8860A

Digital Multimeter

Service Manual

P/N 541250
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The JOHN FLUKE MFG. CO., INC., warrants each instrument it manufactures to be free from defects in material and workmanship under normal use and service for the period of 1-year from date of purchase. This warranty extends only to the original purchaser. This warranty shall not apply to fuses, disposable batteries (rechargeable type batteries are warranted for 90-days), or any product or parts which have been subject to misuse, neglect, accident, or abnormal conditions of operations.

In the event of failure of a product covered by this warranty, John Fluke Mfg. Co., Inc., will repair and calibrate an instrument returned to an authorized Service Facility within 1 year of the original purchase; provided the warrantor's examination discloses to its satisfaction that the product was defective. The warrantor may, at its option, replace the product in lieu of repair. With regard to any instrument returned within 1 year of the original purchase, said repairs or replacement will be made without charge. If the failure has been caused by misuse, neglect, accident, or abnormal conditions of operations, repairs will be billed at a nominal cost. In such case, an estimate will be submitted before work is started, if requested.

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The JOHN FLUKE MFG. CO., INC, will be happy to answer all applications or use questions, which will enhance your use of this instrument. Please address your requests or correspondence to: JOHN FLUKE MFG. CO., INC., P.O. BOX C9090, EVERETT, WASHINGTON 98206, ATTN: Sales Dept. For European Customers: Fluke (Holland) B.V., P.O. Box 5053, 5004 EB, Tilburg, The Netherlands.

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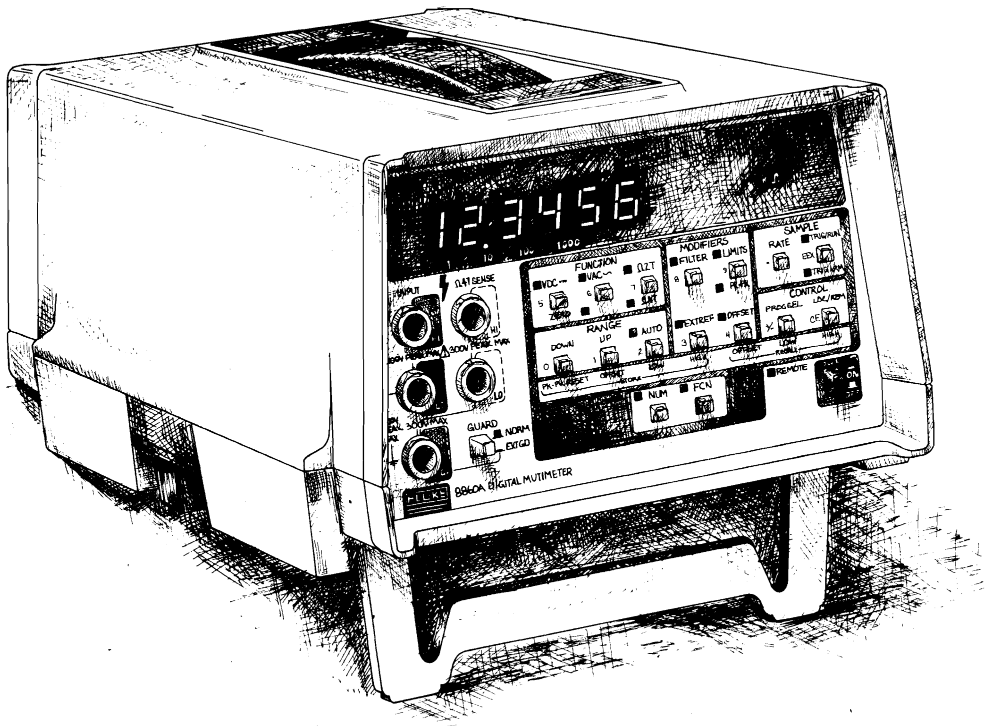
List of Illustrations



8860A Digital Multimeter

Section 1
Introduction and Specifications

WARNING

THESE SERVICING INSTRUCTIONS ARE FOR USE BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING UNLESS YOU ARE QUALIFIED TO DO SO.

1-1. THE 8860A INSTRUCTION MANUAL SET

1-2. The John Fluke Model 8860A Digital Multimeter and its options are documented by a series of seven manuals. These manuals can be separated for use in different locations or joined together in a single three-ring binder.

OPERATOR MANUAL	Describes how to operate and maintain the basic 8860A; briefly describes the options and accessories; includes the installation procedures for all options.
CALIBRATION MANUAL	Contains specifications, maintenance information, performance tests, and procedures for access, calibration, and adjustment.
SERVICE MANUAL	This manual contains the theory of operation, troubleshooting, replaceable parts, and schematics for the basic 8860A and all of its options.
CALCULATING CONTROLLER USER HANDBOOK	Describes how to operate and program the Calculating Controller Option (-004). Includes applications in the appendix.
CALCULATING CONTROLLER REFERENCE GUIDE	Handy pocket-sized guide containing operating information for the Calculating Controller option. Condensed from the above User Handbook.
IEEE-488 INTERFACE OPTION USER HANDBOOK	Describes how to operate the 8860A with the IEEE-488 option (-005) installed. Includes controller examples.
IEEE-488 INTERFACE OPTION REFERENCE GUIDE	Handy pocket-sized guide containing operating information for the IEEE-488 Interface Option. Condensed from the IEEE-488 Interface Option User Handbook.

1-3. THE 8860A DIGITAL MULTIMETER

1-4. The 8860A is a 5½ digit, microprocessor-controlled digital multimeter, capable of making measurements in VDC, true rms VAC (AC or DC-coupled), two-terminal ohms, and four-terminal ohms. The range extends from a resolution of 1 uV and 1 mΩ to 700 VAC, 1000 VDC, and 20 MΩ. The instrument also has a GUARD terminal for making guarded measurements.

1-5. OPTIONS

1-6. Several options are available for use with the 8860A, as listed in Table 1-1. A theory of operation, troubleshooting information, and a list of replaceable parts are given for each option in Section 6 of this manual.

1-7. LIST OF RECOMMENDED TEST EQUIPMENT

1-8. Table 1-2 lists the test equipment required to perform the procedures described in this manual. Substitute equivalent instruments if the recommended models are not available.

1-9. SPECIFICATIONS

1-10. Table 1-3 lists the 8860A specifications.

Table 1-1. 8860A Options

OPTION NO.	NAME	DESCRIPTION
-004	Calculating Controller	Programmable scientific calculator interfaced to control the 8860A
-005	IEEE-488 Interface	Interfaces the 8860A as a talker and listener to the IEEE-488 bus
-006	Rear Input	Allows connection of all analog signals from the rear panel through a single connector
-007	External Reference	Enables connection of an external reference for making ratio measurements

Table 1-2. Recommended Test Equipment

INSTRUMENT TYPE	MINIMUM SPECIFICATIONS	RECOMMENDED MODEL
AC Calibrator	Voltage Range: 0-1000V ac Freq. Range: 20 Hz-300 kHz Voltage Accuracy: 0-100V ac: 20 Hz- 50 Hz .1% 50 Hz- 10 kHz .03% 10 kHz-100 kHz .03% 100 kHz-300 kHz .4% 100-1000V ac: 20 Hz- 50 Hz .15% 50 Hz- 10 kHz .05% 10 kHz-100 kHz .1%	Fluke 5200A, 5205A
DC Calibrator	Voltage Range: 0-1000V dc Accuracy: .003%	Fluke 332B
Oscilloscope	General purpose with 10M probe	Tektronix T932A
Digital Voltmeter	Voltage Accuracy: .01% (V dc) 1.0% (V ac) for 1 volt input at 100 kHz Input Impedance: 10 Megohm or greater in V dc 1 Megohm in parallel with <100 pF in V ac	Fluke 8800A

Table 1-3. 8860A Specifications

DC VOLTS

Ranges .... ±200 mV, 2V, 20V, 200V, 1000V

Ranging .... Fully automatic or manual

Polarity of Input .... Automatic polarity selection and display

Resolution (Max.) .... 0.0005% of full scale (1 μV on 200 mV range) with 5-1/2 digit display.

Accuracy .... Using front panel zero, ±(% input + no. of digits)

5-1/2 DIGIT DISPLAY*

RANGE	24 HR 23°C ±1°C	90 DAY 18°C - 28°C	1 YR 18°C - 28°C	NORMAL MODE REJECTION	
				NO FILTER	FILTER
200 mV	(0.004 + 3)	(0.008 + 3)	(0.01 + 3)	>60 dB 50, 60 Hz	>100 dB 50, 60 Hz
2V-200V	(0.004 + 2)				
1000V					

4-1/2 DIGIT DISPLAY*

RANGE	90 DAY 18°C - 28°C	1 YR 18°C - 28°C	NORMAL MODE REJECTION	
			NO FILTER	FILTER
All	(0.01 + 2)	(0.015 + 3)	>60 dB 50, 60 Hz	>100 dB 50, 60 Hz

*Settling Time: 30 ms to within .01% of input step size, with filter 300 ms.

3-1/2 DIGIT DISPLAY (Available with -004 or -005 options only)

RANGE	1 YR 18°C - 28°C	NORMAL MODE REJECTION	
		NO FILTER	FILTER
All	(0.1 + 1)	None	>40 dB 50, 60 Hz

Settling Time: 5 ms to within .1% of input step size, with filter 250 ms.

Common Mode Rejection

CONDITIONS .... Line frequency switch properly set.
Line frequency at 50 or 60 Hz ±0.1%.
One kilohm in either lead.

4-1/2 AND 5-1/2 DIGIT RATE
Normal Guard .... >130 dB
External Guard (Driven) ...... >150 dB

3-1/2 DIGIT RATE
Normal Guard .... >70 dB
External Guard (Driven) ...... >90 dB

DC, ALL READING RATES ..... >160 dB

Input Resistance

200 mV, 2V RANGES .... >10,000 MΩ
20V, 200V, 1000V RANGES ..... 10 MΩ

Table 1-3. 8860A Specifications (cont)

Input Bias Current (@ 23°C) .... <100 pA

Zero Stability
(after 1 hour warmup) .... ±10 μV for 90 days

Maximum Input .... ±1000V Pk input HI to LO
±500V Pk input LO to Earth
±30V Pk input LO to Guard

AC VOLTS (True RMS, AC only or AC + DC)

Ranges .... 200 mV, 2V, 20V, 200V, 700V

Ranging .... Fully automatic or manual

Resolution (Max) .... 0.0005% F.S. (1 μV on 200 mV range) with 5-1/2 digit display.

Accuracy .... ± (% INPUT + DIGITS), 2V - 700V ranges:
0.5% F.S. to F.S. AC only*;
200 mV range: 1% F.S. to F.S. AC*

FREQUENCY	RANGE(S)	90 DAY 18°C-28°C			1 YR 18°C-28°C		
		% INPUT	DIGITS		% INPUT	DIGITS	
			5-1/2	4-1/2		5-1/2	4-1/2
20 Hz-50 Hz	All	0.25	70 **	10 ***	0.25	100 **	13 ***
50 Hz-10 kHz	All	0.15	70 **	10 ***	0.15	100 **	13 ***
10 kHz-50 kHz	2V-700V	0.4	150	18	0.4	300	33
	200 mV	0.7	150	18	0.7	300	33
50 kHz-100 kHz	2V-700V				1.0	350	38
	200 mV				2.5	350	38
100 kHz-300 kHz	All				8.0	700	73

*For AC + DC operation, add 0.1% of input +50 digits for 5-1/2 digit resolution.
For AC + DC operation, add 0.1% of input + 5 digits for 4-1/2 digit resolution.
**150 digits for 200 mV range
***15 digits for 200 mV range

Bandwidth (typical) .... ≤ 3 dB @ 1 MHz

Crest Factor .... 3 at full range, increasing down range

Input Impedance .... 10 MΩ, ≤ 70 pF

Maximum Input .... 700V rms, 1000V Pk, or 2 x 10^7 volt/Hz, whichever is less.

OHMS (2-terminal or 4-terminal)

Ranges .... 200Ω, 2 kΩ, 20 kΩ, 200 kΩ, 2 MΩ, 20 MΩ

Ranging .... Fully Automatic or Manual

Resolution (Max) .... 0.0005% F.S. (1 mΩ on 200Ω range) with 5-1/2 digit display

Table 1-3. 8860A Specifications (cont)

Accuracy .... Using front panel zero, ±(% of input + no. of digits)

5-1/2 DIGIT DISPLAY

RANGE	24 HR 23°C ±1°C	90 DAY 18°C - 28°C	1 YR 18°C - 28°C
200 Ω	(0.008 + 4)	(0.012 + 4)	(0.015 + 4)
2k-200 kΩ	(0.006 + 2)	(0.01 + 2)	(0.013 + 2)
2M Ω	(0.01 + 3)	(0.014 + 3)	(0.017 + 3)
20M Ω	(0.07 + 3)	(0.09 + 3)	(0.10 + 3)

4-1/2 DIGIT DISPLAY

RANGE	90 DAY 18°C - 28°C	1 YR 18°C - 28°C
200 - 2 MΩ	(0.01 + 2)	(0.02 + 3)
20 MΩ	(0.1 + 2)	(0.14 + 3)

3-1/2 DIGIT DISPLAY

RANGE	1 YR 18°C - 28°C
200Ω - 2 MΩ	(0.1 + 1)
20 MΩ	(0.3 +1)

INPUT CHARACTERISTICS

RANGE	CURRENT THRU RX	OPEN CIRCUIT VOLTAGE
200 Ω	1 mA	6.0V MAX
2 kΩ	1 mA	
20 kΩ	100 μA	
200 kΩ	10 μA	
2 MΩ	1 μA	
20 MΩ	.1 μA	

Maximum Input .... 300V DC or Peak AC

Ohms Settling Times

RANGE	5-1/2 and 4-1/2 DIGIT (TO .01% OF STEP)		3-1/2 DIGIT (TO .1% OF STEP)	
	NO FILTER	FILTER	NO FILTER	FILTER
200 - 20 kΩ	100 ms	<300 ms	<15 ms	<300 ms
200 kΩ		<1.1s		<800 ms
2MΩ		<650 ms	<70 ms*	<500 ms
20MΩ	<1.5s*	<6.8s	<600 ms*	<4.5s

*For these ranges the filter is recommended. This will reduce the effects of noise pick- up common to all high impedance measurements.

Table 1-3. 8860A Specifications (cont)

GENERAL

DISPLAY	RESOLUTION (% FS)	MAX READING/SEC	LINE FREQ. (HZ)	A/D INTEGRATE TIME (MS)
5-1/2	0.0005	2.5	50, 60	100
4-1/2	0.005	15 12	60 50	16-2/3 20
3-1/2*	0.05	30	50, 60	2

*Accessible through IEEE-488 or Calculating Controller options only.

Temperature .... 0°C to +50°C operating; -40°C to +75°C non-operating.

Temperature Coefficient ...... ±0.1 x applicable accuracy specification per °C

Relative Humidity .... ≤80% to +35°C; ≤70% to +50°C

Shock & Vibration .... MIL-T - 28800B, class 4

Power .... 100, 120, 220, 240V AC ±10%, 250VAC MAX., 50 Hz or 60 Hz

Size .... 13.08 cm x 20.45 cm x 32.69 cm (HxWxL) (5.15 in x 8.05 in x 12.85 in) See Figure 1-1.

Weight .... 3.39 kg (7.48 lbs.)

Protection Class 1 .... Relates solely to insulating or grounding properties defined in IEC 348

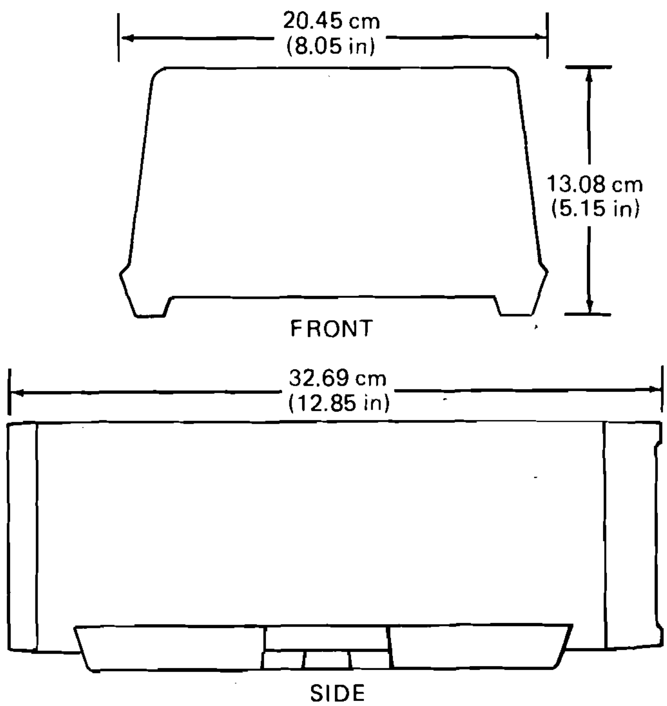


Figure 1-1. Outline Drawing

Section 2
Shipping and Service Information

2-1. SHIPPING INFORMATION

2-2. The 8860A is packaged and shipped in a cardboard container. When you receive the 8860A, inspect the instrument thoroughly for proper contents and possible shipping damage. Special instructions for inspection and claims are included on the shipping container itself.

NOTE

If an option is installed in the 8860A, the rear panel cover plate for that option is shipped with the instrument. If the option is ever removed, install the cover plate over the connector hole as a safety precaution.

2-3. If reshipment is necessary, use the original container. If the original container is not available, order a new one from John Fluke Mfg. Co., Inc.; specify model number 8860A.

2-4. SERVICE INFORMATION

2-5. Each 8860A Digital Multimeter is warranted to the original purchaser for a period of one year from date of delivery. The warranty is located at the front of this manual.

2-6. Factory authorized calibration and service for each Fluke product is available at various worldwide locations. A complete list of these service centers is given in Section 7. If requested, Fluke will provide the customer with an estimate before any work begins for an out-of-warranty instrument.

2-7. QUESTIONS/PROBLEMS

2-8. For additional shipping or service information, contact your nearest John Fluke Sales Representative or Technical Service Center, listed in Section 7.

Section 3
Theory of Operation

3-1. INTRODUCTION

3-2. This section of the manual contains the theory of operation for the 8860A. The theory is presented in two parts, an overall block diagram description followed by a detailed block diagram description. The theory of operation for the options is covered in Section 6 in this manual.

3-3. OVERALL BLOCK DIAGRAM DESCRIPTION

3-4. The overall block diagram description of the 8860A is keyed to the simplified block diagram shown in Figure 3-1. The description concentrates on the guard and measurement circuits.

3-5. Guard Circuit

3-6. The guard circuit establishes a physical and electrical separation between the analog measurement (in-guard) circuits of the 8860A and the control, display, and power supply (out-guard) circuits. The separation provides the shielding and isolating qualities required to enable accurate low-level measurements in the presence of common mode voltages. Since the guard forms a natural division of the 8860A circuitry, circuit functions and components are hereafter referred to as being in-guard or out-guard circuitry.

3-7. In-Guard and Out-Guard Processors

3-8. The 8860A uses two 8-bit microprocessors, one inside the guard (in-guard) and the other outside the guard (out-guard). The in-guard microprocessor implements function and range selection (including autoranging), controls the measurement cycle, and communicates with the out-guard microprocessor via optical couplers.

3-9. When the out-guard microprocessor receives the measurement data, it can modify or analyze the data if an offset, limits, or peak to peak function is selected. The resulting data is then sent to the display. In addition, the out-guard microprocessor monitors and responds to front-panel key selection (function, range, etc.), initiates each A/D conversion cycle, and controls the operation of either of two digital options.

3-10. Voltage Measurements

3-11. When the VDC, VAC, or VAC+VDC function is selected, the unknown voltage applied to the HI and LO INPUT terminals is directed through the input protection circuit to the AC/DC scaling and filtering circuit. AC measurements are either capacitively coupled (VAC) or directly coupled (VAC+VDC) into the scaling amplifier. Here the input voltage is either amplified by 10 (200 mV range), passed unscaled (2V range), or divided by 100 or 1000 (20V, 200V, 1000V ranges). A full-range input on any range is scaled to ± 2V dc or 2V rms (see Table 3-1). Measurements which are strictly dc (VDC, Ω2T, and Ω4T functions) continue directly from the scaling amplifier to the A/D Converter. All ac measurements (VAC and VAC+VDC functions) pass through the RMS-to-DC Converter where they are converted to a dc voltage.

3-12. Resistance Measurements

3-13. When the Ω2T or Ω4T function is selected, two operations occur concurrently at the input terminals:

1. A precision current is applied to the unknown resistor via the HI and LOW INPUT terminals. This current is generated by the Ohms Converter (also known as the Ohms Source). The value of source current for each range (except the 200 ohm range) is established at a level that will generate a two volt full-scale voltage for the 200 ohm range is 200 mV.

2. The voltage generated across the unknown resistor is sensed at the HI and LO INPUT terminals (for Ω2T), or at the Ω4T SENSE HI and LO terminals (for Ω4T). This voltage passes unscaled into the A/D Converter (except on the 200Ω range where it is first amplified by a factor of 10).

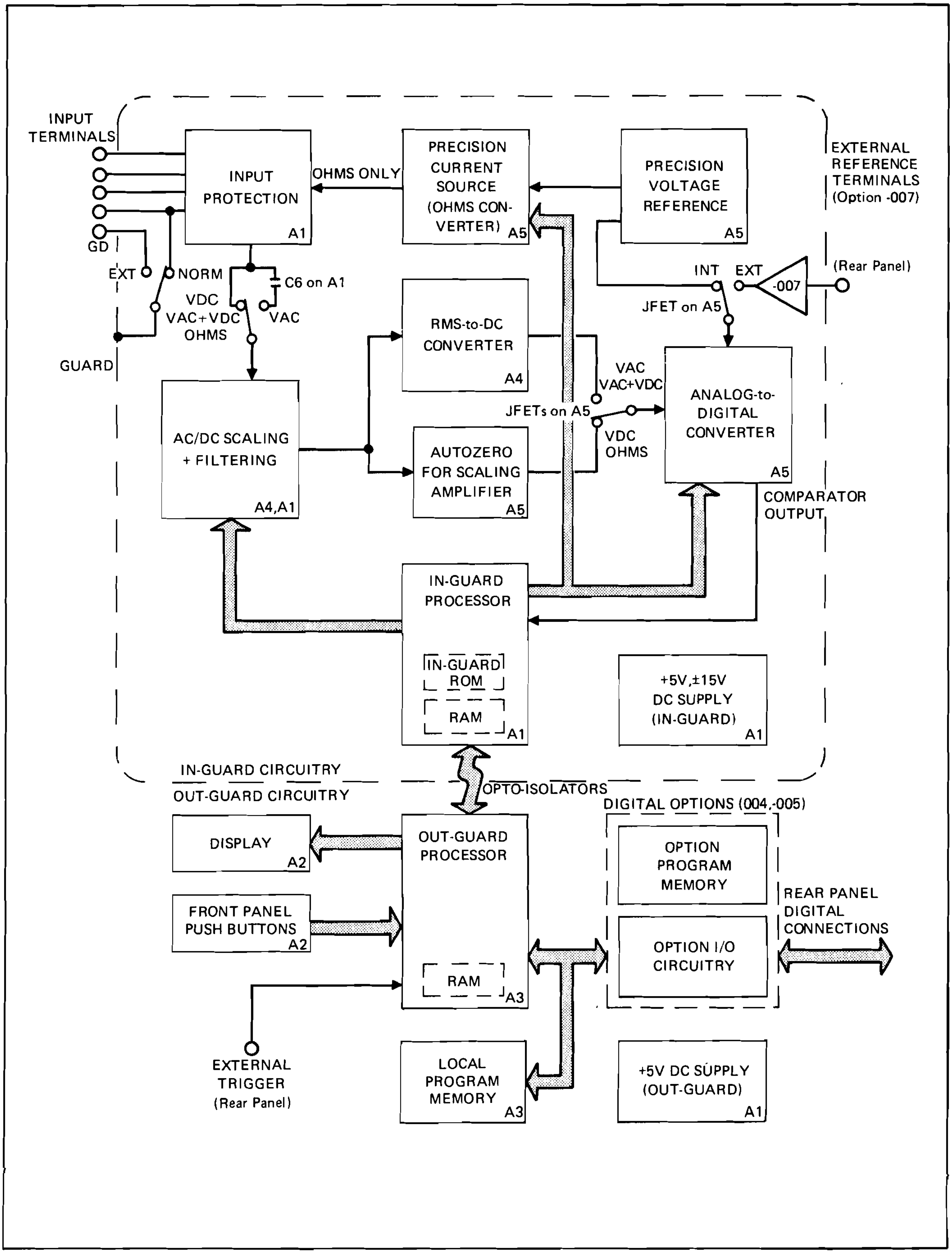


Figure 3-1. 8860A Block Diagram

Table 3-1. Scaling of Input Signals

FUNCTION	RANGE (FULL-SCALE INPUT)	OHMS CONVERTER SOURCE CURRENT (OHMS ONLY	AC/DC SSCALING		FULL-SCALE OUTPUT OF AC/DC SCALING
			INPUT DIVIDER	SCALING AMPLIFIER	
Volts	200 mV	—	÷1	×10	±2V dc
VDC, VAC,	2V	—	÷1	×1	(VDC)
VAC + VDC	20V	—	÷100	×10	or
	200V	—	÷100	×1	2V rms
	1000VDC 700 VAC	—	÷1000	×1	(VAC, VAC + VDC)
Ohms	200 Ω	1 mA	NOT CONNECTED	×10	+2V dc
Ω2T, Ω4T	2 KΩ	1 mA		×1	
	20 KΩ	100 μA		×1	
	200 KΩ	10 μA		×1	
	2 MΩ	1 μA		×1	
	20 MΩ	.1 μA		×1	

3-14. A/D Converter

3-15. The input to the A/D Converter is a scaled dc voltage (2V max) proportional to the 8860A input voltage or resistance. In conjunction with the in-guard microprocessor, the A/D Converter uses a dual-slope integration technique to convert the analog value to a digital representation.

3-16. DETAILED BLOCK DIAGRAM DESCRIPTION

3-17. The following paragraphs describe each of the blocks appearing in the 8860A block diagram, Figure 3-1. The description covers the power supply first, then traces the measurement signal path starting at the input terminals and ending at the display.

3-18. Drawing numbers for the applicable schematic diagrams are shown in parentheses following the description headings. The schematics are located in Section 8 of this manual.

3-19. Circuit descriptions often refer to IC and connector pin-numbers. ICs mentioned in the text are identified by U-numbers, e.g., U6. An IC pin number is identified by a dash and a number following the U-number. For example, U6-1 identifies pin 1 of IC U6. Pin 1 of each integrated circuit is identified on the pcb by a square solder pad. To identify a signal path through a series of connectors, refer to the Interconnect Diagram located in the schematic section. When two boards are connected, the pin numbers on both boards match, although the connector identification numbers (the J and P numbers) may not match. For example, pin J3-42 (Main board) mates to P1-42 (Controller board).

3-20. Power Supply (Schematic 8860-1001)

3-21. The operating voltages for the 8860 are generated on the A1 Main PCB. Operating voltages for the in-guard circuitry include +5, +15, and -15 volts. A separate +5 volt supply provides the operating voltage for the out-guard circuitry. Elsewhere, +9, -9 and -4 volt supplies are derived from the main operating voltages. Table 4-2 lists the circuitry powered by each supply.

3-22. As a troubleshooting aid, the ± 15 volt supplies for the RMS-to-DC Converter and the Ohms Converter can be disconnected by removing jumper wires on the appropriate plug-in board. Refer to Troubleshooting in Section 4 for detailed procedures.

3-23. FUSING

3-24. The replaceable fuse located on the rear panel protects against excessive current in the power supply due to a short circuit. An additional non-replaceable thermal fuse, located inside the transformer, protects the 8860A against fire hazard.

3-25. +5 VOLT SUPPLIES

3-26. Functionally, the +5 volt supplies for the in-guard and the out-guard circuitry are nearly identical. Each has a full-wave rectifier (CR10-13), a filter (C1, C2, C7), and a 5-volt regulator (VR1, VR3).

3-27. +/-15 VOLT SUPPLIES

3-28. The +15 volt supply is regulated by a 15-volt regulator (VR2). The -15 volt supply uses the output of the +15 volt supply as a reference. That is, as the output of the +15 volt supply becomes more positive, the -15 volt output becomes more negative. The tracking is accomplished by a precision inverter (U1, Ω6, R12, and R13) in which the voltage across R13 is equal to the voltage across R12. Power transistor Q6 is not short-circuit protected. Therefore, care must be taken to avoid shorting the -15 volt output to ground.

3-29. Notice the -15 volt supply requires that the +5 volt in-guard supply be working, since U1 is supplied by the +5 volt supply. The +15 volt supply is unaffected by the +5 volt supply.

3-30. CIRCUIT COMMON AND THE GUARD

3-31. The 8860A is capable of making fully floating measurements since its LO INPUT terminal is not internally connected to earth ground. To isolate the sensitive analog circuitry from the digital circuits, a guard is used. The circuitry outside the guard must interact with the outside world via the IEEE-488 option and external trigger BNC jack. Therefore, its common must sit at or close to earth ground. Thus, there are two electrically separate circuit commons: the in-guard common (also referred to as analog common), and the out-guard common (referred to as digital common). The out-guard common is connected through a 10 MΩ resistor to the center pin of the ac line cord, and thereby grounded to earth. The in-guard common is connected to the LO INPUT terminal; it is left floating, and can rise up to ± 500 volts peak above the out-guard common (earth).

3-32. The guard is a separate metal shield which encloses the analog circuitry and in-guard microprocessor. By use of the GUARD switch, the guard may be connected to the in-guard common, or to an external common via the front panel GD terminal. Use of the guard switch and terminal is described in the 8860A Operator Manual.

3-33. Input Protection (Schematic 8860A-1001)

3-34. The input protection circuit, located on the A1 Main PCB Assembly, protects the 8860A against sustained input voltages within its maximum input rating. The circuit also provides protection against voltage transients beyond this range. Sustained voltages beyond the rated range may damage the instrument.

3-35. The input protection description which follows is sectioned according to the various input paths:

1. DC and AC Voltage Sense
2. Ohms Source
3. Ω4T Sense
4. Guard

3-36. The relays located on the A1 Main PCB Assembly are not part of the input protection circuitry. Instead, they route the input signal according to the selected range and function. Additional relay details are provided later in this section under Scaling and Filtering.

3-37. PROTECTION FOR DC AND AC VOLTAGE SENSE

3-38. For dc or ac input signals the sense path is from the INPUT HI terminal through R7 (2 kΩ, 7W resistor). At the junction of R7 and R10, four metal oxide varistors (MOV) RV1 through RV4 are connected to analog LO. These bipolar MOVs limit high voltage transients to ±2 kV at point E3. If the MOVs overheat and fail, they short circuit and thereby continue to provide protection for the scaling circuitry.

3-39. Coils L1 and L2 suppress arcing when the contacts of K1 are switching high voltages. The individual switches on K1, K2, and K4 are wired in series to obtain the 1000V isolation required for input switching. Resistors R10 and R11 protect the contacts of relay K3 from current surges when capacitor C6 discharges through K3.

3-40. OHMS SOURCE PROTECTION

3-41. The protection path for the ohms source is through R6. Varistors RV5 through RV8 limit high voltage transients to ± 2 kV, as described previously. The thermistor RT1 (nominally 1 kΩ) protects against high sustained voltages up to 300V peak. As the temperature of RT1 rises, its resistance increases and effectively isolates the ohms source circuitry from the HI INPUT terminal. The clamp circuit (Q8, Q9, Q10, CR6, R14, and R15) serves two purposes: first, it clamps the open-circuit voltage of the current source (point E8) to about 5V; second it protects the Ohms Converter from voltage spikes at the input by limiting positive spikes to +5V (via Q8 and Q10) and negative spikes to -2V (via CR6 and Q9). Capacitor C16 helps to shunt transient voltages to ground.

3-42. FOUR-TERMINAL OHMS SENSE PROTECTION

3-43. Resistors R8 and R9 provide protection for the 4-terminal ohms sense circuitry. To prevent ac cross talk, FET Q13 grounds the Ω4T input line when VAC or VAC+VDC is selected. Transistor Q7 keeps the Ω4T SENSE LO line within -.7V to +9V of the in-guard common. This clamping of the sense inputs protects JFET A1-E on the AC/DC Scaling circuit.

3-44. GUARD PROTECTION

3-45. Components R25, C17, and R29 prevent the guard from making fast voltage transitions. As a result, voltage spikes at the GD terminal do not reach the guard itself.

3-46. Scaling and Filtering (Schematic 8860A-1004, Sheet 1 of 2)

3-47. The ranging and filtering for the selected function takes place on the AC/DC Scaling PCB (A4). When a range is selected, either manually or automatically, the AC/DC scaling circuitry conditions the input signal to produce a ± 2V dc or 2V rms signal for a full-range input.

3-48. AC/DC SCALING

3-49. The amount of scaling for each range and function is given in Tables 3-1. Figure 3-2 shows how the scaling takes place. Either JFET switch A1-A, A1-B, or Q13 is ON to divide by 1, 100, or 1000. FETs Q12 and Q18 configure the scaling amplifier for a gain of either 1 or 10. For both voltage resistance measurements, a conditioned signal of 2 volts dc at the A/D Converter is recognized as a full scale-input for all ranges.

3-50. For all resistance measurements (except on the 200Ω range) the sense voltage generated across the unknown resistor is scaled to the 2V range by the current source (Ohms Converter). The 200Ω range has a full-scale sense voltage of 200 mV. Consequently, the AC/DC Scaling amplifier multiplies this voltage by 10 to establish the required 2V dc at full scale. The JFET state tables are located with the AC/DC Scaling schematic in Section 8.

3-51. The scaling amplifier (Q17 and U14) is the first amplifier an input signal encounters. In VDC, the differential JFET input stage Q17 provides an input resistance greater than 10,000 MΩ for the 200 mV and 2V ranges. The input divider presents a 10 MΩ input resistance for the higher voltage ranges. Capacitors C2 through C7, connected to the resistive divider, are adjusted to maintain a flat frequency response for the divider ranges.

3-52. The voltage clamp (Q2, Q3, Q7, Q8, VR1, VR2) limits the voltage applied to the scaling amplifier to ±10V peak on the two lowest voltage ranges (both ac and dc) and all ranges of ohms. The other voltage ranges do not require clamping since the largest voltage that can appear at the scaling amplifier is 10V (1000V divided by 100).

3-53. JFET BIAS AMPLIFIERS

3-54. The high-impedance, unity-gain, JFET amplifier, Q16 and U5, follows the input voltage to pull up the gate of each conducting JFET in the scaling circuit. Amplifier U6A performs the same bias function for JFET switches A1-G, Q12, and Q18.

3-55. FILTERING

3-56. A passive and an active filter are a part of the AC/DC Scaling network. Both are shown in simplified form in Figure 3-2.

3-57. If either the Calculating Controller Option (-004) or the IEEE-488 Interface Option (-005) is installed, a settling delay (Modifier A4) may be enabled. In this case, each measurement is initiated only after the filter voltages have settled. The amount of delay is controlled by the in-guard processor.

3-58. Passive Filtering

3-59. The passive filter consists of capacitor C9, JFET Q15, and the resistive component (approximately 100 kilohms) of the input divider. The VDC and the ohms functions allow the filter to be selected using the front panel filter switch. If the filter is not selected, its state is conditional as described in the state table (see schematic). Selecting either the VAC or the VAC+VDC functions disables both filters regardless of other operating conditions.

3-60. 3-Pole Active Filtering

3-61. The front panel FILTER modifier, for certain functions and ranges, inserts a low-pass 3-pole Butterworth filter (U3) with a corner frequency of approximately 7 Hz. It provides additional noise rejection in VDC, Ω2T, and Ω4T.

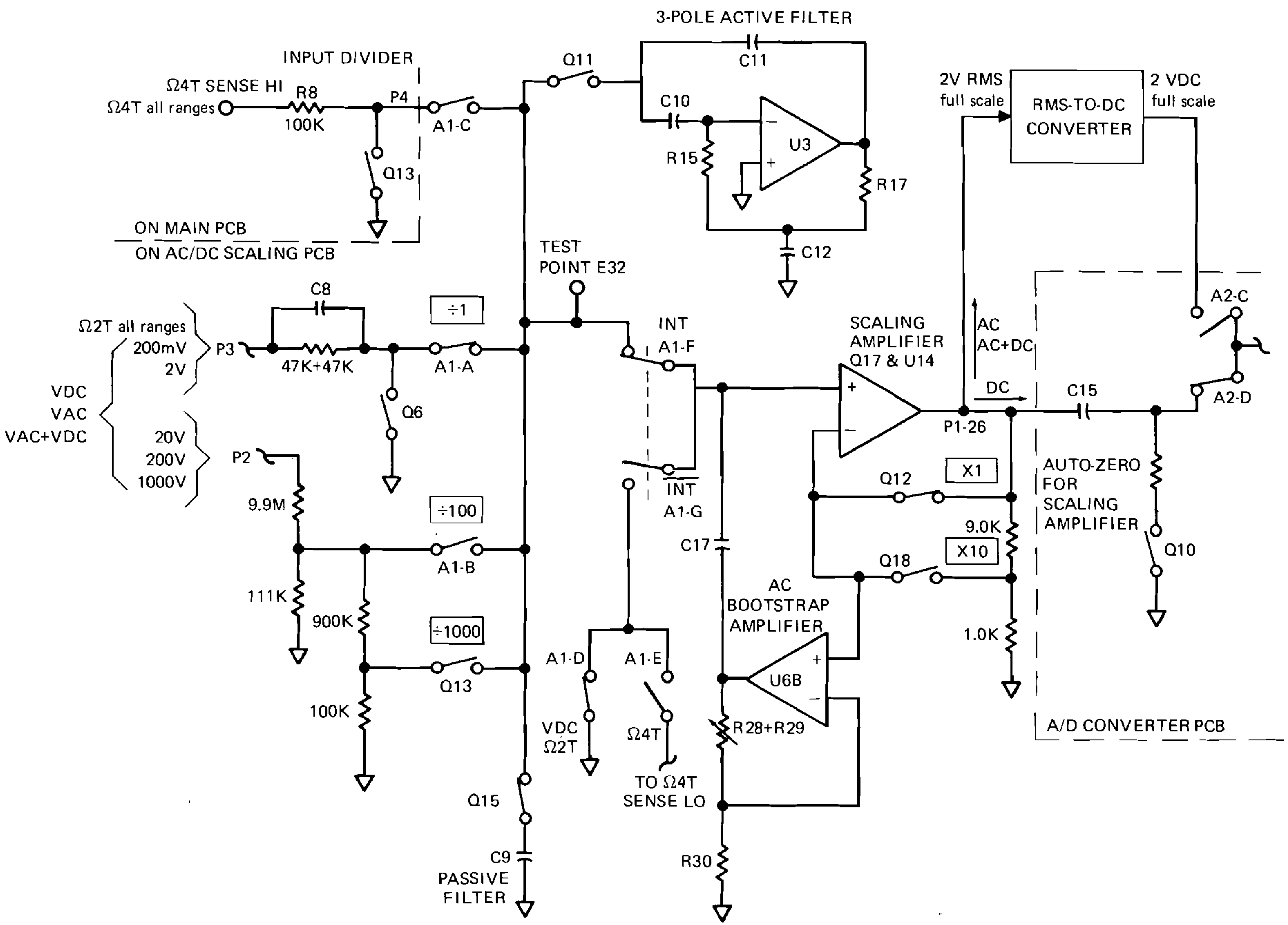
3-62. AUTOZERO

3-63. The scaling amplifier (Q17 & U14) has an inherent input offset voltage which drifts with time and temperature. In the VDC and ohms functions the autozero circuitry eliminates the effect of this error at the start of every VDC or ohms measurement cycle. (In VAC and VAC+VDC the autozero routine is not performed.) Functionally, the auto zero circuit may be divided into the following three groups:

1. Components to momentarily short the input of Q17 to ground through A1-G and either JFET A1-D (for VDC and Ω2T), or A1-E (for Ω4T). The drive signal for A1-G is $\overline{\text{INT}}$.
2. Components to store and subtract the offset voltage from the output of U14: C15 and Q10 located on the A/D Converter board.
3. Components to correct for charge injection during the measurement cycle: C1, R5, C44.

3-64. A functional grouping of the autozero components is shown in Figure 3-3. The auto zero sequence is performed under the control of the in-guard microprocessor as follows: FETs Q10 and A1-G close simultaneously. The input of Q17 is grounded causing capacitor C15 to charge to the combined offset voltage of Q17 and U14. Then Q10 and A1-G open causing the corrected input signal to be applied to the input buffer of the A/D Converter, A2-J.

3-65. In the four-terminal ohms function, the DMM autozeros through JFET A1-E to the Ω4T SENSE LO terminal. This terminal is the measurement reference, giving true four-terminal sense.



NOTE: THE SWITCHES IN THIS DIAGRAM SYMBOLIZE JFET SWITCHES.
THE SWITCH POSITIONS ARE IN THE VDC, 2V RANGE, FILTER NOT CALLED, AND INT CONFIGURATION

Figure 3-2. AC/DC Scaling

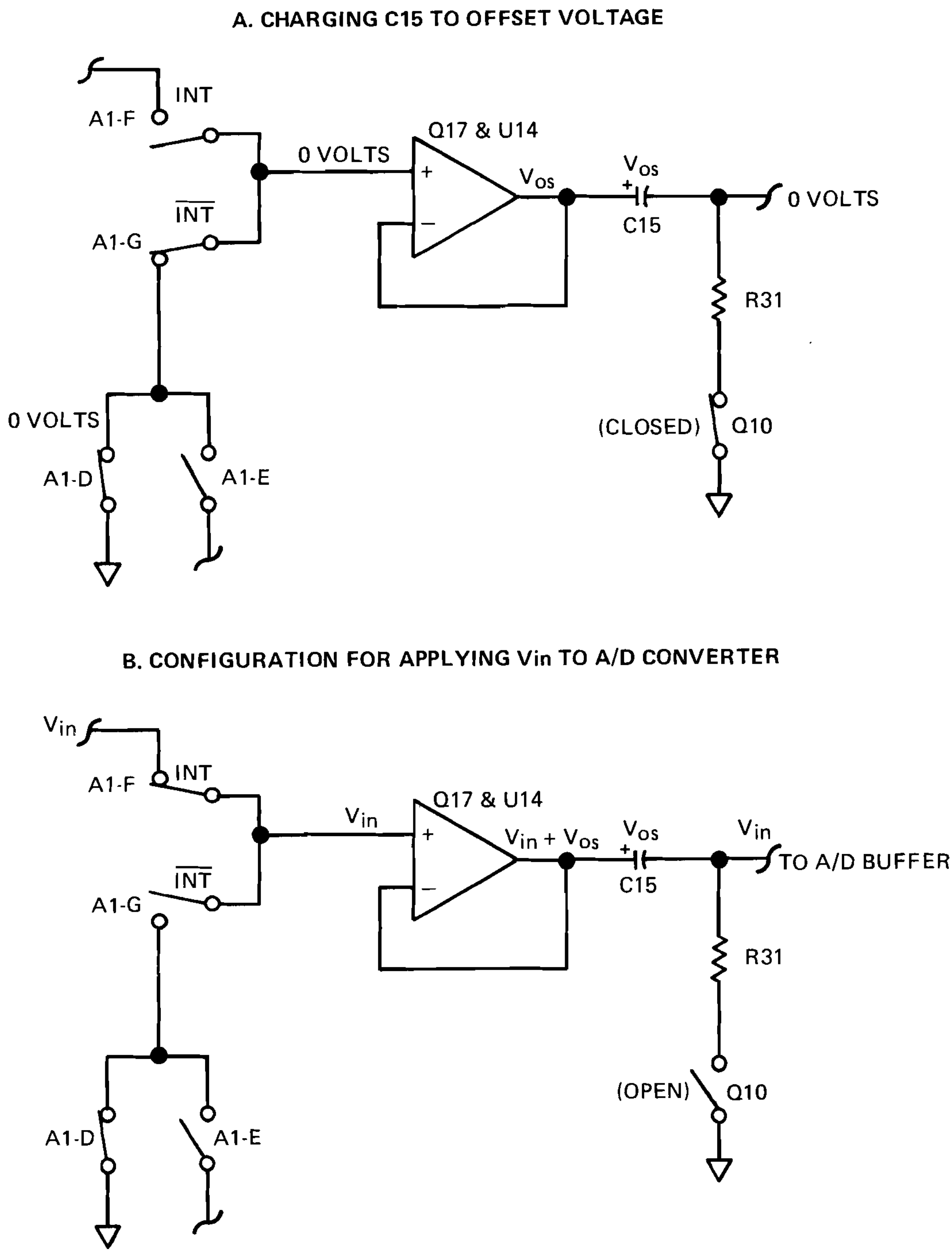


Figure 3-3. Autozero Routine

3-66. During the measurement cycle, switching signals are capacitively coupled into the input node of Q17. Capacitor C1 is driven with the $\overline{\text{INT}}$ signal to correct for charge injection errors.

3-67. AC BOOTSTRAP AMPLIFIER

3-68. Operational amplifier U6B is capacitively coupled to the non-inverting input of Q17. At higher frequencies U6B operates as a bootstrap to compensate for the high frequency rolloff of ac signals in the 200 mV and 2V ranges. The rolloff is due to the parasitic capacitance of the JFET switches connected to pin 17 of A1. Amplifier U6B has a gain of 1.75 to 2.00 (depending on how R29 is set). JFET Q19 is turned on for VDC and ohms measurements to reduce the gain of U6B. This gain reduction eliminates charge transfer through C17 during the autozero process, and keeps input bias current to a minimum. The charge transfer is especially evident when making high resistance (greater than 10 megohm) measurements.

3-69. RMS-to-DC Converter (Schematic 8860A-1004, Sheet 2 of 2)

3-70. The RMS-to-DC Converter, hereafter referred to as the RMS Converter, is located on the AC/DC Scaling PCB. For the VAC and the VAC+VDC functions the converter generates a positive dc voltage with a magnitude equal to the true rms value of the input (up to crest factor of 3). The RMS Converter, shown in Figure 3-4, computes the rms voltage using a log-antilog circuit.

3-71. The following description of the RMS Converter is divided into four separate sections:

1. Absolute Value Converter
2. 2X Log Amplifier
3. Log Feedback Amplifier
4. Antilog Amplifier

3-72. The absolute value converter, composed of U8 and its associated components, forms a full-wave rectifier which converts a bipolar voltage to a positive collector current at U17A. A positive input voltage (Vin) causes a collector current of Vin/40k (I_1 in Figure 3-4). When Vin is positive, I_2 is zero since CR6 is off; diode CR7 is turned on.

3-73. A negative input voltage (Vin) produces the same U17A collector current, but in a different manner. Diode CR6 is turned on, and CR7 is turned off. The negative input voltage appears at the cathode of CR6, inverted (with unity gain). Half of current I_2 flows through the 40 kilohm resistor and the other half (Vin/40k) flows into the collector of U17A.

3-74. The offset compensation amplifier U15 corrects for the dc offset of U8. The correction improves the dc stability of U8 over the operating temperature range of the 8860A.

3-75. The 2X Log Amplifier takes the logarithm of the U17A collector current and multiplies the logarithm by 2. Transistors U17A and U20A are the logarithmic elements in the amplifier. The logarithmic function is derived from the relationship of base-emitter voltage to collector current of a bipolar transistor.

3-76. A few components in the 2X Log Amplifier help to improve stability and high frequency response. For example, Q14, a transconductance amplifier, assures loop stability; RC network R75 and C41 provide ac compensation; and R61 adjusts the loop gain of the circuit to improve high frequency response. Low voltage power supplies are used with U16 to ensure low power dissipation and improved stability.

3-77. The amplifier consisting of U19A and U20B performs the antilog function of the RMS Converter. The collector current of U20B (V3/400 kΩ) is logarithmically related to the difference between its base and emitter voltages (V2 and V1). Capacitor C34 operates as a filter and U19B operates as the log feedback amplifier.

3-78. In operation the output of U19A is a dc voltage equal to five times the rms value of the input to the RMS Converter. At full scale, its output is 10V. Resistive divider network U18 divides the output of U19A by five to obtain a full scale output of 2 volts. Jumper wires W5 through W8 are removed as necessary during factory calibration to bring the divider output within the adjustment range of R67. The output is filtered by R59 and C32 before being applied to the A/D Converter.

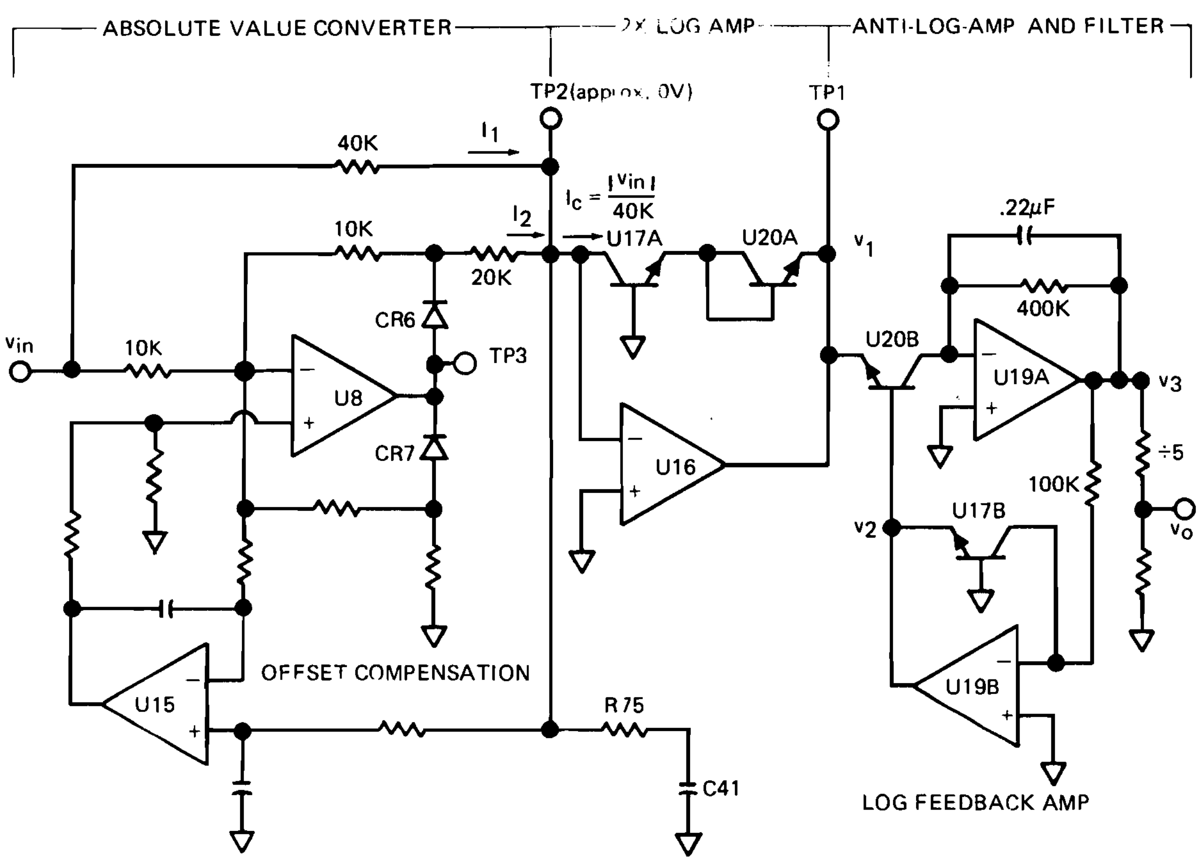
3-79. Jumpers W5 through W8 are selectively cut at the factory during pre-calibration, and should not be altered unless the U17 or U20 transistor arrays are replaced. See Table 4-5 for the jumper selection guide.

3-80. Ohms Converter (Schematic 8860A-1005, Sheet 1 of 2)

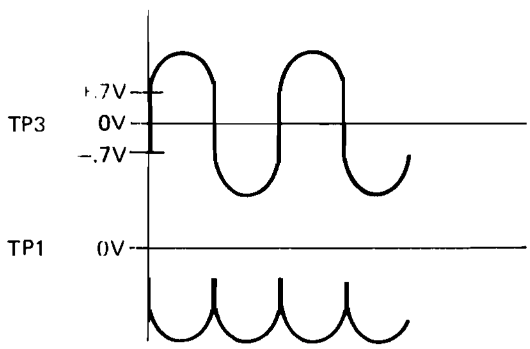
3-81. The Ohms Converter is physically located at the forward end of the A/D and Ohms Converter PCB. The Ohms Converter is enabled when the Ω2T or Ω4T function is selected. Circuit operation is the same for both functions. The Ohms Converter supplies a source current through the unknown resistance (Rx), generating a dc voltage proportional to Rx. This voltage is sensed and measured in the same way as a dc input voltage, but is displayed in ohms.

3-82. SOURCE CURRENT

3-83. Figure 3-5 shows a simplified schematic of the Ohms Converter. Source current for Rx flows through relay K4, to the front panel terminal labeled INPUT HI, through Rx (the resistor being measured), and returns to the source through the INPUT LO terminal. This current is scaled according to the selected resistance range. The scaled values for each range are shown in Table 3-1. The 200Ω range has a 1 mA source current and produces a full-range voltage of 200 mV. All other ranges produce a 2 volt output at full-range.



TYPICAL WAVEFORMS FOR LOW FREQUENCY SINE WAVE INPUT



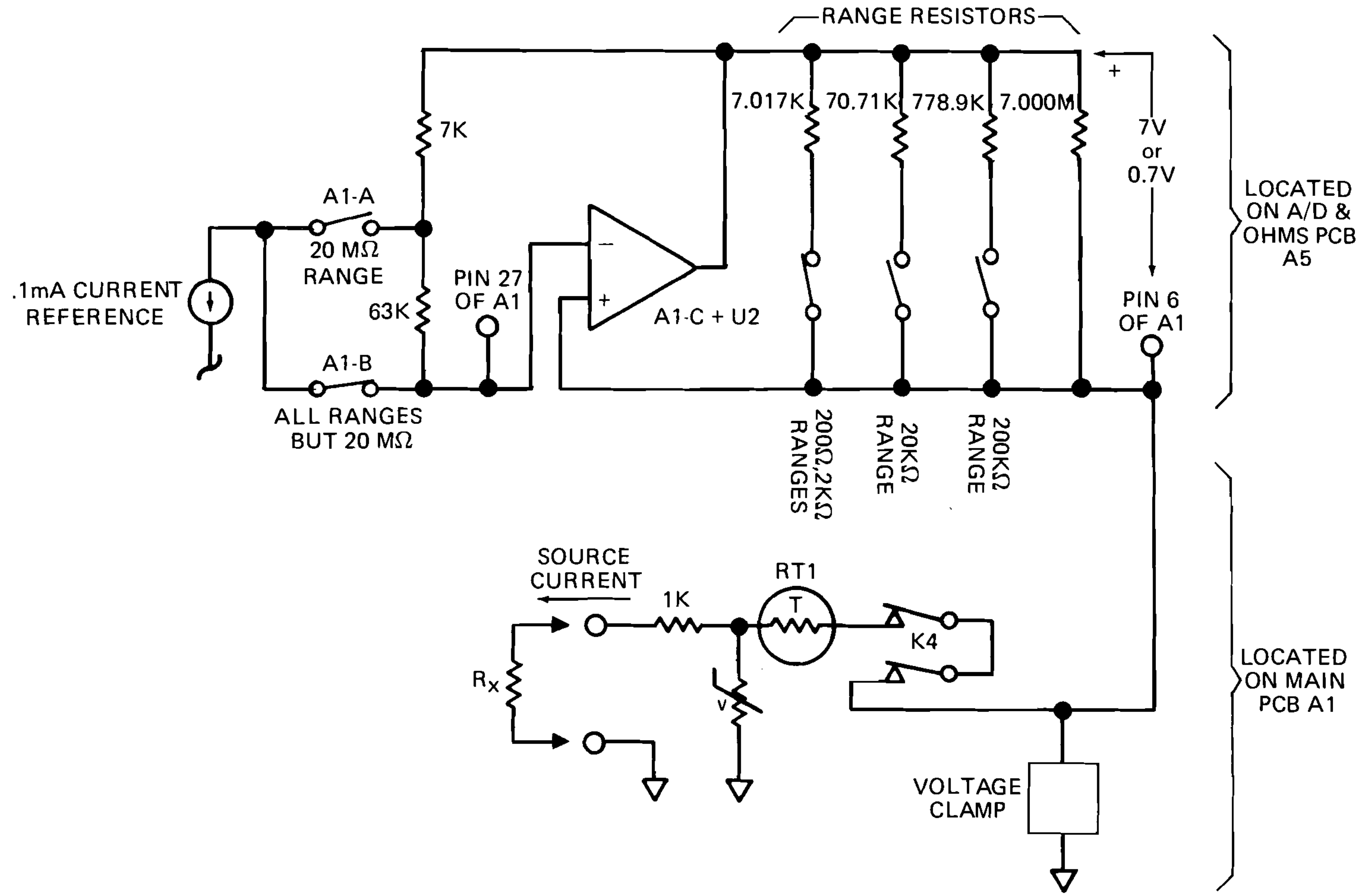
$$v_1 \alpha -\log \frac{|v_{in}|^2}{(40K)^2}$$

$$v_2 \alpha -\log \left(\frac{v_3}{100K}\right)$$

$$v_3 = 400K \text{ antilog } (v_2 - v_1) = 5\sqrt{\overline{v_{in}^2}}$$

$$v_o = \sqrt{\overline{v_{in}^2}}$$

Figure 3-4. RMS-to-DC Converter — Simplified Schematic



The FETs, shown here as switches, are conducting only for the ranges shown.
The FETs are shown switched for the 200Ω and 2KΩ ranges.

Figure 3-5. Ohms Converter—Simplified Schematic

3-84. RANGING VIA JFET SWITCHING

3-85. The ranging resistors are switched into the circuit by a series of JFETs located on the A1 hybrid assembly. ICs U6 and U7 are quad comparators with open-collector outputs. They translate digital control signals to voltage levels suitable for driving JFET switches. The JFET gate voltage requirements are -15 volts for turn off and a value equal to the channel voltage for turn on. The 2 to 4 decoder, U21, controls (through U6 and U7) the selection of four precision range resistors. The U21 truth table is given in Section 8, Ohms Converter.

3-86. On the lowest five resistance ranges, the 0.1 mA reference current flows through 70 kΩ (R9 + 63K + 7K) to produce a constant +7 volt drop across the enabled range resistor. Holding the voltage across the selected range resistors produces the constant source current for Rx. For example, on the 200Ω range, +7 volts across 7 kilohms produces a 1 mA source current. On the 20 MΩ range, JFETs A1-A and A1-B switch the 0.1 mA through the 7 kilohm reference resistor, producing a +0.7 volts drop across the 7 megohm reference resistor. The 0.7 volt drop maintains the 0.1 μA source current for Rx.

3-87. Amplifier U4, configured as a unity-gain amplifier, tracks the channel voltage of the A1 switching FETs. The output of U4 is used to supply the on-state gate bias voltage for all of the A1 switching JFETs. By tracking the voltage at pin 6 of A1, U4 maintains a constant, low junction voltage for all input voltages, thus keeping leakage effects constant. U4 also bootstraps the protection circuit on the main board to minimize leakage errors.

3-88. A/D Converter (Schematic 8860A-1005, Sheet 2 of 2)

3-89. The A/D Converter is located on the A/D and Ohms Converter PCB. Its purpose is to convert a measured quantity from analog to digital form for the purpose of display. Figure 3-6 is a simplified circuit diagram of the A/D Converter. The entire A/D conversion process, including timing, is under the control of the in-guard microprocessor. The A/D Converter indicates the polarity of the input (for selection of the reference) and signals the processor when the correct count has been reached.

3-90. The A/D Converter uses a dual-slope conversion technique and operates in both polarities. The dc voltage input to the A/D Converter represents the unknown resistance or voltage at the 8860A input terminals. This dc voltage is integrated (charges C7) for a fixed amount of time, called the integration period; see Figure 3-7. At the end of this period the input of the A/D converter switches to either an internal or an external reference voltage with a polarity that is opposite that of the input voltage. This discharges capacitor C7 at a controlled rate. A comparator interrupts the microprocessor and ends the discharge period when the charge remaining on C7 is equal to the charge that was present just prior to integration.

3-91. Figure 3-7 illustrates and describes the various periods within a measurement cycle. Figures 4-4 and 4-5 in Section 4 of this manual give the associated JFET timing diagrams and signal waveforms.

3-92. The in-guard microprocessor derives the digital readout by counting at a 1 MHz rate during the discharge cycle. If the counter reached 199,999 counts without being interrupted (in the 5-1/2 digit mode), the display will indicate overrange.

3-93. PRECISION VOLTAGE REFERENCE

3-94. The Precision Voltage Reference, Figure 3-8, provides the voltage standard for all 8860A measurements by establishing a precise discharge rate for C7. Reference amplifier U22 is a temperature compensated 6.5 volt zener reference. Op amp U23A is connected in a bootstrap configuration to supply a very stable +11 volt output to R40 and R41, assuring highly stable currents for U22. Resistor R40 sets the zener current. Resistors R41 and R42 are selected to set the correct temperature compensation current for the reference amplifier.

3-95. Amplifier U23B fixes the collector of U22 at zero volts and buffers the output of U22 for use by the reference divider network, U10. Jumper wires W4-W8 are removed as necessary during factory calibration to bring the reference divider output voltage within the adjustment range of R17. Diode CR11 and R44 assure that the reference circuit always powers up to the correct polarity.

3-96. PRECISION CURRENT REFERENCE

3-97. Amplifier U5 taps 5.480V dc from U10 and applies it to R11 and R12 to generate a precise 0.1 mA dc reference current for the Ohms Converter. JFET Q3 assures a constant output current over the entire compliance voltage range of the Ohms Converter.

3-98. A/D SWITCHING NETWORK

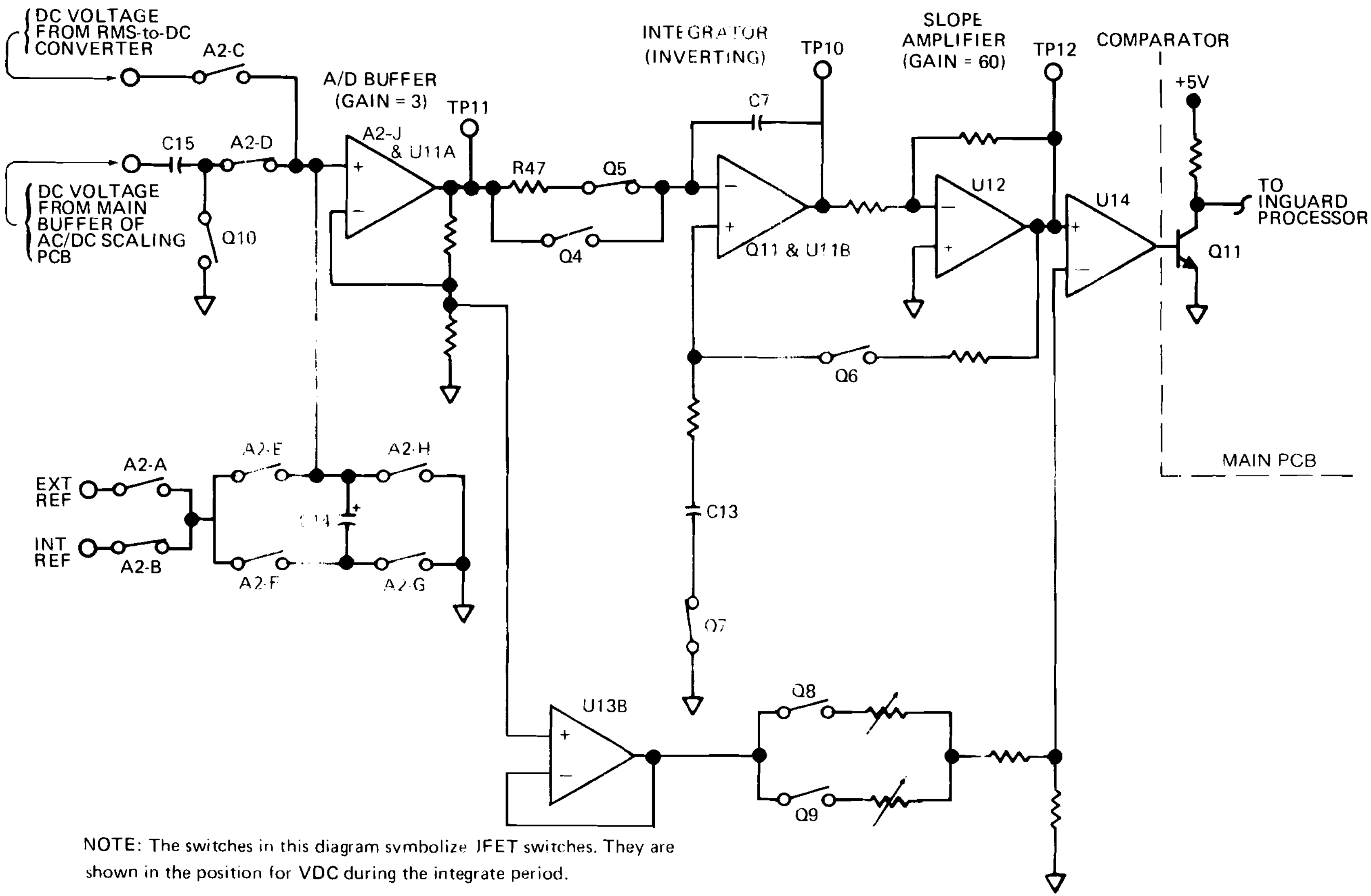
3-99. Hybrid A2 on the A/D Converter PCB contains a series of JFET switches. These switches are used to perform the following functions:

1. Select the VDC, Ohms (via A2-C), or VAC (via A2-D) functions for processing during the integrate period.

2. Enables the internal reference (via A2-B) or the external reference (via A2-A) for use during the counting period. (This selection is made from the front panel.)

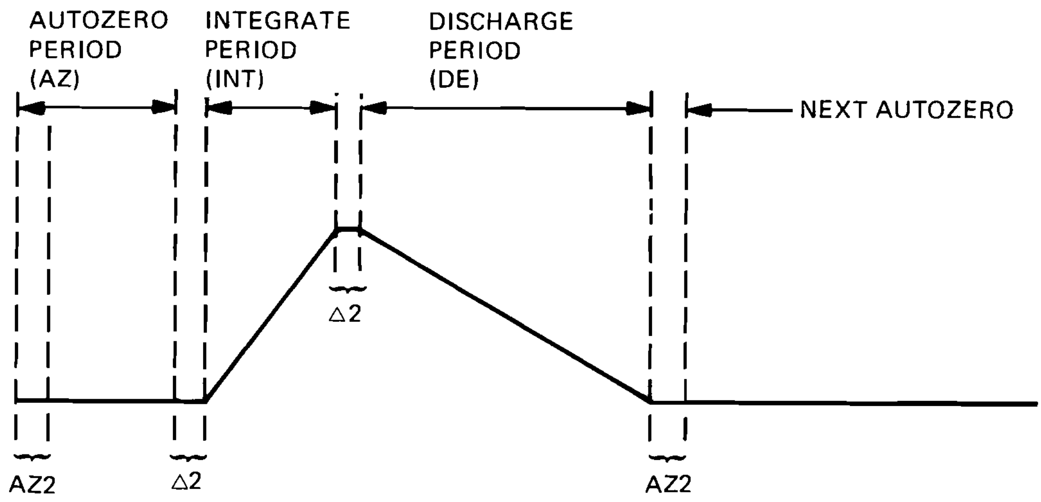
3. Switches the polarity of the 1V reference (via A2-F, G, H, and C14) for the A/D Converter.

3-100. Items 2 and 3 are described further under Internal/External Reference.



NOTE: The switches in this diagram symbolize JFET switches. They are shown in the position for VDC during the integrate period.

Figure 3-6. A/D Converter—Simplified Schematic



AUTOZERO PERIOD (AZ)

The initial small voltages on C7 and C13 are established during this period with Q6 switched on and the A/D buffer input grounded through A2-H. AZ2 assures fast recovery from overloads.

TIME-OUT PERIODS (Delta-2)

Each of these .5 ms periods allows the A/D buffer to respond to the switched-in voltage and settle, before the voltage is applied to the integrator.

INTEGRATE PERIOD (INT)

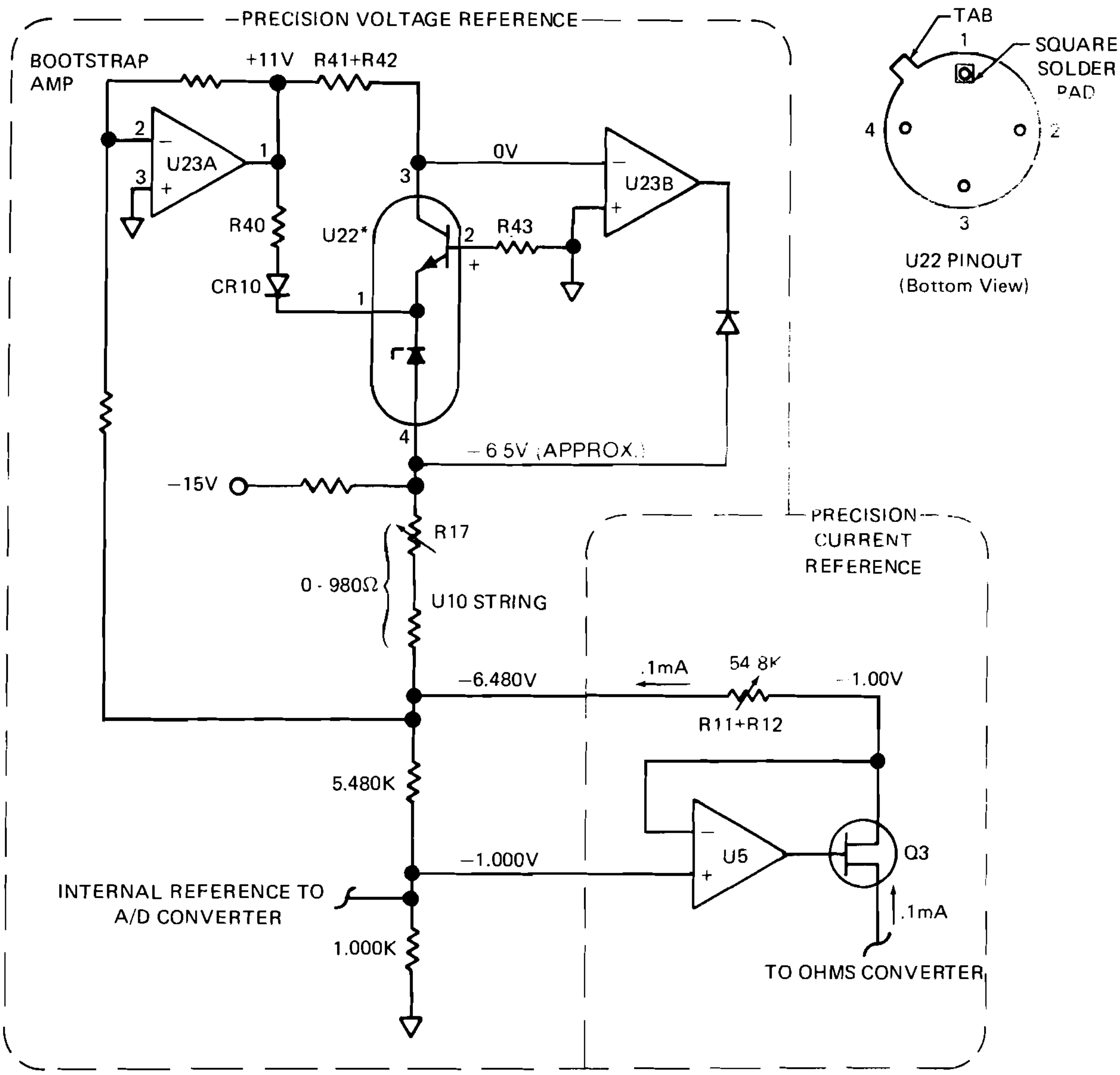
C7 charges to a voltage proportional to the applied input. The length of the integrate period depends on the sample rate chosen, as follows:

RESOLUTION	AC LINE FREQUENCY	INTEGRATION PERIOD (INT)	MEASUREMENT CYCLE (approximate)
5½ digit	50 Hz or 60 Hz	100 ms	400 ms
4½ digit	50 Hz 60 Hz	20 ms 16-2/3 ms	66.7 ms
3½ digit	50 Hz or 60 Hz	2 ms	20 to 50 ms

DISCHARGE PERIOD (DE)

C7 discharges for a length of time proportional to the applied input, during which digital counts accumulate. This count represents the value of the input resistance or voltage being measured. The rate of discharge is the same for all A/D conversion speeds when the internal reference is chosen.

Figure 3-7. A/D Converter Measurement Cycle



*R41, R42, and U22 are replaced only as a set.

Figure 3-8. Precision Voltage and Current References—Simplified Schematic

3-101. The JFET switches of A2 are controlled by comparators U15 through U18, which in turn are controlled by the in-guard microprocessor. The timing for the JFET switches is shown in Figure 4-4. IC U21 decodes two lines from the microprocessor into a 1-of-4 output.

3-102. Amplifiers U13A and U13B supply gate bias to JFET switches which must conduct non-zero voltages. This bias arrangement assures a constant switch resistance for all voltage levels.

3-103. A/D BUFFER

3-104. The A/D buffer, as shown in Figure 3-6, consists of dual JFET A2-J and amplifier U11A. The buffer receives a scaled dc input from the AC/DC scaling circuits, amplifies the input by a factor of 3, and provides the integrator with the amplified signal.

3-105. INTEGRATOR AMPLIFIER

3-106. The integrator consists of Q11, U11B, R47 and C7. JFET Q5 is on during the integrate and discharge periods to allow C7 to charge and discharge. JFET Q5 is switched off for 0.5 ms (Delta-2) before the charge and discharge periods. Clamp transistor Q12 ensures that Q5 does not conduct current during these off times. The Delta-2 periods serve to isolate the integrator from transient voltages due to switching of the A/D buffer input. In addition, input polarity is sensed during the second Delta-2 so that the appropriate reference can be applied to the A/D buffer.

3-107. JFET Q4 is normally off and Q7 is normally on. However, they change state simultaneously for a short time (called AZ2) at the beginning of the autozero period. Q4 switches on during AZ2 to rapidly remove any residual charge on C7. Q7 switches off to minimize disturbance of the charge stored on C13 during the previous autozero. The AZ2 period is the key to high-speed operation of the A/D Converter (4-1/2 and 3-1/2 digit modes). AZ2 also assures rapid overload recovery. Resistors R22 and R23 provide a small amount of linearity correction.

3-108. INTERNAL/EXTERNAL REFERENCE

3-109. The selected reference, internal or external, is applied to the A/D Buffer during the discharge period. The internal reference is a precise +1 or -1 volt level. It is applied with a polarity opposite the scaled dc input voltage in order to discharge C7. The precision -1 volt internal reference is available via JFET A2-B.

3-110. The +1 volt reference is derived by storing the precision -1 volt level on capacitor C14 and then reversing the capacitor's connections. JFETs A2-F and A2-H are switched on for the duration of the autozero period to charge C14. When the positive reference is required, A2-G is switched on during the discharge period.

3-111. An external reference voltage may be of either polarity since the A/D Converter incorporates a precision inversion circuit. The inversion is accomplished by connecting C14 to the reference voltage during autozero and reversing the capacitor's connections during the discharge period.

3-112. SLOPE AMPLIFIER AND COMPARATOR

3-113. Op amp U12 is configured as an inverting amplifier with a gain of 60. Its output is used to improve the accuracy of zero-crossing detection (via U14) at the end of the discharge period, and to assure accurate and repeatable autozeroing of the integrator during the autozero period (via Q6). JFET Q6 conducts during the autozero period to close the loop which initializes the voltages on C7 and C13.

3-114. The comparator is composed primarily of U14, and includes Q11 on the Main PCB. The output of the comparator indicates polarity during the second Delta-2, and interrupts the counter at the end of the discharge period.

3-115. Diodes CR5, 6, 8, and 9 limit the slope amplifier output to ensure pinchoff of Q6 during the integrate and discharge periods. A dc voltage (70 mV to 120 mV) determined by R29 and R30 is applied to U14-4 during the discharge period. When the output of the slope amplifier reaches the same voltage as U14-4, the comparator changes state and interrupts the in-guard microprocessor. Q9 is enabled for positive inputs, and Q8 for negative inputs.

3-116. In-Guard Microprocessor (Schematic 8860A-1001)

3-117. The in-guard controller is an 8-bit microprocessor, complete with RAM and ROM. It plugs into a socket on the Main PCB Assembly and controls the entire measurement cycle. Measurement cycle control includes:

1. Implementing front panel selections: function, range, autoranging, zero, filter, sample rate, external reference, and trigger arm.
2. Timing the JFET switching associated with the A/D Converter.
3. Transmitting the measured value to the out-guard microprocessor at the end of every measurement cycle.

3-118. The in-guard microprocessor controls autoranging. When autoranging is selected, the 8860A begins in the highest range and downranges. If the input signal represents less than 18000 counts (in the 5-1/2 digit mode), the 8860A switches to the next lower range. If at any time the input signal represents more than 199999 counts, the 8860A upranges.

3-119. The front panel ZERO function allows the in-guard microprocessor to store an offset value for the

VDC and resistance measurement functions (2- or 4-terminal). The value is stored in three separate and independent RAM locations, and is subtracted from measured value before sending it to the out-guard microprocessor.

3-120. The in-guard microprocessor is powered by the +5V in-guard supply. A reset circuit at U6-39 momentarily holds the microprocessor in the reset state during power-up to initialize internal conditions.

3-121. Guard-Crossing Circuitry (Schematic 8860A-1001)

3-122. The guard-crossing, located on the Main PCB Assembly, is an optically coupled data transmission path for communication between the in-guard and out-guard microprocessors. The use of opto-isolators allows a differential of up to ± 500 volts between out-guard common and in-guard common.

3-123. Communication between the microprocessors employs detection and correction, and is fully self-restarting when data is lost or incorrectly transmitted. Inadvertent loss of data is usually indicated by an error message on the display.

3-124. In each direction there are two transmission paths, clock and data, which carry parallel signals. Transmissions in either direction, out-guard to in-guard (through U9 and U10) or in-guard to out-guard (through U7 and U8), are fully symmetrical. The following description of one of the guard-crossing data paths applies to all four.

3-125. A digital signal from J3-15 (Controller PCB connector) drives the inverting input of a comparator in U2. The output of the comparator drives the input of optoisolator U10. A low input to U10 produces an isolated high output level (+0.42 to +0.6V dc). This signal drives the inverting input of another comparator (contained in U5) that has a switching threshold of +0.2 volts to 0.35 volts. The output of this comparator (pin 14) drives U6-14, the Receive Clock input to the in-guard microprocessor. The signal is inverted three times in crossing the guard, resulting in a net signal inversion.

3-126. Out-Guard Microprocessor (Schematic 8860A-1003)

3-127. The out-guard controller U2 is an 8-bit microprocessor which plugs into a socket on the A3 Controller PCB Assembly. It is supported with external ROM and expanded I/O capability.

3-128. OUT-GUARD MICROPROCESSOR SOFTWARE

3-129. The out-guard microprocessor (U2) has an external program ROM (U9). This ROM contains the program which operates the 8860A in the local mode; another ROM takes over in the remote mode. From local ROM, the out-guard microprocessor:

1. Reads the front panel keys and internal switches.
2. Communicates front panel selections to the in-guard microprocessor.
3. Passes all triggers to the in-guard microprocessor, including continuous triggers and those from manual, external, and bus sources.
4. Receives measurements from the in-guard microprocessor.
5. Processes numerical data entered from the front panel.
6. Performs limits and peak to peak comparisons.
7. Performs offset subtraction.
8. Controls the display and front panel LEDs.
9. Performs self-diagnostic error checks.
10. Interfaces with the two digital options: the Calculating Controller (-004) and the IEEE-488 Interface (-005).

3-130. Table 3-2 shows how the various ROMs are sectioned into four address spaces, and how each section is accessed using ports P23, P26, and P50. The table also shows the state of the control lines for each ROM device. The RAM internal to the out-guard microprocessor holds the three stored values for offset, high limit, and low limit.

3-131. OUT-GUARD MICROPROCESSOR HARDWARE

3-132. The four major components which suport the operations listed previously are located on the Controller PCB. They are:

1. U2, Out-Guard Microprocessor
2. U9, Local Program Memory (ROM)
3. U10, 8-Bit Latch
4. U3, I/O Expander

3-133. Operating power for the Controller PCB Assembly comes from the +5 volt out-guard supply. At power-up, capacitor C1 charges slowly through an internal resistor in U2 to release the reset line (pin 4) after a delay. This initial delay sets the logic on the Controller PCB Assembly to a known state on power-up.

Table 3-2. Out-Guard ROM Selection

<table>
<tr><th rowspan="2"></th><th rowspan="2" colspan="2">ROM DEVICE</th><th rowspan="2">ROM ADDRESS</th><th colspan="3">PORT NO.</th></tr>
<tr><th>P23 U2-24</th><th>P26 U2-37</th><th>P50 U3-1</th></tr>
<tr><td rowspan="2">BASIC INSTRUMENT (LOCAL ROM)</td><td rowspan="2" colspan="2">U9</td><td>0-2047</td><td>0</td><td>X</td><td>0</td></tr>
<tr><td>2048-4095</td><td>0</td><td>X</td><td>1</td></tr>
<tr><td rowspan="3">OPTION (OPTION ROM)</td><td>IEEE</td><td>CALC.</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">U4</td><td>U10</td><td>0-2047</td><td>1</td><td>0</td><td>X</td></tr>
<tr><td>U19</td><td>2048-4095</td><td>1</td><td>1</td><td>X</td></tr>
<tr><td colspan="7">X = don't care
Device/pin numbers refer to schematic 8860A-1003, Controller circuit board; U2-24, for example, means device U2, pin 24.</td></tr>
</table>

3-134. The out-guard microprocessor communicates with the other ICs (U9, U10, and the two digital options) by way of the data bus, lines D80 through D87. This bus is multiplexed; the data and the eight lower-order address bits appear at different times on these lines. The eight-bit latch (U10) holds the address at its output for the local program memory (U9). The address is latched from the data bus by a signal called ALE (Address Latch Enable). ALE is generated by the out-guard microprocessor.

3-135. The local ROM U9 actually requires a total of 12 address bits. The upper four bits of U9 are static during program memory read operations; the processor outputs them directly to U9 on lines P20 to P23.

3-136. The I/O Expander U3 expands lines P20 through P23 to 16 bits. Table 3-3 shows the functions that are assigned to each pin of U3. Notice that most of the pin assignments are bidirectional (input and output data). This expanded I/O operates the multiplexed display, reads the option identification, and reads the three slide switches S1, S2, and S3. The pin labeled PROG controls the timing of U3.

3-137. The display receives its control from the output ports of U2 and U3. Non-inverting drivers U4, U5 and U7 buffer the port outputs. Resistor network U6, and resistors R4, R5, and R6 are series resistors to limit the drive current to the display LEDs.

3-138. The two D-type flip-flops of U1 operate as signal conditioners for the out-guard microprocessor. The first flip-flop (pins 1-5) is part of the external trigger circuitry. The second (pins 9-13) conditions signals arriving from the installed digital option. The IEEE-488 option uses this line to interrupt the out-guard microprocessor. The Calculating Controller option, however, uses this line as simply another input to the out-guard microprocessor.

3-139. EXTERNAL TRIGGER CIRCUITRY

3-140. The external trigger circuit is designed to trigger from either a switch opening or a rising TTL signal. The signal passes through two stages of conditioning. One-shot U11, when triggered, eliminates switch bounce by producing a positive output pulse of approximately 40 ms. This pulse sets D-type flip-flop U1 to signal the microprocessor that a trigger has been received. The microprocessor clears the flip-flop after it detects the set condition.

3-141. Front Panel Push Buttons (Schematic 8860A-1002)

3-142. The front panel push buttons are scanned by the out-guard microprocessor at the rate of two keys every 2.5 ms (regardless of the A/D sample rate). The out-guard microprocessor interrupts whatever it is doing to perform this function. (The IEEE-488 option causes the scan rate to slow when certain bus interrupts occur. This is because data communication between the GPIA and the out-guard microprocessor has priority over the 2.5 ms scan interrupts.)

3-143. A binary sequence at the input of U1 (pins 13, 14 and 15) sets each of the eight output lines of U1 low, one at a time. In this way the sixteen keys are strobed a column at a time through diodes CR1 through CR8. The two strobed keys are read simultaneously via pins 16 and 17 of J1. A line is low (at zero volts) only if the corresponding key is depressed. Thus the entire keyboard is read over a 20 ms interval.

3-144. Display (Schematic 8860A-1002)

3-145. The same U1 strobe lines that scan the front panel push-buttons also strobe the eight display digits, 6 decimal points, 2 units annunciators, and 15 indicator lights. When pin 1 of U1 goes low, Q1 turns on, activating the first seven segment readout and three indicator lights. Signals applied to the cathodes of the segments determine which segments will light. As this first column of lights is lit, all other columns (transistors Q2 through Q8 and their display lights) are turned off. The eight columns are strobed one at a time, at a rate high enough to make all digits appear to be on at the same time. A timer interrupt occurs every 2.5 ms (except with IEEE-488 Interface) to advance columns. The sequence continues in an unending loop, completing a full cycle once every 20 ms.

Table 3-3. I/O Expander (U3) Pin Assignments

PORT	U3 PIN NO.	OUTPUT FUNCTION		INPUT FUNCTION	
P40	2	Send data	Guard crossing bit	Test Mode 0 switch (S3)	
P41	3	Send clock		Test Mode 1 switch (S1)	
P42	—	(not used)		(not used)	
P43	—	(not used)		(not used)	
P50	1	ROM bank switch control		(pulled to logic 0)	
P51	23	LSB	Annunciator data	50/60 Hz switch (S2)	
P52	22	middle bit		(not used)	
P53	21	MSB		(not used)	
P60	20	LSB	Front panel scan data	ID0	Option Identification
P61	19	middle bit		ID1	
P62	18	MSB		ID2	
P63	17	(not used)		ID3	
P70	13	(not used)		Receive data	Guard crossing bit
P71	14	(not used)		Receive clock	
P72	15	(not used)		Bottom row	Front panel keyboard
P73	16	(not used)		Top row	

Section 4
Troubleshooting

4-1. INTRODUCTION

4-2 This section of the manual contains troubleshooting information for the 8860A. The information is divided into five major parts. They are:

1. General Maintenance
2. Troubleshooting Approach
3. Analog Troubleshooting
4. Digital Troubleshooting
5. Troubleshooting Aids

4-3. GENERAL MAINTENANCE

4-4. Disassembly Procedure

WARNING

TO AVOID ELECTRICAL SHOCK HAZARD, DISCONNECT LINE POWER AND ANY INPUT CONNECTIONS FROM THE 8860A BEFORE STARTING THE DISASSEMBLY PROCEDURE.

4-5. Disassemble the 8860A as follows:

1. Disconnect the 8860A from line power; remove all front (and rear) panel inputs.
2. Remove the four screws located on the bottom of the chassis, and pull the top cover straight up and off.
3. For access to the analog circuitry, remove the guard cover by unscrewing its four top screws (the guard cover is the large metal cover with adjustment holes). Both analog circuit boards can be removed by pulling them straight up.
4. Remove the Display PCB by pulling the bottom off the chassis, disconnecting the five INPUT terminal wires, and pulling the entire front panel assembly forward. The front panel and the circuit board are held together by the connector to the Controller PCB.
5. Refer to Section 8 for identification of the circuit board assemblies. Each assembly unplugs from its connector.

CAUTION

Do not contaminate the area around the INPUT terminal connections on the main PCB or the front end of the AC/DC Scaling PCB. Low level leakage can result in calibration errors.

4-6. Cleaning

4-7. To clean the front panel and exterior surfaces of the 8860A, use a soft cloth dampened with either a mild solution of detergent and water or anhydrous ethyl alcohol.

CAUTION

Do not get water on the transformer. The transformer will absorb the water and eventually fail. Use special care when cleaning the fragile hybrid assemblies; they are easily damaged.

CAUTION

If fluorocarbons or other solvents are used to clean the pcbs, keep it off switches and potentiometers. Solvents will remove the lubricants from these components and shorten service life.

4-8. To clean the interior of the unit, use clean, dry air at low pressure (<20 psi). If contaminants remain, clean the individual pcbs using warm water. The AC/DC Scaling and the A/D and Ohms PCBs may be safely washed with all components intact; the Main PCB requires special handling.

4-9. The Main PCB may also be cleaned using warm water. However, in doing so do not get the armature relays or the transformer wet. The recommended approach is to cover the transformer and remove the armature relays during the washing process. Remove relays K1, K3, and K4 by unplugging them from the pcb; do not remove the reed relay.

4-10. After washing the pcbs, remove excess water using clean dry air at low pressure. Dry the pcbs in an oven at a temperature of 50°C or less.

4-11. Fuse Replacement

WARNING
TO AVOID ELECTRICAL SHOCK HAZARD, DISCONNECT THE POWER CORD BEFORE SERVICING THE FUSE. AC LINE VOLTAGE IS PRESENT WHEN THE POWER CORD IS CONNECTED.

4-12. The power fuse (F1) is accessible from the rear panel. Replace the fuse, if necessary, with an MDL (slow-blow) ¼-ampere fuse with a voltage rating (125V or 250V ac) exceeding the line voltage.

4-13. Static Awareness

4-14. Whenever troubleshooting, follow procedures outlined on the yellow Static Awareness sheet located in this manual. These procedures are intended to prevent damage to MOS devices due to static charge.

4-15. Pin Numbering

4-16. Note that pin 1 of each integrated circuit is identified by a square solder pad on the circuit board. Connector pins are numbered as shown in Section 8, in the figure labeled Interconnection of Assemblies.

4-17. Extender Cards

4-18. The following extender cards are available for troubleshooting the 8860A plug-in pcb assemblies. The extenders may be used during troubleshooting and functional testing. However, all extenders must be removed during the performance test and the calibration procedure. Order by model number.

EXTENDER BOARD	MODEL NUMBER
A/D and Ohms Converter PCB	8860A-4007
AC/DC Scaling PCB	8860A-4008
Calculating Controller (-004) and IEEE-488 Interface (-005)	8860A-4009

4-19. TROUBLESHOOTING APPROACH

4-20. Figure 4-1 shows the recommended approach for troubleshooting the 8860A. When the instrument fails to perform as expected, use Table 4-1 to identify the fault as analog, digital, or power supply related. Then proceed to the analog or digital troubleshooting procedures. If additional circuit details are required after the fault area is located, refer to the theory of operation in Section 3 and the schematic diagrams in Section 8.

4-21. POWER SUPPLY CHECK

4-22. Table 4-2 lists the basic power supply voltages, their test points and tolerances, and the circuits they supply. Test point locations are shown in Figure 4-2. Check each of the power supply voltages using the following procedures:

1. In-Guard Supply
   Connect the common lead of a DMM to In-Guard Common. Measure each of the three in-guard voltages (+5V, +15V, -15V). Each supply voltage should be within the tolerance indicated in Table 4-2.
2. Out-Guard Supply
   Connect the common lead of the DMM to Out-Guard Common. Measure the outguard +5V supply. It should measure within the tolerance indicated in Table 4-2.

NOTE
By clipping jumper wires, you can remove the ±15 volt supply to the RMS-to-DC Converter (wires W3 and W4) and Ohms Converter (wires W10 and W11). This should only be done to help locate a fault which is overloading the ±15 volt supplies.

4-23. ANALOG TROUBLESHOOTING

4-24. A list of test points for troubleshooting the analog section of the 8860A is shown in Table 4-3. Verify the overall operation of the analog section by confirming the presence of these voltages. If a voltage is incorrect, make a detailed check of the indicated circuit location or section. Procedures for troubleshooting the individual analog sections are given in the following paragraphs. The sections are covered in the following order:

- AC/DC Scaling
- RMS-to-DC Converter
- Ohms Converter
- Precision Voltage Reference
- A/D Converter

NOTE
The A/D & Ohms board can be operated with the AC/DC Scaling board removed; however, the reverse is not true. DO NOT TRY TO OPERATE THE AC/DC SCALING BOARD WITH THE A/D & OHMS BOARD REMOVED. (The AC/DC Scaling ground connections are made on the A/D & Ohms board.)

4-25. AC/DC Scaling

4-26. The following procedures assume that the signal path from the front panel INPUT terminals to the AC/DC Scaling PCB has been checked and is operating properly. The AC/DC Scaling Extender Card is necessary for the following procedures.

4-27. The AC/DC Scaling circuitry is functionally divided into two parts, the Front End and the Amplifier Section.

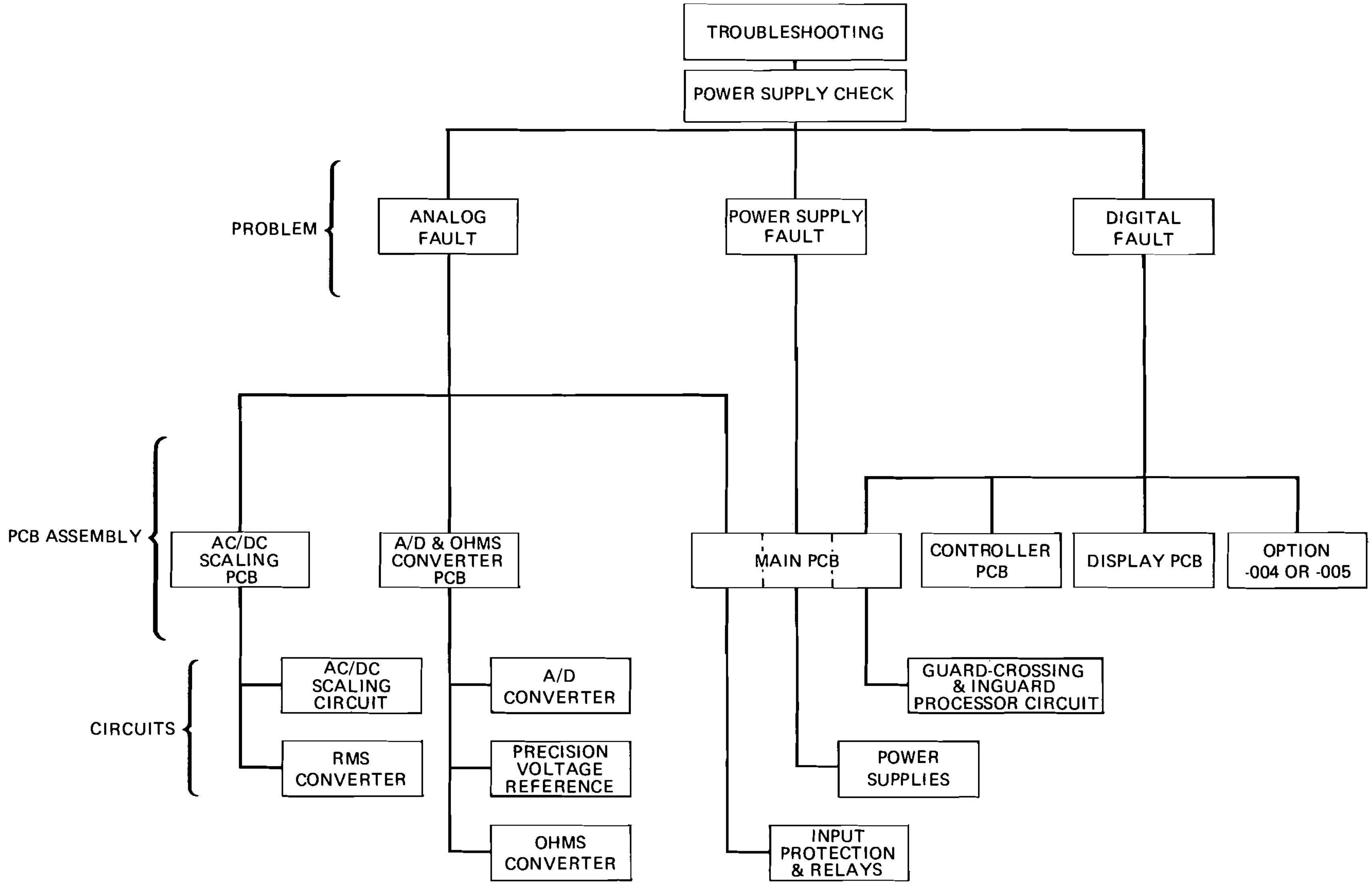


Figure 4-1. Troubleshooting Approach

Table 4-1. Distinguishing Analog and Digital Faults at Front Panel

ANALOG FAULT
An analog fault exists if a measurement reading is incorrect, but the following functions operate correctly: • Front panel indicator lights respond properly when a measurement function is selected (e.g., switch from VDC to VAC to Ω2T). • Decimal point is positioned correctly in response to a range change. • Annunciators (mV, V, Ω, kΩ, MΩ) light up properly for each function and range. • A number can be stored and recalled from the High, Low, or Offset registers. Analog faults are located inside the guard on one of three pcbs: • Main PCB Assembly • AC/DC Scaling PCB Assembly • A/D and Ohms Converter PCB Assembly
DIGITAL FAULT
A digital fault usually exhibits at least one of the following svmptoms: • Display appears faulty; reading does not change or display segments do not light. • One digit is bright, others are off. • All display and indicator lights are off. • Instrument fails to respond to a front panel push button. Digital faults are located on one of four PCB Assemblies: • Controller PCB Assembly • Display PCB Assembly • Main PCB Assembly • Option -004 or -005 PCB Assemblies

1. The Front End includes:
   a. Input Divider U1 and associated capacitors
   b. Voltage clamp circuit
   c. JFET switches, including A1
   d. Active Filter U3

2. The amplifier section includes:
   a. Dual JFET Q17 and amplifier U14
   b. Bootstrap Amplifiers Q16 (with U5), U6A, and U6B

4-28. Proper waveforms for the AC/DC Scaling board are shown in Figure 4-3, for a +1V dc input, VDC. These signals are referred to in Table 4-4, which lists typical fault symptoms for the AC/DC Scaling PCB. When trouble-shooting frequency response problems, voltage test measurements can load the front end circuitry. To avoid circuit loading, measure front end voltages only at the specified test points. Voltages below 2V rms may be injected at various points in the front end (e.g., A1-17, A1-6, A1-9) and measured at appropriate test points.

4-29. Excessive leakage current in the front end JFETs can be pinpointed using the following guidelines:

1. Leakage in a JFET adversely affects a circuit only when the JFET is off (not conducting).
2. The leakage path may be from drain to source, preventing a fully off condition, or from gate to source.
3. Identify and inspect those JFETs that are off when leakage symptom is present. For example, if a dc offset disappears when the filter is enabled (Q11 on), then Q11 is probably defective.

4-30. RMS-to-DC Converter

4-31. Table 4-5 lists some general fault symptoms and corrections for the RMS Converter. Detailed procedures which may be used to check various functional aspects of the RMS Converter are given in the following paragraphs. The first procedure checks the VAC+VDC function. The second checks the VAC function. If a fault is identified, investigate the components that precede the test point location.

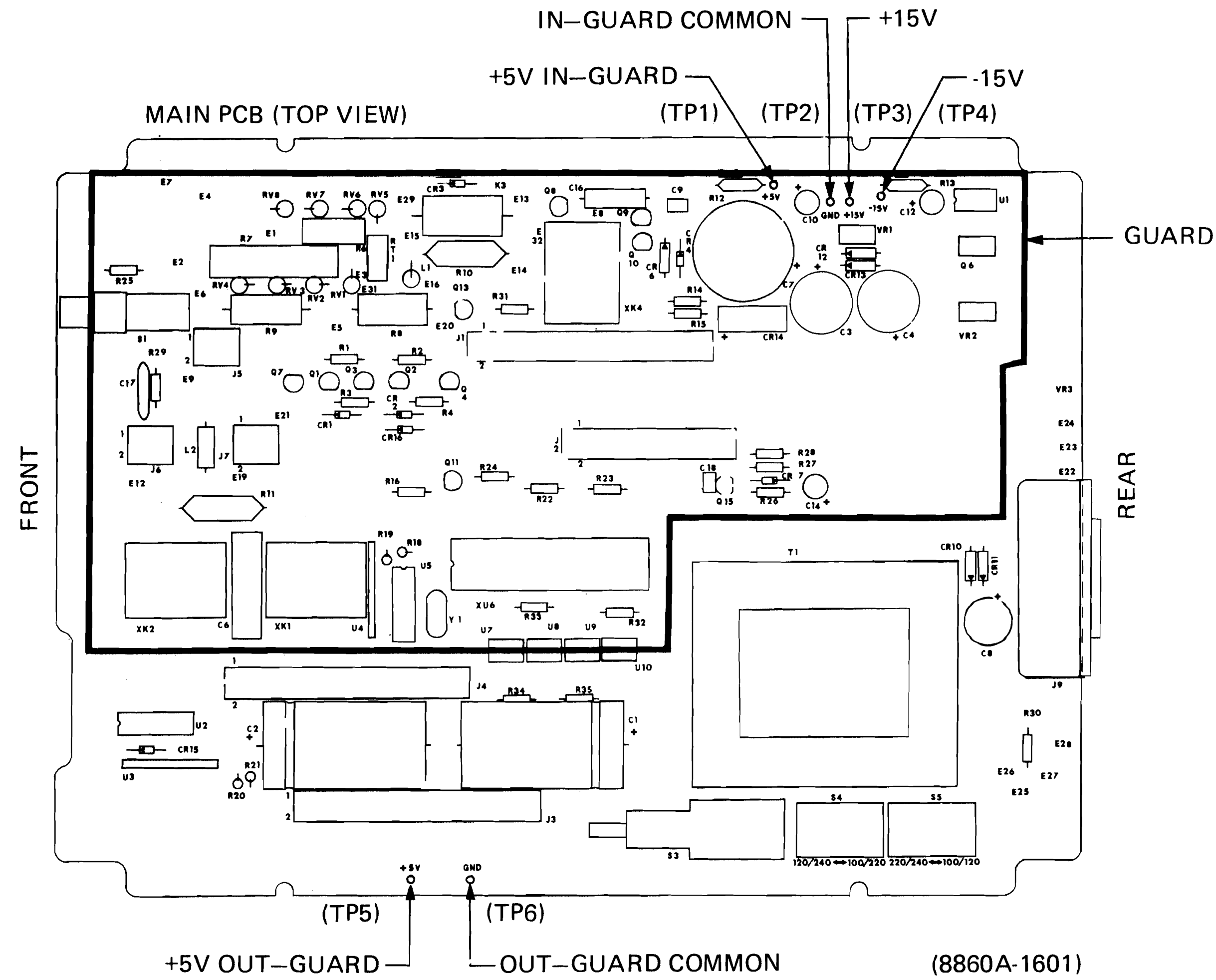


Figure 4-2. Power Supply Test Points

Table 4-2. Power Supply Assignments (Troubleshooting Section, Power Supply)

POWER SUPPLY	TEST POINTS	TOLERANCE	SUPPLIES ONLY THE FOLLOWING CIRCUITRY
In-guard +15V -15V (relative to inguard common, TP2)	TP3 TP4	14.25V to 15.75V -14.25V to -15.75V	On the AC/DC Scaling PCB (A4): all circuitry except comparator reference level (R40, R41) On the A/D & Ohms PCB (A5): all circuitry except U21 and comparator reference level (U20)
In-guard +5V (relative to inguard common, TP2)	TP1	4.7V to 5.3V	On the Main PCB (A1): -15V supply (U1) in-guard processor (U6) opto-isolator circuitry (U5) relay coils (K1-K4) On the AC/DC Scaling PCB (A4): comparator reference level (R40, R41) On the A/D & Ohms PCB (A5): binary to 1-of-4 decoder (U21) comparator reference levels (U20)
Out-guard +5V (relative to outguard common, TP6)	TP5	4.7V to 5.3V	On the Main PCB (A1): opto-isolator circuitry (U2) The entire Display PCB (A2) The entire Controller PCB (A3), which includes: outguard processor local ROM external-trigger one-shot associated latches, flip-flops, and drivers The entire Calculating Controller Option (-004) The entire IEEE-488 Interface Option (-005)
Note: The test points are labeled on the schematic, but not on the circuit board itself.			

4-32. This procedure functionally checks the RMS Converter by tracing a dc signal through the converter while the dc-coupled VAC+VDC function is enabled. Set the 8860A to the VAC+VDC function and the 2V range.

1. Apply +1.000V dc between the HI and LO INPUT terminals of the 8860A.
2. Using the test DMM, measure TP5 on the AC/DC Scaling PCB. The measurement should be within 10 mV of the input value.
3. Move the DMM input to test point E2, the input to the RMS Converter. The voltage measured should be the same as that at TP5.
4. Measure the voltage at TP3, the output of U8. It should measure approximately -1.6V.
5. Reverse the polarity of the input signal and measure the voltage at TP3 again. It should measure approximately +1.6V. If tests 4 and 5 fail, U8, U15, CR6, or CR7 may be at fault.
6. Measure the voltage at TP2. It should be OV ±20mV.
7. Measure the voltage at TP1. It should be -1.2V ±0.1V.
8. Measure the voltage at U19A-1. It should be +5.0V ±25mV.
9. Measure the voltage at E3. It should be +1.0V ±5mV. An offset may be present since auto-zero is not functional for VAC+VDC measurements.

4-33. This procedure functionally checks the RMS Converter by tracing an ac signal through the converter while the VAC function is enabled. Set the 8860A to the VAC function and the 2V range.

Table 4-3. Quick Check to Locate Faulty Analog Circuit

TEST POINTS ON THE MAIN PCB

Use these test points to check the signal path from the front panel input terminals, through the input relays, to the AC/DC Scaling PCB:

TEST POINT	LOCATION	TEST POINT VOLTAGE UNDER THESE CONDITIONS:	
		1V DC INPUT, VAC+VDC, 2V RANGE	1V rms @ 300 Hz INPUT, VAC, 2V RANGE
E2	Junction of W6 and R7	1V dc	—
E19	Junction of W11 and L2 (checks K1)	1V dc	—
E29	Junction of K3 and W12 (checks K3)	1V dc	—
E19	Checks K2	—	1V rms

TEST POINTS ON THE AC/DC SCALING PCB

TEST POINT	LOCATION	TEST POINT VOLTAGE UNDER THESE CONDITIONS:	
		10V DC INPUT, VDC, 20V RANGE TRIG ARM ENABLED	10V DC INPUT, VAC+VDC, 20V RANGE, TRIG ARM DISABLED
TP8	AC/DC Scaling (output of JFET bias amplifier)	100 mV dc +/-25 mV*	100 mV dc +/-25 mV*
TP5	AC/DC Scaling (Output of scaling amplifier)	0V dc +/-10 mV*	1V dc +/-10 mV*
TP2	RMS Converter (U16 inverting input)	0V dc +/-20 mV*	0V dc +/-20 mV*
TP3	RMS Converter (Output of absolute value converter)	0V dc +/-500 mV* (Will be very noisy)	Approx. -1.6V dc
TP1	RMS Converter (Output of 2X log amplifier)	—	Approx. -1.2V dc
E3	RMS Converter (Output of RMS Converter)	0V dc +/-5 mV	1V dc +/-5 mV*

*These are dc offset voltages; the tolerances are approximate. Steady, noise free readings are more important than accuracy.

Table 4-3. Quick Check to Locate Faulty Analog Circuit (cont.)

TEST POINTS ON THE A/D & OHMS CONVERTER PCB					
TEST POINT	LOCATION	TEST POINT VOLTAGE ACCORDING TO RANGE WITH THE INPUT TERMINALS SHORTED			
		200Ω/ 2 kΩ	20 kΩ	200 kΩ/ 2 MΩ	20 MΩ
U1-10	Ohms Converter	8.6V to 9.7V	7.1V to 7.3V	6.95V to 7.05V	0.69V to 0.71V
TP9	Ohms Converter	7.00V below the reading at U1-10			
U10-2	Precision Reference	-0.99980V to -1.00000V dc			
U10-3	Precision Reference	-6.478V to -6.482V dc			
Enable the TRIG ARM function before measuring the following test points:					
TP11	A/D Converter	0Vdc +/-50 mV			
TP12	A/D Converter	0V dc +/-50 mV			
TP13	A/D Converter	0V dc +/-50 mV			
Turn the 8860A power off, and remove the AC/DC Scaling PCB. Turn the power back on, and select the VAC function, 2V range. Temporarily connect A2-7 (A/D input) to U10-2 (-1 volt reference) with a clip-lead wire. The display reading should be a value from .99960 to 1.00020. Reinstall the AC/DC Scaling PCB after this test.					

1. Apply a 1V, 100 Hz sine wave to the 8860A HI and LO INPUT terminals. Using a scope, monitor TP5 on the AC/DC Scaling PCB. The ac input should appear as a clean, undistorted sine wave.
2. Move the scope probe to TP3 of the absolute value converter. The signal should appear as in Figure 3-4 (TP3).
3. Move the scope probe to TP1 of the 2X Log Amplifier. The signal should appear as in Figure 3-4 (TP1). The waveform should be free of oscillations and noise. Waveform symmetry is not critical. If the waveform is not correct the problem is in the 2X log amplifier, the log feedback amplifier, or the antilog amplifier.
4. Using the DMM, measure the dc output voltage of the RMS-to-DC converter at E3. It should measure +1V dc with an applied input of 1V rms ac.

4-34. The following tests should be performed if the RMS-to-DC Converter is functional but will not calibrate properly:

1. Short the 8860A input terminals. Select VAC function, 20V range.
2. Measure the voltage at TP5. It should be 0 ±0.01 mV dc.
3. Measure the voltage at TP2. It should be 0 ±0.01 mV dc.
4. Using a scope, check TP3 to see that R46 can provide adjustment on either side of zero. If the adjustment is not possible, U15 or the 2X log amplifier may be at fault.

4-35. Ohms Converter

4-36. If the voltage at point U1-10 is outside the values given in Figure 4-3 the Ohms Converter is at fault. To isolate the fault, temporarily disable the feedback loop by connecting a short across R4 with a clip lead. Then check the operational amplifier by placing a short across the 8860A INPUT terminals, selecting Ω2T function and 2 MΩ range, and shorting TP9 on the Ohms Converter to (E5). In this configuration, pins 26 and 29 of hybrid A1 should measure within 10 mV of each other (at approximately +12.75V dc). Also, the voltage at U4-6 should be within 7 mV of TP9.

NOTE

Disconnect the jumper from TP9 and E5 before continuing.

4-37. The reference current can be tested by checking the voltage between TP9 and the cathode of CR1 while the 8860A is on the 2 KΩ range. The voltage should be 7.00V dc. (The short across R4 may be left in place.) JFETs Q8

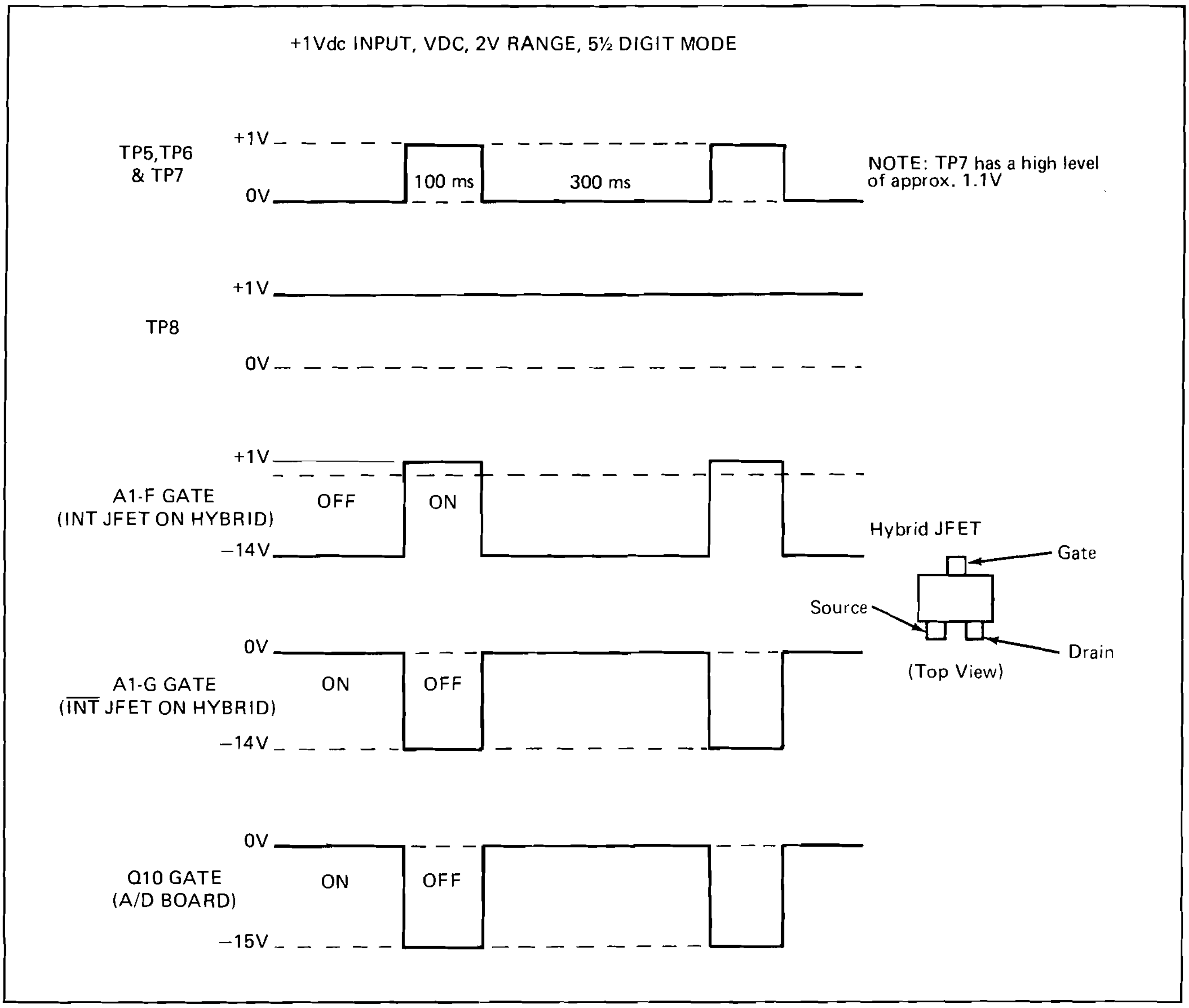


Figure 4-3. AC/DC Scaling Waveforms

and Q9 on the Main PCB are important for leakage control as well as protection. If either JFET leaks excessively, readings on the high-resistance ranges will drift during warm-up.

4-38. If the Ohms Converter malfunctions only on certain ranges, then the output voltages from U6 and U7 should be checked. Use the switch state table shown with the Ohms Converter schematic in Section 8.

4-39. The voltages across the U1 resistors 7.017, 70.71, and 778.9 kilohms should be 7.00V dc when the associated range is selected, and 0.00V dc otherwise. Each resistor can be checked in-circuit for the correct resistance value with an ohmmeter when either the 2MΩ or 20 MΩ range is selected. Isolation between pins 9, 12, and 16 on A1 can also be measured with either the 2 MΩ or 20 MΩ range selected. For example, the resistance between pins 12 and 16 of A1 should be approximately 77.8 kilohms, which is the series value of R3, 70.71 kilohms and 7.017 kilohms.

4-40. Precision Voltage Reference

4-41. Voltage readings at pins 1, 2 and 3 of resistor network U10 should be within the following limits. Refer to the theory of operation (Precision Voltage Reference) in Section 3 for help in troubleshooting the voltage reference.

1. U10-1: 0.0V
2. U10-2: -1.0V ±100 uV
3. U10-3: -6.48V ±1 mV

4-42. The reference amplifier U22, and resistors R41 and R42 must be replaced as a set if U22 is faulty. After U22 is replaced, perform the jumper selection procedure given at the end of this section under Post Repair Procedures.

4-43. A/D Converter

4-44. Troubleshooting information for the A/D Converter is presented in four parts. First, a list of possible problems and symptoms is given in Table 4-6. This is followed by a functional check of the A/D Converter with

Table 4-4. Typical Symptoms of AC/DC Scaling Faults

SYMPTOMS	INSTRUCTIONS OR COMMENTS
DC PROBLEMS	
1. Input bias current at front panel terminals exceeds 100 pA*	
2. Downscale performance in VDC, 200 mV and 20V ranges is out of specification 3. Downscale, low frequency signals read too high on 200 mV range of VAC but not in VAC+VDC (see following note)	Symptom may indicate excessive leakage current in a JFET (dual JFETs Q16 and Q17 are usually not at fault). If the faulty JFET is localized to hybrid A1, replace the entire hybrid assembly. Otherwise, replace discrete JFETs one at a time until the fault clear. Use the guidelines mentioned in the preceding paragraph to identify leaking FETs.
NOTE In VAC and VAC+VDC, the display will indicate a reading (typically less than 400 counts in the 200 mV range) even when the input is shorted. This reading will not affect the rated accuracy over the specified input range and does not indicate a fault condition.	
4. VDC function inoperative, VAC operative	Check for the presence of the waveforms shown in Figure 4-3. Check operation of the INT, $\overline{\text{INT}}$, or A1-D JFETs.
AC PROBLEMS	
1. Excessive peaking of frequency response on the 20, 200, or 700 VAC ranges	Check the voltage at TP8. If it exhibits peaking, then the fault is ahead of the scaling amplifier in the front end. Check both Q6 on the AC/DC Scaling PCB and Q13 on the Main PCB.
2. Poor frequency response on the 200 mV or 2V range, VAC	Check R10, R11, C8, and the JFET switches in the front end. Check U6B and C17, and the voltage at TP7; it should be approximately 2 X Vin. Check the ON resistance of Q12 and Q18. It should be less than 30 ohms.

*To measure input bias current, select VDC and the 200 mV range, short the input terminals and note the display reading. Remove the short and replace it with a 1 megohm resistor in parallel with 0.1 uF capacitor. Note the new reading. A large difference between readings indicates a large input bias current. Calculate the bias current by dividing the difference between voltage readings by 1 megohm. For example, a 100 uV difference corresponds to a 100 pA input bias current

autozero enabled. Next, timing diagrams and waveforms are given for a properly operating A/D Converter. Finally, a few useful troubleshooting tips are given.

4-45. INITIAL A/D CHECK IN AUTOZERO

4-46. Enable the autozero mode by pressing FCN, then TRIG ARM on the front panel, or by changing the setting of switch S3, as shown in Figure 4-6. Measure the voltages at TP11, 10, and 12. If they are within the following limits, autozero is working.

1. TP11 should read OV ±25 mV dc.
2. TP10 should read OV ±10 mV dc.
3. TP12 should read OV ±10 mV dc; its ac-coupled rms voltage should be less than 1 mV ac.

4-47. A/D TIMING DIAGRAM

4-48. A timing diagram for the switching JFETs in the A/D Converter is shown in Figure 4-4.

4-49. A/D WAVEFORMS

4-50. The waveforms for a functional A/D Converter are shown in Figure 4-5. These waveforms occur when the 8860A is operating in the continuous mode rather than locked into the autozero mode.

4-51. With +1V dc applied to the 8860A INPUT terminals, the waveform at TP11 should appear as shown in Figure 4-5. There should be no droop or rise in voltage during the INT (integrate) or DE (discharge) periods. Droop can be caused by either a leaky or shorted JFET or

Table 4-5. Typical Symptoms of RMS Converter Faults

SYMPTOMS	INSTRUCTIONS OR COMMENTS
1. RMS Converter does not respond	Check voltages at TP3 and TP1 as described earlier in this section under RMS-to-DC Converter. If the voltages at TP3 are incorrect, the problem is usually in the absolute value circuitry. If TP1 is incorrect, the problem is probably in the 2X log amplifier, the log feedback amplifier or the anti-log amplifier. If U17 or U20 require changing, jumpers W5 through W8 need to be reconfigured. Refer to the Post Repair Procedures at the end of this section for the jumper replacement procedures.
2. RMS Converter is functional, but the reading is noisy.	U15 may be defective. Also check U16, U8 and the logging arrays (U17 and U20).
3. Poor downscale performance on all ranges.	Check calibration adjustments for TP5 (R27), RMS Zero (R46), RMS offset (R54), or R73. Also check U15 and U19.

Table 4-6. Typical Symptoms of A/D Converter Faults

SYMPTOM	POSSIBLE CAUSE
1. Incorrect Scale Factor	• Precision reference malfunction. • Q10 faulty or has drive signal missing.
2. Nonlinear Response	• One or more JFETs on the A2 hybrid are faulty. • AZ2 or Delta-2 operation is faulty.
3. Persistent Overrange Indication	• Precision reference malfunction. • Integrator, slope amplifier, or A/D comparator malfunction.
4. Unstable (Noisy) Reading	• Faulty op amps or JFETs within the autozero loop. C7 may also be defective.
5. Excessive Offset	• Faulty JFETs in the autozero loop, or drive signals missing. • Q8 or Q9 faulty, or their drive signals are absent. • Offset is not properly adjusted.
6. Full Scale Reading Not Possible	• Integrator malfunction or faulty operation of Q4.

by a defective JFET driver (U15-U17). The figure also shows the correct response to a +1 mV dc and a +1.9V dc input. Notice that the DE width varies in proportion to the magnitude of the input signal.

4-52. The waveform shown in Figure 4-5 for the junction of C7 and Q5 is the signal that should appear at the integrator summing junction with inrange and overrange inputs. Improper response to overrange inputs suggests a malfunction during AZ2, particularly of Q4 or its driver.

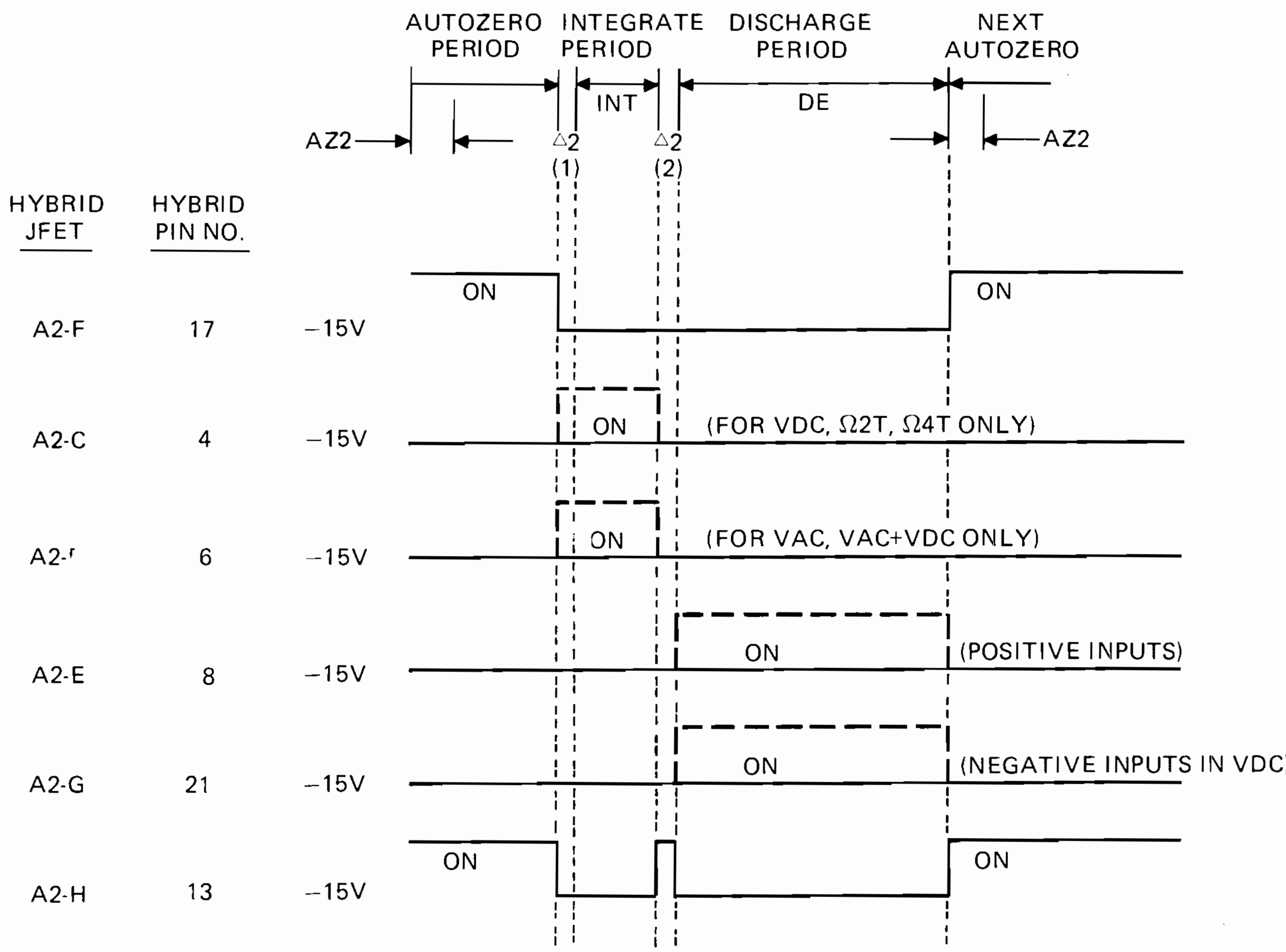
4-53. The waveforms shown for the junction of R47 and Q5 give a quick check of JFET Q5 and transistor Q12. The pulses occur during the two Delta-2 periods.

4-54. The two TP10 waveforms of Figure 4-5 show the normal signal at the integrator output for inputs of +1 V dc and overrange. Note during overrange that the voltage returns very rapidly to zero during the AZ2 period.

4-55. The two TP12 waveforms of Figure 4-5 show the signal that should be present at TP12 for +1V dc and 0.0V dc (shorted) inputs. Voltage limiting is caused by diodes CR5, 6, 8, and 9. When the input voltage is zero, one of two waveforms is present at TP12, depending on the sign of the display (+0.0 or -0.0). The voltage at TP12 should not change more than 3 mV during the integrate period.

4-56. A/D TROUBLESHOOTING TIPS

4-57. Signal paths ahead of the A/D Converter can be bypassed by removing the AC/DC Scaling board and applying dc test voltages to A2-3 for VDC and A2-7 for VAC. When VAC is selected, no polarity sign appears.



NOTE:

1. Each JFET timing diagram represents the gate voltage. In the high state the gate is pulled up to the same voltage as the JFET channel.
2. The transitions with dashed lines are conditional as indicated.
3. Hybrid JFET A2-A is ON and stays ON as long as EXT. REF. is selected. Hybrid JFET A2-B is ON and stays ON as long as EXT. REF. is not selected
4. The lengths of the △ 2 periods are exaggerated for clarity.

Figure 4-4. Timing Diagram for A/D Converter JFETs

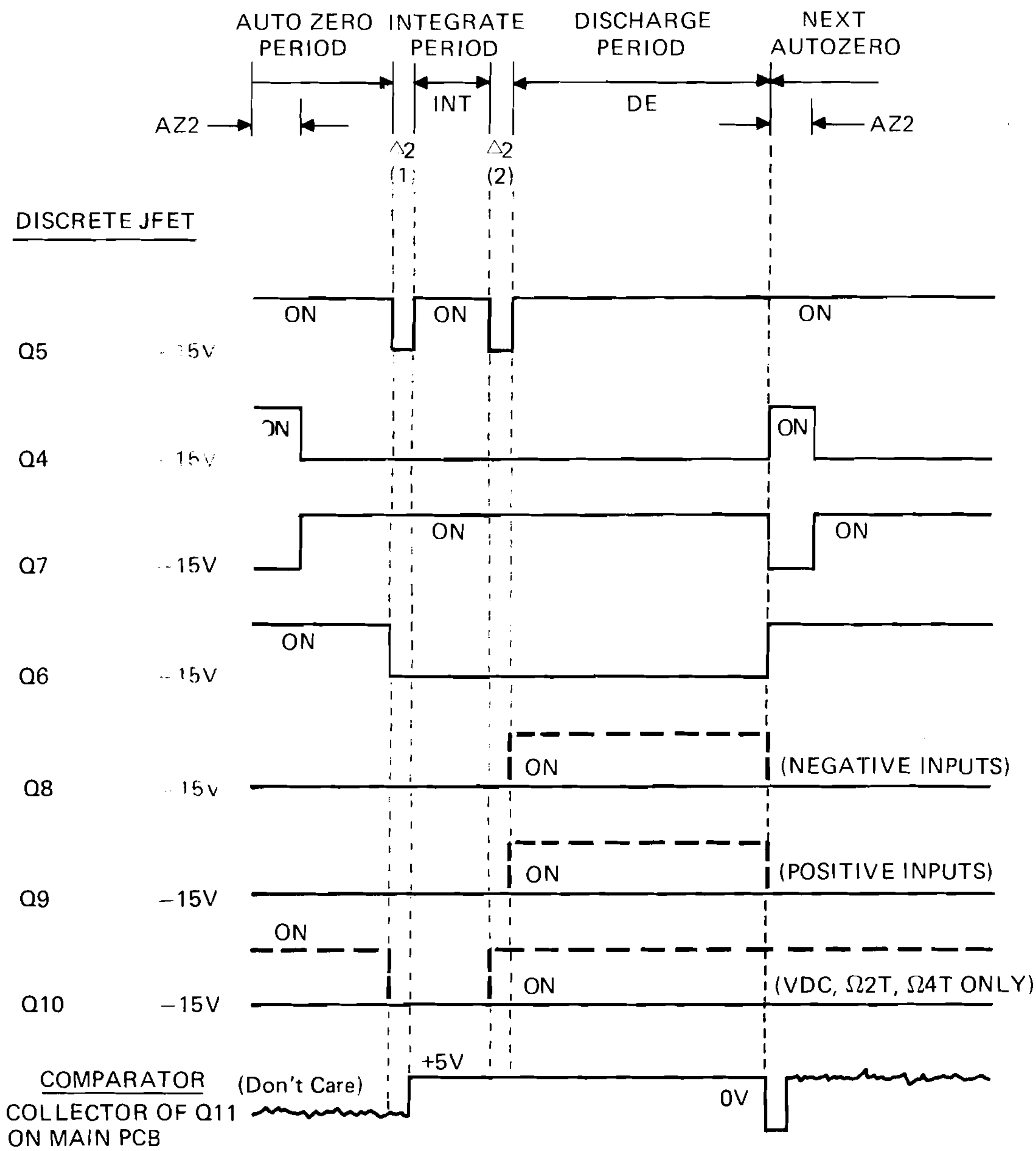


Figure 4-4. Timing Diagram for A/D Converter JFETs (cont)

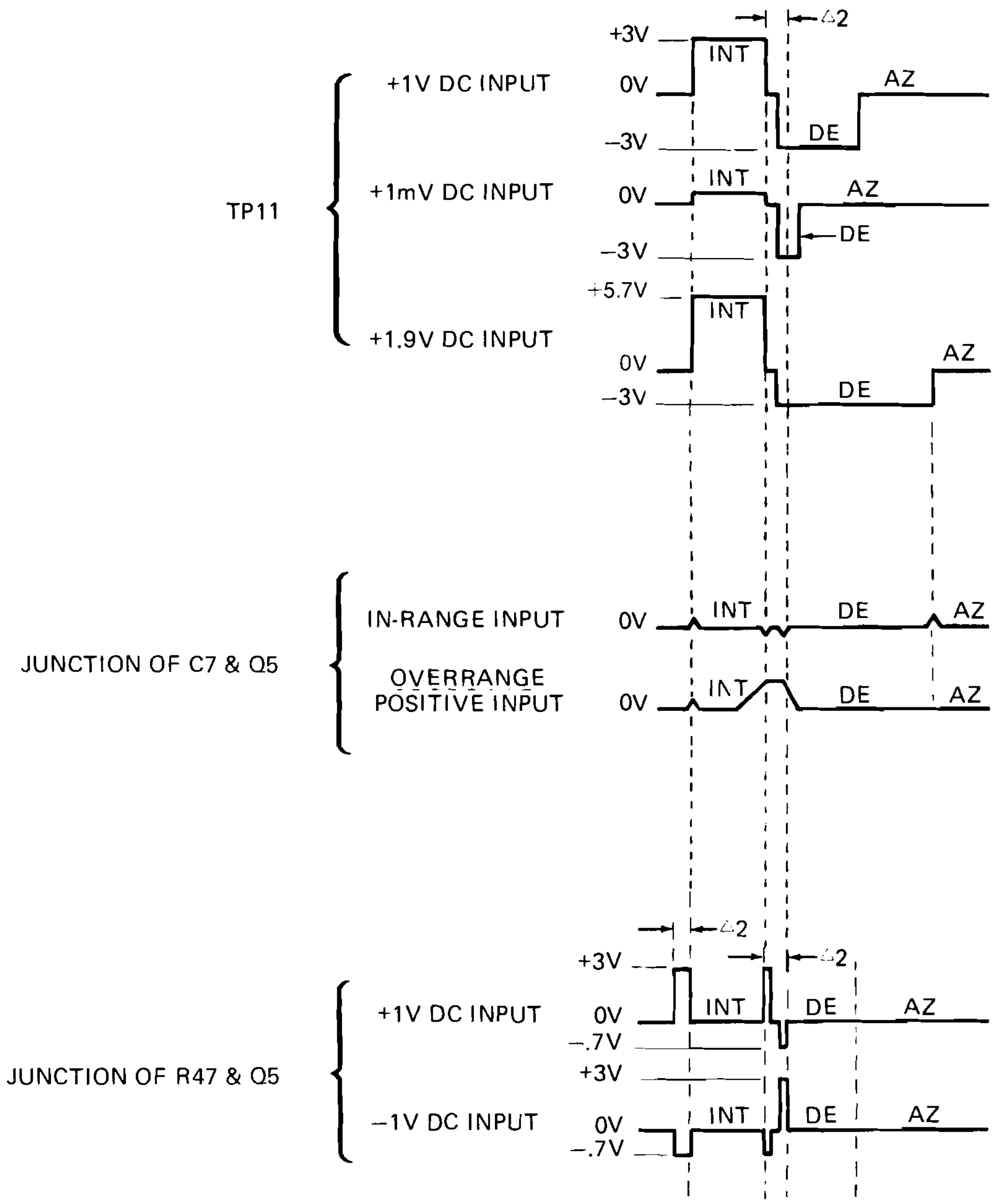


Figure 4-5. Signal Waveforms in A/D Converter

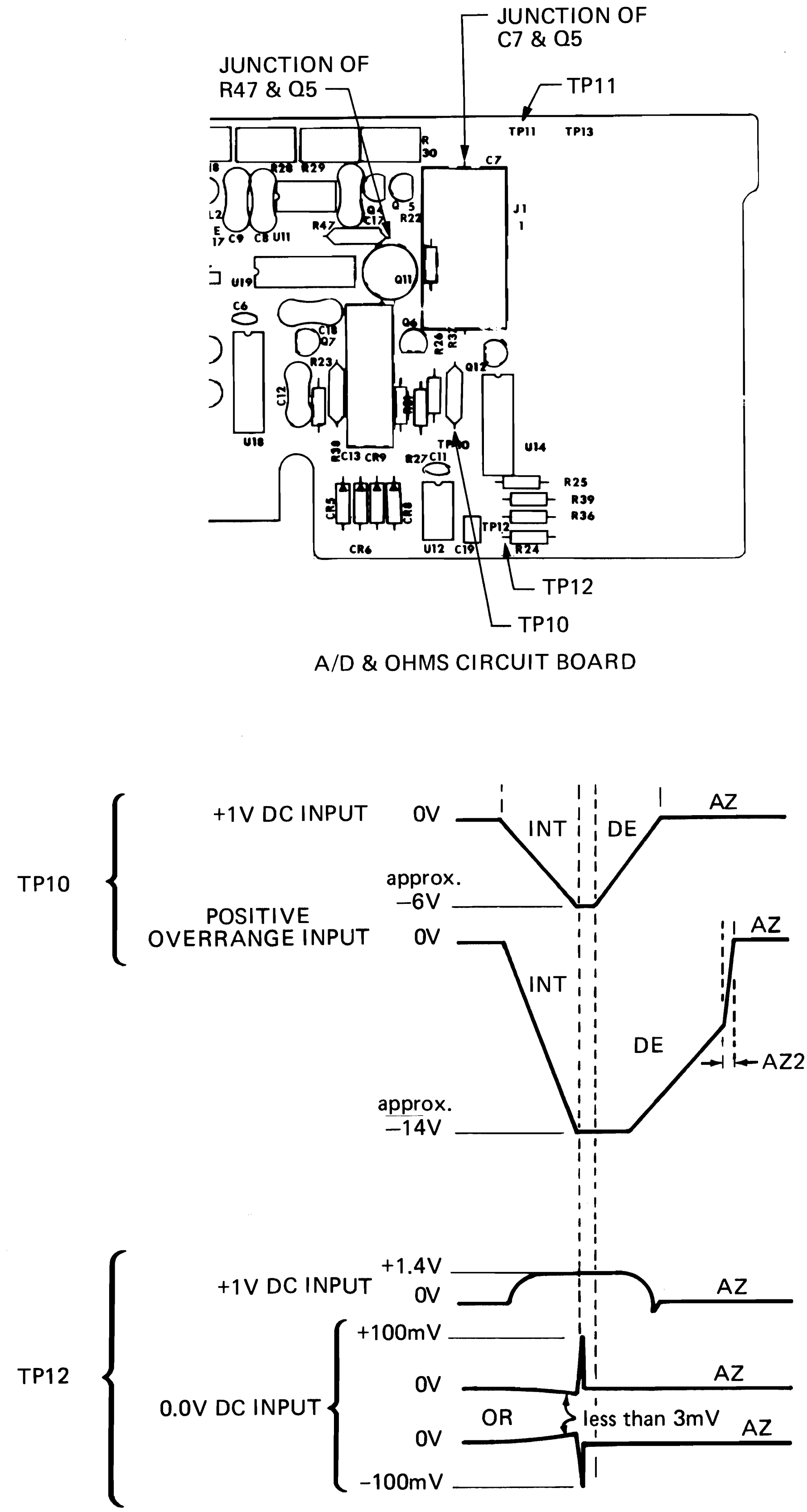


Figure 4-5. Signal Waveforms in A/D Converter (cont)

4-58. Operation in the 4½ or 3½ digit mode makes the A/D cycle easier to observe, due to the higher sample rate. To select the 3½ digit mode, set switch S1 to the TM1 position. This switch, shown in Figure 4-6, is located on the top edge of the Controller PCB.

NOTE

Be sure to return both S1 and S3 slide switches to NORM after trouble shooting. Otherwise the instrument will remain in autozero or in the 3½ digit mode.

4-59. DIGITAL TROUBLESHOOTING OF BASIC INSTRUMENT

4-60. General troubleshooting information for the digital section of the 8860A is given in Table 4-7. The table provides a list of solutions for general symptoms. The symptoms are separated into two categories: error message displayed or no error message displayed. Error code descriptions follow the table.

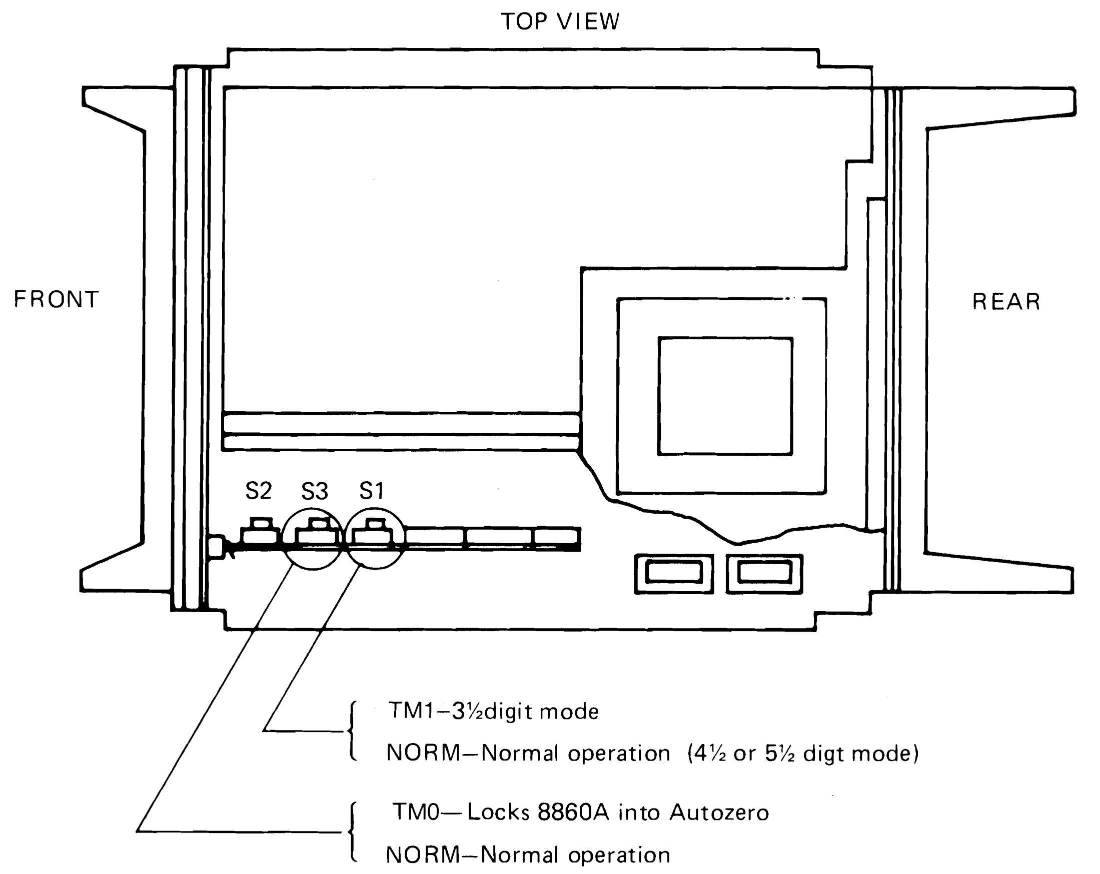
4-61. Error Messages

4-62. Basic instrument error mesages fall into two categories: user errors and internal DMM errors. User errors can generally be corrected at the front panel. They are:

Err 10 — External reference has been selected, but the -007 option circuit board is not installed. To correct, install the option or cancel the selection.

Err 11 — Front panel ZERO function has been attempted, but the input is greater than the allowed range of ±99 uV or ±99 mΩ. To correct, verify that the input terminals are shorted.

Err 13 — Exponent magnitude is too large. This occurs when attempting to enter a number which exceeds ±1.99999 X 10^{99} into the High, Low, or Offset register (e.g., NUM 2 EEX 99 FCN STORE HIGH).



Note:

1. If, while S3 (TM0) is set to Autozero, power is turned off and back on, the display will remain blank. Correct by switching S3 off and back on.
2. Switch S2 is set for the ac line frequency (50 or 60 Hz) to maximize line rejection for the 4½ digit mode.

Figure 4-6. Slide Switches Used in Troubleshooting

Table 4-7. Digital Troubleshooting of Basic Instrument

This table is divided into two sequences: choose the first if an error message is displayed, or the second if an error message is not displayed. Both sequences assume that the fault is digital and not analog. Perform the steps in sequence; stop when the fault disappears. Remove the 8860A from line power before unplugging printed circuit boards or removing components.

IF AN ERROR MESSAGE IS DISPLAYED (Err 12, 14, 15, 16, or 17), the fault is confined to the guard-crossing circuitry, one of the microprocessors, or the interconnections:

SUSPECT AREA	INSTRUCTION
1. Loose Connector	Remove and reseat the Controller PCB (in case it was jarred loose from its connector). Check to see if this clears the fault.
2. Power Supply (Main PCB)	Measure the +5V out-guard supply voltage. It should be +4.7 to +5.3V dc.
3. Out-guard Microprocessor (U2 on Controller PCB)	Replace U2, observing static precautions.
4. In-guard Microprocessor (U1 on Main PCB)	Replace U1.
5. Guard-Crossing Circuitry (on Main PCB)	With any of these error messages, transmissions between micro-processors will stop. Test each opto-isolator individually, as in Table 4-8, and observe the waveform at the noted test point. A good opto-isolator will produce an inverted 5V square wave at the test point.
6. I/O Expander (U3 on Controller PCB)	If the fault has still not cleared, check the PROG control line (pin 7) and data lines (pins 8, 9, 10, 11). Replace this device (U3) if any lines are stuck high or low. (Access these pins from the non-component side of the board.)

IF NO ERROR MESSAGE IS DISPLAYED, then the in-guard microprocessor and guard-crossing circuits are probably good. The fault is instead on either the Controller or Display PCB. The following sequence of steps checks all integrated circuits, U1 through U11, on the Controller PCB. Perform these steps in sequence:

SUSPECT AREA	INSTRUCTION
1. Connector or Slide Switches (on Controller PCB)	Remove and reseat the Controller PCB (in case it was jarred loose from its connectors). Also make sure that slide switches S1 (TM1/NORM) and S3 (TM0/NORM) at the top edge of the board are in their normal position (NORM).
2. Digital Option (-004 or -005)	If present, remove the option PCB (Calculating Controller or IEEE-488). If the fault clears, troubleshoot the option assembly using the procedures given in Section 6 of this manual.
3. Power Supply (on Main PCB)	Check the output of the +5V out-guard supply. It should be 4.7V to 5.3V.
4. Out-guard Microprocessor (U2 on Controller PCB)	Replace U2 observing static precautions. Check pin 4, the reset line. It should be at +5V after power up; if stuck low, C1 may be defective.
5. Crystal	Check line ALE (pin 11 of U2) for a 400 kHz square wave. If this signal is not present, crystal Y1 or capacitors C2 or C3 may be defective. Check either pin of the crystal for a 1V pk-pk sinusoid, 6MHz waveform.

Table 4-7. Digital Troubleshooting of Basic Instrument (cont)

SUSPECT AREA	INSTRUCTION
6. Display PCB	If one or more of the 7-segment display digits never light up, check pins 2, 4, and 6 of U7 on the Controller PCB for activity (these lines scan the display and keyboard). If all lines are switching, the Controller PCB is probably good; check the Display PCB, devices U1 and Q1 through Q8. All U1 outputs should be switching. Also make sure the Controller and display PCBs are firmly seated in their connectors. If at least one of pins 2, 3, or 6 of U7 (on the Controller PCB) is stuck high or low, suspect the Controller PCB, especially devices U3 or U7. Check the corresponding input pins of U7 for activity.
7. Bad LED Display Segment	Replace the 7-segment digit.
8. Segment Drivers	If the same segment on all digits is out, suspect segment driver U4 or U5 on the Controller PCB. Also check the series resistors U6, R4, R5, R6, and the connector (P2).
9. Local Program Memory (ROM) (U9 on Controller PCB)	Replace if a spare is available; check to see if fault has cleared.
10.Control Lines (on Controller PCB)	With a known good out-guard microprocessor in place, look at the control signals $\overline{\text{PSEN}}$, ALE, and PROG generated by the processor; all should be switching. If one is stuck high or low, remove the ICs connected to that line until the line is freed.
11.Data Bus (on Controller PCB)	Check the data bus for a stuck line; all lines should be switching. If a line is stuck high or low, suspect U9 or U10. Check U10 as described in step 12.
12.Address Latch (U10 on Controller PCB)	If you suspect that address latch U10 is faulty, use a dual-trace scope to check its operation. Trigger the scope on ALE and look at the input and output of each bit. If ALE and the latch are working properly, the output follows the input value when ALE is high and latches when ALE goes low.
13.Resistor Network (U8 on Controller PCB)	Check U8 for a bad resistor, using a low-voltage ohmmeter (to prevent diode turn-on). With U8 in the circuit, all resistors should measure somewhere between 5 kΩ and 40 kΩ.
14.External Trigger	U11 and half of U1 is used to condition the external trigger signal (the other half of U1 is used to condition a signal from a digital option). If devices U1 or U11 are faulty, they will not hang up the instrument unless U1-13 is low. This pin should be high when a digital option is not present in the instrument.

Err 18 — An input or offset value exceeds 1999.99V or 19.9999 MΩ. To correct, reduce the value to an acceptable level.

4-63. Error numbers 12, 14, 15, 16, and 17 represent internal DMM errors, and when they persist, generally indicate a hardware failure in the guard-crossing. Hardware faults associated with these error codes are confined to the opto-isolator circuitry, the in-guard microprocessor, the I/O Expander U3, the out-guard microprocessor, or the paths connecting these devices. The troubleshooting procedure is basically the same for each of these errors, and is given in Table 4-7. (A high input voltage transient may cause an Err 14, 15, 16, or 17 to be displayed for up to 4 seconds. This is not considered a fault condition.)

4-64. When the in-guard and out-guard microprocessors communicate, they check the accuracy of the transmission in each direction: Err 12, 14, and 15 indicate errors in communication from in-guard to out-guard circuits; Err 16

Table 4-8. Testing Guard-Crossing Circuitry

1. For out-guard to in-guard circuit paths:
   a. Remove the Controller PCB from connector J3.
   b. Check the clock path by applying a square wave (0 to +5V) to J3-15, and, using a scope, observe the resulting waveform at U6-14. Record the propagation time.
   c. To check the data path, repeat step b using J3-13 as the input and U6-15 as the output.
2. For in-guard to out-guard circuit paths:
   a. Remove U6 (the in-guard microprocessor) and the Controller PCB from their sockets.
   b. Check the clock path by applying a square wave (0 to +5V) to U6-12, and, using a scope observe the resulting waveform at U2-1. Record the propagation time.
   c. To check the data path, repeat step b using U6-13 as the input and U2-2 as the output.
3. The measured propagation times of the two paths should differ by less than 7 us. A greater difference will cause occasional transmission errors. A difference greater than 15 us will cause a continuous error message to be displayed.
4. Measure the voltage at pin 4 of each opto-isolator with the square wave applied as in steps 1 and 2. The high level should be at least 0.42V.
5. If either the propagation delay or the voltage level requirements are not met, replace the opto-isolator.

and 17 indicate errors in communication from out-guard to in-guard circuits.

Err 12 — Measurement data received by the out-guard microprocessor from in-guard circuitry is not BCD. The out-guard microprocessor receives measurement data bit-by-bit. Every four bits is verified as a BCD character (0-9). If a hexadecimal character (A, B, C, D, E, or F) occurs, for whatever reason (e.g., bad data or lost synchronization), Err 12 is declared.

Err 14 — The out-guard microprocessor cannot start receiving data from in-guard circuitry. After transmitting command data to the in-guard circuits, the out-guard microprocessor waits up to 3.5 seconds in remote or 4.2 seconds in local for the in-guard microprocessor to respond. This is enough time for any complete measurement cycle. If the out-guard microprocessor does not receive a message or receives a wrong message, it declares Err 14.

Err 15 — The out-guard microprocessor has received either invalid data or no data. If, after the in-guard microprocessor starts transmitting, the out-guard microprocessor receives the incorrect clock bit, or has to wait longer than 518 μs for data, Err 15 is declared.

Err 16 — The out-guard microprocessor cannot start transmitting to the in-guard microprocessor. When the out-guard microprocessor is ready to transmit to the in-guard circuit, it sends a ready message. If the in-guard microprocessor does not echo the message within 3.4 seconds, Err 16 is declared.

Err 17 A transmission error from the out-guard microprocessor to the in-guard microprocessor has occurred. When data is sent to the in-guard microprocessor, each bit is echoed back to the out-guard microprocessor. The in-guard microprocessor must correctly echo each bit within 495 μs, or Err 17 is declared.

4-65. Messages are transmitted across the guard using parallel clock and data lines. The clock bit toggles with each transmitted data bit. As a data message is sent, the receiving microprocessor returns (echos) the data and clock bits to the sender for comparison. For instance, if the out-guard microprocessor transmits data bit 1, the in-guard microprocessor sends back data bit 1. This echo assures the out-guard microprocessor that the message was correctly received. The data echo occurs for each bit transmitted in either direction. Error 15 or 17 is declared when an echo bit differs from the bit sent.

4-66. Error codes 14 and 16 usually occur when the microprocessors have lost synchronization, and a transmission cannot get started. Errors 15 and 17 mean that the microprocessors started in sync, but then lost a bit. The out-guard microprocessor is the master, and the in-guard microprocessor is the slave. Whenever the echo time period elapses, the in-guard microprocessor defaults to receiving, while the out-guard microprocessor defaults to transmitting.

4-67. Error messages are buffered one deep. If, for example, two errors occur and clear within milliseconds of each other, both errors will be displayed, one after the other, for approximately 1.1 seconds each.

4-68. TROUBLESHOOTING AIDS

4-69. Visual Inspection

4-70. Visual inspection can sometimes quickly locate instrument faults, saving troubleshooting time. Use the Disassembly procedure presented earlier in this section to remove the top cover. Carefully inspect each circuit board for:

- loose or broken wires and component leads
- improperly seated plug-in assemblies
- physically damaged components
- discoloration due to arcing or overheating
- discolored or burnt capacitors or resistors
- cracked or bulging resistors, diodes, thermistors

4-71. Short Circuit in Power Supply

4-72. Current Tracer probes, such as the HP 547A, are usually the best way to locate a short that loads the power supply. To locate such a short, start at the output of the power supply and move the Current Tracer along the supply output path until the short is found. The Current Tracer will glow brightest at the terminal of the shorted component. Shorted logic elements are more difficult to locate because of the small currents involved.

4-73. Intermittent Faults

4-74. To locate intermittent and temperature induced faults, alternately warm and cool the suspect circuits. A heat gun and a can of aerosol circuit cooler are recommended as the heating and cooling agents.

4-75. Connectors with Poor Contacts

4-76. If connectors are suspected of making poor contact, clean the circuit board fingers by rubbing them with a cotton swab moistened with isopropyl alcohol. Do not use abrasives to clean the gold-plated contacts.

4-77. POST REPAIR PROCEDURES

4-78. The 8860A contains a series of factory selected jumpers in the RMS Converter and the Precision Voltage Reference circuits. After either of these circuits have been repaired by parts replacement, it may be necessary to change their jumper settings. The parts that affect the jumper settings are as follows:

- RMS Converter — U17 or U20
- Precision Voltage Reference — U22

4-79. Instructions for verifying and or relocating the jumper settings are given in Tables 4-9 and 4-10. Table 4-9 contains the procedure for the RMS Converter. The procedure for the Precision Voltage Reference is given in Table 4-10.

Table 4-9. Jumper Selection, RMS Converter

After replacing U17 or U20 on the RMS Converter, use the following procedure to verify and/or select the jumper locations:

1. Locate the row of sleeved jumpers adjacent to U18, the RMS resistor network.
2. Solder short lengths of solid wire in place of any jumpers that have been previously cut.
3. Install all pcb assemblies, and turn-on power to the 8860A.
4. Connect a short between the 8860A INPUT terminals, and select the VAC function, 2V range.
5. Connect a DMM between the INPUT LO terminal of the 8860A and each of the following test points on the AC/DC Scaling PCB Assembly. At each test point measure the dc voltage. If necessary, bring the voltage within limits by making the indicated adjustment.

Test Point	Adjustment	DC Voltage Reading
TP5	R27 Buffer Offset	0.0 +/-0.2 mV
TP2	R54 RMS Offset	0.0 +/-0.2 mV
TP3	R46 RMS Zero	0.0 +/-100 mV*

*Reading will be unsteady.

6. Disconnect both the DMM and the short across the INPUT terminals.
7. Connect an AC Calibrator with a 1V, 200 Hz output to the 8860A input terminals.
8. Center the 1V, 200 Hz adjustment (R67) and the 10 mV, 200 Hz adjustment (R73). Record the 8860A display reading.
9. Use the recorded reading and the list at the end of this procedure to determine which jumpers need to be cut.
10. Turn off power to the 8860A, remove the AC/DC Scaling PCB, and cut the appropriate jumpers.
11. Install the PCB in the 8860A, and perform the calibration procedure (see the Calibration Manual).

RECORDED DISPLAY READING	JUMPERS			
	W5	W6	W7	W8
1.00339 to 0.99664	———	———	———	———
0.99663 to 0.99497	———	———	———	cut
0.99496 to 0.98999	———	———	cut	———
0.98998 to 0.98508	———	———	cut	cut
0.98507 to 0.98023	———	cut	———	———
0.98022 to 0.97544	———	cut	———	cut
0.97543 to 0.97071	———	cut	cut	———
0.97070 to 0.96603	———	cut	cut	cut
0.96602 to 0.96141	cut	———	———	———
0.96140 to 0.95685	cut	———	———	cut
0.95684 to 0.95234	cut	———	cut	———
0.95233 to 0.94788	cut	———	cut	cut
0.94787 to 0.94347	cut	cut	———	———
0.94346 to 0.93912	cut	cut	———	cut
0.93911 to 0.93481	cut	cut	cut	———
0.93480 to 0.93056	cut	cut	cut	cut

Table 4-10. Jumper Selection, Precision Voltage Reference

After replacing U22, R41, and R42 in the Precision Voltage Reference Circuit (A/D and Ohms Converter PCB), use the following procedure to verify and/or select the jumper locations:

1. Connect a precision 1.0V dc source to the INPUT terminals of the 8860A; select the VDC function, 2V range.
2. Adjust R17 (+1V CAL) for a display reading of +1.00000. If this adjustment is achieved, the existing jumper locations are correct; perform the calibration procedure (see Calibration Manual). If the adjustment cannot be made, continue with this procedure.
3. Locate the row of sleeved jumpers adjacent to U10 in the Precision Voltage Reference circuit.
4. Solder short lengths of solid wire in place of jumpers which have been previously cut.
5. Install all pcb assemblies, and turn-on power to the 8860A.
6. With the precision 1.0V dc source still connected to the INPUT terminals, turn R7 counterclockwise until the reading no longer decreases. Record the reading.
7. Use the recorded reading and the list at the end of this procedure to determine which jumpers need to be cut.
8. Turn off the 8860A, remove the A/D and Ohms Converter PCB, and cut the appropriate jumpers.
9. Install the pcb in the 8860A, and perform the calibration procedure (see the Calibration Manual).

RECORDED DISPLAY READING	JUMPERS				
	W4	W5	W6	W7	W8
0.99923 to 0.99372	———	———	———	———	———
0.99371 to 0.98827	———	———	———	———	cut
0.98826 to 0.98287	———	———	———	cut	———
0.98286 to 0.97753	———	———	———	cut	cut
0.97752 to 0.97225	———	———	cut	———	———
0.97224 to 0.96703	———	———	cut	———	cut
0.96702 to 0.96186	———	———	cut	cut	———
0.96185 to 0.95675	———	———	cut	cut	cut
0.95674 to 0.95169	———	cut	———	———	———
0.95168 to 0.94669	———	cut	———	———	cut
0.94668 to 0.94173	———	cut	———	cut	———
0.94712 to 0.93683	———	cut	———	cut	cut
0.93682 to 0.93198	———	cut	cut	———	———
0.93197 to 0.92718	———	cut	cut	———	cut
0.92717 to 0.92243	———	cut	cut	cut	———
0.92242 to 0.91773	———	cut	cut	cut	cut
0.91772 to 0.91307	cut	———	———	———	———
0.91306 to 0.90846	cut	———	———	———	cut
0.90845 to 0.90390	cut	———	———	cut	———
0.90389 to 0.89939	cut	———	———	cut	cut
0.89938 to 0.89491	cut	———	cut	———	———
0.89490 to 0.89049	cut	———	cut	———	cut
0.89048 to 0.88610	cut	———	cut	cut	———
0.88609 to 0.88176	cut	———	cut	cut	cut
0.88175 to 0.87746	cut	cut	———	———	———
0.87745 to 0.87321	cut	cut	———	———	cut
0.87320 to 0.86899	cut	cut	———	cut	———
0.86898 to 0.86482	cut	cut	———	cut	cut
0.86481 to 0.86068	cut	cut	cut	———	———
0.86067 to 0.85659	cut	cut	cut	———	cut
0.85658 to 0.85253	cut	cut	cut	cut	———
0.85252 to 0.84851	cut	cut	cut	cut	cut

Section 5
List of Replaceable Parts

TABLE OF CONTENTS

5-1. INTRODUCTION

5-2. This section contains an illustrated parts breakdown of the instrument. A similar parts listing for each of the Options will be found in Section 6. Components are listed alphanumerically by assembly. Both electrical and mechanical components are listed by reference designation. Each listed part is shown in an accompanying illustration.

5-3. 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 Code-to-Name list).
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 (see paragraph 5-7). 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.

5-4. HOW TO OBTAIN PARTS

5-5. Components may be ordered directly from the manufacturer by using the manufacturer's part number, or from the John Fluke Mfg. Co., Inc. or its authorized representatives by using the FLUKE STOCK NUMBER. In the event the part you order has been replaced by a new or improved part, the replacement will accompanied by an explanatory note and installation instructions, if necessary.

5-6. To ensure prompt and efficient handling of your order, include the following information:

1. Quantity.
2. FLUKE Stock Number.
3. Description.
4. Reference Designation.
5. Printed Circuit Board Part Number and Revision Letter.
6. Instrument Model and Serial Number.

5-7. 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.

5-8. 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

Indicated devices are subject to damage by static discharge.

Table 5-1. 8860A Final Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
	FINAL ASSEMBLY FIGURE 5-1 (8860A-5001/TB)	8860A	89535				
A1	MAIN PCB ASSEMBLY	531640	89536	531640	1		
A2	DISPLAY PCB ASSEMBLY	502708	89536	502708	1		
A3	⊗ CONTROLLER PCB ASSEMBLY	502716	89536	502716	1		
A4	AC/DC SCALING PCB ASSEMBLY	526665	89536	526665	1		
A5	⊗ A/D AND OHMS CONVERTER PCB ASSEMBLY	526673	89536	526673	1		
F1	FUSE, SLO-BLO, 1/4 AMP	166306	71400	MDL1-4	1	5	
H1	SCREW, FHP/SS, 4-40 X 3/16	149567	89536	149567	9		
H2	SCREW, PHP/SS, 6-32 X 1/4	385401	89536	385401	4		
H3	SCREW, 6-32 X 1/4	543447	89536	543447	4		
H4	SCREW, PHP THD/FORM, 2-28 X 3/8	493965	89536	493965	2		
H5	SCREW, PHP, 6-32 X 3/8, S/S	334458	89536	334458	1		
H6	SCREW, PHP, 4-40 X 1/4	256156	89536	256156	1		
H7	SCREW, FHP, U/CUT, 6-32 X 1/4	320093	89536	320093	4		
H8	SCREW, PHP, 4-40 X 3/8	256164	89536	256164	1		
H9	WASHER, FLAT, S/STEEL	260471	89536	260471	3		
H10	WASHER, SPLIT/LOCK, S/STEEL	147603	89536	147603	5		
H11	WASHER, SHOULDER	436386	89536	436386	1		
H12	NUT, HEX, S/STEEL, 4-40	147611	89536	147611	3		
MP1	COVER, GUARD	502575	89536	502575	1		
MP2	PANEL, BLANK SUB-	531004	89536	531004	2		
MP3	CUSHION	541896	89536	541896	2		
MP4	COVER, D-SIZE (WITHOUT SHIELD)	516682	89536	516682	1		
MP5	CUSHION	541870	89536	541870	2		
MP6	CUSHION	545871	89536	545871	1		
MP7	RETAINER STRAP, RELAY	381624	77342	27E348	3		
MP8	PANEL, FRONT	502534	89536	502834	1		
MP9	BUTTON, GRAY (FRONT PANEL)	509232	89536	509232	14		
MP10	BUTTON, ORANGE (FRONT PANEL)	509265	89536	509265	1		
MP11	BUTTON (FRONT PANEL)	509356	89536	509356	1		
MP12	DECAL, FRONT PANEL	507574	89536	507574	1		
MP13	DECAL, BASE SIDES	473652	89536	473652	2		
MP14	PANEL, REAR	502559	89536	502559	1		
MP15	GUARD, MAIN BOARD	509273	89536	509273	1		
MP16	PLUG, REAR PANEL	530998	89536	530998	1		
MP17	GUARD, BASE	502567	89536	502567	1		
MP18	INSULATOR, XSTR	508630	55285	7403-09FR-51	1		
MP19	SPRING CONTACT, SHIELD	525261	89536	525261	3		
MP20	BASE (STANDARD)	454702	89536	454702	1		
MP21	BAIL STAND	467555	89536	467555	1		
MP22	LATCH	467548	89536	467548	2		
MP23	FOOT, NON-SKID	467571	89536	467571	4		
MP24	CONN, BNC FE PANEL MOUNT	414201	02660	31-010	1		

Table 5-1. 8860A Final Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
TM1	8860A INSTRUCTION MANUAL SET (NOT SHOWN)	545004	89536	545004	1		
VR3	VOLTAGE REGULATOR, 3-TERMINAL	538108	89536	538108	1	1	
W1	LINE CORD WITH INTRNL CONN, (NOT SHOWN)	343723	89536	343723	1		
W2	WIRE ASSEMBLY (GRN/YEL)	509348	89536	509349	1		
W18	WIRE ASSY, (BLK)	538165	89536	538165	1		
W19	WIRE ASSY, (BRN)	538173	89536	538173	1		
W20	WIRE ASSY, (BLU)	538181	89536	538181	1		
W21	WIRE ASSY, (WHT)	538199	89536	538199	1		
XF1	FUSEHOLDER (BODY/NUT ONLY)	375188	89536	375188	1		1
	FUSEHOLDER CAP (CAP ONLY)	460238	89536	460238	1		1
	LEAD & PROBE ASSEMBLY (NOT SHOWN)	516666	89536	Y8132	1		
	RECOMMENDED SPARE PARTS LIST/KIT	583500	89536	583500			

1 MUST BE ORDERED AS SEPARATE ITEMS.

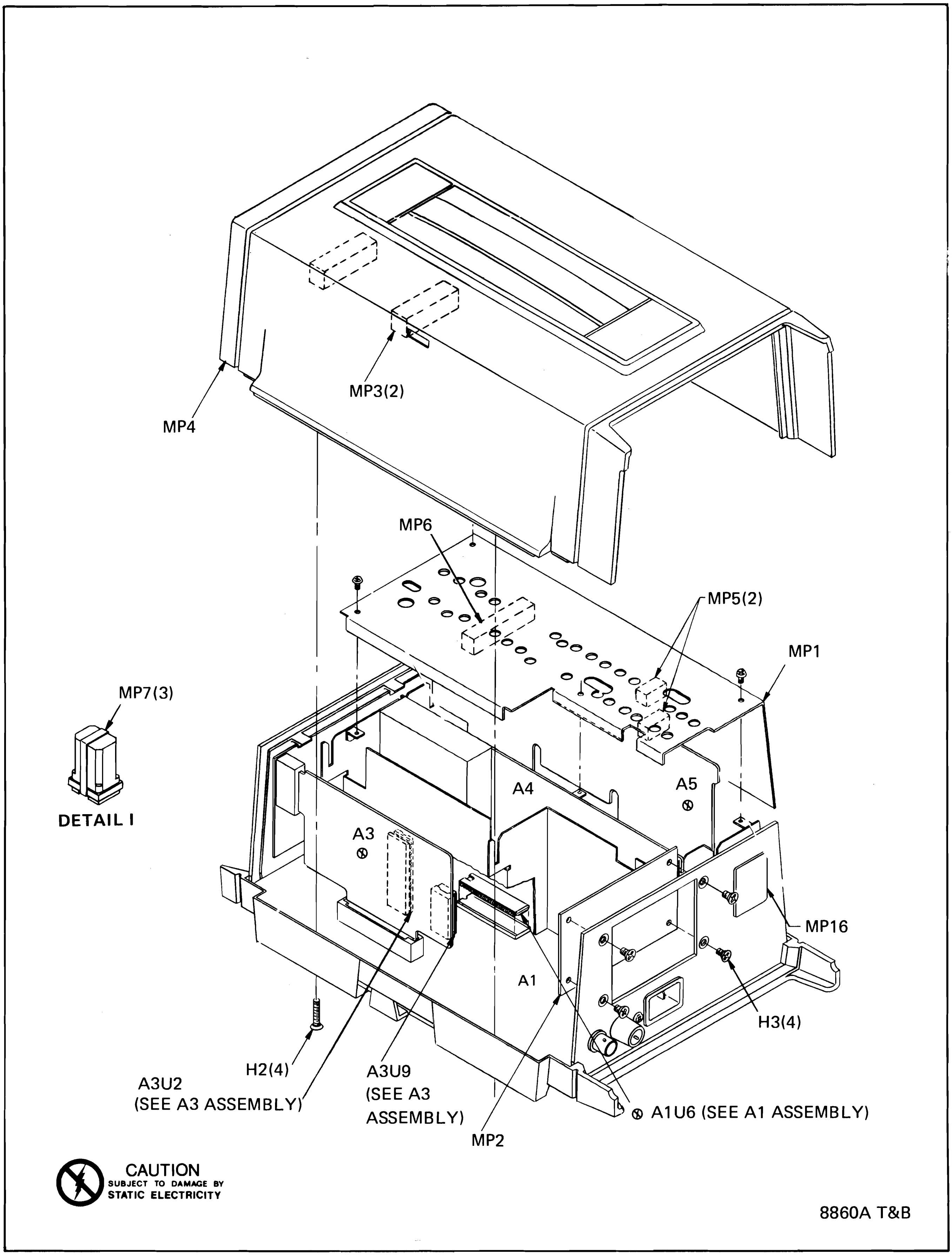


Figure 5-1. Final Assembly

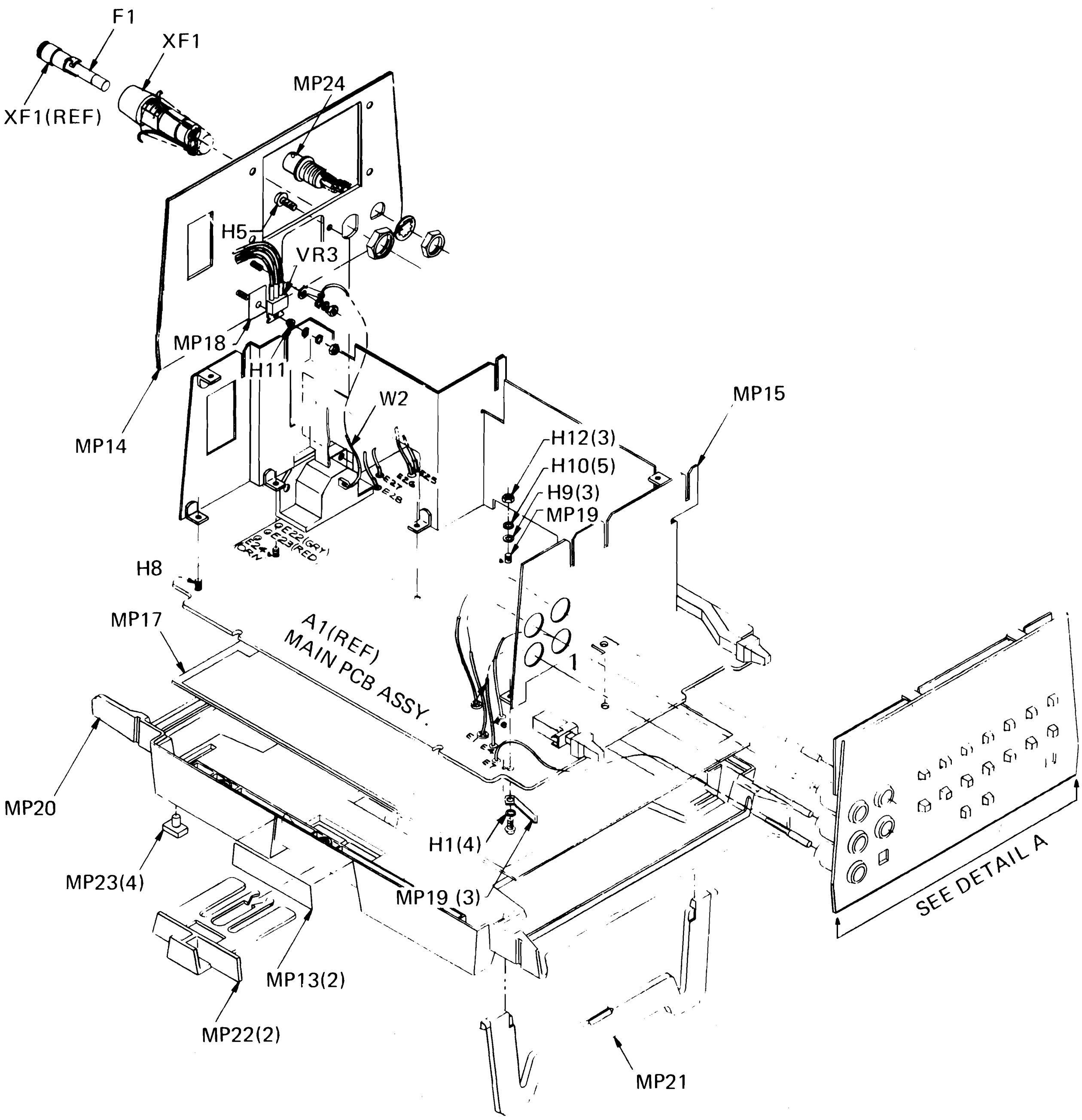


Figure 5-1. Final Assembly (cont)

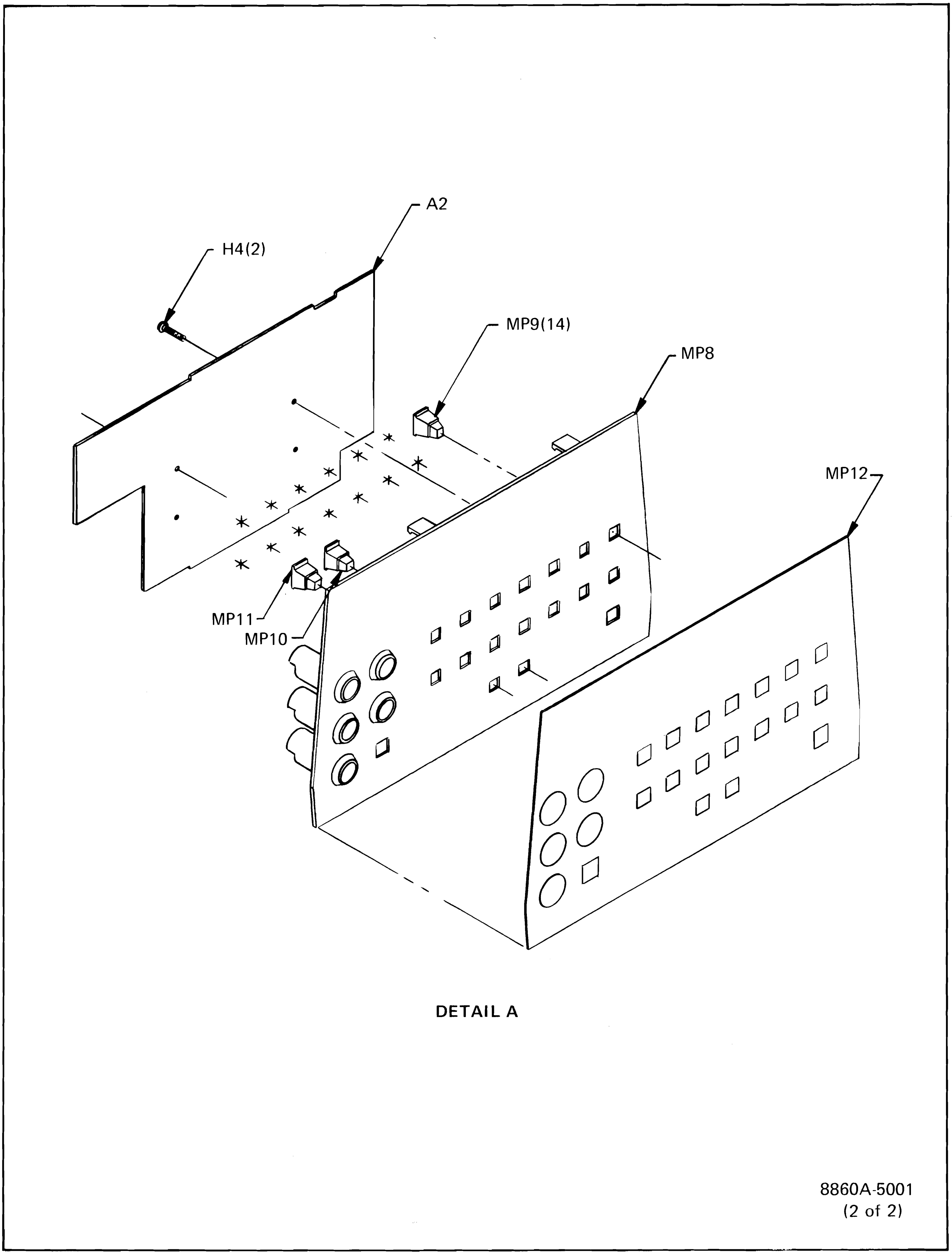


Figure 5-1. Final Assembly (cont)

Table 5-2. Main PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
A1	MAIN PCB ASSEMBLY FIGURE 5-2 (8860A-4001T)	531640	89536	531640	REF		
C1	CAP, ELECT, 4700 UF -10/+100%, 15V	379370	80031	3050HJ472U015	2		
C2	CAP, ELECT, 4700 UF -10/+100%, 15V	379370	80031	3050HJ472U015	REF		
C3	CAP, ELECT, 470 UF -10/+25%, 35V	478792	89536	478792	2		
C4	CAP, ELECT, 470 UF -10/+25%, 35V	478792	89536	478792	REF		
C6	CAP, MYLAR, FXD, 0.047 UF +/-10%, 1000V	529446	03797	1.600.047/10/1000	1		
C7	CAP, ELECT, 4700 UF -10/+100%, 100V	460261	54473	ECE-T16R470OS	1		
C8	CAP, ELECT, 1200 UF -10/+100%, 2000VDC	500322	56289	672D128H6R3DS2C	1		
C9	CAP, CER, 0.22 UF, +/-20%, 50V	519157	51406	RPE111Z5U224M50V	2		
C10	CAP, TA, 4.7 UF +/-20%, 25V	161943	56289	196D475X0025KA1	2		
C12	CAP, TA, 4.7 UF +/-20%, 25V	161943	56289	196D475X0025KA1	REF		
C14	CAP, TA, 2.2 UF +/-20%, 20V	161927	56289	196D225X0020HA1	1		
C16	CAP, MYLAR, 0.0047 UF +/-20%, 200V	106054	56289	192P47202	1		
C17	CAP, CERAM, 0.05 UF -20/+80%, 500V	105676	56289	33C58B	1		
C18	CAP, CER, 0.22 UF, +/-20%, 50V	519157	51406	RPE111Z5U224M50V	REF		
CR1	DIODE, SI, HI-SPEED SWITCHING	203323	07910	1N4448	7	2	
CR2	DIODE, SI, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR3	DIODE, SI, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR4	DIODE, SI, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR6	DIODE, SI	343491	04713	1N4002	5	1	
CR7	DIODE, SI, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR10	DIODE, SI	343491	04713	1N4002	REF		
CR11	DIODE, SI	343491	04713	1N4002	REF		
CR12	DIODE, SI	343491	04713	1N4002	REF		
CR13	DIODE, SI	343491	04713	1N4002	REF		
CR14	RECTIFIER BRIDGE	296509	21845	F903C-22	1	1	
CR15	DIODE, SI, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR16	DIODE, SI, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
E:	WIRE TERMINATIONS						
H1	NUT, 6-32 (NOT SHOWN)	110551	89536	110551	1		
H2	WASHER, EXT/LK #4 (NOT SHOWN)	169235	73734	1322	1		
J1	CONN, 44 CONTACT	542258	00779	1-530843-5	3		
J2	CONN, 30 CONTACT	520163	00779	1-530843-3	1		
J3	CONN, 44 CONTACT	542258	00779	1-530843-5	REF		
J4	CONN, 44 CONTACT	542258	00779	1-530843-5	REF		
J5	CONN, CARD-EDGE	291708	91662	6308-006-313-001	3		
J6	CONN, CARD-EDGE	291708	91662	6308-006-313-001	REF		
J7	CONN, CARD-EDGE	291708	91662	6308-006-313-001	REF		
J9	CONNECTOR, AC	461806	89536	461806	1		
K1	RELAY, DPDT, 4.5V	514240	89536	514240	3		
K2	RELAY, DPDT, 4.5V	514240	89536	514240	REF		
K3	REED RELAY, HV, 1000VDC	520247	71707	UF-40115	1		
K4	RELAY, DPDT, 4.5V	514240	89536	514240	REF		
L1	INDUCTOR 10 UH +/-10%	249078	24759	MR-10	2		
L2	INDUCTOR 10 UH +/-10%	249078	24759	MR-10	REF		
MP1	CONNECTOR (FASTON TAP)	512889	02660	62395-1834	6		
MP2	HEATSINK (TO VR1, VR2 AND Q6)	428805	13103	6046P8	3		
MP3	TERMINAL (TEFLON)(NOT SHOWN)	529297	98291	011-6812-00-0-206	12		

Table 5-2. Main PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
MP4	TERMINAL (TEFLON)(NOT SHOWN)	529305	98291	011-6811-00-0-202	4		
MP5	BUTTON, SWITCH (TO S3) GREEN	445197	89536	445197	1		
MP6	BUTTON, SWITCH (TO S1) GREY	425900	89536	425900	1		
MP8	PUSH ROD	509380	89536	509380	1		
MP9	COVER, AC SWITCH (W/S3)	475681	89536	475681	1		
Q1	XSTR, SI, PNP	195974	64713	2N3906	4	1	
Q2	XSTR, SI, PNP	195974	64713	2N3906	REF		
Q3	XSTR, SI, PNP	195974	64713	2N3906	REF		
Q4	XSTR, SI, PNP	195974	64713	2N3906	REF		
Q6	XSTR, PWR, PNP, SI	325753	09214	D45C5	1	1	
Q7	XSTR, SI, NPN	218396	89536	218396	4	1	
Q8	XSTR, SI, NPN	218396	89536	218396	REF		
Q9	XSTR, SI, NPN	218396	89536	218396	REF		
Q10	XSTR, SI, PNP	340026	07263	MPS6563	1	1	
Q11	XSTR, SI, NPN	218396	89536	218396	REF		
Q13	XSTR, J-FET, N-CHANNEL	343830	89536	343830	2	1	
Q15	XSTR, SI, NPN	218396	89536	218396	REF		
R1	RES, DEP. CAR, 2.2K +/-5%, 1/4W	343400	80031	CR251-4-5P2K2T	4		
R2	RES, DEP. CAR, 2.2K +/-5%, 1/4W	343400	80031	CR251-4-5P2K2T	REF		
R3	RES, DEP. CAR, 2.2K +/-5%, 1/4W	343400	80031	CR251-4-5P2K2T	REF		
R4	RES, DEP. CAR, 2.2K +/-5%, 1/4W	343400	80031	CR251-4-5P2K2T	REF		
R6	RES, FXD WW, 1000 +/-10%, 2W	474080	89536	474080	1		
R7	RES, MTL. FILM, 2K +/-1%, 7W	500033	89536	500033	1		
R8	RES, COMP 100K +/-5%, 2W	285056	89536	285056	2		
R9	RES, COMP 100K +/-5%, 2W	285056	89536	285056	REF		
R10	RES, MTL. FILM, 2K +/-1%, 1/2W	151266	91637	CMF552001F	2		
R11	RES, MTL. FILM, 2K +/-1%, 1/2W	235226	91637	CMF552001F	REF		
R12	RES, MTL. FILM, 10K +/-1%, 1/8W	168260	91637	CMF551002F	2		
R13	RES, MTL. FILM, 10K +/-1%, 1/8W	168260	91637	MFF1-81002F	REF		
R14	RES, DEP. CAR, 1.3K +/-5%, 1/4W	441394	80031	CR251-4-5P1K3	1		
R15	RES, DEP. CAR, 3.6K +/-5%, 1/4W	442343	80031	CR251-4-5P3K6	2		
R16	RES, DEP. CAR, 3.6K +/-5%, 1/4W	442343	80031	CR251-4-5P3K6	REF		
R18	RES, DEP. CAR, 6.2K +/-5%, 1/4W	442368	80031	CR251-4-5P6K2	5		
R19	RES, DEP. CAR, 6.2K +/-5%, 1/4W	442368	80031	CR251-4-5P6K2	REF		
R20	RES, DEP. CAR, 6.2K +/-5%, 1/4W	442368	80031	CR251-4-5P6K2	REF		
R21	RES, DEP. CAR, 6.2K +/-5%, 1/4W	442368	80031	CR251-4-5P6K2	REF		
R22	RES, DEP. CAR, 2.7K +/-5%, 1/4W	386490	80031	CR251-4-5P2K7T	3		
R23	RES, DEP. CAR, 2.7K +/-5%, 1/4W	386490	80031	CR251-4-5P2K7T	REF		
R24	RES, DEP. CAR, 2.7K +/-5%, 1/4W	386490	80031	CR251-4-5P2K7T	REF		
R25	RES, DEP. CAR, 15K +/-5%, 1/4W	348854	80031	CR251-4-5P15K	1		
R26	RES, DEP. CAR, 6.2K +/-5%, 1/4W	442368	80031	CR251-4-5P6K2	REF		
R27	RES, DEP. CAR, 2K +/-5%, 1/4W	441469	80031	CR251-4-5P2K	1		
R28	RES, DEP. CAR 220 +/-5%, 1/4W	342626	80031	CR251-4-5P220ET	1		
R29	RES, COMP, 10M +/-5%, 1/4W	194944	01121	CB1065	2		
R30	RES, COMP, 10M +/-5%, 1/4W	194944	01121	CB1065	REF		
R31	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	1		
R32	RES, DEP. CAR, 150K +/-5%, 1/4W	348938	80031	CR251-4-5P150K	4		
R33	RES, DEP. CAR, 150K +/-5%, 1/4W	348938	80031	CR251-4-5P150K	REF		
R34	RES, DEP. CAR, 150K +/-5%, 1/4W	348938	80031	CR251-4-5P150K	REF		
R35	RES, DEP. CAR, 150K +/-5%, 1/4W	348938	80031	CR251-4-5P150K	REF		

Table 5-2. Main PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
RT1	THERMISTER, 1K, +/-40%	494740	50157	180Q10215	1		
RV1-8	VARISTOR, 390V	423475	09214	V390MAX781	8		
S1	SWITCH, DPDT	520437	89536	520437	1		
S3	SWITCH, POWER, ON-OFF	453605	89536	453605	1		
S4	SWITCH, SLIDE, DPDT	504738	82389	11A-1437	2		
S5	SWITCH, SLIDE, DPDT	504738	82389	11A-1437	REF		
T1	TRANSFORMER, POWER	531558	89536	531558	1		
U1	IC, LIN, OP-AMP	413740	12040	LM307N	1	1	
U2	IC, LIN, QUAD, COMPARATOR	387233	12040	LM339N	2	1	
U3	NETWORK, RESISTOR	520353	89536	520353	2	1	
U4	NETWORK, RESISTOR	520353	89536	520353	REF		
U5	IC, LIN, QUAD, COMPARATOR	387233	12040	LM339N	REF		
U6	IC, MICROCOMPUTER	504563	89536	504563	1	1	
U7	IC, PHOTOTRANSISTOR, OPTICALLY COUPLED	504977	29083	MCT2E	4	1	
U8	IC, PHOTOTRANSISTOR, OPTICALLY COUPLED	504977	29083	MCT2E	REF		
U9	IC, PHOTOTRANSISTOR, OPTICALLY COUPLED	504977	29083	MCT2E	REF		
U10	IC, PHOTOTRANSISTOR, OPTICALLY COUPLED	504977	29083	MCT2E	REF		
VR1	VOLTAGE REGULATOR, LIN, FXD	428847	04713	MC805TP	1	1	
VR2	VOLTAGE REGULATOR, LIN, RCD	413187	04713	MC7815CT	1	1	
VR3	VOLTAGE REGULATOR, 3-TERMINAL	538108	89536	538108	1	1	
W1-W24	JUMPER WIRE (NOT SHOWN)						
XK1	SOCKET RELAY	376665	77342	27E501	3		
XK2	SOCKET RELAY	376665	77342	27E501	REF		
XK4	SOCKET RELAY	376665	77342	27E501	REF		
XU6	SOCKET, IC, 40-PIN	429282	09922	DILB40P-108	1		
Y1	CRYSTAL 4 MHZ, QUARTZ	474072	89536	474072	1	1	

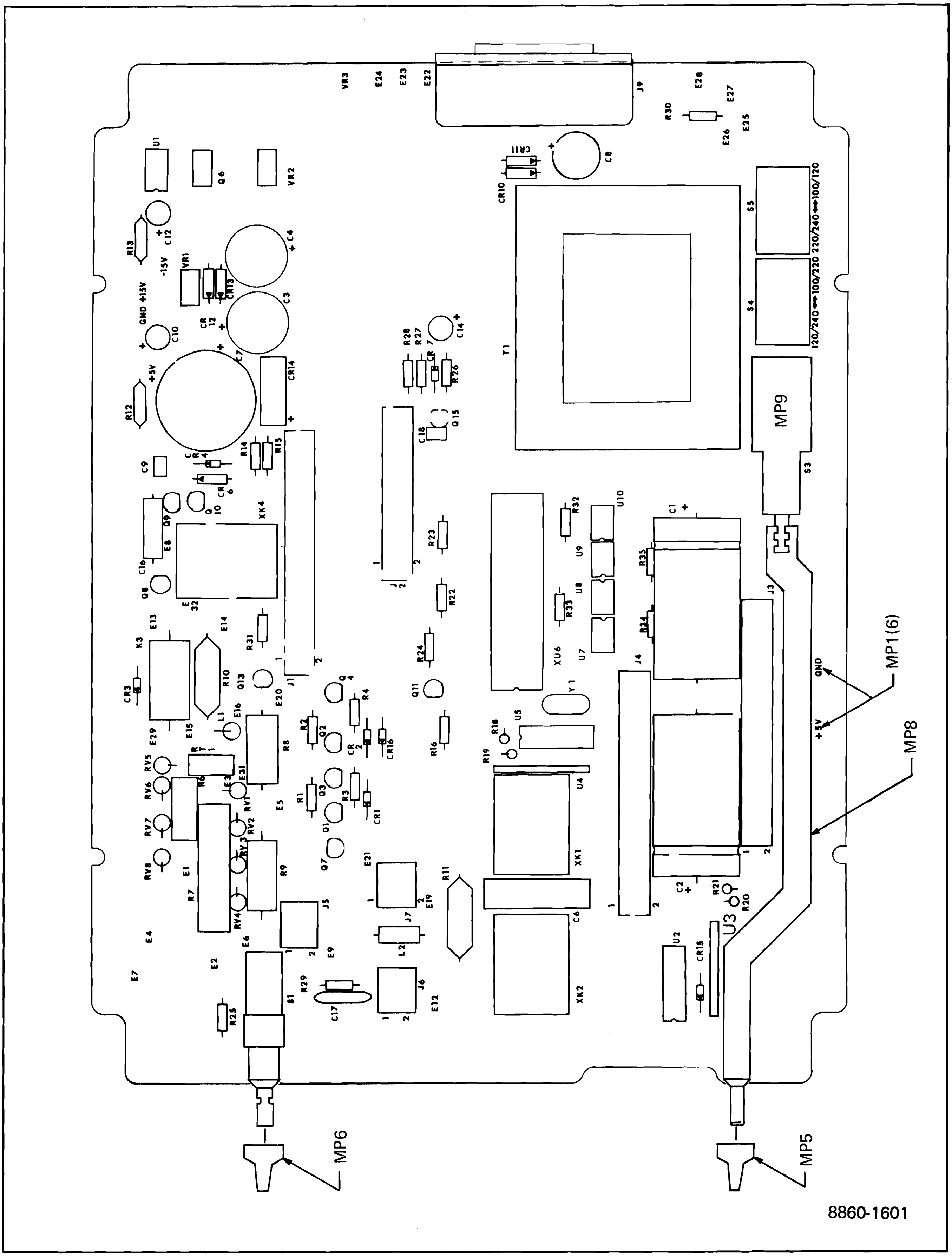
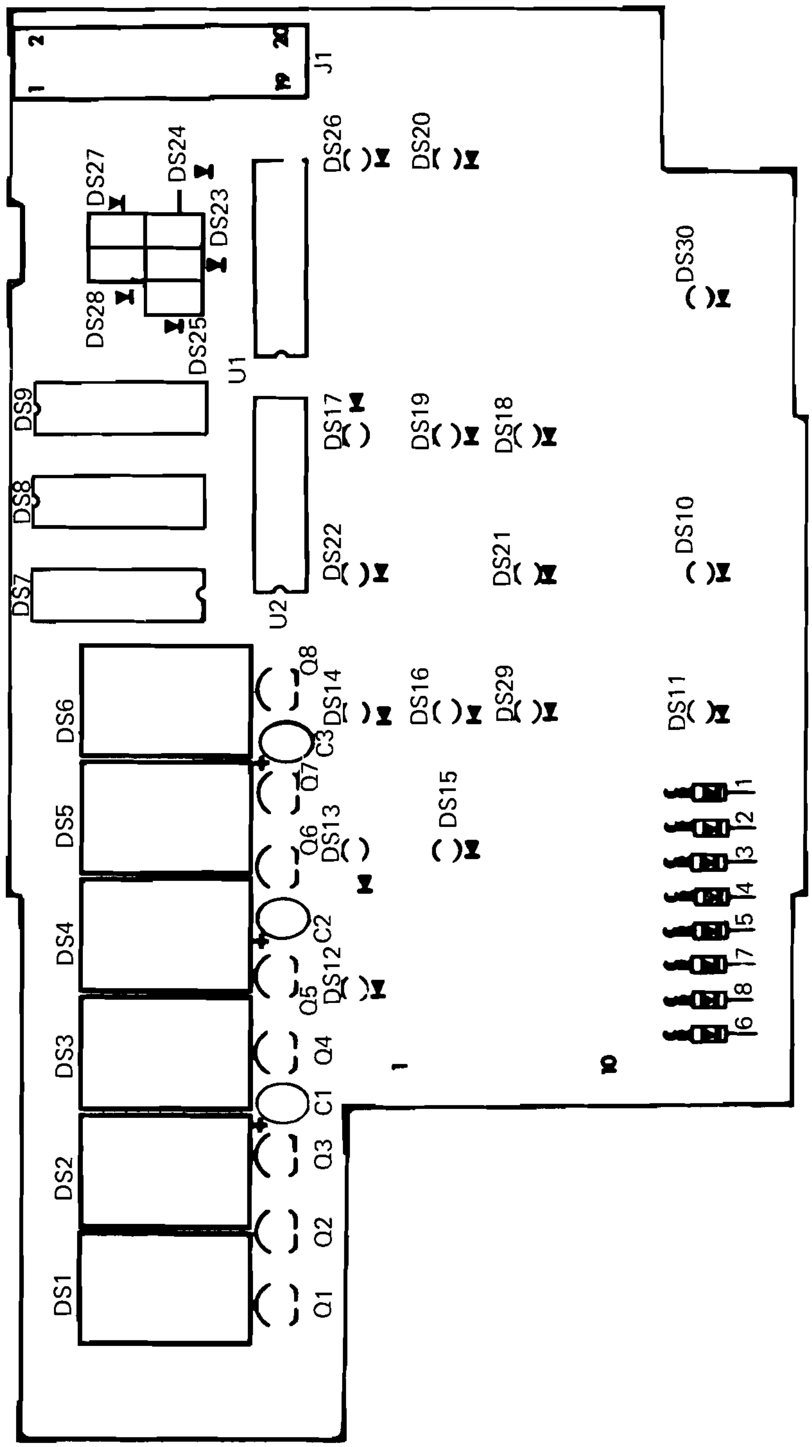


Figure 5-2. A1 Main PCB Assembly

Table 5-3. Display PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
A2	DISPLAY PCB ASSEMBLY FIGURE 5-3 (8860A-4002T)	502708	89536	502708	REF		
C1	CAP, TA, 1UF, +/-20%, 35V	161919	56289	196D105X0020JA1	3		
C2	CAP, TA, 1UF, +/-20%, 35V	161919	56289	196D105X0020JA1	REF		
C3	CAP, TA, 1UF, +/-20%, 35V	161919	56289	196D105X0020JA1	REF		
CR1	DIODE, HI-SPEED SWITCHING	203323	07910	1N4448	8	2	
CR2	DIODE, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR3	DIODE, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR4	DIODE, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR5	DIODE, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR6	DIODE, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR7	DIODE, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
CR8	DIODE, HI-SPEED SWITCHING	203323	07910	1N4448	REF		
DS1	DISPLAY, LED	504787	89536	504787	1	1	
DS2	DISPLAY, LED, 7-SEGMENT	418012	28480	5082-7651	5	1	
DS3	DISPLAY, LED, 7-SEGMENT	418012	28480	5082-7651	REF		
DS4	DISPLAY, LED, 7-SEGMENT	418012	28480	5082-7651	REF		
DS5	DISPLAY, LED, 7-SEGMENT	418012	28480	5082-7651	REF		
DS6	DISPLAY, LED, 7-SEGMENT	418012	28480	5082-7651	REF		
DS7	DISPLAY, LED	495457	28480	QDSP3507	1		
DS8	DISPLAY, LED	504779	89536	504779	1		
DS9	DISPLAY, LED	504779	89536	504779	REF		
DS10-22	DISPLAY, LED	504753	28480	HLMP-1301	16	4	
DS23	LIGHT EMITTING DIODE	504761	14936	MV57124	5	1	
DS24	LIGHT EMITTING DIODE	504761	14936	MV57124	REF		
DS25	LIGHT EMITTING DIODE	504761	14936	MV57124	REF		
DS26	DISPLAY, LED	504753	28480	HLMP-1301	REF		
DS27	LIGHT EMITTING DIODE	504761	14936	MV57124	REF		
DS28	LIGHT EMITTING DIODE	504761	14936	MV57124	REF		
DS29	DISPLAY, LED	504753	28480	HLMP-1301	REF		
DS30	DISPLAY, LED	504753	28480	HLMP-1301	REF		
J1	RECEPTACLE	520189	01295	H421121-18	1		
MP1	KEYBOARD, FRONT PANEL (NOT SHOWN)	504886	89536	504886	1		
MP2	SOCKET, COMPONENT LEAD (NOT SHOWN)	376418	22526	75060-007	42		
Q1	XSTR, SI, PNP, SM. SIG	418707	04713	MPS56562	8	2	
Q2	XSTR, SI, PNP, SM. SIG	418707	04713	MPS56562	REF		
Q3	XSTR, SI, PNP, SM. SIG	418707	04713	MPS56562	REF		
Q4	XSTR, SI, PNP, SM. SIG	418707	04713	MPS56562	REF		
Q5	XSTR, SI, PNP, SM. SIG	418707	04713	MPS56562	REF		
Q6	XSTR, SI, PNP, SM. SIG	418707	04713	MPS56562	REF		
Q7	XSTR, SI, PNP, SM. SIG	418707	04713	MPS56562	REF		
Q8	XSTR, SI, PNP, SM. SIG	418707	04713	MPS56562	REF		
U1	IC, 4-LINE TO 10-LINE DECODER	408716	01295	SN74LS42N	1	1	
U2	RESISTOR NETWORK, 270 OHMS	501239	89536	501239	1	1	

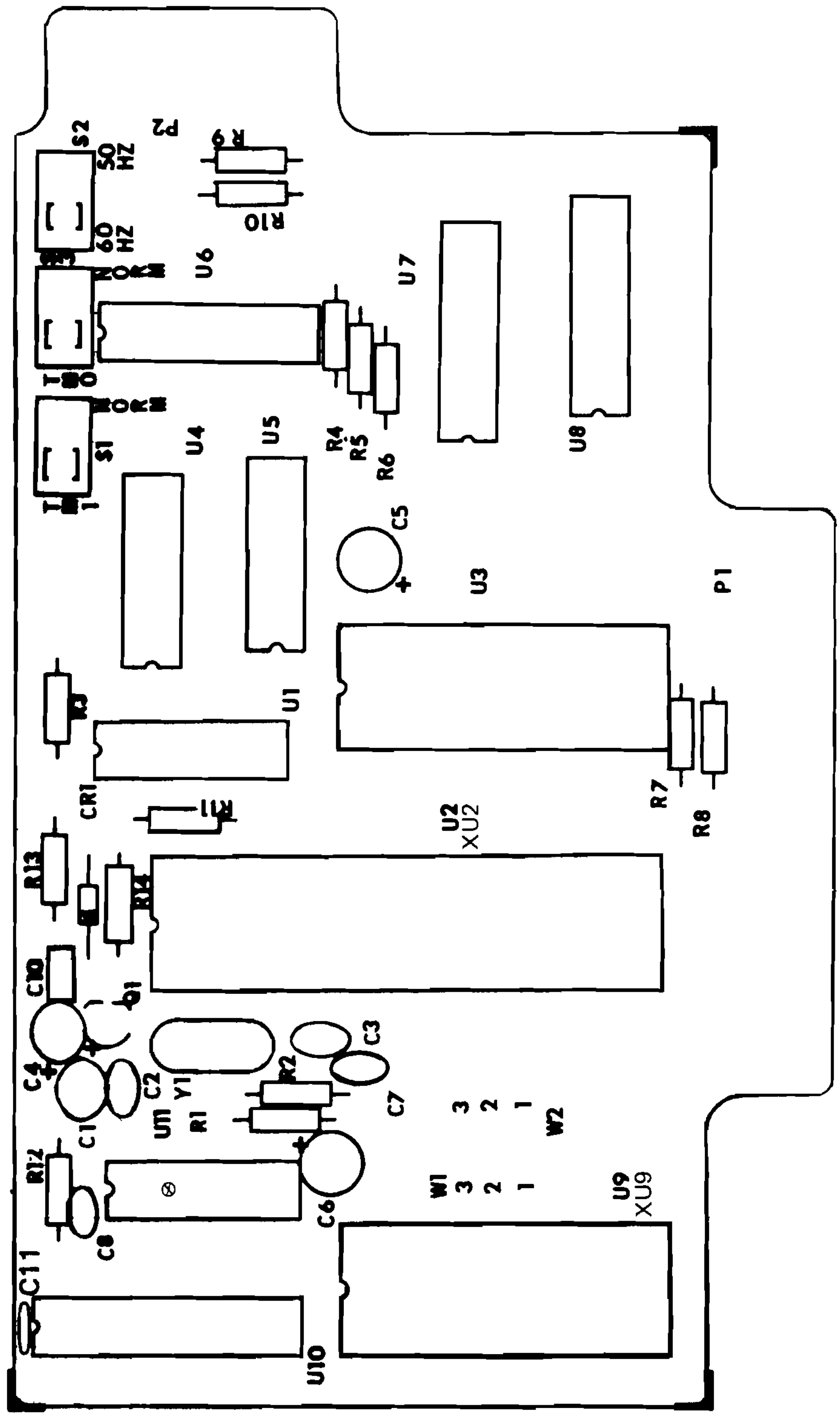


8860A-1602

Figure 5-3. A2 Display PCB Assembly

Table 5-4. A3 Controller PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
A3	⊕ CONTROLLER PCB ASSEMBLY FIGURE 5-4 (8860A-4003T)	502716	89536	502716	REF		
C1	CAP, TA, 1UF, +/-20%, 35V	161919	56289	196D105X0020JA1	4		
C2	CAP, CERAM, 20 PF +/-10%	106369	56289	561CT2HBA102AE200K	2		
C3	CAP, CERAM, 20 PF +/-10%	106369	56289	561CT2HBA102AE200K	REF		
C4	CAP, CERAM, 0.22 UF +/-20%, 50V	519157	51406	RPE111Z5U224M50V	5		
C5	CAP, CERAM, 0.22 UF +/-20%, 50V	519157	51406	RPE111Z5U224M50V	REF		
C6	CAP, CERAM, 0.22 UF +/-20%, 50V	519157	51406	RPE111Z5U224M50V	REF		
C7	CAP, CERAM, 20 PF +/-10%, 500V	357806	71590	CF-102	1		
C8	CAP, CERAM, .05 UF +/-20%, 50V	149161	56289	55C23A1	1		
C10	CAP, CERAM, 0.22 UF +/-20%, 50V	519157	51406	RPE111Z5U224M50V	REF		
C11	CAP, CERAM, 0.22 UF +/-20%, 50V	519157	51406	RPE111Z5U224M50V	REF		
CR1	DIODE, SI, HI-SPEED SWITCHING	203323	07910	1N4448	1	1	
P1	BOARD CONNECTION CIRCUIT						
P2	BOARD CONNECTION CIRCUIT						
Q1	XSTR, SI, NPN	218396	07263	2N3904	1	1	
R1	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	2		
R2	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R3	RES, DEP. CAR, 33K +/-5%, 1/4W	348888	80031	CR251-4-5P33K	2		
R4	RES, DEP. CAR, 51 +/-5%, 1/4W	414540	80031	CR251-4-5P51E	3		
R5	RES, DEP. CAR, 51 +/-5%, 1/4W	414540	80031	CR251-4-5P51E	REF		
R6	RES, DEP. CAR, 51 +/-5%, 1/4W	414540	80031	CR251-4-5P51E	REF		
R7	RES, DEP. CAR, 6.2K +/-5%, 1/4W	442368	80031	CR251-4-5P6K2	4		
R8	RES, DEP. CAR, 6.2K +/-5%, 1/4W	442368	80031	CR251-4-5P6K2	REF		
R9	RES, DEP. CAR, 6.2K +/-5%, 1/4W	442368	80031	CR251-4-5P6K2	REF		
R10	RES, DEP. CAR, 6.2K +/-5%, 1/4W	442368	80031	CR251-4-5P6K2	REF		
R11	RES, DEP. CAR, 33K +/-5%, 1/4W	348888	80031	CR251-4-5P33K	REF		
R12	RES, DEP. CAR, 300K +/-5%, 1/4W	441535	80031	CR251-4-5P300K	1		
R13	RES, DEP. CAR, FXD, 2K +/-5%, 1/4W	441469	80031	CR251-4-5P2K	1		
R14	RES, DEP. CAR, 220 +/-5%, 1/4W	342626	80031	CR251-4-5P220E	1		
S1	SWITCH, SLIDE	477984	79727	GS-115	3	1	
S2	SWITCH, SLIDE	477984	79727	GS-115	REF		
S3	SWITCH, SLIDE	477984	79727	GS-115	REF		
U1	IC, C-MOS, DUAL D F/F	340117	02735	CD4013AE	1	1	
U2	IC, MICRO PROCESSOR	524827	89536	524827	1	1	
U3	IC, N-MOS, INPUT OUTPUT EXPANDER	507293	34649	P8243	1	1	
U4	IC, TTL, DIGITAL, COLLECTOR	328021	01295	SN7417N	2	1	
U5	IC, TTL, DIGITAL, COLLECTOR	328021	01295	SN7417N	REF		
U6	RESISTOR NETWORK, 82 OHMS	478859	89536	478859	1	1	
U7	IC, C-MOS, HEX BUFF/INVERTER	381830	02735	CD650AE	1	1	
U8	RESISTOR NETWORK	501494	89536	501494	1	1	
U9	IC, 4K X 8 BIT	525048	89536	525048	1	1	
U10	IC, TTL, DIGITAL	504514	01295	SN74LS373	1	1	
U11	⊗ IC, C-MOS, MONO/ASTABLE MLTVBRTR	535575	12040	CD4047E	1	1	
XU2	SOCKET, IC, 40-PIN	429282	09922	DILB40P-108	1		
XU9	SOCKET, IC, 24-PIN	418970	91506	324-AG39D	1		
Y1	CRYSTAL, 6 MHZ +/-0.015%	461665	89536	461665	1	1	



CAUTION
SUBJECT TO DAMAGE BY
STATIC ELECTRICITY

8860A-1603

Figure 5-4. A3 Controller PCB Assembly

Table 5-5. A4 AC/DC Scaling PCB Assembly

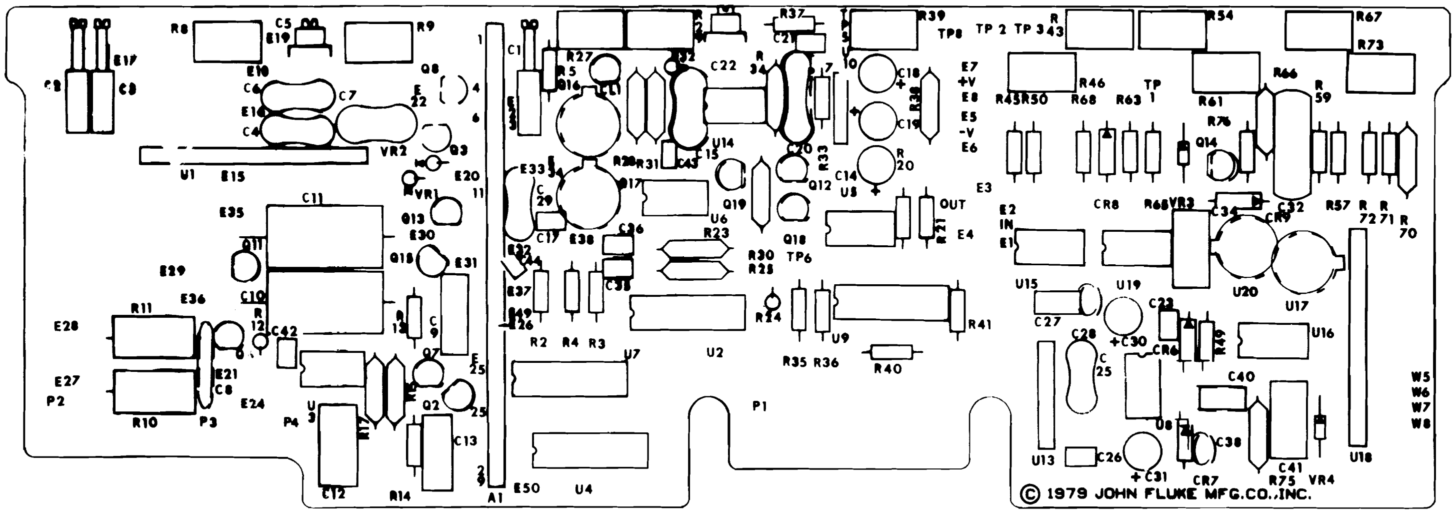
REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
A4	AC/DC SCALING PCB ASSEMBLY FIGURE 5-5 (8860A-4004T)	526665	89536	526665	REF		
A4A1	CIRCUIT, HYBRID, AC/DC	496349	89536	496349	1	1	
C1	CAP, VAR, .25 - 1.5 PF, 2000VDC	435016	72082	530-006	3		
C2	CAP, VAR, .25 - 1.5 PF, 2000VDC	435016	72082	530-006	REF		
C3	CAP, VAR, .25 - 1.5 PF, 2000VDC	435016	72082	530-006	REF		
C4	CAP, MICA, 270 PF, +/-5%, 500V	148452	72136	DM15F271J	1		
C5	CAP, VAR, 1.7 - 10 PF, 250V	375238	56289	GKC10000	2		
C6	CAP, MICA, 27 PF, +/-5%, 500V	177998	72136	DM15E270J	1		
C7	CAP, MICA, 330 PF, +/-5%, 500V	148445	72136	DM15E331J	2		
C8	CAP, CERAM, 68 PF	519181	71590	DD-3R3	1		
C9	CAP, POLYPROP, .033 UF	519850	52763	MKP-1840/1841	1		
C10	CAP, POLYPROP, .22 UF +/-10%, 50V	423210	89536	423210	2		
C11	CAP, POLYPROP, .22 UF +/-10%, 50V	423210	89536	423210	REF		
C12	CAP, MYLAR, .22 UF +/-10%, 100V	436113	73445	C280MAH/A220K	2		
C13	CAP, MYLAR, .047 UF +/-10%, 250V	162008	73445	C280MAE/A47K	1		
C14	CAP, TA, 4.7 UF +/-20%, 25V	161943	56289	196D685X9035KA1	5		
C15	CAP, MICA, 100 PF +/-5%, 500V	148494	72136	DM15F101J	1		
C17	CAP, CERAM, 33PF +/-5%, 100V	354852	80031	2222-638-10339	1		
C18	CAP, TA, 4.7 UF +/-20%, 25V	161943	56289	196D685X9035KA1	REF		
C19	CAP, TA, 4.7 UF +/-20%, 25V	161943	56289	196D685X9035KA1	REF		
C20	CAP, MICA, 680 PF	148403	02799	DM15F101J	1		
C21	CAP, CERAM, 4.7 UF +/-.25%, 100V	362731	89536	362731	3		
C22	CAP, VAR, 1.7 - 10 PF, 250V	375238	56289	GKC10000	REF		
C23	CAP, CERAM, 2.2 PF +/-.25%, 100V	362731	89536	362731	REF		
C25	CAP, MICA, 150 PF +/-5%, 500V	148478	72136	DM15F151J	1		
C26	CAP, CERAM, 2.2 PF +/-.25%, 100V	362731	89536	362731	REF		
C27	CAP, CERAM, .22 UF +/-20%, 50V	309849	71590	CW30C224K	1		
C28	CAP, CERAM, .01 UF +/-20%, 100V	149153	56289	C0238101F103M	2		
C29	CAP, MICA, 330 PF, +/-5%, 500V	148445	72136	DM15E331J	REF		
C30	CAP, TA, 4.7 UF +/-20%, 25V	161943	56289	196D685X9035KA1	REF		
C31	CAP, TA, 4.7 UF +/-20%, 25V	161943	56289	196D685X9035KA1	REF		
C32	CAP, POLY, .47 UF +/-10%, 100V	446807	89536	446807	1		
C34	CAP, POLY, .22 UF +/-10%, 100V	614172	73445	C280MCH/A220K	1		
C35	CAP, CERAM, 22 PF +/-5%, 100V	448449	80031	2222-638-10229	2		
C36	CAP, CERAM, 22 PF +/-5%, 100V	448449	80031	2222-638-10229	REF		
C38	CAP, CERAM, .01 UF +/-20%, 100V	149153	56289	C0238101F103M	REF		
C40	CAP, CERAM, 1.0 PF	436477	80031	2222-638-03108	1		
C41	CAP, MYLAR, .22 UF +/-10%, 100V	436113	73445	C280MAH/A220K	REF		
C42	CAP, CERAM, 4700 PF	362871	72982	8121-A100-W5R-472M	1		
C43	CAP, CERAM, 22 PF +/-5%, 100V	448449	80031	2222-638-10229	REF		
C44	CAP, CERAM, .68 PF +/-1%, 100V	485011	89536	485011	1		
CL1	DIODE, FED, CURRENT REG.	393454	07910	TCR5290	1	1	
CR6	DIODE, LOW-LEAK, LO-CAP	375907	07263	FD7222	4	1	
CR7	DIODE, LOW-LEAK, LO-CAP	375907	07263	FD7222	REF		
CR8	DIODE, LOW-LEAK, LO-CAP	375907	07263	FD7222	REF		
CR9	DIODE, LOW-LEAK, LO-CAP	375907	07263	FD7222	REF		
E1-E49	(SEE INSERT A, WIRE LIST)						
H1	SCREW, FHP, S/S, 6-32 X 1/4 (ON SHIELD)	385401	89536	385401	3		

Table 5-5. A4 AC/DC Scaling PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
MP1	SHIELD, AC/DC (NOT SHOWN)	502591	89536	502591	1		
MP2	SUPPORT, RES. NETWORK (ON SHIELD)	531046	89536	531046	1		
MP3	TERMINAL, FEED-THRU/TEFLON	529305	98291	011-6811-00-0-202	14		
MP4	TERMINAL, FEED-THRU/TEFLON	529297	98291	011-6812-00-0-206	9		
MP5	HEATSINK (WITH U17, U20)	354993	98978	TXC20CB	2		
Q2	XSTR, J-FET, N-CHAN	343830	89536	343830	5	2	
Q3	XSTR, J-FET, N-CHAN	535039	89536	535039	1	1	
Q6	XSTR, J-FET, N-CHAN	343830	89536	343830	REF		
Q7	XSTR, J-FET, N-CHAN	343830	89536	343830	REF		
Q8	XSTR, J-FET, N-CHAN	508697	21845	FS933	1	1	
Q11	XSTR, J-FET, N-CHAN	429977	21845	F2811	1	1	
Q12	XSTR, FET, N-CHAN	261578	89536	261578	3	1	
Q13	XSTR, J-FET, N-CHAN	343830	89536	343830	REF		
Q14	XSTR, SI, PNP	229898	04713	MPS6522	1	1	
Q15	XSTR, J-FET, N-CHAN	343830	89536	343830	REF		
Q16	XSTR, DUAL FET, N-CHAN	419283	89536	419283	1	1	
Q17	XSTR, DUAL FET, N-CHAN	578799	89536	578799	1	1	
Q18	XSTR, FET, N-CHAN	261578	89536	261578	REF		
Q19	XSTR, FET, N-CHAN	386730	12040	SF-1102	1	1	
R2	RES, DEP. CAR, 47K +/-5%, 1/4W	348896	80031	CR251-4-5P47K	6		
R3	RES, DEP. CAR, 47K +/-5%, 1/4W	348896	80031	CR251-4-5P47K	REF		
R4	RES, DEP. CAR, 47K +/-5%, 1/4W	348896	80031	CR251-4-5P47K	REF		
R5	RES, DEP. CAR, 22K +/-5%, 1/4W	348870	80031	CR251-4-5P22K	1		
R8	RES, VAR. CERMET, 200 +/-10%, 1/2W	285148	89536	285148	3		
R9	RES, VAR. CERMET, 200 +/-10%, 1/2W	285148	89536	285148	REF		
R10	RES, COMP, 47K +/-5%, 1/4W	150219	01121	CB4735	2		
R11	RES, COMP, 47K +/-5%, 1/4W	150219	01121	CB4735	REF		
R12	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	3		
R13	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	3		
R14	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R15	RES, MTL FILM, 100K +/-1%, 1/8W	248807	91637	MFF1-81003F	2		
R17	RES, MTL FILM, 100K +/-1%, 1/8W	248807	91637	MFF1-81003F	REF		
R20	RES, DEP. CAR, 3.3K +/-5%, 1/4W	348813	80031	CR251-4-5P3K3	2		
R21	RES, DEP. CAR, 3.3K +/-5%, 1/4W	348813	80031	CR251-4-5P3K3	REF		
R23	RES, MTL FILM, 10K +/-1%, 1/8W	168260	91637	MFF1-81002F	2		
R24	RES, DEP. CAR, 4.3K +/-5%, 1/4W	441576	80031	CR251-4-5P4K3	1		
R25	RES, MTL FILM, 10K +/-1%, 1/8W	168260	91637	MFF1-81002F	REF		
R27	RES, VAR. 50 +/-10%, 1/2W	285122	89536	285122	1		
R28	RES, MTL FILM, 3.83K +/-1%, 1/8W	260323	91637	CMF553831F	1		
R29	RES, VAR. 2K +/-10%, 1/2W	285163	89536	285163	1		
R30	RES, MTL FILM, 3.65K +/-1%, 1/8W	168252	91637	CMF553651F	1		
R31	RES, MTL FILM, 392 +/-1%, 1/8W	260299	91637	MFF1-83920F	1		
R32	RES, DEP. CAR, 7.5K +/-5%, 1/4W	441667	80031	CR251-4-5P7K5	1		
R33	RES, DEP. CAR, 47K +/-5%, 1/4W	348896	80031	CR251-4-5P47K	REF		
R34	RES, MTL FILM, 3.57K +/-1%, 1/8W	226217	91637	MFF1-83571F	1		
R35	RES, DEP. CAR, 47K +/-5%, 1/4W	348896	80031	CR251-4-5P47K	REF		
R36	RES, DEP. CAR, 47K +/-5%, 1/4W	348896	80031	CR251-4-5P47K	REF		
R37	RES, DEP. CAR, 100 +/-5%, 1/4W	348771	80031	CR251-4-5P100E	1		
R38	RES, MTL FILM, 143K +/-1%, 1/8W	291336	91637	MFF1-81433F	1		
R39	RES, VAR. CERMET, 50K +/-10%, 1/2W	288290	89536	288290	1		

Table 5-5. A4 AC/DC Scaling PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
R40	RES, DEP. CAR, 4.7K +/-5%, 1/4W	348821	80031	CR251-4-5P4K7	3		
R41	RES, DEP. CAR, 4.7K +/-5%, 1/4W	348821	80031	CR251-4-5P4K7	REF		
R43	RES, VAR. CERMET, 100 +/-10%, 1/2W	285130	89536	285130	1		
R45	RES, COMP, 22M +/-5%, 1/4W	221986	01121	CB2265	1		
R46	RES, VAR. CERMET, 100K +/-10%, 1/4W	288308	89536	288308	2		
R49	RES, DEP. CAR, 43K +/-5%, 1/4W	442418	80031	CR251-4-5P43K	2		
R50	RES, DEP. CAR, 43K +/-5%, 1/4W	442418	80031	CR251-4-5P43K	REF		
R54	RES, VAR. CERMET, 25K +/-10%, 1/2W	289678	89536	289678	1		
R57	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R59	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R61	RES, VAR. CERMET, 10K +/-10%, 1/2W	285171	89536	285171	1		
R63	RES, DEP. CAR, 6.2K +/-5%, 1/4W	442368	80031	CR251-4-5P6K2	1		
R64	RES, DEP. CAR, 1 +/-5%, 1/4W	357665	80031	CR251-4-5P1E	1		
R65	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R66	RES, MTL FILM, 1K +/-1%, 1/8W	320333	91637	CMF551001F	1		
R67	RES, VAR. CERMET, 200 +/-10%, 1/2W	285148	89536	285148	REF		
R68	RES, DEP. CAR, 120K +/-5%, 1/4W	441386	80031	CR251-4-5P120K	1		
R70	RES, MTL FILM, 402K +/-1%, 1/8W	217984	91637	MFF1-84023F	1		
R71	RES, COMP, 2.7M +/-5%, 1/4W	193490	01121	CB2755	1		
R72	RES, DEP. CAR, 1.8K +/-5%, 1/4W	441444	80031	CR251-4-5P1K8	1		
R73	RES, VAR. CERMET, 100K +/-10%, 1/4W	288308	89536	288308	REF		
R75	RES, MTL FILM, 715 +/-1%, 1/8W	313080	91637	CMF557150F	1		
R76	RES, DEP. CAR, 4.7K +/-5%, 1/4W	348821	80031	CR251-4-5P4K7	REF		
U1	RES. NETWORK, INPUT DIVIDER	510636	89536	510636	1	1	
U2	IC, LIN, QUAD, COMPARATOR	387233	12040	LM339N	4	1	
U3	IC, LIN, OP-AMP	478107	12040	LM308A	1	1	
U4	IC, LIN, QUAD, COMPARATOR	387233	12040	LM339N	REF		
U5	IC, OP-AMP, J-FET INPUT	418780	12040	LF351	1	1	
U6	IC, LIN, J-FET INPUT, DUAL OP-AMP	495192	12040	LF353BN	1	1	
U7	IC, LIN, QUAD, COMPARATOR	387233	12040	LM339N	REF		
U8	IC, LIN, OP-AMP, J-FET INPUT	535856	01295	TL081ACL	1	1	
U9	IC, LIN, QUAD, COMPARATOR	387233	12040	LM339N	REF		
U10	RES. NETWORK, OUTPUT DIVIDER	511196	89536	511196	1	1	
U13	RESISTOR NETWORK	520387	89536	520387	1	1	
U14	IC, LIN, OP-AMP	495051	18324	NE5534N	1	1	
U15	IC, LIN, OP-AMP, PROGRAMMABLE,8 PIN DIP	418913	12040	LM4250CN	1	1	
U16	IC, OP-AMP, MONO, J-FET INPUT	524033	12040	LF356H	1	1	
U17	IC, XSTR ARRAY	504191	89536	504191	2	1	
U18	RES. NETWORK, RMS	511147	89536	511147	1	1	
U19	IC, LIN, SELECTED	473777	89536	473777	1	1	
U20	IC, XSTR ARRAY	504191	89536	504191	REF		
VR1	DIODE, ZENER, 6.2V +/-5%	325811	04713	1N753A	2	1	
VR2	DIODE, ZENER, 6.2V +/-5%	325811	04713	1N753A	REF		
VR3	DIODE, ZENER, 9.1V +/-5%	386557	04713	1N960B	2	1	
VR4	DIODE, ZENER, 9.1V +/-5%	386557	04713	1N960B	REF		
W1-W25	WIRE, JUMPER AND HOOK-UP (SEE INSERT A, WIRE TERMINATIONS Figure 5-5)						



WIRE TERMINATIONS

WIRE LIST		
NO.	FROM	TO
W1	E1	E2
W2	E3	E4
W3	E5	E6
W4	E7	E8
W5	E10	E11
W6	E11	E12
W7	E12	E13

WIRE LIST		
NO.	FROM	TO
W8	E13	E14
W9	E15	E16
W10	E17	E18
W11	E16	E18
W12	E18	E19
W13	E19	E20
W14	E21	E22

WIRE LIST		
NO.	FROM	TO
W15	E22	E23
W16	E24	E25
W17	E25	E26
W18	E27	E28
W19	E29	E30
W20	E31	E32
W21	E32	E33

WIRE LIST		
NO.	FROM	TO
W22	E33	E34
W23	E35	E36
W24	E37	E38
W25	E49	E50

INSERT "A"

8860A-1604

Figure 5-5. A4 AC/DC Scaling PCB Assembly

Table 5-6. A/D And Ohms Converter PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
A5	⊘ A/D AND OHMS CONVERTER PCB ASSEMBLY FIGURE 5-6 (8860A-4005T)	526673	89536	526673	REF		
A5A1	IC, OHMS RANGE HYBRID	496356	89536	496356	1	1	
A5A2	IC, A-D SWITCHING HYBRID	496364	89536	496364	1	1	
C1	CAP, CERAM, .05 UF +/-20%, 50V	175232	56289	C023B101H253M	3		
C2	CAP, FXD, .01 UF +/-20%, 400V	402818	72445	C280MAF/A10K	1		
C3	CAP, CERAM, 33 PF +/-2%, 100V	354852	80031	2222-638-10339	4		
C5	CAP, CERAM, 33 PF +/-2%, 100V	354852	80031	2222-638-10339	REF		
C6	CAP, CERAM, .005 UF +/-20%, 50V	175232	56289	C023B101E502M	REF		
C7	CAP, POLYPRO, 0.47 UF +/-5%, 50V	364042	84411	JF78B	1		
C8	CAP, MICA, 150 PF +/-5%, 500V	148478	02799	DM150F101J	2		
C9	CAP, MICA, 150 PF +/-5%, 500V	148478	02799	DM150F101J	REF		
C10	CAP, CERAM, 33 PF +/-2%, 100V	354852	80031	2222-638-10339	REF		
C11	CAP, CERAM, .005 UF +/-20%, 50V	175232	56289	C023B101E502M	REF		
C12	CAP, MICA, 430 PF +/-5%, 500V	177980	02799	DM430F101J	1		
C13	CAP, POL. CAR, 2.2 UF + -10%, 100V	306522	80031	C280MC	1		
C14	CAP, FXD, 1MF +/-10%, 100V	447847	73445	C280MAH/A1M	2		
C15	CAP, FXD, 1MF +/-10%, 100V	447847	73445	C280MAH/A1M	REF		
C16	CAP, CERAM, 100 PF +/-2%, 100V	369173	80031	2222-638-1010	1		
C17	CAP, MICA, 2 PF +/-10%, 500V	175208	02799	DM02C101D	1		
C18	CAP, MICA, 8 PF +/-10%, 500V	216986	02799	DM08C101K	1		
C19	CAP, CERAM, 33 PF +/-2%, 100V	354852	80031	2222-638-10339	REF		
C20	CAP, MICA, 270 PF +/-5%, 500V	148452	02799	DM270F101J	1		
CL1	DIO, (FED) 0.47 NOM., 400 MW	393454	07910	TCR5290	2	1	
CL2	DIO, (FED) 0.47 NOM., 400 MW	393454	07910	TCR5290	REF		
CR1	DIO, SI, LO-CAP/LO-LEAK	375907	07263	FD7223	7	2	
CR5	DIO, SI, LO-CAP/LO-LEAK	375907	07263	FD7223	REF		
CR6	DIO, SI, LO-CAP/LO-LEAK	375907	07263	FD7223	REF		
CR8	DIO, SI, LO-CAP/LO-LEAK	375907	07263	FD7223	REF		
CR9	DIO, SI, LO-CAP/LO-LEAK	375907	07263	FD7223	REF		
CR10	DIO, SI, LO-CAP/LO-LEAK	375907	07263	FD7223	REF		
CR11	DIO, SI, LO-CAP/LO-LEAK	375907	07263	FD7223	REF		
E	JUMPER WIRE CONNECTIONS						
J1	CONN, HEADER	519751	89536	519751	1		
MP1	SOCKET, COMPONENT LEAD (NOT SHOWN)	376418	22526	75060-007	4		
MP2	TRANSISTOR PAD, SPACER (NOT SHOWN)	152207	07047	10123-DAP	1		
Q3	XSTR, J-FET, N-CHAN	343830	89536	343830	6	2	
Q4	XSTR, FET	429977	89536	429977	2	1	
Q5	XSTR, FET	429977	89536	429977	REF		
Q6	XSTR, J-FET, N-CHAN	343830	89536	343830	REF		
Q7	XSTR, J-FET, N-CHAN	343830	89536	343830	REF		
Q8	XSTR, J-FET, N-CHAN	343830	89536	343830	REF		
Q9	XSTR, J-FET, N-CHAN	343830	89536	343830	REF		
Q10	XSTR, J-FET, N-CHAN	343830	89536	343830	REF		
Q11	XSTR, J-FET, N-CHAN	419283	32293	ITS3079	1	1	
Q12	XSTR, NPN	218396	89536	218396	1	1	
R1	RES, VAR, SIDE-ADJUST, 20K	291609	75378	360S-203AZ	1		
R2	RES, VAR, 2K +/-10%	285163	75378	360T-202AZ	1		
R3	RES, VAR, 200 +/-10%	285148	75378	360T-200AZ	3		

Table 5-6. A/D And Ohms Converter PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
R4	RES, COMP, 4.7M +/-5%, 1/4W	220046	01121	CB4755	1		
R5	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	1		
R6	RES, MTL. FILM, 10K +/-1%, 1/8W	168260	91637	CMF55103	2		
R7	RES, MTL. FILM, 10K +/-1%, 1/8W	168260	91637	CMF55103	REF		
R8	RES, DEP. CAR, 2.0K +/-5%, 1/4W	441469	80031	CR251-4-5P2K	2		
R9	RES, VAR, 20 +/-10%	285114	75378	360T-020A2	1		
R10	RES, VAR, 50 +/-10%	285122	75378	360T-050A2	1		
R11	RES, VAR, 200 +/-10%	285148	75378	360T-200AZ	REF		
R12	RES, 54.7K +/-.05%, 1/4W	492223	89536	492223	1		
R17	RES, VAR, 50, RECT.	267815	11236	190PC500B	1		
R18	RES, VAR, 100K +/-10%	288308	75378	360T-102A2	1		
R19	RES, DEP. CAR, 1M +/-5%, 1/4W	348987	80031	CR251-4-5P1M	1		
R20	RES, DEP. CAR, 10 +/-5%, 1/4W	340075	80031	CR251-4-5P10E	1		
R21	RES, DEP. CAR, 2.0K +/-5%, 1/4W	441469	80031	CR251-4-5P2K	REF		
R22	RES, COMP, 1.5M +/-5%, 1/4W	182857	01121	CB1555	1		
R23	RES, COMP, 10 =/-5%, 1/4W	147868	01121	CB1005	1		
R24	RES, DEP. CAR, 1K +/-5%, 1/4W	343426	80031	CR251-4-5P1K	2		
R25	RES, DEP. CAR, 33K +/-5%, 1/4W	348888	80031	CR251-4-5P33K	2		
R26	RES, DEP. CAR, 8.2K +/-5%, 1/4W	441675	80031	CR251-4-5P8K2	1		
R27	RES, DEP. CAR, 1K +/-5%, 1/4W	343426	80031	CR251-4-5P1K	REF		
R28	RES, VAR, 200 +/-10%	285148	75378	360T-200AZ	REF		
R29	RES, VAR, 5K +/-10%	288282	75378	360T-052A2	2		
R30	RES, VAR, 5K +/-10%	288282	75378	360T-052A2	REF		
R31	RES, DEP. CAR, 82K +/-5%, 1/4W	348912	80031	CR251-4-5P82K	1		
R32	RES, DEP. CAR, 200K +/-5%, 1/4W	441485	80031	CR251-4-5P200K	1		
R36	RES, DEP. CAR, 68K +/-5%, 1/4W	376632	80031	CR251-4-5P68K	1		
R37	RES, MTL. FILM, 6.81K +/-1%, 1/8W	268417	91637	CMF556813F	1		
R38	RES, MTL. FILM, 402K +/-1%, 1/8W	217984	91637	CMF554023	1		
R39	RES, DEP. CAR, 33K +/-5%, 1/4W	348888	80031	CR251-4-5P33K	REF		
R40	RES, MTL. FILM, 3.74K +/-1%, 1/8W	272096	91637	CMF553743F	2		
R41	PART OF U22 REF AMP SET						
R42	PART OF U22 REF AMP SET						
R43	RES, MTL. FILM, 3.74K +/-1%, 1/8W	272096	91637	CMF553743F	REF		
R44	RES, COMP, 3.3K +/-5%, 1/4W	148056	01121	CB3325	1		
R45	RES, MTL. FILM, 64.9K +/-1%, 1/8W	288530	91637	CMF556493F	1		
R46	RES, MTL. FILM, 110K +/-1%, 1/8W	234708	91637	CMF551103F	1		
R47	RES, MTL. FILM, 113K +/-1%, 1/8W	291302	91637	CMF551133F	1		
TP	TEST POINTS						
U1	RESISTOR NETWORK	511097	89536	511097	1	1	
U2	IC, OP AMP	413732	12040	LM308N	2	1	
U4	IC, OP AMP	413732	12040	LM308N	REF		
U5	IC, LINEAR	478107	12040	LM308A	1	1	
U6	IC, LIN, QUAD COMPARATOR	387233	12040	LM339N	6	2	
U7	IC, LIN, QUAD COMPARATOR	387233	12040	LM339N	REF		
U10	RES NETWORK, 5.6K	511048	89536	511048	1	1	
U11	IC, LIN, J-FET	495192	12040	LF353BN	3	1	
U12	IC, LIN, OP AMP	495051	18324	NE5534N	1	1	
U13	IC, LIN, J-FET	495192	12040	LF353BN	REF		
U14	IC, LIN, NPN, 5-XSTR, SIL. ARRAY	248906	02735	CA3046	1	1	
U15	IC, LIN, QUAD COMPARATOR	387233	12040	LM339N	REF		

Table 5-6. A/D And Ohms Converter PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
U16	IC, LIN, QUAD COMPARATOR	387233	12040	LM339N	REF		
U17	IC, LIN, QUAD COMPARATOR	387233	12040	LM339N	REF		
U18	IC, LIN, QUAD COMPARATOR	387233	12040	LM339N	REF		
U19	RES NETWORK, MIXED VALUE +/-2%, 1/8W	520379	89536	520379	1	1	
U20	RES NETWORK, MIXED VALUE +/-2%, 1/8W	520361	89536	520361	1	1	
U21	⊘ IC, C-MOS, DUAL MULTIPLEXER	408369	95303	CD4556BE	1	1	
U22	REF AMP SET (WITH R41 & R42)	523407	89536	532407	1	1	
U23	IC, LIN, J-FET	495192	12040	LF353BN	REF		
W4-W8	JUMPER WIRE CONNECTIONS						

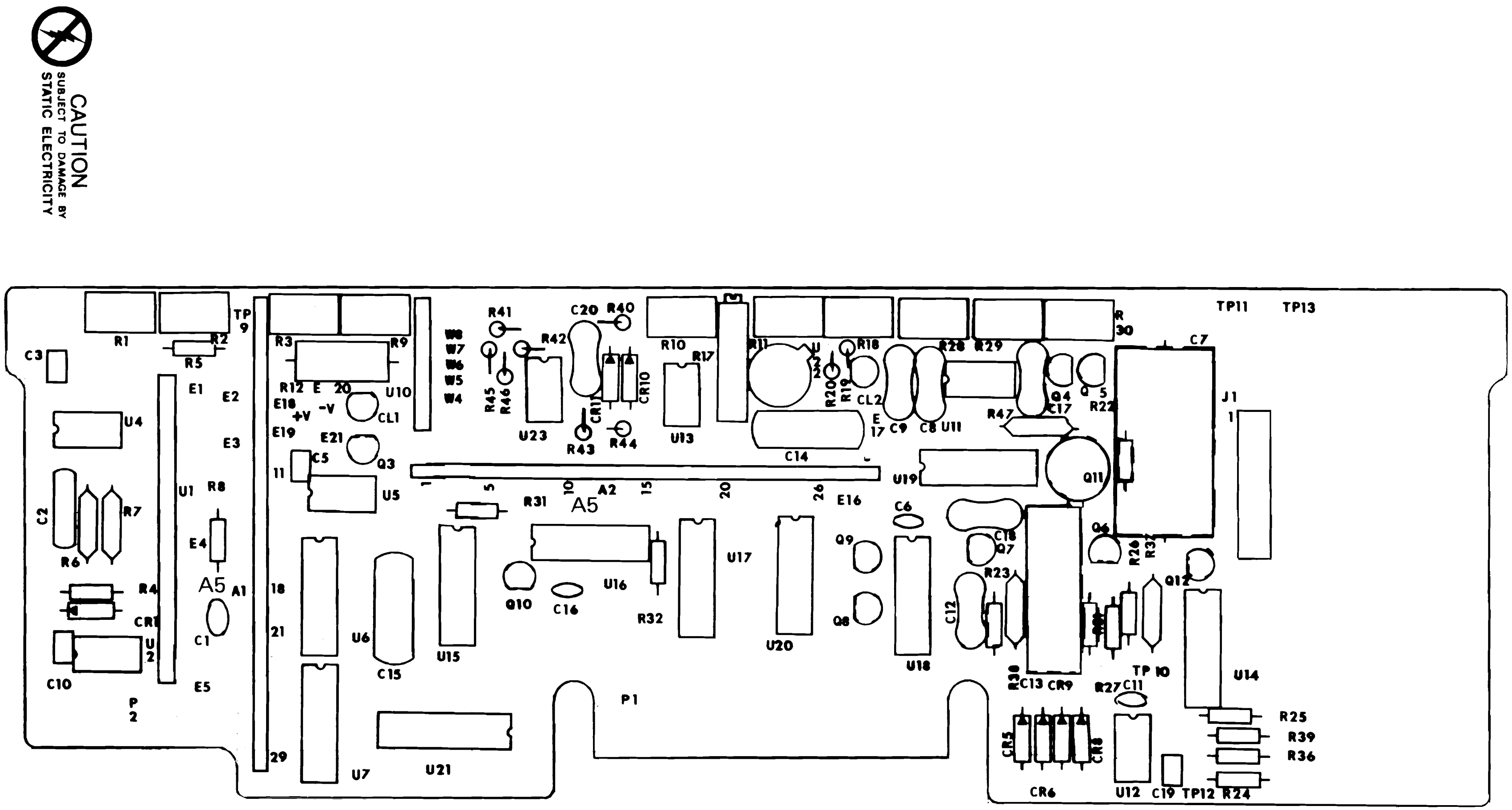


Figure 5-6. A5 A/D and Ohms Converter PCB Assembly

8860A-1605

Section 6
Option Information

TABLE OF CONTENTS

6-1. INTRODUCTION

6-2. This section of the manual contains service information for the 8860A options. Each option has its own subsection which includes: a theory of operation, troubleshooting information, and a list of replaceable parts. The schematics for the options are located in Section 8. The option number is used in the page and paragraph numbers of each option. For instance, option -004 starts on page 004-1.

Option -004
Calculating Controller

004-1. THEORY OF OPERATION

004-2. The Calculating Controller, Option (-004) is composed of the following four circuit boards. The schematic diagram for each circuit board is located in Section 8. A simplified block diagram is shown in Figure 004-1.

- Calculator/Printer PCB Assembly
- Rear Interface PCB Assembly
- Memory Cartridge PCB Assembly
- Control Keyboard PCB Assembly

004-3. The first two boards listed are connected with a ribbon cable and are installed inside the 8860A chassis. The latter two boards are external to the chassis and plug into the connectors on the Rear Interface board. The Calculating Controller main board is described first.

004-4. Local/Remote Switching

004-5. Selecting the local or remote control function switches the program memory which directs the out-guard microprocessor. In local, the local program memory is in control. When remote is selected, the option program memory is in control.

004-6. The local program memory directs the operations mentioned under Out-guard Processor Software in the Theory of Operation for the basic instrument. The additional operations required by the Calculating Controller option are directed by the option program memory when the remote control function is selected.

004-7. In remote, the option program memory calls parts of the local program memory as subroutines. For example, the option program memory calls on the local program memory routine to scan the keyboard and strobe the display. When the 8860A is switched back to local, control returns to the local program memory.

004-8. Option Program Memory

004-9. The program memory is split between two ROMs (U19 and U10) on the Calculating Controller main board. The active ROM is determined by a group of gates (U17). The out-guard microprocessor controls these gates via P26. The ROMs are custom devices, mask-programmed with the Calculating Controller software. Table 3-2 shows how the two ROMs are accessed using ports P23, P26, and P50.

004-10. Calculator

004-11. The number-oriented processor (U5) executes all the math functions and contains the XYZT stack. A divide-by-5 circuit (U16) provides a 400-kHz clock for U5. Processor U5 interfaces to the out-guard microprocessor through U2, an I/O Expander with RAM. For example, when the square root function is executed, U5 performs the calculation and U2 reports the result back to the out-guard microprocessor for display. U2 also receives and responds to switch closures from the handheld Control Keyboard. A 256-byte RAM in U2 holds the contents of the addressable registers R10-R49 and the print buffer.

004-12. The two ports of U10 communicate with the rear panel Data Port. The Data Port is the interface for the optional printer or the user I/O functions, R50-R57. Tri-state buffers U7, U11, U12, and U13 provide bi-directional data buffering to the Data Port. U10 also contains a 2 kbyte ROM.

004-13. Data Bus and Address Bus

004-14. The out-guard microprocessor communicates over the data bus DB0-DB7 with the ROM and I/O expanders (U2, U10, and U19), the Memory Cartridge, the optional printer, and the User I/O. Control lines which identify and route each byte on the data bus are ALE (address latch enable), $\overline{\text{PSEN}}$ (program store enable), $\overline{\text{RD}}$, and $\overline{\text{WR}}$.

- ALE (address latch enable) is a steady 400 kHz.
- PSEN (program select enable) is active whenever

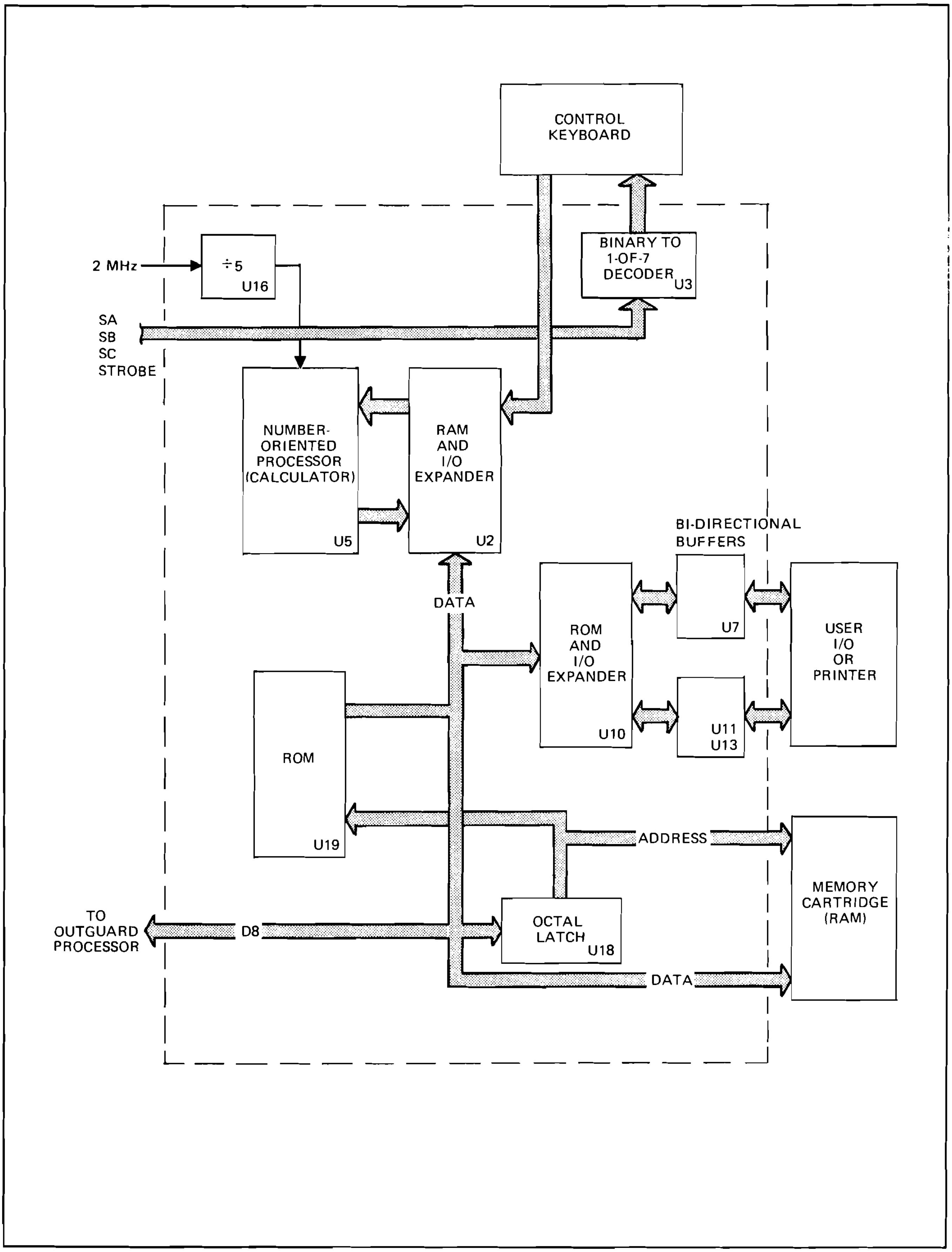


Figure 004-1. Calculating Controller Option-004 Block Diagram

the processor is reading its program ROM, which it does regularly.

- RD (read) and WR (write) are used only when Option -004 or -005 is installed. They are active when the processor is using the data bus for communication other than reading the program memory. For instance, they are active when the processor is reading the Control Keyboard.

004-15. The address and data for ROM U10 are multiplexed over the data bus. By contrast, the address and data for ROM U19 and the Memory Cartridge RAM are carried on separate lines. The 8-bit latch U18 stores the address for these latter two devices. The upper four bits of address, A8-A11, travel on their own lines, P20-P23, to U19 and U10.

004-16. Power Supply

004-17. All circuits operate off the +5V out-guard supply. IC U5, the only P-channel MOS device, requires an additional -4V supply derived through CR1, CR2, CR3, Q1, and the power transformer secondary.

004-18. Three level shifters in U4 convert a TTL level (0V to 5V) to a PMOS level (-4V to +5V) for pins 7, 9, and 11 of U5.

004-19. Memory Cartridge (Schematic 8860A-1013)

004-20. The Memory Cartridge contains two CMOS RAM devices to hold addressable registers R00 through R09 and all of programmable memory, steps 00 through 99. All data and address lines are pulled to ground through 100 kΩ resistors to keep the current drain at a minimum.

004-21. Two silver-oxide watch batteries (TB1, TB2) supply power to the RAMs when the cartridge is not receiving power from the 8860A. Three diodes (CR1 on the memory Cartridge board; CR4 and CR5 on the Calculating Controller main board) prevent the +5V supply from attempting to charge the batteries. The RAM devices draw a current of 50 nA to 1 uA from the batteries at approximately 2.5V.

004-22. Jumper W1 at pin 22 of U1 allows power to be removed from U1 during troubleshooting. If it is discovered that the Memory Cartridge is drawing an excessive amount of current from the batteries, remove this jumper to identify the faulty RAM.

004-23. TROUBLESHOOTING THE CALCULATING CONTROLLER

004-24. Table 004-1 contains troubleshooting information for the Calculating Controller. Before using the table, remove the Option -004 PCB from its slot in the 8860A, and check the operation of the basic DMM. If the DMM is operating properly, reinstall the PCB, and refer to the table.

004-25. The troubleshooting table is a series of symptoms and solutions. Check the unit for the symptoms in sequence. When a symptom is identified, clear the fault using the solutions listed for that fault. All devices mentioned in the table are located on the Calculating Controller PCB.

CAUTION

To avoid instrument damage, remove power from the 8860A before unplugging the circuit board or removing plug-in devices.

004-26. LIST OF REPLACEABLE PARTS

004-27. A list of replaceable parts for the Calculating Controller is given in Table 004-2. Refer to Section 5 of this manual for ordering information.

CAUTION

Indicated devices are subject to damage by static discharge.

Table 004-1. Calculating Controller Troubleshooting

SYMPTOM	INSTRUCTIONS
1. The 8860A does not operate in local when the -004 Option PCB is installed, but works when the board is removed.	•Suspect the Memory Cartridge, U19, U2 or U10. •Remove these devices one at a time, until the basic instrument operates normally (in local). These devices are all in sockets and all sit on the internal bus. Replace the device which clears the fault.
2. With the option installed, the 8860A operates in local but not in remote.	•Replace U10, U19, U2, and U5. •Check U17 (pin 6 is high when pins 4 and 10 are both high). •Check U18 as described in step 7. •Check U12 for high state at pin 9. •Check U16 for 2 MHz at pin 1, and 400 kHz at pin 8. •Check U4 for 400 kHz at pin 2, +4.5V to -3.5V swing. •Check U5, pin 21, for a dc voltage between -3.5V and -4.5V (negative supply). •Check U5, pin 11, for a dc voltage between -3.5V and -4.5V (release of initial reset). •Check U2, pin 28, for a low state (drives U5, pin 11).
3. Cannot store or recall Memory Cartridge data	•Check Q2, Q3, U14 (on Option -004 mainboard); pin 11 of U14 should be high after initial turn-on delay. •Check U15, pin 11, for continuous switching. •Check control lines as described in step 8.
4. User I/O and/or Print functions do not work.	•Replace U10. Check U7, U11, and U13 as follows (with nothing connected to the data port): ·RCL 50 causes pin 1 of U7 and U11 to go low. ·STO 50 causes pin 1 of U13 and U7 to go low. •Check U12. pins 13 and 14, and U10 pin 31 for a low state when nothing is connected to the data port. •With the printer connected (make sure the printer is a 2020A with Option -001 installed; Option -004 or a Model 2030A Printer will also work): U12, pins 14 and 13, and U10 pin 31 should all be high when the printer is on. Pins 1, 6, and 7 of U7 and pin 1 of U11 should remain low for the duration of a print function (Print X, for example). During this time, 18 pulses should occur on pins 4, 5, 9, and 10 of U7 and on pins 37 and 39 of U10.
5. Control Keyboard cannot be read	•Check U3; outputs should sequentially pulse low. •Replace U2 if pins 33 through 36 switch, but are not affected when a key is pressed.
6. Math Functions and XYZT Stack are inoperative.	•Check the following points for switching when a key is pressed (x-exchange-y key, for instance): •Pin 10 of U2, $\overline{WR}$ (normally high), for one negative pulse. •Pin 6 of U15 (normally low) for one positive pulse. •Pin 8 of U15 (normally high) for approximately 12 pulses. •Pins 1 and 3 of U14 (normally high) for approximately 12 pulses. •Pin 4 of U14 (normally high) for one negative pulse. •Pin 5 of U12 (normally high) for approximately 12 pulses. •Check pin 9 of U12 (normally low) to go high on Err 99.
7. Faulty Address Latch (U18)	•Check U18 with a dual-trace scope. Trigger the scope on ALE and look at the input and output of each latch. If ALE and the latch are working properly, then the latch output follows the latch input when ALE is high. The latch input is stored when ALE goes low.
8. Faulty Control Line	•Check $\overline{PSEN}$, pin 20 of U19, for continuous switching. •Check ALE, pin 11 of U2, for continuous switching. •Check $\overline{RD}$, pin 9 of U2, for continuous switching.

Table 004-2. Calculating Controller Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
-004	CALCULATING CONTROLLER ASSEMBLY FIGURE 004-2 (8860A-004)	ORDER	BY	OPTION -004			
	CONTROL KEYBOARD	533588	89536	533588	1		
	MEMORY CARTRIDGE	Y8833	89536	Y8833	1		
	CALCULATOR/PRINTER PCB ASSEMBLY	516328	89536	516328	1		
H1	HARDWARE KIT	512400	89536	512400	2		
MP1	PANEL, (SUB) CAL PRINTER	531038	89536	531038	1		
MP2	INSULATOR	541862	89536	541862	1		
MP3	CUP	541888	89536	541888	1		

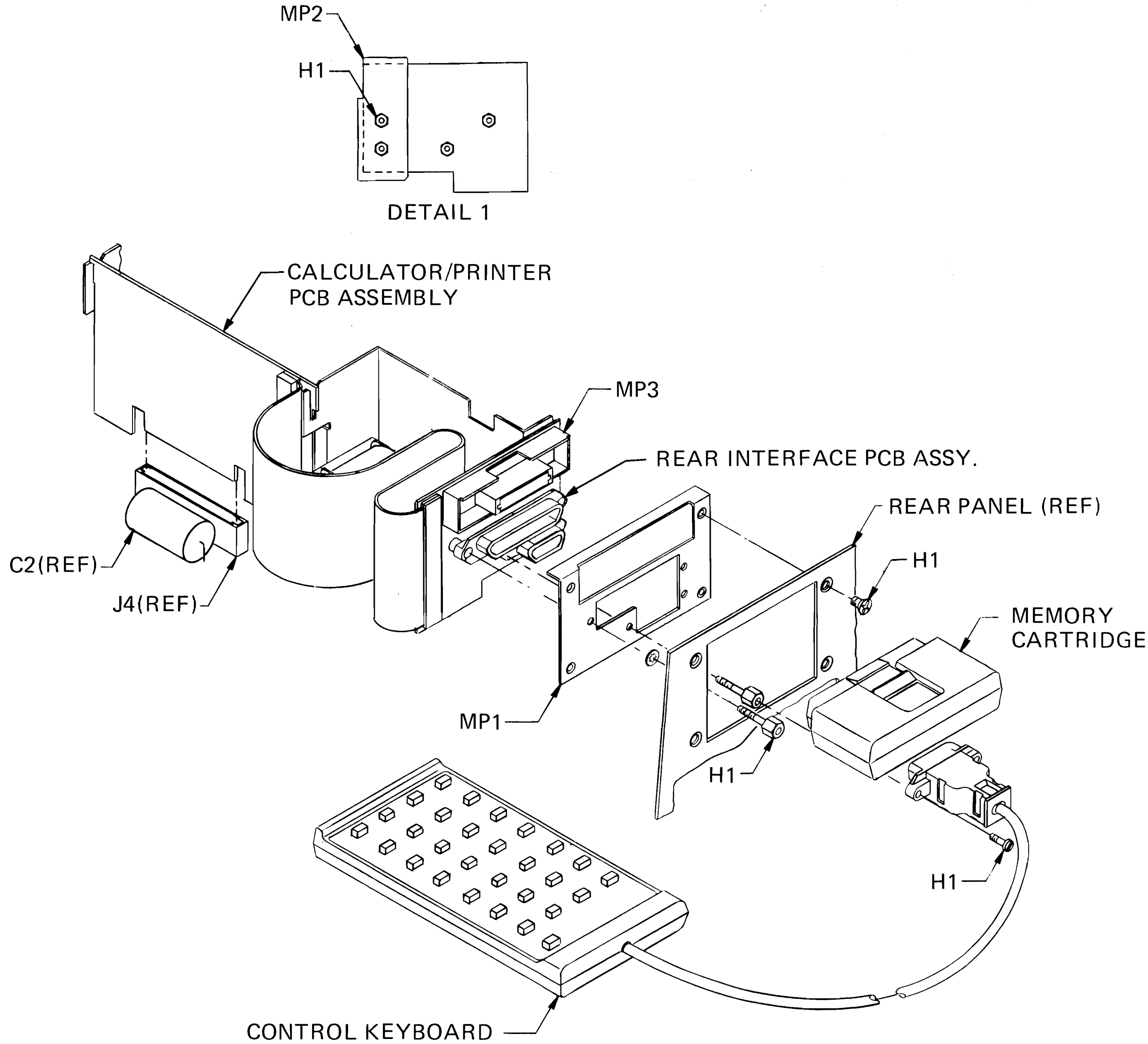


Figure 004-2. Calculating Controller Assembly

Table 004-3. Control Keyboard Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
	CONTROL KEYBOARD ASSEMBLY FIGURE 004-3 (8860A-4026)	533588	89536	533588	REF		
H1	SCREW, FHP, 4-40 X 7/16	542225	89536	542225	2		
MP1	CASE, FRONT	509406	89536	509406	1		
MP2	CASE, REAR	509281	89536	509281	1		
MP3	BUTTON, SLIDE SWITCH (W/S10)	509331	89536	509331	1		
MP4	FOOT, CASE	507624	89536	507624	4		
MP5	BUTTON, GREY	509398	89536	509398	14		
MP6	BUTTON, ORANGE	509364	89536	509364	1		
MP7	BUTTON, WHITE	509372	89536	509372	12		
MP8	BUTTON, DARK GREY	509257	89536	509257	1		
MP9	DECAL	507616	89536	507616	1		
MP10	SPRING (ALL SWITCHES)	414516	00779	62353-3	28		
MP11	CONTACT, FIXED (ALL SWITCHES)	416875	00779	62380-4	28		
P1	HEADER, 14-PIN	519652	22526	65521-114	1		
S10	SWITCH, SLIDE (W/MP3)	477984	79727	GS-115	1		
W1	CALCULATOR CABLE	534099	89536	534099	1		
X	CALCULATOR KEYBOARD PCB	ORDER	NEXT	HIGHER ASSY.			

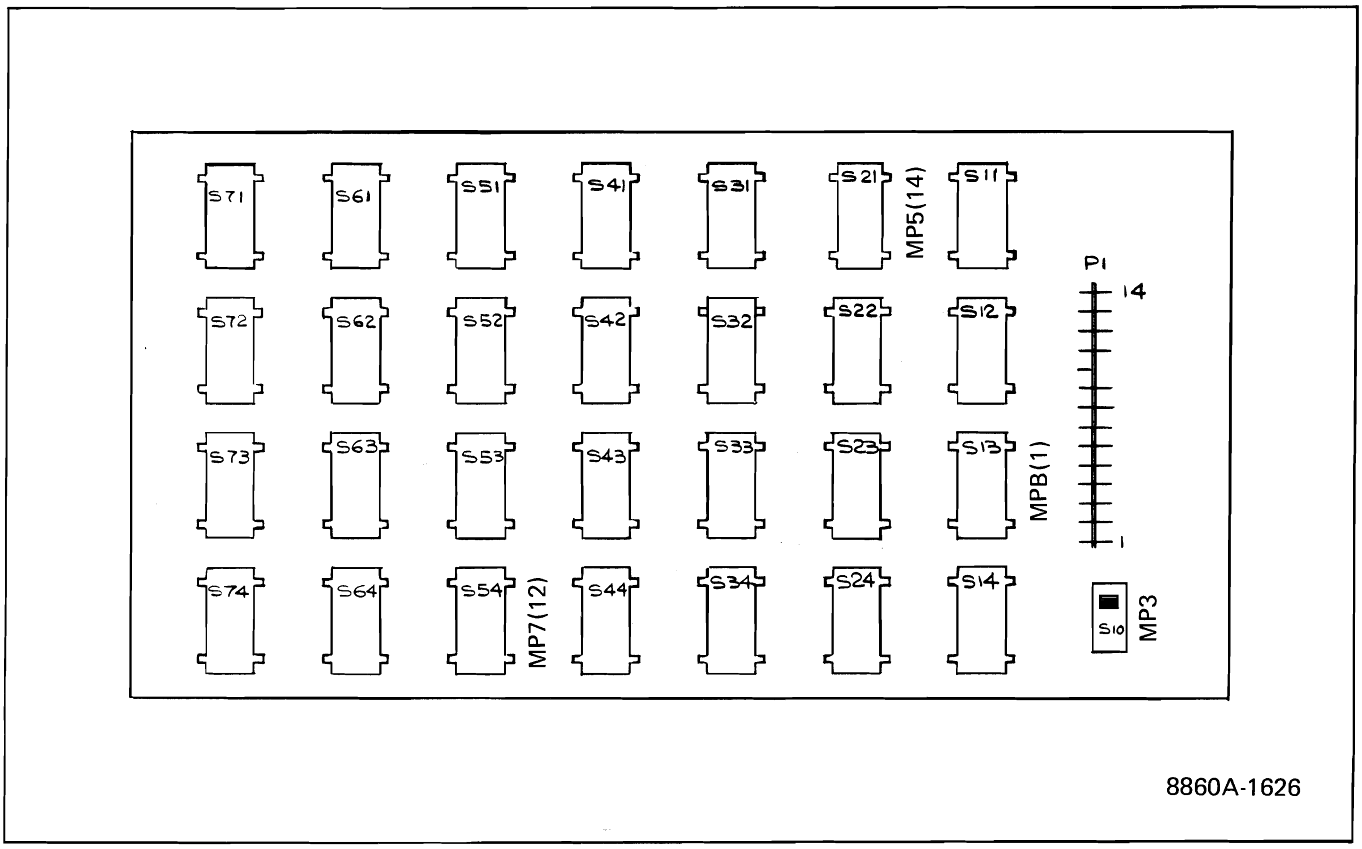


Figure 004-3. Control Keyboard PCB Assembly

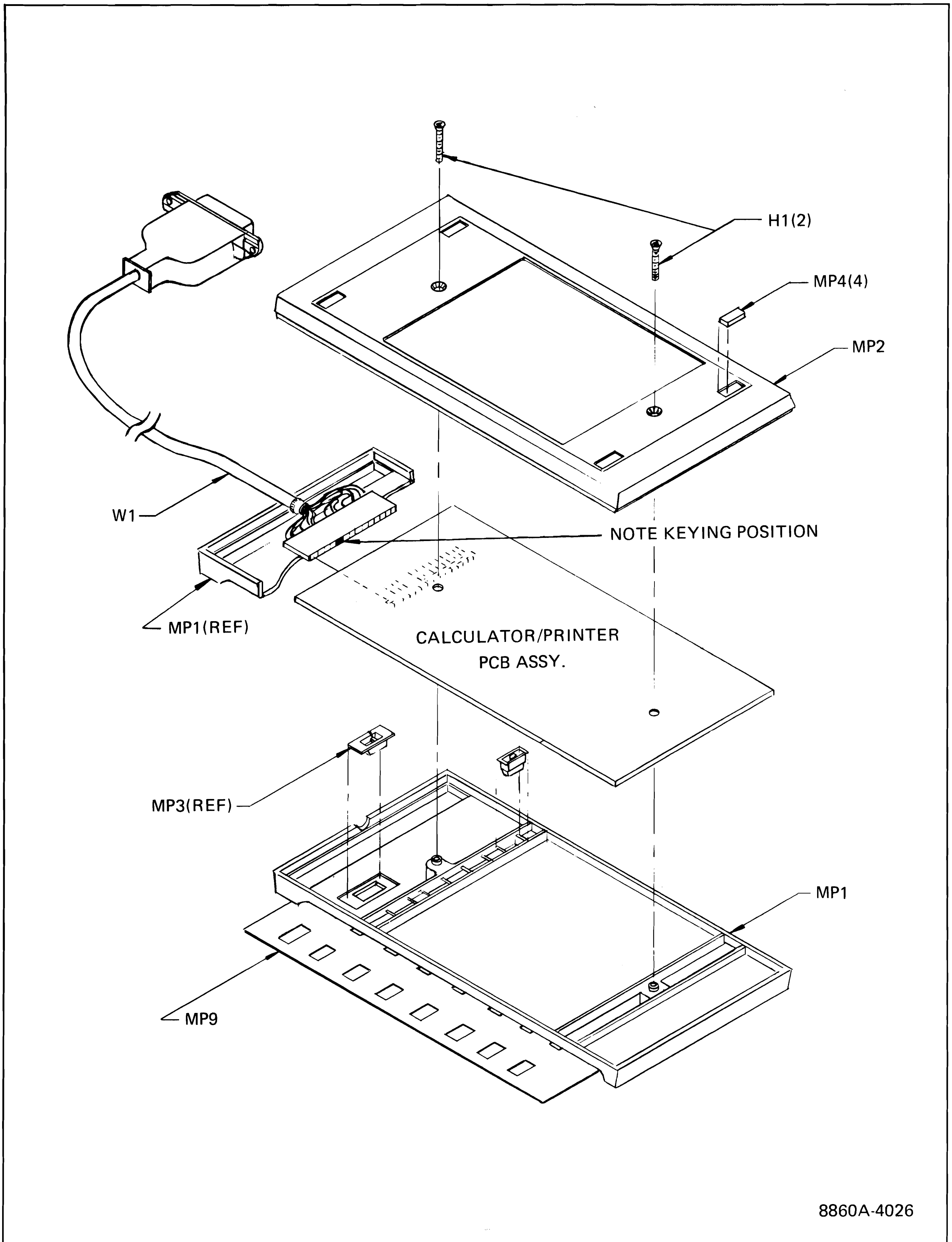


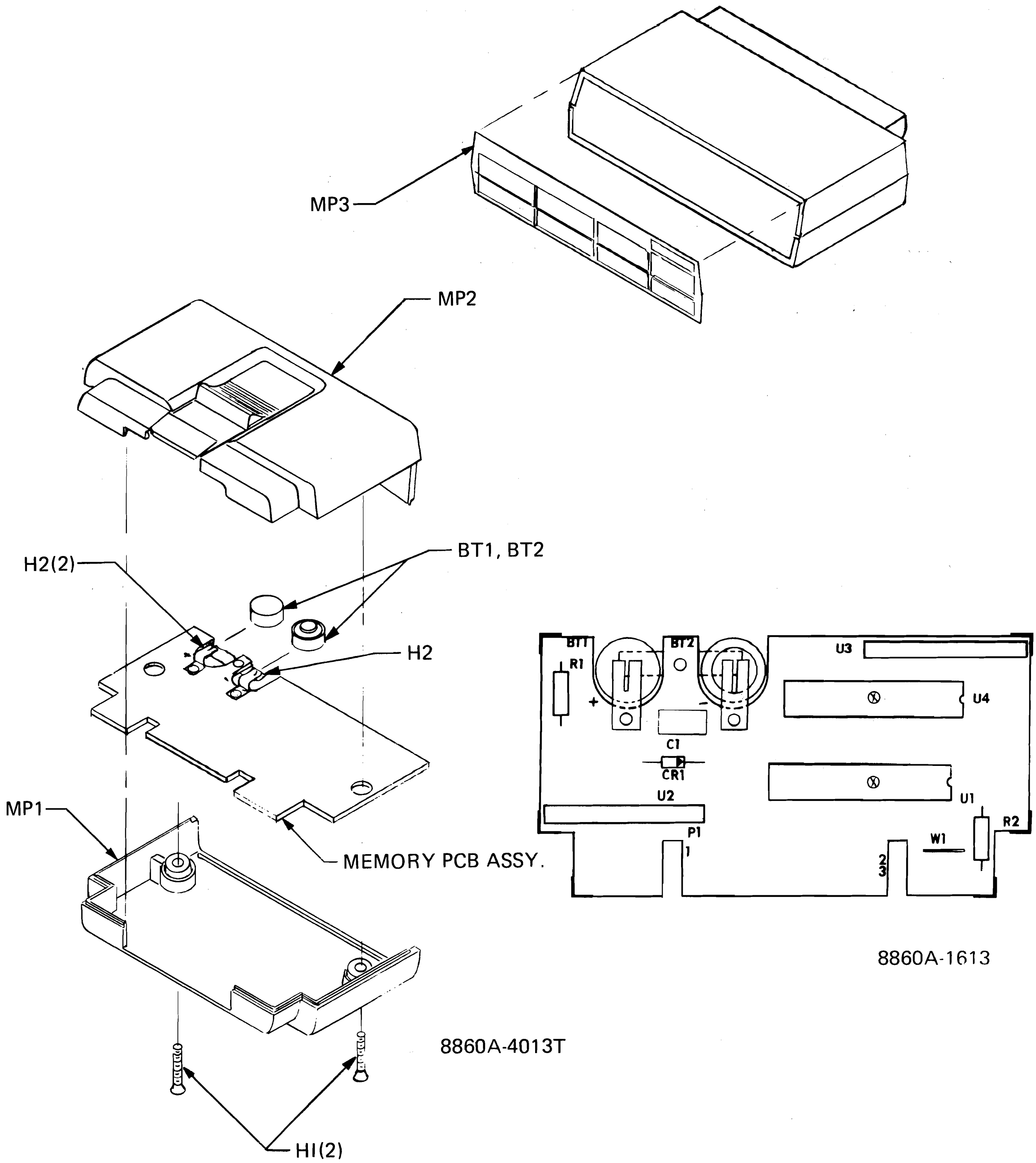
Figure 004-3. Control Keyboard PCB Assembly (cont)

Table 004-4. Memory Cartridge

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
	⊘ MEMORY CARTRIDGE FIGURE 004-4 (Y8833)	ORDER	BY	Y8833			
	MEMORY PCB ASSEMBLY						
BT1	BATTERY, SILVER OXIDE	520221	89536	520221	2		A
BT2	BATTERY, SILVER OXIDE	520221	89536	520221	REF		
C1	CAP, CER, 0.22 UF +/-20%, 50V	309849	71590	CW30C224K	1		B
CR1	DIO, SI, HI-SPEED SWITCHING	203323	07910	1N4448	1	1	B
H1	SCREW FHP, 6-20 X 5/8	529479	89536	529479	2		
H2	SPRING, BATTERY CONTACT	525287	89536	525287	1		
MP1	CASE, BOTTOM	509240	89536	509240	1		
MP2	CASE, TOP	509323	89536	509323	1		
MP3	DECAL, MEMORY MODULE	534438	89536	534438	1		
MP4	SPRING CONTACT (NOT SHOWN)	525287	89536	525287	1		B
P1	BOARD CONNECTION						
R1	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	89536	348920	2		B
R2	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	89536	348920	REF		B
U1	⊘ IC, C-MOS, STATIC RAM, 3-STATE OUTPUT	429860	89536	MCM51L01P65	2	1	B
U2	RESISTOR NETWORK, 100K	461038	89536	461038	2	1	B
U3	RESISTOR NETWORK, 100K	461038	89536	461038	REF		B
U4	⊘ IC, C-MOS, STATIC RAM, 3-STATE OUTPUT	429860	89536	MCM51L01P65	REF		B
W1	JUMPER WIRE	529271	89536	529271			B

A WARNING, DO NOT RECHARGE! BATTERIES MAY EXPLODE OR LEAK.

B ITEMS ON MEMORY PCB ASSEMBLY.



CAUTION
SUBJECT TO DAMAGE BY
STATIC ELECTRICITY

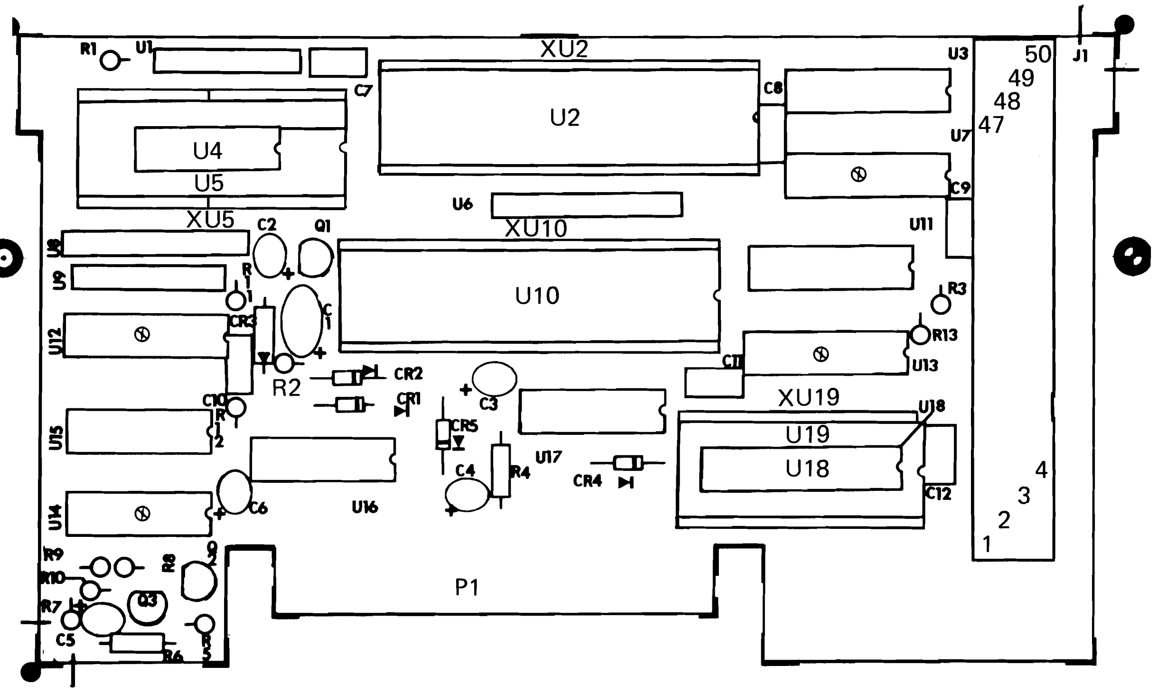
Figure 004-4. Memory Cartridge

Table 004-5. Calculator/Printer PCB Assembly

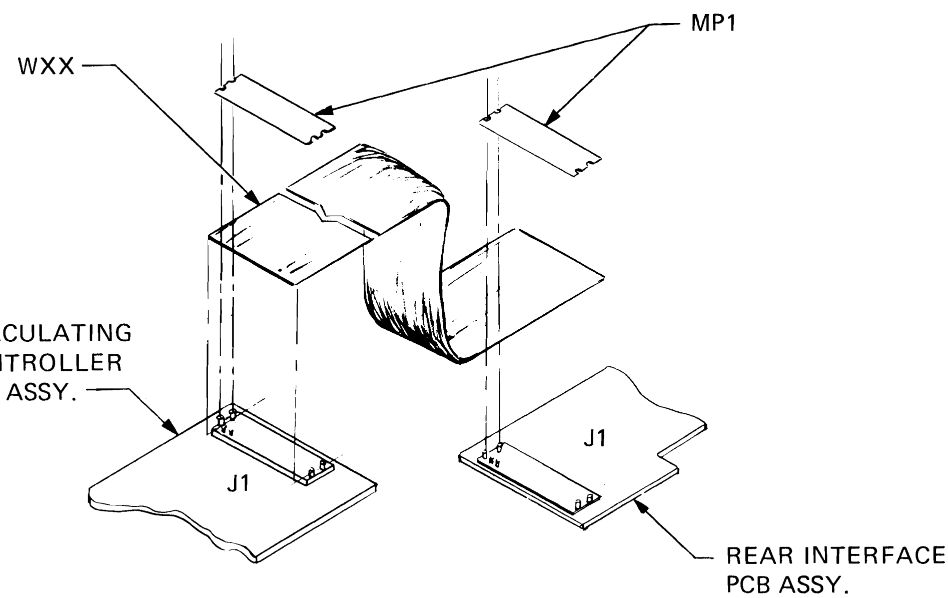
REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
	⊘ CALCULATOR/PRINTER PCB ASSEMBLY FIGURE 004-5 (8860A-4014T)	516328	89536	516328	REF		
	REAR INTERFACE PCB ASSEMBLY	ORDER	NEXT	HIGHER ASSEMBLY			
C1	CAP, TA, 47 UF +/-20%, 20V	348516	56289	A96D476X0020KE4	1		
C2	CAP, TA/DISC, 10 UF +/-20%, 10V	176214	56289	196D106X0010KA1	1		
C3	CAP, TA, 15 UF, 20V	519686	56289	196D156X0020KE4	1		
C4	CAP, TA, 68 UF, 6V/8V	519702	56289	196D686X0008KE4	1		
C5	CAP, TA, 39 MF +/-20%, 6V	163915	56289	196D394X0020KA1	1		
C6	CAP, TA/DISC, 4.7 UF +/-20%, 20V	161943	56289	196D476X0020KA1	1		
C7	CAP, CERAM, 0.22 UF +/-20%, 50V	309849	72982	8131-050-651-022	6		
C8	CAP, CERAM, 0.22 UF +/-20%, 50V	309849	72982	8131-050-651-022	REF		
C9	CAP, CERAM, 0.22 UF +/-20%, 50V	309849	72982	8131-050-651-022	REF		
C10	CAP, CERAM, 0.22 UF +/-20%, 50V	309849	72982	8131-050-651-022	REF		
C11	CAP, CERAM, 0.22 UF +/-20%, 50V	309849	72982	8131-050-651-022	REF		
C12	CAP, CERAM, 0.22 UF +/-20%, 50V	309849	72982	8131-050-651-022	REF		
CR1	DIODE, SIL RECTIFIER, 1A, 100V	343491	03877	1N4002	2	1	
CR2	DIODE, SIL RECTIFIER, 1A, 100V	343491	03877	1N4002	REF		
CR3	DIODE, ZENER, 400 MW, 4.7V	524058	14552	1N751	1	1	
CR4	DIODE, SI, HI-SPEED SWITCHING	203323	06001	1N4448	2	1	
CR5	DIODE, SI, HI-SPEED SWITCHING	203323	06001	1N4448	REF		
J1	CONN, 50-PIN	519918	52152	3426-0000T	1		
MP1	COVER, CONN (TO J1)	519934	89536	519934	2		
P1	BOARD CONNECTION						
P26	BOARD CONNECTION						
Q1	XSTR, SI, PNP	195974	64713	2N3906	3	1	
Q2	XSTR, SI, PNP	195974	64713	2N3906	REF		
Q3	XSTR, SI, PNP	195974	64713	2N3906	REF		
R1	RES, DEP. CAR, 27K +/-5%, 1/4W	441501	89536	441501	1		
R2	RES, DEP. CAR, 470 +/-5%, 1/4W	343434	89536	343434	1		
R3	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	89536	348839	2		
R4	RES, DEP. CAR, 82 +/-5%, 1/4W	442277	89536	442277	1		
R5	RES, DEP. CAR, 33K +/-5%, 1/4W	348888	89536	348888	1		
R6	RES, DEP. CAR, 2K +/-5%, 1/4W	441469	89536	441469	1		
R7	RES, DEP. CAR, 39K +/-5%, 1/4W	442400	89536	442400	1		
R8	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	89536	348839	REF		
R9	RES, DEP. CAR, 1.1K +/-5%, 1/4W	348797	89536	348797	1		
R10	RES, DEP. CAR, 270 +/-5%, 1/4W	348789	89536	348789	1		
R11	RES, DEP. CAR, 2.7K +/-5%, 1/4W	386490	89536	386490	1		
R12	RES, DEP. CAR, 5.6K +/-5%, 1/4W	442350	89536	442350	1		
R13	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	89536	348920	1		
U1	RESISTOR NETWORK, SIP, 3.6K +/-2%, 1/8W	478818	89536	478818	1	1	
U2	IC, 2K X 8 BIT RAM, PROGRAMMABLE TIMER	524884	34649	P8155	1	1	
U3	IC, DEMULTIPLEXER	508473	01295	SN74LS156N	1	1	
U4	IC, LIN, QUAD COMPARATOR	387233	12040	LM339N	1	1	
U5	MICROCOMPUTER, PROCESSOR, MOS/LSI	524066	12040	MM57109	1	1	
U6	RESISTOR NETWORK, 10K	412924	89536	412924	1	1	
U7	⊘ IC, C-MOS, HEX NON-INVERT BUFFER	407759	12040	MM80C97N	3	1	
U8	RESISTOR NETWORK, 5.1 X 1K	519694	89536	519694	1	1	

Table 004-5. Calculator/Printer PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
U9	RESISTOR NETWORK, 10K	500876	89536	500876	1	1	
U10	IC, DIGITAL 2KX8 BIT ROM	524876	34649	P8355	1	1	
U11	IC, 3-STATE BUFFER	454819	07263	4009PC	1	1	
U12	⊘ IC, C-MOS, HEX NON-INVERT BUFFER	407759	12040	MM80C97N	REF		
U13	⊘ IC, C-MOS, HEX NON-INVERT BUFFER	407759	12040	MM80C97N	REF		
U14	⊘ IC, C-MOS, QUAD 2-IN & GATE	408401	02735	CD4081BE	1	1	
U15	IC, QUAD 2-IN POS-OR GATE	393108	01295	SN74LS32N	1	1	
U16	IC, TTL MSI, DECADE COUNTER	402545	01295	SN74LS90N	1	1	
U17	IC, TTL MSI, QUAD 2-IN POS-NAND GATE	393033	07263	74LS00PC	1	1	
U18	IC, TTL, OCTAL "D"TYPE F/F	504514	01295	SN74LS373	1	1	
W1	CABLE, 50-STRAND FLAT	404822	89536	404822	1		
XU2	SOCKET, 40-PIN	429282	09922	DILB40P-108	2		
XU5	SOCKET, 7-PIN	520809	30035	SS-109-1-07	4		
XU10	SOCKET, 40-PIN	429282	09922	DILB40P-108	REF		
XU18	SOCKET, 12-PIN	417733	30035	SS-109-1-12	2		
XU19	SOCKET, 12-PIN	417733	30035	SS-109-1-12	REF		



8860A-1614



DETAIL A

CAUTION
SUBJECT TO DAMAGE BY
STATIC ELECTRICITY

8860A-1614

Figure 004-5. Calculator/Printer PCB Assembly

Table 004-6. Rear Interface PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
	REAR INTERFACE PCB ASSEMBLY FIGURE 004-6 (8860A-4024)	ORDER	NEXT	HIGHER ASSEMBLY	REF		
J1	CONNECTOR, 50-POSITION	519918	52152	3426-0000T	1		
J2	CONNECTOR, 24-POSITION	519397	01295	H421121-18	1		
J3	CONNECTOR, 36-POSITION	479261	00779	552235-1	1		
J4	CONNECTOR, 14-POSITION	512392	00779	552212-1	1		
U1	IC, RES. NETWORK, 56K +/-2%, 1/8W	529131	89536	529131	1	1	

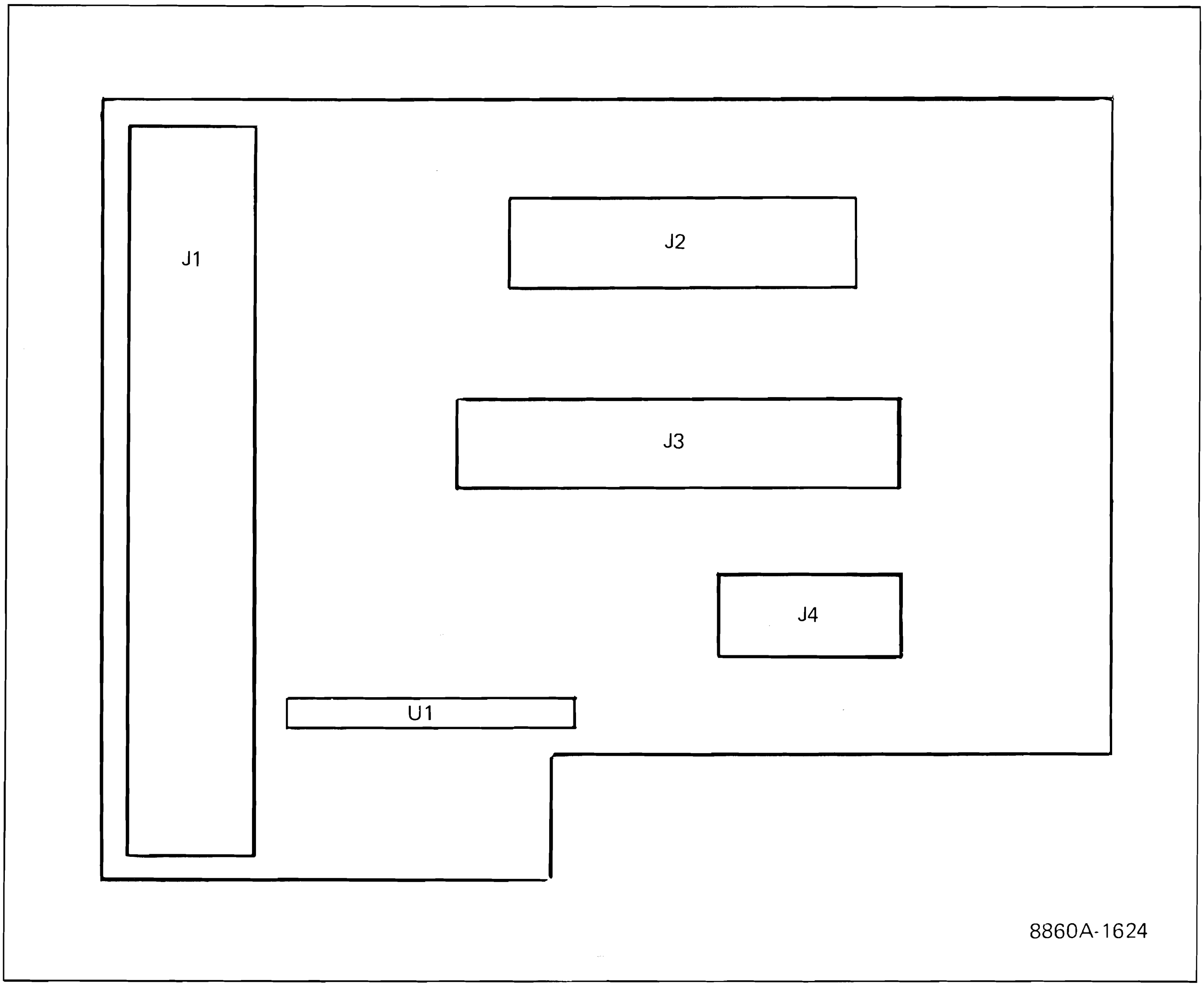


Figure 004-6. Rear Interface PCB Assembly

Option -005

IEEE-488 Interface

005-1. THEORY OF OPERATION

005-2. The IEEE-488 Interface, Option -005, consists of two circuit boards: the IEEE-488 Interface PCB (Schematic 8860A-1015) and the Rear Interconnect PCB (Schematic 8860A-1025). These boards are connected with a ribbon cable. The IEEE connector and the six IEEE address switches are located on the Rear Interconnect PCB. The schematic diagram for each of the two circuit boards is located in Section 8.

005-3. A simplified schematic of the IEEE-488 Interface is shown in Figure 005-1. The IEEE-488 Bus is located at the left, the 8860A basic instrument is at the right.

005-4. Local/Remote Switching

005-5. When the IEEE-488 Interface is installed, the option program memory (U4) is in control for both local and remote operation. Control can be passed to the local program memory (U9 on the Controller PCB), but is always returned to the option program memory. For example, the option program memory calls on the local program memory to perform the measurement routine. When the measurement cycle is finished and the result is obtained, the option program memory again becomes active.

005-6. General Purpose Interface Adapter

005-7. The main device on the IEEE-488 Interface PCB is U1, the general purpose interface adapter (GPIA). This device is designed specifically to interface 8-bit microprocessor data and address buses to the IEEE-488 bus. The GPIA handles the bus protocol functions, including the bus handshake. The GPIA communicates with the bus through two bidirectional bus transceivers (U2 and U5).

005-8. The GPIA contains the serial poll register where the present 8860A measurement status is stored. When a serial poll occurs, the contents of this register are loaded directly onto the IEEE-488 bus.

005-9. Data Bus and Address Bus

005-10. The internal 8-bit data bus, DB0 through DB7, carries information between the devices (GPIA, ROM, RAM) and the out-guard microprocessor. The 8-bit address used by each of these devices is latched by U10. Gates U6 and U8 are used to enable devices (U1, U3, and/or U4) to read or write on the internal bus.

005-11. The rear panel IEEE address switches and the Talk-Only switches connect to the data bus through a hex inverter (U11). The tri-state outputs are enabled by a line from U1. The switch output is read at regular intervals.

005-12. Option Program Memory

005-13. The program memory is contained in U4. Figure 3-2 in Section 3 of this manual shows how the ROM is partitioned and how it is accessed from ports P23, P26, and P50. This ROM (U4) is a custom device that is mask-programmed with the IEEE-488 Interface software.

005-14. DATA STORAGE RAM

005-15. A 128-byte RAM (U3) is used for storing I/O data that appears on the data bus. It contains the input buffer for handling input commands, the output buffer for handling output data, and locations for other data storage.

005-16. TROUBLESHOOTING THE IEEE-488 OPTION

005-17. The following troubleshooting procedure requires that the basic 8860A is working properly. Before starting the procedure, remove the IEEE-488 Interface from its slot in the 8860A, and check the operation of the basic DMM. If the 8860A is operating properly, reinstall the option pcb and proceed with the troubleshooting information given in Table 005-1.

005-18. The troubleshooting table is a series of symptoms and solutions. Check the unit for the symptoms in sequence. When a symptom is identified, clear the fault using the solutions listed for that fault. All devices mentioned in the table are located on the IEEE-488 Interface PCB.

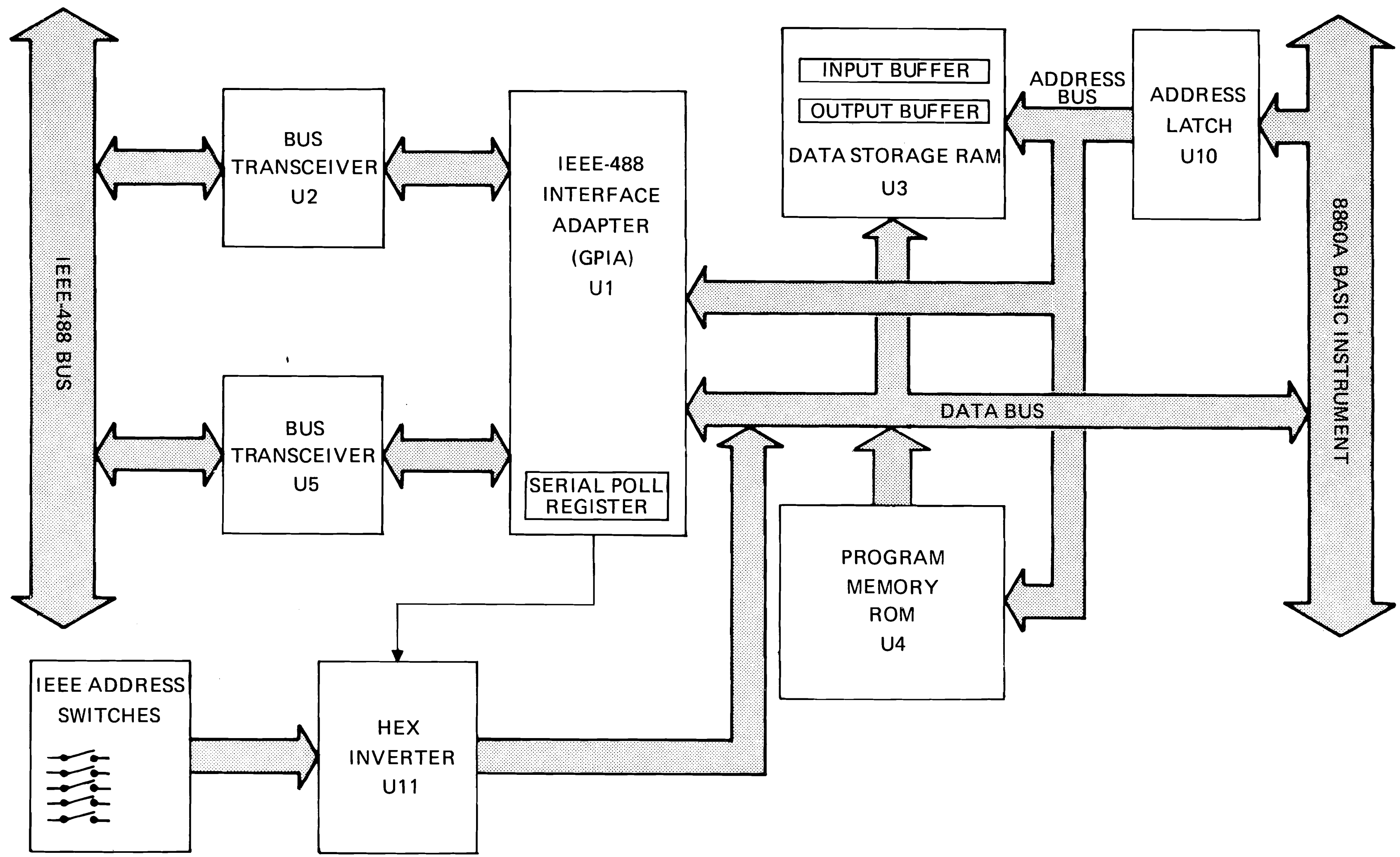


Figure 005-1. IEEE-488 Interface Block Diagram

Table 005-1. IEEE-488 Interface Troubleshooting

SYMPTOM	INSTRUCTIONS
1. Any fault—(initial check)	•Check ALE at U10-11 for 400 kHz. •Check for a high state (+5V) at U1-19 to ensure that reset is released. •Check for a high state (+5V) at U1-4 ($\overline{ASE}$, address switch enable).
2. The 8860A does not respond to front panel local controls (or IEEE-488 bus commands) when the -005 Option is installed.	•Suspect, U1, U3, U4, U6, U8, or U11. Remove these devices one at a time, until the 8860A returns to proper operation. These devices are socketed (except U11) and all sit on the internal bus.
3. The 8860A operates properly from the front panel (with the -005 Option installed), but will not respond to IEEE-488 but commands.	•Suspect U1, U3, U2, U5, U6, U8 (in that order).
4. The displayed IEEE address (using PROG SEL) is different than that selected at the rear panel IEEE switches.	•Suspect faulty IEEE address switches or U11.
5. Faulty Address Latch (U10)	•Check U10 with a dual-trace scope. Trigger the scope on ALE and look at the input and output of each bit. If ALE and the latch are working properly, then the output follows the input value when ALE is high and latches when ALE goes low.

CAUTION

To avoid instrument damage, remove power from the 8860A before unplugging the circuit board or removing plug-in devices.

005-19. LIST OF REPLACEABLE PARTS

005-20. A list of replaceable parts for the IEEE-488 Interface is given in Table 005-2. Refer to Section 5 of this manual for ordering information.

CAUTION

Indicated devices are subject to damage by static discharge.

Table 005-2. IEEE-488 Interface

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
-005	IEEE-488 INTERFACE FIGURE 005-2 (8860A-005)	ORDER	BY	OPTION -005			
	IEEE-488 INTERFACE PCB ASSEMBLY	516310	89536	516310	1		
	REAR INTERCONNECT PCB ASSEMBLY	521294	89536	521294	1		
H1	HARDWARE KIT	543736	89536	543736	1		
MP1	PANEL, (SUB) IEEE INTERFACE	531020	89536	531020	1		

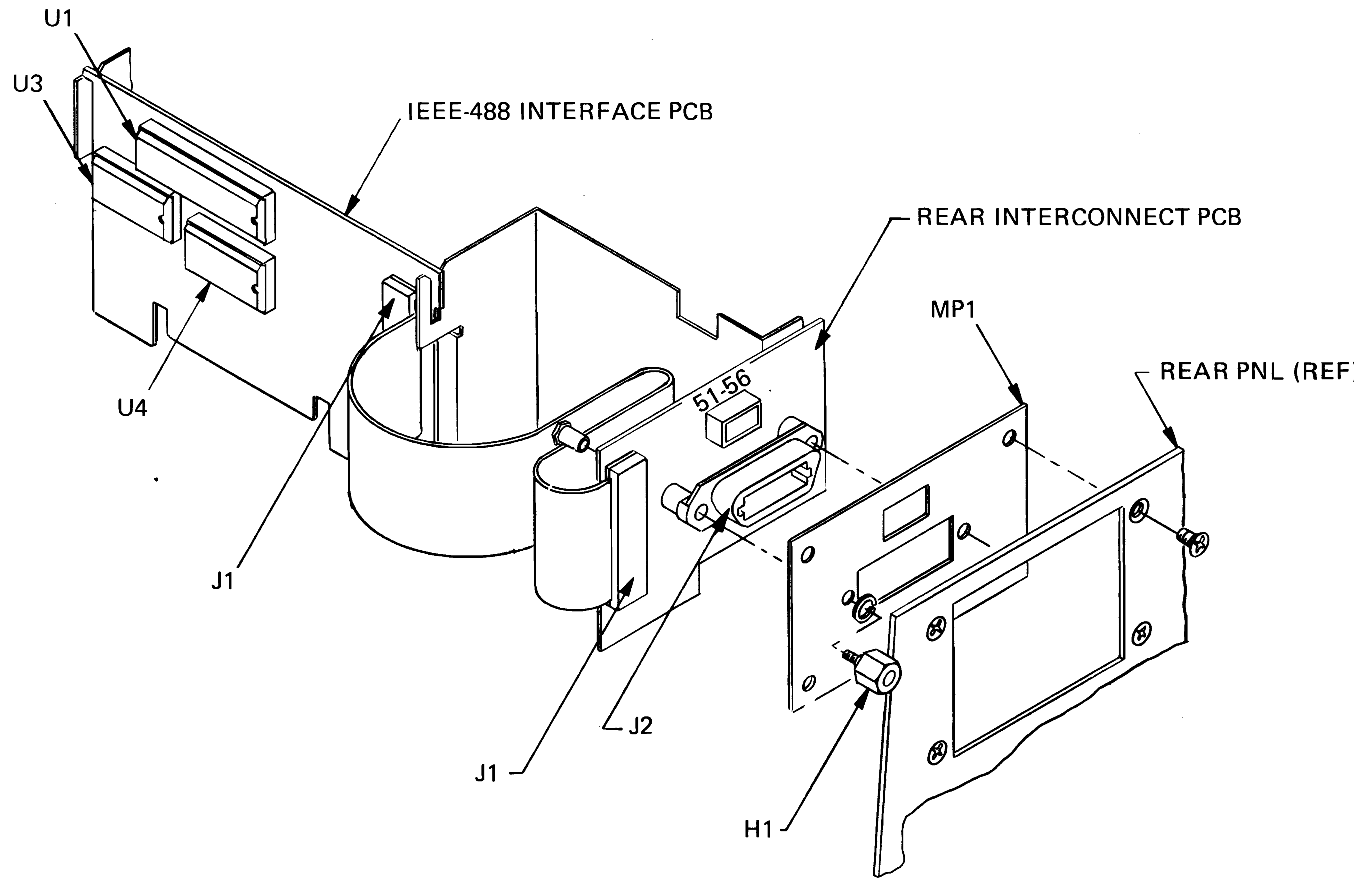


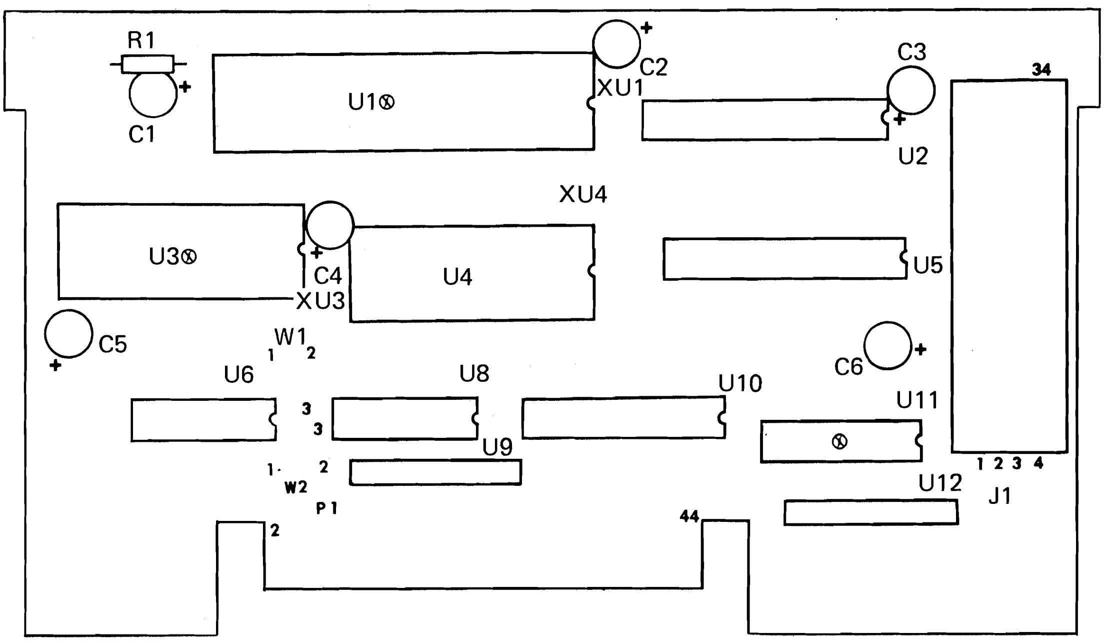
Figure 005-2. IEEE-488 Interface Assembly

8860A-005

8860A-005

Table 005-3. IEEE-488 Interface PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
	⊗ IEEE-488 INTERFACE PCB ASSEMBLY FIGURE 005-3 (8860A-4015T)	516310	89536	516310	REF		
C1	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0020JA1	6		
C2	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0020JA1	REF		
C3	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0020JA1	REF		
C4	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0020JA1	REF		
C5	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0020JA1	REF		
C6	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0020JA1	REF		
J1	CONNECTOR BODY	295337	52152	3402-0000T	1		
MP1	COVER, CONNECTOR (TO J1)	295329	52152	3402-0001T	2		
MP2	MYLAR INSULATOR (NOT SHOWN)	443903	89536	443903	1		
R1	RES, DEP. CAR, 2.7K +/-5%, 1/4W	386490	80031	CR251-4-5P2K7T	1		
U1	⊗ IC, MOS, N-CHANNEL, SI	477794	04713	MC68488P	1	1	
U2	IC, BUS TRANSCIEVER, DIGITAL	524835	04713	MC3447P	2	1	
U3	⊗ IC, MOS RAM, 128 X 8 BIT	524843	07263	F6810PC	1	1	
U4	IC, DIGITAL, 4K X 8 BIT, MOS ROM	535070	55576	SYP233	1	1	
U5	IC, BUS TRANSCIEVER, DIGITAL	524835	04713	MC3447P	REF		
U6	IC, POS NOR, TOTEM POLE OUTPUTS	393041	01295	SN74LS02N	1	1	
U8	IC, TTL, QUAD, 2-INPUT, POS, NAND GATE	393033	01295	SN74SL00N	1	1	
U9	RES. NETWORK, SIP, 33K +/-2%, 1/8W	484741	89536	484741	1	1	
U10	IC, TTL, OCTAL "D" TYPE F/F	504514	01295	SN74LS373	1	1	
U11	⊗ IC, C-MOS, 3-STATE, INVERTER BUFFER	454819	07263	40098PC	1	1	
U12	RES. NETWORK, SIP, 4.7K +/-2%, 1/8W	412916	89536	412916	1	1	
W1	CABLE, 34 STRAND	519926	89536	519926			
XU1	SOCKET, IC, 40 PIN	429282	09922	DILB40P-108	1		
XU3	SOCKET, IC, 24 PIN	376236	91506	324-AG39D	2		
XU4	SOCKET, IC, 24 PIN	376236	91506	324-AG39D	REF		



8860A-1615

Figure 005-3. IEEE-488 Interface PCB Assembly

Table 005-4. Rear Interconnect PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
	REAR INTERCONNECT PCB ASSEMBLY FIGURE 005-4 (8860A-4025)	521294	89536	521294	REF		
J1	CONNECTOR, 34 POS	295337	52152	3402-0000T	1		
J2	CONNECTOR, 24 POS	513234	00779	552224-1	1		
S1-6	SWITCH, DIL, 6-POS, SPST, ASSY	454124	00779	435166-4	1	1	

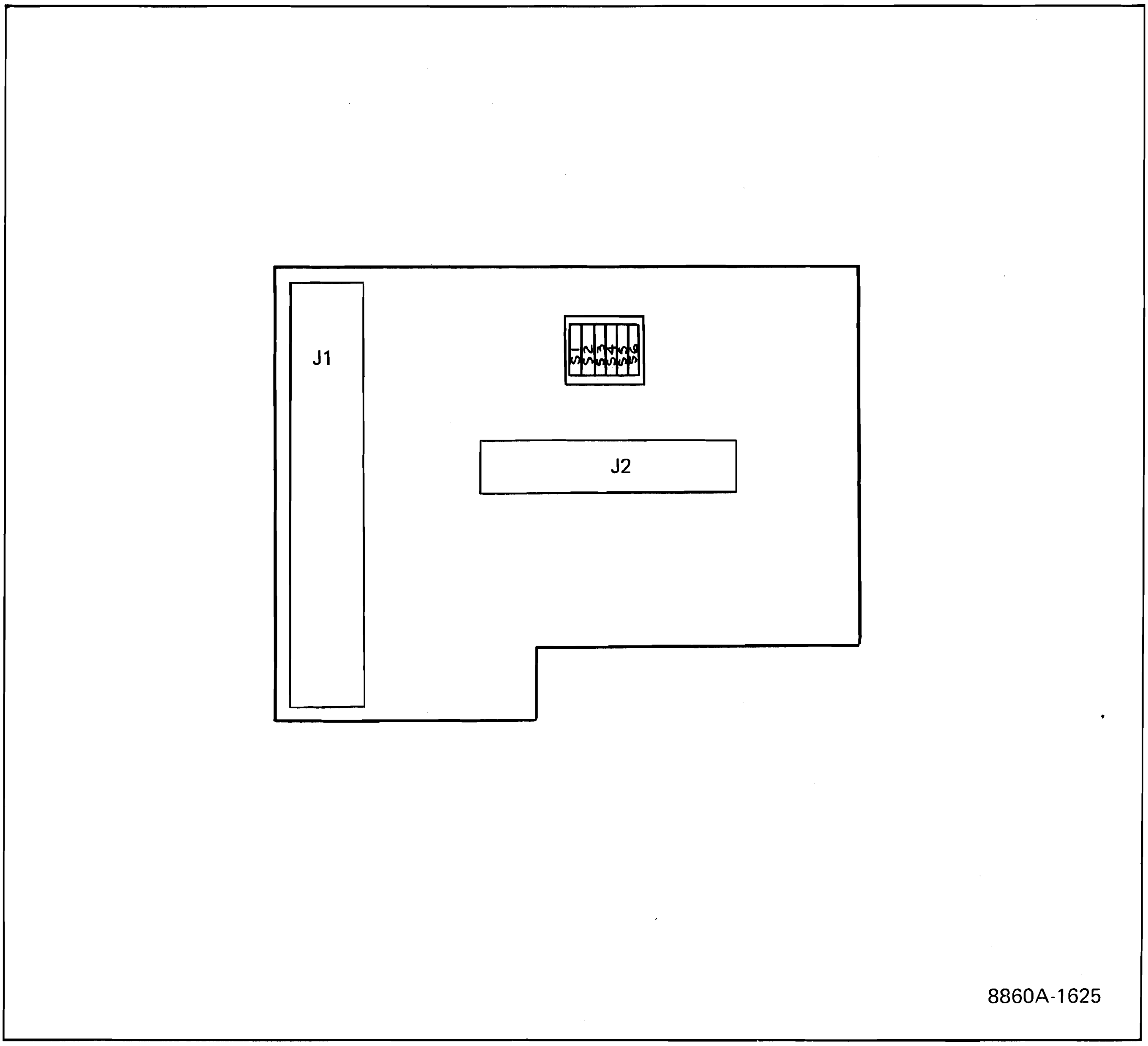


Figure 005-4. Rear Interconnect PCB Assembly

Option -006
Rear Input

006-1. THEORY OF OPERATION

006-2. The Rear Input, Option -006, consists of a circuit board and a 20-pin connector. The circuit board mounts on the A/D and Ohms PCB. A schematic diagram for the option is shown in Figure 006-1.

006-3. The Rear Input option electrically relocates the five INPUT terminal connections from the front panel banana jacks to a 20-pin connector mounted to the rear panel. This enables all voltage and resistance measurement connections (both two- and four-terminal) to be made at the rear panel.

006-4. TROUBLESHOOTING

006-5. Any fault which occurs in the Rear Input connector will usually consist of either poorly soldered connections or broken wires, which can be traced visually or with an ohmmeter. The two ceramic capacitors ensure stable readings by suppressing high voltage ac crosstalk to the A/D Converter.

006-6. LIST OF REPLACEABLE PARTS

006-7. A list of replaceable parts for the Rear Input Assembly is given in Table 006-1. Refer to Section 5 of this manual for ordering information.

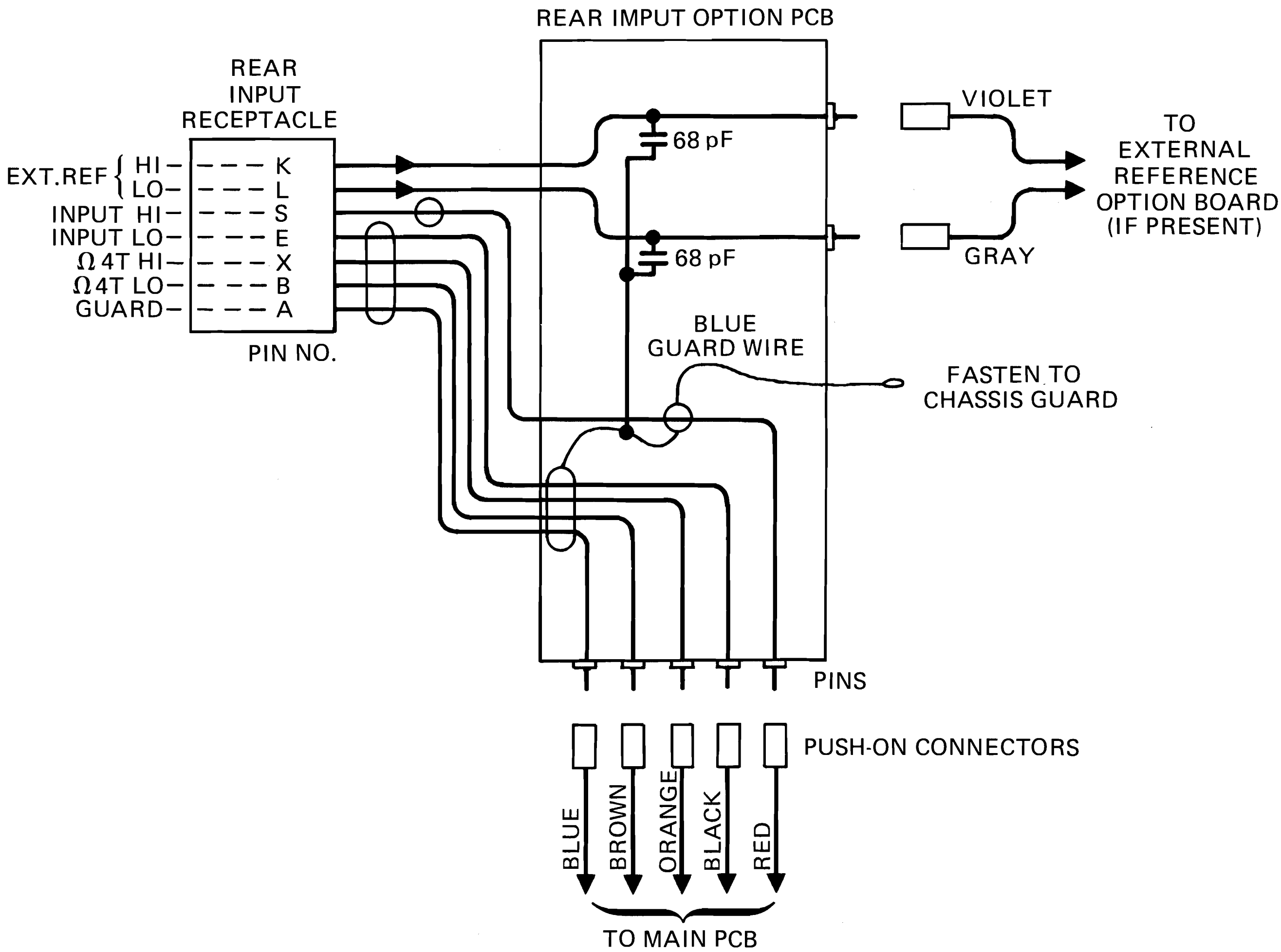


Figure 006-1. Rear Input Option Schematic

Table 006-1. Rear Input

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
-006	REAR INPUT FIGURE 006-2 (8860A-006)	ORDER	BY	OPTION -006			
	REAR INPUT PCB ASSEMBLY	538264	89536	538264	1		
H1	NUT, HEX 4-40	147611	89536	147611	3		
H2	SCREW, 4-40 X 1/4 PHP	256156	89536	256156	2		
H3	SCREW, 4-40 X 3/16 PHP	149567	89536	149567	2		
H4	SCREW, 6-32 X 1/4 FH UC	320093	89536	320093	2		
KIT	HARDWARE CONNECTOR KIT	541797	89536	541797	1		
MP1	BRACKET, ANGLE 4-40	474239	89536	474239	2		

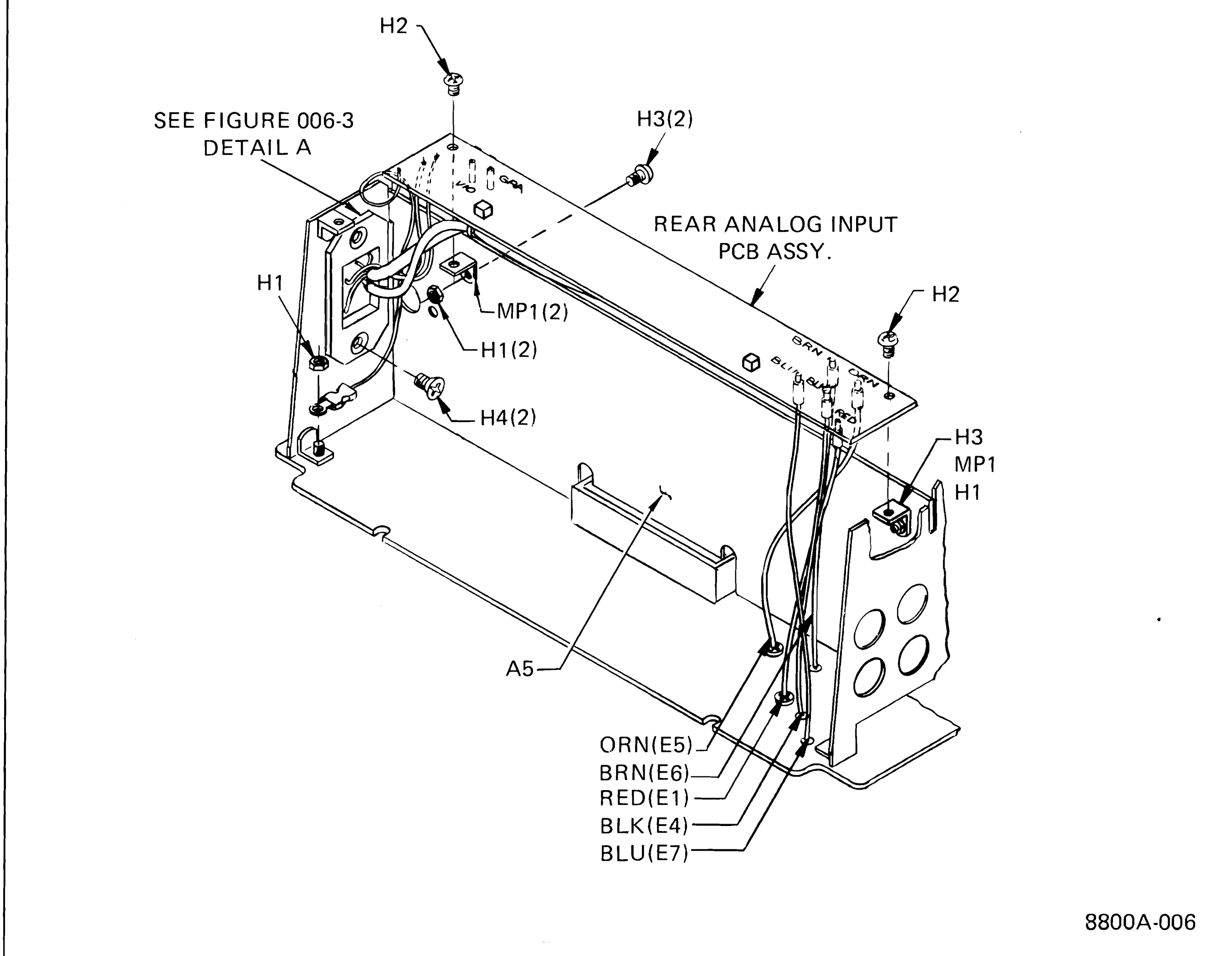


Figure 006-2. Rear Input

Table 006-2. Rear Input PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
	REAR INPUT PCB ASSEMBLY FIGURE 006-3 (8860A-4027)	538264	89536	538264	REF		
C1	CAP, CER, 68 PF +/-2%, 100V	519181	71590	DD-3R3	2		
C2	CAP, CER, 68 PF +/-2%, 100V	519181	71590	DD-3R3	REF		
H1	NUT, HEX, 2-56	355453	73734	67023	2		
H2	SCREW, 2-56 X 3/4	530246	89536	530246	2		
J1	CONNECTOR 20-PIN RECEPT.	369249	91662	00-8016-020-000-707	1		
MP1	CABLE TIE	172080	06383	SST-1M	2		
MP2	RECEPTACLE PIN	529263	00779	350491-1	7		
MP3	MOUNTING BLOCK	516765	89536	516765	1		
W1	CHASSIS GROUND WIRE ASSY.	537795	89536	537795	1		
W2	WIRE ASSEMBLY - SINGLE COND.	537738	89536	537738	1		
W3	CABLE ASSY. 4-COND	537712	89536	537712	1		
W4	GRAY WIRE ASSY.	537753	89536	537753	1		
W5	VIOLET WIRE ASSY.	537704	89536	537704	1		
W6	ORANGE WIRE ASSEMBLY	537720	89536	537720	1		
W7	BLUE WIRE ASSEMBLY	537746	89536	537746	1		

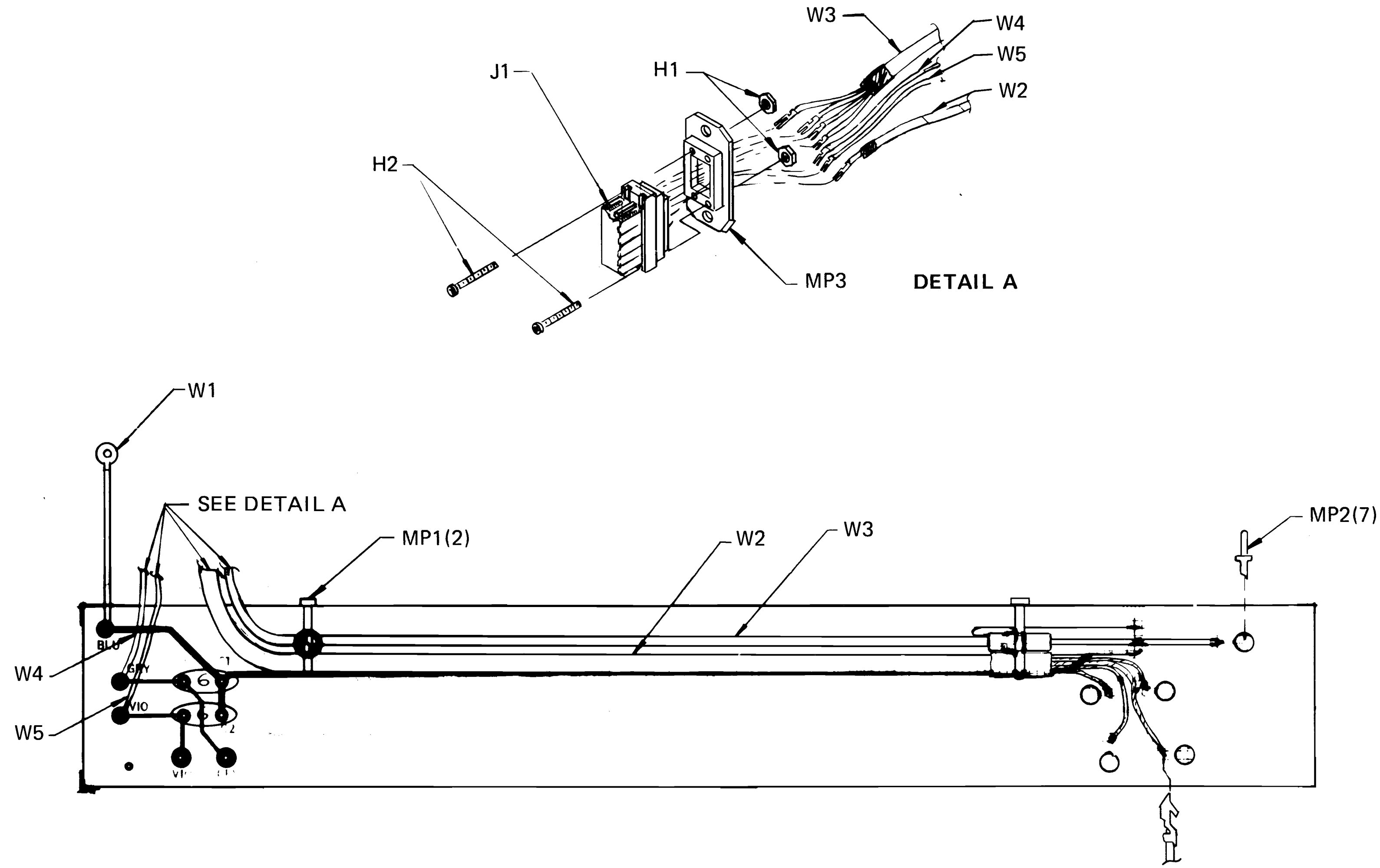


Figure 006-3. Rear Input PCB Assembly

8860A-006

Option -007
External Reference

007-1. THEORY OF OPERATION

007-2. The External Reference, Option -007, consists of a single circuit board and a dual banana connector. The circuit board mounts on the A/D and Ohms PCB. The schematic (8860A-1016) is located in Section 8.

007-3. The External Reference is a conditioning circuit which divides an externally applied dc voltage by 10 and changes the polarity of the result. If, for example, a +10V dc signal is applied at the input, a -1V dc signal appears at the output, P1-2. The circuit contains a two-pole active Butterworth low-pass filter to give 40 dB of noise rejection at 50 Hz.

007-4. The input buffer amplifier U2 is connected with a gain of one-half in a differential-input configuration. The floating input allows the option to receive a voltage which is not ground-referenced. The output of U2 is filtered by U3, which in turn is divided by five. This is the reference voltage sent on to the A/D Converter. Precision resistor network U1 contains all of the required voltage divider networks.

007-5. Protection devices Q1 and Q2 protect against overvoltages appearing at the external reference input terminals. Variable resistor R1 helps correct for the dc offset voltages of U2 and U3. Variable resistors R4 and R5 are calibration adjustments.

007-6. When selected, the output of the external reference replaces the internal reference used to discharge the A/D integrator. The external reference polarity is detected at pin P1-5 by the in-guard microprocessor which reverses the polarity (at the A/D Converter) if necessary, in order to discharge the capacitor. Thus, the polarity is selected to be opposite that of the applied input. Such a reversal is necessary, for instance, when the 8860A is measuring an ac voltage with a negative external reference.

007-7. Pins P1-6 and P1-7 form a shorting link to tell the in-guard microprocessor that the external reference is installed. If the option is not installed, an error message is displayed when external reference (EXT REF) is selected at the front panel.

007-8. TROUBLESHOOTING

007-9. Troubleshooting the External Reference for a failed IC is a matter of tracing the signal path. Use the A/D and Ohms Extender Card for easy circuit access.

007-10. Connect the External Reference input LO to the front panel INPUT LO. Apply a +10v dc signal at the external reference input HI. The following signals should be present on the External Reference PCB.

1. -5V dc at U2-6 and U3-6
2. -1V dc at the output, P1-2.

007-11. When a step input is applied to the External Reference, the settling time of the External Reference circuitry should not exceed 5 seconds. If either C3 or C4 is defective, the response of the external reference may be very slow.

007-12. LIST OF REPLACEABLE PARTS

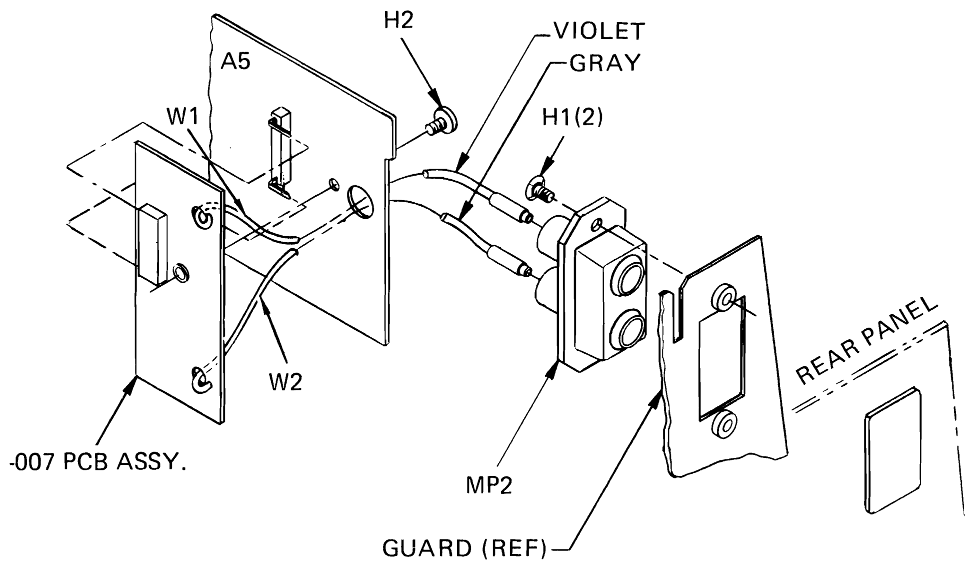
007-13. A list of replaceable parts for the External Reference is given in Table 007-1. Refer to Section 5 of this manual for ordering information.

CAUTION

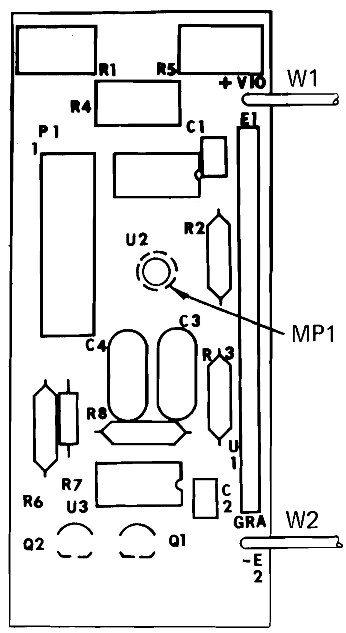
Indicated devices are subject to damage by static discharge.

Table 007-1. External Reference

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO.	TOT QTY	REC QTY	NOTE
-007	EXTERNAL REFERENCE FIGURE 007-1 (8860A-4016T)	ORDER	BY	OPTION -007			
C1	CAP, CERAM, 33 PF +/-2%, 100V	354852	80031	2222-638-10339	2		
C2	CAP, CERAM, 33 PF +/-2%, 100V	354852	80031	2222-638-10339	REF		
C3	CAP, MYLAR, .22 UF +/-10%, 100V	436113	73445	C280MAH/A220K	2		
C4	CAP, MYLAR, .22 UF +/-10%, 100V	436113	73445	C280MAH/A220K	REF		
H1	SCREW, FH, UC, 6-321/4	320093	89536	320093	2		
H2	SCREW, FHP/SS, 6-32 X 3/4	114504	89536	114504	1		
MP1	SPACER, CENTER	352021	89536	352021	1		
MP2	MOUNTING BLOCK	530980	89536	530980	1		
P1	CONNECTOR, 9-POSITION	519744	89536	519744	1		
Q1	XSTR, J-FET	343830	12040	NSSF50024	2	1	
Q2	XSTR, J-FET	343830	12040	NSSF50024	REF		
R1	RES, VAR, 50K +/-10%, 1/2W	288290	75378	360S-502AZ	1		
R2	RES, MTL. FILM, 150K +/-1%, 1/8W	241083	91637	CMF551503F	2		
R3	RES, MTL. FILM, 150K +/-1%, 1/8W	241083	91637	CMF551503F	REF		
R4	RES, VAR. CERMET, 1K +/-10%, 1/2W	285155	71450	360S102A	2		
R5	RES, VAR, CER, 1K +/-10%,1/2W	285155	71420	360S102A	REF		
R6	RES, MTL. FILM, 37.4K +/-1%, 1/8W	226241	91637	CMF553742F	1		
R7	RES, DEP. CAR, 1 +/-5%, 1/4W	357665	80031	CR251-4-5P1E	1		
R8	RES, MTL. FILM, 301K +/-1%, 1/8W	289488	91637	CMF55301C2F	1		
U1	RESISTOR NETWORK	510990	89536	510990	1	1	
U2	IC, LIN, OP-AMP, MTL. CAN	478107	12040	308A	2	1	
U3	IC, LIN, OP-AMP, MTL. CAN	478107	12040	308A	REF		
W1	WIRE ASSEMBLY, VIOLET	538215	89536	538215	1		
W2	WIRE ASSEMBLY, GRAY	538207	89536	538207	1		



8860A-007



8860A-1616

Figure 007-1. External Reference, option 007

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

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

Federal Supply Codes for Manufacturers

00213
Nytronics Comp. Group Inc.
Subsidiary of Nytronics Inc.
Formerly Sage Electronics
Rochester, New York

00327
Welwyn International, Inc.
Westlake, Ohio

00656
Aerovox Corp.
New Bedford, Massachusetts

00686
Film Capacitors, Inc.
Passaic, New Jersey

00779
AMP Inc.
Harrisburg, Pennsylvania

01121
Allen-Bradley Co.
Milwaukee, Wisconsin

01281
TRW Electronic Comp.
Semiconductor Operations
Lawndale, California

01295
Texas Instruments, Inc.
Semiconductor Group
Dallas, Texas

01537
Motorola Communications &
Electronics Inc.
Franklin Park, Illinois

01686
RCL Electronics Inc.
Manchester, New Hampshire

01730
Replaced by 73586

01884
Use 56289
Sprague Electric Co.
Dearborn Electronic Div.
Lockwood, Florida

02114
Ferroxcube Corp.
Saugerties, New York

02131
General Instrument Corp.
Harris ASW Div.
Westwood, Maine

02395
Rason Mfg. Co.
Brooklyn, New York

02533
Snelgrove, C.R. Co., Ltd.
Don Mills, Ontario, Canada
M3B 1M2

02606
Fenwal Labs
Div. of Travenal Labs.
Morton Grove, Illinois

02660
Bunker Ramo Corp., Conn Div.
Formerly Amphenol-Borg
Electric Corp.
Broadview, Illinois

02799
Areo Capacitors, Inc.
Chatsworth, California

03508
General Electric Co.
Semiconductor Products
Syracuse, New York

03614
Replaced by 71400

03651
Replaced by 44655

03797
Eldema Div.
Genisco Technology Corp.
Compton, California

03877
Transistron Electronic Corp.
Wakefield, Massachusetts

03888
KDI Pyrofilm Corp.
Whippany, New Jersey

03911
Clairex Electronics Div.
Clairex Corp.
Mt. Vernon, New York

03980
Muirhead Inc.
Mountainside, New Jersey

04009
Arrow Hart Inc.
Hartford, Connecticut

04062
Replaced by 72136

04202
Replaced by 81312

04217
Essex International Inc.
Wire & Cable Div.
Anaheim, California

04221
Aemco, Div. of
Midtex Inc.
Mankato, Minnesota

04222
AVX Ceramics Div.
AVX Corp.
Myrtle Beach, Florida

04423
Telonic Industries
Laguna Beach, California

04645
Replaced by 75376

04713
Motorola Inc. Semiconductor
Products
Phoenix, Arizona

04946
Standard Wire & Cable
Los Angeles, California

05082
Replaced by 94988

05236
Jonathan Mfg. Co.
Fullerton, California

05245
Components Corp. now
Corcom, Inc.
Chicago, Illinois

05277
Westinghouse Electric Corp.
Semiconductor Div.
Youngwood, Pennsylvania

05278
Replaced by 43543

05279
Southwest Machine &
Plastic Co.
Glendora, California

05397
Union Carbide Corp.
Materials Systems Div.
New York, New York

05571
Use 56289
Sprague Electric Co.
Pacific Div.
Los Angeles, California

05574
Viking Industries
Chatsworth, California

05704
Replaced by 16258

05820
Wakefield Engineering Inc.
Wakefield, Massachusetts

06001
General Electric Co.
Electronic Capacitor &
Battery Products Dept.
Columbia, South Carolina

06136
Replaced by 63743

06383
Panduit Corp.
Tinley Park, Illinois

06473
Bunker Ramo Corp.
Amphenol SAMS Div.
Chatsworth, California

06555
Beede Electrical Instrument Co.
Penacook, New Hampshire

06739
Electron Corp.
Littleton, Colorado

06743
Clevite Corp.
Cleveland, Ohio

06751
Components, Inc. Semcor Div.
Phoenix, Arizona

06860
Gould Automotive Div.
City of Industry, California

06961
Vernitron Corp., Piezo
Electric Div.
Formerly Clevite Corp., Piezo
Electric Div.
Bedford, Ohio

06980
Eimac Div.
Varian Associates
San Carlos, California

07047
The Ross Milton Co.
South Hampton, Pennsylvania

07115
Replaced by 14674

07138
Westinghouse Electric Corp.,
Electronic Tube Div.
Horsehead, New York

07233
TRW Electronic Components
Cinch Graphic
City of Industry, California

07256
Silicon Transistor Corp.
Div. of BBF Group Inc.
Chelmsford, Massachusetts

07261
Aumet Corp.
Culver City, California

07263
Fairchild Semiconductor
Div. of Fairchild Camera
& Instrument Corp.
Mountain View, California

07344
Bircher Co., Inc.
Rochester, New York

07597
Burndy Corp.
Tape/Cable Div.
Rochester, New York

07792
Lerma Engineering Corp.
Northampton, Massachusetts

07910
Teledyne Semiconductor
Formerly Continental Device
Hawthorne, California

07933
Use 49956
Raytheon Co.
Semiconductor Div. HQ
Mountain View, California

08225
Industro Transistor Corp.
Long Island City, New York

Federal Supply Codes for Manufacturers (cont)

08261
Spectra Strip Corp.
Garden Grove, California

08530
Reliance Mica Corp.
Brooklyn, New York

08806
General Electric Co.
Miniature Lamp Products Dept
Cleveland, Ohio

08863
Nylomatic Corp.
Norrisville, Pennsylvania

08988
Use 53085
Skottie Electronics Inc.
Archbald, Pennsylvania

09214
G.E. Co. Semi-Conductor
Products Dept.
Power Semi-Conductor
Products OPN Sec.
Auburn, New York

09353
C and K Components
Watertown, Massachusetts

09423
Scientific Components, Inc.
Santa Barbara, California

09922
Burndy Corp.
Norwalk, Connecticut

09969
Dale Electronics Inc.
Yankton, S. Dakota

10059
Barker Engineering Corp.
Formerly Amerace, Amerace
ESNA Corp.
Kenilworth, New Jersey

11236
CTS of Berne
Berne, Indiana

11237
CTS Keene Inc.
Paso Robles, California

11358
CBS Electronic Div.
Columbia Broadcasting System
Newburyport, Minnesota

11403
Best Products Co.
Chicago, Illinois

11503
Keystone Columbia Inc.
Warren, Michigan

11532
Teledyne Relays
Hawthorne, California

11711
General Instrument Corp.
Rectifier Division
Hicksville, New York

11726
Qualidyne Corp.
Santa Clara, California

12014
Chicago Rivet & Machine Co.
Bellwood, Illinois

12040
National Semiconductor Corp.
Danburry, Connecticut

12060
Diodes, Inc.
Chatsworth, California

12136
Philadelphia Handle Co.
Camden, New Jersey

12300
Potter-Brumfield Div.
AMF Canada LTD.
Guelph, Ontario, Canada

12323
Presin Co., Inc.
Shelton, Connecticut

12327
Freeway Corp. formerly
Freeway Washer & Stamping Co.
Cleveland, Ohio

12443
The Budd Co. Polychem Products
Plastic Products Div.
Bridgeport, Pennsylvania

12615
U.S. Terminals Inc.
Cincinnati, Ohio

12617
Hamlin Inc.
Lake Mills, Wisconsin

12697
Clarostat Mfg. Co.
Dover, New Hampshire

12749
James Electronics
Chicago, Illinois

12856
Micrometals
Sierra Madre, California

12954
Dickson Electronics Corp.
Scottsdale, Arizona

12969
Unitrode Corp.
Watertown, Massachusetts

13103
Thermalloy Co., Inc.
Dallas, Texas

13327
Solitron Devices Inc.
Tappan, New York

13511
Amphenol Cadre Div.
Bunker-Ramo Corp.
Los Gatos, California

13606
Use 56289
Sprague Electric Co.
Transistor Div.
Concord, New Hampshire

13839
Replaced by 23732

14099
Semtech Corp.
Newbury Park, California

14140
Edison Electronic Div.
Mc Gray-Edison Co.
Manchester, New Hampshire

14193
Cal-R-Inc. formerly
California Resistor, Corp.
Santa Monica, California

14298
American Components, Inc.
an Insilco Co.
Conshohocken, Pennsylvania

14655
Cornell-Dublier Electronics
Division of Federal Pacific
Electric Co. Govt. Control Dept.
Newark, New Jersey

14752
Electro Cube Inc.
San Gabriel, California

14869
Replaced by 96853

14936
General Instrument Corp.
Semi Conductor Products Group
Hicksville, New York

15636
Elec-Trol Inc.
Saugus, California

15801
Fenwal Electronics Inc.
Div. of Kidde Walter and Co., Inc.
Framingham, Massachusetts

15818
Teledyne Semiconductors,
formerly Amelco Semiconductor
Mountain View, California

15849
Litton Systems Inc. Useco Div.
formerly Useco Inc.
Van Nuys, California

15898
International Business
Machines Corp.
Essex Junction, Vermont

15909
Replaced by 14140

16258
Space-Lok Inc.
Burbank, California

16299
Corning Glass
Electronic Components Div.
Raleigh, North Carolina

16332
Replaced by 28478

16473
Cambridge Scientific Ind.
Div. of Chemed Corporation
Cambridge, Maryland

16742
Paramount Plastics
Fabricators, Inc.
Downey, California

16758
Delco Electronics
Div. of General Motors Corp.
Kokomo, Indiana

17001
Replaced by 71468

17069
Circuit Structures Lab.
Burbank, California

17338
High Pressure Eng. Co., Inc.
Oklahoma City, Oklahoma

17545
Atlantic Semiconductors, Inc.
Asbury Park, New Jersey

17856
Siliconix, Inc.
Santa Clara, California

17870
Replaced by 14140

18178
Vactec Inc.
Maryland Heights, Missouri

18324
Signetics Corp.
Sunnyvale, California

18612
Vishay Resistor Products Div.
Vishay Intertechnology Inc.
Malvern, Pennsylvania

18736
Voltronics Corp.
Hanover, New Jersey

18927
GTE Sylvania Inc.
Precision Material Group
Parts Division
Titusville, Pennsylvania

19451
Perine Machinery & Supply Co.
Seattle, Washington

19701
Electro-Midland Corp.
Mepco-Electra Inc.
Mineral Wells, Texas

20584
Enochs Mfg. Inc.
Indianapolis, Indiana

Federal Supply Codes for Manufacturers (cont)

20891
Self-Organizing Systems, Inc.
Dallas, Texas

21604
Bucheye Stamping Co.
Columbus, Ohio

21845
Solitron Devices Inc.
Transistor Division
Riveria Beach, Florida

22767
ITT Semiconductors
Palo Alto, California

23050
Product Comp. Corp.
Mount Vernon, New York

23732
Tracor Inc.
Rockville, Maryland

23880
Stanford Applied Engrng.
Santa Clara, California

23936
Pamotor Div., Wm. J. Purdy Co.
Burlingame, California

24248
Replaced by 94222

24355
Analog Devices Inc.
Norwood, Massachusetts

24655
General Radio
Concord, Massachusetts

24759
Lenox-Fugle Electronics Inc.
South Plainfield, New Jersey

25088
Siemen Corp.
Isilen, New Jersey

25403
Amperex Electronic Corp.
Semiconductor &
Micro-Circuits Div.
Slatersville, Rhode Island

27014
National Semiconductor Corp.
Santa Clara, California

27264
Molex Products
Downers Grove, Illinois

28213
Minnesota Mining & Mfg. Co.
Consumer Products Div.
St. Paul, Minnesota

28425
Serv-/-Link formerly
Bohannan Industries
Fort Worth, Texas

28478
Deltrol Controls Div.
Deltrol Corporation
Milwaukee, Wisconsin

28480
Hewlett Packard Co.
Corporate HQ
Palo Alto, California

28520
Heyman Mfg. Co.
Kenilworth, New Jersey

29083
Monsanto, Co., Inc.
Santa Clara, California

29604
Stackpole Components Co.
Raleigh, North Carolina

30148
AB Enterprise Inc.
Ahoskie, North Carolina

30323
Illinois Tool Works, Inc.
Chicago, Illinois

31091
Optimax Inc.
Colmar, Pennsylvania

32539
Mura Corp.
Great Neck, New York

32767
Griffith Plastic Corp.
Burlingame, California

32879
Advanced Mechanical
Components
Northridge, California

32897
Erie Technological Products, Inc.
Frequency Control Div.
Carlisle, Pennsylvania

32997
Bourns Inc.
Trimpot Products Division
Riverside, California

33173
General Electric Co.
Products Dept.
Owensboro, Kentucky

34333
Silicon General
Westminister, California

34335
Advanced Micro Devices
Sunnyvale, California

34802
Electromotive Inc.
Kenilworth, New Jersey

37942
P.R. Mallory & Co., Inc.
Indianapolis, Indiana

42498
National Radio
Melrose, Massachusetts

43543
Nytronics Inc.
Transformer Co. Div.
Geneva, New York

44655
Ohmite Mfg. Co.
Skokie, Illinois

49671
RCA Corp.
New York, New York

49956
Raytheon Company
Lexington, Massachusetts

50088
Mostek Corp.
Carrollton, Texas

50579
Litronix Inc.
Cupertino, California

51605
Scientific Components Inc.
Linden, New Jersey

53021
Sangamo Electric Co.
Springfield, Illinois

54294
Cutler-Hammer Inc. formerly
Shallcross, A Cutter-Hammer Co.
Selma, North Carolina

55026
Simpson Electric Co.
Div. of Am. Gage and Mach. Co.
Elgin, Illinois

56289
Sprague Electric Co.
North Adams, Massachusetts

58474
Superior Electric Co.
Bristol, Connecticut

60399
Torin Corp. formerly
Torrington Mfg. Co.
Torrington, Connecticut

63743
Ward Leonard Electric Co., Inc.
Mount Vernon, New York

64834
West Mfg. Co.
San Francisco, California

65092
Weston Instruments Inc.
Newark, New Jersey

66150
Winslow Tele-Tronics Inc.
Eaton Town, New Jersey

70485
Atlantic India Rubber Works
Chicago, Illinois

70563
Amperite Company
Union City, New Jersey

70903
Belden Corp.
Geneva, Illinois

71002
Birnback Radio Co., Inc.
Freeport, New York

71400
Bussmann Mfg.
Div. of McGraw-Edison Co.
Saint Louis, Missouri

71450
CTS Corp.
Elkhart, Indiana

71468
ITT Cannon Electric Inc.
Santa Ana, California

71482
Clare, C.P. & Co.
Chicago, Illinois

71590
Centrelab Electronics
Div. of Globe Union Inc.
Milwaukee, Wisconsin

71707
Coto Coil Co., Inc.
Providence, Rhode Island

71744
Chicago Miniature Lamp Works
Chicago, Illinois

71785
TRW Electronics Components
Cinch Connector Operations Div.
Elk Grove Village
Chicago, Illinois

72005
Wilber B. Driver Co.
Newark, New Jersey

72092
Replaced by 06980

72136
Electro Motive Mfg. Co.
Williamantic, Connecticut

72259
Nytronics Inc.
Pelham Manor, New Jersey

72619
Dialight Div.
Amperex Electronic Corp.
Brooklyn, New York

72653
G.C. Electronics
Div. of Hydrometals, Inc.
Brooklyn, New York

72665
Replaced by 90303

72794
Dzus Fastener Co., Inc.
West Islip, New York

72928
Gulton Ind. Inc.
Gudeman Div.
Chicago, Illinois

Federal Supply Codes for Manufacturers (cont)

72982
Erie Tech. Products Inc.
Erie, Pennsylvania

73138
Bechman Instrument Inc.
Helipot Division
Fullerton, California

73293
Hughes Aircraft Co.
Electron Dynamics Div.
Torrance, California

73445
Amperex Electronic Corp.
Hicksville, New York

73559
Carling Electric Inc.
West Hartford, Connecticut

73586
Circle F Industries
Trenton, New Jersey

73734
Federal Screw Products, Inc.
Chicago, Illinois

73743
Fischer Special Mfg. Co.
Cincinnati, Ohio

73899
JFD Electronics Co.
Components Corp.
Brooklyn, New York

73949
Guardian Electric Mfg. Co.
Chicago, Illinois

74199
Quan Nichols Co.
Chicago, Illinois

74217
Radio Switch Corp.
Marlboro, New Jersey

74276
Signalite Div.
General Instrument Corp.
Neptune, New Jersey

74306
Piezo Crystal Co.
Carlisle, Pennsylvania

74542
Hoyt Elect. Instr. Works
Penacook, New Hampshire

74970
Johnson E.F., Co.
Waseca, Minnesota

75042
TRW Electronics Components
IRC Fixed Resistors
Philadelphia, Pennsylvania

75376
Kurz-Kasch Inc.
Dayton, Ohio

75378
CTS Knights Inc.
Sandwich, Illinois

75382
Kulka Electric Corp.
Mount Vernon, New York

75915
Littlefuse Inc.
Des Plaines, Illinois

76854
Oak Industries Inc.
Switch Div.
Crystal Lake, Illinois

77342
AMF Inc.
Potter & Brumfield Div.
Princeton, Indiana

77638
General Instrument Corp.
Rectifier Division
Brooklyn, New York

77969
Rubbercraft Corp. of CA. LTD.
Torrance, California

78189
Shakeproof
Div. of Illinois Tool Works Inc.
Elgin, Illinois

78277
Sigma Instruments, Inc.
South Braintree, Massachusetts

78488
Stackpole Carbon Co.
Saint Marys, Pennsylvania

78553
Eaton Corp. Engineered
Fastener Div.
Tinnerman Plant
Cleveland, Ohio

79136
Waldes Kohinoor Inc.
Long Island City, New York

79497
Western Rubber Company
Goshen, Indiana

79963
Zierick Mfg. Corp.
Mt. Kisko, New York

80031
Electro-Midland Corp.
Mepco Div.
A North American Phillips Co.
Norristown, New Jersey

80145
LFE Corp., Process Control Div.
formerly API Instrument Co.
Chesterland, Ohio

80183
Use 56289
Sprague Products
North Adams, Massachusetts

80294
Bourns Inc., Instrument Div.
Riverside, California

80583
Hammarlund Mfg. Co., Inc.
Red Bank, New Jersey

80640
Arnold Stevens, Inc.
South Boston, Massachusetts

81073
Grayhill, Inc.
La Grange, Illinois

81312
Winchester Electronics
Div. of Litton Industries Inc.
Oakville, Connecticut

81483
Therm-O-Disc Inc.
Mansfield, Ohio

81483
International Rectifier Corp.
Los Angeles, California

81590
Korry Mfg. Co.
Seattle, Washington

81741
Chicago Lock Co.
Chicago, Illinois

82305
Palmer Electronics Corp.
South Gate, California

82389
Switchcraft Inc.
Chicago, Illinois

82415
North American Phillips
Controls Corp.
Frederick, Maryland

82872
Roanwell Corp.
New York, New York

82877
Rotron Inc.
Woodstock, New York

82879
ITT Royal Electric Div.
Pawtucket, Rhode Island

83003
Varo Inc.
Garland, Texas

83058
The Carr Co., United Can Div.
of TRW
Cambridge, Massachusetts

83298
Bendix Corp.
Electric Power Div.
Eatontown, New Jersey

83330
Herman H. Smith, Inc.
Brooklyn, New York

83478
Rubbercraft Corp.
of America, Inc.
West Haven, Connecticut

83594
Burroughs Corp.
Electronic Components Div.
Plainfield, New Jersey

83740
Union Carbide Corp.
Battery Products Div.
formerly Consumer Products Div.
New York, New York

84171
Arco Electronics
Great Neck, New York

84411
TRW Electronic Components
TRW Capacitors
Ogallala, Nebraska

84613
Fuse Indicator Corp.
Rockville, Maryland

84682
Essex International Inc.
Industrial Wire Div.
Peabody, Massachusetts

86577
Precision Metal Products
of Malden Inc.
Stoneham, Massachusetts

86684
Radio Corp. of America
Electronic Components Div.
Harrison, New Jersey

86928
Seastrom Mfg. Co., Inc.
Glendale, California

87034
Illuminated Products Inc.
Subsidiary of Oak Industries Inc.
Anahiem, California

88219
Gould Inc.
Industrial Div.
Trenton, New Jersey

88245
Litton Systems Inc.
Useco Div.
Van Nuys, California

88419
Cornell-Dubilier Electronic Div.
Federal Pacific Co.
Fuquay-Varian, North Carolina

88486
Plastic Wire & Cable
Jewitt City, Connecticut

88690
Replaced by 04217

89536
John Fluke Mfg. Co., Inc.
Seattle, Washington

89730
G.E. Co., Newark Lamp Works
Newark, New Jersey

Federal Supply Codes for Manufacturers (cont)

90201
Mallory Capacitor Co.
Div. of P.R. Mallory Co., Inc.
Indianapolis, Indiana

90211
Use 56365
Square D Co.
Chicago, Illinois

90215
Best Stamp & Mfg. Co.
Kansas City, Missouri

90303
Mallory Battery Co.
Div. of Mallory Co., Inc.
Tarrytown, New York

91094
Essex International Inc.
Suglex/IWP Div.
Newmarket, New Hampshire

91293
Johanson Mfg. Co.
Boonton, New Jersey

91407
Replaced by 58474

91502
Associated Machine
Santa Clara, California

91506
Augat Inc.
Attleboro, Massachusetts

91637
Dale Electronics Inc.
Columbus, Nebraska

91662
Elco Corp.
Willow Grove, Pennsylvania

91737
Use 71468
Gremar Mfg. Co., Inc.
ITT Cannon/Gremar
Santa Ana, California

91802
Industrial Devices, Inc.
Edgewater, New Jersey

91833
Keystone Electronics Corp.
New York, New York

91836
King's Electronics Co., Inc.
Tuckahoe, New York

91929
Honeywell Inc.
Micro Switch Div.
Freeport, Illinois

91934
Miller Electric Co., Inc.
Div. of Aunet
Woonsocket, Rhode Island

92194
Alpha Wire Corp.
Elizabeth, New Jersey

93332
Sylvania Electric Products
Semiconductor Products Div.
Woburn, Massachusetts

94145
Replaced by 49956

94154
Use 94988
Wagner Electric Corp.
Tung-Sol Div.
Newark, New Jersey

94222
Southco Inc. formerly
South Chester Corp.
Lester, Pennsylvania

95146
Alco Electronic Products Inc.
Lawrence, Massachusetts

95263
Leecraft Mfg. Co.
Long Island City, New York

95264
Replaced by 98278

95275
Vitramon Inc.
Bridgeport, Connecticut

95303
RCA Corp.
Receiving Tube Div.
Cincinnati, Ohio

95348
Gordo's Corp.
Bloomfield, New Jersey

95354
Methode Mfg. Corp.
Rolling Meadows, Illinois

95712
Bendix Corp.
Electrical Components Div.
Microwave Devices Plant
Franklin, Indiana

95987
Weckesser Co. Inc.
Chicago, Illinois

96733
San Fernando Electric Mfg. Co.
San Fernando, California

96853
Gulton Industries Inc.
Measurement and Controls Div.
formerly Rustrak Instruments Co.
Manchester, New Hampshire

96881
Thomson Industries, Inc.
Manhasset, New York

97540
Master Mobile Mounts, Div. of
Whitehall Electronics Corp.
Ft. Meyers, Florida

97913
Industrial Electronic
Hardware Corp.
New York, New York

97945
Penwalt Corp.
SS White Industrial Products Div.
Piscataway, New Jersey

97966
Replaced by 11358

98094
Replaced by 49956

98159
Rubber-Teck, Inc.
Gardena, California

98278
Malco A Microdot Co., Inc.
Connector & Cable Div.
Pasadena, California

98291
Sealectro Corp.
Mamaroneck, New York

98388
Royal Industries
Products Div.
San Diego, California

98743
Replaced by 12749

98925
Replaced by 14433

99120
Plastic Capacitors, Inc.
Chicago, Illinois

99217
Bell Industries Elect.
Comp. Div.
formerly Southern Elect. Div.
Burbank, California

99392
STM
Oakland, California

99515
ITT Jennings Monrovia Plant
Div. of ITT Jennings formerly
Marshall Industries Capacitor Div.
Monrovia, California

99779
Use 29587
Bunker-Ramo Corp.
Barnes Div.
Landsdowne, Pennsylvania

99800
American Precision Industries Inc.
Delevan Division
East Aurora, New York

99942
Centrelab Semiconductor
Centrelab Electronics Div. of
Globe-Union Inc.
El Monte, California

Toyo Electronics
(R-Ohm Corp.)
Irvine, California

National Connector
Minneapolis, Minnesota

Appendix 7A
Manual Change Information

INTRODUCTION

This appendix contains information necessary to backdate the manual to conform with earlier pcb configurations. To identify the configuration of the pcb's used in your instrument, refer to the revision letter (marked in ink) on the component side of each pcb assembly. Table 7A-1 defines the assembly revision levels documented in this manual.

NEWER INSTRUMENTS

As changes and improvements are made to the instrument, they are identified by incrementing the revision letter marked on the affected pcb assembly. These changes are documented on a supplemental change/errata sheet which, when applicable, is inserted at the front of the manual.

OLDER INSTRUMENTS

To backdate this manual to conform with earlier assembly revision levels, perform the changes indicated in Table 7A-1.

CHANGES

The following design changes, unless otherwise noted, affect only Section 5 and Section 8 of this manual:

- Section 5, parts list and component location drawings
- Section 8, schematics and component location drawings

The material affected within these sections is easily determined by the type of change. See Table 7A-2.

Table 7A-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 desending 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	Main PCB Assembly	531640	●	4	6	15	X																
A2	Display PCB Assembly	502708	●	●	+	X																	
A3	Controller PCB Assembly	502716	●	9	14	20	X																
A4	AC/DC Scaling PCB Assembly	504804	2	+	+	3	7	10	11	12	13	16	17	18	19	X							
A5	A/D And Ohms Converter PCB Assembly	526673	●	1	+	5	8	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.
\+ = Change did not affect manual.

Table 7A-2. Material Affected By a Change

TYPE OF CHANGE	MATERIAL AFFECTED = •		
	Parts List	Schematic	Component Location
Electrical Value	•	•	
Part Number	•		
Hardware	•		•
Size/Location (physical)			•
Addition/Deletion (electrical)	•	•	•

Change #1 13321
A/D and Ohms Converters PCB Assembly

Change R5
FROM: Res, dep car, 10k ±5%, ¼W/ 348839/ 89536/ 348839
TO: Res, dep car, 100k ±5%, ¼W/ 348920/ 89536/ 348920

Change #2 13322
AC/DC Scaling PCB Assembly

Change C35 and C36
FROM: Cap, cer, 15pF ±2%, 100V/ 369074/ 89536/ 369074
TO: Cap, cer, 12pF ±2%, 100V/ 376871/ 89536/ 376871

Change R37
FROM: Res, dep car, 200 ±5%, ¼W/ 441451/ 80031/ 441451
TO: Res, dep car, 2k ±5%, ¼W/ 441469/ 80031/ 441469

Change #3 13636
AC/DC Scaling PCB Assembly

Change R30
FROM: Res, mf, 511k ±1%, ⅛W/ 292868/ 89536/ 292868
TO: Res, mf, 2k ±1%, ⅛W/ 235226/ 89536/ 235226

Change R28
FROM: Res, mf, 3.83k ±1%, ⅛W, 235143, 89536/ 235143
TO: Res, mf, 1.19k ±1%, ⅛W, 349126/ 89536/ 349126

Change R29
FROM: Res, var, 1k ±10%, ½W/ 285155/ 89536/ 285155
TO: Res, var, 500 ±10%, ½W/291120/ 89536/ 291120

Change C17
FROM: Cap, cer, 33pF ±2%, 100V, 354852/ 89536/ 354852
TO: Cap, cer, 22pF ±5%, 100V, 448449/ 89536/ 448449

Change the part number of Q19
FROM: 386730/ 89536/ 386730
TO: 261578/ 89536/ 261578

Change R37
FROM: Res, dep car, 100 ±5%, ¼W/ 348771/ 89536/ 348771
TO: Res, dep car, 200 ±5%, ¼W/ 441451/ 89536/ 441451

Change R5
FROM: Res, dep car, 22k ±5%, ¼W, 348870/ 89536/ 348870
TO: Res, dep car, 10k ±5%, ¼W, 348839/ 89536/ 348839

Change R2, R3, R4, R33, R35, and R36
FROM: Res, dep car, 47k ±5%, ¼W/ 348896/ 89536/ 348896
TO: Res, dep car, 22k ±5%, ¼W/ 348870/ 89536/ 348870

Change R68
FROM: Res, dep car, 100k ±5%, ¼W/ 348920/ 89536/ 348920
TO: Res, dep car, 91k ±5%, ¼W/ 441709/ 89536/ 441709

Delete C43
Cap, cer, 22pF ±5%, 100V/ 448449/ 89536/ 448449

Delete C44
Cap, cer, 0.68pF, 458011/ 89536/ 458011

Delete CR9
Diode, Si, low cap, 375907/ 89536/ 375907

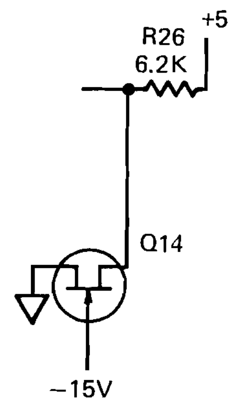
Change #4 13643
Main PCB Assembly

Add Q14
Transistor, JFET/ 343830/ 89536/ 343830

Delete C18
Cap, Ta, 22uF ±20%, 15V/ 423012/ 89536/ 423012

Delete CR7
Diode, Si/ 203323/ 89536/ 203323

Change schematic to:



Change #5 13834
A/D and Ohms Converters PCB Assembly

Change C1
FROM: Cap, cer, .005 uF ±20%, 50V/ 175232/ 89536/ 175232
TO: Cap, cer, .05 uF ±20%, 50V/ 149161/ 89536/ 149161

Change R26
FROM: Res, dep car, 8.2k ±5%, ¼W/ 441675/89536/ 441675
TO: Res, dep car, 6.8k ±5%, ⅛W/ 368761/ 89536/ 368761

Change #6 13835
Main PCB Assembly

Change R32, R33, R34, and R35
FROM: Res, dep car, 150k ±5%, ¼W/ 348938/ 89536/ 348938
TO: Res, dep car, 390k ±5%, ¼W/ 442475/ 89536/ 442475

Change #7 13899
AC/DC Scaling PCB Assembly

Change U17
FROM: IC, Xstr array, dual/ 504191/ 89536/ 504191
TO: IC, Xstr array, quad/ 445213/ 89536/ 445213

Change R68
FROM: Res, dep car, 120k ±5%, ¼W/ 441386/ 89536/ 441386
TO: Res, dep car, 100k ±5%, ¼W/ 348920/ 89536/ 348920

Delete U20
IC, Xstr array, dual/ 504191/ 89536/ 504191

Delete R66
Res, mf, 1k ±1%, ⅛W/ 320309/ 89536/ 320309

Delete
Heatsink, xstr, U17 and U20/ 354993/ 89536/ 354993

Add R60
Res, var, 3 ±25%, ½W/ 347963/ 89536/ 347963
Connect between U17-7 and U17-4/5.
Locate between R54 and R67.

Add R64
Res, dep car, 1 ±5%, ¼W/ 357665/ 89536/ 357665
Connect between U17-10 and junction of R68/ U17-2.
Locate between R50 and R68.

Change #8 13925
A/D and Ohms Converter PCB Assembly

Change R6 and R7
FROM: Res, mf, 10k ±1%, ⅛W/ 168260/ 89536/ 168260
TO: Res, mf, 20k ±1%, ⅛W/ 291872/ 89536/ 291872

Change #9 13936
Controller PCB Assembly

Change U6
FROM: Res, network, 82/ 478859/ 89536/ 478859
TO: Res, network, 51/ 501502/ 89536/ 501502

Change #10 13965
AC/DC Scaling PCB Assembly

Change R24
FROM: Res, dep car, 4.3k ±5%, ¼W/ 441576/ 89536/ 441576
TO: Res, dep car, 6.8k ±5%, ⅛W/ 368761/ 89536/ 368761

Change U19
FROM: IC, op amp, linear / 473777/ 89536/ 473777
TO: IC, op amp, linear / 507947/ 89536/ 507947

Change #11 13970
AC/DC Scaling PCB Assembly

Change C21
FROM: Cap, cer, 2.2 pF ±2%, 100V/ 362731/ 89536/ 362731
TO: Cap, cer, 4.7 pF ±2%, 100V/ 362772/ 89536/ 362772

Change #12 14385
AC/DC Scaling PCB Assembly

Change R75
FROM: Res, mf, 715 ±1%, ⅛W/ 313080/ 89536/ 313080
TO: Res, mf, 806 ±1%, ⅛W/ 223552/ 89536/ 223552

Change #13 14397
AC/DC Scaling PCB Assembly

Add Q10
Xstr, JFET/ 343830/ 89536/ 343830
Connect in parallel with Q11.
Locate between U1 and R11.

Change Q3
FROM: Xstr, JFET/ 535039/ 89536/ 535039
TO: Xstr, JFET/ 343830/ 89536/ 343830

Change Q8
FROM: Xstr, JFET/ 508697/ 89536/ 508697
TO: Xstr, JFET/ 343830/ 89536/ 343830

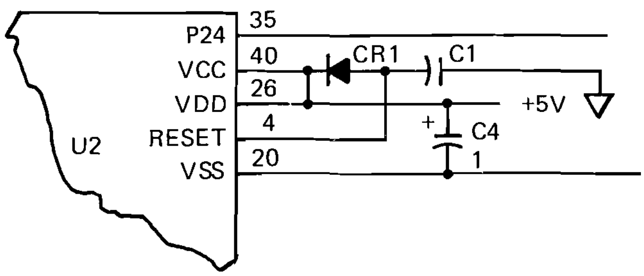
Change Q11
FROM: Xstr, JFET/ 429977/ 89536/ 429977
TO: Xstr, JFET/ 343830/ 89536/ 343830

Change R30
FROM: Res, mf, 4.99k ±1%, ⅛W/ 168252/ 89536/ 168252
TO: Res, mf, 5.11k ±1%, ⅛W/ 294868/ 89536/ 294868

Change #14 14528
Controller PCB Assembly

Delete
C10/ Cap, cer, .22 uF ±2%, 50V/ 519157/ 89536/ 519157
Q1 / Xstr, NPN/ 218396/ 89536/ 218396
R13/ Res, dep car, 2k ±5%, ¼W/ 441469/ 89536/ 441469
R14/ Res, dep car, 220 ±5%, ¼W/ 342626/ 89536/ 342626

Change schematic to:



Change #15 14529
Main PCB Assembly

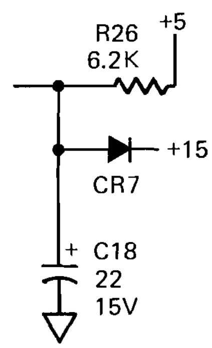
Change C8
FROM: Cap, elect, 1200 uF -10/ +100%, 200V/ 500322/ 89536/ 500322
TO: Cap, Ta, 150 uF ±20%, 20V/ 422576/ 89536/ 422576

Change C9
FROM: Cap, cer, .22 uF ±20%, 50V/ 519157/ 89536/ 519157
TO: Cap, Ta 150 uF ±20%, 20V/ 422576/ 89536/ 422576

Change C18
FROM: Cap, cer, .22 uF ±20%, 50V/ 519157/ 89536/ 519157
TO: Cap, Ta 22 uF ±20%, 15V/ 423012/ 89536/ 423012

Delete
C14/ Cap, Ta, 2.2 uF ±20%, 20V/ 161927/ 89536/ 161927
Q15/ Xstr, Si, NPN/ 218396/ 89536/ 218396
R27/ Res, dep car, 2k ±5%, ¼W/ 441469/ 89536/ 441469
R28/ Res, dep car, 220 ±5%, ¼W/ 342626/ 89536/ 342626

Change schematic to:



Change #16 14624
AC/DC Scaling PCB Assemebly

Change C35 and C36
FROM: Cap, cer, 22 pF ±5%, 100V/ 448449/ 89536/ 448449

TO: Cap, cer, 15 pF ±2%, 100V/ 369074/ 89536/ 369074

Change #17 14663
AC/DC Scaling PCB Assembly

Change R28
FROM: Res, mf, 3.4k ±1%, ⅛W/ 260323/ 89536/ 260323
TO: Res, mf, 3.83k ±1%, ⅛W/ 235143/ 89536/ 235143

Change R29
FROM: Res, var, 2k ±10%, ½W/ 285163/ 89536/ 285163
TO: Res, var, 1k ±10%, ½W/ 285155/ 89536/ 285155

Change #18 14872
AC/DC Scaling PCB Assembly

Change C32
FROM: Cap, mylar, .47 uF ±10%, 100V/ 369124/ 89536/ 369124

TO: Cap, mylar, .47 uF ±10%, 100V/ 446807/ 89536/ 446807

Change C34
FROM: Cap, poly, .22 uF ±10%, 100V/ 614172/ 89536/ 614172
TO: Cap, mylar, .22 uF ±10%, 100V/ 436113/ 89536/ 436113

Change #19 14887
AC/DC Scaling PCB Assembly

Add C24
Cap, cer, .22 uF ±20%, 50V/ 309849/ 89536/ 309849
Connect between Pins 2 and 3 of U13.
Locate between C25 and C26.

Change #20 15061
Controller PCB Assembly

Change C4, C5, and C6
FROM: Cap, cer, .22 uF ±20%, 50V/ 519157/ 89536/ 519157
TO: Cap, Ta 1 uF ±20%, 35V/ 161919/ 89536/ 161919

Delete C11
Cap, cer, .22 uF ±20%, 50V/ 519157/ 89536/ 519157

CHANGE #1 - 15061
Rev.-D, A3 Controller PCB Assembly (8860A-4003)

On page 5-14, Table 5-4, change the TOT QTY of C1,
FROM: 4
TO: 1

ERRATA #1

On page 5-10, Table 5-2:
CHANGE: U6|IC, MICROCOMPUTER |504563|89536|504563|1|1
TO: U6|IC, MICROCOMPUTER, MOS 8-BIT|536334|89536|536334|1|1

NOTE

When replacing U6 (P/N 536334), check to see if it is a dual piggy back assembly with a 6.2k, 1/4W resistor on the A1 Main PCB across pins 39 and 40 of U6. If so, this resistor should be removed before installing the replacement unit.

ERRATA #2

On page 5-16, Table 5-5, change the TOT QTY of C35,
FROM: 2
TO: 3

CHANGE #2 - 18685
Rev.-R, A4 AC/DC Scaling PCB Assembly (8860A-4004)

On page 5-16, Table 5-5:
CHANGE: C13|CAP,MYLAR,.047 UF +/-10%,250V|162008|73445|C280MAE/A47K|1
TO: C13|CAP, POLY, .47 UF +/-10%, 50V|714725|60935|168

On page 8-12, Figure 8-6, change the value of C13,
FROM: .047
TO: .47

CHANGE #3 - 19282
Rev.-A, Calculator/Printer PCB Assembly (8860A-4014)

On page 004-12, Table 004-5:
ADD: U19|IC, NMOS, 2K X 8-BIT ROM|536359|89536|536359|1

CHANGE #4 - 19323
Rev.-G, A1 Main PCB Assembly (8860A-4001)

On page 5-10, Table 5-2:
CHANGE: U7-U10|IC,PHOTOTRANSISTOR,OPTICALLY COUPLED|504977|29083|MCT2E
TO: U7-U10|IC, OPTO-ISOLATOR |312298|29083|Q1813

CHANGE/ERRATA INFORMATION

ISSUE NO: 2 5/84

This change/errata contains information necessary to ensure the accuracy of the following manual. Enter the corrections in the manual if either one of the following conditions exist:

1. The revision letter stamped on the indicated PCB is equal to or higher than that given with each change.

2. No revision letter is indicated at the beginning of the change/errata.

MANUAL

Title:	8860A Service
Print Date:	June 1981
Rev.- Date:	---

C/E PAGE EFFECTIVITY

Page No.	Print Date
1	5/84

Section 8
Schematic Diagrams

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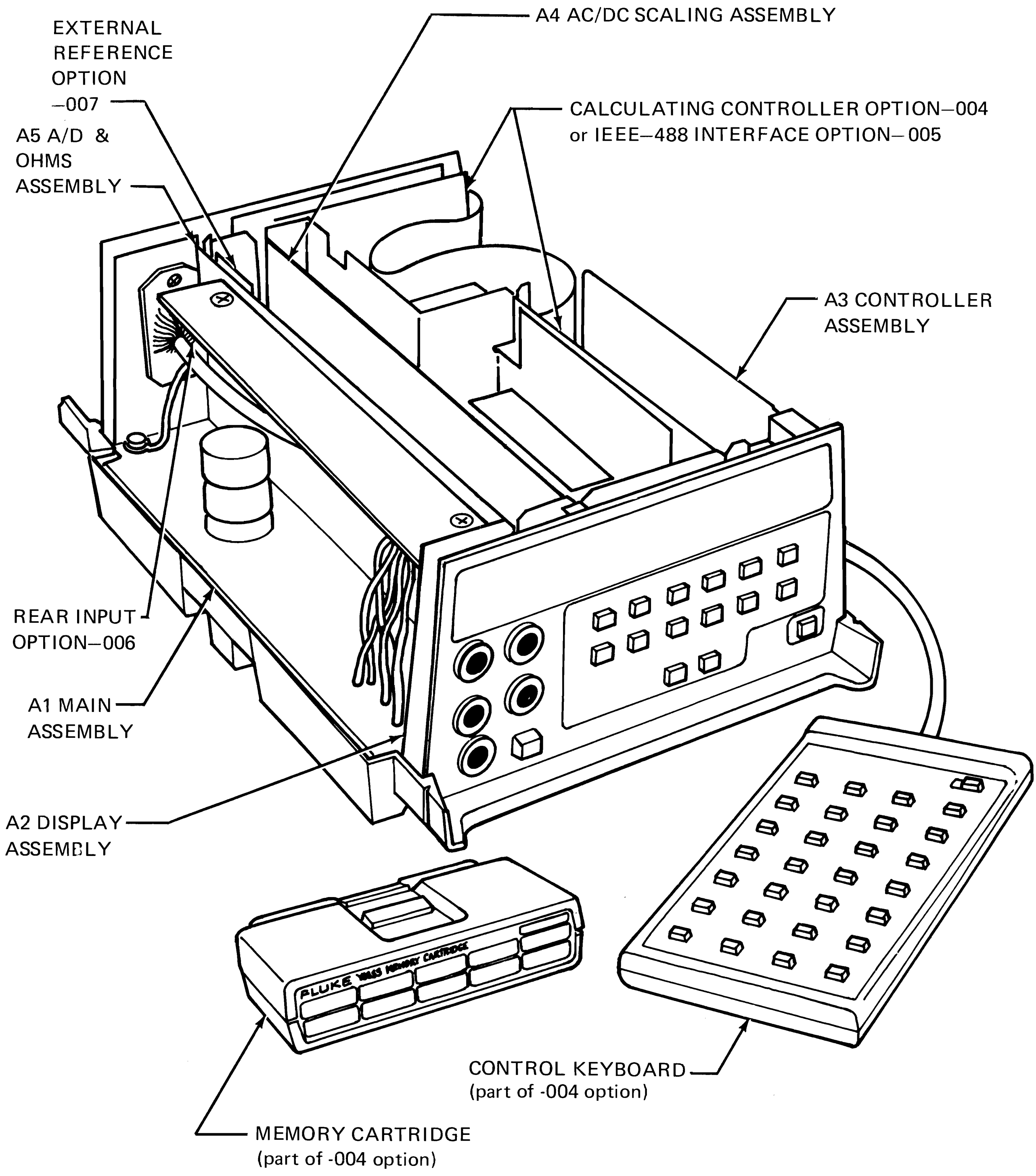


Figure 8-1. 8860A PCB Locations

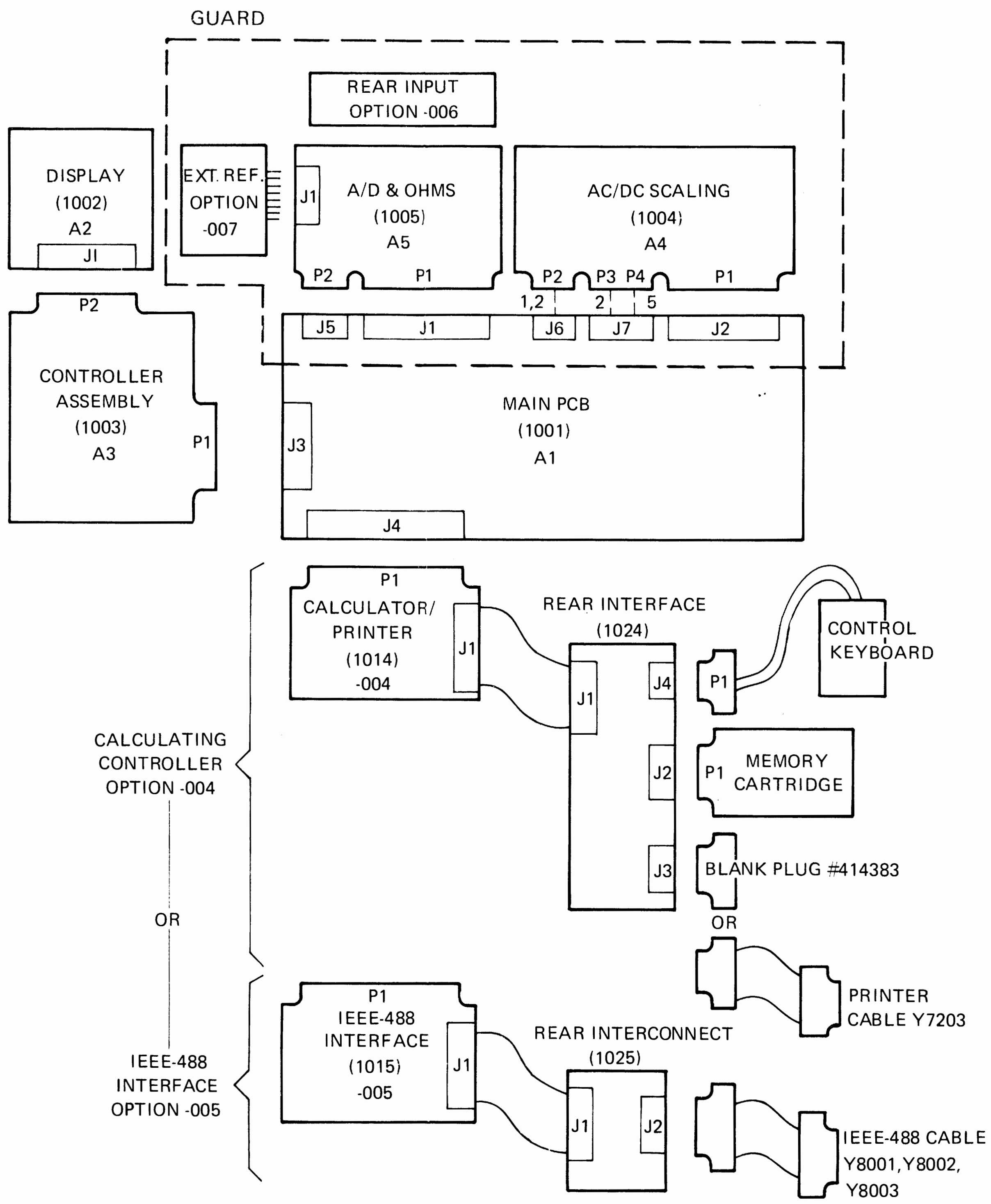
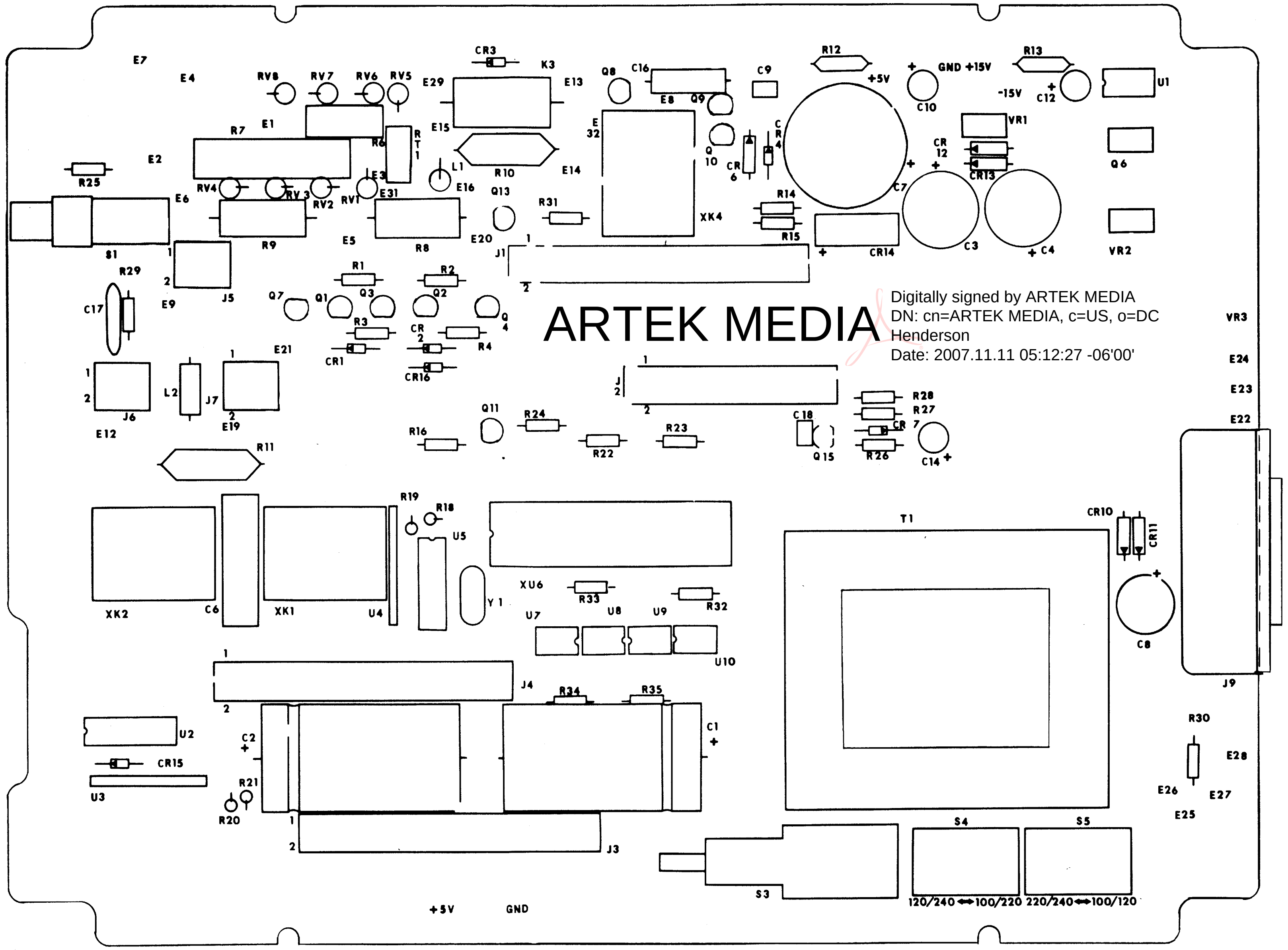


Figure 8-2. 8860A PCB Interconnect Diagram



RELAY STATE TABLE

OFF = Relay coil de-energized, contacts are in the relaxed position shown on the schematic.
ON = Relay coil energized, contacts are switched opposite the position shown on the schematic.

SWITCH	VDC	VAC	VAC +VDC	Ω2T	Ω4T	
RELAY K1						
200 mV	ON	OFF	ON	ON	ON	200 Ω
2 V	ON	OFF	ON	ON	ON	2 KΩ
20 V	OFF	OFF	OFF	ON	ON	20 KΩ
200 V	OFF	OFF	OFF	ON	ON	200 KΩ
1000 V	OFF	OFF	OFF	ON	ON	2 MΩ
				ON	ON	20 MΩ
RELAY K2						
200 mV	ON	ON	OFF	ON	ON	200 Ω
2 V	ON	ON	OFF	ON	ON	2 KΩ
20 V	OFF	OFF	OFF	ON	ON	20 KΩ
200 V	OFF	OFF	OFF	ON	ON	200 KΩ
1000 V	OFF	OFF	OFF	ON	ON	2 MΩ
				ON	ON	20 MΩ
RELAY K3						
200 mV	OFF	OFF	ON	OFF	OFF	200 Ω
2 V	OFF	OFF	ON	OFF	OFF	2 KΩ
20 V	ON	OFF	ON	OFF	OFF	20 KΩ
200 V	ON	OFF	ON	OFF	OFF	200 KΩ
1000 V	ON	OFF	ON	OFF	OFF	2 MΩ
				OFF	OFF	20 MΩ
RELAY K4						
All ranges	OFF	OFF	OFF	ON	ON	

JFET STATE TABLE

FET Q13 (ON = conducting, OFF = non-conducting)						
All ranges	OFF	ON	ON	OFF	OFF	

8860A-1601

Figure 8-3. A1 Main PCB Assembly

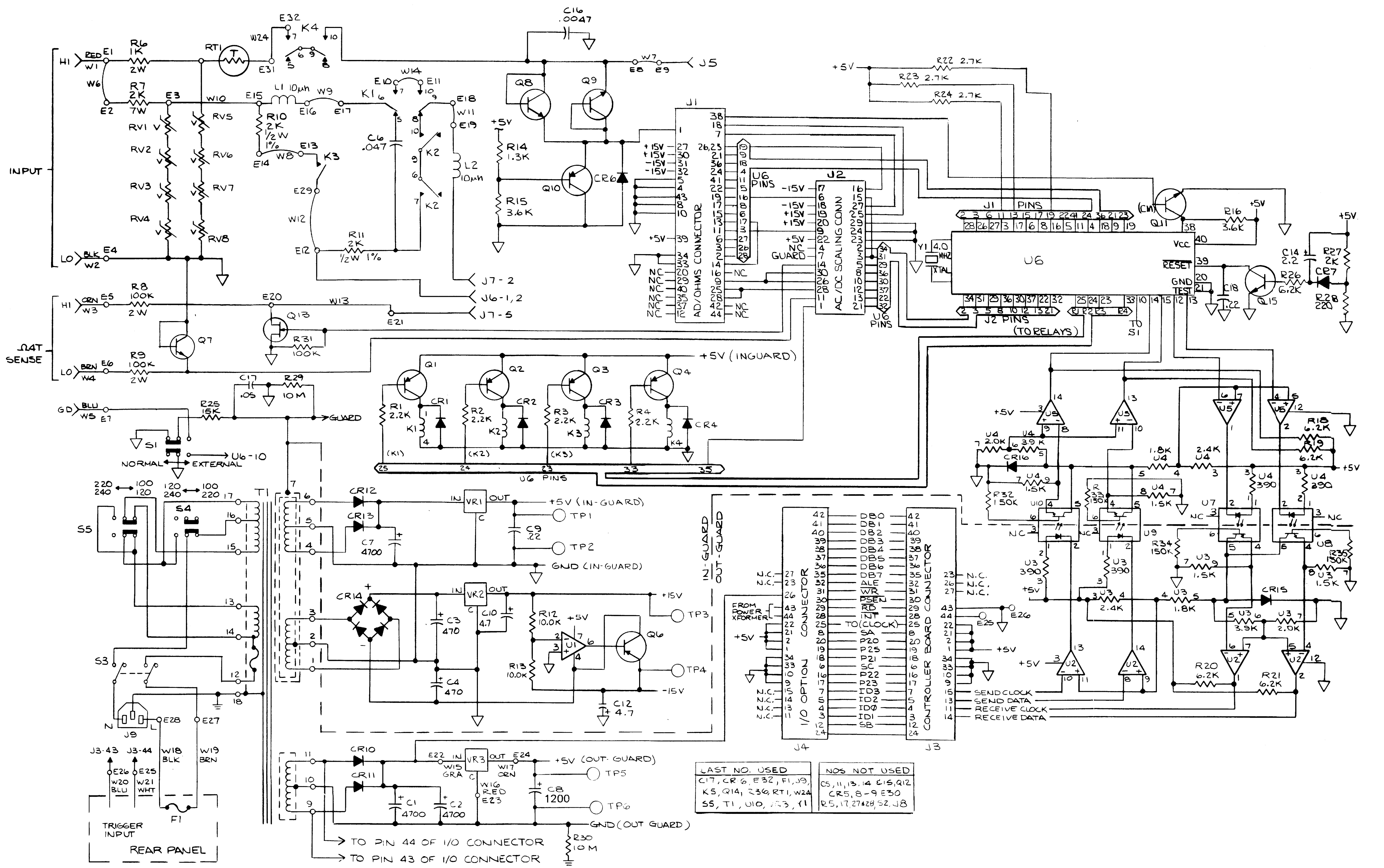
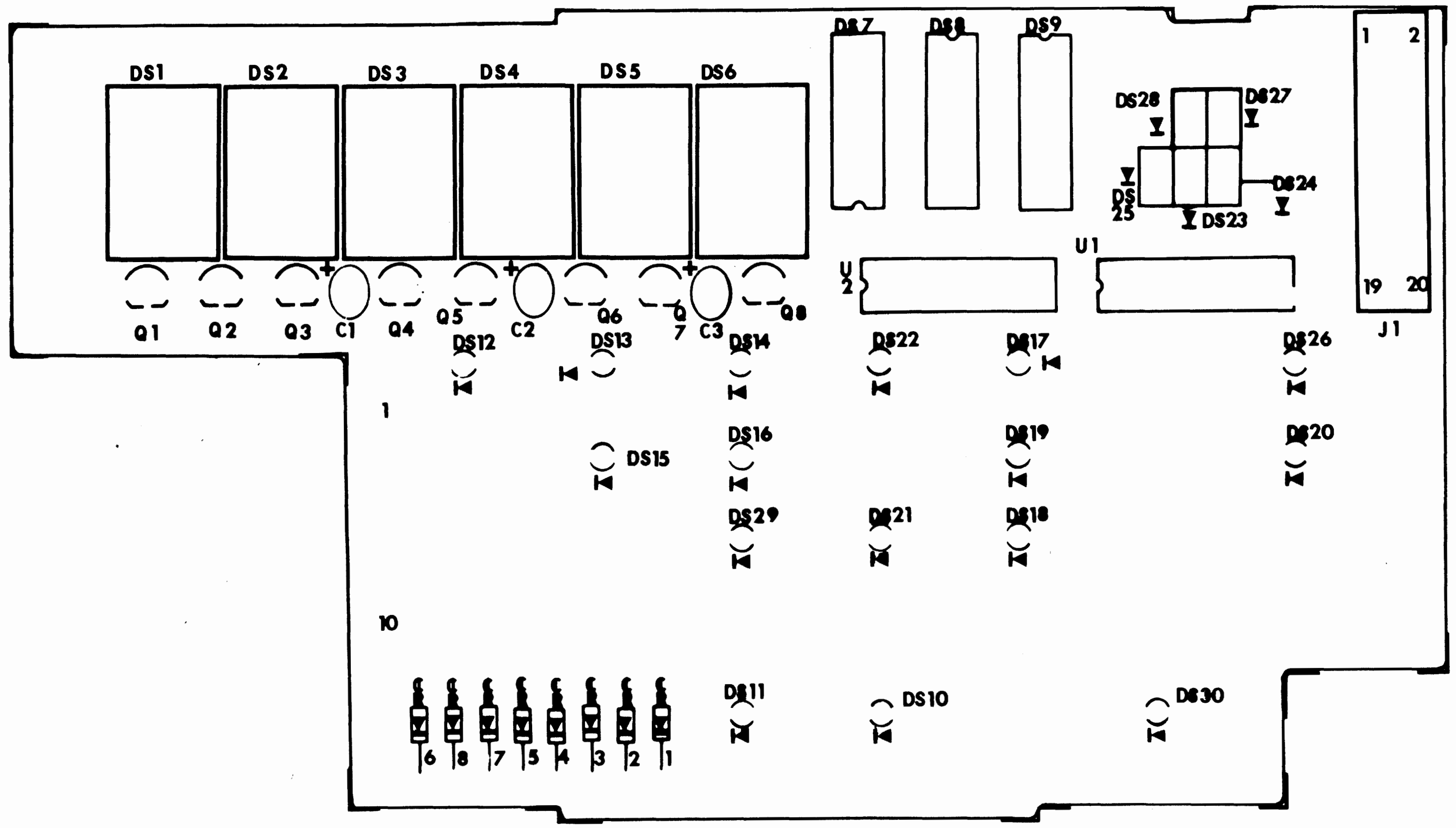


Figure 8-3. A1 Main PCB Assembly (cont)



8860A-1602

Figure 8-4. A2 Display PCB Assembly

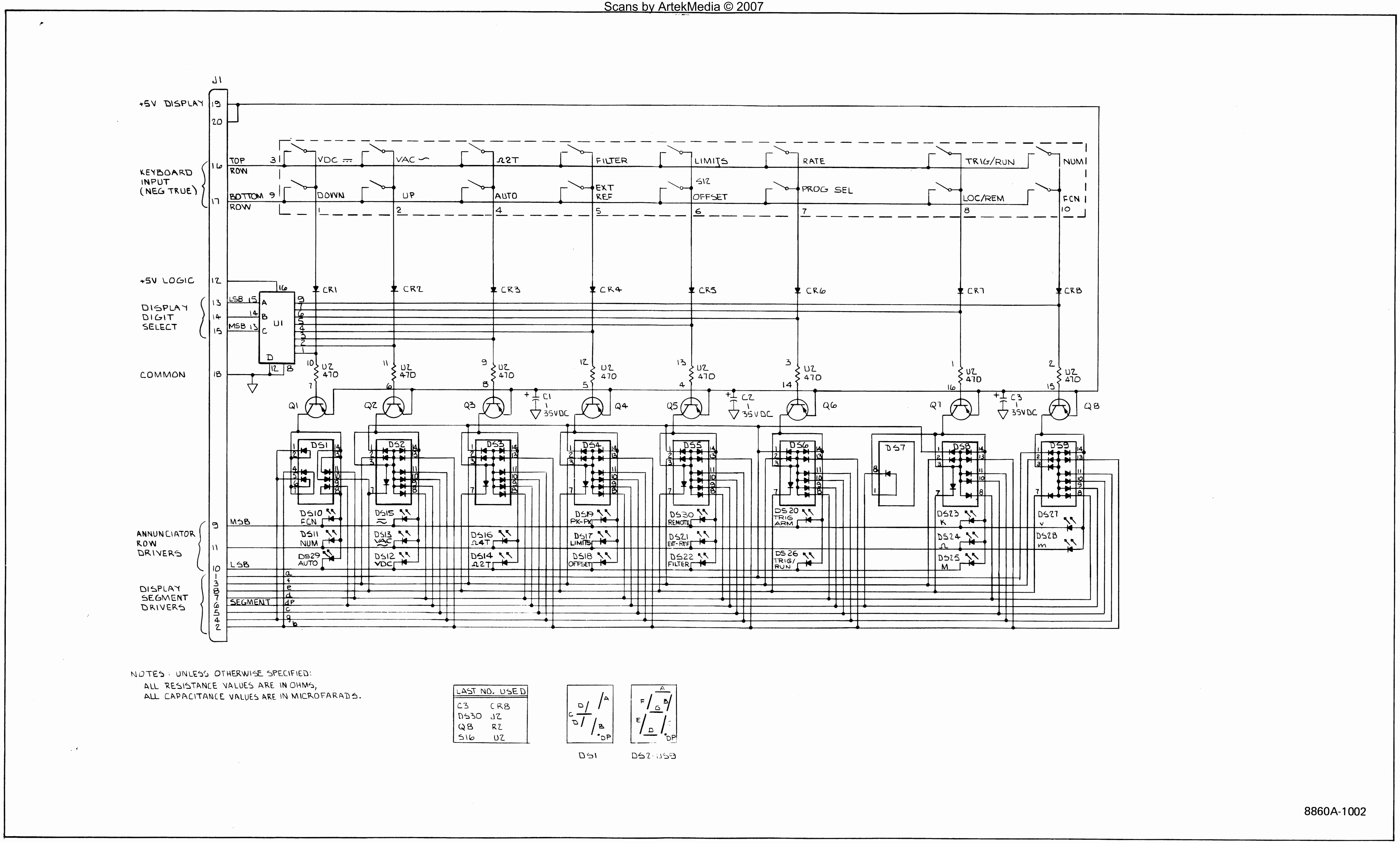
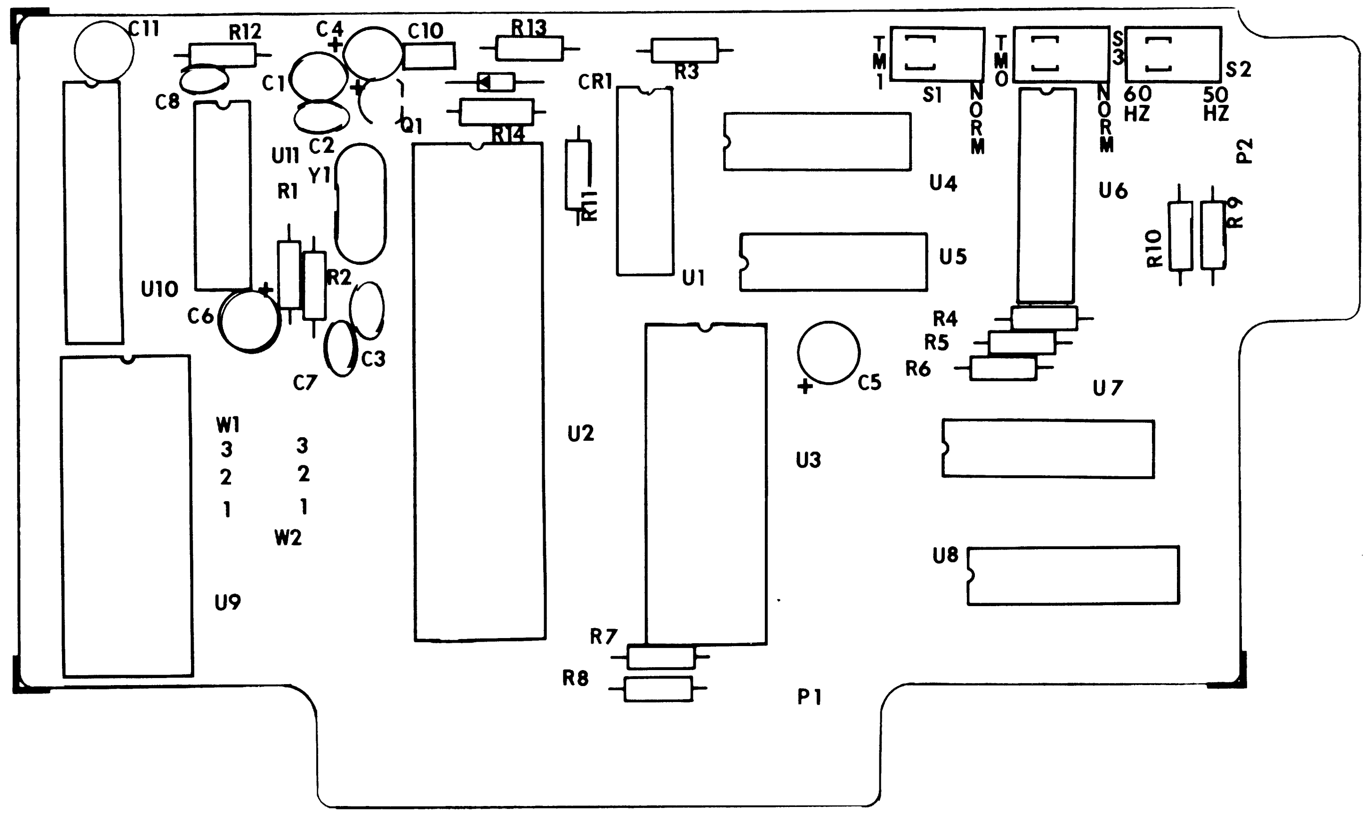
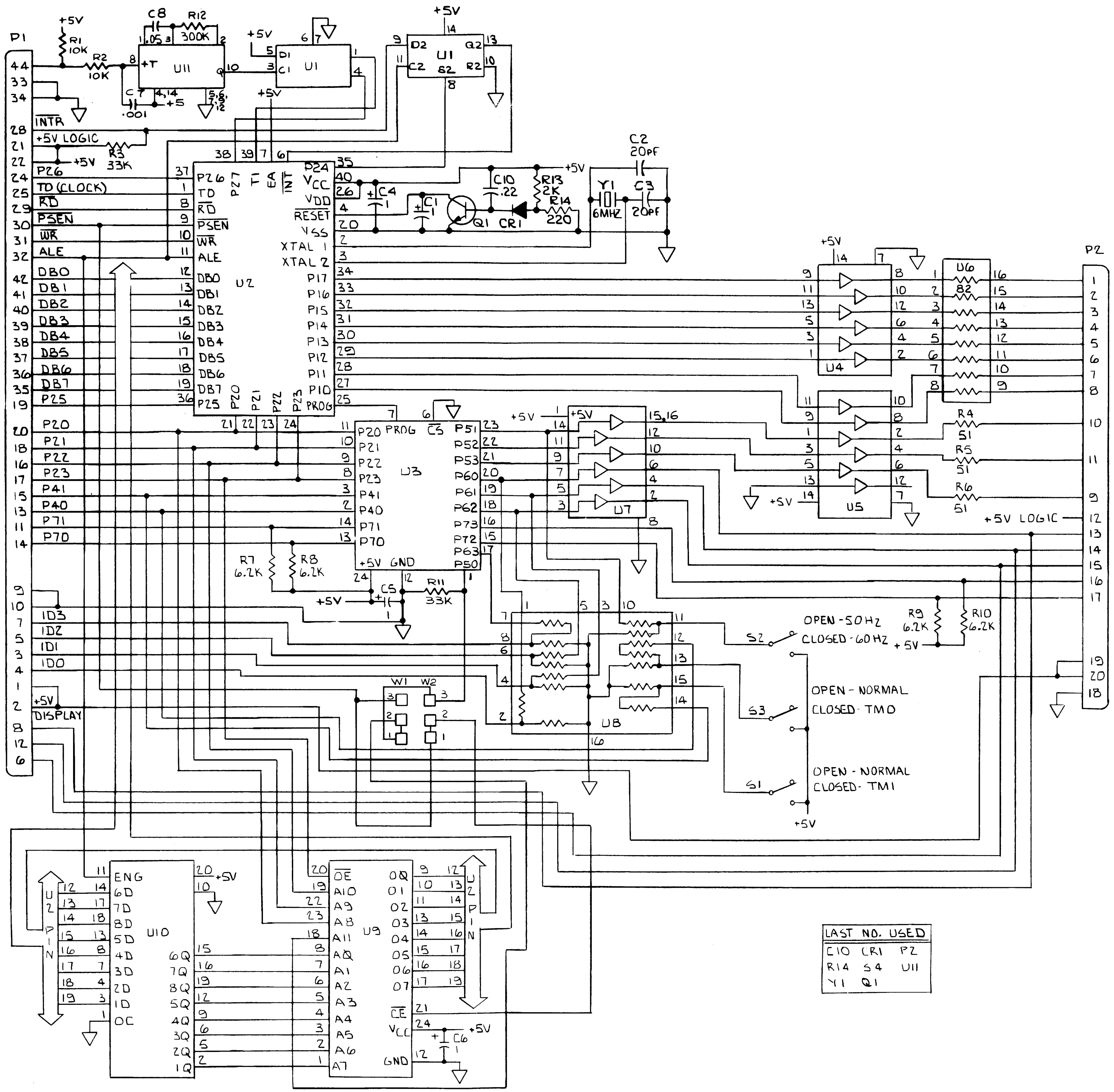


Figure 8-4. A2 Display PCB Assembly (cont)



8860A-1603

Figure 8-5. A3 Controller PCB Assembly

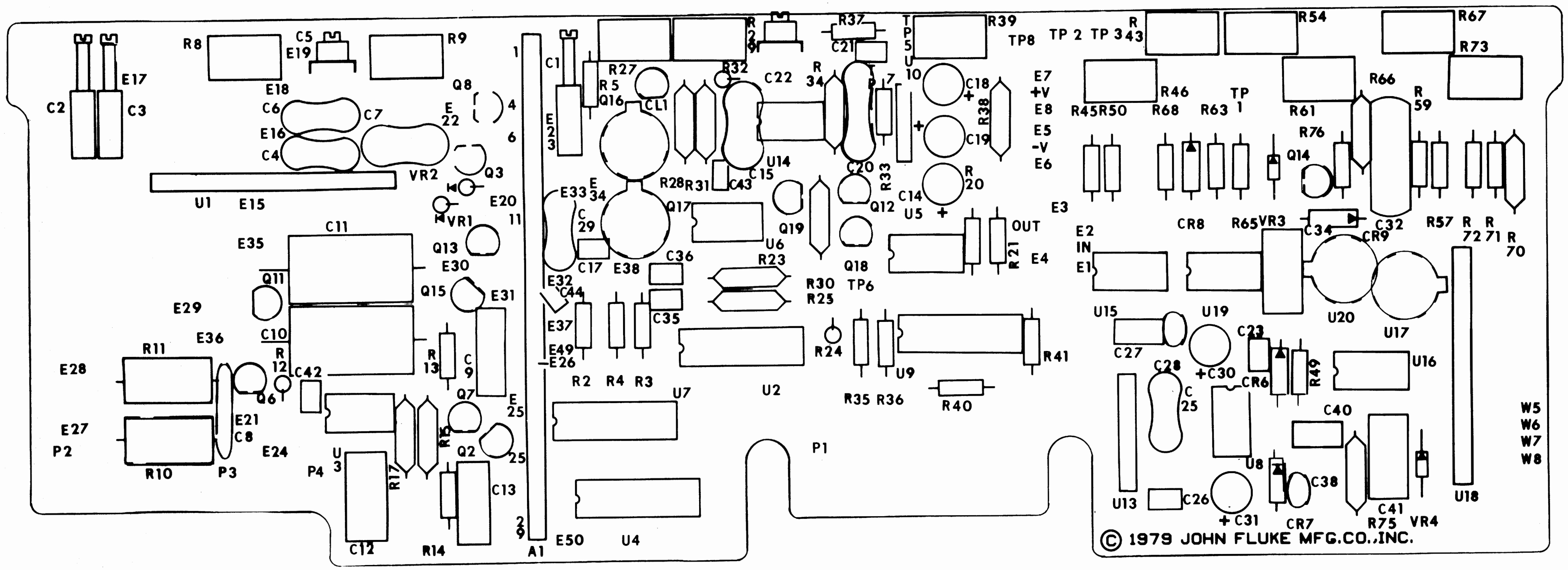


NOTES: UNLESS OTHERWISE SPECIFIED:
1. ALL RESISTANCE VALUES IN OHMS, ALL CAPACITANCE VALUES IN MICROFARADS.

LAST NO. USED		
C10	CR1	P2
R14	S4	U11
Y1	Q1	

8860A-1003

Figure 8-5. A3 Controller PCB Assembly (cont)



8860A-1604

Figure 8-6. A4 AC/DC Scaling PCB Assembly

JFET STATE TABLES

OFF = FET is not conducting.
ON = FET is conducting.

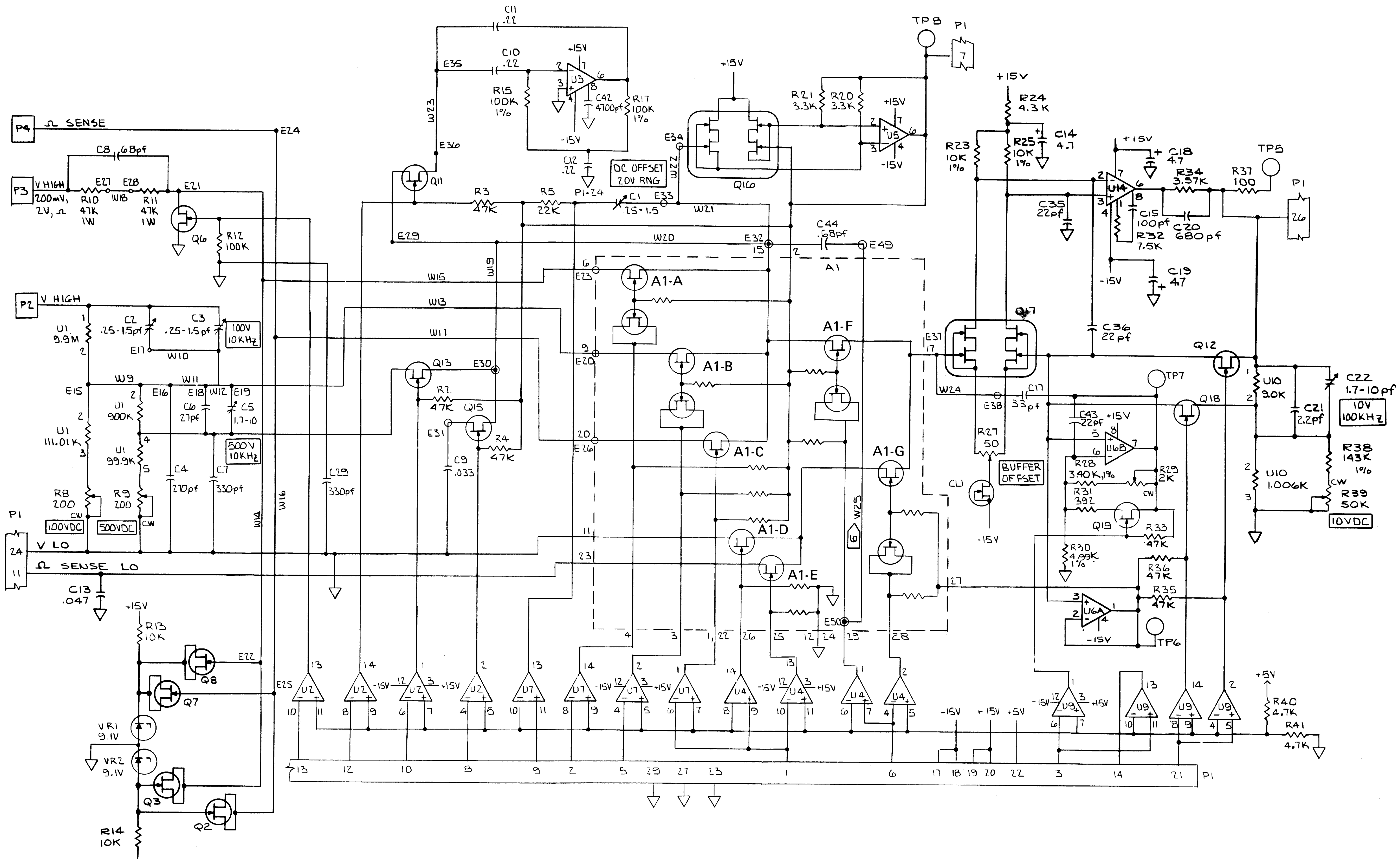
	VDC	VAC	VAC +VDC	Ω2T	Ω4T	
Q6						
200 mV, 2V	OFF	OFF	OFF	OFF	OFF	200 Ω, 2KΩ
20 V-1000 V	ON	ON	ON	OFF	OFF	20 kΩ - 20 MΩ
A1-A (gate pin 4)						
200 mV, 2V	ON	ON	ON	ON	OFF	200 Ω, 2KΩ
20 V-1000 V	OFF	OFF	OFF	ON	OFF	20 K - 20 MΩ
A1 - C (gate pin 22), A1 - E (gate pin 25)						
All ranges	OFF	OFF	OFF	OFF	ON	
A1 - D (gate pin 26)						
All ranges	ON	ON	ON	ON	OFF	
A1 - B (gate pin 3)						
200 mV, 2V	OFF	OFF	OFF	OFF	OFF	200 Ω, 2 KΩ
20 V, 200 V	ON	ON	ON	OFF	OFF	20 KΩ, 200 KΩ
1000 V	OFF	OFF	OFF	OFF	OFF	2 MΩ, 20 MΩ
Q13						
200 mV, 2V	OFF	OFF	OFF	OFF	OFF	200 Ω, 2KΩ
20 V, 200 V	OFF	OFF	OFF	OFF	OFF	20 KΩ, 200 KΩ
1000 V	ON	ON	ON	OFF	OFF	2 MΩ, 20 MΩ
A1 - F (gate pin 29)						
All ranges	INT	ON	ON	INT	INT	
A1 - G (gate pin 28)						
All ranges	$\overline{\text{INT}}$	OFF	OFF	$\overline{\text{INT}}$	$\overline{\text{INT}}$	

	VDC	VAC	VDC +VAC	Ω2T	Ω4T	
Q19						
All ranges	ON	OFF	OFF	ON	ON	
Q12						
200 mV	OFF	OFF	OFF	OFF	OFF	200 Ω
2 V	ON	ON	ON	ON	ON	2 KΩ
20 V	OFF	OFF	OFF	ON	ON	20 KΩ
200 V, 1000 V	ON	ON	ON	ON	ON	200 KΩ - 20 MΩ
Q18						
200 mV	ON	ON	ON	ON	ON	200 Ω
2 V	OFF	OFF	OFF	OFF	OFF	2 KΩ
20 V	ON	ON	ON	OFF	OFF	20 K Ω
200 V, 1000 V	OFF	OFF	OFF	OFF	OFF	200 K Ω - 20 MΩ

	VDC	VDC +FIL	VAC	VAC +VDC	Ω2T	Ω2T +FIL	Ω4T	Ω4T +FIL	
Q11 (3-Pole Active Filter)									
200 mV-1000 V	OFF	ON	OFF	OFF	OFF	ON	OFF	ON	200 Ω - 200 KΩ
	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	2 MΩ, 20 MΩ
Q15 (Passive Filter)									
200 mV-1000 V	*	ON	OFF	OFF	*	ON	*	ON	200 Ω - 200 KΩ
	*	ON	OFF	OFF	OFF	ON	OFF	ON	2 MΩ , 20 MΩ

* = ON when in 4½ or 5½ digit mode, or if autoranging in 3½ digit mode
OFF when in 3½ digit mode, and not autoranging.

Figure 8-6. A4 AC/DC Scaling PCB Assembly (cont)



6 W25 MAY BE REMOVED

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Figure 8-6. A4 AC/DC Scaling PCB Assembly (cont)

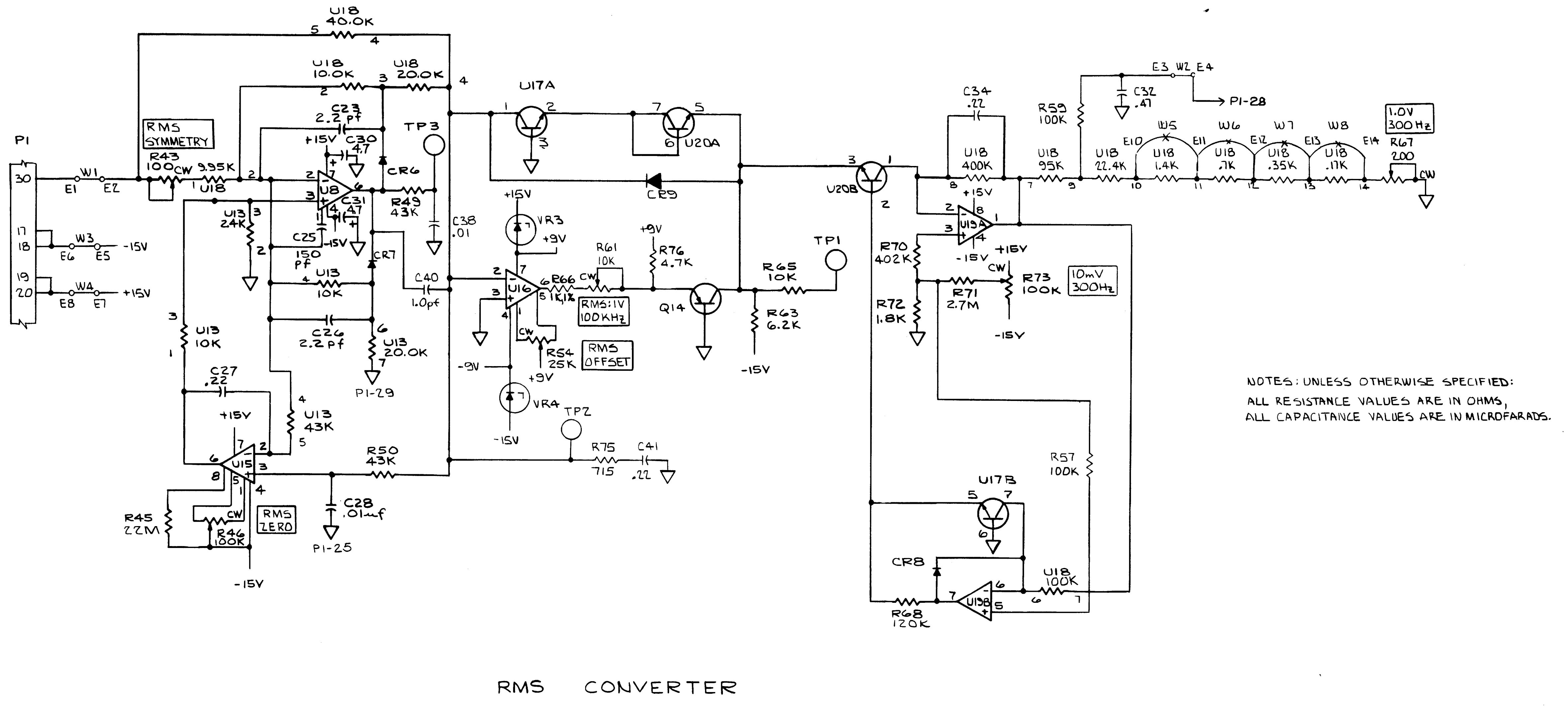

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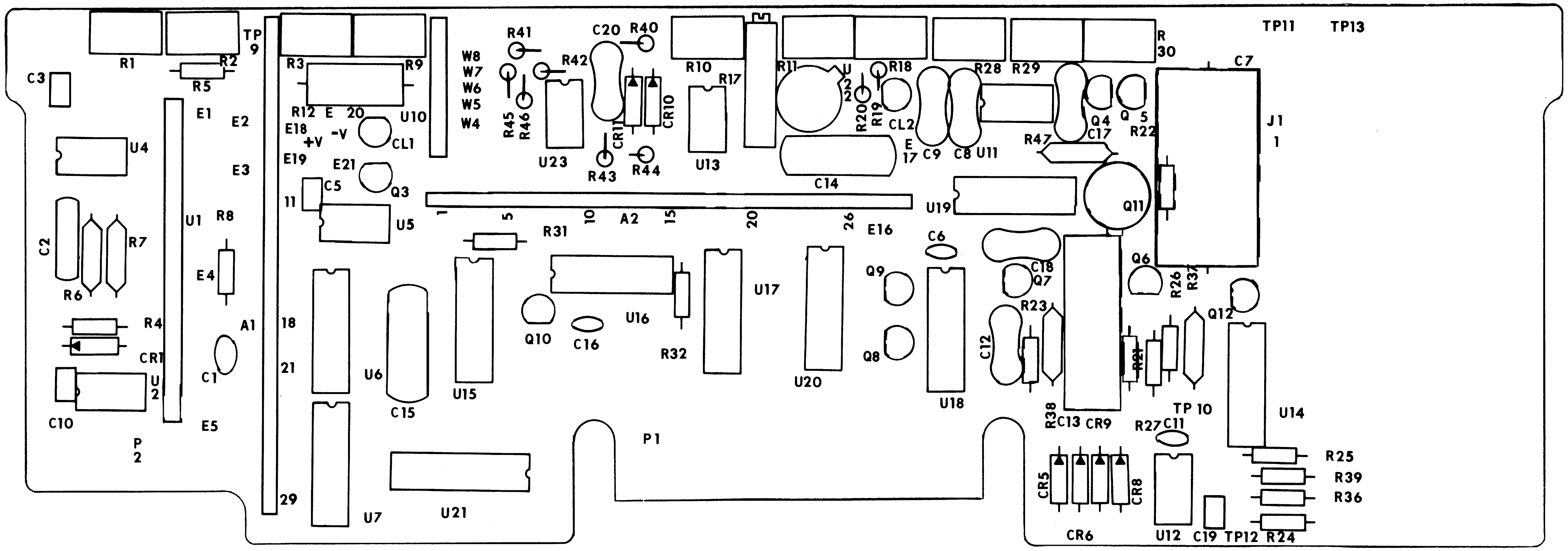
Figure 8-6. A4 AC/DC Scaling PCB Assembly (cont)



8860A-1605

Figure 8-7. A5 A/D and Ohms Converter PCB Assembly

JFET STATE TABLE

ON = JFET is conducting
OFF = JFET is not conducting

OHMS CONVERTER
For Ω2T and Ω4T functions, the JFETs on the A1 hybrid circuit are switched as follows:

(gate-pin 12) A1 - E, F	(pin 13) A1 - G, H	(pin 11) A1 - I, J	(pin 18) A1 - D	(pin 21) A1 - A	(pin 24) A1 - B	
ON	OFF	OFF	OFF	OFF	ON	200 Ω
ON	OFF	OFF	OFF	OFF	ON	2 kΩ
OFF	ON	OFF	OFF	OFF	ON	20 kΩ
OFF	OFF	ON	OFF	OFF	ON	200 kΩ
OFF	OFF	OFF	ON	OFF	ON	2 MΩ
OFF	OFF	OFF	ON	ON	OFF	20 MΩ

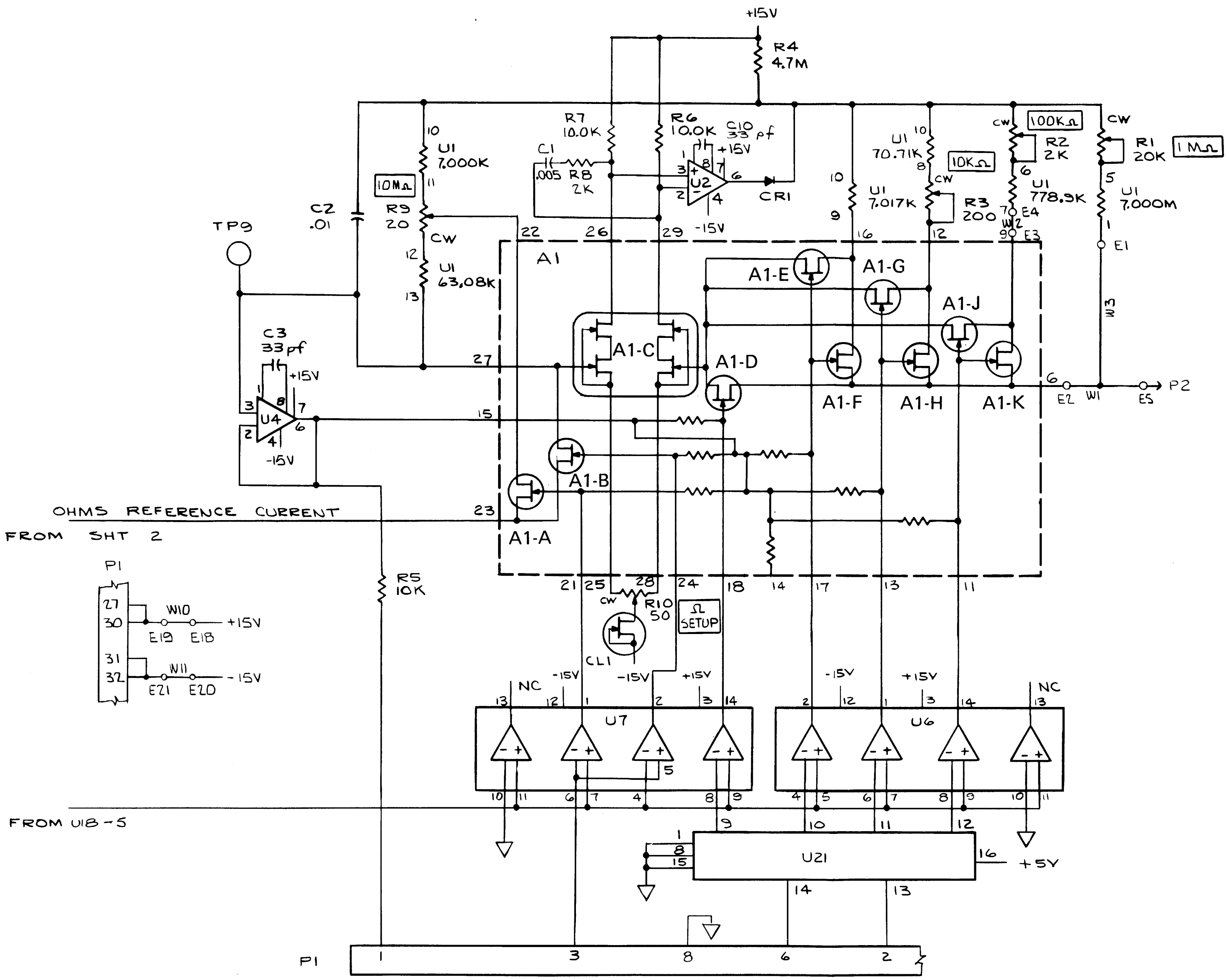
(When a function other than Ω2T or Ω4T is selected, these FETs default to the 2 MΩ position.)

U21 BINARY TO 1 - OF - 4 DECODER TRUTH TABLE

	INPUTS		OUTPUTS			
PIN #	13	14	9	10	11	12
	0	0	1	1	1	0
	0	1	1	1	0	1
	1	0	1	0	1	1
	1	1	0	1	1	1

0 = 0V
1 = +5V

Figure 8-7. A5 A/D and Ohms Converter PCB Assembly (cont)



NOTES:-

ALL RESISTANCE VALUES ARE IN OHMS,
ALL CAPACITANCE VALUES ARE IN MICROFARADS.

LAST NO. USED
A2, C20, CL2, CR11, E21, J1, P1, Q12, R47, U23, W11, TP5

NOS NOT USED
C4 CR2,3,7 Q1,2 R13-16, 33-35 U3,8,9

OHMS CONVERTER

8860A-1005
(1 of 2)

Figure 8-7. A5 A/D and Ohms Converter
PCB Assembly (cont)

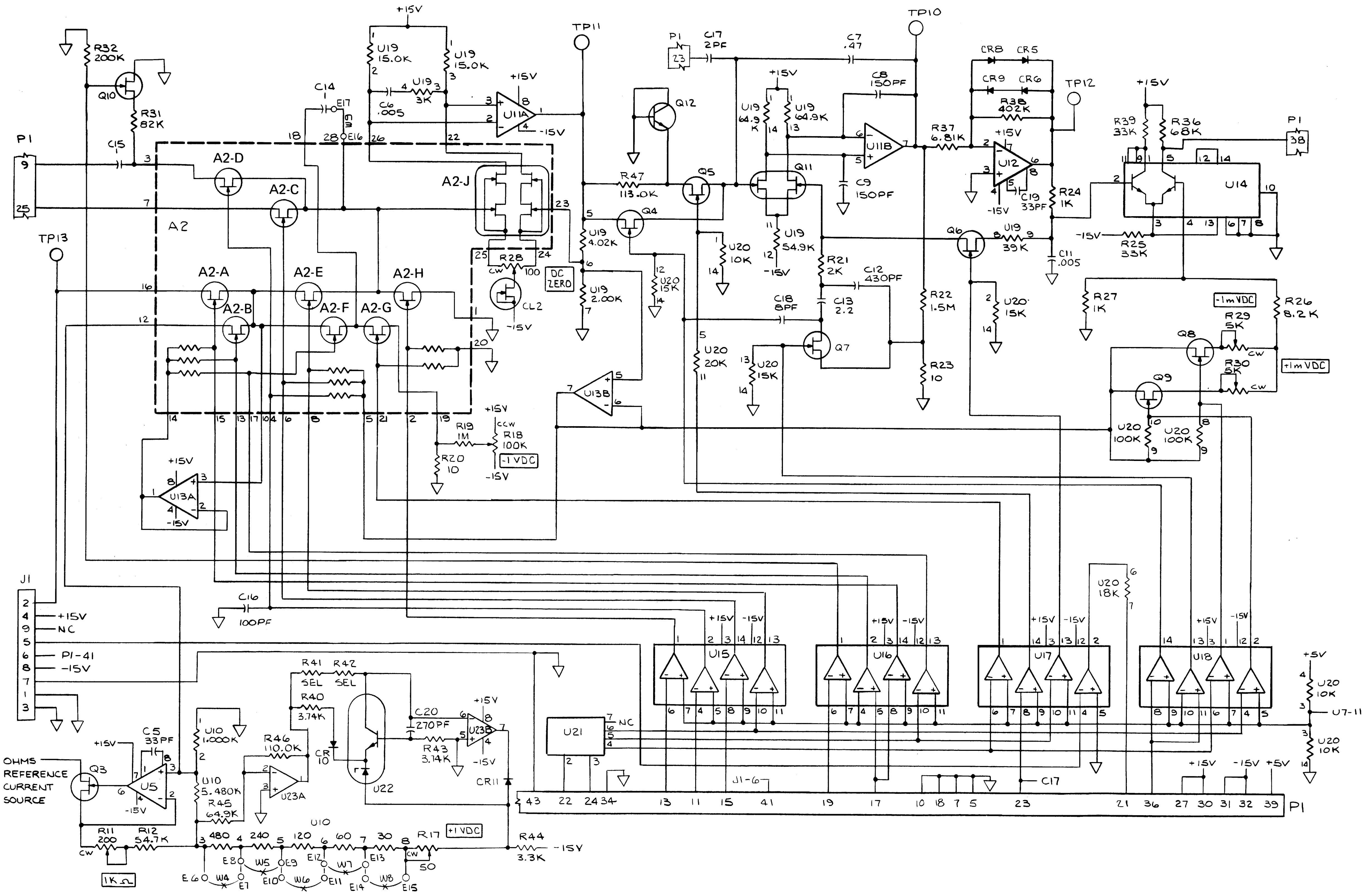


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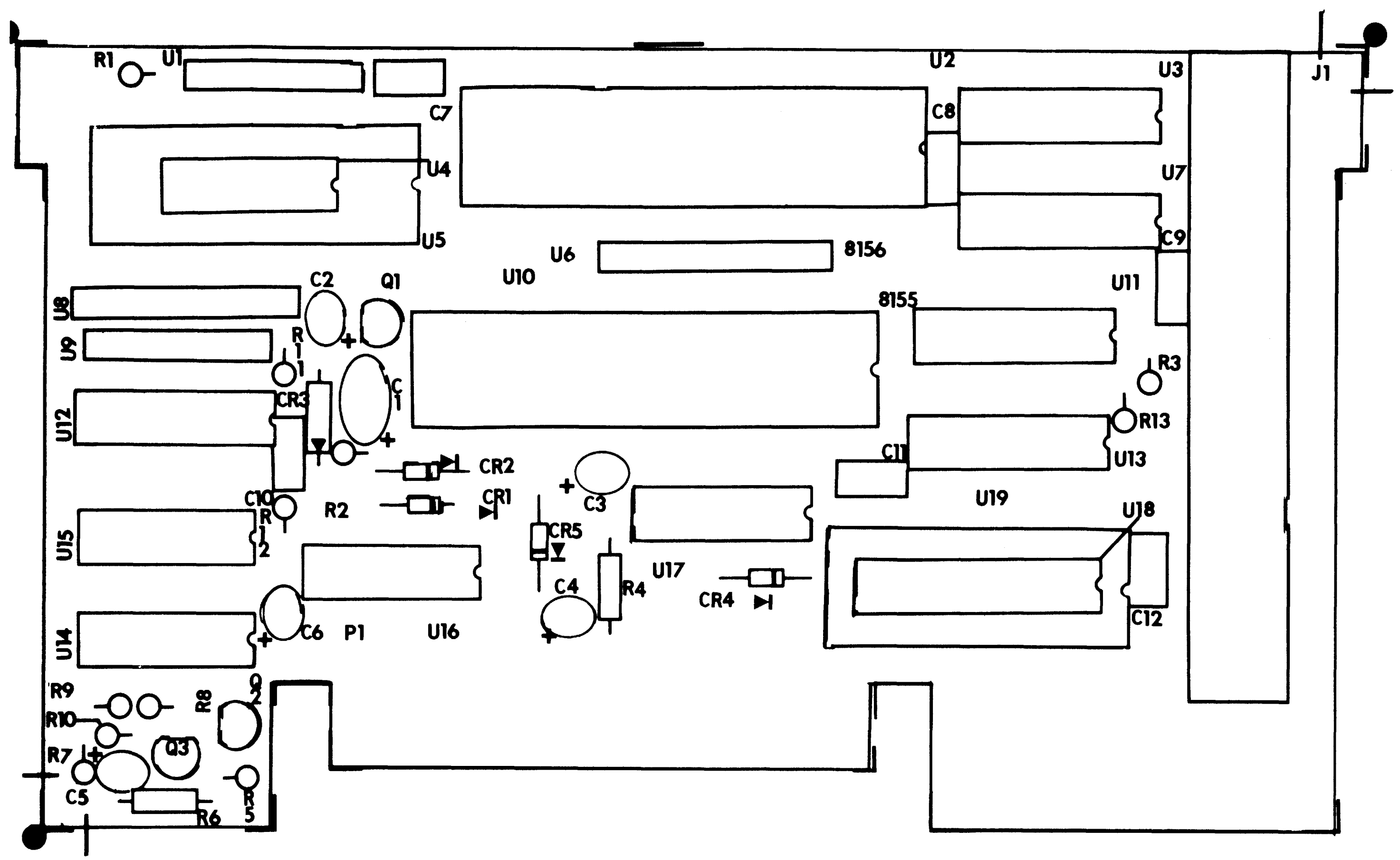
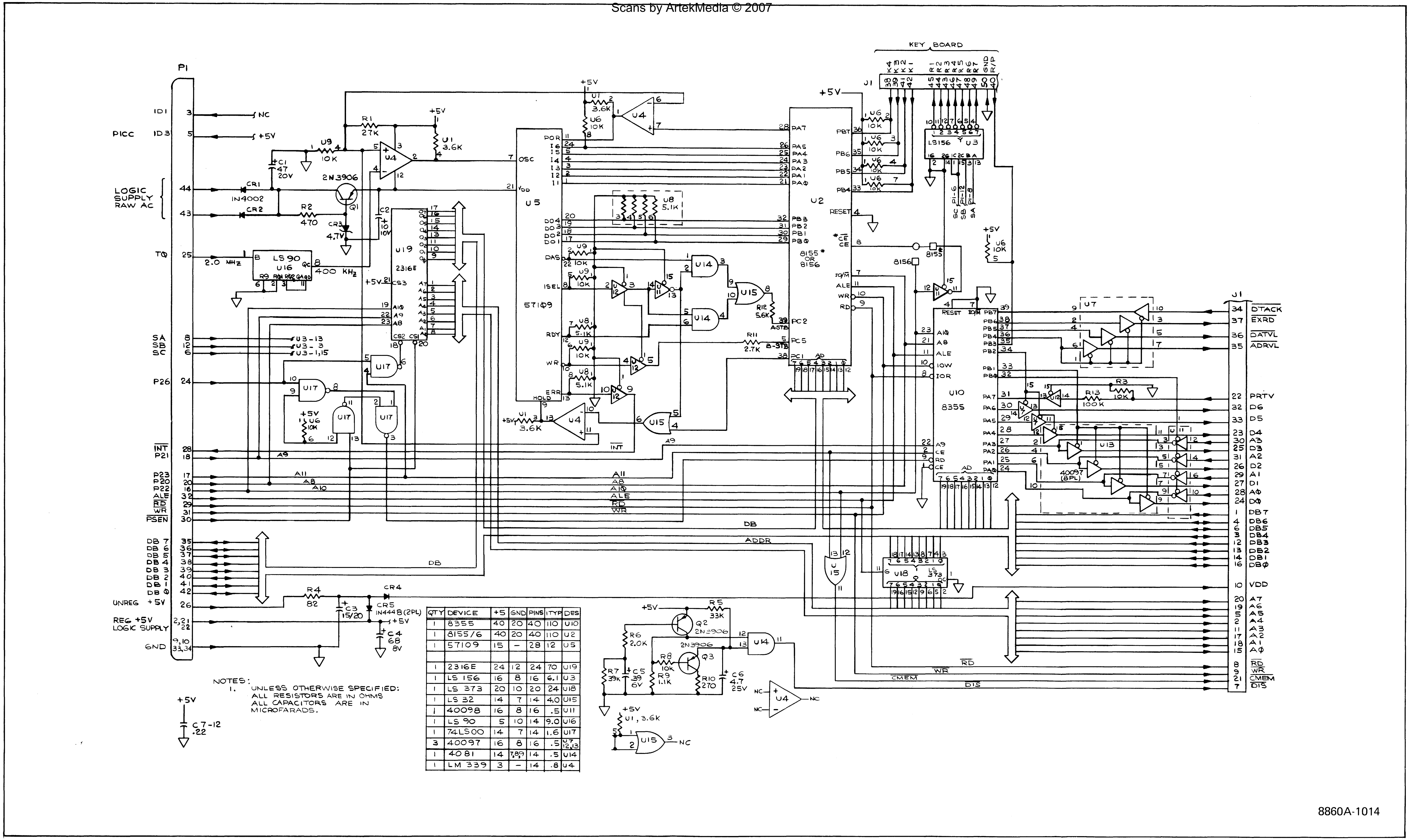
Figure 8-7. A5 A/D and Ohms Converter PCB Assembly (cont)



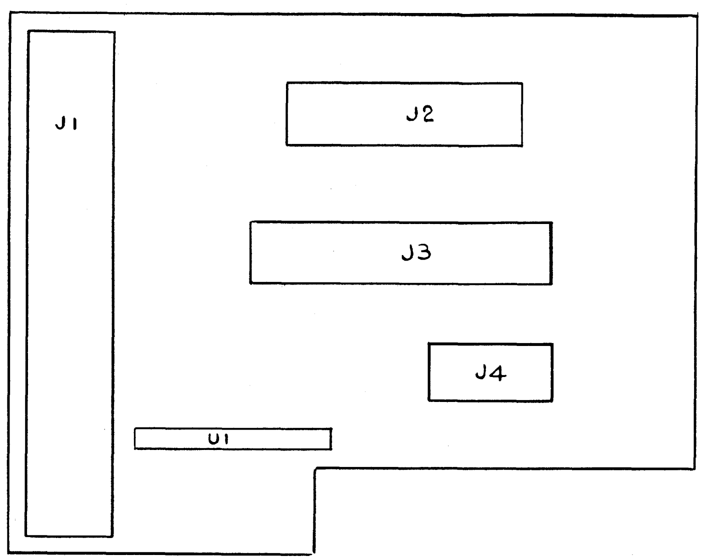
8860A-1614

Figure 8-8. Calculator/Printer PCB Assembly

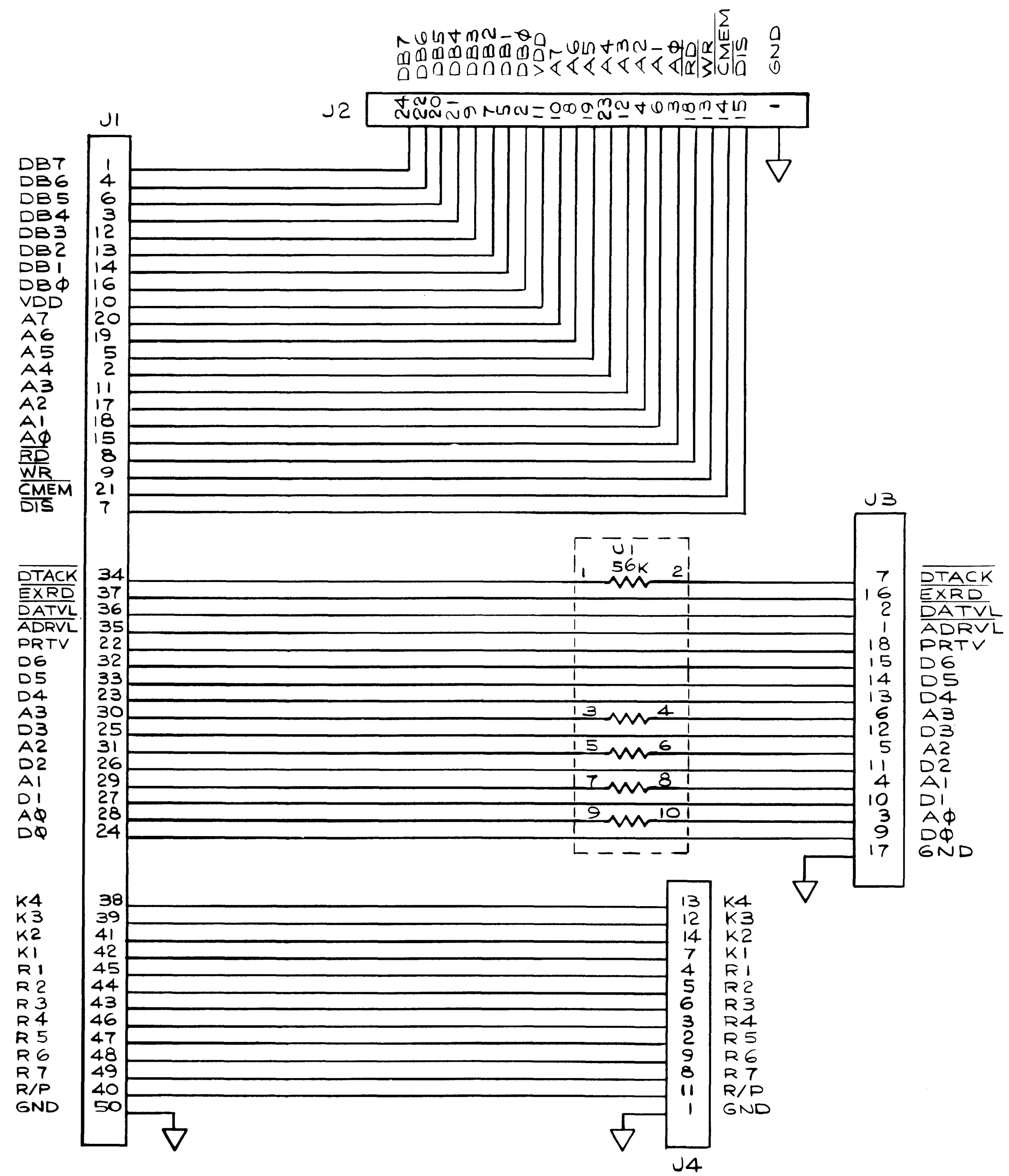


QTY	DEVICE	+5	GND	PINS	ITYP	DES
1	8355	40	20	40	110	U10
1	8155/6	40	20	40	110	U2
1	57109	15	–	28	12	U5
1	2316E	24	12	24	70	U19
1	LS 156	16	8	16	6.1	U3
1	LS 373	20	10	20	24	U18
1	LS 32	14	7	14	4.0	U15
1	40098	16	8	16	.5	U11
1	LS 90	5	10	14	9.0	U16
1	74LS00	14	7	14	1.6	U17
3	40097	16	8	16	.5	U7 12,13
1	4081	14	7,8,9	14	.5	U14
1	LM 339	3	–	14	.8	U4

Figure 8-8. Calculator/Printer PCB Assembly (cont)

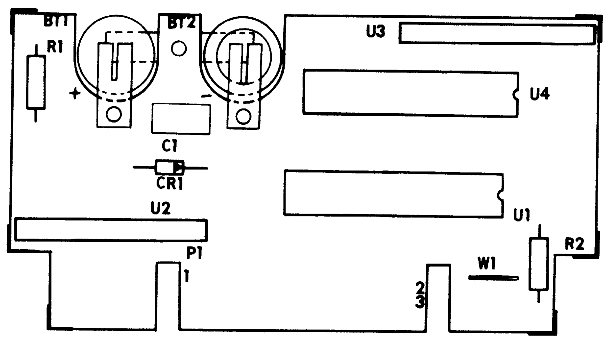


8860A-1624

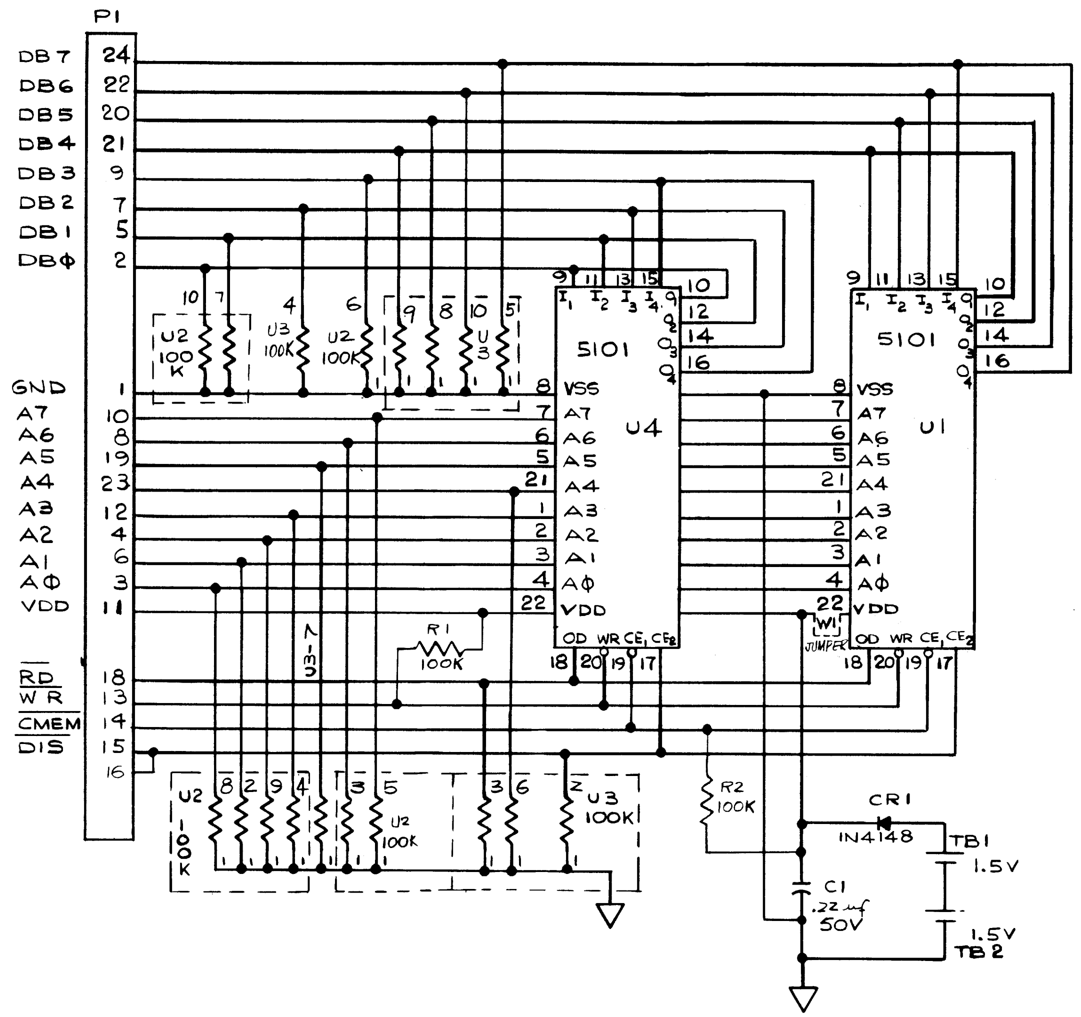


8860A-1024

Figure 8-9. Rear Interface PCB Assembly

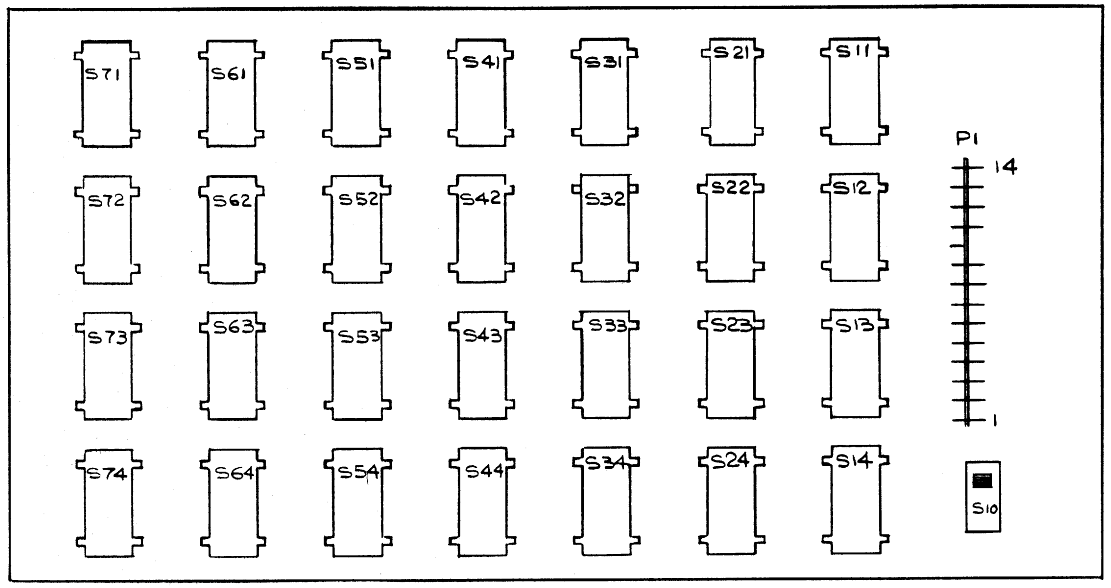


8860A-1613

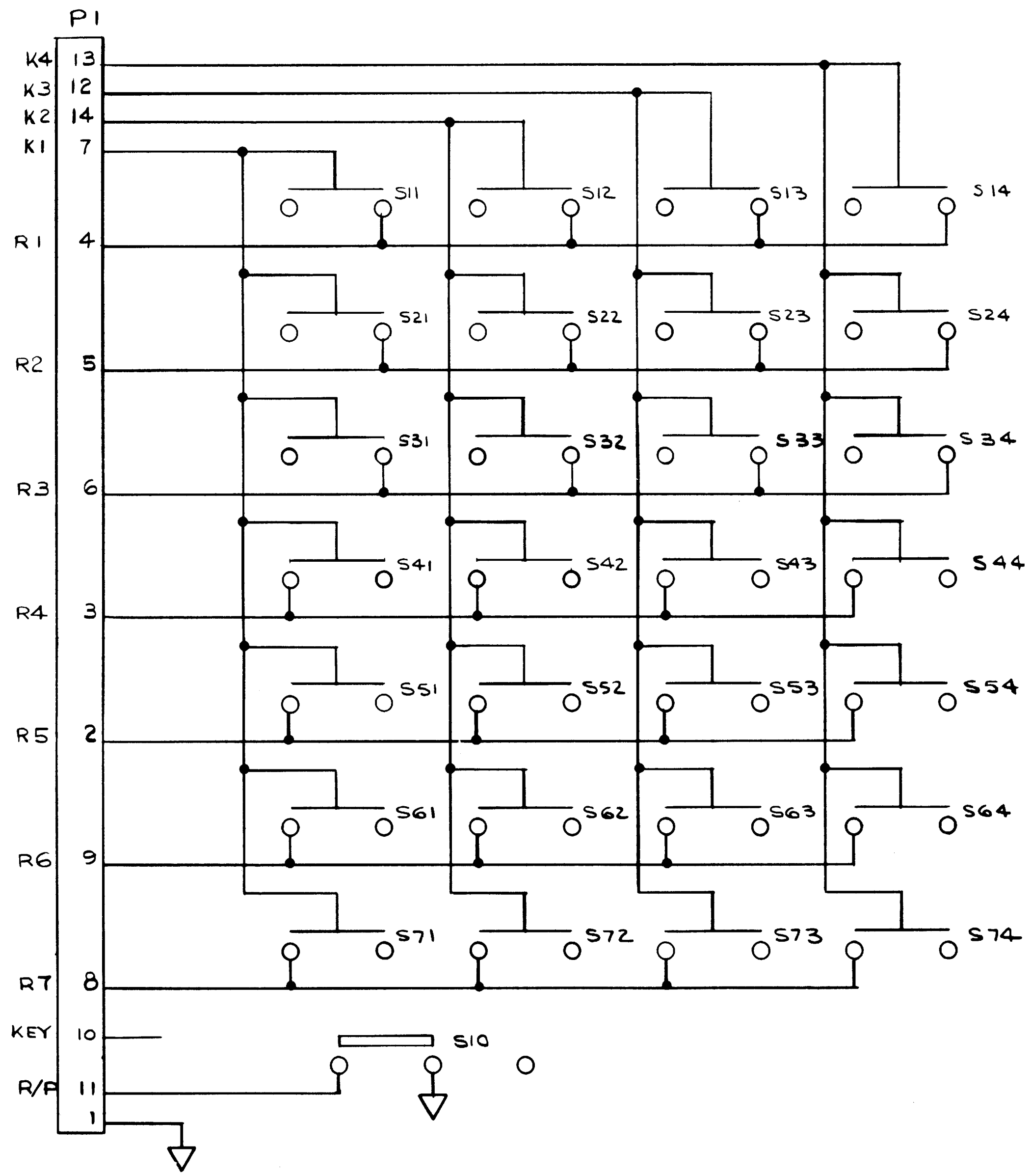


8860A-1013

Figure 8-10. Memory Cartridge PCB Assembly

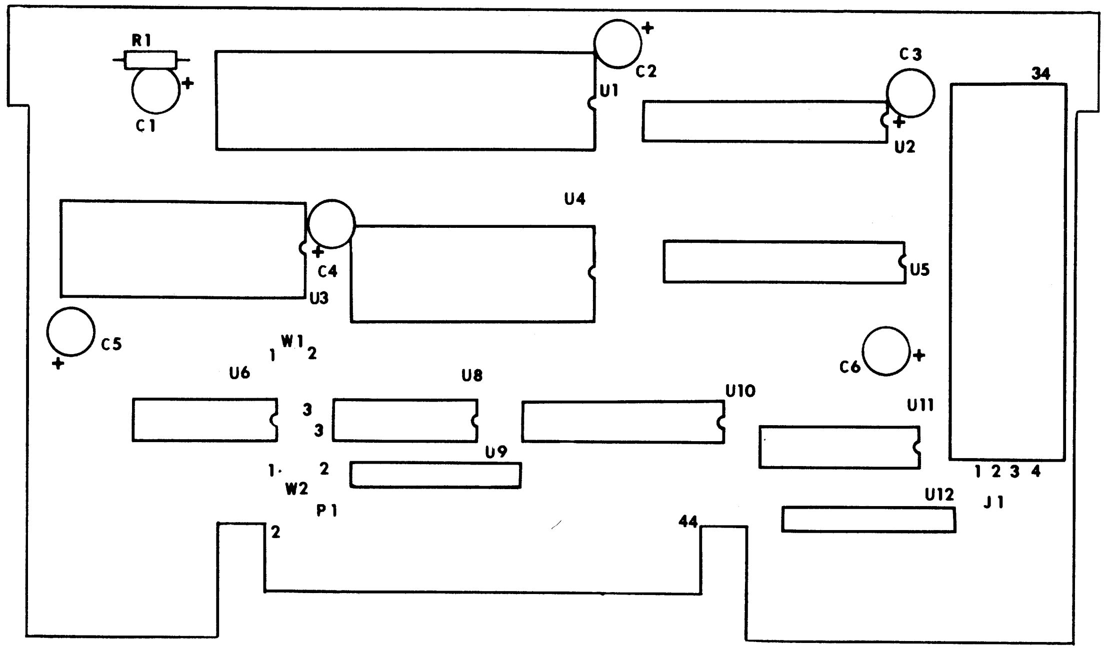


8860A-1626

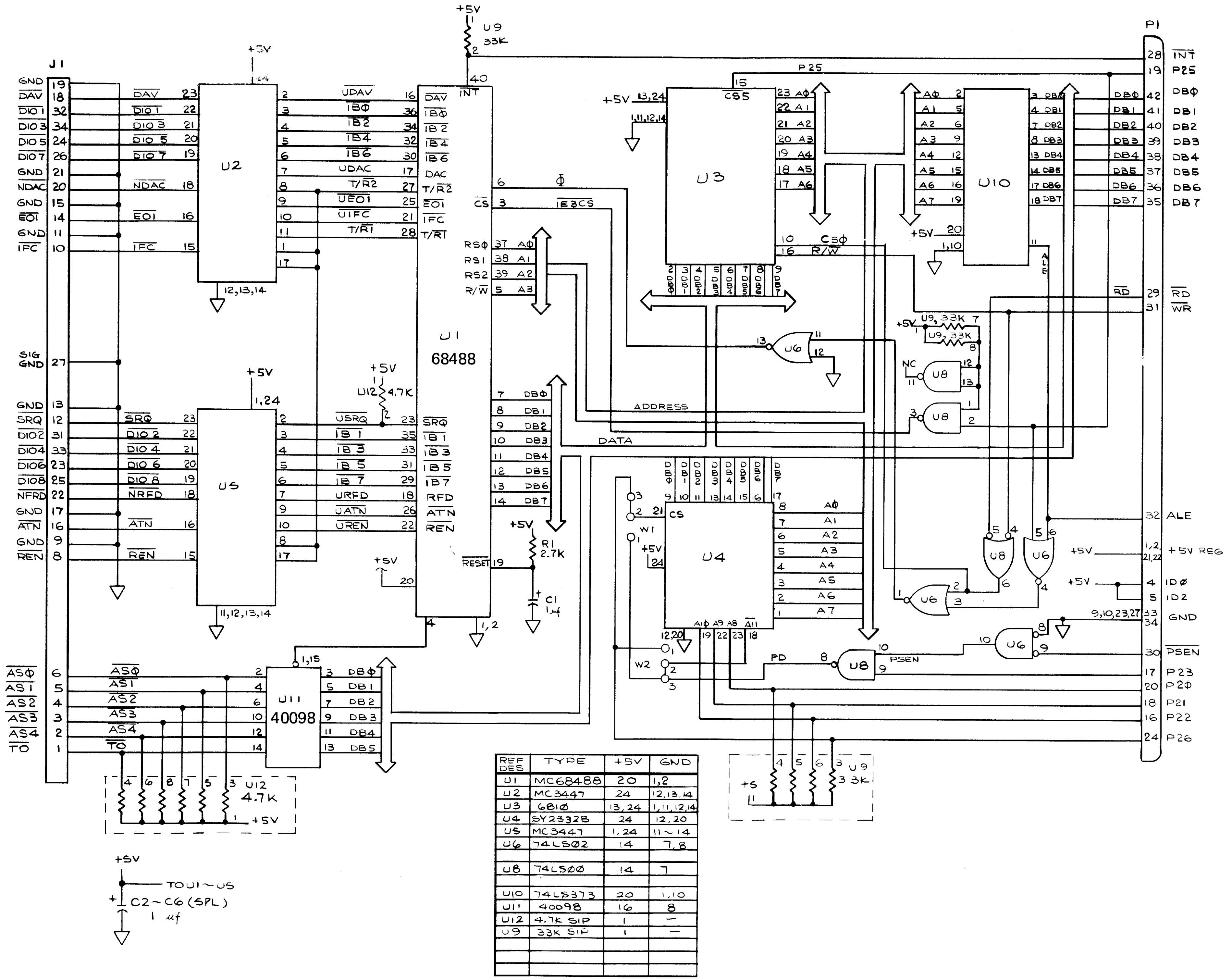


8860A-1026

Figure 8-11. Control Keyboard PCB Assembly



8860A-1615

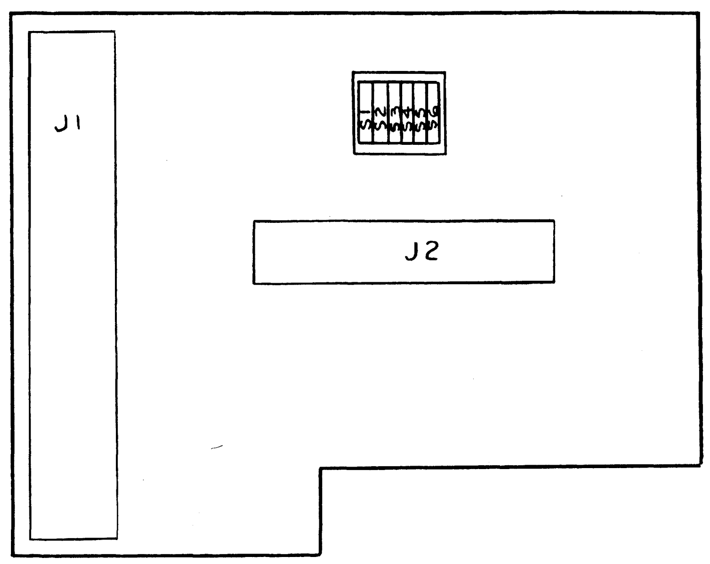


REF DES	TYPE	+5V	GND
U1	MC68488	20	1,2
U2	MC3447	24	12,13,14
U3	681Ø	13,24	1,11,12,14
U4	SY2332B	24	12,20
U5	MC3447	1,24	11 ~ 14
U6	74LSØ2	14	7,8
U8	74LSØØ	14	7
U10	74LS373	20	1,10
U11	40098	16	8
U12	4.7K SIP	1	—
U9	33K SIP	1	—

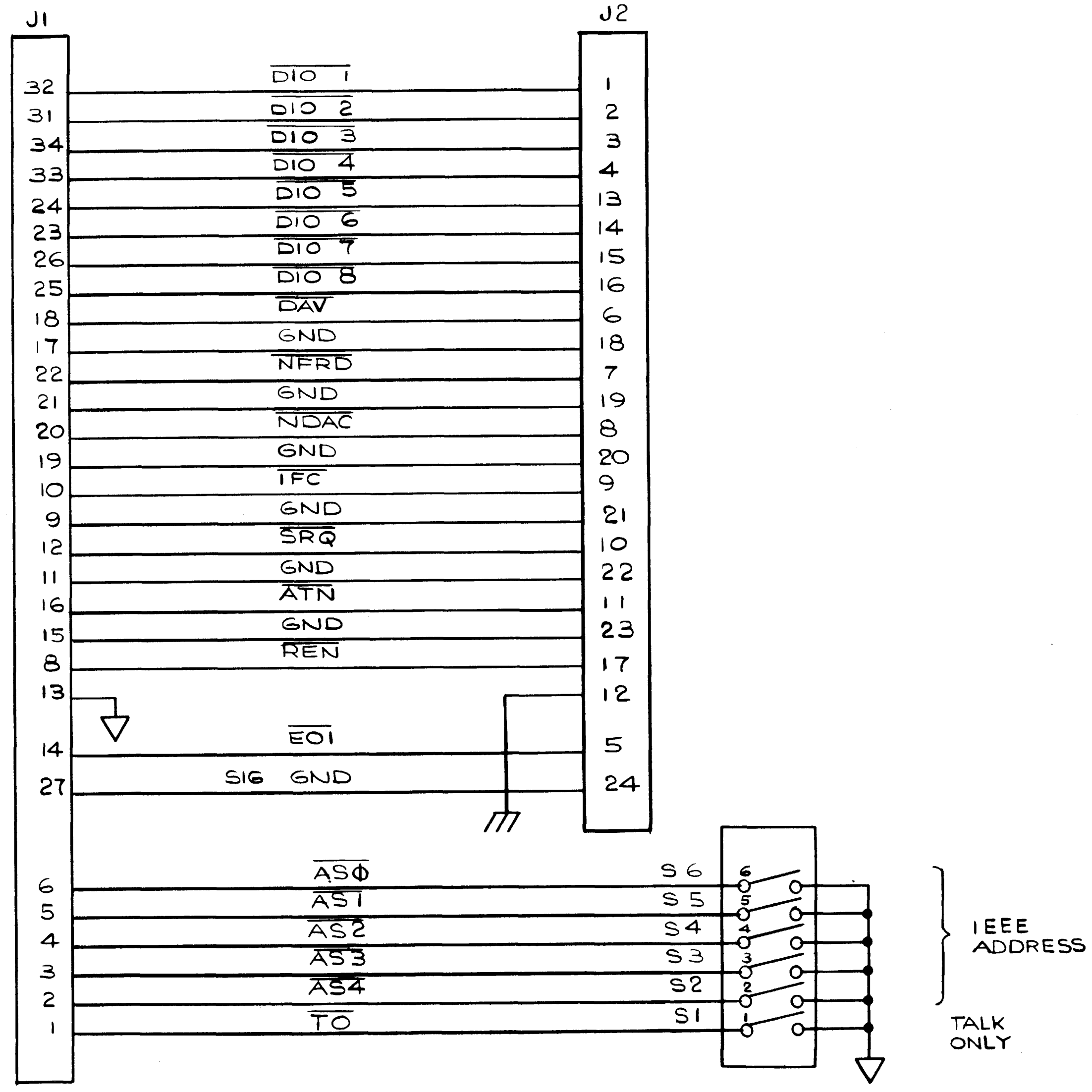
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL RESISTORS ARE IN OHMS,
ALL CAPACITORS ARE IN MICROFARADS.

8860A-1015

Figure 8-12. IEEE-488 Interface PCB Assembly



8860A-1625



8860A-1025

Figure 8-13. Rear Interconnect PCB Assembly

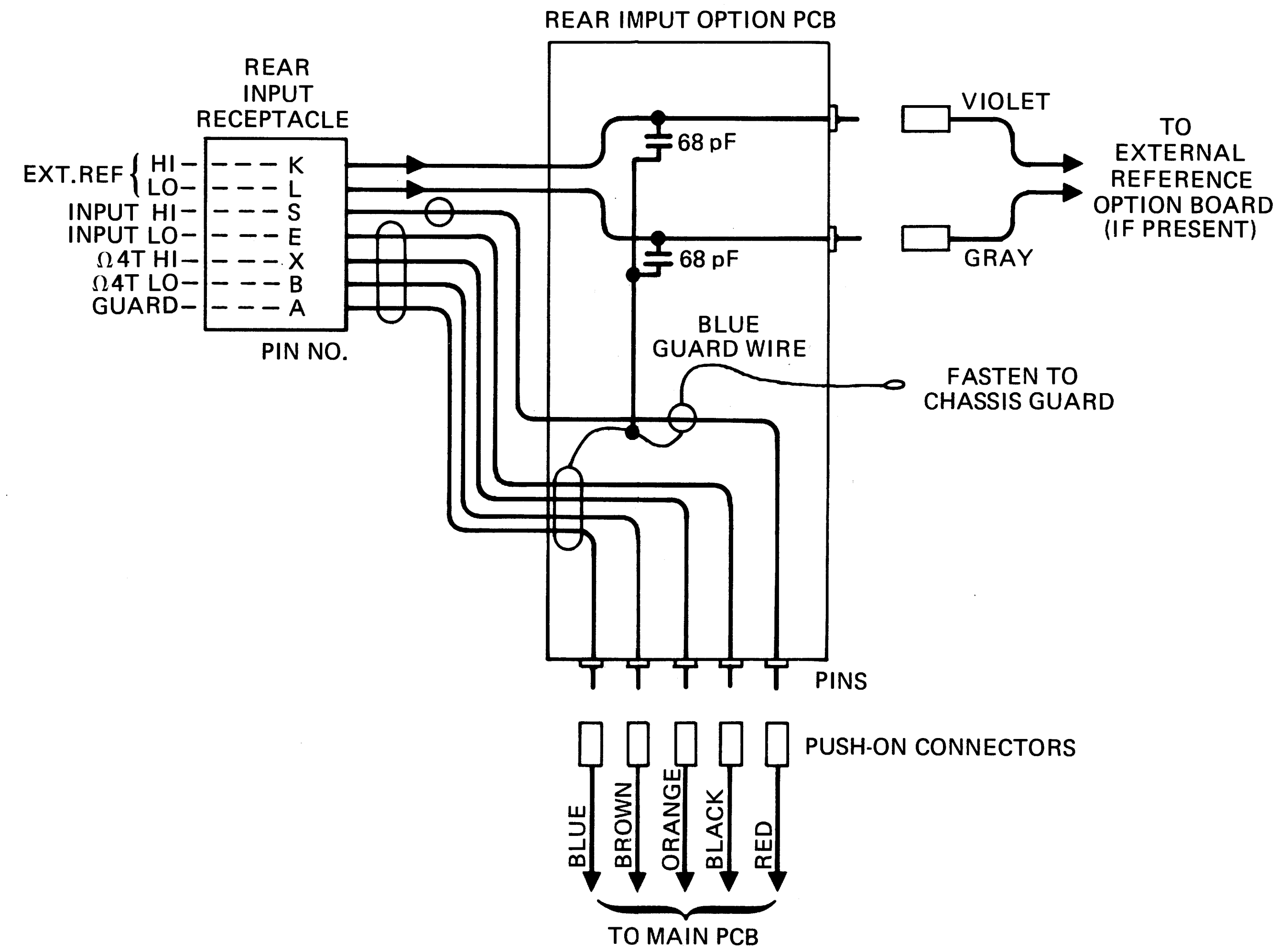
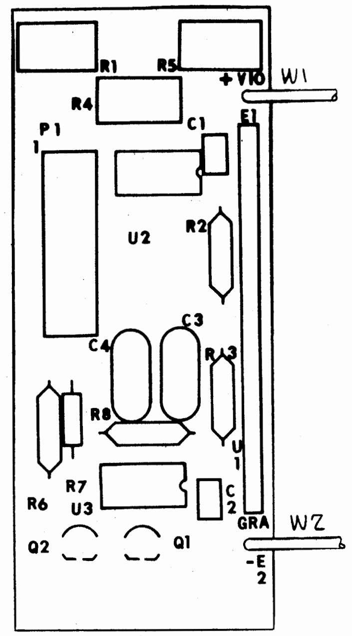
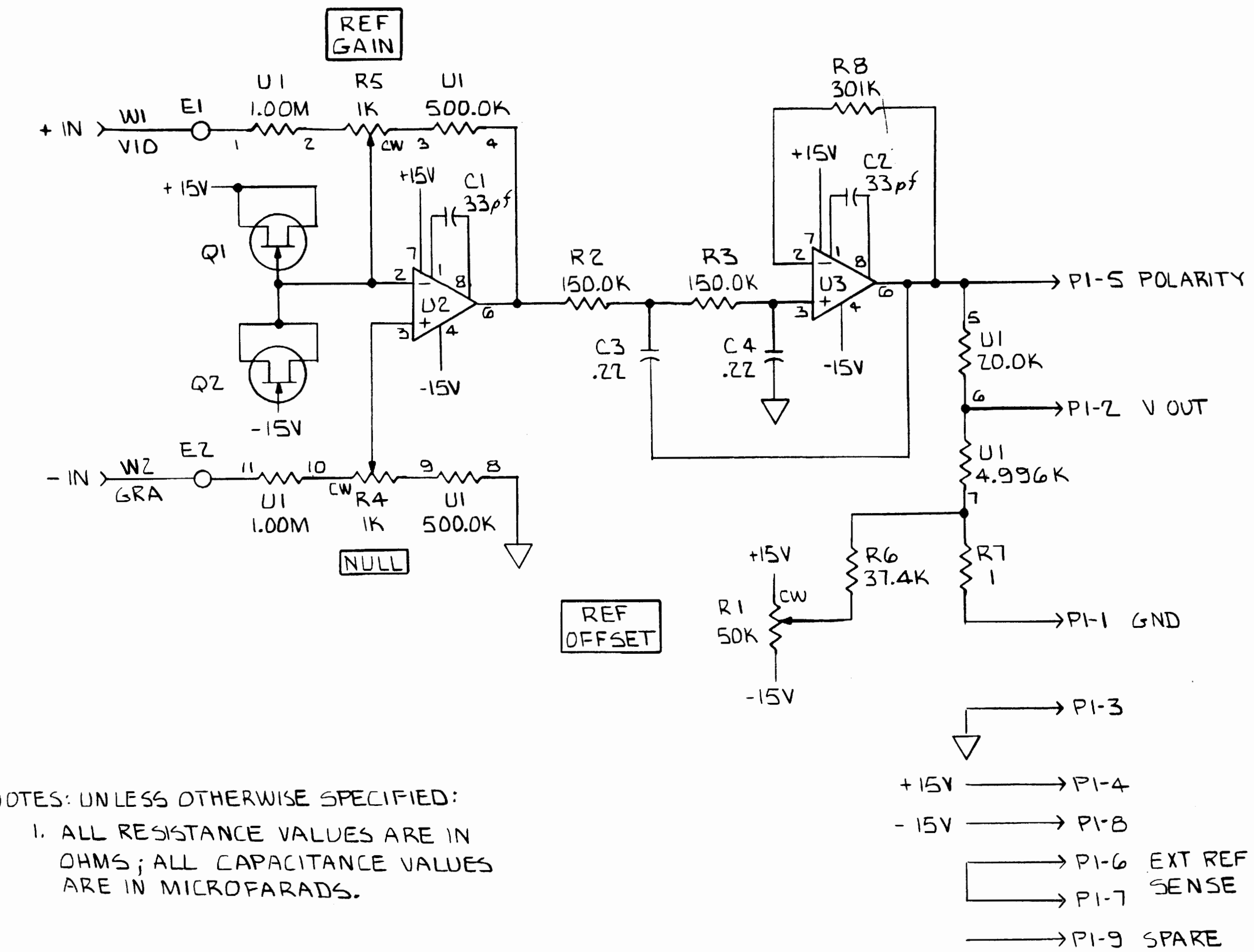


Figure 8-14. Rear Input PCB Assembly, Option -006



8860A-1616



NOTES: UNLESS OTHERWISE SPECIFIED:

1. ALL RESISTANCE VALUES ARE IN OHMS; ALL CAPACITANCE VALUES ARE IN MICROFARADS.

LAST NO. USED		
C4 P1	Q2	U3
E2	R8	W2

8860A-1016

Figure 8-15. External Reference PCB Assembly, Option -007