User's Manual

Model 520

Cryogenic Temperature Indicator/Controller

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LakeShore®

Lake Shore Cryotronics, Inc.
575 McCorkle Blvd.
Westerville, Ohio 43082-8888 USA

E-Mail Addresses:
sales@lakeshore.com
service@lakeshore.com

Visit Our Website:
www.lakeshore.com

Fax: (614) 891-1392
Telephone: (614) 891-2243

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Figure 1.1 Model 520 Cryogenic Temperature Controller

SECTION I

General Information

1.1 Introduction

This section contains a description of the Model 520 Thermometer/Controller, its applications, general specifications, major assemblies supplied and accessory equipment available.

1.2 Description and Applications

The Model 520 Cryogenic Temperature Thermometer/Controller is housed in an aluminum case and is rack mountable with the RM-5H rack mount kit in a standard 19" relay panel. All connections are at the rear of the case with all normal operating controls on the front panel. The instrument is line operated from either 115 volt or 230 volt mains, 50 or 60 Hertz.

The controller has the performance features needed for use with silicon or gallium-arsenide diodes, germanium, carbon-glass, platinum, or other resistance thermometers, or any sensor with a voltage response less than four volts or a resistance of less than 40,000 ohms. The 520 is designed to accept a voltage signal or resistance equivalent signal from a temperature sensitive transducer, compare this signal with an internal set point voltage or resistance equivalent voltage, amplify and process their difference (error signal), and drive an external heating element.

Sensor currents from 1 microampere to 3 milliamperes can be selected from the front panel. Use of analog control means constant and immediate correction for temperature changes. Ample range of gain, reset, and rate have been designed into the 520 to assure fast response, low offset error, and high stability.

The Gain control of the Model 520 has 1X and 3X steps similar to those for the current supply. As a result, loop gain of the system can be kept constant even when sensor current must be changed to avoid sensor self-heating or because of low signal value.

A heater output current of up to one ampere is available to drive up to a 25 ohm load. Smaller load resistances will reduce the maximum power below 25 watts as will higher resistance loads due to the voltage limiting of the power supply of the output stage. The maximum heater current may be set from 10 mA to 1 ampere in 1X and 3X steps which enables output power to be varied in decade steps over five orders of magnitude.

Manual control of the heater output current is available from the front panel. Additionally, the user can manually add a fixed current to the controlled current. This manual offset often produces improved control in relatively stable systems and applications since all the heater power is not contributed via Controller gain.

The 520 can be used to accurately measure temperature by being operated in the open loop mode. The sensor is nulled against the set-point using the built-in meter, thus the set-point becomes a read-out of the actual sensor signal, either voltage or resistance. Referral to the V(T) or R(T) calibration table for the particular sensor yields the actual temperature reading.

In the resistance mode, the set point is directly in ohms, thus the user is freed from constant use of Ohms Law to read or control temperatures. In the diode mode, the set-point is calibrated in volts since most diode temperature calibrations are provided as voltage as a function of temperature at a constant current.

Multi-sensor inputs for the Model 520 are possible with the accessory Model SW-10A Sensor Selector. Up to 10 sensors can be connected to the 520. Selection is made via front-panel pushbuttons on the SW-10A.

1.3 General Specifications

The following specifications for the Model 520 Cryogenic Temperature Thermometer/Controller are applicable when used with cryogenic thermometers.

Input:

Temperature Range: 1.4 to 380K with Lake Shore DT-500 Series Sensors; 0 to 4 volts for other diode sensors; 0-40 ohms to 0-40K ohms for resistance sensors (4 ranges, selected by Sensor Current selector).

Recommended Sensors: DT-500 Series silicon or TG-100 Series gallium-arsenide diode sensors; CGR-1 carbon-glass, GR-200 germanium, or PT-100 platinum resistance sensors. (Order sensors separately.) Calibration required over appropriate temperature range to provide V(T) or R(T) data. Resistors with either positive or negative temperature coefficients can be utilized.

Sensor Input: Separate diode and resistor inputs. 4-terminal input for each type. Can be connected in 2-wire configuration.

Sensor Excitation: 1, 3, 10, 30, 100, 300, 1000, and 3000 microamperes (resistors) or 1, 10, 100, and 1000 microamperes (diodes) selected from the front panel.

Temperature Control:

Set Point: Selected via 5 front-panel digital thumbwheel switches from 00000 to 39999. Decimal point is automatically positioned depending on sensor type and sensor current selected to indicate 0.0000 to 3.9999 volts, 00.000 to 39.999 ohms, 000.00 to 399.99 ohms, 0000.0 to 3999.9 ohms, or 00000 to 39999 ohms. Optional BCD control with Interface.

Typical Controllability: ± 0.0005K for temperatures below 30K, ± 0.005K at higher temperatures with silicon diodes in a properly designed system.

Control Modes: Automatic: Proportional (gain), integral (reset), and derivative (rate) set from front-panel controls. Manual: 0 to 100% of full output can be set from front-panel. Manual and Automatic modes can be used simultaneously.

Heater Output: 0-25 watts into 25 ohm load or 0-10 watts into 10 ohm load (rear-panel switch-selected). Heater current can be limited at 10mA, 30mA, 100mA, 300mA, and 1A (approximate decade power increments).

Temperature Readout:

Method: Sensor voltage is nulled against set-point equivalent voltage using front-panel thumbwheels in MANual mode. Temperature is determined from V(T) or R(T) tables (requires sensor calibrated over appropriate temperature range).

Accuracy: ± 100 microvolts ± calibration error of Sensor.

General:

Dimensions, Weight: 432mm wide x 146mm high x 330mm deep (17 in. x 5-3/4 in. x 13 in.). Style L, full-rack package. Net weight 8 kg (18 lbs.).

Power: 105-125 or 210-250 VAC (switch selected), 50 or 60 Hz, 50 watts.

1.4 Major Assemblies Supplied

The Model 520 Cryogenic Temperature Thermometer/Controller includes as standard equipment, in addition to the controller proper, the following additional components:

A. One Operating and Service Manual

B. One 14-pin male connector (LSCI Stock #106-070) and 12 pins (8 required) (LSCI Stock #106-060). Assembly mates with J1 connector on Model 520 Rear Panel.

1.5 Options and Accessories Available

Model 5201 Interface. Allows remote digital control of set-point and provides BCD output of Sensor voltage divided by two.

Model SW-10A. 10-Sensor Selector Switch. Pushbutton selection of any one of up to 10 sensors. Dimensions: 216mm wide x 102mm high x 330mm deep (8½ in. x 4 in. x 13 in.). Style L half-rack package.

Model RM-3H. Rack mount kit to mount either one or two SW-10A in standard 3½ in. rack space.

Model RH-5F. Rack ears with handles to mount Model 520 in standard 5¼ in. rack space.

1.6 Temperature Sensors

Model DT-500 Silicon Diode Sensors. (Refer to Lake Shore Series DT-500 Technical Data for details.)

DT-500K	DT-500P-GR
DT-500KL	DT-500FP
DT-500K-T05	DT-500P-GR Mini
DT-500KL-T05	DT-500FP-HRC-6
DT-500P	DT-500FP-HRC-7
DT-500CU-36	DT-500DRC
DT-500-CU-DRC-36	

Model TG-100 GaAs Sensors. (Refer to Lake Shore TG-100 Technical Data for details.)

TG-100P	TG-100FP

Model CGR-1 Carbon Glass Resistor Sensors. (Refer to Lake Shore CGR-1 Technical Data for details.)

CGR-1-500	CGR-1-2000
CGR-1-1000	CGR-1-3000
CGR-1-1500	

Model GR-200 Germanium Resistor Sensors. (Refer to Lake Shore GR-200 Technical Data for details.)

GR-200A-30,50,100,250,500
GR-200A-1000,1500,2500,5000
GR-200B-500,1000,1500,2500,5000

Model PT-100 Platinum Resistance Sensors. (Refer to Lake Shore PT-100 Technical Data for details.)

PT-101	PT-103
PT-102	PT-1001

Sensor Calibration. (Other ranges also available.)

Type	Range-K	Type	Range-K
0.05A	0.05-6.0	1.4F	1.4-300
0.1A	0.1 -6.0	1.4G	1.4-380
0.3A	0.3 -6.0	4B	4.0-40
1.4A	1.4 -6.0	4F	4.0-300
1.4B	1.4 -40	4G	4.0-380

1.7 Repacking for Shipment

If the 520 appears to be operating incorrectly, please discuss the problem with a factory representative before returning the instrument. He may be able to suggest several field tests which could avoid the unnecessary returning of a satisfactory instrument to the factory when the malfunction is elsewhere. If these tests determine that the fault is in the instrument, the representative will provide shipping and labeling instructions for returning it. In order to expedite the repair of the instrument, contact the factory for a Returned Goods Authorization (RGA) number. Include the instrument's model and serial numbers in all written correspondence.

When returning an instrument, please attach a tag securely to the instrument itself (not on the shipping carton) clearly stating:

A. Owner and Address

B. Instrument Model and Serial Numbers

C. Malfunction Symptoms

D. Description of External Connections and Cryostats

E. Returned Goods Authorization Number

If the original carton is available, repack the instrument in a plastic bag, place it in the carton using original spacers to protect protruding controls. Seal the carton with strong paper or nylon tape. Affix shipping labels and "FRAGILE" warnings.

If the original carton is not available, pack the instrument similar to the above procedure, being careful to use spacers or suitable packing material on all sides of the instrument.

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SECTION II

Installation

2.1 Introduction

This section of the manual contains the necessary information and instructions for installation of the Model 520 Cryogenic Temperature Thermometer/Controller. Included are the initial inspection procedures, power requirements, recommended grounding connections, interface connector diagrams along with pin designations, and recommended temperature sensor connections.

2.2 Initial Inspection

This instrument was carefully inspected both mechanically and electrically before shipment. It should be free of mars or scratches and in perfect electrical order upon receipt. Immediately upon receipt the instrument should be inspected for any damage that may have occurred in transit. If the shipment container or cushioning material is damaged, it should be kept until the contents of the shipment have been checked for completeness and the instrument has been mechanically and electrically checked. Procedures for checking the electrical performance of the 520 are given in Section V. If there is mechanical damage or the instrument does not perform electrically, notify LSCI immediately. If the shipping container is damaged or the cushioning material shows signs of stress, be sure to file appropriate claims with the carrier and/or insurance company, and notify LSCI of the claims filing. Save the shipping materials for inspection by the carrier.

Be sure to inventory all components supplied before discarding any shipping material. In case of part(s) shortages, please advise LSCI. The standard LSCI warranty as given in the front of this manual is applicable to the Model 520.

2.3 Power Requirements

Before connecting the power cable to line voltage, verify that the instrument is set for the proper line voltage and fused accordingly. The line voltage and fuse data are shown on the rear panel of the instrument, adjacent to the fuse holder.

The line voltage can be changed by switching line selector switch S2, located on the rear panel (Figure 3.2, Key No. 17, Page 14).

Nominal permissible line voltage fluctuation is ± 10% at 50 to 60 Hertz.

2.4 Grounding Requirements

2.4.1 Instrument Grounding

To protect operating personnel, the National Electrical Manufacturer's Association (NEMA) recommends, and some local codes require, instrument panels and cabinets to be grounded. This instrument is equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument.

2.4.2 Temperature Sensor Grounding

Refer to Figure 2.1 for illustrated individual sensor wiring configurations recommended for optimizing system performance.

2.5 Instrument Installation

2.5.1 Bench Use

The Model 520 is shipped with feet and a tilt ball installed and is ready for use as a bench instrument. As with any precision instrument, the 520 should not be subjected to excessive shock and vibrations, such as the kind that usually accompany high vacuum pumping systems.

2.5.2 Rack Mounting

The Model 520 can be installed in a standard 19" instrument rack by using the optional rack mounting kit RM-5H. The basic hardware and front handles are contained in the RM-5H kit. A typical rack mount installation is shown in Figure 2.2.

2.6 Sensor and Heater Connections

2.6.1 Sensor Input Connections

The 520 is supplied with a 14-pin male connector LSCI Stock #106-070) and 12 pins (4 spares) (LSCI Stock #106-060) which mate with connector J1 on the rear panel (Figure 3.2, Key No. 27, page 14). This connector interfaces both a resistance thermometer and a diode thermometer to the Model 520 Thermometer/Controller. Table 2.1 lists the pin assignments for the connector. Figure 2.1 shows the sensor connections for both the diode and resistance thermometers. The recommended cable diagrams for the sensor diode and resistance thermometer are given in Figure 2.1. The use of a four wire diode connection is highly recommended to avoid introducing lead IR drops in the voltage sensing pair which is translated into a temperature measurement error or a control offset from setpoint temperature. The alternate wiring scheme shown in Figure 2.1 (....) may be used for the diode, in less critical applications where control is important, but small temperature offsets can be tolerated.

2.6.2 Heater Connections

The power output stage is a current drive with a maximum current available of one ampere. The voltage supply for the current drive can be selected to have an output of 10 volts on a low setting or 25 volts on a high setting (Figure 3.2, Key No. 22, Page 14); therefore, if your heater resistance is ten ohms or less, the low resistance setting should be used so as to minimize power dissipation within the instrument. The maximum power deliverable to the load is therefore equal to the load resistance as long as the resistance does not exceed 25 ohms for loads greater than 25 ohms, the minimum power to the load is $(25)^2/R$ where R is your load resistance and it is assumed that the lead resistance to the heating element is negligible.

The Heating element should be floated to preclude the possibility of any of the heater current being coupled into the thermometer sensor leads. Electrical feedback in addition to the desired thermal feedback, may cause oscillations and certainly will cause erroneous temperature readings.

Inspect the heater element fuse FU2, (Figure 3.2, Key No. 21, Page 14) for proper value (3AG, 1.0A, Fast Blow, or smaller current rating if desired). This fuse should not blow under most circumstances since the output stage is a current stage with an upper limit of one ampere rather than a voltage stage with maximum current depending on output resistance.

Table 2.1

Sensor Connections

J1 Pin Assignments	1	+I	Diode
	2	+V	Diode
	3	-V	Diode
	7	-I	Diode
	8	+I	Resistor
	12	+V	Resistor
	13	-V	Resistor
	14	-I	Resistor

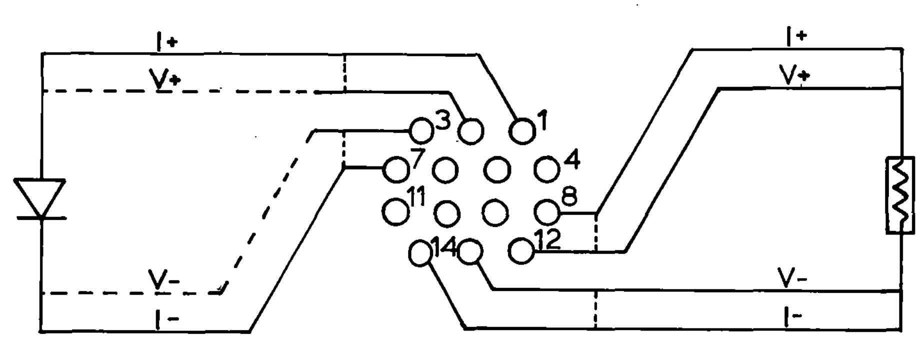

Figure 2.1

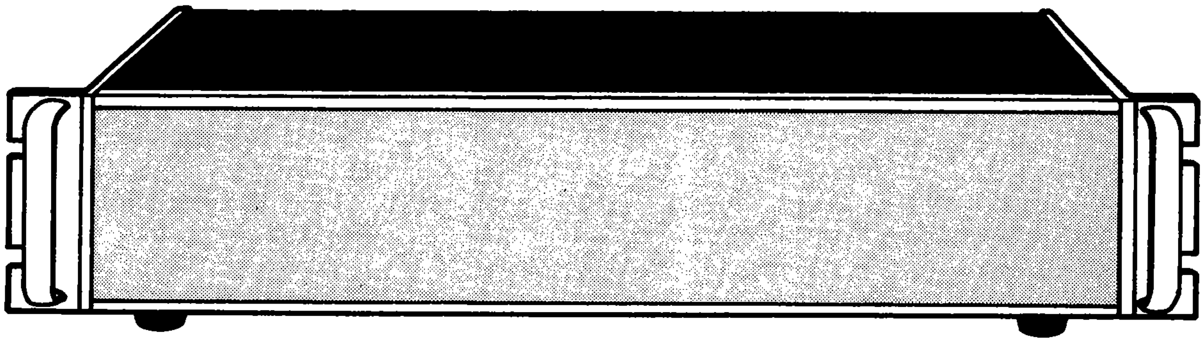

Figure 2.2 Typical RM-3F & RM-5F Rack Mounting Installation

SECTION III

Operating Instructions

3.1 Introduction

This section contains a description of the operating controls and their adjustments under normal operating conditions. These instructions are predicated upon the instrument having been installed as outlined in Section II. The diode polarity as shown in Figure 2.1 in particular must be correct. A diode sensor and/or a resistance thermometer is assumed to be connected, as shown in Figure 2.1. In addition, a resistive heating element is assumed to have been connected to the "Heater" terminals (Figure 3.2, Key No. 23).

3.2 Controls, Indicators and Connectors

The operating controls, indicators and connectors on the instrument's front and rear panels are shown in Figures 3.1 and 3.2. The numbers with leaders to various controls in the figures are keyed to the entries in Table 3.1.

No. Key	Name	Function
1	SET POINT - VOLTS	Digital set point of sensor voltage
	SET POINT - OHMS 0-39.999, 399.99, 3999.9, or 39999.	Digital set point of sensor resistance
2	Sensor Voltage Alert	LED turns on in the resistance mode when the voltage limit has been exceeded. Fully counterclockwise is approximately 1 mV; fully clockwise is approximately 40 mV.
3	Volts LED	LED turns on to indicate decimal point when in the diode mode (Key No. 14).
4	Ohms decimal LED's	LED which is on depends on the Sensor Current selected (Key No. 16) and indicates decimal point and maximum range of set point resistance.
5	GAIN	Gain Multiplier, x1, x3, x10, x30, and x100.

No. Key	Name	Function
6	GAIN	Variable gain 1-10. Together with gain multiplier, allows adjustment of overall controller gain over 1000 to 1 range.
7	Control Mode	MAN position permits user to control the current to the heater with the heater current knob (Key No. 8). AUTO uses controller to set output power to force error signal to zero. MIX allows both a manual output component as well as an error component of output power.
8	Heater Current Control	Sets the amount of manual heater current when the Control Mode is either MAN or MIX.
9	Reset	Adjusts auto-reset time constant of integrator. Effectively determines time constant of integrator between 100 and 1 seconds, "MIN" and "MAX" respectively, or "OFF".
10	Rate	Adjusts auto-rate time constant of differentiator. Effectively sets differentiator time constant between 1 and 100 seconds, "MIN" and "MAX" respectively, or "OFF".
11	POWER	A.C. line switch (ON/OFF) and pilot light.
12	HTR CURRENT RANGE MILLIAMPERES	Switch selected current selector. Use of a low setting will avoid inadvertent boil-off in setting up system, and/or system oscillations.
13	HEATER CURRENT	Monitors heater element current. Full scale deflection corresponds to HTR CURRENT RANGE switch (Key No. 12) setting.
14	Diode - Res (-) Res (+)	Switch for selecting diode temperature sensor or resistive temperature sensors with either positive (+) or negative (-) temperature coefficient for their R vs. T curves.

Key No.	Name	Function
15	NULL SENSOR VOLTAGE	Indicates the difference between the set point voltage and the sensor output voltage. Meter is non-linear for large errors of either sign. See page and for discussion.
16	SENSOR CURRENT MICROAMPERES	Selector switch for determining the level of dc current for the temperature sensor. 10μA is recommended for diode sensors.
17	115 - 230 VAC	A.C. line voltage selector slide switch (50-60 Hz).
18	.4 - .75A SB	A.C. line fuse (FU1). 115 VAC - 0.75 AMP., 230 VAC - 0.4 AMP.
19	NO LABEL	A.C. line cord.
20	RESISTANCE HIGH - LOW	Selector switch to match load resistance to controller output stage. HIGH is for a load greater than 10 ohms, 25 ohms optimum. LOW is for a load of 10 ohms or less, 10 ohms optimum.
21	1 AMP	Heater element line fuse, 1 AMP Fast Blow
22	GND	Chassis ground terminal
23	HEATER HIGH - LOW	Heater element lead terminals (Grey is the HIGH side and black is the LOW side).
24	NO LABEL	Heat sink for output transistor.
25	NO LABEL	Potentiometer used for setting the resistive sensor voltage limit. (See Key No. 2.)
26	J2	40 pin connector for "REMOTE" BCD in/out option
27	J1	Sensor cable receptacle (14 pin, LSCI #106-142). See Table 2.1 for sensor(s) connections.

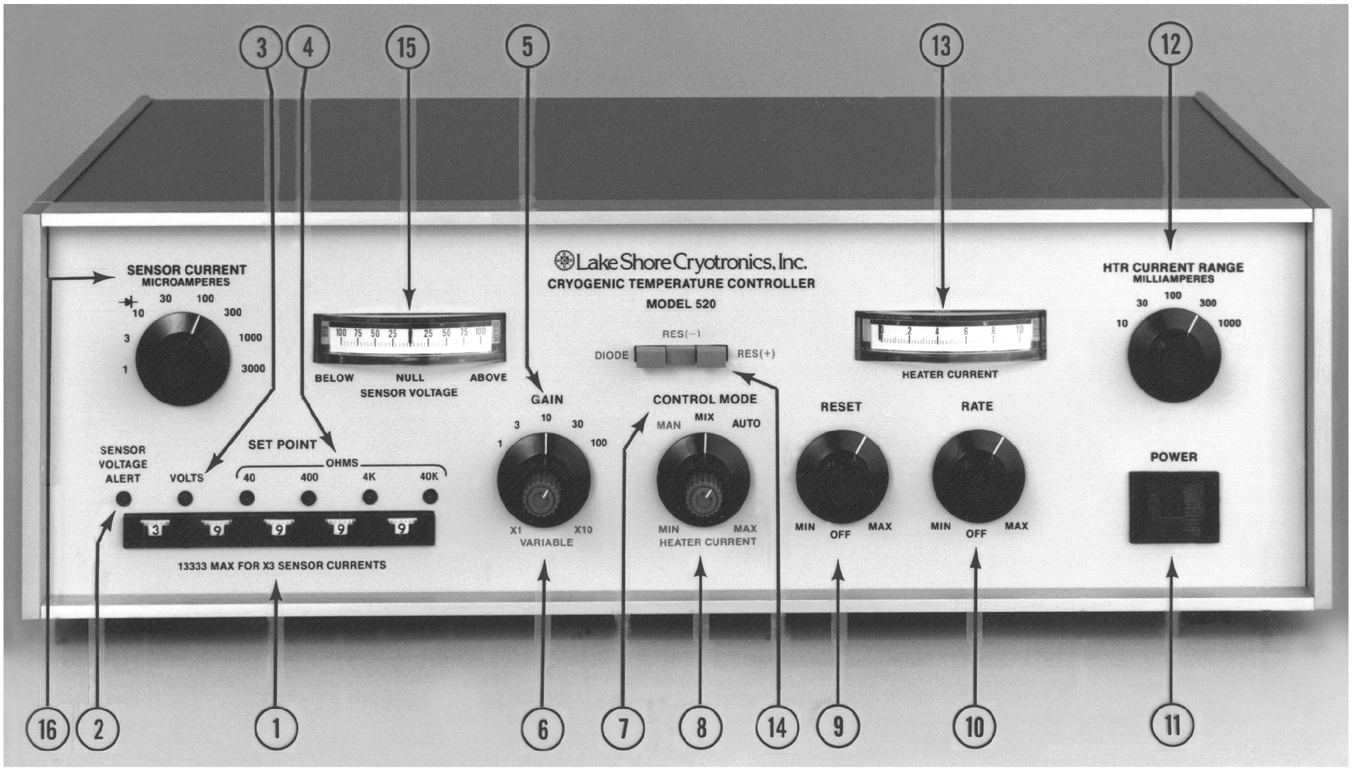

Figure 3.1 Model 520 Cryogenic Temperature Controller Front Panel

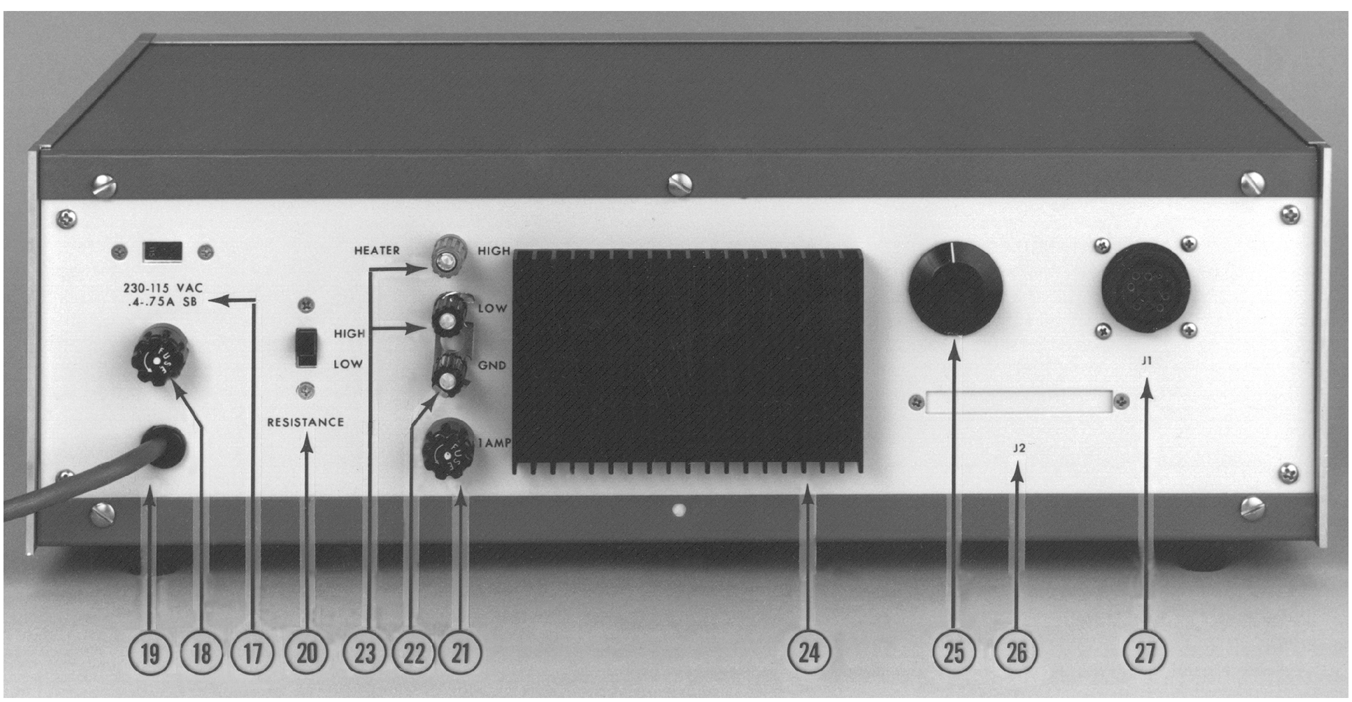

Figure 3.2 Model 520 Cryogenic Temperature Controller Rear Panel

3.3 Initial Checks

Initial checks, calibration checks, and servicing procedures are described in Section V, MAINTENANCE.

3.4 Temperature Readout Mode

To use the 520 as a cryogenic thermometer to measure the temperature of a calibrated sensor, initially position the switches and controls as follows:

A. Sensor selector switch (Key No. 14) to type of sensor.
B. HTR CURRENT RANGE (Key No. 12) to 10.
C. HEATER CURRENT Potentiometer (Key No. 8) to "MIN".
D. CONTROL MODE switch (Key No. 7) to "MAN".
E. GAIN (Key Nos. 5 and 6) to minimum setting.
F. RESET (Key No. 9) to off.
G. RATE (Key No. 10) to off.
H. POWER switch (Key No. 11) to on.

The null meter will probably deflect off scale (either left or right) when the power switch is turned on. If either a diode or a negative temperature coefficient resistor (RES[-]) is being monitored, and the deflection is to the right, the set point voltage or resistance is less than the sensor voltage or resistance. If the deflection is to the left, the set point voltage or resistance is greater than the sensor voltage or resistance. Therefore, in order to null the meter, turn the set point in the direction that you wish the needle to move. If you are monitoring a platinum resistor which has a positive temperature coefficient (RES[+]), the above instructions must be reversed with regard to sign.

If the null meter will not null regardless of the set point value, check to make sure that the printed circuit card located behind the thumbwheel digits has not worked loose from its proper position during shipping. This possibility can easily be observed by removal of the top cover.

Adjust the set point until the "NULL" meter is centered while increasing the "GAIN" toward maximum. Increasing the set point will move the meter pointer to the left; decreasing the set point will deflect the meter pointer to the right. After centering the meter pointer at zero, the set point can be read directly to 100 μvolts for diodes and to five places for resistors. A table of relative sensitivity for the null meter as a function of gain setting for diodes is given in Table 4.1

After determining the set point, refer to the appropriate sensor calibration chart to ascertain the sensor temperature.

3.5 Constant Temperature Control Mode

Assume that a calibrated sensor is to be used as described in paragraph 3.4. To maintain a constant temperature, determine the corresponding set point from the sensor calibration chart. Set this voltage on the "SET POINT" switches.

Position controls as indicated below:

A. Sensor Selector Switch (Key No. 14) to type of sensor.
B. CONTROL MODE switch (Key No. 7) to "AUTO".
C. HTR CURRENT RANGE (Key No. 12) to 1000 milliamperes.
D. GAIN (Key Nos. 5 and 6) to minimum settings.
E. RESET (Key No. 9) to off.
F. RATE (Key No. 10) to off.
G. SET POINT switch (Key No. 1) to set point corresponding to desired temperature.
H. POWER switch (Key No. 11) to on.

If the block or sample holder whose temperature is to be controlled is colder than the set point temperature, the null meter will deflect to the right: Slowly increase the "GAIN" setting (Key Nos. 5 and 6). The "HEATER CURRENT" meter should show an immediate up scale deflection proportional to the "GAIN" setting. The "NULL" meter should start to come off its full right deflection position as the gain is increased. As the sample holder temperature approaches the set point temperature, the NULL meter will approach center scale and the "HEATER CURRENT" meter will assume a steady value even with a further increase in the gain setting. Continue to increase the gain until an incremental change in gain produces a negligible reduction in the null error, but not so high as to produce oscillations.

To further reduce the null error, rotate the "RESET" gain control (Key No. 9) out of the detent (off) position in the clockwise direction. As the control is advanced, the null meter should approach the center position with unobservable error. Leave the "RESET" vernier in the position required to reduce the null error to zero, but below any level which induces oscillations.

After achieving a stable operating point, reduce the HTR CURRENT RANGE switch (Key No. 9) to a lower setting. As lower settings are dialed in the per cent (%) of maximum, heater current being used should increase. The optimum area for control can be obtained by keeping the meter pointer between 0.2 and 0.7 on the meter face.

Abruptly decrease the set point temperature by 5 Kelvin. The sensor temperature now represents a temperature warmer than that represented by the set point. The NULL meter should deflect to the left and the HEATER CURRENT should go to zero immediately. As the sample holder cools, the NULL METER pointer should return toward zero.

As the NULL METER pointer approaches zero, the HEATER CURRENT will increase from zero to the new steady state value required to maintain the sample at the lower temperature requested. The NULL METER should read zero as the HEATER CURRENT stabilizes at its new value.

Now abruptly increase the set point vernier control by 5 Kelvin. The sensor voltage or resistance now represents a temperature colder than that represented by the set point. The NULL meter should deflect to the right and the HEATER CURRENT meter should deflect toward full scale. As the sample holder heats, the NULL meter pointer will tend to zero and the HEATER CURRENT meter reading will decrease toward its new steady state value. As the NULL meter centers, the HEATER CURRENT should stabilize at the new constant value required to maintain the desired temperature.

A sketch of the temperature versus time pattern described above is given in Figure 3.3. Observe that there is no temperature overshoot or oscillation when the "GAIN" and "RESET" controls are properly adjusted. (This statement presupposes that the sample holder, heater, and sensor may be accurately modeled as a simple R-C type time constant thermal circuit.)

If oscillation or overshoot are observed when changing the set point voltage in small increments, reduce the GAIN and increase the RESET time constant (rotate CCW) settings until oscillations are no longer observed and/or adjust the HTR CURRENT RANGE (Key No. 12) to a lower setting.

Normally at cryogenic temperatures, the above adjustments will result in a stable system with good transient response due to the short time constants encountered at these temperatures. For these constants, the rate switch should remain in an off position. If, however, the transient response of the system must be improved, this can be done by the addition of rate (or derivative) to the control functions.

Physically, the effect can be described as introducing anticipation into the system. The system reacts not only to the magnitude and integral (RESET) of the error, but also its probable value in the future. If the error is changing rapidly, then the controller responds faster. The net result is to speed up the response of the system.

To increase system response (if needed) take the "RATE" control (Key No. 10) out of the detent (off) position in the clockwise direction. For various settings of the control, observe the transient response to a change in set point. Too short a time constant may result in oscillation and an unstable system. A change in gain may be necessary to eliminate oscillation or overshoot.

3.6 MAN and MIX Control Mode

By placing the Control Mode switch (Key No. 8) in either MAN or MIX, a manually settable constant current may be supplied to the heater element. The magnitude of the current is determined by the setting of the

MAN HEATER current potentiometer (Key No. 8) and the HTR CURRENT RANGE (Key No. 12). The current supplied to the heater is indicated on the HEATER CURRENT meter. The full scale reading of the meter corresponds to the HTR CURRENT RANGE switch setting. MAN HEATER CURRENT MODE allows the user to hold a temperature for a short period of time in an open loop condition while he uses the null meter and the digital set point to a second sensor. This is accomplished by adjusting the MAN HEATER current (Key No. 8) such that the heater current (Key No. 13) does not vary when switched from Auto to MAN or MIX (Key No. 7).

The MIX mode can be useful under certain conditions where the load on the controller is not varying by much and very good stability of the control point is desired. In some systems, by using the manual reset to provide most of the desired output power, the control parameters of the controller (i.e., gain in particular) may be increased so as to significantly improve the stability of the control point. Please note that the control circuit can both add and subtract power from the manual reset power setting.

3.7 Remote Parallel BCD Input/Output Option

The remote programming option consists of a TTL parallel 18-bit input of set point voltage and a TTL parallel 17-bit output of one-half of the sensor voltage. It is assumed that the sensor voltage output can be multiplied by two within the computer. The cable pin-out connections are indicated in Tables 3.2 and 3.3.

The internal and external BCD input of the set point is accomplished by setting connector J2 pin-38 high (+5V) for external BCD or low (0 V) for internal BCD.

The BCD output of one-half of the sensor voltage is present at all times independent of the internal or external status of the BCD set point input.

3.8 Grounding

The chassis is grounded by the 3 lead power cable to the electrical supply common ground. The common lead of the controller circuitry ("LOW") terminal of the heater output - (Key 23, Fig. 3.2) can be externally connected to the chassis ground terminal. Although the grounding of the controller common is normal operation practice, the common "LOW" terminal may be disconnected from chassis ground if doing so helps to eliminate accidental ground loops within the system.

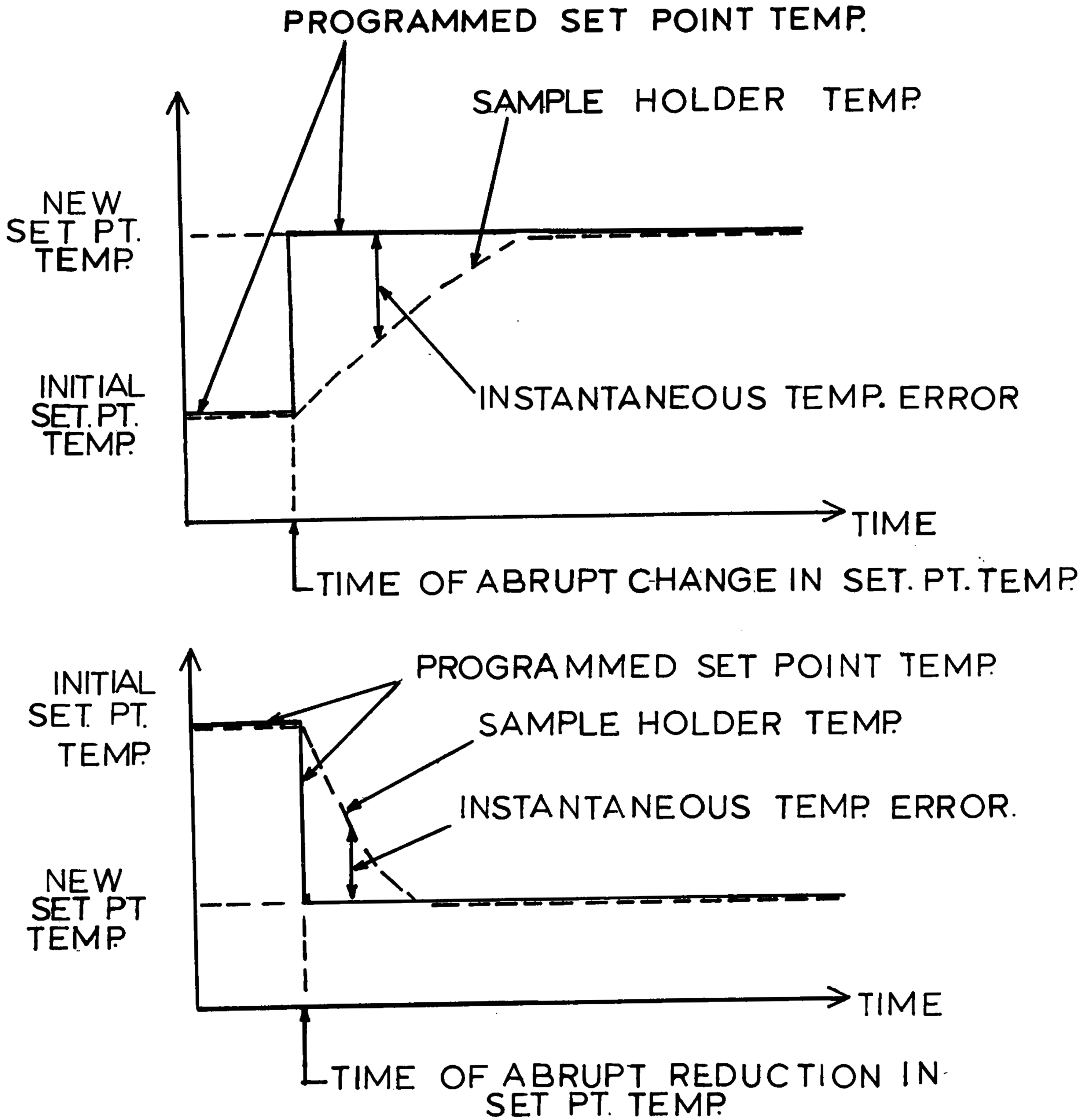

Figure 3.3 Temperature versus Time Characteristics of Controller

Table 3.2

Parallel BCD Output of Sensor Voltage/Input of Set Point

2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39

PIN	BCD VOLTAGE OUTPUT	PIN	BCD VOLTAGE SET POINT INPUT
1	.0001	2	.0008
3	.0002	4	.0004
5	.0004	6	.0002
7	.0008	8	.0001
9	.001	10	.008
11	.002	12	.004
13	.004	14	.002
15	.008	16	.001
17	.01	18	.08
19	.02	20	.04
21	.04	22	.02
23	.08	24	.01
25	.1	26	.8
27	.2	28	.4
29	.4	30	.2
31	.8	32	.1

PIN	BCD VOLTAGE OUTPUT	PIN	BCD VOLTAGE SET POINT INPUT
33	1.	34	2
35	DATA VALID	36	1
37		38	If high (+5V) Select Remote Set Point
39	Common Ground		
		40	Common Ground

Note: BCD output is one-half of actual sensor voltage.

SECTION IV

Theory of Operation

4.1 Introduction

This section contains the theory of operation of the Model 520 Cryogenic Temperature Thermometer/Controller.

In some applications, it may be required for an experienced user to modify the gain, reset or rate range. The information given within this section should make these modifications straightforward.

4.2 General Description

Refer to Figures 5.1, 5.2, 5.3 and 5.4 as an aid in the following discussion. A precision current source causes a DC current to bias the control sensor. For a diode sensor, the recommended current is 10 microamperes. For a resistance thermometer, the current choices range from 1 to 3000 microamperes in 1X and 3X steps. The current chosen is a compromise between increasing the current to maximize signal size and keeping the signal small so that self-heating of the thermometer does not give erroneous temperature data. Therefore, to keep the self-heating to a minimum, a voltage signal between 1 and 3 millivolts will give the best results. For example, a Germanium at 30 Kelvin will have a self-heating error of 6 or 7 mK with a 10 mV excitation. If this type of temperature rise or error is not a problem within the system, then the larger signal strength should be used because of the improved signal to noise ratio. While the power dissipation for a germanium or carbon glass resistance thermometer is measured in nanowatts, power dissipation for a platinum resistance thermometer is measured in microwatts. The recommended power dissipation for a platinum resistance thermometer is 10 microwatts or less. For a 100 ohm platinum, this corresponds to 1 milliampere at the lower temperatures and 300 microamperes at or near room temperature.

If a diode thermometer is used for control, its voltage signal is first buffered and then inverted in sign. If a resistance thermometer is used for control, its millivolt signal is amplified by 100 and inverted in sign by means of an instrumentation amplifier, which makes its magnitude and sign the same order of magnitude as the voltage signal from a diode thermometer.

In the case of a resistance thermometer, the output from the instrumentation amplifier is compared to the sensor alert voltage and if that output exceeds the user selected value, the sensor alert LED is lit to indicate that the voltage across the sensor has exceeded the user set limit. This comparator does not introduce an error or offset in the sensor voltage signal under any conditions.

The digital set point is converted to an analog voltage by using two three-digit D/A converters. One converter transforms the three most significant digits to its corresponding voltage and the other converter transforms the two least significant digits to its corresponding voltage. These two voltages are summed by means of a summing amplifier and then inverted again to result in a positive voltage signal which is opposite in sign from the processed sensor voltage.

The processed negative sensor voltage and the positive set point voltage are then summed through two selected precision resistors and amplified by a gain stage with a range of 1000 to 1. The result is zero current at the summing junction when the set point voltage is just equal in magnitude to the processed sensor voltage. If a difference exists between these two voltages, this error signal, because of the virtual ground of the gain amplifier, becomes a current which is amplified as a voltage by the variable gain operational amplifier U19. This amplified voltage error is displayed on the NULL meter and also applied through an inverter to (1) an integrator circuit (reset), (2) a bound or clamping circuit and (3) a differentiator circuit (rate) in the case of a diode sensor or a negative temperature coefficient resistance thermometer. In the case of a positive temperature coefficient resistor, the sign of the error signal is reversed and the inversion of the amplified error signal must be avoided so that the control circuit will add power when the sensor temperature is below the set point temperature and reduce power when the sensor temperature is high compared to the set point temperature.

The amplified error signal, its integral and differential, are summed as current by the operational amplifier U23. This amplifier then drives the output power circuit. The current from the power amplifier is metered by the output current meter. Changing the current range from 10 mA to 1 Amp changes the voltage gain of the output stage from 0.1 to 10. Closed loop control action is achieved through the thermal path between the heater element and the temperature sensor.

4.3 Detailed Description

A. Power Supplies

There are seven regulated supply voltages within the Model 520. They are designated as P/S-1 through P/S-7 (Figure 5.4). P/S-1, consisting of a diode bridge CR1 and regulator U1, supplies a regulated 15 volts and an unregulated 20 volts to the circuit comprising the constant current source and its associated switching. P/S-2 through P/S-5 consist of diode bridge CR2 with regulators U2 through U5 which supply +15, +8, -8, and -15 volts respectively. The ±15 volt supplies power the D/A converters while all the amplifiers run off ±8 volts. P/S-6, consisting of diode bridge CR3 and regulator U6, supplies the +5 volts for the D/A convertors and the BCD option.

P/S-7 consisting of switch S9, half wave rectifier diodes CR4 and CR5, and regulator U7 supply the regulated output power stage. The output voltage is approximately 16 volts on the low scale and 33 volts on the high scale.

B. Constant Current Supply

A precision reference voltage is generated with respect to the positive voltage of supply P/S-1 by an internally temperature stabilized precision voltage reference U8 whose current is set by resistor R3. Resistors R4 through R22 together with switch wafer S1A set the appropriate current on each range together with the feedback circuit which consists of operational amplifier U9 and the p-channel FET U10. This current is directed to the appropriate sensor by means of switch S2. Trimpots R4 through R11 adjust the current independent of each other for their appropriate value as shown on Figure 5.2.

The entire constant current supply was designed to be fully floating so that the sensor can be at a potential different from ground potential.

C. Set Point Voltage

The digital set point consists of two digital-to-analog converters which in combination give a set point linearity of better than 0.025%. The three digit D/A converter U15 converts the three most significant digits to their equivalent voltage. Since this conversion must be accurate to two orders of magnitude beyond its least significant digit in order to add the two least significant digits of the set point without error, both the zero and the gain of U15 must be trimmed. The zero is adjusted by trimpot U39 and the gain is adjusted by means of trimpot U38. The two least significant digits of the set point are input to the two least significant digits of the three digit D/A converter U16. Therefore, when the resultant voltages of the two converters are summed by operational amplifier U17, the ratio of R49/R48 is chosen to be 100. Operational amplifier U18 is an inverter to correct the sign of the summed voltages while R52 is a trimpot to adjust the magnitude of the summed voltages to correct for the accuracy specifications of the resistors used for these two amplifiers.

D. Summing Variable Gain Amplifier

The negative processed sensor voltage and the positive set point voltage are summed and amplified by the variable gain amplifier U19. Two precision selected resistors R37 and R58 or R56/R57 in place of R58 are used to create an error signal current which is amplified by the amplifier to give an amplified error signal. Switch wafer S1C and R56 through R58 allow the set point to read directly in resistance by scaling the set point current with the sensor current.

Capacitor C13 is present for high frequency stability. The chopper stabilized amplifiers U19, U13, U14, U17, and U18 achieve their low offset by comparing the inverting and non-inverting input voltages in a nulling amplifier, nulled by alternate clock phases. For the gain amplifier U19, this charge is stored on capacitors C29 and C30, with corresponding capacitors for the other four amplifiers.

The gain range is determined by switch S3 and resistors R61 through R64. The variable gain range is controlled by trimpot R67 with the total feedback circuit consisting of resistors R59 through R68. Increasing or decreasing the sensor current by a factor of three would change the loop gain of the instrument by the same factor. Therefore, switch wafer S2D together with wafer switch S1D adjust the amplifier gain by shorting out resistor R60 on the X3, X30, X300, and X3K scales so that the overall loop gain is not changed.

Since the Model 520 controller is capable of using both positive and negative temperature coefficient sensors, a sign change must be made for the negative temperature coefficient sensors so that the control circuit will add power when the processed sensor voltage is greater than the set point voltage and reduce power when the inverse is true. This is accomplished by means of the inversion amplifier U20 and the switch wafers S2F and S2G.

E. Null Meter Circuit

The output of the variable gain amplifier is fed to the null meter circuit as well as the rest of the control circuits. The Null Meter is desensitized for large errors by placing two germanium diodes across its terminals. The result is a linear scale for errors less than 50% of full deflection in either direction with a high non-linearity for large errors. The sensor-set point error can be related to gain settings by the following table for small errors. The units/division are the set point units which are selected by the user.

Table 4.1

Translation of Null error versus set-point deviation as a function of gain:

Gain	Sensor Set Point Error, S.P. Unit/Div.
1	800
3	270
10	80
30	27
100	8
500	2.7
1000	0.8

F. Automatic Reset Circuit, Bounding Circuit

The bound circuit and variable gain integrator are realized by operational amplifiers U21 and U22 respectively. Note that for an under temperature condition, the voltage applied to these amplifiers is positive and the integrator will integrate unless the input voltage exceeds approximately 2 volts. Above this voltage input, the comparator output goes negative to close to -8 volts and diode CR14 conducts and causes the integrator to shut down effectively taking it out of the control circuit. For an over temperature condition, the input voltage is negative and the integrator output is clamped by the germanium diode CR15 to approximately -0.4 volts.

However, with the input signal between zero and two volts, the integrator is operational and ultimately, once the system is controlling and stable, the voltage developed across the integrating capacitor C36 becomes just equal to the error signal which would be required to hold the set point temperature under open loop conditions. Since this voltage is now present on the capacitor of the reset amplifier, it is no longer needed at the output of the gain summing amplifier resulting in the error signal reducing to zero.

The switch in series with R77 in the feedback loop is closed when the RESET control is in the off position and the amplifier gain is approximately 0.001.

G. Automatic Rate Circuit

For most cryogenic applications, the addition of rate will not greatly enhance the system response. However, in some applications, rate may be extremely useful. The blocking capacitor C34 will only pass a signal for a rapidly varying input. The rate potentiometer R89 allows the time constant of that differentiator to be varied over nearly two orders of magnitude. With the RATE switch closed, the circuit is effectively disabled from the controller since the gain is less than 0.001.

H. Output Power Amplifier

The output power stage consists of a summing amplifier (U23a) and a current mirror with its associated current network, an output current limit network and a heater current metering circuit. The summing amplifier U23a adds the currents from the gain, reset, and rate stages through R83, R84, and R85 when in the AUTO or MIX mode. Switch S4 adds in manual reset under the MIX or MAN positions through the resistor group R91, R92 and R94. The zener and diodes CR17, CR18 and CR19 limit the amplifier output. The buffer amplifier U23b transfers this voltage to the resistor R98 and through the series string to R99 and the FET U25. The resistors R96 and R97 are present to provide a load to the buffer amplifier and for stability.

The output amplifier U24 drives the output FET U26 such that the current in the output circuit is mirrored to the output by establishing the voltage across the selected range resistor R109 through R114 to equal the voltage developed across R99. The output current is therefore only dependent on the voltage developed across R99 and the magnitude of the selected range resistor. The zener CR16 limits the voltage across U24 to 24 volts on the high load resistance range (Switch S9).

I. Heater Current Metering

The heater load current is measured by the heater current ammeter, shunted by resistor R103 through R107 as appropriate. Approximately .5 volts appears across the the Heater Current Meter (M2) and its appropriate shunt resistor.

SECTION V

Maintenance and Calibration

5.1 Introduction

This section contains maintenance and calibration information for the Model 520. This section also includes an illustrated parts breakdown as well as schematics for the unit.

5.2 General Maintenance

Clean the 520 periodically to remove dust, grease and other contaminants. Use the following procedure:

A. Clean the front and back panels and case with a soft cloth dampened with a mild detergent and water solution. Caution: Do not use aromatic hydrocarbons or chlorinated solvents to clean the 520. They may react with the plastic materials used in the unit or the silk screen printing on the front and back panels.

B. Clean the surface of the printed circuit boards (pcb) using clean, dry air at low pressure. If grease is encountered, spray with Freon T.F. degreaser and remove grime with dry, low-pressure air.

5.3 Access Information

5.3.1 Fuse Replacement

The line fuse is accessible from the rear of the 520. Use the following procedure to check and/or replace the fuse:

A. Set the POWER switch of OFF and unplug the unit. The fuse holder is located on the back panel just above the power cord.

B. Gently push in on the cap of the fuse holder and turn counter-clockwise and remove from holder.

C. Remove and inspect fuse. If replacement is required, use MDL 3/4 amp fuse for 90-125 VAC operation and MDL 4/10 amp fuse for 210-250 VAC operation.

D. Insert fuse and cap into fuse holder, push in and turn clockwise to lock cap in place.

5.3.2 Model 5201 BCD Option Installation

The installation of the Model 5201 BCD option is performed as follows:

A. Remove instrument cover.

B. Locate and remove shorting pcb installed in internal edge connector J8 (see Figure 5.1 - Component Layout - A1 Main PCB).

C. Insert the Model 5201 pcb into connector J8 (the board is configured such that the option board can be installed in only one way, with the components side to the front of the unit and connection cable to the back).

D. Route 40 pin ribbon connector to rear panel access slot J2 and secure with screws provided.

E. Replace instrument cover.

5.4 Operational Checks

Replace the temperature sensors shown in Figure 2.1 with precision resistors to simulate the sensors. Remove the heater element leads and place a 25 watt, 25 ohm resistor across the heater output terminals.

With the Diode selected as the sensor and a 100K ohm resistor in place of the diode, set the sensor current selector switch to 10 microamperes. A potential of 1.00 volts should be developed across the resistor. With the gain set to a high value and the Control Mode selector switch set to MAN, attempt to null the error with a set point in the vicinity of 1.0 volts. The null meter should swing smoothly as the set point voltage is varied in the vicinity of the null.

While still in the MAN position, set the HTR CURRENT RANGE switch to 1000. Vary the Heater Current Control potentiometer from zero toward its maximum. The current meter should increase linearly along with the advance of the pot. With the Heater Current Control pot set to give mid-scale heater current meter deflection, rotate the HTR CURRENT RANGE switch through all of its positions. The heater current meter indication should remain approximately at mid-scale in all of the positions.

Zero the null meter with the set point voltage controls. Turn the RESET and GAIN controls to mid-scale position. Set the HTR CURRENT RANGE switch to 1000. Position the mode control switch to AUTO. Abruptly change the set point voltage sufficiently to cause a +10 unit deflection of the NULL meter to the right. The heater current meter deflection will consist of two components. The first is a rapid step rise due to the steady null error and a second, gradually rising component due to the RESET circuit integrating the steady error. The heater current meter will gradually rise toward full scale deflection. The rate at which the heater current rises is determined by the RESET time constant setting. The rate is a minimum in the counterclockwise position and a maximum in the fully clockwise position.

Abruptly change the set point voltage to cause -10 units deflection of the NULL meter to the left. The HEATER CURRENT meter should gradually decrease from full scale deflection to zero. The rate at which the current meter goes to zero is in part determined by the reset bounding circuit.

Similar tests should be performed for the Res(-) and Res(+) modes. If the instrument does not respond to the tests as outlined, refer to Section 5.6 for the Troubleshooting procedure.

5.5 Calibration

The test equipment necessary for calibration is as follows:

A. Digital voltmeter/multimeter, 4½ digits or more.

B. Test cable and precision resistors to simulate the temperature sensors.

C. Precision voltage source.

Refer to Figure 5.1 - Component Layout - A1 Main PCB for adjustment trimpot locations.

5.5.1 Current Sources

The eight independent sensor current values have been factory calibrated to better than ± .01% of value. To check the sensor current, a precision resistance of not less than .01% tolerance should be connected across the I+ and I- leads for one of the two sensor type inputs (J1 pins 1 and 7 for diode or pins 8 and 14 for resistors).

Place the digital voltmeter across the precision resistance. Select the current range to be checked (the corresponding voltage read on the voltmeter is given by V = I x R; where I is the current selected and R is the precision resistance).

Below is listed the current ranges and adjustment trimpots for each range. Adjust the proper trimpot for that range to achieve the desired voltage across the precision resistance.

Sensor Current (microamperes)	Adjustment Trimpot
1	R4
3	R5
10	R6
30	R7
100	R8
300	R9
1000	R10

5.5.2 Set Point

A. Place voltmeter from Analog Ground to the output of the most significant Set Point DAC (Pin 15 or 19 of U15).

B. Dial a set point of 0.0000 on front panel set point switches.

C. Adjust trimpot R39 until voltmeter zeroes past the 100μV place.

D. Dial a set point of 3.9900.

E. Adjust R38 until voltmeter reads 3.9900 V.

F. Place voltmeter at output of set point DAC summing amplifier (Pin 10 of U18).

G. Go between minimum and maximum values of set point and adjust trimpot R52 for optimum linearity.

5.5.3 Diode Input Buffer

A. Select diode as the type of sensor.

B. Apply a voltage source across the diode voltage input pins (J1 pin 2 is V+, pin 3 is V-).

C. Place a voltmeter from ground to pin 10 of U14.

D. Input a voltage of 4.0000 volts from the voltage source.

E. Adjust R35 to read 4.0000 volts on the voltmeter.

F. Scan the range between a 0.0000 volts and 4.0000 volts to assure linearity.

5.5.4 Resistor Input Amplifier

A. Select resistor as the type of sensor.

B. Apply a voltage source across the resistor voltage input pins (J1 pin 12 is V+, pin 13 is V-).

C. Place a voltmeter from ground to pin 9 of U11.

D. Input a voltage of 0.000 millivolts from the voltage source.

E. Adjust R24 until voltmeter reads 0.0000 V.

F. Input 40.000 millivolts.

G. Adjust R27 until voltmeter reads 4.0000 V.

5.5.5 3X Current Summing

A. Select resistor as the type of sensor.

B. Input 30.000 millivolts to resistor input leads (J1 pin 12 is V+, pin 13 is V-).

C. Dial in 1 0000 on set point switches.

D. Select a 3X current source setting (3, 30, 300 or 3000 microamperes).

E. Set gain to X100.

F. Adjust R57 until null meter nulls at its center position.

5.6 Troubleshooting

When troubleshooting the 520, use the following precautions to prevent damage due to static discharge:

A. Set the 520 POWER switch to OFF before removing or installing components or pbcs.

B. Minimize handling of static sensitive components.

C. Use ground straps to discharge repair personnel static before handling devices.

D. Use conductive or anti-static containers for storage and transport of components or circuit boards.

E. Keep parts in their original containers.

F. Pick up static sensitive components only by the body.

G. Do not slide static sensitive components over any surface.

H. Avoid plastic, vinyl and styrofoam in the work area.

I. Perform all repairs at a static-free work station.

J. Only grounded tip soldering irons and anti-static type de-soldering devices should be used.

A troubleshooting guide for the 520 is given in Table 5.1. To properly use the guide, complete the operational check given earlier in this section and note any discrepancies. Locate the problem in the Symptom column and perform the appropriate tests for the possible causes as listed next to the Symptom. Corrective actions are given for the various possible causes. Schematics and component layouts for the various pcb assemblies are given later in this section.

The test equipment necessary for troubleshooting is as follows:

A. Digital voltmeter/multimeter, 4½ digits or more.

B. Test cable and precision resistors to simulate the temperature sensors.

C. Power resistor to simulate the heater.

5.7 Replaceable Parts

Below is a list of Tables and Figures for the 520 schematics, replaceable parts list and illustrated components layouts.

The parts lists include the following information:

A. Reference Designation or Item Number

B. Description of each part

C. LSCI Stock Number

D. Abbreviated Manufacturer (see end of section for Cross Reference of Parts Manufacturers, Table 5.10)

E. Manufacturer Part Number or Type

F. Total Quantity per assembly or component

5.7.1 How to Obtain Parts

Components may be ordered directly from the manufacturer by using the manufacturer's part number, or from LSCI or authorized LSCI representative by using the LSCI part number.

To ensure proper handling of your order, include the following information:

A. Quantity

B. LSCI Stock Number

C. Description

D. Reference designation or item number

E. Assembly number

F. Instrument model and serial number

Table 5.1

Troubleshooting Guide for Model 520

Symptom	Possible Cause/Corrective Action
1. General Failure	1. Blown fuse. Replace fuse one. 2. 115/230 V line switch set to 230 V using a 115 V line. Set switch to 115 V. 3. Power supply failure. Verify the D.C. potential at the output of the power supply regulators (U1-U7) with respect to their respective grounds. If any of these regulators has no output, then check to see if it has input voltage. If it has input voltage, but no output, replace the regulator. If it has no input voltage, check to see if there is AC voltage at the input of the rectifier for that supply. If there is AC input and no DC output, replace the rectifier. If there is no input, replace TX1.
2. No Sensor Current	1. No reference. Verify that the output of the reference (pin 1 to pin 2 of U8) is approximately 6.95 V. If it is not, then replace U8.
3. Instrument doesn't null properly	1. Verify that the shorting board or a BCD option board is plugged into J8. 2. Set point problem. Verify that the output voltage of U18 (pin 10 to GND) corresponds to the set point switches on the front panel. If it doesn't, then check to see if the voltage is at the output of U19 (pin 10 to GND). If it is, replace U18. If it is not, then verify the output of the digital to analog converters. Pins 15, 19 of U15 to GND should corresond to the three most significant digits of the set point. Pins 15, 19 of U16 to GND should

Table 5.1, cont'd.

Troubleshooting Guide for Model 520

Symptom	Possible Cause/Corrective Action
3. Instrument doesn't null properly, cont'd.	correspond to the two least significant digits of the set point. If the voltages are present, replace U17. If the voltage at one or both of the DAC outputs is not there, verify the digital code inputs. If the input codes are correct, replace the DAC. If the input codes are wrong, replace set point switch. 3. Input problem. Verify that the output of the input buffer (DIODE) or amplifier (RESISTOR) is correct. For diode input, check if input voltage is present at pin 5 of U13. If it is not, check for improper input connection. If it is, check to see if it is also at pin 10 of U13, and its negative value at pin 10 of U14. If it is not at one of these outputs, replace that amplifier. For resistor input, check to see if the input voltage is present at pin 1 of U11. If it is not, check for improper input connection. If it is correct, check to see the output (pin 9) is equal to -100 times the input. If it is not, replace U11. 4. Summing problem. Verify that the output (pin 10) of U19 is approximately zero when input voltage is equal to set point voltage. If it is not, replace U19.
4. No heater current	1. Blown fuse. Replace fuse two. 2. Output stage problem. Set control mode to MANual and rotate the manual heater potentiometer on the front panel. Verify that the voltage at pin 1 of U23 ranges from 0 to approximately 2.8V. If this is incorrect, replace U23. Then check if the voltage across R99 varies between 0 and 1 volt. If it doesn't, try replacing U23 and/or U25. If everything is correct to this point, try replacing U23 and/or U26.

Table 5.2 Parts List - A1 Main Schematics
(LSCI Part # 113-096)

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
A1A1	MODEL 520 MAIN BOARD P.C. BOARD ARTWORK #: D278-83-01B	111-036	CDT		1
A1A2	SHORTING BOARD	111-030	CDT		1
C1	CAP,ELECT,470MF,35V	101-001	PANS	ECE-A-1VV-471S	3
C2	CAP,POLY,.68MF,100V	101-009	PLSY	160.68J100G	7
C3	CAP,ELECT,470MF,35V	101-001	PANS	ECE-A-1VV-471S	REF
C4	CAP, POLY,.68MF,100V	101-009	PLSY	160.68J100G	REF
C5	CAP, POLY,.68MF,100V	101-009	PLSY	160.68J100G	REF
C6	CAP, ELECT,470MF,35V	101-001	PANS	ECE-A-1VV-471S	REF
C7	CAP, POLY,.68MF,100V	101-009	PLSY	160.68J100G	REF
C8	CAP, POLY,.68MF,100V	101-009	PLSY	160.68J100G	REF
C9	CAP,ELECT,2200MF	101-057	PANS	ECE-A-1CV-222S	1
C10	CAP, POLY,.68MF,100V	101-009	PLSY	160.68J100G	REF
C11	CAP,ELECT,4000MF	101-056	MEP/EL	3186BA402U050BMA2	1
C12	CAP,POLY,0.1MF,100V	101-008	PLSY	160.1K100G	4
C13	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	13
C14	CAP,MICA,150PF,500V	101-013	CDE	CD15CD151G03	1
C15	CAMp,MYLAR,.0015MF,100V	101-004	CDE	WMF1D15	1
C16	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C17	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C18	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C19	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C20	CAP,POLY,1MF,100V	101-011	PLSY	1501K100FC	4
C21	CAP, POLY,1MF,100V	101-011	PLSY	1501K100FC	REF
C22	CAP,MYLAR,.01,100V	101-020	SPRG	416P-10391	2
C23	CAP,MYLAR,.01,100V	101-020	SPRG	146P-10391	REF
C24	CAP,POLY,1MF,100V	101-011	PLSY	1501K100FC	REF
C25	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C26	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C27	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C28	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C29	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C30	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C31	CAP,POLY,.1MF,100V	101-008	PLSY	160.1K100G	REF
C32	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C33	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1533	REF
C34	CAP,POLY.,1MF,100V	101-011	PLSY	1501K100FC	REF
C35	CAP,POLY,0.1MF,100V	101-008	PLSY	160.1K100G	REF
C36	CAP,POLY,.68MF,100V	101-010	PLSY	150.68J100FC	1
C37	CAP, POLY,0.1MF,100V	101-008	PLSY	160.1K100G	REF
C38	CAP,POLY,.68MF,100V	101-009	PLSY	160.68J100G	REF

Table 5.2, cont'd.

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
CR1	BRIDGE RECTIFIER	102-029		WO2M	3
CR2	BRIDGE RECTIFIER	102-029		WO2M	REF
CR3	BRIDGE RECTIFIER	102-029		WO2M	REF
CR4	DIODE, RECTIFIER	102-008	MOT	MR501	2
CR5	DIODE, RECTIFIER	102-008	MOT	MR501	REF
CR12	DIODE, SIL, G.P.	102-003	FARC	IN459A	4
CR13	DIODE, SIL, G.P.	102-003	FARC	IN459A	REF
CR14	DIODE, SIL, G.P.	102-003	FARC	IN459A	REF
CR15	DIODE, SIL, G.P.	102-003	FARC	IN459A	REF
CR16	DIODE, ZENER, 24V	102-033	MOT	IN4749A	1
CR17	DIODE, ZENER, 4.7V	102-036	MOT	IN750A	1
CR18	DIODE, SIL, SIG.	102-004	GE	IN4148	2
CR19	DIODE, SIL, SIG.	102-004	GE	IN4148	REF
H1	HEAT SINK	110-021	AV	601-30-020B	3
H2	1/4 #4 METAL SCREW	110-112			6
H3	4-40 KEP NUT	110-108			3
H4	4-40 x ¼" PHMS	110-102			3
H5	6-32 X ½" PHMS	110-122			2
H6	6-32 KEP NUT	110-129			2
J1	10 PIN TRANS. CONNECTOR	106-135	AMP	1-380991-0	1
J8	50 PIN CONNECTOR	106-133	EDAC	307-050-520-202	1
R1	RES,MTF,261Ω,1%,¼W	103-230			1
R2	RES,MTF,6.65K,1%,¼W	103-324			1
R3	RES,MTF,3.74K,1%,¼W	103-296			1
R4	POT, 1M	103-013	BOR	3006P-1-105	1
R5	POT, 500K	103-031	BOR	3006P-1-504	1
R6	POT, 100K	103-014	BOR	3006P-1-104	1
R7	POT, 50K	103-012	BOR	3006P-1-503	1
R8	POT, 10K	103-030	BOR	3006P-1-103	3
R9	POT, 5K	103-010	BOR	3006P-1-502	2
R10	POT, 1K	103-029	BOR	3006P-1-102	1
R11	POT, 500Ω	103-008	BOR	3006P-1-501	2
R12	RES,MTF,2.15K,1%,¼W	103-280			1
R13	RES,MTF,6.49K,1%,¼W	103-322			1
R14	RES,MTF,21.5K,1%,¼W	103-370			1
R15	RES,MTF,64.9K,1%,¼W	103-407			2
R16	RES,MTF,215K,1%,¼W	103-441			2
R17	RES,MTF,649K,1%,¼W	103-465			1
R18	RES,MTF,2M,1%,¼W	103-106			3
R19	RES,MTF,82.5K,1%,¼W	103-414			1
R20	RES,MTF,2.2M,1%,¼W	103-107			3
R21	RES,MTF,2.2M,1%,¼W	103-107			REF
R22	RES,MTF,2.2M,1%,¼W	103-107			REF

Table 5.2, cont'd.

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
R24	RES,MTF,10K,1%,¼W	103-358			11
R25	POT, 10K	103-030	BOR	3006P-1-103	REF
R26	RES,MTF,10K,1%,¼W	103-358			REF
R27	POT, 10K	103-030	BOR	3006P-1-103	REF
R28	RES,MTF,1M,1%,¼W	103-472			2
R29	RES,MTF,12.1K,1%,¼W	103-360			1
R31	RES,MTF,365Ω,1%,¼W	103-233			1
R32	RES,MTF,196Ω,1%,¼W	103-225			1
R33	RES,MTF,10K,1%,¼W	103-358			REF
R34	RES,MTF,9.76K,1%,¼W	103-355			1
R35	POT,500Ω	103-008	BOR	3006P-1-501	REF
R36	RES,MTF,4.99K,1%,¼W	103-308			3
R37	RES,VISHAY,100K,.01%	103-017	VISH	S102C	2
R38	POT, 100K	103-005	BOR	3059Y-1-104	2
R39	POT, 100K	103-005	BOR	3059Y-1-104	REF
R40	RES,MTF,301K,1%,¼W	103-448			2
R41	RES,MTF,301K,1%,¼W	103-448			REF
R42	RES,MTF,3.92K,1%,¼W	103-298			1
R43	RES,MTF,174K,1%,¼W	103-435			2
R44	RES,MTF,10K,1%,¼W	103-358			REF
R45	RES,MTF,174K,1%,¼W	103-435			REF
R46	RES,MTF,4.75K,1%,¼W	103-306			2
R47	RES,MTF,4.75K,1%,¼W	103-306			REF
R48	RES,MTF,1K,.1%,¼W	103-491	VISH	S102C1K0000 0.1%	1
R49	RES,MTF,100K,.1%,¼W	103-492	VISH	S102C100K00 0.1%	1
R50	RES,MTF,499Ω,1%,¼W	103-251			1
R51	RES,MTF,976Ω,1%,¼W	103-262			1
R52	POT, 50Ω	103-033	BOR	3006P-1-500	1
R53	RES,MTF,10K,1%,¼W	103-358			REF
R54	RES,MTF,4.99K,1%,¼W	103-308			REF
R55	RES,MTF,10K,1%,¼W	103-358			REF
R56	RES,MTF,28.7K,1%,¼W	103-376			1
R57	POT, 5K	103-010	BOR	3006P-1-502	REF
R58	RES,VISHAY,100K,.01%	103-017	VISH	S102C	REF
R59	RES,MTF,33.2K,1%,¼W	103-381			1
R60	RES,MTF,64.9K,1%,¼W	103-407			REF
R61	RES,MTF,3.24K,1%,¼W	103-291			1
R62	RES,MTF,1K,1%,¼W	103-265			5
R63	RES,MTF,332Ω,1%,¼W	103-232			2
R64	RES,MTF,100Ω,1%,¼W	103-216			5
R65	RES,MTF,10K,1%,¼W	103-358			REF
R66	RES,MTF,1K,1%,¼W	103-265			REF
R68	RES,MTF,100Ω,1%,¼W	103-216			REF
R69	RES,MTF,1K,1%,¼W	103-265			REF
R70	RES,MTF,1.18K,1%,¼W	103-267			1
R71	RES,MTF,1K,1%,¼W	103-265			REF

Table 5.2, cont'd.

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
R72	RES,MTF,49.9K,1%,¼W	103-397			5
R73	RES,MTF,49.9K,1%,¼W	103-397			REF
R75	RES,MTF,100Ω,1%,¼W	103-216			REF
R76	RES,MTF,1.96M,1%,¼W	103-106			REF
R77	RES,MTF,100Ω,1%,¼W	103-216			REF
R78	RES,MTF,100K,1%,¼W	103-420			6
R79	RES,MTF,4.99K,1%,¼W	103-308			REF
R80	RES,MTF,2K,1%,¼W	103-278			2
R81	RES,MTF,100K,1%,¼W	103-420			REF
R82	RES,MTF,1M,1%,¼W	103-472			REF
R83	RES,MTF,100K, 1%,¼W	103-420			REF
R84	RES,MTF,215K,1%,¼W	103-441			REF
R85	RES,MTF,215K,1%,¼W	103-441			REF
R86	RES,MTF,100K,1%,¼W	103-420			REF
R87	RES,MTF,1.96M,1%,¼W	103-106			REF
R88	RES,MTF,100Ω,1%,¼W	103-216			REF
R90	RES,MTF,1K,1%,¼W	103-265			REF
R91	RES,MTF,10K,1%,¼W	103-358			REF
R93	RES,MTF,49.9K,1%,¼W	103-397			REF
R94	RES,MTF,100K,1%,¼W	103-420			REF
R95	RES,MTF,100K,1%,¼W	103-420			REF
R96	RES,MTF,10K,1%,¼W	103-358			REF
R97	RES,MTF,49.9K,1%,¼W	103-397			REF
R98	RES,MTF,562Ω,1%,¼W	103-242			1
R99	RES,MTF,200Ω,1%,¼W	103-226			1
R100	RES,MTF,10K,1%,¼W	103-358			REF
R101	RES,MTF,2K,1%,¼W	103-278			REF
R102	RES,MTF,49.9K,1%,¼W	103-397			REF
R115	RES,MTF,10K,1%,¼W	103-358			REF
R116	RES,MTF,332Ω,1%,¼W	103-232			REF
S3R67	SWITCH AND POT ASSEMBLY				1
	SWITCH:	105-070	S-G	49719-SKPCB-1	
	POTENTIOMETER:	103-037		CM44307-10K	
S4R92	SWITCH AND POT ASSEMBLY				1
	SWITCH:	105-071	S-G	49734-SKPCB-1	
	POTENTIOMETER:	103-037		CM44307-10K	
S5R74	SWITCH AND POT ASSEMBLY	113-085			2
	SWITCH:				
	POTENTIOMETER:	103-036		CM43318-100K	
	HOLDER	110-177		DH-2	
S6R89	SWITCH AND POT ASSEMBLY	113-085			REF
	SWITCH:				
	POTENTIOMETER:	103-036		CM43318-100K	
	HOLDER	110-177		DH-2	

Table 5.2, cont'd.

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
S10	SET POINT SWITCH				1
	ASSEMBLY	105-031	EECO	2A216056G	
		105-032	EECO	3A216056G	
U1	+15V REGULATOR	102-025	MOT	MC7815CT	2
U2	+15V REGULATOR	102-025	MOT	MC7815CT	REF
U3	+8V REGULATOR	102-034	MOT	MC7808CT	1
U4	-15V REGULATOR	102-028	MOT	MC7915CT	1
U5	-8V REGULATOR	102-027	MOT	MC7908CT	1
U6	+5V REGULATOR	102-022	MOT	MC7805CT	1
U8	VOLTAGE REFERENCE	102-011	NATL	LM399H	1
U9	IC,LIN,OP AMP	104-013	NATL	LM308N	1
U10	FET, P-CH	102-020	SIL	3N163	1
U11	IC,LIN,INST. AMP	104-083	AD	AD524CD	1
U12	IC,LIN,OP AMP	104-001	PMI	OPO7EP	2
U13	IC,LIN,OP AMP	104-050	DAIN	ICL7650CPD	6
U14	IC,LIN,OP AMP	104-050	DAIN	ICL7650CPD	REF
U15	IC, DAC	104-085	BB	DAC80-CCD-V	2
U16	IC, DAC	104-085	BB	DAC80-CCD-V	REF
U17	IC,LIN, OP AMP	104-050	DAIN	ICL7650CPD	REF
U18	IC,LIN, OP AMP	104-050	DAIN	ICL7650CPD	REF
U19	IC,LIN,OP AMP	104-050	DAIN	ICL7650CPD	REF
U20	IC,LIN,OP AMP	104-001	PMI	OPO7EP	REF
U21	IC,LIN, DUAL OP AMP	104-084	NATL	LM353N	1
U22	IC,LIN, OP AMP	104-050	DAIN	ICL7650CPD	REF
U23	IC,DUAL OP AMP	104-007	MOT	MC1458PI	2
U24	IC,DUAL OP AMP	104-007	MOT	MC1458PI	REF
U25	FET, N-CH PWR	102-045	SPTX	VN0106N5	1
XU9	SOCKET, IC,DIP,8 PIN	106-107	AUG	508-AGIID	6
XU11	SOCKET, IC,DIP,16 PIN	106-105	AUG	516-AGIID	1
XU12	SOCKET, IC, DIP,8 PIN	106-107	AUG	508-AGIID	REF
XU13	SOCKET, IC, DIP,14 PIN	106-106	AUG	514-AGIID	6
XU14	SOCKET, IC, DIP, 14 PIN	106-106	aug	514-AGIID	REF
XU15	SOCKET, IC, DIP, 24 PIN	106-103	AUG	524-AGIID	2
XU16	SOCKET, IC, DIP, 24 PIN	106-103	AUG	524-AGIID	REF
XU17	SOCKET, IC, DIP, 14 PIN	106-106	AUG	514-AGIID	REF
XU18	SOCKET, IC, DIP, 14 PIN	106-106	AUG	514-AGIID	REF
XU19	SOCKET, IC, DIP, 14 PIN	106-106	AUG	514-AGIID	REF
XU20	SOCKET, IC, DIP, 8 PIN	106-107	AUG	508-AGIID	REF
XU21	SOCKET, IC, DIP, 8 PIN	106-107	AUG	508-AGIID	REF
XU22	SOCKET, IC, DIP, 14 PIN	106-106	AUG	514-AGIID	REF
XU23	SOCKET, IC, DIP, 8 PIN	106-107	AUG	508-AGIID	REF
XU24	SOCKET, IC, DIP, 8 PIN	106-107	AUG	508-AGIID	REF

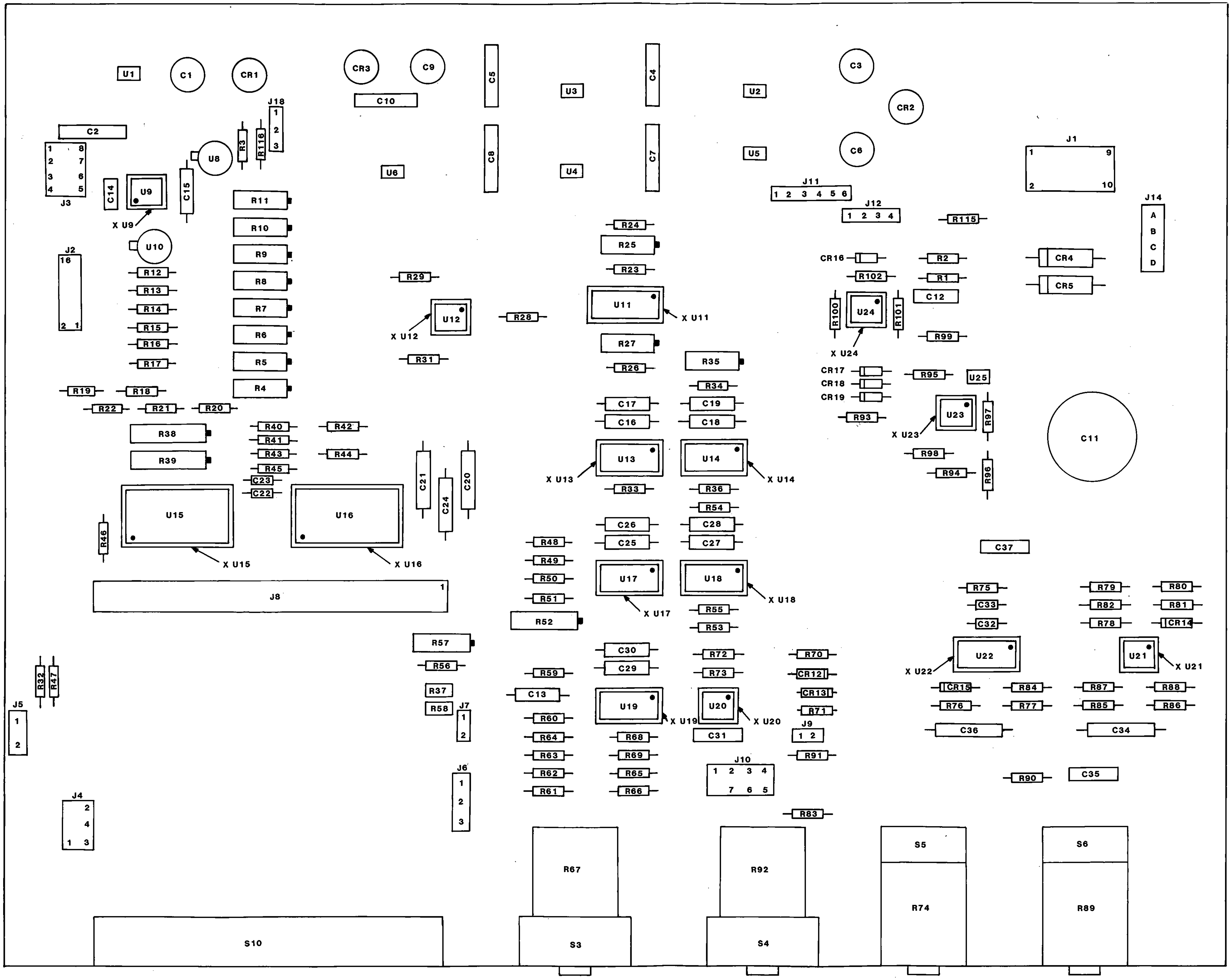

Figure 5.1

Component Layout –

A1 Main PCB

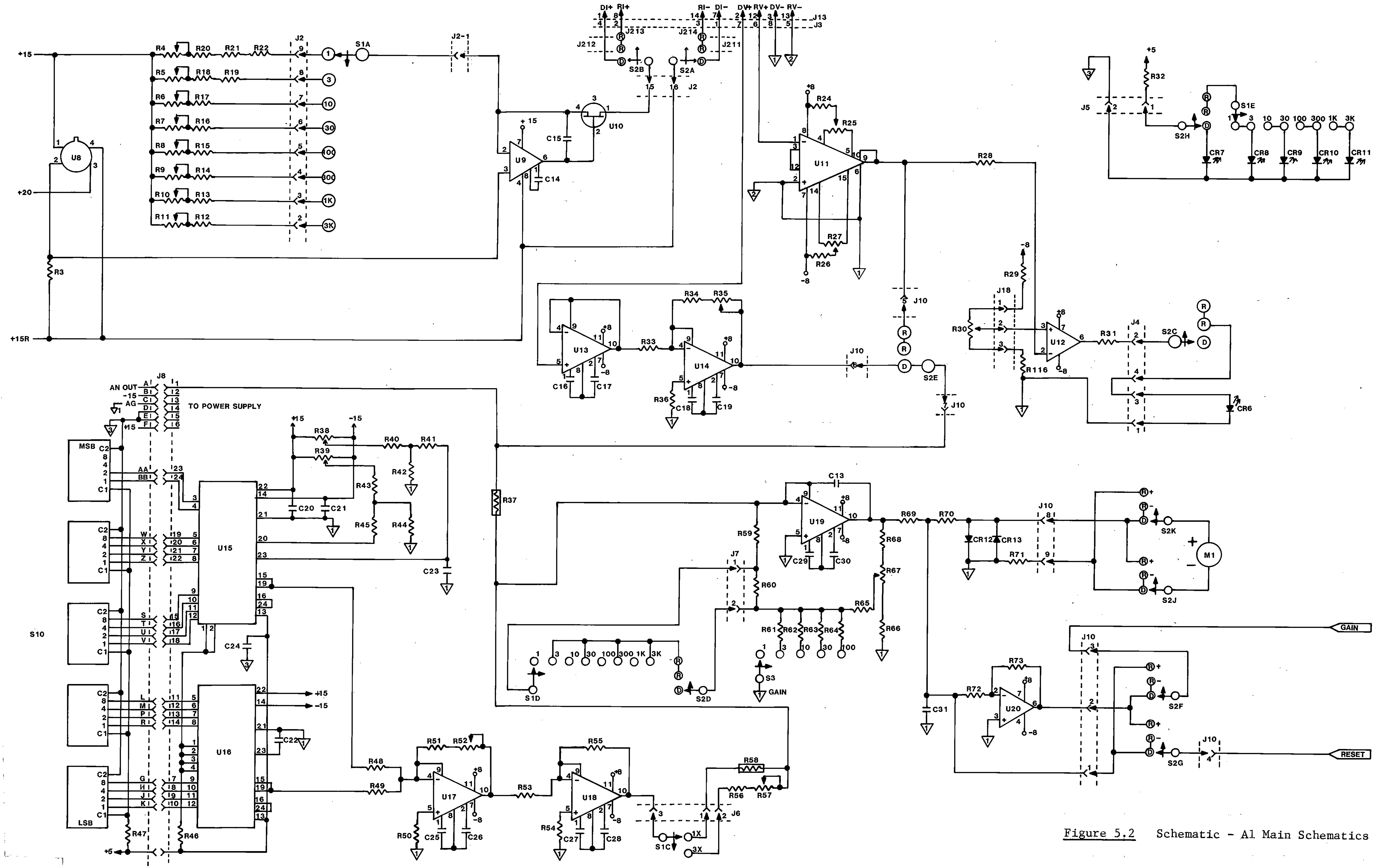

Figure 5.2 Schematic - A1 Main Schematics

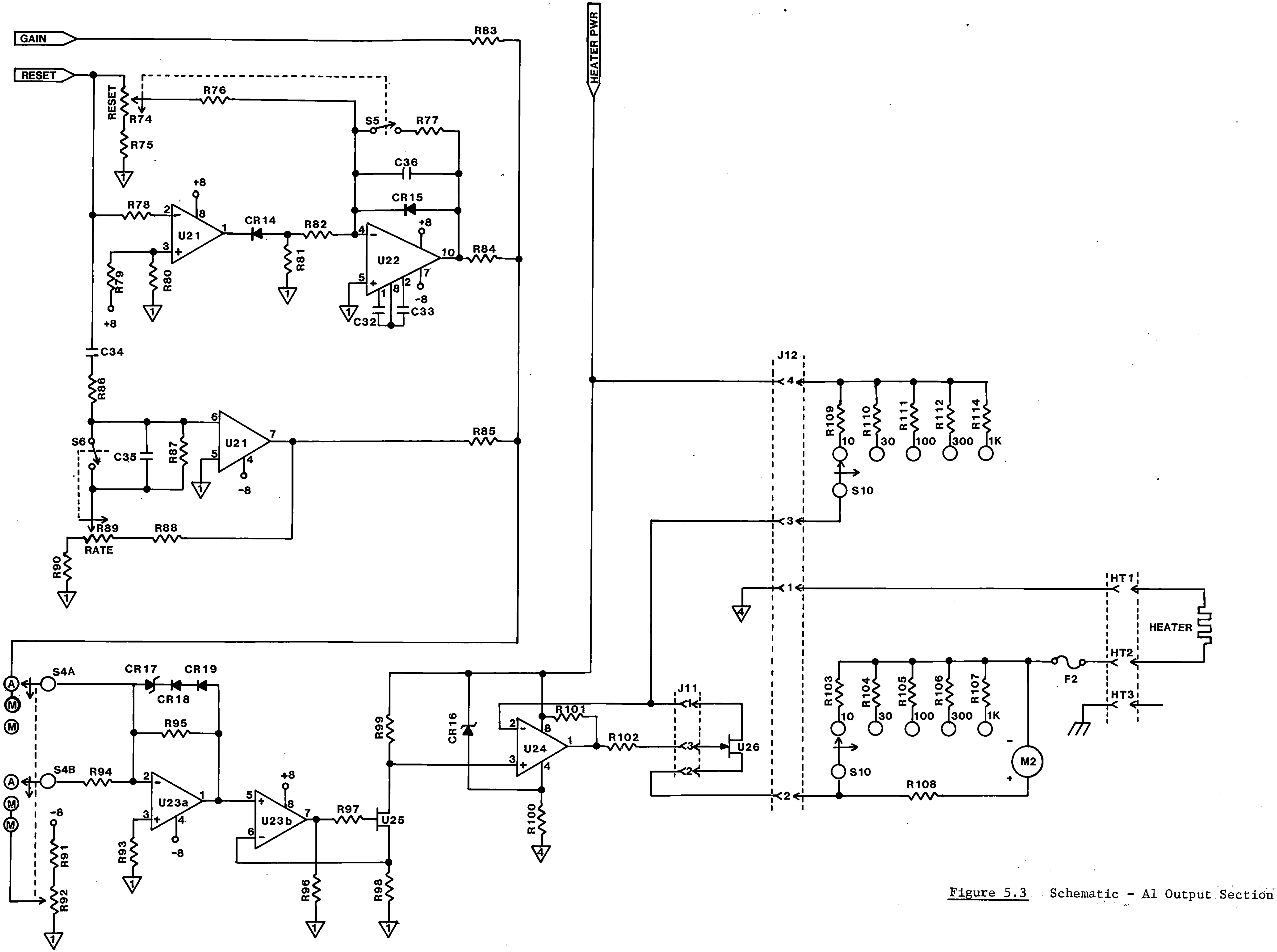

Figure 5.3 Schematic - A1 Output Section

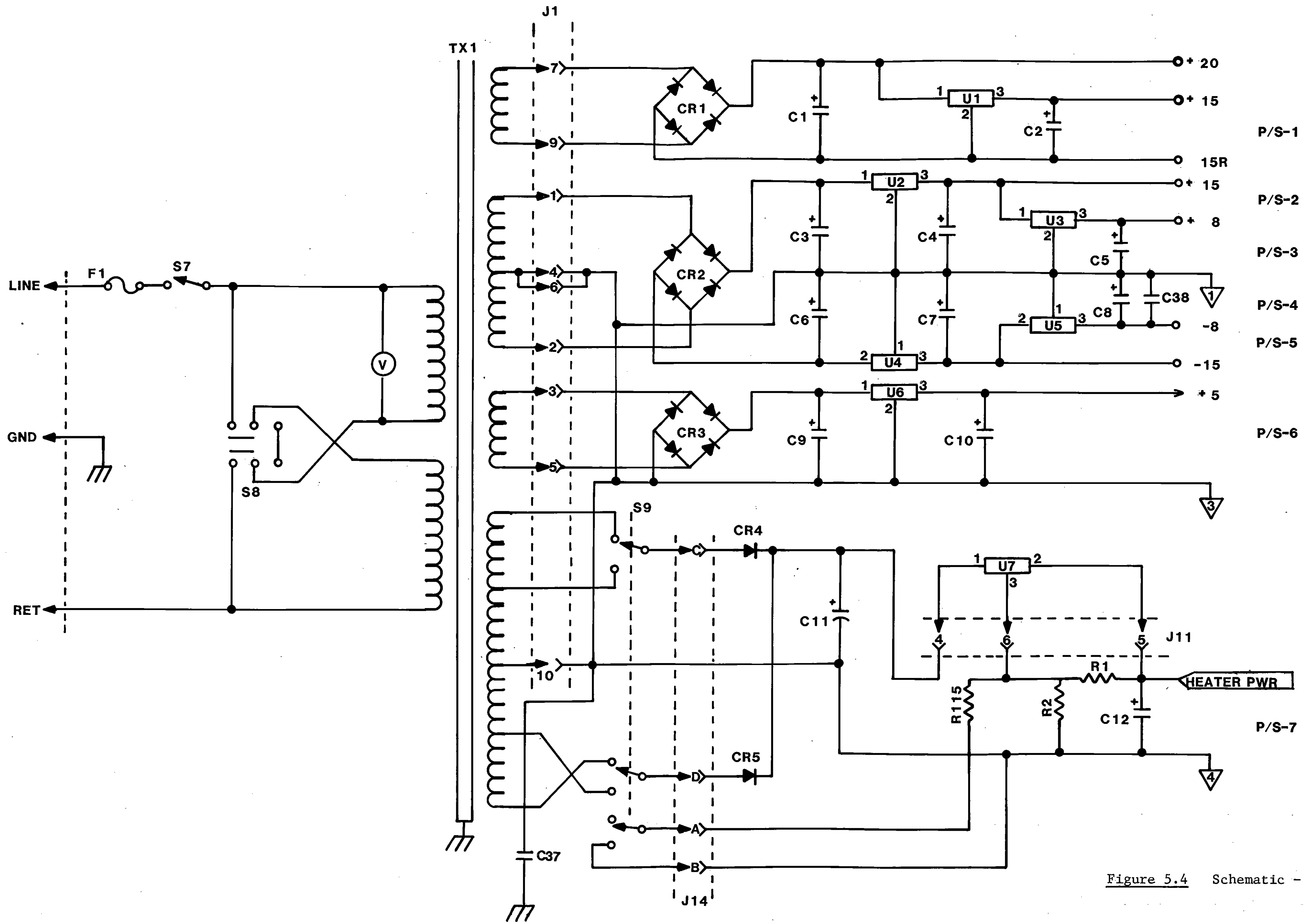

Figure 5.4 Schematic - A1 Power Supply

Table 5.3 Parts List - A2 Front Panel Assembly
(LSCI Part # 108-037)

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
	SENSOR CURRENT SWITCH	105-076	CNLB	PA-1015	1
CR6	LED	102-046	DLT	558-0101-003	6
CR7	LED	102-046	DLT	558-0101-003	REF
CR8	LED	102-046	DLT	558-0101-003	REF
CR9	LED	102-046	DLT	558-0101-003	REF
CR10	LED	102-046	DLT	558-0101-003	REF
CR11	LED	102-046	DLT	558-0101-003	REF
HI	6-32 x 3/8" STANDOFFS	110-137	HHS	8423	2
H2	6-32 KEP NUTS	110-129			2
H3	6-32 NUTS	110-130			4
H4	6-32 LOCK WASHERS	110-132			4
M1	NULL METER	110-033	JWL	E-25 100/0/100	1
M2	HEATER CURRENT METER	110-032	JWL	E-25 0-1 DC MA	1
MP1	MODEL 520 FRONT PANEL DWG: PAINTED AND SILK SCREENED ARTWORK#:	107-094	LSCI		
S7	POWER SWITCH	105-048		DLA3A125V C9	1
S2	RES.+, RES -, DIODE SELECTOR SWITCH	105-073	CNLB	P10637	1
SA11	HEATER CURRENT RANGE SWITCH ASSEMBLY	113-100	LSCI		1

Table 5.4 Parts List - A3 Rear Panel Assembly
(LSCI Part # 108-038)

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
A5	HEATER CURRENT DRIVER TRANSISTOR HEAT SINK ASSEMBLY	113-106			1
F1	MAIN FUSE				
	FUSEHOLDER:	106-007	LIT	342004A	2
	FUSE:				
	90-125V 3/4A	110-019	BUS	MDL 3/4A	
	210-250V 4/10A	110-016	BUS	MDL 4/10A	
F2	HEATER FUSE				
	FUSEHOLDER:	106-007	LIT	342004A	REF
	FUSE:	110-020	BUS	MDL 1A	1
H1	STRAIN RELIEF	110-006	HHS	939	1
H2	4X40X¼" FHMS	110-105			4
H3	4X40X3/8" PHMS	110-101			4
H4	4-40 KEP NUTS	110-108			8
H5	PLASTIC BOARD GUIDES	110-039	AMCO	37N1643	2
HT1	GRAY BINDING POST	106-002	EFJ	111-0113-001	1
HT2	BLACK BINDING POST	106-001	EFJ	111-0103-001	2
HT3	BLACK BINDING POST	106-001	EFJ	111-0103-001	REF
J1	14 PIN CONNECTOR &	106-142	AMP	206043-1	1
	TERMINALS	106-061	AMP	66399-3	8
MP2	MODEL 520 REAR PANEL DWG #: ANODIZED AND SILK SCREENED ARTWORK #:	107-095	LSCI		1
R64	POT, 10K	103-038		CM38800-10K	1
S8	115/230 SELECTOR SWITCH	105-014		46206LFR	1
S9	3 POLE, 2 POS. SLIDE SW.	105-072	SWCF	50209L	1
W1	LINE CORD:				1
	STANDARD	112-021	BEL	17239	
	CEE:	112-019	BEL	17740C	

Table 5.5 Parts List - A4 Transformer Assembly (LSCI Part # 113-097)

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
H1	CONTACTS, FEMALE	106-058	AMP	60617-1	10
H2	STANDOFFS	110-169			4
H3	8 X 32 X 2-3/4" SCREWS FHMS	110-170			4
H5	8-32 NUTS	110-144			4
H6	#8 LOCK WASHERS	110-171			4
H7	MOUNTING BRACKET	107-072		B239-82-01-A	1
H8	SHOULDER WASHERS	110-161	C. COIL	54008	4
J5	CONNECTOR, FEMALE, 10 PIN	106-134	AMP	1-480285-0	1
T1	TRANSFORMER	109-015	TECO	8088	1

Table 5.6 Parts List - A5 Heater Current Heat Sink Assembly (LSCI Part # 113-106)

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
H1	HEAT SINK	110-034	AVVID	AV 60585 2-3/4"	1
H2	HEAT SINK INSULATORS	110-004			2
H3	SHOULDER WASHERS	110-176			2
H4	HEX SOCKET 4X40X3/8"	110-152			4
H5	4-40 NUTS	110-106			3
H6	4-40 KEP NUT	110-108			1
U7	IC, LIN, V. REG.	102-048	NATL	LM317T	1
J26	FET, P-CH, POWER	102-044	IRF	IRF9532	1

Table 5.7 Parts List - SA11 Heater Current Range Assembly (LSCI Part # 113-100)

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
H1	SHORTING WIRE, 1.5" LONG	---	LSCI		2
H2	SHORTING WIRE, 1.5" LONG	---	LSCI		REF
R109	RES,100Ω,1%,¼W	103-216			1
R110	RES,30.1Ω,1%,¼W	103-209			1
R111	RES,10Ω,1%,¼W	103-206			1
R112	RES,3.01Ω,1%,½W	103-122			1
R114	RES,1Ω,5%,2.5W	103-120			1
R108	RES,422Ω,1%,¼W	103-236			1
R103	RES,54.9Ω,1%,3W	103-479			1
R104	RES,16.9Ω,1%,3W	103-478			1
R105	RES,4.97Ω,1%,3W	103-477			1
R106	RES,1.64Ω,1%,3W	103-476			1
R107	RES,.49Ω,1%,3W	103-475			1
S11	2 POLE - 5 POS. ROTARY SWITCH WITH CARRIAGE HOLDER		CNLB	PA-1013	1

Table 5.8 Parts List - A7 Final Assembly
(LSCI Part # 1020)

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
A1	MODEL 520 MAIN BOARD ASSEMBLY	113-096	LSCI		1
A2	FRONT PANEL ASSEMBLY	108-037	LSCI		1
A3	REAR PANEL ASSEMBLY	108-038	LSCI		1
A4	TRANSFORMER ASSEMBLY	113-097	LSCI		1
A6	WIRING ASSEMBLIES DWG. #:	112-032	LSCI		1
A7	ENCLOSURE	108-004	LSCI		1
H1	6-32 x 3/8" PHMS	110-121			5
H2	6-32 x 3/8" FHMS	110-127			4
H3	6-32 KEP NUTS	110-129			4
H4	KNOBS, SINGLE	105-054	BUC	SS-70TS2-2BLK	5
H5	KNOBS, DOUBLE	105-055	BUC	SS-50L/70CTSL	2
H6	RIBBON CABLE HOLDERS	110-167		CFCC-8	2
	520 IC KIT	113-091			1
J1	J1 MATE CONNECTOR AND TERMINALS	106-070	AMP AMP	206044-1 206070-1	1
		106-060	AMP		8

Table 5.9 Parts List - Model 5201 BCD Option
PCB Assembly
(LSCI Part # 1000-031)

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
A1	Model 520 BCD Option P.C. Board Artwork: C274-83-01	111-039	CDT		1
C1	CAP, POLY, 0.1MF, 100V	101-008	PLSY	160.1K100G	1
C2	CAP, POLY, .68MF, 100V	101-009	PLSY	160.68J100G	5
C3	CAP, MICA,390PF,500V	101-016	CDE	CD15CD391G03	1
C4	CAP,POLY,.68MF,100V	101-009	PLSY	160.68J100G	REF
C5	CAP,POLY,.22MF,100V	101-050	PLSY	.22/10/100/DB	1
C6	CAP,MYLAR,.033MF,100V	101-005	CDE	WMF1S33	1
C7	CAP,POLY,.68MF,100V	101-009	PLSY	160.68J100G	REF
C8	CAP,POLY,.68MF,100V	101-009	PLSY	160.68J100G	REF
C9	CAP,POLY,.68MF,100V	101-009	PLSY	160.68J100G	REF
C10	CAP,TANT,1.5MF,10V	101-007	SPRG	150D155X9010A2	1
C11	CAP,MICA,330PF,500V	101-015	CDE	CD15CD331G03	1
CR1	DIODE	102-002		IN743A	2
CR2	DIODE	102-002		IN743A	REF
P2	40 PIN HEADER	106-049	3M	3432-2003	1
R1	RES,MTF,100K,1%,¼W	103-420			2
R2	RES,MTF,100K,1%,¼W	103-420			REF
R3	RES,MTF,649Ω,1%,¼W	103-247			1
R4	RES,MTF,196Ω,1%,¼W	103-225			1
R5	POT,100K	103-014	BOR	3006P-1-104	1
R6	RES,MTF,562Ω,1%,¼W	103-242			1
R7	RES,MTF,301K,1%,¼W	103-448			1
R8	RES,MTF,36.5K,1%,¼W	103-384			1
R9	RES,MTF,200K,1%,¼W	103-439			1
R10	RES,MTF,1.96M,1%,¼W	103-106			1
R11	RES,MTF,866Ω,1%,¼W	103-250			1
R12	RES,MTF,10K,1%,¼W	103-358			1
R13	RES,MTF,33.2K,1%,¼W	103-381			1
U1	IC, A/D CONVERTER	104-059	DAIN	ICL71C03ACPI	1
U2	IC, A/D SUPPORT CHIP	104-051	DAIN	ICL8052ACPD	1
U3	IC,DUAL ONE SHOT	104-037	NAT	74123	1
U4	IC, 4 BIT LATCH	104-045	TI	74LS175	5
U5	IC, 4 BIT LATCH	104-045	TI	74LS175	REF
U6	IC, 4 BIT LATCH	104-045	TI	74LS175	REF
U7	IC, 4 BIT LATCH	104-045	TI	74LS175	REF
U8	IC, 4 BIT LATCH	104-045	TI	74LS175	REF
U9	IC, INVERTER	104-033	NAT	7404	4
U10	IC, INVERTER	104-033	NAT	7404	REF
U11	IC, INVERTER	104-033	NAT	7404	REF
U12	IC, INVERTER	104-033	NAT	7404	REF

Table 5.9, cont'd.

ITEM NO.	DESCRIPTION	LSCI STOCK NO.	MFR	MFR PART NO.	TOT QTY
U13	IC, AND-OR SELECT	104-020	NAT	CD4019BCN	5
U14	IC, AND-OR SELECT	104-020	NAT	CD4019BCN	REF
U15	IC, AND-OR SELECT	104-020	NAT	CD4019BCN	REF
U16	IC, AND-OR SELECT	104-020	NAT	CD4019BCN	REF
U17	IC, AND-OR SELECT	104-020	NAT	CD4010BCN	REF
U18	IC, TIMER	104-028		7555	1
XU1	SOCKET, IC, 28 PIN	106-111	AUG	703-4028	1
XU2	SOCKET, IC, 14 PIN	106-106	AUG	514-AGIID	5
XU3	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	11
XU4	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	REF
XU5	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	REF
XU6	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	REF
XU7	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	REF
XU8	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	REF
XU9	SOCKET, IC, 14 PIN	106-106	AUG	514-AGIID	REF
XU10	SOCKET, IC, 14 PIN	106-106	AUG	514-AGIID	REF
XU11	SOCKET, IC, 14 PIN	106-106	AUG	514-AGIID	REF
XU12	SOCKET, IC, 14 PIN	106-106	AUG	514-AGIID	REF
XU13	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	REF
XU14	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	REF
XU15	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	REF
XU16	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	REF
XU17	SOCKET, IC, 16 PIN	106-105	AUG	516-AGIID	REF
XU18	SOCKET, IC, 8 PIN	106-107	AUG	508-AGIID	1

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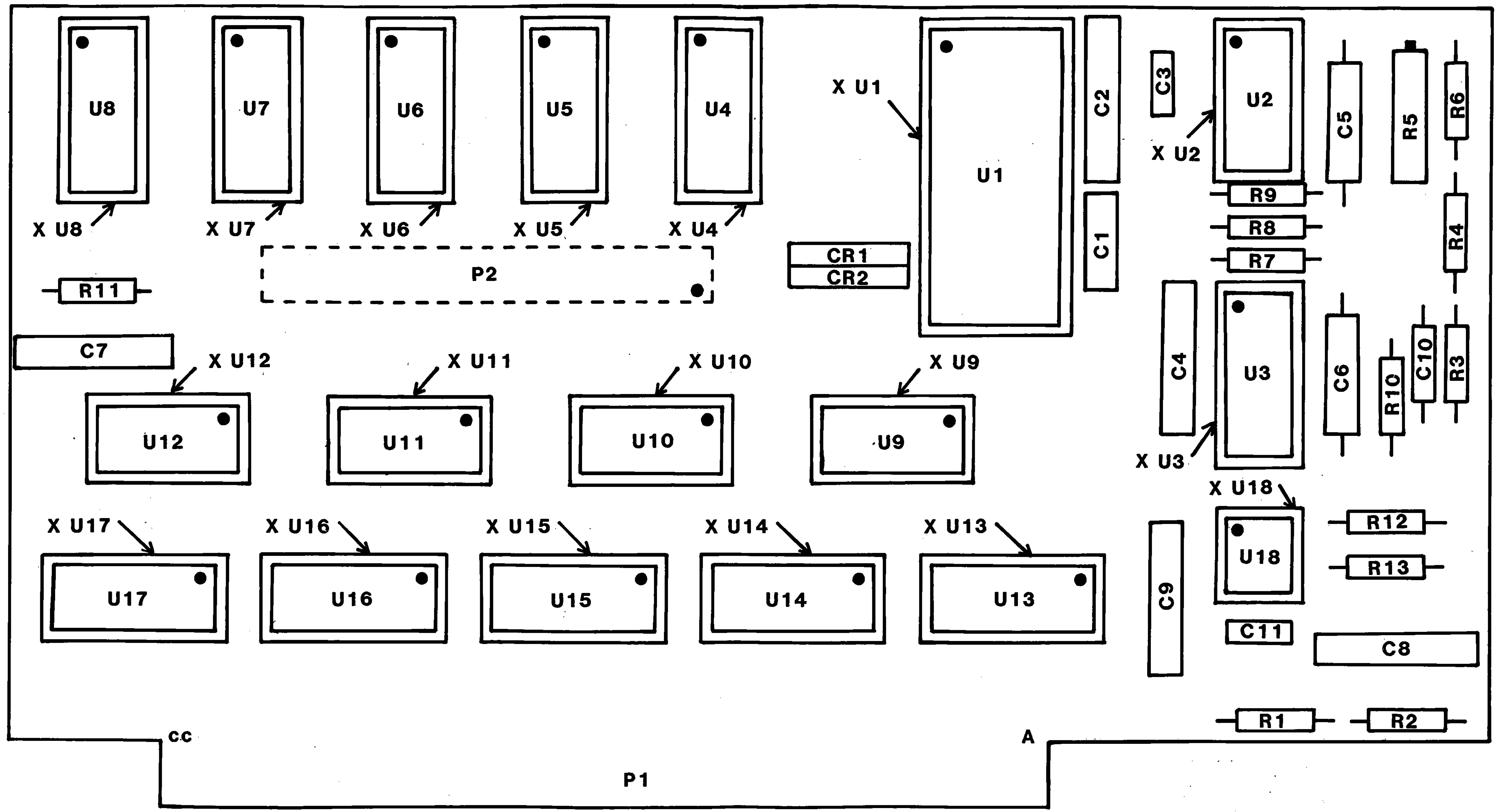

Figure 5.5 Component Layout - Model 5201 BCD Option PCB

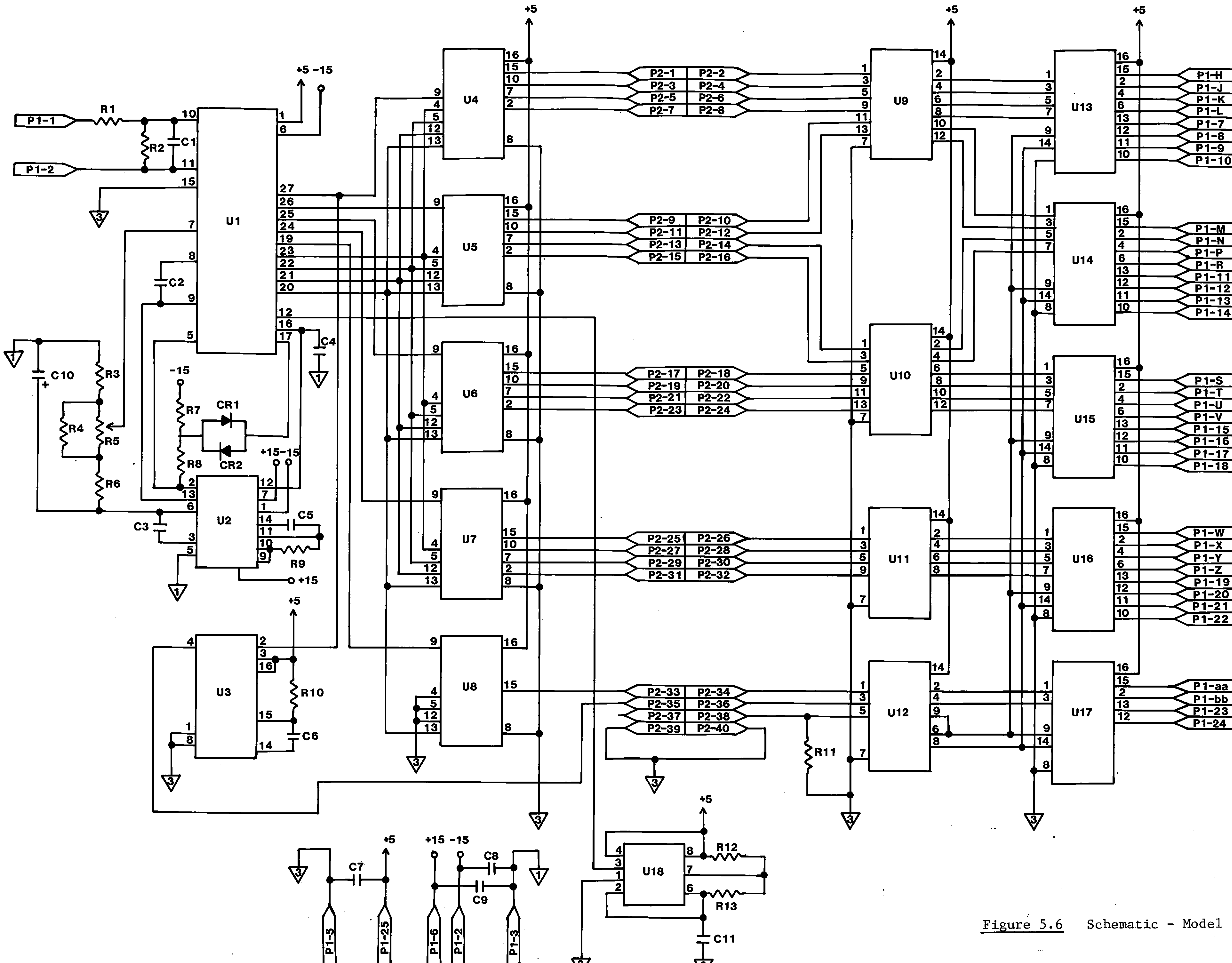

Figure 5.6 Schematic - Model 5201 BCD Option

Table 5.10

Cross Reference of Parts Manufacturers

AD	Analog Devices Rt. #1 Industrial Park P.O. Box 280 Norwood, MA 02062 (617) 329-4700
AMCO	Amco Electronics Div. of G.A.W. Electronics 9181 Gazette Ave. Chatsworth, CA 91311 (213) 882-9027
AMP	Amp, Inc. Harrisburg, PA 17105 (717) 564-0100
AUG	Augat, Inc. 33 Perry Ave. P.O. Box 779 Attleboro, MA 02703 (617) 222-2202
AV	Aavid Engineering, Inc. 30 Cook Court Box 400 Laconia, NH 03247 (603) 524-4443
BB	Burr-Brown Intl. Airport Ind. Park P.O. Box 11400 Tucson, AZ 85734 (602) 746-1111
BEL	Belden Electronic Div. Belden Corp. Richmond, IN 47374
BOR	Bourns, Inc. 1200 Columbia Ave. Riverside, CA 92507 (714) 781-5050
BUC	Buckeye Stamping Co. 555 Marion Rd. Columbus, OH 43207 (614) 445-8433
BUS	Bussman Div./McGraw Edison P.O. Box 14460 St. Louis, MO 63178 (314) 394-2877
CDE	Cornell-Dubilier 150 Avenue L Newark, NJ 07101
CENT	Centralab, Inc. 5855 N. Glen Park Road P.O. Box 2032 Milwaukee, WI 53201 (414) 228-7380
DLT	Dialight (Dialco) 203 Harrison Place Brooklyn, NY 11237 (212) 497-7600
EDAC	EDAC, Inc. 20 Railside Rd. Don Mills, ON, Canada M3A 1A4 (416) 445-2292
EECO	EECO, Inc. 1601 E. Chestnut Ave. Santa Ana, CA 92701 (714) 835-6000
EFJ	E.F. Johnson Company Components Division 299 Tenth Ave., S.W. Waseca, MN 56093 (507) 835-6222
FLD	Fairchild 474 Ellis Street Mountain View, CA 94042 (415) 962-5011
GE	General Electric Company Semiconductor Products Dept. Electronics Park Syracuse, NY 13201

Table 5.10, cont'd.

Cross Reference of Parts Manufacturers

HHS	H.H. Smith 812 Snediker Avenue Brooklyn, NY 11207 (212) 272-9400
IR	International Rectifier Semiconductor Division 233 Kansas Street El Segundo, CA 90245 (213) 772-2000
ISL	Intersil, Inc. 10710 N. Tantau Ave. Cupertino, CA 95014 (408) 996-5000
JWL	Jewell Electronics, Inc. Grenier Field Box 4038 Manchester, NH 03108 (603) 669-6400
LIT	Littlefuse, Inc. 800 E. Northwest Highway Des Plaines, IL 60016 (312) 824-1188
LSCI	Lake Shore Cryotronics, Inc. 64 East Walnut Street Westerville, OH 43081 (614) 891-2243
MEP/EL	Mepco/Electra, Inc. 6071 St. Andrews Rd. Columbia, SC 29210 (803) 772-2500
3M	3M/Electronic Prods. Div. 3M Center St. Paul, MN 55101 (612) 733-3351
NAT	National Semiconductor Corp. 2900 Semiconductor Drive Santa Clara, CA 95051 (408) 737-5000
PAN	Panasonic Co. - E.C.D. P.O. Box 1503 Seacaucus, NJ 07094 (201) 348-5230
PLSY	Plessey Capacitors, Inc. 5334 Sterling Center Dr. WestLake Village, CA 91361 (213) 889-4120
PMI	Precision Monolithics, Inc. 1500 Space Park Drive Santa Clara, CA 95050 (408) 246-9222
S-G	Standard-Grigsby, Inc. 920 Rathbone Ave. Aurora, IL 60507 (312) 844-4300
SFT	Switchcraft 5555 N. Elston Ave. Chicago, Il 60630 (312) 792-2700
SIL	Siliconix 2201 Laurelwood Road Santa Clara, CA 95054 (408) 246-8000
SPRG	Sprague Products Corp. 551 Marshall Street North Adams, MA 01247 (413) 664-4481
SPTX	Supertex, Inc. 1225 Bordeaux Drive Sunnyvale, CA 94086 (408) 744-0100
TECO	TECO Corporation P.O. Box A Winnesquam, NH 03289 (603) 524-1998

Table 5.10, cont'd.

Cross Reference of Parts Manufacturers

TI	Texas Instruments, Inc. P.O. Box 22512 Dallas, TX 75265
VISH	Vishay 63 Lincoln Highway Malvern, PA 19355 (215) 644-1300