

## NOTE

This manual documents the 5450A Resistance Calibrator and its assemblies at the revision levels shown in Section 8. If your instrument contains assemblies with different revision letters, it will be necessary for you to either update or backdate this manual. Refer to the supplemental change/errata sheet for newer assemblies, or to the backdating sheet in Section 8 for older assemblies.

# 5450A Resistance Calibrator

## Instruction Manual

P/N 713800  
March 1984

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\*For European customers, Air Freight prepaid.

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5450A Resistance Callibrator



# Section 1

## Introduction & Specifications

### 1-1. INTRODUCTION

The Fluke 5450A Resistance Calibrator is designed to facilitate manual or automated calibration of the resistance measuring circuitry of high-quality digital multimeters (DMMs). The 5450A provides cardinal point resistances in the range of  $1\Omega$  to  $100\text{ M}\Omega$ . Resistances may be selected either at decade points (e.g.,  $1\Omega$ ,  $10\Omega$ ,  $100\Omega$ , etc.) or at  $\times 1.9$  points (e.g.,  $1.9\Omega$ ,  $19\Omega$ ,  $190\Omega$ , etc.).

The 5450A display indicates the value of the selected resistance and can also indicate the error of the instrument being calibrated (the unit under test, or UUT), expressed in percent or parts-per-million (ppm).

The 5450A may be controlled from the front panel or by remote control via the IEEE-488 interface bus. All functions available on the front panel are also available over the IEEE-488 bus.

The UUT may be connected directly to the 5450A front panel terminals using banana plugs,

or to five-way low-thermal binding posts on the rear panel.

The 5450A is calibrated with its covers installed and may be calibrated remotely via the IEEE-488 bus. Calibration constants are stored in electrically alterable read-only memory (EAROM).

Accessories available for the 5450A include a rack mounting kit, rack mounting ears, and IEEE-488 interface bus cables.

### 1-2. SPECIFICATIONS

Specifications for the model 5450A are given in Table 1-1. An outline drawing is shown in Figure 1-1.

The accuracy specifications assume that the ambient temperature is held within the limits specified and that the relative humidity is held at or below 80% unless indicated. A minimum 2-hour warm-up time is also assumed.

Table 1-1. Specifications

**FOUR-WIRE OPERATION**

The four-wire specifications apply to the four-wire measurement configuration in which the OUTPUT terminals are used for test current and the SENSE terminals are used for sensing voltage.

FOUR-WIRE ACCURACY SPECIFICATIONS <sup>1</sup>							
NOMINAL VALUE	NOMINAL <sup>2</sup> TOLERANCE (±ppm)	NORMAL I RANGE <sup>4</sup> $I_L < I < I_U$		ABSOLUTE UNCERTAINTY <sup>2</sup> (±ppm unless indicated)			
		Lower Limit $I_L$	Upper Limit $I_U$	23°C ±1°C, 70% RH		23°C ±5°C, 70% RH <sup>3</sup>	
				24 Hours	90 Days	90 Days	1 Year
SHORT		10 mA	500 mA	.1 mΩ	.1 mΩ	.1 mΩ	.1 mΩ
1Ω	1000	10 mA	100 mA	50	62	75	110
1.9Ω	1000	10 mA	75 mA	40	52	65	100
10Ω	500	10 mA	25 mA	18	20.5	25	33
19Ω	500	10 mA	25 mA	16	18.5	23	31
100Ω	175	10 mA	15 mA	7.5	9	11	16
190Ω	150	10 mA	15 mA	7	8.5	10.5	15.5
1 kΩ	100	700 μA	2.5 mA	5.5	7	8.5	13.5
1.9 kΩ	100	500 μA	2.5 mA	5	6.5	8	13
10 kΩ	60	50 μA	1 mA	5	6.5	8	13
19 kΩ	50	50 μA	1 mA	4.5	6	7.5	12.5
100 kΩ	50	5 μA	250 μA	6	7.5	9	14
190 kΩ	50	5 μA	250 μA	5.5	7	8.5	13.5
1 MΩ	50	5 μA	50 μA	7.5	10	11.5	19
1.9 MΩ	50	5 μA	25 μA	7.7	10	11.5	19
10 MΩ	100	.5 μA	5 μA	16	24	26	50
19 MΩ	100	.25 μA	2.5 μA	20	28	30	56
100 MΩ	500	.05 μA	.5 μA	65	90	120	200

## Notes:

- The above table assumes the 5450A was calibrated according to the procedure specified in Section 4-28.
- The actual value of each resistance is determined to the accuracy given under ABSOLUTE UNCERTAINTY. These values can differ from the nominal values by the amount given under NOMINAL TOLERANCE.
- Above 70% relative humidity the accuracy degrades for values above 190 kΩ. For these values use the following table for ABSOLUTE UNCERTAINTY to 80% RH:

Nominal Value	90 Days 23°C ±5°C	1 Year 23°C ±5°C
1 MΩ	12.5 ppm	20 ppm
1.9 MΩ	13.5 ppm	21 ppm
10 MΩ	36 ppm	60 ppm
19 MΩ	50 ppm	76 ppm
100 MΩ	140 ppm	220 ppm

- The accuracy degrades for current outside the limits given under NORMAL I RANGE, which begins at the given lower limit ( $I_L$ ) and ends at the given upper limit ( $I_U$ ). For a description and derating factors, see FOUR-WIRE CURRENT DERATING FACTORS, below.

Table 1-1. Specifications (cont)

OTHER FOUR-WIRE SPECIFICATIONS							
NOMINAL VALUE	STABILITY <sup>1,2</sup> (±ppm)				MAXIMUM CURRENT <sup>4</sup> (I <sub>MAX</sub> ) (direct current)	MAXIMUM VOLTAGE <sup>4</sup> (V <sub>MAX</sub> ) (direct voltage)	TEMPERATURE COEFFICIENT <sup>5</sup> 0°C-18°C & 28°C-50°C (±ppm/°C) (add to accuracy spec)
	23°C ±1°C, 70% RH		23°C ±5°C, 70% RH <sup>3</sup>				
	24 Hours	90 Days	90 Days	1 Year			
SHORT					500 mA	0.25V	
1Ω	30	42	55	90	400 mA	0.4V	6
1.9Ω	20	32	45	80	300 mA	0.57V	6
10Ω	7	9.5	14	22	100 mA	1V	2.5
19Ω	5	7.5	12	20	100 mA	1.9V	2.5
100Ω	2	3.5	5.5	10.5	25 mA	2.5V	1.5
190Ω	1.5	3	5	10	25 mA	4.75V	1.5
1 kΩ	2	3.5	5	10	10 mA	10V	1.5
1.9 kΩ	1.5	3	4.5	9.5	10 mA	19V	1.5
10 kΩ	2	3.5	5	10	2.5 mA	25V	1.5
19 kΩ	1.5	3	4.5	9.5	2.5 mA	47.5V	1.5
100 kΩ	2	3.5	5	10	500 μA	50V	1.5
190 kΩ	1.5	3	4.5	9.5	250 μA	50V	1.5
1 MΩ	2.5	5	6.5	14	50 μA	50V	1.5
1.9 MΩ	2.5	5	6.5	14	25 μA	50V	1.5
10 MΩ	10	18	20	44	5 μA	50V	3
19 MΩ	14	22	24	50	2.5 μA	50V	4
100 MΩ	40	65	95	175	.5 μA	50V	10

## Notes:

1. This table can be used to determine the absolute uncertainty for four-wire operation when the 5450A is calibrated by means other than the procedure presented in Section 4-28. For each resistance value, add the uncertainty of the calibration technique used to the stability figure given above for the desired conditions.
2. The accuracy degrades for current outside the limits given under NORMAL I RANGE in the FOUR-WIRE ACCURACY SPECIFICATIONS, above. For a description and derating factors, see FOUR-WIRE DERATING FACTORS, below.
3. Above 70% relative humidity the accuracy degrades for values above 190 kΩ. For these values use the following table for STABILITY to 80% RH:

Nominal Value	90 Days 23°C ±5°C	1 Year 23°C ±5°C
1 MΩ	7.5 ppm	15 ppm
1.9 MΩ	8.5 ppm	16 ppm
10 MΩ	30 ppm	54 ppm
19 MΩ	44 ppm	70 ppm
100 MΩ	115 ppm	195 ppm

4. The maximum current and voltage given are the maximum that will not permanently change any resistance values. Operation above these limits may require recalibrating the instrument afterwards.
5. The temperature coefficient applies to both the ABSOLUTE UNCERTAINTY and the STABILITY, above.

Table 1-1. Specifications (cont)

FOUR-WIRE CURRENT DERATING FACTORS		
NOMINAL VALUE	OVER/UNDER I NORMALIZATION K	
	I < I <sub>L</sub> Note 1	I <sub>U</sub> < I < I <sub>MAX</sub> Note 2
SHORT	5x10 <sup>-1</sup>	None
1Ω	2x10 <sup>2</sup>	1x10 <sup>-4</sup>
1.9Ω	1x10 <sup>2</sup>	2x10 <sup>-4</sup>
10Ω	5x10 <sup>1</sup>	3x10 <sup>-4</sup>
19Ω	2.6x10 <sup>1</sup>	3x10 <sup>-4</sup>
100Ω	5x10 <sup>0</sup>	2x10 <sup>-3</sup>
190Ω	2.6x10 <sup>0</sup>	2x10 <sup>-3</sup>
1 kΩ	5x10 <sup>-1</sup>	2x10 <sup>-2</sup>
1.9 kΩ	2.6x10 <sup>-1</sup>	2x10 <sup>-2</sup>
10 kΩ	5x10 <sup>1</sup>	2x10 <sup>-7</sup>
19 kΩ	2.6x10 <sup>1</sup>	2x10 <sup>-7</sup>
100 kΩ	3x10 <sup>0</sup>	2x10 <sup>-6</sup>
190 kΩ	1.6x10 <sup>0</sup>	I <sub>U</sub> = I <sub>MAX</sub>
1 MΩ	5x10 <sup>0</sup>	I <sub>U</sub> = I <sub>MAX</sub>
1.9 MΩ	2.6x10 <sup>0</sup>	I <sub>U</sub> = I <sub>MAX</sub>
10 MΩ	1x10 <sup>0</sup>	I <sub>U</sub> = I <sub>MAX</sub>
19 MΩ	5.3x10 <sup>-1</sup>	I <sub>U</sub> = I <sub>MAX</sub>
100 MΩ	1x10 <sup>-1</sup>	I <sub>U</sub> = I <sub>MAX</sub>

## Notes:

- For  $I < I_L$ , errors occur due to thermally generated voltages within the 5450A. Use the following equation to determine the error in ppm (or milliohms for the SHORT), and add this to the ABSOLUTE UNCERTAINTY or STABILITY, above.

$$\text{ppm (or milliohms for SHORT)} = K \times (I_L - I) / (I_L \times I)$$

where: K is the constant from the above table;  
 I and I<sub>L</sub> are expressed in mA for SHORT to 1.9 kΩ;  
 I and I<sub>L</sub> are expressed in μA for 10 kΩ to 100 MΩ.

- For  $I_U < I < I_{MAX}$ , error occurs due to self-heating of the resistors in the 5450A. Use the following equation to determine the error (in ppm), and add this to the ABSOLUTE ACCURACY or STABILITY, above.

$$\text{ppm} = K \times (I^2 - I_U^2)$$

where: K is the constant from the above table;  
 I and I<sub>U</sub> are expressed in mA for SHORT to 1.9 kΩ;  
 I and I<sub>U</sub> are expressed in μA for 10 kΩ to 100 MΩ.

Table 1-1. Specifications (cont)

**TWO-WIRE OPERATION**

The two-wire specifications apply to the OUTPUT terminals and assume the use of the 2 WIRE COMPensation feature. The 2 WIRE COMPensation feature compensates for the connection resistance, which may include user cabling (such as test leads or system cabling). The compensation value can be calibrated at the time the instrument is calibrated, or for better accuracy, every 24 hours.

To find the two-wire accuracy specification, take the accuracy values from the TWO-WIRE SPECIFICATIONS table (below), add any error specified in notes 2 and 4 (below), convert the result to ppm, and add the result to the values given in the FOUR-WIRE ACCURACY SPECIFICATIONS and OTHER FOUR-WIRE SPECIFICATIONS tables, above. Above 190 k $\Omega$  the two-wire specifications are the same as the four-wire specifications.

<b>TWO-WIRE SPECIFICATIONS</b> <sup>1, 2, 3, 4</sup>			
<b>NOMINAL VALUE</b>	<b>MINIMUM CURRENT</b>	<b>ADD TO 4-WIRE ACCURACY SPECIFICATION</b> <b>23°C <math>\pm</math>5°C</b> <b>90 Days</b> <b>(<math>\pm</math>m<math>\Omega</math>)</b>	<b>ADD TO 4-WIRE ACCURACY SPECIFICATION</b> <b>TOC <math>\pm</math>5°C (18°C-28°C)</b> <b>24 Hours</b> <b>(<math>\pm</math>m<math>\Omega</math>)</b>
1 $\Omega$	1 mA	25 m $\Omega$	12 m $\Omega$
1.9 $\Omega$	1 mA	25 m $\Omega$	12 m $\Omega$
10 $\Omega$	1 mA	20 m $\Omega$	10 m $\Omega$
19 $\Omega$	1 mA	20 m $\Omega$	10 m $\Omega$
100 $\Omega$	1 mA	25 m $\Omega$	12 m $\Omega$
190 $\Omega$	1 mA	25 m $\Omega$	12 m $\Omega$
1 k $\Omega$	.1 mA	100 m $\Omega$	35 m $\Omega$
1.9 k $\Omega$	.1 mA	100 m $\Omega$	35 m $\Omega$
10 k $\Omega$	10 $\mu$ A	200 m $\Omega$	125 m $\Omega$
19 k $\Omega$	10 $\mu$ A	200 m $\Omega$	125 m $\Omega$
100 k $\Omega$	1 $\mu$ A	1000 m $\Omega$	1000 m $\Omega$
190 k $\Omega$	1 $\mu$ A	1000 m $\Omega$	1000 m $\Omega$

## Notes:

- Specifications apply for both front and rear panel terminals regardless of which terminals were used during calibration.
- If user cabling is included in the 2-wire compensation value, add to the specification the variations in cabling resistance for the appropriate time period and temperature.
- The 2-wire compensation value may be calibrated every 24 hours as described in Section 2 (see "2-Wire Enhancement"). The ambient temperature at which this calibration is performed (called temperature of calibration, or TOC) may be between 18°C and 28°C. The 24-hour specification applies for the range TOC  $\pm$ 5°C, but does not apply above 28°C or below 18°C.
- Add to the 24-hour specification the error (in milliohms) of the DMM used when measuring the short.

Table 1-1. Specifications (cont)

IEEE-488 INTERFACE FUNCTION SUBSETS		
SH1	Source handshake	Complete capability
AH1	Acceptor handshake	Complete capability
T8	Talker	Basic talker, unaddress if MLA
L4	Listener	Basic listener, unaddress if MTA
SRO	Service request	No capability
RL1	Remote/local	Complete capability
PPO	Parallel poll	No capability
DC1	Device clear	Complete capability
DTO	Device trigger	No capability
CO	Controller	No capability
E2	Electrical interface	Three-state drivers

GENERAL SPECIFICATIONS	
Interface .....	IEEE Standard 488-1978 (IEEE-488)
Warm-up time .....	2 hours from environment of 18°C to 28°C 4 hours from environment of 0°C to 40°C
Maximum Voltages:	
Any terminal to ground: .....	60V dc
Between HI & LO: .....	See V <sub>MAX</sub> under OTHER FOUR-WIRE SPECIFICATIONS
Between LO & GD: .....	60V dc if EXT GD selected, 2V dc otherwise.
Altitude .....	0 to 10,000 feet (operating) 0 to 40,000 feet (storage)
Vibration .....	3.1g maximum
Power Requirements .....	100, 120, 220, or 240V ac ±10% 50 to 60 Hz ±5%, <50W
Weight .....	9.3 kg (20.4 lbs) 15.9 kg (35 lbs) shipping weight
Dimensions .....	See Figure 1-1 8.89 cm H x 55.37 cm L x 43.18 cm W (3.5 in H x 21.8 in L x 17.00 in W)  Shipping dimensions: 25.4 cm H x 67.3 cm L x 53.8 cm W (10 in H x 26-1/2 in L x 21-3/16 in W)
Protection Class .....	Class 1 as defined in safety standards IEC 348 and ANSI C39.5

Table 1-1. Specifications (cont)

TEMPERATURE AND HUMIDITY		
CONDITION	TEMPERATURE	RELATIVE HUMIDITY
Storage	-40°C to 0°C 0°C to 75°C	Not controlled ≤95% RH
Operating	0°C to 40°C 40°C to 50°C	≤80% RH ≤50% RH

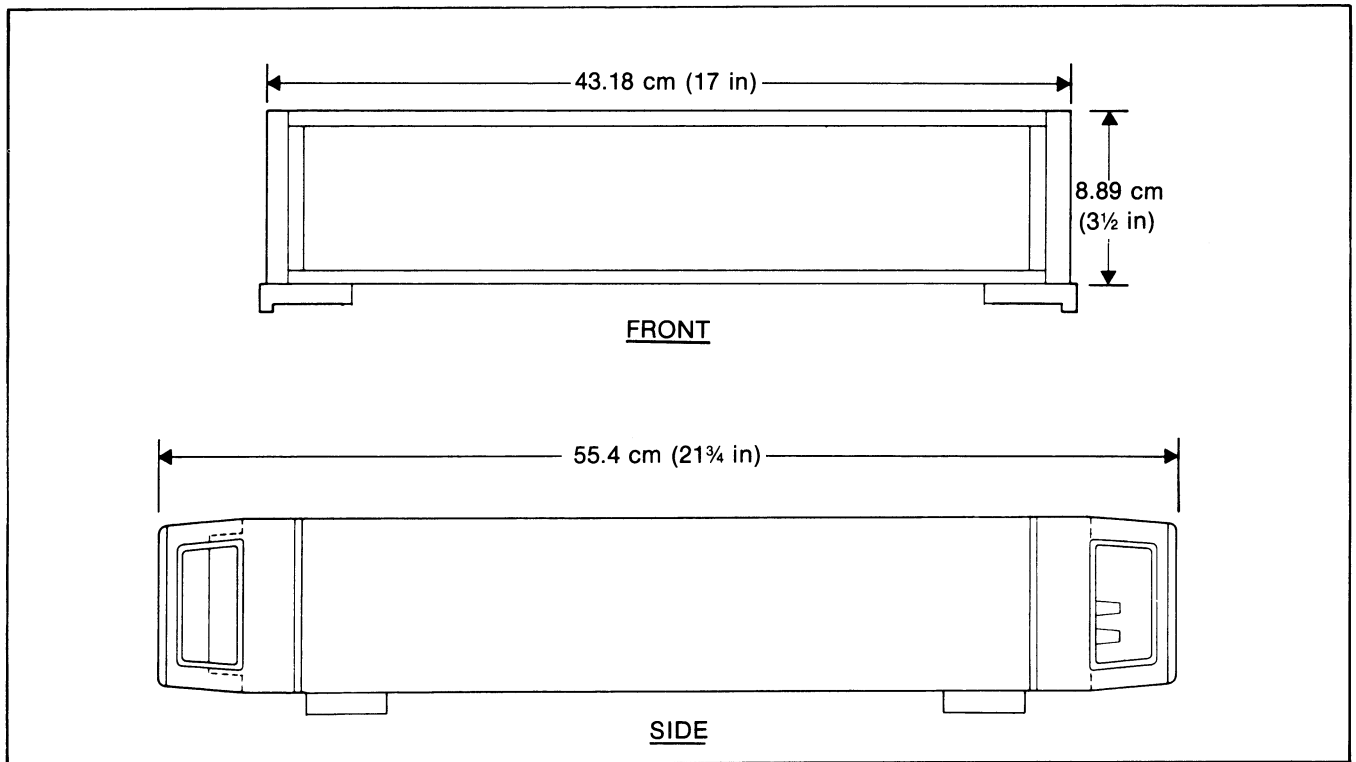


Figure 1-1. Outline Drawing





## Section 2

# Operating Instructions

### 2-1. INTRODUCTION

This section contains installation and operating instructions for the 5450A Resistance Calibrator. It is recommended this section be read and understood before any attempt is made to operate the instrument. Should any difficulties arise during operation, contact the nearest John Fluke sales representative. A list of sales offices is given in Section 7.

### 2-2. SHIPPING INFORMATION

The 5450A is packaged and shipped in a foam-packed container. Upon original delivery of the instrument, the purchaser should thoroughly inspect the product and check all materials in the container against the packing list. The manufacturer will not be responsible for shortages against the packing list unless notified immediately upon receipt. If the instrument is damaged in any way, a claim should be filed with the carrier immediately. (To obtain a quotation for repair of shipment damage, contact the nearest Fluke Technical Service Center. A list of Service Centers is given in Section 7.)

### 2-3. INPUT LINE POWER

The 5450A can be internally configured to operate from line voltages of 100, 120, 220, or 240V ac  $\pm 10\%$  at frequencies of 50 to 60 Hz  $\pm 5\%$ . The factory-selected line voltage setting is marked on the rear panel immediately to the left of the fuse. If the 5450A is set to a voltage that is incorrect for the application, refer to the instructions in Section 4 for changing the setting.

### 2-4. INSTALLATION

The 5450A is designed to be used either on the work bench or mounted in standard deep 24-inch equipment racks. For bench-top operation, the 5450A is equipped with tilt bails and non-marring feet. The tilt bails (located below

the front panel) can be used to tilt the instrument to a convenient operating position. Rack mounting accessories available for the 5450A are listed in Table 2-1. The rack mounting accessories include installation instructions.

**Table 2-1. Rack Mounting Accessories**

NAME	MODEL NUMBER
3½" Rack Adapter with 22"-24" slides	Y8598
3½" Rack Adapter only	Y8599

### 2-5. IEEE-488 CONNECTION

The IEEE-488 connector on the rear panel allows the 5450A to be connected to an instrument controller (such as the Fluke 1722A) for remote-controlled operation. The IEEE-488 connector mates with standard 24-conductor IEEE-488 cables. The cables may be stacked at the connector.

IEEE-488 connections are confined to the following limits:

1. No more than 15 devices may be connected in a single IEEE-488 bus system.
2. The total length of cable used in one IEEE-488 bus system must not exceed 20 meters.
3. The total length of cable must also not exceed 2 meters times the number of devices in the system.

Combinations of 1-, 2-, and 4-meter IEEE-488 cables can be used, to meet the cable length restrictions. For example, when a system consists only of the 5450A and a controller, the number of devices is 2. Multiplying by 2 meters, the maximum length of the cable that can be used is 4 meters (2 devices x 2 meters/device = 4 meters).

Therefore, a 1-, 2-, or 4-meter cable could be used to connect the 5450A to the controller. When connecting more than 10 devices, the length of cables used should not total more than 20 meters. Available cables are listed in Table 2-2.

**Table 2-2. IEEE-488 Cable Accessories**

MODEL NUMBER	NAME
Y8021	IEEE Standard Cable, 1 Meter
Y8022	IEEE Standard Cable, 2 Meters
Y8023	IEEE Standard Cable, 4 Meters

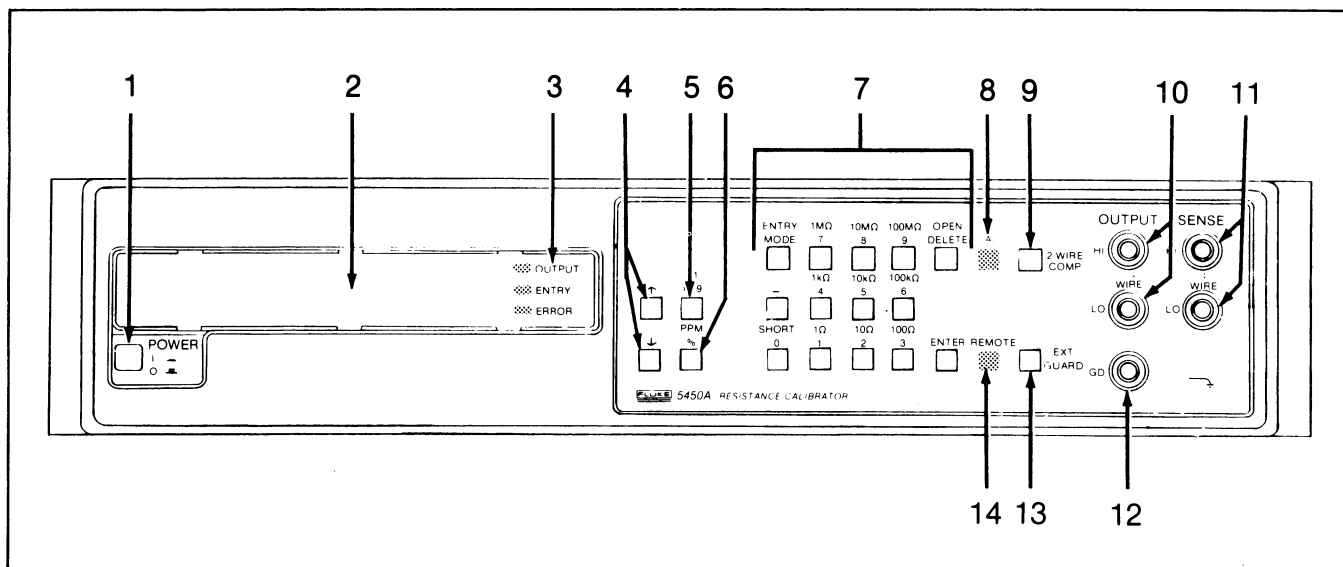
**2-6. CONTROLS AND INDICATORS**

Front panel controls, indicators, and connectors are shown in Figure 2-1 and described in Table 2-3. Rear panel controls, indicators, and connectors are shown in Figure 2-2 and described in Table 2-4.

**2-7. OPERATING NOTES**

**2-8. Rear Panel Settings**

The rear panel switches provide for setting the IEEE-488 bus address, connecting the IEEE-488 cable shielding, enabling the calibration mode, and configuring the instrument for the type of calibration to be performed.



**Figure 2-1. Front Panel Controls, Indicators, and Connectors**

**Table 2-3. Front Panel Controls, Indicators, and Connectors**

ITEM NO.	NAME	FUNCTION
1	POWER switch	Turns the 5450A on (1) and off (0).
2	Display	<p>Eight alphanumeric 14-segment LEDs.</p> <p>In the OUTPUT mode (OUTPUT light on), the display indicates the output resistance that the 5450A is actually sourcing. The last character is blank (for ohms), K (for kilohms), or M (for megohms).</p> <p>In the ENTRY mode (ENTRY light on), the display may indicate K (for kilohms), M (for megohms), or blank (for ohms), prompting the operator to enter the UUT reading via the 5450A keyboard, and indicating the units the 5450A expects the reading to be in. The display indicates the numbers as they are entered.</p> <p>In the ERROR mode (ERROR light on), the display indicates the error of the UUT in parts-per-million (PPM) or percent (PCT).</p>

Table 2-3. Front Panel Controls, Indicators, and Connectors (cont)

ITEM NO.	NAME	FUNCTION
3	Mode annunciators  OUTPUT light  ENTRY light  ERROR light	These indicate whether the 5450A is in the OUTPUT, ENTRY, or ERROR mode.  When on, the OUTPUT mode is selected.  When on, the ENTRY mode is selected.  When on, the ERROR mode is selected.
4	↑↓ (up and down arrows)	Used in the OUTPUT mode. Pressing the up arrow selects the next higher decade of output resistance. If the output is presently 19 MΩ or 100 MΩ, pressing the up arrow selects an OPEN. Pressing the down arrow selects the next lower decade of output. If the output is presently 1Ω or 1.9Ω, pressing the down arrow selects a SHORT.
5	x1/x1.9 switch	Used in the OUTPUT mode. Toggles the output resistance between decade values (e.g., 10 kΩ, 100 kΩ, etc.) and x1.9 values (e.g., 19 kΩ, 190 kΩ, etc.). When the x1/x1.9 switch is lit, x1.9 values are selected.
6	PPM/% switch	Used in the ERROR mode. Toggles the displayed UUT error between percent (PCT) and parts-per-million (PPM). If the error is too large to display in PPM, the display indicates -----PPM. When the PPM/% switch is lit, PCT is selected.
7	Main Keyboard  OUTPUT mode  ENTRY mode  ERROR mode	14 pushbutton switches. White functions are enabled in the OUTPUT and ERROR modes; dark orange functions are enabled in the ENTRY mode.  In the OUTPUT mode, pressing a switch selects the nominal resistor value shown in white. If the x1.9 switch is lit, the output is the nominal value times 1.9. Pressing the ENTRY MODE switch selects the ENTRY mode.  In the ENTRY mode, the keyboard is shifted for entering the UUT reading. The DELETE switch deletes displayed characters. After the UUT reading is keyed in, pressing the ENTER switch selects the ERROR mode.  In the ERROR mode, the 5450A computes and displays the UUT error. Pressing any switch except ENTRY MODE, EXT GUARD, or PPM/% selects the OUTPUT mode again.
8	CAL LED	The CALibration LED indicates that the rear panel CALIBRATION switch is enabled.  <p style="text-align: center;"><b>CAUTION</b></p> <p><b>Do not attempt to operate the 5450A while the CAL LED is lit unless you are calibrating the instrument, as the internal calibration constants may be inadvertently modified.</b></p>

Table 2-4. Front Panel Controls, Indicators, and Connectors (cont)

ITEM NO.	NAME	FUNCTION
9	2 WIRE COMP switch	<p>The 2 WIRE COMPensation switch is used to compensate the characterized value of the internally stored resistance to accommodate UUTs that have a 2-wire resistance measuring circuit (i.e., that do not have separate source terminals). When the 2 WIRE COMP switch is lit, 2-wire compensation is in effect.</p> <p style="text-align: center;"><b>NOTE</b></p> <p><i>If set improperly, the 2 WIRE COMP switch can cause the 5450A display values to be incorrect.</i></p>
10	OUTPUT terminals	<p>Connects the UUT to the 5450A's internal resistors in either 2-wire or 4-wire configurations. In the 4-wire configuration, the UUT source terminals are connected to the 5450A OUTPUT terminals. The front panel OUTPUT terminals are wired in parallel with the rear panel OUTPUT terminals.</p>
11	SENSE terminals	<p>Connects the sense terminals of the UUT to the 5450A's internal resistors when the UUT is in the 4-wire configuration. The front panel SENSE terminals are wired in parallel to the rear panel SENSE terminals.</p>
12	GD (guard) terminal	<p>Connects to the internal guard chassis. The GD terminal is connected to the OUTPUT LO terminal via a 100Ω resistor to reduce noise and leakage. If the EXT GUARD switch LED is on, the GD terminal is not tied to OUTPUT LO. The GD terminal is wired in parallel to the rear panel GUARD terminal.</p>
13	EXT GUARD switch	<p>The EXTernal GUARD switch toggles the 5450A between internal guard (LED off) and external guard (LED on). In internal guard, the GD and OUTPUT LO terminals are connected via a 100Ω resistor. In external guard, these terminals are not tied together. This switch is used for special configurations such as occur when calibrating the 5450A.</p>
14	REMOTE LED	<p>The REMOTE LED indicates that the 5450A has been addressed by the IEEE-488 bus. The instrument may be returned to local mode by pressing any front panel switch unless LOCAL LOCKOUT has been remotely programmed.</p>

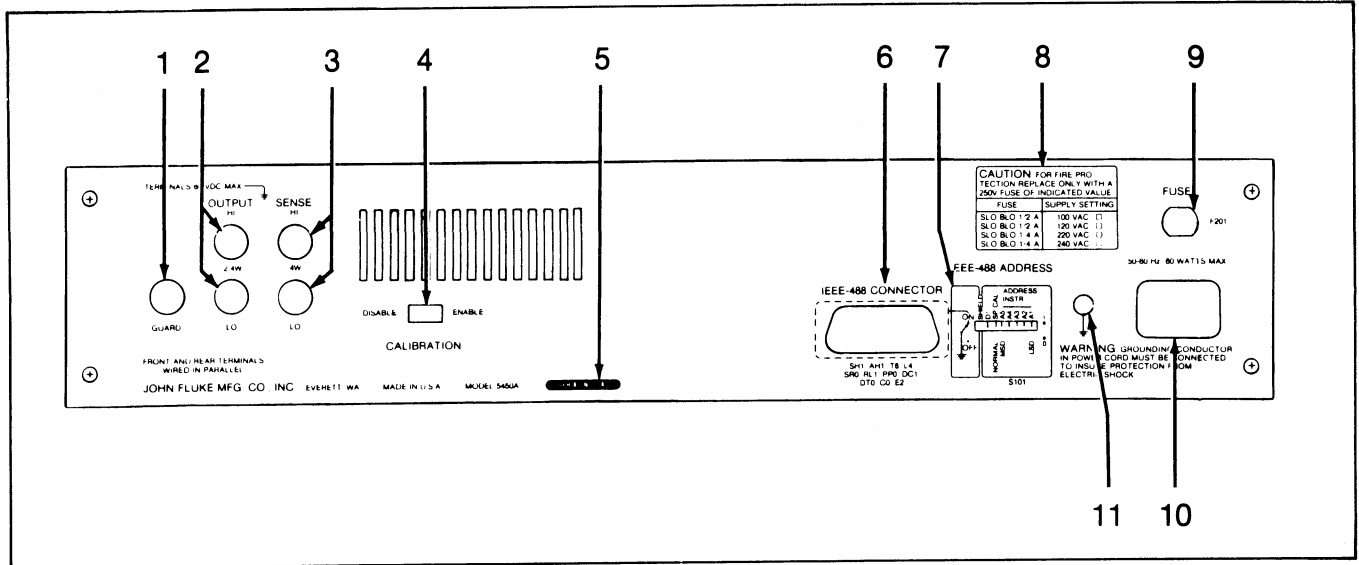


Figure 2-2. Rear Panel Controls, Indicators, and Connectors

Table 2-4. Rear Panel Controls, Indicators, and Connectors

ITEM NO.	NAME	FUNCTION
1	GUARD terminal	Connects to the internal guard chassis. The GUARD terminal is connected to the OUTPUT LO terminal via a 100Ω resistor to reduce noise and leakage. If the EXT GUARD switch LED is on, the GUARD terminal is not tied to OUTPUT LO. The GUARD terminal is wired in parallel to the front panel GD terminal.
2	OUTPUT terminals	Connects the UUT to the 5450A's internal resistors in either 2-wire or 4-wire configurations. In the 4-wire configuration, the UUT source terminals are connected to the 5450A OUTPUT terminals. The rear panel OUTPUT terminals are wired in parallel with the front panel OUTPUT terminals.
3	SENSE terminals	Connects the sense terminals of the UUT to the 5450A's internal resistors when the UUT is in the 4-wire configuration. The rear panel SENSE terminals are wired in parallel to the front panel SENSE terminals.
4	CALIBRATION switch	When in the ENABLE position, allows the 5450A's internal calibration constants to be modified. Normally covered by a calibration sticker.
5	Serial number	
6	IEEE-488 CONNECTOR	Standard 24-pin IEEE-488 receptacle used to connect the 5450A to an instrument controller.
7	IEEE-488 ADDRESS switches A1-A5 NORMAL/SP CAL	Eight recessed toggle switches.  Used to set the IEEE-488 instrument address of the 5450A.  NORMAL (down): Used for normal ratio calibration method specified in Section 4 of this manual.

Table 2-4. Rear Panel Controls, Indicators, and Connectors (cont)

ITEM NO.	NAME	FUNCTION
		SP CAL (up): Allows calibration by general calibration methods such as in a standards calibration laboratory.
	D1	Not used.
	SHIELD	OFF (down): Disconnects IEEE-488 interface cable shield (pin 12) from 5450A ground.  ON (up): Normal position. Connects IEEE-488 interface cable shield (pin 12) to 5450A ground.
8	FUSE/SUPPLY SETTING	Indicates the internally configured line-voltage selection and fuse sizes for the 5450A.
9	FUSE	Line power fuse.
10	Line power receptacle	Receptacle for line power cord.
11	Ground	Chassis ground.

## 2-9. IEEE-488 ADDRESS SWITCHES

The rear panel IEEE-488 address switches are used to set the 5450A to a known address so that the controller may talk and listen to the 5450A. In addition, one of the switches is used to specify the type of calibration to be performed. The switches operate as follows:

- SHIELD switch

Setting the SHIELD switch to the ON (up) position connects the shield on the IEEE-488 interface cable (pin 12) to the 5450A ground. Setting the switch to the OFF (down) position disconnects pin 12 from the 5450A ground. The SHIELD switch is typically ON to avoid instrument emissions and noise susceptibility.

- D1 switch

The D1 switch is not used.

- NORMAL/SP CAL switch

The NORMAL/SP CAL switch configures the 5450A for the type of calibration to be performed. The switch is placed in the down (NORMAL) position when the 5450A is to be calibrated using the procedure described in Section 4 of this manual. If the user wishes to calibrate the 5450A by alternate methods, the switch should be placed in the up (SPeCial CALibration) position. For details, refer to Section 4. The switch is active only when the CALIBRATION switch is enabled.

- INSTR ADDRESS switches (A1-A5)

Switches A1-A5 are used to select the IEEE-488 address of the 5450A. A1 sets the "1-bit", A2 sets the "2-bit", A3 sets the "4-bit", and so on. A bit is set to 1 when the respective switch is in the up position, and is set to 0 when the switch is in the down position. Table 2-5 shows the switch positions for each possible address.

## 2-10. CALIBRATION SWITCH

The CALIBRATION switch places the 5450A in the calibration mode. The calibration mode should be enabled only when calibrating the 5450A. When the switch is in the DISABLE position, the calibration constants stored in the 5450A are protected from being changed. When the switch is in the ENABLE position, the front panel CAL LED illuminates and the internally stored calibration constants may be changed.

After the instrument has been calibrated and the switch has been set to the DISABLE position, it is important that the CALIBRATION switch be covered with a calibration sticker.

### CAUTION

**If the 5450A is operated with the CALIBRATION switch in the ENABLE position, the internal calibration constants may be inadvertently modified during normal operation. If this occurs, do not use the instrument; return it to the appropriate calibration facility for recalibration.**

Table 2-5. IEEE-488 Addresses

DISPLAYED VALUE	INSTR ADDRESS				
	A5	A4	A3	A2	A1
00	DN	DN	DN	DN	DN
01	DN	DN	DN	DN	UP
02	DN	DN	DN	UP	DN
03	DN	DN	DN	UP	UP
04	DN	DN	UP	DN	DN
05	DN	DN	UP	DN	UP
06	DN	DN	UP	UP	DN
07	DN	DN	UP	UP	UP
08	DN	UP	DN	DN	DN
09	DN	UP	DN	DN	UP
10	DN	UP	DN	UP	DN
11	DN	UP	DN	UP	UP
12	DN	UP	UP	DN	DN
13	DN	UP	UP	DN	UP
14	DN	UP	UP	UP	DN
15	DN	UP	UP	UP	UP
16	UP	DN	DN	DN	DN
17	UP	DN	DN	DN	UP
18	UP	DN	DN	UP	DN
19	UP	DN	DN	UP	UP
20	UP	DN	UP	DN	DN
21	UP	DN	UP	DN	UP
22	UP	DN	UP	UP	DN
23	UP	DN	UP	UP	UP
24	UP	UP	DN	DN	DN
25	UP	UP	DN	DN	UP
26	UP	UP	DN	UP	DN
27	UP	UP	DN	UP	UP
28	UP	UP	UP	DN	DN
29	UP	UP	UP	DN	UP
30	UP	UP	UP	UP	DN

## 2-11. Connecting to a Unit under Test

### 2-12. SELECTING CABLES

Cables used to connect the 5450A to the unit under test (UUT) should be high-quality COAX or twisted pair shielded cables. Cables with a separate shield conductor are not necessary for typical bench applications, but can be advantageous in systems applications. Such cables are readily available in various lengths from manufacturers such as Pomona Electronics. The cables should generally be kept as short as possible.

### 2-13. FRONT AND REAR TERMINALS

#### CAUTION

**To prevent instrument damage, input potentials must not exceed 60V dc to chassis from any terminal. In addition, the voltage from HI to LO terminals must not exceed the maximum voltage shown in the specifications for the selected resistor.**

The 5450A provides both front and rear panel terminals. The front panel terminals are wired in parallel with the rear panel terminals.

All of the terminals are low-thermal alloy and accept standard banana plugs. The SENSE and OUTPUT terminals may be connected directly to twin banana plugs with 3/4-inch spacing. The rear panel terminals may also be connected to spade type connectors, which offer lower contact resistance than banana plugs.

It is generally inadvisable to connect cables to the front and rear terminals at the same time. The unused cables may degrade the specifications of the 5450A.

### 2-14. 4-WIRE CONNECTIONS

UUTs for the 5450A typically use a 4-wire circuit to measure resistance. Two leads from the UUT provide a constant current or a voltage source to the resistance being measured. Two other leads are used to measure (or sense) the voltage drop developed across the resistance. The advantage of the 4-wire technique is that it eliminates the effects of lead and contact resistance.

For UUTs that use the 4-wire measurement technique, the UUT source leads are connected to the 5450A OUTPUT terminals and the UUT sense leads are connected to the 5450A SENSE terminals.

### 2-15. 2-WIRE CONNECTIONS

Some UUTs, usually meters with lower accuracy, use a 2-wire circuit to measure resistance. The disadvantage of this type of measurement is that the lead and contact resistance of the leads and paths add directly to the

resistance. (Consequently, some meters allow lead compensation.)

The 5450A features a 2 WIRE COMP switch which compensates for lead and contact resistance. The 2 WIRE COMP switch should normally be enabled (lit) when calibrating 2-wire UUTs. When the 2 WIRE COMP switch is enabled, the 5450A automatically adds the value of its internal lead and contact resistance to the value of the 4-wire resistance and displays this sum to the operator. For even higher accuracy, this internal compensation value may be updated daily. (For instructions, see the heading "2-Wire Enhancement" in this section.)

UUTs that use the 2-wire measurement technique are connected directly to the 5450A OUTPUT terminals.

### 2-16. GUARD CONNECTIONS

If the 5450A is used in a systems environment, it may be advantageous to use shielded cables for OUTPUT and SENSE connections. If shielded cables are used, the shields of the cables may be connected to the GD (or GUARD) terminal of the 5450A. This helps shield the measurement system from EMI and may also provide additional protection from ground current errors.

## 2-17. Powering Up the 5450A

#### CAUTION

**Do not power up the 5450A while the CALIBRATION switch is in the ENABLE position, as the internal calibration constants may be inadvertently modified.**

Before powering up the 5450A, ensure that the line voltage is properly selected and the line power cord is connected to a suitable outlet. To turn the 5450A on, press the front panel POWER switch.

When the 5450A is turned on, all display segments light briefly to test the display. If any segments are unlit, the 5450A should be repaired.

The display then indicates the instrument's IEEE-488 address for approximately 2 seconds. The address may be changed using the rear panel IEEE-488 ADDRESS switches. (For instructions, see the heading "IEEE-488 Address Switches" in this section.)

The display may then briefly indicate another message (such as "5450A"). If so, this message has been entered during a previous calibration. Contact the appropriate calibration facility if the instrument displays a message that you do not fully understand.



Once the preliminary messages have been displayed, the display should read OPEN and the OUTPUT light should turn on. This indicates that the 5450A is in the OUTPUT mode and is sourcing infinite resistance. The 5450A requires 2 hours of warm-up before meeting the specifications given in Section 1.

### 2-18. Selecting an Output

To select an output resistance, the 5450A must be in the OUTPUT mode (the OUTPUT light should be on). If the 5450A is in the ENTRY mode, it is possible to return it to the OUTPUT mode by pressing either the up arrow, down arrow, or x1/x1.9 switches, or by pressing the DELETE switch several times. If the 5450A is in the ERROR mode, it is possible to return it to the OUTPUT mode by pressing any front panel switch except ENTRY MODE, EXT GUARD or PPM/%.

If the UUT is a 2-wire device, it should be connected to the OUTPUT terminals only. In this case, ensure that the 2 WIRE COMP switch is lit. If the UUT is a 4-wire device, it should be connected to both the OUTPUT and SENSE terminals. In this case, ensure that the 2 WIRE COMP switch is unlit.

#### NOTE

*When 2 WIRE COMP is selected, internal lead and contact resistance is added to the 4-wire resistance value to create the displayed resistance. Consequently, calibration errors will occur if the 2 WIRE COMP switch is set incorrectly.*

In typical applications, the EXT GUARD switch should not be lit. The EXT GUARD switch is provided to allow for special configurations such as those that occur when calibrating the 5450A.

To select a decade value (i.e., 1 $\Omega$ , 10 $\Omega$ , etc.), ensure that the x1/x1.9 switch is unlit. To select a x1.9 value (i.e., 1.9 $\Omega$ , 19 $\Omega$ , etc.), ensure that the x1/x1.9 switch is lit.

To select an output range, press the switch on the main keyboard that has the desired resistance written above it in white characters. For example, press the 10 k $\Omega$  switch to cause the 5450A to source a nominal 10 k $\Omega$ . If the x1/x1.9 switch is lit, the output will be a nominal 19 k $\Omega$ .

To select a resistance that is one decade higher than that presently selected, press the up arrow switch. If the output is presently 100 M $\Omega$  or 19 M $\Omega$ , pressing the up arrow switch selects OPEN (infinite resistance).

To select a resistance that is one decade lower than that presently selected, press the down arrow switch. If the output is presently 1 $\Omega$  or 1.9 $\Omega$ , pressing the down arrow switch selects a SHORT (nominally zero resistance).

In the OUTPUT mode, the 5450A displays the actual, characterized value of its output resistance instead of the nominal value selected. For example, the 5450A might display 9.99987 when the nominal value 10.00000 is selected.

For 4-wire configurations (when the 2 WIRE COMP switch is unlit), the 5450A displays the resistance between the internal junction of the OUTPUT HI and SENSE HI terminals and the internal junction of the OUTPUT LO and SENSE LO terminals.

For 2-wire configurations (when the 2 WIRE COMP switch is lit), the 5450A displays the resistance between the OUTPUT HI and OUTPUT LO terminals at the front or rear panel. The 2 WIRE COMP offset may be characterized to include the resistance of a specific set of test leads. (See the heading "2-Wire Enhancement" in this section.)

### 2-19. Computing Error

The 5450A can automatically calculate and display the error of the UUT in percent or parts-per-million (ppm). The 5450A computes the UUT error by comparing the UUT reading (entered into the 5450A by the operator) to the characterized value of the resistance presently being sourced by the 5450A.

To enter the UUT reading, press the ENTRY MODE switch. The LED in the ENTRY MODE switch will light, and the ENTRY light will turn on, prompting the operator for an entry.

#### NOTE

*Any computed error would be meaningless when the 5450A is sourcing an OPEN. Therefore, the ENTRY MODE switch is inactive when an OPEN is selected.*

Then, using the main keyboard, enter the UUT reading. The rightmost digit of the display indicates the units for which the 5450A expects the entry: blank for ohms, K for kilohms, and M for megohms.

Use of the decimal point (.) is optional. If the decimal point is not explicitly entered, the 5450A assumes that the decimal point is in the same position as it was when the output resistance was displayed.

If an error is made while entering the UUT reading, press the DELETE switch to erase the last character entered. If the leftmost character is erased, the 5450A returns to the OUTPUT mode.

The entry is concluded by pressing the ENTER switch. If any of the rightmost digits are not entered prior to pressing the ENTER switch, they are assumed to be zeros.

Once the ENTER switch has been pressed, the 5450A changes to the ERROR mode. (This is indicated by the ERROR light turning on.)

The error may be displayed in percent or ppm. If the PPM/% switch is lit, the error is displayed in percent; otherwise, the error is displayed in ppm. The percent sign is shown in the display as PCT, and ppm is shown as PPM.

While in the ERROR mode, pressing the ENTRY MODE switch reselects the ENTRY mode. (This is useful if the UUT reading has changed.) In this case, the 5450A displays the UUT reading previously entered. The entry may be changed after using the DELETE switch. Then, pressing the ENTER switch causes the 5450A to recompute the UUT error.

To return to the OUTPUT mode, press any switch except ENTRY MODE, EXT GUARD, or PPM/%. Another output resistance may then be selected.

## 2-20. 2-Wire Enhancement

To decrease the uncertainty of the 5450A while calibrating 2-wire UUTs, the 5450A provides the capability of accommodating a short-term, user-performed calibration of the 5450A's lead and contact resistance. This short-term calibration updates the 2 WIRE COMP offset which is added to the 4-wire values of resistance. A selected test lead may be included in this characterization by making the measurement at the end of the test lead instead of directly at the 5450A OUTPUT terminals. If the measurement is made right at the terminals, it is valid for the other set of terminals as well.

Once characterized, the value may be used for 24 hours, or until the 5450A is turned off, whichever occurs first. For the specifications when using this optional capability, see Section 1.

To perform this characterization:

1. Connect a calibrated high-accuracy DMM (such as the Fluke 8505A or Fluke 8520A) to either the front or rear panel OUTPUT HI and LO terminals of the 5450A. Connect the DMM source HI and sense HI terminals together at the OUTPUT HI terminals of the 5450A. Connect the DMM source LO and sense LO terminals together at the OUTPUT LO terminal of the 5450A.
2. Select a SHORT from the 5450A.
3. Press 2 WIRE COMP. (The LED in the switch should light.)
4. Press ENTRY MODE.

5. After the external DMM is fully settled on the lowest resistance range, use the 5450A main keyboard to enter the value displayed by the external DMM.
6. Press ENTER.
7. The 5450A now displays the error of the new zero (in PPM or %) from the zero stored during the last complete calibration.
8. Press ENTRY MODE then press ENTER again. This stores the entered offset as the new offset to be used in subsequent 2-wire calculations.

The 5450A will use the new 2-wire compensation value until the 5450A is powered down. The improved specifications apply for 24 hours after enhancement. To erase the new compensation value and resume use of the offset value entered during the last complete calibration, cycle the POWER switch off and back on again.

## 2-21. REMOTE OPERATION

### 2-22. Introduction

The 5450A may be remotely controlled by an IEEE-488 controller, such as the Fluke Model 1722A Instrument Controller. A controller can facilitate the automated calibration of UUTs by operating the 5450A with a computer program.

Introductory literature about the IEEE-488 interface bus is available from local Fluke representatives, including "IEEE Standard 488-1978 Digital Interface for Programmable Instrumentation" (AB-36) and "Communication Over the IEEE-488 Bus" (B0079).

Remotely programming the 5450A involves a series of simple commands that correspond closely to front panel operation.

A typical automated sequence would begin by the controller programming the 5450A to provide a particular resistance. The controller would next request the characterized value of the 5450A resistance. The controller would then request the UUT to take a reading on the desired resistance range and transmit the reading back to the controller. Finally, the controller would compute the actual error and compare it to the error allowable for the particular UUT. The actual error could then be logged and the next range of the UUT could be verified.

A semi-automated sequence can be used for UUTs that are not remotely programmable. In this case, a typical sequence would be the same as above except that the UUT would be controlled manually, and the controller would solicit the UUT reading from the operator.

## 2-23. Capabilities

All functions available on the front panel (except for the POWER switch) are available using remote commands. The 5450A can become a listener for responding to remote commands. The 5450A can also become a talker in order to send the controller the instrument's status and the actual values of the programmed resistance.

The 5450A supports the ANSI/IEEE Standard 488-1978 function subsets listed in the specifications in Section 1 of this manual.

## 2-24. Device Clear

The universal bus command DCL (device clear) and the addressed bus command SDC (selective device clear) may be used to place the 5450A back to a known reset condition. The instrument is set back to the power-up conditions of OUTPUT MODE, OPEN, X1, PPM, EXT GUARD OFF, and 2 WIRE COMP OFF.

## 2-25. Local/Remote Operation

In typical operation, the 5450A front panel REMOTE light turns on when the 5450A is addressed as a listener or talker and data is being transferred. The REMOTE light remains on if the instrument is in REMS (REMOte State). If the user presses any of the front panel switches, the instrument returns to local control and the REMOTE light turns off.

The universal bus command LLO (local lockout) may be used to disable the controls on the front panel of the 5450A. The bus command LOCAL reenables the 5450A

controls. The front panel controls can also be reenabled by cycling the 5450A POWER switch.

## 2-26. Command Separators and Terminators

The individual commands sent to the 5450A must be separated by either a comma (,) or a semicolon (;). Each sequence of commands must be terminated by a carriage return (CR), line feed (LF), and/or an "end or identify" (EOI). If spaces (blanks) are sent to the 5450A, they are ignored. As the 5450A is case-insensitive, any command can be sent in either uppercase, lowercase, or a combination of the two.

When the 5450A is addressed as a talker, the string sent back to the controller is concluded by an LF and an EOI.

## 2-27. Remote Error Handling

If the 5450A receives a remote command containing an error, the remainder of the erroneous command is ignored. The 5450A responds to an error by setting two bits of the internal SPL byte: the least significant bit (with a binary weighting of 1), and RSV (bit 6, with a binary weighting of 64). When the SPL byte is read by the controller, the error bit is reset to zero.

## 2-28. Command Set

The set of device-dependent commands for the 5450A is shown in Tables 2-6 and 2-7. Table 2-6 shows the commands that correspond on a one-to-one basis with the front panel switches. Table 2-7 shows the additional commands that correspond to pushing several front panel switches in sequence. Note that most of the commands use the same nomenclature as the front panel.

**Table 2-6. Simple IEEE-488 Commands**

COMMAND	RESULT
UP;	Increments the decade of the selected resistance, just like the up arrow switch.
DN; or DOWN;	Decrements the decade of the selected resistance, just like the down arrow switch.
X1/X1.9;	Toggles the selected resistance between x1 and x1.9 values, just like the x1/x1.9 switch.
X1;	Selects decade values of resistance (e.g., 10 k $\Omega$ , 100 k $\Omega$ , etc). Equivalent to setting the x1/x1.9 switch to x1 (LED off).
X1.9;	Selects x1.9 values of resistance (e.g., 19 k $\Omega$ , 190 k $\Omega$ , etc.). Equivalent to setting the x1/x1.9 switch to x1.9 (LED on).
PPM/%;	Toggles the error display units between % and PPM (parts-per-million), just like the PPM/% switch.
PPM;	Selects display of UUT error in PPM (parts-per-million). Equivalent to setting the PPM/% switch to PPM (LED off).

Table 2-6. Simple IEEE-488 Commands (cont)

COMMAND	RESULT
% ; or PCT ;	Selects display of UUT error in percent. Equivalent to setting the PPM/% switch to % (LED on).
ENTRY MODE ;	Selects the ENTRY mode. Conditions the 5450A to receive a following numeric value which represents the UUT display. Performs the same function as the ENTRY MODE switch.
SHORT ;	Programs the 5450A to a SHORT (near 0 ohms).
OPEN ;	Programs the 5450A to OPEN (infinite resistance).
0 ; - 9 ; and . ;	<p>The commands 0 ; 1 ; 2 ; 3 ; 4 ; 5 ; 6 ; 7 ; 8 ; 9 ; and . ; perform the same function as the corresponding front panel switches:</p> <p>If the 5450A is in the OUTPUT or ERROR mode, the digits 0 through 9 select the corresponding decade of resistance to be sourced (i.e., 0 = short, 1 = 1<math>\Omega</math>, 2 = 10<math>\Omega</math>, 3 = 100<math>\Omega</math>, 4 = 1 k<math>\Omega</math>, 5 = 10 k<math>\Omega</math>, 6 = 100 k<math>\Omega</math>, 7 = 1 M<math>\Omega</math>, 8 = 10 M<math>\Omega</math>, 9 = 100 M<math>\Omega</math>). The resistance actually sourced may be modified by the X1.9 command.</p> <p>If the 5450A is in the ENTRY mode (selected using the ENTRY MODE command), the digits 0 through 9 may be used in conjunction with the decimal point (.) to enter the UUT display for computation of UUT error. In this case, the digits are followed by the ENTER command to select the ERROR mode.</p>
DELETE ;	If the 5450A is in the ENTRY mode, the DELETE command causes the 5450A to delete the last numeric character entered. This command performs the same function as the DELETE switch.
ENTER ;	Active in the ENTRY mode. Enters numbers programmed in the ENTRY mode, computes UUT error, and selects the ERROR mode. Performs the same function as the ENTER switch.
2 WIRE COMP ;	Toggles the 2 WIRE COMP function on or off, depending on the previous state of this function. Performs the same function as the 2 WIRE COMP switch.
2 WIRE COMP ON ;	Causes 2 WIRE COMP to be active.
2 WIRE COMP OFF ;	Causes 2 WIRE COMP to be deactivated.
EXT GUARD ;	Toggles the EXT GUARD function on or off, depending on the previous state of this function. This command performs the same function as the EXT GUARD switch.
EXT GUARD ON ;	Causes EXT GUARD to become active.
EXT GUARD OFF ;	Causes EXT GUARD to be deactivated.

Table 2-7. Extended IEEE-488 Commands

COMMAND	RESULT																								
OUTPUT <number>;	Selects the OUTPUT mode, and programs the 5450A to source the resistance specified by <number>. <number> is expressed in ohms and may consist of 0-9, ., + or E.																								
ENTRY <number>;	Enters the <number> into the display and computes the resulting error. The instrument is left in the ERROR mode, displaying error in PPM or PCT. <number> is expressed in ohms and may consist of 0-9, ., + or E.																								
PERSONALITY <string>;	The personality string is displayed to the operator for approximately 2 seconds during power-up and may also be read by the STAT or STATUS command. When the instrument is originally delivered, the string is set to "5450A". The string may be redefined using the PERSONALITY <string> command. <string> may consist of up to eight alphanumeric characters. Since the 5450A ignores spaces, spaces must be indicated by a % character in the string. The 5450A must be in the CALIBRATION ENABLE mode to successfully execute this command.																								
CLEAR;	Programs the 5450A to the power-up condition (OUTPUT MODE, OPEN, X1, PPM, 2 WIRE COMP OFF and EXT GUARD OFF). The CLEAR command works exactly like the interface messages DCL and SDC.																								
VALUE; or ?;	Requests the 5450A to return the characterized value of the resistance presently selected. The number returned is the value in ohms and may contain a decimal point and "E". The number is preceded by a space and is terminated by an LF and an EOI. If an OPEN is presently selected, the number returned is 1E50.																								
STAT; or STATUS;	<p>Requests a 50-character message from the 5450A which describes the state of the instrument. The message is followed by an LF and an EOI. The character assignments are:</p> <table border="0" data-bbox="670 1171 1458 1612"> <tr> <td style="padding-right: 20px;">1-10</td> <td>5450A display including decimal point (1st character is sign if negative)</td> </tr> <tr> <td>11-16</td> <td>5450A mode ("OUTPUT", "ENTRY " or "ERROR ")</td> </tr> <tr> <td>17-20</td> <td>"X1 " or "X1.9"</td> </tr> <tr> <td>21-23</td> <td>"PPM" or "% "</td> </tr> <tr> <td>24-28</td> <td>"SPCAL", "CAL ", or " "</td> </tr> <tr> <td></td> <td>(Blanks mean CALIBRATION DISABLED)</td> </tr> <tr> <td>29-31</td> <td>"EXT" or " "</td> </tr> <tr> <td>32-37</td> <td>"2 WIRE" or " "</td> </tr> <tr> <td>38-45</td> <td>Personality message</td> </tr> <tr> <td>46-47</td> <td>00 if no error has occurred; 01 if an error has occurred</td> </tr> <tr> <td>48-49</td> <td>"D1" or " "</td> </tr> <tr> <td>50</td> <td>50 Not used</td> </tr> </table>	1-10	5450A display including decimal point (1st character is sign if negative)	11-16	5450A mode ("OUTPUT", "ENTRY " or "ERROR ")	17-20	"X1 " or "X1.9"	21-23	"PPM" or "% "	24-28	"SPCAL", "CAL ", or " "		(Blanks mean CALIBRATION DISABLED)	29-31	"EXT" or " "	32-37	"2 WIRE" or " "	38-45	Personality message	46-47	00 if no error has occurred; 01 if an error has occurred	48-49	"D1" or " "	50	50 Not used
1-10	5450A display including decimal point (1st character is sign if negative)																								
11-16	5450A mode ("OUTPUT", "ENTRY " or "ERROR ")																								
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29-31	"EXT" or " "																								
32-37	"2 WIRE" or " "																								
38-45	Personality message																								
46-47	00 if no error has occurred; 01 if an error has occurred																								
48-49	"D1" or " "																								
50	50 Not used																								
ERR; or ERROR;	Requests a numeric value of the most recently computed UUT error in PPM. If an error has not been computed since power up, or the result of the last calculation resulted in an error greater than or equal to 2E6 PPM, 1E50 is returned.																								

**2-29. Programming Examples**

The following examples show programs for the Fluke 1722A Instrument Controller. For the purpose of these examples, it is assumed that the 5450A is set to the IEEE-488 address of 7.

Example 1: Initializing the 5450A to a power-up condition.

```
PRINT @7, "CLEAR;"
```

Example 2: Programming the 5450A to 10 k $\Omega$ .

```
PRINT @7, "5;"
```

or

```
PRINT @7, "OUTPUT 10000;"
```

Example 3: Determining the actual value of the 10 k $\Omega$  nominal resistance selected in Example 2.

```
PRINT @7, "VALUE;"  
INPUT @7, A1
```

or

```
PRINT @7, "?;"  
INPUT @7, A1
```

Example 4: Stringing the previous commands together.

```
PRINT @7, "CLEAR; OUTPUT 10000; ?;"  
INPUT @7, A1
```

## Section 3

# Theory of Operation

### 3-1. INTRODUCTION

This section describes the internal operation of the 5450A Resistance Calibrator in two steps. First, a functional description describes the various functional blocks of the instrument and how they are related. Then, a circuit description examines each functional block in more detail, describing how each block works.

### 3-2. FUNCTIONAL DESCRIPTION

A functional block diagram for the 5450A is shown in Figure 3-1. As this figure shows, the 5450A consists of four functional blocks: the display circuit, the digital circuit, the analog circuit, and the power supply circuit.

The display circuit receives information from the digital circuit and displays this information via the front panel annunciators and alphanumeric display. The display circuit also sends signals to the digital circuit when the operator presses the front panel switches.

The digital circuit controls the 5450A. The microprocessor on the digital circuit decodes operator inputs from the display circuit and translates this information into signals to be sent back to the display circuit and the analog circuit. The digital circuit also contains the IEEE-488 interface circuitry which provides for remote operation of the 5450A.

The analog circuit provides the stimulus to the unit under test (UUT). The circuit contains the relays, relay logic, and resistors to provide the appropriate resistance source to the external terminals.

The power supply circuit of the 5450A provides supply voltages to all other circuits in the 5450A.

### 3-3. CIRCUIT DESCRIPTION

The four major circuits of the 5450A shown in Figure 3-1 are laid out on five printed circuit assemblies (PCAs): the Digital PCA, the Memory PCA, the Analog PCA, the Display PCA, and the Power Supply PCA. For reference, the location of the five PCAs is shown in Section 5. Detailed schematics are provided in Section 9.

The digital circuit is laid out on the Digital PCA and the Memory PCA. The Digital PCA consists of the microprocessor and IEEE-488 controller circuitry. The Memory PCA contains the ROMs and the EAROM for use by the microprocessor.

The power supply circuit is distributed throughout the instrument. The major components are the Power Supply PCA and power transformer, which are housed together in the transformer compartment towards the rear of the instrument.

The display circuit is contained on the Display PCA, which is located behind the front panel bezel. The Display PCA contains the front panel switches and light emitting diode (LED) displays.

The analog circuit is contained on the Analog PCA, which contains resistors, relays, and relay decoding logic.

### 3-4. Power Supply Circuit

The 5450A power supply circuit consists of the power supply assembly (which consists of the the transformer and Power Supply PCA) and also consists of circuitry on the Digital PCA (providing regulation for the digital +5V dc voltage supply), the Analog PCA (providing rectification, regulation, and filtering of voltages for the logic and relays), and the Display PCA (providing regulation for the Display PCA supply).

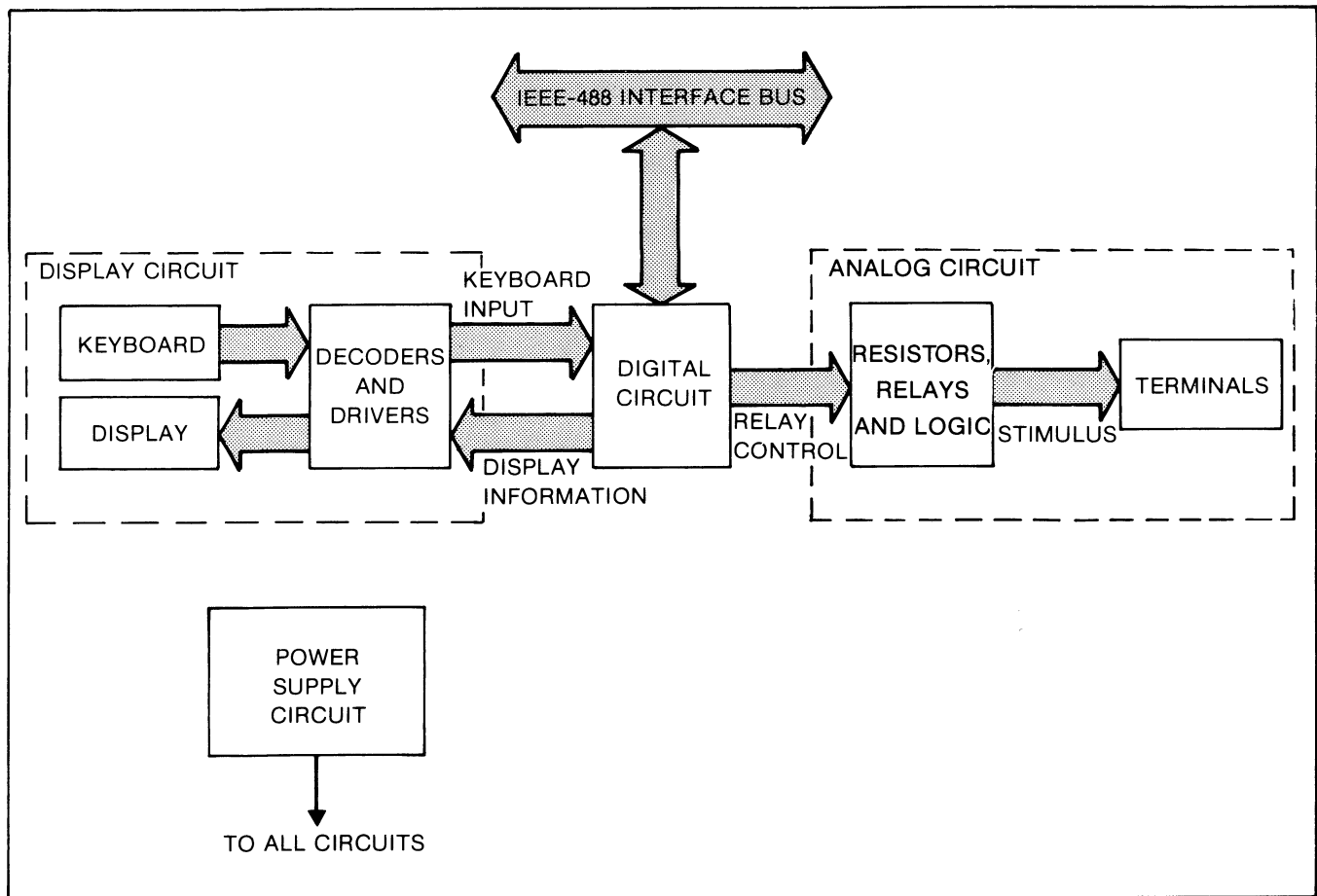


Figure 3-1. Functional Block Diagram

Power transformer T1 provides all voltages to the circuits of the 5450A. The input voltage comes from plug/line filter J10. The voltage is fed through rear panel fuse F201. A spare F201 is contained on the side of the transformer compartment inside the 5450A. The supply is switched via the front panel POWER switch.

### 3-5. ANALOG SUPPLY CIRCUIT

One secondary winding of power transformer T1 goes to the Analog PCA via J2. This signal is full-wave rectified via CR4 and CR5. Prior to rectification, the low and high leads are fused by 2-amp fast-blow fuses (F1 and F2). A spare fuse is located on the power supply chassis to replace either F1 or F2. The voltage is filtered by C8 and regulated to +5V dc by VR1. The resulting +5V dc voltage is called VCC and is used to supply the digital components on the Analog PCA.

VCC is also indirectly used to energize the relays on the Analog PCA. An unregulated voltage of approximately 8V dc is applied for about 15 ms across the relay coils to energize the relay. The pulse is provided by turning on Q1 and by limiting the amplitude with R2, Q1, CR1, and CR3. To eliminate the heating of the coils (and the subsequent increase of thermal EMFs), the voltage across

the relay coils is then reduced to approximately 3.5V dc by sending VCC through CR2 and turning off Q1 to provide a relay holding voltage. The signal to drive the relays is referenced as RELAY PWR. The logic to create the pulse is discussed under the Analog Circuit heading later in this section.

### 3-6. DIGITAL SUPPLY CIRCUIT

The primary +5V dc signal for the logic components on the Digital PCA and Memory PCA is called VCC. The return for this voltage is called VSS. To indicate when power is applied, CR201 lights up when VCC is present. (CR201 is located near the large filter capacitor on the Digital PCA.)

On the Digital PCA, regulator U202 takes the rectified output from CR1 and CR2 on the Power Supply PCA and, with its associated components, provides the unguarded +5V operating voltage for the logic circuits. R210, in parallel with U202, provides an increased load capability. Test jumper J201 disconnects the supply, R210, and the load, so that the supply can be checked without a load. The variable resistor R204 is used to adjust VCC to the nominal +5V dc. The voltage may be



easily set while monitoring the voltage across TP201 (VCC) and TP202 (VSS).

### 3-7. DISPLAY SUPPLY CIRCUIT

The Display PCA uses the VUNREG output from the Power Supply PCA. This rectified and filtered signal is regulated on the Display PCA by U14 to create a +5V regulated signal called VLED. This supply is used for all the components on the Display PCA. The signal is returned via VUNREG RETURN.

### 3-8. Display Circuit

The Display PCA has two primary functions. First, it displays information to the operator. Second, it accepts the operator's instructions via the front panel switches. The display consists of four, two-character, fourteen-segment displays. The switches provide digital inputs to the microprocessor and operate completely in full duplex mode. All information is transferred to the microprocessor, and the resultant front panel indication is sent back to the display.

### 3-9. DISPLAYS

The alphanumeric display characters (DS1-DS4) are duplexed. Each character has two cathodes and eight anodes. Segments A1-G1 are enabled (lit) when cathode K1 or K3 is low and the appropriate anode(s) are high. Segments A2-G2 are enabled when the appropriate anode(s) are high and K2 or K4 is low. DP2 is lit when the DP anode is high and K2 is low. DP4 is lit when DP anode is high and K4 is low.

The characters are turned on in pairs. The cathode K1 of DS1 is enabled at the same time as cathode K1 of DS3. Next, cathodes K2 of DS1 and K2 of DS3 are enabled. This sequence continues until K4 of DS2 and K4 of DS4 are enabled, after which the cathodes of DS5-DS4 are enabled. The sequence is then repeated. This process is interrupt-driven by the microprocessor, and as such, periodically begins based on time-synchronized interrupts to the microprocessor. Cycles begin about each 20 ms for a 60 Hz line source.

Data lines D0-D7 provide input information to the display. As a sequence begins, data is strobed into decoder U12. The output from pins 5 and 6 of U12 enable latches U11 or U1. The output is gated from U12 to U11 and U1 by U9 when the input to U9 ( $\overline{SEG}$ ) is low. Data indicating the anodes to be lit is latched into U11 and U1 before each is disabled. Once these latches have stored the information to be displayed, U10 is used to decode the data lines into a cathode signal to drive the desired cathodes of DS1-DS4 low. The latch U10 is enabled by the signal  $\overline{DIGIT}$  going low. Source drivers U15 and U2 provide the current to the display characters, and U7, U8, and U15 sink the current. The LEDs in the switches are

driven similarly, with the unary bit of U12 (U12-4) activating the cathodes, and U11 or U1 driving the anodes.

### 3-10. SWITCHES

The switches S1-S20 on the display are read once during each refresh cycle of the Display PCA. U10 sequentially enables each column of switches (e.g., S2 and S1 or S6, S5, S4, and S3). As the column is enabled, the  $\overline{SW}$  signal is set low to gate the column through three-state driver U13. The column is then read by the microprocessor via D0, D1, D3, D4, and D5 lines.

### 3-11. Digital Circuit

The digital circuit is contained on the Digital PCA and the Memory PCA. The Memory PCA contains ROMs and EAROM. The Digital PCA is divided into three separate sections: the digital controller, the IEEE-488 interface, and the power supply. The first two sections of the Digital PCA are described below; the third section (the power supply) is discussed under a previous heading. Certain portions of the Digital PCA circuitry are not used in this particular application of the PCA; this circuitry is not discussed.

### 3-12. CLOCK CIRCUIT

The microprocessor is provided with a 4 MHz square wave by the clock circuit. Crystal Y1 is an 8 MHz oscillator that clocks the standard binary counter, U20. Outputs from the counter, in addition to the 4 MHz output, are 2 MHz, which is not used in this particular application, and 1 MHz, for use in the IEEE-488 circuitry. The parallel inverters at U19-10 and U19-12, with R6, keep the rise and fall time of the clock within specifications. Ringing is kept within acceptable limits by R7.

### 3-13. MICROPROCESSOR

The microprocessor is a single component with fully decoded and timed output signals to control standard memory or peripheral circuits. Supply voltage for the device is 5V dc. The only clock required is a single-phase, 5V, 4 MHz square wave.

The internal register configuration of the microprocessor contains 208 bits of read/write memory accessible to the program. The registers include two sets of general-purpose accumulator and flag registers that may be used as four 16-bit pairs or as eight 8-bit individuals. Also included is a 16-bit stack pointer that allows implementation of multiple-level interrupts and unlimited subroutine nesting. Tabular data manipulation and relocatable code implementation is accomplished with the two 16-bit registers. The memory refresh and interrupt vector registers are not used in this application. The last register is a 16-bit program counter.

## 3-14. RESET

The instrument circuitry is automatically reset at power up. When one-shot U36-12 is triggered, it provides U22-13 and 12 with a high and low signal respectively to provide a reset to the controller assembly. Line voltage (FLINE) input from U23-11 triggers U36, releasing the counter U28, which in turn clocks U22 on a count of eight to remove the reset. This places the reset on the circuit for a predetermined time during power up.

When power is removed, U36-12 times out and sets U22 to apply a reset to the circuitry. Resistor R19 and capacitor C29 provide a timeout for resetting the instrument by shorting test points TP9 and TP10 together.

## 3-15. WAIT

A WAIT signal is input to the microprocessor at U18-24 to indicate that the addressed memory or I/O device needs an extended bus cycle. The signal can be generated by the IEEE-488 circuit or by U9 as a result of an M1 output from the microprocessor. M1 is active when the microprocessor is performing an op code fetch cycle. The M1 memory access is shorter than all other cycles, in order to provide for the refresh cycle (not used). One WAIT state is added to allow for the access time of the ROMs.

## 3-16. INTERRUPT

Two sources of interrupts are used in the 5450A. These are the IEEE-488 circuit and the phase-locked loop circuit. The interrupt signals are combined in a wired-OR circuit for an input to the microprocessor at U18-16. R26 is a passive pull-up for the line, and in conjunction with C31, filters high frequency chassis noise (10 MHz) to prevent spurious inputs. U17-4 in the OR circuit is active (low) from an interrupt from the IEEE-488. Line-synchronous interrupts (MARK) are generated by U17-6 each time the phase-locked loop output has a positive transition. The MARK is enabled and cleared by signal MARK EN at U35-1 from U8-19.

The microprocessor output is synchronized to the line frequency by the phase locked loop (PLL). The line frequency input (U29-14) is multiplied by 8 by the PLL circuitry U28 and U29. The PLL output (U29-4), which is eight times the input frequency, provides a clock for MARK interrupts (U35-3) and display blanking (U21-1).

## 3-17. ANALOG PCA DATA TRANSFER

The Digital PCA transfers information to the Analog PCA via the cable connected to J15 on the Digital PCA. Data transferred to the Analog PCA decodes to relay calls and to a signal to toggle the voltage used to energize the relays. Data transferred from the Analog PCA is a digital indication that the CALIBRATION switch is either enabled or disabled. The data lines of J15 (D0-D7) are tri-state and may be used to send or receive data.

To send information to the Analog PCA, the following sequence occurs: U18 conditions address lines A0, A1, A2, A3, A6, and A7 to indicate that data is to be sent to the Analog PCA. At the same time, D0-D7 of U18 are set to indicate the particular relay that is to be called. Once this data is available, U18 pulls IOREQ (U18-20) low. At this time, the address information (A0, A1, A2, A3, A6, A7) is decoded in U25, U16, and U34 to set the WRITE0 signal low at U25-14 and J15-3. This signal is sent to the Analog PCA via J15-2 and indicates that the data on J15-9 through J15-16 is valid to be decoded.

Once all the relay data is latched into the Analog PCA, the address lines of U18 are set to make the WRITE1 line (J15-6) go low. This enables the relay drivers and pulses relay voltage high (approximately 8V dc). About 15 ms later, the same sequence occurs again. This time, the result of the WRITE1 line going low is to toggle the voltage for the relays low (approximately 3.5V dc). The STATUS1 signal (J15-1) is used to clear all of the relay latches on the Analog PCA.

To receive information about the status of the CALIBRATION switch from the Analog PCA, the following sequence occurs: U18 conditions data lines A0, A1, A2, A3, A6, and A7 to indicate that data is to be received from the Analog PCA. Once this data is available, U18 pulls IOREQ low. At this time, this address information is decoded in U25, U16, and U34 to set the READ0 signal low at U25-13 and J15-2. This signal is sent to the Analog PCA and passes the status of the CALIBRATION switch to D7 (J1-9). U18 then reads the data lines to input this information.

## 3-18. MEMORY SELECT

The memory for the digital controller consists of four RAMs (random access memory), three ROMs (actually PROMS, programmable read-only memory), one EAROM (electrically alterable read-only memory), and the necessary control circuits. The ROMs and EAROM and decoder circuit are located on the Memory PCA above and towards the front of the Digital PCA.

The A10, A11, A12, A13, and A15 address lines of U18 are decoded by U2 to generate the chip select signal for the RAM ICs (pin 8 on U4, U5, U6, and U7). The lower address lines of U18 (A0-A9) are directly decoded by the RAMs.

The ROMs and EAROM located on the Memory PCA are connected by two cables to the Digital PCA. The first cable connects to U14 on the Digital PCA and carries the data (D0-D7) and lower order addresses (A0-A10). The second cable connects to P16 on the Digital PCA and carries the upper address lines (A11-A15), MEMREQ, WR, RFSH, and RESET. The high-order address signals from P16 are decoded by U1 on the Memory PCA to set OE on the appropriate ROM to enable output.

In addition to the two digital signal cables that originate on the Digital PCA, the Memory PCA has another cable that originates on the Analog PCA. This cable normally connects VCC to  $\overline{WE}$  (write enable) on the EAROM. This disables the possibility of writing data to the EAROM. This is particularly important to prevent undesired writes during instrument power-up sequences. When the rear panel CALIBRATION switch is in the ENABLE position, the  $\overline{WE}$  line to the EAROM is connected to  $\overline{WR}$  from the Digital PCA. This allows data to be written into the EAROM.

### 3-19. DISPLAY BLANK

The phase-locked loop clocks U21-1 to count toward eight. If it reaches that count without being reset by the SW signal from U25-8, U21-6 goes high and blanks the front panel display. This prevents the possibility of the microprocessor stopping for some reason when data is latched into the front panel and destroying the LEDs by allowing too long a duty cycle.

### 3-20. IEEE-488 INTERFACE

All utilized device interface functions defined by the IEEE-488 interface standard (IEEE Standard 488-1978) are performed within U101. The bidirectional data lines (DI01-DI08) from U108 and U109 are normally three-state drivers; however, when parallel poll is selected (not used in the 5450A), they change to open collector. The control lines in U110 are bidirectional under the control of U101. Control lines NRFD, NDAC, and SRQ have open collector outputs; the remaining control lines are three-state.

The interface is addressed from the digital controller with A7 high and A6 low in conjunction with  $\overline{IOREQ}$  low. A0, A1, and A2 are used to address the internal registers in U101. Switch S103 places the instrument IEEE-488 address on the bus when U102 is enabled from U101. Timing is provided by a 1 MHz clock derived from the 4 MHz clock on the Digital PCA. The 1MHz clock is synchronized to the microprocessor I/O access cycle by U103, U104, and U105.

### 3-21. Analog Circuit

The analog circuit is contained on the Analog PCA, which resides on the right when the instrument is viewed from the front. The Analog PCA contains the resistors, the relays to select the resistors, and the logic necessary to decode and energize the relays from signals received from the Digital PCA. The nature of the digital signals originating from the Digital PCA is discussed in the digital circuit description earlier in this section. The Analog PCA also contains regulation and filtering for its 5V dc power supply, logic, and relays. This circuitry is discussed in the power supply circuit description earlier in this section.

The Analog PCA has two sections, the digital section and the analog section. Each is described below.

#### 3-22. DIGITAL SECTION

The digital section of the Analog PCA consists of the logic to decode the logic commands from the Digital PCA and energize the relays.

To deenergize relays, the following sequence occurs:  $\overline{STATUS0}$  (J1-1) becomes low. This signal goes to U1-4 to provide a larger drive capability. The signal originating from U1-6 clears all the latches on the Analog PCA, which deenergizes all of the relays. Simultaneously, the signal resets U2, which is the flip-flop that specifies whether the relays will receive a high or low voltage to the coils. The reset sets low voltage.

Data lines D0-D7 are then set to the desired relay call by the microprocessor. This data is transferred to the output of U4 (U4-11 through U4-18) by  $\overline{WRITE0}$  going low.  $\overline{WRITE0}$ , which is low, goes through U1 to cause  $\overline{EN}$  (U4-12) to go low. The output of U4 is decoded two ways. The output of U4-11 through U4-14 is decoded by U5 to chip-enable either U6, U9, U14, or U16 to receive the data. The output of U4-15 through U4-18 consists of the data that will be latched into the enabled IC (U6, U9, U14, or U16). The actual latch occurs when the output of decoder U5 goes low, thus setting  $\overline{EN}$  low for the desired latch. The actions described in this paragraph are repeated until all of the relays to be energized are latched into U6, U9, U14, and U16.

Once the relay data is clocked into the latches,  $\overline{WRITE1}$  goes low momentarily. This not only toggles U2 to condition the relay voltage to be high (RELAY PWR), it transfers the data held in U6, U9, U14, and U16 to U8, U10, U13, and U15. These latches directly drive U7, U11, U12, U17, and U18, which are the relay current sinks. These current sinks also contain transient suppressor diodes. Approximately 15 ms after  $\overline{WRITE1}$  goes low to energize the relays,  $\overline{WRITE1}$  goes low again. This time, the result is to toggle flip-flop U2 to condition the relay power supply to go to the lower-voltage holding state. This supply is discussed in more detail in the description of the power supply, above.

The status of the CALIBRATION switch is read back to the Digital PCA periodically. The setting of the CALIBRATION switch (S1) ties U4-11 either to VCC via a pull-up resistor (R1), or to low. The read occurs when  $\overline{READ0}$  goes low, indicating that U4 is to be a driver to the Digital PCA as opposed to a receiver.  $\overline{READ0}$  also asserts  $\overline{EN}$  on U4. The Digital PCA then reads D7 (U4-9).

#### 3-23. ANALOG SECTION

The analog section of the Analog PCA contains the resistors, relays, and cabling to provide the appropriate

stimulus. There are three special concerns that need to be addressed with the printed circuit board layout, cabling, and relays: thermal EMFs, contact resistance, and leakage.

Thermal EMFs are small voltages (in the microvolt region) that are generated when dissimilar metals are placed together and the temperature is elevated (similar to the effect of a thermocouple). In the lower resistance values, where measurement voltage levels are small, the effect of thermal EMFs on total measurement uncertainty can become significant. EMFs are combated in the 5450A via several techniques. First, when possible, similar metals are used in critical areas. For example, the front panel terminals and lugs are both made of similar, low thermal alloy to minimize thermal EMFs. Secondly, to reduce the temperature gradient in the relays, the energization voltages are reduced once the relay is once actuated.

Contact resistance inside the relays can be significant for 2-wire units under test (UUTs). Generally, the effect of contact resistance is minimal for 4-wire resistance measurements because the input impedance of the measuring device is high on the sense leads, and the source leads typically carry constant current. Since the contact resistance of the 5450A is compensated in the 2-wire configuration (by the 2 WIRE COMP feature), repeatability is the primary concern. To minimize contact resistance and maximize repeatability, in most signal paths, the relays are high-quality, gold-plated, cross-bar type relays with paralleled contacts.

Another consideration of the analog connection circuitry is that of leakage. Leakage is the parasitic resistance between the high and low leads of a connection due to the resistance of dielectric materials such as the printed circuit board itself. The effects of leakage are increased in

high-humidity environments. The 5450A specifications allow for this effect. In addition, in the higher resistance ranges, reed-type relays are used to greatly reduce the leakage. The reed-type relays offer higher levels of thermal EMFs and contact resistance than the telephone-type relays used in the lower resistance ranges. However, the effects of thermal EMFs and contact resistances are minimized since typical UUTs measure higher resistances with commensurately higher voltages.

The other leakage reduction techniques used include the use of Teflon standoffs and hand wiring in critical areas. Because of leakage, it is important that the special handling outlined in the service section of this manual be strictly observed.

The resistors used in the 5450A are of the highest quality. In most cases, several resistors (two or four) are matched by TC (temperature coefficient) in equal and opposite amounts to allow a lower temperature coefficient for the value. The primary resistances of the 5450A are achieved by a "chain" of resistors. For example, to achieve 19 $\Omega$ , a 9 $\Omega$  resistor (actually four 36 $\Omega$  resistors in parallel) is connected in series with a 10 $\Omega$  resistor (actually four 40 $\Omega$  resistors in parallel). 100 $\Omega$  is achieved by putting a 81 $\Omega$  resistor in series with the previous two, and so on. The exceptions to this in the 5450A are the 1 $\Omega$  and 1.9 $\Omega$  resistors, which are not chained together or used in conjunction with higher resistances.

Another function of the 5450A Analog PCA is to program the external guard resistor. This low-accuracy 100 $\Omega$  resistor ties OUTPUT LO terminal to the GUARD terminal during normal operation. In the event that external guard is requested (by the EXT GUARD switch), K34 is energized to disconnect this resistor. The resistors that are called to generate any particular configuration are shown in Table 3-1.

Table 3-1. Relay Truth Table

	SHORT	1 Ohm	1.9 Ohm	10 Ohm	19 Ohm	100 Ohm	190 Ohm	1 KOhm	1.9 KOhm	10 KOhm	19 KOhm	100 KOhm	190 KOhm	1 MOhm	1.9 MOhm	10 MOhm	19 MOhm	100 MOhm	EXT GUARD	
K1																				
K2																				
K3																				
K4																				
K5																				
K6																				
K7																				
K8																				
K9																				
K10																				
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K33																				
K34																				

BLACK AREA INDICATES ENERGIZED RELAY

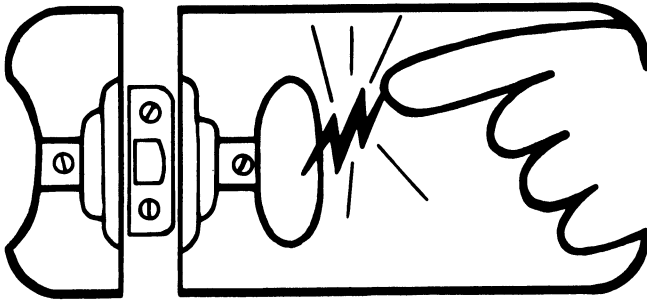




# static awareness



A Message From  
**John Fluke Mfg. Co., Inc.**

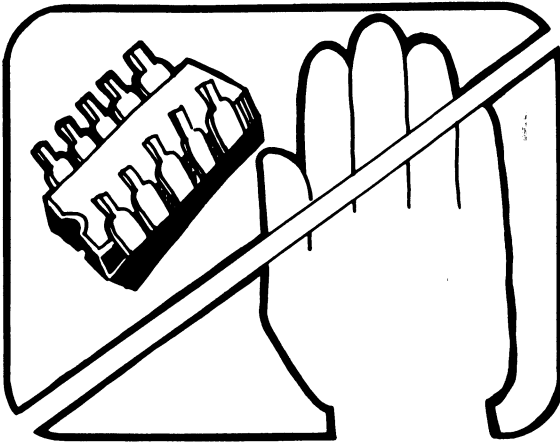


Some semiconductors and custom IC's can be damaged by electrostatic discharge during handling. This notice explains how you can minimize the chances of destroying such devices by:

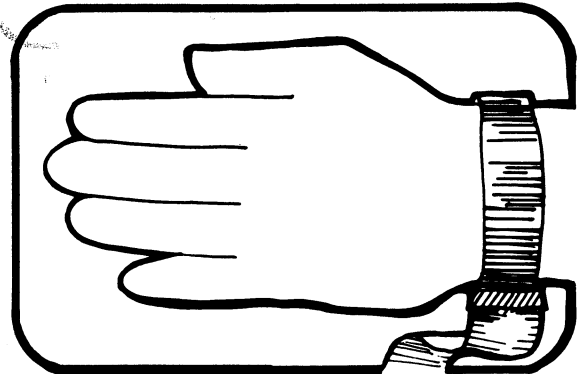
1. Knowing that there is a problem.
2. Learning the guidelines for handling them.
3. Using the procedures, and packaging and bench techniques that are recommended.

The Static Sensitive (S.S.) devices are identified in the Fluke technical manual parts list with the symbol "⊗"

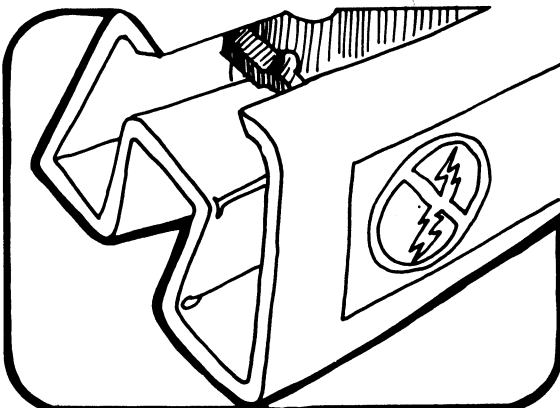
The following practices should be followed to minimize damage to S.S. devices.



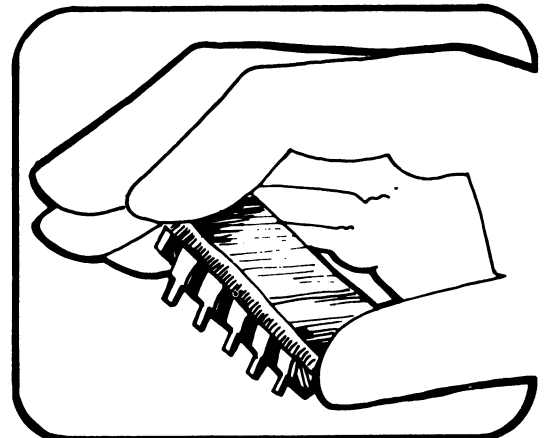
1. MINIMIZE HANDLING



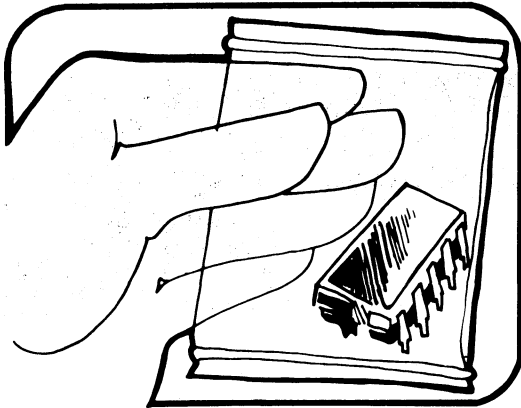
3. DISCHARGE PERSONAL STATIC BEFORE HANDLING DEVICES. USE A HIGH RESISTANCE GROUNDING WRIST STRAP.



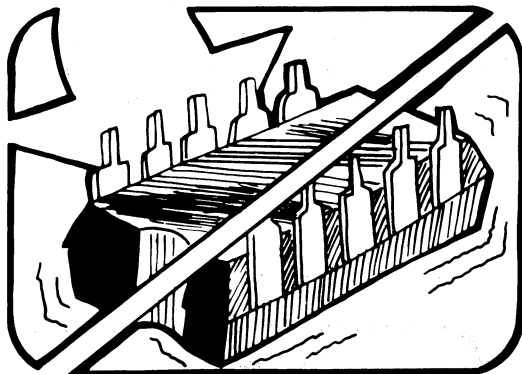
2. KEEP PARTS IN ORIGINAL CONTAINERS UNTIL READY FOR USE.



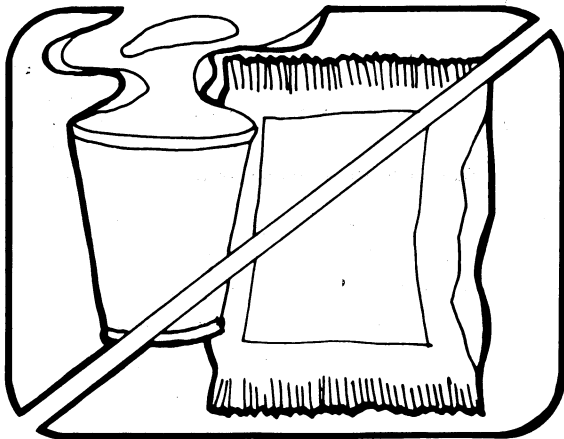
4. HANDLE S.S. DEVICES BY THE BODY



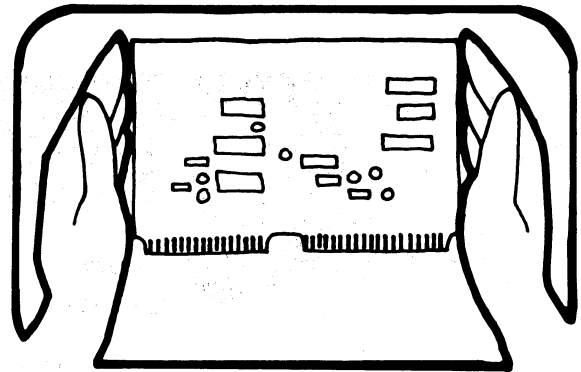
5. USE STATIC SHIELDING CONTAINERS FOR HANDLING AND TRANSPORT



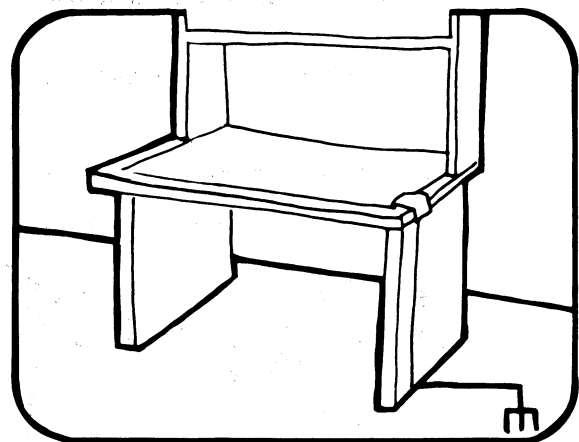
6. DO NOT SLIDE S.S. DEVICES OVER ANY SURFACE



7. AVOID PLASTIC, VINYL AND STYROFOAM® IN WORK AREA



8. WHEN REMOVING PLUG-IN ASSEMBLIES, HANDLE ONLY BY NON-CONDUCTIVE EDGES AND NEVER TOUCH OPEN EDGE CONNECTOR EXCEPT AT STATIC-FREE WORK STATION. PLACING SHORTING STRIPS ON EDGE CONNECTOR HELPS TO PROTECT INSTALLED SS DEVICES.



9. HANDLE S.S. DEVICES ONLY AT A STATIC-FREE WORK STATION
10. ONLY ANTI-STATIC TYPE SOLDER-SUCKERS SHOULD BE USED.
11. ONLY GROUNDED TIP SOLDERING IRONS SHOULD BE USED.

A complete line of static shielding bags and accessories is available from Fluke Parts Department, Telephone 800-526-4731 or write to:

JOHN FLUKE MFG. CO., INC.  
PARTS DEPT. M/S 86  
9028 EVERGREEN WAY  
EVERETT, WA 98204

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## Section 4 Maintenance

### WARNING

**THESE SERVICE INSTRUCTIONS ARE FOR USE BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING OTHER THAN THAT CONTAINED IN THE OPERATING INSTRUCTIONS UNLESS YOU ARE QUALIFIED TO DO SO.**

#### 4-1. INTRODUCTION

This section contains information regarding the maintenance of the 5450A Resistance Calibrator. The section includes routine maintenance, disassembly, performance test/calibration, and troubleshooting.

A 90-day or one-year calibration cycle may be used depending on the specifications necessary for the particular application of the 5450A. The test equipment required for the calibration procedure is given in Table 4-1. Test equipment with equivalent specifications may also be used. To aid in troubleshooting, a DMM (such as a Fluke 77) and a logic probe are also recommended.

Suggested cables to interconnect the test equipment during calibration are listed in Table 4-2. As many of the cables are non-standard, the table includes construction details.

#### 4-2. SERVICE INFORMATION

The 5450A is warranted for a period of one year upon shipment of the instrument to the original purchaser. Conditions of the warranty are given in the front of this manual. Malfunctions that occur within the limits of the warranty will be corrected at no cost to the user. For in-warranty repair, call the the Fluke Technical Service Center designated to service your area. A complete list of Technical Service Centers is given in Section 7.

Instruments returned for repair or calibration should be shipped via United Parcel Service or "Best Way" prepaid. The instrument should be shipped in the original packing carton, or if it is not available, in any suitable container that is rigid and of adequate size. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material. Dated proof-of-purchase may be required for in-warranty repairs. If requested, an estimate will be provided before work is begun on instruments that are beyond the warranty period.

#### 4-3. GENERAL MAINTENANCE

##### 4-4. Setting Line Voltage

### WARNING

**TO AVOID SHOCK HAZARD, PERFORM THE VOLTAGE SELECTION PROCEDURE EXACTLY AS PRESENTED. LINE POWER VOLTAGE MAY BE PRESENT IF THE PROCEDURE IS NOT FOLLOWED EXACTLY.**

If the line voltage set at the factory is incorrect for your application, it may be reset to 100, 120, 220, or 240V ac. To reset the power supply to a new voltage:

1. Ensure that the instrument is disconnected from all power sources.

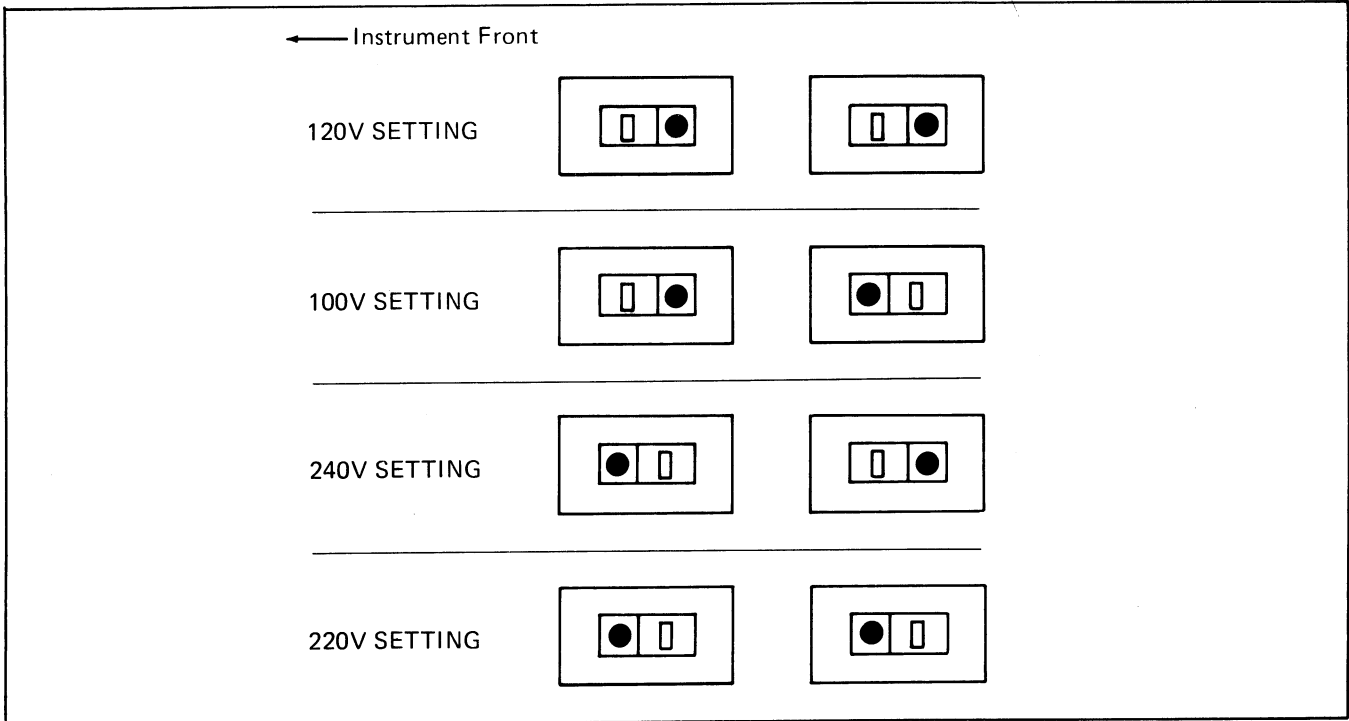
2. Remove the top cover by removing the six Philips head screws on the top of the instrument and lifting the cover free of the instrument.
3. Remove the power supply cover at the left rear of the instrument by loosening the four Philips heads screws securing the top cover to the remainder of the power supply chassis. Lift the cover free of the instrument.
4. Two slide switches located on the PCA are used to select the desired line voltage. Figure 4-1 shows the switch settings for the four possible input line voltages. Set the switches using the dot and slot as pictured.
5. Reinstall the power supply cover and the instrument top cover.
6. It is also important to change the rear panel indication of voltage to prevent a future user from connecting the instrument to the incorrect voltage. The existing mark can be removed with toluene.
7. After the line voltage settings are changed, ensure that the correct fuse is installed for the setting selected. For 100 or 120V ac, use a slo-blo 1/2-amp fuse. For 220 or 240V ac, use a slo-blo 1/4-amp fuse. The following section describes how to change the line fuse.

Table 4-1. Required Test Equipment

EQUIPMENT TYPE	REQUIRED SPECIFICATIONS	RECOMMENDED MODEL
DC Voltage Calibrator (Source 2)	Linearity: 2.5 ppm from 0.1V to 0.2V 0.8 ppm from 5V to 10V 0.2 ppm for a 0.05% change in output at 1V, 5V, 10V, and 19V  Short-Term Stability (1 min) and Noise (0.1 Hz to 10 Hz): 0.2 $\mu$ V from 0.1V to 1V 1.0 $\mu$ V from 5V to 10V 2 $\mu$ V at 19V  Output Voltage Range: 0.1V to 19V (Note 1)	Fluke 5440A
DC Voltage/Current Source (Source 1)	Short-Term Stability (1 min) and Noise (0.1 Hz to 10 Hz): 0.25 ppm from 5V to 19V 0.5 ppm at 10 mA 2 ppm at 70 mA and 100 mA Output Uncertainty: 0.05% at 500 mA  Voltages used: 5V to 19V (Note 1) Current used: 10 mA to 500 mA (Note 1)	Fluke 5100B
Precision Divider	Ratio Accuracy (at 10:1): 0.2 ppm with up to 19V input Input Resistance: $\geq$ 100 k $\Omega$	Fluke 752A
Null Detector	Short-Term Stability (1 min) and Noise (0.1 Hz to 10 Hz): 0.2 $\mu$ V on 3 $\mu$ V range  Input Resistance: $\geq$ 5x10 <sup>12</sup> HI input to Ground $\geq$ 2x10 <sup>11</sup> LO input to Ground	Fluke 845AB
10 k $\Omega$ Standard Resistor	Absolute Uncertainty: $\leq$ 2 ppm	ESI SR104
1 $\Omega$ Standard Resistor	Absolute Uncertainty: $\leq$ 5 ppm	Guildline 933 0/1
NOTE 1: For sources with a 10V range but no 20V range, the calibration can be performed with 10V instead of 19V.		

**Table 4-2. Required Cables**

<b>CABLES NEEDED:</b>	
2 Each:	1-meter (36-inch) cable with a copper spade lug on each end of the center conductor and a 15-cm (6-inch) shield wire on each end terminated with a banana plug.
1 Each:	1.25-meter (48-inch) cable same as above.
2 Each:	50-cm (18-inch) cable same as above.
1 Each:	50-cm (18-inch) cable same as above except on one end use a solid copper insulated alligator clip or a copper circuit-hook type clip instead of a spade lug. Beware of using copper-plated steel alligator clips; test the clip by filing it to ensure it is solid copper.
<b>MATERIAL NEEDED FOR CONSTRUCTION:</b>	
Cable: Coaxial cable RG58U or RG58A/U, 4.25 meters (14.5 feet).	
Connectors: 11 copper or gold-plated copper spade lugs (Fluke P/N 271718). 12 banana plugs.	
<b>CONSTRUCTION HINTS:</b>	
After soldering the spade lugs on the cable's center conductor, use heat-shrink tubing to cover the spade-lug solder connection and exposed cable conductor. Add a stranded 22-gauge or larger wire for the 15-cm (6-inch) shield extension wire.	
<b>ADDITIONAL CABLES NEEDED:</b>	
2 Each:	1-meter (36-inch) dual-banana to dual-banana shielded cable. Available from Pomona Electronics as part number 1167-36.



**Figure 4-1. Line Voltage Selection Switches**

#### 4-5. AC Line Power Fuse Replacement

##### WARNING

**TO AVOID SHOCK HAZARD, PERFORM THE FUSE REPLACEMENT PROCEDURE EXACTLY AS PRESENTED. LINE POWER VOLTAGE MAY BE PRESENT IF THE PROCEDURE IS NOT FOLLOWED EXACTLY.**

Ensure that the new fuse is the proper type for the line voltage being used. Fuse types according to line voltage are as follows:

For 100 or 120V ac, use slo-blo 1/2A  
For 220 or 240V ac, use slo-blo 1/4A

To replace the line power fuse, use the following procedure:

1. On the front panel of the 5450A, push the POWER switch to the off (out) position.
2. Disconnect the 5450A power cord from line power.
3. On the rear panel of the 5450A, locate the fuse holder in the upper right corner of the rear panel.
4. Turn the fuse holder about 1/4-turn counterclockwise.
5. Pull the fuse holder from the 5450A. The fuse is attached to the fuse holder.
6. Place a new fuse in the fuse holder.
7. Insert the fuse and fuse holder back into the rear panel.
8. Push the fuse holder in as far as it will go and turn it about 1/4 turn clockwise.
9. Connect the line power cord to line power.
10. On the front panel of the 5450A, push the POWER switch to the on (in) position. If the line power fuse blows when power is on, the instrument requires service; contact your nearest Fluke service center (a complete list of service centers is given in Section 7 of this manual).

#### 4-6. Cleaning

Use the following procedure periodically to clean the 5450A of dust, grease, and other contamination:

1. Clean the front panel and case with a soft cloth dampened with a mild solution of detergent and water.
2. Clean the surface of each PCA using clean dry air at low pressure (<20 psi). If grease is encountered, spray the PCA with SPRAYON T.M.C Cleaner (rosin flux remover) or equivalent and remove grime with dry, low-pressure air.

##### CAUTION

**Rosin flux remover can damage plastic parts such as the relays and front panel lens. Use caution to avoid damage. Remove relays from sockets before applying to Analog PCA.**

#### 4-7. Handling Precautions

##### 4-8. STATIC-SENSITIVE DEVICES

##### CAUTION



**This instrument contains CMOS components which can be damaged by static discharge. Static-sensitive components in the instrument are indicated on the parts list by the symbol above. To prevent damage, take the following precautions when troubleshooting and/or repairing the instrument:**

- Perform all work at a static-free work station.
- Do not handle components or PCAs by their connectors.
- Wear static ground straps.
- Use conductive foam to store components.
- Remove all plastic, vinyl, and styrofoam from the work area.
- Use a grounded, temperature-regulated soldering iron.

##### 4-9. LEAKAGE-SENSITIVE HANDLING

The Analog PCA is sensitive to dirt and contamination. Consequently, all efforts must be made to prevent handling this assembly. If the PCA must be handled, hold it only by the edges. Be very careful to keep fingers away from the PCA in the relay and resistor area. If a component that is to be replaced requires soldering, use the following special precautions:

Use a mildly activated rosin-core solder if available.

After any soldering/desoldering activity, immediately clean the solder joint with Freon T.F.

Degreaser. Hold the PCA so the Freon drips off the nearest edge. Do not let it drip over the resistor and relay area any more than is unavoidable.

front of the instrument and slide the cover forward to disengage the tabs at the rear of the guard chassis.

#### 4-10. Replacement of Selected Components

Some of the resistors used in the 5450A are selected to meet the required temperature coefficient specifications of the instrument. For example, there are four 40Q resistors used to generate the 10Q resistance, four 36Q resistors used in conjunction with the 10Q set to generate 19Q, and so on. These resistors are carefully matched with ones of similar resistance, but with equal and opposite temperature coefficients, to meet the rigid requirements of the 5450A specifications. Should a resistor need replacement, order a set for the specific value to ensure that the instrument specifications are not degraded.

#### 4-11. Disassembly and Reassembly

##### 4-12. INTRODUCTION

Each of the following procedures deals with the removal/replacement of a single part or printed circuit assembly (PCA) from the instrument. The procedures are listed in a disassembly sequence; however, all steps may not be required to obtain access to the desired part or assembly of the instrument. Reassembly can be accomplished by performing the steps of the applicable procedure in a logically reversed sequence.

##### 4-13. TOP/BOTTOM COVER

Use the following procedure to remove the top and/or bottom cover. (To access the bottom cover, place the instrument upside down.)

1. Remove the three screws across the front edge of the cover.
2. Remove the three screws across the rear edge of the cover.
3. Lift the cover straight up, guiding it out of the grooves in the side panels.

##### 4-14. TOP ANALOG GUARD COVER

Use the following procedure to remove the top analog guard cover from the analog section of the instrument. Prior to starting, the top cover must be removed from the instrument.

1. Remove the two screws at the front of the top analog guard cover securing the cover to the guard chassis.
2. Using the finger hole located in the front center of the guard cover, slide the cover toward the rear of the instrument, then lift up the front of the guard chassis top to a position above the

##### 4-15. INNER ANALOG GUARD COVER

Use the following procedure to remove the inner analog guard cover from the 1Ω and 1.9Ω resistors in the analog section. Prior to starting, the top cover and top analog guard cover must be removed.

1. Remove the two screws at the top corners of the top analog guard cover securing the cover to the Analog PCA.
2. Lift the cover up and away from the Analog PCA.

##### 4-16. FRONT PANEL DISPLAY ASSEMBLY

Use the following procedure to remove the Display Printed Circuit Assembly (PCA). The front panel must be removed to gain access to the Display PCA and its components. To remove the two screws mentioned below, the top cover and top analog guard cover must be removed. The memory assembly must also be hinged up and out of the way.

1. Remove the two screws located on the rear upper corners of the front panel. These screws are located inside the front metal frame.
2. Using both hands, squeeze the top and bottom of the panels together to clear the tabs holding the panel in place.
3. Once the panel is clear of the tabs, move the panel forward to clear the tabs.
4. Remove the wires connecting the front panel input connectors to the Analog PCA using an 11/32-inch open-end wrench.

#### NOTE

*To facilitate the replacement of wires on terminals during assembly, the color codes are molded into the panel next to each terminal. Wires must be positioned so that adjacent sleeving does not touch.*

5. Disconnect the ribbon cable connecting the Display PCA to J11 on the Digital PCA.
6. Remove the four screws securing the Display PCA to the frame and lift the PCA clear of the instrument.

## 4-17. ANALOG ASSEMBLY

**WARNING**

**TO AVOID SHOCK HAZARD, ENSURE THAT POWER HAS BEEN REMOVED FROM THE INSTRUMENT PRIOR TO WORKING IN THE TRANSFORMER AND POWER SUPPLY AREA.**

Use the following procedure to remove the Analog Printed Circuit Assembly (PCA). Prior to starting, the top cover, the top analog guard cover, the power supply cover, and the front panel must be removed.

1. Unplug the cables connecting to J1, J2, J3, and J4 of the analog assembly. Route the cables through the opening in the bulkhead into the power supply compartment.
2. Unplug the ribbon cable at the rear of the Analog PCA connected to the VR1 connector.
3. About 3 inches from the front and 3-1/2 inches from the left of the PCA, remove a nut connecting a black wire to the Analog PCA.
4. Remove the seven screws holding the Analog PCA to the guard chassis. One screw is located near each corner, one is on the middle of each of the left and right sides, and one is located in the center of the PCA. Note that a green wire is attached to the screw in the front right corner and also the right rear corner.
5. Lift up the front of the PCA, with the left side raised slightly higher than the right. Slide the PCA forward and to the left until it is free of the chassis.

## 4-18. TRANSFORMER AND POWER SUPPLY ASSEMBLY

**WARNING**

**TO AVOID SHOCK HAZARD, ENSURE THAT POWER HAS BEEN REMOVED FROM THE INSTRUMENT PRIOR TO WORKING IN THE TRANSFORMER AND POWER SUPPLY AREA.**

Use the following procedure to remove the transformer and Power Supply Printed Circuit Assembly (PCA) from the instrument. Prior to starting, the top cover, the bottom cover, and the top analog guard cover must be removed from the instrument.

1. Loosen the four retaining screws and remove the cover from the transformer compartment.

(The transformer compartment, which houses the Power Supply PCA and power transformer, is located at the left rear of the instrument.)

2. Disconnect the cable clamp on the front of the transformer compartment.
3. Disconnect the green and red wires connecting to TP1 and TP2 of the Power Supply PCA. The green and red wires are housed in a cable; pull this cable through the grommet at the rear of the transformer compartment.
4. Disconnect the wire connected to J4 on the Analog PCA. Pull this wire through the bulkhead and out the grommet at the rear of the transformer compartment.
5. A cable from the Analog PCA terminates within the transformer compartment. Bring this cable back through the center bulkhead and into the transformer compartment.
6. Remove the six screws attaching the transformer compartment to the frame. Four are used on the outside frame and two on the center frame. This process is slightly easier if K15 is temporarily unplugged from the Analog PCA.
7. Lift the transformer compartment containing the transformer and Power Supply PCA straight up and out of the instrument compartment.

## 4-19. MEMORY ASSEMBLY

Remove the Memory Printed Circuit Assembly (PCA) from the instrument compartment using the following procedure. Prior to removing the Memory PCA, remove the top cover.

1. Remove the two screws at the corners of the Memory PCA that are near the center bulkhead of the instrument.
2. At this time the Memory PCA may be hinged up to facilitate access to the underside of itself or the Digital PCA below. To completely remove the Memory PCA, continue with the following steps.
3. Unplug the cables connected to J1, J2, and J3.
4. Remove the two screws attaching the hinges to the outside frame.
5. Lift the Memory PCA clear from the 5450A.

#### 4-20. DIGITAL ASSEMBLY

Use the following procedure to remove the Digital Printed Circuit Assembly (PCA) from the instrument compartment. Prior to starting, the top and bottom covers must be removed from the instrument.

1. Remove the three screws holding C201 to the outside frame.
2. Remove the two hex-head bolts and nuts securing the IEEE-488 connector to the rear panel.
3. Disconnect the green input line-power ground wire from the lug on the rear of the Digital PCA (P30).
4. Disconnect the four cables that are plugged into the top of the Digital PCA. (Two go to the Memory PCA, one to the Display PCA, and one to the Analog PCA.)
5. Remove the nut from the screw along the center bulkhead securing the ground wire. Lift the wire from the screw.
6. From below, remove the five screws securing the Digital PCA to the tabs in the instrument compartment.
7. Lift up the front of the Digital PCA and slide it forward and out of the instrument compartment.

#### 4-21. BOTTOM ANALOG GUARD COVER

Use the following procedure to remove the bottom analog guard cover from the analog section. Prior to starting, the bottom cover, top cover, and top analog guard cover must first be removed from the instrument.

1. Remove the screw from the center of the Analog PCA. (The screw is accessible from the top of the instrument.)
2. Turn the instrument so that the top side is facing downward.
3. Remove the six screws holding the bottom analog guard cover to the instrument guard chassis.
4. Using the finger hole in the bottom analog guard cover, lift the cover up and away from the 5450A chassis.

#### 4-22. PERFORMANCE TEST/CALIBRATION PROCEDURE

##### 4-23. Introduction

Since the calibration procedure and performance verification test require virtually the same procedure, the

two are presented together. (Even the CALIBRATION switch is in the ENABLE position for both.) The only difference is that, in the calibration procedure, new calibration constants are entered into the instrument. In the performance verification test, calibration constants are not entered, even though the CALIBRATION switch is in the ENABLE position.

Two features make the 5450A easy to calibrate. First, the 5450A is calibrated by storing calibration constants in EAROM (electrically alterable read only memory). Consequently, calibration does not require that the covers be removed from the instrument. Second, the 5450A has been designed so that it can be calibrated without heavy dependence on special equipment and standards. The necessary equipment is shown in Table 4-1.

To enter calibration constants, the 5450A is used just as if calibrating a UUT. The UUT reading is entered by pressing the ENTRY MODE switch, then the numeric switches, and then the ENTER switch (at which time the ERROR light turns on). However, when the UUT reading is entered while the CALIBRATION switch is in the ENABLE position, the 5450A EAROM is automatically programmed with the entered value. This value then becomes the number that is displayed when that particular resistance is requested during normal operation. Similarly, when a value is entered for a SHORT while 2 WIRE COMP is enabled, the value becomes the new 2 WIRE COMP offset. To completely calibrate the 5450A, it is necessary to enter data for 17 resistors (1 $\Omega$ -100 M $\Omega$  and 1.9 $\Omega$ -19 M $\Omega$ ) and a short.

To support the calibration procedure that is presented in this manual, the 5450A uses special internal configurations. These configurations are selected when the CALIBRATION switch is in the ENABLE position and the rear panel SP CAL/NORMAL switch is in the NORMAL position. The configurations are indicated in the display by CAL, CAL1, CAL2, 4W 0CAL, or 2W 0CAL when the instrument is in the OUTPUT mode.

The 5450A requires a calibration environment of 23°C $\pm$ 1.5°C (70.7°F-76.1°F) and less than 70% RH. The calibration procedure goes faster if a calculator with a minimum resolution and accuracy of eight digits is used for the necessary calculations.

#### 4-24. Calibration Philosophy

##### 4-25. TRANSFER OF STANDARDS

The 5450A is calibrated by transferring the accuracy of two external standard resistors to the 5450A. A 1 $\Omega$  standard is used to calibrate the 5450A's 1 $\Omega$  and 1.9 $\Omega$  resistors, and a 10 k $\Omega$  standard is used to calibrate the 5450A's 10 k $\Omega$  and 19 k $\Omega$  resistors. The setup used for this transfer is shown in Figure 4-2.

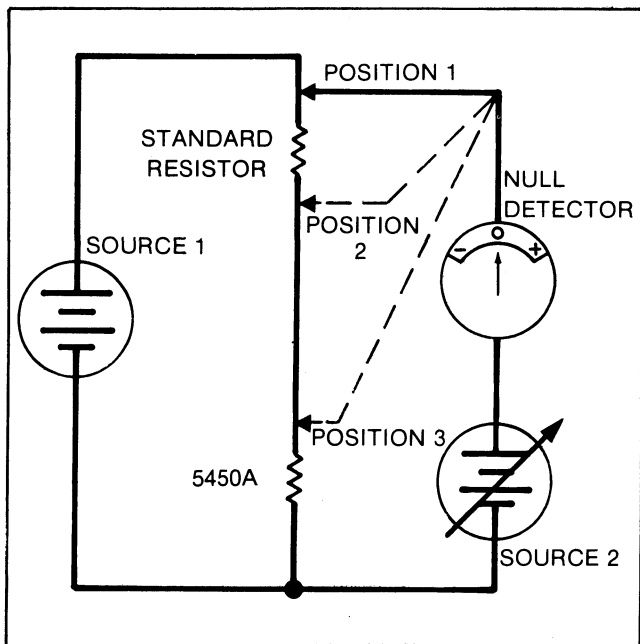


Figure 4-2. Transfer of Standard Resistance

Source 1 creates a voltage across the standard resistor and the 5450A. When calibrating the 1 $\Omega$  and 1.9 $\Omega$  resistors, Source 1 is set to a constant current. When calibrating the 10 k $\Omega$  and 19 k $\Omega$  resistors, Source 1 is set to a constant voltage. The accuracy of Source 1 is not important; however, Source 1 must be stable and have low noise content.

Source 2 is used in conjunction with the Null Detector as a highly accurate voltmeter to measure the ratio of the voltage divider created by the standard resistor and the 5450A. The excellent linearity of Source 2 assures an accurate transfer of the standards.

The Null Detector is first connected to the top of the standard resistor (position 1), and is zeroed by adjusting the voltage of Source 2. The Null Detector is then connected to the bottom of the standard resistor (position 2), and is zeroed by adjusting the output voltage of Source 2. Finally, the Null Detector is connected to the top of the 5450A resistor (position 3), and is zeroed by adjusting the output of Source 2.

The three voltages measured in the above paragraph are then used in conjunction with the known value of the standard resistor to compute the value of the 5450A resistor. The absolute accuracy of Source 2 is unimportant, but a high accuracy of linearity is required. The above steps are repeated for the 5450A's 1 $\Omega$ , 1.9 $\Omega$ , 10 k $\Omega$ , and 19 k $\Omega$  resistors.

#### 4-26. RATIO CALIBRATION

Once the values of the 10 k $\Omega$  and 19 k $\Omega$  resistors are known, a ratio technique is used to obtain the values of

the remaining resistors in the 5450A. The 10 k $\Omega$  value is ratioed up to the 100 k $\Omega$ , 1 M $\Omega$ , 10 M $\Omega$ , and 100 M $\Omega$  ranges, and down to the 1 k $\Omega$ , 100 $\Omega$  and 10 $\Omega$  ranges. The 19 k $\Omega$  value is ratioed up to the 190 k $\Omega$ , 1.9 M $\Omega$ , and 19 M $\Omega$  ranges, and down to the 1.9 k $\Omega$ , 190 $\Omega$ , and 19 $\Omega$  resistors.

To accommodate this ratio technique, the 5450A uses special internal configurations that connect its internal resistors as a ratio divider. These special configurations are automatically selected when the rear panel NORMAL/SP CAL switch is in the NORMAL position and the 5450A rear panel CALIBRATION switch is in the ENABLE position.

The 5450A SENSE terminals are switched between the upper and lower taps of the resistor divider using the front panel up-arrow and down-arrow switches. (See Figure 4-3.) To sense the upper tap (CAL1), press the up-arrow switch; the 5450A will display "CAL1". To sense the lower tap (CAL2), press the down-arrow switch; the 5450A will display "CAL2". While ratioing up, the 5450A displays the cardinal value of the combined resistor value (10X). While ratioing down, the 5450A displays the cardinal value of the lower decade resistor (X).

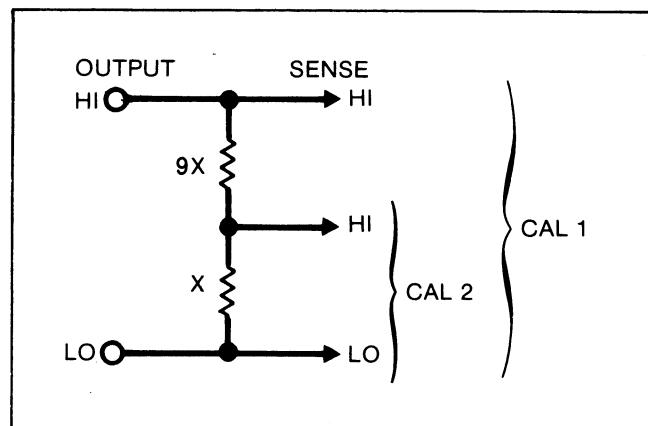


Figure 4-3. Internal Ratio Divider

The configuration for ratio calibration is shown in Figure 4-4. Initially, Source 1 is set to provide a constant voltage or current, depending on the range. The 5450A is set to a non-divided output (CAL1), and the Reference Divider is connected to provide a non-divided output. Source 1 is set to an appropriate voltage or current, and then Source 2 is adjusted to zero the Null Detector. The 5450A is then set to a divided output (CAL2) by pressing the down-arrow switch, and the Reference Divider is connected to provide a divided output of 10:1. The Null Detector is then zeroed by adjusting Source 2. In this case the first and second settings of Source 2 are very near one another.

The two voltage measurements are used to calculate the actual 5450A divider ratio. This divider ratio is in turn



applied to the known upper or lower resistance (depending on whether the ratio is made in an upward or downward direction) to determine the unknown resistance value. This procedure is applied upward and downward from both the 10 k $\Omega$  and 19 k $\Omega$  cardinal points until the remainder of the calibration points are known.

#### 4-27. CALIBRATING THE SHORT

The 5450A SHORT may be accessed in either a 2-wire or 4-wire measurement configuration. The 4-wire access is accurate enough that it is not calibrated; instead, it is specified from nominally zero ohms.

The 2-wire access is calibrated in the 2-wire configuration. This configuration uses only the OUTPUT terminals of the 5450A and includes the lead and contact resistance within the 5450A. The calibrated resistance of the access to the 2-wire short is algebraically added to the displayed output when the 2 WIRE COMP switch is enabled (LED on).

The 2-wire access to the short is calibrated by applying a known constant current to the OUTPUT terminals. The voltage is then measured at the OUTPUT terminals, and the resistance is calculated by applying Ohm's law.

The 2-wire access to the short may optionally be calibrated with a cabling of the user's choice, using either the front panel or rear panel terminals. If this approach is used, the ultimate user of the instrument must be advised that errors will occur if the same cable is not used when calibrating 2-wire UUTs.

#### 4-28. Calibration Procedure

##### 4-29. SETUP

Before beginning the 5450A calibration procedure, obtain a copy or make a functional duplicate of the Calibration Worksheet shown in Table 4-3. Enter the date and serial number of the 5450A.

Ensure that the environment is at  $23^{\circ}\text{C} \pm 1.5^{\circ}\text{C}$  ( $70.7^{\circ}\text{F}$ - $76.1^{\circ}\text{F}$ ) and less than 70% RH, and that the required calibration equipment is ready. The 5450A requires a 2-hour warm-up time. Ensure that the other required equipment is adequately warmed up and self-calibrations are performed where necessary, such as for the 5440A Direct Voltage Calibrator and 752A Reference Divider. (It is necessary to self-calibrate the 752A only for the 10:1 ratio.) Also zero the offset of the Null Detector. During the calibration procedure, frequently recheck the offset of the Null Detector.

Remove the rear panel calibration sticker of the 5450A and place the CALIBRATION switch in the ENABLE position. Ensure that the rear panel NORMAL/SP CAL switch is placed in the NORMAL position. The front panel CAL LED should light.

To improve calibration results, it is recommended that during the calibration procedure the calibrator wear a grounding wrist strap as is normally used to prevent electrostatic damage to static-sensitive components. Otherwise, static voltage generated by body movement can affect the more-sensitive calibrations, especially at high resistances.

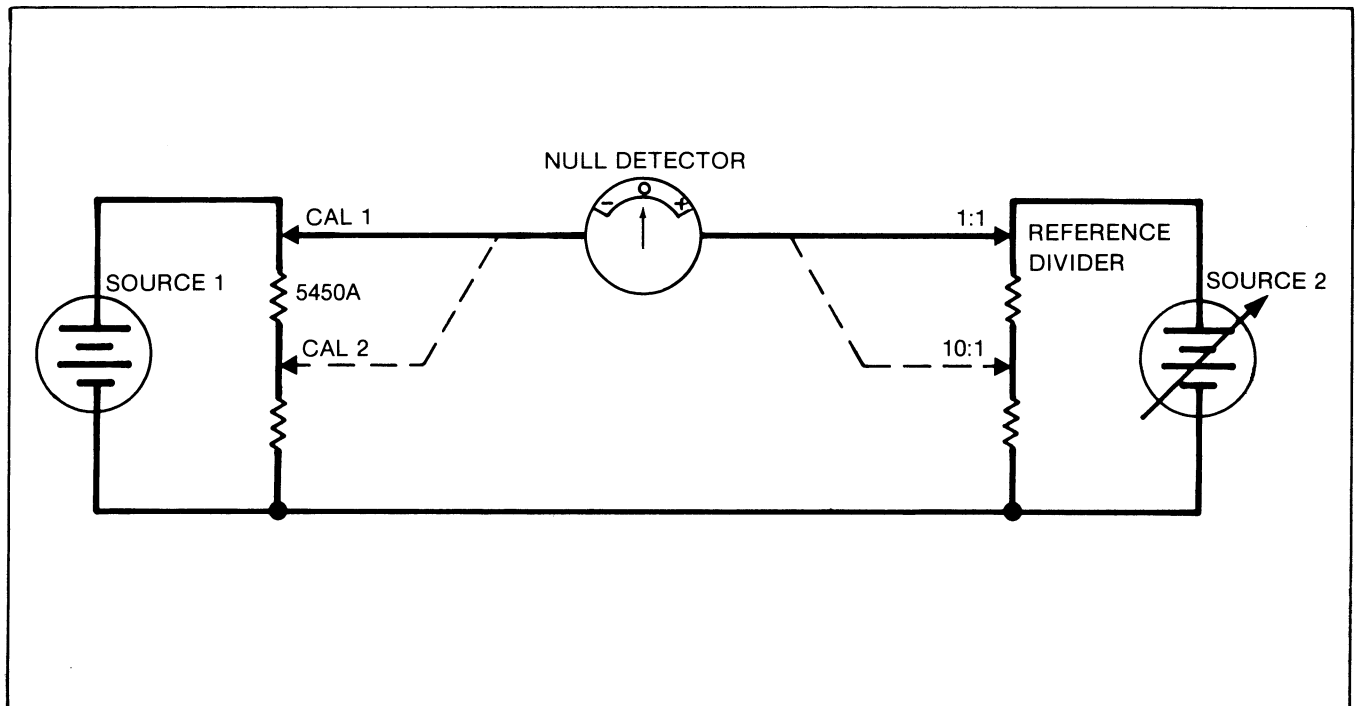


Figure 4-4. Ratio Calibration

Table 4-3. Calibration Worksheet

5450A SERIAL NUMBER _____			DATE _____		
5450A RESISTOR	CERTIFIED VALUE OF STANDARD RESISTOR	READING #1	READING #2	READING #3	5450A ACTUAL VALUE
1Ω	_____	_____	_____	_____	_____
1.9Ω	_____	_____	_____	_____	_____
10 kΩ	_____	_____	_____	_____	_____
19 kΩ	_____	_____	_____	_____	_____
5450A RESISTOR	REFERENCE VALUE <sup>1</sup>	CAL1 READING	CAL2 READING	5450A ACTUAL VALUE	
100 kΩ	10 kΩ	_____	_____	_____	
1 MΩ	100 kΩ	_____	_____	_____	
10 MΩ	1 MΩ	_____	_____	_____	
100 MΩ	10 MΩ	_____	_____	_____	
190 kΩ	19 kΩ	_____	_____	_____	
1.9 MΩ	190 kΩ	_____	_____	_____	
19 MΩ	1.9 MΩ	_____	_____	_____	
1 kΩ	10 kΩ	_____	_____	_____	
100Ω	1 kΩ	_____	_____	_____	
1.9 kΩ	19 kΩ	_____	_____	_____	
190Ω	1.9 kΩ	_____	_____	_____	
10Ω	100Ω	_____	_____	_____	
19Ω	190Ω	_____	_____	_____	
		<b>CURRENT</b>	<b>VOLTAGE</b>	<b>5450A ACTUAL VALUE</b>	
2W 0Ω		_____	_____	_____	

NOTE 1: In computations, use the 5450A actual value for the nominal value shown here.

## 4-30. Connections

The connections necessary for the normal calibration procedure are presented in Figures 4-5, 4-6, and 4-7. Each of these figures show both a connection diagram and a physical layout of the test equipment.

Except where noted, use shielded cables with spade-type connectors for all cabling connections. Spade-type connectors are important because they help keep lead and contact resistance low and consistent. Banana plugs are used where contact integrity is less critical. Also, a cable with a clip on one end is used for the Null Detector input when the connection is changed repeatedly. The clip clips over a small piece of copper wire connected to the appropriate terminal.

## 4-31. TRANSFER OF STANDARDS

To transfer the accuracy of the external resistance standards to the 5450A, refer to Table 4-4. For each line of Table 4-4, use the following procedure. Items in bold (e.g., **STANDARD RESISTOR**) refer to headings in Table 4-4.

*NOTE*

*The EXT GUARD feature of the 5450A should be selected (LED on) during the entire transfer.*

*If Source 2 is a 5440A, it should be set to the INTERNAL guard mode which connects OUTPUT LO to GUARD through a relay.*

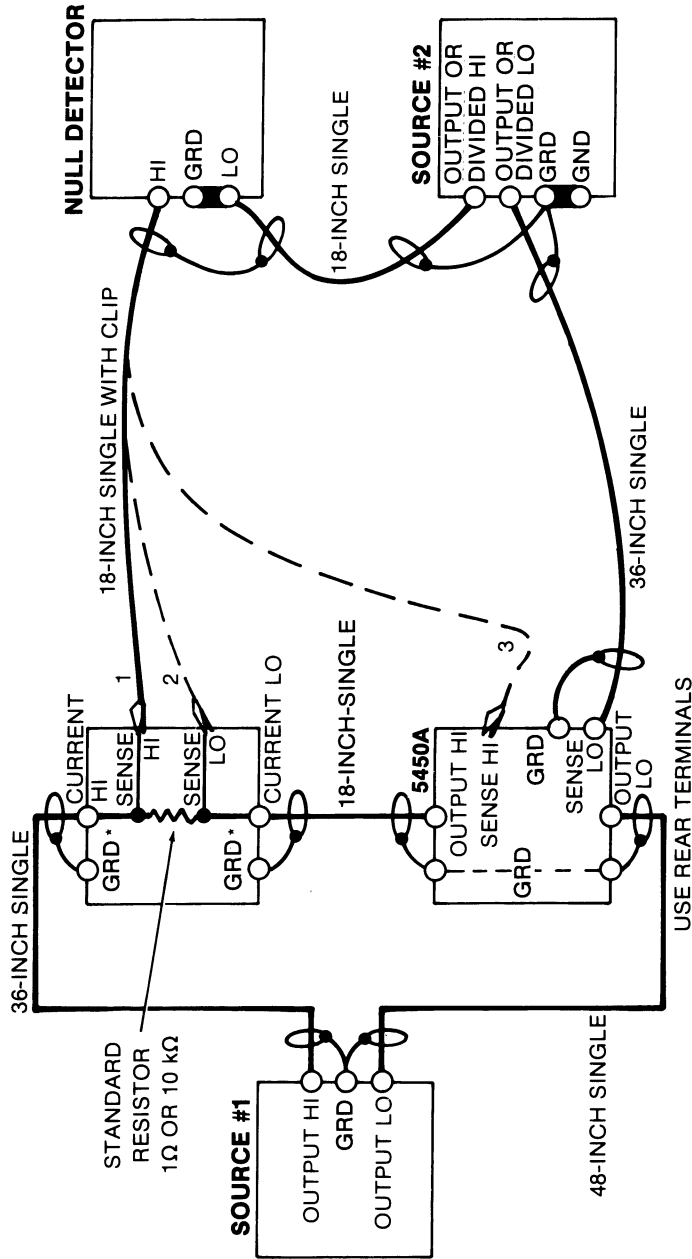
1. Connect the 5450A as shown in Figure 4-5. Note that the GUARD is connected to GROUND only at Source 2. Initially, connect the Null Detector HI input to the Standard Resistor SENSE HI terminal (shown as connection 1 in Figure 4-5). Use the **STANDARD RESISTOR** referenced in Table 4-4.
2. Enter the actual value of the **STANDARD RESISTOR** into the worksheet.
3. Select the **5450A RESISTOR** on the front panel of the 5450A. The 5450A will display the nominal value of the resistor followed by "CAL".
4. Ensure that the Null Detector ZERO/OPR switch is set to ZERO.
5. Set Source 1 to provide **SOURCE 1 SETTING** output, and set Source 1 to operate.
6. Set Source 2 to provide **SOURCE 2 SETTING Reading 1**, and set Source 2 to operate.
7. Perform the nulling procedure shown in Table 4-5. (Use the values from Table 4-4 for **NULL DETECTOR Sensitivity** and **NULL DETECTOR Zero Limit**.) Record the final Source 2 voltage on the calibration worksheet as **READING #1**.
8. Set Source 2 to provide **SOURCE 2 SETTING Reading 2**. Change the connection at the input to the Null Detector to that shown as connection 2 in Figure 4-5.
9. Perform the nulling procedure shown in Table 4-5. Record the final Source 2 voltage on the calibration worksheet as **READING #2**.
10. Change the connection at the input to the Null Detector to that shown as connection 3 in Figure 4-5.
11. Perform the nulling procedure shown in Table 4-5. Record the final Source 2 voltage on the calibration worksheet as **READING #3**.
12. Change the connection at the input to the Null Detector to that shown as connection 1 in Figure 4-5. Set Source 2 to the voltage entered as Reading #1 on the worksheet. Set the Null Detector to OPR (operate) and to the **NULL DETECTOR Sensitivity** range as shown in Table 4-4. Allow time for the reading to settle. If the Null Detector reading differs from zero by more than **ALLOWABLE DRIFT**, go to the next step. Otherwise, set the Null Detector to ZERO and go to step 19.

*NOTE*

*If the reading has changed, it is due to short-term drift of Source 1. To minimize this drift, be sure that Source 1 has had plenty of warm-up time. It helps to keep Source 1 operating as much as possible to keep its internal temperature constant. Errors can be minimized by taking measurements as quickly as possible.*

13. Adjust Source 2 until the Null Detector reading is again zero within the limits given in **NULL DETECTOR Zero Limit**. Set the Null Detector to ZERO. Record the final Source 2 voltage on the calibration worksheet as the new **Reading #1**.
14. Set Source 2 to the voltage entered as Reading #2 on the worksheet. Change the connection at the input to the Null Detector to that shown as position 2 in Figure 4-5. Set the Null Detector to OPR.

**CONNECTION DIAGRAM**



NOTES:



Shorting Bar

\*This guard terminal may not be available on some standard resistors. If not, use case or shield. If neither is available, connect shields together.

**Figure 4-5. Connections for Transfer of Standard Resistance**

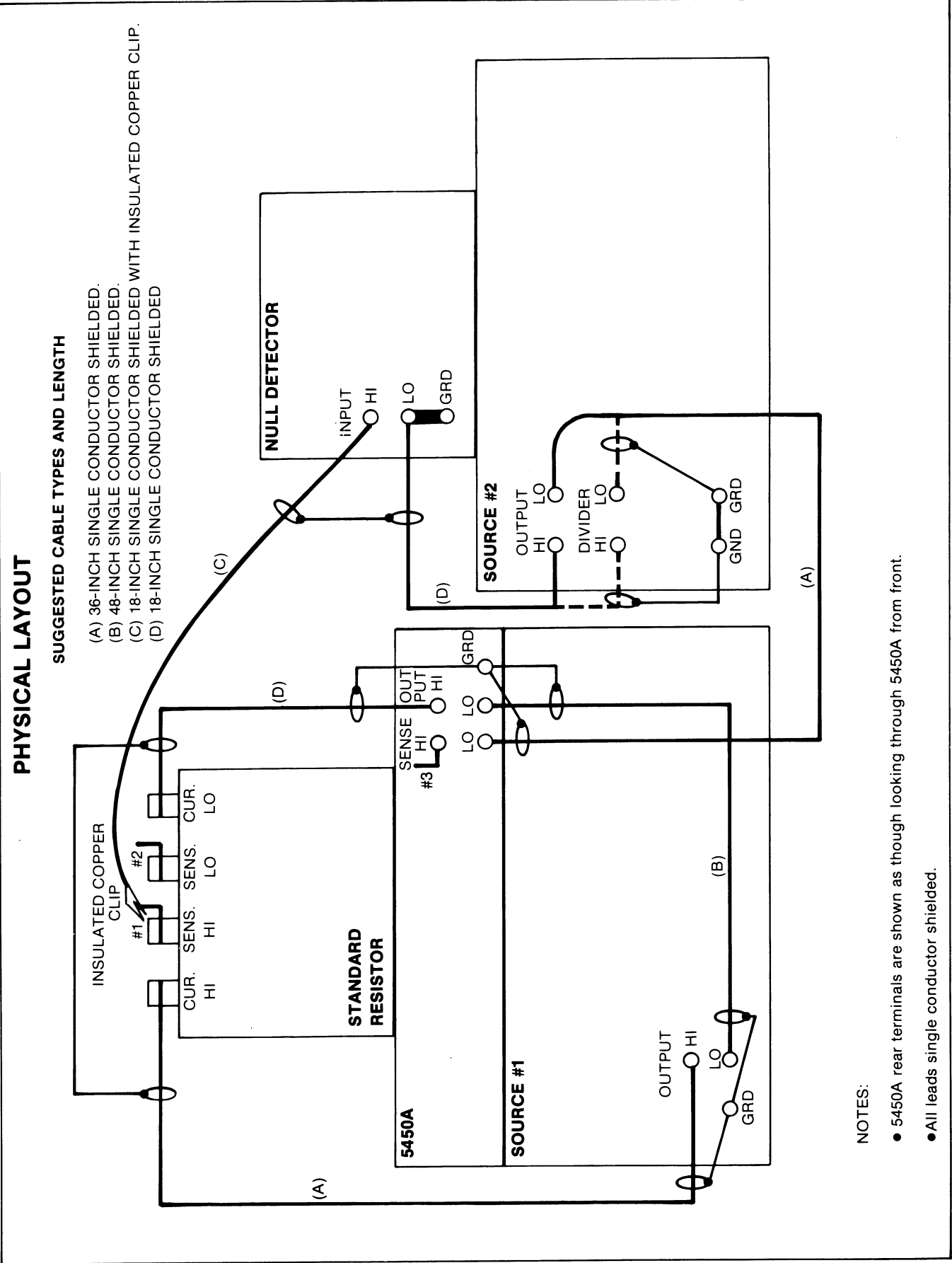
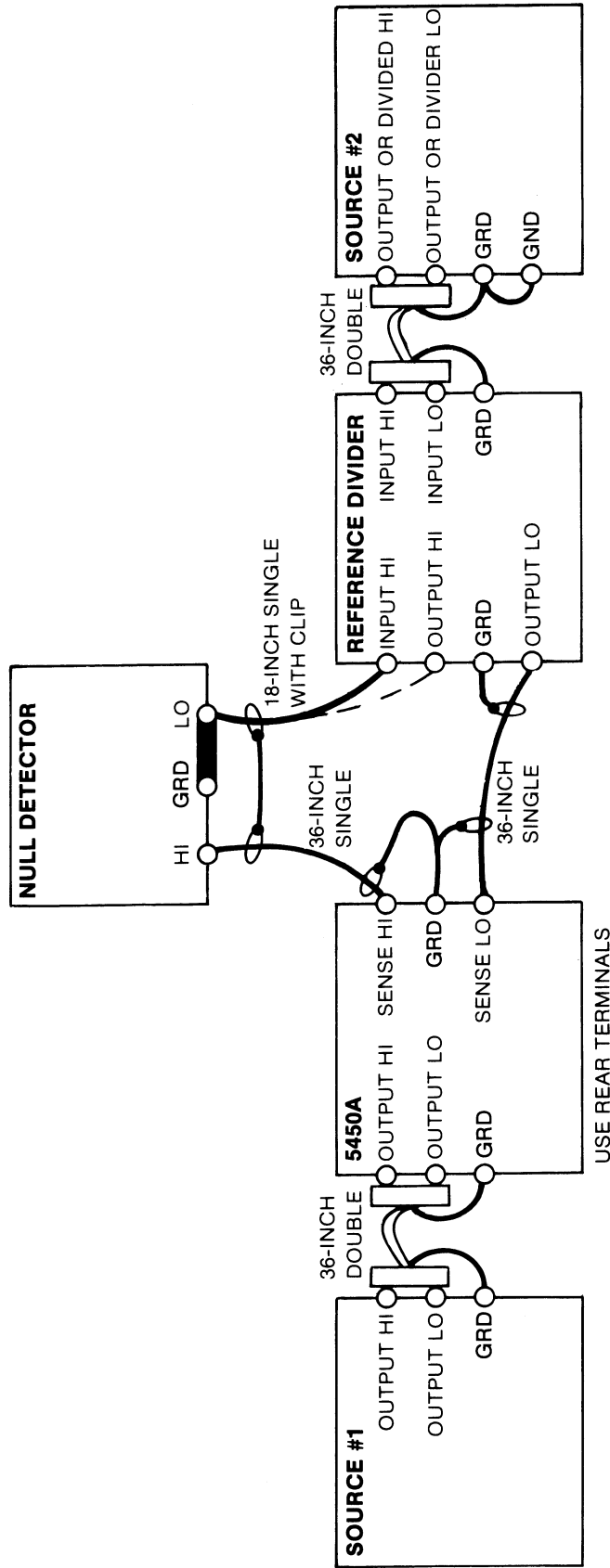


Figure 4-5. Connections for Transfer of Standard Resistance (cont)

**CONNECTION DIAGRAM**



**Figure 4-6. Connections for Ratio Calibration**

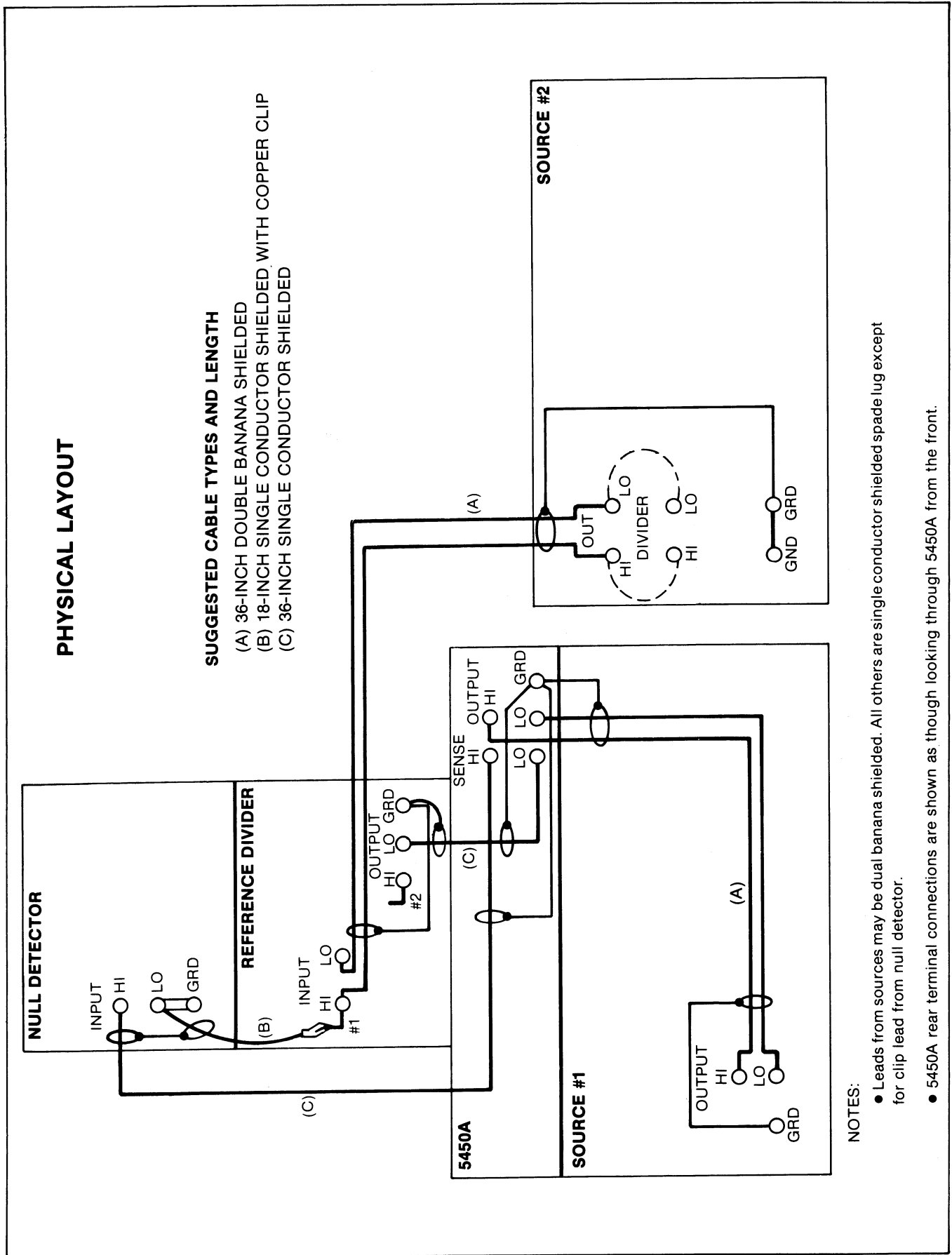
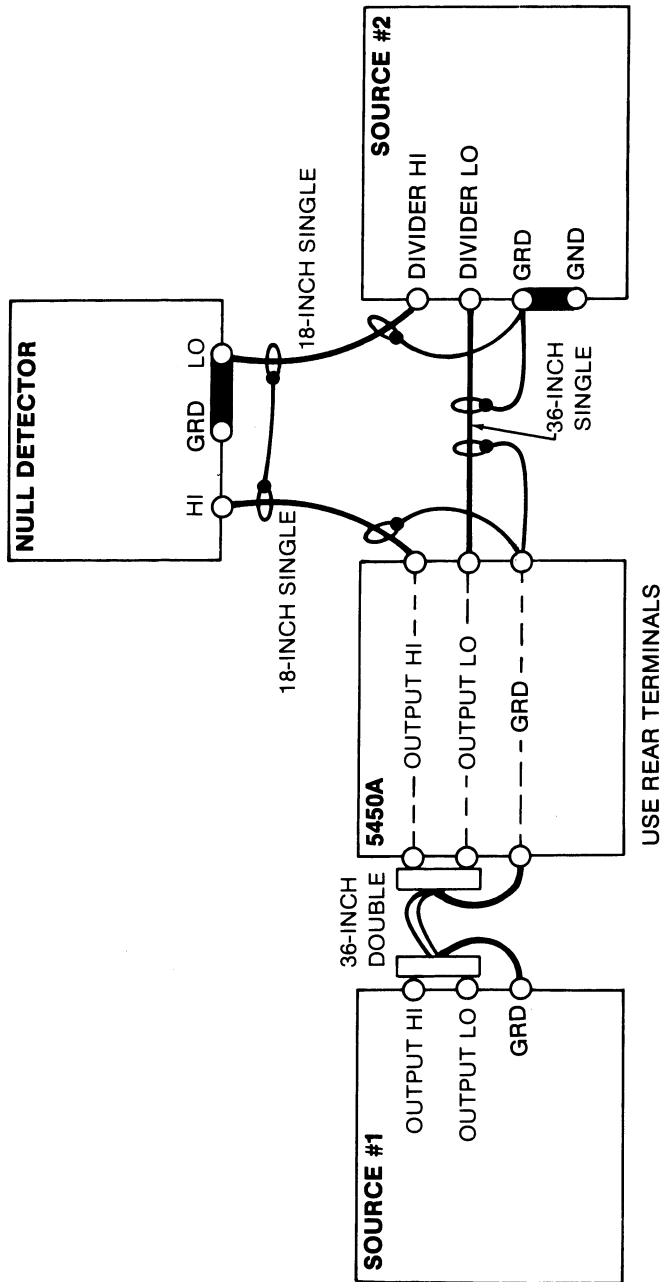


Figure 4-6. Connections for Ratio Calibration (cont)

**CONNECTION DIAGRAM**



**Figure 4-7. Connections for Callbrating the Short**



### PHYSICAL LAYOUT

#### SUGGESTED CABLE TYPES AND LENGTHS:

- (A) 18-INCH SINGLE CONDUCTOR SHIELDED
- (B) 36-INCH SINGLE CONDUCTOR SHIELDED
- (C) 36-INCH DOUBLE-BANANA TO DOUBLE-BANANA

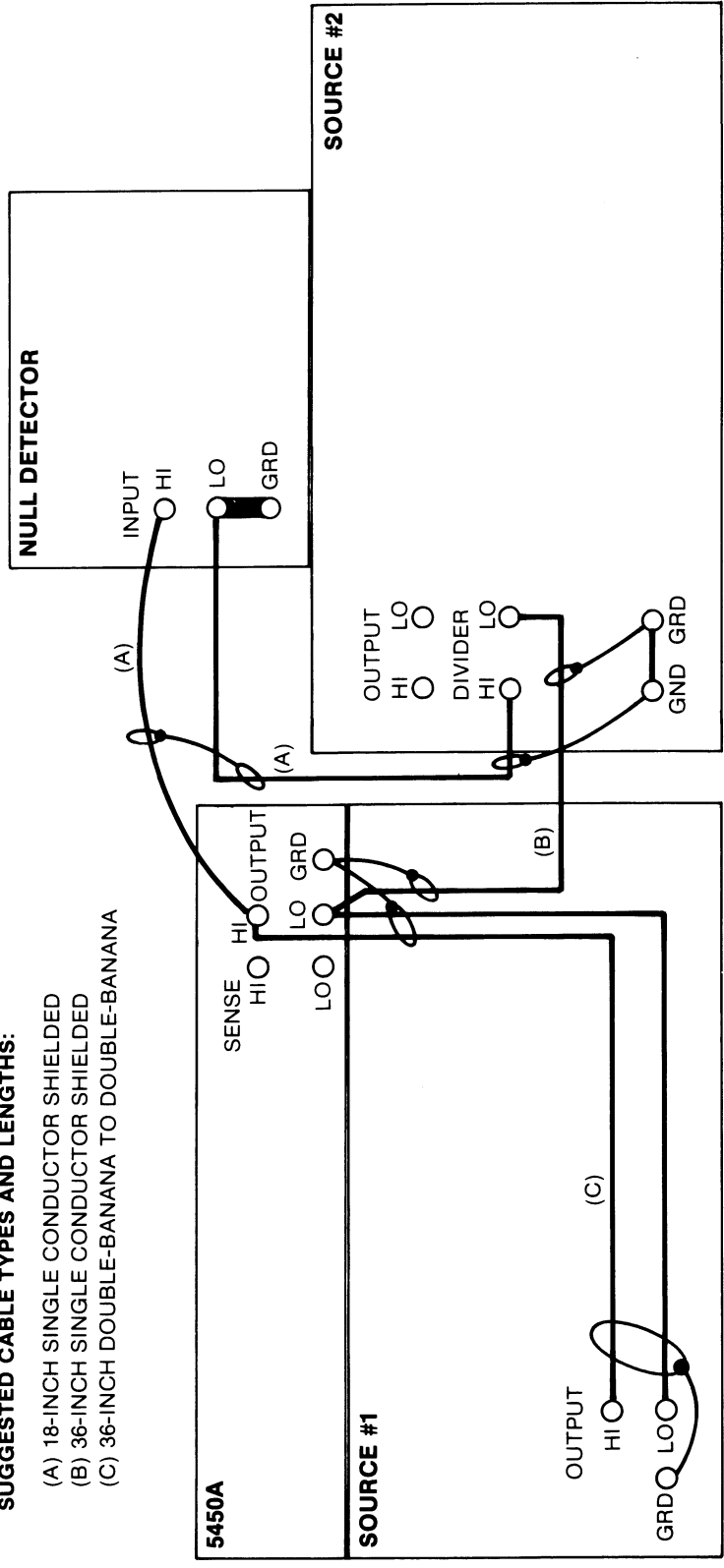


Figure 4-7. Connections for Calibrating the Short (cont)

Table 4-4. Calibration Data for Transfer of Standards

5450A RESISTOR	STANDARD RESISTOR	SOURCE 1 SETTING	SOURCE 2 SETTING		NULL DETECTOR		ALLOWABLE DRIFT
			Reading 1	Reading 2	Sensitivity	Zero Limit	
1Ω*	1Ω	100 mA	0.2V	0.1V	3 μV	0.2 μV	0.4 μV
1.9Ω*	1Ω	70 mA	0.2V	0.14V	3 μV	0.2 μV	0.4 μV
10 kΩ	10 kΩ	10V	10V	5V	10 μV	1 μV	3 μV
19 kΩ	10 kΩ	10V	10V	6.552V	10 μV	1 μV	3 μV

\*If a Fluke 5440A is used as Source 2, use the DIVIDED OUTPUT for these steps.

Table 4-5. Nulling Procedure

STEP	ACTION
1.	Set the Null Detector to the 3 mV range and then to OPR (operate).
2.	Decrement the range switch until the reading on the Null Detector is no longer near zero.
3.	Adjust the output of Source 2 until the Null Detector is again near zero.
4.	Decrease the Null Detector Range and again zero the Null Indicator.
5.	Repeat steps 2 through 4 until the Null Detector <b>NULL DETECTOR Sensitivity</b> range is reached. On that range, adjust Source 2 until the Null Detector zero is obtained within the limits given in <b>NULL DETECTOR Zero Limit</b> .
<b>NOTE</b>	
<i>The reading on this range may vary back and forth due to noise in the Sources. Under these conditions, adjust Source 2 until the average reading is zero within the limits given.</i>	
6.	Set the Null Detector ZERO/OPR switch to ZERO.

15. Adjust Source 2 until the Null Detector reading is again zero within the limits given in **NULL DETECTOR Zero Limit**. Set the Null Detector to ZERO. Record the final Source 2 voltage on the calibration worksheet as the new Reading #2.

16. Set Source 2 to the voltage entered as Reading #3 on the worksheet. Change the connection at the input to the Null Detector to that shown as position 3 in Figure 4-5. Set the Null Detector to OPR.

17. Adjust Source 2 until the Null Detector reading is again zero within the limits given in **NULL DETECTOR Zero Limit**. Set the Null Detector to ZERO. Record the final Source 2 voltage on the calibration worksheet as the new Reading #3.

18. Go back to step 12.

19. Compute the value of the 5450A resistor by applying the following formula to the values in the calibration worksheet:

$$R = \frac{\text{STANDARD RESISTANCE} \times \text{READING \#3}}{\text{READING \#1} - \text{READING \#2}}$$

20. Enter R into the worksheet as the 5450A ACTUAL VALUE.

21. Perform the next line of Table 4-4. If the transfer of standards is complete, set the Sources to standby and the Null Detector to ZERO. Then proceed to the ratio calibration procedure.

## 4-32. RATIO CALIBRATION

Connect the 5450A as shown in Figure 4-6. Note that the GUARD is connected to GROUND only at Source 2. Initially, connect the Null Detector LO input to the Reference Divider HI input, shown as position 1 in Figure 4-6. Select the 10:1 output from the Reference Divider. Select the 5450A EXT GUARD feature (LED on). Ensure that the Null Detector OPR/ZERO switch is set to the ZERO position.

For each line in Table 4-6, perform the following procedure. Information shown in bold (e.g., **5450A RESISTOR**) refers to headings in Table 4-6.

1. Select the **5450A RESISTOR** from the front panel of the 5450A. The 5450A will display the nominal value of the resistor followed by "CAL1".
2. Set Source 1 to provide **SOURCE 1 SETTING** dc output and set Source 1 to operate. If Source 1 is already set appropriately, leave it set to operate.
3. Set Source 2 to provide **SOURCE 2 SETTING** dc output and set Source 2 to operate.
4. Perform the Nulling Procedure shown in Table 4-5, using the values from Table 4-6 under CAL1 for **NULL DETECTOR Sensitivity** and **NULL DETECTOR Zero Limit**. Record the final Source 2 voltage on the calibration worksheet as the CAL1 READING.
5. Connect the Null Detector LO input to the HI output of the Reference Divider, shown as connection 2 in Figure 4-6.
6. Press the down-arrow switch on the 5450A front panel. The 5450A will display the nominal value **5450A RESISTOR** followed by "CAL2".
7. Perform the Nulling Procedure shown in Table 4-5 using the data from Table 4-6 for CAL2. Record the final Source 2 voltage on the calibration worksheet as the CAL2 READING.
8. Press the up-arrow switch on the 5450A front panel. The 5450A should now display the nominal value **5450A RESISTOR** followed by "CAL1".
9. Connect the Null Detector LO input to the HI input of the Reference Divider. Set Source 2 to the CAL1 READING value recorded earlier. Set the Null Detector to the **NULL DETECTOR Sensitivity CAL1 Range**. Allow time for the reading to settle. If the Null Detector reading differs from zero by more than **ALLOWABLE DRIFT**, then go to the next step. Otherwise, set the Null Detector to ZERO and go to step 15.

Table 4-6. Ratio Calibration Data

5450A RESISTOR	SOURCE 1 SETTING	SOURCE 2 SETTING	NULL DETECTOR				ALLOWABLE DRIFT	REFERENCE VALUE	EQUATION NUMBER
			Sensitivity		Zero Limit				
			CAL1	CAL2	CAL1	CAL2			
100 k $\Omega$	19V	19V	10 $\mu$ V	3 $\mu$ V	2 $\mu$ V	0.3 $\mu$ V	5 $\mu$ V	10 k $\Omega$	1
1 M $\Omega$	19V	19V	10 $\mu$ V	3 $\mu$ V	2 $\mu$ V	0.3 $\mu$ V	5 $\mu$ V	100 k $\Omega$	1
10 M $\Omega$	19V	19V	10 $\mu$ V	3 $\mu$ V	2 $\mu$ V	0.3 $\mu$ V	5 $\mu$ V	1 M $\Omega$	1
100 M $\Omega$	19V	19V	10 $\mu$ V	3 $\mu$ V	4 $\mu$ V	0.3 $\mu$ V	7 $\mu$ V	10 M $\Omega$	1
190 k $\Omega$	19V	19V	10 $\mu$ V	3 $\mu$ V	2 $\mu$ V	0.3 $\mu$ V	5 $\mu$ V	19 k $\Omega$	1
1.9 M $\Omega$	19V	19V	10 $\mu$ V	3 $\mu$ V	2 $\mu$ V	0.3 $\mu$ V	5 $\mu$ V	190 k $\Omega$	1
19 M $\Omega$	19V	19V	10 $\mu$ V	3 $\mu$ V	2 $\mu$ V	0.3 $\mu$ V	5 $\mu$ V	1.9 M $\Omega$	1
1 k $\Omega$	10V	10V	10 $\mu$ V	3 $\mu$ V	1 $\mu$ V	0.2 $\mu$ V	2.5 $\mu$ V	10 k $\Omega$	2
100 $\Omega$	5V	5V	10 $\mu$ V	3 $\mu$ V	1 $\mu$ V	0.2 $\mu$ V	1 $\mu$ V	1 k $\Omega$	2
1.9 k $\Omega$	10V	10V	10 $\mu$ V	3 $\mu$ V	1 $\mu$ V	0.2 $\mu$ V	2.5 $\mu$ V	19 k $\Omega$	2
190 $\Omega$	5V	5V	10 $\mu$ V	3 $\mu$ V	1 $\mu$ V	0.2 $\mu$ V	1 $\mu$ V	1.9 k $\Omega$	2
10 $\Omega$ *	10 mA	1V	3 $\mu$ V	3 $\mu$ V	0.2 $\mu$ V	0.2 $\mu$ V	0.5 $\mu$ V	100 $\Omega$	2
19 $\Omega$ *	10 mA	1.9V	10 $\mu$ V	3 $\mu$ V	0.2 $\mu$ V	0.2 $\mu$ V	0.5 $\mu$ V	190 $\Omega$	2

\*If a Fluke 5440A is used as Source 2, use the DIVIDED OUTPUT for these steps.

10. Adjust Source 2 until the Null Detector reading is again zero within the limits given in **NULL DETECTOR Zero Limit CAL1**. Set the Null Detector to ZERO. Record the final Source 2 voltage on the calibration worksheet as the new **CAL1 READING**.
11. Press the down-arrow switch on the 5450A front panel. The 5450A will display the nominal value of **5450A RESISTOR** followed by "CAL2".
12. Connect the Null Detector LO input to the HI output of the Reference Divider, shown as position 2 in Figure 4-6.
13. Set Source 2 to the CAL2 READING recorded earlier. Set the Null Detector to the **NULL DETECTOR Sensitivity CAL2** range. Set the Null Detector to OPR.
14. Adjust Source 2 until the Null Detector reading is again zero within the limits given in **NULL DETECTOR Zero Limit CAL2**. Set the Null Detector to ZERO. Record the final Source 2 voltage on the calibration worksheet as the new **CAL2 READING**. Go back to Step 8.
15. Compute the actual value of the 5450A resistor by applying the equation specified in Table 4-6 by **EQUATION NUMBER**:

EQUATION 1:

$$R = \frac{10 \times 5450A \text{ ACTUAL VALUE} \times \text{CAL1 READING}}{\text{CAL2 READING}}$$

EQUATION 2:

$$R = \frac{5450A \text{ ACTUAL VALUE} \times \text{CAL2 READING}}{10 \times \text{CAL1 READING}}$$

#### NOTE

*The "5450A ACTUAL VALUE" used in the above equations is a value already determined in a previous step of the calibration procedure and entered on the worksheet. The column labeled REFERENCE VALUE on the calibration worksheet indicates which previous value to use. For example, to determine the 100 kΩ value, the equation uses the 5450A ACTUAL VALUE determined by using the 10 kΩ standard. The 1 MΩ value is determined by using the 100 kΩ value, and so forth.*

16. Enter the computed resistance into the 5450A ACTUAL VALUE column of the worksheet.

#### 4-33 CALIBRATING THE SHORT

Connect the 5450A as shown in Figure 4-7. Ensure that the Null Detector OPR/ZERO switch is set to the ZERO position.

#### NOTE

*It may be desired to calibrate the 2-wire short with a particular cable to be used with the 5450A when calibrating 2-Wire UUTs. If this is the case, include the desired cable between the 5450A OUTPUT terminals and the connections shown.*

1. Select the 2-wire zero calibration configuration by selecting the 2 WIRE COMPensation feature (LED on) and selecting the SHORT. (The 5450A will display "2W 0CAL".) The EXT GUARD should also be selected (LED on).
2. Set Source 1 to provide 500 mA.
3. Initially set Source 2 to 80 mV. (If Source 2 is a Fluke 5440A, use the DIVIDED OUTPUT.)
4. Perform the nulling procedure shown in Table 4-5 until a null is obtained on the 100 uV range of the Null Detector with an error of less than 40 uV. Set the Null Detector to ZERO.
5. Enter the current (0.5 amps) into the CURRENT position of the worksheet.
6. Enter the voltage of Source 2 as the VOLTAGE in the calibration worksheet.
7. Set Source 1 and Source 2 to standby.
8. Compute the ACTUAL VALUE using the formula:

$$\text{ACTUAL VALUE} = \frac{\text{VOLTAGE}}{\text{CURRENT}}$$

9. Enter the ACTUAL VALUE on the worksheet.

#### 4-34. CONCLUDING THE PERFORMANCE TEST

If only performing the performance verification test, return the rear panel CALIBRATION switch to the DISABLE position. Then, perform the following procedure for each resistor on the worksheet:

1. Select the output resistance from the 5450A indicated in the first column.
2. Press the ENTRY MODE switch and then, using the main keyboard, enter the ACTUAL

VALUE indicated in the worksheet. If an incorrect number is pressed, it can be deleted by pressing the DELETE switch. Press the ENTER switch to compute the error.

3. Verify that the displayed error (in PPM) is within the 4-wire accuracy specifications given in Section 1. Use the specification for the appropriate calibration period. For example, if calibrating the 5450A on a 90-day cycle, select the 90-day accuracy specification.

This concludes the performance verification test. If a full calibration is to be performed, return the rear panel CALIBRATION switch to the ENABLE position and continue with the following procedure.

#### 4-35. ENTERING THE CALIBRATION CONSTANTS

The worksheet now contains all of the 5450A actual values to be entered into the non-volatile memory of the 5450A. For each ACTUAL VALUE shown on the worksheet:

1. Select the output from the 5450A indicated in the worksheet as 5450A RESISTOR. The 5450A should display the resistance followed by CAL, CAL1, or CAL2. When entering the 0 $\Omega$  value, the display should indicate 2W 0CAL.
2. Press the ENTRY MODE switch and then, using the main keyboard, enter the ACTUAL VALUE indicated in the worksheet. If an incorrect numeric is pressed, it can be deleted by pressing the DELETE switch. Press the ENTER switch to enter the constant into non-volatile 5450A memory.
3. The 5450A will display the change in the constant as an error in PPM or % (depending whether PPM or % is selected). To exit the ERROR mode and enter the OUTPUT mode, press any front panel switch except ENTRY MODE or PPM/%.

#### 4-36. CONCLUDING THE CALIBRATION PROCEDURE

To conclude the calibration procedure, first disconnect all leads to the 5450A.

At this time, it is possible to change the "personality" message of the 5450A if an IEEE-488 instrument controller, such as the Fluke 1722A, is available. The personality message appears on the display of the 5450A when the instrument is powered-up, and may also be read by an IEEE-488 instrument controller. As delivered from the factory, the personality message is "5450A".

The personality message is programmed using the PERSONALITY command. For example, using the Fluke 1722A, and with the 5450A set at bus address 4, the command

```
PRINT@4,"PERSONALITY A3045;"
```

would replace the personality message with "A3045". In this example, A3045 could represent an asset number. Other uses of the personality message could include the 5450A serial number, a user code, a due date for the next calibration, or other facility-dictated needs. The personality message can be written into the 5450A only when the CALIBRATION switch is in the ENABLE position.

After the calibration procedure (or performance test) has been completed, set the rear panel CALIBRATION switch to the DISABLE position. In this position, the EAROM hardware and firmware are both protected from inadvertent changes. Place a calibration sticker over the CALIBRATION switch to provide calibration integrity until the next calibration. Since it is possible to remove the top cover and change the CALIBRATION switch setting without disturbing the rear panel sticker, it may be desirable to place a calibration sticker over one of the six screws that secure the top cover to the frame.

#### 4-37. Alternate Calibration Procedures

The preceding paragraphs describe the normal calibration procedure. This procedure was designed to meet the necessary accuracy requirements with test equipment that calibration facilities are likely to already have in place.

If desired, the calibration facility may use a different selection of equipment or procedure to calibrate. Such alternate procedures are supported by placing the 5450A rear panel switch to SP CAL (SPecial CALibration) and the rear panel CALIBRATION switch to the ENABLE position. When this configuration is used, the 5450A functions exactly the same as when the CALIBRATION switch is in the DISABLE position. However, the non-volatile calibration memory can still be altered by ENTERing values.

The exact value of each resistor may be determined as the particular facility sees fit, and entered into non-volatile memory by the following sequence:

1. Select the particular resistance from the front panel.
2. Press the ENTRY MODE switch.
3. Use the numeric switches to enter the known value of the resistor.
4. Press the ENTER switch.

The 5450A displays the error from the last entered value for the resistor in PPM or %, depending on the state of the PPM/% switch. Pressing any switch except ENTRY MODE, EXT GD and %/PPM returns the 5450A to the OUTPUT mode of operation.

To determine the specifications of the 5450A when an alternate calibration technique has been used, use the stability specifications shown in Section 1 of this manual. The total uncertainty of each resistance value is determined by adding the stability specification to the calibration uncertainty of the particular resistance.

#### 4-38. TROUBLESHOOTING

##### 4-39. Introduction

The following discussion is intended to help in the repair of an instrument that is malfunctioning or completely non-operational. The discussion seeks to isolate the problem to one of the four major circuits, and then to one or more components. While proceeding, refer to the schematic drawings in Section 9. If further troubleshooting is required, refer to the theory of operation in Section 3.

##### 4-40. Power Supply Isolation

If the 5450A is completely non-operational after power is applied and the POWER switch is pressed, there may be a fault in either the rear panel input fuse (F201) or the front panel POWER switch. Remove fuse F201 and check for continuity. If it is good, remove the cover to the power supply, power up the instrument, and measure the voltage between TP1 and TP2 on the Power Supply PCA. If line voltage is not present, check that the front panel POWER switch is functioning properly.

Check for approximately 5V dc between TP202 and TP201 on the Digital PCA. If a voltage is present, but not 5V dc  $\pm$  50 mV, adjust R204 on the Digital PCA to obtain the proper voltage. Check the voltage between TP2 and TP3 on the Display PCA. It should be 5V dc  $\pm$  .25V dc. Check the voltage between TP2 and TP4 on the Analog PCA. It should be 5V dc  $\pm$  .25V. If any of these voltages are present, the primary circuit to the power transformer is functional. If none are present, analyze the circuit of the Power Supply PCA and then the power transformer itself. If all of these voltages are correct, the power supply circuitry is operating properly.

If the voltage is incorrect on the Analog PCA, check fuses F1 and F2 on the Analog PCA. (A spare fuse is located on the transformer chassis.) If the voltage is still not correct, check VR1, CR4, CR5, and associated circuitry. If the voltage is not correct on the Display PCA, check regulator U14. If the voltage is not correct on the Digital PCA, check the operation of U202 and associated circuitry. Note that on the 5V regulated supply VCC, the

load may be disconnected at J201 so that the effects of circuit loading can be eliminated.

##### 4-41. Analog Assembly Isolation

If the 5450A switches and display operate normally, but the output of the SENSE and OUTPUT terminals is incorrect, it is likely that the problem is on the Analog PCA. If the relays do not move at all when different front panel switches are pressed (the relays can be checked visually or aurally), the problem may be the relay coil voltage supply. Check the voltage between TP3 and TP4 on the Analog PCA. The voltage should be about 4.5-5V dc when OPEN is selected, and about 3.5-4.5V dc when other outputs are selected. If the voltage is incorrect, check U2, Q1, CR1, CR2 and the associated circuitry.

If relay energization voltage is present, the problem may be the digital commands from the Digital PCA; however, the output of the same data lines is used for the Display PCA. The inputs READ0, WRITE0, STATUS0, and WRITE1 should each change states in the course of a programming cycle. Observe each with a logic probe. READ0 cyclically changes states regardless of whether the instrument has been commanded to change outputs, so the logic probe should show oscillation. If any of these control lines do not change state properly, suspect U25 on the Digital PCA. If none of the relays operate, suspect the Analog PCA components U1, U4, or U5 and their associated circuitry.

To isolate the problem to a minimum number of relays, use the truth table shown in the schematic diagrams and on the top analog guard cover. Examine the specific relays used for the resistance value that does not function properly. Next, for each of the relays, choose another output resistance that uses that same relay. If the other resistance works properly, the relay in question may be eliminated from consideration. Continue this process until the number of suspect relays cannot be reduced. Most of the relays are mounted on sockets for easy substitution. To help locate the faulty relay, substitute a similar relay from elsewhere in the instrument.

If one of the relays does not actuate, suspect the relay itself, the associated sink (U7, U12, or U18), or the associated latches (U6, U8, U9, U10, U13, U14, U15, or U16). If all of the relays from a particular latch do not actuate, suspect the latch (e.g., U6, U8, or U12) or decoder U5.

##### 4-42. Display Assembly Isolation

If the display or front panel switches do not work properly, this may indicate a problem on the Display PCA or the Digital PCA. If the Digital PCA is not functioning properly (i.e., the microprocessor is not functioning), the front panel REMOTE light will be on, and all other front panel displays will be off. If any of the

display digits, LEDs, or switches work at all (with the exception of the REMOTE LED), it is likely that the Digital PCA is working properly.

If the left four display digits work properly, but not the right four, suspect U1 or U2. If the right four display digits work properly, but not the left four, suspect U11 or U15. If one-half of a character is not functioning properly, suspect one of the sink components (U7, U8, or U16) or the decoder U10. If the switches do not work properly, suspect Z1, the switches themselves, or U13. If only one of the segments on only one of the displays does not work, it is very likely that the problem lies within the display itself (DS1, DS2, DS3, or DS4). The data lines are paralleled to the instrument memory so it is unlikely that the data lines are malfunctioning if the instrument is otherwise functioning.

#### 4-43. Digital Assembly Isolation

##### NOTE

*A troubleshooting tape is available to troubleshoot the digital circuitry of the 5450A using the Fluke 9010A Micro-System Troubleshooter and a 9000-Z80 Pod. The tape may be ordered as Fluke Model Number 9000-9713.*

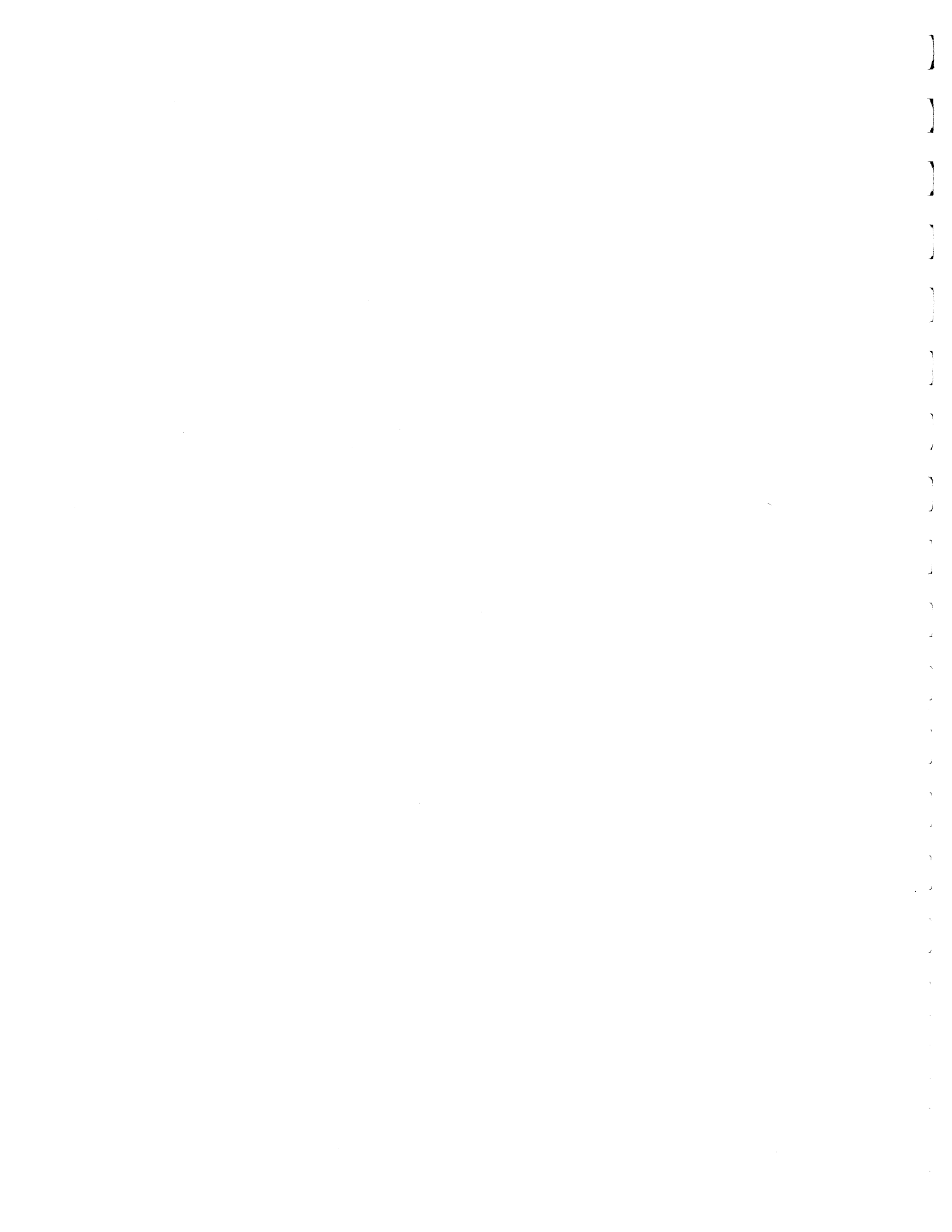
If the instrument is completely non-operational or seriously malfunctioning, it is probable that the problem lies in the Digital PCA or the power supply. See the discussion regarding power supply isolation prior to continuing with troubleshooting the Digital PCA. As

noted in the previous paragraphs, if the microprocessor is not operating properly, the display of the instrument will normally be blank with the exception of the REMOTE LED.

For the microprocessor to operate normally, interrupt signals must be present at TP6. These can be observed with a logic probe. If the interrupt is not present, examine the circuitry surrounding and including U29, U28, U32, U23, U33, U35, and U17 that creates the  $\overline{\text{INT}}$  signal. Another prerequisite for the microprocessor is the 4-MHz clock signal, which can be observed at TP7 with a logic probe. If this signal is not present, examine the circuitry involving Y1, U19, and U20.  $\overline{\text{RESET}}$  at TP3 should be examined to verify that it is high. If  $\overline{\text{RESET}}$  is low, examine the circuit consisting of U22, U36, and U28.

To ensure that the ROMs are being enabled, examine  $\overline{\text{OE}}$  (output enable), pin 22 of U2, U3, and U4 on the Memory PCA. If the logic probe does not indicate a changing signal, consider problems with the circuitry of U1 on the Display PCA. If all of these signals look proper, use a logic probe on each remaining data, address, and output pin of the microprocessor (U18) to ensure that all outputs are changing. A pin that does not change could indicate a fault in U18 or in the associated circuitry pulling the pin high or low.

If it is necessary to replace the EAROM (U5 on the Memory PCA), it is necessary to initialize the new part with nominal values. This is performed by placing the rear panel CALIBRATION switch in the ENABLE position, then powering up the 5450A. The instrument must be recalibrated after the EAROM is replaced.





## Section 5

# List of Replaceable Parts

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A5 Power Supply Assembly .....	5-7	5-16	5-6	5-16

**5-1. INTRODUCTION**

This section contains an illustrated parts breakdown of the 5450A Resistance Calibrator. Components are listed alphanumerically by assembly. Both electrical and mechanical components are listed by reference designation. The location of each listed part is shown in an accompanying illustration.

Parts lists include the following information:

1. Reference designation.
2. Description of each part.
3. Fluke stock number.
4. Federal supply code for manufacturers. (See Section 7 for list of names and codes.)
5. Manufacturer's part number.
6. Total quantity of components per assembly.
7. Recommended quantity. This entry indicates the recommended number of spare parts necessary to support one to five instruments for a period of 2 years. This list presumes an availability of common electronic parts at the maintenance site. For maintenance for 1 year or more at an isolated site, it is recommended that at least one of each assembly in the instrument be stocked. In the case of optional subassemblies, plug-ins, etc., that are not always part of the instrument, or are deviations from the basic instrument model, the REC QTY column lists the recommended spares quantity for the items in that particular assembly.

**5-2. HOW TO OBTAIN PARTS**

Components may be ordered directly from the manufacturer by using the manufacturer's part number or from the John Fluke Manufacturing Co., Inc, or its authorized representatives by using the Fluke Part Number. In the event that the part ordered has been replaced by a new or improved part, the replacement will be accompanied by an explanatory note and installation instructions if necessary.

To ensure prompt and efficient handling of your order, include the following information.

1. Quantity.
2. Fluke part number.
3. Description.
4. Reference designation.
5. Printed circuit board part number and revision letter.
6. Instrument model and serial number.

A Recommended Spare Parts Kit for your basic instrument is available from the factory. This kit contains those items listed in the REC QTY column of the parts list in the quantities recommended.

Parts price information is available from the John Fluke Mfg. Co., Inc. or its representatives. Prices are also available in a Fluke Replacement Parts Catalog which is available on request.

**CAUTION**  
⊗ or ✱  
**INDICATED DEVICES ARE SUBJECT TO  
DAMAGE BY STATIC DISCHARGE.**

TABLE 5-1. RESISTANCE CALIBRATOR  
5450A

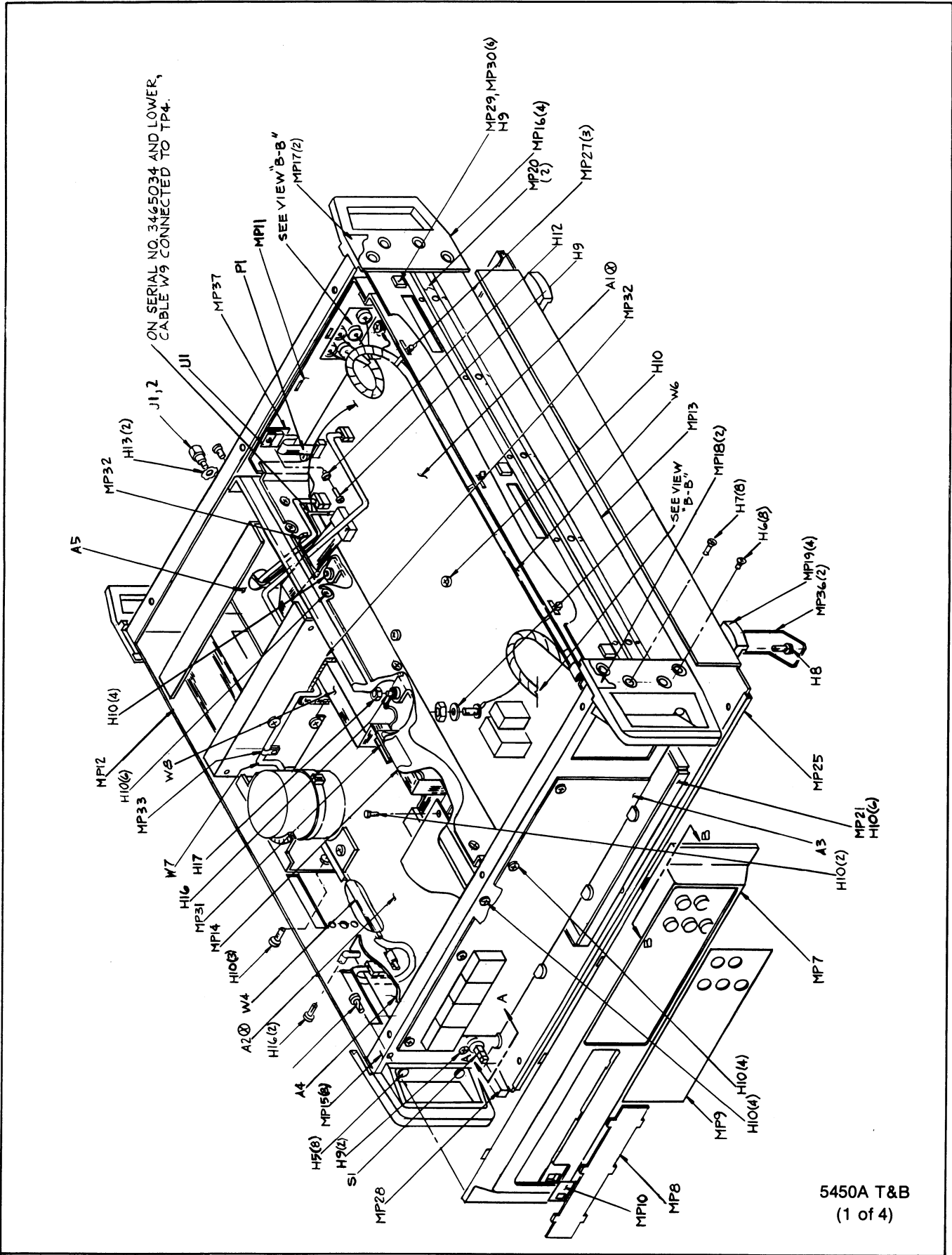
REFERENCE DESIGNATOR A->NUMERICS-->	S	DESCRIPTION	FLUKE STOCK --NO--	MFRS SPLY CODE	MANUFACTURERS PART NUMBER --OR GENERIC TYPE--	TOT QTY	R S	N T -E
		* 5450A FINAL ASSEMBLY						
A	1	* ANALOG ASSEMBLY	713545	89536	713545	001		
A	2	* DIGITAL ASSEMBLY	713578	89536	713578	001		
A	3	* DISPLAY ASSEMBLY	713602	89536	713602	001		
A	4	* MEMORY PCA	713610	89536	713610	001		
A	5	* POWER SUPPLY PCB	713644	89536	713644	001		

TABLE 5-2. FINAL ASSEMBLY  
(SEE FIGURE 5-1.) 5450A-7201

713446

REFERENCE DESIGNATOR	NUMERICS	DESCRIPTION	FLUKE STOCK	MFRS SPLY CODE	MANUFACTURERS PART NUMBER	TOT QTY	R S T	N O T
A->	----	S-----	---NO---	----	--OR GENERIC TYPE--	QTY	-Q-	-E-
E	1	POST, BINDING, GROUNDING TYPE	225623	20584	3576	001	05	
E	2	POST, BINDING, GROUNDING TYPE	225615	20584	3575	001		
E	3, 4	LUG, SOLDER	101022	89536	101022	002		
F	1	FUSE, 1/4 X 1-1/4, SLOW, 0.5A, 250V	109322	71400	MDL1-2	001		
FL	1	FILTER, LINE	321273	05245	3EF2	001		
H	1	NUT, METAL 4-40 CAPTIVE EXT LOCKWASHER	195255	89536	195255	002		
H	2	WASHER, LOCK, EXTRNL, STEEL, 0.500 ID	175943	89536	175943	001		
H	3	WASHER, LOCK, INTRNL, STEEL, 0.267 ID	110817	89536	110817	002		
H	4	NUT, METAL 1/4-28 HEX STEEL	110619	89536	110619	002		
H	5	SCREW, CAP, LH SCKT, STEEL, 8-32X3/8	295105	89536	295105	008		
H	6	SCREW, MACHINE, FHP, S STEEL, 8-32X3/8	320085	89536	320085	008		
H	7	SCREW, MACHINE, FHP, STEEL, 8-32X1/2	114355	89536	114355	008		
H	8	SCREW, MACHINE, PHP SEMS, STEEL, 6-32X1/2	177030	89536	177030	004		
H	9	SCREW, MACHINE, PHP SEMS, STEEL, 4-40X1/4	185918	89536	185918	011		
H	10	SCREW, MACHINE, PHP SEMS, STEEL, 6-32X3/8	177022	89536	177022	042		
H	11	SCREW, MACHINE, PHP, STEEL, 4-40X3/16	129882	73734	19022	002		
H	12	WASHER, SHLDR, NYLON, #3	485417	89536	485417	001		
H	13	WASHER, LOCK, INTRNL, STEEL, #4	110403	89536	110403	002		
H	14	SCREW, MACHINE, FHUP, S STEEL, 6-32X1/4	320093	89536	320093	012		
H	16	SCREW, 6-32 X 3/4	309963	89536	309963	001		
H	17	NUT, KEP #6	152819	89536	152819	001		
H	18	WASHER, COPPER, #8	721688	89536	721688	010		
H	19	NUT, BRASS, 8-32	631614	89536	631614	005		
J	1, 2	CONN, CABLE, RIBBON, SCREW LOCK	494773	89536	494773	002		
MP	1	PANEL, REAR	713479	89536	713479	001		
MP	2	POLYOLEFIN #14 .120ID EXPAND BLK	149450	89536	149450	000		
MP	3	BINDING-POST-ASSY-CP-RED	637892	89536	637892	002		
MP	4	BINDING-POST-ASSY-CP-BLK	637900	89536	637900	002		
MP	5	BINDING-POST-ASSY-I		536	637876	001		
MP	6	NAMEPLATE, SERIAL		536	472795	001		
MP	7	FRONT PANEL MOLDED		536	713651	001		
MP	8	DISPLAY LENS		536	732545	001		
MP	9	DECAL FRONT PANEL		536	721951	001		
MP	10	DECAL, PWR ON-OFF		536	721969	001		
MP	11	GUARD CHASSIS ASSY		536	713677	001		
MP	12	CHASSIS SIDE, LEFT		536	491084	001		
MP	13	CHASSIS SIDE, RIGHT		536	491092	001		
MP	14	BULKHEAD CENTER		536	713685	001		
MP	15	PANEL, FRONT		536	491175	001		
MP	16	CORNER HANDLE, FROI		536	656157	004		
MP	17	DECAL, REAR CORNER		536	685230	002		
MP	18	DECAL, FRONT CORNER		536	659201	002		
MP	19	FOOT, SINGLE BAIL		536	653923	004		
MP	20	SIDE TRIM 18"		536	525998	002		
MP	21	COVER BOTTOM GUARD		536	713511	001		
MP	22	FOOT, GREY		152	SJ-5003	001		
MP	23	COVER, TOP GUARD		536	713495	001		
MP	24	COVER, TOP 18" PACK		536	491183	001		
MP	25	COVER, BOTTOM 18" P		536	491191	001		
MP	26	POLYOLEFIN #8 SLEE		536	113837	000		
MP	27	CABLE, NYLON STRAP		536	172080	005		01
MP	28	ACTUATOR, SWITCH		536	502690	001		
MP	29	INSULATOR, FASTENF		536	372342	006		
MP	30	SPACER, INSULATED		536	372334	006		
MP	31	FLAT CABLE CLAMP		536	529461	001		
MP	32	GROMMET MATL., NATURAL	285254	89536	285254	000		
MP	33	CLAMP, CABLE	165951	31827	3-4-1	001		
MP	34	COVER PLATE, TRANSFORMER	496893	89536	496893	001		
MP	35	SLEEVEING, POLYOL, #1/2, .500 I.D., CLR	218529	89536	218529	001		
MP	36	BAIL, INSTRUMENT	707877	89536	707877	002		
MP	37	INSULATOR, TRANSISTOR 7403-09FR-51	508630	89536	508630	001		
MP	38	FUSE HLDR, BODY W/NUT,	375188	89536	375188	001		
MP	39	FUSE HLDR, CAP, 1/4 X 1-1/4 FUSE	460238	89536	460238	001		
P	1	FLEX STRIP	605212	89536	605212	001		01
S	1	SWITCH, POWER	507871	71468	SCH. 1XF. 0003-01	001		
TM	1	INSTRUCTION MANUAL 5450A	713800	89536	713800	001		
U	1	* IC, VOLT REG, FIXED, +5 VOLTS, 1.5 AMPS	428847	04713	MC7805CT	001		
W	1	WIRE	578609	89536	578609	001		
W	2	#18 AWG TEFLON GREEN/YELLOW	386177	89536	386177	001		
W	3	#22 HOOK-UP PER MIL-W-16878C, BLACK	115774	89536	115774	001		
W	4	CABLE, POWER SWITCH, ASSY.	496877	89536	496877	001		
W	5	WIRE, BUS, 14 AWG, TINNED COPPER	115451	89536	115451	001		
W	6	HARNESS ASSY, OUTPUT	713735	89536	713735	001		
W	7	CABLE ASSY, CAL SWITCH	713750	89536	713750	001		
W	8	CABLE ASSY, SHIELDED	733337	89536	733337	001		
W	9	CABLE, GROUND	732495	89536	732495	001		
		RECOMMENDED SPARE PARTS KIT 5450A (CUSTOMERS OPTION)	717157	89536	717157	AR		

265223  
285429  
271486  
159038  
159020  
5450A (893065)  
713578  
#290



5450A T&B  
(1 of 4)

Figure 5-1. Final Assembly

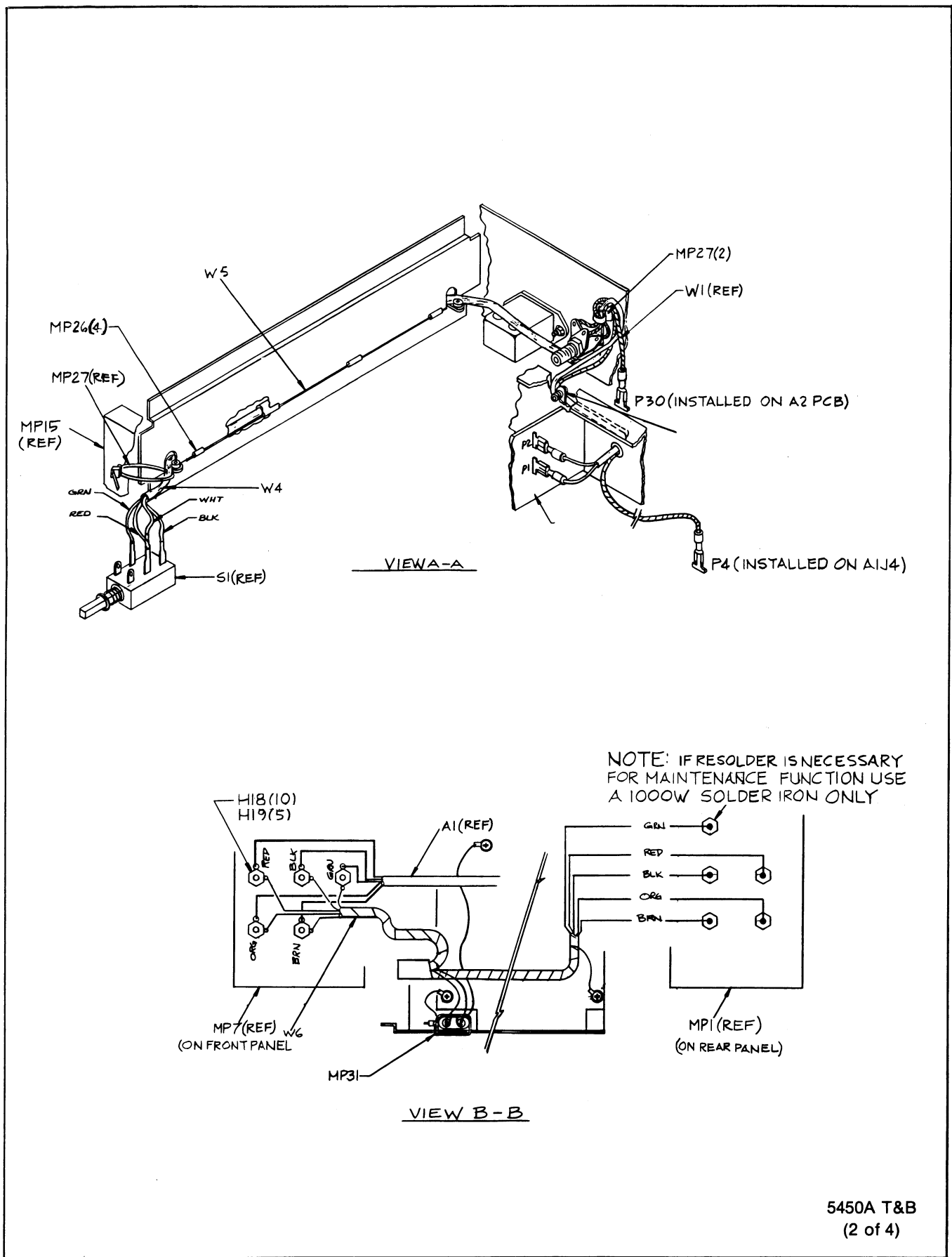
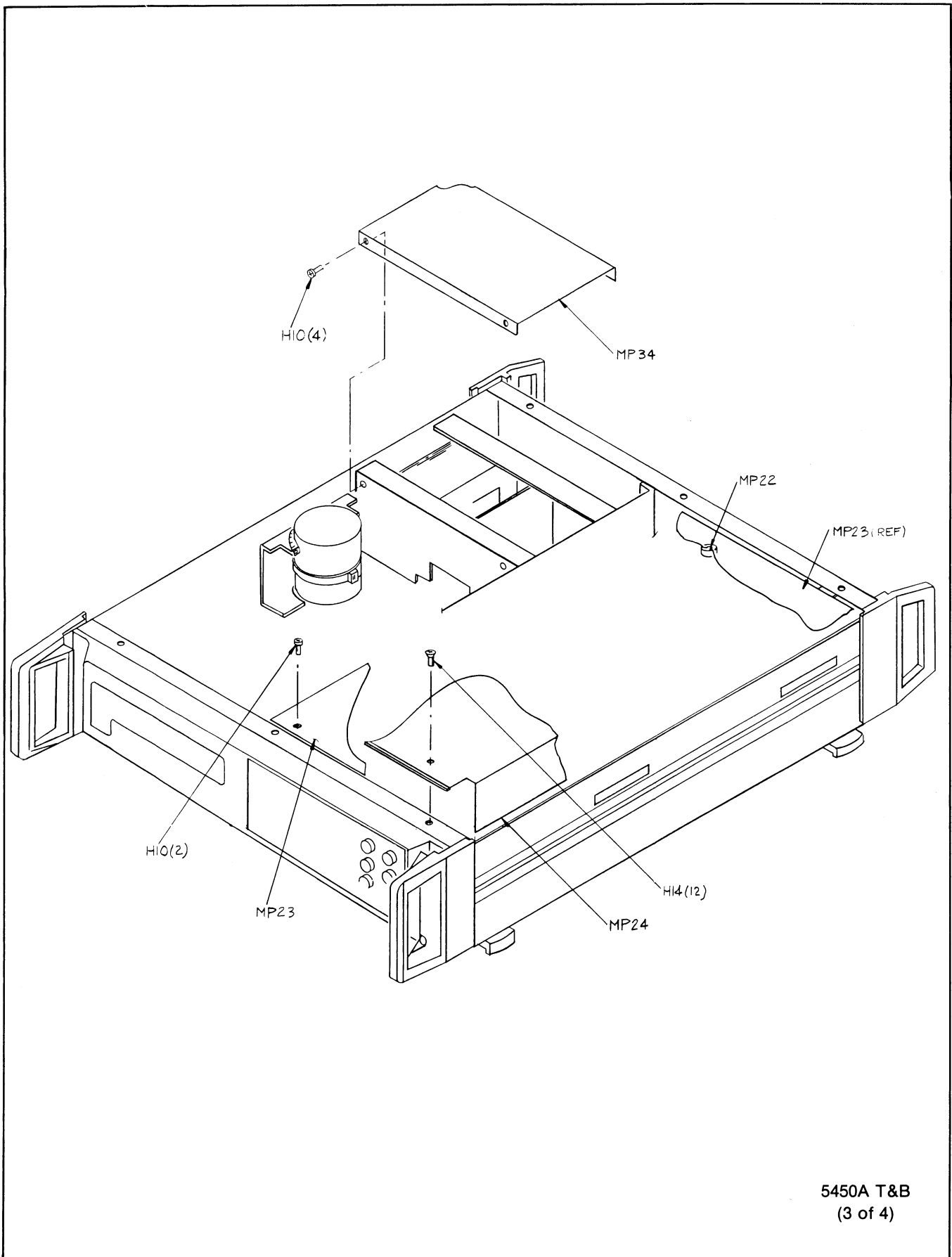


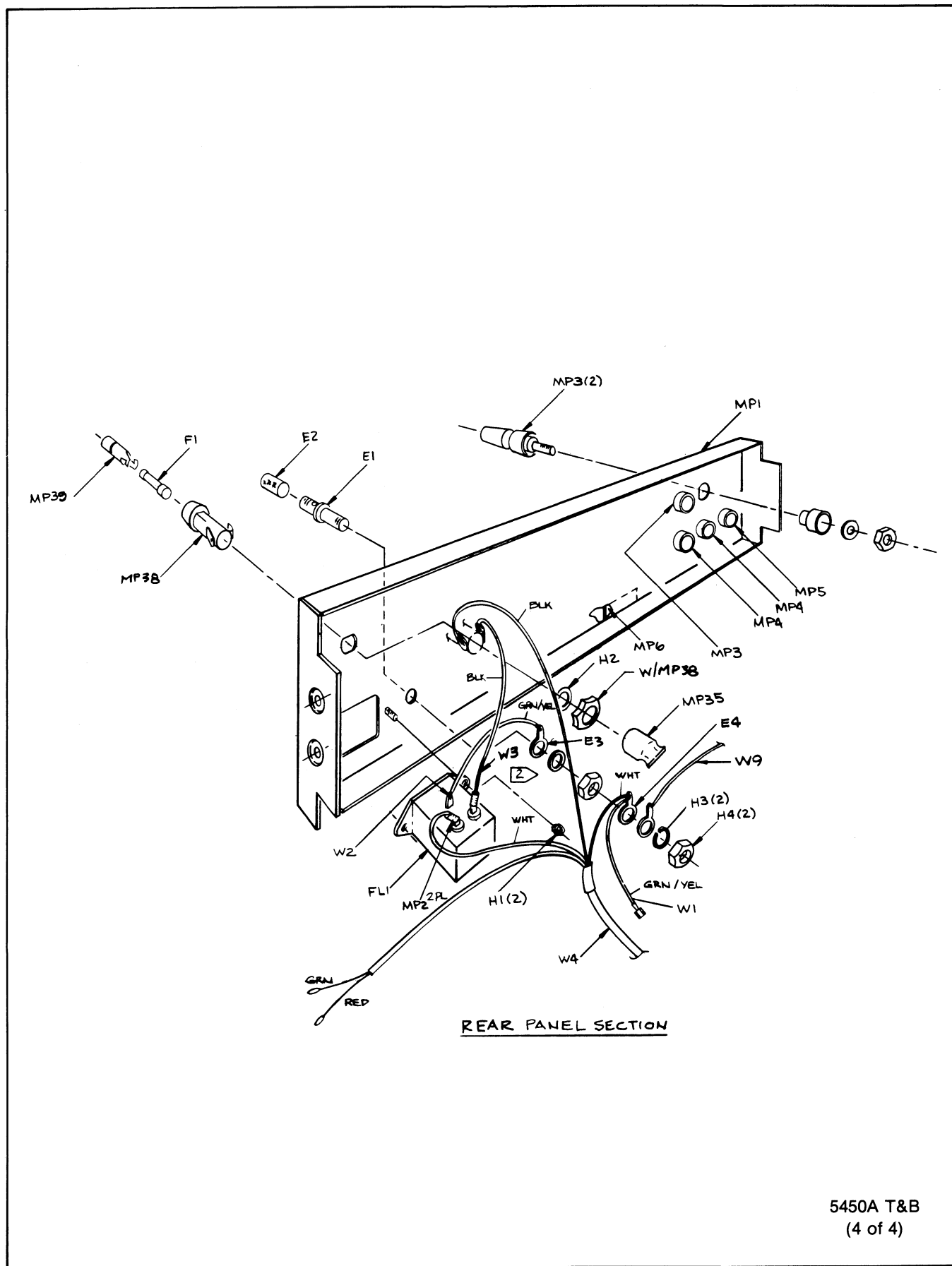
Figure 5-1. Final Assembly (cont)

5450A T&B  
(2 of 4)



5450A T&B  
(3 of 4)

Figure 5-1. Final Assembly (cont)



5450A T&B  
(4 of 4)

Figure 5-1. Final Assembly (cont)

TABLE 5-3. A1 ANALOG ASSEMBLY  
(SEE FIGURE 5-2.) 5450A-4001

713537

REFERENCE DESIGNATOR	A->NUMERICS-->	S	-----DESCRIPTION-----	FLUKE STOCK --NO--	MFRS SPLY CODE-	MANUFACTURERS PART NUMBER --OR GENERIC TYPE--	TOT QTY	R S -R	N O -E
C	1-	6	CAP,CER,0.022UF,+100-20%,40V,Z5U	358325	72982	8121-A050-651-223Z	006	01	
C	7		CAP,CER,0.22UF,+20%,50V,Z5U	309849	71590	CW3C0C224K	001		
C	8		CAP,AL,1500UF,+30-20%,16V	603480	89536	603480	001		
CR	1,	2	* DIODE,SI,100 PIV,1.5 AMP	116111	05277	1N4817	002	01	
CR	3		* ZENER,UNCOMP,9.1V,5%,28.0MA,1.0W	459917	12969	UZ8709	001	01	
CR	4,	5	* DIODE,SI,100 PIV,5.0 AMP	483701	14099	5FF10	002	01	
E	1,	2	STANDOFF,TERM,TEFLON	271650	12615	SL890823	002		
F	1,	2	FUSE,1/4 X 1-1/4,FAST,2A,250V	109173	89536	109173	002	01	
H	1		SCREW,MACHINE,PHP,STEEL,6-32X3/16	381087	89536	381087	002		
H	2		SCREW,MACHINE,PHP,STEEL,8-32X3/8	114124	89536	114124	002		
H	3		NUT,HEX DBL CHAMFER 8-32NNC-2B BRASS	631614	89536	631614	001		
H	4		WASHER,FLAT,BRASS,#8,0.032 THK	631606	89536	631606	001		
H	5		SCREW,MACHINE,PHP,STEEL,4-40X5/16	152116	89536	152116	002		
H	6		NUT,METAL 4-40 CAPTIVE EXT LOCKWASHER	195255	89536	195255	002		
H	7		TERMINAL,TEFLON TERMINAL	720797	89536	720797	005		
J	1		SOCKET,DIP,0.100 CTR,16 PIN	387324	71785	133-59-02-062	001		
J	2,	3	POST CONTACT W/CARRIER STRIP	417329	89536	417329	006		
J	4		TERMINAL,CONNECTOR	512889	02660	62395	001		
K	1,	4, 7-	RELAY,ARMATURE,6 FORM C,4.5VDC	602953	89536	602953	011		
K	15			602953					
K	2,	3, 6,	RELAY,ARMATURE,2 FORM C,4.5VDC	514240	89536	514240	010		
K	17-	22, 31		514240					
K	5,	16, 30	RELAY,ARMATURE,4 FORM C,4.5VDC	422931	77342	R10-E3713-3	003		
K	23-	29	RELAY,REED,1 FORM A,4.5VDC	544031	89536	544031	007		
K	32,	33	RELAY,REED,1 FORM A,4.5V,HI IR	720821	89536	720821	002		
K	34		RELAY,REED,1 FORM B,5VDC	529677	71707	E-9174	001		
MP	1		ANALOG PCB, BARE	713529	89536	713529	001		
MP	2		SPACER,SWAGED,RND,BRASS,8-32X0.437	494559	89536	494559	001		
MP	3		FUSE HLDR,CLIP,PCB,1/4 DIA FUSE	485219	91833	3529	004		
MP	4		SPACER,SWAGED,RND,BRASS,6-32X1.450	460402	89536	460402	002		
MP	5		CAN,RESISTOR SET	723130	89536	723130	001		
MP	6		SLEEVING #22 TEFLON,.027ID	196717	89536	196717	000		
MP	8		SPRING,RELAY SOCKET,2 POLE	376459	77342	20C249	010		
MP	9		SPRING,RELAY SOCKET,4 POLE	500108	77342	20C250	003		
MP	10		SPRING,RELAY SOCKET,6 POLE	417188	77342	20C251	011		
Q	1		* TRANSISTOR,SI,BV=60V,65W,T0-220	386128	01295	T1P120	001	01	
R	1,	3	RES,CF,1K,+5%,0.25W	343426	80031	CR251-4-5P1K	002	01	
R	2		RES,CC,360,+5%,0.5W	192559	89536	192559	001		
R	4		RES,CF,100,+5%,0.25W	348771	80031	CR251-4-5P100E	001		
R	5-	39	RESISTOR SET	713768	89536	713768	001		
R	40-	43	RES,CAR,COMP,1K +/-10%,1/8W	153916	01121	BB1021	004		
S	1		MINI,PCB MTG,.3AMP AT 125V,#MSS2250R	354878	89536	354878	001		
TP	1-	7	CONN,TAB,FASTON,PRESS-IN,0.110 WIDE	512889	02660	62395	007		
U	1		* IC,TTL,QUAD 2-INPUT AND GATE	292987	89536	292987	001	01	
U	2		* IC,LSTTL,DUAL D F/F,+EDG TRG,W/CLR	393124	01295	SN74LS74N	001	01	
U	3		* IC,TTL,HEX INVERTER W/OPEN COLLECTOR	407593	01295	SN7406N	001	01	
U	4		* IC,LSTTL,OCTL BUS TRNSVCR W/3-ST OUT	477406	01295	SN74LS245N	001		
U	5		* IC,LSTTL,3-8 LINE DCDR W/ENABLE	407585	01295	SN74LS138N	001	01	
U	6,	9, 14,	* IC,LSTTL,8BIT ADDR SABLE LATCH,W/CLR	419242	01295	SN74LS259N	004	01	
U	16			419242					
U	7,	11, 12,	* IC,ARRAY,7 TRANS,NPN,DARLINGTON PAIRS	454116	01295	ULN2003	005	01	
U	17,	18		454116					
U	8,	10, 13,	* IC,LSTTL,OCTAL D F/F,+EDG TRG,W/CLEAR	454892	01295	SN74LS273N	004	01	
U	15			454892					
W	1		WIRE,BUS,24 AWG,TINNED COPPER	115477	89536	115477	001		
W	2		CABLE ASSY,FRONT OUTPUT	713743	89536	713743	001		
X	1		SOCKET,SIP,0.100 CTR,4 PIN	461756	00779	583773-1	001		
XK	1,	4, 7-	RELAY SOCKET,6 POLE	281253	89536	281253	011		
XK	15			281253					
XK	2,	3, 6,	RELAY SOCKET,2 POLE	376665	77342	27E501	009		
XK	17-	22		376665					
XK	5,	16	RELAY SOCKET,4 POLE	441964	77342	R10273606	002		
XK	30		RELAY SOCKET,4 POLE	720672	89536	720672	001		
XK	31		RELAY SOCKET,2 POLE	720680	89536	720620	001		



NOTE: R40-R43 ARE INCLUDED IN SIP P/N 414557 ON INSTRUMENTS S/N 3465034 AND LOWER.

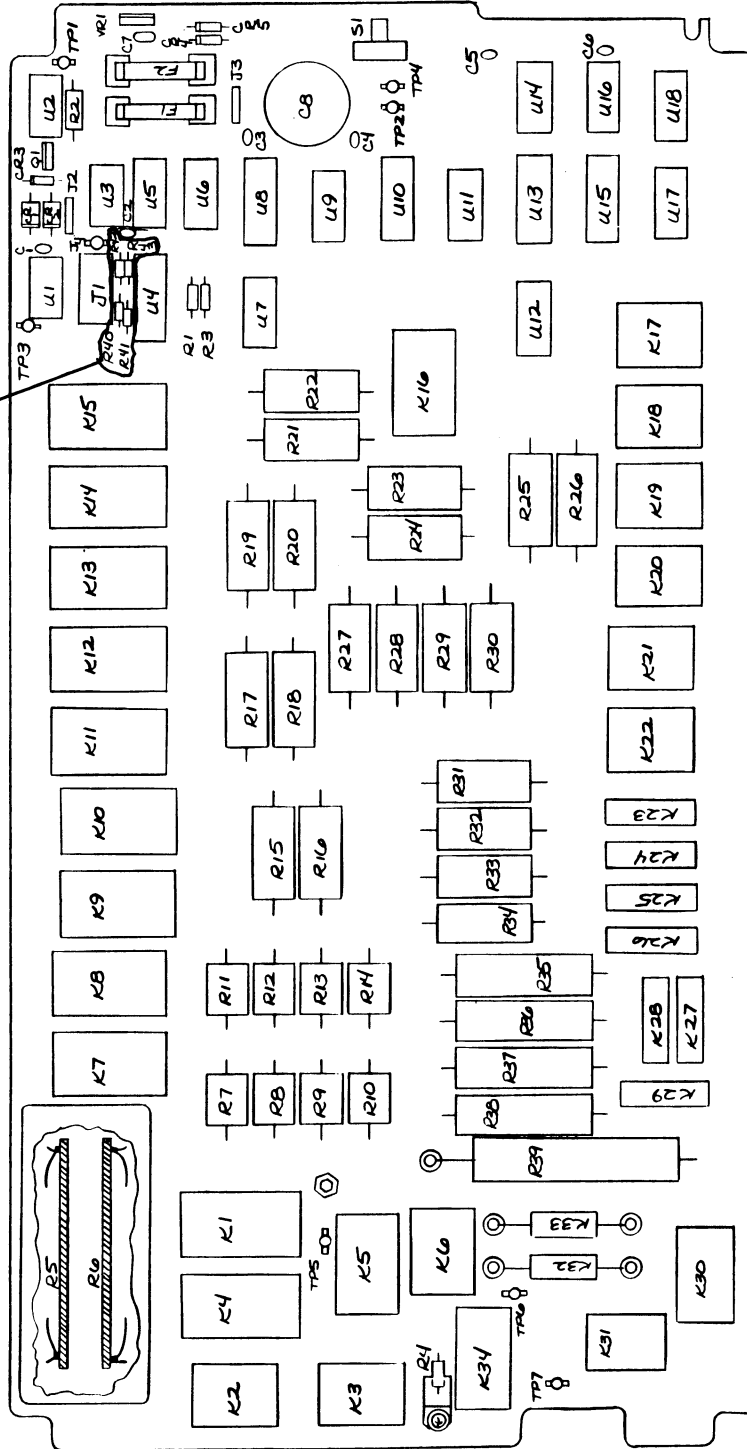


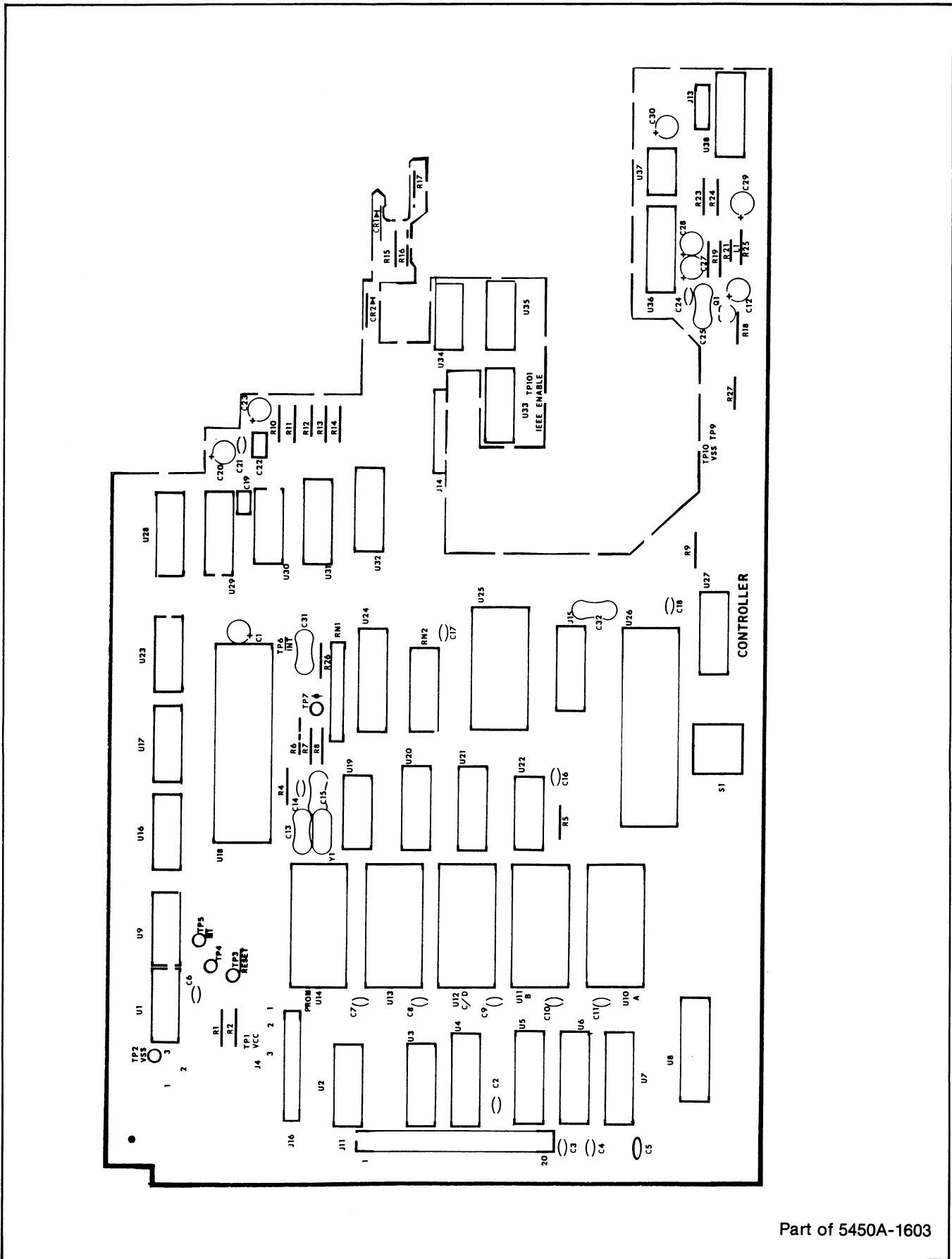
Figure 5-2. A1 Analog Assembly

TABLE 5-4. A2 DIGITAL ASSEMBLY  
(SEE FIGURE 5-3.) 5450A-4002

REFERENCE DESIGNATOR	S	DESCRIPTION	FLUKE STOCK NO	MFRS SPLY CODE	MANUFACTURERS PART NUMBER OR GENERIC TYPE	TOT QTY	R S T	N O E
MP 6		5450A-LABEL	713818	89536	713818	001		
U 4, 5	*	IC, 1K X 4 STAT RAM	483479	34649	P2114A-5	002	01	
C 201		CAP, AL, 2200UF, +75-10%, 15V	479220	56289	32DX223G015BA2A	001	01	
H 1		SCREW, MACHINE, PHP, S STEEL, 4-40X5/16	335141	89536	335141	001		
H 2		SCREW, MACHINE, PHP, S STEEL, 4-40X1-7/16	403782	89536	403782	001		
H 3		SCREW, MACHINE, PHP, STEEL, 10-32X5/16	417105	89536	417105	002		
H 4		WASHER, SHLDR, NYLON, #4	436386	86928	5607-45	001		
H 5		P-NUT, 4-40	380196	24347	KF2-440	002		
H 6		MACHINE, THD FORM, PWHF, STEEL, 5-20X5/16	494641	89536	494641	002		
J 8		CONN, CABLE, RIBBON, PLUG, PWB EDGE, 24	485763	00779	552791-1	001		
MP 1		BRACKET, CAPACITOR/REGULATOR	490490	89536	490490	001		
MP 2		NYLON GROMMET MATL, "CATERPILLAR"	102277	89536	102277	000		
MP 3		CABLE TIE, NYLON, 11X.180, SST-35	501734	89536	501734	001		
MP 4		INSULATOR, TRANSISTOR 7403-09FR-51	508630	89536	508630	001		
MP 7		KEY, POLARIZINGOLARIZING	424572	89536	424572	001		
P 201		CONNECTING LINK	523167	89536	523167	001		
R 210		RES, WW, 13, +-5%, 5W	520197	89536	520197	001		
U 6, 7	*	IC, 1K X 4 STAT RAM	483479	34649	P2114A-5	002	01	
U 18		IC, NMOS, 8 BIT MICROCOMPUTER	478073	50088	MK3880-4CPU	001		
U 25	*	IC, TTL, 4-16 LINE DCDR W/DUAL STROBE	293217	01295	SN74154N	001	01	
U 108-110	*	IC, LSTTL, QUAD BUS XCVR W/3-STATE OUT	453480	04713	MC3448P	003	01	
U 202	*	IC, VOLT REG, ADJ, 1.2 TO 37 V, 1.5 AMPS	460410	12040	LM317T	001	01	
XF 11		SOCKET, SIP, 0.100 CTR, 20 PIN	443077	00779	583773-9	001		
CR 1, 2	*	DIODE, SI, BV= 75.0V, IO=150MA, 500 MW	203323	07910	1N4448	002	01	
CR 202, 203	*	DIODE, SI, 100 PIV, 1.0 AMP	343491	01295	1N4002	002	01	
R 1, 2, 4,		RES, CF, 1K, +-5%, 0.25W	573170	80031	CR251-4-5P1K	008		
R 5, 8, 14,			573170					
R 15, 26			573170					
R 7, 23, 24		RES, CF, 51, +-5%, 0.25W	572990	80031	CR251-4-5P51E	003		
R 9, 16, 19,		RES, CF, 10K, +-5%, 0.25W	573394	80031	CR251-4-5P10K	005		
R 101, 102			573394					
R 10		RES, MF, 100K, +-1%, 0.125W, 100PPM	248807	91637	CMF551003F	001		
R 11		RES, MF, 681K, +-1%, 0.125W, 100PPM	381517	91637	CMF556813F	001		
R 12		RES, MF, 1.5K, +-1%, 0.125W, 100PPM	313098	91637	CMF551501F	001		
R 13		RES, MF, 10K, +-1%, 0.125W, 100PPM	168260	91637	CMF551002F	001		
R 17		RES, CF, 100K, +-5%, 0.25W	573584	80031	CR251-4-5P100K	001		
R 18		RES, MF, 28K, +-1%, 0.125W, 100PPM	291385	91637	CMF552802F	001		
R 21		RES, MF, 82.5K, +-1%, 0.125W, 100PPM	246223	91637	CMF558252F	001		
R 25		RES, CF, 270, +-5%, 0.25W	573071	80031	CR251-4-5P270E	001		
R 27		RES, CF, 750, +-5%, 0.25W	573162	80031	CR251-4-5P750E	001		
R 104		RES, CF, 100, +-5%, 0.25W	573014	80031	CR251-4-5P100E	001		
R 105		RES, CF, 470, +-5%, 0.25W	573121	80031	CR251-4-5P470E	001		
R 202		RES, MF, 249, +-1%, 0.125W, 25PPM	448043	91637	CMF552490F	001		
R 203		RES, MF, 649, +-1%, 0.125W, 100PPM	309955	91637	CMF556490F	001		
R 205		RES, CF, 390, +-5%, 0.25W	573105	80031	CR251-4-5P390E	001		
U 1, 35	*	IC, CMOS, DUAL D F/F, +EDG TRG	418830	12040	MM74C74	002	01	
U 2, 3	*	IC, LSTTL, 3-8 LINE DCDR W/ENABLE	407585	01295	SN74LS138N	002		
U 8	*	IC, LSTTL, OCTAL D F/F, +EDG TRG, W/CLEAR	454892	01295	SN74LS273N	001	01	
U 9, 103, 105	*	IC, LSTTL, DUAL D F/F, +EDG TRG, W/CLR	393124	01295	SN74LS74N	003	01	
U 16	*	IC, LSTTL, QUAD 2 INPUT NAND GATE	393033	01295	SN74LS00N	001	01	
U 17	*	IC, LSTTL, HEX INVERTER W/OPEN COLLECT	394536	01295	SN74LS05	001	01	
U 19	*	IC, TTL, HEX INVERTER	292979	01295	SN7404N	001	01	
U 20	*	IC, LSTTL, SYNC DIV BY 16 BINARY COUNTR	495598	01295	SN74LS163N	001	01	
U 21, 26	*	IC, CMOS, DUAL SYNC BINRY UP CNTR	355164	04713	MC14520BCP	002	01	
U 22	*	IC, CMOS, DUAL D F/F, +EDG TRIG	340117	02735	CD4013AE	001	01	
U 23	*	IC, CMOS, QUAD 2 IN NAND W/SCHMT TRIG	404632	02735	CD4039BE	001	01	
U 24	*	IC, LSTTL, OCTL BUS TRNSCVR W/3-ST OUT	477406	01295	SN74LS245N	001	01	
U 27, 31	*	IC, CMOS, HEX BUFFER W/3-STATE OUTPUT	407759	12040	MM80C97N	002	01	
U 30	*	IC, LSTTL, QUAD 2 INPUT NOR GATE	393041	01295	SN74LS02N	001	01	
U 32	*	IC, CMOS, PRESETTABLE DIV BY N COUNTER	478313	02735	CD4018BE	001	01	
U 33	*	IC, TTL, QUAD 2 INPUT AND GATE	393066	01295	SN74LS08N	001	01	
U 34, 106	*	IC, LSTTL, HEX INVERTER	393058	01295	SN74LS04N	002	01	
U 36	*	IC, LSTTL, RETRG MONOSTAB MULTIVB W/CLR	404186	01295	SN74LS123N	001	01	
U 37	*	IC, TTL, DUAL AND DRVR W/OPEN COLLECTOR	329706	01295	SN75452P	001	01	
U 39	*	IC, LSTTL, QUAD 2 IN NAND W/SCHMT TRIG	504449	01295	SN74LS132N	001	01	
U 102	*	IC, LSTTL, OCTL BUFFER W/3-ST&NOR ENABL	429902	12040	DM81LS95N	001	01	
U 104	*	IC, LSTTL, QUAD 2 INPUT OR GATE	393108	01295	SN74LS32N	001	01	
U 107	*	IC, LSTTL, QUAD INTERFACE BUS TRNSCVR	428649	04713	MC3446P	001	01	

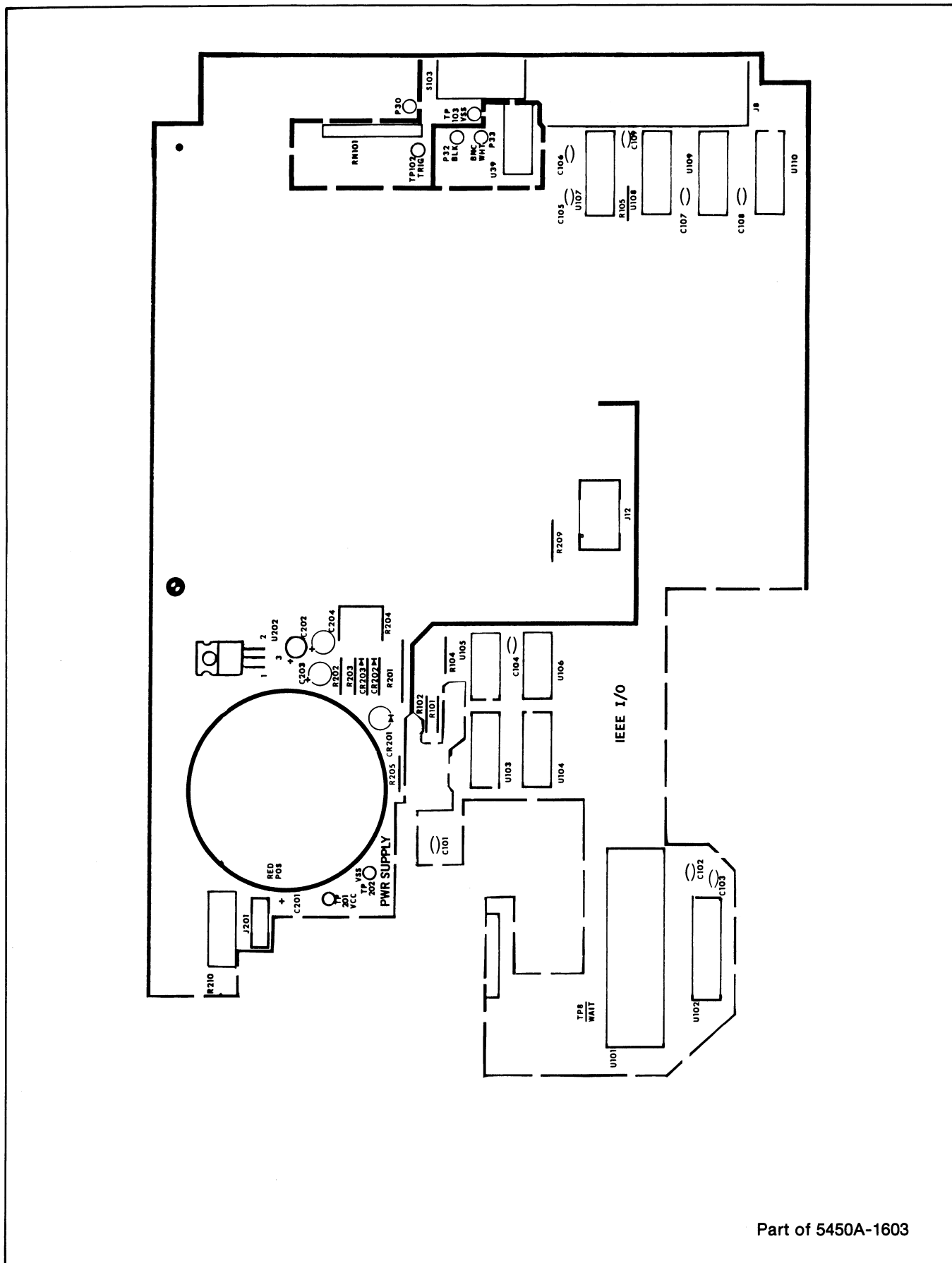
TABLE 5-4. A2 DIGITAL ASSEMBLY (CONT)

REFERENCE DESIGNATOR A->NUMERICS-->	S	DESCRIPTION	FLUKE STOCK --NO--	MFRS SPLY CODE--	MANUFACTURERS PART NUMBER --OR GENERIC TYPE--	TOT QTY	R S -Q -E	N D T -E
C 1		CAP, TA, 10UF, +-20%, 10V	176214	56289	196D106X0010KA1	001		
C 2- 11, 14,		CAP, CER, 0.025UF, +-20%, 100V, Z5W	168435	56289	C023B101H253M	024		
C 16- 18, 21,			168435					
C 24, 101-108			168435					
C 12, 204		CAP, TA, 22UF, +-20%, 15V	423012	56289	196D226X0015KA1	002		
C 13, 32		CAP, MICA, 47PF, +-5%, 500V	148536	72136	CM15E470J	002		
C 15		CAP, CER, 0.05UF, +80-20%, 25V, Y5U	148924	72982	5855-000-Y5U0-503Z	001		
C 19, 22		CAP, CER, 0.01UF, +-20%, 100V, X7R	407361	72982	8121-A100-W5R-103M	002		
C 20, 27, 28,		CAP, TA, 1UF, +-10%, 35V	161919	56289	196D010X0035G	004		
C 30			161919					
C 23		CAP, TA, 39UF, +-20%, 6V	163915	56289	196D394X0020KA1	001		
C 25, 31		CAP, MICA, 100PF, +-5%, 500V	148494	72136	DM15F101J	002		
C 29, 203		CAP, TA, 10UF, +-20%, 15V	193623	56289	196D106X0015A1	002		
C 109		CAP, CER, 0.01UF, +80-20%, 100V, Z5V	149153	56289	C023B101F103M	001		
C 202		CAP, TA, 0.22UF, +-20%, 35V	161331	56289	196D224X0035HA1	001		
CR 20	*	LED, RED, CLIP MOUNT, LUM INT=0.8MCD	429555	12040	NLS5053	001		01
J 12		CONN, PWB EDGE, REC, 0.150 CTR, 8 POS	354951	00779	583407-5	001		
J 13		SOCKET, SIP, 0.100 CTR, 4 PIN	461756	00779	583773-1	001		
J 14, 15		SOCKET, DIP, 0.100 CTR, 16 PIN	276535	91506	316-AG39D	002		
J 16		CONN, PWB, HEADER, SIP, 0.100, 11 PIN	494666	00779	1-640456-1	001		
J 201		CONN, PWB, SCKT STRIP, SIP, 0.100, 5 POS	417899	52072	CA-05S-TSD	001		
L 1		CHOKER, 6TURN	320911	89536	320911	001		
MP 5		SPACER, RND, SOLUBLE, 0.062IDX0.1560D	296319	32559	T0806	002		
MP 8		CONN, TAB, FASTON, PRESS-IN, 0.110 WIDE	512889	02660	62395	018		01
Q 1	*	TRANSISTOR, SI, PNP, SMALL SIGNAL	195974	64713	2N3906	001		
R 6		RES, CF, 150, +-5%, 0.25W	343442	80031	CR251-4-5P150	001		
R 201		RES, WW, 0.1, +-10%, 2W	485672	89536	485672	001		
R 204		RES, VAR, CERM, 200, +-10%, 0.5W	275743	89536	275743	001		
R 209		RES, CC, 10K, +-10%, 0.5W	108118	01121	EB1031	001		
RN 1, 101		RES, NET, SIP, 10 PIN, 9 RES, 10K, +-2%	414003	89536	414003	002		
RN 2		RES, NET, DIP, 16 PIN, 15 RES, 10K, +-5%	355305	89536	355305	001		
S 1		SWITCH, MOMENTARY SHADOW MD DISC	507319	89536	507319	001		
S 103		SWITCH, DIP, 8-POSITION	495168	95146	DYS-8	001		
XU 4- 7		SOCKET, DIP, 0.100 CTR, 18 PIN	418228	91506	318-AG39D	004		
XU 10- 14, 25		SOCKET, DIP, 0.100 CTR, 24 PIN	376236	91506	324-AG39D	005		
XU 18, 26, 101		SOCKET, DIP, 0.100 CTR, 40 PIN	429282	09922	DILB40P-108	003		
Y 1	*	CRYSTAL, 8MHZ, +-0.5%, HC-18/U	485060	89536	485060	001		01



Part of 5450A-1603

Figure 5-3. A2 Digital Assembly



Part of 5450A-1603

Figure 5-3. A2 Digital Assembly (cont)

TABLE 5-5. A3 DISPLAY ASSEMBLY  
(SEE FIGURE 5-4.) 5450A-4003

713594

REFERENCE DESIGNATOR	A->NUMERICS	S	DESCRIPTION	FLUKE STOCK NO	MFRS SPLY CODE	MANUFACTURERS PART NUMBER OR GENERIC TYPE	TOT QTY	R S -Q	N O T -E
C	1- 4		CAP, CER, 0.022UF, +100-20%, 40V, Z5U	358325	72982	8121-A050-651-223Z	004		
C	5		CAP, TA, 2.2 UF, +/-20%, 35V	585185	89536	585185	001		
DS	1- 4		DIODE, LED, RED, 2 X 14 SEGMENTS	478065	50579	DL02614	004	01	
DS	5- 9		LED, RED, RECTANGLE, PCB MOUNT	504761	14936	MV57124	005	01	
H	1		SCREW, MACHINE, PHP, STEEL, 4-40X1/4	129890	73734	19022	001		
H	2		NUT, METAL 4-40 HEX, BRASS	152074	89536	152074	001		
H	3		WASHER, LOCK, SPLIT, STEEL, #4	185710	89536	185710	001		
J	1		CABLE, JUMPER, 20COND, 2.100, 1-86946-9	500975	89536	500975	001		
MP	1		DISPLAY PCB, BARE	713586	89536	713586	001		
MP	2		PUSHBUTTON SQUARE	420638	89536	420638	001	01	
MP	3		PUSHBUTTON-SQUARE, DARK PUTTY GREY	406728	89536	406728	003		
MP	4		PUSHBUTTON-SQUARE-, WHITE	406744	89536	406744	011		
MP	5		SPACER, LED .150 LG	434399	89536	434399	005	01	
MP	6		BRKT, LED BEZEL	713826	89536	713826	001		
R	1		RES, CF, 270, +-5%, 0.25W	348789	80031	CR251-4-5P270E	001	01	
S	1		SWITCH, MOMENTARY, DISC KYBD, ILL, RD ORG	524082	89536	524082	001	03	
S	2, 3, 5-		SWITCH, MOMENTARY SHADOW MD DISC	507319	89536	507319	015		
S	7, 9- 13,			507319					
S	15- 19			507319					
S	4, 8		MOMENTARY SWITCH DARK DARK PUTTY GRAY	525170	89536	525170	002	01	
S	14, 20		SWITCH, MOMENTARY, DISC KYBD, ILL, LT PTY	507335	89536	507335	002		
TP	1- 3		CONN, TAB, FASTON, PRESS-IN, 0.110 WIDE	512889	02660	62395	003		
U	1, 11	*	IC, LSTTL, OCTAL D F/F, +EDG TRG, W/CLEAR	454892	01295	SN74LS273N	002		
U	2, 15	*	IC, BIPLR, BCHNL DRIVER	685412	89536	685412	002	01	
U	7, 8, 16	*	IC, ARRAY, 7 TRANS, NPN, DARLINGTON PAIRS	454116	01295	ULN2003	003	01	
U	9	*	IC, LSTTL, QUAD 2 INPUT NAND GATE	393033	01295	SN74LS00N	001	01	
U	10, 12	*	IC, LSTTL, 8BIT ADDRABLE LATCH, W/CLR	419242	01295	SN74LS259N	002	01	
U	13	*	IC, CMOS, HEX BUFFER W/3-STATE OUTPUT	407759	12040	MM80C97N	001	01	
U	14	*	IC, VOLT REG, FIXED, +5 VOLTS, 1.5 AMPS	428847	04713	MC7805CT	001	01	
Z	1		RES, NET, DIP, 14 PIN, 7 RES, 1K, +-5%	407445	89536	407445	001		

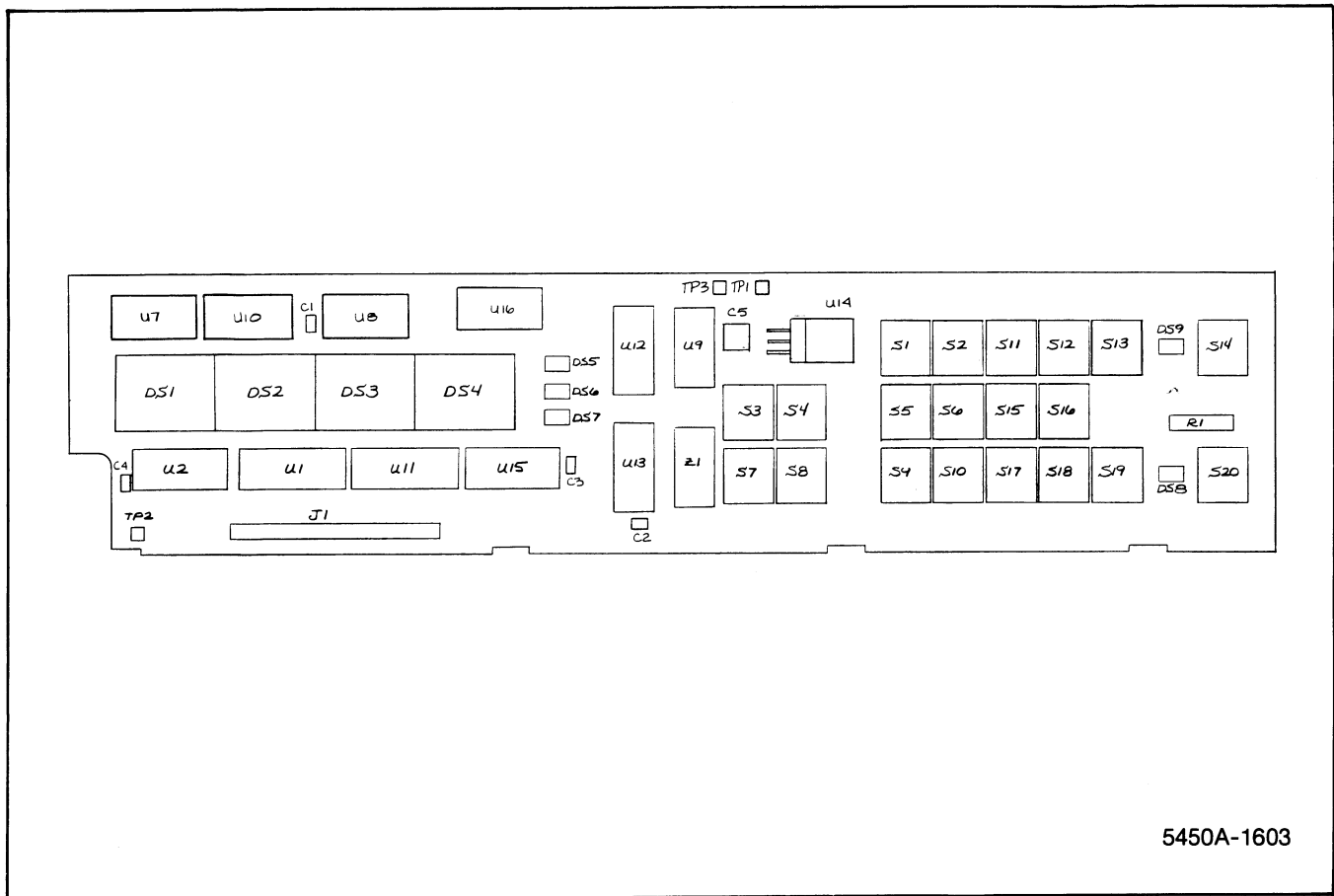
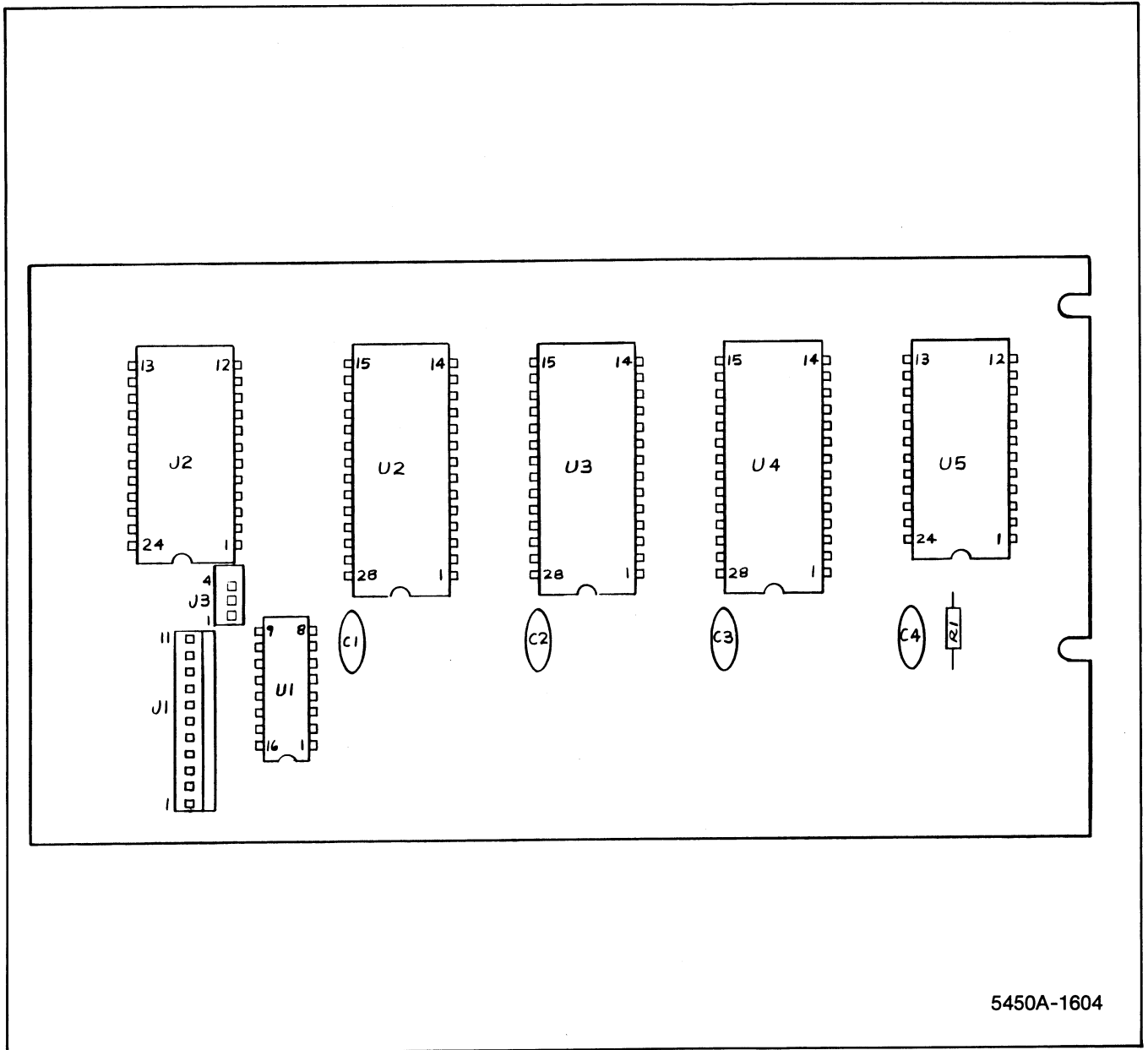


Figure 5-4. A3 Digital Assembly

TABLE 5-6. A4 MEMORY ASSEMBLY  
(SEE FIGURE 5-5.) 5450A-4004

713727

REFERENCE DESIGNATOR	A->NUMERICS	S	DESCRIPTION	FLUKE STOCK NO	MFRS SPLY CODE	MANUFACTURERS PART NUMBER OR GENERIC TYPE	TOT QTY	R S T	N O T
C	1- 4		CAP, CER, 0.025UF, +-20%, 100V, Z5W	168435	56289	C023B101H253M	004	01	
H	1		SCREW, MACHINE, PHP SEMS, STEEL, 4-40X1/4	185918	89536	185918	002		
J	1		CONN, PWB, HEADER, SIP, 0.100, 11 PIN	494666	00779	1-640456-1	001		
J	2		SOCKET, DIP, 0.100 CTR, 24 PIN	376236	91506	324-AG39D	001		
J	3		CONN, PWB, HEADER, SIP, 0.100, 4 POS	417329	89536	417329	001		
MP	1		MEMORY PCB, BARE	713719	89536	713719	001		
MP	2		HINGE, STANDOF, 4-40 X 3/4 BRASS/CAD	354779	89536	354779	002		
P	1		CABLE ASSY MEMORY EXPANDER	527978	89536	527978	001	01	
P	2		CABLE ASSY, DIP CONN, 24 CONDUCT, 3.00"	519140	52072	CAD24P02261CC003	001		
R	1		RES, CC, 10K, +-10%, 0.125W	246975	01121	BB1031	001		
U	1		* IC, LSTTL, 3-8 LINE DCDR W/ENABLE	407585	01295	SN74LS138N	001		
U	2- 4		* IC, 8K X 8 EPROM	605030	89536	605030	003	01	
U	5		* IC, 512 X 8 EEPROM	685545	89536	685545	001	01	
X	1		SOCKET, DIP, 0.100 CTR, 24 PIN	376236	89536	376236	001		
X	3- 5		SOCKET, DIP, 0.100 CTR, 28 PIN	448217	91506	328-AG39D	003		

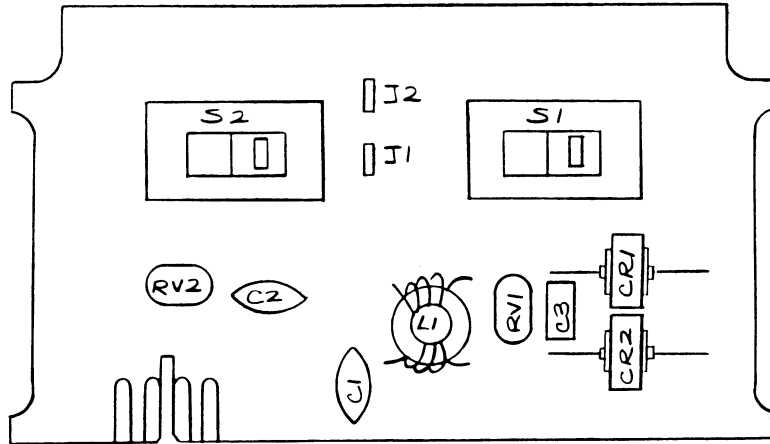


5450A-1604

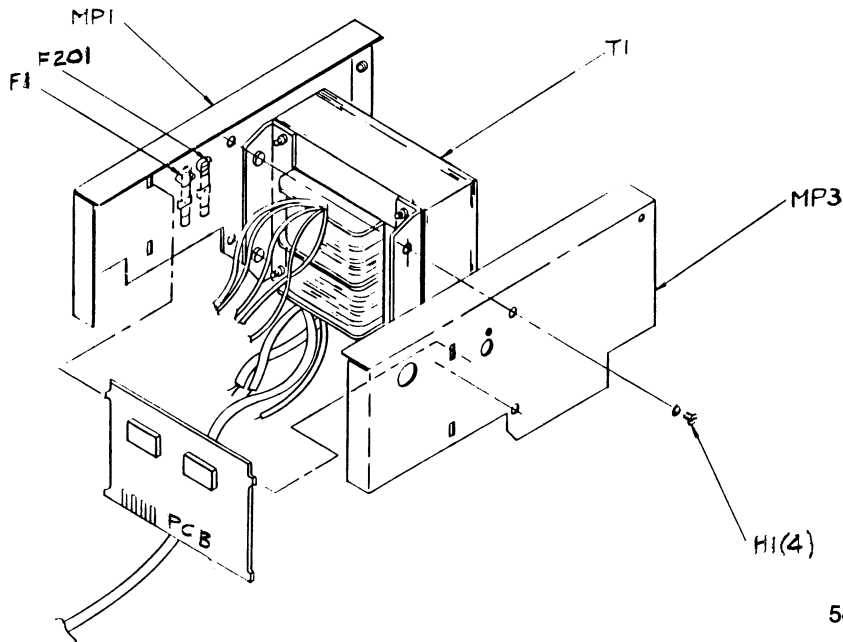
Figure 5-5. A4 Memory Assembly

TABLE 5-7. A5 POWER SUPPLY ASSEMBLY 713636  
(SEE FIGURE 5-6.) 5450A-4005P

REFERENCE DESIGNATOR	A->NUMERICS-->	S	-----DESCRIPTION-----	FLUKE STOCK --NO--	MFRS SPLY CODE-	MANUFACTURERS PART NUMBER --OR GENERIC TYPE--	TOT QTY	R -Q	N O T -E
C	1, 2		CAP, CER, 0.22UF, +-20%, 50V, Z5U	309849	71590	CW3COC224K	002	01	
C	3		CAP, CER, 1.0UF, +-20%, 50V, Z5U	436782	72982	8131-050-601-105M	001		
CR	1, 2	*	DIODE, SI, 100 PIV, 22.0 AMP	325746	04713	MR751	002	01	
F	1		FUSE, 1/4 X 1-1/4, FAST, 2A, 250V	109173	71400	AGC2	001	05	
F	201		FUSE, 1/4 X 1-1/4, SLOW, 0.5A, 250V	109322	71400	MDL1-2	001	05	
H	1		SCREW, MACHINE, PHP, STEEL, 8-32X1/4	228890	89536	228890	004		
J	1, 2		CONN, TAB, FASTON, PRESS-IN, 0.110 WIDE	512889	02660	62395	002	01	
L	1		COMMON MODE CHOKE .200 MH	492116	89536	492116	001		
MP	1		XFMR PWB	713628	89536	713628	001		
MP	2		BRACKET, XFMR FRONT	713503	89536	713503	001		
MP	3		BRACKET, TRANSFORMER REAR	491126	89536	491126	001		
RV	1		VARIATOR, 33V, +-10%, 1.0MA	485391	89536	485391	001	01	
RV	2		VARIATOR, 22V, +-20%, 1.0MA	500777	89536	500777	001		
S	1, 2		SWITCH, SLIDE DPDT	234278	89536	234278	002	01	
T	1		POWER TRANSFORMER	713453	89536	713453	001		



5450A-1605



5450A-1505

Figure 5-6. A5 Power Supply Assembly



## Section 6

# Option & Accessories

### 6-1. INTRODUCTION

This section documents the options and accessories available for use with the 5450A. At this printing, there are no options, and the accessories are limited to a choice of a composite rack mounting kit or individual rack ears. Each is described in the following accessories subsection.

### 6-2. RACK ADAPTER ONLY (Y8599)

The 5450A can be rack mounted using Rack Adapter Kit Y8599. Use the following procedure to install the kit:

1. Peel off the nameplate decals from the front side handles of the 5450A.
2. Remove the front corner screws that match the hole pattern in the rack mounting ears. (Do not remove any other screws.)
3. Attach the rack mounting ears to the front handles of the 5450A using the screws supplied in the kit.

### 6-3. RACK ADAPTER WITH 22- TO 24-INCH SLIDES (Y8598)

The 5450A can be rack mounted using Rack Adapter Kit Y8598. Use the procedure given previously to install the rack mounting ears provided in the kit. Use the following procedure to install the slides:

1. Remove the horizontal side trim decal from both sides of the instrument.
2. Refer to Figure 6-1. Using the screws supplied with the kit, attach the chassis section (B) of the slide kit to each side of the 5450A.
3. Install the cabinet section (C) of the slide kit in the equipment rack. Bar units, #10-32 KEP

nuts, and flat head and binder head #10-32 screws are enclosed for mounting the slides to the front and rear vertical cabinet members. Flat head screws are used when the front cabinet members are countersunk.

4. The rear support bracket (enclosed) allows adjustment from 0 to 2-1/2 inch beyond the end of the slide.
5. Pull the center section of the slide out through the front of the equipment rack until it locks in the extended position.
6. Depress the spring locks on the chassis section (B) and insert the instrument between the extended slide sections.
7. Remove the four molded feet and bails from the bottom cover.

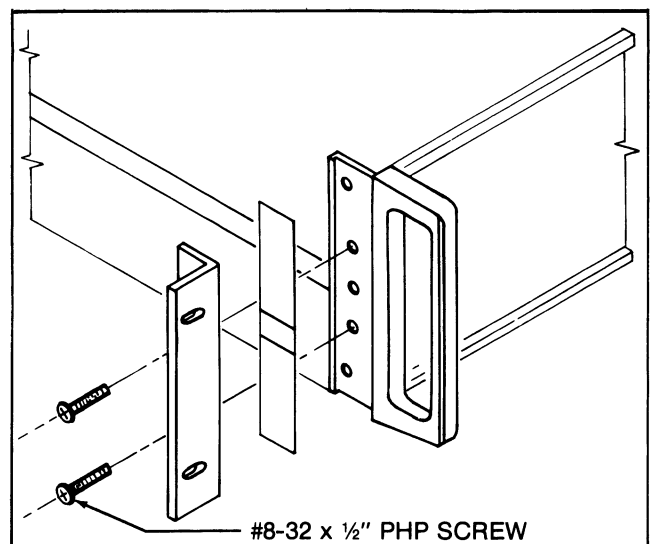
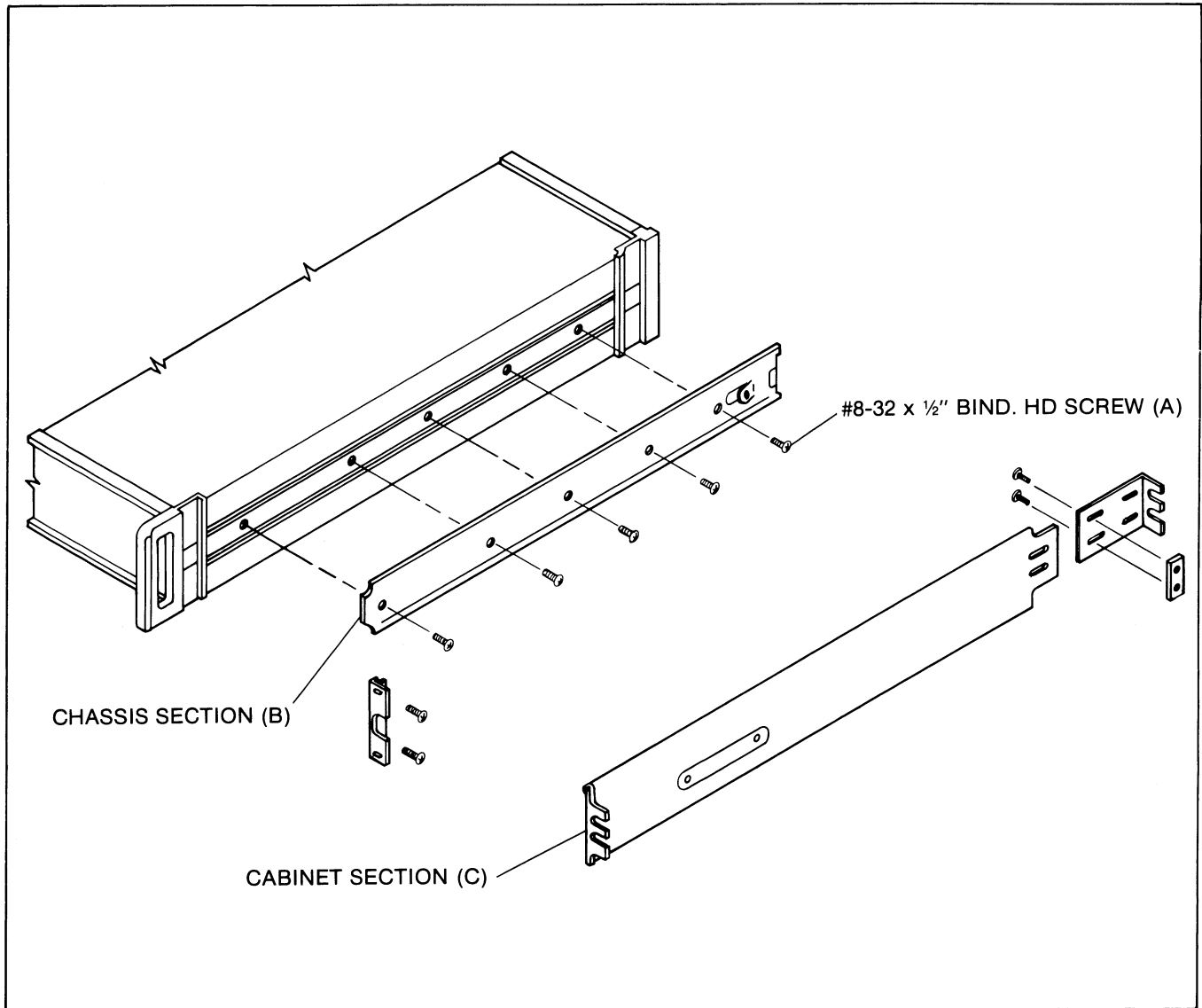


Figure 6-1. Rack Adapter Installation



**Figure 6-2. Rack Slide Installation**

Section 7  
**General Information**

7-1. This section of the manual contains generalized user information as well as supplemental information to the List of Replaceable Parts contained in Section 5.

## List of Abbreviations and Symbols

<b>A or amp</b>	ampere	<b>hf</b>	high frequency	<b>(+) or pos</b>	positive
<b>ac</b>	alternating current	<b>Hz</b>	hertz	<b>pot</b>	potentiometer
<b>af</b>	audio frequency	<b>IC</b>	integrated circuit	<b>p-p</b>	peak-to-peak
<b>a/d</b>	analog-to-digital	<b>if</b>	intermediate frequency	<b>ppm</b>	parts per million
<b>assy</b>	assembly	<b>in</b>	inch(es)	<b>PROM</b>	programmable read-only memory
<b>AWG</b>	american wire gauge	<b>intl</b>	internal	<b>psi</b>	pound-force per square inch
<b>B</b>	bel	<b>I/O</b>	input/output	<b>RAM</b>	random-access memory
<b>bcd</b>	binary coded decimal	<b>k</b>	kilo ( $10^3$ )	<b>rf</b>	radio frequency
<b>°C</b>	Celsius	<b>kHz</b>	kilohertz	<b>rms</b>	root mean square
<b>cap</b>	capacitor	<b>kΩ</b>	kilohm(s)	<b>ROM</b>	read-only memory
<b>ccw</b>	counterclockwise	<b>kV</b>	kilovolt(s)	<b>s or sec</b>	second (time)
<b>cer</b>	ceramic	<b>lf</b>	low frequency	<b>scope</b>	oscilloscope
<b>cermet</b>	ceramic to metal(seal)	<b>LED</b>	light-emitting diode	<b>SH</b>	shield
<b>ckt</b>	circuit	<b>LSB</b>	least significant bit	<b>Si</b>	silicon
<b>cm</b>	centimeter	<b>LSD</b>	least significant digit	<b>serno</b>	serial number
<b>cmrr</b>	common mode rejection ratio	<b>M</b>	mega ( $10^6$ )	<b>sr</b>	shift register
<b>comp</b>	composition	<b>m</b>	milli ( $10^{-3}$ )	<b>Ta</b>	tantalum
<b>cont</b>	continue	<b>mA</b>	milliampere(s)	<b>tb</b>	terminal board
<b>crt</b>	cathode-ray tube	<b>max</b>	maximum	<b>tc</b>	temperature coefficient or temperature compensating
<b>cw</b>	clockwise	<b>mf</b>	metal film	<b>tcxo</b>	temperature compensated crystal oscillator
<b>d/a</b>	digital-to-analog	<b>MHz</b>	megahertz	<b>tp</b>	test point
<b>dac</b>	digital-to-analog converter	<b>min</b>	minimum	<b>u or μ</b>	micro ( $10^{-6}$ )
<b>dB</b>	decibel	<b>mm</b>	millimeter	<b>uhf</b>	ultra high frequency
<b>dc</b>	direct current	<b>ms</b>	millisecond	<b>us or μs</b>	microsecond(s) ( $10^{-6}$ )
<b>dmm</b>	digital multimeter	<b>MSB</b>	most significant bit	<b>uut</b>	unit under test
<b>dvm</b>	digital voltmeter	<b>MSD</b>	most significant digit	<b>V</b>	volt
<b>elect</b>	electrolytic	<b>MTBF</b>	mean time between failures	<b>v</b>	voltage
<b>ext</b>	external	<b>MTTR</b>	mean time to repair	<b>var</b>	variable
<b>F</b>	farad	<b>mV</b>	millivolt(s)	<b>vco</b>	voltage controlled oscillator
<b>°F</b>	Fahrenheit	<b>mv</b>	multivibrator	<b>vhf</b>	very high frequency
<b>FET</b>	Field-effect transistor	<b>MΩ</b>	megohm(s)	<b>vlf</b>	very low frequency
<b>ff</b>	flip-flop	<b>n</b>	nano ( $10^{-9}$ )	<b>W</b>	watt(s)
<b>freq</b>	frequency	<b>na</b>	not applicable	<b>ww</b>	wire wound
<b>FSN</b>	federal stock number	<b>NC</b>	normally closed	<b>xfmr</b>	transformer
<b>g</b>	gram	<b>(-) or neg</b>	negative	<b>xstr</b>	transistor
<b>G</b>	giga ( $10^9$ )	<b>NO</b>	normally open	<b>xtal</b>	crystal
<b>gd</b>	guard	<b>ns</b>	nanosecond	<b>xtlo</b>	crystal oscillator
<b>Ge</b>	germanium	<b>opnl ampl</b>	operational amplifier	<b>Ω</b>	ohm(s)
<b>GHz</b>	gigahertz	<b>p</b>	pico ( $10^{-12}$ )	<b>μ</b>	micro ( $10^{-6}$ )
<b>gmV</b>	guaranteed minimum value	<b>para</b>	paragraph		
<b>gnd</b>	ground	<b>pcb</b>	printed circuit board		
<b>H</b>	henry	<b>pF</b>	picofarad		
<b>hd</b>	heavy duty	<b>pn</b>	part number		

### Federal Supply Codes for Manufacturers

00213 Nytronics Comp. Group Inc. Subsidiary of Nytronics Inc. Formerly Sage Electronics Rochester, New York	02660 Bunker Ramo Corp., Conn Div. Formerly Amphenol-Borg Electric Corp. Broadview, Illinois	04946 Standard Wire & Cable Los Angeles, California	06751 Components, Inc. Semcor Div. Phoenix, Arizona
00327 Welwyn International, Inc. Westlake, Ohio	02799 Areo Capacitors, Inc. Chatsworth, California	05082 Replaced by 94988	06860 Gould Automotive Div. City of Industry, California
00656 Aerovox Corp. New Bedford, Massachusetts	03508 General Electric Co. Semiconductor Products Syracuse, New York	05236 Jonathan Mfg. Co. Fullerton, California	06961 Vernitron Corp., Piezo Electric Div. Formerly Clevite Corp., Piezo Electric Div. Bedford, Ohio
00686 Film Capacitors, Inc. Passaic, New Jersey	03614 Replaced by 71400	05245 Components Corp. now Corcom, Inc. Chicago, Illinois	06980 Eimac Div. Varian Associates San Carlos, California
00779 AMP Inc. Harrisburg, Pennsylvania	03651 Replaced by 44655	05277 Westinghouse Electric Corp. Semiconductor Div. Youngwood, Pennsylvania	07047 The Ross Milton Co. South Hampton, Pennsylvania
01121 Allen-Bradley Co. Milwaukee, Wisconsin	03797 Eldema Div. Genisco Technology Corp. Compton, California	05278 Replaced by 43543	07115 Replaced by 14674
01281 TRW Electronic Comp. Semiconductor Operations Lawndale, California	03877 Transistron Electronic Corp. Wakefield, Massachusetts	05279 Southwest Machine & Plastic Co. Glendora, California	07138 Westinghouse Electric Corp., Electronic Tube Div. Horsehead, New York
01295 Texas Instruments, Inc. Semiconductor Group Dallas, Texas	03888 KDI Pyrofilm Corp. Whippany, New Jersey	05397 Union Carbide Corp. Materials Systems Div. New York, New York	07233 TRW Electronic Components Cinch Graphic City of Industry, California
01537 Motorola Communications & Electronics Inc. Franklin Park, Illinois	03911 Clairex Electronics Div. Clairex Corp. Mt. Vernon, New York	05571 Use 56289 Sprague Electric Co. Pacific Div. Los Angeles, California	07256 Silicon Transistor Corp. Div. of BBF Group Inc. Chelmsford, Massachusetts
01686 RCL Electronics Inc. Manchester, New Hampshire	03980 Muirhead Inc. Mountainside, New Jersey	05574 Viking Industries Chatsworth, California	07261 Aumet Corp. Culver City, California
01730 Replaced by 73586	04009 Arrow Hart Inc. Hartford, Connecticut	05704 Replaced by 16258	07263 Fairchild Semiconductor Div. of Fairchild Camera & Instrument Corp. Mountain View, California
01884 Use 56289 Sprague Electric Co. Dearborn Electronic Div. Lockwood, Florida	04062 Replaced by 72136	05820 Wakefield Engineering Inc. Wakefield, Massachusetts	07344 Bircher Co., Inc. Rochester, New York
02114 Ferroxcube Corp. Saugerties, New York	04202 Replaced by 81312	06001 General Electric Co. Electronic Capacitor & Battery Products Dept. Columbia, South Carolina	07597 Burndy Corp. Tape/Cable Div. Rochester, New York
02131 General Instrument Corp. Harris ASW Div. Westwood, Maine	04217 Essex International Inc. Wire & Cable Div. Anaheim, California	06136 Replaced by 63743	07792 Lerma Engineering Corp. Northampton, Massachusetts
02395 Rason Mfg. Co. Brooklyn, New York	04221 Aemco, Div. of Midtex Inc. Mankato, Minnesota	06383 Panduit Corp. Tinley Park, Illinois	07910 Teledyne Semiconductor Formerly Continental Device Hawthorne, California
02533 Snelgrove, C.R. Co., Ltd. Don Mills, Ontario, Canada M3B 1M2	04222 AVX Ceramics Div. AVX Corp. Myrtle Beach, Florida	06473 Bunker Ramo Corp. Amphenol SAMS Div. Chatsworth, California	07933 Use 49956 Raytheon Co. Semiconductor Div. HQ Mountain View, California
02606 Fenwal Labs Div. of Travenal Labs. Morton Grove, Illinois	04423 Telonic Industries Laguna Beach, California	06555 Beede Electrical Instrument Co. Penacook, New Hampshire	08225 Industro Transistor Corp. Long Island City, New York
	04645 Replaced by 75376	06739 Electron Corp. Littleton, Colorado	
	04713 Motorola Inc. Semiconductor Products Phoenix, Arizona	06743 Clevite Corp. Cleveland, Ohio	

### Federal Supply Codes for Manufacturers (cont)

08261 Spectra Strip Corp. Garden Grove, California	11726 Qualidyne Corp. Santa Clara, California	13606 Use 56289 Sprague Electric Co. Transistor Div. Concord, New Hampshire	16299 Corning Glass Electronic Components Div. Raleigh, North Carolina
08530 Reliance Mica Corp. Brooklyn, New York	12014 Chicago Rivet & Machine Co. Bellwood, Illinois	13839 Replaced by 23732	16332 Replaced by 28478
08806 General Electric Co. Miniature Lamp Products Dept Cleveland, Ohio	12040 National Semiconductor Corp. Danbury, Connecticut	14099 Semtech Corp. Newbury Park, California	16473 Cambridge Scientific Ind. Div. of Chemed Corporation Cambridge, Maryland
08863 Nylomatic Corp. Norrisville, Pennsylvania	12060 Diodes, Inc. Chatsworth, California	14140 Edison Electronic Div. Mc Gray-Edison Co. Manchester, New Hampshire	16742 Paramount Plastics Fabricators, Inc. Downey, California
08988 Use 53085 Skottie Electronics Inc. Archbald, Pennsylvania	12136 Philadelphia Handle Co. Camden, New Jersey	14193 Cal-R-Inc. formerly California Resistor, Corp. Santa Monica, California	16758 Delco Electronics Div. of General Motors Corp. Kokomo, Indiana
09214 G.E. Co. Semi-Conductor Products Dept. Power Semi-Conductor Products OPN Sec. Auburn, New York	12300 Potter-Brumfield Div. AMF Canada LTD. Guelph, Ontario, Canada	14298 American Components, Inc. an Insilco Co. Conshohocken, Pennsylvania	17001 Replaced by 71468
09353 C and K Components Watertown, Massachusetts	12323 Presin Co., Inc. Shelton, Connecticut	14655 Cornell-Dublier Electronics Division of Federal Pacific Electric Co. Govt. Control Dept. Newark, New Jersey	17069 Circuit Structures Lab. Burbank, California
09423 Scientific Components, Inc. Santa Barbara, California	12327 Freeway Corp. formerly Freeway Washer & Stamping Co. Cleveland, Ohio	14752 Electro Cube Inc. San Gabriel, California	17338 High Pressure Eng. Co., Inc. Oklahoma City, Oklahoma
09922 Burndy Corp. Norwalk, Connecticut	12443 The Budd Co. Polychem Products Plastic Products Div. Bridgeport, Pennsylvania	14869 Replaced by 96853	17545 Atlantic Semiconductors, Inc. Asbury Park, New Jersey
09969 Dale Electronics Inc. Yankton, S. Dakota	12615 U.S. Terminals Inc. Cincinnati, Ohio	14936 General Instrument Corp. Semi Conductor Products Group Hicksville, New York	17856 Siliconix, Inc. Santa Clara, California
10059 Barker Engineering Corp. Formerly Amerace, Amerace ESNA Corp. Kenilworth, New Jersey	12617 Hamlin Inc. Lake Mills, Wisconsin	15636 Elec-Trol Inc. Saugus, California	17870 Replaced by 14140
11236 CTS of Berne Berne, Indiana	12697 Clarostat Mfg. Co. Dover, New Hampshire	15801 Fenwal Electronics Inc. Div. of Kidde Walter and Co., Inc. Framingham, Massachusetts	18178 Vactec Inc. Maryland Heights, Missouri
11237 CTS Keene Inc. Paso Robles, California	12749 James Electronics Chicago, Illinois	15818 Teledyne Semiconductors, formerly Amelco Semiconductor Mountain View, California	18324 Signetics Corp. Sunnyvale, California
11358 CBS Electronic Div. Columbia Broadcasting System Newburyport, Minnesota	12856 Micrometals Sierra Madre, California	15849 Litton Systems Inc. Useco Div. formerly Useco Inc. Van Nuys, California	18612 Vishay Resistor Products Div. Vishay Intertechnology Inc. Malvern, Pennsylvania
11403 Best Products Co. Chicago, Illinois	12954 Dickson Electronics Corp. Scottsdale, Arizona	15898 International Business Machines Corp. Essex Junction, Vermont	18736 Voltronics Corp. Hanover, New Jersey
11503 Keystone Columbia Inc. Warren, Michigan	12969 Unitrode Corp. Watertown, Massachusetts	15909 Replaced by 14140	18927 GTE Sylvania Inc. Precision Material Group Parts Division Titusville, Pennsylvania
11532 Teledyne Relays Hawthorne, California	13103 Thermalloy Co., Inc. Dallas, Texas	16258 Space-Lok Inc. Burbank, California	19451 Perine Machinery & Supply Co. Seattle, Washington
11711 General Instrument Corp. Rectifier Division Hicksville, New York	13327 Solitron Devices Inc. Tappan, New York		19701 Electro-Midland Corp. Mepco-Electra Inc. Mineral Wells, Texas
	13511 Amphenol Cadre Div. Bunker-Ramo Corp. Los Gatos, California		20584 Enochs Mfg. Inc. Indianapolis, Indiana

### Federal Supply Codes for Manufacturers (cont)

20891 Self-Organizing Systems, Inc. Dallas, Texas	28480 Hewlett Packard Co. Corporate HQ Palo Alto, California	43543 Nytronics Inc. Transformer Co. Div. Geneva, New York	70903 Belden Corp. Geneva, Illinois
21604 Bucheys Stamping Co. Columbus, Ohio	28520 Heyman Mfg. Co. Kenilworth, New Jersey	44655 Ohmite Mfg. Co. Skokie, Illinois	71002 Birnback Radio Co., Inc. Freeport, New York
21845 Solitron Devices Inc. Transistor Division Riveria Beach, Florida	29083 Monsanto, Co., Inc. Santa Clara, California	49671 RCA Corp. New York, New York	71400 Bussmann Mfg. Div. of McGraw-Edison Co. Saint Louis, Missouri
22767 ITT Semiconductors Palo Alto, California	29604 Stackpole Components Co. Raleigh, North Carolina	49956 Raytheon Company Lexington, Massachusetts	71450 CTS Corp. Elkhart, Indiana
23050 Product Comp. Corp. Mount Vernon, New York	30148 AB Enterprise Inc. Ahoskie, North Carolina	50088 Mostek Corp. Carrollton, Texas	71468 ITT Cannon Electric Inc. Santa Ana, California
23732 Tracor Inc. Rockville, Maryland	30323 Illinois Tool Works, Inc. Chicago, Illinois	50579 Litronix Inc. Cupertino, California	71482 Clare, C.P. & Co. Chicago, Illinois
23880 Stanford Applied Engrng. Santa Clara, California	31091 Optimax Inc. Colmar, Pennsylvania	51605 Scientific Components Inc. Linden, New Jersey	71590 Centrelab Electronics Div. of Globe Union Inc. Milwaukee, Wisconsin
23936 Pamotor Div., Wm. J. Purdy Co. Burlingame, California	32539 Mura Corp. Great Neck, New York	53021 Sangamo Electric Co. Springfield, Illinois	71707 Coto Coil Co., Inc. Providence, Rhode Island
24248 Replaced by 94222	32767 Griffith Plastic Corp. Burlingame, California	54294 Cutler-Hammer Inc. formerly Shallcross, A Cutter-Hammer Co. Selma, North Carolina	71744 Chicago Miniature Lamp Works Chicago, Illinois
24355 Analog Devices Inc. Norwood, Massachusetts	32879 Advanced Mechanical Components Northridge, California	55026 Simpson Electric Co. Div. of Am. Gage and Mach. Co. Elgin, Illinois	71785 TRW Electronics Components Cinch Connector Operations Div. Elk Grove Village Chicago, Illinois
24655 General Radio Concord, Massachusetts	32897 Erie Technological Products, Inc. Frequency Control Div. Carlisle, Pennsylvania	56289 Sprague Electric Co. North Adams, Massachusetts	72005 Wilber B. Driver Co. Newark, New Jersey
24759 Lenox-Fugle Electronics Inc. South Plainfield, New Jersey	32997 Bourns Inc. Trimpot Products Division Riverside, California	58474 Superior Electric Co. Bristol, Connecticut	72092 Replaced by 06980
25088 Siemen Corp. Isilen, New Jersey	33173 General Electric Co. Products Dept. Owensboro, Kentucky	60399 Torin Corp. formerly Torrington Mfg. Co. Torrington, Connecticut	72136 Electro Motive Mfg. Co. Williamantic, Connecticut
25403 Amperex Electronic Corp. Semiconductor & Micro-Circuits Div. Slatersville, Rhode Island	34333 Silicon General Westminister, California	63743 Ward Leonard Electric Co., Inc. Mount Vernon, New York	72259 Nytronics Inc. Pelham Manor, New Jersey
27014 National Semiconductor Corp. Santa Clara, California	34335 Advanced Micro Devices Sunnyvale, California	64834 West Mfg. Co. San Francisco, California	72619 Dialight Div. Amperex Electronic Corp. Brooklyn, New York
27264 Molex Products Downers Grove, Illinois	34802 Electromotive Inc. Kenilworth, New Jersey	65092 Weston Instruments Inc. Newark, New Jersey	72653 G.C. Electronics Div. of Hydrometals, Inc. Brooklyn, New York
28213 Minnesota Mining & Mfg. Co. Consumer Products Div. St. Paul, Minnesota	37942 P.R. Mallory & Co., Inc. Indianapolis, Indiana	66150 Winslow Tele-Tronics Inc. Eaton Town, New Jersey	72665 Replaced by 90303
28425 Serv-/Link formerly Bohannon Industries Fort Worth, Texas	42498 National Radio Melrose, Massachusetts	70485 Atlantic India Rubber Works Chicago, Illinois	72794 Dzus Fastener Co., Inc. West Islip, New York
28478 Deltrol Controls Div. Deltrol Corporation Milwaukee, Wisconsin		70563 Amperite Company Union City, New Jersey	72928 Gulton Ind. Inc. Gudeman Div. Chicago, Illinois

### Federal Supply Codes for Manufacturers (cont)

72982 Erie Tech. Products Inc. Erie, Pennsylvania	75382 Kulka Electric Corp. Mount Vernon, New York	80583 Hammarlund Mfg. Co., Inc. Red Bank, New Jersey	83594 Burrhoughs Corp. Electronic Components Div. Plainfield, New Jersey
73138 Bechman Instrument Inc. Helipot Division Fullerton, California	75915 Littlefuse Inc. Des Plaines, Illinois	80640 Arnold Stevens, Inc. South Boston, Massachusetts	83740 Union Carbide Corp. Battery Products Div. formerly Consumer Products Div. New York, New York
73293 Hughes Aircraft Co. Electron Dynamics Div. Torrance, California	76854 Oak Industries Inc. Switch Div. Crystal Lake, Illinois	81073 Grayhill, Inc. La Grange, Illinois	84171 Arco Electronics Great Neck, New York
73445 Amperex Electronic Corp. Hicksville, New York	77342 AMF Inc. Potter & Brumfield Div. Princeton, Indiana	81312 Winchester Electronics Div. of Litton Industries Inc. Oakville, Connecticut	84411 TRW Electronic Components TRW Capacitors Ogallala, Nebraska
73559 Carling Electric Inc. West Hartford, Connecticut	77638 General Instrument Corp. Rectifier Division Brooklyn, New York	81483 Therm-O-Disc Inc. Mansfield, Ohio	84613 Fuse Indicator Corp. Rockville, Maryland
73586 Circle F Industries Trenton, New Jersey	77969 Rubbercraft Corp. of CA. LTD. Torrance, California	81483 International Rectifier Corp. Los Angeles, California	84682 Essex International Inc. Industrial Wire Div. Peabody, Massachusetts
73734 Federal Screw Products, Inc. Chicago, Illinois	78189 Shakeproof Div. of Illinois Tool Works Inc. Elgin, Illinois	81590 Korry Mfg. Co. Seattle, Washington	86577 Precision Metal Products of Malden Inc. Stoneham, Massachusetts
73743 Fischer Special Mfg. Co. Cincinnati, Ohio	78277 Sigma Instruments, Inc. South Braintree, Massachusetts	81741 Chicago Lock Co. Chicago, Illinois	86684 Radio Corp. of America Electronic Components Div. Harrison, New Jersey
73899 JFD Electronics Co. Components Corp. Brooklyn, New York	78488 Stackpole Carbon Co. Saint Marys, Pennsylvania	82305 Palmer Electronics Corp. South Gate, California	86928 Seastrom Mfg. Co., Inc. Glendale, California
73949 Guardian Electric Mfg. Co. Chicago, Illinois	78553 Eaton Corp. Engineered Fastener Div. Tinnerman Plant Cleveland, Ohio	82389 Switchcraft Inc. Chicago, Illinois	87034 Illuminated Products Inc. Subsidiary of Oak Industries Inc. Anahiem, California
74199 Quan Nichols Co. Chicago, Illinois	79136 Waldes Kohinoor Inc. Long Island City, New York	82415 North American Phillips Controls Corp. Frederick, Maryland	88219 Gould Inc. Industrial Div. Trenton, New Jersey
74217 Radio Switch Corp. Marlboro, New Jersey	79497 Western Rubber Company Goshen, Indiana	82872 Roanwell Corp. New York, New York	88245 Litton Systems Inc. Useco Div. Van Nuys, California
74276 Signalite Div. General Instrument Corp. Neptune, New Jersey	79963 Zierick Mfg. Corp. Mt. Kisko, New York	82877 Rotron Inc. Woodstock, New York	88419 Cornell-Dubilier Electronic Div. Federal Pacific Co. Fuquay-Varian, North Carolina
74306 Piezo Crystal Co. Carlisle, Pennsylvania	80031 Electro-Midland Corp. Mepco Div. A North American Phillips Co. Norristown, New Jersey	82879 ITT Royal Electric Div. Pawtucket, Rhode Island	88486 Plastic Wire & Cable Jewett City, Connecticut
74542 Hoyt Elect. Instr. Works Penacook, New Hampshire	80145 LFE Corp., Process Control Div. formerly API Instrument Co. Chesterland, Ohio	83003 Varo Inc. Garland, Texas	88690 Replaced by 04217
74970 Johnson E.F., Co. Waseca, Minnesota	80183 Use 56289 Sprague Products North Adams, Massachusetts	83058 The Carr Co., United Can Div. of TRW Cambridge, Massachusetts	89536 John Fluke Mfg. Co., Inc. Seattle, Washington
75042 TRW Electronics Components IRC Fixed Resistors Philadelphia, Pennsylvania	80294 Bourns Inc., Instrument Div. Riverside, California	83298 Bendix Corp. Electric Power Div. Eatontown, New Jersey	89730 G.E. Co., Newark Lamp Works Newark, New Jersey
75376 Kurz-Kasch Inc. Dayton, Ohio		83330 Herman H. Smith, Inc. Brooklyn, New York	
75378 CTS Knights Inc. Sandwich, Illinois		83478 Rubbercraft Corp. of America, Inc. West Haven, Connecticut	



### Federal Supply Codes for Manufacturers (cont)

90201 Mallory Capacitor Co. Div. of P.R. Mallory Co., Inc. Indianapolis, Indiana	91836 King's Electronics Co., Inc. Tuckahoe, New York	95354 Methode Mfg. Corp. Rolling Meadows, Illinois	98291 Seaelectro Corp. Mamaroneck, New York
90211 Use 56365 Square D Co. Chicago, Illinois	91929 Honeywell Inc. Micro Switch Div. Freeport, Illinois	95712 Bendix Corp. Electrical Components Div. Microwave Devices Plant Franklin, Indiana	98388 Royal Industries Products Div. San Diego, California
90215 Best Stamp & Mfg. Co. Kansas City, Missouri	91934 Miller Electric Co., Inc. Div. of Aunet Woonsocket, Rhode Island	95987 Weckesser Co. Inc. Chicago, Illinois	98743 Replaced by 12749
90303 Mallory Battery Co. Div. of Mallory Co., Inc. Tarrytown, New York	92194 Alpha Wire Corp. Elizabeth, New Jersey	96733 San Fernando Electric Mfg. Co. San Fernando, California	98925 Replaced by 14433
91094 Essex International Inc. Suglex/IWP Div. Newmarket, New Hampshire	93332 Sylvania Electric Products Semiconductor Products Div. Woburn, Massachusetts	96853 Gulton Industries Inc. Measurement and Controls Div. formerly Rustrak Instruments Co. Manchester, New Hampshire	99120 Plastic Capacitors, Inc. Chicago, Illinois
91293 Johanson Mfg. Co. Boonton, New Jersey	94145 Replaced by 49956	96881 Thomson Industries, Inc. Manhasset, New York	99217 Bell Industries Elect. Comp. Div. formerly Southern Elect. Div. Burbank, California
91407 Replaced by 58474	94154 Use 94988 Wagner Electric Corp. Tung-Sol Div. Newark, New Jersey	97540 Master Mobile Mounts, Div. of Whitehall Electronics Corp. Ft. Meyers, Florida	99392 STM Oakland, California
91502 Associated Machine Santa Clara, California	94222 Southco Inc. formerly South Chester Corp. Lester, Pennsylvania	97913 Industrial Electronic Hardware Corp. New York, New York	99515 ITT Jennings Monrovia Plant Div. of ITT Jennings formerly Marshall Industries Capacitor Div. Monrovia, California
91506 Augat Inc. Attleboro, Massachusetts	95146 Alco Electronic Products Inc. Lawrence, Massachusetts	97945 Penwalt Corp. SS White Industrial Products Div. Piscataway, New Jersey	99779 Use 29587 Bunker-Ramo Corp. Barnes Div. Landsdowne, Pennsylvania
91637 Dale Electronics Inc. Columbus, Nebraska	95263 Leecraft Mfg. Co. Long Island City, New York	97966 Replaced by 11358	99800 American Precision Industries Inc. Delevan Division East Aurora, New York
91662 Elco Corp. Willow Grove, Pennsylvania	95264 Replaced by 98278	98094 Replaced by 49956	99942 Centrelab Semiconductor Centrelab Electronics Div. of Globe-Union Inc. El Monte, California
91737 Use 71468 Gremar Mfg. Co., Inc. ITT Cannon/Gremar Santa Ana, California	95275 Vitramon Inc. Bridgeport, Connecticut	98159 Rubber-Teck, Inc. Gardena, California	Toyo Electronics (R-Ohm Corp.) Irvine, California
91802 Industrial Devices, Inc. Edgewater, New Jersey	95303 RCA Corp. Receiving Tube Div. Cincinnati, Ohio	98278 Malco A Microdot Co., Inc. Connector & Cable Div. Pasadena, California	National Connector Minneapolis, Minnesota
91833 Keystone Electronics Corp. New York, New York	95348 Gordo's Corp. Bloomfield, New Jersey		



# U.S. SALES AREAS for all Fluke products

## **AL, Huntsville**

John Fluke Mfg. Co., Inc.  
4920 Corporate Drive  
Suite J  
Huntsville, AL 35805-6202  
(205) 830-9671

## **AZ, Tempe**

John Fluke Mfg. Co., Inc.  
2211 S. 48th Street  
Suite B  
Tempe, AZ 85282  
(602) 438-8314

## **CA, Burbank**

John Fluke Mfg. Co., Inc.  
2020 N. Lincoln Street  
Burbank, CA 91504  
(213) 849-7181

## **Irvine**

P.O. Box 19676  
Irvine, CA 92713-9676  
16969 Von Karman  
Suite 100  
Irvine, CA 92714  
(714) 863-9031

## **San Diego**

John Fluke Mfg. Co., Inc.  
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(312) 392-9510

### MD, Rockville

John Fluke Mfg. Co., Inc.  
(301) 770-1576

### NJ, Paramus

John Fluke Mfg. Co., Inc.  
(201) 262-9550

### TX, Dallas

John Fluke Mfg. Co., Inc.  
(214) 869-0311

### WA, Everett

John Fluke Mfg. Co., Inc.  
(206) 356-5560

## Other Countries

### Argentina, Buenos Aires

Coasin S.A.  
Tel: 552-5248  
TLX: (390) 22284

### Australia, Brisbane

Elmeasco Instruments Pty. Ltd.  
Tel: 369-8688  
TLX: (790) AA44062

### Australia, Concord

Elmeasco Instruments Pty. Ltd.  
Tel: 736-2888  
TLX: (790) AA25887

### Australia, Ringwood

Elmeasco Instruments Pty. Ltd.  
Tel: 879-2322  
TLX: (790) AA36206

### Austria, Vienna

Walter Rekersch  
Elektronische Gerate GmbH & Co.  
Tel: 235555  
TLX: (847) 134759

### Belgium, Brussels

Fluke (Belgium) SA/NA  
Tel: 2164090  
TLX: (846) 26312

### Brazil, Sao Paulo

Hi-Tek Eletronica Ltda.  
Tel: 421-5477  
TLX: (1391) 1135589

### Canada, Burnaby, BC

Allan Crawford Associates Ltd.  
Tel: (604) 294-1326  
TLX: 0454247

### Canada, Calgary, AB

Allan Crawford Associates Ltd.  
Tel: (403) 291-3417  
TLX: 03821186

### Canada, Mississauga, ON

Allan Crawford Associates Ltd.  
Tel: (416) 890-2010  
TLX: 0696 1235

### Canada, St. Laurent, PQ

Allan Crawford Associates Ltd.  
Tel: (514) 731-8564  
TLX: 05824944

### Chile, Santiago

Intronica Chile Ltda.  
Tel: 44940  
TLX: (332) 240301

### China, Peoples Republic of

Instrimpex - Fluke Service Center  
Tel: 65-7281

### Colombia, Bogota

Sistemas E Instrumentacion, Ltda.  
Tel: 232-4532  
TLX: (396) 45787

### Denmark, Ballerup

Tage Olson A/S  
Tel: 658111  
TLX: (855) 35293

### Ecuador, Quito

Proteco Coasin Cia., Ltda.  
Tel: 526759  
TLX: (393) 2865

### Egypt and Sudan

Electronic Engineering Liaison Office  
Tel: 695705  
TLX: (927) 22782

### England, Watford, Herts

Fluke (Great Britain) LTD  
Tel: 40511  
TLX: (851) 934583

### Finland

Instrumentarium Elektronikka  
Tel: 358-0-5281  
TLX: (857) 124426

### France

M.B. Electronique S.A.  
Tel: 9568131  
TLX: (842) 695414

### Greece, Athens

Hellenic Scientific Representations  
Tel: 7211140  
TLX: (863) 219330

### Hong Kong, Wanchai

Schmidt & Co (H.K.) Ltd.  
Tel: 8330-222  
TLX: (780) 74766

### India, Bangalore

Hinditron Services Pvt. Ltd.  
Tel: 33139  
TLX: (953) 845741

### India, Bombay

Hinditron Services Pvt. Ltd.  
Tel: 8121316  
TLX: (953) 112326

### India, New Delhi

Hinditron Services Pvt. Ltd.  
Tel: 640380  
TLX: (953) 316458

### Indonesia, Jakarta Pusat

P.T. Dwi Tunggal Jaya Sakti  
Tel: 584685  
TLX: (796) 47308

### Israel, Ramat Hasharon

R.D.T. Electronics Engineering Ltd.  
Tel: 483211  
TLX: (922) 32143

### Italy, Milan

Sistrel S.p.A.  
Tel: 6181893  
TLX: (843) 334643

### Japan, Tokyo

John Fluke Mfg. Co., Inc.  
Japan Branch  
Tel: 434-0181  
TLX: (781) 242-4331

### Korea, Republic of

Electro-Science Korea Co.  
Tel: 784-9942  
TLX: MYOUNG K24283

### Malaysia, Petaling Jaya

Mecomb Malaysia SDN BHD  
Tel: 743422  
TLX: (784) MA37764

### Mexico

Industrial, S.A. (Mexel)  
Diagonal No. 27  
Entre Calle de Eugenia Y Ave.  
Colonia del Valle  
C.P. 03100, Mexico  
Tel: 660-4323  
TLX: (383) 1771038

### Netherlands, Tilburg

Fluke (Nederland) B.V.  
Tel: 352455  
TLX: (844) 52683

### New Zealand, Auckland

McLean Information Technology, Ltd.  
Tel: 501-801, 501-219  
TLX: (791) 21570

### Norway, Oslo

Morgenstjerne & Co. A/S  
Tel: 356110  
TLX: (856) 71719

### Pakistan, Karachi

International Operations (PAK), Ltd.  
Tel: 221127, 239052  
TLX: (952) 24494

### Peru, Lima

Importaciones Y Representaciones  
Electronicas S.A.  
Tel: 288650  
TLX: (394) 25663

### Philippines, Republic of

Spark Radio & Electronics Corp.  
Tel: 775192  
TLX: (722) 27901

### Portugal, Lisbon

Decada Espectral Equipamentos  
de Electronica, Lda.  
Tel: 2103420  
TLX: (832) 15515

### Republic of Singapore, Singapore

Rank O'Connor's (PTE) Limited  
Tel: 4737944  
TLX: (786) RS21023

### Republic of South Africa

Fluke S.A. (Pty) Ltd.  
Tel: 786-3170  
TLX: (960) 424328

### Spain, Madrid

Equipos y Sistemas S.A.  
Tel: 458-0150  
TLX: (831) 42856

### Sweden, Vallingby

Teleinstrument AB  
Tel: 380370  
TLX: (854) 15770

### Switzerland, Zurich

Traco Electronic AG  
Tel: 2010711  
TLX: (845) 815570

### Taiwan, Taipei

Schmidt Electronics Corp.  
Tel: 5013468  
TLX: (785) 11111

### Thailand, Bangkok

Measuretronix Ltd.  
Tel: 378-2516  
TLX: (788) 82796

### Turkey, Istanbul

Erkman Elektronik Aletler  
Tel: 4415461  
TLX: (821) 24399

### Uruguay, Montevideo

Coasin Uruguay S.A.  
Tel: 789015  
TLX: (398) UY23010

### Venezuela, Caracas

Coasin C.A.  
Tel: 239-0967  
TLX: (395) 21027

### West Germany, Ismaning/Munich

Fluke (Deutschland) GmbH  
Tel: 96050  
TLX: (841) 0522472



John Fluke Mfg. Co., Inc., P.O. Box C9090, Everett, WA 98206

Fluke (Holland) B.V., P.O. Box 2269, 5600 CG, Eindhoven, The Netherlands. Phone (040) 458045, TLX 51846  
Litho in U.S.A. 11/85

## Section 8

# Manual Change Information

### 8-1. INTRODUCTION

This section contains information necessary to backdate this manual to conform to earlier printed circuit assembly (PCA) configurations. To identify the configuration of the PCAs used in your instrument, refer to the revision letter (marked in ink) on the component side of each PCA. Table 8-1 defines the PCA revision levels documented in this manual.

### 8-2. NEWER INSTRUMENTS

As changes and improvements are made to the instrument, they are identified by incrementing the revision letter marked on the affected PCA. These

changes are documented on a supplemental change/errata sheet which, when applicable, is inserted at the front of the manual.

### 8-3. OLDER INSTRUMENTS

To backdate this manual to conform with earlier assembly revision levels, perform the changes indicated in Table 8-1.

### 8-4. CHANGES

There are no backdating changes at this printing. All PCA assemblies are documented at their original revision level.

**Table 8-1. Manual Status and Backdating Information**

Ref Or Option No.	Assembly Name	Fluke Part No.	* To adapt manual to earlier rev configurations perform changes in descending order (by no.), ending with change under desired rev letter																		
			-	A	B	C	D	E	F	G	H	J	K	L	M	N	P				
A1	Analog PCA	713545	●	X																	
A2	Digital PCA	713578	●	X																	
A3	Display PCA	713602	●	●	X																
A4	Memory PCA	713610	●	X																	
A5	Power Supply PCA	713644	●	X																	
			* X = The PCB revision levels documented in this manual. ● = These revision letters were never used in the instrument. - = No revision letter on the PCB.																		





## Section 9

# Schematic Diagrams

<b>FIGURE</b>	<b>TITLE</b>	<b>DRAWING NO.</b>	<b>PAGE</b>
8-1.	A1 Analog PCA .....	5450A-1001	9-2
8-2.	A2 Digital PCA .....	5450A-1002	9-5
8-3.	A3 Display PCA .....	5450A-1003	9-10
8-4.	A4 Memory PCA .....	5450A-1004	9-12
8-5.	A5 Power Supply PCA .....	5450A-1005	9-13

NOTE: R40-R43 ARE INCLUDED IN SIP P/N 414557 ON INSTRUMENTS S/N 3465034 AND LOWER.

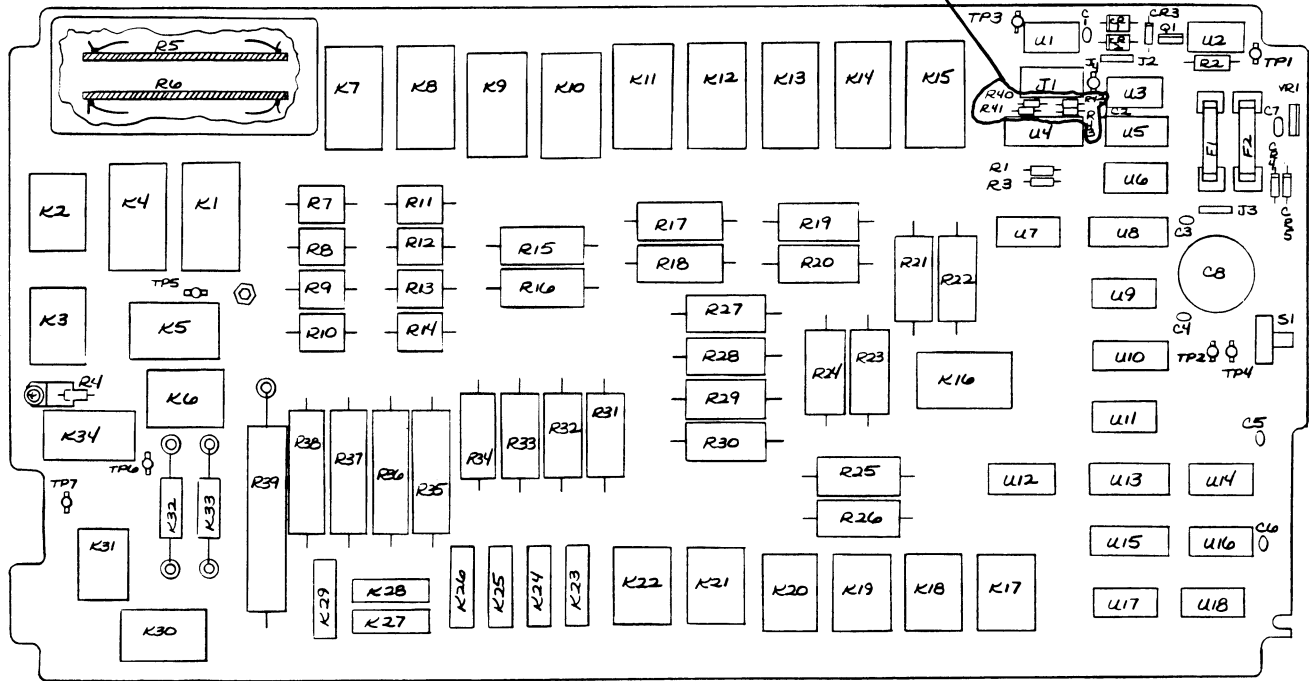

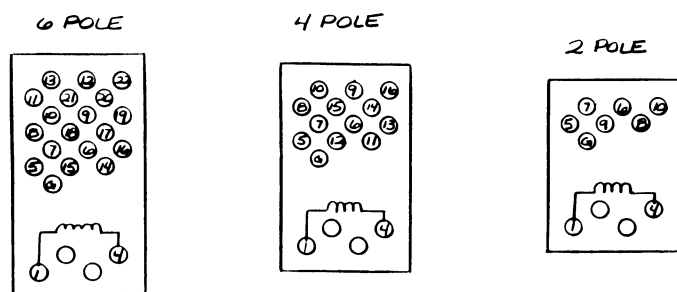


Figure 9-1. A1 Analog PCA

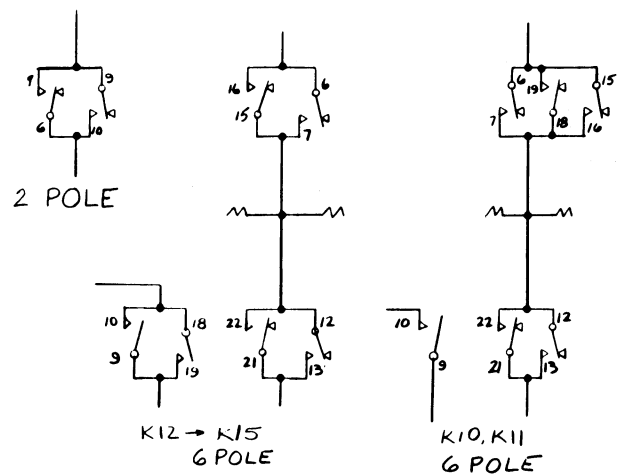
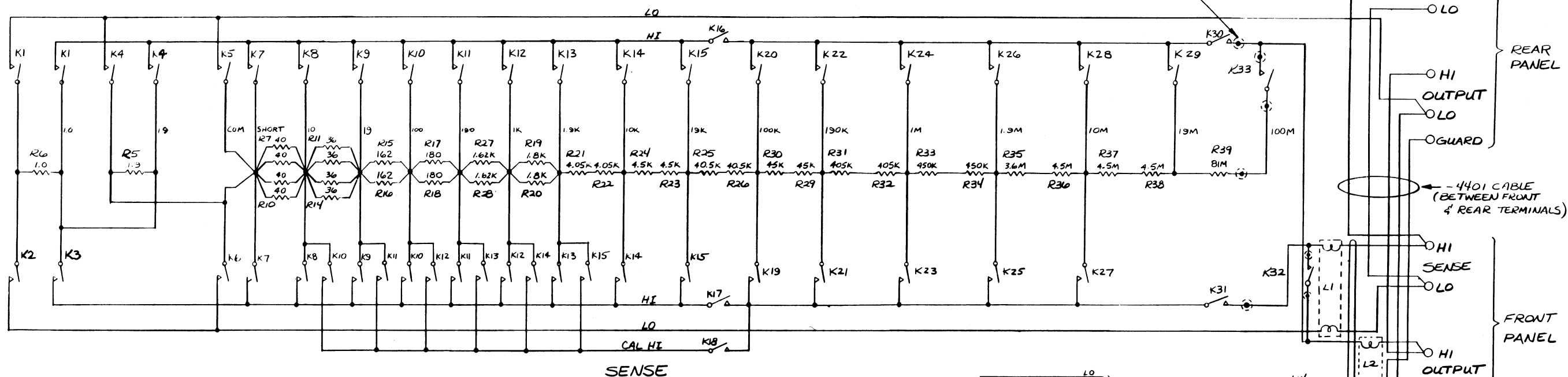
NOTES: UNLESS OTHERWISE SPECIFIED

- 1.  REPRESENTS TELFON STANDOFF (7PL).
- 2. RESISTORS R5-R39 ARE A SPECIALLY MATCHED SET.
- 3. ALL RESISTORS ARE IN OHMS.
- 4. ALL CAPACITORS ARE IN MICROFARADS.

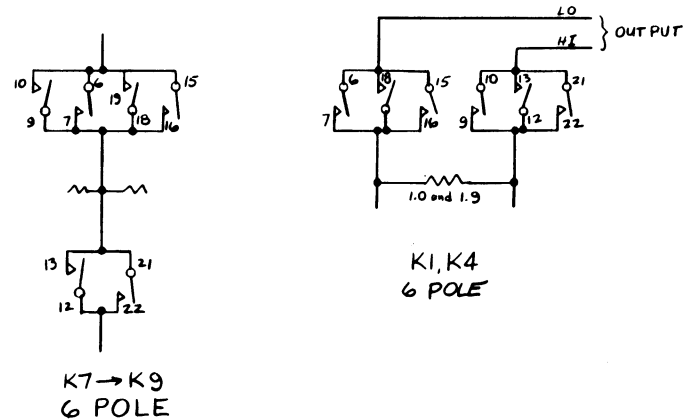


TOP VIEW

OUTPUT

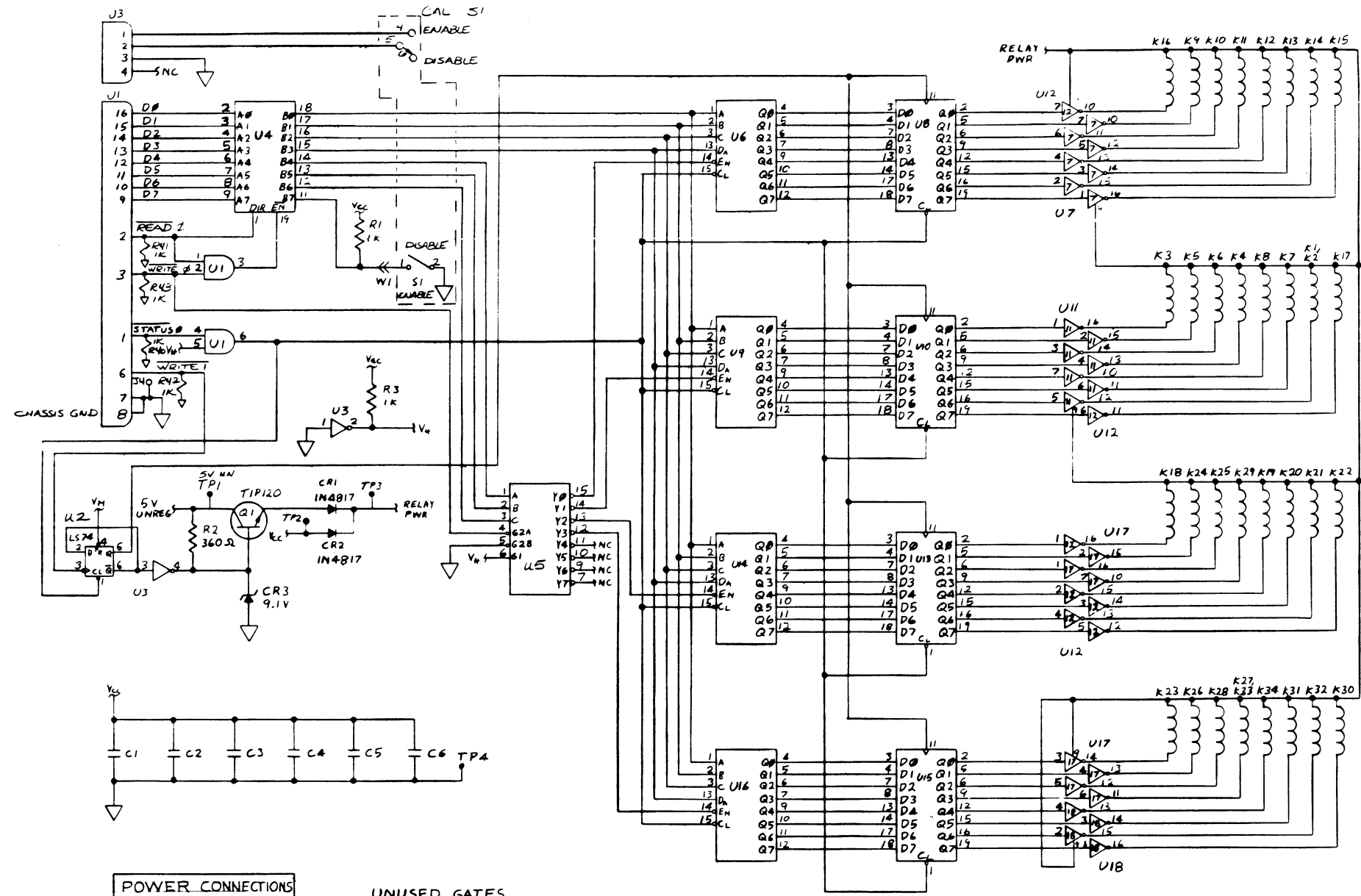


RELAY TYPE	RELAY NUMBER
2 POLE	K2, K3, K6, K17 - K22, K31
4 POLE	K5, K16, K30
6 POLE	K1, K4, K7 - K15
REED SP. 03/1	K23 - K29
REED SP. 03/0	K32, K33
REED FORM B	K34



5450A-1001  
(1 of 2)

Figure 9-1. A1 Analog PCA (cont)

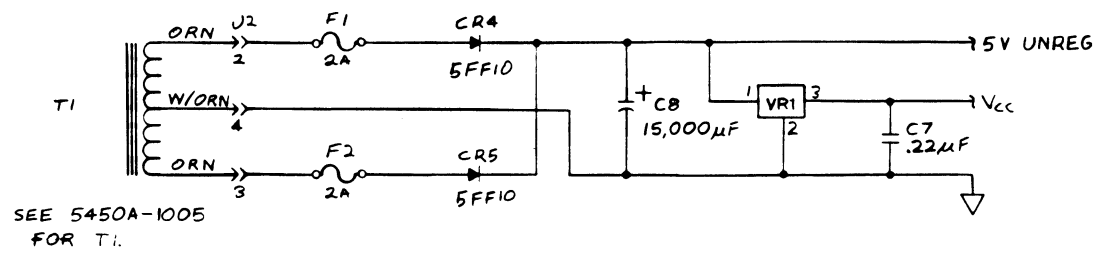
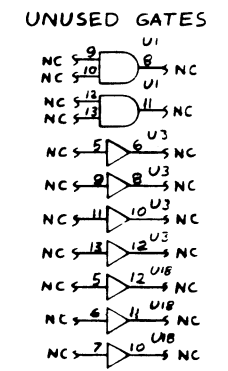


DISPLAY	CALIBRATE, ENABLE (RELAYS CLOSED)
4W CAL	K5, K6, K7, K16, K17, K30, K31
2W CAL	K5, K6, K7, K16, K17, K30, K31
1.0 CAL	K1, K2, K3, K16, K17, K30, K31
1.9 CAL	K4, K6, K16, K17, K30, K31
10 CAL 1	K5, K6, K16, K17, K30, K31
10 CAL 2	K5, K6, K16, K17, K30, K31
19 CAL 1	K5, K6, K16, K17, K30, K31
19 CAL 2	K11, K17, K30, K31
100 CAL 1	K11, K17, K30, K31
100 CAL 2	K11, K17, K30, K31
190 CAL 1	K11, K17, K30, K31
190 CAL 2	K11, K17, K30, K31
1K CAL 1	K11, K17, K30, K31
1K CAL 2	K11, K17, K30, K31
1.9K CAL 1	K11, K17, K30, K31
1.9K CAL 2	K11, K17, K30, K31
10K CAL	K11, K17, K30, K31
19K CAL	K11, K17, K30, K31
100K CAL 1	K11, K17, K30, K31
100K CAL 2	K11, K17, K30, K31
190K CAL 1	K11, K17, K30, K31
190K CAL 2	K11, K17, K30, K31
1M CAL 1	K11, K17, K30, K31
1M CAL 2	K11, K17, K30, K31
1.9M CAL 1	K11, K17, K30, K31
1.9M CAL 2	K11, K17, K30, K31
10M CAL 1	K11, K17, K30, K31
10M CAL 2	K11, K17, K30, K31
19M CAL 1	K11, K17, K30, K31
19M CAL 2	K11, K17, K30, K31
100M CAL 1	K11, K17, K30, K31
100M CAL 2	K11, K17, K30, K31

RESISTANCE	CALIBRATE-DISABLE (RELAYS CLOSED)
SHORT	K5, K6, K7, K16, K17, K30, K31
1 OHM	K1, K2, K3
1.9 OHM	K3, K4, K6
10 OHM	K5, K6, K8
19 OHM	K5, K6, K9
100 OHM	K5, K6, K10
190 OHM	K11
1K OHM	K12
1.9K OHM	K13
10K OHM	K14
19K OHM	K15, K16, K17
100K OHM	K19, K20
190K OHM	K21, K22
1M OHM	K23, K24
1.9M OHM	K25, K26, K30, K31
10M OHM	K28, K30, K32
19M OHM	K29, K30, K32
100M OHM	K5, K6, K27, K32, K33

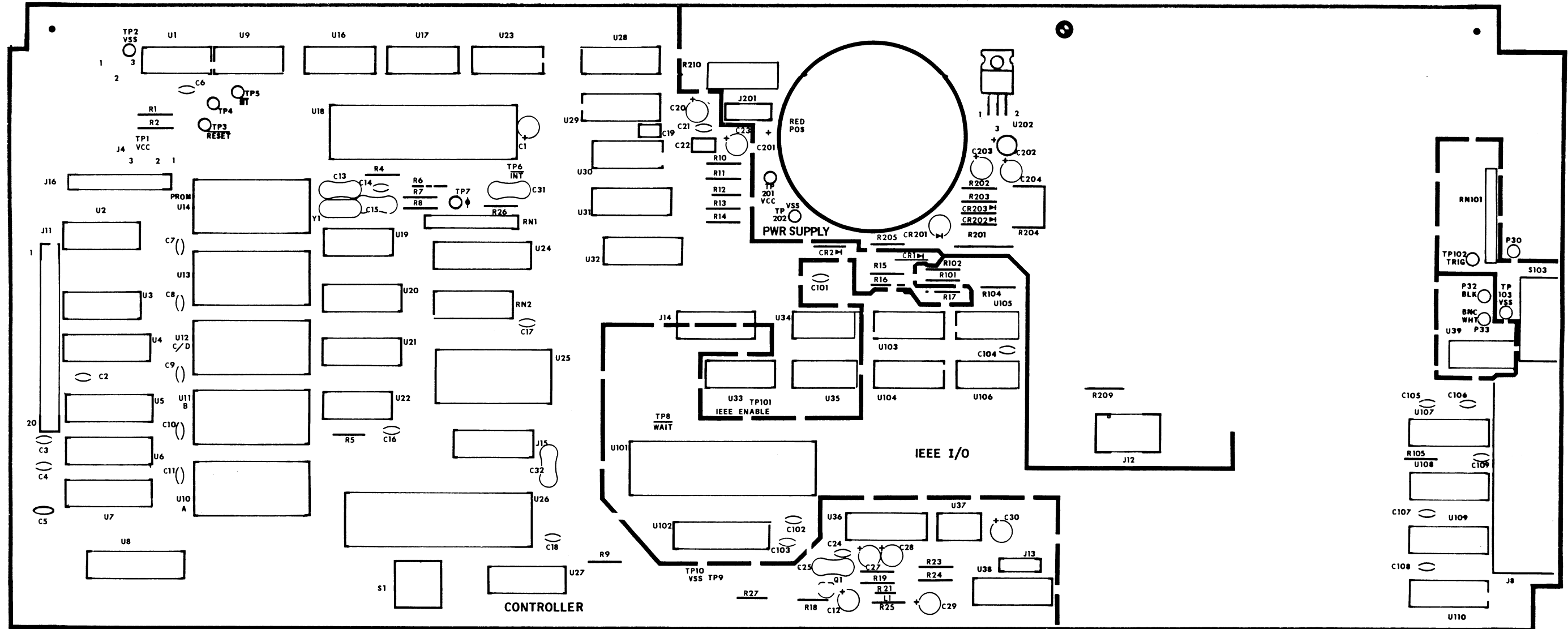
EXT GUARD - K34 ENERGIZED (OPEN)

POWER CONNECTIONS				
PART	VCC	RELAY PWR	GRD	
U1	14	-	7	
U2	14	-	7	
U3	14	-	7	
U4	20	-	10	
U5	16	-	8	
U6	16	-	8	
U7	-	9	8	
U8	20	-	10	
U9	16	-	8	
U10	20	-	10	
U11	-	9	8	
U12	-	9	8	
U13	20	-	10	
U14	16	-	8	
U15	20	-	10	
U16	16	-	8	
U17	-	9	8	
U18	-	9	8	



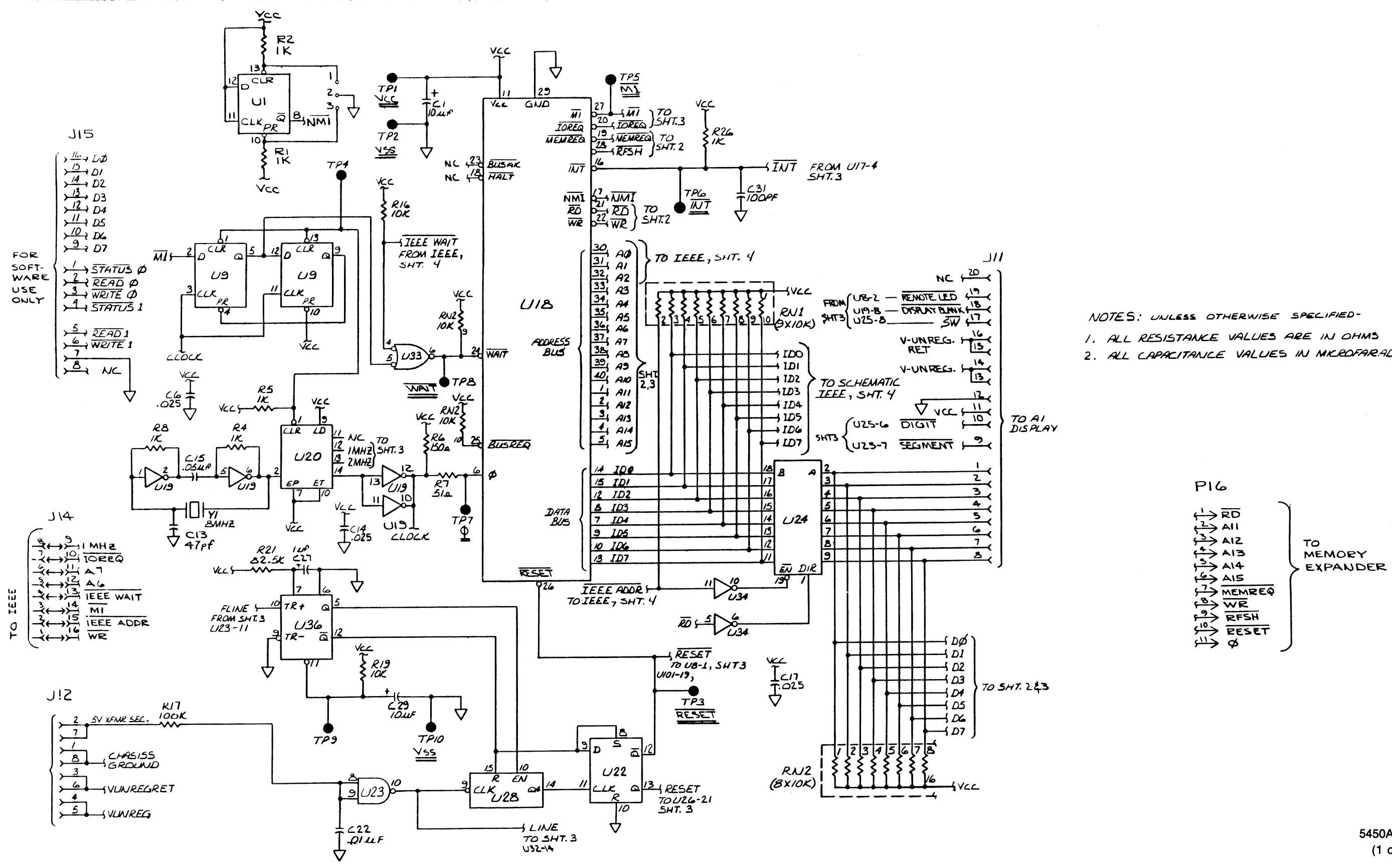
SEE 5450A-1005 FOR T1.

Figure 9-1. A1 Analog PCA (cont)



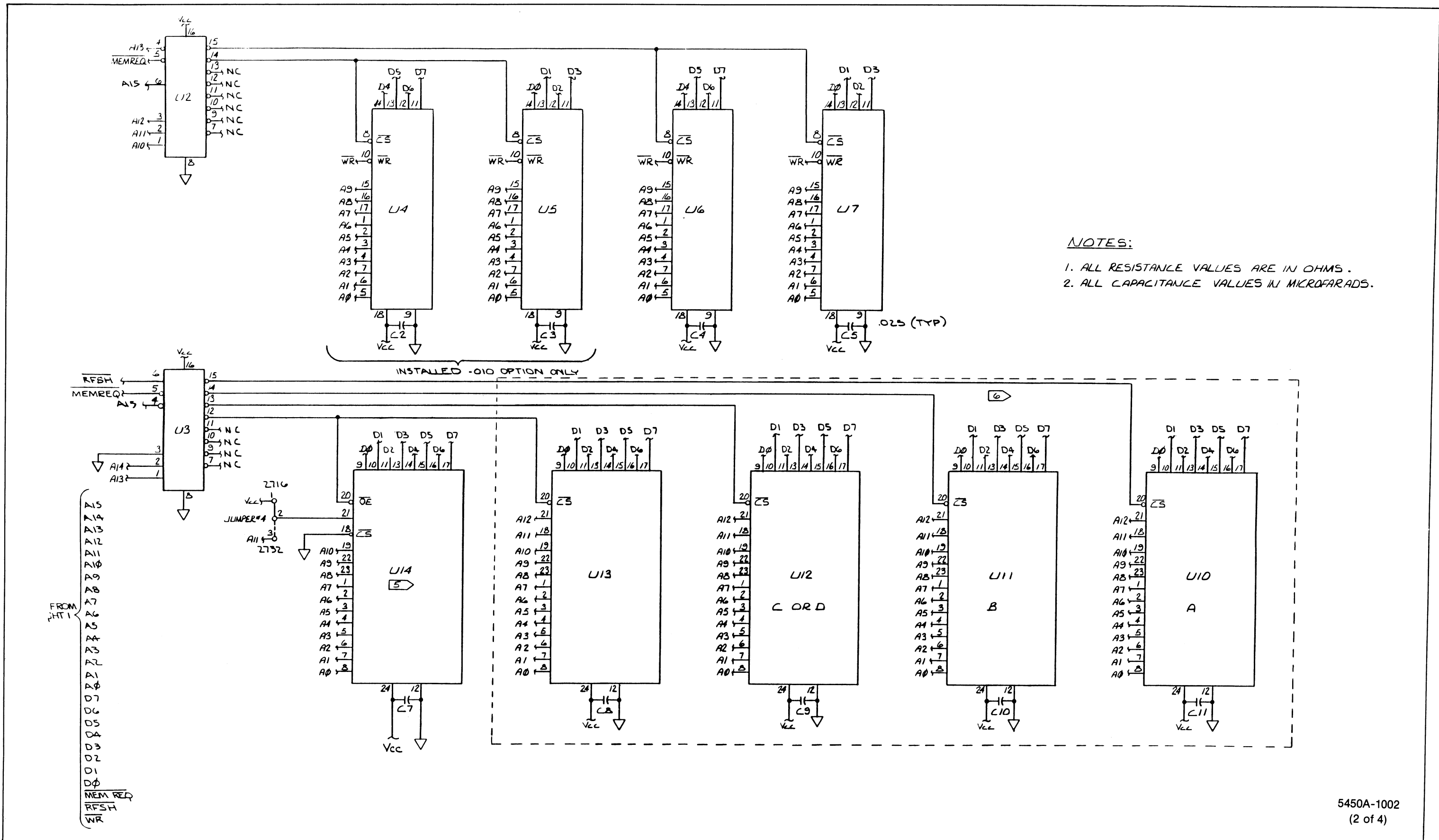
5450A-1602

Figure 9-2. A2 Digital PCA



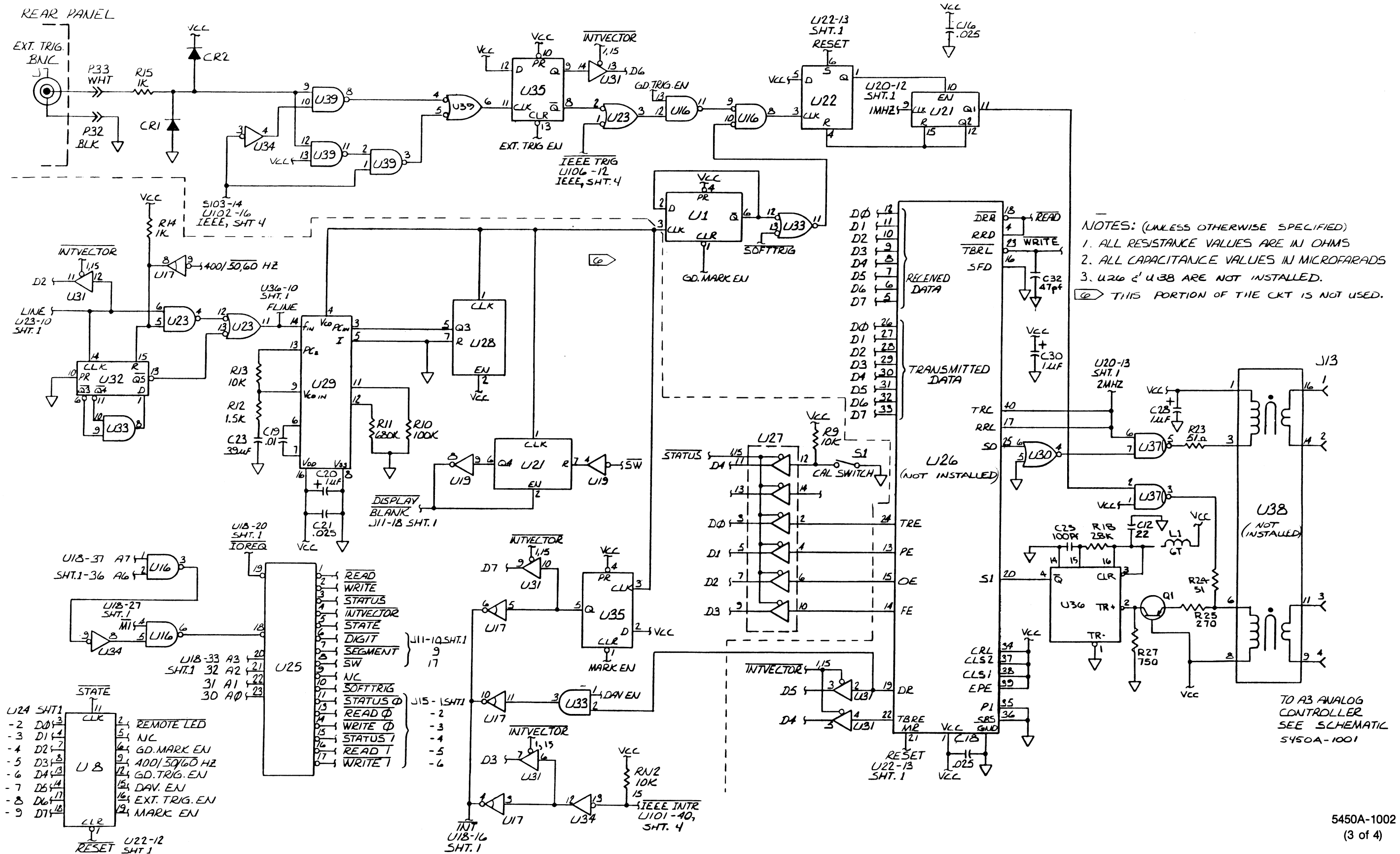
NOTES: UNLESS OTHERWISE SPECIFIED-  
 1. ALL RESISTANCE VALUES ARE IN OHMS  
 2. ALL CAPACITANCE VALUES IN MICROFARADS

Figure 9-2. A2 Digital PCA (cont)



**NOTES:**  
 1. ALL RESISTANCE VALUES ARE IN OHMS.  
 2. ALL CAPACITANCE VALUES IN MICROFARADS.

Figure 9-2. A2 Digital PCA (cont)



NOTES: (UNLESS OTHERWISE SPECIFIED)  
 1. ALL RESISTANCE VALUES ARE IN OHMS  
 2. ALL CAPACITANCE VALUES IN MICROFARADS  
 3. U26 & U38 ARE NOT INSTALLED.  
 THIS PORTION OF THE CRT IS NOT USED.

U24 SHT.1	
-2	D0
-3	D1
-4	D2
-5	D3
-6	D4
-7	D5
-8	D6
-9	D7
CLR	
U22-12 RESET SHT.1	

U25	
1	READ
2	WRITE
3	STATUS
4	INTVECTOR
5	STATE
6	DIGIT
7	SEGMENT
8	SW
9	NC
10	SOFTTRIG
11	STATUS 0
12	READ 0
13	WRITE 0
14	STATUS 1
15	READ 1
16	WRITE 1
17	WRITE 1

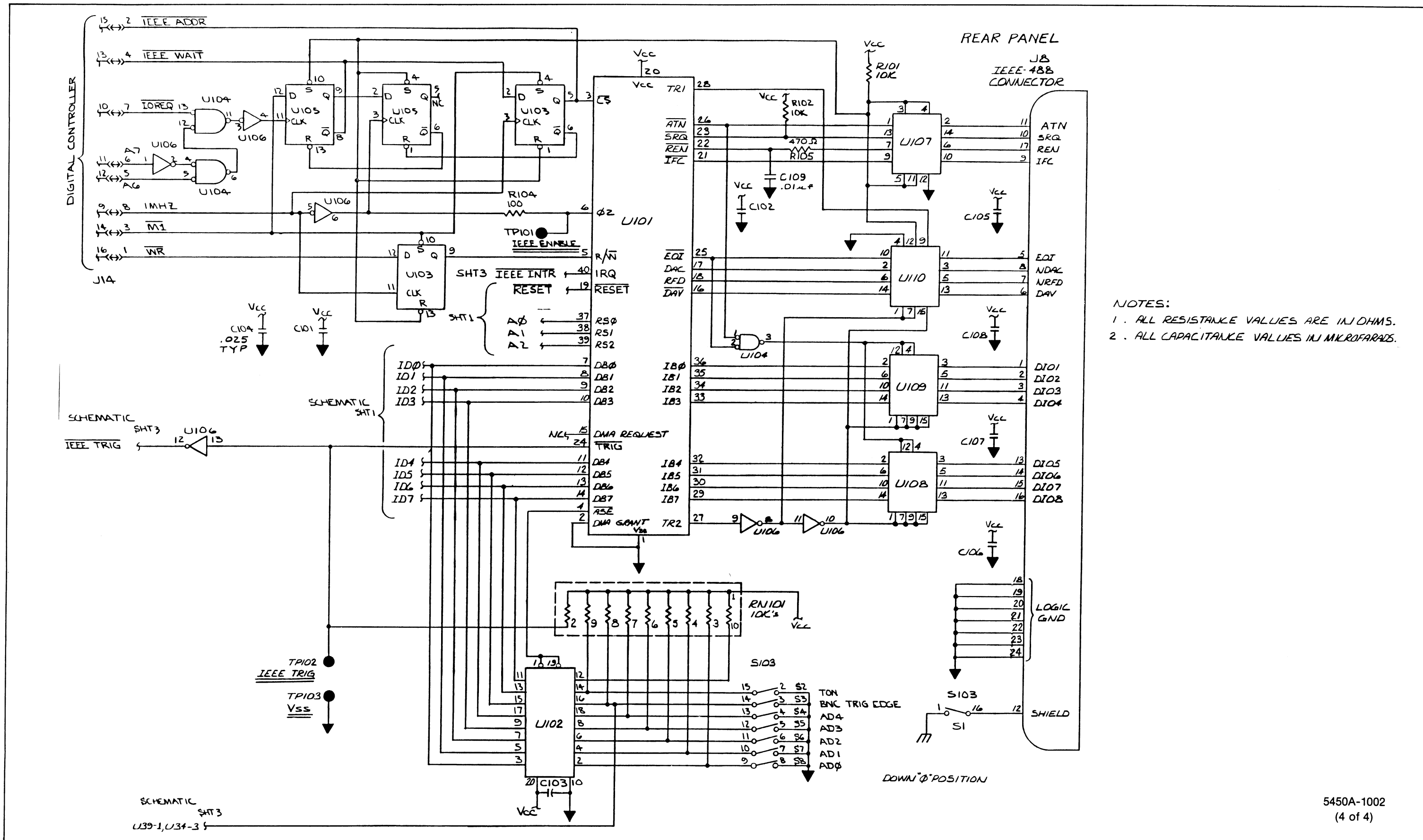
  

U8	
1	STATE
2	REMOTE LED
3	NC
4	GD.MARK EN
5	400/50/60 HZ
6	GD.TRIG. EN
7	DAV. EN
8	EXT. TRIG. EN
9	MARK EN
10	CLR

TO A3 ANALOG CONTROLLER SEE SCHEMATIC 5450A-1001

Figure 9-2. A2 Digital PCA (cont)





NOTES:  
 1. ALL RESISTANCE VALUES ARE IN OHMS.  
 2. ALL CAPACITANCE VALUES IN MICROFARADS.

5450A-1002  
 (4 of 4)

Figure 9-2. A2 Digital PCA (cont)

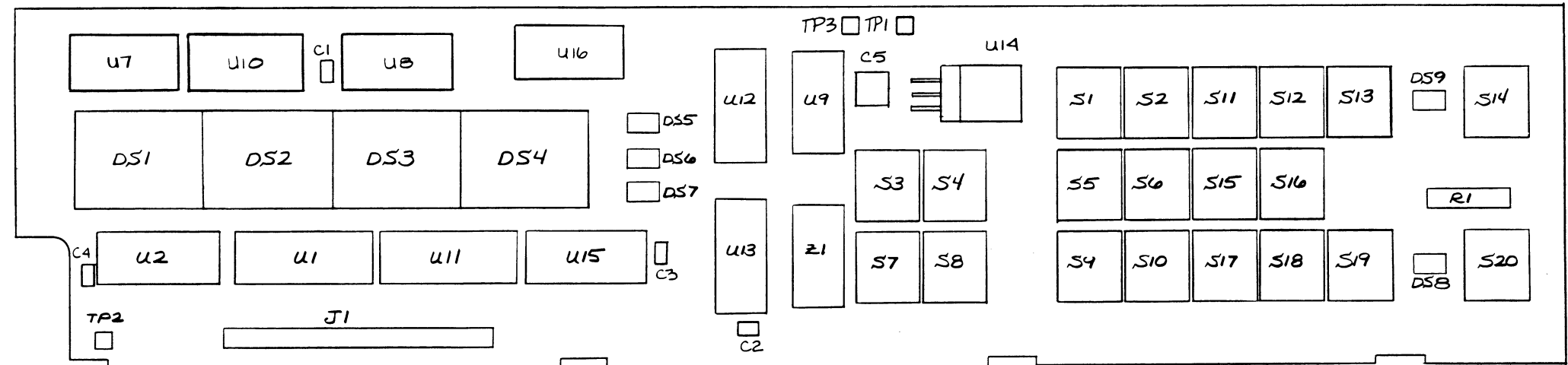
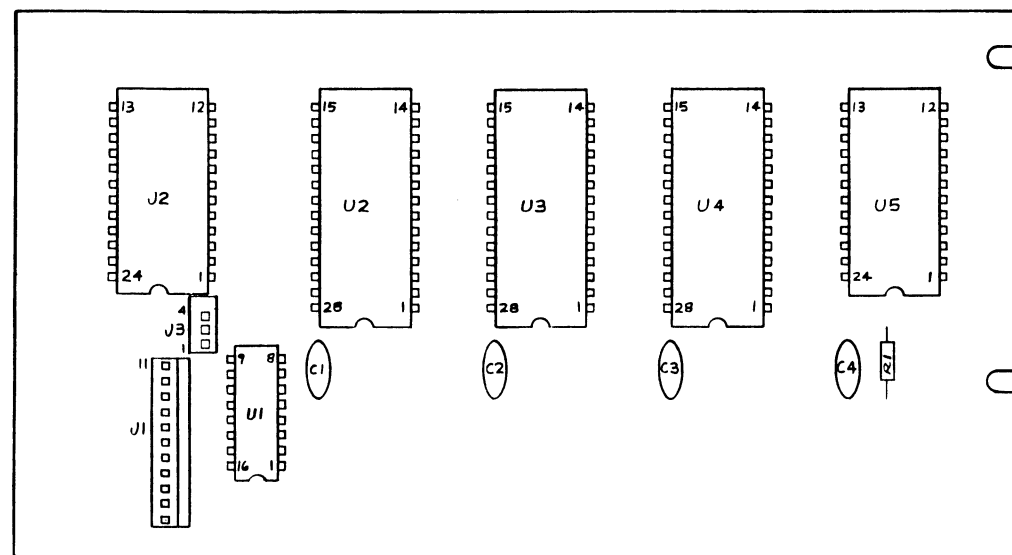


Figure 9-3. A3 Display PCA

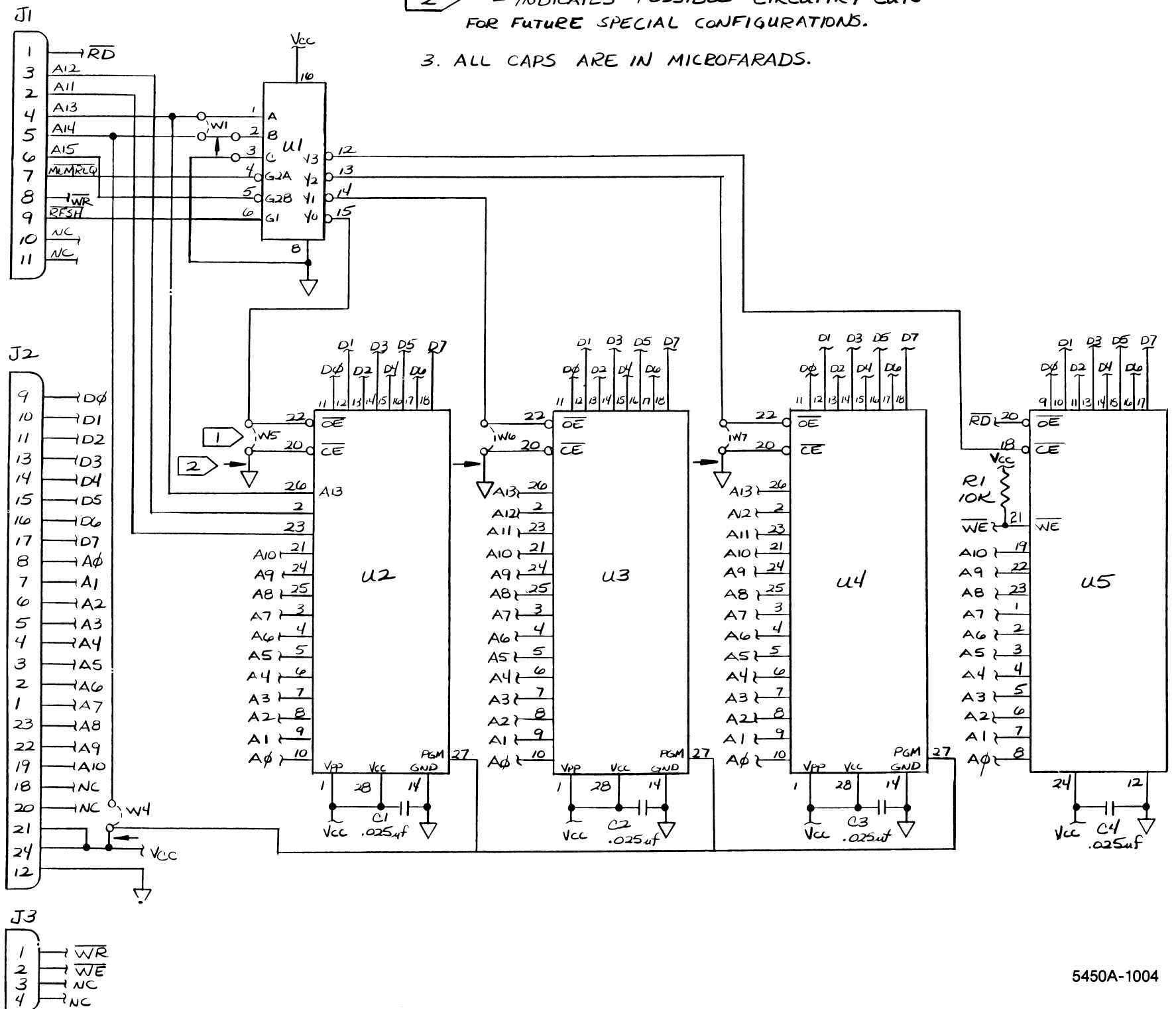


NOTES:

- 1 W - NUMBERS INDICATE JUMPERS NEEDED FOR SPECIAL PCB CONFIGURATION.
- 2 → INDICATES POSSIBLE CIRCUITRY CUTS FOR FUTURE SPECIAL CONFIGURATIONS.
- 3. ALL CAPS ARE IN MICROFARADS.

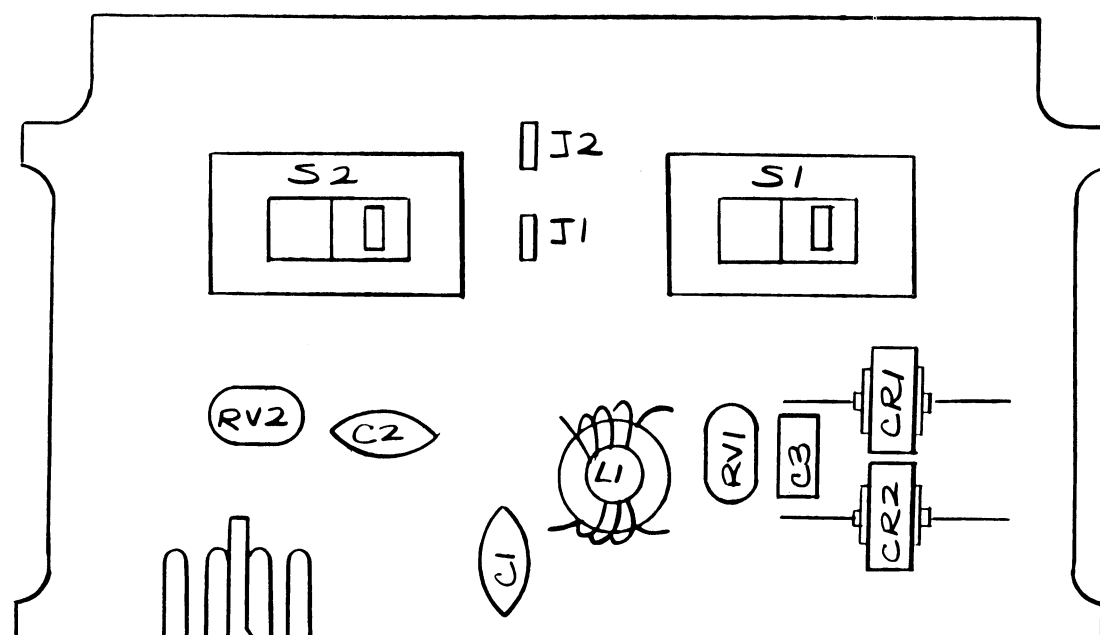


5450A-1604

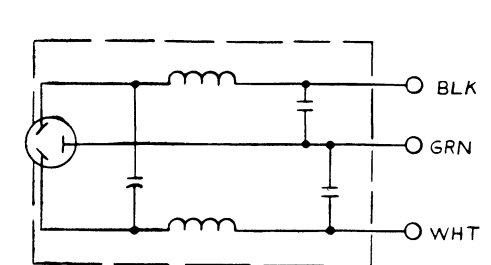


5450A-1004

Figure 9-4. A4 Memory PCA

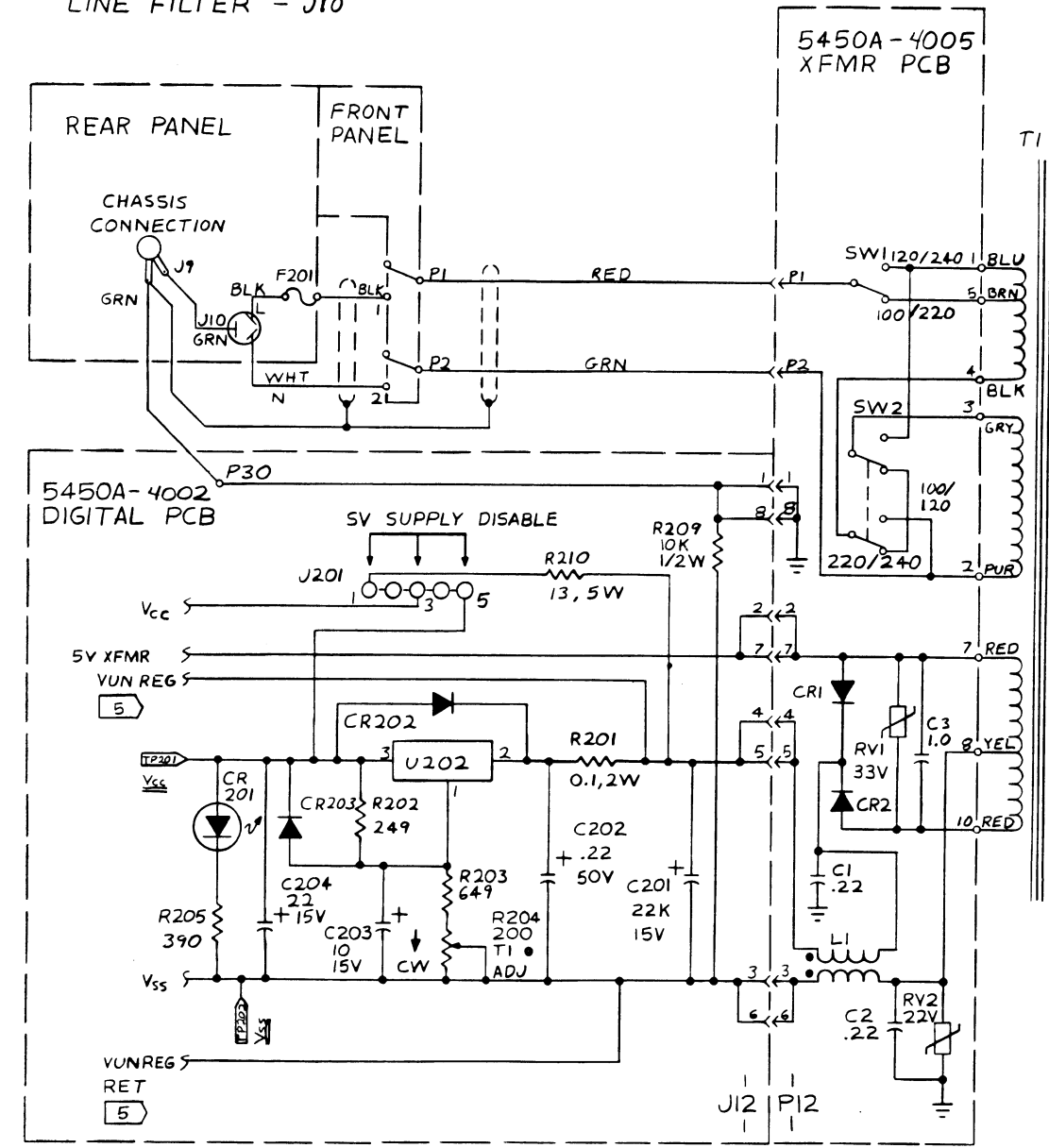


5450A-1605



LINE FILTER - J10

- NOTES: UNLESS OTHERWISE SPECIFIED
1. ALL RESISTANCE VALUES IN  $\Omega$ .
  2. ALL CAPACITANCE VALUES IN  $\mu F$ .
- 5 ONLY TO FRONT PANEL.



5450A-1005

Figure 9-5. A5 Power Supply PCA