2190A
Digital Thermometer

Instruction Manual

P/N 489229
June 1978
Rev. 1 6/79

FLUKE®

WARRANTY

Notwithstanding any provision of any agreement the following warranty is exclusive:

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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If any failure occurs, the following steps should be taken:

1. Notify the JOHN FLUKE MFG. CO., INC., or nearest Service facility, giving full details of the difficulty, and include the model number, type number, and serial number. On receipt of this information, service data, or shipping instructions will be forwarded to you.

2. On receipt of the shipping instructions, forward the instrument, transportation prepaid. Repairs will be made at the Service Facility and the instrument returned, transportation prepaid.

SHIPPING TO MANUFACTURER FOR REPAIR OR ADJUSTMENT

All shipments of JOHN FLUKE MFG. CO., INC., instruments should be made via United Parcel Service or "Best Way"* prepaid. The instrument should be shipped in the original packing carton; or if it is not available, use any suitable container that is rigid and of adequate size. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material.

CLAIM FOR DAMAGE IN SHIPMENT TO ORIGINAL PURCHASER

The instrument should be thoroughly inspected immediately upon original delivery to purchaser. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument is damaged in any way, a claim should be filed with the carrier immediately. (To obtain a quotation to repair shipment damage, contact the nearest Fluke Technical Center.) Final claim and negotiations with the carrier must be completed by the customer.

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.

*For European customers, Air Freight prepaid.

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

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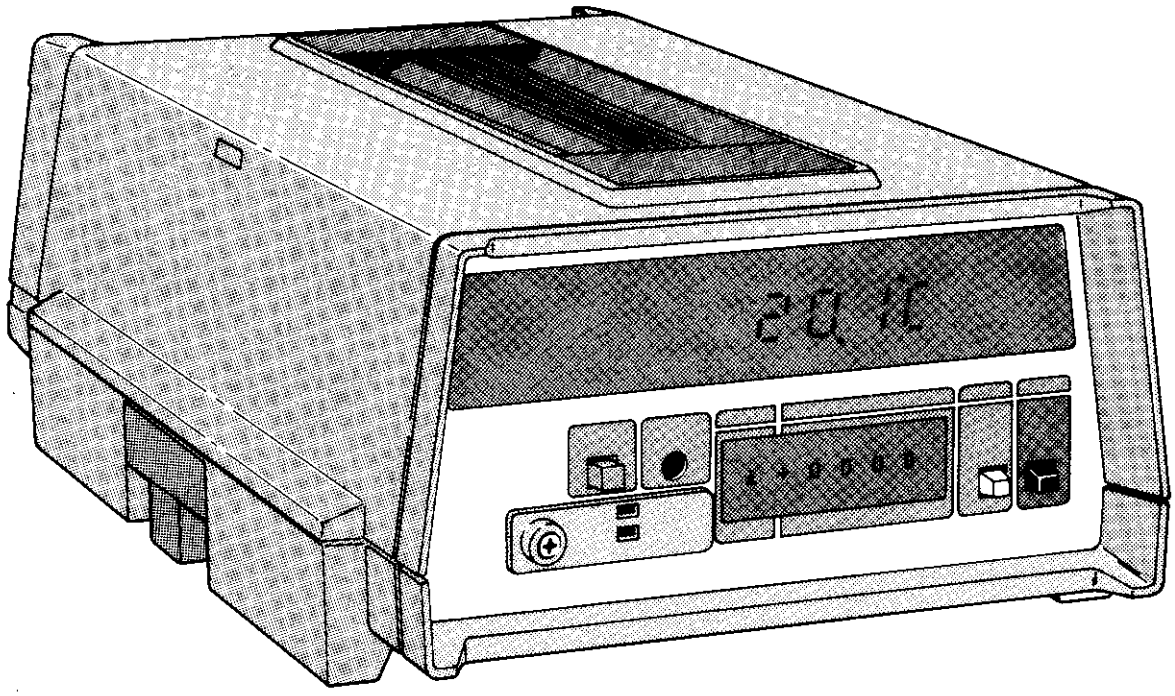


2190A Digital Thermometer

Section 1
Introduction & Specifications

1-1. INTRODUCTION

1-2. The Model 2190A Digital Thermometer is a portable, stackable, five digit, thermocouple thermometer capable of temperature measurements over a range of -252°C to +2471°C (-486°F to +4480°F) with a resolution of 0.1°. The instrument features automatic reference-junction compensation, eliminating the requirement for an ice bath reference-junction; front panel switch selection of Fahrenheit or Celsius readings; switch selectable thermocouple inputs; switch selectable input line voltage; dual-slope measurement techniques; and digital linearization (microcomputer controlled) of the thermocouple inputs.

1-3. The instrument display has six high-intensity, seven segment LEDs, and leading zero suppression. Five of the LEDs are used to display numeric data, including a minus sign for negative temperature readings. The remaining LED displays the selected temperature scale character (°F or °C). The symbol "O.C." is displayed when an open-thermocouple is detected at the thermocouple input terminals.

1-4. Screw-type input connectors, on a removable module, are provided for attaching the selected thermocouple. The terminals are an integral part of an isothermal block which serves as a portion of the reference-junction compensation circuit. This circuit removes the need for an ice bath reference junction (0°C or 32°F) since it provides the electrical equivalent automatically.

1-5. Selection of the temperature scale for display is made with a front panel pushbutton. The scale selected, Celsius or Fahrenheit, is displayed as either the character °C or °F as the last character in the temperature reading. A scale change can be made at any time, and has no effect on the calibration of the instrument.

1-6. The measurement range of the 2190A is determined by the type of thermocouple used as the input device. The type of microcomputer installed in your instrument will determine the type of thermocouples that may be used. The specifications table identifies the type of thermocouples that are presently available for use in the 2190A, and Section 2 gives the procedure for identifying the microcomputer type. The version required must be specified when ordering the instrument. Choice of the thermocouple type is accomplished by selecting the applicable switch position on the removable input module using the table printed beside the switch on the pcb. Recalibration is not required if the thermocouple type is changed.

NOTE

The letter C is not an ISA/ANSI thermocouple desgnation. C is used for convenience only to represent Tungsten-5% Rhenium versus Tungsten-26% Rhenium alloy.

1-7. The instrument is in a PTI (Portable Test Instrument) case. This lightweight, durable plastic case makes the instrument truly portable when used with the Y2003 or Y2009 external power sources and can be stacked for one handle portability.

1-8. Options and accessories available for the 2190A are listed in Tables 1-1 and 1-2 respectively. Detailed information concerning each item listed is given in Section 6 of this manual, Option and Accessory Information.

Table 1-1. 2190A Options

OPTION	DESCRIPTION
21X0-002	Output Option
21X0-006	Limits Option

1-9. Four input line voltages are available for switch selection. Selection may be made for 100, 120, 220 or 240 volts ±10%, as required to meet local conditions. Frequency may vary between 50 to 440 Hertz for all voltage selections. Refer to Section 4 of this manual on how to change the selected input line voltage. The instrument will also operate with an external input of 12V dc.

1-10. SPECIFICATIONS

1-11. Specifications for the 2190A Digital Thermometer are given in Table 1-3.

Table 1-2. 2190A Accessories

ACCESSORIES	DESCRIPTION	ACCESSORIES	DESCRIPTION
Y2001	Multipoint Selector, Thermocouple	Y2019	Panel Mount PTI-DIN, B size (for Y2003 and Y2009)
Y2002	Alarms Output	Y2020	Panel Mount PTI-DIN, C size (for 2190A, Y2002 and Y2023)
Y2003	Calibrator, Thermocouple Indicator	Y2022	Divider, Thermometer Calibrator
Y2009	Battery Pack, 12V Rechargeable	Y2023	Accessory Case
Y2010	Rack Panel PTI, single, A size (for Y2001)	Y2024	Power Cord, 3-way
Y2011	Rack Panel PTI, double, A size (for Y2001)	P20J	J-Type Thermocouple Probe
Y2012	Rack Panel PTI, single, B size (for Y2003 and Y2009)	P20K	K-Type Thermocouple Probe
Y2013	Rack Panel PTI, double, B size (for Y2003 and Y2009)	P20T	T-Type Thermocouple Probe
Y2014	Rack Panel PTI, single, C size (for 2190A, Y2002 and Y2023)	P20E	E-Type Thermocouple Probe
Y2015	Rack Panel PTI, double, C size (for 2190A, Y2002 and Y2023)	Y2026	Cable, Output Unit, RS-232-C
Y2018	Panel Mount PTI-DIN, A size (for Y2001)	Y2027	Rack Panel PTI, double, (combination A and C size)
		Y2030	Thermocouple Input Module

Table 1-3. Specifications

2190A Digital Thermometer

Thermocouple Types: Determined by type of microcomputer.

MICROCOMPUTER TYPE	THERMOCOUPLE TYPE
1	J, K, T, C, and R
2	J, K, E, S, and R
3	JDIN*, K, TDIN*, B and R

*European standard

Display: °F or °C, switch-selectable, 7-segment LED's 1.1 cm high.
Resolution: 0.1°.
Measurement Method: Dual slope integration, under microcomputer control. 100 ms integration period, three readings per second.
Linearization Technique: Computer algorithm, 4th order curve fit.
Warm-Up to Rated Accuracy: 5 minutes.
Reference Junction Compensation: 0.005° per degree from 25°C.
Temperature Coefficient: ±15 ppm/°C from 25°C.
Stability: ±175 ppm in 90 days, 200 ppm per year.
Common Mode Rejection: ≥160 dB at dc, 50, 60, and 400 Hz ±0.1%, with 100Ω unbalance at input.
Common Mode Voltage: 350V dc or 250V ac rms max.
Normal Mode Rejection: ≥90 dB at dc, 50, 60, and 400 Hz ±0.1%.
Zero Drift: Automatic zero correction.
Input Connection: Two wires, on screw terminal isothermal block.
Input Impedance: 1000 MΩ at dc.
Max. Source Impedance: 2 kΩ.
Power: 12V dc or 100,120, 220 or 240V ac ±10%, selectable, 50 to 400 Hz; 8W typical.
Size and Weight: Style C case, 2.1 kg (4 lbs. 9 oz.), typical.
Overrange (Overload) Detection: The thermometer display flashes either positive full scale or negative full scale depending on the polarity of the overload (voltage).
Open Circuit Detection: A source impedance of 3 kΩ or more causes the thermometer to display a flashing "O.C.". An internal switch allows a user to simulate a + overload or overload which can be used to control limits or alarms for failsafe control.

Table 1-3. Specifications (cont)

2190A Total Instrument Accuracy Specifications

MICROCOMPUTER TYPE #1

Thermocouples		Maximum Error					
		±Degrees C			±Degrees F		
Type	Applicable Portion of Temp. Range, °C	At Cal.	90 Dys 20°C to 30°C	1 Yr 15°C to 35°C	At Cal.	90 Dys 68°F to 86°F	1 Yr 59°F to 95°F
J	-128 to 0	0.18	0.19	0.21	0.20	0.23	0.26
	0 to 900	0.18	0.31	0.36	0.20	0.47	0.58
K	-132 to 0	0.18	0.19	0.21	0.30	0.33	0.37
	0 to 1350	0.18	0.39	0.47	0.30	0.72	0.87
T	-243 to 0	0.18	0.20	0.22	0.30	0.35	0.39
	0 to 400	0.18	0.22	0.25	0.30	0.41	0.46
R	0 to 1708	0.31	0.59	0.70	0.47	1.01	1.20
C	0 to 2471	0.18	0.60	0.75	0.30	1.11	1.37

MICROCOMPUTER TYPE #2

Thermocouples		Maximum Error					
		±Degrees C			±Degrees F		
Type	Applicable Portion of Temp. Range, °C	At Cal.	90 Dys 20°C to 30°C	1 Yr 15°C to 35°C	At Cal.	90 Dys 68°F to 86°F	1 Yr 59°F to 95°F
J	-128 to 0	0.18	0.19	0.21	0.20	0.23	0.26
	0 to 900	0.18	0.31	0.36	0.20	0.47	0.58
K	-132 to 0	0.18	0.19	0.21	0.30	0.33	0.37
	0 to 1350	0.18	0.39	0.47	0.30	0.72	0.87
E	-252 to 0	0.18	0.20	0.22	0.30	0.35	0.40
	0 to 1000	0.18	0.33	0.39	0.30	0.61	0.72
R	0 to 1708	0.31	0.59	0.70	0.47	1.01	1.20
S	0 to 1685	0.22	0.50	0.60	0.38	0.92	1.10

MICROCOMPUTER TYPE #3

Thermocouples		Maximum Error					
		±Degrees C			±Degrees F		
Type	Applicable Portion of Temp. Range, °C	At Cal.	90 Dys 20°C to 30°C	1 Yr 15°C to 35°C	At Cal.	90 Dys 68°F to 86°F	1 Yr 59°F to 95°F
J DIN*	-100 to 0	0.18	0.19	0.20	0.30	0.32	0.36
	0 to 760	0.18	0.28	0.33	0.30	0.52	0.61
K	-50 to 0	0.18	0.18	0.20	0.20	0.22	0.25
	0 to 1372	0.18	0.39	0.48	0.20	0.63	0.78
T DIN*	-200 to 0	0.18	0.20	0.21	0.30	0.34	0.38
	0 to 400	0.18	0.22	0.25	0.30	0.41	0.46
B	420 to 1815	0.21	0.52	0.62	0.37	0.95	1.15
R	140 to 1700	0.18	0.46	0.56	0.20	0.74	0.93

*European Standard

Table 1-3. Specifications (cont)

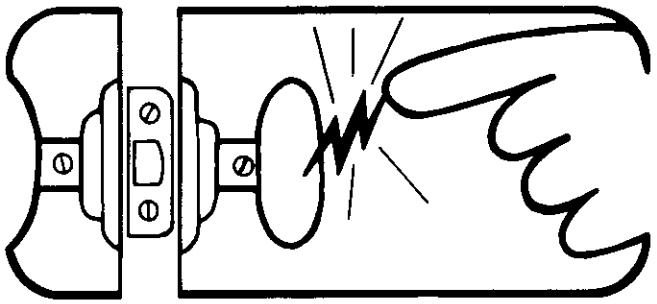
PTI Common Specifications (2190A and Accessories)
Storage Temperature: −40°C to +75°C, except Y2003 or Y2009 is 0 to 40°C.
Operating Temperature: 0 to 50°C, except Y2003 and Y2009 is 0 to 40°C.
Relative Humidity: ≤80%, non-condensing, from 0 to 50°C.
Shock and Vibration: Meets MIL-T-2800 specifications.

PTI Case Dimensions
Style A: 5.72 cm H x 20.45 cm W x 32.64 cm D (2.25 in. H x 8.05 in.W x 12.85 in. D).
Style B: 8.20 cm H x 20.45 cm W x 32.64 cm D (3.23 in. H x 8.05 in. W x 12.85 in. D).
Style C: 10.49 cm H x 20.45 cm W x 32.64 cm D (4.13 in H x 8.05 in. W x 12.85 in. D).

static awareness

A Message From

John Fluke Mfg. Co., Inc.

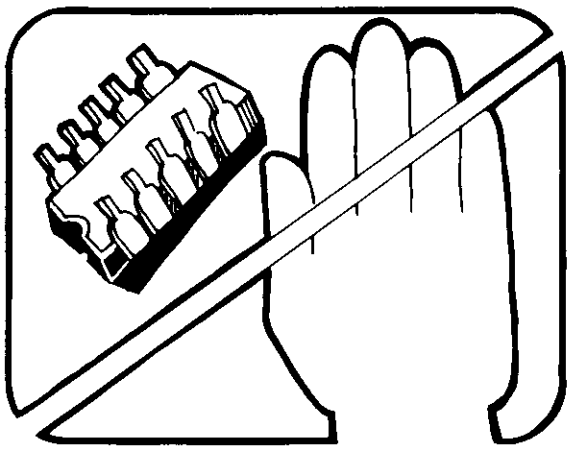


Some semiconductors and custom IC's can be damaged by electrostatic discharge during handling. This notice explains how you can minimize the chances of destroying such devices by:

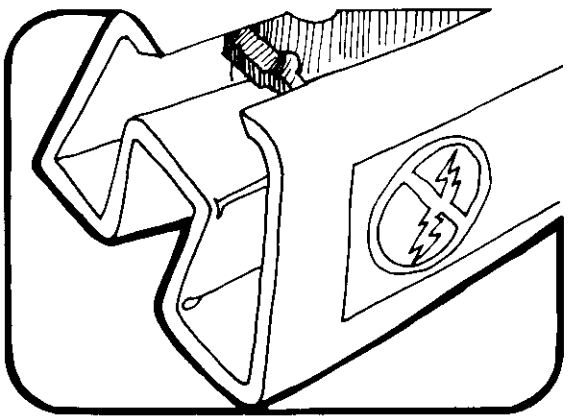
1. Knowing that there is a problem.
2. Learning the guidelines for handling them.
3. Using the procedures, and packaging and bench techniques that are recommended.

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

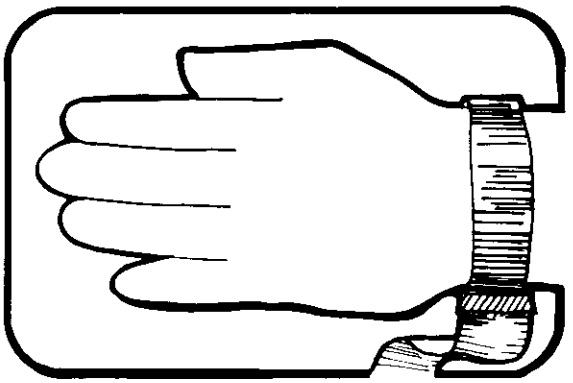
The following practices should be followed to minimize damage to S.S. devices.



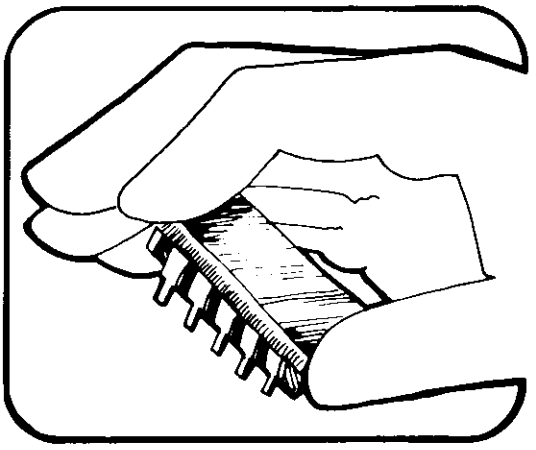
1. MINIMIZE HANDLING



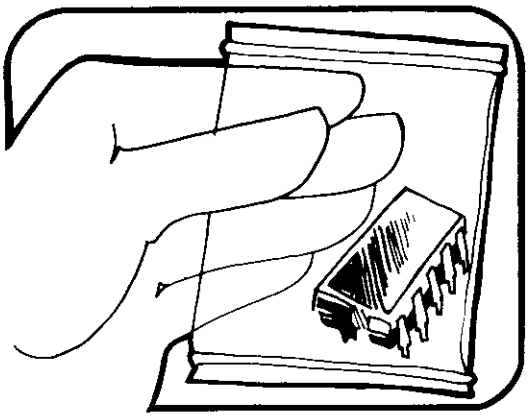
2. KEEP PARTS IN ORIGINAL CONTAINERS UNTIL READY FOR USE.



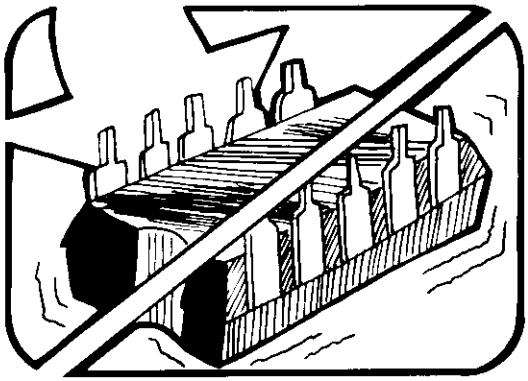
3. DISCHARGE PERSONAL STATIC BEFORE HANDLING DEVICES



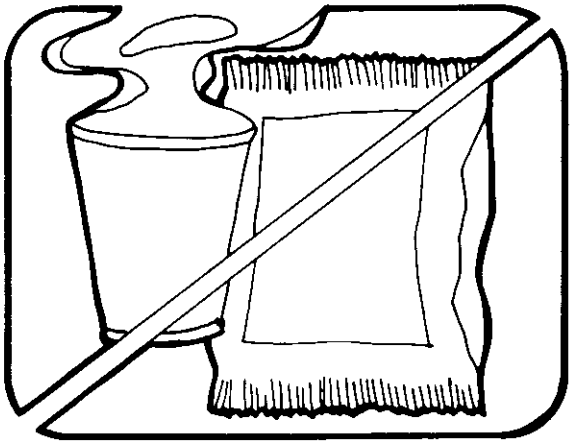
4. HANDLE S.S. DEVICES BY THE BODY



5. USE ANTI-STATIC CONTAINERS FOR HANDLING AND TRANSPORT



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



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

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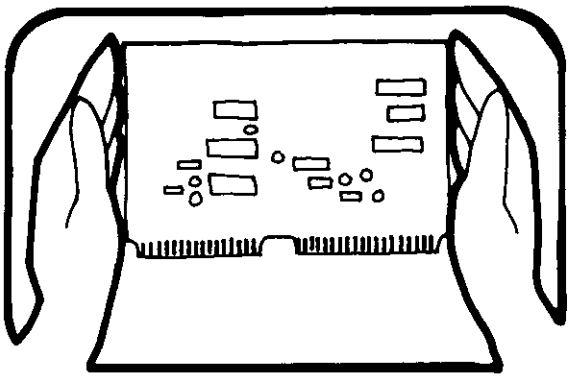
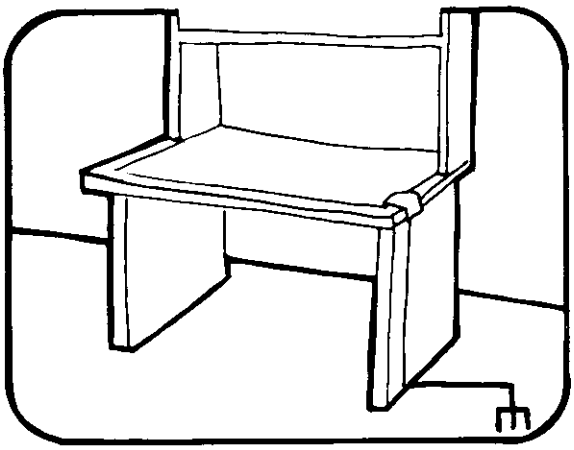


8. WHEN REMOVING PLUG-IN ASSEMBLIES, HANDLE ONLY BY NON-CONDUCTIVE EDGES AND NEVER TOUCH OPEN EDGE CONNECTOR EXCEPT AT STATIC-FREE WORK STATION. PLACING SHORTING STRIPS ON EDGE CONNECTOR USUALLY PROVIDES COMPLETE PROTECTION TO INSTALLED SS DEVICES.



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

Anti-static bags, for storing S.S. devices or pcbs with these devices on them, can be ordered from the John Fluke Mfg. Co., Inc.. See section 5 in any Fluke technical manual for ordering instructions. Use the following part numbers when ordering these special bags.

John Fluke Part No.	Description
453522	6" X 8" Bag
453530	8" X 12" Bag
453548	16" X 24" Bag
454025	12" X 15" Bag
Pink Poly Sheet	Wrist Strap
30"x60"x60 Mil	P/N TL6-60
P/N RC-AS-1200	$7.00
$20.00	

® Dow Chemical

J0089B-07U7810/SE EN Litho in U.S.A.

Section 2
Operating Instructions

2-1. INTRODUCTION

2-2. This section of the manual contains information regarding installation and operation of the 2190A Digital Thermometer. It is recommended that the contents of this section be read and understood before any attempt is made to operate the instrument. Should any difficulties arise during operation, please contact your nearest Fluke Technical Service Center, or the John Fluke Mfg. Co., Inc.; P.O. Box 43210; Mountlake Terrace, WA 98043; Tel (206) 774-2211. A list of Technical Service Centers is located in Section 7 of the manual.

2-3. SHIPPING INFORMATION

2-4. The 2190A is packaged and shipped in a foam-packed container. Upon receipt of the instrument, a thorough inspection should be made to reveal any possible shipping damage. Special instructions for inspection and claims are included on the shipping carton.

2-5. If reshipment of the instrument is necessary, the original container should be used. If the original container is not available, a new one can be obtained from the John Fluke Mfg. Co., Inc. Please reference the instrument model number when requesting a new shipping container.

2-6. INPUT POWER

2-7. The 2190A will operate at any of four switch selected input line voltages. All operate at frequencies from 50 to 440 Hertz. A decal on the instrument rear panel defines the original setting of the line voltage selection switches. Refer to Section 4 of this manual for instruction on verifying or changing the input line voltage switch settings.

CAUTION

Before connecting the 2190A to the local ac line verify that the present setting of the instrument matches the local line voltage.

2-8. The rear panel ac input connector is a three-prong, U-ground connector which permits the instrument to be connected, via the power cord, to the applicable line voltage. The offset prong on this connector is connected to the 2190A transformer shield and should be connected through the power cord to a high quality earth ground. The rear panel external 12V dc connector accepts two wires from an external supply. The two receptacles are marked for polarity.

2-9. INSTALLATION

2-10. The 2190A and its individually packaged accessories are installed in PTI (Portable Test Instrument) cases. These cases are stackable, allowing the operator to fasten them together and transport a series of instruments as one unit. The maximum weight for the stacked units is forty pounds.

2-11. Prepare the 2190A for operation by plugging the input line power cord into the applicable power source or connecting the external input connector to an external 12V dc source.

2-12. OPERATING FEATURES

2-13. The location of the 2190A controls, indicators, and connectors are shown and described in Figure 2-1 and Table 2-1 respectively.

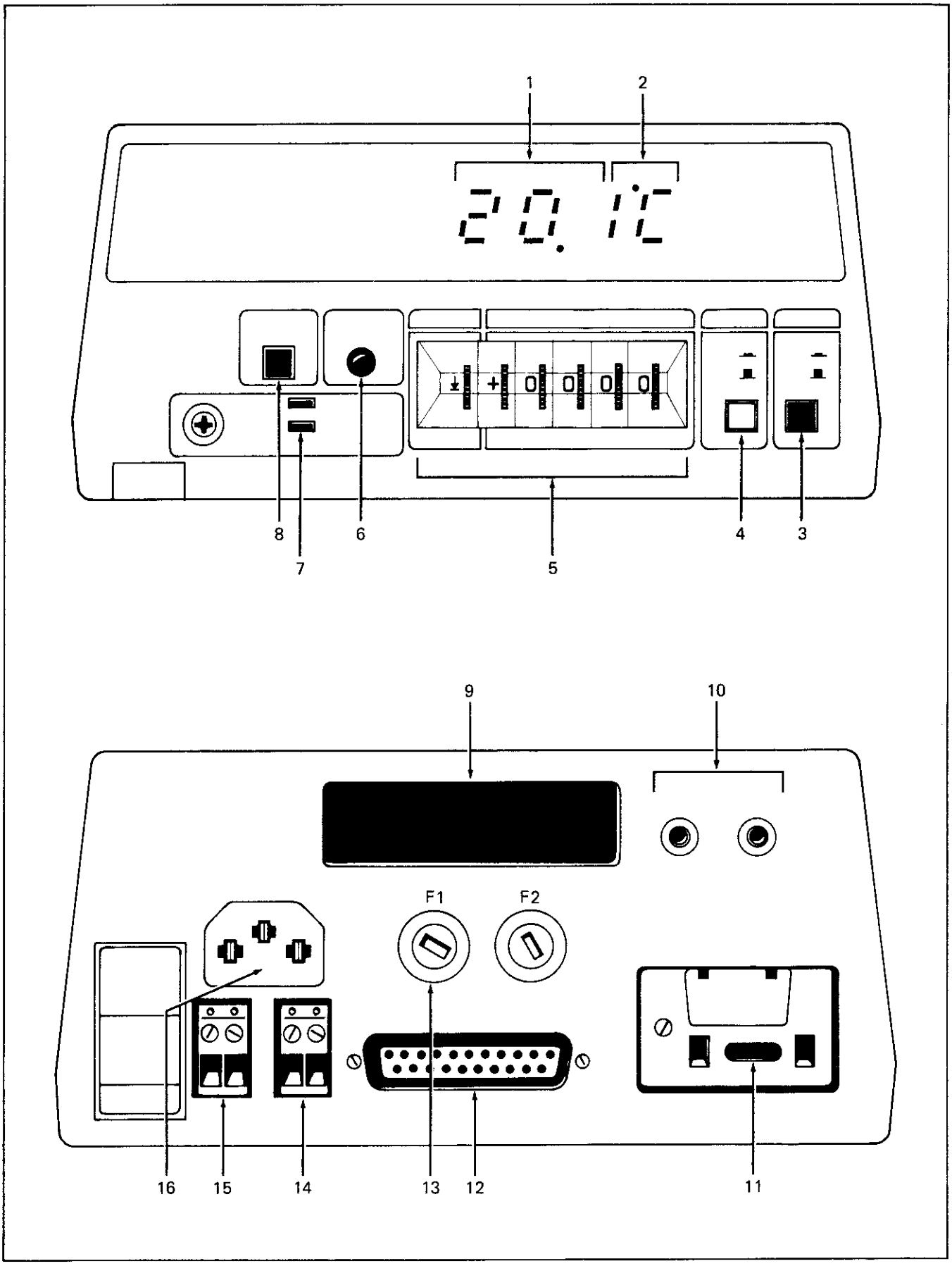


Figure 2-1. Controls and Indicators

Table 2-1. 2190A Controls, Indicators and Connectors

REF	NAME	FUNCTION
1	Digital Display	Displays a five digit readout of the measured input temperature. Leading zero suppression and a fixed decimal point are included. A minus sign is displayed for negative temperature measurements.
2	Temperature Scale Indicator	Displays the temperature scale represented by the digital display data; °C or °F.
3	Power Switch	Applies or removes power from the instrument.
4	SCALE	Selects the temperature scale for display; °C or °F.
5	LIMIT and FUNCTION	Used with the −006 Limit Option, if installed. Limit is a numeric set with thumbwheels to the value used by the selected function. FUNCTION, in combination with the LIMIT numeric sets an upper (>) or lower (≤) limit value which, if exceeded, will illuminate an indicator and close relay contacts accessible on the rear panel. The third function (△) causes the thermometer to display the difference between the actual reading and the value set on the LIMIT switches. The last two functions examine, and display, the maximum (↑) or minimum (↓) reading recorded in microcomputer since the last reset by the INITIALIZE MAX/MIN pushbutton switch.
6	LIMIT EXCEEDED	Part of the −006 Limits Option. Indicator illuminates when the preset limits have been exceeded.
7	CALIBRATION	Cover for calibration adjustments used in the calibration procedure.
8	INITIALIZE MAX/MIN	Part of the −006 Limits Option. Resets the accumulated maximum and minimum readings stored by the microcomputer.
9	DIGITAL OUTPUT	If Option −002 is installed, connector for the ASCII coded data for the output unit.
10	ANALOG OUTPUT	If Option −002 is installed, banana jack connector for an analog output of 1 mV per degree.
11	INPUT CONNECTOR	Connection and access point for Thermocouple Input Module with isothermal block for thermocouple connection and selection.
12	ACCESSORY CONNECTOR	Cable connector for electrical connection from accessory units.
13	FUSES	Fuses for the input line power (F1) and the external 12V dc input (F2).
14	LIMITS	If the Limits feature is installed, provides an output terminal for a relay contact closure to signal when the set limits have been exceeded.
15	±12 VDC	Input terminals for the external 12V dc power source.
16	LINE VOLTAGE CONNECTOR	Input connector for the input line voltage.

2-14. OPERATING NOTES

2-15. The following paragraphs describe various conditions that could effect operation of the thermometer. The operator should familiarize himself with these conditions prior to operating the 2190A.

2-16. Option Information

2-17. Supplementary operating instructions are necessary when operating a 2190A equipped with one of the available options. Detailed information regarding the operation of each available option is given in Section 6 of this manual, Option and Accessory Information.

2-18. Fuse Replacement

2-19. The ac line input and external dc input are individually fuse protected. Both fuses are readily accessible on the outside of the rear panel. The ac line input fuse (F1) should be replaced with a 1/8A slo-blo fuse if either 100 or 120 volts has been selected as the input line voltage. Use a 1/16A replacement if 220 or 240 volts have been selected. The external dc input (F2) requires a 3/4A slo-blo fuse for a replacement.

2-20. Overload Thermocouple Indication

2-21. The front panel display, in addition to providing a measurement reading, provides an indication of an overload on the input thermocouple. When the measurement range of the selected thermocouple is exceeded the display flashes either the full-scale positive or full-scale negative reading, dependent on the polarity of the overload. The blinking indication does not necessarily indicate that the instrument is exposed to a damaging input condition.

2-22. Open Thermocouple Indication

2-23. If the thermocouple is open, or not connected to the input terminals, the display flashes the characters "O.C.". A signal from the rear panel relay contacts can also be obtained if the Limits Option (-006) is installed. To accomplish this, select either the positive (+OL) or negative (OL) position on S4, located on the Main PCB (refer to Section 4 for access to the Main PCB), depending upon whether the Limits Option is set to greater than (>), or less than or equal (≤). If the limits are set for >, the S4 switch should be set to +OL for an open thermocouple to close the relay contacts for a signal. Conversely, for a signal with a ≤ limit, OL should be selected.

2-24. Microcomputer Identification

2-25. The type of microcomputer installed in your instrument will determine the types of thermocouples that may be used. To determine the type of microcomputer you are using, connect the 2190A to line power and turn it on. For approximately the first ten seconds, the 2190A will display its model number, a decimal point, and the type of microcomputer in use. Example: "2190.1" indicates type 1 microcomputer in use. Table 2-2 lists the microcomputer types with the thermocouples that they are programmed for.

2-26. OPERATION

2-27. Thermocouple Installation

2-28. Select the desired thermocouple range using the following procedure:

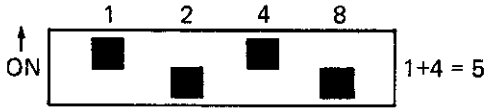
1. Remove the Thermocouple Input Module from the instrument through the access port on the rear panel, refer to Figure 2-2.

2. Connect the selected thermocouple to the input terminals on the isothermal block.

Table 2-2. Thermocouple Input Module Switch Settings.

DISPLAY READING AT TURN ON		TYPE SELECT SWITCH SETTING (S1)									
MODEL NO.	MICROCOMPUTER TYPE	0	1	2	3	4	5	6	7	8*	9*
2190.	1	J	K	T		C		R		CAL	CAL
2190.	2	J	K		E		S	R		CAL	CAL
2190.	3	J**	K	T**		B		R		CAL	CAL

Example: To select a switch setting of 5, position the thermocouple type select switches as shown:



* In these positions the display will have a maximum range of 99 999 μV with 1 μV resolution.

** DIN standard

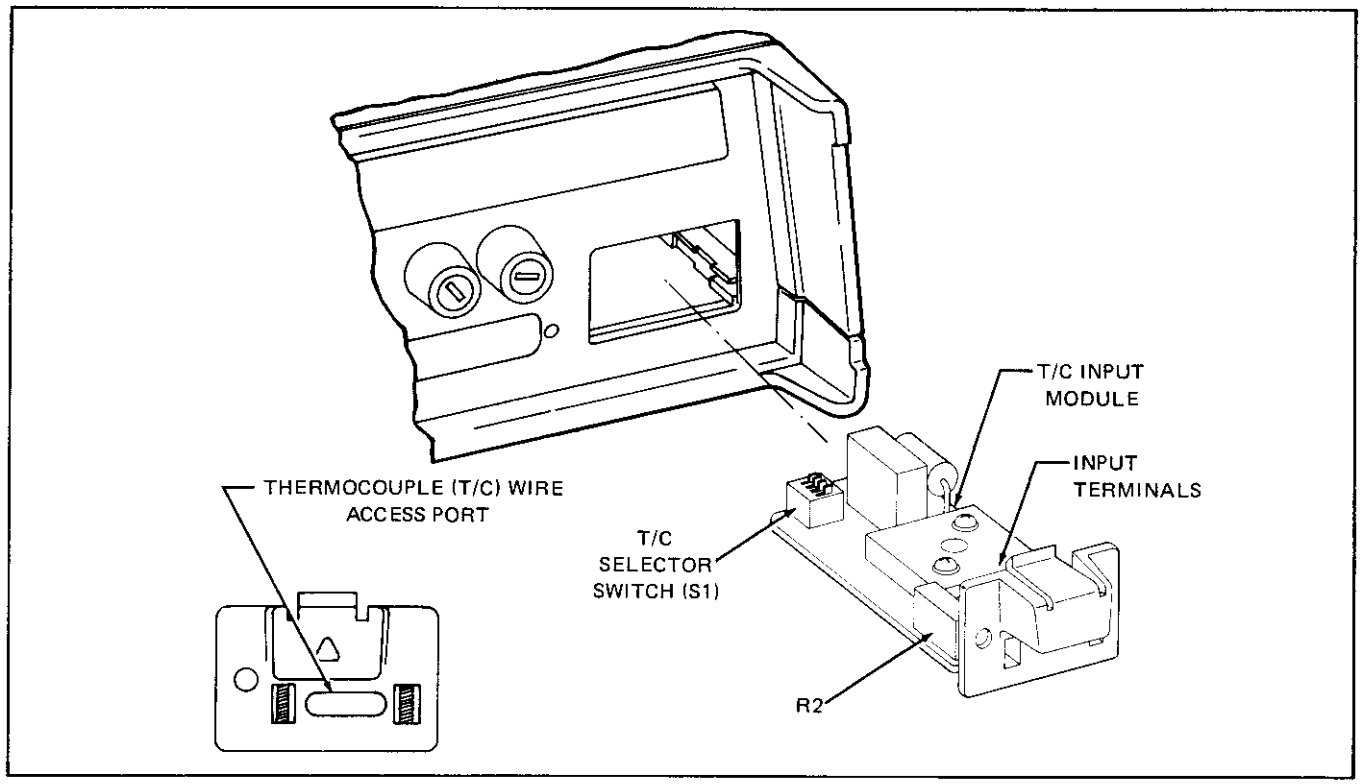


Figure 2-2. Thermocouple PCB Access

3. Set the thermocouple selector switch to the setting shown in Table 2-2 and on the pcb beside the isothermal block, for the thermocouple installed.

4. Connect the Thermocouple Input Module to the instrument Main PCB through the access port on the rear panel.

2-29. Thermometer Operation

2-30. Operate the 2190A Digital Thermometer using the following procedure:

1. Verify that the instrument has the correct thermocouple connected, or install the desired thermocouple using the procedure previously given in this section.

2. Connect the input line cord to the applicable power source.

3. Select the temperature scale desired for display with the front panel SCALE switch (in for °C and out for °F).

NOTE

If Option -006 is installed the FUNCTION thumbwheels must be set for Limits (> or ≤) for a direct temperature reading.

4. Select POWER ON.

NOTE

Refer to Section 6 of this manual or applicable accessory manuals, for instructions on the operation of any installed options or connected accessories.

5. Expose the thermocouple probe to an unknown temperature or the temperature to be monitored, within the thermocouple's specified range (see Specifications in Section 1).

6. The probe temperature, in the scale selected, is displayed on the front panel.

2-31. Voltage Measurements

2-32. The 2190A may be used to measure positive or negative voltages up to 99.999 mV with 1 μV resolution. When using the 2190A to measure voltages, the temperature units (°C, °F) are to be ignored. Since the decimal point will be fixed, ignore it and read the display in μV. Example: 99 mV input = display of "9900.0" °F or °C. Use the following steps to measure voltages with your 2190A.

1. Remove the 2190A's Thermocouple Input Module, refer to Figure 2-2.

2. On the Thermocouple Input Module, set select switches to position #8 or #9 (refer to Table 2-2 for switch selection, and Table 2-3 for switch functions). Replace the Thermocouple Input Module.

NOTE

For the following steps the source resistance must be kept below 2 kΩ or a 0.1 μF capacitor must be placed across TC+, TC-.

3. Connect the unknown voltage to TC+ and TC-.

4. Turn the 2190A on, display will now read in μV units.

Table 2-3. T/C Input Module Switch Functions

SWITCH	SWITCH POSITION	SWITCH FUNCTIONS
S1	0 - 6	Programs the microcomputer (μc) for each T/C probe type (see Table 2-2).
	7	Not Used
	8, 9	"CAL", programs the μc to read μV (bypasses the linearization program).

Section 3
Theory of Operation

3-1. INTRODUCTION

3-2. This section of the manual contains an overall functional description, followed by a brief circuit analysis of the 2190A Digital Thermometer. Simplified circuit diagrams are provided, as necessary, to supplement the text. Detailed schematics are given in Section 8 of this manual.

3-3. OVERALL FUNCTIONAL DESCRIPTION

3-4. The Model 2190A Digital Thermometer, shown in Figure 3-1, is a 5-digit microcomputer controlled thermocouple thermometer capable of resolving 0.1°C or 0.1°F over temperature range of -252° to 2471°C or -486° to 4480°F. It features a reference-junction compensator (eliminating the need for an ice bath reference-junction), dual-slope A/D conversion technique, microcomputer control logic, and a 5-digit display with temperature scale indicator.

3-5. In operation, the 2190A executes a continuous series of measurement cycles to update the temperature display. The measurement cycle is controlled entirely by the microcomputer and includes three major subcycles; the Auto-Zero, Integrate, and Read periods. Each subcycle controls the operation of the analog section of a dual-slope integrator, which in turn, generates a compare output, which is used by the microcomputer to generate the proper control signals. (In addition to these major subcycles, a recovery signal is applied at the end of the read period to assist the Auto-Zero period.)

3-6. The configuration of the analog section during each phase of the measurement cycle, is established by the condition of microcomputer controlled FET switches. The measurement cycle begins with the Auto-Zero period. During this period, the input to the Buffer Amplifier is connected to ground through an FET switch and the accumulated dc offset voltages present in the analog section are sampled and held by the Auto-Zero capacitor. This voltage is used later in the measurement cycle to cancel measurement errors introduced by offset voltages present in the analog circuitry. As a result, the final measurement is proportional to the thermocouple probe output voltage and does not include offset errors.

3-7. During the Integrate period, the thermocouple input voltages (probe voltage and input terminal voltages) are applied to the integrator and the algebraic sum of these voltages is integrated over a 100 ms period. At the end of this period the thermocouple input voltages are removed from the integrator and the Read period is started.

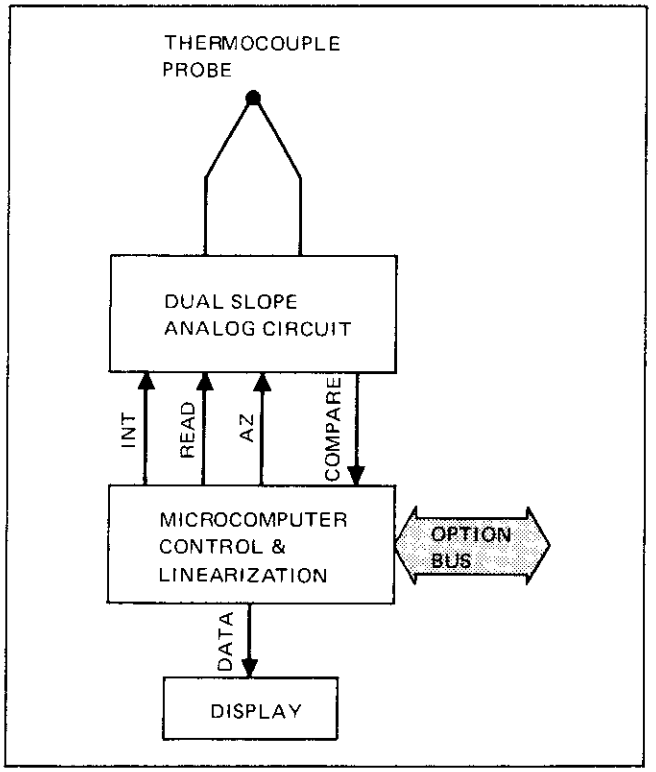


Figure 3-1. 2190A Simplified Block Diagram

3-8. A reference voltage is applied to the integrator during the Read period, causing the integrator capacitor to be discharged at a linear rate. When the integrator output reaches the voltage stored on the Auto-Zero capacitor a compare signal is generated to end the Read period. The duration of the Read period is translated by the microcomputer to provide a digital indication proportional to the thermocouple probe voltage.

3-9. To compensate for the error voltage present on the input terminals, the microcomputer configures the analog portion to do a complete conversion cycle on the reference-junction voltage every 11th read cycle. This voltage is generated by a transistor which is at the same temperature as the input terminals. The microcomputer uses the number generated during the Read period to compensate the input voltage and display the actual probe temperature.

3-10. CIRCUIT ANALYSIS

3-11. Circuit analysis of the 2190A is discussed in two sections; digital and analog. The digital section is covered first and particular attention is paid to the control it exercises on the analog section. The analysis of the analog section covers the analog measurement circuitry and the power supply.

3-12. Digital Section

3-13. The digital section of the 2190A consists of a single-chip microcomputer (U4), which has a self-contained, programmed, read only memory; a hex CMOS open drain buffer (U3) and an LED display. Its function is to convert the non-linear thermocouple probe voltage, as measured by the analog section, into a linear digital display, provide the necessary control signals to the analog section and to provide control for all accessories on an accessory bus. The 2190A LED display provides a direct reading of the probe temperature in °C or °F.

3-14. The microcomputer contains all 2190A program, control logic, and linearizing capability and provides the display with all signals necessary to update the display. The linearization of the non-linear input signal is accomplished by selecting one-of-several programs which compute the correct temperature using a 4th-order, curve-fit approximation of the probe output. The operating program is selected to match a particular thermocouple type and is enabled by the numeric setting corresponding to the thermocouple type in use. The rotary switch is located on the thermocouple input assembly next to a table showing the switch setting applicable to the thermocouple type in use.

3-15. Measurement data is continuously strobed out of the microcomputer in decoded-seven-segment, character-serial format and sent to the LED display. With an overload condition the display flashes on and off. An "O.C." display indicates an open thermocouple probe condition.

3-16. The basic measurement cycle shown in Figure 3-2, consists of three major subcycles; a 100 ms minimum Auto-Zero period, a 100 ms Integrate period, and a variable Read period. The total measurement cycle time consists of 300 ms; 100 ms to integrate, up to 100 ms to the Read period, and the remaining time to the Auto-Zero period. (Auto-Zero time will vary from 100 to 200 ms.) To accomodate settling times in the analog section a (Δ) 2, (1 ms nominal) hold signal is inserted at the beginning and at the end of the Integrate period.

3-17. Analog Section

3-18. ANALOG MEASUREMENT CIRCUIT

3-19. The analog circuit is shown in simplified form in Figure 3-3. It consists of a thermocouple input circuit, a reference-junction compensator, a voltage reference, a buffer amplifier, an integrator, a gain stage, a comparator, and a combination of FET switches. The switches are shown in their open state and are closed by the measurement cycle commands generated by the microcomputer.

3-20. The Thermocouple Input circuit consists of an R-C filter and a pair of voltage protection diodes. The difference between the thermocouple probe voltage and the input terminal voltage is passed through the filter and appears at FET switch Q15. The R-C filter increases the normal mode rejection capability of the 2190A.

3-21. The reference-junction compensator consists of an isothermal block, a pair of screw type input terminals and a transistor temperature sensor, (all on the Thermocouple Input Assembly). The isothermal block maintains a negligible temperature differential between the input terminals and the temperature sensing transistor. Thermocouple voltages introduced by the dissimilar metals at the input terminals vary as the isothermal block adjusts to ambient temperature. Temperature changes are sensed by the forward biased transistor to produce a correction voltage which is read by the analog measurement circuitry every eleven cycles. The reading is saved by the microcomputer and is used to compensate for the error voltages present at the input terminals. Predictable characteristics of a forward-biased P-N junction allow the reference-junction compensator to function over a wide temperature range. This correction voltage occurs at FET switch Q17.

3-22. The voltage reference consists of a thin-film resistor network supplied by an accurate 6.2V dc reference voltage. The divider is set to provide 100 mV and 200 mV. These voltages appear at FET switches Q12 and Q13, respectively.

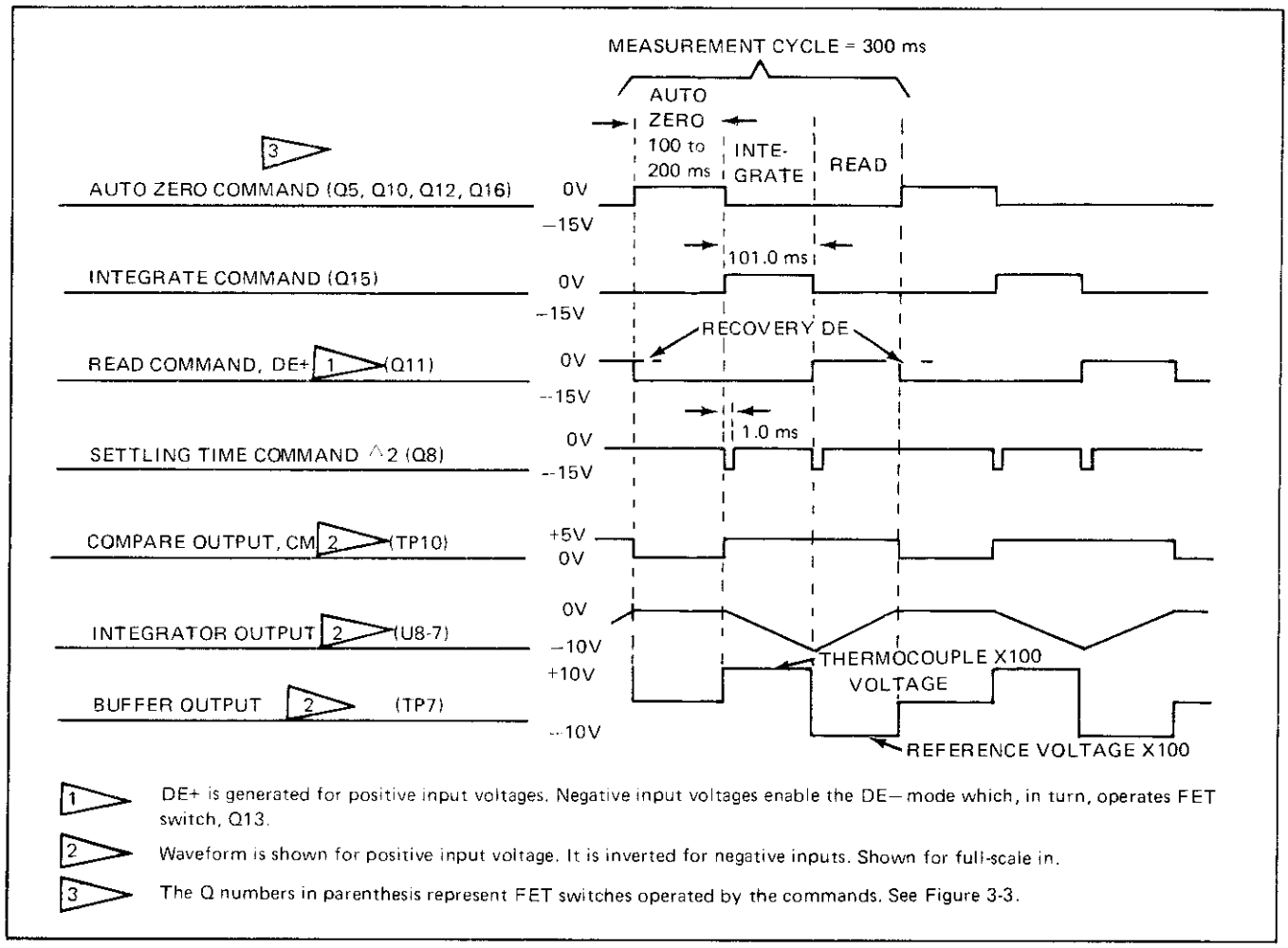


Figure 3-2. Measurement Cycle Waveforms

3-23. The Buffer, Integrator, Gain Stage, and Comparator Amplifiers combine to perform the analog functions of the Integrate, Read, and Auto-Zero periods. The Buffer is used to provide integrator inputs during all three periods. The Integrator integrates the Buffer output voltage during the Integrate and Read periods and, in combination with the Gain Stage, functions as a closed-loop amplifier during the Auto-Zero period.

3-24. During the first phase of each measurement cycle, the analog section goes through an Auto-Zero period. During this time, four auto-zero switches (Q12, Q16, Q6, and Q10) are closed by the Auto-Zero command from the microcomputer. Two of the switches (Q12 and Q16) charge the reference capacitor to 100 mV. Switch Q16 also zeroes the input to the buffer amplifier. The third switch, Q6 connects the Integrator and Gain Stage into a closed-loop configuration and allows the auto-zero capacitor (C10) to charge to a value which is proportional to the algebraic sum of all the offset voltages present in the Buffer, Integrator, and Gain Stage. At the end of the Auto-Zero period, switches Q12, Q16, Q6 and Q10 are opened. The VREF capacitor and the auto-zero capacitor retain their charge for use later in the measurement cycle.

3-25. The Integrate period (see Figure 3-2) starts on the leading edge of the integrate command from the microcomputer; switch Q15 is closed and switch Q8 is opened. The thermocouple input voltage is applied through switch Q15 to the buffer input. After a 1 ms settling period, switch Q8 closes and the buffer output is applied to the Integrator for 100 ms. As the integrator capacitor charges, the Integrator drives the comparator (through the Gain Stage) to either 0 or +5V dc to indicate the polarity of the thermocouple input voltage, negative or positive, respectively. At the end of the Integrate period, the integrate capacitor is charged to a level and polarity which are proportional to the thermocouple input voltage and switches Q15 and Q8 return to the open state.

3-26. The Read period starts at the end of the Integrate period and one-of-two Read modes is enabled depending upon the input polarity sensed by the comparator during the Integrate period. If a positive input is sensed, a positive Read mode is enabled. Similarly, a negative Read mode is enabled when a negative input is sensed.

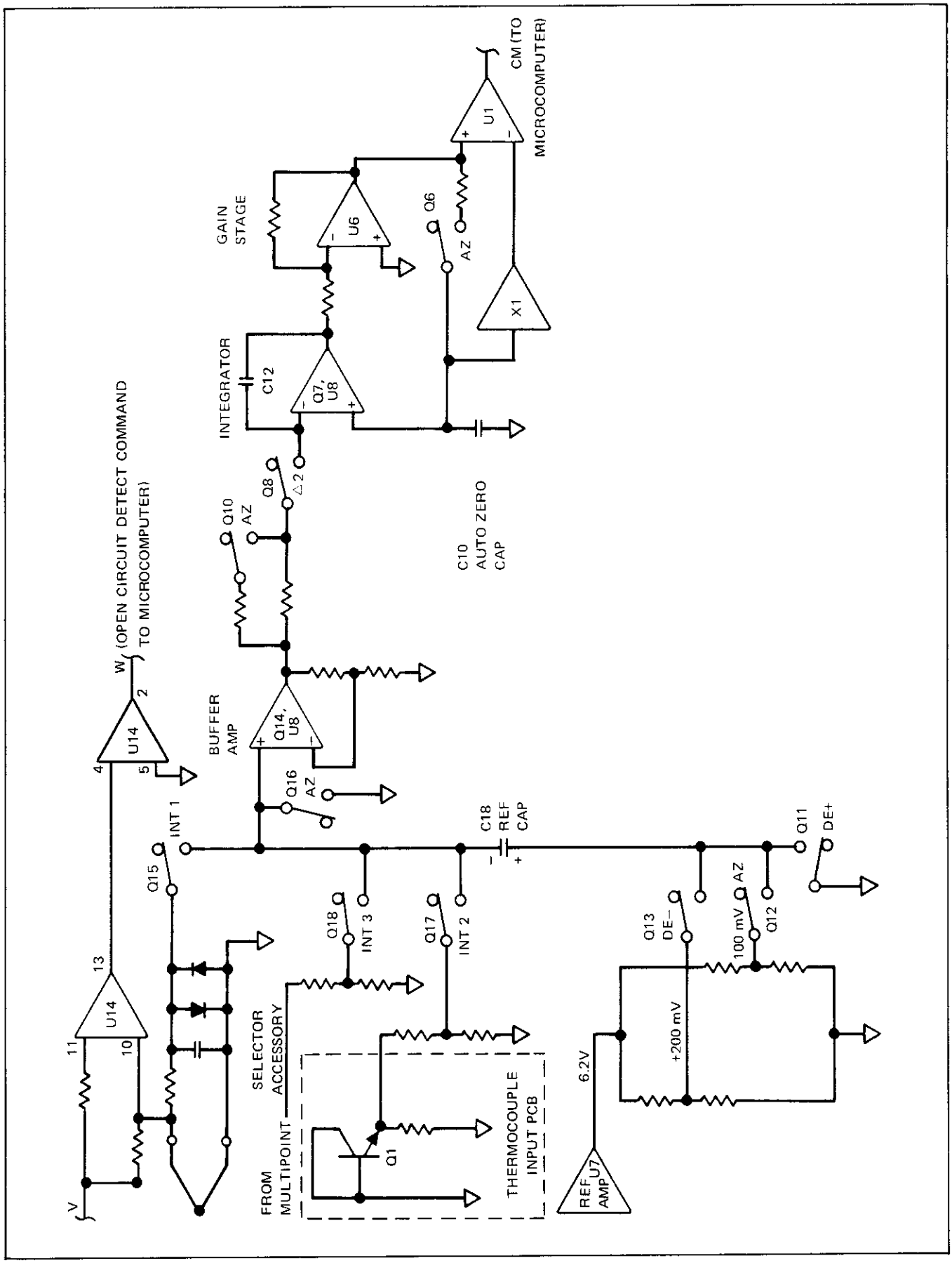


Figure 3-3. Simplified Schematic — Analog Section

3-27. If the positive Read mode is commanded, FET switch Q11 is closed. This grounds the positive end of the VREF capacitor which effectively applies -100 mV to the input of the buffer.

3-28. If the negative Read mode is commanded, switch Q13 is closed connecting the positive end of the VREF capacitor to +200 mV. Therefore, the voltage applied to the buffer is the algebraic sum of 200 mV and the voltage across the reference capacitor. This effectively applies +100 mV to the input of the buffer.

3-29. After a 1 ms settling time, switch Q8 closes and the buffer output voltage is applied to the integrator input, causing the integrator capacitor to discharge at a linear rate determined by the reference voltage. The discharge continues until the integrator voltage reaches the comparator trip point, which is referenced to the voltage on the auto-zero capacitor. When this level is reached the comparator changes state, commanding the microcomputer to terminate the Read period. To facilitate Auto-Zero, the microcomputer then calls a reference voltage opposite in polarity to the one previously used. When the integrator again reaches the trip point, the microcomputer immediately begins the Auto-Zero period.

3-30. Offset voltages present during the Integrate and Read periods are cancelled by offset voltages that were sampled and held during the Auto-Zero period. However, during conversion within the microcomputer, the temperature corresponding to the reference-junction voltage is added to the measurement data and, as a result, the displayed temperature is equal to the thermocouple probe temperature.

3-31. O.C. DETECTOR

3-32. The open thermocouple detector (U14 and its associated circuitry) on the thermometer is used to determine whether or not the impedance at the input terminals exceeds a predetermined level. It therefore provides an indication of a broken or faulty thermocouple. A square wave is applied to the input of the thermometer and its magnitude is compared to a reference square wave. If the reference is exceeded, an open circuit condition is detected. This occurs at a nominal 2 kΩ.

3-33. POWER SUPPLY

3-34. The 2190A power supply consists of a DC-to-DC Converter and voltage regulating circuitry. AC inputs are made via the input power cord, line fuse, and power transformer/rectifier. External +12 volt dc inputs can also be made directly to the DC-to-DC Converter via line TB1 (see Main PCB schematic, Section 8). The function of the power supply is to provide +5, +15, and -15 dc operation voltages for the 2190A circuitry. The power supply can be driven from AC line or 12V dc external source. The DC-to-DC conversion and voltage regulation is accomplished using conventional power supply design techniques.

Section 4
Maintenance

WARNING

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

4-1. INTRODUCTION

4-2. This section of the manual provides information about warranty, factory service, maintenance, performance testing, routine recalibration, and recalibration after repair. The performance test is recommended when the instrument is received and later as a preventive maintenance tool or for testing after repair. The test verifies performance at several temperatures within the range of a given thermocouple type. Specifications are provided both for annual and for a more precise 90-day performance-testing cycle.

4-3. SERVICE INFORMATION

4-4. The instrument is warranted for a period of 1-year upon delivery to the original purchaser. The WARRANTY is located on the back of the title page located in the front of this manual.

4-5. Factory authorized calibration and service for each Fluke product is available at various worldwide locations. A complete list of these service centers is included in Section 7 of this manual. If requested, an estimate will be provided to the customer before any work is begun on instruments that are beyond the warranty period.

4-6. GENERAL MAINTENANCE

4-7. Instrument Disassembly

4-8. Removal of the instrument from its case is necessary only for maintenance. Routine calibration can be done without such removal. Disassemble the thermometer using the following procedure:

1. Remove the Thermocouple Input PCB Assembly through its access port in the rear panel.

2. Remove the four screws on the bottom of the instrument that secure the two halves together and lift the top cover free.

3. Remove the Output Option, if installed and required, by removing the three screws connecting it to the Main PCB, disconnecting the interconnect cables at J1 and J3, and lifting the Option PCB clear.

4. Remove the screw securing the center of the Main PCB to the bottom portion of the case.

5. Lift the Main PCB, complete with front and rear panels, clear of the case.

6. Remove the front panel, if required, by disconnecting the guard screw at the lower right corner; disconnecting the front panel interconnect cable at J6; disconnecting, if installed, the Limits Option interconnect cable at J4, and moving the front panel forward.

7. Remove the rear panel, if required, by removing the three screws attaching it to the Main PCB; disconnecting the wires from the input line power connector; unsoldering the wires from two fuse holders and moving the rear panel free.

8. Perform reassembly in the reverse order.

4-9. Input Line Power Selection

4-10. Input line power voltage is selected by positioning the slot on two switches. Figure 4-1, shows the switches on the right edge of the Main PCB set for 120 volt ac operation. Table 4-1, lists the switch settings for other line voltages available.

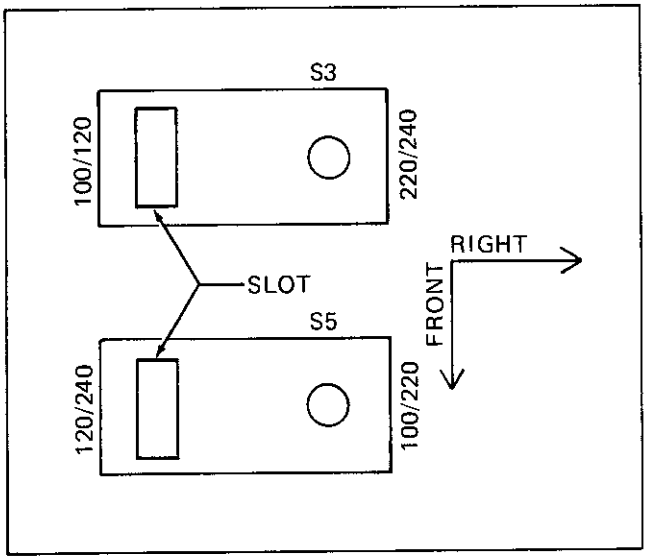


Figure 4-1. Line Voltage Selection Switches

Table 4-1. Line Voltage Selection Switches Positioning

VOLTAGE	S3 SLOT (REAR SW)	S5 SLOT (FRONT SW)
100	Left	Right
120	Left	Left
220	Right	Right
240	Right	Right

4-11. Cleaning

4-12. Clean the instrument periodically to remove dust, grease, and other contamination. Use the following procedure:

CAUTION

Do not use aromatic hydrocarbons or chlorinated solvents for cleaning. They will react with plastic materials used in the manufacture of the instrument.

1. Clean the front panel and case with a soft cloth dampened with a mild solution of detergent and water.

2. Clean the surface of the pcb using clean, dry air at low pressure (≤20 psi). If grease is encountered, spray with Freon T.F. Degreaser or anhydrous alcohol and remove grime with clean, dry air at low pressure.

4-13. Fuse Replacement

WARNING

DISCONNECT THE UNIT FROM LINE POWER BEFORE ATTEMPTING FUSE REPLACEMENT.

4-14. The 2190A has two fuses, both accessible on the rear panel. F1 is for the input line power and should be replaced, when necessary, with a 1/8A MDL (slo-blo) fuse when the input line power selected is 100V or 120V. When the input power selected is 220V or 240V, F1 should be replaced with a 1/16A MDL fuse. F2 is for the 12V dc external power and requires 3/4A MDL fuse.

4-15. Service Tools

4-16. No special tools are required for maintenance or repair.

4-17. PERFORMANCE TEST

4-18. The performance tests listed here (Ambient Temperature or Ice Bath Test) perform the same function, specifically, verifying instrument performance to its specifications. Either test may be used for initial acceptance, verifying calibration, or as an aid in troubleshooting. Both tests need not be performed. If the thermometer fails to meet specifications in either performance test, the calibration adjustment procedure or troubleshooting should be performed, as determined by qualified personnel.

4-19. Table 4-2, lists the equipment required for the performance test and calibration adjustment procedure. If the recommended model of test equipment is not

available, a substitute that meets the minimum use specifications may be used. The test should be conducted with an ambient temperature of 25 ±2°C (77.0 ±3.6°F).

4-20. Ambient Temperature Test

4-21 Use the following procedure to test the instrument at ambient temperature:

1. Turn the POWER switch OFF and remove the line power cord from the line voltage source.

2. Select the switch position on the Thermocouple Input Module corresponding to the microcomputer and thermocouple type in use, see Table 2-2.

3. Connect the equipment as shown in Figure 4-2.

Table 4-2. Test Equipment Requirements

TEST EQUIPMENT	MINIMUM USE SPECIFICATIONS	RECOMMENDED MODEL
Thermocouple Wires	Type K preferred	Omega or manufacture specification
Mercury Thermometer (either °C or °F)	0.02° C resolution 0.05°F resolution	Princo Model ASTM56C Princo Model ASTM56F
Dewar Flask/Cap	1-pint capacity	Thermos
DC Voltage Calibrator	Output Voltage 0 to 10V Accuracy: 0.002% Resolution: 100 uV	Fluke Model 343A
Voltage Divider 100:1 Kelvin-Varley Divider (Shunt output with 1 uF capacitor)	Ratio: 0.005%	Fluke Y2022 or Fluke 720A or Fluke 750A
Variable Line-Voltage Transformer	100, 115, 230V ac, as required, ±10%	General Radio VARIAC W5HM
Decade Resistor	Accuracy: 1% Ranges: 1k, 10k, and 100k	General Radio 1434
Voltmeter	100 uV resolution	Fluke 8800A

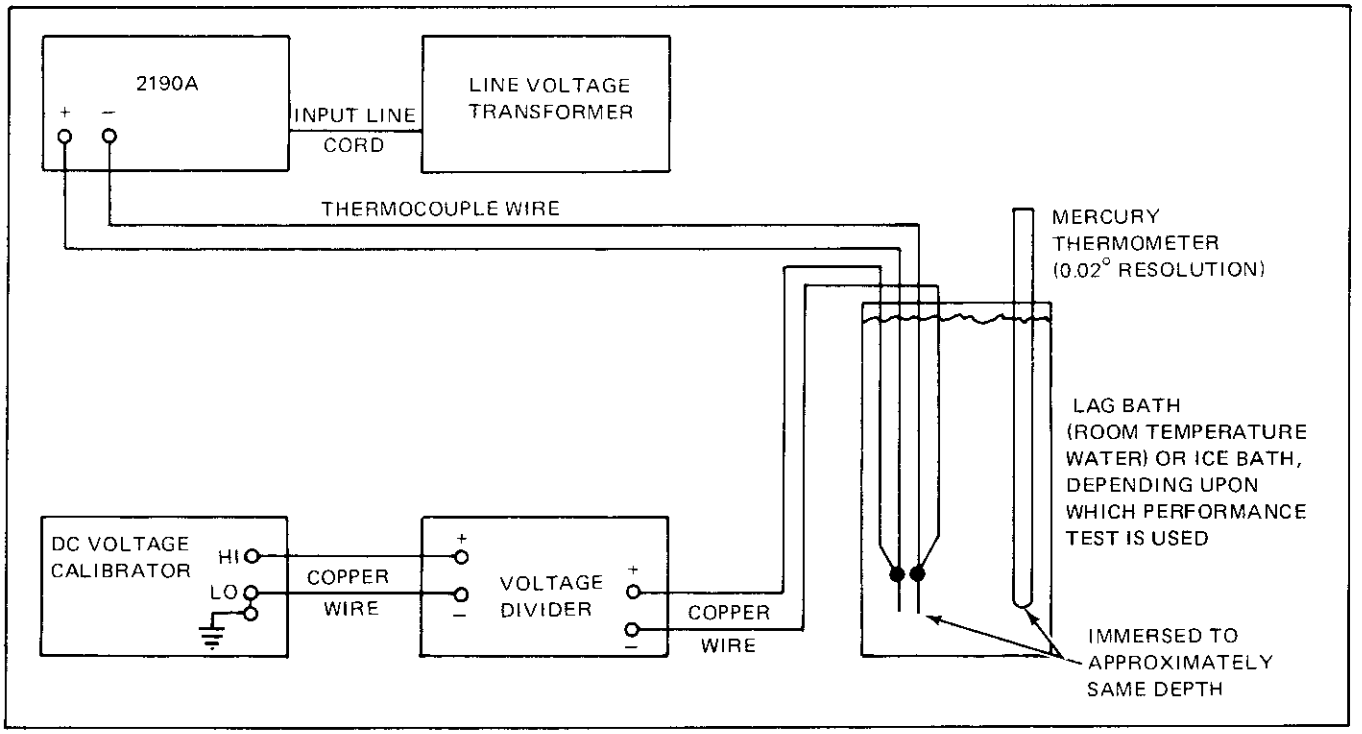


Figure 4-2. Equipment Connections

NOTE

Whenever the 720A or 750A is used as the divider a 1 μF capacitor must be placed across its output terminals, otherwise an open thermocouple condition will result.

4. Verify that the POWER switch is OFF, then adjust the line voltage transformer for the nominal input line voltage.

5. Turn the POWER switch ON.

6. Allow the 2190A to stabilize (at least 5 minutes).

7. Select the temperature scale (°C or °F) on the 2190A to agree with the temperature scale of the mercury thermometer in the lag bath.

8. Read the temperature of the mercury thermometer and find the corresponding mV reading to this temperature (refer to the Thermocouple Reference Tables in Section 7B of this manual). Interpolation may be used as necessary.

9. Algebraically subtract the mV reading found in step 8 from the first value found under the "Divider Output mV" column of Table 4-3, for the microcomputer and corresponding thermocouple type in use.

10. Obtain a divider output equal to the result found in step 9 by adjusting the calibrator, or if using the 720A or 750A, adjust the divider.

11. Verify that the 2190A reads the value listed in Table 4-3, within the limits specified (90-day or 1-year as required).

12. Repeat steps 8, 9, 10, and 11 for the remaining voltages in the "Divider Output mV" column.

13. Set the line voltage transformer for line voltage minus ten percent and repeat the test for one thermocouple type.

14. Set the line voltage transformer for line voltage plus ten percent and repeat the test for one thermocouple type.

15. Set the line voltage transformer for the input line voltage.

16. Disconnect the thermocouple from the input terminals.

17. This completes the performance test.

4-22. Ice Bath Construction

4-23. To construct an ice point bath, use the following procedure:

1. Prepare a thermos by drilling two holes in its cap to accept the thermometer and thermocouple wires or use a standard laboratory cork.

2. Fill the thermos with shaved or crushed ice made from distilled water.

3. Fill the thermos with enough distilled water so that the ice becomes slush, but not enough to float the ice.

NOTE

As the ice melts, siphon off the excess water and add more ice. Allow approximately 5 to 10 minutes for the water to drop back to the freezing point.

4. Replace the thermos cap or cork and insert thermocouple wires and thermometer as shown in Figure 4-2.

Table 4-3. Performance Test Values

THERMOCOUPLE TYPE	DIVIDER OUTPUT mV	°F (2190A DISPLAY)		°C (2190A DISPLAY)	
		90 DAY	1 YEAR	90 DAY	1 YEAR
MICROCOMPUTER TYPE #1					
J	−5.553	−190 ± 0.2	−190 ± 0.2	−123.3 ± 0.2	−123.3 ± 0.2
	−2.483	−60.0 ± 0.2	−60.0 ± 0.2	−51.1 ± 0.2	−51.1 ± 0.2
	23.317	800.0 ± 0.2	800.0 ± 0.3	426.7 ± 0.2	426.7 ± 0.2
K	−4.230	−190 ± 0.3	−190 ± 0.3	−123.3 ± 0.2	−123.3 ± 0.2
	−1.929	−60 ± 0.3	−60 ± 0.3	−51.1 ± 0.2	−51.1 ± 0.2
	26.975	1200 ± 0.5	1200 ± 0.5	648.9 ± 0.3	648.9 ± 0.3
	52.939	2400 ± 0.7	2400 ± 0.7	1315.6 ± 0.4	1315.6 ± 0.4

Table 4-3. Performance Test Values (cont)

THERMOCOUPLE TYPE	DIVIDER OUTPUT mV	°F (2190A DISPLAY)		°C (2190A DISPLAY)	
		90 DAY	1 YEAR	90 DAY	1 YEAR
MICROCOMPUTER TYPE #1 (cont)					
T	−6.105	−400 ± 0.3	−400 ± 0.3	−240.0 ± 0.2	−240.0 ± 0.2
	−4.009	−190 ± 0.3	−190 ± 0.3	−123.3 ± 0.2	−123.3 ± 0.2
	8.062	350 ± 0.3	350 ± 0.3	176.7 ± 0.2	176.7 ± 0.2
	20.458	740 ± 0.4	740 ± 0.4	393.3 ± 0.2	393.3 ± 0.2
C	0.522	100 ± 0.3	100 ± 0.3	37.8 ± 0.2	37.8 ± 0.2
	19.947	2000 ± 0.6	2000 ± 0.7	1093.3 ± 0.4	1093.3 ± 0.4
	36.539	4100 ± 1.1	4100 ± 1.2	2260.0 ± 0.6	2260.0 ± 0.6
R	1.508	400 ± 0.4	400 ± 0.4	240.0 ± 0.3	240.0 ± 0.3
	8.141	1500 ± 0.6	1500 ± 0.7	815.6 ± 0.4	815.6 ± 0.2
	20.275	3100 ± 0.9	3100 ± 1.0	1704.4 ± 0.6	1704.4 ± 0.6
MICROCOMPUTER TYPE #2					
J	−5.553	−190 ± 0.2	−190 ± 0.2	−123.3 ± 0.2	−123.3 ± 0.2
	−2.483	−60.0 ± 0.2	−60.0 ± 0.2	−51.1 ± 0.2	−51.1 ± 0.2
	23.317	800.0 ± 0.2	800.0 ± 0.3	426.7 ± 0.2	426.7 ± 0.2
K	−4.230	−190 ± 0.3	−190 ± 0.3	−123.3 ± 0.2	−123.3 ± 0.2
	−1.929	−60 ± 0.3	−60 ± 0.3	−51.1 ± 0.2	−51.1 ± 0.2
	26.975	1200 ± 0.5	1200 ± 0.5	648.9 ± 0.3	648.9 ± 0.3
	52.939	2400 ± 0.7	2400 ± 0.7	1315.6 ± 0.4	1315.6 ± 0.4
E	−9.604	−400 ± 0.3	−400 ± 0.3	−240.0 ± 0.2	−240.0 ± 0.2
	−6.471	−200 ± 0.3	−200 ± 0.3	−128.9 ± 0.2	−128.9 ± 0.2
	35.562	900 ± 0.3	900 ± 0.4	482.2 ± 0.2	482.2 ± 0.2
	75.024	1800 ± 0.6	1800 ± 0.6	982.2 ± 0.3	982.2 ± 0.3
R	1.508	400 ± 0.4	400 ± 0.4	240.0 ± 0.3	240.0 ± 0.3
	8.141	1500 ± 0.6	1500 ± 0.7	815.6 ± 0.4	815.6 ± 0.2
	20.275	3100 ± 0.9	3100 ± 1.0	1704.4 ± 0.6	1704.4 ± 0.6
S	1.962	500 ± 0.3	500 ± 0.4	260.0 ± 0.2	260.0 ± 0.2
	7.514	1500 ± 0.5	1500 ± 0.6	815.6 ± 0.3	815.6 ± 0.3
	17.993	3100 ± 0.8	3100 ± 0.9	1704.4 ± 0.5	1704.4 ± 0.5
MICROCOMPUTER TYPE #3					
JDIN*	−4.33	−130.0 ±0.3	−130.0 ±0.3	−90.0 ±0.2	−90.0 ±0.2
	10.95	392.0 ±0.3	392.0 ±0.4	200.0 ±0.2	200.0 ±0.2
	42.92	1382.0 ±0.5	1382.0 ±0.5	750.0 ±0.3	750.0 ±0.3
K	−1.527	−40.0 ±0.3	−40.0 ±0.3	−40.0 ±0.2	−40.0 ±0.2
	26.975	1200.0 ±0.5	1200.0 ±0.5	648.9 ±0.3	648.9 ±0.3
	52.939	2400.0 ±0.7	2400.0 ±0.7	1315.6 ±0.4	1315.6 ±0.4
TDIN*	−5.510	−310.0 ±0.3	−310.0 ±0.3	−190.0 ±0.2	−190.0 ±0.2
	2.480	140.0 ±0.3	140.0 ±0.3	60.0 ±0.2	60.0 ±0.2
	20.380	734.0 ±0.4	734.0 ±0.4	390.0 ±0.2	390.0 ±0.2
B	0.891	797.0 ±0.5	797.0 ±0.5	425.0 ±0.3	425.0 ±0.3
	6.780	2192.0 ±0.7	2192.0 ±0.8	1200.0 ±0.4	1200.0 ±0.4
	13.690	3290.0 ±0.9	3290.0 ±1.0	1810.0 ±0.5	1810.0 ±0.5
R	1.508	400.0 ±0.4	400.0 ±0.4	240.0 ±0.3	240.0 ±0.3
	8.141	1500.0 ±0.6	1500.0 ±0.6	815.6 ±0.4	815.6 ±0.4
	20.275	3100.0 ±0.9	3100.0 ±0.9	1704.4 ±0.6	1704.4 ±0.6

*European Standard

4-24. Ice Bath Test

4-25. Use the following procedure to test the 2190A using an ice point bath:

1. Repeat steps 1 through 7 of ambient temperature test; verify that the temperature of the water is at the freezing point.

2. Using Table 4-3 (for the corresponding microcomputer and thermocouple type) obtain a divider output equal to the first value of the "Divider Output mV" column and verify that the 2190A reads within the limits specified, 90-day or 1-year.

3. Repeat step 2 for the remaining voltages in the "Divider Output mV" column.

4. Repeat steps 13 through 17 of ambient temperature test.

4-26. CALIBRATION ADJUSTMENT PROCEDURE

4-27. The thermometer should be calibrated at either 90-day or annual periods, depending upon the accuracy desired, and any time that repairs are made to the instrument. Either scale can be verified by executing the performance test previously given. The microcomputer can also be changed without effecting the calibration of the instrument.

4-28. Equipment Preparation

4-29. Prepare the equipment for calibration using the following procedure:

1. Remove the top cover from the instrument.

2. Select switch setting of 9 (CAL) on the Thermocouple Input Module to disable the reference-junction circuitry (see Table 2-2).

3. Connect the equipment as shown in Figure 4-3. Refer to Table 4-2 for the applicable test equipment models.

NOTE

Insure the instrument warm-up period has been sufficient to reach rated accuracy (at least 5 minutes).

4. Select the desired temperature scale.

NOTE

If the Limits Option is installed select the LIMITS (≤ or ≥) function.

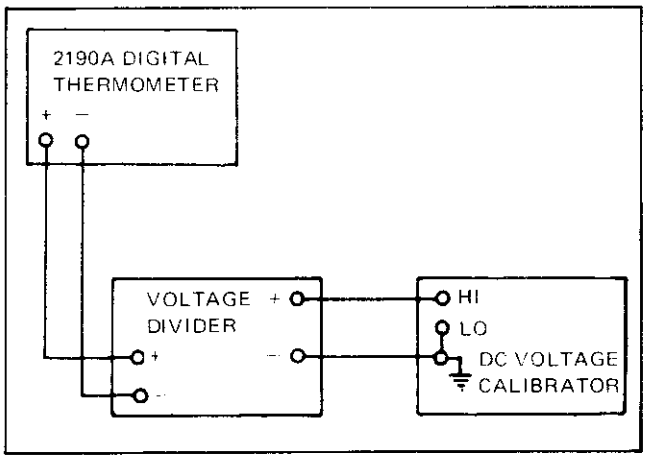


Figure 4-3. Calibration Adjustment Connections

4-30. Zero Adjustment

4-31. Perform zero adjustment using the following procedure:

1. Select a thermometer input, from the voltage divider, of 10.2 μV dc.

2. Record the thermometer display.

3. Reverse the polarity of the input by reversing the polarity of the calibrator output.

4. Record the thermometer display.

5. Adjust ZERO (R31) through the front panel access port and repeat steps 1 through 4 as required to obtain the same value in both step 2 and 4.

6. Adjust R14 for a thermometer display of 1.0 of the same polarity as the input.

7. Connect a test DMM between TP16 (HI) and TP1 (LO).

8. Adjust R17 for a DMM reading between 6.1999 and 6.2001V dc. Ignore any thermometer display.

4-32. Reference Adjustment

4-33. Perform the reference adjustment using the following procedure:

1. Select a thermometer input, from the voltage divider, of 99 mV dc.

2. Adjust +FS (R29) through the front panel access port for a display between 9899.9 and 9900.1.

3. Reverse the polarity of the input by reversing the polarity of the calibrator output.

4. Adjust FS (R30) through the front panel access port for a display between 9899.9 and 9900.1.

5. Select a thermometer input, from the voltage divider, of 45 mV dc and verify the thermometer reads between 4499.9 and 4500.1.

4-34. Reference-Junction Adjustment

4-35. Perform the reference-junction adjustment using the following procedure:

1. Disconnect the voltage divider from the calibrator and the thermometer.

2. Select a calibrator output of +0.5785V dc.

CAUTION

Verify that the calibrator output is correct before applying it to the instrument.

3. Connect the calibrator between TP1 (HI) and TP17 (LO). Select switch position 1 (K) on the Thermocouple Input PCB Assembly, and short the thermocouple + and - input terminals with a short piece of copper bus wire.

4. Adjust R5 for a thermometer display of 77.0° F.

5. Disconnect the calibrator from the thermometer and remove the short on the thermocouple input terminals.

4-36. Thermocouple Input Calibration

4-37. Perform the thermocouple input calibration using the following procedure:

1. Connect a thermocouple to the thermometer input terminals (K-type preferred) select the applicable switch position and insert the probe into a lag bath.

2. Allow the system to stabilize, then adjust R1 on the Thermocouple Input Module through the rear access port for a temperature display equal to reading of the lag bath thermometer.

3. Calibration of the 2190A is complete. Disconnect all test equipment from the instrument.

4-38. SELECTED COMPONENT REPLACEMENT OR ADJUSTMENT

4-39. If the reference-junction transistor (Q1 on the Thermocouple Input PCB Assembly) is replaced or the negative supplies repaired, the reference-junction bias resistor R3 must also be replaced. R3 is a selected resistor and must be individually matched to Q1. Prior to the matching procedure, calibrate the instrument using the standard procedure through the reference-junction adjustment and then replace the thermocouple input calibration portion of the procedure with the following:

1. Connect a thermocouple probe to the input terminals and select the applicable switch setting on the Thermocouple Input PCB Assembly (K-type thermocouple preferred) and insert the probe into a lag bath.

2. Center the reference-junction potentiometer R1.

3. Connect a decade box (see Table 4-2) in place of the reference-junction bias resistor.

4. Adjust the decade-resistance box for the value from Table 4-4 that causes the temperature to read closest to the lag bath temperature as monitored on the mercury thermometer.

5. Remove power, disconnect the decade box, and connect the resistor selected from the table.

6. Reapply power, allow the system to stabilize at its rated accuracy (at least 5 minutes), then adjust R1 through the rear panel access port for a temperature display equal to the reading of the lag bath mercury thermometer.

7. Calibration and component selection is complete. Disconnect all test equipment from the instrument.

Table 4-4. Bias Resistor Values

VALUE	JOHN FLUKE PART NUMBER	VALUE	JOHN FLUKE PART NUMBER
49.9k	268821	110k	234708
52.3k	237248	124k	288407
54.9k	271353	140k	289439
57.6k	289116	162k	375998
60.4k	291419	191k	375923
63.4k	235382	237k	288373
68.1k	236828	309k	235283
73.2k	23722	332k	289504
78.7k	289058	464k	271908
84.5k	229492	562k	235358
90.9k	223537	1.05M	260737
100k	248807	∞	OPEN

4-40. Multipoint Potentiometer Adjustment

4-41. The multipoint potentiometer (R57) is set at the factory and should not require further adjustment unless one of the other resistors in the divider (R1 and R2) or the capacitor (C19) require replacement. Adjustment of the potentiometer requires that a Y2001 Multipoint Selector be connected to the instrument. Adjust R57 subsequent to replacement of any of the four affected components (C19, R1, R2, or R57) using the following procedure:

1. Connect a Y2001 Multipoint Selector to the instrument.

2. Short the input to one channel on the Y2001 and select that channel on the front panel.

3. Obtain an output of 578.5 mV dc from a test dc calibrator.

4. Apply the output of the dc calibrator to TP1 (LO) and TP18 (HI).

5. Adjust R57 for a thermometer display of 77.0° F.

4-42. TROUBLESHOOTING

4-43. Troubleshooting for the 2190A consists of the tabular flow chart in Table 4-5. When a step on the flow chart is completed check for a decision transfer. If no decision is required perform the next step of the table in sequence.

Table 4-5. 2190A Troubleshooting

STEP NO.	ACTION	Go to the step number given for correct response	
		YES	NO
1	Short the thermocouple input.		
2	Set the thermocouple selector switch to position 8 or 9 (Cal. pos.).		
3	Apply power to the thermometer.		
4.	Does the display read 2190.X for ten seconds and then change to 0°C (0°F)? NOTE: X = A numeral depending on the version of software installed.	14	5
5	Does any portion of the display illuminate?	13	6
6	Measure between TP2 and TP4 for +5 ±10% VDC, between TP1 and TP3 for +15 ±5% VDC, and between TP1 and TP2 for -15 ±5% VDC.		
7	Are all voltages correct?	12	8
8	Measure between Pin 8 of T2 and the negative end of C21 for a DC voltage greater than 10.3V and for a peak to peak wave form between Pins 8 and 9 of T2 approximately twice the value of the DC voltage measured at Pin 8.		
9	Are both signals present and correct?	11	10
10	Check the inverter circuit that drives the transformer (T2). Repair as required then resume at Step 3.		
11	Check the transformer secondaries and if any are bad, check the individual regulators and their associated components. NOTE: Analog circuitry may load down the ±15V supplies. Repair as required then resume at Step 3.		
12	Check the +5V path the the Display PCB and the Display PCB Connector. Repair as required then resume at Step 3.		
13	Check the strobes (U4-3, 4, 5, 6, 19) and display seven segment control lines (U4-8, 9, 10, 11, 12, 13, 14). Repair as required then resume at Step 3.		
14	Remove the input short.		

Table 4-5. 2190A Troubleshooting (cont)

STEP NO.	ACTION	Go to the step number given for correct response	
		YES	NO
15	Does the display read "O.C."?	17	16
16	Check U14-1, U14-2, U14-13 outputs and their associated components. Repair as required then resume at Step 14.		
17	Set the thermocouple selector switch to the setting of the type thermocouple to be connected in the next step.		
18	Connect a thermocouple to the thermometer and measure some known temperature.		
19	Is the displayed temperature correct?	41	20
20	Does the display read a flashing "O.C."?	21	22
21	Check the thermocouple components and the open thermocouple circuit (U14-1, U14-2, U14-13 and their associated components). Repair as required then resume at Step 17.		
22	Can the Calibration Adjustment Procedure be performed?	41	23
23	Are the control signals at U4 pins 26 through 32 toggling between high and low logic levels? NOTE: The INT 3 signal at pin 28 of U4 will remain low (0V) unless the multipoint selector accessory (Y2001) is connected. (Use TP2 as common.)	25	24
24	Replace the microcomputer U4 then resume at Step 17.		
25	Are the outputs of U3 and TP14 toggling between high and low logic levels? NOTE: The output at pin 9 of U3 will remain low (0V) unless the multipoint selector accessory (Y2001) is connected.	27	26
26	Check U3, Q4 and their associated components. Repair as required then resume at Step 17.		
27	Is the waveform at TP7 as shown in Figure 3-2 (Magnitude & Polarity varies with the input signal)?	34	28
28	Is there-6.2 Vdc at TP16. (Use TP1 as common.)	30	29
29	Check the Reference Circuit providing an input at U7-3 from the divider R18, R19, R17, R20, and VR1. Repair as required and resume at Step 17.		
30	Check from TP1 (analog ground) to U9-6 for 100 mV dc and for 200 mV dc at U9-9.		
31	Are both voltages present?	33	32
32	Check Q11, Q12, Q13 and associated components. Repair as required then resume at Step 17.		
33	Check the Thermocouple Input PCB plus U8-1, Q14, Q15, Q17, and their associated components. Repair as required then resume at Step 17.		
34	Is the waveform at U8-7 as shown in Figure 3-2 (Magnitude & Polarity varies with the input signal)?	38	35
35	Check the operation of Q7, Q8, Q9, Q10, U8 and their associated components. If any defective components are found, repair as required and resume at Step 13. If none are found proceed to the next step.		
36	Connect TP2 and TP5 with a jumper to lock the instrument in the Auto Zero period.		
37	Check U8, U2, U6 and their associated components. This circuit should now function as a closed loop amplifier. Repair as required. Remove the jumper between TP2 and TP5 and resume at Step 17.		

Table 4-5. 2190A Troubleshooting (cont)

STEP NO.	ACTION	Go to the step number given for correct response	
		YES	NO
38	Does TP10 toggle between the high and low logic levels?	40	39
39	Check U1 and its associated components then resume at Step 17.		
40	Replace the microcomputer U4, then resume at Step 17.		
41	Troubleshooting of the 2190A is complete. Remove all test equipment, reconnect any cables removed and close the instrument.		

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 per assembly or component.

7. Recommended Quantity: This entry indicates the recommended number of spare parts necessary to support one to five instruments for a period of two years. This list presumes an availability of common electronic parts at the maintenance site. For maintenance for one year or more at an isolated site, it is recommended that at least one of each assembly in the instrument be stocked. In the case of optional subassemblies, plug-ins, etc., that are not always part of the instrument, or are deviations from the basic instrument model, the REC QTY column lists the recommended quantity of the item 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. factory or authorized representative 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 be 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.

6. Instrument Model and Serial Number.

CAUTION

Indicated devices are subject to damage by static discharge.

Table 5-1. Final Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	FINAL ASSY, 2190A DIGITAL THERMOMETER FIGURE 5-1						
A1	Ⓐ MAIN PCB ASSEMBLY (THERMOMETER PCB ASSEMBLY)	469395	89536	469395	1		
A2	DISPLAY PCB ASSY	464479	89536	464479	1		
A3	THERMOCOUPLE INPUT PCB ASSY	464461	89536	464461	1		
F1	FUSE, U.S.				1	5	
	FOR 100/120V OPERATION						
	SLO-BLO, 1/8 AMP	166488	71400	MDL1-8A			
	FOR 220/240V OPERATION						
	SLO-BLO, 1/16 AMP	163030	71400	MDL1-16A			
	FUSE, METRIC				1	5	
	FOR 100/120V OPERATION						
	SLO-BLO, 1/8 AMP	467233	89536	467233			
	FOR 220/240V OPERATION						
	SLO-BLO, 1/16 AMP	467381	89536	467381			
F2	FUSE, SLO-BLO, 3/4 AMP	109256	71400	MDL3-4A	1	5	
H1	SCREW, FHP, 4-40 X 3/8	493932	89536	493932	1		
H2	SCREW, FHP, 6-32 X 5/8	335158	89536	335158	2		
H3	SCREW, PHP, 6-20 X 3/8	288266	89536	288266	1		
H4	SCREW, PHP, 4-40 X 1/4	256156	89536	256156	3		
H5	SCREW, PHP, 4-40 X 3/8	256164	89536	256164	2		
H6	SCREW, FHP, 6-32 X 5/8	114876	89536	114876	4		
MP1	DECAL, RETAINER	473645	89536	473645	2		
MP2	HANDLE	454751	89536	454751	1		
MP3	RETAINER, HANDLE	467563	89536	467563	2		
MP4	GUARD, COVER, C-SIZE	464115	89536	464115	1		
MP5	COVER, C-SIZE	454736	89536	454736	1		
MP6	BASE, STANDARD	454702	89536	454702	1		
MP7	SOLDER, LUG	151431	79963	329	1		
MP8	GUARD, BASE	464404	89536	464404	1		
MP9	REAR PANEL	464149	89536	464149	1		
MP10	OUTPUT OPTION COVER	464412	89536	464412	1		
MP11	LIMITS COVER	464156	89536	464156	1		
MP12	LATCH	467548	89536	467548	2		
MP13	BAIL, STAND	467555	89536	467555	1		
MP14	FOOT, NON-SKID	467571	89536	467571	4		
MP15	DECAL, REAR PANEL	454645	89536	454645	1		
MP16	FRONT PANEL	472282	89536	472282	1		
MP17	CALIBRATION COVER	471490	89536	471490	1		
MP18	DECAL, BOTTOM	473629	89536	473629	1		
MP19	DECAL, BASE SIDES	473652	89536	473652	2		
MP20	DECAL, FRONT PANEL	453233	89536	453233	1		
MP21	CARD GUIDE	464164	89536	464164	2		
U4	IC, UC, PROGRAMMED FOR SELECTED THERMOCOUPLES.	ORDER	BY	THERMOCOUPLE TYPE	1		
	IC, UC, PROGRAMMED FOR J, K, T, C, & R THERMOCOUPLES. (TYPE-1)	473264	89536	473264			
	IC, UC, PROGRAMMED FOR J, K, E, S, & R THERMOCOUPLES. (TYPE-2)	473371	89536	473371			

Table 5-1. Final Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	IC, UC, PROGRAMMED FOR J DIN, T DIN, K, R, & B THERMOCOUPLES. (TYPE-3)	504530	89536	504530			
W1	POWER CORD (NOT SHOWN)	343723	89536	343723	1		
W2	CABLE ASSY	475228	89536	475228	1		
XF1	FUSEHOLDER, HIGH HEAD, US	375188	89536	375188	2		
XF1-1	FUSECAP	460238	89536	460238	2		
XF1-E	FUSEHOLDER, HIGH HEAD, METRIC	467274	89536	467274	2		
	INSTRUCTION MANUAL	489229	89536	489229	1		

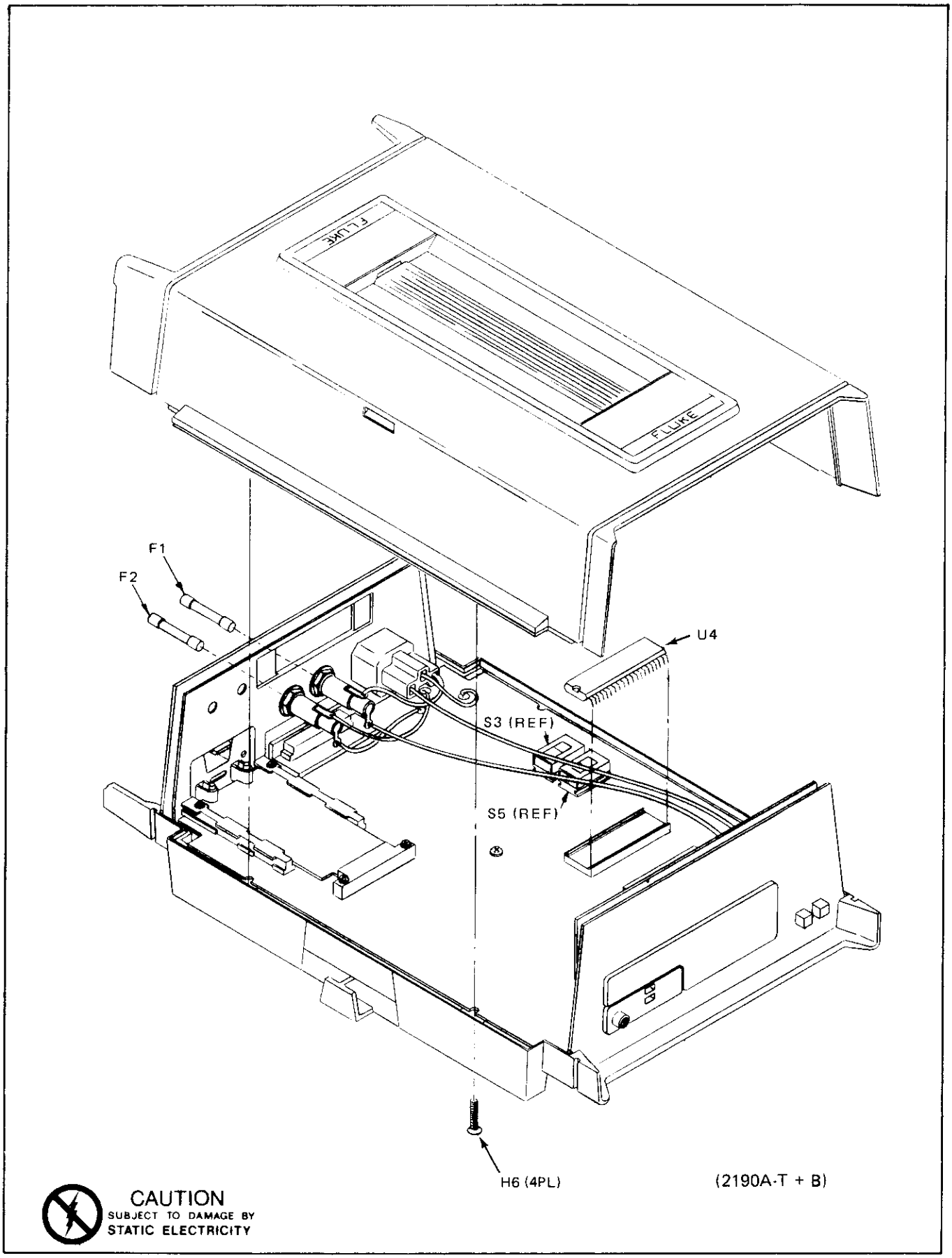


Figure 5-1. Final Assembly

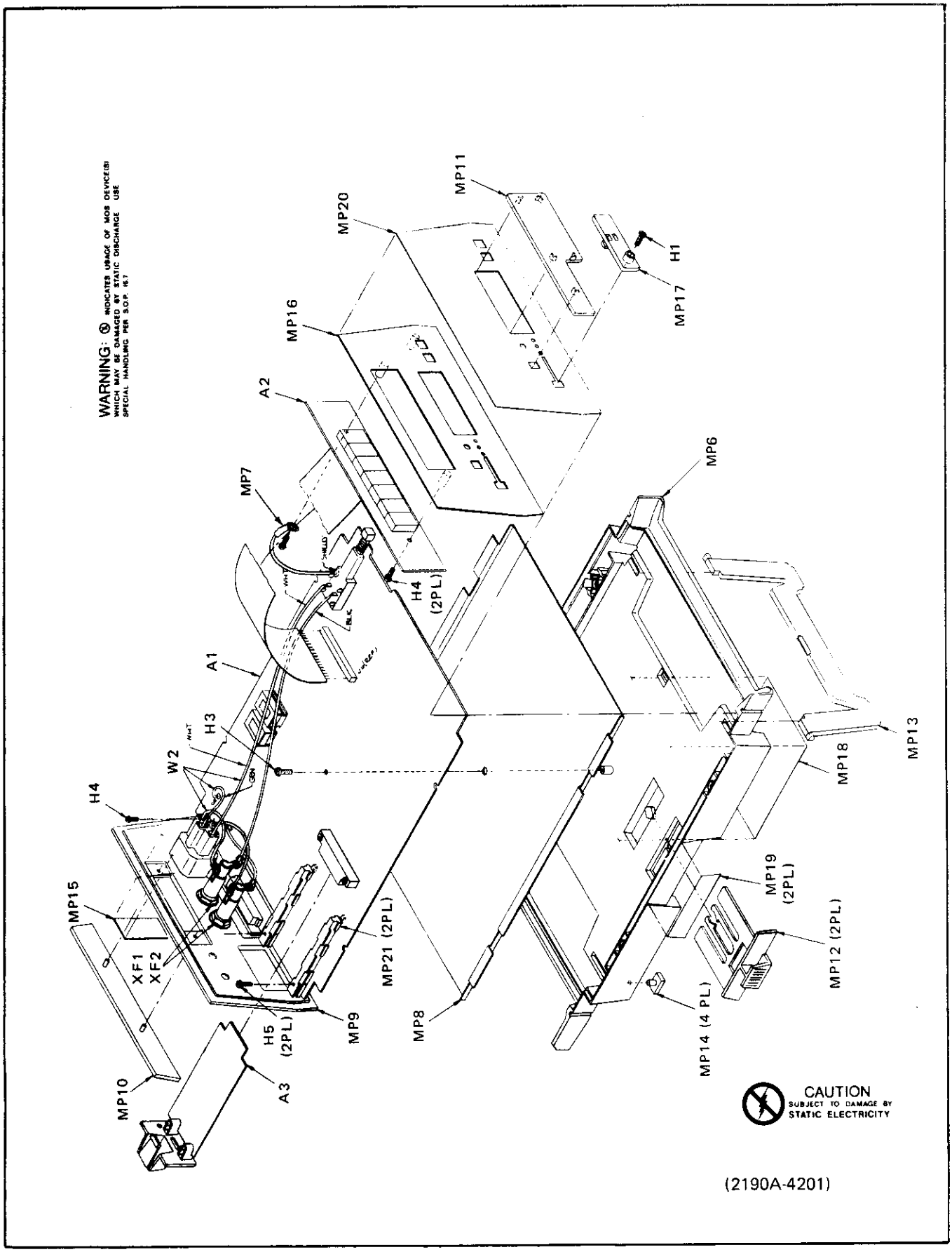


Figure 5-1. Final Assembly (cont)

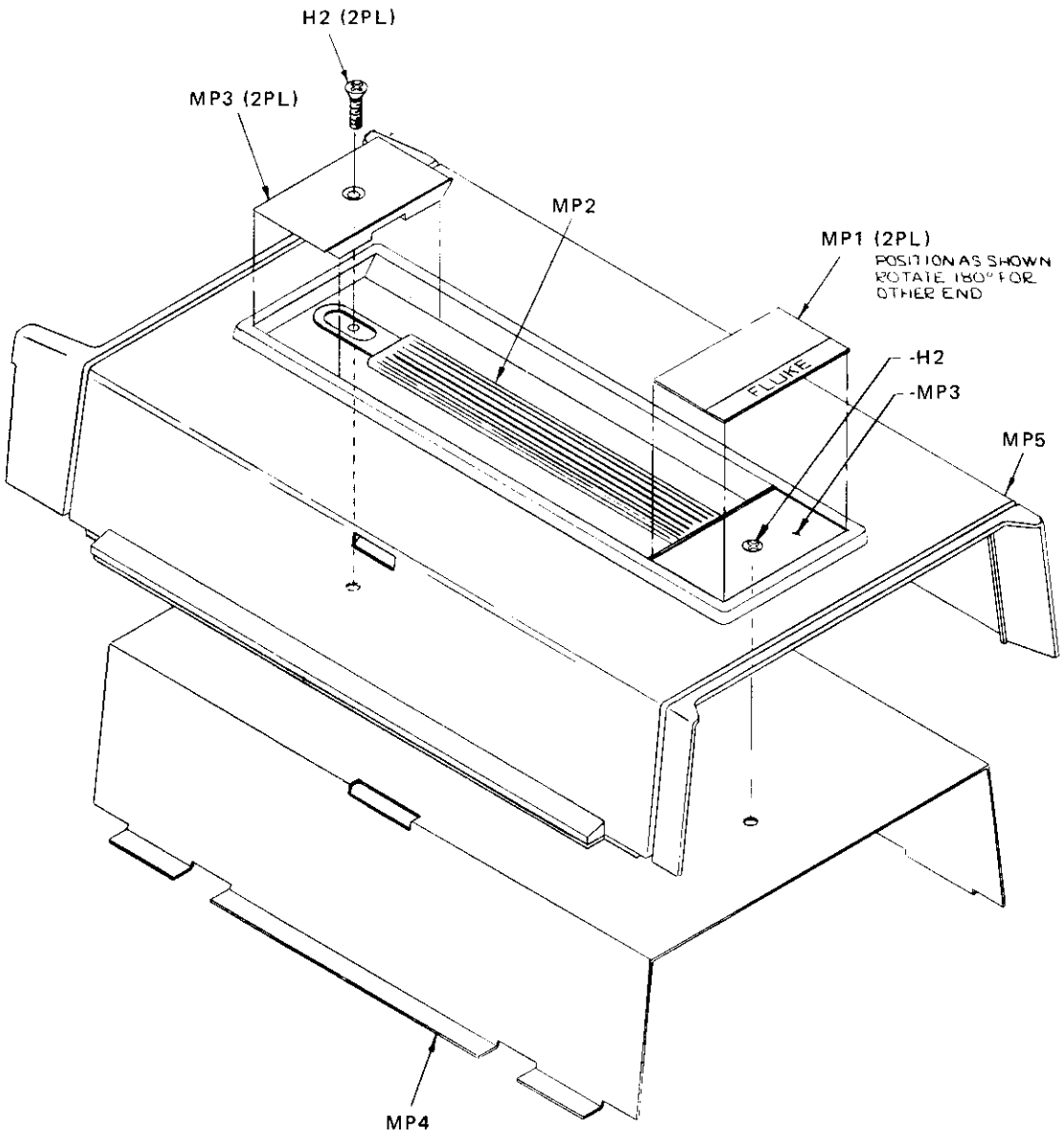


Figure 5-1. Final Assembly (cont)

Table 5-2. A1 Main PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A1	Ⓟ MAIN PCB ASSEMBLY (THERMOMETER PCB ASSEMBLY) FIGURE 5-2 (2190A-4001T)	469395	89536	469395	REF		
C1	CAP, MICA, 47 PF +/-5%, 500V	148536	71236	DM15E470J	1		
C2	CAP, PLYPRPLN, 0.47 UF +/-5%, 50V	364042	84411	JF78B	1		
C3	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	13		
C4	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C5	CAP, CER, 0.0012 UF +/-10%, 500V	106732	71590	CF122	1		
C6	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C7	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C8	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C9	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C10	CAP, POLYCARB, 2.2 UF +/-10%, 100V	306522	80031	C280MCH/A2M2	1		
C11	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C12	CAP, MICA, 430 PF +/-5%, 500V	177980	72136	DM15F431J	4		
C13	CAP, MICA, 430 PF +/-5%, 500V	177980	72136	DM15F431J	REF		
C14	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C15	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C16	CAP, MICA, 430 PF +/-5%, 500V	177980	72136	DM15F431J	REF		
C17	CAP, MICA, 430 PF +/-5%, 500V	177980	72136	DM15F431J	REF		
C18	CAP, TA, 10 UF +/-20%, 35V	417683	56289	196D106X0035PE4	1		
C19	CAP, CER, 10,000 PF -20/+80%, 500V	335786	72982	5835-000-Y5U-103Z	2		
C20	CAP, CER, 10,000 PF -20/+80%, 500V	335786	72982	5835-000-Y5U-103Z	REF		
C21	CAP, ELECT, 4000 UF -10/+100%, 25V	370734	80031	3044TS043U025	1	1	
C23	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0035JA1	5		
C24	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C25	CAP, TA, 39 UF +/-20%, 20V	358234	56289	196D396X0020PE4	1		
C26	CAP, TA, 22 UF +/-20%, 35V	394775	56289	196D226X0035TE4	2		
C27	CAP, TA, 22 UF +/-20%, 35V	394775	56289	196D226X0035TE4	REF		
C28	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C29	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C30	CAP, POLY, 0.047 UF +/-10%, 250V	162008	73445	C280MAE/A47K	1		
C31	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0035JA1	REF		
C32	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0035JA1	REF		
C33	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C34	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0035JA1	REF		
C35	CAP, CER, 0.22 UF +/-20%, 50V	309849	71590	CW30C224K	1		
C36	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0035JA1	REF		
CR3	RECTIFIER BRIDGE, 2 AMP	392910	09423	FB200	1	1	
CR4	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	12	3	
CR5	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR6	DIODE, SI, RECTIFIER	116111	05277	1N4817	1	1	
CR7	DIODE, SI, RECTIFIER	379412	04713	1N4933	2	1	
CR8	DIODE, SI, RECTIFIER	379412	04713	1N4933	REF		
CR9	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR10	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR11	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR12	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR13	DIODE, FET, CURRENT REGULATOR	348482	89536	348482	2	1	
CR14	DIODE, FET, CURRENT REGULATOR	348482	89536	348482	REF		

Table 5-2. A1 Main PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
CR15	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR16	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR17	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR18	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR19	DIODE, ZENER	393579	04713	1N4567	1	1	
CR20	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR21	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
H1	SCREW, PHP, 4-40 X 1/2	156380	73734	19032	2		
H2	SCREW, PHP, 4-40 X 1/2	152132	73734	19026	2		
H3	SCREW, PHP, 4-40 X 3/8	152124	73734	19024	2		
H4	LOCKWASHER, SPLIT, #4	110395	89536	110395	2		
H5	WASHER, FLAT	147728	73734	1402	2		
J1	CONNECTOR, SOCKET, 4-POS.	461756	00779	583773-1	1		
J2	CONNECTOR, RECEPTACLE, 12-CONTACTS	474007	05574	2VH6/1AKC15	1		
J3	CONNECTOR, SOCKET, 6-POS.	448209	00779	1-583773-3	1		
J4	CONNECTOR, SOCKET, 7-POS.	484030	00779	1-583773-4	1		
J5	CONNECTOR, "D" SHELL, 25-CONTACTS	461996	00779	206584-1	1		
J6	CONNECTOR, SOCKET, 18-POS.	435024	00779	583773-8	1		
K1	RELAY, DRY REED	357582	71707	UF-40070	1		
MP1	BUTTON, GREEN (TO S1)	445197	89536	445197	1		
MP2	BUTTON, LT. PUTTY GREY (TO S2)	425900	89536	425900	1		
MP3	SPACER, DISO-PAD (NOT SHOWN)	296319	32559	TO-8-06	2		
MP4	INSERT, POLARIZING (NOT SHOWN)	407254	89536	407254	1		
Q2	TRANSISTOR, FET, N-CHANNEL	343830	89536	343580	8	2	
Q3	TRANSISTOR, FET, N-CHANNEL	343830	89536	343580	REF		
Q4	TRANSISTOR, SI, NPN	218396	89536	218396	4	1	
Q5	TRANSISTOR, SI, NPN	218396	89536	218396	REF		
Q6	TRANSISTOR, FET, N-CHANNEL	376475	89536	376475	6	2	
Q7	TRANSISTOR, FET, DUAL N-CHANNEL	419283	89536	419283	1	1	
Q8	TRANSISTOR, FET, N-CHANNEL	376475	89536	376475	REF		
Q9	TRANSISTOR, FET, N-CHANNEL	343830	89536	343580	REF		
Q10	TRANSISTOR, FET, N-CHANNEL	429977	89536	429977	1	1	
Q11	TRANSISTOR, FET, N-CHANNEL	376475	89536	376475	REF		
Q12	TRANSISTOR, FET, N-CHANNEL	376475	89536	376475	REF		
Q13	TRANSISTOR, FET, N-CHANNEL	376475	89536	376475	REF		
Q14	TRANSISTOR, DUAL, FET	476911	78425	476911	1	1	
Q15	TRANSISTOR, FET, N-CHANNEL	376475	89536	376475	REF		
Q16	TRANSISTOR, FET, N-CHANNEL	343830	89536	343580	REF		
Q17	TRANSISTOR, FET, N-CHANNEL	343830	89536	343580	REF		
Q18	TRANSISTOR, FET, N-CHANNEL	343830	89536	343580	REF		
Q19	TRANSISTOR, SI, NPN, PWR	477331	04713	MDS01A	2	1	
Q20	TRANSISTOR, SI, NPN, PWR	477331	04713	MDS01A	REF		
Q21	TRANSISTOR, SI, NPN	218396	89536	218396	REF		
Q22	TRANSISTOR, SI, PNP, PWR	473207	01295	TIP30	1	1	
Q23	TRANSISTOR, SI, NPN	218396	89536	218396	REF		
Q24	TRANSISTOR, FET, N-CHANNEL	343830	89536	343580	REF		
Q25	TRANSISTOR, FET, N-CHANNEL	343830	89536	343580	REF		
R1	RES, SET (R1 & R2)	479030	89536	479030	2	1	
R2	RES, SET (R1 & R2)	479030	89536	479030	REF		
R3	RES, SET (R3 & R4)	479030	89536	479030	REF		

Table 5-2. A1 Main PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
R4	RES, SET (R3 & R4)	479030	89536	479030	REF		
R5	RES, VAR, 200 +/-10%, 1/2W	275743	89536	275743	2	1	
R6	RES, DEP. CAR, 1K +/-5%, 1/4W	343426	80031	CR251-4-5P1K	1		
R7	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	5		
R8	RES, DEP. CAR, 3.3K +/-5%, 1/4W	348813	80031	CR251-4-5P3K3	2		
R9	RES, DEP. CAR, 43K +/-5%, 1/4W	442418	80031	CR251-4-5P43K	1		
R10	RES, DEP. CAR, 27K +/-5%, 1/4W	441501	80031	CR251-4-5P27K	1		
R11	RES, MTL. FILM, 10.02K +/-0.1%, 1/8W	352245	89536	352245	4		
R12	RES, MTL. FILM, 10.02K +/-0.1%, 1/8W	352245	89536	352245	REF		
R13	RES, MTL. FILM, 1K +/-1%, 1/8W	168229	91637	CMF551001F	1		
R14	RES, VAR, 500K +/-10%, 1/2W	474387	11236	360T-504A	1	1	
R15	RES, MTL. FILM, 49.9 +/-1%, 1/8W	305896	91637	CMF5549R9F	1		
R16	RES, MTL. FILM, 169K +/-1%, 1/8W	289454	91637	CMF551693F	1		
R17	RES, VAR, 500 +/-10%, 1/2W	325613	89536	325613	1	1	
R18	SET, ZENER, REF (VR1, R18, R19)	377283	89536	377283	REF		
R19	SET, ZENER, REF (VR1, R18, R19)	377283	89536	377283	REF		
R20	RES, MTL. FILM, 61.9K +/-1%, 1/8W	237230	91637	CMF556192F	1		
R21	RES, MTL. FILM, 215K +/-1%, 1/8W	289470	94637	CMF552153F	1		
R22	RES, DEP. CAR, 12K +/-5%, 1/4W	348847	80031	CR251-4-5P12K	1		
R23	RES, MTL. FILM, 22.1K +/-1%, 1/8W	235234	91637	CMF552212F	1		
R24	RES, MTL. FILM, 221 +/-1%, 1/8W	340794	91637	CMF552210F	1		
R25	RES, MTL. FILM, 100 +/-0.1%, 1/8W	357400	91637	CMF551000B	1		
R26	RES, MTL. FILM, 10.02K +/-0.1%, 1/8W	352245	89536	352245	REF		
R27	RES, MTL. FILM, 10.02K +/-0.1%, 1/8W	352245	89536	352245	REF		
R28	RES, MTL. FILM, 200 +/-0.1%, 1/8W	474262	91637	CMF552000B	1		
R29	RES, VAR, 1K +/-20%, 1/2W	267856	75378	190PC102B	2	1	
R30	RES, VAR, 1K +/-20%, 1/2W	267856	75378	190PC102B	REF		
R31	RES, VAR, 20K +/-20%, 1/2W	267898	75378	109PC203B	1	1	
R32	RES, MTL. FILM, 10 +/-10%, 1/8W	268789	91637	CMF55R100F	1		
R33	RES, COMP, 22M +/-5%, 1/4W	221986	01121	CB2265	1		
R34	RES, DEP. CAR, 3.3K +/-5%, 1/4W	348813	80031	CR251-4-5P3K3	REF		
R35	RES, DEP. CAR, 330 +/-5%, 1/4W	368720	80031	CR251-4-5P330E	2		
R37	RES, DEP. CAR, 100 +/-5%, 1/4W	348771	80031	CR251-4-5P100E	1		
R38	RES, MTL. FILM, 0.09K +/-1%, 1/8W	221663	91637	CMF559091F	1		
R39	RES, MTL. FILM, 1.02K +/-1%, 1/8W	223545	91637	CMF551021F	1		
R40	RES, MTL. FILM, 4.32K +/-1%, 1/8W	294819	91637	CMF554321F	1		
R41	RES, MTL. FILM, 10K +/-1%, 1/8W	168260	91637	CMF551002F	1		
R43	RES, COMP, 16K +/-5%, 1/4W	221606	01121	CB1635	1		
R44	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R45	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	3		
R46	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R47	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R48	RES, MTL. FILM, 150K +/-1%, 1/8W	241083	91637	CMF551503F	1		
R49	RES, MTL. FILM, 681K +/-1%, 1/8W	381517	91637	CMF556813F	1		
R50	RES, DEP. CAR, 47K +/-5%, 1/4W	348896	80031	CR251-4-5P47K	1		
R51	RES, MTL. FILM, 38.3K +/-1%, 1/8W	241372	91637	CMF553832F	1		
R52	RES, MTL. FILM, 133K +/-1%, 1/8W	289074	91637	CMF551333F	1		
R53	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R54	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	REF		
R55	RES, DEP. CAR, 5.1K +/-5%, 1/4W	368712	80031	CR251-4-5P5K1	1		

Table 5-2. A1 Main PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
R56	RES, MTL. FILM, 10.2K +/-1%, 1/8W	293605	91637	CMF551022F	1		
R57	RES, VAR, 200 +/-10%, 1/2W	275743	89536	275743	REF		
R58	RES, DEP. CAR, 51K +/-5%, 1/4W	376434	80031	CR251-4-5P51K	1		
R59	RES, DEP. CAR, 39K +/-5%, 1/4W	442400	80031	CR251-4-5P39K	2		
R60	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R61	RES, DEP. CAR, 470K +/-5%, 1/4W	342634	80031	CR251-4-5P470K	2		
R62	RES, DEP. CAR, 4.7K +/-5%, 1/4W	348821	80031	CR251-4-5P4K7	2		
R63	RES, DEP. CAR, 470K +/-5%, 1/4W	342634	80031	CR251-4-5P470K	REF		
R64	RES, DEP. CAR, 4.7K +/-5%, 1/4W	348821	80031	CR251-4-5P4K7	REF		
R65	RES, MTL. FILM, 309K +/-1%, 1/8W	235283	91637	CMF553093F	1		
R66	RES, DEP. CAR, 39K +/-5%, 1/4W	442400	80031	CR251-4-5P39K	REF		
R67	RES, MTL. FILM, 100K +/-1%, 1/8W	248807	91637	CMF551003F	1		
R68	RES, MTL. FILM, 64.9K +/-1%, 1/8W	288530	91637	CMF556492F	1		
R69	RES, MTL. FILM, 226K +/-1%, 1/8W	320879	91637	CMF552263F	1		
R70	RES, DEP. CAR, 330 +/-5%, 1/4W	368720	80031	CR251-4-5P330E	REF		
S1/S2	SWITCH ASSEMBLY	483891	89536	483891	1		
S3	SWITCH, SLIDE, DPDT	234278	82389	XW1649	2		
S4	SWITCH, SLIDE, DPDT	423129	89536	423129	1		
S5	SWITCH, SLIDE, DPDT	234278	82389	XW1649	REF		
T1	TRANSFORMER, PWR	464370	89536	464370	1		
T2	TRANSFORMER, INVERTER	461954	89536	461954	1		
TB1	TERMINAL BLOCK	479006	89536	479006	2		
TB2	TERMINAL BLOCK	479006	89536	479006	REF		
U1	IC, VOLTAGE COMPARATOR	352195	12040	LM311CN	1	1	
U2	IC, LINEAR OP-AMP	429837	12040	LF356H	1	1	
U3	Ⓐ IC, C-MOS, HEX, OPEN DRAIN BUFFERS	473389	12040	MM74C906N	1	1	
U5	RES, NETWORK, 47K	413286	89536	413286	1	1	
U6	IC, LINEAR, OP-AMP	472779	12040	LF3B6N	1	1	
U7	IC, LINEAR, OP-AMP	413740	12040	LM307N	1	1	
U8	IC, LINEAR, DUAL OP-AMP	478032	04713	MC4558NCP1	1	1	
U9	RES, NETWORK	448480	89536	448480	1	1	
U10	IC, LINEAR, OP-AMP	418566	12040	LM358N	1	1	
U11	IC, LINEAR, NEG VOL REG	413179	12040	LM340T-15	1	1	
U12	IC, LINEAR, VOL REF, RCD	413187	12040	402644	1	1	
U13	RES, NETWORK	402644	89536	402644	1	1	
U14	IC, LINEAR, QUAD, COMPARATOR	387233	12040	LM339N	1	1	
VR1	ZENER, REF, SET (VR1, R18, R19)	377283	89536	377283	1	1	
VR2	DIODE, ZENER	186163	07910	1N974B	2	1	
VR3	DIODE, ZENER	186163	07910	1N974B	REF		
XQ22	HEATSINK (NOT SHOWN)	428805	13103	6046PB	1		
XU3	SOCKET, IC, 14-PIN	370304	91506	314-AG39D	1		
XU4	SOCKET, IC, 40-PIN	418988	91506	340-AG39D	1		
Y1	CRYSTAL, QUARTZ	474072	89536	474072	1	1	

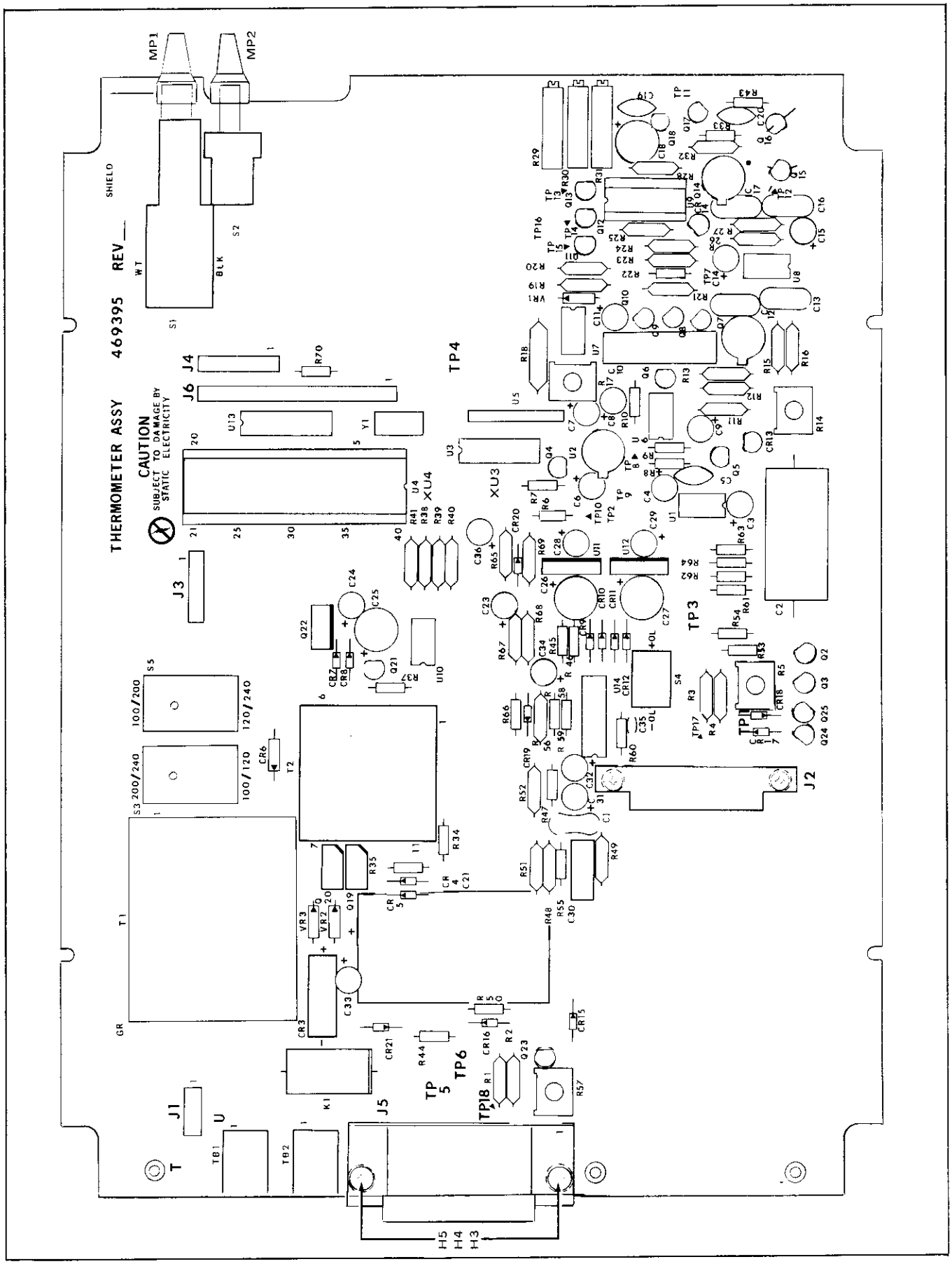


Figure 5-2. A1 Main PCB Assembly

Table 5-3. A2 Display PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A2	DISPLAY PCB ASSEMBLY FIGURE 5-3 (2190A-4002T)	464479	89536	464479	REF		
DS1	DIODE, LED DISPLAY, 7-SEGMENT, RED	418012	28480	5082-7651	6	2	
DS2	DIODE, LED DISPLAY, 7-SEGMENT, RED	418012	28480	5082-7651	REF		
DS3	DIODE, LED DISPLAY, 7-SEGMENT, RED	418012	28480	5082-7651	REF		
DS4	DIODE, LED DISPLAY, 7-SEGMENT, RED	418012	28480	5082-7651	REF		
DS5	DIODE, LED DISPLAY, 7-SEGMENT, RED	418012	28480	5082-7651	REF		
DS7	DIODE, LED DISPLAY, 7-SEGMENT, RED	418012	28480	5082-7651	REF		
MP1	DECAL, PART NO. (NOT SHOWN)	477042	89536	477042	1		
P6	CABLE, FLAT, 18 POS, 6-INCH	474411	00779	1-86947-7	1		
Q1	TRANSISTOR, SI, PNP	195974	04713	2N3906	13	3	
Q2	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q3	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q4	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q5	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q6	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q7	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q8	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q9	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q10	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q11	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q12	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
Q13	TRANSISTOR, SI, PNP	195974	04713	2N3906	REF		
R1	RES, DEP. CAR, 100 +/-5%, 1/4W	348771	80031	CR251-4-5P100E	2		
R2	RES, DEP. CAR, 100 +/-5%, 1/4W	348771	80031	CR251-4-5P100E	REF		
U1	IC, LIN, NPN, 5-TRANSISTOR ARRAY	418574	02735	CA3083E	1	1	
U2	RESISTOR NETWORK, 1K	407445	89536	407445	1	1	
U3	RESISTOR NETWORK, 82 OHM	478859	89536	478859	1	1	

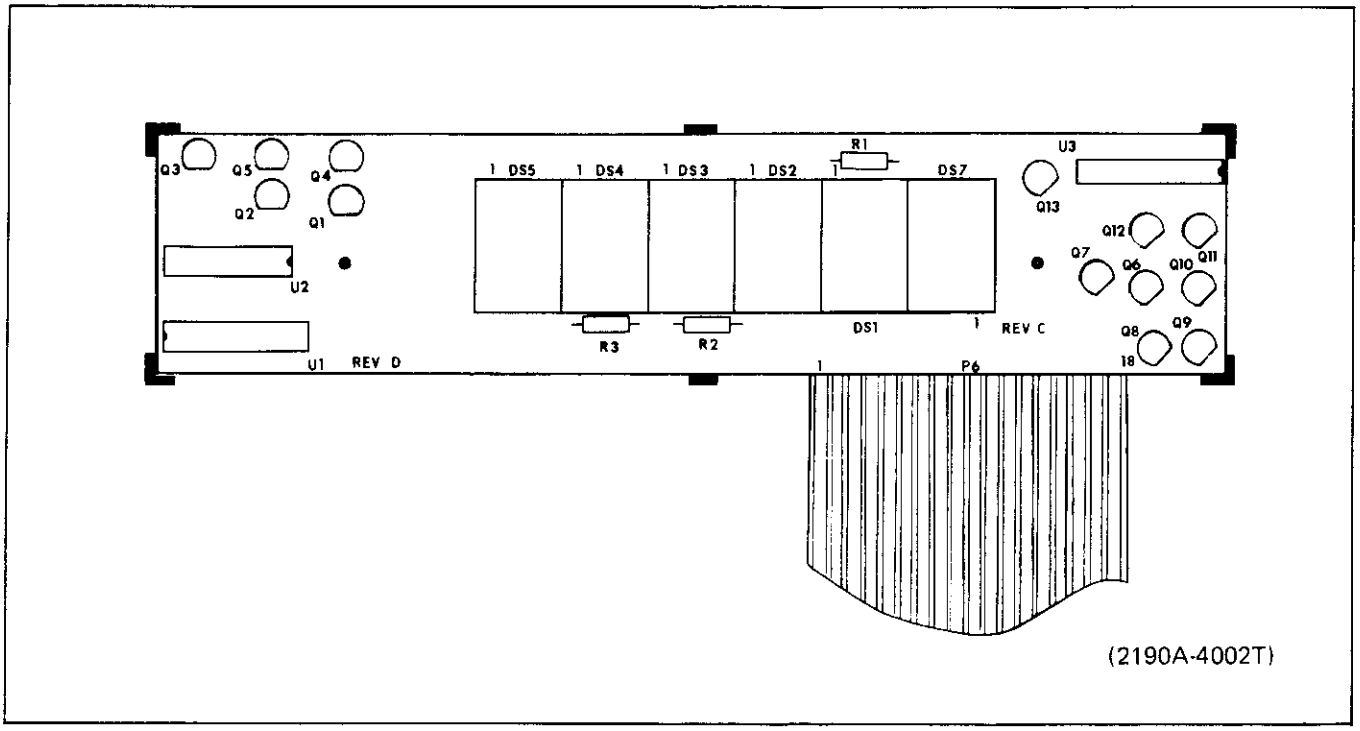


Figure 5-3. A2 Display PCB Assembly

Table 5-4. A3 Thermocouple Input PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A3	THERMOCOUPLE INPUT PCB ASSY FIGURE 5-4 (2190A-4003T)	469403	89536	469403	REF		
C1	CAP, POLYCARB, 2.2 UF +/-10%, 100V	306522	80031	C280MCH/A2M2	1		
C2	CAP, MICA, 100 PF +/-5%, 500V	148494	72136	DM15F101J	1		
C3	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0035JA1	2		
C4	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196D105X0035JA1	REF		
H1	P-NUT, BROACHING, 4-40	380196	24347	KF2-440	2		
H2	SCREW, SEMS, 4-40 X 3/8	281196	89536	281196	4		
H3	SCREW, PHP, 4-40 X 7/16	403782	73734	19025	2		
H4	SCREW, PHP, 6-32 X 1/4	152140	73734	19042	2		
H5	WASHER, FIBER, #4	110890	89536	110890	2		
	WASHER, SPLIT, #4	110395	89536	110395	2		
MP1	INSULATOR (NOT SHOWN)	473561	89536	473561	1		
MP2	INPUT DRAWER	464123	89536	464123	1		
MP3	NEGATIVE THERMOCOUPLE INPUT (NOT SHOWN)	472399	89536	472399	1		
MP4	POSITIVE THERMOCOUPLE INPUT (NOT SHOWN)	472381	89536	472381	1		
Q1	XSTR, SI, NPN	329698	12040	SM07042	1	1	
R1	RES, VAR, 50 K +/-10%, 1/2W	330688	75378	190PC503B	1	1	
R2	RES, MTL. FILM, 150K +/-1%, 1/8W	241083	91637	CMF551503F	1		
R4	RES, COMP, 47K +/-10%, 2W	110015	01121	HB4731	1		
S1	SWITCH, MODULE	408559	00779	435166-2	1		
U1	IC, LIN, NEG FIXED VOLTAGE REGULATOR	473819	12040	LN79L12ACZ	1		

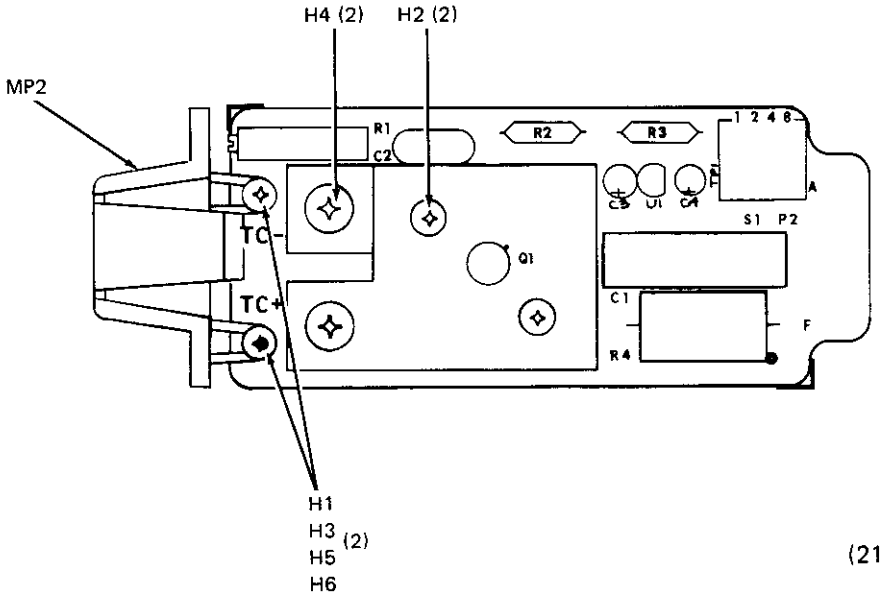


Figure 5-4. A3 Thermocouple Input PCB Assembly

Section 6
Option & Accessory Information

TABLE OF CONTENTS

6-1. INTRODUCTION

6-2. This section of the manual contains information on the accessories and options available for the 2190A Digital Thermometer.

6-3. ACCESSORY INFORMATION

6-4. The portion of this section dealing with accessories contains the details of all accessories available for the 2190A.

6-5. OPTION INFORMATION

6-6. Each of the options available for the 2190A are described separately in a subsection identified with the option name and number. The option description contains the information on the operating instructions and maintenance not covered in the main body of the text plus a complete list of replaceable parts for the option.

Accessories

600-1. GENERAL

600-2. Table 1-2 contains a list of the accessories available for use with the 2190A Digital Thermometer. The following paragraphs contain information on the types of accessories. Instructions for use accompany each accessory. In all cases, order using the accessory number listed.

600-3. MULTIPOINT SELECTOR, (Y2001)

600-4. The multipoint selector allows the operator to manually select and monitor one of up to ten channels. Two separate thermocouple types (maximum of five each if two types used) may be connected to the unit. Up to ten multipoint selectors may be connected in series.

600-5. ALARMS OUTPUT (Y2002)

600-6. The Alarms Output accessory provides controls to permit up to four separate limits settings, so that there is an operator indication at more than one temperature point. The four thumbwheel controls allow the simultaneous setting of a high and low in any combination.

600-7. CALIBRATOR, THERMOCOUPLE INDICATOR (Y2003)

600-8. This accessory, when used in conjunction with the 2190A, provides a variable output for calibration of less sensitive thermocouple devices than the 2190A. The 2190A display is controlled by the calibrator millivolt output (-10 to +90 mV dc) and the less sensitive thermometer may be adjusted to the 2190A displayed temperature. The Y2003 can perform remote calibrations using its self-contained battery pack as a source and can supply external power to the thermometer from this battery pack.

600-9. BATTERY PACK, 12V RECHARGEABLE (Y2009)

600-10. The rechargeable battery pack provides the 2190A and its accessories with portability. The output is +12V dc at a maximum of 750 mA for a total of 2.2 ampere-hours.

600-11. DIVIDER, THERMOMETER CALIBRATION (Y2022)

600-12. The device is a preset 100 to 1 divider to provide the precision millivolt outputs from a DC Calibrator required for calibration. The device wires into the Thermocouple Input PCB in place of the thermocouple probe during calibration. Refer to the Y2022 Instruction Manual for the schematic and additional information.

600-13. RACK PANELS

600-14. Available are rack mounting panels in three sizes and two types for the standard 19-inch electronics equipment racks. The "A" size for the multipoint selector is available in panels that will accomodate either one or two instruments. The "B" size panel for the calibrator and/or battery pack is also available for single or double instruments, as is the "C" size used for the 2190A Thermometer and the Alarms Output.

600-15. PANEL MOUNTS

600-16. The panel mounts provide the hardware to install the instrument in any panel in which a hole the size of the instrument front panel can be cut. It is available for the three instrument sizes required, "A", "B", and "C".

600-17. THERMOCOUPLE PROBES

600-18. Thermocouple probes are available from the John Fluke Mfg. Co., Inc. as determined by microcomputer type, see Table 1-3, Specifications.

600-19. ACCESSORY CASE (Y2023)

600-20. The accessory case is a "C" size PTI case which contains a storage drawer. This provides the operator that has several instruments in a stacked group, storage space for test equipment and spare and/or alternate thermocouple probes and wires.

600-21. POWER CORD, 3-WAY (Y2024)

600-22. This accessory is a specially constructed power cord with three female and one male connectors that allow the operator to connect up to "C" size or smaller PTI instruments with one line power cord.

600-23. CABLE OUTPUT UNIT, RS-232-C (Y2026)

600-24. The Y2026 is an interface device which allows direct mating between any RS-232-C device and the -002 Output Option. The Y2026 consists of: two 25-pin connectors, one 36-pin connector, and an accessory cable to provide connection between the 36-pin output and the -002 Output Option. It will be necessary for the user to provide the cable between the 25-pin outputs and the RS-232-C devices.

600-25. THERMOCOUPLE INPUT MODULE (Y2030)

600-26. The Y2030 is the thermocouple input module compatible with the 2190A Digital Thermometer only. Basically the Y2030 compensates for errors introduced by ambient temperature variations and allows the user to select the proper microcomputer program for the thermocouple type in use. For additional information and the schematic, please refer to the Model Y2030 Instruction Manual.

Option -002
Output

602-1. INTRODUCTION

602-2. The 21X0-002 Option is an analog and digital output unit. It provides either the 2180A or 2190A Model Thermometer with a recording output for a permanent record, when required. The option may be ordered with the unit for factory installation or is available as a kit for installation in the field.

602-3. The analog output is available on the rear panel at two flush banana jacks with the polarity indicated. The output is a scaled voltage source of 1 millivolt per degree of temperature, regardless of the temperature scale selected, with the polarity as read on the display. For example, a reading of 251°F would output +251 mV dc; 97.3°C would output +97.3 mV dc; and -31.9°F would output -31.9 mV dc.

602-4. The digital output is a clocked message that can be in two different formats to match the requirement of the customer's equipment. Output on one set of lines is a bit parallel, byte serial message format designed for printer interface. Also available are the standard EIA RS-232-C and current loop bit serial outputs. Both formats provide the channel number, the current reading displayed, and any out of range or open thermocouple information.

602-5. SPECIFICATIONS

602-6. Specifications for the Output Option, 21X0-002, are as listed in Table 602-1.

602-7. INSTALLATION

602-8. Options for field installation can be installed using the following procedure:

1. Disconnect the thermometer from all input power sources.

2. Remove the screws on the bottom of the case that fasten the top and bottom of the PTI case together and remove the top half of the case.

3. Remove the center mounting screw that attaches the Main PCB to the case and lift the pcb clear of the case.

4. Attach the four spacers supplied with the option to the component side of the pcb in the holes forming a rough rectangular pattern (do not use the fifth hole on the corner, next to U1).

Table 602-1. Specifications

Analog Output
- **Type:** Linearized and isolated.
- **Voltage:** 1.0 mV/ °C or °F from −425 mV to 4.5V, 5 mA max.
- **Temperature Coefficient:** 200 ppm/ °C from 25°C.
- **Noise:** ≤100 uV at 100 Hz bandwidth.
- **Accuracy:** ±0.1% of reading ±1 mV.
- **Zero Drift:** 200 uV/°C from 25°C,
- **Warm-Up Time:** 5 minutes, to rated accuracy.

Digital Output
- **Types:** Three, E.I.A. Standard RS-232-C Type 2, TTY current loop, and parallel ASCII.
- **Connector:** 36-pin AMP "Champ".
- **Serial Baud Rates:** 110, 150, 300, 600, 1200, 2400, 4800, 9600, switch-selectable.
- **RS-232-C Signals:** Transmitted Data, Request to Send, Clear to Send, Data Set Ready, Signal Common.
- **Parallel ASCII Signals:** Data 8 lines, instrument address 3 lines, Address Valid, Data Valid, Acknowledge, ground, +5V.
- **Parallel ASCII Data Rate:** Three readings per second.
- **Parallel ASCII Interface:** Plug-to-plug compatible with similar Fluke equipment.
- **TTY Current Loop Signals:** Source and controlled sink, 20 mA.
- **Out-of-Limit Signal:** Exclamation point transmitted with Option 21X0-006 only; not with Y2002.
- **Battery Operation:** 4 to 5 hours typical at 25°C on fully charged Y2003 or Y2009.

5. Reinstall the Main PCB in the bottom half of the case.

6. On the Output Unit PCB use Table 602-2 and S1 to select the desired baud rate, select position 0 on the Function switch S2, and select the PTI Bus Address using S3.

7. Connect the Output Unit cables to the connectors on the Main PCB.

8. Attach the Output Unit PCB to the spacers, component side down, and the connector to the rear panel access port.

9. Replace the PTI cover on the instrument and reconnect the input power sources, if required, at this time.

602-9. OUTPUT CONNECTIONS

602-10. All connections between the Output Unit Option and external instruments are made using the rear panel connectors previously described. The analog output is from standard banana jacks. The digital output female connector has a mating male connector accompanying the option. This allows the customer to custom make a cable between the thermometer output option and the receiving device. Table 602-3, is the pin-out data for the digital output connector.

NOTE

Standard RS-232-C signals are output on 25-pins, the connector on the -002 Output Option is 36-pins, therefore, the user must either hard wire the connection between the -002 Output Option or order the Y2026.

602-11. OPERATION

602-12. Once the Output Unit Option is installed the only operator functions deal with the connection of external equipment to the analog or digital output connectors.

602-13. The positive and negative analog terminals have available a dc millivolt output, with the same polarity, and proportional to the temperature displayed. For example, if the thermometer displayed +105.7°F the analog output would be +105.7 mV dc and for -53.1°C the output would be -53.1 mV dc. The full resolution of the temperature display (tenths or hundredths of degrees) is reflected on the output.

602-14. The digital output can be connected to a printer or any device accepting parallel ASCII data, or to a device accepting RS-232-C or Current Loop signals. Connections for all three types of signals are available simultaneously on the 36-pin output connector previously described.

602-15. THEORY OF OPERATION

602-16. The Output Unit Option converts the temperature displayed by the output into a format usable by the customer's equipment. The output may be available as a scaled analog voltage or as formatted parallel and serial ASCII digital output. The following paragraphs describe operation of the Accessory Bus that handles communication between the instrument and the options, the analog output circuitry and the digital output circuitry. Refer to the schematic in Section 8 during the following discussion.

602-17. Accessory Bus Communication

602-18. The option communicates with the thermometer on the clocked bit serial accessory bus. Transmitted on the bus are channel number, range,

Table 602-2. Switch Selection

SWITCH POSITION	SWITCH BANK				S1 BAUD RATE	S2 FUNCTION	S3 ADDRESS
	1	2	3	4			
0	OFF	OFF	OFF	OFF	110	OPERATE	ADR 0
1	ON	OFF	OFF	OFF	150	CAL 1	ADR 1
2	OFF	ON	OFF	OFF	300	CAL 2	ADR 2
3	ON	ON	OFF	OFF	600	CAL 3	ADR 3
4	OFF	OFF	ON	OFF	1200	CAL 4	ADR 4
5	ON	OFF	ON	OFF	2400	CAL 1	ADR 5
6	OFF	ON	ON	OFF	4800	CAL 2	ADR 6
7	ON	ON	ON	OFF	9600	CAL 3	ADR 7
8	OFF	OFF	OFF	ON	110	PLOT 1	ADR 8
9	ON	OFF	OFF	ON	150	PLOT 2	ADR 9

conversion type, scale, and digits of the temperature reading. When the $\overline{\text{WRTADR}}$ line is held low, $\overline{\text{DCLK}}$ clocks the address of the Output Unit (4) followed by the thermometer data to the microcomputer on the $\overline{\text{DATA}}$ line. Once into the microcomputer, the data is converted, formatted, and output to the analog and digital output circuitry.

Table 602-3. Digital Output Connector Pin-Out

PIN NO.	FUNCTION	MNEMONIC	USE
1	Address Valid	ADRVAL	PTI Bus
2	Data Valid	DATVAL	PTI Bus
3-6	Printer Address	A0-A3	PTI Bus
7	Acknowledge	ACK	PTI Bus
8	Not Used		
9-16	Data	D0-D7	PTI Bus
17	Ground		PTI Bus
18	+5 Volts		PTI Bus
19-24	Not Used		
30	Transmitted Data		RS232 Interface
31	Request to send		RS232 Interface
32	Clear to send		RS232 Interface
33	Data set ready		RS232 Interface
34	Signal Common		RS232 Interface
35	S0+		Current Loop
36	S0-		Current Loop

602-19. Analog Circuitry

602-20. The temperature reading received by the microcomputer is used to generate an integrate control signal, the length of which is proportional to the magnitude of the temperature reading. This signal is used to turn on (close) the FET switches Q6 and U12-2, open the switches U11-2, U11-3 and U12-3, and set the output polarity with switches at U12-9 and U12-10. (U12-9 is closed when a negative reading is being processed and U12-10 when a positive signal is being processed.)

602-21. With Q6 on, the capacitor C1 is charged linearily to a voltage proportional to the length of the control signal at Q6. When Q6 has been on for the time required, it is opened, and switch U11-13 is closed, so the output of U13-8 can be sampled and held on C2. After 10 ms, switch U11-3 opens and switch U11-11 closes to zero the integrate capacitor C1, until the next conversion cycle.

602-22. The voltage held on C2 is buffered by U13-7. U13-14 either passes the voltage directly to the output stage, or amplifies it by -1 as controlled by switches U12-9 and U12-10 which alternate states to set the polarity. The output stage at U13-1 has a constant gain of -1.

602-23. Digital Output Circuitry

602-24. The thermometer reading transmitted on the accessory bus every 333 ms is formatted by the microcomputer and, if requested, made available on the Parallel ASCII PTI Bus, RS-232-C, and current loop outputs. Refer to the schematics in Section 8 during the following description.

602-25. Eight data, four address, a data valid, an address valid, and an acknowledge line are used by the Parallel ASCII PTI Bus interface. The external device requests data from the Output Unit by applying the preselected address to the address lines. The address is preselected by setting switch S3 to the desired number (0-9). When the proper address is decoded the tri-state output buffers (U8 and U9) are enabled, and the microcomputer and external device notified that the Output Unit has a valid address. When the conversion process is complete, the microcomputer applies the first character of the formatted data to the output lines and pulls the $\overline{\text{DATVAL}}$ line low. The external device reads the data and pulls the $\overline{\text{ACK}}$ line low, causing the Output Unit to reply with a new character. The process is repeated until data transfer is complete. The message formats are shown in Figure 602-1.

602-26. After transfer to the printer lines is complete, the microcomputer checks the DATA SET READY and CLEAR TO SEND lines from the RS-232-C interface. If both lines are high, the same message as was output on the print lines, is output on the RS-232-C and current loop lines in a bit serial format. Since the thermometer cycle rate of 333 ms is shorter than the time required to output data at baud rate of 1200 and less, a message is not transmitted during every instrument cycle.

602-27. CALIBRATION

602-28. Analog circuitry in the option should be calibrated every 90 days or after any repair of the unit. The procedure following assumes that power is supplied to the unit and that a digital voltmeter capable of reading 10 μV on the 1 volt, or equivalent range, i.e., a Fluke Model 8800A, is available.

1. Remove power from the instrument.

2. Remove the top cover from the thermometer.

3. Remove the screws attaching the option pcb to the Main PCB.

4. Leaving the interconnect cables connected, turn the option pcb to the right, while facing the instrument, exposing the component side and making the switches and adjustments accessible.

5. Connect the DMM to the Analog Output Connector.

6. Apply power to the instrument and allow if to warm-up for a minimum of 5 minutes.

7. Set the FUNCTION switch (S2) to position 1 (CAL 1).

8. Adjust R26 for an output of 0 ±0.1 mV dc.

9. Set the FUNCTION switch to position 2 (CAL 2).

10. Adjust R26 for an output of 0 ±0.1 mV dc.

11. Set FUNCTION switch to position 3 (CAL 3).

12. Adjust R11 for an output of −10V ±1 mV dc.

13. Set FUNCTION switch to position 4 (CAL 4).

14. Adjust R19 for an output of +10V ±1 mV dc.

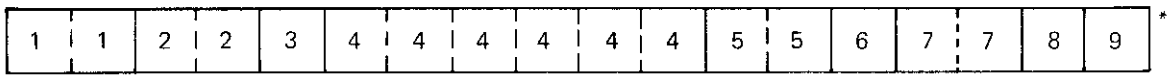
15. Remove power and the test DMM, then reinstall the option pcb on the Main PCB and the top cover on the instrument.

602-29. TROUBLESHOOTING

602-30. Troubleshooting for the 2190A Option -002, Output Unit, consists of the tabular flow chart in Table 602-4. When a step on the flow chart is completed, check for a decision transfer. If no decision is required, perform the next step of the table in sequence.

602-31. LIST OF REPLACEABLE PARTS

602-32. Table 602-5 is a list of replaceable parts for the Output Option. Refer to Section 5 for an explanation of the columnar entries.



1 Two digit channel number

2 Two blanks

3 Sign – plus or minus

4 Five Digit Numeric with a decimal point for tenths

5 Two character temperature scale. Either °C or °F on PTI Bus and either blank C or blank F on RS 232C, the degree symbol (°) is transmitted to the printer as a "d".

6 Character "!" when preset limits are exceeded. One blank if signal within limits

7 Two character display – "OL" for overload, "OC" for open circuit or open thermocouple or two blanks if operating normally

8 Carriage return

9 Line Feed

NOTE

This eighteen character message can be sent as: ASCII parallel, RS232C, or Current Loop.

*Each block represents one ASCII character. The parity bit is always sent as zero.

Figure 602-1. Message Format

Table 602-4. Output Option Troubleshooting

STEP NO.	ACTION	Go to the step number given for correct response	
		YES	NO
	NOTE *These tests are based on the assumption that the 2180A/2190A has been thoroughly checked out and is free of troubles prior to beginning the test of the Output Option –002.*		
1	Obtain a reading on the 2190A (the input can be shorted for a display of approximately the ambient temperature).		
2	Is the Output option's analog output equal to the 1 mV per degree specified?	16	3
3	From pin 20 (common isolated) on U7 is there +5 volts to pin 40 of U7, +15 volts to pin 4 of U13, and –15 volts to pin 11 of U13?	5	4
4	Check for a 12V dc input at P1 pins 1 and 4, an≈20 kHz squarewave from T1 pin 8 to pins 7 and 9, >5.5V at the emitter of Q12, >17.5V at the input of U19, and more negative than –17.5V dc at the input of U20. Repair as required then resume at step 1.		
5	Are the signals at pins 24, 25, and 38 of U7 toggling (vary between a logic high and logic low)?	7	6
6	Check the input, cabling and U1 if all signals are absent. Check the individual line's components if one is absent. Repair as required then resume at step 1.		
7	Are the signals at pins 10 through 15 of U7 toggling?	9	8
8	Check U7 and its clock input from Y1 (4 MHz and opposite in phase from common to pin 1 and 2). Repair as required then resume at step 1.		
9	Are the following signals on U6 as stated: pins 5 and 11 toggling; pins 1 and 3 opposite, and reverse when the output sign is changed; pin 13 low except in CAL 1 position; and pin 9 varying with the length of charge time?	11	10
10	Check U5 and U6. Repair as required then resume at step 1.		
11	Is the signal at the gate of FET switch Q6 toggling between common and –15V?	13	12
12	Check Q14, CR17 and their associated components. Repair as required then resume at step 1.		
13	Perform the Output Option Calibration procedure.		
14	Are all points adjustable within the stated tolerance?	16	15
15	Check the components associated with each adjustment. Since the ICs U11, U12, and U13 are multi-parts units they effect all circuits. Repair as required then resume at step 1.		
16	Obtain a reading and vary the BAUD rate selection switch through its range while observing the output at each BAUD rate setting.		
17	Is the data transmitted correctly at all BAUD rates?	34	18
18	Is the data transmitted correctly at one or more BAUD rates?	19	20
19	Check the BAUD rate selection switch S1. Repair as required then resume at step 16.		
20	Are CLEAR TO SEND (CTS) and DATA SET READY (DSR) at U7-8 and U7-9 respectively at a logic low?	22	21

Table 602-4. Output Option Troubleshooting (cont)

STEP NO.	ACTION	Go to the step number given for correct response	
		YES	NO
	NOTE *This is with a receiving device attached. If not attached tie pins 32 and 33 of J7 high to simulate an accepting device.*		
21	Check the interface from the RS232C device, Q8, Q9 and their associated components. Repair as required then resume at step 16.		
22	Is the signal at pin 3 of U7 toggling?	24	23
23	Check U7. Repair as required then resume at step 16.		
24	Does the signal at pin 30 of J7 in reference to pin 34 of J7 toggle while a message is transmitted?	26	25
25	Check Q4, Q5, U18, and their associated components. Repair as required then resume at step 16.		
26	Is the output data available on the PTI Bus?	26	27
27	Is the signal at U10-6 low?	29	28
28	Verify that the input address and address switch setting are the same. Check the address decoding circuit in U10, U16, U17, U15, U21, S3 and their associated components. Repair as required then resume at step 26.		
29	Is $\overline{\text{ADRVAL}}$ low at pin 1 of J7?	31	30
30	Check the tri-state buffer U8 and it's enabling signal. Repair as required then resume at step 26.		
31	Do the $\overline{\text{DATVAL}}$, $\overline{\text{ACK}}$ and D0 through D7 signals on pins 2, 7, and 9 through 16 of J7 respectively toggle?	33	32
32	Check the tri-state buffers U8 and U9, the microcomputer U7, and the $\overline{\text{ACK}}$ input from the PTI Bus. Since the RS232C output has already been checked, the input to U7 has been verified. Repair as required then resume at step 26.		
33	Check the connector, interconnecting cable and receiving device. Repair as required then resume at step 26.		
34	Troubleshooting of the Output Option is complete.		

Table 602-5. A4 Output Option PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
002	⊘ OUTPUT OPTION-002 PCB ASSEMBLY FIGURE 602-2 (2180A-4020T)	-002	89536	2190A-002	REF		
C1	CAP, POLYSTRN, 0.56 UF +/-10%, 100V	284851	89536	284851	1		
C2	CAP, POLYPRPLN, 0.47 UF +/-10%, 50V	363085	89536	363085	1		
C3	CAP, CER, 0.22 UF +/-20%, 50V	309849	71590	CW30C224K	1		
C4	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	8		
C5	CAP, TA, 39 UF +/-20%, 20V	358234	56289	196D396X0020PE4	1		
C6	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C7	CAP, TA, 22 UF +/-20%, 35V	394775	56289	196D226X0035TE4	2		
C8	CAP, TA, 22 UF +/-20%, 35V	394775	56289	196D226X0035TE4	REF		
C9	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C10	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C11	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C12	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196105X0035JA1	2		
C13	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C14	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C15	CAP, TA, 10 UF +/-20%, 20V	330662	56289	196D106X0020KA1	REF		
C16	CAP, TA, 1 UF +/-20%, 35V	161919	56289	196105X0035JA1	REF		
C17	CAR, CER, 0.025 UF +/-20%, 100V	168435	56289	C023B10H253M	1		
CR1	DIODE, ZENER	393579	07910	1N4567	1	1	
CR3	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	10	2	
CR4	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR5	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR6	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR7	DIODE, ZENER, 36V	186163	07910	1N974B	2	1	
CR8	DIODE, ZENER, 36V	186163	07910	1N974B	REF		
CR9	DIODE, SI, RECTIFIER	379412	04713	1N4933	2	1	
CR10	DIODE, SI, RECTIFIER	379412	04713	1N4933	REF		
CR11	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR12	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR13	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR14	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR15	DIODE, ZENER, 6.2V	325811	07910	1N752A	1	1	
CR16	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
CR17	DIODE, SI, HI-SPEED SWITCH	203323	07910	1N4448	REF		
H1	SCREW, PHP, 4-40 X 3/8 (NOT SHOWN)	152124	73734	19024	2		
H2	LOCKWASHER (NOT SHOWN)	110395	89536	110395	2		
H3	NUT, HEXAGON (NOT SHOWN)	147611	89536	147611	2		
H4	HARDWARE KIT (FOR J7)	435750	00779	552565-1	1		
J7	CONNECTOR	414409	00779	552241-1	1		
J8	JACK, INPUT	492314	89536	492314	2		
P1	CABLE, JUMPER	474148	00779	86942-3	1		
P3	CABLE, JUMPER	474155	00779	86942-5	1		
Q1	TRANSISTOR, SI, NPN	218396	04713	2N3904	8	2	
Q2	TRANSISTOR, SI, NPN	218396	04713	2N3904	REF		
Q3	TRANSISTOR, SI NPN	218396	04713	2N3904	REF		
Q4	TRANSISTOR, SI, NPN	218396	04713	2N3904	REF		
Q5	TRANSISTOR, SI, NPN	218396	04713	2N3904	REF		
Q6	TRANSISTOR, FET, N-CHANNEL	429977	89536	429977	1	1	
Q7	TRANSISTOR, FET, N-CHANNEL	343830	89536	343830	1	1	

Table 602-5. A4 Output Option PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
Q8	TRANSISTOR, SI, NPN	218396	04713	2N3904	REF		
Q9	TRANSISTOR, SI, NPN	218396	04713	2N3904	REF		
Q10	TRANSISTOR, SI, NPN, PWR	477331	04713	MDS01A	REF		
Q11	TRANSISTOR, SI, NPN, PWR	477331	04713	MDS01A	REF		
Q12	TRANSISTOR, SI, PNP, PWR	473207	01295	T1P30	1	1	
Q13	TRANSISTOR, SI, NPN	218396	04713	2N3904	REF		
Q14	TRANSISTOR, SI, PNP	195974	04713	2N3906	1	1	
R1	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	12		
R2	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R3	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R4	RES, DEP. CAR, 220K +/-5%, 1/4W	348953	80031	CR251-4-5P220K	3		
R5	RES, DEP. CAR, 2.2K +/-5%, 1/4W	343400	80031	CR251-4-5P2K2	4		
R6	RES DEP. CAR, 220K +/-5%, 1/4W	348953	80031	CR251-4-5P220K	REF		
R7	RES, DEP. CAR, 2.2K +/-5%, 1/4W	343400	80031	CR251-4-5P2K2	REF		
R8	RES, DEP. CAR, 220K +/-5%, 1/4W	348953	80031	CR251-4-5P220K	REF		
R9	RES, DEP. CAR, 2.2K +/-5%, 1/4W	343400	80031	CR251-4-5P2K2	REF		
R10	RES, MTL. FILM, 16.9K +/-1%, 1/8W	267146	91637	CMF551692F	1		
R11	RES, VAR, 25K +/-20%, 1/2W	285213	75378	190PC2538	1	1	
R12	RES, MTL. FILM, 102K +/-1%, 1/8W	291286	91637	CMF551023F	1		
R13	RES, MTL. FILM, 2K +/-1%, 1/8W	235226	91637	CMF552001F	1		
R14	RES, MTL. FILM, 750K +/-1%, 1/8W	271361	91637	CMF55751F	2		
R15	RES, VAR, 100K +/-20%, 1/2W	268581	75378	190PC104B	2	1	
R16	RES, MTL. FILM, 60.4K +/-1%, 1/8W	291419	91637	CMF556042F	2		
R17	RES, MTL. FILM, 60.4K +/-1%, 1/8W	291419	91637	CMF556042F	REF		
R18	RES, MTL. FILM, 3.92K +/-1%, 1/8W	294801	91637	CMF553921F	2		
R19	RES, VAR, 100 +/-10%, 1/2W	275735	11236	360T-101A	1		
R20	RES, MTL. FILM, 3.92K +/-1%, 1/8W	294801	91637	CMF553921F	REF		
R21	RES, MTL. FILM, 10K +/-1%, 1/8W	168360	91637	CMF551002F	3		
R22	RES, MTL. FILM, 10K +/-1%, 1/8W	168360	91637	CMF551002F	REF		
R23	RES, DEP. CAR, 100 +/-5%, 1/4W	348771	80031	CR251-4-5P100E	2		
R24	RES, MTL. FILM, 750K +/-1%, 1/8W	271361	91637	CMF55751F	REF		
R25	RES, MTL. FILM, 1K +/-1%, 1/8W	168229	91637	CMF551001F	1		
R26	RES, VAR, 100K +/-20%, 1/2W	268581	75378	190PC104B	REF		
R27	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R28	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R29	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R30	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R31	RES, DEP. CAR, 2.2K +/-5%, 1/4W	343400	80031	CR251-4-5P2K2	REF		
R32	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R33	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R34	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R35	RES, DEP. CAR, 5.1K +/-5%, 1/4W	368712	80031	CR251-4-5P5K1	1		
R36	RES, DEP. CAR, 47K +/-5%, 1/4W	348896	80031	CR251-4-5P47K	1		
R37	RES, DEP. CAR, 240 +/-5%, 1/4W	376624	80031	CR251-4-5P240E	1		
R38	RES, DEP. CAR, 3.9K +/-5%, 1/4W	342600	80031	CR251-4-5P3K9	1		
R39	RES, DEP. CAR, 6.8K +/-5%, 1/4W	368761	80031	CR251-4-5P6K8	2		
R40	RES, DEP. CAR, 4.3K +/-5%, 1/4W	441576	80031	CR251-4-5P4K3	1		
R41	RES, DEP. CAR, 6.8K +/-5%, 1/4W	368761	80031	CR251-4-5P6K8	REF		
R42	RES, DEP. CAR, 3.3K +/-5%, 1/4W	348813	80031	CR251-4-5P3K3	1		
R43	RES, DEP. CAR, 330 +/-5%, 1/4W	368720	80031	CR251-4-5P330E	1		

Table 602-5. A4 Output Option PCB Assembly (cont)

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
R44	RES, MTL. FILM, 1.02K +/-1%, 1/8W	223545	91637	CMF551021F	1		
R45	RES, MTL. FILM, 10K +/-1%, 1/8W	168360	91637	CMF551002F	REF		
R46	RES, MTL. FILM, 9.09K +/-1%, 1/8W	221663	91637	CMF559091F	1		
R47	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R48	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R49	RES, MTL. FILM, 4.32K +/-1%, 1/8W	294819	91637	CMF554321F	1		
R50	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R51	RES, DEP. CAR, 39K +/-5%, 1/4W	442400	80031	CR251-4-5P39K	1		
R52	RES, MTL. FILM, 100K +/-1%, 1/8W	248807	91637	CMF551003F	1		
R53	RES, MTL. FILM, 64.9K +/-1%, 1/8W	288530	91637	CMF556492F	1		
R54	RES, MTL. FILM, 226K +/-1%, 1/8W	320879	91637	CMF552263F	1		
R55	RES, MTL. FILM, 309K +/-1%, 1/8W	235283	91637	CMF553093F	1		
S1	SWITCH MODULE, SPST	408559	00779	435166-2	3		
S2	SWITCH MODULE, SPST	408559	00779	435166-2	REF		
S3	SWITCH MODULE, SPST	408559	00779	435166-2	REF		
T1	TRANSFORMER, DC-DC CONV	461954	89536	461954	1		
U1	Ⓐ IC, C-MOS, HEX BUFFER/INVERTER	381830	04713	MC14050CP	1	1	
U2	OPTO-ISOLATOR	380014	01295	T1L116	3	1	
U3	OPTO-ISOLATOR	380014	01295	T1L116	REF		
U4	OPTO-ISOLATOR	380014	01295	T1L116	REF		
U5	RES, NETWORK	413286	89536	413286	1	1	
U6	Ⓐ IC, C-MOS, HEX, OPEN DRAIN BUFFERS	473389	12040	MM74C906N	1	1	
U7	Ⓐ IC, MICROPROCESSOR, MOS	495309	04713	MC3870/14	1	1	
U8	Ⓐ IC, C-MOS, TRI-STATE, HEX, NON-INV BUFF	407759	04713	MC14503CP	2	1	
U9	Ⓐ IC, C-MOS, TRI-STATE, HEX, NON-INV BUFF	407759	04713	MC14503CP	REF		
U10	Ⓐ IC, C-MOS, HEX INVERTERS	404681	04713	MC1406BCP	1	1	
U11	Ⓐ IC, C-MOS, QUAD, BI-LATERAL SW	363838	02735	CD4016AE	2	1	
U12	Ⓐ IC, C-MOS, QUAD, BI-LATERAL SW	363838	02735	CD4016AE	REF		
U13	IC, LINEAR, OP-AMP, J-FET INPUT	483438	89536	483438	1	1	
U14	TRANSISTOR, J-FET, N-CHANNEL	460014	89536	460014	1	1	
U15	RES, NETWORK	412726	89536	412726	2	1	
U16	Ⓐ IC, C-MOS, QUAD, EXCLUSIVE OR	355222	02735	CD4030AE	1	1	
U17	Ⓐ IC, C-MOS, DUAL 4-INPUT, NOR GATE	363820	04713	MC14025CP	1	1	
U18	IC, LINEAR, OP-AMP, J-FET INPUT	454454	89536	454454	1	1	
U19	IC, LINEAR, VOL REG, FXD	413187	04713	MC7815CP	1	1	
U20	IC LINEAR, NEG, VOL REG	413179	04713	MC7915CT	1	1	
U21	RES, NETWORK	412726	89536	412726	REF		
U22	IC, LINEAR, LO-PWR DUAL VOL COMP	478354	12040	LM393N	1	1	
XU7	SOCKET, IC, 40-PIN	418988	91506	340-AG39D	1		
XU14	SOCKER, IC, 8-PIN	478016	91506	308-AG39D	1		
Y1	CRYSTAL	474072	89536	474072	1		

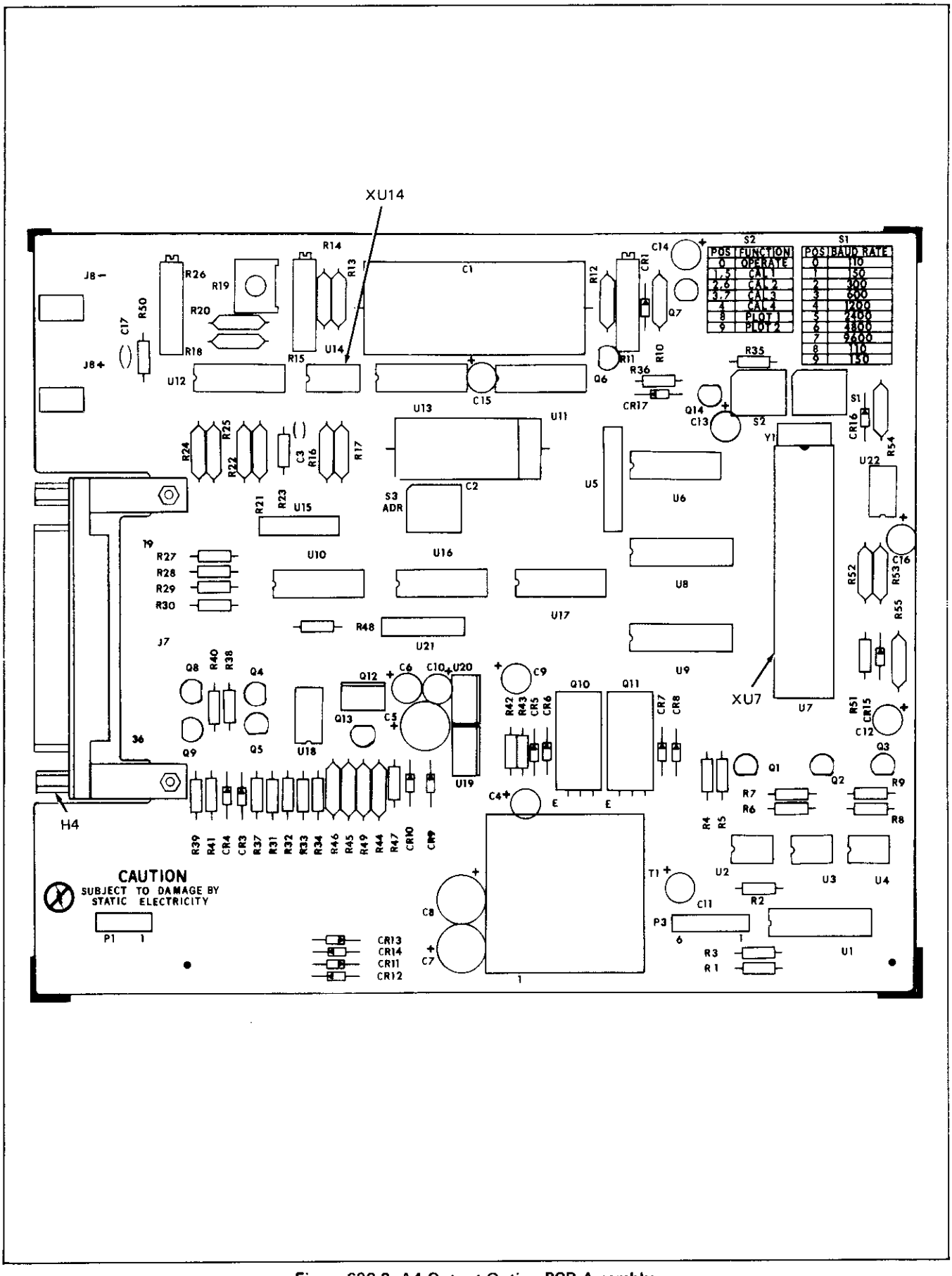


Figure 602-2. A4 Output Option PCB Assembly

Option -006
Limits

606-1. INTRODUCTION

606-2. The 21X0-006 Limits Option gives the 2180A and 2190A Digital Thermometers the capability of providing both visual and electrical indications (alarms) when the temperature measurement exceeds either of a pair of selectable maximum/minimum limit values. Also selectable are, all for a single point, the delta function (displays the difference between the preset value and the temperature read), and the maximum/minimum display function (the highest or lowest temperature read since the last reset by the INITIALIZE MAX/MIN switch).

606-3. The Limits Option is available as factory installed with initial order or may be ordered as a field installable kit for addition to the instrument.

606-4. SPECIFICATIONS

606-5. Specifications for the Limits Option, 21X0-006, are as listed in Table 606-1.

Table 606-1. Specifications

Limits Function: lights LED and activates Form A (SPST) relay when a preset limit is exceeded. Contacts rated at 10 VA, 184V dc or 130V ac rms max, 0.5A max, resistive.
Min/Max Function: Store min or max readings, resettable from front panel.
△ **Temperature Function:** Reads ± temperature deviations from preset nominal temperature.
Installable: Factory or field, through pre-punched front panel.

Function:	Limit:
≤ Low Limit	−9999°
> High Limit	+9999°
Store min reading	Not used
Store max reading	Not used
△ ± Deviation from	Nominal

606-6. INSTALLATION

606-7. Options for field installation can be installed using the following procedure:

WARNING

HAZARDOUS VOLTAGES MAY BE PRESENT WITHIN THE INSTRUMENT. ONLY QUALIFIED PERSONNEL SHOULD PERFORM THIS INSTALLATION PROCEDURE.

1. Disconnect the thermometer from all power sources.

2. Remove the screws on the bottom of the case that fasten the top and bottom of the PTI case together and remove the top half of the case.

3. Remove the hole plugs from the Limits section of the front panel and attach the standoffs supplied with the option to the front panel.

4. Position the Limits PCB so that the thumbwheel LED and pushbutton switch line up with the applicable front panel ports.

5. Attach the Limits PCB to the Main PCB using the screws supplied with the option.

6. Connect the cable on the Limits PCB to J4 on the Main PCB.

7. Replace the PTI cover on the instrument and reconnect to input power sources, if required at this time.

606-8. OPERATING NOTES

606-9. Installation of the Limits Option enables the low current single contact relay (K1) on the thermometer Main PCB. The contact points are available on a rear panel connector block.

NOTE

Once installed there are no provisions for disabling the Limits Option. If a temperature display is desired without the relay or LED indications select one of the Limits Functions (> or ≠) and the maximum setting on the numeric thumbwheel switches.

606-10. OPERATION

606-11. The position and general description of the Limits Option front panel controls is given in Section 2. A more detailed description of the three functions is given in the following paragraphs.

606-12. Limits Function

606-13. The limits function is enabled when the function portion of the thumbwheel is set in either the ≤ or > position. The front panel LED illuminates and the rear panel relay contacts close when either of the preset conditions are met. In the greater than (>) function the indications (LED and relay contacts) result from any temperature reading that exceeds the value set on the limit thumbwheel. The less than (≤) function gives its indication when the temperature read by the thermometer is equal to, or less than, the value set on the limit thumbwheels. The thumbwheel LSD is a whole number, fractional entries cannot be made.

606-14. Delta Function

606-15. When the delta (Δ) function is selected on the thumbwheel the thermometer display reads the difference between the temperature at the thermocouple and the whole number setting of the thumbwheels. The formula used for the computation is:

T displayed = T at thermocouple - T thumbwheel setting (in degrees)

606-16. MINIMUM/MAXIMUM Display Function

606-17. The microcomputer acculmulates and stores the highest and lowest temperatures recorded since the last reset. When the maximum (⤒) function is selected the highest temperature recorded and stored in the microcomputer is displayed. Selection of the minimum function (⤓) displays the lowest recorded temperature since the last reset. To record the current temperature for either function, select the applicable function and depress the front panel reset switch.

606-18. THEORY OF OPERATION

606-19. The -006 Option supplies the thermometer with the function and numeric data selected on the front panel mechanical thumbwheel switches. When a Limits function is selected the data is stored for comparison on the option pcb. All communication between the option and the thermometer is done on the clocked serial accessory bus. This bus transmits and receives addresses, thumbwheel data, reset data, and limit status. Refer to the schematic in Section 8 during the Theory of Operation discussion.

606-20. Addressing

606-21. Each of the options on the bus is addressed with a different code. The thermometer uses the address "6" to talk to the Limits Option. To talk to any option, the $\overline{\text{WRTADR}}$ (P4-3) line must be brought low with $\overline{\text{WRT}}$ (P4-4) high, followed by the applicable four address bits applied to the $\overline{\text{DATA}}$ (P4-5) line in succession, toggling $\overline{\text{DCLK}}$ (P4-6) for each bit. This clocks the address into the shift register (U2-15) where it is compared to the Limits Option address and, if valid, (U1-1 low) enables the gates required to shift data to the thermometer (U5-11) and into the limits option (U5-2). Details of the data transfer are in subsequent paragraphs.

606-22. Limits Option Outputs

606-23. Before the thermometer can input data from the Limits Option the Limits circuitry must be addressed as described previously (U1-1 low). Once addressed, the $\overline{\text{WRTADR}}$ and $\overline{\text{WRT}}$ lines go high. The low to high transition of $\overline{\text{WRTADR}}$ (U3-6) loads the shift registers from the thumbwheel and RESET switches. The two lines enable the output data line (U1-13) and as the the thermometer accepts the data it clocks the serial output shift registers with $\overline{\text{DCLK}}$, transferring the data from the shift register to the thermometer.

606-24. In the thermometer the data is processed by the microcomputer to perform the proper action. For the limits function, the output is compared to the state of the limits and, if exceeded, the indicator illuminated and the relay energized. For the delta function, the temperature is compared against the transmitted value and the difference displayed. If either the maximum or minimum function is selected the stored value is displayed, but, in addition, the status of the RESET switch is checked.

606-25. Limits Option Inputs

606-26. The thermometer transmits to the Limits Option only the limits exceeded status. After the option

has been addressed, (U1-1) $\overline{\text{WRTADR}}$ goes high to disable the addressing circuit (U4-13), while $\overline{\text{WRT}}$ stays low to enable the limits exceeded input (U5-8) so that $\overline{\text{DCLK}}$ can clock the data into the latch (U5-1). A limits exceeded indication clocks a high into the latch resulting in a low at the output (U6-12) to turn on CR1. The limits not exceeded or another function selected, loads a low into the latch to turn off the indicator.

606-27. CALIBRATION

606-28. The Limits Option has no variable components and does not require calibration.

606-29. TROUBLESHOOTING

606-30. Troubleshooting for the 2190A Option -006, Limits, consists of the tabular flow chart in Table 606-2. When a step on the flow chart is completed, check for a decision transfer. If no decision is required, perform the next step of the table in sequence.

606-31. LIST OF REPLACEABLE PARTS

606-32. Table 606-3 is a list of replaceable parts for the Limits Option. Refer to Section 5 for an explanation of the columnar entries.

Table 606-2. Limits Option Troubleshooting

STEP NO.	ACTION	Go to the step number given for correct response	
		YES	NO
	NOTE *These tests are based on the assumption that the 2180A/2190A has been thoroughly checked out and is free of troubles prior to beginning the test of the Limits Option –006.*		
1	Select the less than or equal function (≤) and set the thumbwheels for a numeric such that the thermocouple input exceeds the preset numeric (e.g., thumbwheels set at +1111 and the ambient temperature used as the thermocouple input).		
2	Does the LIMIT indicator illuminate and the rear panel relay contacts close?	26	3
3	Is the +5V dc input from the Main PCB present?	5	4
4	Check the +5 Vdc input, repair as required then resume at Step 1.		
5	Does the signal at U1-1 toggle (vary between logic high and logic low) when viewed with a scope?	13	6
6	Do the $\overline{\text{WRT}}$, $\overline{\text{WRTADR}}$ and $\overline{\text{DCLK}}$ lines toggle?	8	7
7	Check the inputs on the cable from the microcomputer on the Main PCB. Repair as required then resume at Step 1.		
8	Does the $\overline{\text{DATA}}$ line toggle?	10	9
9	Check the cabling and Q1, Q2, U3-8 and their associated components. Repair as required then resume at Step 1.		
10	Are the clock and data signals present at pins 1 and 15 of U2, respectively?	12	11
11	Check U1, U2-2, 11, 12, 13 and U3. Repair as required then resume at Step 1.		
12	Check U4 for the clock and U6 for loading of the data line. Repair as required then resume at Step 1.		
13	Is the function code (≤) a BCD 0 with pins 4, 5, and 6 of U7 low, the sign (+) at U7-7 high, the numeric MSD BCD code as set at pins 1, 15, 14 and 13 of U9, the second MSD BCD code as set at pins 4, 5, 6, and 7 of U11?	15	14
14	Check the switches and their associated components. Reapir as required then resume at Step 1.		
15	Is the clock present at U7-10, U9-10, and U11-10?	17	16
16	Check U4-10, U1-13 and their inputs. Repair as required then resume at Step 1.		

Table 606-2. Limits Option Troubleshooting (cont)

STEP NO.	ACTION	Go to the step number given for correct response	
		YES	NO
17	Does the signal at U11-3, U9-3, and U7-3 toggle?	19	18
18	Check U11, U9, and U7. Repair as required then resume at Step 1.		
19	Does the $\overline{\text{DATA}}$ line toggle?	21	20
20	Check Q1, Q2, U3, U5-10 and their associated components. Repair as required then resume at Step 1.		
21	Are the clock and data signals present at pins 11 and 9 of U6, respectively?	23	22
22	Check U5 for the clock, repair as required then resume at Step 1.		
23	Is the collector of Q9 low?	25	24
24	Check Q9, Q3, U6-12 and their associated components. Repair as required then resume at Step 1.		
25	Check the indicator CR1 and the relay on the Main PCB. Repair as required then resume at Step 1.		
26	Set the FUNCTION switch to greater than (>) and input a temperature from the thermocouple that exceeds the preset limit.		
27	Does the LIMIT indicator illuminate and the relay contacts close?	29	28
28	Check for a Function BCD code of 1 (001) at pins 4, 5, and 6 of U7. The sign at U7-7 is high for plus and low for minus. Check that the thumbwheel switches reflect the BCD codes set on them. Repair as required then resume at Step 1.		
29	Set the FUNCTION switch to the Delta (△) position and set the thumbwheels to the desired base.		
30	Is the difference between the thermocouple input and the preset base displayed?	32	31
31	Check for a Function of BCD code of 2 (010) at pins 4, 5, and 6 of U7. Check that the thumbwheel switches reflect the BCD codes set on them. Repair as required then resume at Step 29.		
32	Set the FUNCTION switch to the minimum (⤓) position and depress the INITIALIZE MIN/MAX switch.		
33	Does the thermometer display reflect the lowest temperature input from the thermocouple since the switch was depressed?	35	34
34	Check for a Function BCD code of 3 (011) at pins 4, 5, and 6 of U7. Check U2-4 and 5, U4-3 and 4, U6-1, the initialize switch S7 and their associated components. Repair as required then resume at Step 32.		
35	Set the FUNCTION switch to the MAXIMUM (⤒) position and depress the INITIALIZE MIN/MAX switch.		
36	Does the thermometer display reflect the highest temperature input from the thermocouple since the switch was depressed?	38	37
37	Check for a Function BCD code of 4 (100) at pins 4, 5, and 6 of U7. Repair as required then resume at Step 35.		
38	Troubleshooting of the 21X0-006 Limits Option is complete.		

Table 606-3. A5 Limits Option PCB Assembly

REF DES	DESCRIPTION	FLUKE STOCK NO.	MFG SPLY CODE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
006	Ⓟ LIMITS OPTION-006 PCB ASSEMBLY FIGURE 606-3 (2180A-4060T)	-006	89536	2190A-006	REF		
CR1	LED, RED	385914	09214	SSL-22	1	1	
MP1	LED, STANDOFF ASSY (NOT SHOWN)	472548	89536	472548	1		
P4	CABLE	474379	00779	86946-6	1		
Q1	TRANSISTOR, SI, PNP	195974	04713	2N3906	1	1	
Q2	TRANSISTOR, SI, NPN	218396	04713	2N3904	3	1	
Q3	TRANSISTOR, SI, NPN	218396	04713	2N3904	REF		
Q9	TRANSISTOR, SI, NPN	218396	04713	2N3904	REF		
R1	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	6		
R2	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R3	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R4	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R5	RES, DEP. CAR, 100K +/-5%, 1/4W	348920	80031	CR251-4-5P100K	1		
R6	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R7	RES, DEP. CAR, 240 +/-5%, 1/4W	376624	80031	CR251-4-5P240E	1		
R8	RES, DEP. CAR, 10K +/-5%, 1/4W	348839	80031	CR251-4-5P10K	REF		
R9	RES, DEP. CAR, 20K +/-5%, 1/4W	441477	80031	CR251-4-5P20K	1		
R10	RES, DEP. CAR, 2.2K +/-5%, 1/4W	343400	80031	CR251-4-5P2K2	1		
S1-6	THUMBWHEEL SWITCH ASSEMBLY	472803	89536	472803	1		
S7-1	PUSHBUTTON, BLUE (NOT SHOWN)	472332	89536	4723322	1		
S7-2	SWITCH COVER (NOT SHOWN)	401299	89536	401299	1		
S7-3	SWITCH ACTUATOR (NOT SHOWN)	412106	89536	412106	1		
S7-4	SWITCH SPRING (NOT SHOWN)	414516	00779	62312	1		
S7-5	SWITCH CONTACT (NOT SHOWN)	416875	00779	62313	1		
U1	Ⓟ IC, C-MOS, DUAL 4-INPUT, POS NAND GATE	355206	04713	MC14012CP	1	1	
U2	Ⓟ IC, C-MOS, DUAL 4-BIT STATIC SHIFT RESTR	340125	04713	MC14015BCP	1	1	
U3	Ⓟ IC, C-MOS, HEX INVERTER	404681	04713	MC1406BCP	1	1	
U4	Ⓟ IC, C-MOS, 3-INPUT, INV NOR GATE	355172	04713	MC14001CP	1	1	
U5	Ⓟ IC, C-MOS, 3-INPUT, NOR GATE	355180	04713	MC14025CP	1	1	
U6	Ⓟ IC, C-MOS, DUAL, D-TYPE F/F	340117	04713	MC14013CP	1	1	
U7	Ⓟ IC, C-MOS, 8-STAGE, STATIC SHIFT REGSTR	380766	12040	MM5621AN	3	1	
U8	RES, NETWORK, 100K	412908	89536	412908	3	1	
U9	Ⓟ IC, C-MOS, 8-STAGE, STATIC SHIFT REGSTR	380766	12040	MM5621AN	REF		
U10	RES, NETWORK, 100K	412908	89536	412908	REF		
U11	Ⓟ IC, C-MOS, 8-STAGE, STATIC SHIFT REGSTR	380766	12040	MM5621AN	REF		
U12	RES, NETWORK, 100K	412908	89536	412908	REF		

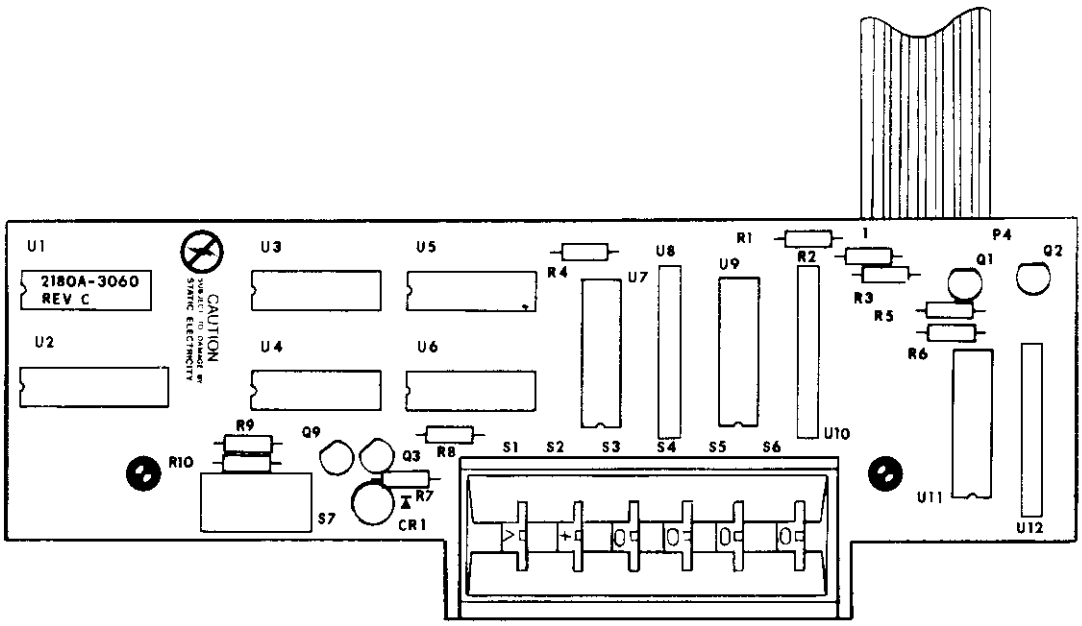


Figure 606-1. A5 Limits Option PCB Assembly

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

U.S. SALES AREAS for all Fluke products

AK, Anchorage
Harry Lang & Associates
1371 Hillcrest Drive #303
Anchorage, AK 99503
(907) 279-5741

AL, Huntsville
John Fluke Mfg. Co., Inc.
3322 S. Memorial Parkway
Suite 96
Huntsville, AL 35801
(205) 881-6220

AZ, Tempe
John Fluke Mfg. Co., Inc.
2125 S. 48th Street
Suite 104
Tempe, AZ 85282
(602) 967-8724

Tucson
(602) 790-9881

CA, Los Angeles
John Fluke Mfg. Co., Inc.
20902 South Bonita St.
Carson, CA 90746
(213) 538-3900
or (714) 761-2449

San Diego
John Fluke Mfg. Co., Inc.
9601 Aero Drive, Suite 290
San Diego, CA 92123
(714) 226-1254

Santa Clara
John Fluke Mfg. Co., Inc.
2300 Walsh Ave., Bldg. K
Santa Clara, CA 95051
(408) 727-0513

Tustin
John Fluke Mfg. Co., Inc.
15445 Red Hill Ave., Suite F
Tustin, CA 92680
(714) 838-8863

CO, Denver
John Fluke Mfg. Co., Inc.
1980 South Quebec St. #4
Denver, CO 80231
(303) 750-1222

CT, Hartford
John Fluke Mfg. Co., Inc.
Glen Locken East
41-C New London Turnpike
Glastonbury, CT 06033
(203) 659-3541

FL, Orlando
John Fluke Mfg. Co.,Inc.
940 N. Fern Creek Ave.
Orlando, FL 32803
(305) 896-4881

GA, Atlanta
John Fluke Mfg. Co., Inc.
2700 Delk Rd., Suite 250
Marietta, GA 30067
(404) 953-4747

HI, Honolulu
EMC Corporation
2979 Ualena St.
Honolulu, HI 96819
(808) 836-1138

IA, Iowa City
(319) 354-2811

IL, Chicago
John Fluke Mfg. Co., Inc.
3740 Industrial Ave.
Rolling Meadows, IL 60008
(312) 398-0850

IN, Indianapolis
John Fluke Mfg. Co., Inc.
877 Purdue
Suite 101
Indianapolis, IN 46268
(317) 875-7870

KS, Kansas City
John Fluke Mfg. Co., Inc.
4550 W. 109th St., Suite 130
Shawnee Mission, KA 66211
(913) 381-9800

LA, New Orleans
(504) 455-0814

MA, Burlington
John Fluke Mfg. Co., Inc.
25 "B" Street
Burlington MA 01803
(617) 273-4674

MD, Baltimore
(301) 792-7060

Rockville
John Fluke Mfg. Co., Inc.
5640 Fishers Lane
Rockville, MD 20852
(301) 770-1570

MI, Detroit
John Fluke Mfg. Co., Inc.
13955 Farmington Rd.
Livonia, MI 48154
(313) 522-9140

MN, Bloomington
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1801 E. 79th St., Suite 9
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Tel: 637944, 239052
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Fluke S.A. (Pty) Ltd.
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Traco Electronic AG
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Schmidt Scientific Far East Ltd.
Tel: 5414600
TLX: 11111 Schmidt

Thailand, Bangkok
Measuretronix Ltd.
Tel: 3143369, 3143430
TLX: 81143 DEJOBKK TH

Turkey, Istanbul
Erkman Elektronik Aletler
Tel: (01) 5461
TLX: 23353

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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 with an X.

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

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

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	469395	●	●	●	●	X																		
A2	Display PCB Assembly	464479	●	●	●	X																			
A3	Thermocouple PCB Assembly	464461	●	●	●	●	1	X																	
A4	Output Option PCB Assembly	469320	●	●	●	●	X																		
A5	Limits Option PCB Assembly	469338	●	●	●	●	●	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 #1, ECO-12061

On page 5-14, Table 5-4, make the following changes:

DELETE: C3, C4/Cap, TA, 1.0 uF ±20%, 2 kV DC/161919/56289/196D105X0035JA1/2

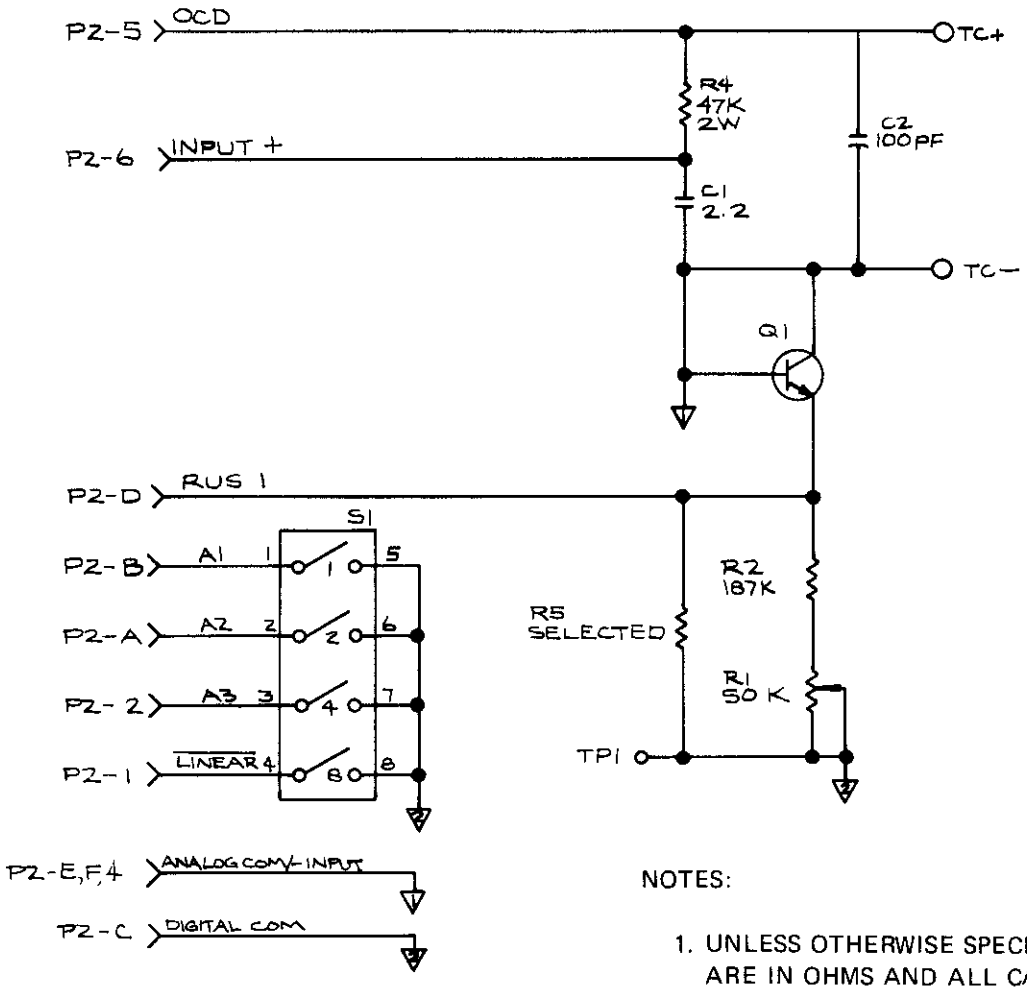
DELETE: U1/IC, Linear/473819/04713/MC79L12ACP/1

FROM: R2/Res, Mtl. Film, 150k ±1%, 1/8W/241083/91637/CMF551503F/1
TO: R2/Res, Mtl. Film, 187k ±1%, 1/8W/291641/91637/CMF551873F/1

On page 5-14 and 8-8, A3 Thermocouple Input PCB Assembly, make the following changes:

DELETE: C3, C4, and U1.

On page 8-9, replace Figure 8-3, A3 Thermocouple Input PCB Assembly (cont), with the following:



NOTES:

1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCES ARE IN OHMS AND ALL CAPACITANCES ARE IN MICROFARADS.
2. ALL RESISTORS ARE ¼W, 5% UNLESS OTHERWISE NOTED.
3. ALL GRAPHIC SYMBOLS ARE IN ACCORDANCE WITH ANSI Y32.2 AND Y32.14.
4. ▽ DENOTES ANALOG COMMON.
   ▽2 DENOTES DIGITAL COMMON. DIGITAL COMMON IS −15V WITH RESPECT TO ANALOG COMMON.

Section 7B
Thermocouple Reference Tables

Table 7B-1. Thermocouple Reference Tables

Temperature in °C, Reference Junction at 0°C

°C	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	0.000	−0.000	−0.000	0.001	−0.001	−0.001	−0.001	0.001	−0.002	−0.002	−0.002
10	−0.002	0.002	−0.002	−0.002	0.002	−0.002	0.002	−0.002	0.003	−0.003	−0.003
20	−0.003	0.003	−0.003	−0.003	−0.003	−0.002	−0.002	−0.002	0.002	−0.002	−0.002
30	−0.002	−0.002	−0.002	0.002	−0.002	0.001	−0.001	0.001	−0.001	−0.001	−0.000
40	−0.000	−0.000	−0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002
50	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.006
60	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.010	0.010	0.011	0.011
70	0.011	0.012	0.012	0.013	0.014	0.014	0.015	0.015	0.016	0.017	0.017
80	0.017	0.018	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.024	0.025
90	0.025	0.026	0.026	0.027	0.028	0.029	0.030	0.031	0.031	0.032	0.033

Temperature in °F, Reference Junction at 32°F

°F	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.004	0.004	0.004
10	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002
20	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000
30	0.000	0.000	0.000	0.000	−0.000	0.000	−0.001	−0.001	0.001	−0.001	−0.001
40	−0.001	−0.001	0.001	0.001	−0.001	0.001	−0.002	−0.002	0.002	−0.002	−0.002
50	−0.002	0.002	0.002	−0.002	0.002	−0.002	0.002	0.002	−0.002	−0.002	0.002
60	0.002	−0.002	−0.002	−0.003	0.003	0.003	−0.003	−0.003	0.003	0.003	−0.003
70	−0.003	0.003	0.003	0.003	−0.003	0.003	−0.003	0.002	−0.002	−0.002	−0.002
80	−0.002	0.002	0.002	0.002	−0.002	0.002	−0.002	0.002	−0.002	−0.002	−0.002
90	0.002	0.002	−0.002	−0.002	−0.002	−0.001	0.001	−0.001	0.001	0.001	−0.001
100	0.001	0.001	−0.001	−0.001	0.000	−0.000	0.000	−0.000	0.000	0.000	0.000
110	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002
120	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.004	0.004
130	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006
140	0.006	0.006	0.007	0.007	0.007	0.007	0.008	0.008	0.008	0.009	0.009

TYPE

B

Platinum -6% Rhodium
vs
Platinum -30% Rhodium

Table 7B-1. Thermocouple Reference Tables (cont)

Temperature in °F, Reference Junction at 32°F

°F	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS									
0°	−.234	−.227	−.220	−.213	−.206	−.198	−.191	−.184	.177	−.169
10°	−.162	−.155	−.148	−.140	.133	.126	−.118	−.111	−.104	−.096
20°	−.089	−.082	−.074	−.067	−.060	−.052	−.045	−.037	−.030	−.023
30°	−.015	−.008	.000	.007	.014	.022	.029	.037	.044	.052
40°	.059	.067	.074	.082	.089	.097	.104	.112	.120	.127
50°	.135	.142	.150	.157	.165	.173	.180	.188	.196	.203
60°	.211	.218	.226	.234	.241	.249	.257	.264	.272	.280
70°	.288	.295	.303	.311	.319	.326	.334	.342	.350	.357
80°	.365	.373	.381	.389	.396	.404	.412	.420	.428	.436
90°	.443	.451	.459	.467	.475	.483	.491	.499	.506	.514

TYPE C*

Tungsten -5% Rhenium vs Tungsten -26% Rhenium

*Not an ANSI Standard

Temperature in °C, Reference Junction at 0°C

°C	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
−40	−2.254	−2.308	−2.362	−2.416	−2.469	−2.522	−2.575	−2.628	−2.681	−2.734	−2.787
−30	−1.709	−1.764	−1.819	−1.874	−1.929	−1.983	−2.038	−2.092	−2.146	−2.200	−2.254
−20	−1.151	−1.208	−1.264	−1.320	−1.376	−1.432	−1.487	−1.543	−1.599	−1.654	−1.709
−10	−0.581	−0.639	−0.696	−0.754	−0.811	−0.868	−0.925	−0.982	−1.038	−1.095	−1.151
0	0.000	−0.059	−0.117	−0.176	−0.234	−0.292	−0.350	−0.408	0.466	−0.524	0.581
0	0.000	0.059	0.118	0.176	0.235	0.295	0.354	0.413	0.472	0.532	0.591
10	0.591	0.651	0.711	0.770	0.830	0.890	0.950	1.011	1.071	1.131	1.192
20	1.192	1.252	1.313	1.373	1.434	1.495	1.556	1.617	1.678	1.739	1.801
30	1.801	1.862	1.924	1.985	2.047	2.109	2.171	2.233	2.295	2.357	2.419
40	2.419	2.482	2.544	2.607	2.669	2.732	2.795	2.858	2.921	2.984	3.047
50	3.047	3.110	3.173	3.237	3.300	3.364	3.428	3.491	3.555	3.619	3.683
60	3.683	3.748	3.812	3.876	3.941	4.005	4.070	4.134	4.199	4.264	4.329
70	4.329	4.394	4.459	4.524	4.590	4.655	4.720	4.786	4.852	4.917	4.983
80	4.983	5.049	5.115	5.181	5.247	5.314	5.380	5.446	5.513	5.579	5.646
90	5.646	5.713	5.780	5.846	5.913	5.981	6.048	6.115	6.182	6.250	6.317

TYPE E

Nickel - Chromium vs Copper - Nickel

Table 7B-1. Thermocouple Reference Tables (cont)

TYPE E — Nickel - Chromium vs Copper - Nickel

Temperature in °F. Reference Junction at 32°F

°F	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	−1.026	−0.994	−0.963	−0.931	−0.900	0.868	−0.836	−0.805	0.773	−0.741	−0.709
10	−0.709	−0.677	−0.645	−0.613	0.581	−0.549	−0.517	0.485	−0.453	−0.421	0.389
20	−0.389	−0.357	−0.324	−0.292	−0.260	−0.227	0.195	−0.163	−0.130	−0.098	−0.065
30	−0.065	−0.033	0.000	0.033	0.065	0.098	0.131	0.163	0.196	0.229	0.262
40	0.262	0.295	0.327	0.360	0.393	0.426	0.459	0.492	0.525	0.558	0.591
50	0.591	0.624	0.658	0.691	0.724	0.757	0.790	0.824	0.857	0.890	0.924
60	0.924	0.957	0.990	1.024	1.057	1.091	1.124	1.158	1.192	1.225	1.259
70	1.259	1.292	1.326	1.360	1.394	1.427	1.461	1.495	1.529	1.563	1.597
80	1.597	1.631	1.665	1.699	1.733	1.767	1.801	1.835	1.869	1.903	1.937
90	1.937	1.972	2.006	2.040	2.075	2.109	2.143	2.176	2.212	2.247	2.281
100	2.281	2.316	2.350	2.385	2.419	2.454	2.489	2.523	2.558	2.593	2.627
110	2.627	2.662	2.697	2.732	2.767	2.802	2.837	2.872	2.907	2.942	2.977
120	2.977	3.012	3.047	3.082	3.117	3.152	3.187	3.223	3.258	3.293	3.329
130	3.329	3.364	3.399	3.435	3.470	3.506	3.541	3.577	3.612	3.648	3.683
140	3.683	3.719	3.755	3.790	3.826	3.862	3.898	3.933	3.969	4.005	4.041

TYPE J — Iron vs Copper - Nickel

Temperature in °C. Reference Junction at 0°C

°C	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
−40	−1.960	−2.008	−2.055	−2.102	−2.150	−2.197	−2.244	−2.291	−2.338	−2.384	−2.431
−30	−1.481	−1.530	−1.578	−1.626	−1.674	−1.722	−1.770	−1.818	−1.865	−1.913	−1.960
−20	−0.995	−1.044	−1.093	−1.141	−1.190	−1.239	−1.288	−1.336	−1.385	−1.433	−1.481
−10	−0.501	−0.550	−0.600	−0.650	−0.699	−0.748	−0.798	−0.847	−0.896	−0.945	−0.995
0	0.000	−0.050	−0.101	−0.151	−0.201	−0.251	−0.301	−0.351	−0.401	−0.451	−0.501
0	0.000	0.050	0.101	0.151	0.202	0.253	0.303	0.354	0.405	0.456	0.507
10	0.507	0.558	0.609	0.660	0.711	0.762	0.813	0.865	0.916	0.967	1.019
20	1.019	1.070	1.122	1.174	1.225	1.277	1.329	1.381	1.432	1.484	1.536
30	1.536	1.588	1.640	1.693	1.745	1.797	1.849	1.901	1.954	2.006	2.058
40	2.058	2.111	2.163	2.216	2.268	2.321	2.374	2.426	2.479	2.532	2.585
50	2.585	2.638	2.691	2.743	2.796	2.849	2.902	2.956	3.009	3.062	3.115
60	3.115	3.168	3.221	3.275	3.328	3.381	3.435	3.488	3.542	3.595	3.649
70	3.649	3.702	3.756	3.809	3.863	3.917	3.971	4.024	4.078	4.132	4.186
80	4.186	4.239	4.293	4.347	4.401	4.455	4.509	4.563	4.617	4.671	4.725
90	4.725	4.780	4.834	4.888	4.942	4.996	5.050	5.105	5.159	5.213	5.268

TYPE J — Iron vs Copper - Nickel

Temperature in °F. Reference Junction at 32°F

°F	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	−0.885	−0.858	−0.831	0.803	−0.776	0.748	0.721	0.694	0.666	0.639	−0.611
10	−0.611	0.583	−0.556	−0.528	0.501	−0.473	−0.445	−0.418	−0.390	−0.362	0.334
20	0.334	−0.307	−0.279	−0.251	0.223	−0.195	0.168	−0.140	0.112	0.084	−0.056
30	−0.056	−0.028	0.000	0.028	0.056	0.084	0.112	0.140	0.168	0.196	0.224
40	0.224	0.253	0.281	0.309	0.337	0.365	0.394	0.422	0.450	0.478	0.507
50	0.507	0.535	0.563	0.592	0.620	0.648	0.677	0.705	0.734	0.762	0.791
60	0.791	0.819	0.848	0.876	0.905	0.933	0.962	0.990	1.019	1.048	1.076
70	1.076	1.105	1.134	1.162	1.191	1.220	1.248	1.277	1.306	1.335	1.363
80	1.363	1.392	1.421	1.450	1.479	1.507	1.536	1.565	1.594	1.623	1.652
90	1.652	1.681	1.710	1.739	1.768	1.797	1.826	1.855	1.884	1.913	1.942
100	1.942	1.971	2.000	2.029	2.058	2.088	2.117	2.146	2.175	2.204	2.233
110	2.233	2.263	2.292	2.321	2.350	2.380	2.409	2.438	2.467	2.497	2.526
120	2.526	2.555	2.585	2.614	2.644	2.673	2.702	2.732	2.761	2.791	2.820
130	2.820	2.849	2.879	2.908	2.938	2.967	2.997	3.026	3.056	3.085	3.115
140	3.115	3.145	3.174	3.204	3.233	3.263	3.293	3.322	3.352	3.381	3.411

Table 7B-1. Thermocouple Reference Tables (cont)

TYPE JDIN*
Iron vs Copper - Nickel

Temperature in °C. Reference Junction at 0°C

°C	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	0.00	0.05	0.10	0.16	0.21	0.26	0.31	0.36	0.42	0.47	0.52
10	0.52	0.57	0.63	0.68	0.73	0.78	0.84	0.89	0.94	1.00	1.05
20	1.05	1.10	1.16	1.21	1.26	1.31	1.37	1.42	1.47	1.53	1.58
30	1.58	1.63	1.69	1.74	1.79	1.84	1.90	1.95	2.00	2.06	2.11
40	2.11	2.16	2.22	2.27	2.33	2.38	2.43	2.49	2.54	2.60	2.65
50	2.65	2.70	2.76	2.81	2.87	2.92	2.97	3.03	3.08	3.14	3.19
60	3.19	3.24	3.30	3.35	3.41	3.46	3.51	3.57	3.62	3.68	3.73
70	3.73	3.78	3.84	3.89	3.95	4.00	4.05	4.11	4.16	4.22	4.27
80	4.27	4.32	4.38	4.43	4.49	4.54	4.60	4.65	4.71	4.77	4.82
90	4.82	4.87	4.93	4.98	5.04	5.09	5.15	5.20	5.26	5.32	5.37

*European Standard

TYPE K
Nickel - Chromium vs Nickel - Aluminum

Temperature in °C. Reference Junction at 0°C

°C	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
−40	−1.527	−1.563	−1.600	−1.636	−1.673	−1.709	1.745	1.781	1.817	1.853	−1.889
−30	−1.156	−1.193	−1.231	−1.268	−1.305	−1.342	1.379	1.416	1.453	1.490	−1.527
−20	−0.777	−0.816	−0.854	−0.892	−0.930	−0.968	−1.005	−1.043	−1.081	−1.118	−1.156
−10	−0.392	−0.431	−0.469	−0.508	−0.547	−0.585	−0.624	−0.662	−0.701	−0.739	−0.777
0	0.000	−0.039	−0.079	−0.118	−0.157	−0.197	−0.236	−0.275	−0.314	−0.353	−0.392
0	0.000	0.039	0.079	0.119	0.158	0.198	0.238	0.277	0.317	0.357	0.397
10	0.397	0.437	0.477	0.517	0.557	0.597	0.637	0.677	0.718	0.758	0.798
20	0.798	0.838	0.879	0.919	0.960	1.000	1.041	1.081	1.122	1.162	1.203
30	1.203	1.244	1.285	1.325	1.366	1.407	1.448	1.489	1.529	1.570	1.611
40	1.611	1.652	1.693	1.734	1.776	1.817	1.858	1.899	1.940	1.981	2.022
50	2.022	2.064	2.105	2.146	2.188	2.229	2.270	2.312	2.353	2.394	2.436
60	2.436	2.477	2.519	2.560	2.601	2.643	2.684	2.726	2.767	2.809	2.850
70	2.850	2.892	2.933	2.975	3.016	3.058	3.100	3.141	3.183	3.224	3.266
80	3.266	3.307	3.349	3.390	3.432	3.473	3.515	3.556	3.598	3.639	3.681
90	3.681	3.722	3.764	3.805	3.847	3.888	3.930	3.971	4.012	4.054	4.095

Temperature in °F. Reference Junction at 32°F

°F	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	−0.692	−0.671	0.650	0.628	−0.607	−0.585	0.564	0.543	−0.521	−0.500	−0.478
10	−0.478	−0.457	−0.435	0.413	0.392	0.370	0.349	0.327	−0.305	−0.284	−0.262
20	−0.262	−0.240	−0.218	−0.197	−0.175	−0.153	−0.131	−0.109	0.088	0.066	−0.044
30	−0.044	−0.022	0.000	0.022	0.044	0.066	0.088	0.110	0.132	0.154	0.176
40	0.176	0.198	0.220	0.242	0.264	0.286	0.308	0.331	0.353	0.375	0.397
50	0.397	0.419	0.441	0.464	0.486	0.508	0.530	0.553	0.575	0.597	0.619
60	0.619	0.642	0.664	0.686	0.709	0.731	0.753	0.776	0.798	0.821	0.843
70	0.843	0.865	0.888	0.910	0.933	0.955	0.978	1.000	1.023	1.045	1.068
80	1.068	1.090	1.113	1.135	1.158	1.181	1.203	1.226	1.248	1.271	1.294
90	1.294	1.316	1.339	1.362	1.384	1.407	1.430	1.452	1.475	1.498	1.520
100	1.520	1.543	1.566	1.589	1.611	1.634	1.657	1.680	1.703	1.725	1.748
110	1.748	1.771	1.794	1.817	1.839	1.862	1.885	1.908	1.931	1.954	1.977
120	1.977	2.000	2.022	2.045	2.068	2.091	2.114	2.137	2.160	2.183	2.206
130	2.206	2.229	2.252	2.275	2.298	2.321	2.344	2.367	2.390	2.413	2.436
140	2.436	2.459	2.482	2.505	2.528	2.551	2.574	2.597	2.620	2.643	2.666

Table 7B-1. Thermocouple Reference Tables (cont)

TYPE R
Platinum vs Platinum -13% Rhodium

Temperature in °C, Reference Junction at 0°C

°C	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	0.000	0.005	0.011	0.016	0.021	0.027	0.032	0.038	0.043	0.049	0.054
10	0.054	0.060	0.065	0.071	0.077	0.082	0.088	0.094	0.100	0.105	0.111
20	0.111	0.117	0.123	0.129	0.135	0.141	0.147	0.152	0.158	0.165	0.171
30	0.171	0.177	0.183	0.189	0.195	0.201	0.207	0.214	0.220	0.226	0.232
40	0.232	0.239	0.245	0.251	0.258	0.264	0.271	0.277	0.283	0.290	0.296
50	0.296	0.303	0.310	0.316	0.323	0.329	0.336	0.343	0.349	0.356	0.363
60	0.363	0.369	0.376	0.383	0.390	0.397	0.403	0.410	0.417	0.424	0.431
70	0.431	0.438	0.445	0.452	0.459	0.466	0.473	0.480	0.487	0.494	0.501
80	0.501	0.508	0.515	0.523	0.530	0.537	0.544	0.552	0.559	0.566	0.573
90	0.573	0.581	0.588	0.595	0.603	0.610	0.617	0.625	0.632	0.640	0.647

Temperature in °F, Reference Junction at 32°F

°F	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	-0.089	-0.087	-0.084	-0.082	-0.079	-0.076	-0.073	-0.071	-0.068	-0.065	-0.063
10	0.063	-0.060	-0.057	-0.054	-0.051	-0.049	-0.046	-0.043	-0.040	-0.037	-0.035
20	-0.035	0.032	0.029	-0.026	-0.023	0.020	0.017	-0.015	-0.012	-0.009	-0.006
30	0.006	-0.003	0.000	0.003	0.006	0.009	0.012	0.015	0.018	0.021	0.024
40	0.024	0.027	0.030	0.033	0.036	0.039	0.042	0.045	0.048	0.051	0.054
50	0.054	0.057	0.060	0.064	0.067	0.070	0.073	0.076	0.079	0.082	0.086
60	0.086	0.089	0.092	0.095	0.098	0.101	0.105	0.108	0.111	0.114	0.118
70	0.118	0.121	0.124	0.127	0.131	0.134	0.137	0.141	0.144	0.147	0.150
80	0.150	0.154	0.157	0.161	0.164	0.167	0.171	0.174	0.177	0.181	0.184
90	0.184	0.188	0.191	0.194	0.198	0.201	0.205	0.208	0.212	0.215	0.218
100	0.218	0.222	0.225	0.229	0.232	0.236	0.239	0.243	0.246	0.250	0.253
110	0.253	0.257	0.261	0.264	0.268	0.271	0.275	0.278	0.282	0.286	0.289
120	0.289	0.293	0.296	0.300	0.304	0.307	0.311	0.315	0.318	0.322	0.326
130	0.326	0.329	0.333	0.337	0.340	0.344	0.348	0.351	0.355	0.359	0.363
140	0.363	0.366	0.370	0.374	0.378	0.381	0.385	0.389	0.393	0.397	0.400

TYPE S
Platinum vs Platinum -10% Rhodium

Temperature in C, Reference Junction at 0 C

C	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	0.000	0.005	0.011	0.016	0.022	0.027	0.033	0.038	0.044	0.050	0.055
10	0.055	0.061	0.067	0.072	0.078	0.084	0.090	0.095	0.101	0.107	0.113
20	0.113	0.119	0.125	0.131	0.137	0.142	0.148	0.154	0.161	0.167	0.173
30	0.173	0.179	0.185	0.191	0.197	0.203	0.210	0.216	0.222	0.228	0.235
40	0.235	0.241	0.247	0.254	0.260	0.266	0.273	0.279	0.286	0.292	0.299
50	0.299	0.305	0.312	0.318	0.325	0.331	0.338	0.345	0.351	0.358	0.365
60	0.365	0.371	0.378	0.385	0.391	0.398	0.405	0.412	0.419	0.425	0.432
70	0.432	0.439	0.446	0.453	0.460	0.467	0.474	0.481	0.488	0.495	0.502
80	0.502	0.509	0.516	0.523	0.530	0.537	0.544	0.551	0.558	0.566	0.573
90	0.573	0.580	0.587	0.594	0.602	0.609	0.616	0.623	0.631	0.638	0.645
100	0.645	0.653	0.660	0.667	0.675	0.682	0.690	0.697	0.704	0.712	0.719
110	0.719	0.727	0.734	0.742	0.749	0.757	0.764	0.772	0.780	0.787	0.795
120	0.795	0.802	0.810	0.818	0.825	0.833	0.841	0.848	0.856	0.864	0.872
130	0.872	0.879	0.887	0.895	0.903	0.910	0.918	0.926	0.934	0.942	0.950
140	0.950	0.957	0.965	0.973	0.981	0.989	0.997	1.005	1.013	1.021	1.029

Table 7B-1. Thermocouple Reference Tables (cont)

TYPE S
Platinum vs Platinum -10% Rhodium

Temperature in °F, Reference Junction at 32°F

°F	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	−0.092	−0.089	−0.086	−0.084	−0.081	−0.078	−0.075	−0.073	−0.070	−0.067	−0.064
10	−0.064	−0.061	−0.058	−0.056	−0.053	−0.050	−0.047	−0.044	−0.041	0.038	−0.035
20	−0.035	−0.033	−0.030	−0.027	−0.024	−0.021	−0.018	−0.015	−0.012	−0.009	−0.006
30	−0.006	−0.003	0.000	0.003	0.006	0.009	0.012	0.015	0.018	0.021	0.024
40	0.024	0.027	0.030	0.033	0.037	0.040	0.043	0.046	0.049	0.052	0.055
50	0.055	0.058	0.062	0.065	0.068	0.071	0.074	0.077	0.081	0.084	0.087
60	0.087	0.090	0.093	0.097	0.100	0.103	0.106	0.110	0.113	0.116	0.119
70	0.119	0.123	0.126	0.129	0.133	0.136	0.139	0.142	0.146	0.149	0.152
80	0.152	0.156	0.159	0.163	0.166	0.169	0.173	0.176	0.179	0.183	0.186
90	0.186	0.190	0.193	0.197	0.200	0.203	0.207	0.210	0.214	0.217	0.221
100	0.221	0.224	0.228	0.231	0.235	0.238	0.242	0.245	0.249	0.252	0.256
110	0.256	0.259	0.263	0.266	0.270	0.274	0.277	0.281	0.284	0.288	0.291
120	0.291	0.295	0.299	0.302	0.306	0.309	0.313	0.317	0.320	0.324	0.328
130	0.328	0.331	0.335	0.339	0.342	0.346	0.350	0.353	0.357	0.361	0.365
140	0.365	0.368	0.372	0.376	0.379	0.383	0.387	0.391	0.394	0.398	0.402

TYPE T
Copper vs Copper - Nickel

Temperature in °C, Reference Junction at 0°C

°C	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
−40	−1.475	−1.510	−1.544	−1.579	−1.614	−1.648	−1.682	−1.717	−1.751	1.785	−1.819
−30	−1.121	−1.157	1.192	−1.228	−1.263	−1.299	−1.334	−1.370	−1.405	−1.440	1.475
−20	0.757	0.794	0.830	0.867	0.903	0.940	0.976	1.013	1.049	1.085	1.121
−10	0.383	0.421	0.458	0.496	0.534	0.571	0.608	0.646	0.683	0.720	0.757
0	0.000	0.039	0.077	0.116	0.154	0.193	0.231	0.269	0.307	0.345	0.383
0	0.000	0.039	0.078	0.117	0.156	0.195	0.234	0.273	0.312	0.351	0.391
10	0.391	0.430	0.470	0.510	0.549	0.589	0.629	0.669	0.709	0.749	0.789
20	0.789	0.830	0.870	0.911	0.951	0.992	1.032	1.073	1.114	1.155	1.196
30	1.196	1.237	1.279	1.320	1.361	1.403	1.444	1.486	1.528	1.569	1.611
40	1.611	1.633	1.695	1.738	1.780	1.822	1.865	1.907	1.950	1.992	2.035
50	2.035	2.078	2.121	2.164	2.207	2.250	2.294	2.337	2.380	2.424	2.467
60	2.467	2.511	2.555	2.599	2.643	2.687	2.731	2.775	2.819	2.864	2.908
70	2.908	2.953	2.997	3.042	3.087	3.131	3.176	3.221	3.266	3.312	3.357
80	3.357	3.402	3.447	3.493	3.538	3.584	3.630	3.676	3.721	3.767	3.813
90	3.813	3.859	3.906	3.952	3.998	4.044	4.091	4.137	4.184	4.231	4.277

Temperature in °F, Reference Junction at 32°F

°F	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	−0.674	−0.654	−0.633	−0.613	−0.592	−0.571	−0.550	−0.529	−0.509	0.488	−0.467
10	−0.467	−0.446	0.425	−0.404	−0.383	−0.362	−0.341	−0.320	0.299	0.277	−0.256
20	−0.256	−0.235	−0.214	−0.193	−0.171	−0.150	−0.129	−0.107	−0.086	0.064	0.043
30	−0.043	−0.022	0.000	0.022	0.043	0.065	0.086	0.108	0.130	0.151	0.173
40	0.173	0.195	0.216	0.238	0.260	0.282	0.303	0.325	0.347	0.369	0.391
50	0.391	0.413	0.435	0.457	0.479	0.501	0.523	0.545	0.567	0.589	0.611
60	0.611	0.634	0.656	0.678	0.600	0.722	0.745	0.767	0.789	0.812	0.834
70	0.834	0.857	0.879	0.902	0.924	0.947	0.969	0.992	1.014	1.037	1.060
80	1.060	1.082	1.105	1.128	1.151	1.173	1.196	1.219	1.242	1.265	1.288
90	1.288	1.311	1.334	1.357	1.380	1.403	1.426	1.449	1.472	1.495	1.518
100	1.518	1.542	1.565	1.588	1.611	1.635	1.658	1.681	1.705	1.728	1.752
110	1.752	1.775	1.799	1.822	1.846	1.869	1.893	1.917	1.940	1.964	1.988
120	1.988	2.011	2.035	2.059	2.083	2.107	2.131	2.154	2.178	2.202	2.226
130	2.226	2.250	2.274	2.298	2.322	2.347	2.371	2.395	2.419	2.443	2.467
140	2.467	2.492	2.516	2.540	2.565	2.589	2.613	2.638	2.662	2.687	2.711

Table 7B-1. Thermocouple Reference Tables (cont)

Temperature in °C. Reference Junction at 0°C

°C	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
0	0.00	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.32	0.36	0.40
10	0.40	0.44	0.48	0.52	0.56	0.60	0.64	0.68	0.72	0.76	0.80
20	0.80	0.84	0.88	0.92	0.96	1.00	1.05	1.09	1.13	1.17	1.21
30	1.21	1.25	1.29	1.34	1.38	1.42	1.46	1.50	1.55	1.59	1.63
40	1.63	1.67	1.71	1.76	1.80	1.84	1.88	1.92	1.97	2.01	2.05
50	2.05	2.09	2.14	2.18	2.22	2.26	2.31	2.35	2.39	2.44	2.48
60	2.48	2.52	2.57	2.61	2.65	2.69	2.74	2.78	2.82	2.87	2.91
70	2.91	2.95	3.00	3.04	3.09	3.13	3.17	3.22	3.26	3.31	3.35
80	3.35	3.39	3.44	3.48	3.53	3.57	3.62	3.66	3.71	3.75	3.80
90	3.80	3.84	3.89	3.93	3.98	4.02	4.07	4.11	4.16	4.20	4.25

*European Standard

TYPE

TDIN*

Copper
vs
Copper - Nickel

Section 8
Schematic Diagrams

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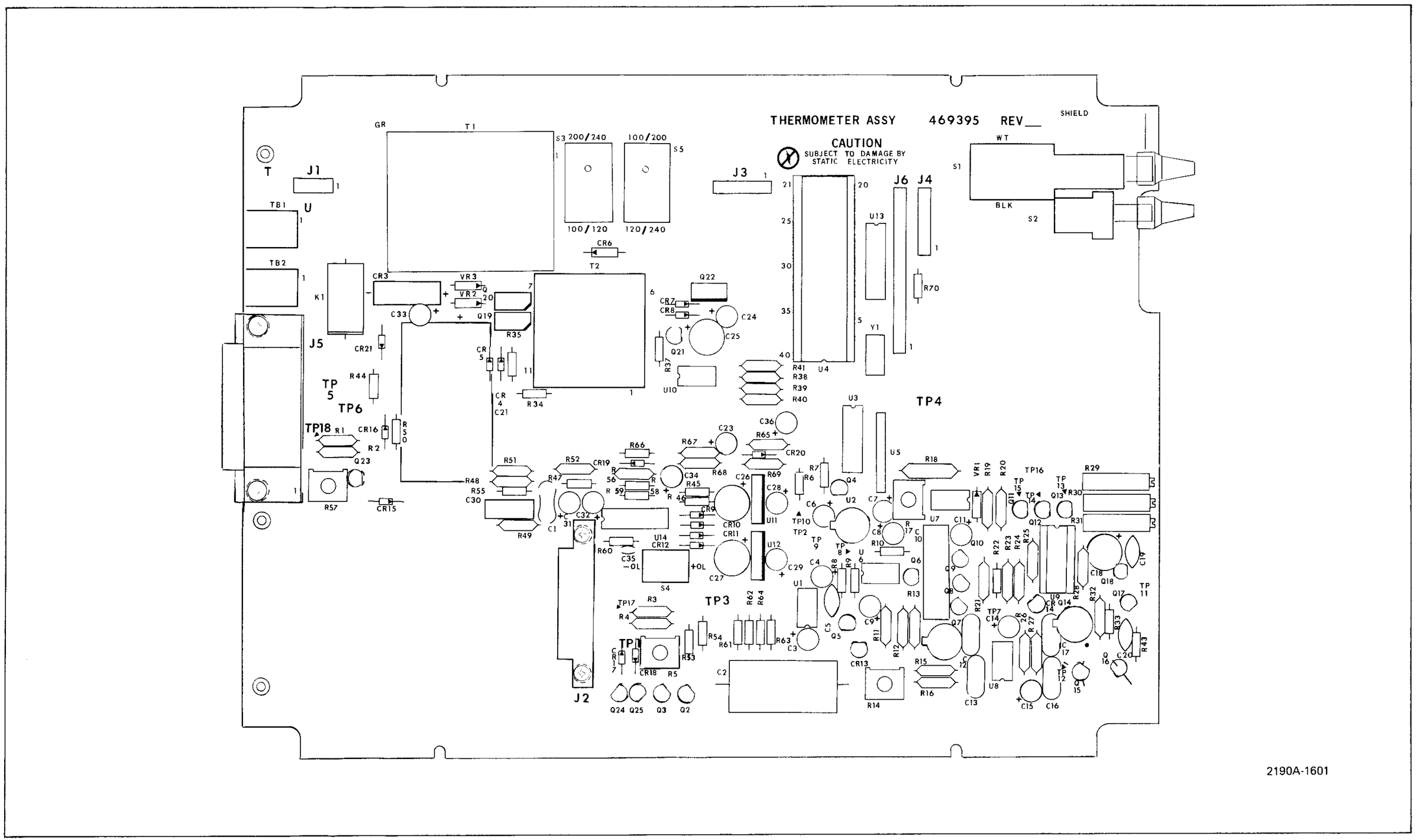
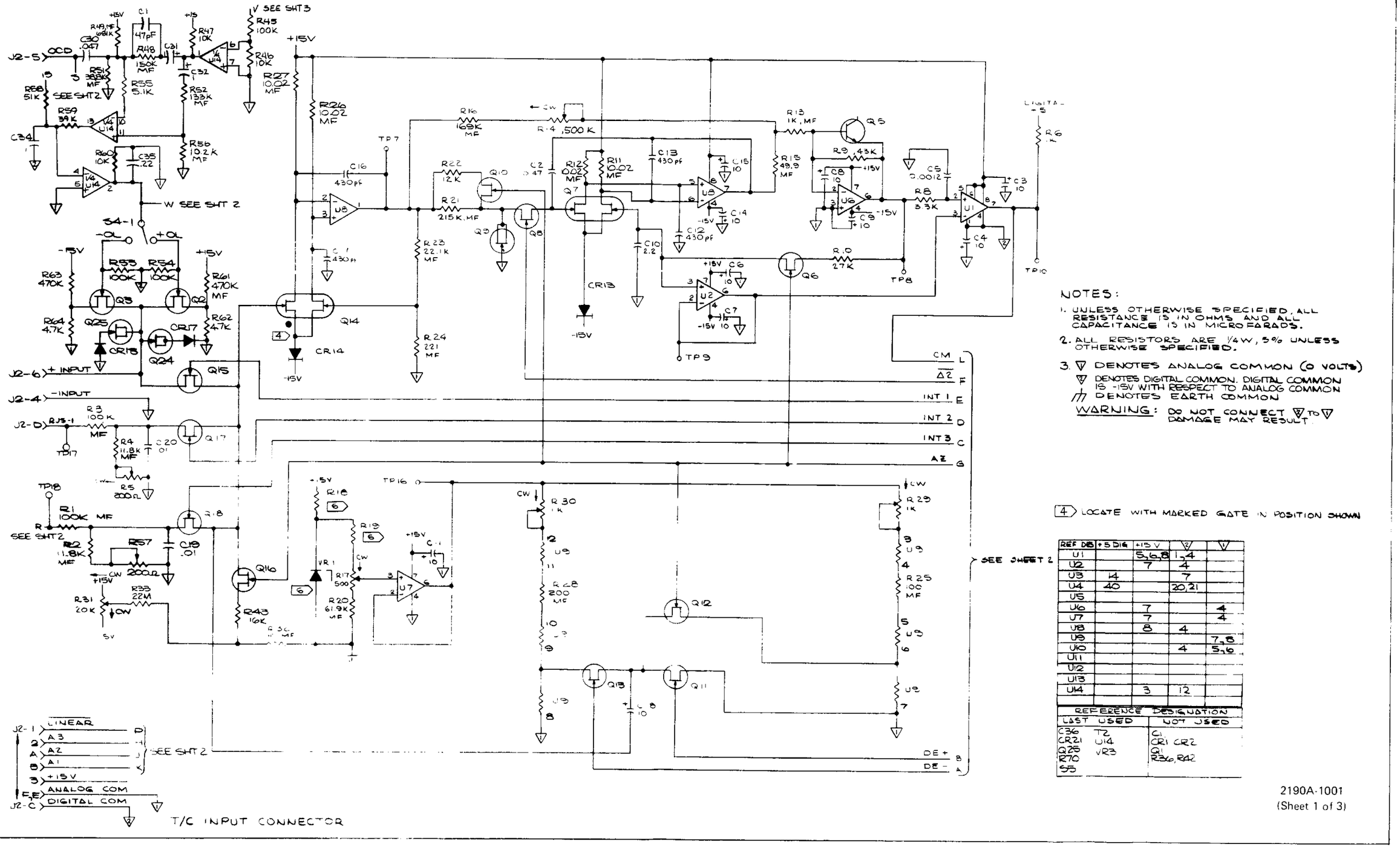


2190A-1601

Figure 8-1. A1 Main PCB Assembly



NOTES:

1. UNLESS OTHERWISE SPECIFIED, ALL RESISTANCE IS IN OHMS AND ALL CAPACITANCE IS IN MICROFARADS.
2. ALL RESISTORS ARE ¼W, 5% UNLESS OTHERWISE SPECIFIED.
3. ▽ DENOTES ANALOG COMMON (0 VOLTS)
   ▼ DENOTES DIGITAL COMMON. DIGITAL COMMON IS -15V WITH RESPECT TO ANALOG COMMON
   /// DENOTES EARTH COMMON

   WARNING: DO NOT CONNECT ▼ TO ▽ DAMAGE MAY RESULT

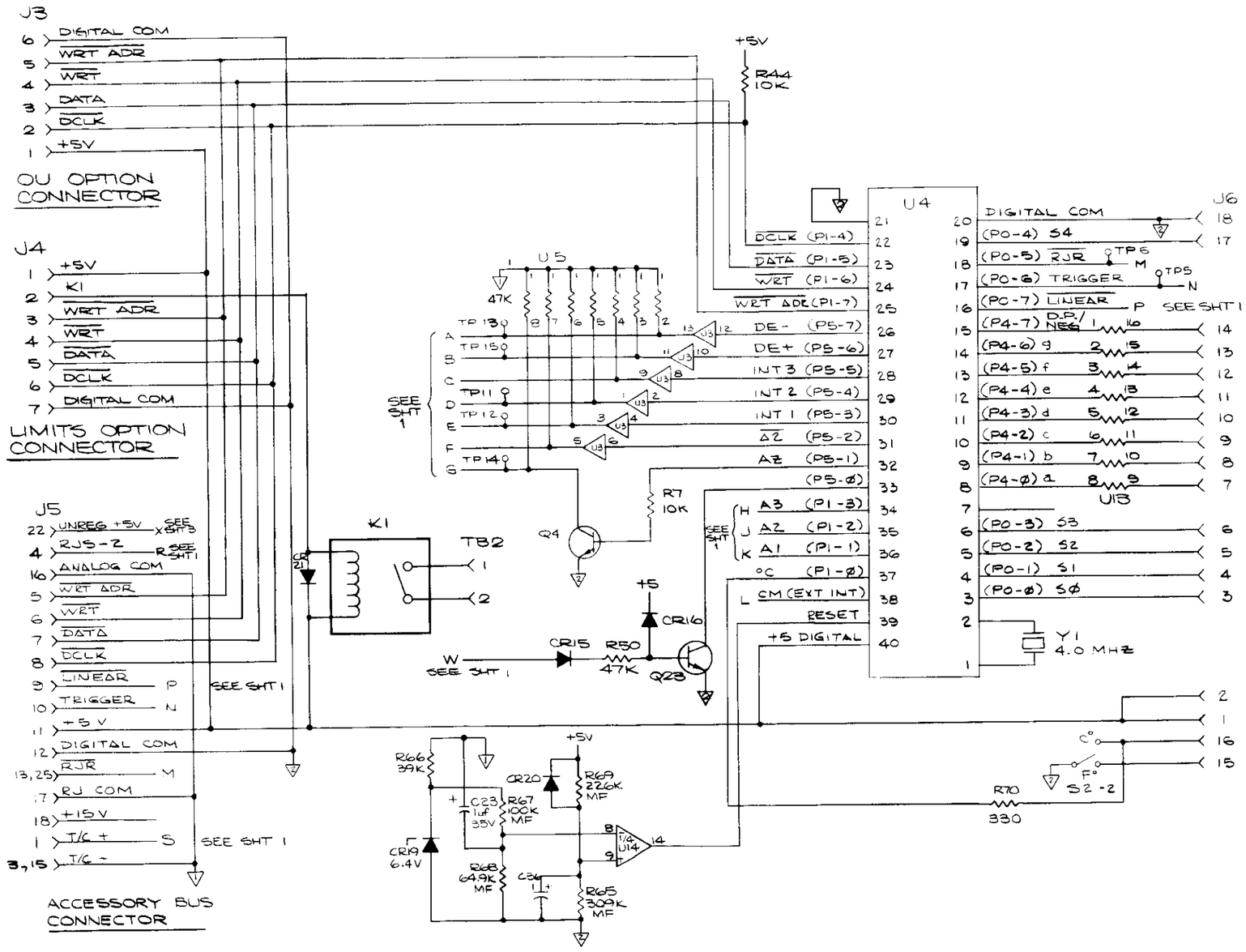
4 LOCATE WITH MARKED GATE IN POSITION SHOWN

REF DES	+5 DIG	+15 V	▼	▽
U1		5,6,8	1,3,4	
U2		7	4	
U3	14		7	
U4	40		20,21	
U5				
U6		7		4
U7		7		4
U8		8	4	
U9				7,8
U10			4	5,6
U11				
U12				
U13				
U14		3	12	

REFERENCE DESIGNATION	
LAST USED	NOT USED
C36 T2 CR21 U14 Q25 VR3 R70 S5	C1 CR1 CR2 Q1 R36, R42

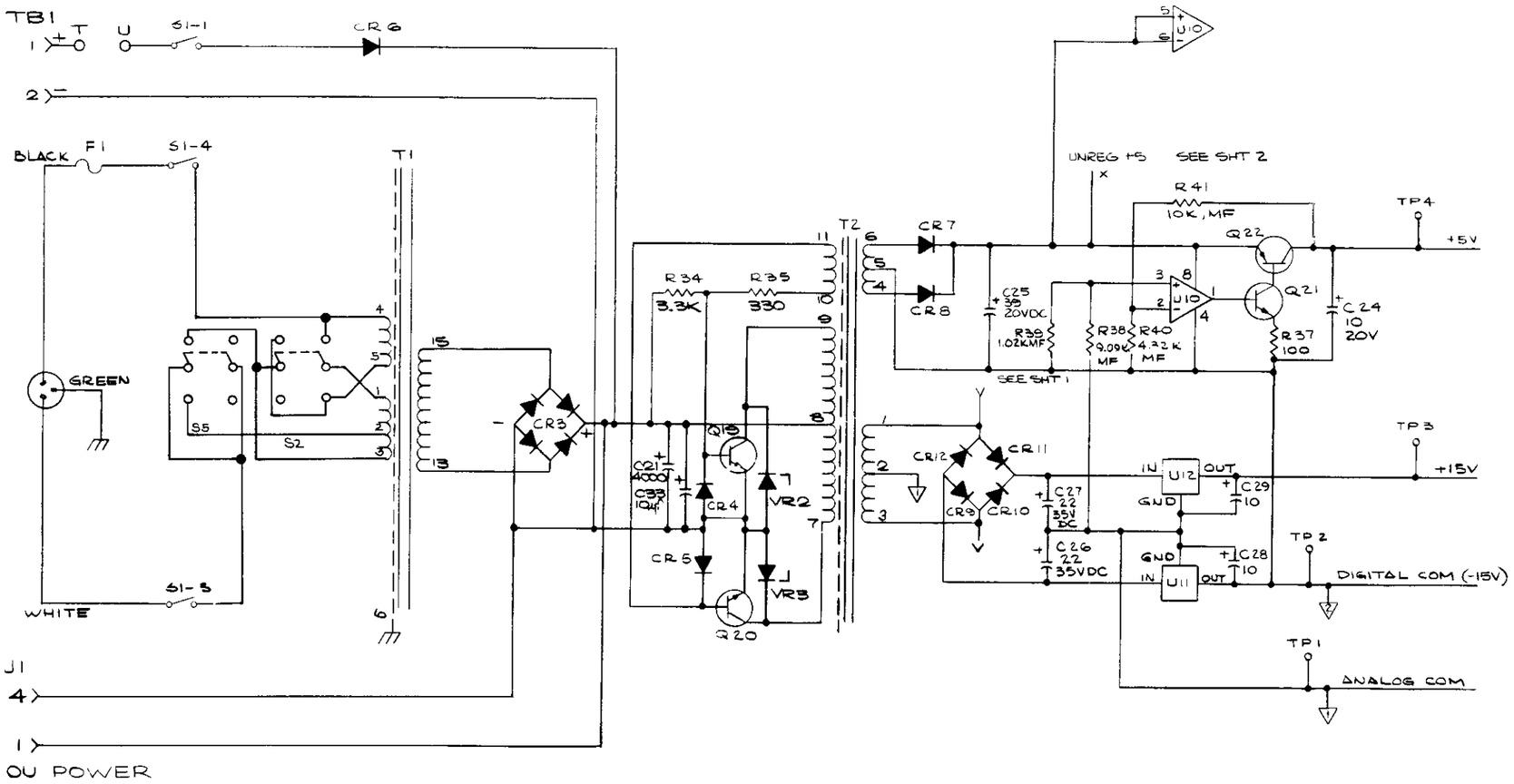
2190A-1001
(Sheet 1 of 3)

Figure 8-1. A1 Main PCB Assembly (cont)



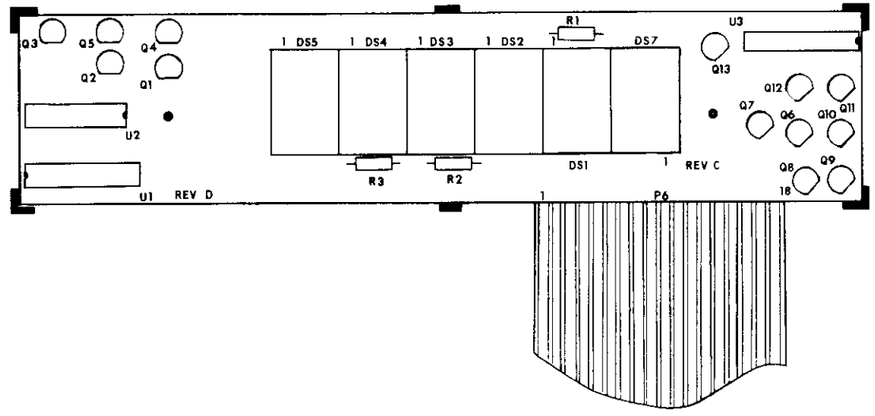
2190A-1001
(Sheet 2 of 3)

Figure 8-1. A1 Main PCB Assembly (cont)



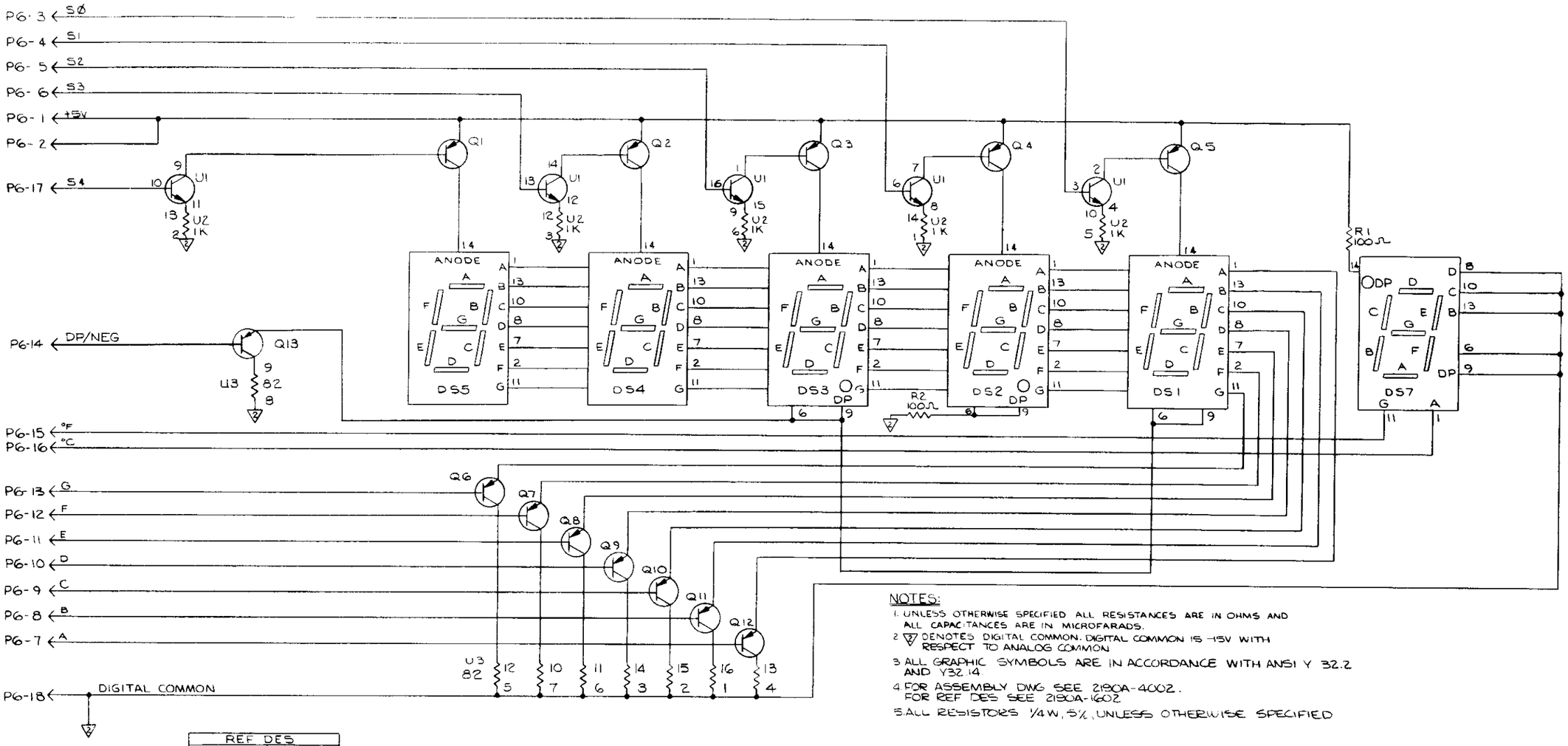
2190A-1001
(Sheet 3 of 3)

Figure 8-1. A1 Main PCB Assembly (cont)



2190A-1602

Figure 8-2. A2 Display PCB Assembly



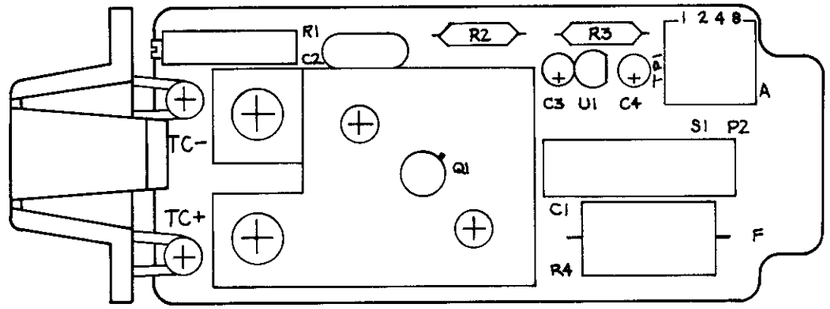
REF DES	
LAST USED	NOT USED
R2, Q13, U3, DS1-5 & 7	DS6.

NOTES:

1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCES ARE IN OHMS AND ALL CAPACITANCES ARE IN MICROFARADS.
2. ▽ DENOTES DIGITAL COMMON. DIGITAL COMMON IS −15V WITH RESPECT TO ANALOG COMMON.
3. ALL GRAPHIC SYMBOLS ARE IN ACCORDANCE WITH ANSI Y 32.2 AND Y32.14.
4. FOR ASSEMBLY DWG SEE 2190A-4002. FOR REF DES SEE 2190A-1602.
5. ALL RESISTORS 1/4W, 5%, UNLESS OTHERWISE SPECIFIED.

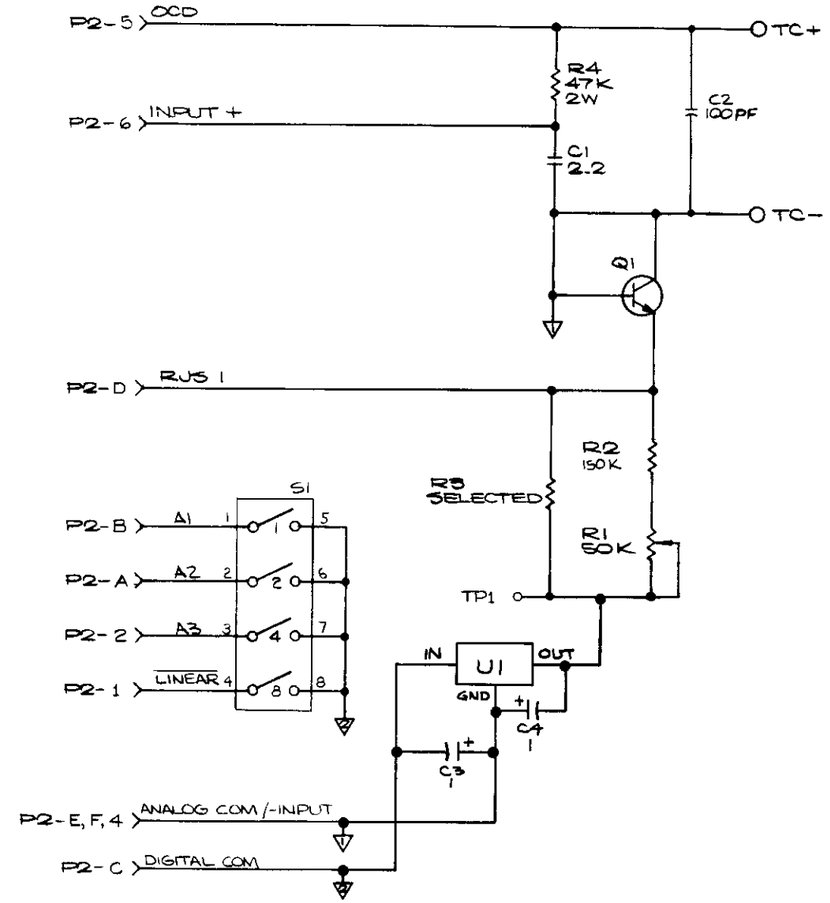
2190A-1002

Figure 8-2. A2 Display PCB Assembly (cont)



2190A-1603

Figure 8-3. A3 Thermocouple Input PCB Assembly

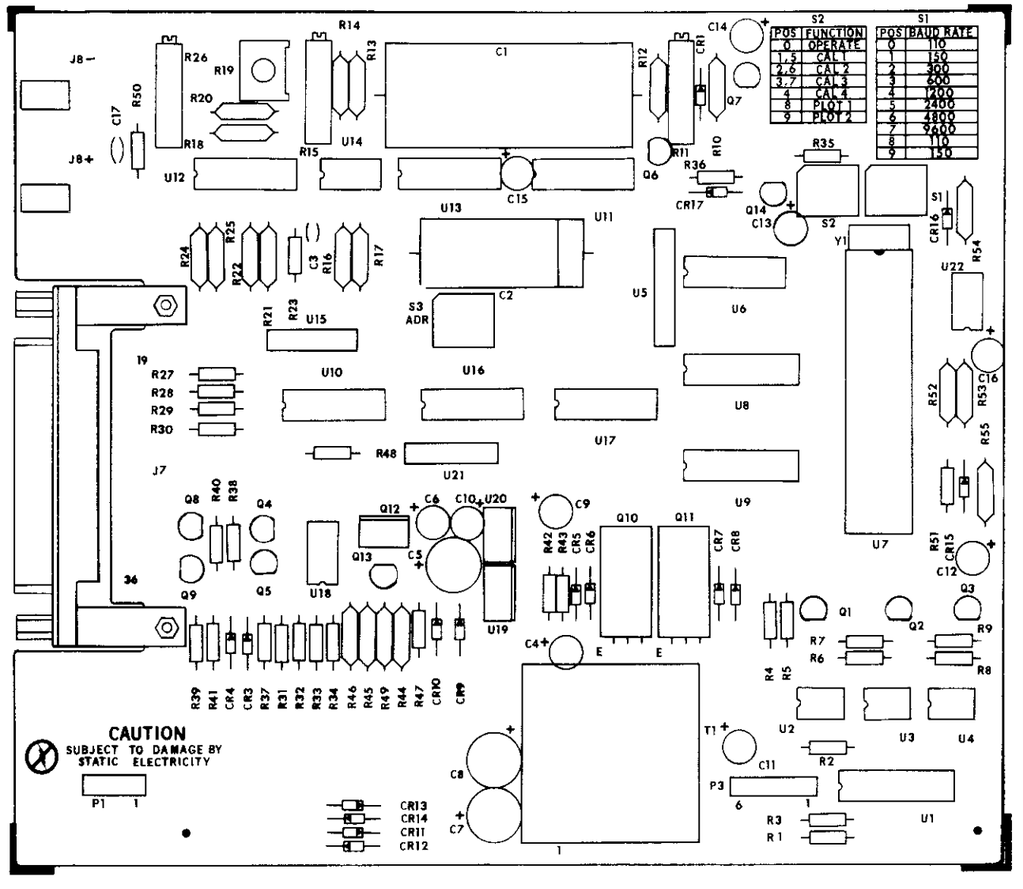


NOTES:

1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCES ARE IN OHMS AND ALL CAPACITANCES ARE IN MICROFARADS.
2. ALL RESISTORS ARE ¼W, 5% UNLESS OTHERWISE NOTED.
3. ALL GRAPHIC SYMBOLS ARE IN ACCORDANCE WITH ANSI Y32.2 AND Y32.14.
4. ▽ DENOTES ANALOG COMMON
   ▼ DENOTES DIGITAL COMMON. DIGITAL COMMON IS -15V WITH RESPECT TO ANALOG COMMON
5. FOR ASSY DWG SEE 2190A-4003
   FOR REF DES DWG SEE 2190A-1603

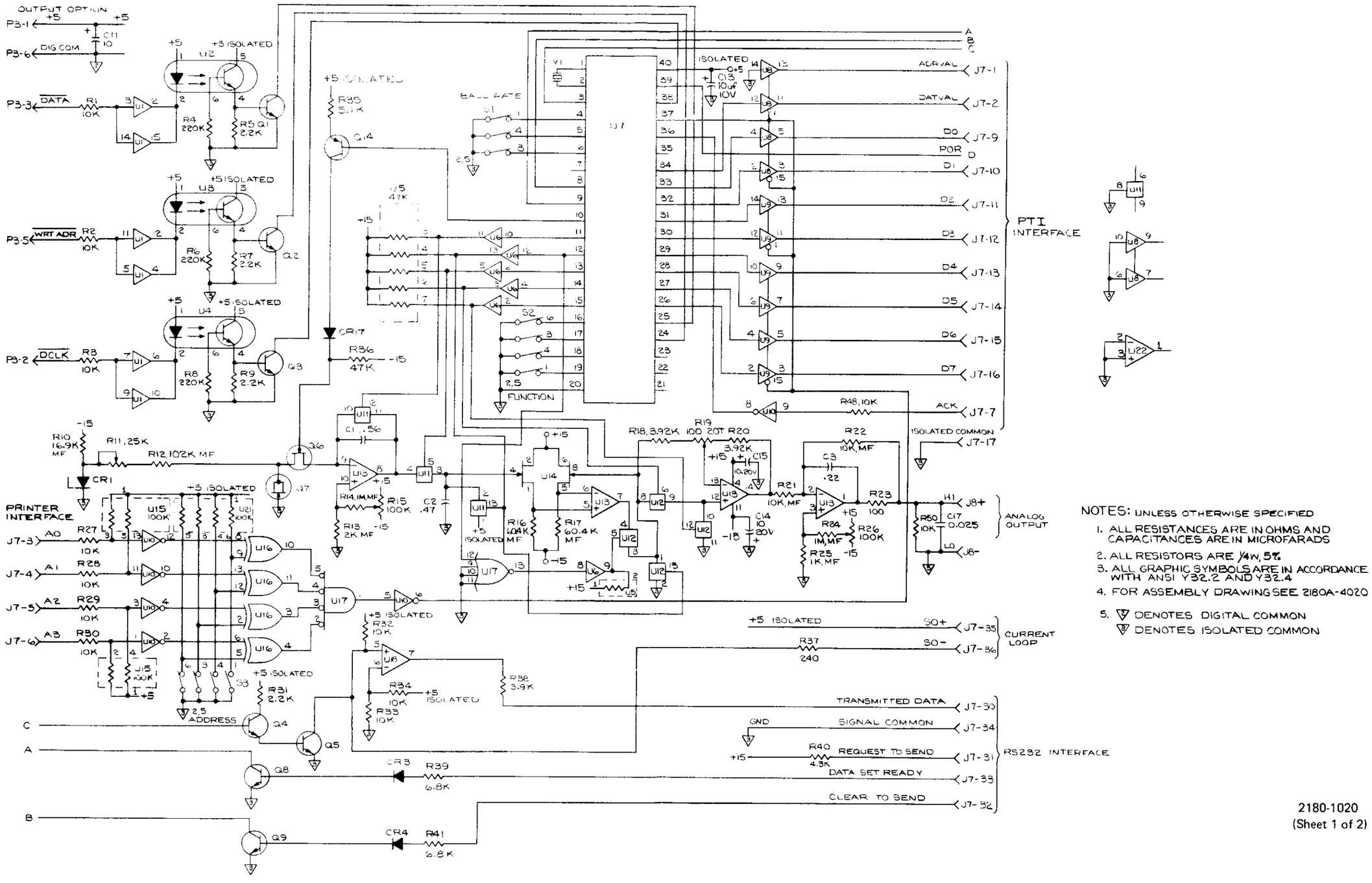
2190A-1003

Figure 8-3. A3 Thermocouple Input PCB Assembly (cont)



2180–1620

Figure 8-4. A4 -002 Output Option PCB Assembly



NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL RESISTANCES ARE IN OHMS AND CAPACITANCES ARE IN MICROFARADS
2. ALL RESISTORS ARE ¼W, 5%
3. ALL GRAPHIC SYMBOLS ARE IN ACCORDANCE WITH ANSI Y32.2 AND Y32.4
4. FOR ASSEMBLY DRAWING SEE 2180A-4020
5. ▽ DENOTES DIGITAL COMMON
   ▽ DENOTES ISOLATED COMMON

2180-1020
(Sheet 1 of 2)

Figure 8-4. A4 -002 Output Option PCB Assembly (cont)

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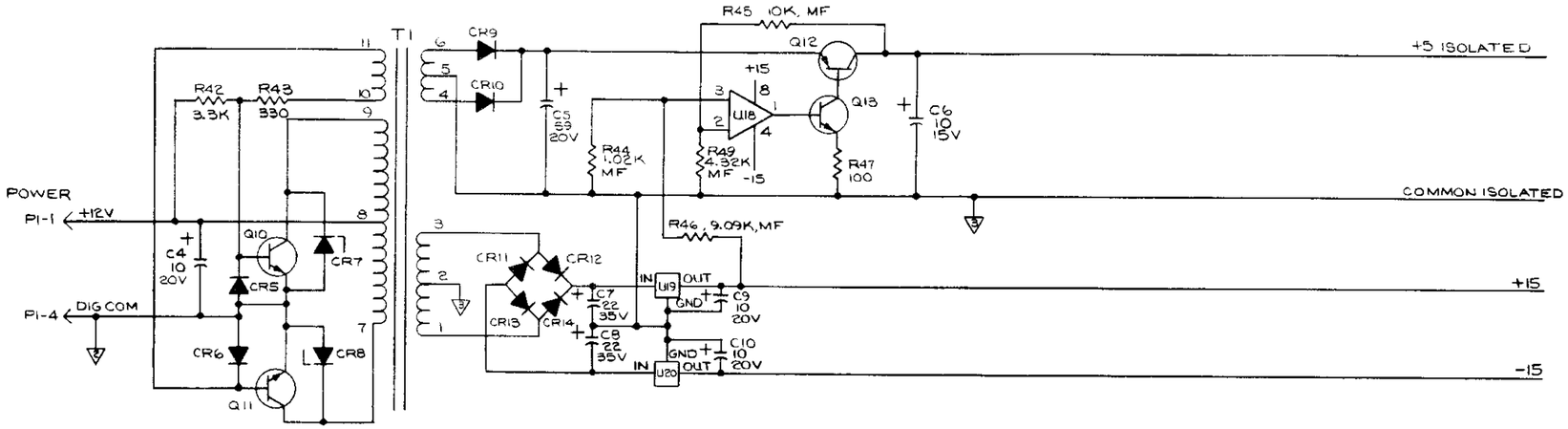
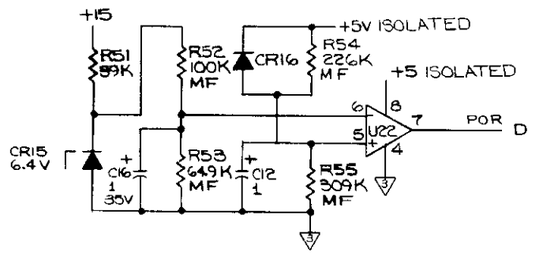




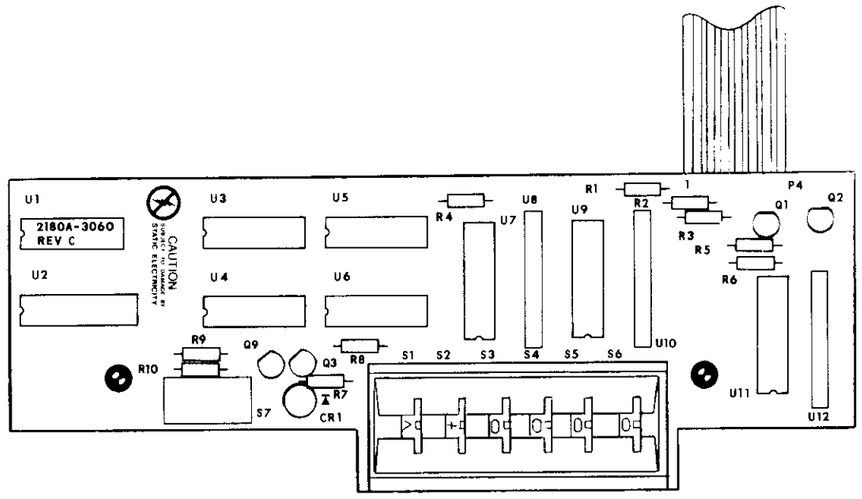
REF DESIGNATIONS	
LAST USED	NOT USED
C17	
CR17	CR2
U22	
R55	
Q14	
S3	
T1	

DES	+5	GND	+5 ISOLATED	+15	-15	GND ISOLATED
U1	1	8				
U2	1		5			
U3	1		5			
U4	1		5			
U5				1		
U6			14			7
U7			40			20
U8			16			8
U9			16			8
U10			14			7
U11				14		7
U12				14		7
U13				4	11	
U14				256		
U15,U21			1			
U16			14			7
U17			14			7
U18				8	4	

DES	+5	GND	+5 ISOLATED	+15	-15	GND ISOLATED
U22		4	8			

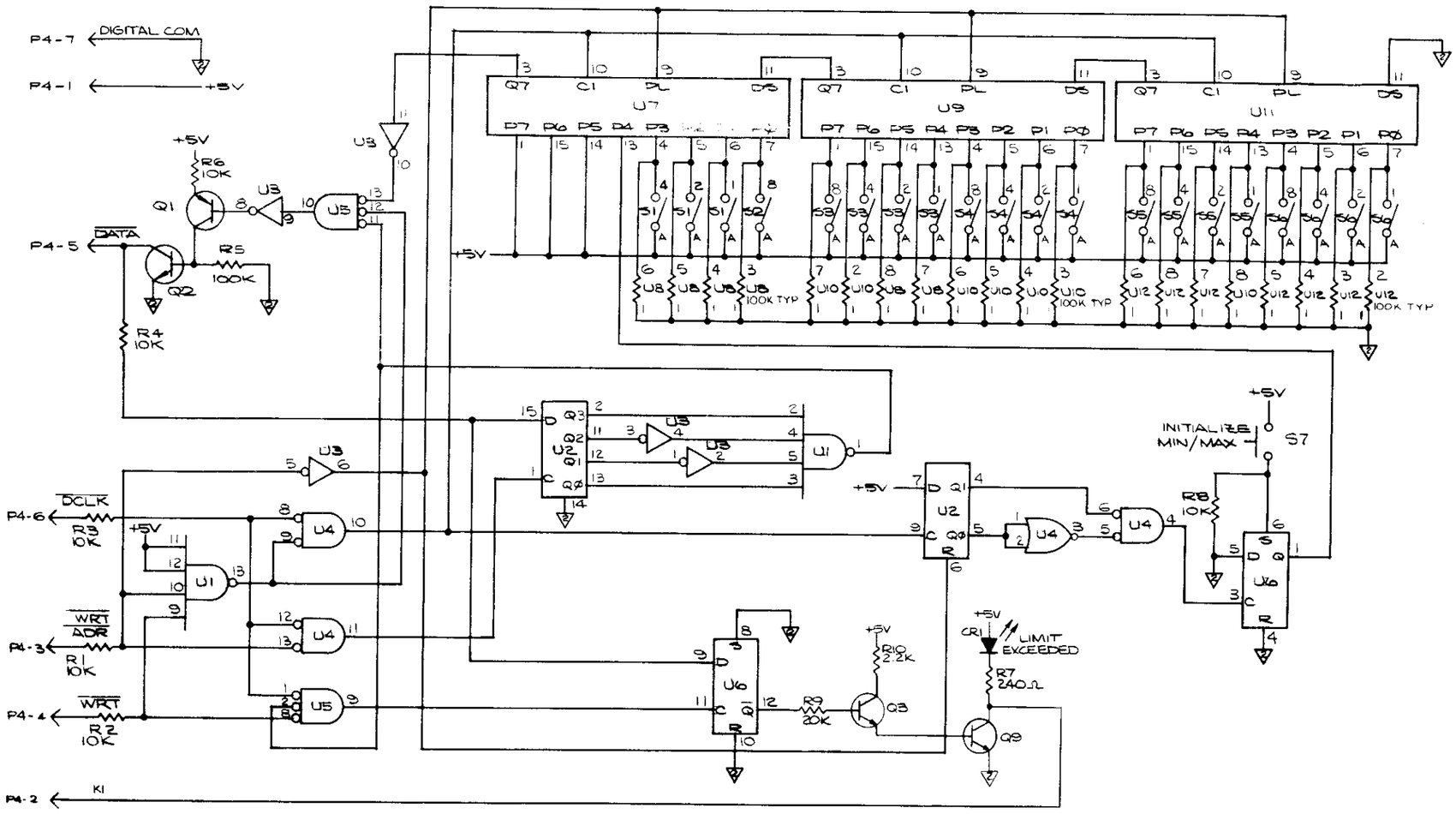
2180A–1020
(Sheet 2 of 2)

Figure 8-4. A4 -002 Output Option PCB Assembly (cont)



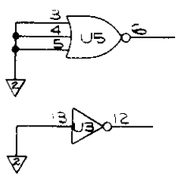
2180A-1660

Figure 8-5. A5 -006 Limits Option PCB Assembly



NOTES:

1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCES ARE IN OHMS AND ALL CAPACITANCES ARE IN MICROFARADS.
2. ALL RESISTORS ARE 1/4W, 5% UNLESS OTHERWISE NOTED.
3. ALL GRAPHIC SYMBOLS ARE IN ACCORDANCE WITH ANSI Y32.2 & Y32.14.
4. FOR ASSY DRAWING SEE 2180A-4060.
5. FOR REF. DES. DRAWING SEE 2180A-16660.
6. ▽ DENOTES DIGITAL COMMON. DIGITAL COMMON IS -15V WITH RESPECT TO ANALOG COMMON



IC.	+5V	▽
U1	14	7
U2	16	8
U3	14	7
U4	14	7
U5	14	7
U6	16	8
U7	16	8
U9	16	8
U11	16	8

REF DES	
LAST USED	NOT USED
U12, R8, S7, Q9	Q4, Q5, Q6, Q7, Q8

2180A-1060

Figure 8-5. A5 -006 Limits Option PCB Assembly (cont)

A1–A3	Program Lines
ADRVAL	Address Valid
ANALOG COMMON	Measurement Common
AZ	Auto-Zero
CM	Compare input to the microcomputer
°C	Degrees Celsius
°F	Degrees Fahrenheit
△2	Hold Command
DATA	Data on Bus
DATVAL	Data Valid
DCLK	Data Clock
DE–	Read a minus input
DE+	Read a plus input
DIGITAL COMMON	–15V with respect to Analog Common
DP/NEG	Decimal Point/Negative
INT 1	Integrate unknown voltage 1
INT 2	Integrate unknown voltage 2
INT 3	Integrate unknown voltage 3
LINEAR	Microcomputer Display Linear Counts
OCD	Open Thermocouple Detector
RJ COMMON	Reference Junction Common
RJR	Reference Junction Request
RJS-1	Reference Junction Sense 1
RJS-2	Reference Jucntion Sense 2
S0-S4	Strobe Lines
T/C–	Thermocouple Negative
T/C+	Thermocouple Positive
WRT	Write
WRT ADD	Write Address (Transmitting Address)
–INPUT	Input Negative
+ INPUT	Input Positive

Figure 8-6. Mnemonics