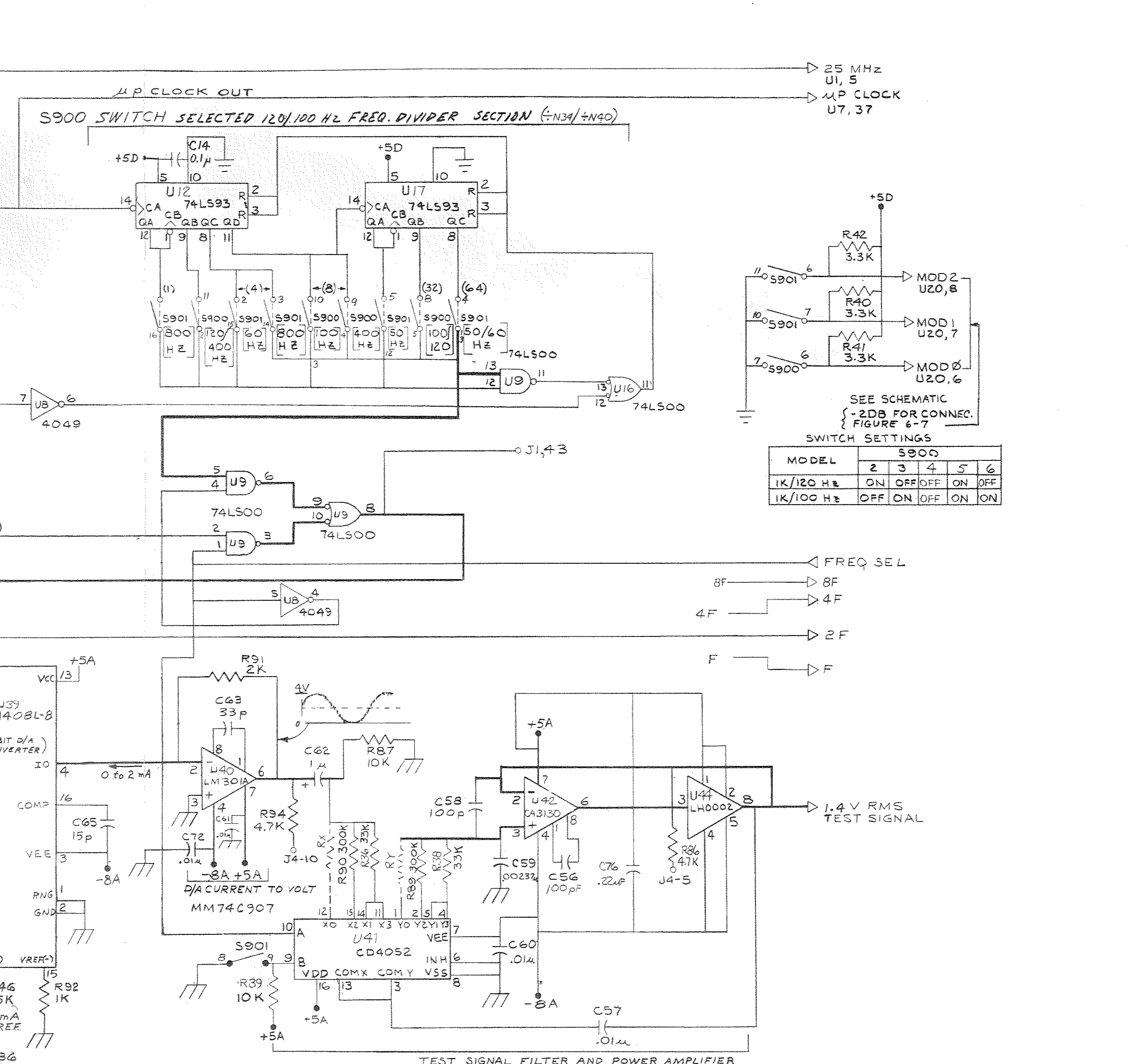
Ref FMC Column
in Parts Lists

| Code | Manufacturer |
|---|---|
| 00136 | McCoy Elctrns.,Mt.Holly Springs,PA 17065 |
| 00192 | Jones Mfg.,Chicago,IL 60181 |
| 00194 | Walsco Elctrns.,Los Angeles,CA 90018 |
| 00327 | Welwyn Intntl.,Westlake,OH 44145 |
| 00434 | Schweber Elctrns.,Westburg,NY 11590 |
| 00656 | Aerovox.,New Bedford,MA 02745 |
| 00779 | AMP Inc.,Harrisburg,PA 17105 |
| 01009 | Alden Products.,Brockton,MA 02413 |
| 01121 | Allen Bradley.,Milwaukee,WI 53204 |
| 01255 | Litton Inds.,Beverly Hills,CA 90213 |
| 01281 | TRW.,Lawndale,CA 90260 |
| 01295 | TI.,Dallas,TX 75222 |
| 01526 | GE.,Waynesboro,VA 22980 |
| 01930 | Amerock.,Rockford,IL 61101 |
| 01963 | Cherry Elctrc.,Waukegan,IL 60085 |
| 02111 | Spectrol Elctrns.,City of Industry,CA 91745 |
| 02114 | Ferroxcube.,Saugerties,NY 12477 |
| 02606 | Fenwall Lab.,Morton Grove,IL 60053 |
| 02639 | GE.,Schenectady,NY 12307 |
| 02660 | Amphenol.,Broadview,IL 60153 |
| 02735 | RCA.,Somerville,NJ 08876 |
| 02768 | Fastex.,Desplains,IL 60016 |
| 03042 | Carter Ink.,Cambridge,MA 02142 |
| 03508 | GE.,Syracuse,NY 13201 |
| 03550 | Vanguard Elctrns.,Inglewood,CA 90302 |
| 03636 | Grayburne.,Yonkers,NY 10701 |
| 03877 | Transitron Elctrns.,Wakefield,MA 01880 |
| 03888 | KDI Pyrofilm.,Whippany,NJ 07981 |
| 03911 | Clairex.,New York,NY 10001 |
| 04009 | Arrow Hart.,Hartford,CT 06106 |
| 04643 | Digitronics.,Albertson,NY 11507 |
| 04713 | Motorola.,Phoenix,AZ 85008 |
| 04919 | Component Mfg.,W.Bridgewater,MA 02379 |
| 05079 | Tansistor Elctrns.,Bennington,VT 05201 |
| 05245 | Corcom.,Chicago,IL 60639 |
| 05276 | ITT Elctrns.,Pomona,CA 91766 |
| 05402 | Controls Co.of Amer.,Melrose Pk,IL 60160 |
| 05574 | Viking Inds.,Chatsworth,CA 91311 |
| 05624 | Barber Colman.,Rockford,IL 61101 |
| 05748 | Barnes Mfg.,Mansfield,OH 44901 |
| 05820 | Wakefield Eng.,Wakefield,MA 01880 |
| 06383 | Panduit.,Tinley Pk,IL 60477 |
| 06406 | Truelove & Maclean.,Waterbury,CT 06708 |
| 06665 | Precision Monolith.,Santa Clara,CA 95050 |
| 06743 | Clevite.,Cleveland,OH 44110 |
| 06795 | WLS Stamp.,Cleveland,OH 44104 |
| 06915 | Richco Plstc.,Chicago,IL 60646 |
| 06928 | Teledyne Kntcs.,Soland Bch,CA 92075 |
| 06978 | Aladdin Elctrns.,Nashville,TN 37210 |
| 07047 | Ross Milton.,Southampton,PA 18966 |
| 07126 | Digitran.,Pasadena,CA 91105 |
| 07127 | Eagle Signal.,Baraboo,WI 53913 |
| 07233 | Cinch Graphik.,City of Industry,CA 91744 |
| 07261 | Avnet.,Culver City,CA 90230 |
| 07263 | Fairchild.,Mountain View,CA 94040 |
| 07387 | Birtcher.,N.Los Angeles,CA 90032 |
| 07595 | Amer.Semicond.,Arlington Hts,IL 60004 |
| 07699 | Magnetic Core.,Newburgh,NY 12550 |
| 07707 | USM Fastener.,Shelton,CT 06484 |
| 07828 | Bodine.,Bridgeport,CT 06605 |
| 07829 | Bodine Elctrc.,Chicago,IL 60618 |
| 07910 | Cont Device.,Hawthorne,CA 90250 |
| 07983 | State Labs.,New York,NY 10003 |
| 07999 | Borg Inst.,Delavan,WI 53115 |
| 08524 | Deutsch Fastener.,Los Angeles,CA 90045 |
| 08556 | Bell Elctrc.,Chicago,IL 60632 |
| 08730 | Vemaline Prod.,Franklin Lakes,NJ 07417 |
| 09213 | GE.,Buffalo,NY 14220 |
| 09353 | C&K Components.,Watertown,MA 02172 |
| 09408 | Star-Tronics.,Georgetown,MA 01830 |
| 09823 | Burgess Battery.,Freeport,IL 61032 |
| 09856 | Fenwal Elctrns.,Framingham,MA 01701 |
| 09922 | Burndy.,Norwalk,CT 06852 |
| 10025 | Glasseal Prod.,Linden,NJ 07036 |
| 10389 | Chicago Switch.,Chicago,IL 60647 |
| 11236 | CTS of Berne.,Berne,IN 46711 |
| 11599 | Chandler Evans.,W.Hartford,CT 06101 |
| 11983 | Nortronics.,Minneapolis,MN 55427 |
| 12040 | National.,Santa Clara,CA 95051 |
| 12045 | Elctrc Transistors.,Flushing,NY 11354 |
| 12498 | Teledyne.,Mountain View,CA 94043 |
| 12617 | Hamlin.,Lake Millis,WI 53551 |
| 12672 | RCA.,Woodbridge,NJ 07095 |
| 12697 | Clarostat.,Dover,NH 03820 |
| 12856 | Micrometals.,City of Industry,CA 91744 |
| 12954 | Dickson Elctrns.,Scottsdale,AZ 85252 |
| 12969 | Unitrode.,Watertown,MA 02172 |
| 13094 | Electrocraft.,Hopkins,MN 55343 |
| 13103 | Thermalloy.,Dallas,TX 75234 |
| 13148 | Vogue Inst.,Richmond Hill,NY 11418 |
| 13150 | Vernitron.,Laconia,NH 03246 |
| 13327 | Solitron Devices.,Tappan,NY 10983 |
| 13715 | Fairchild.,San Rafael,CA 94903 |
| 13919 | Burr Brown.,Tucson,AZ 85706 |
| 14010 | Anadex Inst.,Van Nuys,CA 91406 |
| 14195 | Elctrc Controls.,Wilton,CT 06897 |
| 14196 | American Labs.,Fullerton,CA 92634 |
| 14332 | Relton.,Arcadia,CA 91006 |
| 14433 | ITT.,W.Palm Beach,FL 33402 |
| 14482 | Watkins & Johnson.,Palo Alto,CA 94304 |
| 14608 | Corbin.,Berlin,CT 06037 |
| 14655 | Cornell Dubilier.,Newak,NJ 07101 |
| 14674 | Corning Glass.,Corning,NY 14830 |
| 14749 | Acopian.,Easton,PA 18042 |
| 14752 | Electrocube.,San Gabriel,CA 91776 |
| 14889 | R&G Sloan.,Sun Valley,CA 91352 |
| 14908 | Elctrc Inst & Spclty.,Stoneham,MA 02180 |
| 14936 | General Inst.,Hicksville,NY 11802 |
| 15238 | ITT.,Lawrence,MA 08142 |
| 15476 | Digital Equip.,Maynard,MA 01754 |
| 15605 | Cutler Hammer.,Milwaukee,WI 53202 |
| 15782 | Houston Inst.,Bellaire,TX 77401 |
| 15801 | Fenwal Elctrns.,Framingham,MA 01701 |
| 15819 | Sinclair & Rush.,St.Louis,MO 63111 |
| 16037 | Spruce Pine Mica.,Spruce Pine,NC 28777 |
| 16068 | Intntl Diode.,Jersey City,NJ 07304 |
| 16179 | Omni Spectra.,Farmington,MI 48024 |
| 16301 | Astrolab.,Linden,NJ 07036 |
| 16352 | Codi.,Fairlawn,NJ 07410 |
| 16485 | Sterling Inst.,New Hyde Park,NY 11040 |
| 16636 | Indiana General.,Oglesby,IL 61348 |
| 16758 | Delco.,Kokomo,IN 46901 |
| 16950 | Precision Dynamics.,Burbank,CA 91504 |
| 16952 | Amer Micro Devices.,Summerville,SC 29483 |
| 17117 | Elctrc Molding.,Woonsocket,RI 02895 |
| 17540 | Mohawk Spring.,Schiller Park,IL 60176 |
| 17745 | Angstrohm Precsn.,Hagerstown,MD 21740 |
| 17771 | Singer.,Somerville,NJ 08876 |
| 17850 | Zeltex.,Concord,CA 94520 |
| 17856 | Siliconix.,Santa Clara,CA 95054 |
| 18324 | Signetics.,Sunnyvale,CA 94086 |
| 18542 | New Prod Eng.,Wabash,IN 46992 |
| 18677 | Scanbe.,El Monte,CA 91731 |
| 18736 | Computer Diode.,S.Fairlawn,NJ 07936 |
| 18795 | Cycon.,Sunnyvale,CA 94086 |
| 18911 | Durant.,Watertown,WI 53094 |
| 19178 | Zero.,Monson,MA 01057 |
| 19209 | GE.,Gainesville,FL 32601 |
| 19373 | Eastron.,Haverhill,MA 01830 |
| 19396 | Paktron.,Vienna,VA 22180 |
| 19617 | Cabtron.,Chicago,IL 60622 |
| 19644 | LRC Elctrns.,Horseheads,NY 14845 |
| 19701 | Electra.,Independence,KS 67301 |
| 20093 | Elect Inds.,Murray Hill,NJ 07974 |
| 20754 | KMC.,Long Valley,NJ 07853 |
| 21335 | Fafnir Bearing.,New Britian,CT 06050 |
| 21688 | Raytheon.,Norwood,MA 02062 |
| 21759 | Lenox Fugle.,Watchung,NJ 07060 |
| 22526 | Berg Elctrcs.,New Cumberland,PA 17070 |
| 22589 | Electro Space Fabrctrs.,Topton,PA 19562 |
| 22753 | UID Elctrcs.,Hollywood,FL 33022 |
| 23338 | Wavetek.,San Diego,CA 92112 |
| 23342 | Avnet Elctrcs.,Franklin Park,IL 60131 |
| 23936 | Pamotor.,Bulingham,CA 94010 |
| 24351 | Indiana Gnrl Elctrc.,Keasby,NJ 08832 |
| 24355 | Analog Devices.,Cambridge,MA 02142 |
| 24444 | General Semicond.,Tempe,AZ 85281 |
| 24446 | GE.,Schenectady,NY 12305 |
| 24454 | GE.,Syracuse,NY 13201 |
| 24455 | GE.,Cleveland,OH 44112 |
| 24602 | EMC Technlgy.,Cherry Hill,NJ 08034 |
| 24655 | Gen Rad.,Concord,MA 01742 |
| 24759 | Lenox Fugle.,S.Plainfield,NJ 07080 |
| 25008 | Vactite.,Berkeley,CA 94710 |
| 25289 | EG&G.,Bedford,MA 01730 |
| 26601 | Tri-County Tube.,Nunda,NY 14517 |
| 26805 | Omni Spectra.,Waltham,MA 02154 |
| 26806 | American Zettler.,Costa Mesa,CA 92626 |
| 27014 | National.,Santa Clara,CA 95051 |
| 27545 | Hartford Universal Ball.,Rocky Hill,CT 06067 |
| 28480 | HP.,Palo Alto,CA 94304 |
| 28520 | Heyman Mfg.,Kenilworth,NJ 07033 |
| 28875 | IMC Magnetics.,Rochester,NH 03867 |
| 28959 | Hoffman Elctrcs.,El Monte,CA 91734 |
| 30043 | Solid State Devices.,LaMirada,CA 90638 |
| 30646 | Beckman Inst.,Cedar Grove,NJ 07009 |
| 30874 | IBM.,Armonk,NY 10504 |
| 30985 | Permag Magnetics.,Toledo,OH 43609 |
| 31019 | Solid State Scntfc.,Montgomerville,PA 18936 |
| 31514 | Standford Appld Engs.,Costa Mesa,CA 92626 |
| 31814 | Analogic.,Wakefield,MA 01880 |
| 31951 | Triridge.,Pittsburgh,PA 15231 |
| 32001 | Jensen.,Chicago,IL 60638 |
| 33095 | Spectrum Control.,Fairview,PA 16415 |
| 33173 | GE.,Owensboro,KY 42301 |
| 34141 | Koehler.,Marlboro,MA 01752 |
| 34156 | Semicoa.,Costa Mesa,CA 92626 |
| 34333 | Silicon Genrl.,Westminster,CA 92683 |
| 34335 | Advanced Micro Devices.,Sunnyvale,CA 94086 |
| 34649 | Intel.,Santa Clara,CA 95051 |
| 34677 | Solitron Devices.,Jupiter,FL 33458 |
| 35929 | Constanta.,Montreal,QUE,CAN |
| 36462 | National Ltd.,Montreal,QUE,CAN |
| 37942 | Mallory.,Indianapolis,IN 46206 |
| 38443 | Marlin Rockwell.,Jamestown,NY 14701 |
| 39317 | McGill Mfg.,Valpariso,IN 46383 |
| 40931 | Honeywell.,Minneapolis,MN 55408 |
| 42190 | Muter.,Chicago,IL 60638 |
| 42498 | National.,Melrose,MA 02176 |
| 43334 | New Departure-Hyatt.,Sandusky,OH 44870 |
| 43991 | Norma Hoffman.,Stanford,CT 06904 |
| 49671 | RCA.,New York,NY 10020 |
| 49956 | Raytheon.,Waltham,MA 02154 |
| 50088 | Mostek.,Carrollton,TX 75006 |
| 50101 | GHZ Devices.,S.Chelmsford,MA 01824 |
| 50507 | Micro Networks.,Worcester,MA 01606 |
| 50522 | Monsanto.,Palo Alto,CA 94304 |
| 50721 | Datel Systems.,Canton,MA 02021 |
| 51167 | Aries Elctrcs.,Frenchtown,NJ 08825 |
| 51553 | Diablo Systems.,Hayward,CA 94545 |
| 51642 | Centre Eng.,State College,PA 16801 |
| 52648 | Plessey.,Santa Ana,CA 92705 |
| 52676 | SKF Inds.,Philadelphia,PA 19132 |
| 52763 | Stettner Trush., Cazenovia, NY 13035 |
| 53021 | Sangamo Elctrc.,Springfield,IL 62705 |
| 53184 | Xciton.,Latham,NY 12110 |
| 53421 | Tyton.,Milwaukee,WI 53209 |
| 54294 | Shallcross.,Selma,NC 27576 |
| 54297 | Assoc Prec Prod.,Huntsville,AL 35805 |
| 54715 | Shure Bros.,Evanston,IL 60202 |
| 56289 | Sprague.,North Adams,MA 01247 |
| 57771 | Stimpson.,Bayport,NY 11705 |
| 58553 | Superior Valve.,Washington,PA 15301 |
| 59730 | Thomas & Betts.,Elizabeth,NJ 07207 |
| 59875 | TRW.,Cleveland,OH 44117 |
| 60399 | Torrington.,Torrington,CT 06790 |
| 61007 | Townsend.,Braintree,MA 02184 |
| 61637 | Union Carbide.,New York,NY 10017 |
| 61864 | United Carr Fast.,Boston,MA |
| 63060 | Victoreen.,Cleveland,OH 44104 |
| 63743 | Ward Leonard.,Mt.Vernon,NY 10550 |
| 65083 | Westinghouse.,Bloomfield,NJ 07003 |
| 65092 | Weston.,Newark,NJ 07114 |
| 70106 | Acushnet Cap.,New Bedford,MA 02742 |
| 70109 | Adams & Westlake.,Elkhart,IN 46514 |
| 70417 | Chrysler.,Detroit,MI 48231 |
| 70485 | Atlantic India Rubber.,Chicago,IL 60607 |
| 70563 | Amperite.,Union City,NJ 07087 |
| 70611 | Ark-Les Switch.,Watertown,MA 02172 |
| 70892 | Bead Chain.,Bridgeport,CT 06605 |
| 70903 | Belden.,Chicago,IL 60644 |
| 71126 | Bronson.,Beacon Falls,CT 06403 |
| 71279 | Cambridge Thermionic.,Cambridge,MA 02138 |
| 71294 | Canfield.,Clifton Forge,VA 24422 |
| 71400 | Bussmann.,St.Louis,MO 63107 |
| 71450 | CTS.,Elkhart,IN 46514 |
| 71468 | Cannon.,Los Angeles,CA 90031 |
| 71482 | Clare.,Chicago,IL 60645 |
| 71590 | Centralab.,Milwaukee,WI 53212 |
| 71666 | Continental Carbon.,New York,NY |
| 71707 | Coto Coil.,Providence,RI 02905 |
| 71729 | Crescent Box.,Philadelphia,PA 19134 |
| 71744 | Chicago Min Lamp.,Chicago,IL 60640 |
| 71785 | Cinch.,Chicago,IL 60624 |
| 71823 | Darnell.,Downey,CA 90241 |
| 72136 | Electromotive.,Willimantic,CT 06226 |
| 72228 | Continental Screw.,New Bedford,MA 02742 |
| 72259 | Nytronics.,Berkeley Hts,NJ 07922 |
| 72619 | Dialight.,Brooklyn,NY 11237 |
| 72699 | General Inst.,Newark,NJ 07104 |
| 72765 | Drake.,Chicago,IL 60631 |
| 72794 | Dzus Fastener.,W.Islip,NY 11795 |
| 72825 | Eby.,Philadelphia,PA 19144 |
| 72962 | Elastic Stop Nut.,Union,NJ 07083 |
| 72982 | Erie.,Erie,PA 16512 |
| 73445 | Amperex Elctrcs.,Hicksville,NY 11801 |
| 73559 | Carling Elctrc.,Hartford,CT 06110 |
| 73690 | Elco Resistor.,New York,NY |
| 73803 | TI.,Attleboro,MA 02703 |
| 73899 | JFD Elctrcs.,Brooklyn,NY 11219 |
| 73957 | Groov-Pin.,Ridgefield,NJ 07657 |
| 74193 | Heinemann.,Trenton,NJ 08602 |
| 74199 | Quam Nichols.,Chicago,IL 60637 |
| 74445 | Holo-Krome.,Hartford,CT 06110 |
| 74545 | Hubbell.,Stratford,CT 06497 |
| 74861 | Industrial Cndnsr.,Chicago,IL 60618 |
| 74868 | Amphenol.,Danbury,CT 06810 |
| 74970 | Johnson.,Waseca,MN 56093 |
| 75042 | IRC(TRW).,Burlington,IA 52601 |
| 75376 | Kurz-Kasch.,Dayton,OH 45401 |
| 75382 | Kuka.,Mt Vernon,NY 10551 |
| 75491 | Lafayette.,Syosset,NY 11791 |
| 75608 | Linden.,Providence,RI 02905 |
| 75915 | Littelfuse.,Des Plains,IL 60016 |
| 76005 | Lord Mfg.,Erie,PA 16512 |
| 76149 | Mallory Elctrc.,Detroit,MI 48204 |
| 76241 | Maurey.,Chicago,IL 60616 |
| 76381 | 3 M Co.,St.Paul,MN 55101 |
| 76385 | Minor Rubber.,Bloomfield,NJ 07003 |
| 76487 | Millen.,Malden,MA 02148 |
| 76545 | Mueller Elctr.,Cleveland,OH 44114 |
| 76684 | National Tube.,Pittsburg,PA |
| 76854 | Oak Inds.,Crystal Lake,IL 60014 |
| 77132 | Dot Fastener.,Waterbury,CT 06720 |
| 77147 | Patton MacGuyer.,Providence,RI 02905 |
| 77166 | Pass Seymour.,Syracuse,NY 13209 |
| 77263 | Pierce Roberts Rubber.,Trenton,NJ 08638 |
| 77315 | Platt Bros.,Waterbury,CT 06720 |
| 77339 | Positive Lockwasher.,Newark,NJ |
| 77342 | AMF.,Princeton,IN 47570 |
| 77542 | Ray-o-Vac.,Madison,WI 53703 |
| 77630 | TRW.,Camden,NJ 08103 |
| 77638 | General Inst.,Brooklyn,NY 11211 |
| 78189 | Shakeproof.,Elgin,IL 60120 |
| 78277 | Sigma Inst.,Braintree,MA 02184 |
| 78429 | Airco Speer.,St Marys,PA 15867 |
| 78488 | Stackpole.,St Marys,PA 15867 |
| 78553 | Tinnerman.,Cleveland,OH |
| 78711 | Telephonics.,Huntington,NY 11743 |
| 79089 | RCA.,Harrison,NJ 07029 |
| 79136 | Waldes Kohinoor.,New York,NY 11101 |
| 79497 | Western Rubber.,Goshen,IN 46526 |
| 79725 | Wiremold.,Hartford,CT 06110 |
| 79727 | Continental Wirt.,Philadelphia,PA 19101 |
| 79840 | Mallory Controls.,Frankfort,IN 46041 |
| 79963 | Zierick.,Mt Kisco,NY 10549 |
| 80009 | Tektronix.,Beaverton,OR 97005 |
| 80030 | Prestole Fastener.,Toledo,OH 43605 |
| 80048 | Vickers.,St Louis,MO 63166 |
| 80103 | Lambda.,Melville,NY 11746 |
| 80183 | Sprague.,N.Adams,MA 01247 |
| 80211 | Motorola.,Franklin Pk,IL 60131 |
| 80251 | Formica.,Cincinnati,OH 45232 |
| 80258 | Standard Oil.,Lafeyette,IN 47902 |
| 80294 | Bourns Labs.,Riverside,CA 92506 |
| 80368 | Sylvania.,New York,NY 10017 |
| 80431 | Air Filter.,Milwaukee,WI 53218 |
| 80583 | Hammarlund.,New York,NY 10010 |
| 80740 | Beckman Inst.,Fullerton,CA 92634 |
| 80756 | TRW Ramsey.,St Louis,MO 63166 |
| 80894 | Pure Carbon.,St Marys,PA 15857 |
| 81030 | Int'l Inst.,Orange,CT 06477 |
| 81073 | Grayhill.,LaGrange,IL 60525 |
| 81143 | Isolantite.,Stirling,NJ 07980 |
| 81312 | Winchester.,Oakville,CT 06779 |
| 81349 | Military Specifications |
| 81350 | Joint Army-Navy Specifications |
| 81483 | Int'l Rectifier.,El Segundo,CA 90245 |
| 81741 | Chicago Lock.,Chicago,IL 60641 |
| 81831 | Filtron.,Flushing,NY 11354 |
| 81840 | Ledex.,Dayton,OH 45402 |
| 81860 | Barry Wright.,Watertown,MA 02172 |
| 82219 | Sylvania.,Emporium,PA 15834 |
| 82227 | No.Amer.Philips.,Cheshire,CT 06410 |
| 82273 | IN Pattern & Model.,LaPort,IN 46350 |
| 82389 | Switchcraft.,Chicago,IL 60630 |
| 82567 | Reeves Hoffman.,Carlisle,PA 17013 |
| 82647 | Metals & Controls.,Attleboro,MA 02703 |
| 82807 | Milwaukee Resistor.,Milwaukee,WI 53204 |
| 82877 | Rotron.,Woodstock,NY 12498 |
| 82901 | IN General Magnet.,Valparaiso,IN 46383 |
| 83003 | Varo.,Garland,TX 75040 |
| 83014 | Hartwell.,Placentia,CA 92670 |
| 83033 | Meissner.,Mt Carmel,IL 62863 |
| 83058 | Carr Fastener.,Cambridge,MA 02142 |
| 83186 | Victory Eng.,Springfield,NJ 07081 |
| 83259 | Parker Seal.,Culver City,CA 90231 |
| 83330 | H.H.Smith.,Brooklyn,NY 11207 |
| 83361 | Bearing Spclty.,San Francisco,CA |
| 83587 | Solar Elctrc.,Warren,PA 16365 |
| 83594 | Burroughs.,Plainfield,NJ 07061 |
| 83740 | Union Carbide.,New York,NY 10017 |
| 83766 | Mass Engrg.,Quincy,MA 02171 |
| 83781 | National Elctrcs.,Geneva,IL 60134 |
| 84411 | TRW.,Ogallala,NB 69153 |
| 84835 | Lehigh Metals.,Cambridge,MA 02140 |
| 84970 | Sarkes Tarzian.,Bloomington,IN 47401 |
| 84971 | TA Mfg.,Los Angeles,CA 90039 |
| 85604 | Kepco.,Flushing,NY 11352 |
| 86420 | Payson Casters.,Gurnee,IL 60031 |
| 86577 | Prec Metal Prod.,Stoneham,MA 02180 |
| 86684 | RCA.,Harrison,NJ 07029 |
| 86687 | REC.,New Rochelle,NY 10801 |
| 86800 | Cont Elctrcs.,Brooklyn,NY 11222 |
| 88140 | Cutler Hammer.,Lincoln,IL 62656 |
| 88204 | GTE Sylvania.,Ipswitch,MA 01938 |
| 88219 | Gould Nat Battery.,Trenton,NJ 08607 |
| 88419 | Cornell Dubilier.,Fuquay Varina,NC 27526 |
| 88627 | K&G Mfr.,New York,NY |
| 89265 | Potter & Brumfield.,Princeton,IN 47671 |
| 89482 | Holtzer Cabot.,Boston,MA 02119 |
| 89665 | United Transformer.,Chicago,IL |
| 89870 | Berkshire Transformer.,Kent,CT 06757 |
| 90201 | Mallory Cap.,Indianapolis,IN 46206 |
| 90303 | Mallory Bat.,Tarrytown,NY 10591 |
| 90634 | Gulton Inds.,Metuchen,NJ 08840 |
| 90750 | Westinghouse.,Boston,MA 02118 |
| 90952 | Hardware Prod.,Reading,PA 19602 |
| 91032 | Continental Wire.,York,PA 17405 |
| 91146 | Cannon.,Salem,MA 01970 |
| 91210 | Gerber.,Mishawaka,IN 46544 |
| 91293 | Johanson.,Boonton,NJ 07005 |
| 91417 | Harris.,Melbourne,FL 32901 |
| 91506 | Augat Bros.,Attleboro,MA 02703 |
| 91598 | Chandler.,Wethersfield,CT 06109 |
| 91637 | Dale Elctrcs.,Columbus,NE 68601 |
| 91662 | Elco.,Willow Grove,PA 19090 |
| 91719 | General Inst.,Dallas,TX 75220 |
| 91836 | Kings Elctrcs.,Tuckahoe,NY 11223 |
| 91916 | Mephisto Tool.,Hudson,NY 12534 |
| 91929 | Honeywell.,Freeport,IL 61032 |
| 92519 | Electra Insul.,Woodside,NY 11377 |
| 92678 | Edgerton Germeshuasen.,Boston,MA 02115 |
| 92702 | IMC Magnetics.,Westbury,NY 11591 |
| 92739 | Ampex.,Redwood City,CA 94063 |
| 92966 | Hudson Lamp.,Kearny,NJ 07032 |
| 93332 | Sylvania.,Woburn,MA 01801 |
| 93346 | Amer Elctrcs Labs.,Lansdale,PA 19446 |
| 93618 | R&C Mfg.,Ramsey,PA 16671 |
| 93916 | Cramer.,New York,NY 10013 |
| 94144 | Raytheon.,Quincy,MA 02169 |
| 94154 | Wagner Elctrc.,Livingston,NJ 07039 |
| 94271 | Weston.,Archibald,PA 18403 |
| 94322 | Tel Labs.,Manchester,NH 03102 |
| 94589 | Dickson.,Chicago,IL 60619 |
| 94696 | Magnecraft.,Chicago,IL 60630 |
| 94800 | Atlas Ind.,Brookline,NH 03033 |
| 95076 | Garde.,Cumberland,RI 02864 |
| 95121 | Quality Comp.,St Marys,PA 15857 |
| 95146 | Alco Elctrcs.,Lawrence,MA 01843 |
| 95238 | Continental Conn.,Woodside,NY 11377 |
| 95275 | Vitramon.,Bridgeport,CT 06601 |
| 95348 | Gordos.,Bloomfield,NJ 07003 |
| 95354 | Methode.,Rolling Meadow,IL 60008 |
| 95794 | Amer Brass.,Torrington,CT 06790 |
| 95987 | Weckesser.,Chicago,IL 60646 |
| 96095 | Aerovox Hi Q.,Olean,NY 14760 |
| 96341 | Microwave Assoc.,Burlington,MA 01801 |
| 96906 | Military Standards |
| 97918 | Linemaster Switch.,Woodstock,CT 06281 |
| 98291 | Sealectro.,Mamaroneck,NY 10544 |
| 98474 | Compar.,Burlingame,CA 94010 |
| 98821 | North Hills.,Glen Cove,NY 11542 |
| 99017 | Protective Closures.,Buffalo,NY 14207 |
| 99117 | Metavac.,Flushing,NY 11358 |
| 99313 | Varian.,Palo Alto,CA 94303 |
| 99378 | Atlee.,Winchester,MA 01890 |
| 99800 | Delevan;E.Aurora,NY 14052 |
| 99934 | Renbrandt.,Boston,MA 02118 |
| 99942 | Centralab.,Milwaukee,WI 53201 |

JANUARY 1978

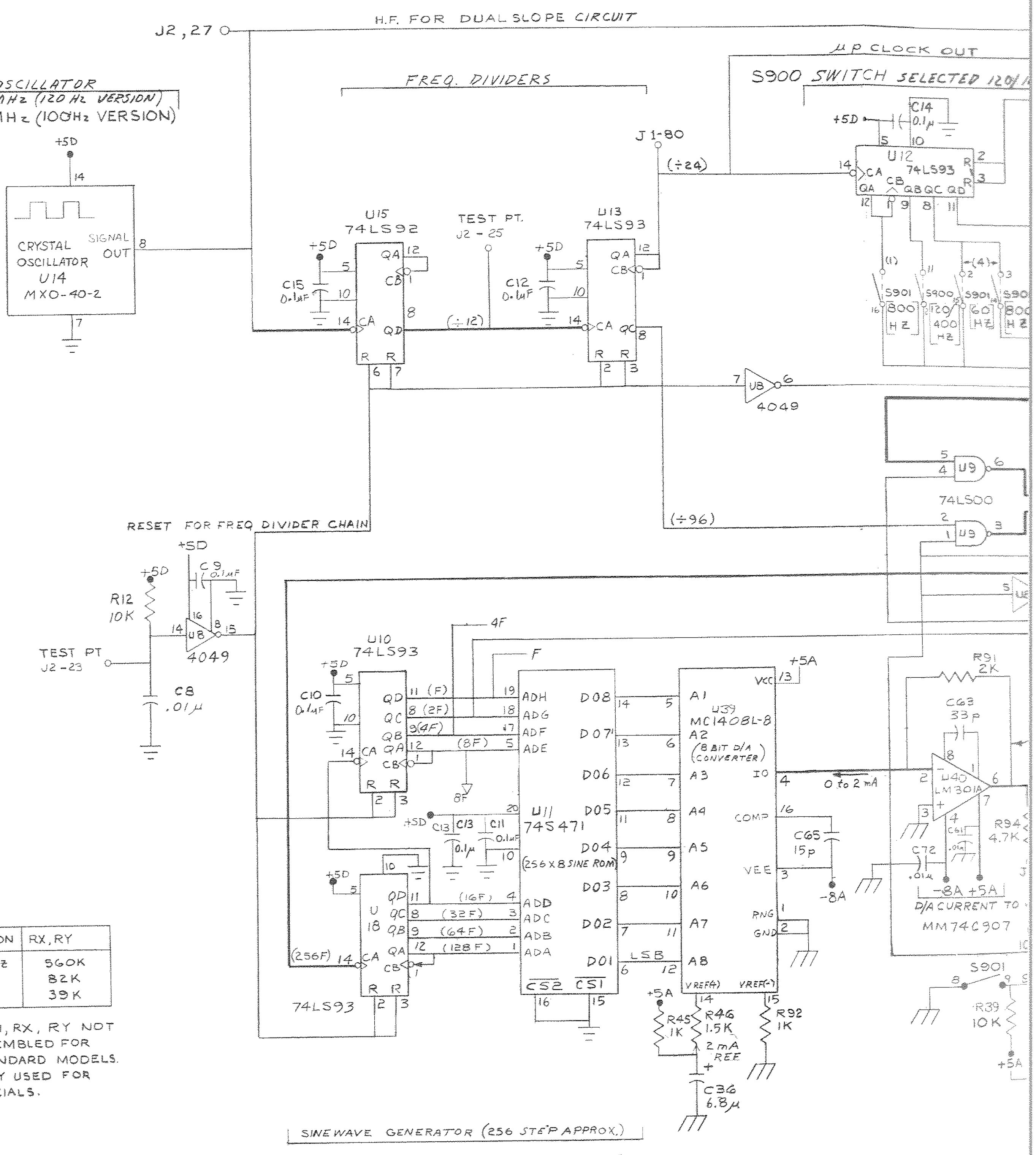



| MODEL | S900 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| IK/120 Hz | ON | OFF | OFF | ON | OFF |
| IK/100 Hz | OFF | ON | OFF | ON | ON |

Figure 6-3. Main (MB) board, -4700, clock and test signal sources.

RESISTANCE IS IN OHMS, K = $10^3$, M = $10^6$
CAPACITANCE IS IN FARADS, μ = $10^{-6}$, p = $10^{-12}$
VOLTAGES EXPLAINED IN INSTRUCTION BOOK SERVICE NOTES
= PANEL CONTROL = REAR CONTROL
= SCREWDRIVER CONTROL WT = WIRE TIE TP = TEST POINT
COMPLETE REFERENCE DESIGNATION INCLUDES SUBASSEMBLY LETTER, C-R1, B-R1, ETC.

CONNECTIONS
OUTPUT LEAVES SUBASSEMBLY
INPUT FROM DIFFERENT SUBASSEMBLY
OUTPUT REMAINS ON SUBASSEMBLY
INPUT FROM SAME SUBASSEMBLY




| FREQ OPTION | RX, RY |
|---|---|
| 50HZ/60HZ | 560K |
| 400HZ | 82K |
| 800HZ | 39K |

SPECIAL RESISTOR VALUES FOR RX, AND RY

NOTE: S901, RX, RY NOT ASSEMBLED FOR STANDARD MODELS. ONLY USED FOR SPECIALS.

NOTE: *Orientation*: Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; gray ckt pattern (if any) = parts side, black = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

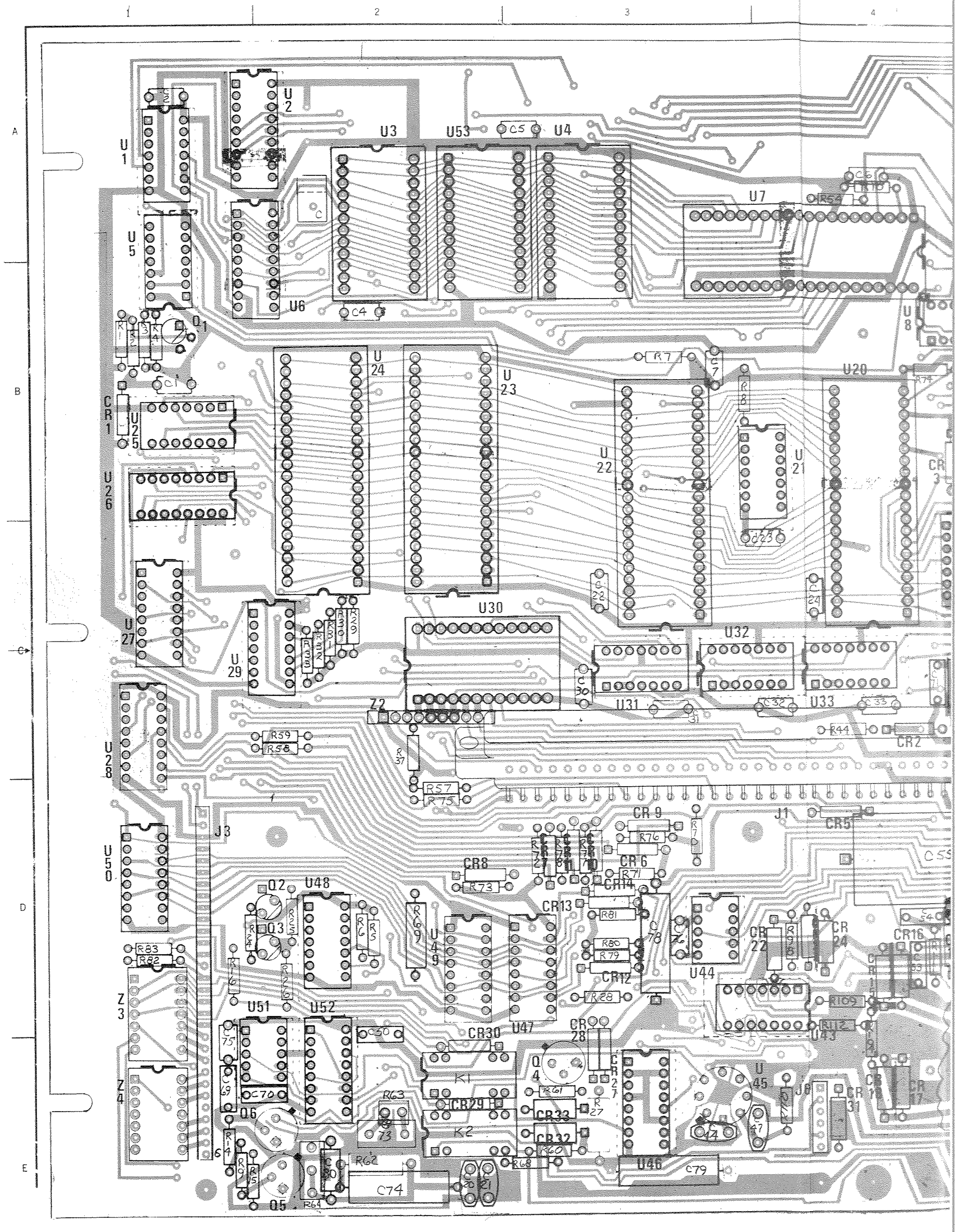
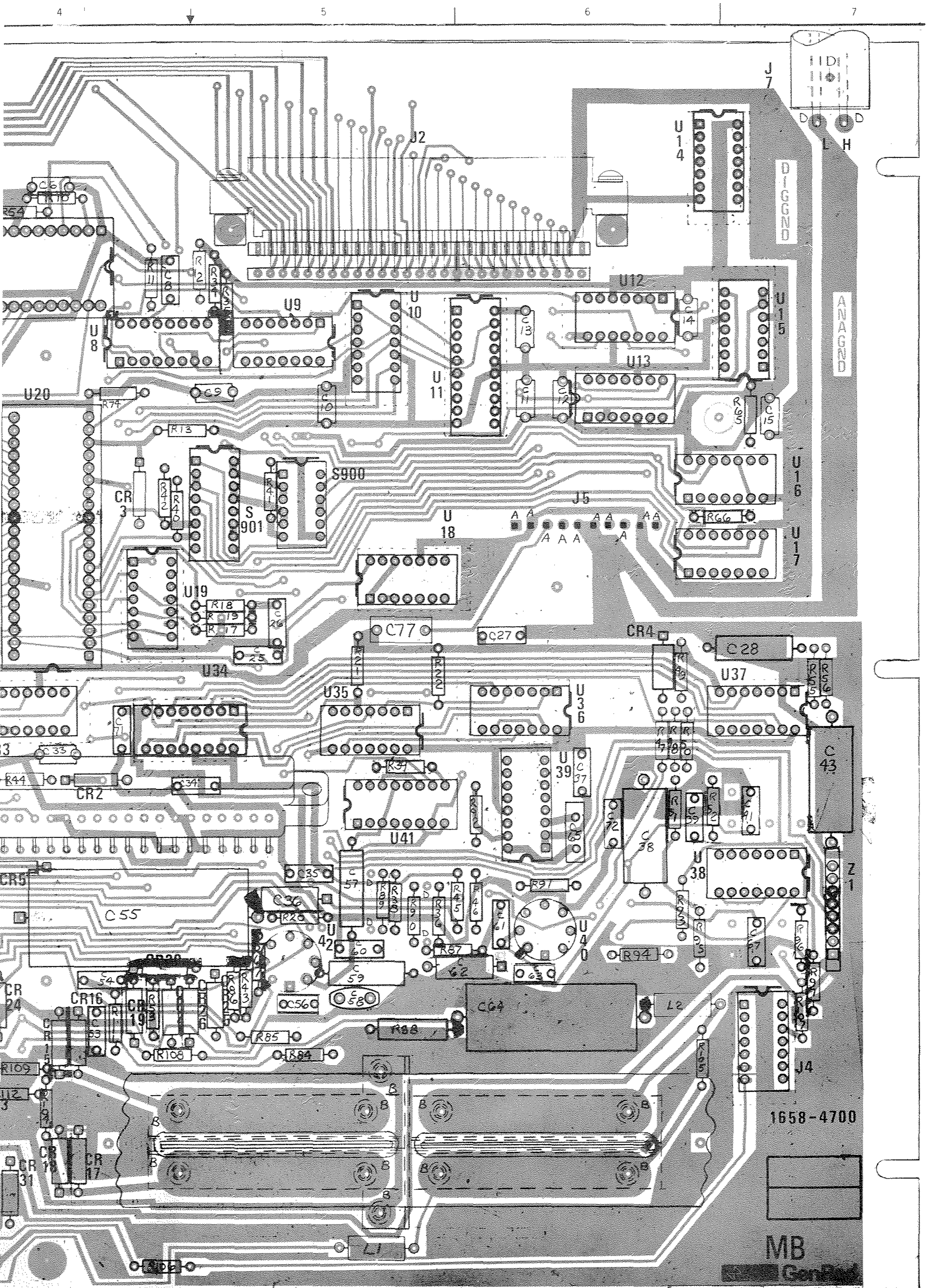



Figure 6-4. Main (MB) board, 1658-4700,



board, 1658-4700, layout. (Refer to Table 5-11.)

NOTE: 1. SOME OF THE CONNECTIONS TO U20 ARE OMITTED FROM THIS DIAGRAM AND ARE SHOWN ON 1658-4700-2DB

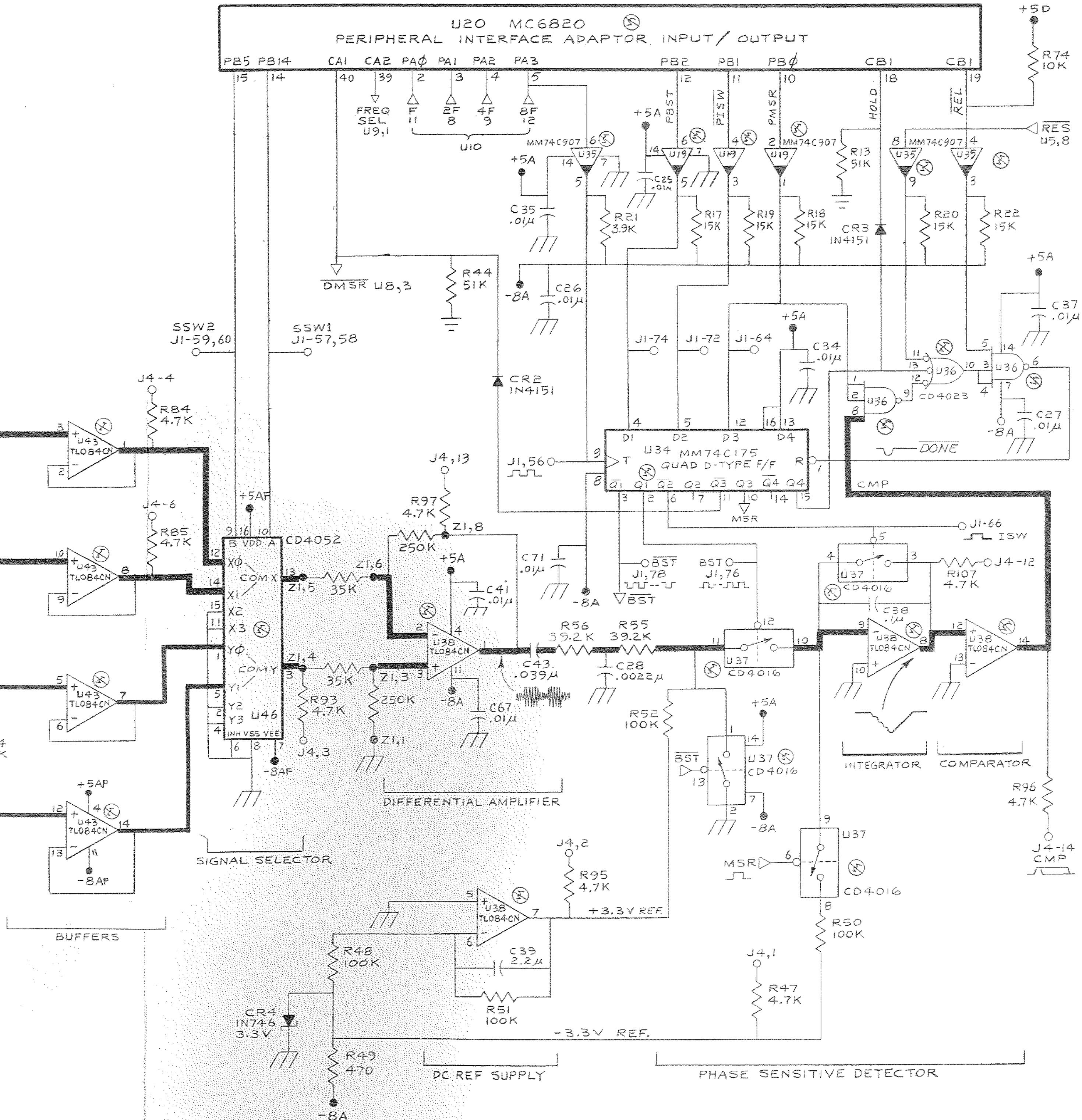
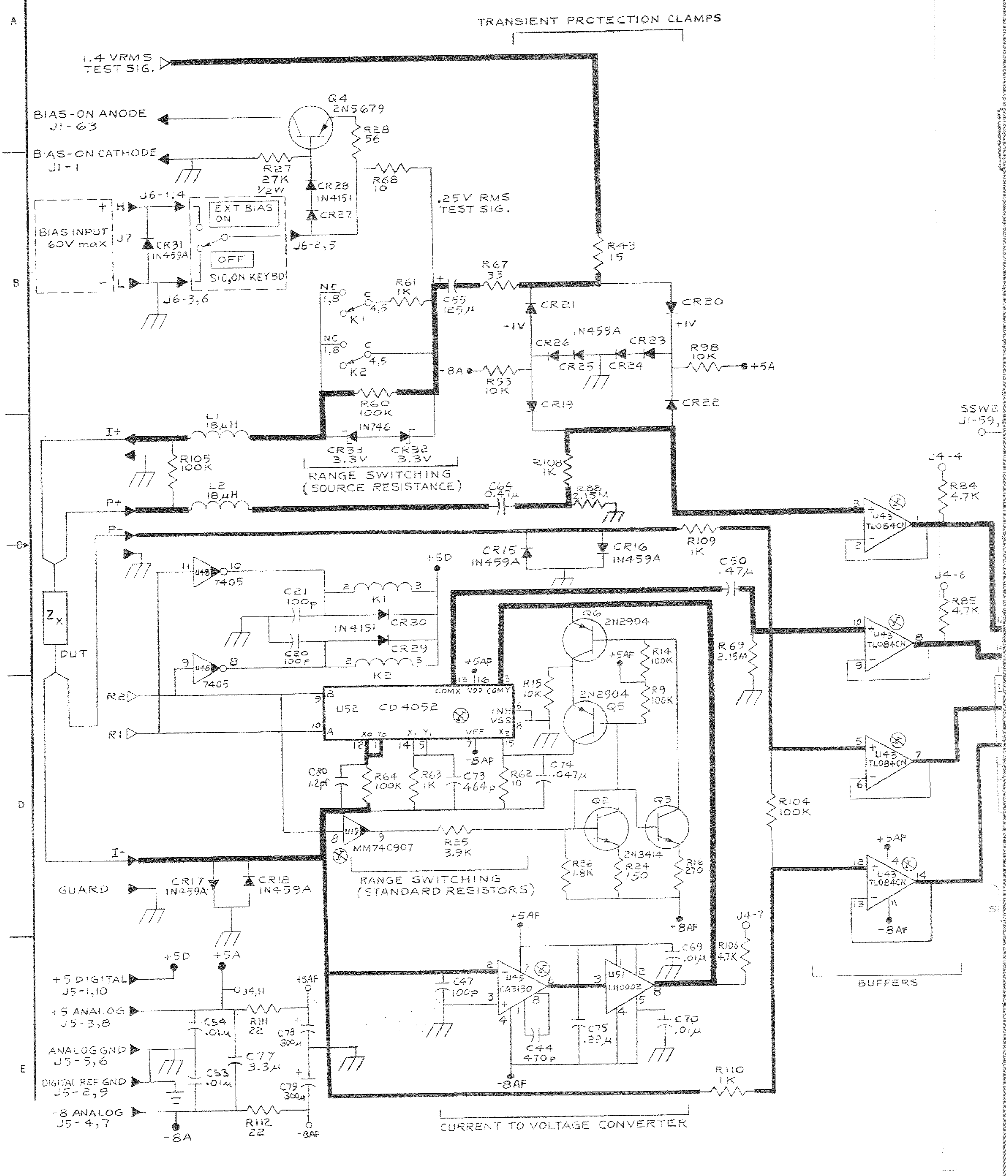
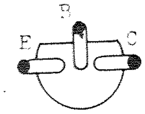



Figure 6-5. Main (MB) board, -4700, analog front end and detector.

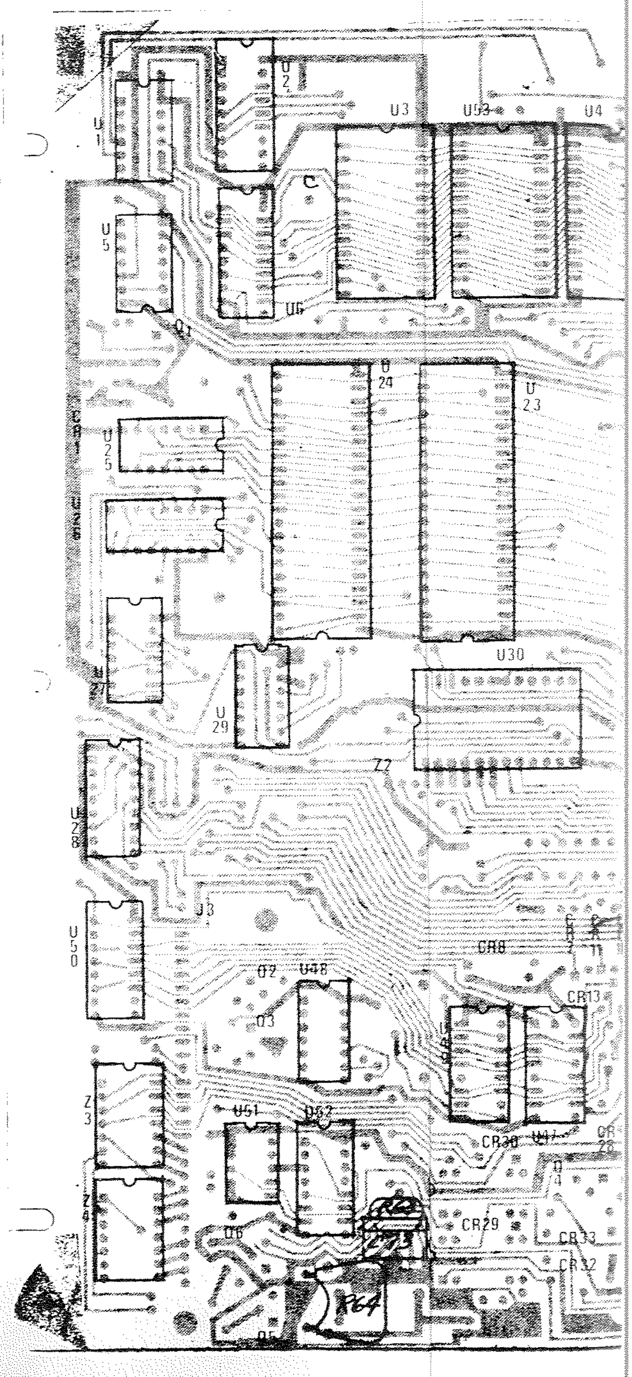
[redacted]



TRANSIENT PROTECTION CLAMPS
1.4 VRMS TEST SIG.
BIAS-ON ANODE J1-63
BIAS-ON CATHODE J1-1
Q4 2N5679
R28 56
R27 27K 1/2W
R68 10
CR28 1N4151
CR27
.25V RMS TEST SIG.
BIAS INPUT 60V max
J6-1,4
J7
CR31 1N459A
EXT BIAS ON
OFF
S10,ON KEYBD
J6-2,5
J6-3,6
R43 15
R67 33
C55 125μ
R61 1K
K1
K2
CR21
CR20
-1V
+1V
1N459A
CR26
CR23
CR25
CR24
R98 10K
+5A
-8A
R53 10K
R60 100K
CR19
CR22
1N746
L1 18μH
I+
CR33 3.3V
CR32 3.3V
RANGE SWITCHING (SOURCE RESISTANCE)
R105 100K
R108 1K
C64 0.47μ
R88 2.15M
L2 18μH
P+
P-
R109 1K
CR15 1N459A
CR16 1N459A
+5D
U48 7405
C21 100p
C20 100P
1N4151
CR30
CR29
C50 .47μ
Q6 2N2904
Q5 2N2904
R14 100K
R9 100K
R15 10K
+5AF
Zx
DUT
R2
R1
U52 CD4052
COMX VDD COMY
INH
VSS
VEE
R69 2.15M
C80 1.2pf
R64 100K
R63 1K
C73 464p
R62 10
C74 .047μ
-8AF
Q2
Q3
2N3414
R26 1.8K
R24 150
R16 270
U19
MM74C907
R25 3.9K
I-
RANGE SWITCHING (STANDARD RESISTORS)
GUARD
CR17 1N459A
CR18 1N459A
R104 100K
SSW2 J1-59
J4-4
R84 4.7K
U43 TL084CN
J4-6
R85 4.7K
J4-7
R106 4.7K
BUFFERS
U45 CA3130
U51 LH0002
C47 100P
C44 470P
C75 .22μ
C69 .01μ
C70 .01μ
R110 1K
CURRENT TO VOLTAGE CONVERTER
+5 DIGITAL J5-1,10
+5 ANALOG J5-3,8
ANALOG GND J5-5,6
DIGITAL REF GND J5-2,9
-8 ANALOG J5-4,7
J4,11
C54 .01μ
C53 .01μ
R111 22
R112 22
C77 3.3μ
C78 300μ
C79 300μ
-8A




Q1...3
BOTTOM VIEW




Fig

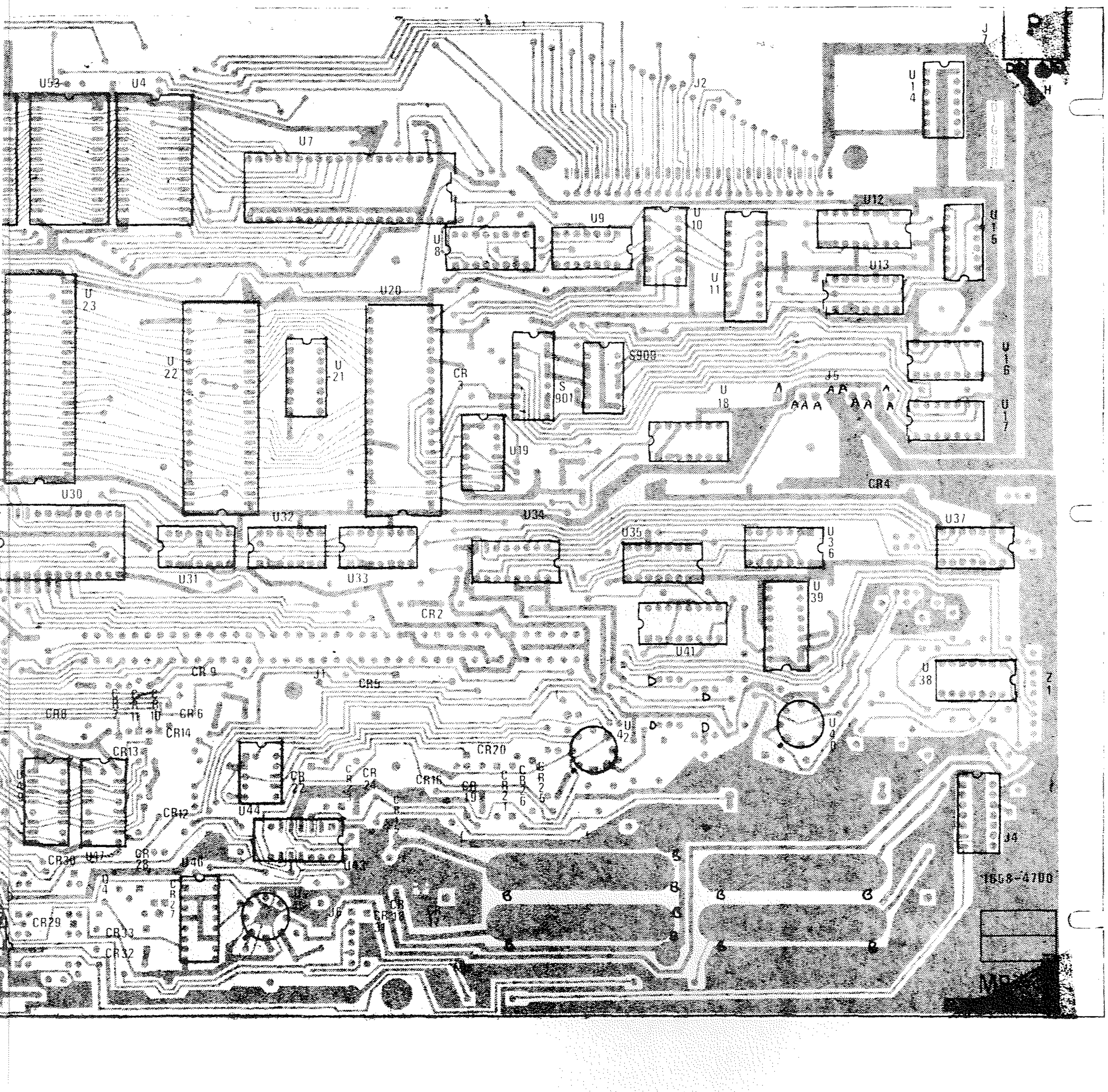



Figure 6-6. Main (MB) board, 1658-4700, integrated-circuit locator.

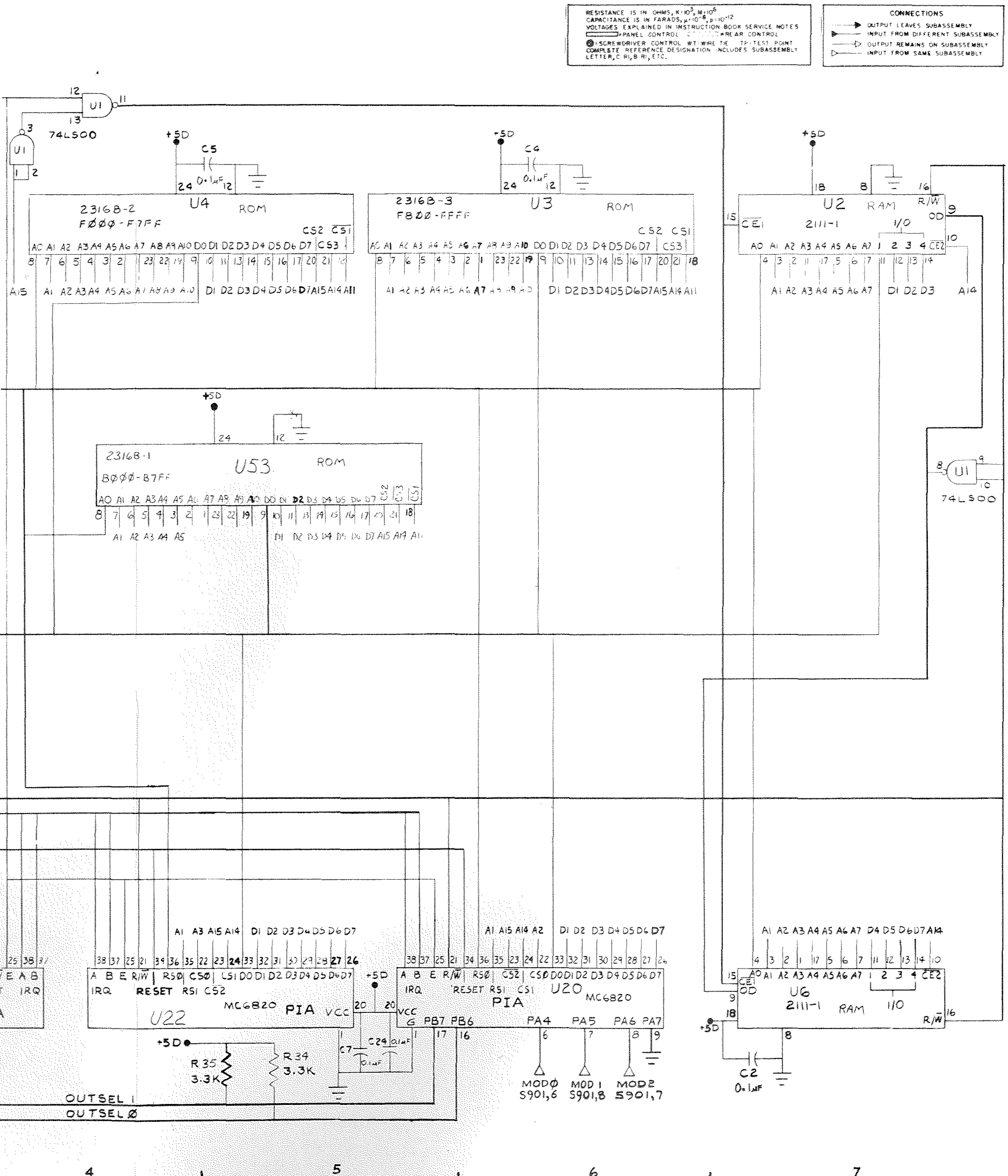
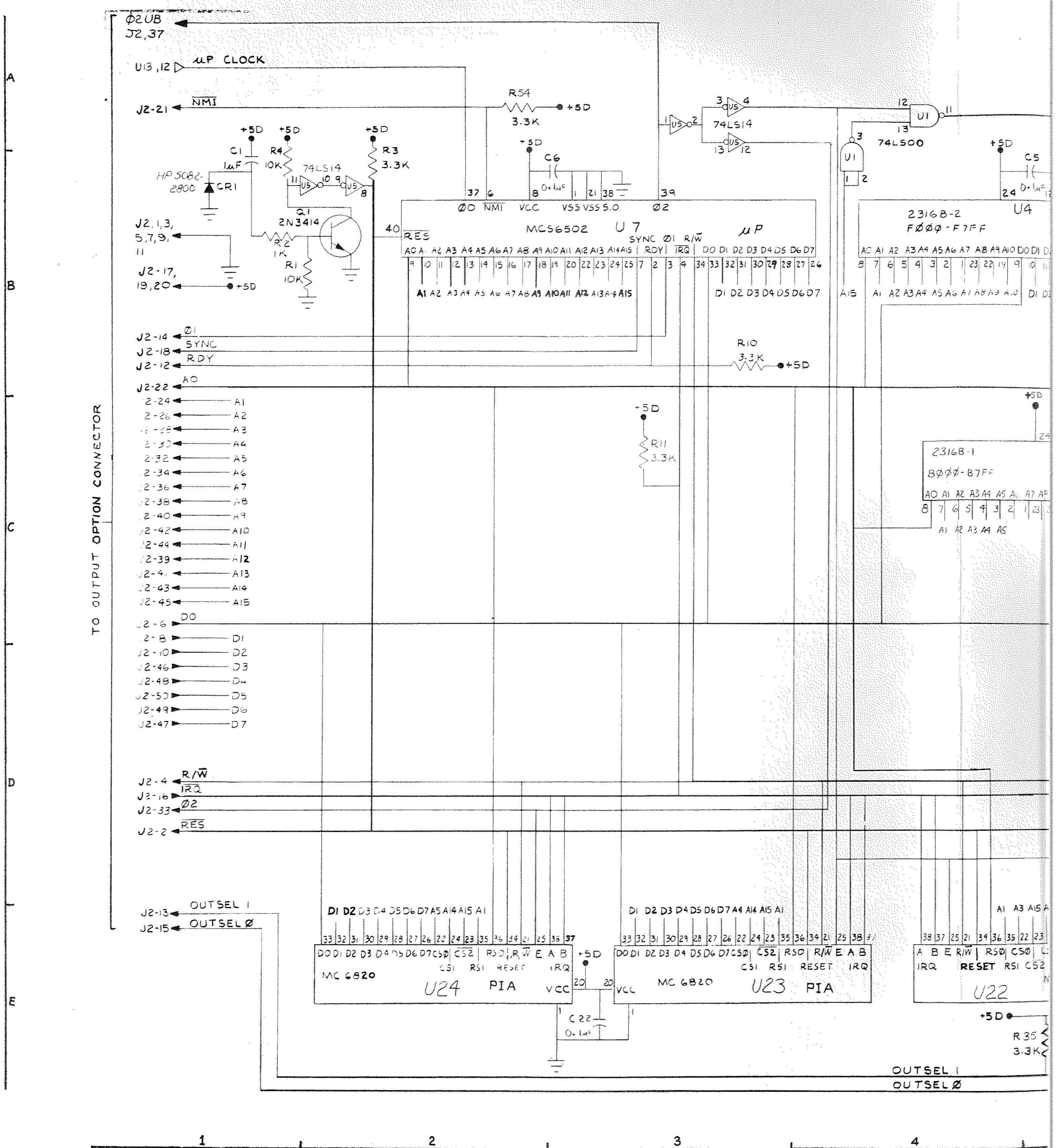



Figure 6-7. Main (MB) board, -4700, digital processor, memories, interfaces.



TO OUTPUT OPTION CONNECTOR
Ø2UB
J2,37
U13,12
µP CLOCK
J2-21
NMI
R54
3.3K
+5D
74LS14
74LS00
C1
1µF
HP 5082-2800
CR1
R4
10K
R3
3.3K
Q1
2N3414
R2
1K
R1
10K
C6
0.1µF
MCS6502
U7
µP
RES
SYNC
RDY
IRQ
R/W
2316B-2
FØØØ-F7FF
U4
U1
U5
C5
J2-17, 19,20
J2,1,3, 5,7,9, 11
J2-14
J2-18
J2-12
R10
3.3K
J2-22
R11
3.3K
2316B-1
BØØØ-B7FF
J2-4
J2-16
J2-33
J2-2
Ø2
J2-13
OUTSEL 1
J2-15
OUTSEL Ø
MC 6820
U24
PIA
MC 6820
U23
PIA
U22
C22
0.1µF
R35
3.3K
RESET
VCC
A
B
C
D
E
1
2
3
4

## ELECTRICAL PARTS LIST

ANALOG AND CONTROL PC BOARD MB P/N 1658-4700

| REFDES | | DESCRIPTION | PART NO. | FMC | MFGR PART NUMBER |
|---|---|---|---|---|---|
| C | 1 | CAP CER MONO 2.2UF 20PCT 50VGP | 4400-2060 | 72982 | 8141-M050-651-225M |
| C | 2 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 4 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 5 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 6 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 7 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 8 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 9 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 10 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 11 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 12 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 13 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 14 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 15 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 20 | CAP CER DISC 100PF 5PCT 500V | 4404-1105 | 72982 | 0831082Z5D00101J |
| C | 21 | CAP CER DISC 100PF 5PCT 500V | 4404-1105 | 72982 | 0831082Z5D00101J |
| C | 22 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 23 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 24 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 25 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 26 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 27 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 28 | CAP MYLAR .0022UF 10 PCT 200V | 4860-7329 | 56289 | 410P .0022 UF 10PCT |
| C | 30 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 31 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 32 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 33 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 34 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 35 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 36 | CAP TANT 6.8 UF 20PCT 6V | 4450-4800 | 56289 | 150D685X0006A2 |
| C | 37 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 38 | CAP POLYPROPYL 0.1UF 10PCT 200V | 4863-3000 | 84411 | X363UW 0.1UF 10PCT |
| C | 39 | CAP CER MONO 2.2UF 20PCT 50VGP | 4400-2080 | 72982 | 8141-M050-651-225M |
| C | 41 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 43 | CAP MYLAR .039UF 10PCT 200V | 4860-8009 | 56289 | 410P .039 UF 10PCT |
| C | 44 | CAP CER DISC 470PF 5PCT 500V | 4404-1475 | 72982 | 0831082Z5D00471J |
| C | 47 | CAP CER DISC 100PF 5PCT 500V | 4404-1105 | 72982 | 0831082Z5D00101J |
| C | 50 | CAP CER MONO .0047UF 10PCT 50V | 4400-6358 | 72982 | 8141-50-X7R-474K |
| C | 53 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 54 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 55 | CAP ALUM 125UF 100V | 4450-6156 | 56289 | 43D125G100GJ6 |
| C | 56 | CAP CER DISC 100PF 5PCT 500V | 4404-1105 | 72982 | 0831082Z5D00101J |
| C | 57 | CAP MYLAR .01UF 2 PCT 100V | 4860-7650 | 56289 | 410P .01 UF 2PCT |
| C | 58 | CAP CER DISC 100PF 5PCT 500V | 4404-1105 | 72982 | 0831082Z5D00101J |
| C | 59 | CAP MYLAR .00237UF 2 PCT 100V | 4860-7336 | 56289 | 410P .00237 UF 2PCT |
| C | 60 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 61 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 62 | CAP TANT 1.0 UF 20PCT 35V | 4450-4300 | 56289 | 150D105X0035A2 |
| C | 63 | CAP CER DISC 33PF 5PCT 500V | 4404-0335 | 72982 | 0831082Z5D00330J |
| C | 64 | CAP MYLAR .47UF 10 PCT 100V | 4860-8248 | 56289 | 410P 0.47 UF 10PCT |
| C | 65 | CAP CER DISC 15PF 5PCT 500V | 4404-0155 | 72982 | 0831082Z5D00150J |
| C | 67 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 69 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 70 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 71 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 72 | CAP CER DISC .01UF 80/20PCT 100V | 4401-3100 | 72982 | 0805540Z5U00103Z |
| C | 73 | CAP MICA 464PF 1PCT 500V | 4710-0535 | 81349 | CM05FD464FN |
| C | 74 | CAP MYLAR .047UF 2PCT 100V | 4860-8201 | 56289 | 410P .047UF 2PCT |
| C | 75 | CAP CER MONO 0.22UF 20PCT 50VGP | 4400-2052 | 72982 | 8131-M050-651-224M |
| C | 76 | CAP CER MONO 0.22UF 20PCT 50VGP | 4400-2052 | 72982 | 8131-M050-651-224M |
| C | 77 | CAP CER MONO 3.3UF 20PCT 50VGP | 4400-2082 | 72982 | 8151-M050-651-335M |
| C | 78 | CAP TANT 300 UF 20PCT 10V WET | 4450-5724 | 33173 | 69F933 |
| C | 79 | CAP TANT 300 UF 20PCT 10V WET | 4450-5724 | 33173 | 69F933 |
| C | 80 | CAP CER TUB 1.2PF 5PCT 500V | 4400-0120 | 95121 | QC 1.2PF 5PCT 500V |

## ELECTRICAL PARTS LIST (cont)

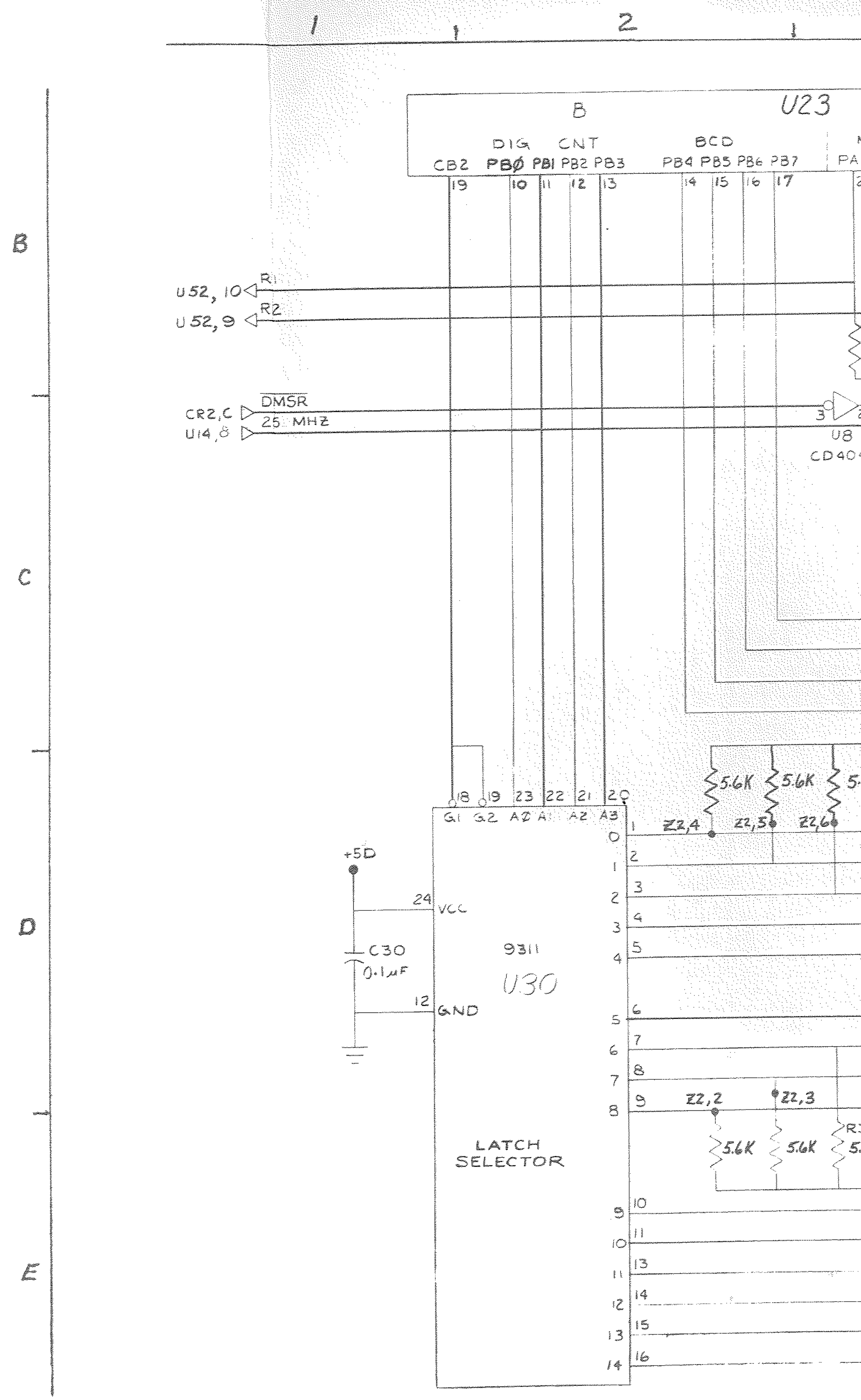
ANALOG AND CONTROL PC BOARD MB P/N 1658-4700

| REFDES | | DESCRIPTION | PART NO. | FMC | MFGR PART NUMBER |
|---|---|---|---|---|---|
| CR | 1 | DIODE HP5082-2800 IR 200NA SI | 6082-1034 | 28480 | HP-5082-2800 |
| CR | 2 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 3 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 4 | ZENER 1N746 3.3V 10PCT .4W | 6083-1005 | 14433 | IN746 |
| CR | 5 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 6 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 7 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 8 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 9 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 10 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 11 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 12 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 13 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 14 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 15 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 16 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 17 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 18 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 19 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 20 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 21 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 22 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 23 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 24 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 25 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 26 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 27 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 28 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 29 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 30 | DIODE 1N4151 75PIV IR.1UA SI | 6082-1001 | 14433 | 1N3604 |
| CR | 31 | DIODE 1N459A 175PIV IR.025UA SI | 6082-1011 | 14433 | 1N459A |
| CR | 32 | ZENER 1N746 3.3V 10PCT .4W | 6083-1005 | 14433 | IN746 |
| CR | 33 | ZENER 1N746 3.3V 10PCT .4W | 6083-1005 | 14433 | IN746 |
| J | 1 | CONNECTOR PC 40 POS DR | 1657-0400 | 24655 | 1657-0400 |
| J | 2 | CONNECTOR PC 25 POS DR | 4230-5008 | 24655 | 4230-5008 |
| J | 3 | HEADER FEMALE 30 CONT | 4230-8048 | 30146 | 929850-30 |
| J | 6 | HEADER FEMALE 6 CONT | 4230-8044 | 30146 | 929850-6 |
| J | 7 | BIAS TERMINAL | 1658-6002 | 24655 | 1658-6002 |
| JA | 2 | HEADER FEMALE 27 CONT | 4230-8045 | 30146 | 929850-27 |
| JB | 2 | HEADER FEMALE 27 CONT | 4230-8045 | 30146 | 929850-27 |
| K | 1 | RELAY REED DRY 5V FORM 1A | 6090-2080 | 14908 | 1192-1A-5 |
| K | 2 | RELAY REED DRY 5V FORM 1A | 6090-2080 | 14908 | 1192-1A-5 |
| L | 1 | CHOKE MOLDED 18.0 UH 10PCT | 4300-2500 | 99800 | 1537-42 |
| L | 2 | CHOKE MOLDED 18.0 UH 10PCT | 4300-2500 | 99800 | 1537-42 |
| Q | 1 | TRANSISTOR 2N3414 | 8210-1290 | 56289 | 2N3414 |
| Q | 2 | TRANSISTOR 2N3414 | 8210-1290 | 56289 | 2N3414 |
| Q | 3 | TRANSISTOR 2N3414 | 8210-1290 | 56289 | 2N3414 |
| Q | 4 | TRANSISTOR 2N5679 | 8210-1223 | 04713 | 2N5679 |
| Q | 5 | TRANSISTOR 2N2904 | 8210-1074 | 04713 | 2N2904 |
| Q | 6 | TRANSISTOR 2N2904 | 8210-1074 | 04713 | 2N2904 |
| R | 1 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 2 | RES COMP 1.0 K 5PCT 1/4W | 6099-2105 | 81349 | RCR07G102J |
| R | 3 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 4 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 5 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 6 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 7 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 8 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 9 | RES COMP 100 K 5PCT 1/4W | 6099-4105 | 81349 | RCR07G104J |
| R | 10 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 11 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 12 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 13 | RES COMP 51 K OHM 5PCT 1/4W | 6099-3515 | 81349 | RCR07G513J |
| R | 14 | RES COMP 100 K 5PCT 1/4W | 6099-4105 | 81349 | RCR07G104J |
| R | 15 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |

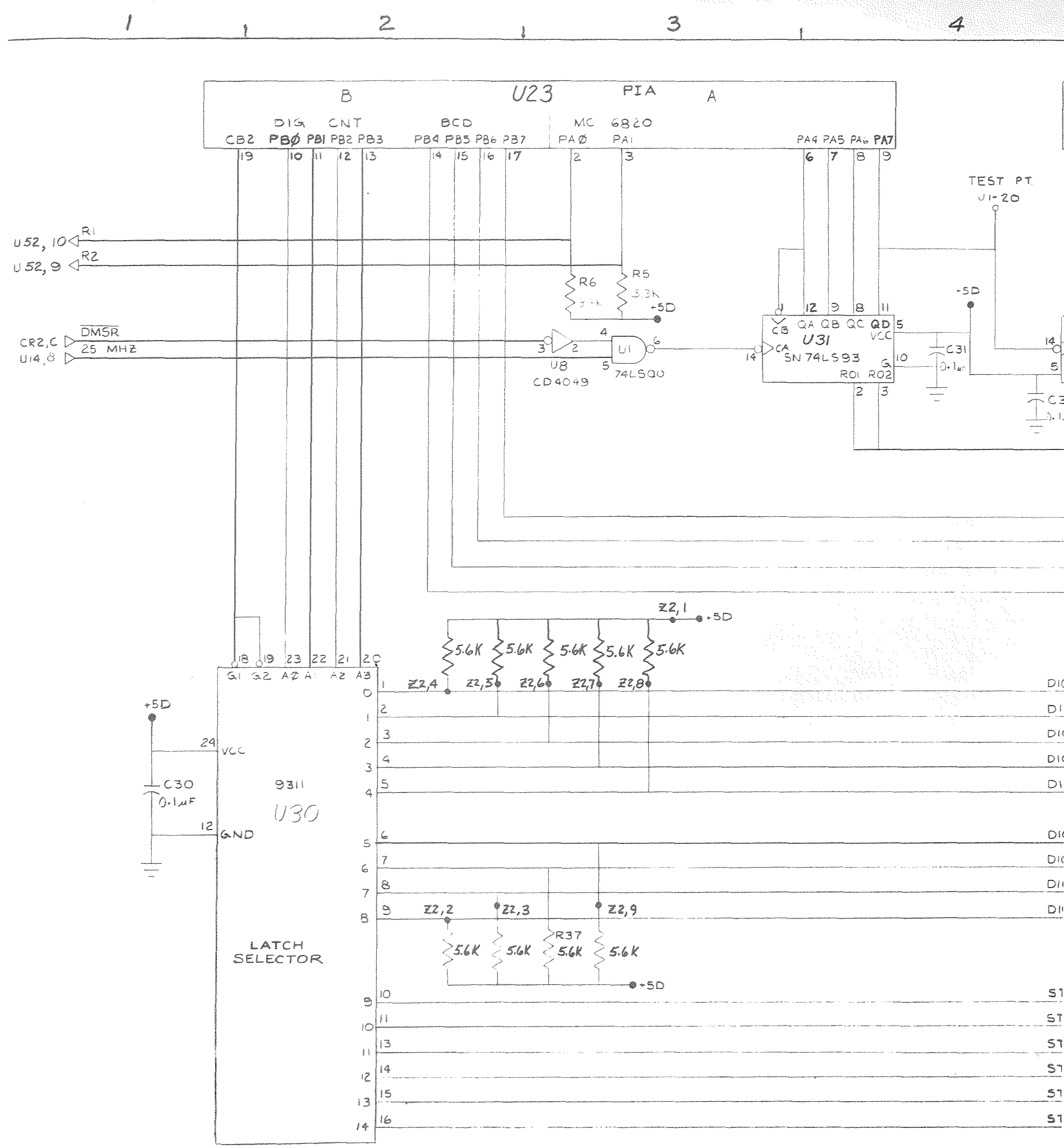
ELECTRICAL PARTS LIST (cont)

ANALOG AND CONTROL PC BOARD MB P/N 1658-4700

| REFDES | | DESCRIPTION | PART NO. | FMC | MFGR PART NUMBER |
|---|---|---|---|---|---|
| R | 16 | RES COMP 270 OHM 5PCT 1/4W | 6099-1275 | 81349 | RCR07G271J |
| R | 17 | RES COMP 15 K 5PCT 1/4W | 6099-3155 | 81349 | RCR07G153J |
| R | 18 | RES COMP 15 K 5PCT 1/4W | 6099-3155 | 81349 | RCR07G153J |
| R | 19 | RES COMP 15 K 5PCT 1/4W | 6099-3155 | 81349 | RCR07G153J |
| R | 20 | RES COMP 15 K 5PCT 1/4W | 6099-3155 | 81349 | RCR07G153J |
| R | 21 | RES COMP 3.9 K 5PCT 1/4W | 6099-2395 | 81349 | RCR07G392J |
| R | 22 | RES COMP 15 K 5PCT 1/4W | 6099-3155 | 81349 | RCR07G153J |
| R | 24 | RES COMP 150 OHM 5PCT 1/4W | 6099-1155 | 81349 | RCR07G151J |
| R | 25 | RES COMP 3.9 K 5PCT 1/4W | 6099-2395 | 81349 | RCR07G392J |
| R | 26 | RES COMP 1.8 K 5PCT 1/4W | 6099-2185 | 81349 | RCR07G182J |
| R | 27 | RES COMP 27 K 5PCT 1/2W | 6100-3275 | 81349 | RCR20G273J |
| R | 28 | RES COMP 56 OHM 5PCT 1/4W | 6099-0565 | 81349 | RCR07G560J |
| R | 29 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 30 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 31 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 32 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 33 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 34 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 35 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 36 | RES COMP 33 K 5PCT 1/4W | 6099-3335 | 81349 | RCR07G333J |
| R | 37 | RES COMP 5.6 K 5PCT 1/4W | 6099-2565 | 81349 | RCR07G562J |
| R | 38 | RES COMP 33 K 5PCT 1/4W | 6099-3335 | 81349 | RCR07G333J |
| R | 39 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 40 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 41 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 42 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 43 | RES COMP 15 OHM 5PCT 1/4W | 6099-0155 | 81349 | RCR07G150J |
| R | 44 | RES COMP 51 K OHM 5PCT 1/4W | 6099-3515 | 81349 | RCR07G513J |
| R | 45 | RES COMP 1.0 K 5PCT 1/4W | 6099-2105 | 81349 | RCR07G102J |
| R | 46 | RES COMP 1.5 K 5PCT 1/4W | 6099-2155 | 81349 | RCR07G152J |
| R | 47 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 48 | RES FLM 100K 1 PCT 1/8W | 6250-3100 | 81349 | RN55D1003F |
| R | 49 | RES COMP 470 OHM 5PCT 1/4W | 6099-1475 | 81349 | RCR07G471J |
| R | 50 | RES COMP 100 K 5PCT 1/4W | 6099-4105 | 81349 | RCR07G104J |
| R | 51 | RES FLM 100K 1 PCT 1/8W | 6250-3100 | 81349 | RN55D1003F |
| R | 52 | RES COMP 100 K 5PCT 1/4W | 6099-4105 | 81349 | RCR07G104J |
| R | 53 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 54 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 55 | RES FLM 39.2K 1 PCT 1/8W | 6250-2392 | 81349 | RN55D3922F |
| R | 56 | RES FLM 39.2K 1 PCT 1/8W | 6250-2392 | 81349 | RN55D3922F |
| R | 57 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 58 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 59 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 60 | RES COMP 100 K 5PCT 1/4W | 6099-4105 | 81349 | RCR07G104J |
| R | 61 | RES COMP 1.0 K 5PCT 1/4W | 6099-2105 | 81349 | RCR07G102J |
| R | 62 | RES PWR WW 10 OHM .02PCT 10PPM | 6620-1036 | 24655 | 6620-1036 |
| R | 63 | RES FLM 1K .02PCT 10PPM | 6619-5070 | 24655 | 6619-5070 |
| R | 64 | RES FLM 100K .02PCT 10PPM | 6619-6000 | 24655 | 6619-6000 |
| R | 65 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 66 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 67 | RES COMP 33 OHM 5PCT 1/4W | 6099-0335 | 81349 | RCR07G330J |
| R | 68 | RES COMP 10 OHM 5PCT 1/4W | 6099-0105 | 81349 | RCR07G100J |
| R | 69 | RES FLM 2.15M 1 PCT 1/4W | 6350-4215 | 81349 | RN60D2154F |
| R | 70 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 71 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 72 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 73 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 74 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 75 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 76 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 77 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 78 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 79 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 80 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 81 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 82 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 83 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 84 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 85 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 86 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 87 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 88 | RES FLM 2.15M 1 PCT 1/4W | 6350-4215 | 81349 | RN60D2154F |
| R | 89 | RES COMP 300 K OHM 5PCT 1/4W | 6099-4305 | 81349 | RCR07G304J |



1
2
B
C
D
E
U23
B
DIG CNT
BCD
CB2 PBØ PB1 PB2 PB3
PB4 PB5 PB6 PB7
PA
U52, 10
R1
U52, 9
R2
CR2,C
DMSR
25 MHZ
U14,8
U8
+5D
C30
0.1μF
VCC
GND
9311
U30
LATCH
SELECTOR
G1 G2 A0 A1 A2 A3
Z2,4
Z2,5
Z2,6
Z2,2
Z2,3
5.6K



1
2
3
4
U23
PIA
A
B
DIG CNT
BCD
MC 6820
CB2 PBØ PB1 PB2 PB3
PB4 PB5 PB6 PB7
PAØ PA1
PA4 PA5 PA6 PA7
TEST PT.
U1-20
U52, 10
R1
U52, 9
R2
R6
R5
3.3K
+5D
CR2,C
DMSR
25 MHZ
U14,8
U8
CD4049
U1
74LS00
U31
SN 74LS93
CA
CB
QA QB QC QD
VCC
G
R01 R02
C31
0.1µF
Z2,1
Z2,2
Z2,3
Z2,4
Z2,5
Z2,6
Z2,7
Z2,8
Z2,9
5.6K
R37
G1 G2 AØ A1 A2 A3
VCC
GND
9311
U30
C30
0.1µF
LATCH
SELECTOR

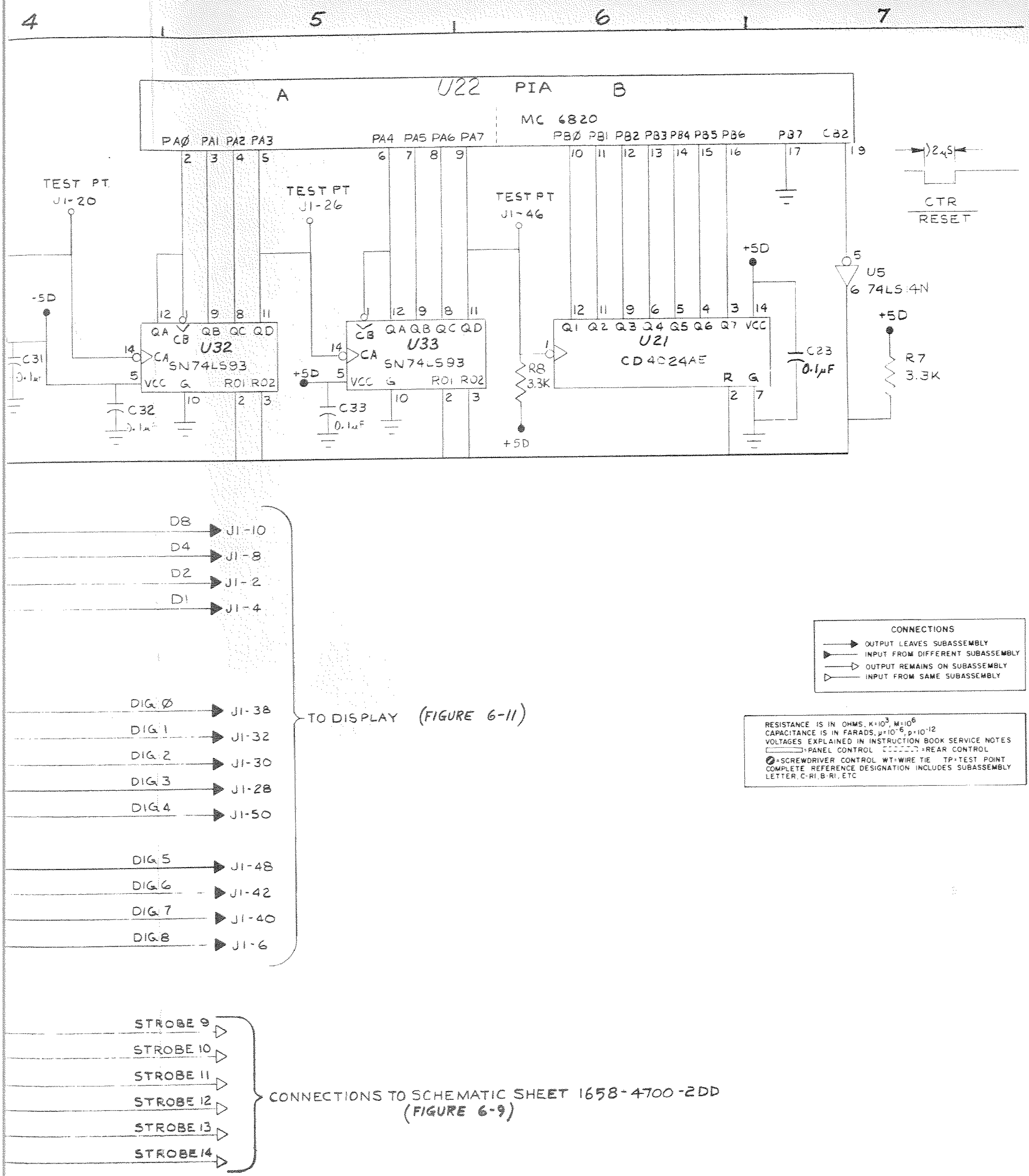



Figure 6-8. Main (MB) board, -4700, measurement counter, display driver.

## ELECTRICAL PARTS LIST (cont)

ANALOG AND CONTROL PC BOARD MB P/N 1658-4700

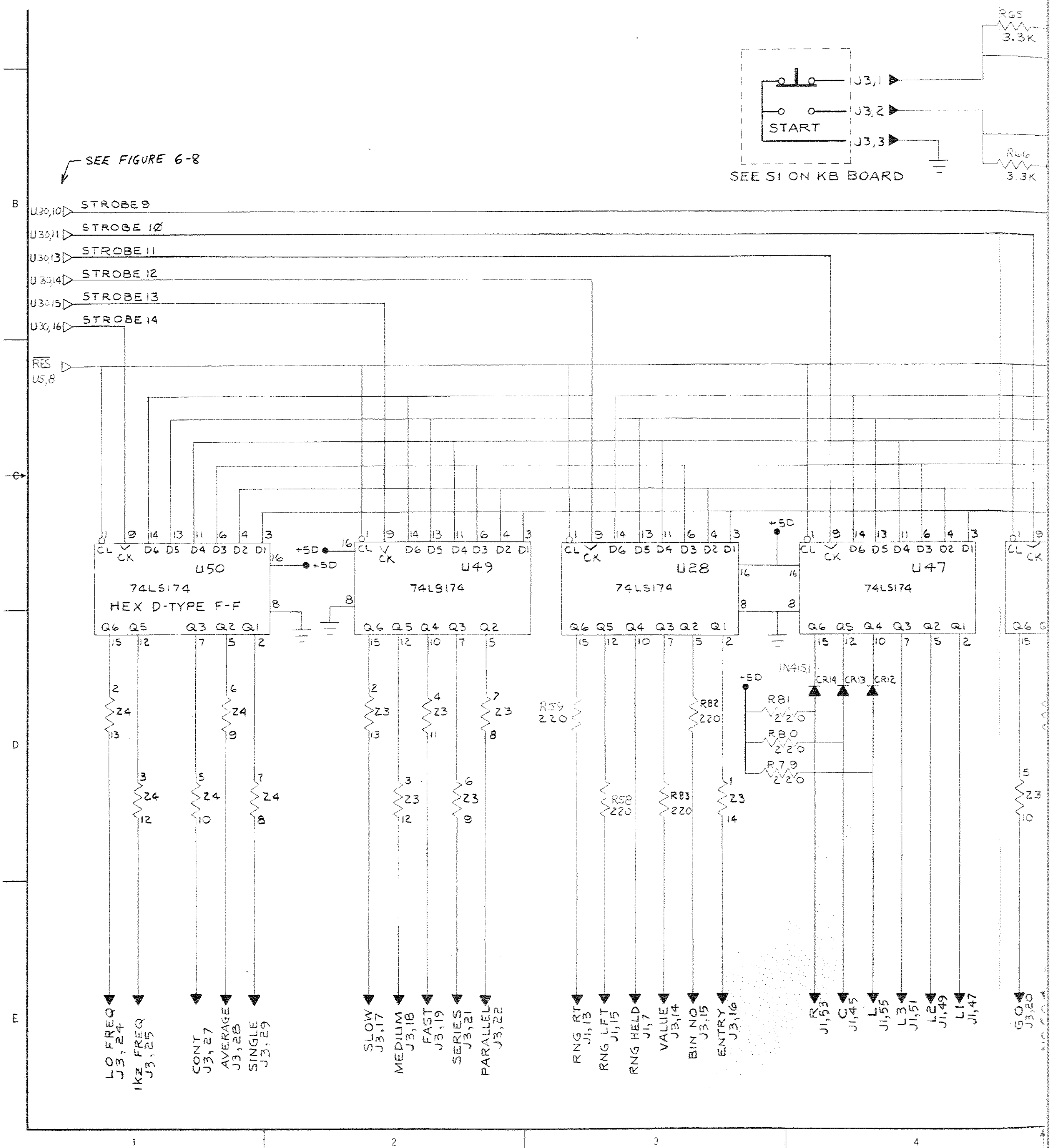
| REFDES | | DESCRIPTION | PART NO. | FMC | MFGR PART NUMBER |
|---|---|---|---|---|---|
| R | 90 | RES COMP 300 K OHM 5PCT 1/4W | 6099-4305 | 81349 | RCR07G304J |
| R | 91 | RES COMP 2.0 K OHM 5PCT 1/4W | 6099-2205 | 81349 | RCR07G202J |
| R | 92 | RES COMP 1.0 K 5PCT 1/4W | 6099-2105 | 81349 | RCR07G102J |
| R | 93 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 94 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 95 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 96 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 97 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 98 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 104 | RES COMP 100 K 5PCT 1/4W | 6099-4105 | 81349 | RCR07G104J |
| R | 105 | RES COMP 100 K 5PCT 1/4W | 6099-4105 | 81349 | RCR07G104J |
| R | 106 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 107 | RES COMP 4.7 K 5PCT 1/4W | 6099-2475 | 81349 | RCR07G472J |
| R | 108 | RES COMP 1.0 K 5PCT 1/4W | 6099-2105 | 81349 | RCR07G102J |
| R | 109 | RES COMP 1.0 K 5PCT 1/4W | 6099-2105 | 81349 | RCR07G102J |
| R | 110 | RES COMP 1.0 K 5PCT 1/4W | 6099-2105 | 81349 | RCR07G102J |
| R | 111 | RES COMP 22 OHM 5PCT 1/4W | 6099-0225 | 81349 | RCR07G220J |
| R | 112 | RES COMP 22 OHM 5PCT 1/4W | 6099-0225 | 81349 | RCR07G220J |
| S | 900 | SWITCH TOGGLE 6STA SPST PC | 7910-2030 | 31514 | 1006-692 |
| U | 1 | IC DIGITAL SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U | 2 | ICD (STATIC PROTECT REQ) | 5627-1001 | 34649 | P2111A-4 |
| U | 3 | ICD (STATIC PROTECT REQ) | 5627-0005 | 24655 | 5627-0005 |
| U | 4 | ICD (STATIC PROTECT REQ) | 5627-0004 | 24655 | 5627-0004 |
| U | 5 | ICD SN74LS14N HX SCHMT-TR INVERT | 5431-8614 | 01295 | SN74LS14N |
| U | 6 | ICD (STATIC PROTECT REQ) | 5627-1001 | 34649 | P2111A-4 |
| U | 7 | ICD (STATIC PROTECT REQ) | 5431-2402 | 24655 | 5431-2402 |
| U | 8 | ICD (STATIC PROTECT REQ) | 5431-7021 | 86684 | CD4049AE |
| U | 9 | IC DIGITAL SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U | 10 | ICD SN74LS93N 4BIT BIN COUNTER | 5431-8693 | 01295 | SN74LS93N |
| U | 11 | ICD (STATIC PROTECT REQ) | 5627-0002 | 24655 | 5627-0002 |
| U | 12 | ICD SN74LS93N 4BIT BIN COUNTER | 5431-8693 | 01295 | SN74LS93N |
| U | 13 | ICD SN74LS93N 4BIT BIN COUNTER | 5431-8693 | 01295 | SN74LS93N |
| U | 15 | IC DIGITAL SN74LS92 | 5431-8692 | 01295 | SN74LS92 |
| U | 16 | IC DIGITAL SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U | 17 | ICD SN74LS93N 4BIT BIN COUNTER | 5431-8693 | 01295 | SN74LS93N |
| U | 18 | ICD SN74LS93N 4BIT BIN COUNTER | 5431-8693 | 01295 | SN74LS93N |
| U | 19 | ICD (STATIC PROTECT REQ) | 5431-7042 | 12040 | MM74C907 |
| U | 20 | ICD (STATIC PROTECT REQ) | 5431-2450 | 04713 | MC6820A |
| U | 21 | ICD (STATIC PROTECT REQ) | 5431-7008 | 04713 | MC14024BCP |
| U | 22 | ICD (STATIC PROTECT REQ) | 5431-2450 | 04713 | MC6820A |
| U | 23 | ICD (STATIC PROTECT REQ) | 5431-2450 | 04713 | MC6820A |
| U | 24 | ICD (STATIC PROTECT REQ) | 5431-2450 | 04713 | MC6820A |
| U | 25 | IC DIGITAL SN74LS04N | 5431-8604 | 01295 | SN74LS04N |
| U | 26 | IC DIGITAL SN74LS174N | 5431-8774 | 01295 | SN74LS174N |
| U | 27 | IC DIGITAL SN74LS174N | 5431-8774 | 01295 | SN74LS174N |
| U | 28 | IC DIGITAL SN74LS174N | 5431-8774 | 01295 | SN74LS174N |
| U | 29 | ICD SN74LS20N D 4IN POS NAND GA | 5431-8620 | 01295 | SN74LS20N |
| U | 30 | ICD 9311 24D MSI 10F16 DECODER | 5431-9617 | 18324 | 9311/74154 |
| U | 31 | ICD SN74LS93N 4BIT BIN COUNTER | 5431-8693 | 01295 | SN74LS93N |
| U | 32 | ICD SN74LS93N 4BIT BIN COUNTER | 5431-8693 | 01295 | SN74LS93N |
| U | 33 | ICD SN74LS93N 4BIT BIN COUNTER | 5431-8693 | 01295 | SN74LS93N |
| U | 34 | ICD (STATIC PROTECT REQ) | 5431-7041 | 12040 | MM74C175 |
| U | 35 | ICD (STATIC PROTECT REQ) | 5431-7042 | 12040 | MM74C907 |
| U | 36 | ICD (STATIC PROTECT REQ) | 5431-7009 | 86684 | CD4023AE |
| U | 37 | ICD (STATIC PROTECT REQ) | 5431-7003 | 86684 | CD4016AE |
| U | 38 | ICL (STATIC PROTECT REQ) | 5432-7001 | 01295 | TL084CN |
| U | 39 | D/A CONV 8 BIT MONOLITHIC | 5429-5043 | 50721 | DAC108BC |
| U | 40 | IC LINEAR LM301A | 5432-1004 | 12040 | LM301AH |
| U | 41 | ICD (STATIC PROTECT REQ) | 5431-7032 | 86684 | CD4052AE |
| U | 42 | ICL (STATIC PROTECT REQ) | 5432-7000 | 86684 | CA3130T |
| U | 43 | ICL (STATIC PROTECT REQ) | 5432-7001 | 01295 | TL084CN |
| U | 44 | IC LINEAR LH0002CN | 5432-1062 | 12040 | LH0002CN |
| U | 45 | ICL (STATIC PROTECT REQ) | 5432-7000 | 86684 | CA3130T |
| U | 46 | ICD (STATIC PROTECT REQ) | 5431-7032 | 86684 | CD4052AE |
| U | 47 | IC DIGITAL SN74LS174N | 5431-8774 | 01295 | SN74LS174N |
| U | 48 | ICD SN7405N 14D HX INV COL 5V | 5431-8105 | 01295 | SN7405N |
| U | 49 | IC DIGITAL SN74LS174N | 5431-8774 | 01295 | SN74LS174N |
| U | 50 | IC DIGITAL SN74LS174N | 5431-8774 | 01295 | SN74LS174N |
| U | 51 | IC LINEAR LH0002CN | 5432-1062 | 12040 | LH0002CN |
| U | 52 | ICD (STATIC PROTECT REQ) | 5431-7032 | 86684 | CD4052AE |
| U | 53 | ICD (STATIC PROTECT REQ) | 5627-0003 | 24655 | 5627-0003 |

ELECTRICAL PARTS LIST (cont)

ANALOG AND CONTROL BOARD MB P/N 1658-4700

| REF DES | | DESCRIPTION | PART NO. | FMC | MFG PT. NO. |
|---|---|---|---|---|---|
| Z | 1 | THIN FILM RESISTOR NETWORK | 1658-0800* | 24655 | 1658-0800 |
| Z | 2 | RESISTOR NETWORK 5.6K 5PCT | 6741-0104 | 24655 | 6741-0104 |
| Z | 3 | RESISTOR NETWORK | 1657-0810* | 24655 | 1657-0810 |
| Z | 4 | RESISTOR NETWORK | 1657-0810 | 24655 | 1657-0810 |

* NOTE: AN OPEN CIRCUIT IN A RESISTOR NETWORK CAN BE REPAIRED BY SHUNTING AN EXTERNAL RESISTOR ACROSS THE APPROPRIATE TERMINALS.
1658-0800 pins 1-2, 2-3, 6-7, or 7-8: 125 kΩ ± 0.2%
1658-0800 pins 3-4 or 5-6: 35 kΩ ± 0.2%
1657-0810 (each section): 220 Ω ± 5%.
6741-0104 has a common point (pin 1); each resistor is 5.6 kΩ ± 5%.



SEE FIGURE 6-8
SEE S1 ON KB BOARD
START
J3,1
J3,2
J3,3
R65 3.3K
R66 3.3K
U30,10 STROBE 9
U30,11 STROBE 10
U30,13 STROBE 11
U30,14 STROBE 12
U30,15 STROBE 13
U30,16 STROBE 14
RES U5,8
U50
74LS174
HEX D-TYPE F-F
U49
74LS174
U28
74LS174
U47
74LS174
+5D
1N4151
CR14
CR13
CR12
R81 220
R80 220
R79 220
R59 220
R58 220
R82 220
R83 220
Z4
Z3
LO FREQ J3,24
1kz FREQ J3,25
CONT J3,27
AVERAGE J3,28
SINGLE J3,29
SLOW J3,17
MEDIUM J3,18
FAST J3,19
SERIES J3,21
PARALLEL J3,22
RNG RT J1,13
RNG LFT J1,15
RNG HELD J1,7
VALUE J3,14
BIN NO J3,15
ENTRY J3,16
R J1,53
C J1,45
L J1,55
L3 J1,51
L2 J1,49
L1 J1,47
GO J3,20

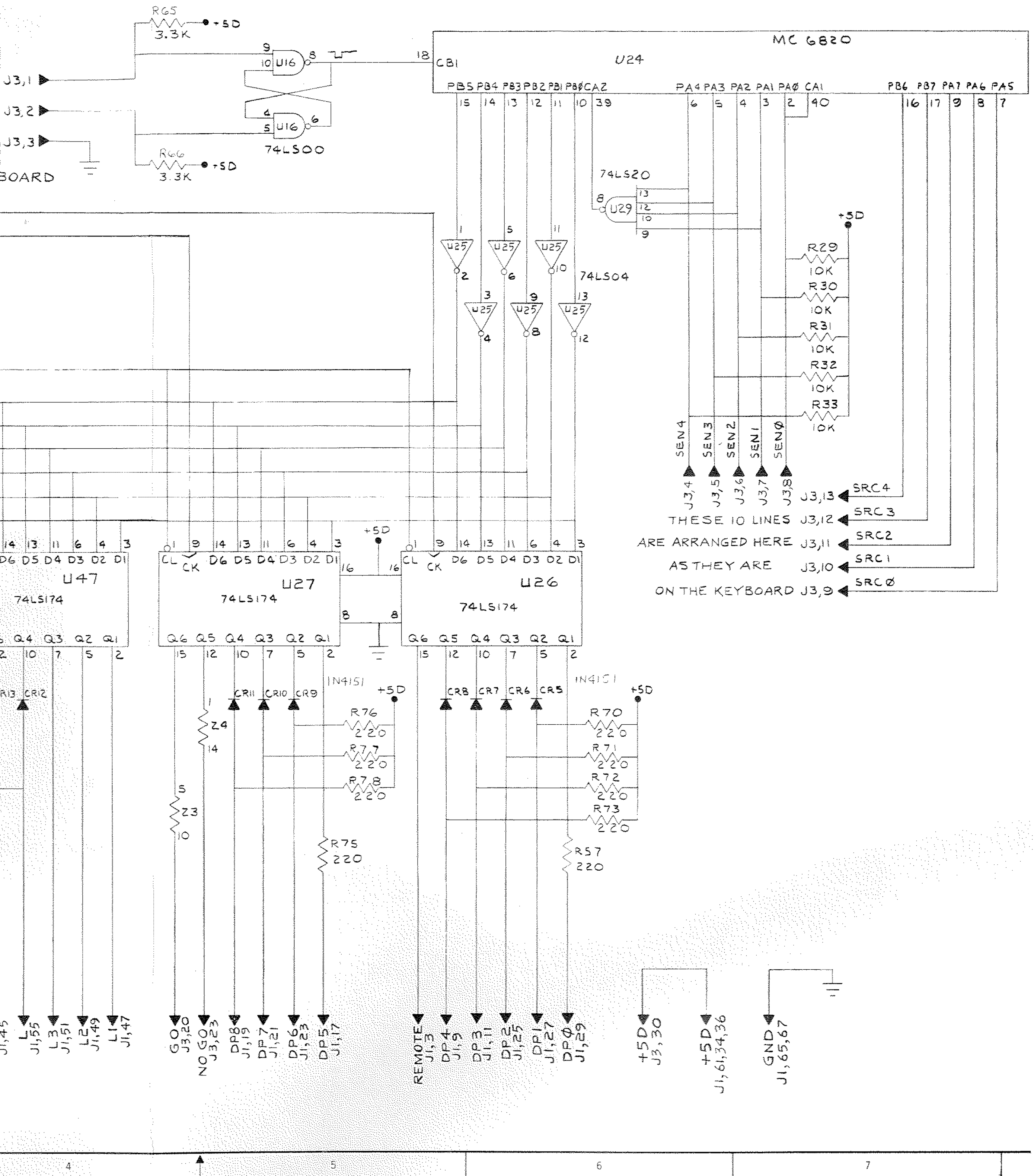


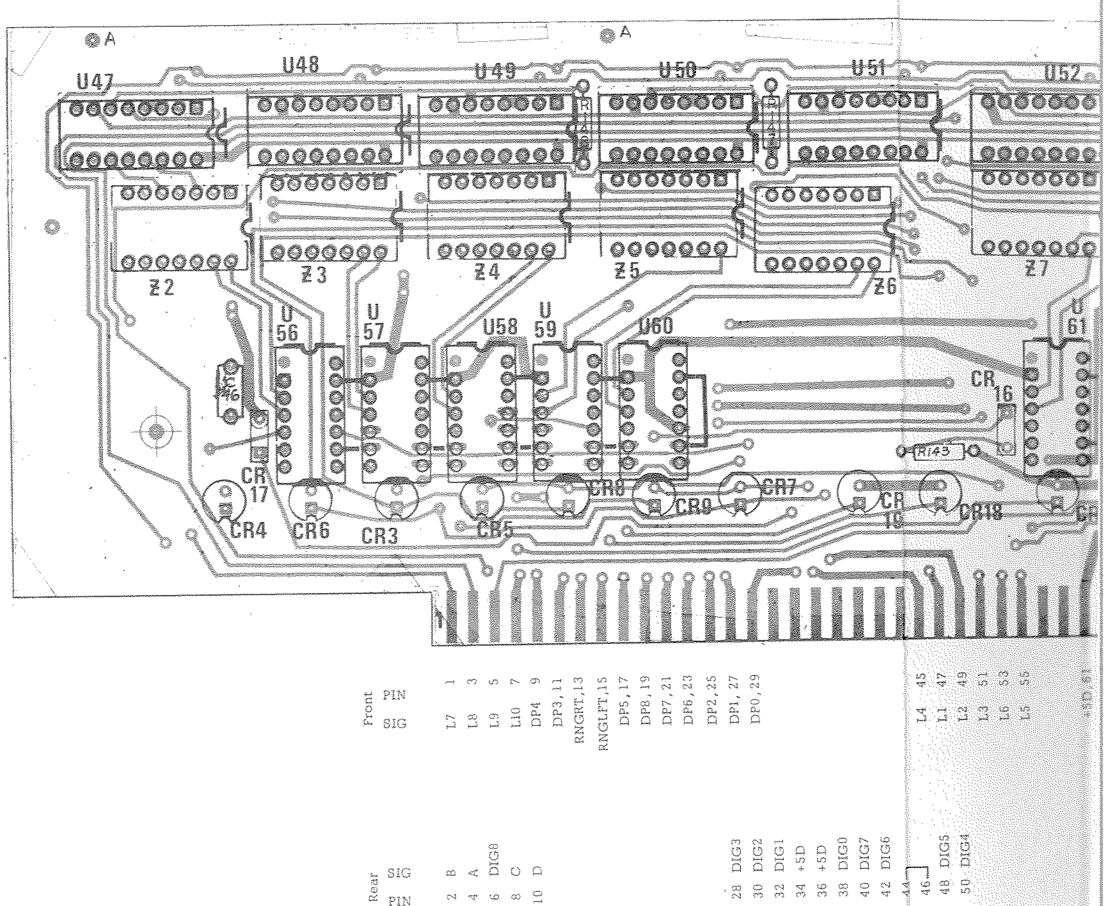
Figure 6-9. Main (MB) board, -4700, keyboard and display-LED interfaces.

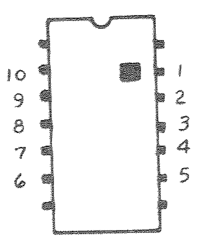
## ELECTRICAL PARTS LIST

DISPLAY BOARD ASM DB P/N 1658-4715

| REFDES | | DESCRIPTION | PART NO. | FMC | MFGR PART NUMBER |
|---|---|---|---|---|---|
| C | 46 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| CR | 3 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 4 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 5 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 6 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 7 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 8 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 9 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 10 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 11 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 12 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 13 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 16 | LED RED | 6084-1110 | 72619 | 555-3007 |
| CR | 17 | LED RED | 6084-1110 | 72619 | 555-3007 |
| CR | 18 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 19 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| R | 142 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 143 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 144 | RES COMP 220 OHM 5PCT 1/4W | 6099-1225 | 81349 | RCR07G221J |
| R | 145 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 146 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 147 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 148 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| U | 47 | ICD (STATIC PROTECT REQ) | 5431-7037 | 04713 | MC14511CP |
| U | 48 | ICD (STATIC PROTECT REQ) | 5431-7037 | 04713 | MC14511CP |
| U | 49 | ICD (STATIC PROTECT REQ) | 5431-7037 | 04713 | MC14511CP |
| U | 50 | ICD (STATIC PROTECT REQ) | 5431-7037 | 04713 | MC14511CP |
| U | 51 | ICD (STATIC PROTECT REQ) | 5431-7037 | 04713 | MC14511CP |
| U | 52 | ICD (STATIC PROTECT REQ) | 5431-7037 | 04713 | MC14511CP |
| U | 53 | ICD (STATIC PROTECT REQ) | 5431-7037 | 04713 | MC14511CP |
| U | 56 | INDICATOR DIGITAL .300 CHARACTER | 5437-1400 | 28480 | 5082-7613 |
| U | 57 | INDICATOR DIGITAL .300 CHARACTER | 5437-1400 | 28480 | 5082-7613 |
| U | 58 | INDICATOR DIGITAL .300 CHARACTER | 5437-1400 | 28480 | 5082-7613 |
| U | 59 | INDICATOR DIGITAL .300 CHARACTER | 5437-1400 | 28480 | 5082-7613 |
| U | 60 | INDICATOR DIGITAL .300 CHARACTER | 5437-1400 | 28480 | 5082-7613 |
| U | 61 | INDICATOR DIGITAL .300 CHARACTER | 5437-1400 | 28480 | 5082-7613 |
| U | 62 | INDICATOR DIGITAL .300 CHARACTER | 5437-1400 | 28480 | 5082-7613 |
| U | 63 | INDICATOR DIGITAL .300 CHARACTER | 5437-1400 | 28480 | 5082-7613 |
| U | 64 | INDICATOR DIGITAL .300 CHARACTER | 5437-1400 | 28480 | 5082-7613 |
| Z | 2 | RESISTOR NETWORK | 1657-0810 | 24655* | 1657-0810 |
| Z | 3 | RESISTOR NETWORK | 1657-0810 | 24655 | 1657-0810 |
| Z | 4 | RESISTOR NETWORK | 1657-0810 | 24655 | 1657-0810 |
| Z | 5 | RESISTOR NETWORK | 1657-0810 | 24655 | 1657-0810 |
| Z | 6 | RESISTOR NETWORK | 1657-0810 | 24655 | 1657-0810 |
| Z | 7 | RESISTOR NETWORK | 1657-0810 | 24655 | 1657-0810 |
| Z | 8 | RESISTOR NETWORK | 1657-0810 | 24655 | 1657-0810 |
| Z | 9 | RESISTOR NETWORK | 1657-0810 | 24655 | 1657-0810 |
| Z | 10 | RESISTOR NETWORK | 1657-0810 | 24655 | 1657-0810 |

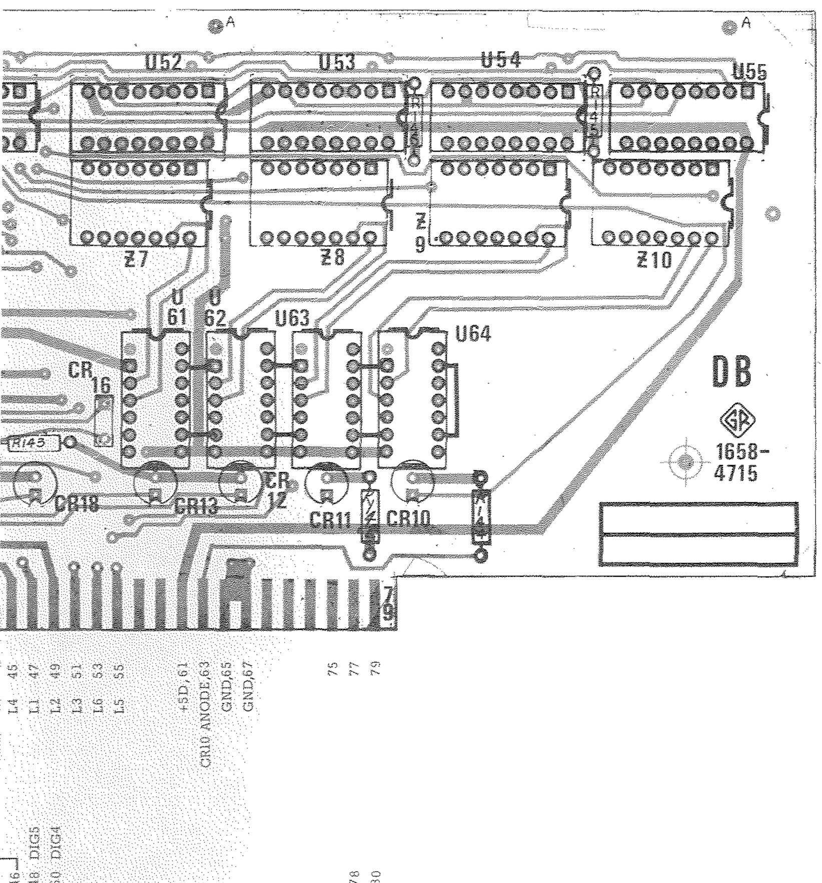
* NOTE: AN OPEN CIRCUIT IN A RESISTOR NETWORK CAN BE REPAIRED BY SHUNTING AN EXTERNAL RESISTOR ACROSS THE APPROPRIATE TERMINALS.
1657-0810 (each section): 220 $\Omega \pm$ 5%.



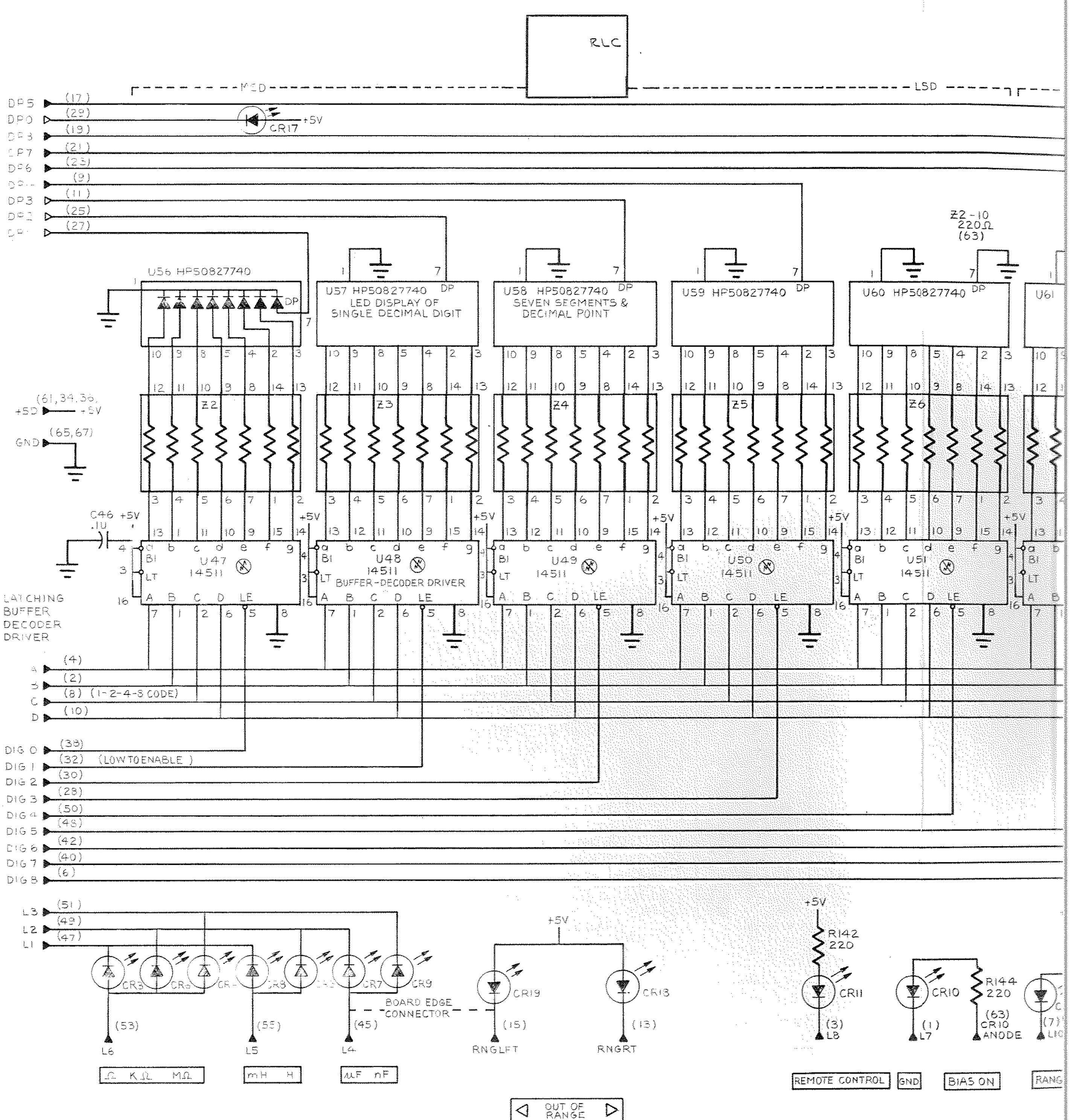

Bottom view of
U56...64

Figure 6-10. Display




NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; gray ckt pattern = parts side, black (if any) = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

Figure 6-10. Display (DB) board, 1658-4715, layout.


RLC
MSD
LSD
U56 HP50827740
U57 HP50827740 LED DISPLAY OF SINGLE DECIMAL DIGIT
U58 HP50827740 SEVEN SEGMENTS & DECIMAL POINT
U59 HP50827740
U60 HP50827740
Z2-10 220Ω (63)
CR17
+5V
C46 .1U
U47 14511
U48 14511 BUFFER-DECODER DRIVER
U49 14511
U50 14511
U51 14511
LATCHING BUFFER DECODER DRIVER
(1-2-4-8 CODE)
(LOW TO ENABLE)
DIG 0
DIG 1
DIG 2
DIG 3
DIG 4
DIG 5
DIG 6
DIG 7
DIG 8
L3
L2
L1
BOARD EDGE CONNECTOR
RNGLFT
RNGRT
R142 220
CR11
CR10
R144 220
CR10 ANODE
Ω KΩ MΩ
mH H
μF nF
OUT OF RANGE
REMOTE CONTROL
GND
BIAS ON

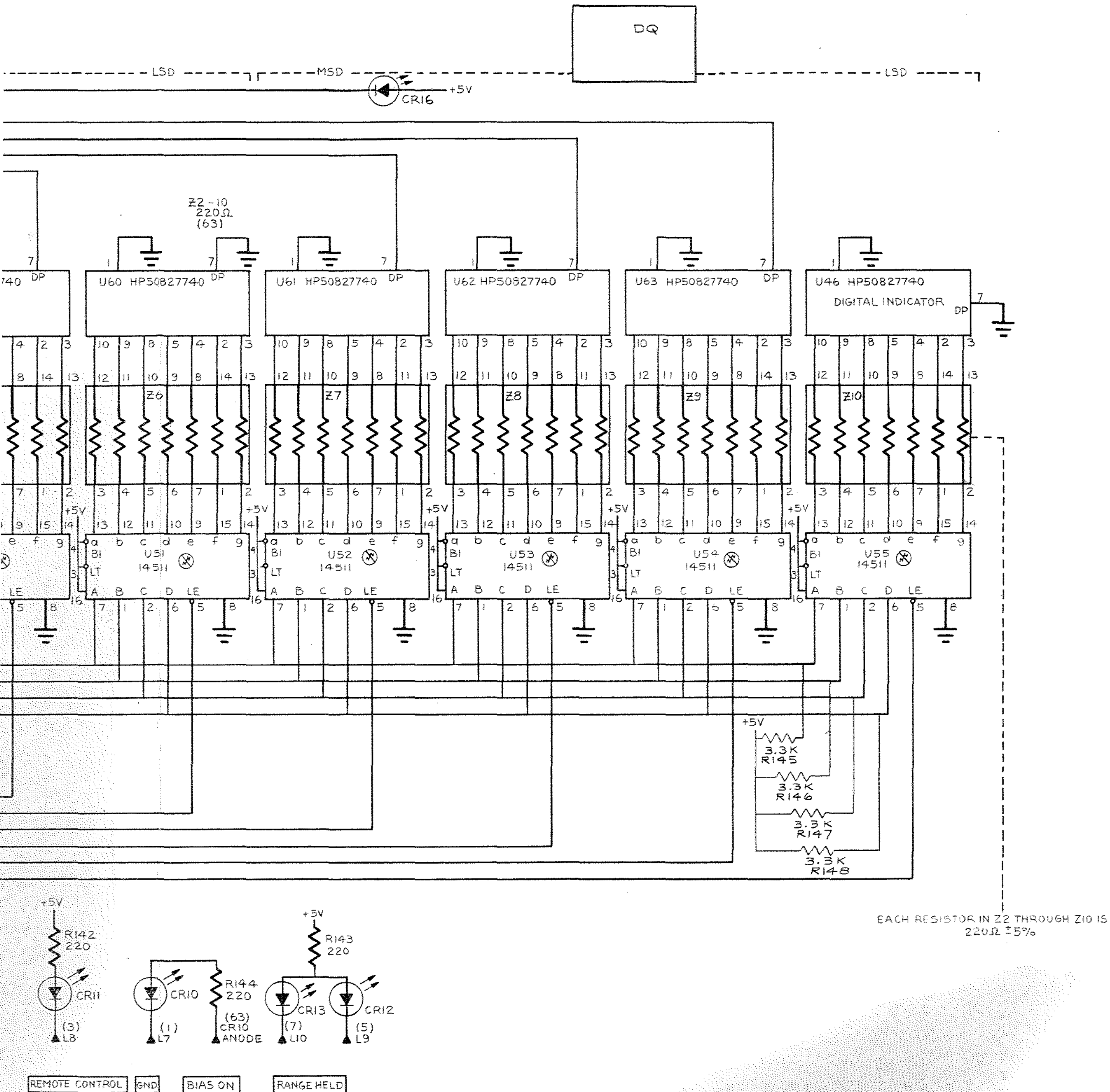
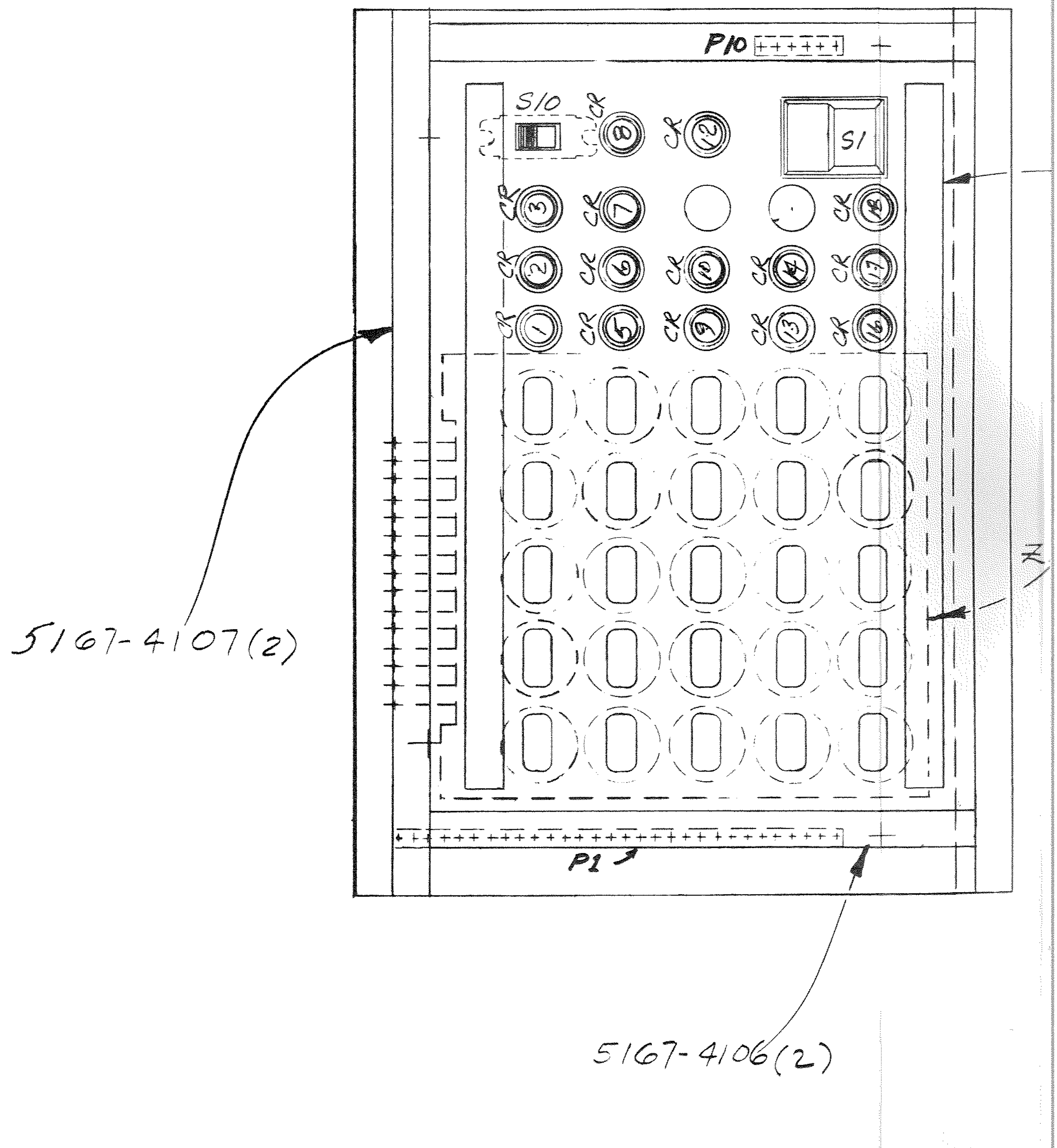



**Figure 6-11. Display (DB) board, 1658-4715, diagram.**

## ELECTRICAL PARTS LIST

KEYBOARD ASM PC BOARD KB P/N 1658-4710

| REFDES | | DESCRIPTION | PART NO. | FMC | MFGR PART NUMBER |
|---|---|---|---|---|---|
| CR | 1 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 2 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 3 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 5 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 6 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 7 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 8 | LED GREEN | 6084-1055 | 28480 | 5082-4950 |
| CR | 9 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 10 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 12 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 13 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 14 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 16 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 17 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| CR | 18 | LED RED MV5023 | 6084-1104 | 71744 | CM4-23 |
| P | 1 | CONN 30 PIN .025 SQ POST | 4230-8095 | 30146 | 929647-02-30 |
| P | 10 | CONN 6 PIN .025SQ POST | 4230-8096 | 30146 | 929647-02-06 |
| S | 1 | SWITCH PUSH MOMENT DPST | 7870-1571 | 31918 | TYPE SR BLACK |
| S | 10 | SWITCH SLIDE 2POS DPDT STEADY | 7910-0470 | 10389 | 23-021-118 |
| ZS | 2 | SWITCH PUSHBUTTON MULT KEYBOARD | 7880-3200 | 24655 | 7880-3200 |




Figu

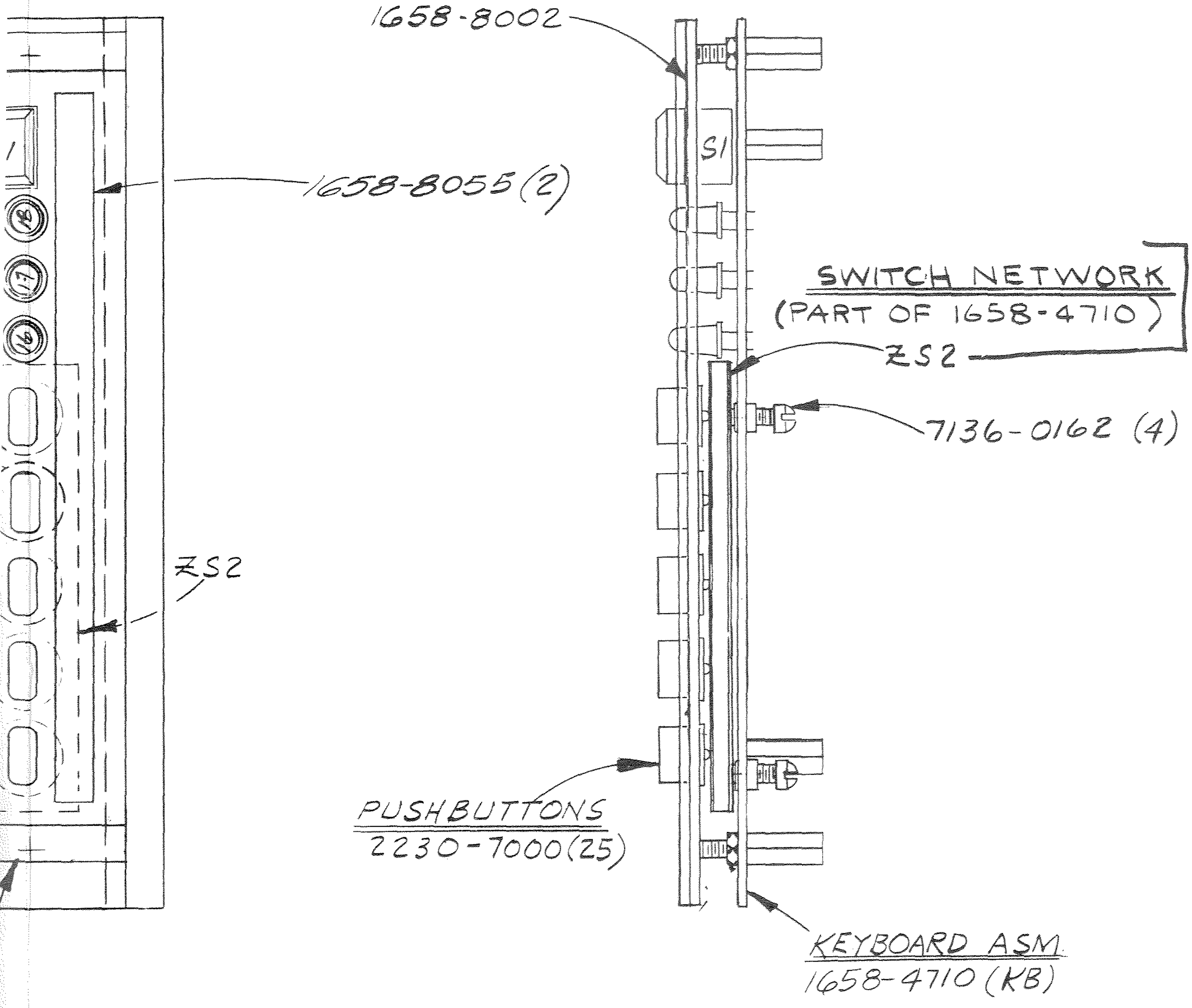



Figure 6-12. Keyboard module assembly, 1658-4200.

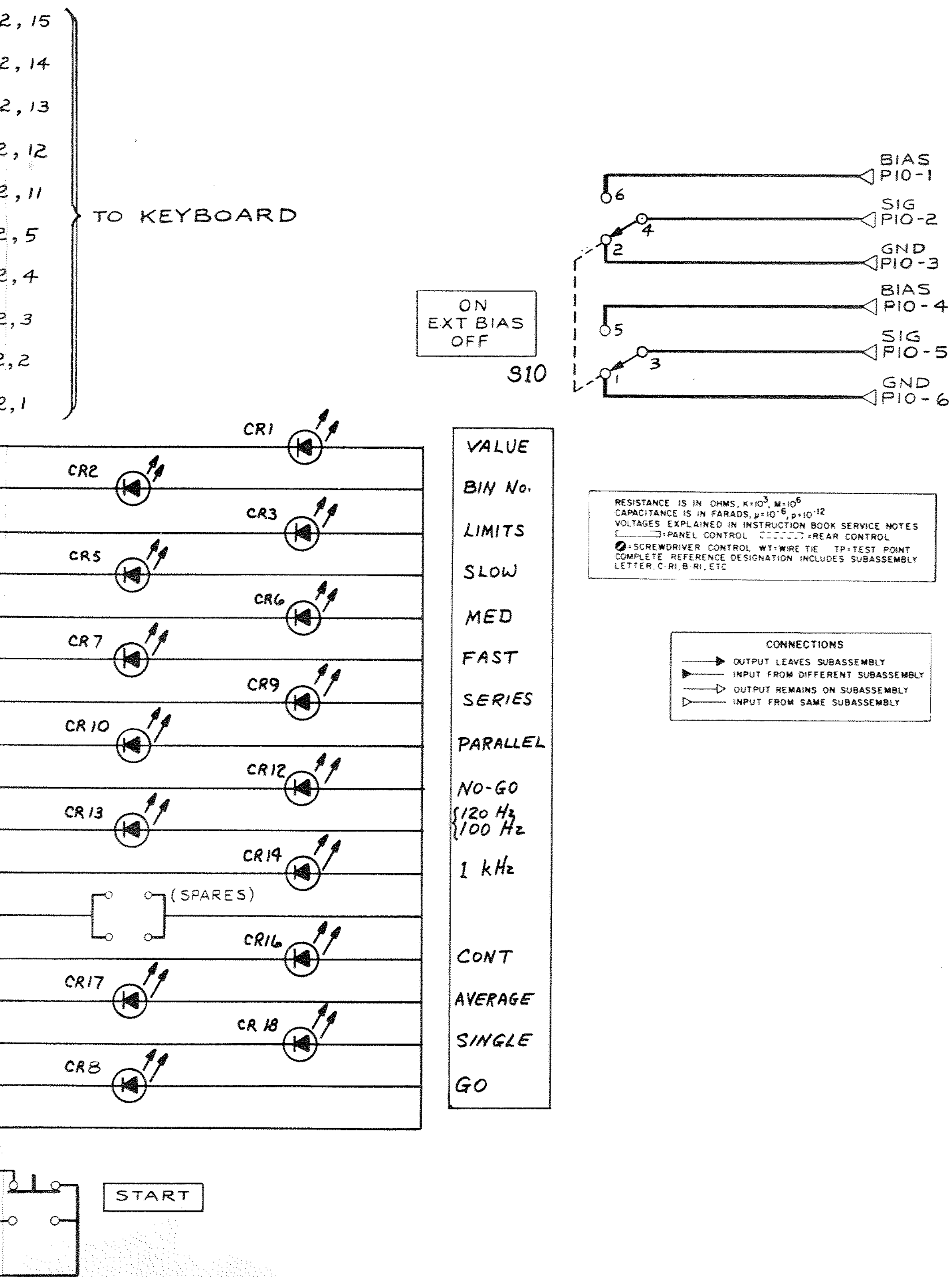
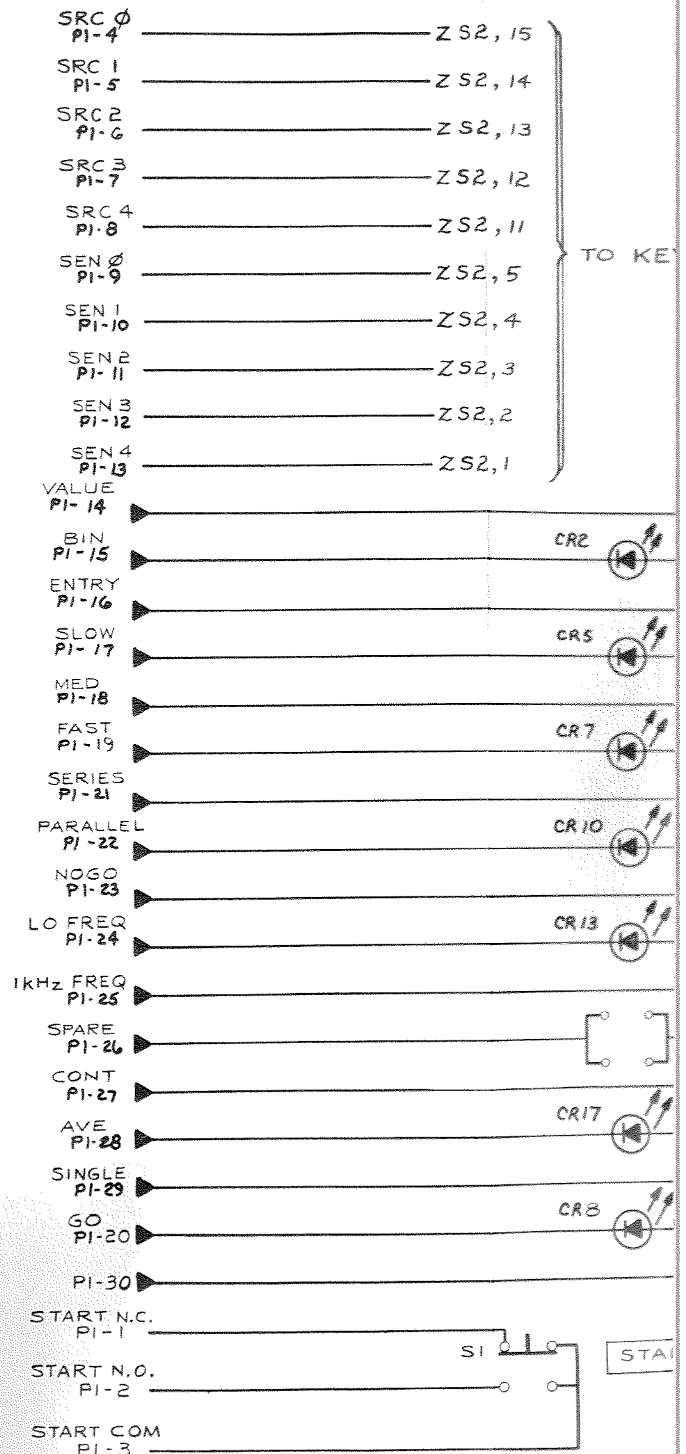



**Figure 6-14.** Keyboard (KB) circuit board, -4710, diagram.



SRC Ø P1-4
ZS2, 15
SRC 1 P1-5
ZS2, 14
SRC 2 P1-6
ZS2, 13
SRC 3 P1-7
ZS2, 12
SRC 4 P1-8
ZS2, 11
SEN Ø P1-9
ZS2, 5
SEN 1 P1-10
ZS2, 4
SEN 2 P1-11
ZS2, 3
SEN 3 P1-12
ZS2, 2
SEN 4 P1-13
ZS2, 1
TO KE
VALUE P1-14
BIN P1-15
CR2
ENTRY P1-16
SLOW P1-17
CR5
MED P1-18
FAST P1-19
CR7
SERIES P1-21
PARALLEL P1-22
CR10
NOGO P1-23
LO FREQ P1-24
CR13
1kHz FREQ P1-25
SPARE P1-26
CONT P1-27
AVE P1-28
CR17
SINGLE P1-29
GO P1-20
CR8
P1-30
START N.C. P1-1
S1
STA
START N.O. P1-2
START COM P1-3

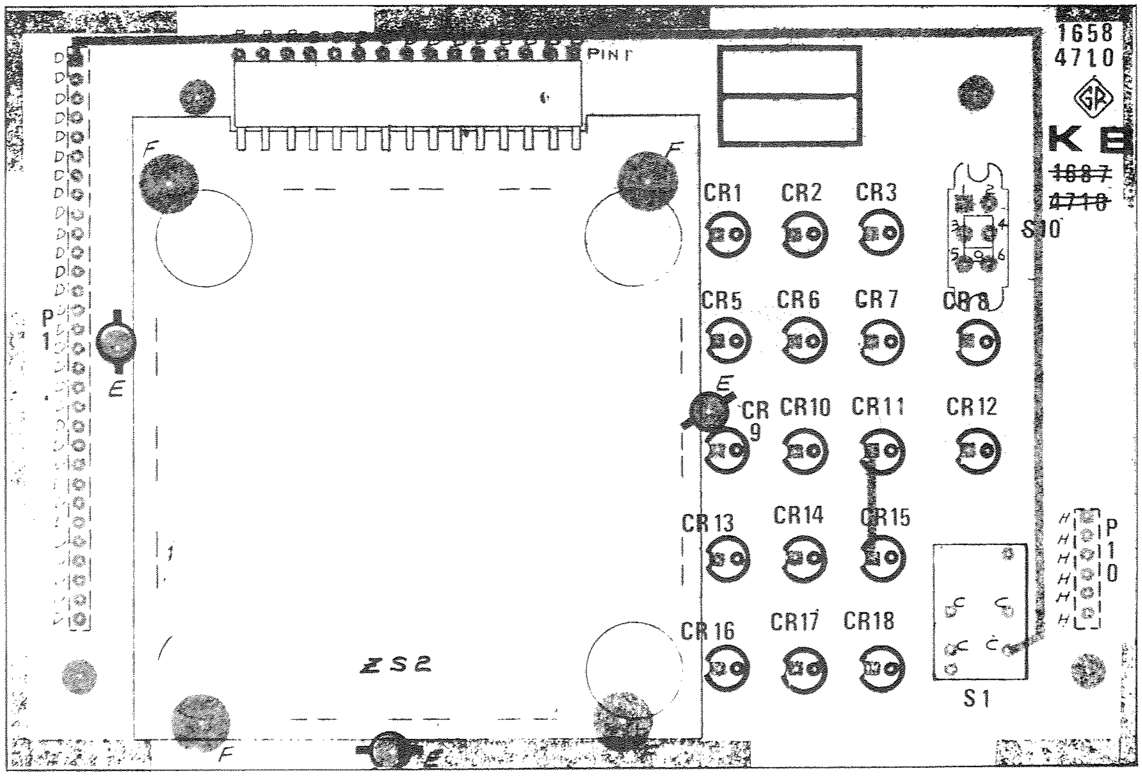



Figure 6-13. Keyboard (KB) circuit board, 1658-4710, layout.

## ELECTRICAL PARTS LIST

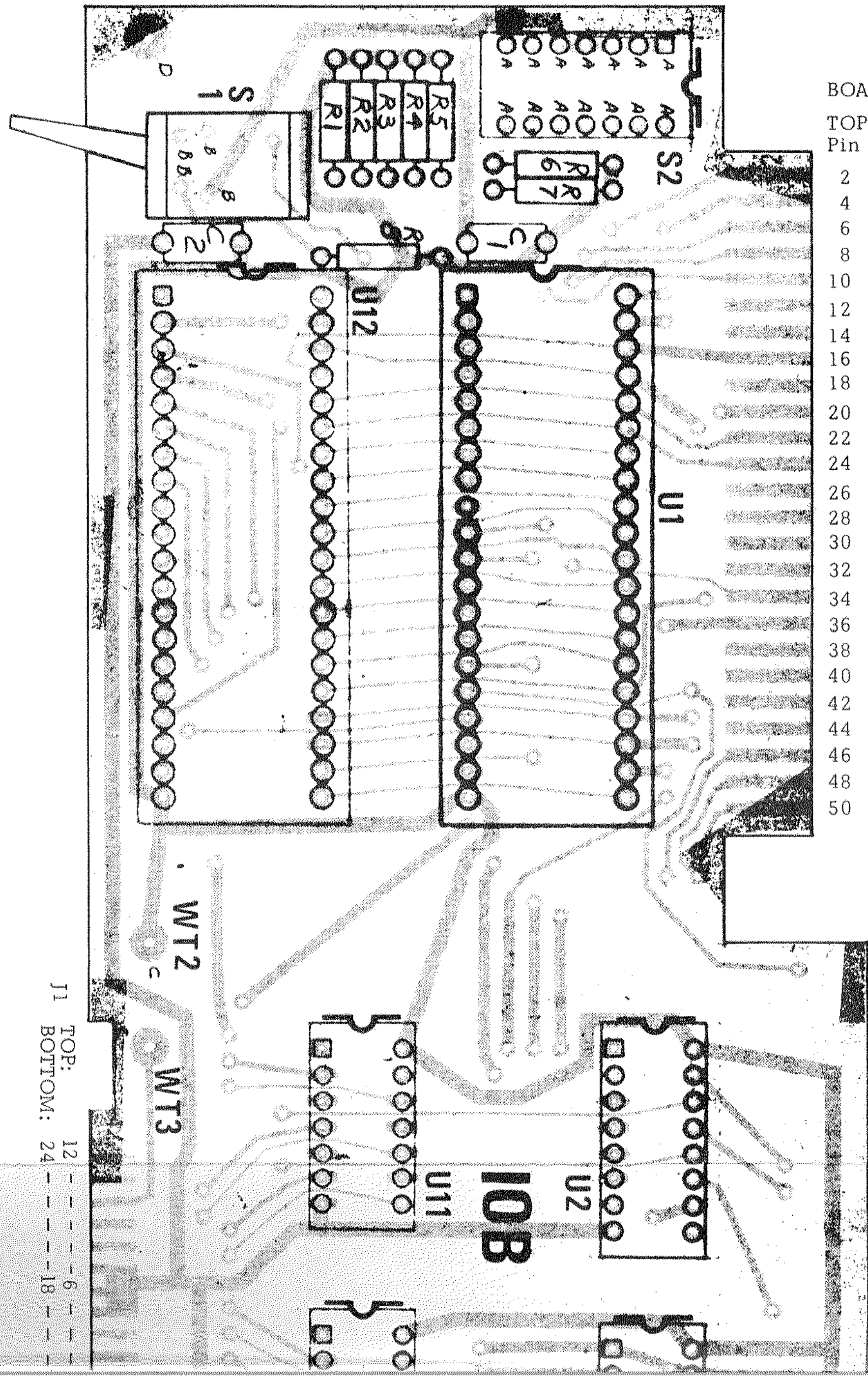
INTERFACE OPTION ASM P/N 1658-4020

| REFDES | | DESCRIPTION | PART NO. | FMC | MFGR PART NUMBER |
|---|---|---|---|---|---|
| J | 1 | RECPT MICRO RIB 24 CONT | 4230-4024 | 02660 | 57-40240 |
| J | 2 | CONN PNL 24FEM CONT MICRO RIB | 4230-4824 | 02660 | 57-20240-2 |

NOTE: THIS ASSEMBLY INCLUDES THE 1658-4720 CIRCUIT BOARD; SEE BELOW.

INTERFACE OPTION PC BOARD 108 P/N 1658-4720

| REFDES | | DESCRIPTION | PART NO. | FMC | MFGR PART NUMBER |
|---|---|---|---|---|---|
| C | 1 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 2 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 3 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 4 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| C | 5 | CAP CER MONO 0.1UF 20PCT 50VGP | 4400-2050 | 72982 | 8131-M050-651-104M |
| CR | 1 | DIODE RECTIFIER 1N4003 | 6081-1001 | 14433 | 1N4003 |
| R | 1 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 2 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 3 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 4 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 5 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 6 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 7 | RES COMP 10 K 5PCT 1/4W | 6099-3105 | 81349 | RCR07G103J |
| R | 8 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| R | 9 | RES COMP 3.3 K 5PCT 1/4W | 6099-2335 | 81349 | RCR07G332J |
| S | 2 | SWITCH TOGGLE 6STA SPST PC | 7910-2030 | 31514 | 1006-692 |
| S | 12 | SWITCH TOGGLE PC 2CKT STEADY | 7910-1920 | 05402 | T8001 |
| U | 1 | ICD MC6820A 40D PIA FOR MPU | 5431-2450 | 04713 | MC6820A |
| U | 2 | ICD DM8097 | 5431-9685 | 12040 | DM8097 |
| U | 3 | ICD DM8097 | 5431-9685 | 12040 | DM8097 |
| U | 4 | IC DIGITAL SN74LS04N | 5431-8604 | 01295 | SN74LS04N |
| U | 5 | ICD MC3441 | 5431-9684 | 04713 | MC3441 |
| U | 6 | ICD MC3441 | 5431-9684 | 04713 | MC3441 |
| U | 7 | ICD MC3440 | 5431-9686 | 04713 | MC3440 |
| U | 8 | ICD MC3441 | 5431-9684 | 04713 | MC3441 |
| U | 9 | IC DIGITAL SN74LS02N | 5431-8602 | 01295 | SN74LS02N |
| U | 10 | ICD SN7406N 14D HX INV COL 30V | 5431-8106 | 01295 | SN7406N |
| U | 11 | ICD SN7406N 14D HX INV COL 30V | 5431-8106 | 01295 | SN7406N |
| U | 12 | ICD MC6820A 40D PIA FOR MPU | 5431-2450 | 04713 | MC6820A |

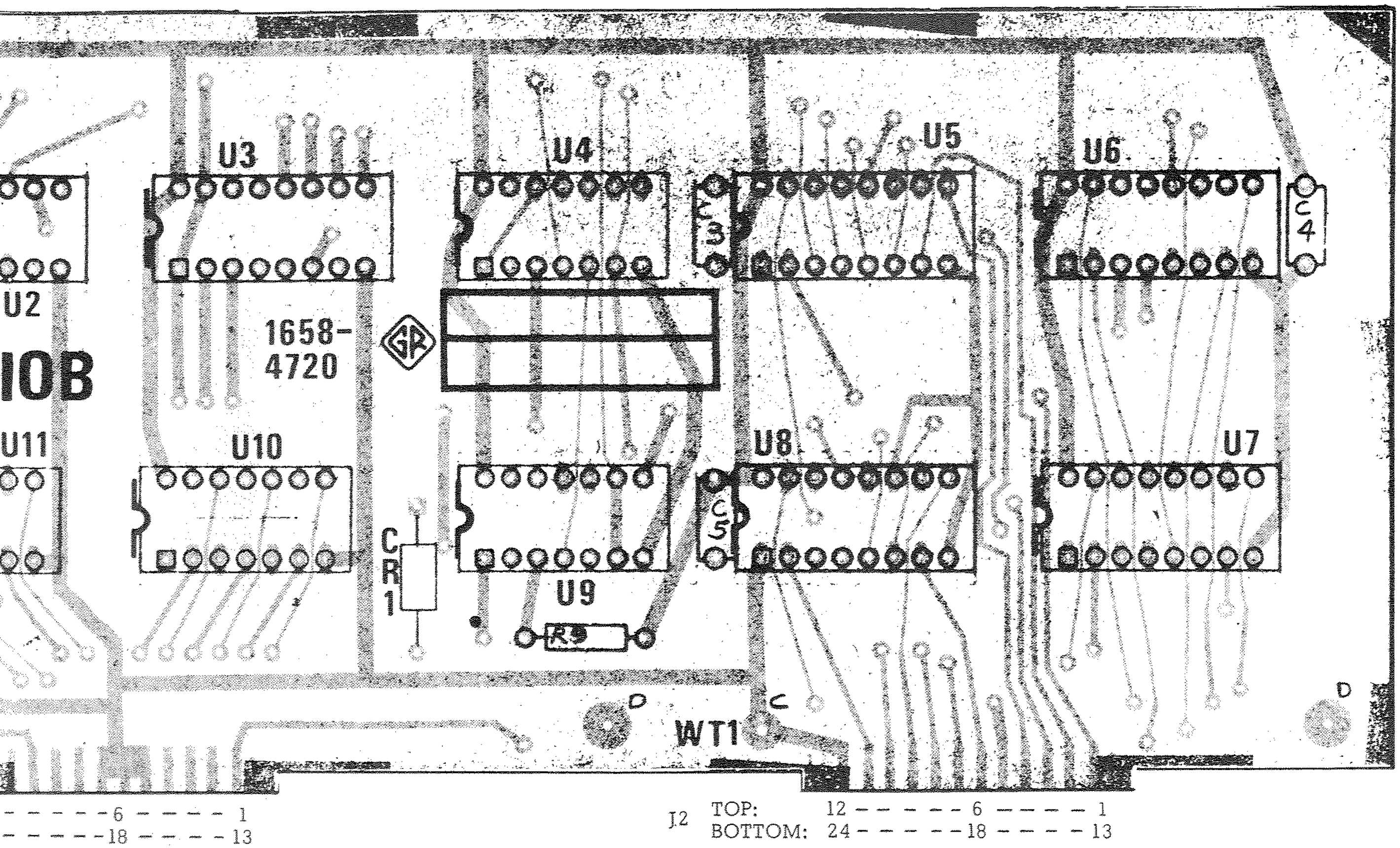



P2

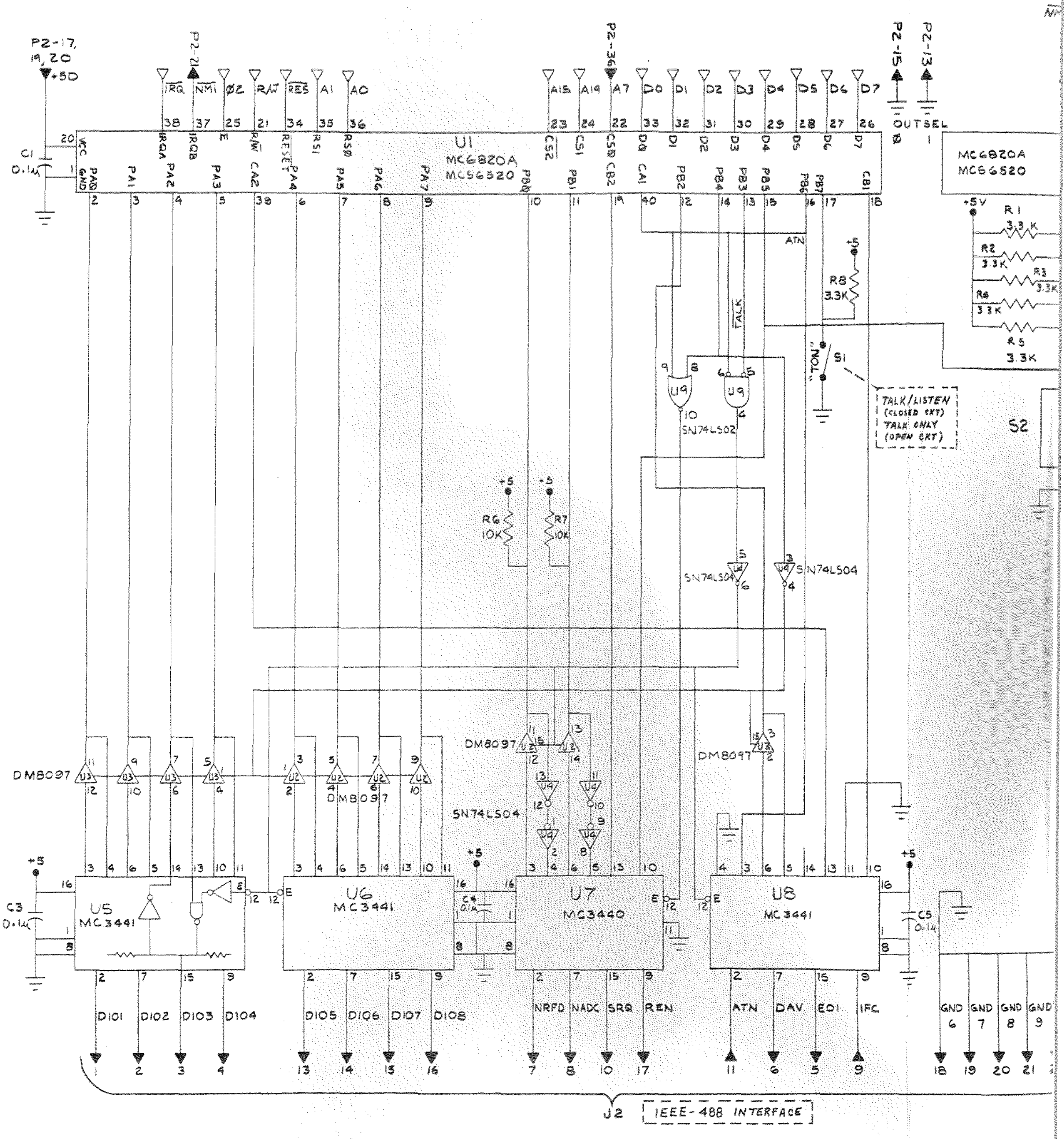
BOARD-EDGE CONNECTOR

| TOP Pin | Signal | BOTTOM Pin | Signal |
|---|---|---|---|
| 2 | $\overline{RES}$ | 1 | GND |
| 4 | R/$\overline{W}$ | 3 | GND |
| 6 | DØ | 5 | GND |
| 8 | D1 | 7 | GND |
| 10 | D2 | 9 | GND |
| 12 | | 11 | GND |
| 14 | | 13 | GND |
| 16 | $\overline{IRQ}$ | 15 | GND |
| 18 | | 17 | +5D |
| 20 | +5D | 19 | +5D |
| 22 | AØ | 21 | $\overline{NMI}$ |
| 24 | A1 | 23 | |
| 26 | | 25 | |
| 28 | | 27 | |
| 30 | | 29 | |
| 32 | | 31 | |
| 34 | A6 | 33 | Ø2 |
| 36 | A7 | 35 | |
| 38 | | 37 | |
| 40 | | 39 | |
| 42 | | 41 | |
| 44 | | 43 | A14 |
| 46 | D3 | 45 | A15 |
| 48 | D4 | 47 | D7 |
| 50 | D5 | 49 | D6 |

Figure 6-15. Interface option (IOB) bo




erface option (IOB) board, 1658-4720, layout.



U1
MC6820A
MCS6520
MC6820A
MC66520
P2-17, 19, 20
+5D
P2-21
P2-36
P2-15
P2-13
OUTSEL
C1 0.1µ
R1 3.3K
R2 3.3K
R3 3.3K
R4 3.3K
R5 3.3K
R6 10K
R7 10K
R8 3.3K
ATN
TALK
"TON"
S1
TALK/LISTEN (CLOSED CKT) TALK ONLY (OPEN CKT)
S2
U9
SN74LS02
SN74LS04
DM8097
U5 MC3441
U6 MC3441
U7 MC3440
U8 MC3441
C3 0.1µ
C4 0.1µ
C5 0.1µ
DIO1
DIO2
DIO3
DIO4
DIO5
DIO6
DIO7
DIO8
NRFD
NADC
SRQ
REN
ATN
DAV
EOI
IFC
GND 6
GND 7
GND 8
GND 9
J2
IEEE-488 INTERFACE

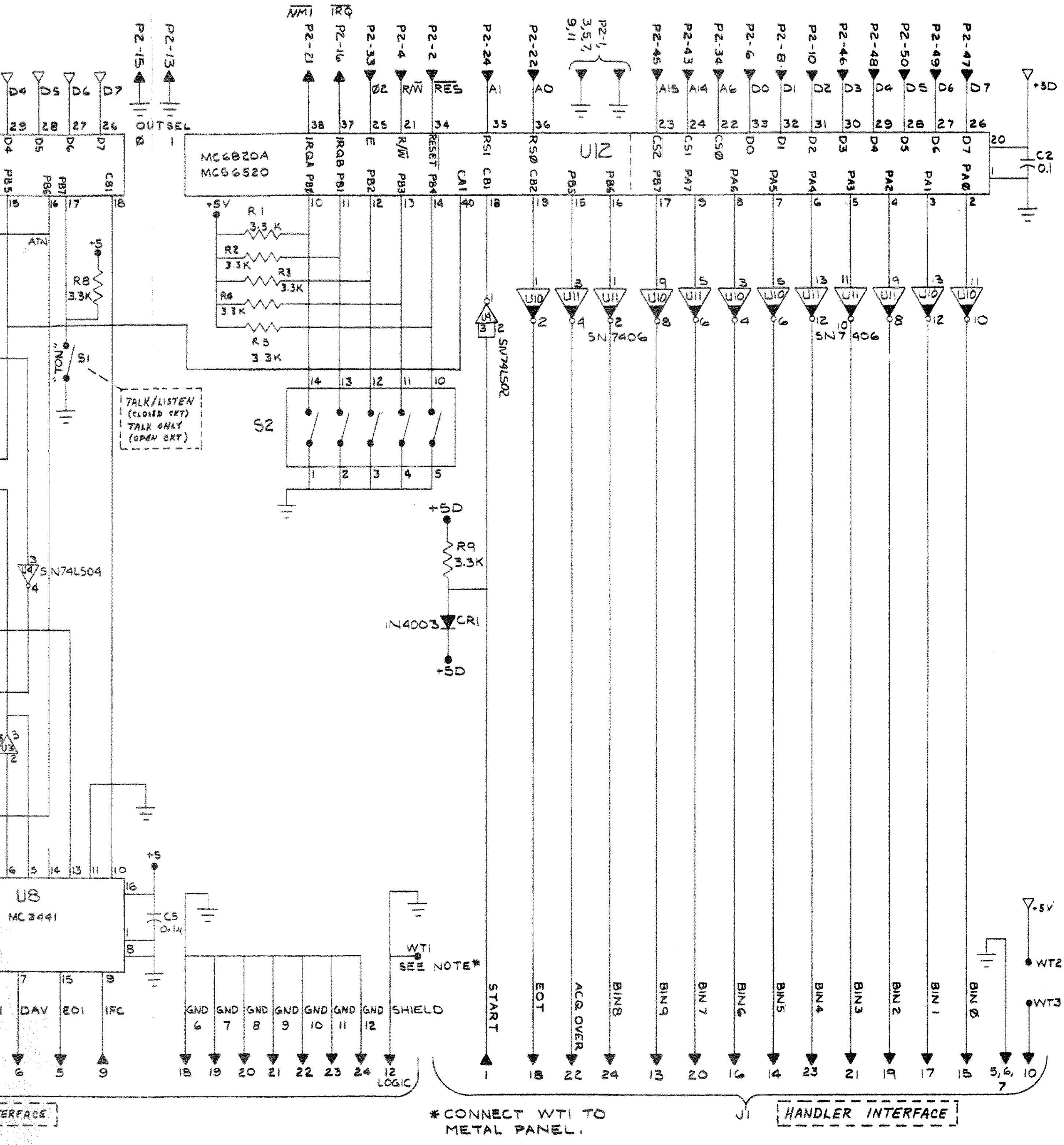



Figure 6-16. Interface option (IOB) board, 1658-4720, diagram.

## ELECTRICAL PARTS LIST

POWER SUPPLY ASM V    P/N 1658-4000

| REFDES | | DESCRIPTION | PART NO. | FMC | MFGR PART NUMBER |
|---|---|---|---|---|---|
| C | 1 | CAP ALUM 18000 UF 20V | 4450-6231 | 24655 | 4450-6231 |
| C | 2 | CAP ALUM 4500 UF 40V | 4450-6221 | 90201 | CGS 4500UF 40V |
| C | 5 | CAP TANT 1.0 UF 20PCT 35V | 4450-4300 | 56289 | 150D105X0035A2 |
| C | 6 | CAP TANT 1.0 UF 20PCT 35V | 4450-4300 | 56289 | 150D105X0035A2 |
| CR | 1 | DIODE BRIDGE | 6081-1032 | 24655 | 6081-1032 |
| CR | 2 | DIODE BRIDGE | 6081-1032 | 24655 | 6081-1032 |
| CR | 3 | DIODE BRIDGE | 6081-1032 | 24655 | 6081-1032 |
| CR | 4 | DIODE BRIDGE | 6081-1032 | 24655 | 6081-1032 |
| F | 1 | FUSE SLO-BLOW 1/2A 250V | 5330-1000 | 75915 | 313 .500 |
| J | 101 | RECEPTACLE POWER UL STD 15A250V | 4240-0250 | 82389 | EAC-302 |
| S | 2 | SWITCH SLIDE 2 POS DPDT STEADY | 7910-0832 | 82389 | 11A-1266 |
| T | 1 | TRANSFORMER POWER | 0485-4095 | 24655 | 0485-4095 |
| U | 1 | IC LINEAR LM323 | 5432-1048 | 12040 | LM323K |

NOTE: THIS ASSEMBLY INCLUDES THE 1657-4720 BOARD; SEE BELOW.

POWER SUPPLY PC BOARD    P/N 1657-4720

| REFDES | | DESCRIPTION | PART NO. | FMC | MFGR PART NUMBER |
|---|---|---|---|---|---|
| C | 3 | CAP TANT 1.0 UF 20PCT 35V | 4450-4300 | 56289 | 150D105X0035A2 |
| C | 4 | CAP TANT 1.0 UF 20PCT 35V | 4450-4300 | 56289 | 150D105X0035A2 |
| C | 7 | CAP TANT 1.0 UF 20PCT 35V | 4450-4300 | 56289 | 150D105X0035A2 |
| C | 8 | CAP CER MONO .01 UF 10PCT 50V | 4400-6351 | 72982 | 8121-M050-W5R-103K |
| C | 9 | CAP CER MONO .01 UF 10PCT 50V | 4400-6351 | 72982 | 8121-M050-W5R-103K |
| C | 10 | CAP CER MONO .01 UF 10PCT 50V | 4400-6351 | 72982 | 8121-M050-W5R-103K |
| C | 11 | CAP TANT 1.0 UF 20PCT 35V | 4450-4300 | 56289 | 150D105X0035A2 |
| CR | 5 | DIODE RECTIFIER 1N4003 | 6081-1001 | 14433 | 1N4003 |
| CR | 6 | DIODE RECTIFIER 1N4003 | 6081-1001 | 14433 | 1N4003 |
| CR | 7 | DIODE RECTIFIER 1N4003 | 6081-1001 | 14433 | 1N4003 |
| CR | 8 | DIODE RECTIFIER 1N4003 | 6081-1001 | 14433 | 1N4003 |
| CR | 9 | RECT 1N4140 100PIV 3A SI A1XM | 6081-1014 | 14433 | 1N4140 |
| CR | 10 | RECT 1N4140 100PIV 3A SI A1XM | 6081-1014 | 14433 | 1N4140 |
| S | 1 | SWITCH PUSH PUSH AC UL 6A | 7870-1570 | 24655 | 7870-1570 |
| U | 2 | IC LINEAR LM342P-5 | 5432-1058 | 12040 | LM342P-5 |
| U | 3 | IC LINEAR LM320MP-8 | 5432-1059 | 12040 | LM320MP-8 |

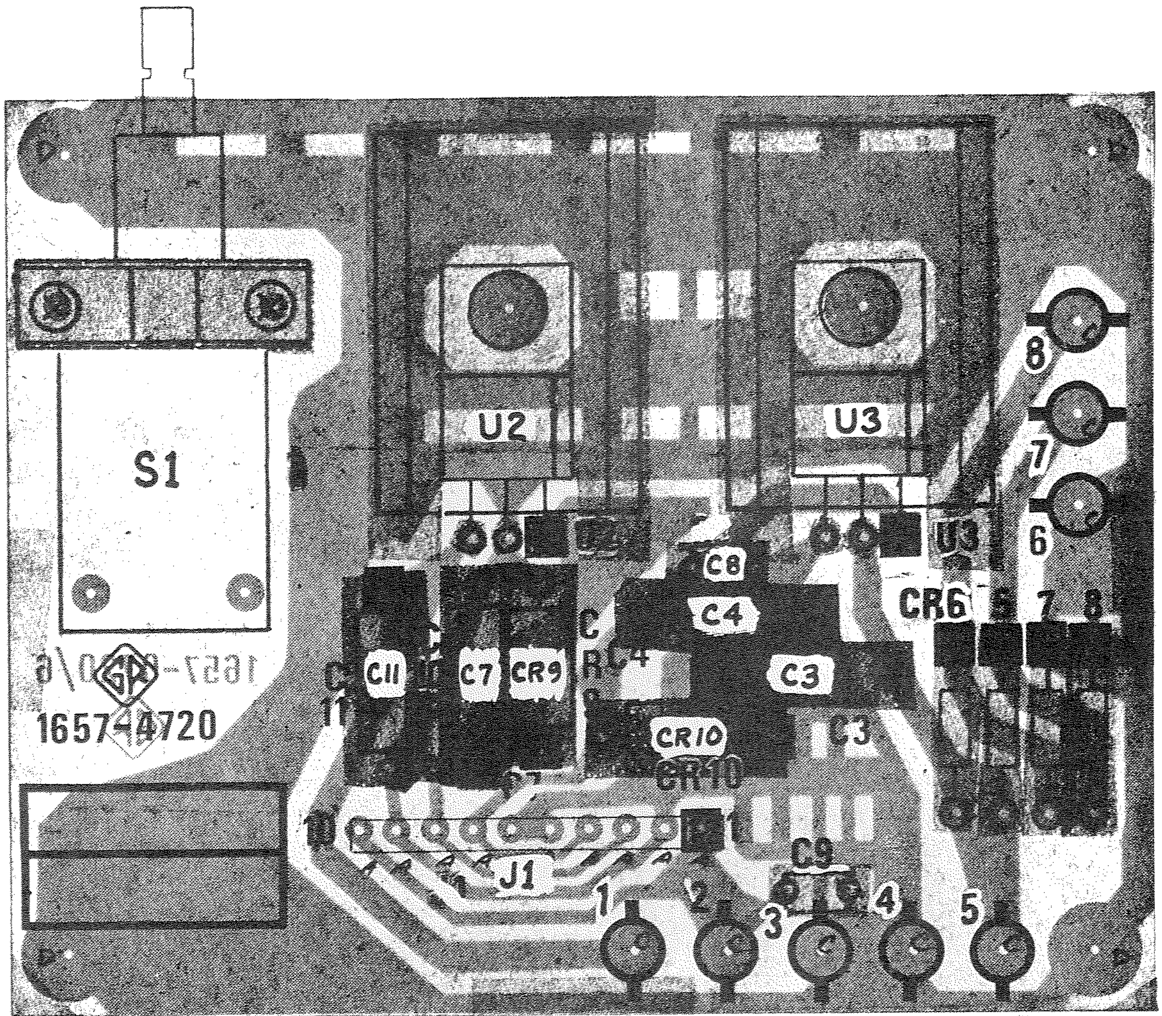
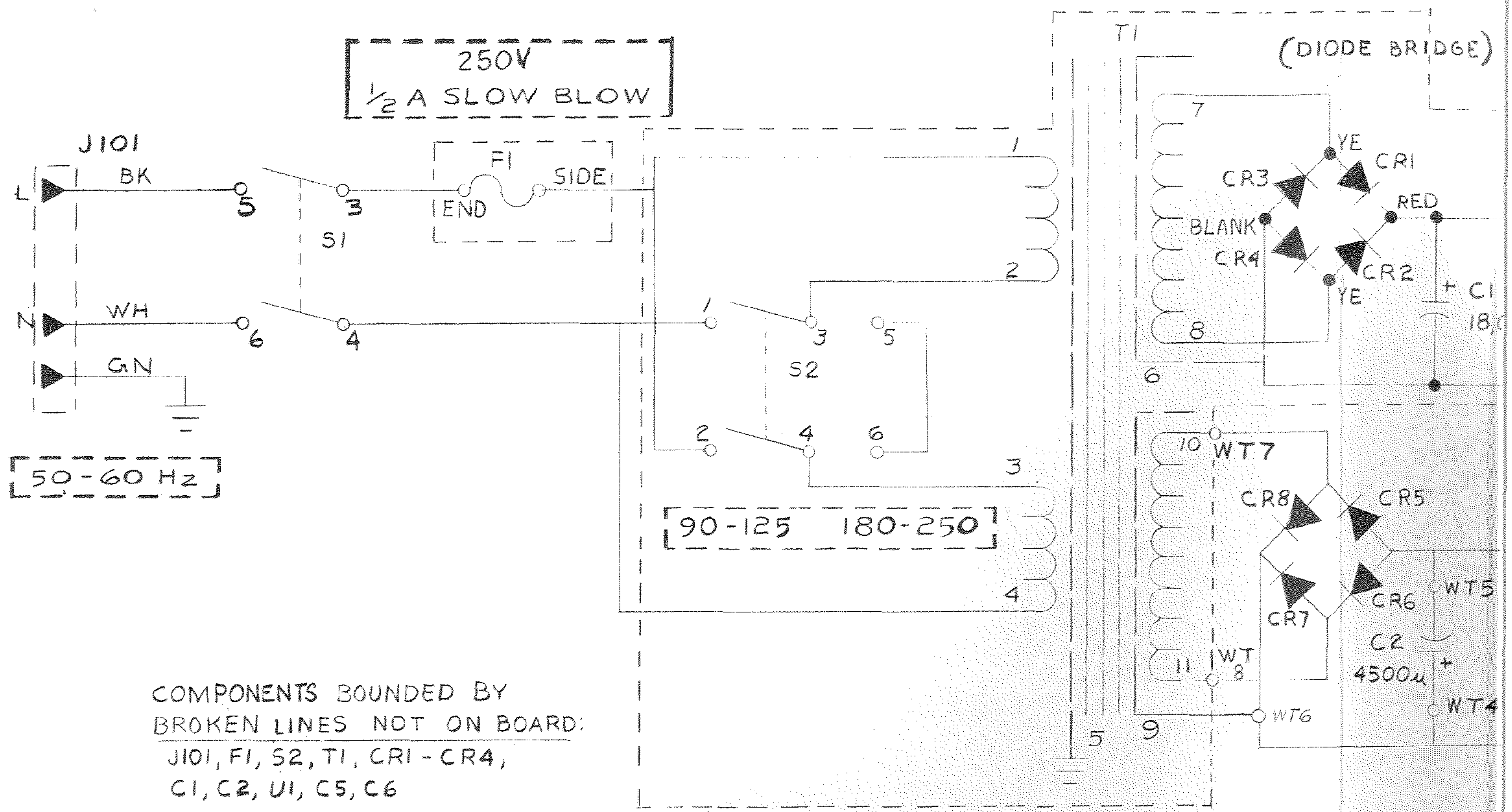
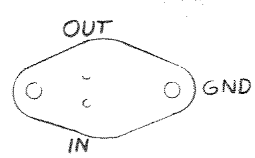



Figure 6-17. Power supply (V) board, 1657-4720, layout.




COMPONENTS BOUNDED BY BROKEN LINES NOT ON BOARD:
J101, F1, S2, T1, CR1 - CR4, C1, C2, U1, C5, C6

U1
LM323K




BOTTOM VIEW

RESISTANCE IS IN OHMS, $K=10^3$, $M=10^6$
CAPACITANCE IS IN FARADS, $\mu=10^{-6}$, $p=10^{-12}$
VOLTAGES EXPLAINED IN INSTRUCTION BOOK SERVICE NOTES
=PANEL CONTROL =REAR CONTROL
=SCREWDRIVER CONTROL WT=WIRE TIE TP=TEST POINT
COMPLETE REFERENCE DESIGNATION INCLUDES SUBASSEMBLY LETTER, C-R1, B-R1, ETC.

CONNECTIONS

- OUTPUT LEAVES SUBASSEMBLY
- INPUT FROM DIFFERENT SUBASSEMBLY
- OUTPUT REMAINS ON SUBASSEMBLY
- INPUT FROM SAME SUBASSEMBLY

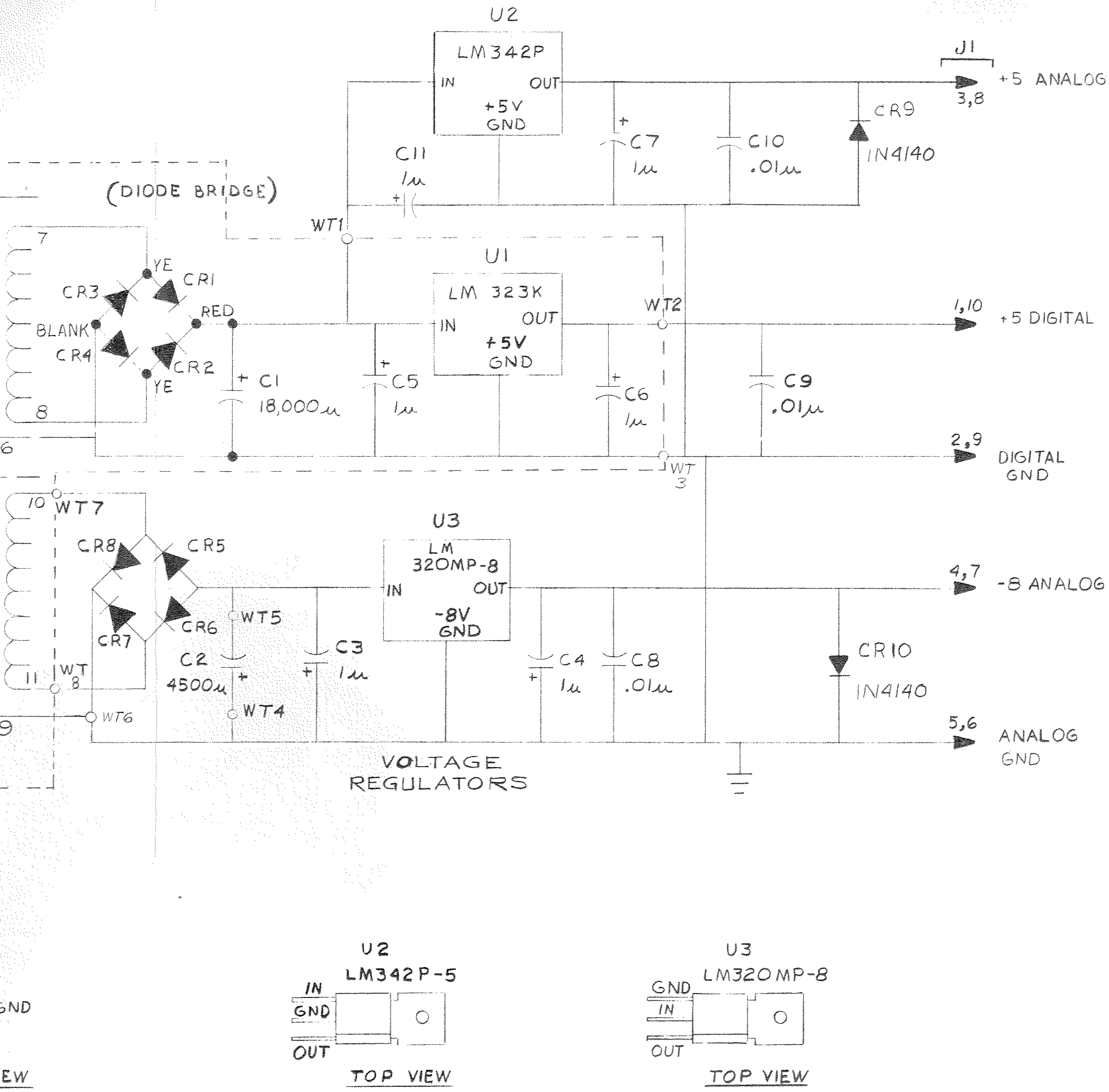



Figure 6-18. Power supply (V) assembly, 1658-4000, diagram.

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