GenRad

GR1658 RLC Digibridge®

Form 1658-0120-D

Instruction Manual

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GR 1658
RLC Digibridge®

Form 1658-0120-D

Concord, Massachusetts, U.S.A. 01742
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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): 375x112x 343 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.

Form 1658-0110-A

OPERATION REFERENCE INFORMATION

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: ◁	◁ OUT OF RANGE ▷	Overrange; ▷
better accuracy is available on a lower range.*	(both arrows lighted) WRONG PARAMETER R/Q, L/Q, or C/D.	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 mode is ENTRY.

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.

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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 1-1
1.2 GENERAL DESCRIPTION 1-1
1.3 CONTROLS, INDICATORS, AND CONNECTORS 1-1
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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.

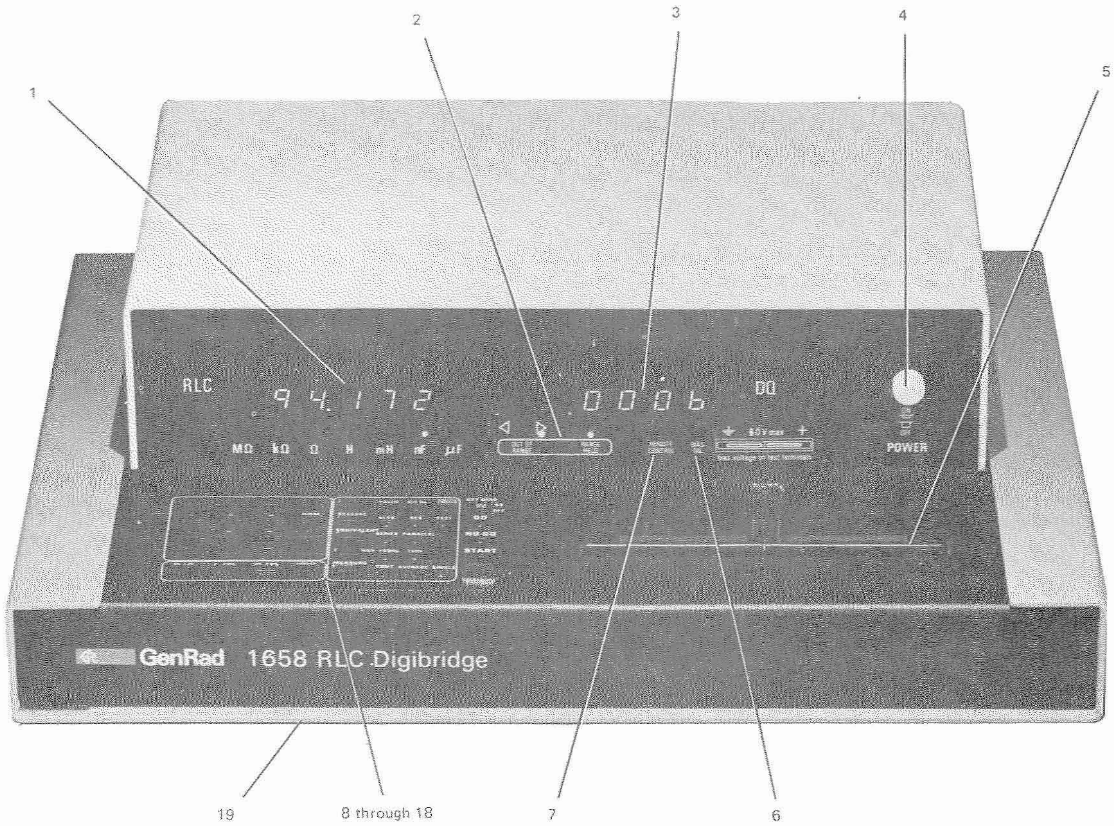
1.3 CONTROLS, INDICATORS, AND CONNECTORS.

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.)



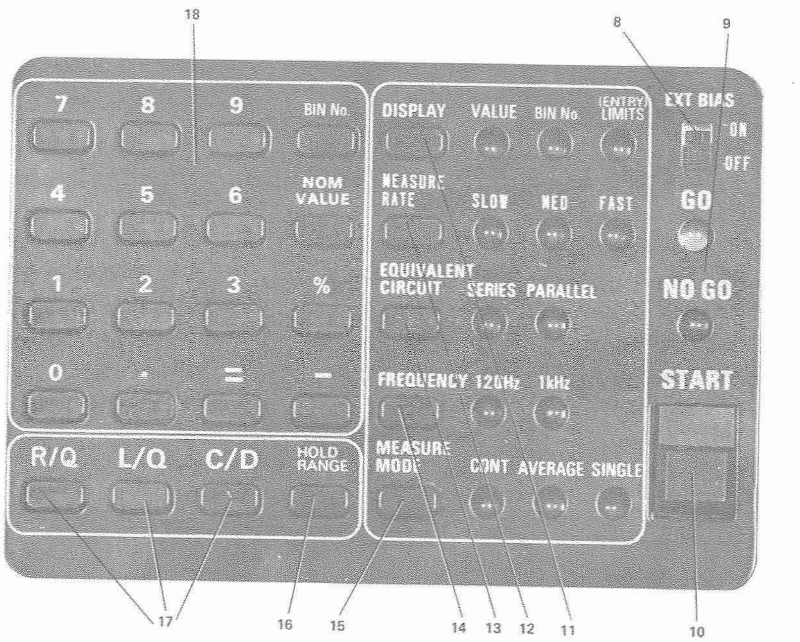


Figure 1-1. Front controls and displays. Upper, whole instrument. Lower, keyboard, detail.

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.

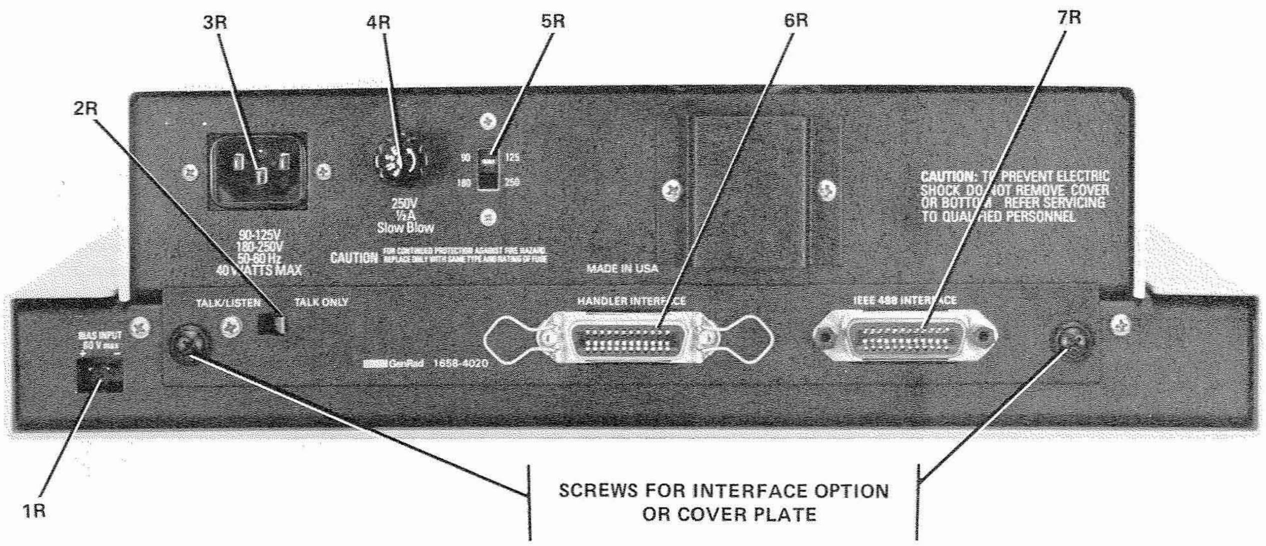


Figure 1-2. Rear controls and connectors.

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:

◁	OUT OF RANGE	▷
Underrange: better accuracy is available on a lower 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

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2.1 UNPACKING AND INSPECTION.

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

2.2 DIMENSIONS. Figure 2-1.

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.

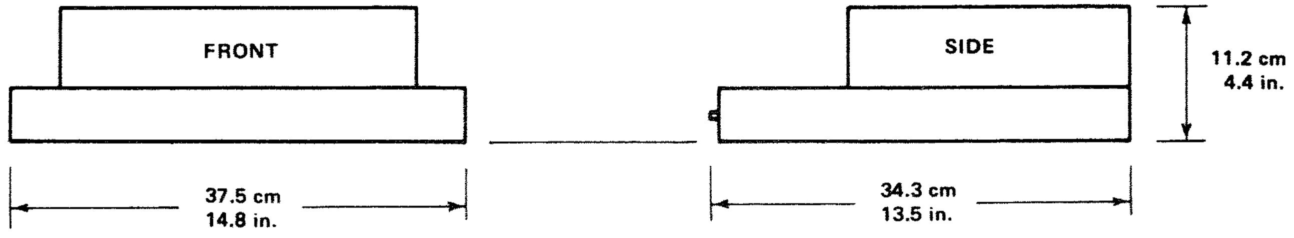

Figure 2-1. Overall dimensions

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.

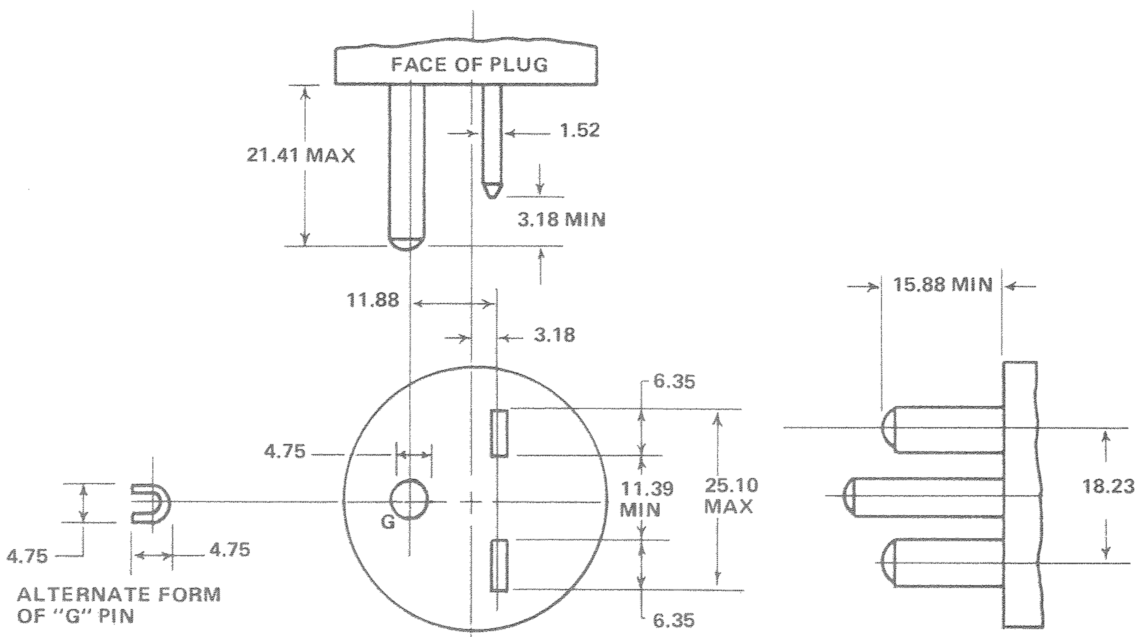

Figure 2-2 Configuration of 250-V 15-A plug. Dimensions in mm. This is listed as NEMA 6-15P. Use for example Hubbell plug number 5666.

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-μF 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-Ω 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 Ω, 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.

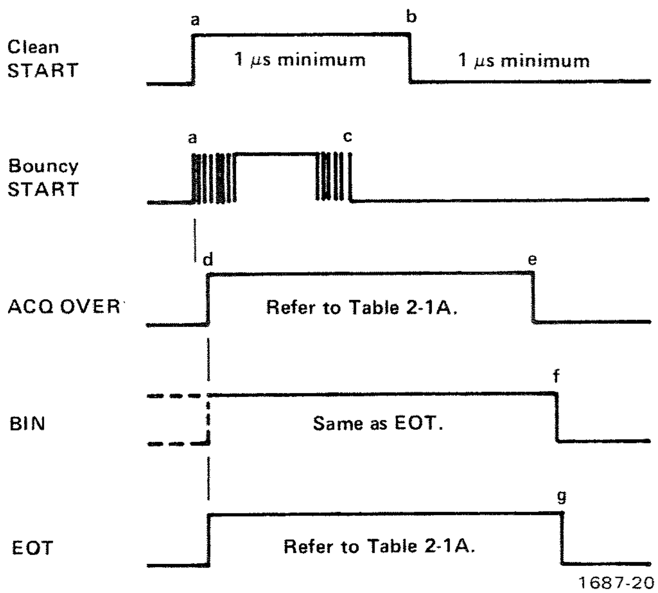

Figure 2-2A. Handler interface timing diagram. External circuitry must keep a-b > 1 μs, b-a > 1 μs, and (if START is not "debounced") a-c < 20 ms. The DUT can be disconnected after "e." The selected "BIN" line goes low at "f"; the others stay high. Refer to Table 2-1A for the values of ACQ OVER and EOT.

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

			Time from START signal to	
Test Frequency	**Line Frequency**	**Measurement Speed**	**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

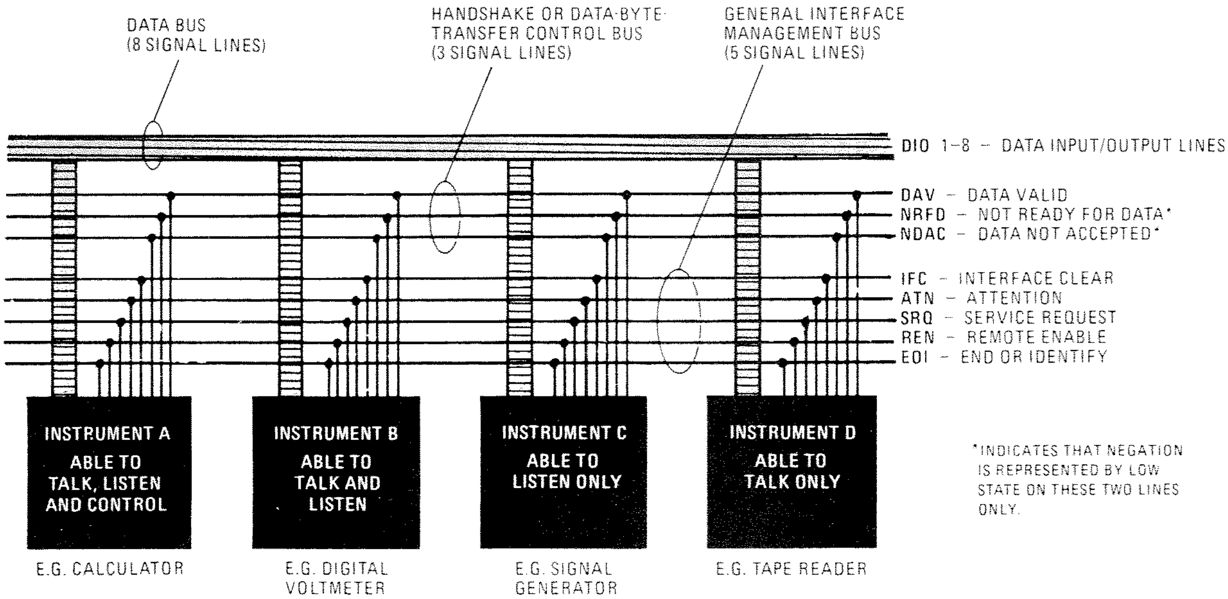

Figure 2-3. Block diagram of a generalized system interconnected by the 16-signal-line bus specified in the IEEE Standard 488. Reprinted from *Electronics,* November 14, 1974; copyright McGraw-Hill, Inc., 1974.

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 2 3 4 13 14 15 16	DI01 DI02 DI03 DI04 DI05 DI06 DI07 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.

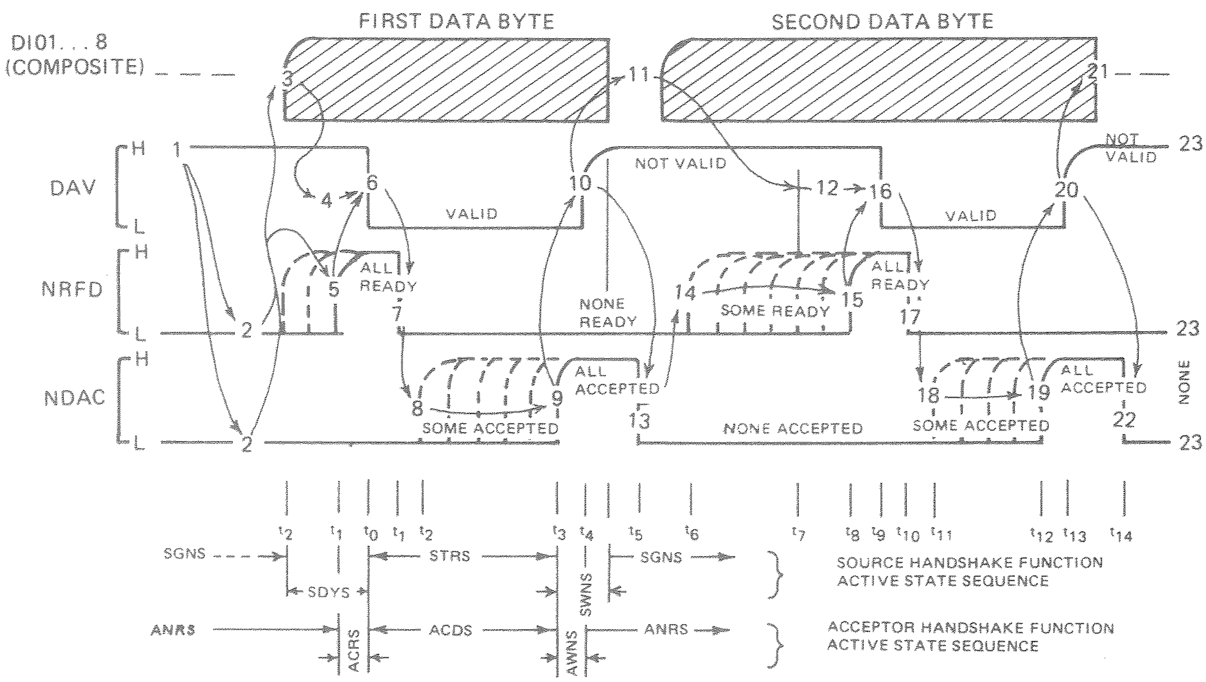

Figure 2-4. The handshake process, illustrated by timing diagrams of the pertinent signals for a system with one talker and several listeners. For details, refer to the Standard.

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

Table 2-6

DQ-VALUE DATA OUTPUT FORMAT

Character sequence	Purpose	Allowed characters	Meaning
1, 2	Format	(space)	---
3	Parameter	D	Dissipation factor
		Q	Quality factor
4 . . . 9	Format	(space)	---
10 . . . 15	Number	012345 6789. (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	---	(CR)	The customary "carriage-return" and "line-feed" characters,
17	Delimiter	(LF)	end of string.

Table 2-7

BIN-NUMBER DATA OUTPUT FORMAT

Character sequence	Purpose	Allowed characters	Meaning
1	Pass/fail	(space) F	GO (bins 1 . . . 8) NO-GO (bin 0 or 9)
2	Format	(space)	———
3 4 5	Label	B I N	The word "BIN".
6, 7	Format	(space)	———
8	Category	01234 56789	Bin number assignment.
9 10	——— Delimiter	(CR) (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

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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.

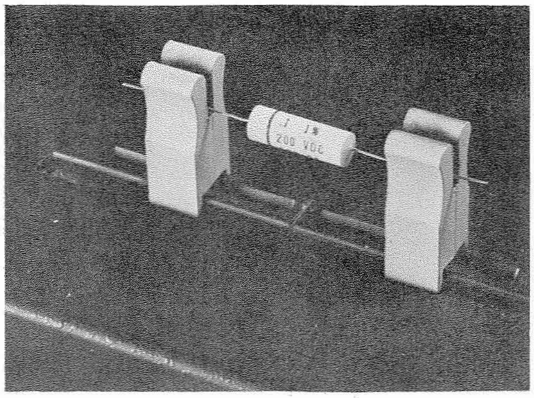

Figure 3-1A. Use of the test fixture adaptors.

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.

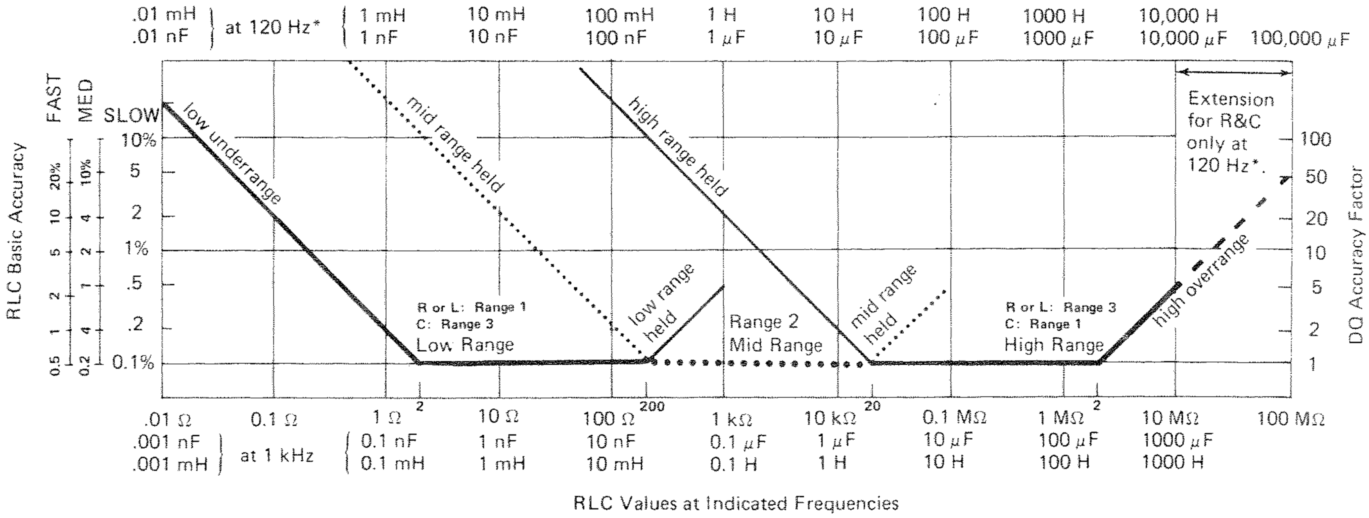

Figure 3-2. RLC basic accuracy as a percent of reading. Heavy lines (solid and dotted) represent auto-ranging (range not held). Lighter lines represent reduced-accuracy operation due to a range being held. Range 2 is dotted. Notice that L and C scales above graph are for 120 Hz (*equally valid for 100 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%.

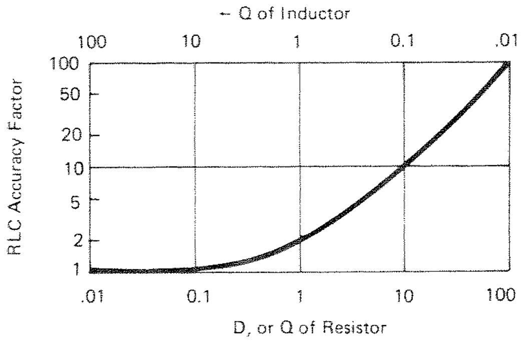

Figure 3-3. RLC accuracy factor (or cross term), as a function of D or Q. Multiply the RLC basic accuracy by this factor to obtain complete RLC accuracy. Notice that for nearly "pure" resistance or reactance, this factor is unity.

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

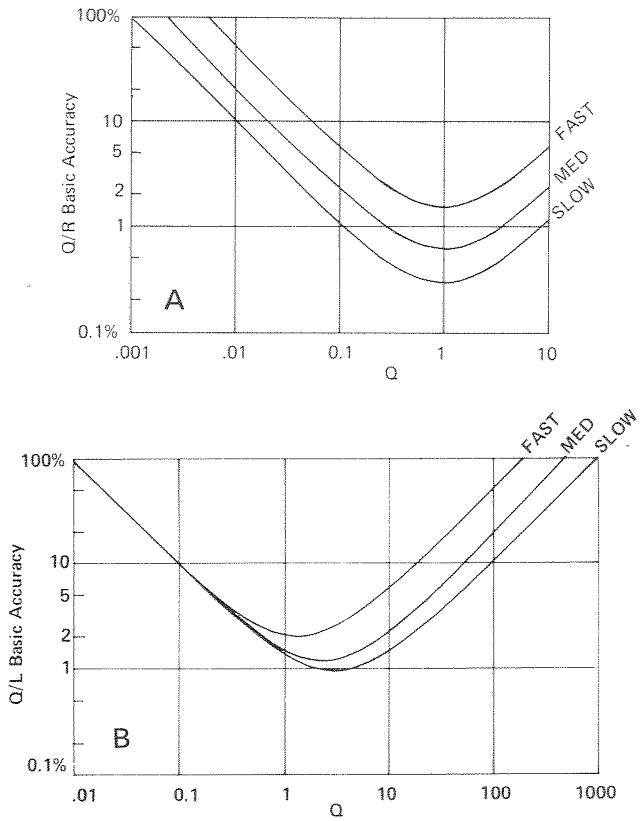

Figure 3-4. Q basic accuracy as a percent of reading. Each curve applies for one measurement rate, as labeled. For measurements on any of the range extensions, multiply by the DQ accuracy factor, shown in Figure 3-2. A. Q of resistors. B. Q of inductors.

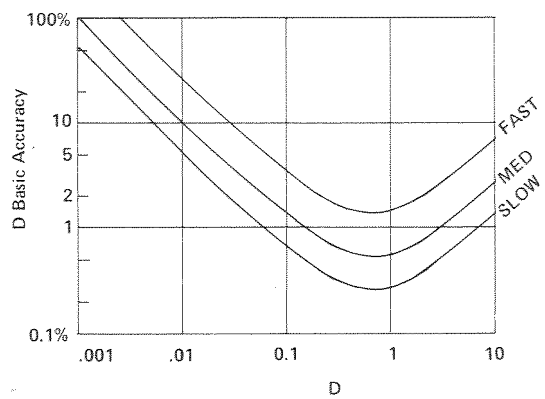

Figure 3-5. D basic accuracy as a percent of reading (for capacitors). Each curve applies to one measurement rate, as labeled. For measurements on any of the range extensions, multiply by the DQ accuracy factor, shown in Figure 3-2.

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

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

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

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

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

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

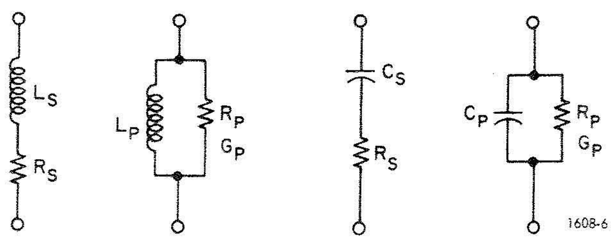

Figure 3-6. Equivalent circuits and mathematical relationships for lossy inductors and capacitors.

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 ØØØØØ, 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-μF 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 μF, 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.

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.

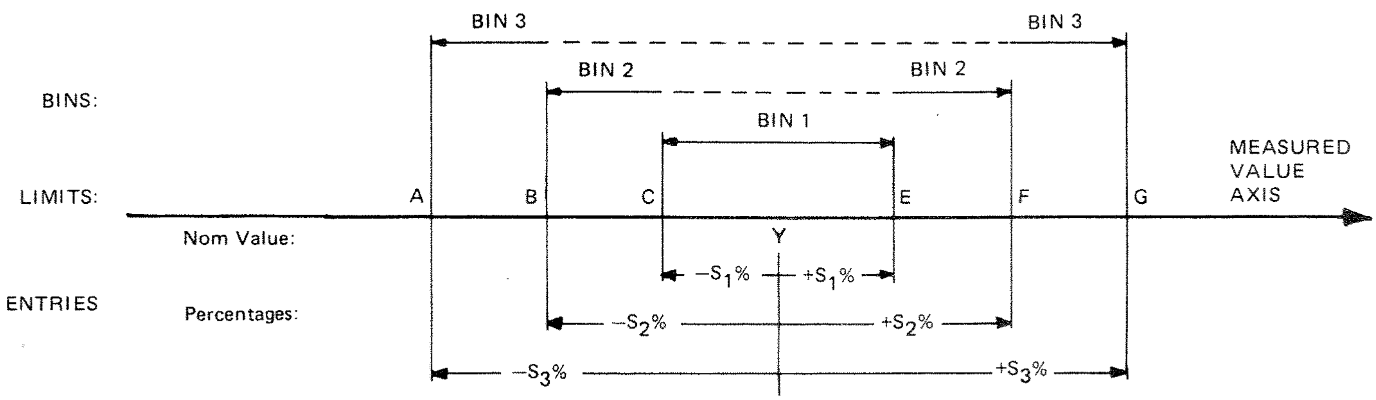

Figure 3-7. Nested limits. A single nominal value Y is used and all limit pairs are symmetrical in this basic plan.

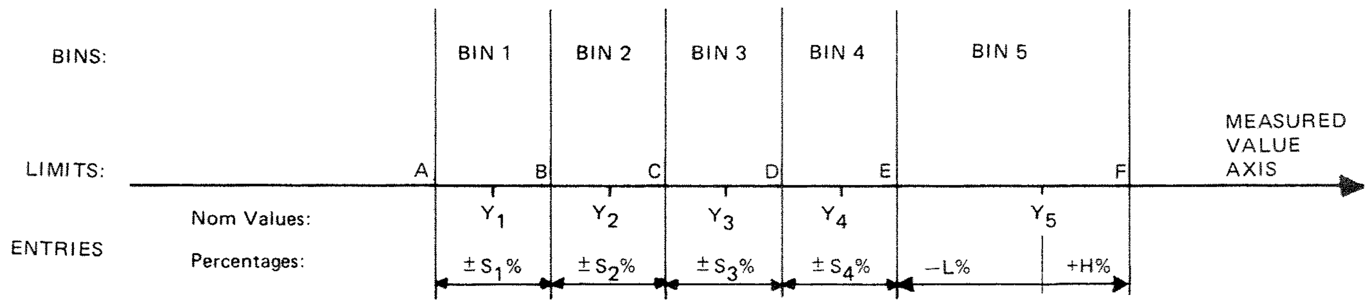

Figure 3-8. Sequential limits. A different nominal value is entered for each bin and all limit pairs are symmetrical except for the unsymmetrical pair shown for example in bin 5.

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 $Q < .001$, $R = 33\ k\Omega \pm 0.35\%$, $\pm 1\%$, $\pm 5\%$, $+7\ -9\%$.

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 μF, 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 μF.

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 μF 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 μF, 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-Ω 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
4.2 PRINCIPAL FUNCTIONS 4-2

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.

*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.

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.

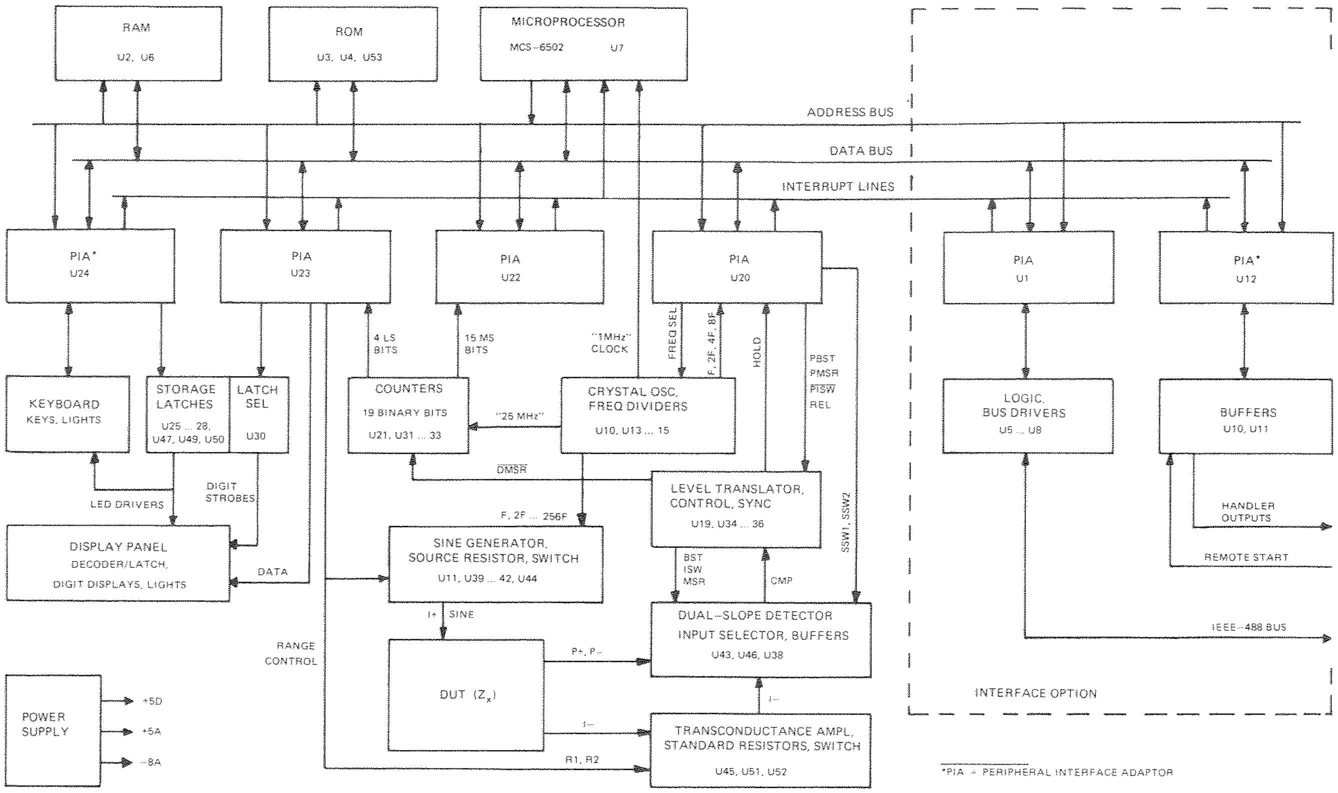

Figure 4-1. Functional block diagram.

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.

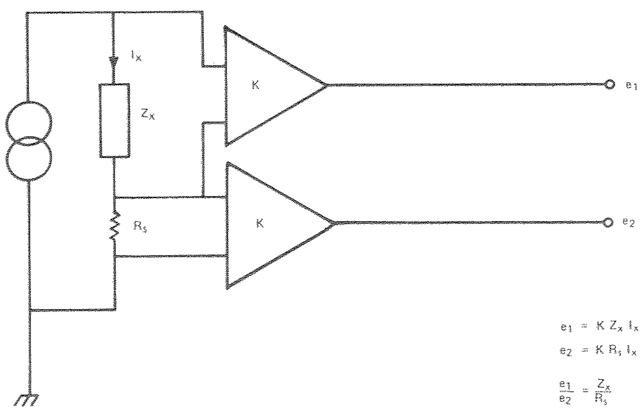

Figure 4-2. Elementary measurement circuit.

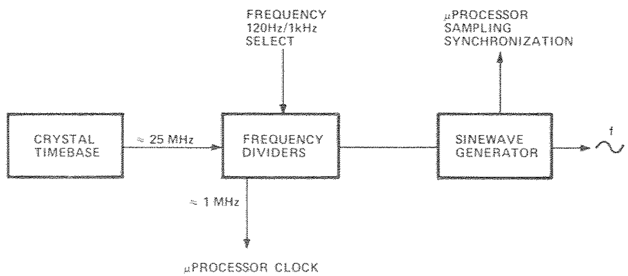

Figure 4-3. Frequency and timing source. A push-button determines the frequency select function. Several clocks and synchronizing pulses as well as the measurement signal f are derived from the accurate time-base signal.

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.

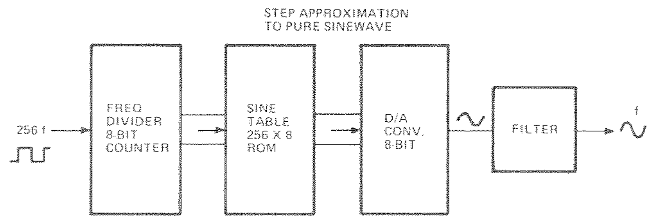

Figure 4-4. Sine wave generator. Given a square wave at 256 f, from preceding dividers, this generator uses a ROM containing the mathematical sine function to form a finely stepped approximation to a sine wave at frequency f. A filter provides smoothing.

Service and Maintenance—Section 5

5.1 CUSTOMER SERVICE 5-1
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5 7 PERIODIC MAINTENANCE 5-11
5.8 TROUBLE ANALYSIS 5-13

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	0.9978 to 1.0022 Ω
10.00 Ω	1 kHz	SERIES	SLOW	.01	0.1	09.989 to 10.011 Ω
10.00 Ω	1 kHz	SERIES	MEDIUM	.01	0.2	09.979 to 10.021 Ω
10.00 Ω	1 kHz	SERIES	FAST	.01	0.5	09.949 to 10.051 Ω
100.0 Ω	1 kHz	SERIES	SLOW	-.01, +.02	0.1	099.89 to 100.12 Ω
100.0 Ω	1 kHz	SERIES	MEDIUM	-.01, +.02	0.2	099.79 to 100.22 Ω
100.0 Ω	1 kHz	SERIES	FAST	-.01, +.02	0.5	099.49 to 100.52 Ω
1.000 kΩ	1 kHz	SERIES	SLOW	.01	0.1	0.9989 to 1.0011 kΩ
1.000 kΩ	1 kHz	SERIES	MEDIUM	.01	0.2	0.9979 to 1.0021 kΩ
1.000 kΩ	1 kHz	SERIES	FAST	.01	0.5	0.9949 to 1.0051 kΩ
10.00 kΩ	1 kHz	PARALLEL	SLOW	.01	0.1	09.989 to 10.011 kΩ
10.00 kΩ	1 kHz	PARALLEL	MEDIUM	.01	0.2	09.979 to 10.021 kΩ
10.00 kΩ	1 kHz	PARALLEL	FAST	.01	0.5	09.949 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	0.9989 to 1.0011 MΩ
1.000 MΩ	120 Hz†	PARALLEL	SLOW	.01	0.1	0.9989 to 1.0011 MΩ
1.000 MΩ	1 kHz	PARALLEL	MEDIUM	.01	0.2	0.9979 to 1.0021 MΩ
1.000 MΩ	120 Hz†	PARALLEL	MEDIUM	.01	0.2	0.9979 to 1.0021 MΩ
1.000 MΩ	120 Hz†	PARALLEL	FAST	.01	0.5	0.9949 to 1.0051 MΩ
1.000 MΩ	1 kHz	PARALLEL	FAST	.01	0.5	0.9949 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 (μF)	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-μF 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 μF 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 μF.

d. Remove the 1-μF 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 μF); 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 μF.

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 μF. Calculate the difference D2 = (1.0000 μF) – displayed measurement. Units of D2 are μF. 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 μF. In step f, the nominal is 1.0000, the display is 1.0024; then D2 = –.0024 μF. The factor K is therefore –.0018 (no units required).

h. Reset the capacitance-standard dial to:
CAPACITANCE – 10 μF.

Read the RLC display and correct it by adding 10K. (For example, if display is 10.023 μF, corrected measurement [for K = –.0018] is 10.005 μF.) 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 μF.

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.

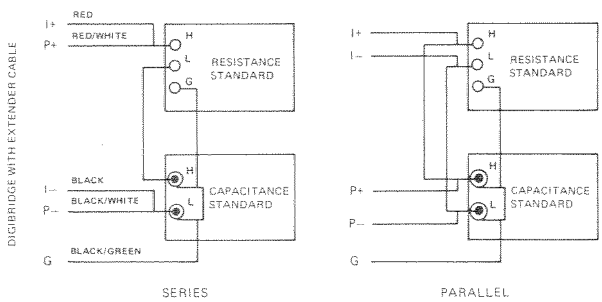


Figure 5-1. Series and parallel connections of standards for D accuracy checks.

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

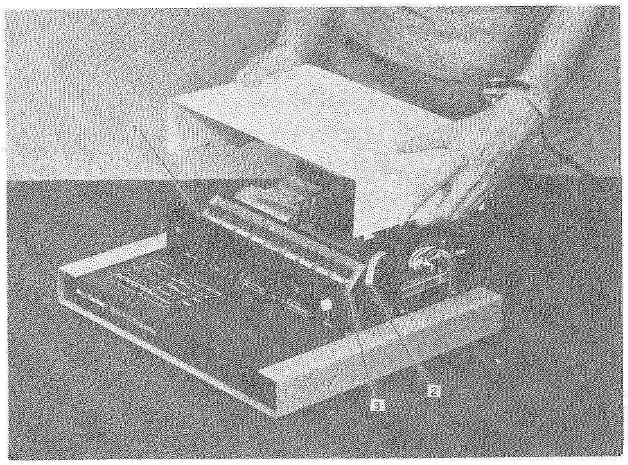


Figure 5-2. Removal of top cover. Items 1 and 3 are screws that hold the display board. Item 2 is ribbon cable 1657-0200 that connects power supply to main board.

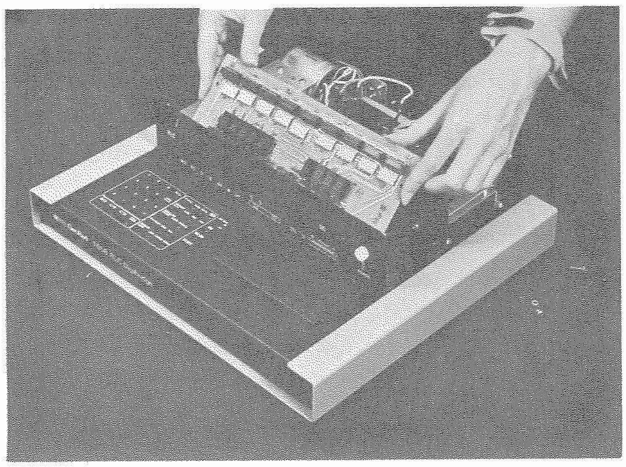


Figure 5-3. Removal of the display board.

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.

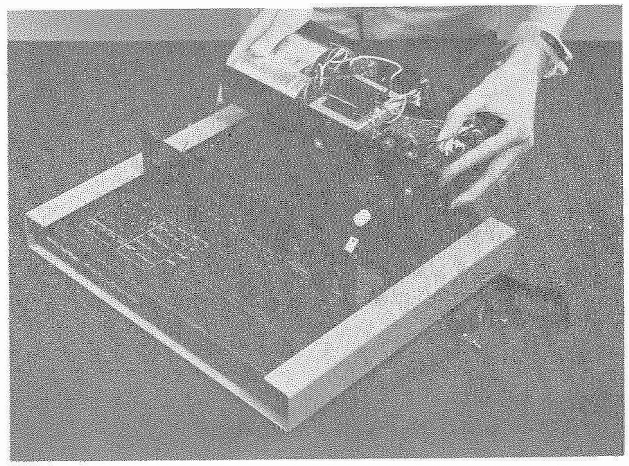


Figure 5-4. Removal of the power supply. The ribbon cable must be disconnected first. The display board can be left in place, but has been removed in this picture.

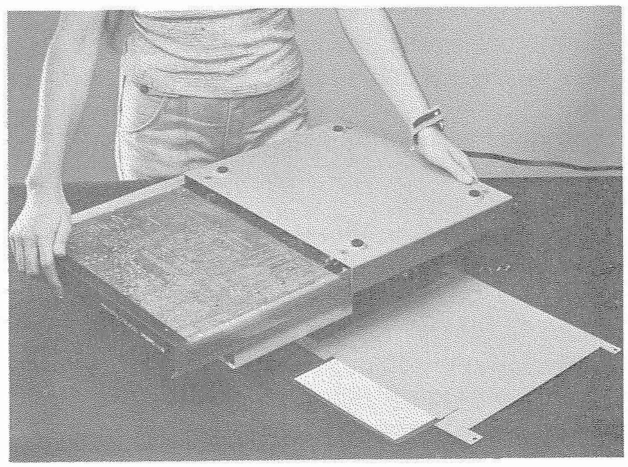


Figure 5-5. Removal of the bottom shell. The top cover has been temporarily installed as a support.

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

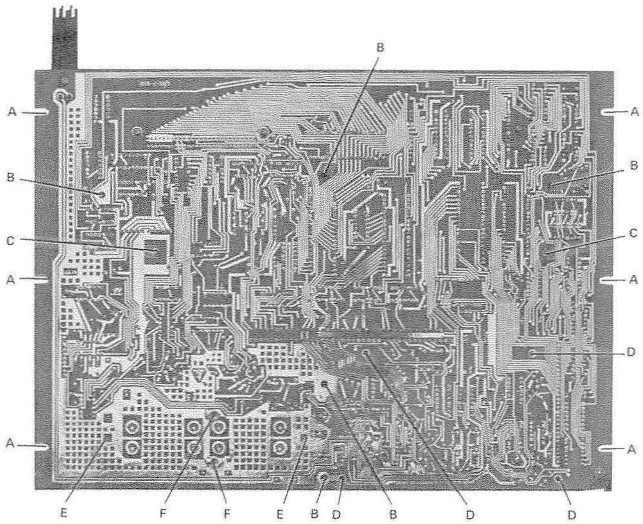


Figure 5-6. Locations of screws on the main board, bottom view. Screws at A and B hold the board to the chassis. Screws at C hold brackets for display board; D, the keyboard module; E and F, the test fixture guide block. All except F are accessed from this side.

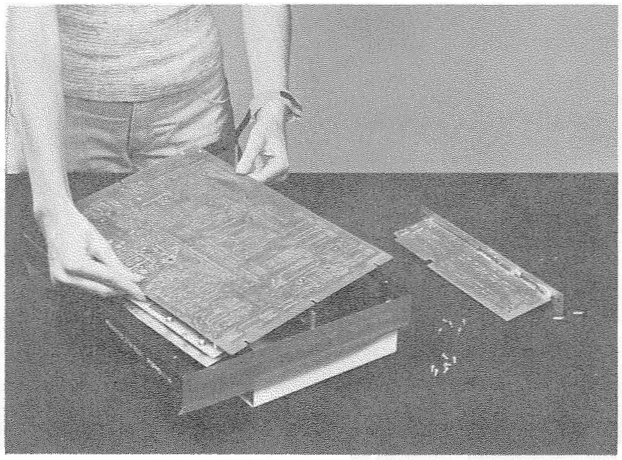


Figure 5-7. Removal of the MB board. The ribbon cable must be disconnected first. Prior removal of the display board also is highly recommended. Because the board is partially enclosed by the main chassis, some motions are necessary: toward front, disengaging bias connector, tilting, turning as shown,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

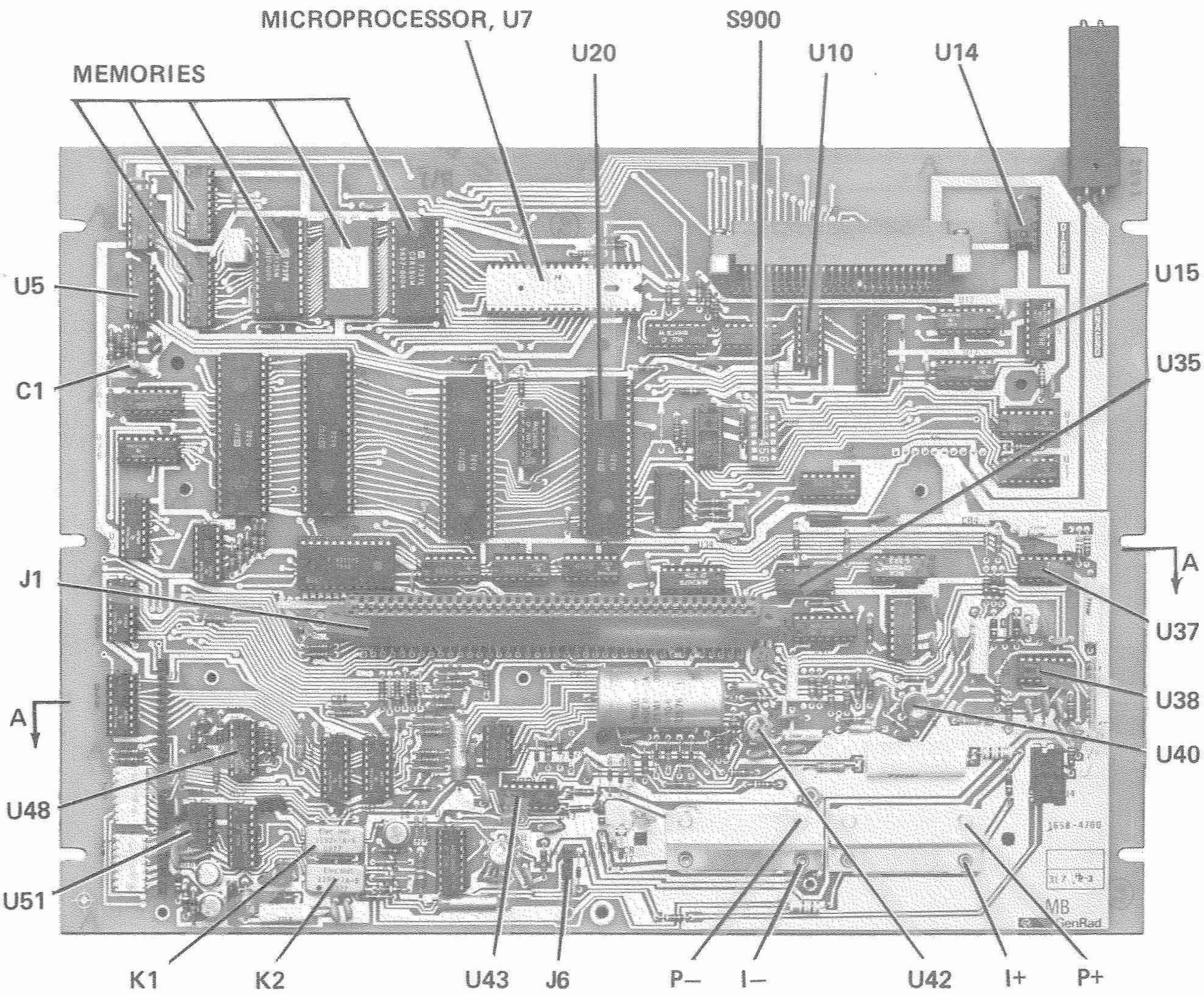


Figure 5-8. Main or MB board, top view. Functional conversion between 1658-9700 and 1658-9800 involves replacement of precision oscillator and depressing switch tabs; locations indicated. Arrows A–A indicate approximately the area of analog circuitry.

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

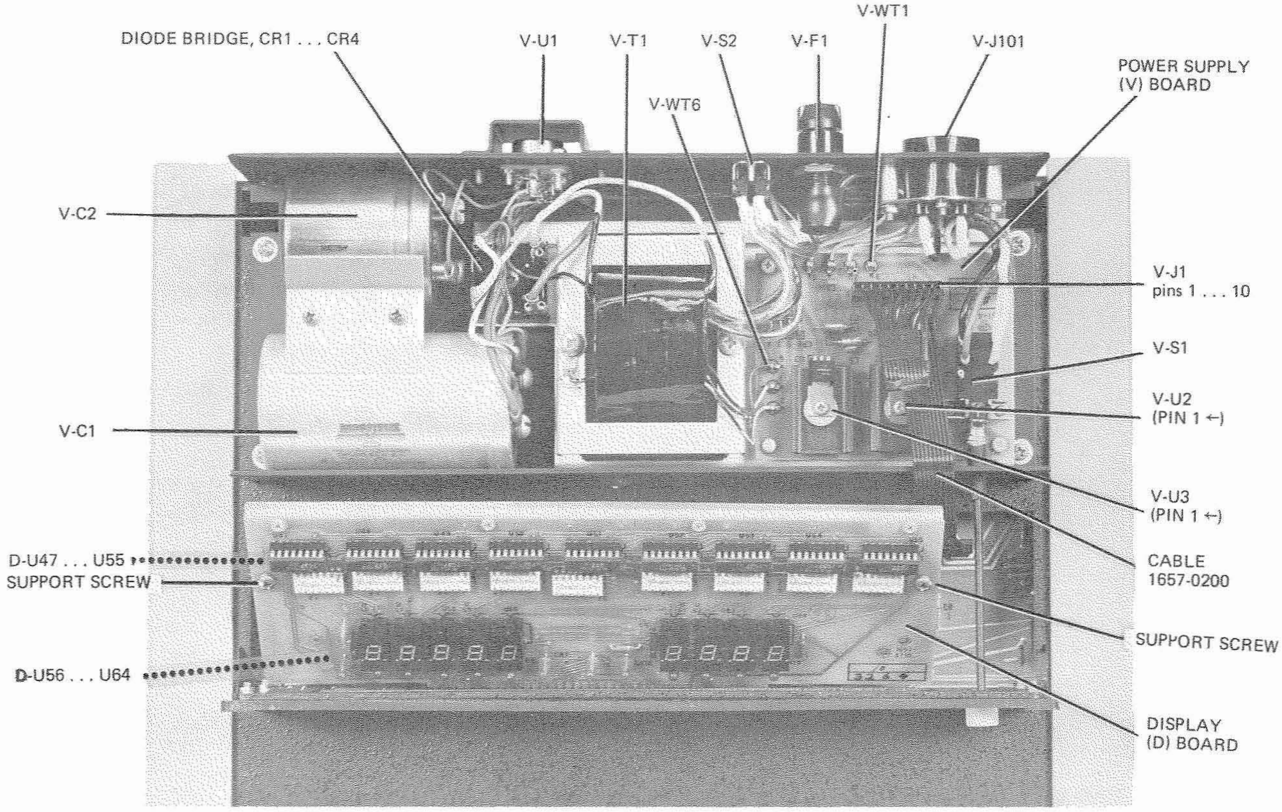


Figure 5-9. Power supply (V assembly) and display or DB board, shown in the instrument, with top cover off.

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).

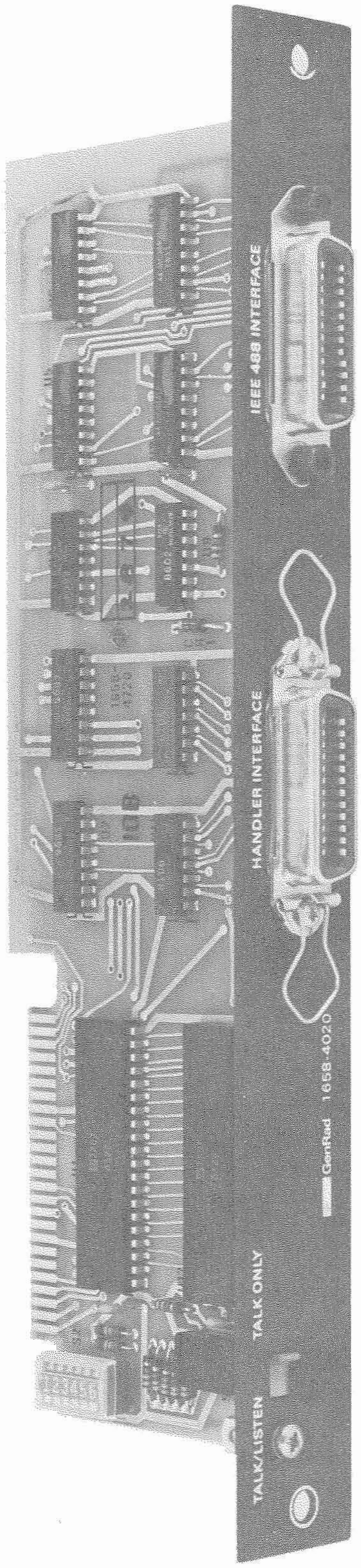


Figure 5-10. Interface option assembly 1658-4020, including the interface option board (IOB) 1658-4720.

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

Table 5-11

MB– BOARD PARTS LOCATIONS

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

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 μF and 3 kΩ, 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.

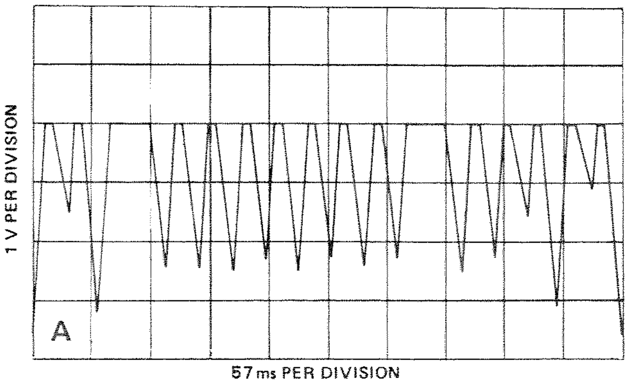
NOTE

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.



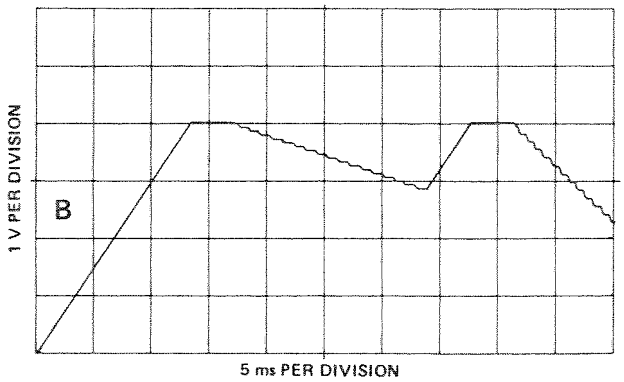


Figure 5-11. Integrator output waveform for the conditions of para 5.8.4: VALUE, SLOW, SERIES, 1 kHz, CONT, R/Q, autorange; DUT is 1 Ω. The waveform repeats every 570 ms, including 16 staircases, for a complete measurement cycle. The expansion, B, shows typical detail in the first 2 staircases. Each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

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.

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.

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.

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.

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.

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.

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.

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.

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.

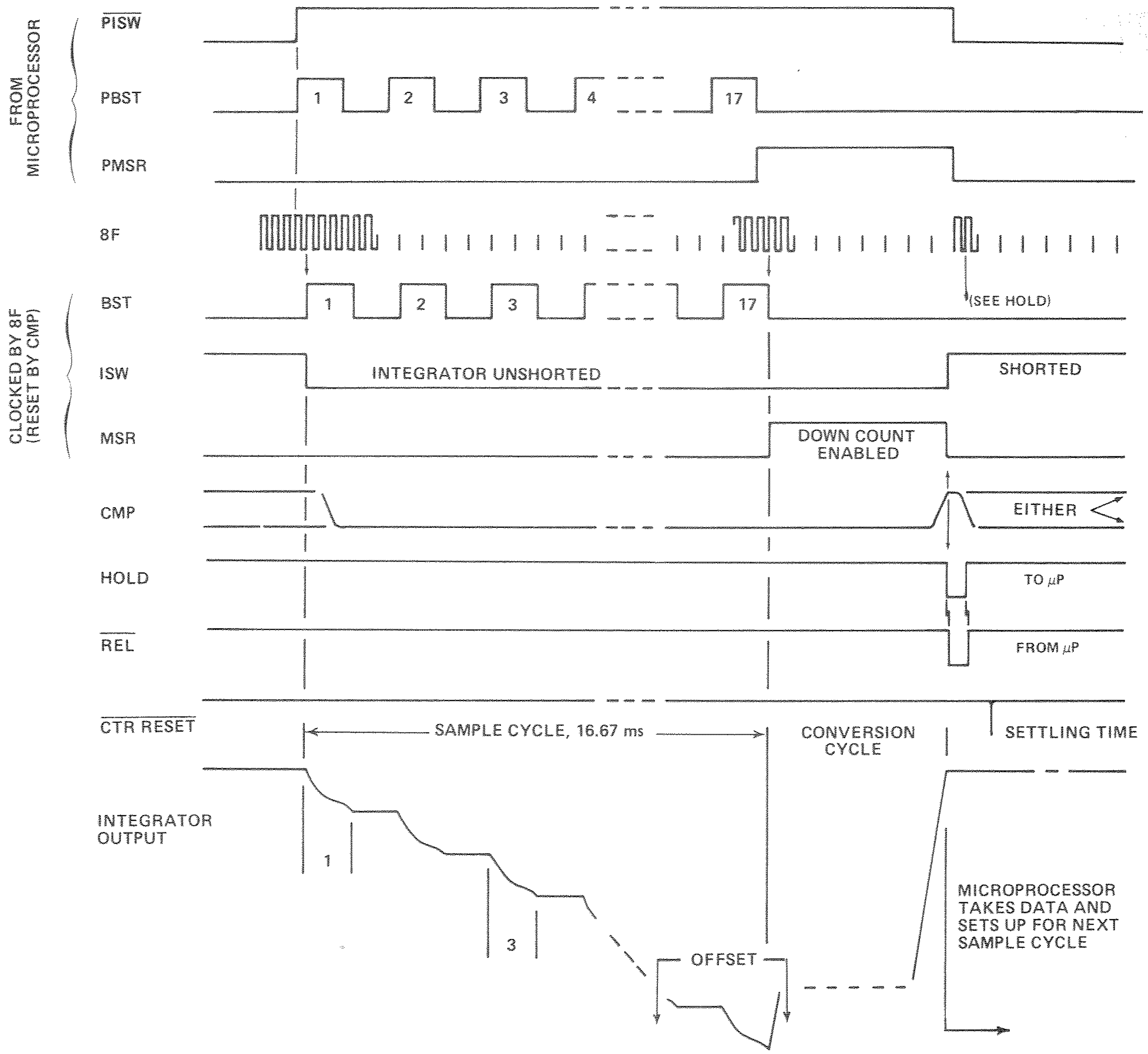


Figure 5-12. Timing diagram. One complete staircase cycle for a typical SLOW- or MEDIUM-rate 1-kHz measurement on a 1658-9700. The 3 main divisions are: sample cycle (stair steps down), conversion cycle (smooth ramp up, during which a counter arrives at digital value of signal being sampled), and data-taking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

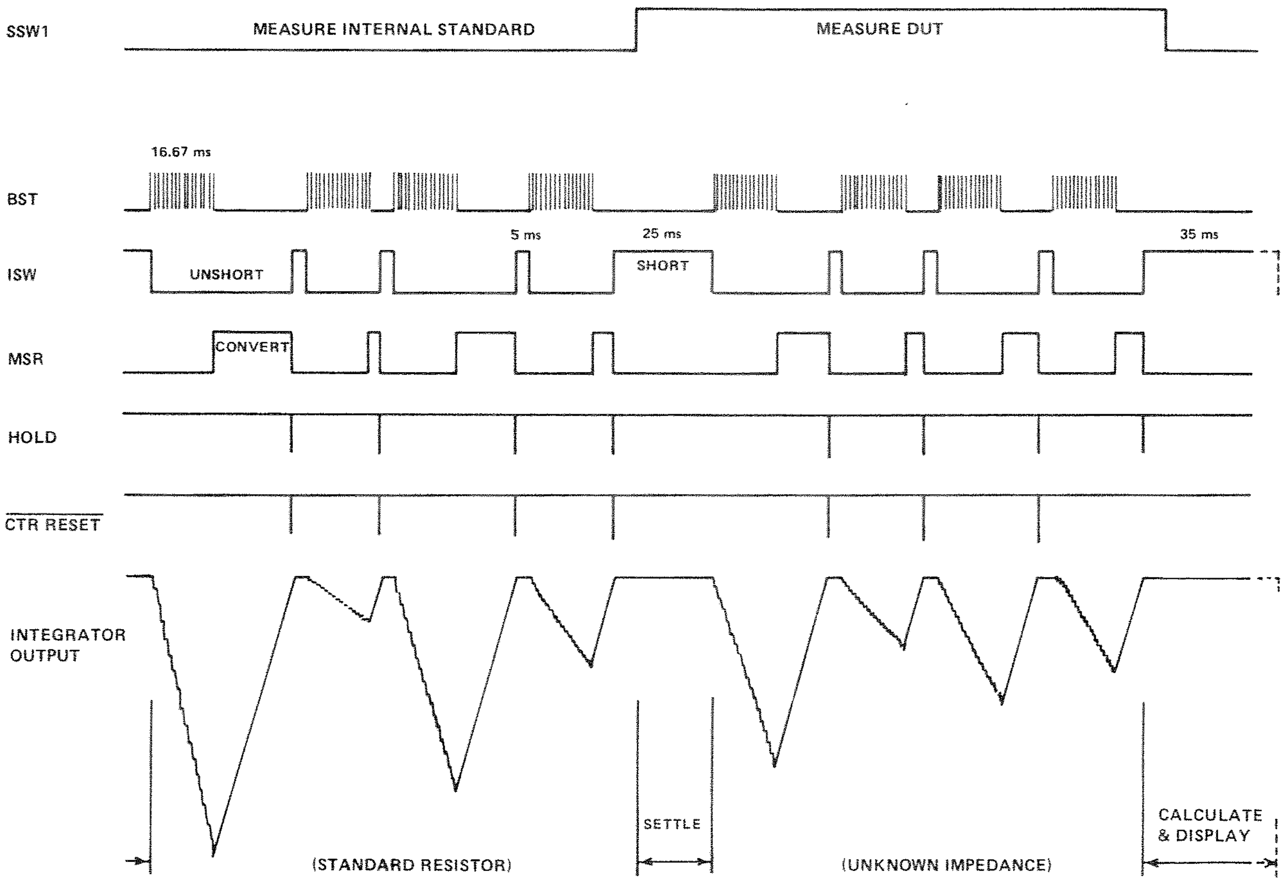


Figure 5-13. Timing diagram. One complete measurement cycle for a typical MEDIUM-rate 1-kHz measurement on a 1658-9700. There are 8 staircase cycles, one with each phase of BST for the signal from the standard and one with each phase of BST for the signal from the DUT.

Parts Lists and Diagrams—Section 6

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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.

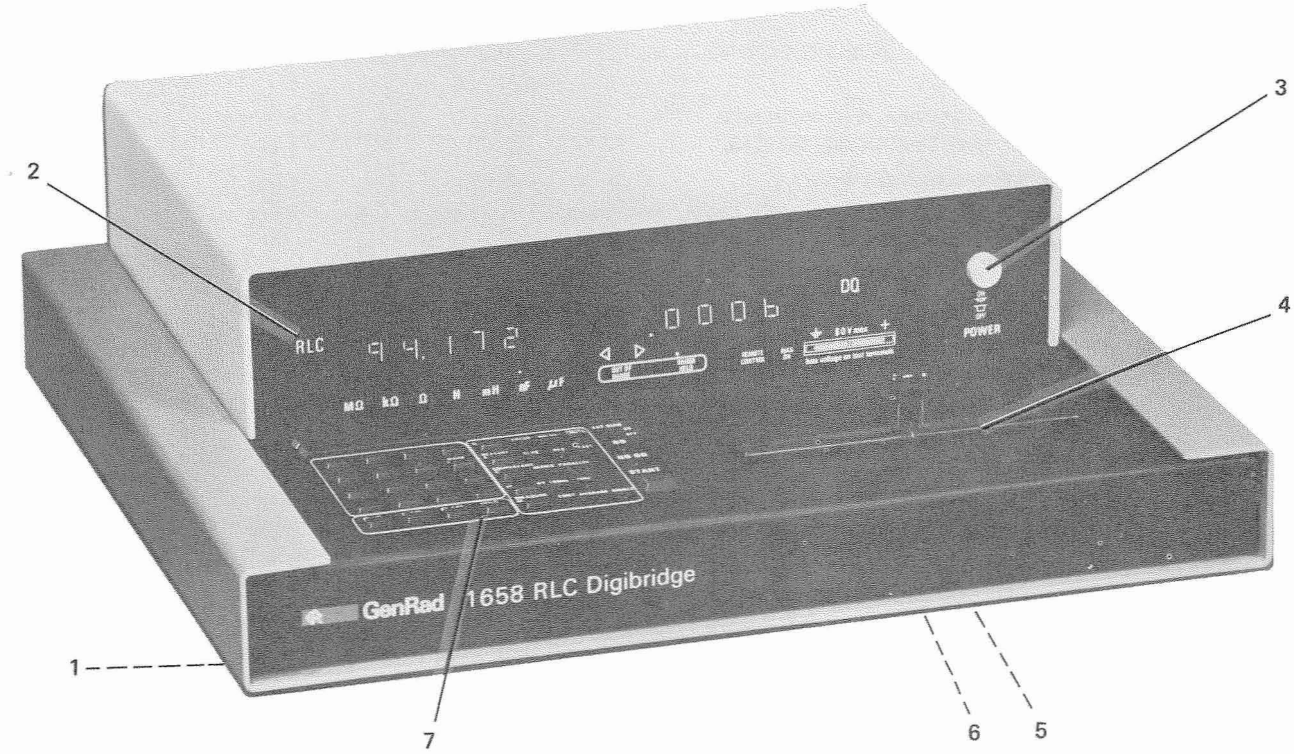


Figure 6-1. Front view, showing replaceable mechanical parts.

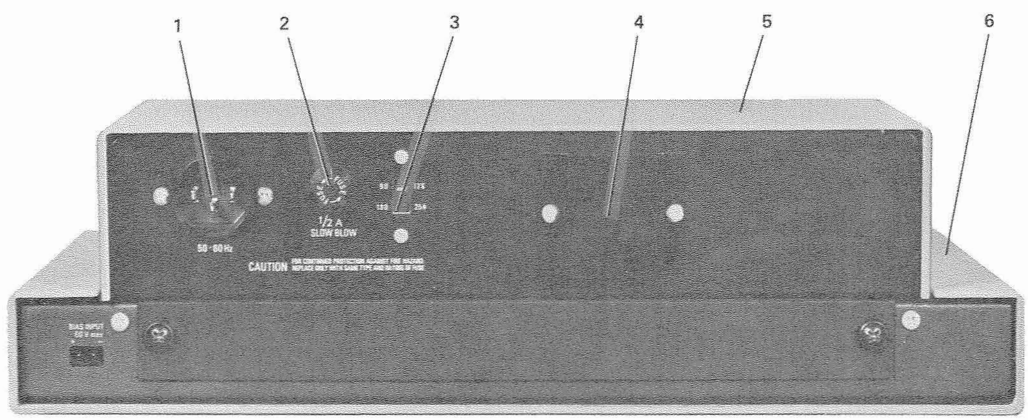


Figure 6-2. Rear view, showing replaceable mechanical parts. Notice that item 1 is slightly different from the picture (more rectangular than round).

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

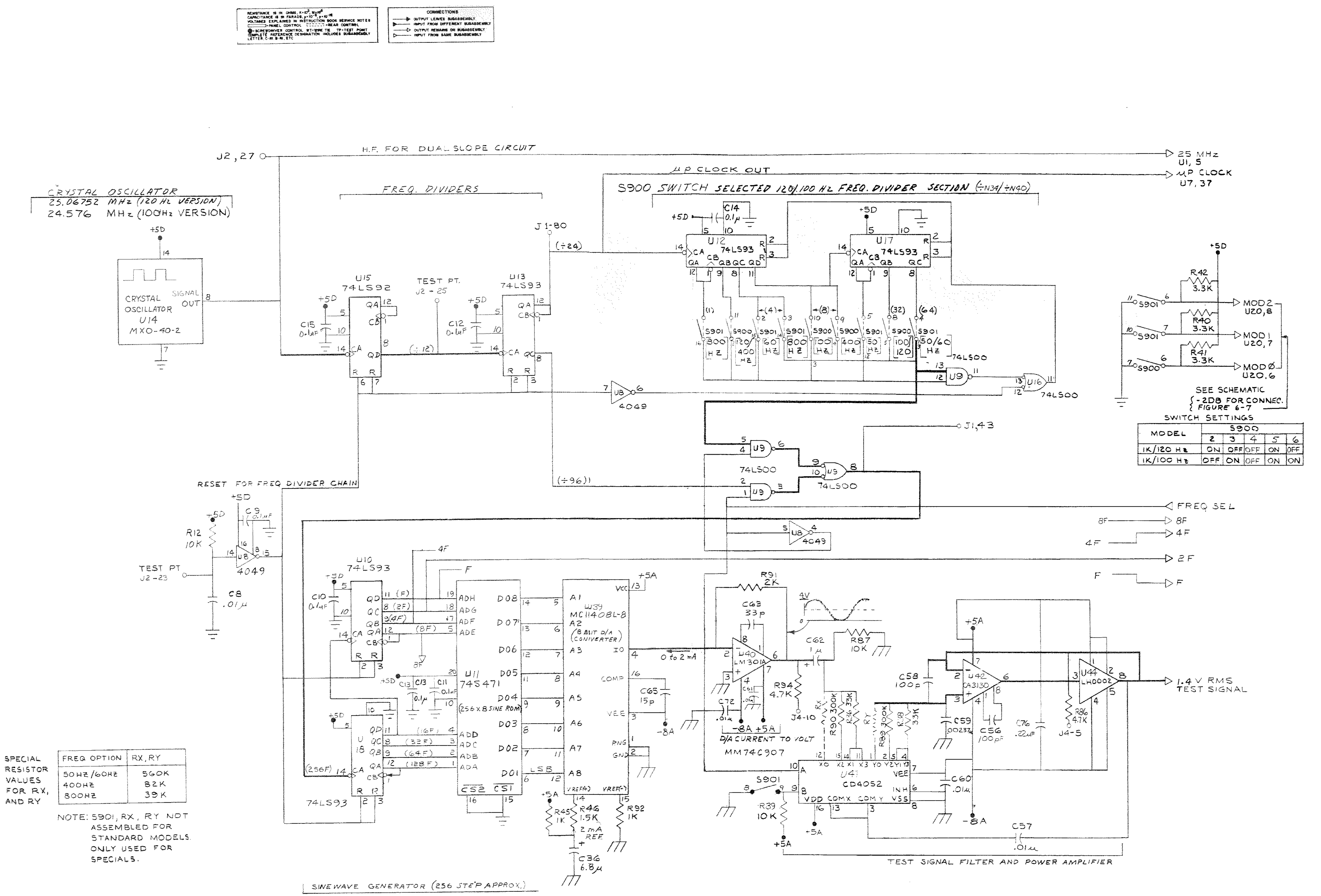
FEDERAL SUPPLY CODE
FOR MANUFACTURERS

From Defense Logistics Agency Microfiche

H4-2 SB 708-42 GSA-FSS H4-2

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	Ommi 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	Kulka.,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



MODEL	S900 2	3	4	5	6
1K/120 Hz	ON	OFF	OFF	ON	OFF
1K/100 Hz	OFF	ON	OFF	ON	ON

FREQ OPTION	RX, RY
50Hz/60Hz	560K
400Hz	82K
800Hz	39K

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

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).

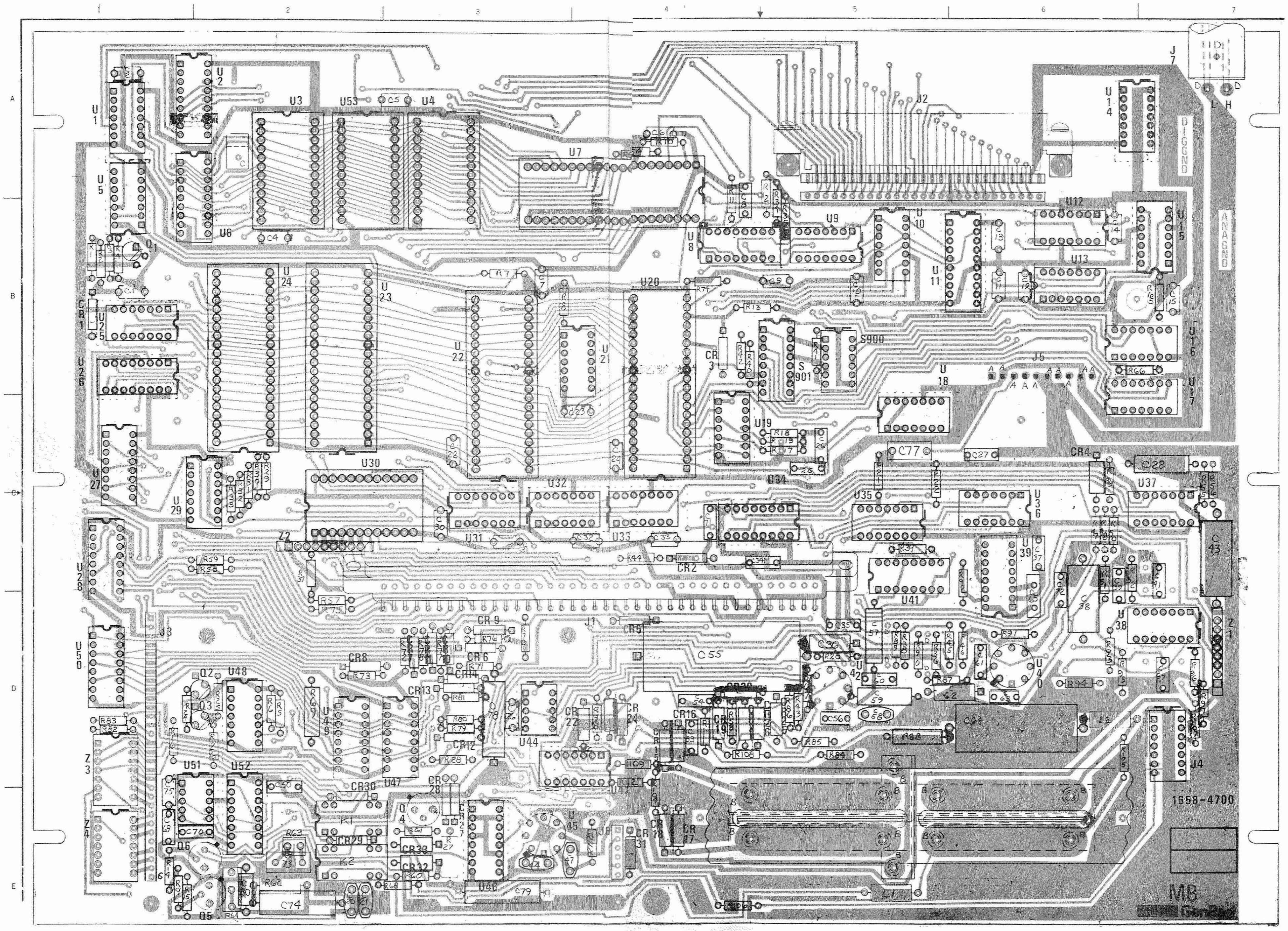


Figure 6-4. Main (MB) board, 1658-4700, layout. (Refer to Table 5-11.)

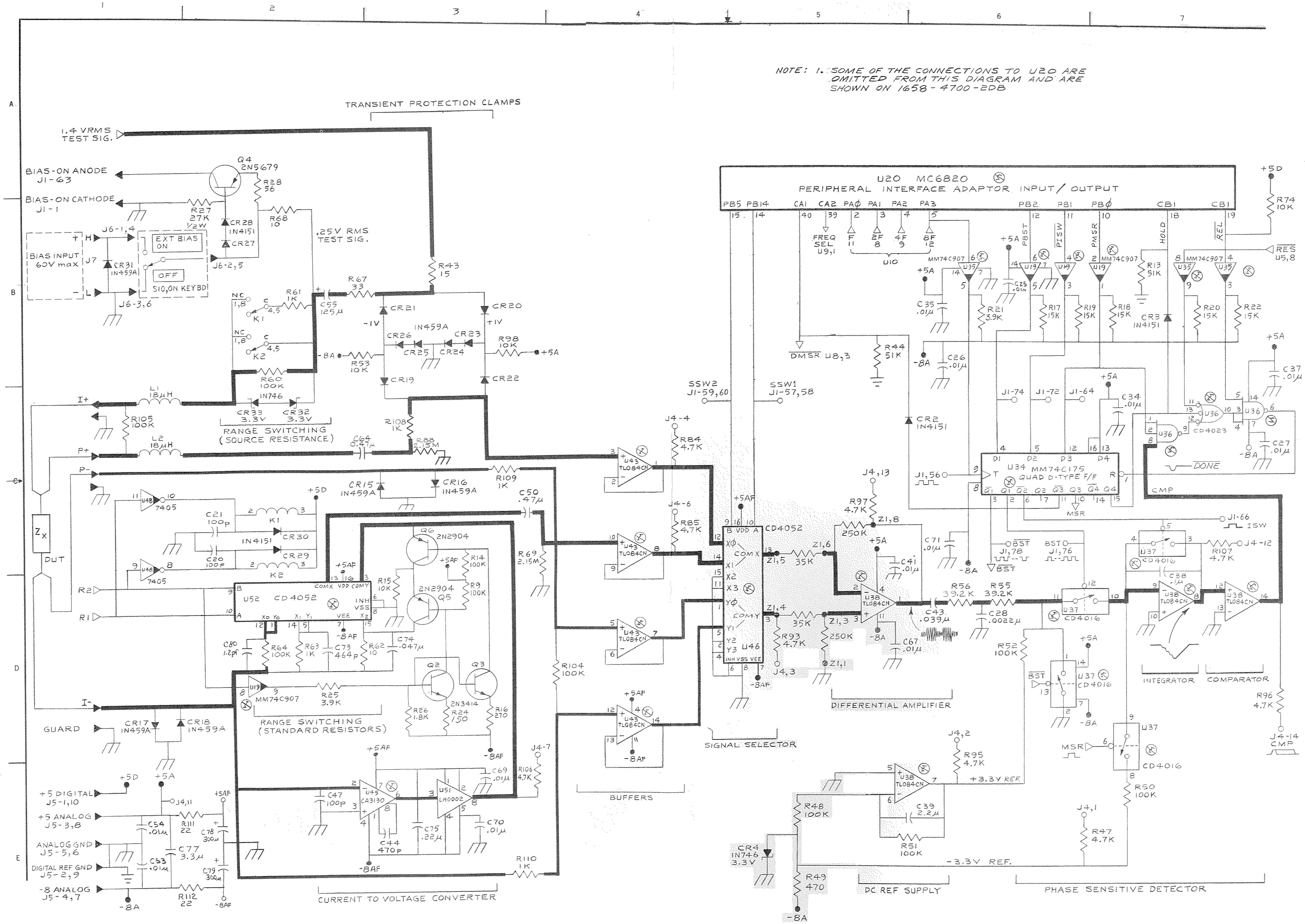
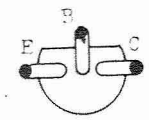


Figure 6-5. Main (MB) board, -4700, analog front end and detector.



Q1...3
BOTTOM VIEW

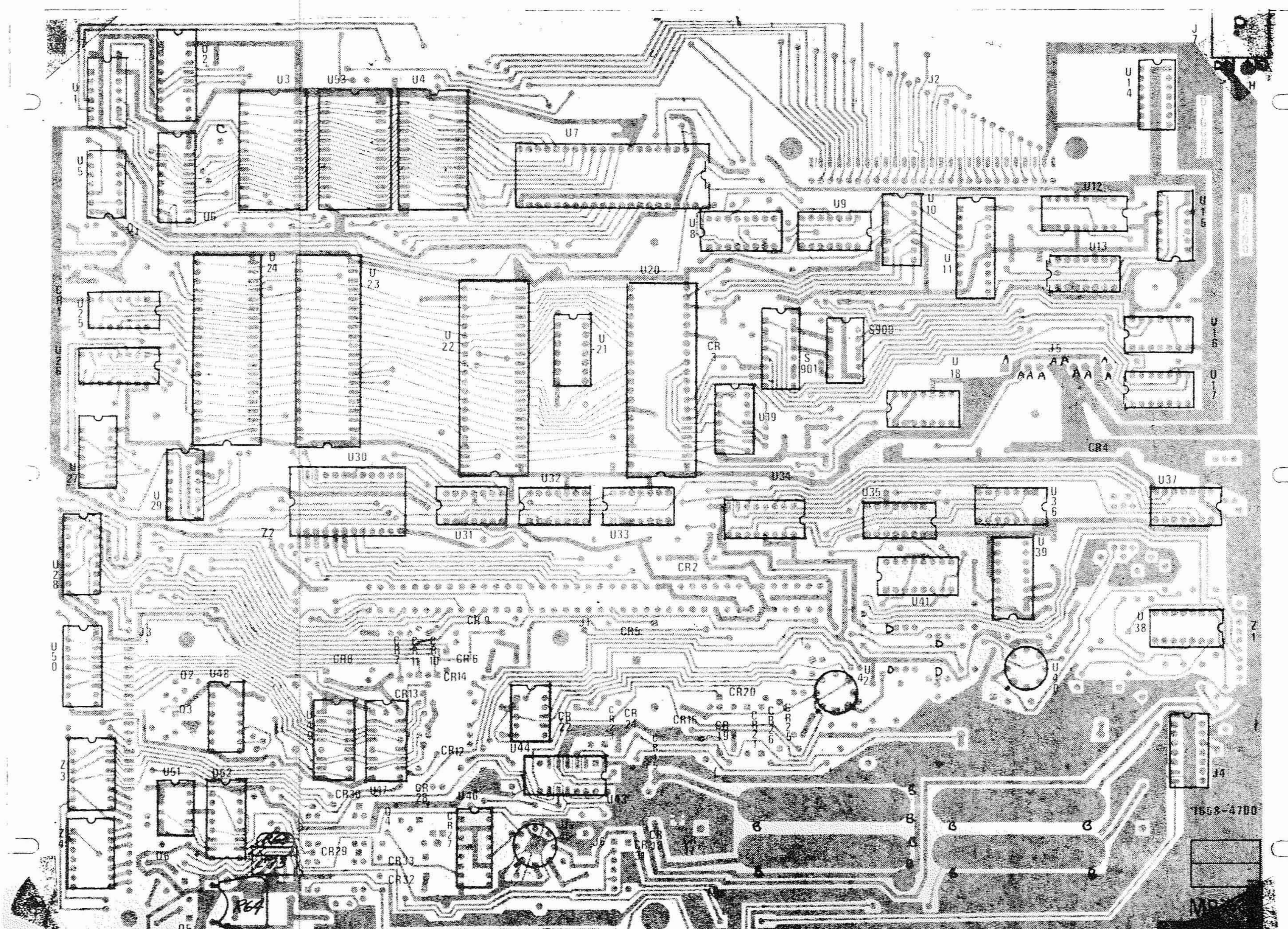


Figure 6-6. Main (MB) board, 1658-4700, integrated-circuit locator.

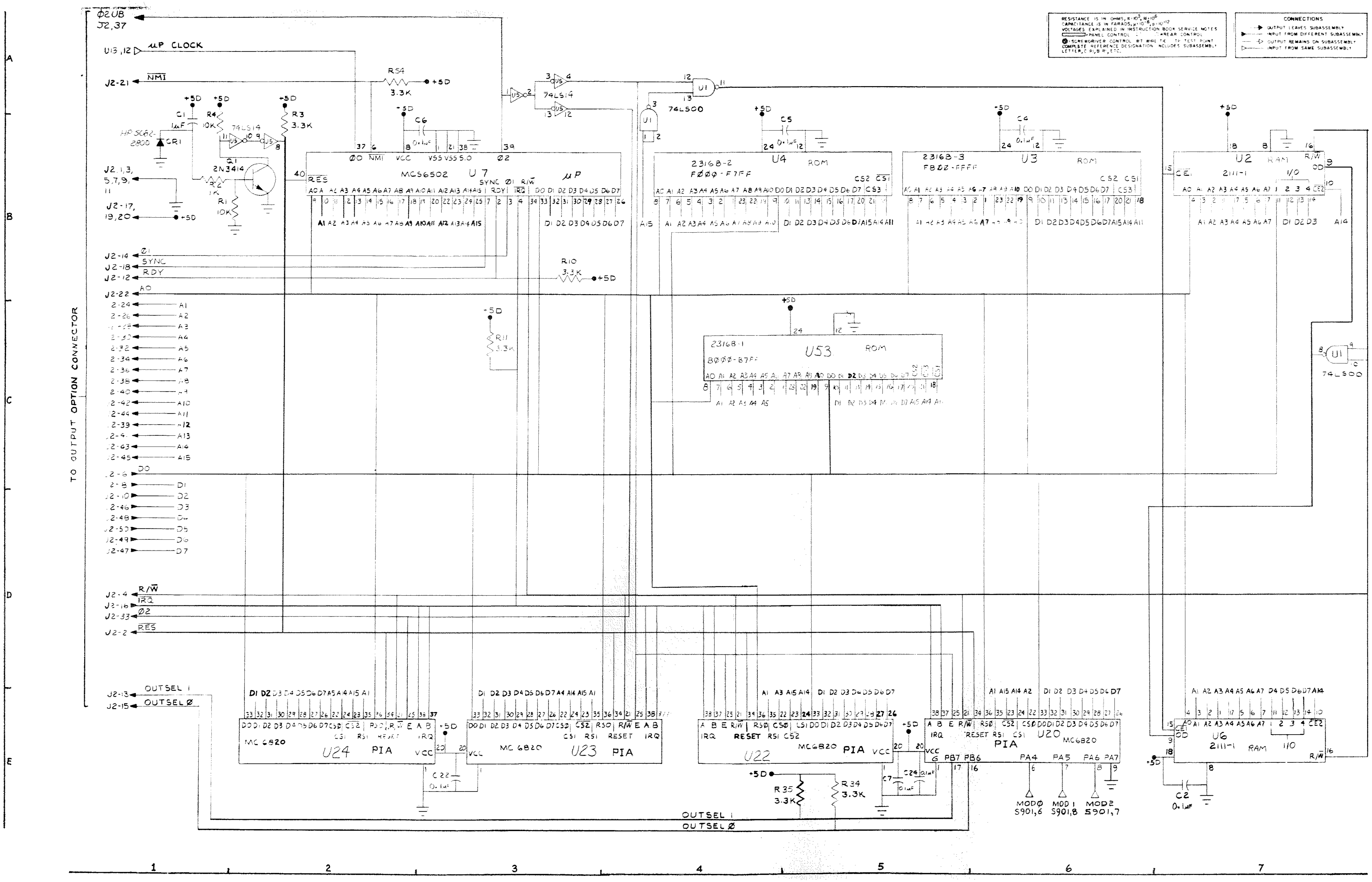


Figure 6-7. Main (MB) board, -4700, digital processor, memories, interfaces.

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	4400-2080	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	1N746
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	1N746
CR	33	ZENER 1N746 3.3V 10PCT .4W	6083-1005	14433	1N746
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

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

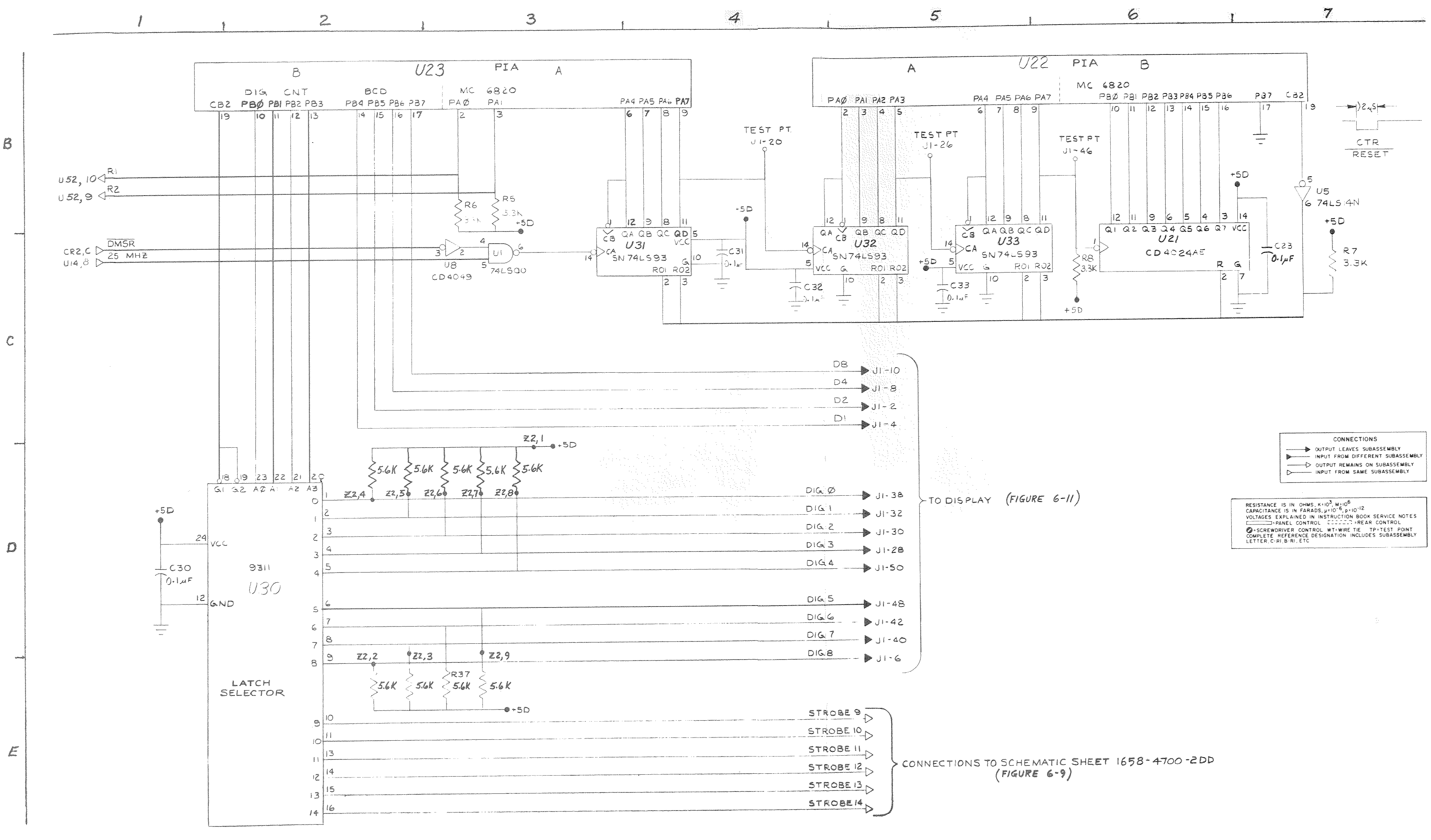


Figure 6-8. Main (MB) board, -4700, measurement counter, display driver.

ELECTRICAL PARTS LIST (cont)

ANALOG AND CONTROL PC BOARD M8 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 1OF16 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%.

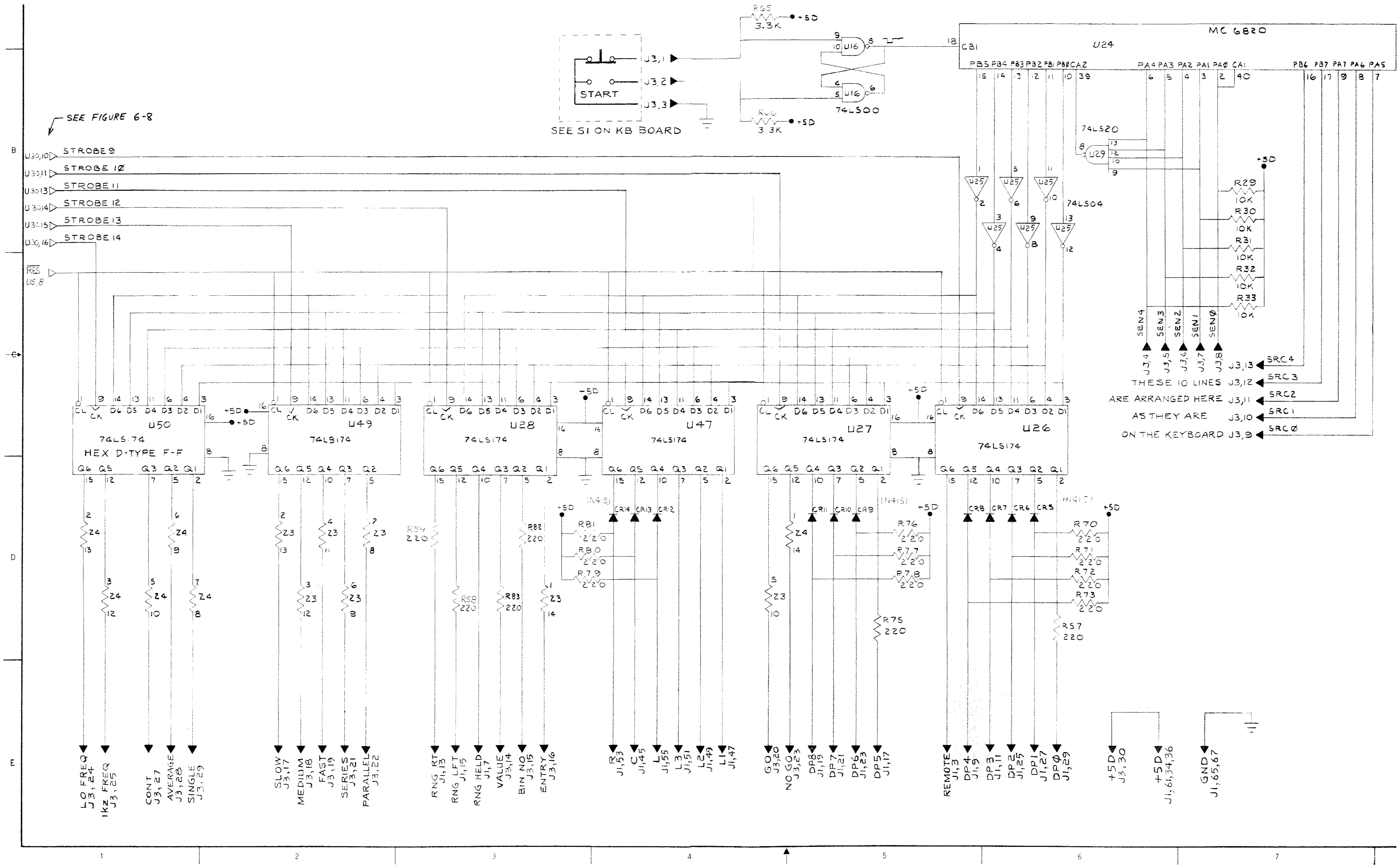


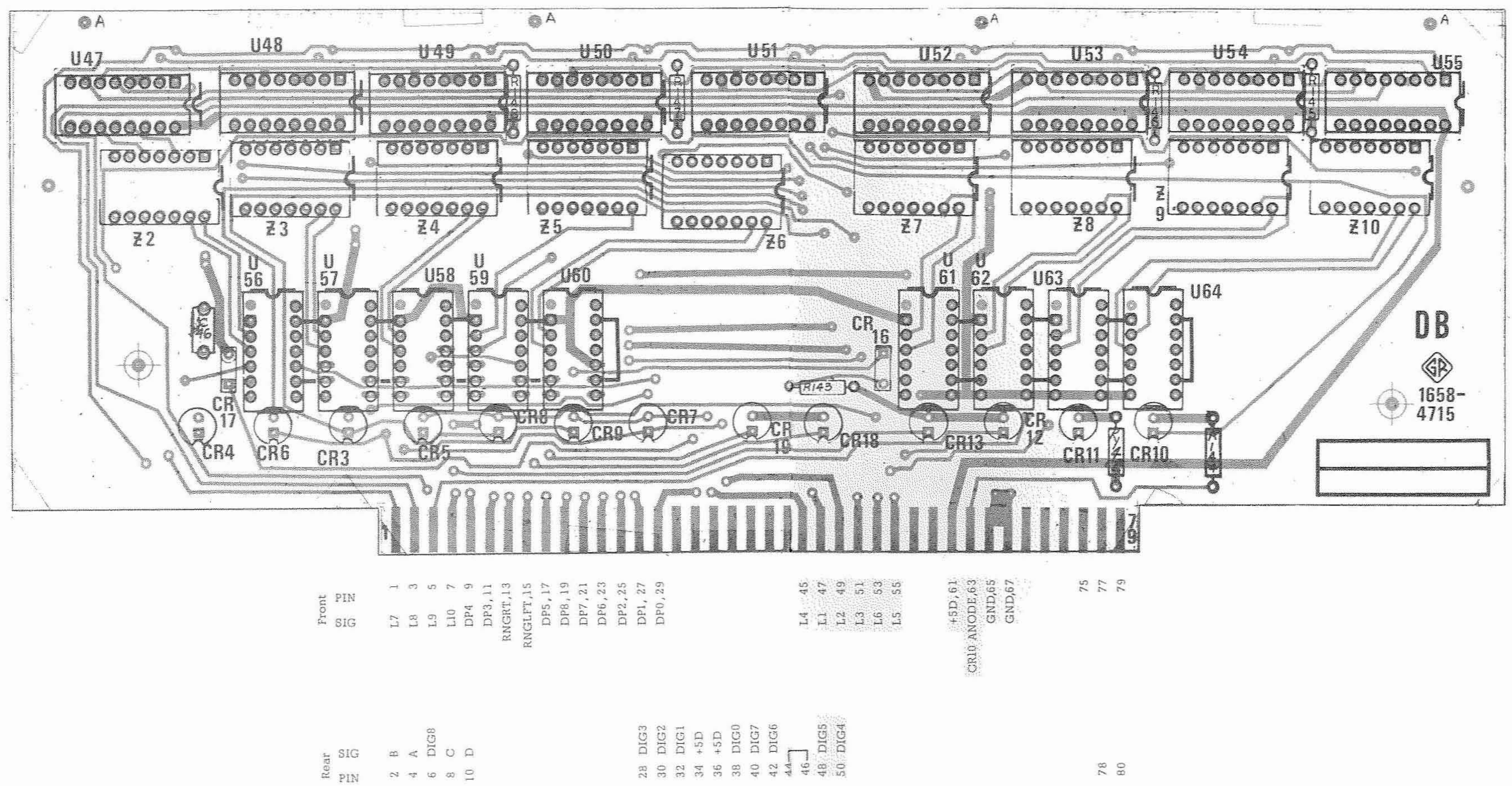
Figure 6-9. Main (MB) board, -4700, keyboard and display-LED interfaces.

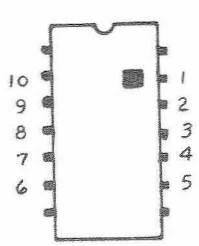
ELECTRICAL PARTS LIST

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 Ω ± 5%.





Bottom view of U56...64

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.

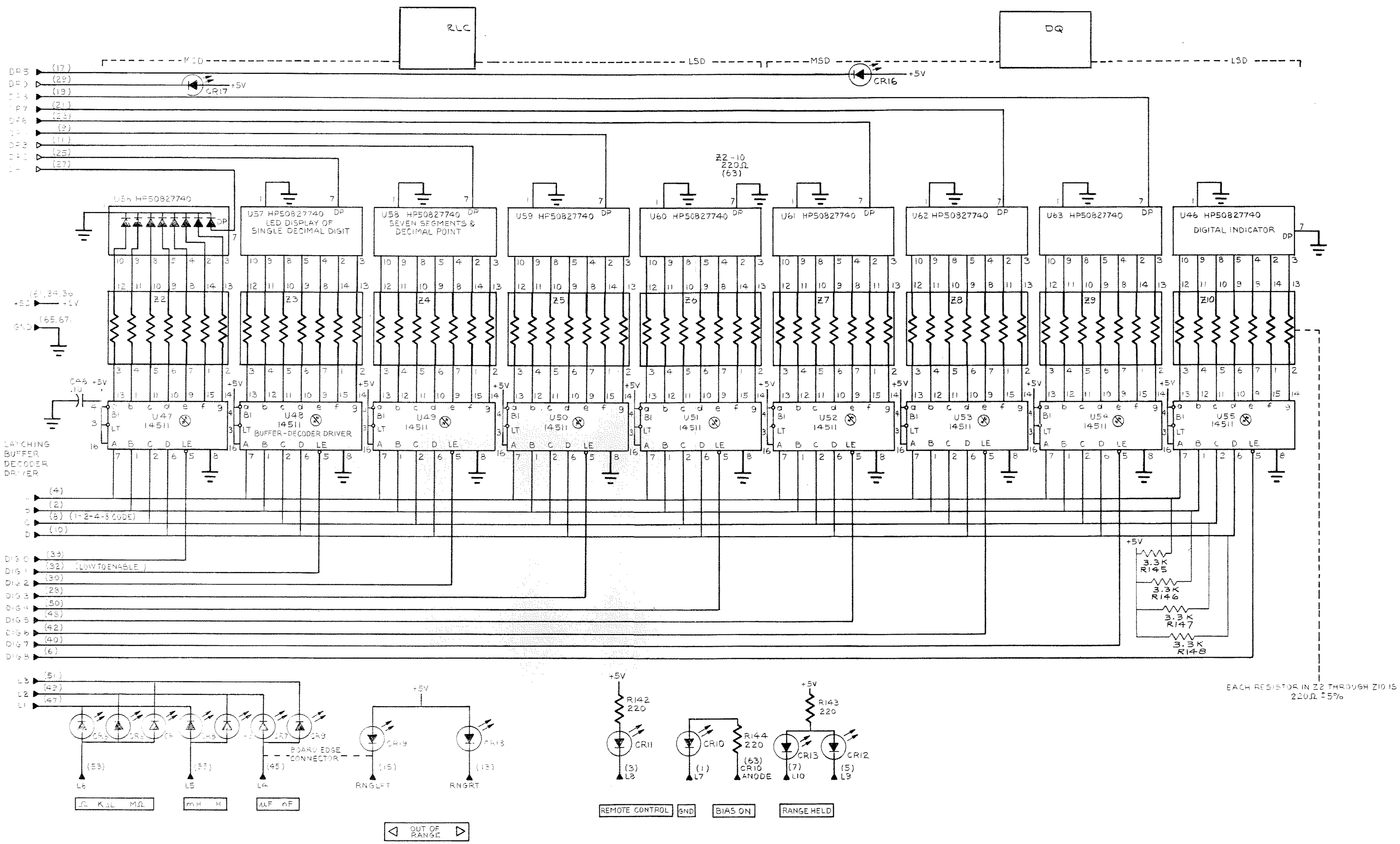


Figure 6-11. Display (DB) board, 1658-4715, diagram.

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

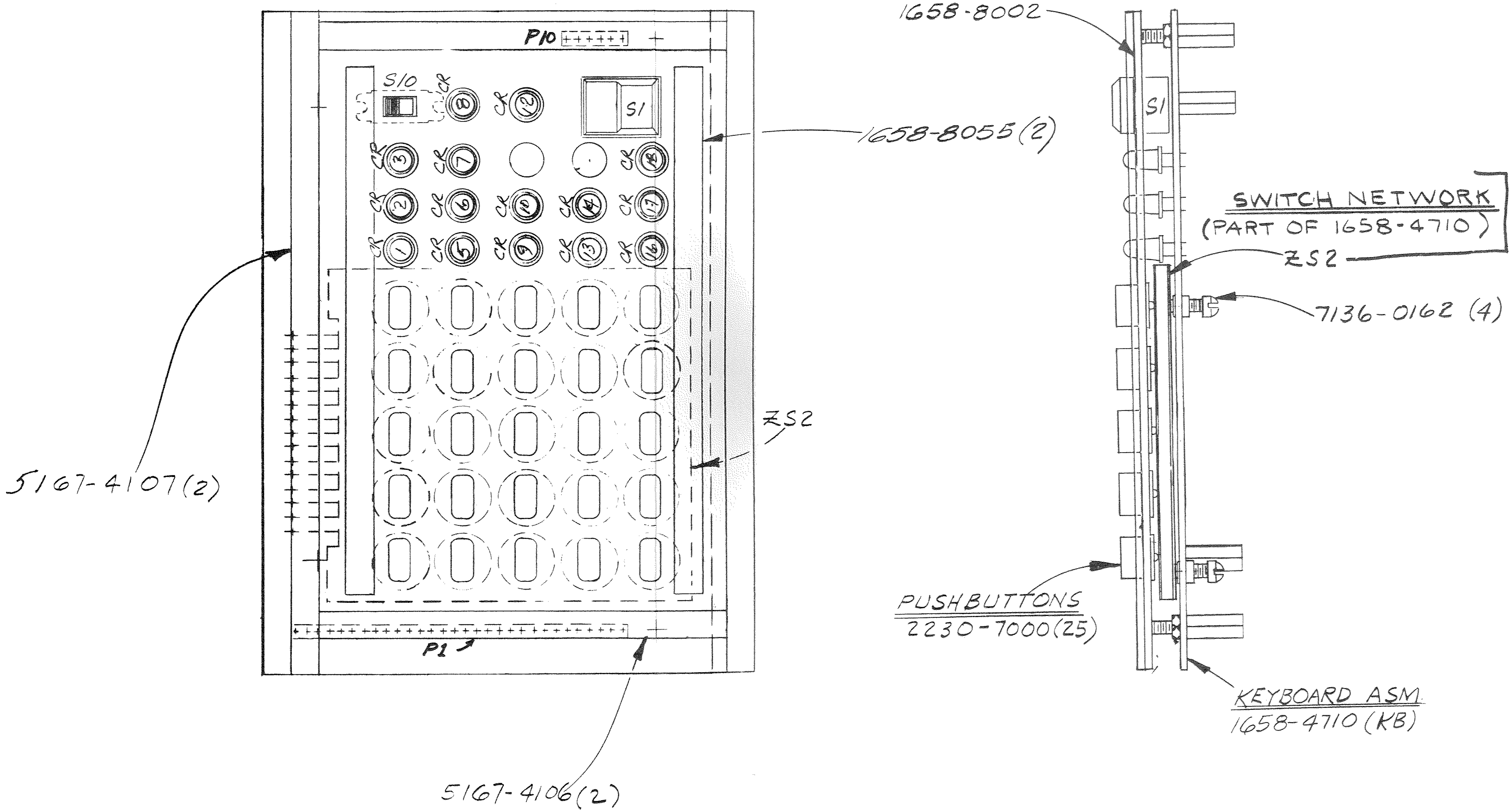


Figure 6-12. Keyboard module assembly, 1658-4200.

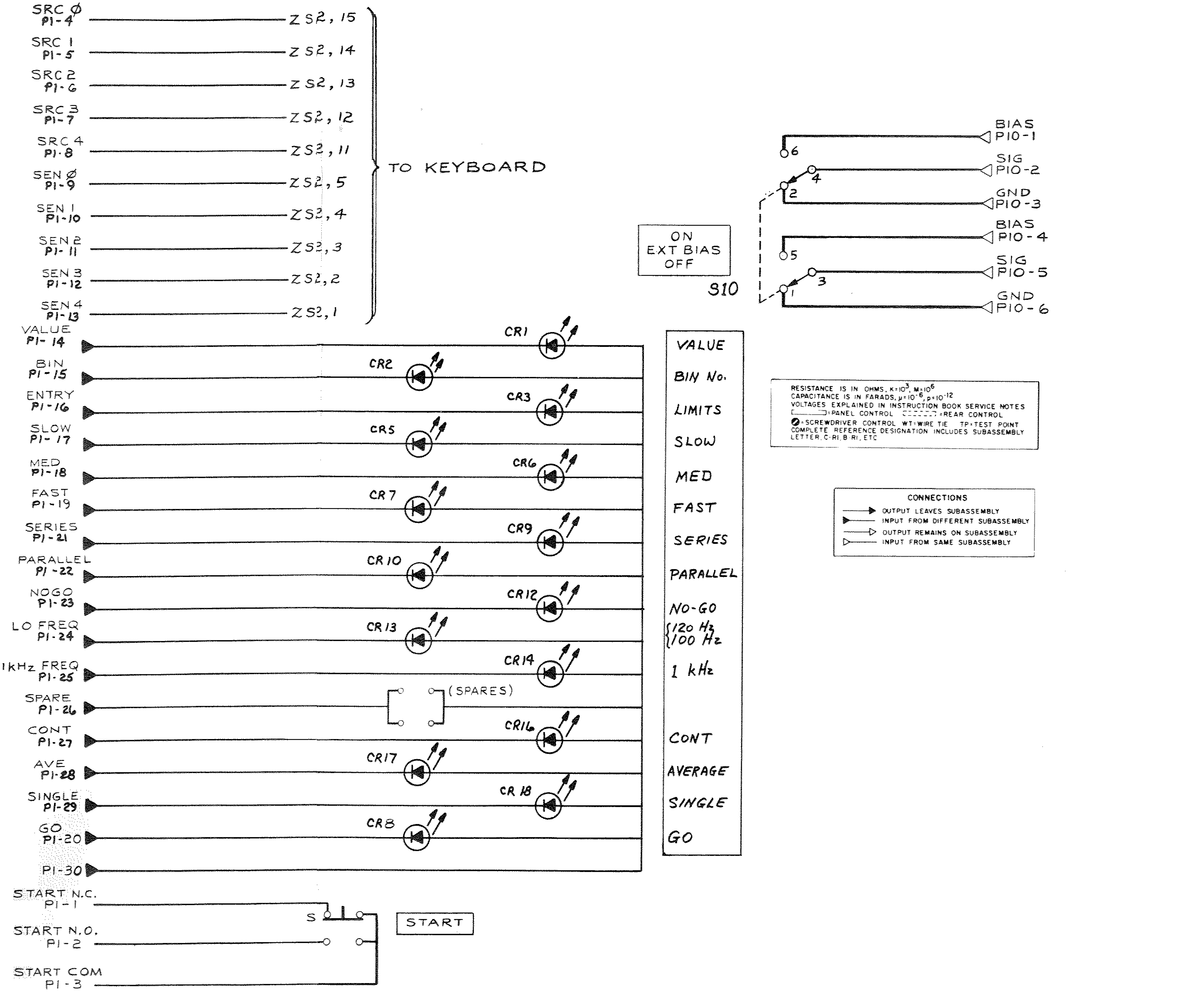


Figure 6-14. Keyboard (KB) circuit board, -4710, diagram.

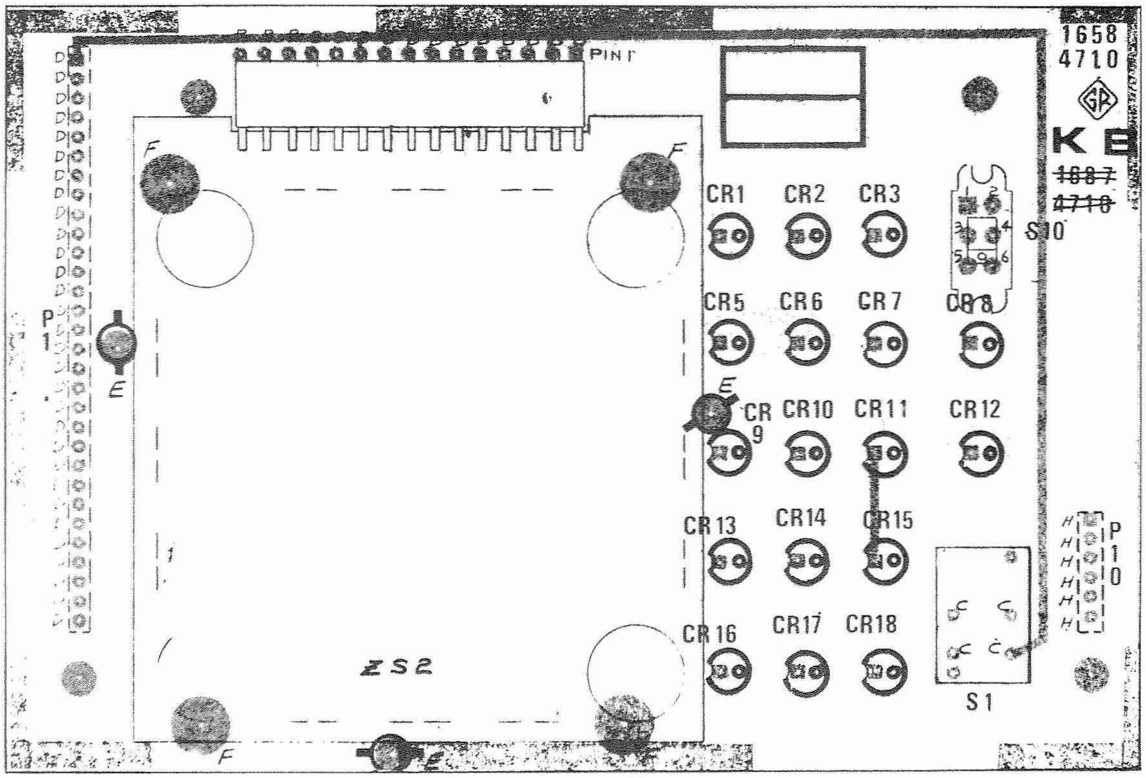


Figure 6-13. Keyboard (KB) circuit board, 1658-4710, layout.

ELECTRICAL PARTS LIST

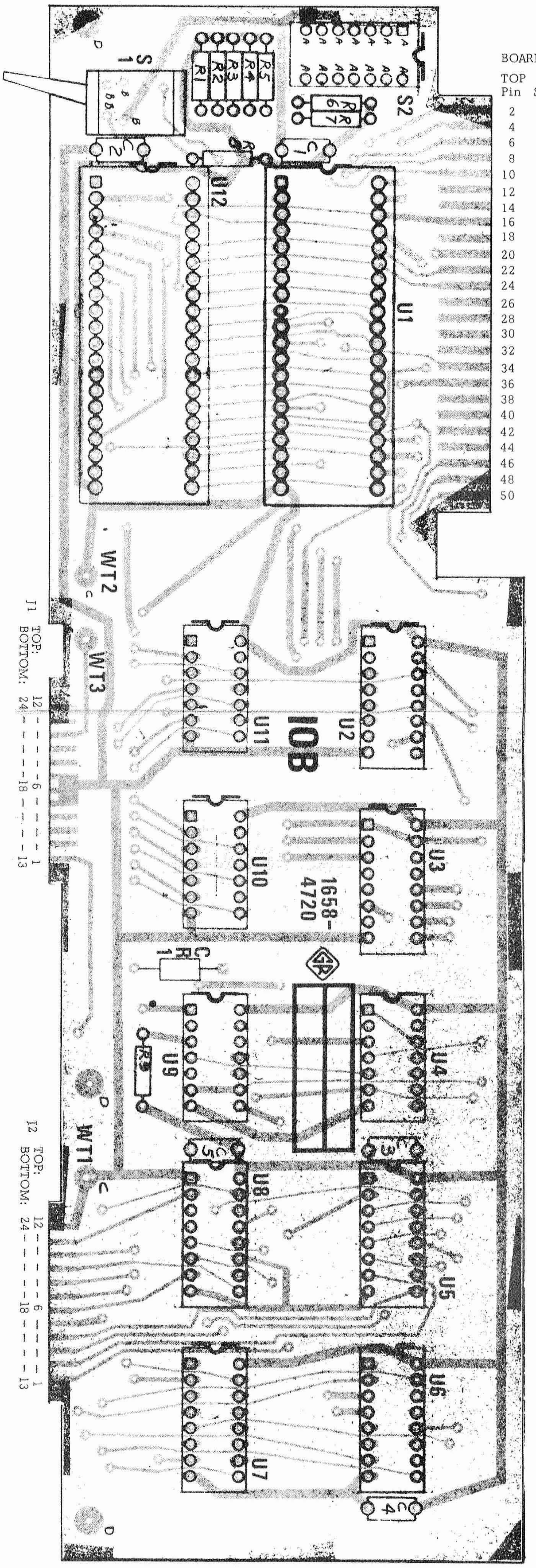
INTERFACE OPTION ASM P/N 1658-4020

REFDES		DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
J	1	RECPT MICRO RIB 24 CCNT	4230-4024	02660	57-40240
J	2	CCNN 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 IOB 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) board, 1658-4720, layout.

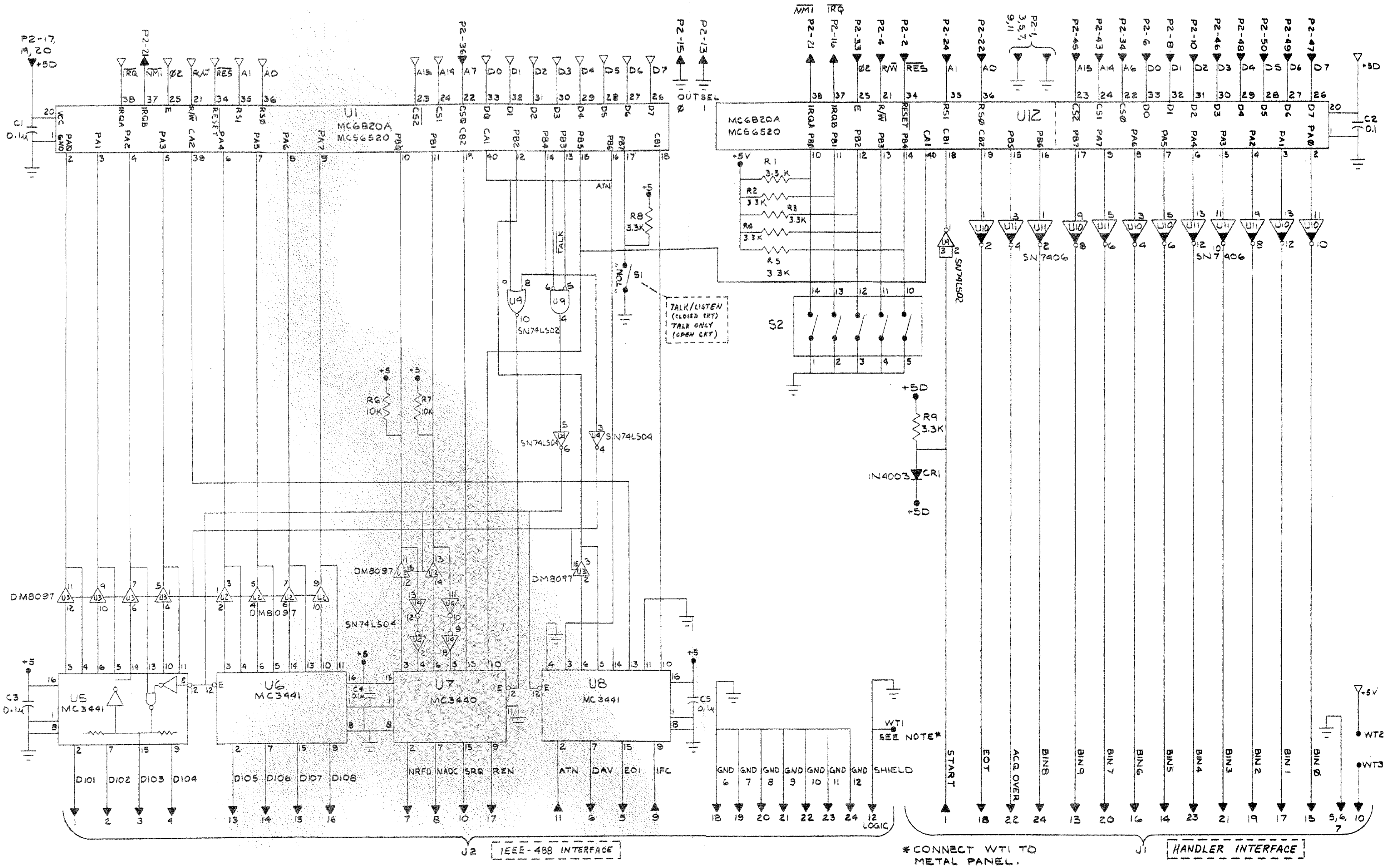


Figure 6-16. Interface option (IOB) board, 1658-4720, diagram.

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

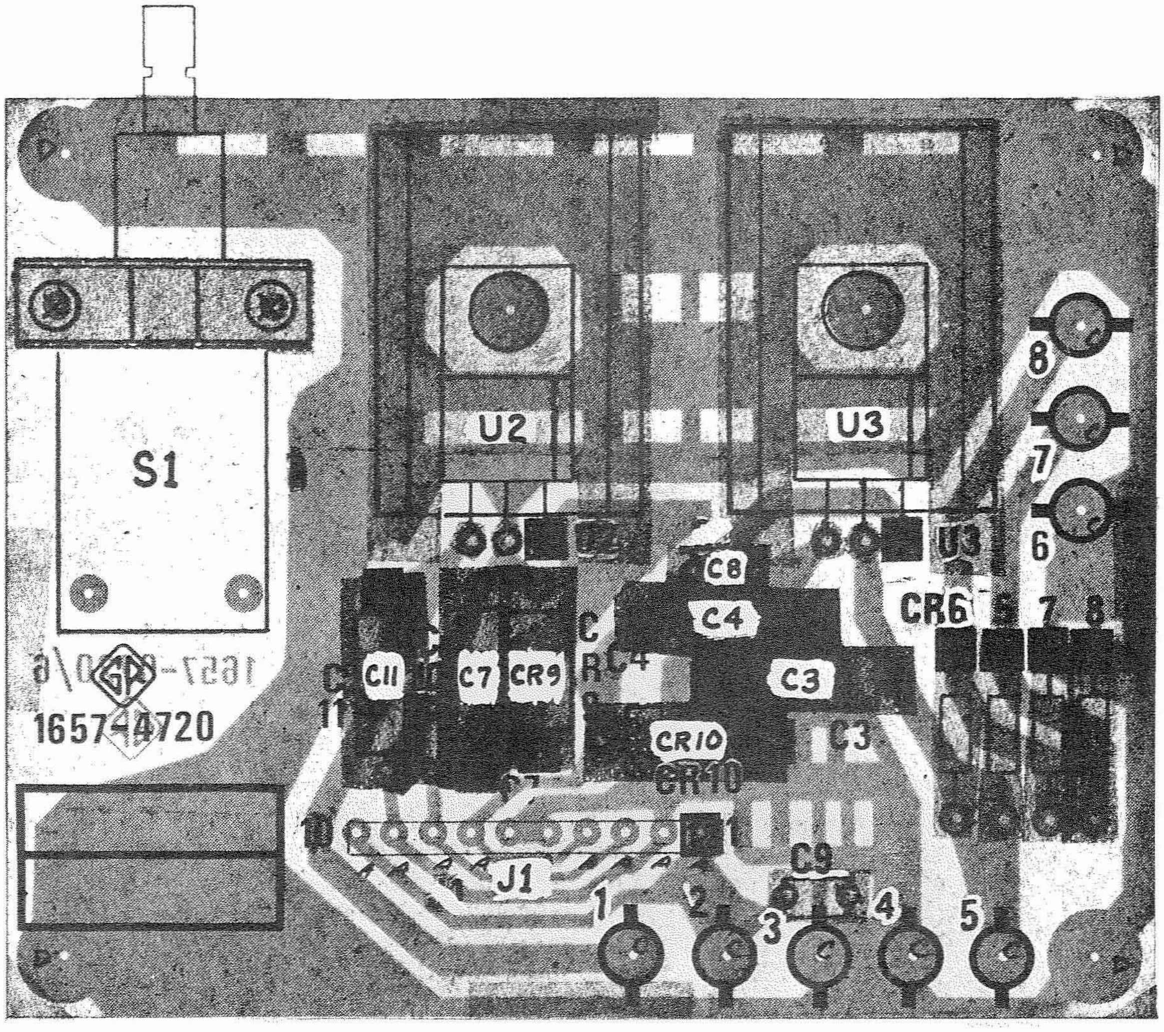
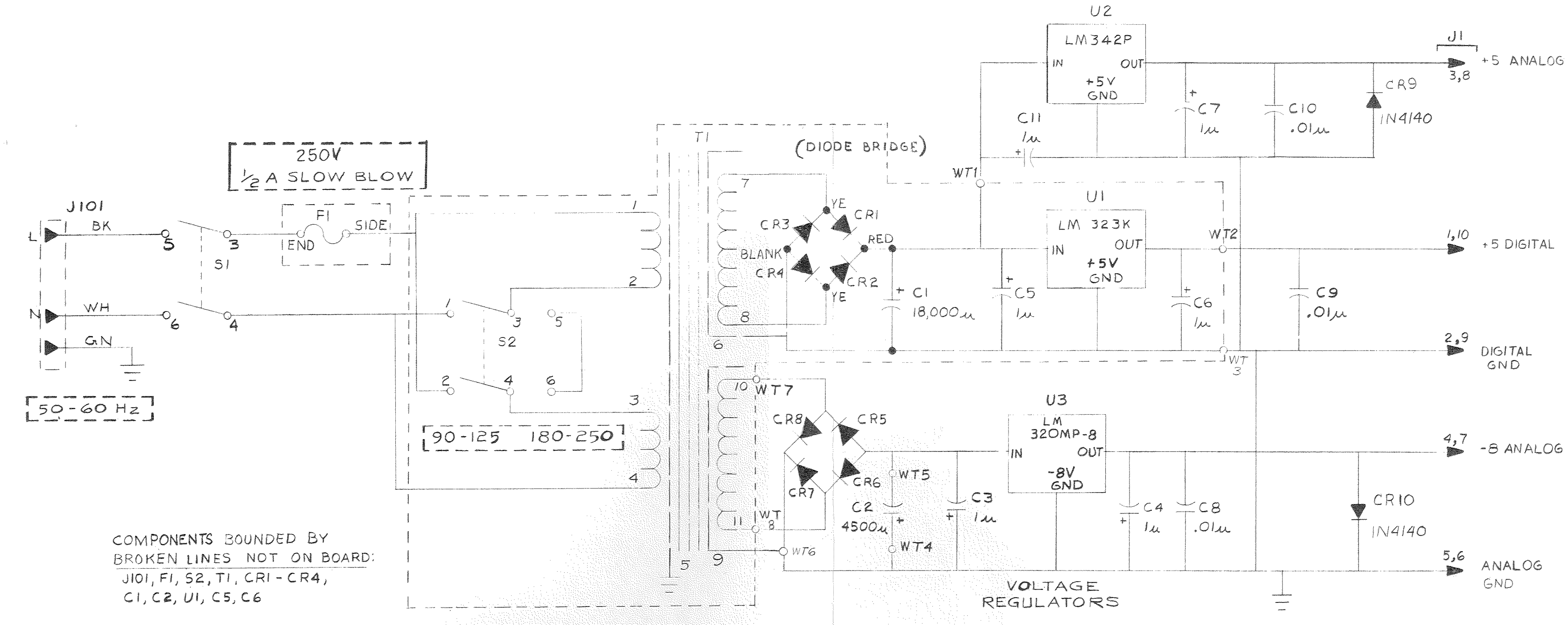
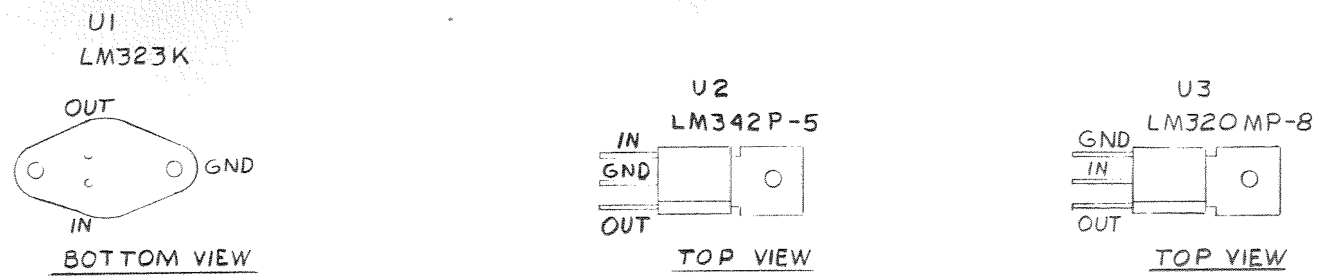


Figure 6-17. Power supply (V) board, 1657-4720, layout.





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

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

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