Sorensen
A **Raytheon** Company

Instruction Manual for

HPD Series Power Supplies

This manual covers models:

15 – 20
30 – 10
60 – 5

HPD SERIES MANUAL - ADDENDUM SHEET

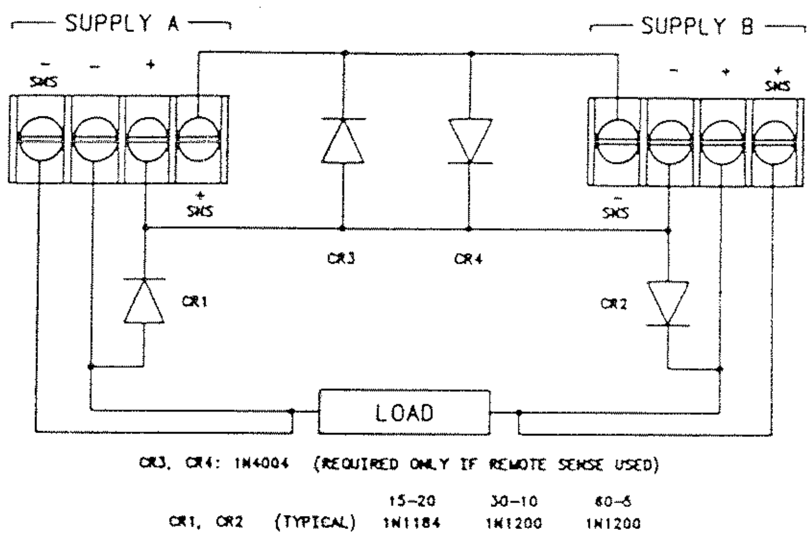
For series operation of HPD power supplies, the following procedure should be followed:

2.5.4 Series Operation (Voltage Mode Only)

The series connection is used to obtain a higher voltage single output supply. Connect the (-) terminal of one supply to the (+) terminal of the next supply. The total voltage available is the sum of the maximum voltages of each supply (add voltmeter readings).

Figure 2-1

Series Operation With and Without OVP



Notes:

Maximum allowable sum of the output voltages is 400v. This is limited by the output to ground isolation specification.

The maximum allowable current for a series string of power supplies is the lowest output current of any supply in the string.

Use of remote sense is not essential for series connection. Where used, refer to notes on remote sensing.

CR3 and CR4 protect sense circuits during transient events which may cause supply outputs to collapse (such as momentary current limit events).

Sorensen HPD Series DC Power Supply

TECHNICAL MANUAL

Release 4.1

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SECTION 1

FEATURES AND SPECIFICATIONS

1.1 PURPOSE

This manual contains operation and maintenance instructions for the HPD Series of high performance switching laboratory power supplies. Its purpose is to provide sufficient maintenance data to ensure long operating life. The series consists of 3 basic models. The basic models are designated by the HPD prefix, followed by the voltage and current rating. For example, the HPD 60-5 model number signifies that this is a single unit rated at 0 to 60 Vdc output at a maximum of 5 Amps while the HPD 15-20 is a single unit rated at 0 to 15 Vdc at 20 Amps.

Five major sections form the manual divisions:

Section 1 - Description of series features and specifications.

Section 2 - Installation and operating instructions.

Section 3 - Theory of operation.

Section 4 - Maintenance and service procedures.

Section 5 - Drawings, schematics, and parts lists.

1.2 DESCRIPTION

The HPD Series laboratory power supplies are designed to provide highly stable continuously variable output voltage and current for a broad range of development and system requirements. The HPD Series employs high frequency switching regulator technology to achieve high power density and small package size, and a linear post-regulator circuit for low output noise.

1.3 OPERATING MODES

The HPD Series supply has two basic operating modes; Constant Voltage and Constant Current. In the former, the output voltage is regulated at the front panel selected value, and the output current varies with the load. In constant current operation, the output current is regulated at the selected value and the output voltage varies as a function of load.

1.3.1 Automatic Crossover

The automatic crossover system enables the unit to transfer operating modes as a function of load requirements. For example, if the load current attempts to increase above the setting of the current adjust control, the unit will switch automatically from the voltage to the current mode. If the load requirements are lowered, return to the voltage mode will occur automatically.

1.3.2 Sense Connections

To compensate for losses in power leads connected to the output, sense connections are provided beside the output terminals. With remote sense leads in place, the voltage is regulated at the point where the sense lines are connected to the output leads. With the sense lines disconnected, the voltage is regulated at the output terminals.

1.4 EQUIPMENT FEATURES

- o Simultaneous digital display of both voltage and current.
- o Unique analog bar graphs display both voltage and current for ease of monitoring transient changes under varying loads.
- o Ten turn potentiometer voltage control permits high resolution setting of the output voltage.
- o Current adjust potentiometer permits current limiting which is fully adjustable from zero to the rated output.
- o Automatic mode crossover into current or voltage mode.
- o Impedance-switched remote sensing permits the voltage at the load to be displayed with no switch ambiguity.
- o Output connections are via a four terminal barrier strip on the back panel.
- o Flexible output configuration: Multiple units can be connected in parallel or series without damage and are short circuit proof.
- o The modular design provides for easy replacement or repair of plug connected sub-assemblies.
- o High frequency switching technology allows high power density, providing increased power output in a smaller, very light package.
- o A broad range of optional functions are readily available,
  - Over-Voltage Protection (OVP)
  - External TTL Shutdown
  - Remote Voltage & Current Programming
  - IEEE 488 Interface

1.5 SPECIFICATIONS

1.5.1 Electrical Specifications

Output voltage and current ratings for each model (single unit) are as follows:

Model Number	Voltage	Current*
HPD 15-20	0 - 15V	20A
HPD 30-10	0 - 30V	10A
HPD 60-5	0 - 60V	5A

* measured at 30 degrees C. De-rate linearly to zero at 70 degrees C.

	Voltage Mode	Current Mode
Line Regulation (100 - 130VAC)	0.01% + 2mV	0.01% + 1mA
Load Regulation (0 - 100% Remotely Sensed)	0.01% + 2mV	
(10 - 100%)		0.01% + 1mA
Noise and Ripple, maximum (RMS/p-p)	5mV/50mV	5mA/20mA
Temperature Coefficient (after 60 minutes)	0.015% per degree C	0.02% per degree C
Drift (over 8 hrs after 60 minutes)	0.02%0.03%	

Transient Response
- recovery to 50mV band
- +/- 50% load change in range of 25% to 100% of rated load less than 500usec

Ambient operation range	0-30 degrees C for full rated output (De-rate linearly to zero at 70 degrees C)
Storage Temperature	-55 to +85 degrees C
Humidity Range	0-80% RH non-condensing
Voltage Resolution	0.02% of full scale
Meter Accuracy	1% of full scale + 1 count.
Input	100-130Vac, 57-63Hz, 6A RMS (47-440Hz with 20% output current de-rating)
Maximum voltage differential, output to safety ground	400Vdc

1.5.2 Mechanical Specifications

	Height	Width	Depth	Weight
Single Unit	132mm	109mm	297mm	2.5kg
	5.2in	4.3in	11.7in	5.5lbs

1.6 OPTIONAL ACCESSORIES

The available options for the HPD Series power supplies are: Over-Voltage Protection (OVP), Remote ON/OFF, Remote Voltage Programming and/or Current Programming, and an IEEE 488 Interface.

Options are available in two different configurations. Option M5 provides over-voltage protection (OVP), remote 0-10V programming, and remote ON/OFF. Option M9 includes the IEEE 488 interface allowing output voltage and current programming directly in volts and amperes with 12-bit resolution from other IEEE 488/GPIB equipped instruments or controllers. Over-voltage protection and 8-bit digital read-back of voltage and current are also provided with this option.

1.6.1 Option Specifications

Over-Voltage Protection	Trip Voltage range: 3.0V to Full Output + 10%
Remote ON/OFF	Standard TTL: High = 3V minimum: Output - OFF Low = 0.8V maximum: Output - ON
Remote Programming	Voltage Control Coefficient Voltage: 1V/10% of output +/- .1% Current: 1V/10% of output +/- .1%
Rear Panel Connector	
Option M5	25 pin female D-sub type
Option M9	IEEE 488 connector
Programming Resolution, Option M9	Voltage: +/- 0.03% Current: +/- 0.03%
Programming Accuracy, Option M9	Voltage: +/- 0.05% Current: +/- 0.05%
Read-Back Resolution, Option M9	Voltage: +/- 0.4% Current: +/- 0.4%
Read-Back Accuracy, Option M9	Voltage: +/- 0.5% Current: +/- 0.5%

SECTION 2

INSTALLATION AND OPERATING INSTRUCTIONS

2.1 GENERAL

After unpacking, an initial inspection should be performed to assure that the unit is in good working order. If it is determined that the unit is damaged, the carrier should be notified immediately. Repair problems should be directed to the Service Department, Sorensen Co., 5555 N. Elston Avenue, Chicago, IL, 60630, (312) 775-0843.

2.2 INITIAL INSPECTION

The power supply comes complete with an IEC power cord set and technical manual. The equipment should be inspected for damage as follows:

a. Inspect for obvious signs of physical damage.

b. Turn front panel controls from stop to stop. Rotation should be smooth.

c. Test the action of the power switch. Switching action should be positive.

d. If internal damage is suspected, remove the cover and check the components and printed circuit board for damage. Reinstall cover.

2.3 INSTALLATION

Before connecting the unit to an AC outlet, make sure that the power switch is in the extended (OFF) position and the voltage and current controls are in their fully counter clockwise positions. The AC line voltage should be 115V (nominal).

A voltage control mode indicator (green) is located above the voltage control knob. A current limit mode indicator (red) is located above the current limit adjust knob. The power supply outputs are located on the back panel terminal block.

If the output voltage is to be biased relative to ground, the power supply outputs may be biased up to a maximum of 400Vdc with respect to the chassis.

Plug the line cord into a grounded AC outlet. Push the power switch to turn on the power supply. The red current LED should light and the meter reading should remain zero.

To use the power supply in the Constant Voltage mode, turn the current control to its extreme clockwise position and set the voltage control to the desired voltage. To operate the supply in the Constant Current mode, turn the voltage control 1/2 turn clockwise and the current control fully counter clockwise. Connect a shorting lead across the output terminals and set the desired maximum value of current limit by turning the control slowly clockwise. Then disconnect the shorting lead from the output terminals. The power supply will now automatically switch into the current limiting mode (current regulation) as soon as the set current level is reached and will not exceed this level at any output voltage. As soon as the supply starts operating in current mode, the red current mode LED will turn on.

2.4 ELECTRICAL CHECK

2.4.1 Voltage Mode

To check voltage mode operation, proceed as follows:

a. Rotate VOLTAGE and CURRENT controls fully counterclockwise.

b. Connect a DVM, rated better than .5% accuracy, to the front panel binding posts (+ and -).

c. Connect the IEC power cord set to the unit, then to an appropriate power source and set the POWER switch to ON.

d. Rotate the CURRENT control 1/2 turn clockwise. Slowly rotate the VOLTAGE control clockwise and observe the digital meters. Minimum control range should be from 0 to maximum rated output. Compare the test meter with the panel voltage meter on the left (green). Observe the bar graph meter to see that it tracks as the voltage rises and that the voltage mode indicator lamp is ON.

e. Set the POWER switch to OFF.

2.4.2 Current Mode

To check current mode operation, proceed as follows:

a. Rotate VOLTAGE and CURRENT controls fully counterclockwise.

b. Rotate the VOLTAGE control 1/2 turn clockwise.

c. Connect a DC ammeter across the front panel binding posts (+ and -). Select leads of sufficient current carrying capacity and an ammeter range compatible with the unit's rated current output. The ammeter should have an accuracy of better than .5%.

d. Set the POWER switch to ON.

e. Rotate the CURRENT control slowly clockwise. The control range should be from zero to the maximum rated output. Compare the test meter reading with the reading on the panel current meter (red). Also check that the current bar graph meter follows the rise in current and that the current mode indicator light is ON.

f. Set the POWER switch to OFF.

2.5 STANDARD OPERATION

Reliable performance of the power supply can be obtained if certain basic precautions are taken when connecting it for use on the lab bench or installing it in a system.

To obtain a stable, low noise output, careful attention should be paid to factors such as conductor ratings, system grounding techniques, and the particular way the AC input, DC output, and remote sensing connections are made.

A conductor size that satisfies the current rating requirements should be used. To overcome impedance and coupling effects, however, larger wire and shorter leads are recommended.

2.5.1 Grounding

Proper grounding connections should be made to avoid paths between separate ground points. To avoid ground loop problems, there must be only one ground return point in a power system.

2.5.2 Load Connection

Proper connection of distributed loads is an important aspect of power supply application. A most common mistake is to connect leads from the power supply to one load and then from that load to other loads. In this parallel power distribution method, voltage at each load depends on the current drawn by the other loads and DC ground loops are developed. Except for low current applications, this method should not be used.

A preferred way to distribute power is by the radial distribution method in which power is connected individually to each load from a single pair of terminals designated as the positive and negative distribution terminals. The pair of terminals may be the power supply output terminals, the load terminals, or a distinct set of terminals specially established for distribution. Connecting the sense leads to these terminals will compensate for losses and minimize the effect of one load upon another.

2.5.3 Multiple Supplies

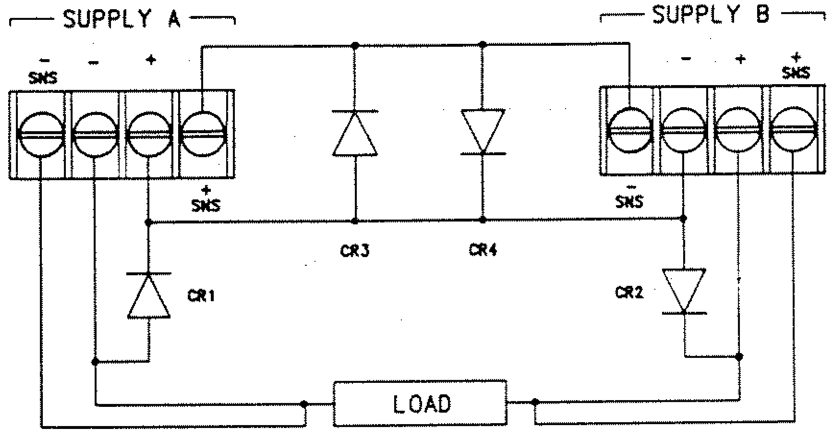
The HPD Series power supplies may be operated with outputs in series or parallel. For independent operation of each supply, the procedure as previously outlined applies.

2.5.4 Series Operation (Voltage Mode Only)

The series connection is used to obtain a higher voltage single output supply. Connect the (-) terminal of one supply to the (+) terminal of the next supply. The total voltage available is the sum of the maximum voltages of each supply (add voltmeter readings).

Figure 2-1

Series Operation With and Without OVP



Notes:

Maximum allowable sum of the output voltages is 400v. This is limited by the output to ground isolation specification.

The maximum allowable current for a series string of power supplies is the lowest output current of any supply in the string.

Use of remote sense is not essential for series connection. Where used, refer to notes on remote sensing.

CR3 and CR4 protect sense circuits during transient events which may cause supply outputs to collapse (such as momentary current limit events).

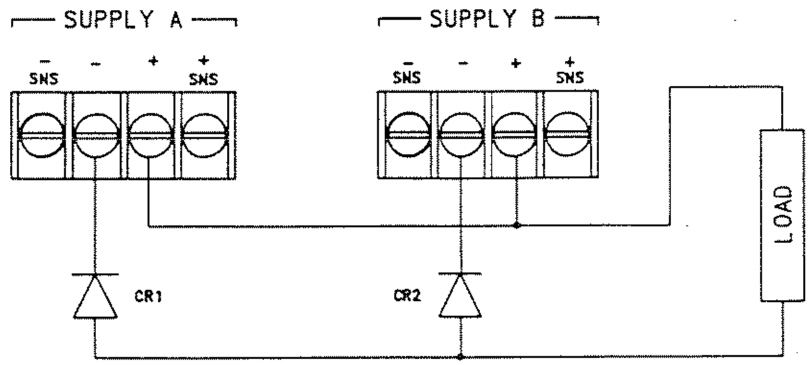
2.5.5 Parallel Operation

The parallel connection is used to obtain a higher current single output supply. Set all of the outputs to the same voltage before connecting the (+) terminals and (-) terminals in parallel. The total current available is the sum of the maximum currents of each supply. The maximum voltage available at the load is equal to the voltage of the lowest rated supply. When two supplies are paralleled, the supply with the higher voltage setting will be in the current limiting mode, while the other supply controls the output voltage.

For parallel operation with OVP equipped units be sure that all OVP trip points are set higher than the maximum output voltage. To prevent the internal OVP fuse from blowing during OVP trip events, external blocking diodes should be added as shown in Figure 2-2.

Figure 2-2

Parallel Operation With OVP Equipped Units



	15-20	30-10	60-5
CR1, CR2 (TYPICAL)	1N1184	1N1200	1N1200
P(max)/DIODE	20W	10W	5W

2.5.6 Split Supply Operation

The split connection is used to obtain two positive voltages with a common ground, or a positive-negative supply. To obtain two positive voltages, connect the negative terminals of both supplies together. The positive terminals will supply the required voltages with respect to the common connection.

To obtain a positive-negative supply, connect the negative terminal of the left section to the positive terminal of the right section. The left section (positive terminal) then provides a positive voltage relative to the common connection and the right section (negative terminal) provides a negative voltage. The current limits (current controls) can be set independently. The maximum current available in split operation is equal to the lowest individual rating of the supplies.

2.5.7 Remote Sensing

Remote sensing permits regulation with respect to the point of load connection, rather than at the output terminals of the power supply. Connecting the positive and negative sense lines to the point where the metered output voltage is desired will automatically compensate for the voltage losses in the main power leads (provided these losses do not exceed .5v/line). With the voltmeter reading 10.0 volts, for example, and having the sense lines connected directly to the load, the load voltage will stay at exactly 10.0 volts regardless of the voltage drops in the power leads, no matter how much current is drawn. NEVER use the sense connections without the normal power lead connections to the output terminals, and avoid reversing positive and negative lead connections.

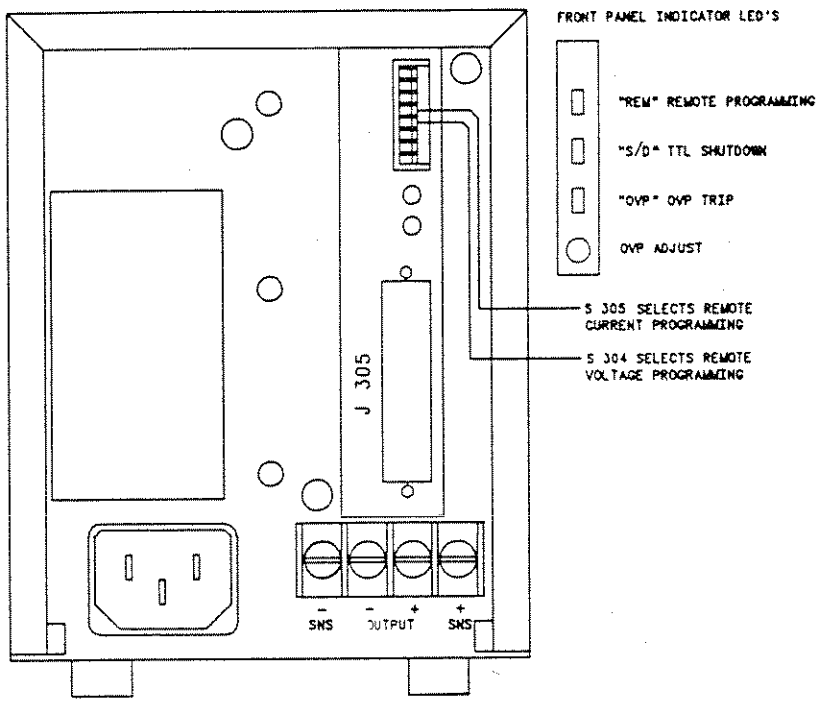
Sense wires can be any size (24AWG or larger) but in high noise environments or when lowest power supply ripple is required, sense wires must be twisted and/or shielded.

Power wires must be dimensioned to limit resistive drop to less than 0.5v per line.

2.6 OPERATION WITH ANALOG INTERFACE INSTALLED (OPTION M5)

Figure 2-3

Connector, Controls and Indicators



To use this option, a mating 25 pin D-subminiature connector (included) and cable must be constructed, using the following connector pin-out table:

Table 2-1
Option Card Connector J305 Detail
(D-subminiature 25 Pin Female) *

Pin Number	Function
1	N/C
14	N/C
2	External Shutdown Return
15	External Shutdown Input (TTL High Level)
3	N/C
16	External Current Programming Input (0 to 10 volts)
4	External Programming Return
17	External Voltage Programming Input (0 to 10 volts)
5	External Programming Return
18	N/C
6	+10V Reference (2 mA maximum)
19	N/C
7	N/C
20	N/C
8	N/C
21	N/C
9	N/C
22	Positive Sense
10	Positive Output
23	Positive Output
11	Positive Output
24	Return
12	Return
25	Return Sense
13	Return

NOTE: Do not tie pins 4 or 5 to any other points on J305.

* Mating connector - 25 pin male ITT Cannon DB25P or equivalent.

2.6.1 Over-Voltage Protection (OVP)

The OVP circuit allows for protection of the load in the event of a remote programming error, incorrect voltage control adjustment, or power supply failure. The protection circuit monitors the output and reduces the output voltage and current to zero whenever a preset voltage limit is exceeded. The OVP adjustment is accessible from the front panel directly below the option indicators at the top left edge of each front panel. Use a small flat blade screwdriver taking care not to over-stress the control.

The trip threshold may be set as low as 3.0V, thus providing load protection at low output voltage levels. A red LED on the front panel indicates when the OVP circuit has been activated. To set the level at which the output of the unit will be automatically clamped to zero volts, follow this sequence:

a. Turn the OVP control fully clockwise.

b. Adjust the output to the desired trip voltage.

c. Slowly turn the OVP control counterclockwise until the red OVP indicator lamp lights.

d. Turn the POWER switch to OFF.

e. Turn the voltage control knob to minimum.

f. Turn the POWER switch back ON and increase the voltage to check that the power supply shuts off the output at the desired voltage.

An over-voltage condition on the output will cause the OVP indicator to light and clamp the output to zero until the over-voltage is removed and power is turned OFF and back ON to reset the OVP circuit.

2.6.2 Remote ON/OFF (TTL Shut Down)

This feature is useful in test applications requiring remote ON-OFF control of the output. The remote ON-OFF control circuit uses a TTL compatible input to remotely control (disable or enable) the power supply output. A logic level signal between pin 15 (positive) and pin 2 (common) on the rear connector determines the output conditions:

TTL LOW = OUTPUT ON
TTL HIGH = OUTPUT OFF

A yellow LED on the front panel indicates when the shutdown circuit is activated. The input line is optically isolated and can therefore be accessed by circuits with a voltage differential of up to 400Vdc.

2.6.3 Remote Programming

The voltage and current outputs of the power supply can be programmed by external voltage sources. Zero to full output is linearly proportioned to a zero to 10V control signal. Before activating the remote program mode, ensure that the voltage and current knobs on the front panel are in their fully counterclockwise position. These controls are disabled during remote programming and cannot be used to control the output.

The remote programming mode is selected by setting the DIP switch accessible from the rear panel as follows:

Closing switch #4 enables external voltage programming.
Closing switch #5 enables external current programming.

For both voltage and current programming, switches #4 and #5 should be closed. A flashing green LED on the front panel indicates when the remote programming mode is enabled.

To control the voltage from zero to full output, a zero to 10V signal should be applied between pin 17 (positive) and pin 5 (common) on the rear connector(Vv-pgm).

V Gain Equation: Vout = Vv-pgm (Rated maximun output voltage/10)

NOTE

Pins 4 and 5 are at negative sense potential but not connected to it. Do not tie pins 4 or 5 to any other points on the rear connector.

Similarly, to control the current limiting from zero to full output, a zero to 10V signal should be applied between pin 16 (positive) and pin 4 (common) on the rear connector (Vi-pgm). Use a separate isolated supply for voltage and current programming.

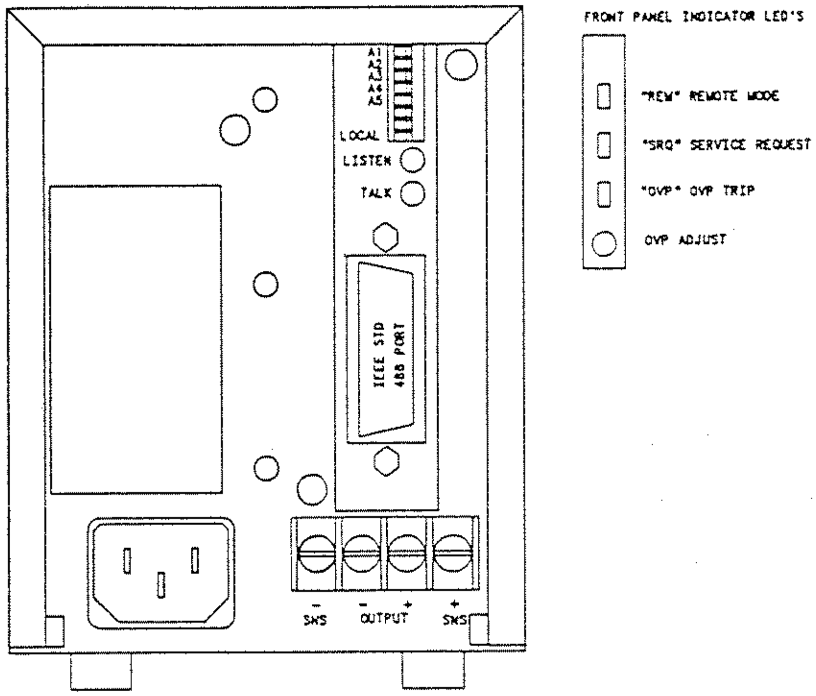
I Gain Equation: $I_{out} = V_{i\text{-}pgm}$ (Rated maximum output current/10)

Any noise or AC component present on the programming source will be amplified by the gain factor of the control stage. Where minimum noise is required a low noise program source must be used, and should be connected to the power supply using a shielded twisted pair.

2.7 OPERATION WITH THE IEEE 488 INTERFACE INSTALLED (OPTION M9)

Figure 2-4

Connector, Controls and Indicators



The IEEE 488 interface connects to the IEEE 488 bus with the standard connector system, having the following pin assignment:

Table 2-2
IEEE 488 Interface Connector Detail

Pin		Pin	
1	D101	13	D105
2	D102	14	D106
3	D103	15	D107
4	D104	16	D108
5	EOI	17	REN
6	DAV	18	GND 6
7	NRFD	19	GND 7
8	NDAC	20	GND 8
9	IFC	21	GND 9
10	SRQ	22	GND 10
11	ATN	23	GND 11
12	SHIELD	24	LOGIC GND

Option M9 provides a microprocessor-based programming interface which allows direct programming of the output voltage and current in volts and amperes with 12-bit resolution using the IEEE standard 488-1978 interface bus (or General Purpose Interface Bus [GPIB]). Over-voltage protection (OVP) and digital read-back of voltage and current to 8-bit precision are standard. This option would normally be used in conjunction with a programmable controller with IEEE 488 capability. The following section details how to program the HPD Series power supply with IEEE 488 capability and assumes the operator is familiar with the IEEE 488 bus structure and the particular IEEE 488 controller being used.

2.7.1 Interface Functions

The following interface functions defined by IEEE Standard 488 are implemented:

SH1 Source Handshake
AH1 Acceptor Handshake
T6 Talker
L4 Listener
SR1 Service Request
RL1 Remote Local
PP1 Parallel Poll
DC1 Device Clear
DT1 Device Trigger
E1 Open Collector Drivers

Multi-line Control Functions

The Source Handshake, Acceptor Handshake, Talker, and Listener functions are ordinarily implemented by the interface card and the controller, and require no action by the user. The Listen and Talk indicators on the rear panel turn on when the power supply is addressed to be a listener or talker. (The talker function includes serial poll).

Service Request

Service Request is a uni-line message asserted by the power supply at Power On (nonmaskable), and for certain other events selected by the user; namely, Invalid Syntax, Range Error, Output Disabled, Limit Mode, and Over-Voltage. The power supply powers on with all service requests masked.

The SRQ indicator, a yellow LED on the front panel, turns on at power-on and whenever the power supply requests service from the controller, and remains on until the controller conducts a serial poll. The SRQ indicator remains on if the service request condition remains after a poll. (Note: in Local mode, the SRQ LED will remain on since no serial poll is conducted.)

Serial Poll

In a serial poll, the controller polls each device on the bus, one at a time. The power supply responds with an eight bit status byte on the data lines. The following table defines each bit, indicating what causes the bit to be set and reset, and the state of the corresponding front panel indicators.

Table 2-3
Serial Poll Status Byte

DIO Line	Decimal Weight	Maskable SRQ?	Description	Bit Reset by	Front Panel Indicator
1	1	Yes	OVER-VOLTAGE: Set when OVP circuit trips	Power Off/On if OVP condition ceases	OVP LED on
2	2	Yes	RANGE ERROR: Set when programmed value exceeds model maximum values or soft limits	Serial Poll	-
3	4	-	Not used	Always zero	-
4	8	Yes	LIMIT MODE: Set when unit is programmed for constant voltage "MDV" but switches to constant current "MDC", or vice versa	Serial Poll if the limit mode operation ceases after the SRQ	Mode LEDs show the state of the power supply but not of the limit bit
5	16	Yes	DISABLE: Set when disabled with "S" command	Re-enable with "R", "GO" or device trigger	Voltage & current at zero
6	32	Yes	INVALID: Set for syntax error	Serial Poll	-
7	64	-	REQUEST SERVICE: Set when power supply requests service, indicates whether unit was requesting service when polled	Serial Poll if SRQ condition ceases	SRQ LED on
8	128	No	POWER-ON: Set when unit initializes at power-on	Serial Poll	-

Power-on (PON) always requests service. Therefore, if a momentary power dropout causes the interface memory to lose its programmed values, PON alerts the user that the power supply has been initialized and is in initial mode.

All unmasked status bits will accumulate in the status byte until a serial poll is conducted, regardless of whether that condition still exists. Masked bits will return to zero when polled.

Parallel Poll

Parallel poll allows the controller to determine quickly which of a number of instruments on the bus requested service. The parallel poll response corresponds to bit #7 of a serial poll status byte. Parallel poll does not reset the service request. The power supply must be configured remotely to respond to a parallel poll with either a "1" or "0" on one of the DIO lines if the unit is requesting service.

Remote/Local

The remote/local function allows the power supply to operate in either local or remote (IEEE 488) control. The power supply may be switched from REM to LOC and back to REM without loss of the programmed values. The user can send a Local Lockout to the power supply via the IEEE 488 bus to disable the remote switch on the rear panel. With Local Lockout, the controller determines if the unit operates in local or remote mode. This enables the controller to prevent anyone from returning the power supply to local control.

Device Clear

The power supply will implement Device Clear regardless of whether the unit is in local or remote control. Device Clear is typically used to send all or selected devices to a known state with a single command. The power supply will be set to Initial Conditions after Device Clear.

Device Trigger

Device Trigger will enable the most recently programmed values whether the unit is in local or remote control. If the power supply is in local mode, the new values will be implemented when switched from local to remote control. Device Trigger is typically used to synchronize the operation of a number of addressed devices.

2.7.2 Address Selection

The IEEE 488 bus address switches are located on the rear panel. Any address from 00 to 30 (decimal) is a valid IEEE 488 address. The power supply will operate on whatever address is set on the address switches. The power supply address is the total value of switches selected.

The switches on the rear panel are as follows:

Function	Switch	Address Value Open (Left)	Address Value Closed (Right)
A1 (LSB)	8 (top)	1	0
A2	7 .	2	0
A3	6 .	4	0
A4	5 .	8	0
A5 (MSB)	4 .	16	0
-	3 .	-	-
-	2 .	-	-
REM/LOC*	1 (bottom)	LOCAL	REMOTE

* Determines power on condition

2.7.3 Device Dependent Command Set

Device dependent commands are device dependent messages. For the power supply to receive them, they must be sent over the IEEE 488 bus when the power supply has been addressed as a listener.

The following commands are implemented:

V aaa.aaa	Output Voltage
C bbb.bbb	Current Limit
MXV aaa.aaa	Maximum Programmable Voltage
MXC bbb.bbb	Maximum Programmable Current
S	Disable Output
R	Enable Output
GO	Enable Output, Implement Mode Command
MSK cc	Set Service Request Conditions
MD d	Voltage or Current Mode
T	Trigger Read-back

Input Value Range:		Model#	Vmax (Volts)	Imax (Amps)
aaa.aaa	= 0 to Vmax	15-20	15	20
bbb.bbb	= 0 to Imax			
cc	= 0 to 63	30-10	30	10
d	= V or C			
		60-5	60	5

2.7.4 Syntax

a. Spaces within a command are optional.

b. Commands may be sent in any order.

c. Multiple commands separated by commas or semicolons may be sent on one line.

d. Commands must be terminated with EOI, LF EOI, or CR LF EOI. (In most instances, a terminator is automatically transmitted at the end of the controller's output string).

e. Numbers will be truncated after the third decimal position.

f. Leading and trailing zeros will be ignored.

g. Numbers that are not within the listed range will invalidate the command.

h. MXV, MXC, S, R, GO, and MSK are implemented upon receipt of the commands.

i. MD, the mode command, is implemented upon receipt of the GO command.

j. The output commands V and C are implemented upon receipt of a GO, R or Device Trigger command (IEEE 488 addressed command).

k. Commands may be sent in upper or lower case letters.

2.7.5 Initial Conditions

The power supply initializes at power-on with the following conditions:

a. Local or Remote Mode - dependent on the setting of switch #8 ("LOCAL")

b.	Programmed Voltage	= 0 volts	(V0.000)
c.	Programmed Current	= 0 amps	(C0.000) *
d.	Soft Voltage Limit	= Model Vmax	(MXVaaa.aaa)
e.	Soft Current Limit	= Model Imax	(MXCbbb.bbb)
f.	Mode	= Voltage Mode	(MD V)
g.	Interrupt Mask	= 00	(MSK 00)

* The programmed current limit must be set greater than 0 to enable the output of the power supply in voltage mode.

Any number of digits may be sent, but only six will be used. A decimal point must be sent if needed, but may be left out if not needed. Numbers will be truncated after the third decimal place. Numbers must be unsigned integers or real numbers without exponents.

2.7.6 Device Dependent Command Descriptions

V aaa.aaa - programs the output voltage of the power supply, from 0 to Vmax in volts. The voltage command will be stored if the power supply has been addressed to Listen, but will not be implemented until receipt of a GO, R or Device Trigger command. Note that any subsequent voltage value received by the power supply prior to receipt of a GO, R or Device Trigger command will supersede the previous value.

C bbb.bbb - programs the current limit of the power supply, from 0 to Imax in amperes. Factors described in the preceding paragraph for voltage also apply to current.

NOTE

If the power supply receives an invalid request (syntax error, value out of range or greater than soft limit), the power supply output will remain at its present value. A service request will be generated if the Invalid bit (#6) is unmasked in the SRQ byte.

MXV aaa.aaa
MXC bbb.bbb - sets the maximum output V/I to which the output can be programmed in remote mode. Soft limits protect the load in situations in which a damaging output V/I is inadvertently programmed. If the output V/I values to be programmed are determined by a series of measurements and computations, an unexpected combination of values could result in an unacceptably high output. However, if the V/I values exceed the soft limits, the power supply will consider the new values as an invalid request and the outputs will remain at the previous values.

The soft limit values are compared to all incoming values. If the incoming value is valid, it is stored in the power supply interface buffer. Therefore, if a value is sent to the power supply but not implemented by a GO, R or Device Trigger command, that value will not be affected by any subsequently received soft limit values. (The present programmed output values are also not affected). It is good practice to program soft limit values first, before programming the output.

S (set) - used to disable (turn off) the output of the power supply. An SRQ is generated if the Disable bit (#5) of the SRQ byte is unmasked. The power supply will continue to receive and store commands. The previous value or the most recently programmed output value will be re-enabled upon receipt of a GO, R or Device Trigger command.

R (reset) - used to enable the output of the supply. It implements the V and C commands (but does not implement MDV or MDC commands).

GO - similar to the R (reset) command but implements not only the V and C commands but also the MDV and MDC mode commands. (The IEEE 488 Device Trigger [addressed command] is identical to the GO command and is used to synchronize instruments on the bus).

MSK cc - used to program the power supply to make service requests on user-specified conditions. The two digit code should be an integer from 00 to 63.

00 - All Service Requests masked (disabled)
01 - Over-Voltage
02 - Range Error (out of range or exceeds soft limits)
04 - Not used
08 - Limit Mode
16 - Disabled Output (S command received)
32 - Invalid Request (Syntax error)

The above mask codes can be added, to select combinations of conditions.

MD d (mode) - designates the power supply as either a voltage source (MDV) or current source (MDC). If not masked, the power supply will request service when:

a. The unit switches to constant current while operating in MDV

or,

b. The unit switches to constant voltage while operating in MDC.

NOTE

The power supply will momentarily switch to constant current mode when a new output voltage value is programmed. The mode sense circuitry will detect this momentary transition and will request service if the Limit Mode bit (#4) is unmasked. (To avoid an SRQ while the output is changing to a new value, the Limit Mode bit should be unmasked after the voltage command has been implemented.)

T (trigger) - causes the power supply to read the present value of output voltage and current. In addition, the mode and status conditions are returned if unmasked.

2.7.7 Read-back Format

```
N
L  C
O  V   xx.xxV xx.xxA CR LF*
D
```

Where:

N - power supply operating normally (no SRQ, or SRQ bits masked)
L - power supply in limit mode when measurement taken
O - over-voltage protection tripped
D - power supply output disabled by "S" command
C - power supply in constant current mode
V - power supply in constant voltage mode
xx.xx - numbers representing output volts and output amps
CR LF - carriage return, line feed

If the power supply is addressed to talk before a T (trigger) readback command, the following message is sent:

OKAY CR LF*

For proper termination of the readback command the complete output string including CR LF should be read (23 bytes total).

* - EOI is asserted true concurrent with linefeed

2.7.8 Sample Programming Session

The following sample command sequences are typical applications of a 488 interface equipped HPD series power supply. The underlined control commands are controller dependent, and will vary with different systems.

TTL Testing Sequence using the HPD 60-5:

REM	Conduct serial poll to clear the Power On SRQ
SPOLL	
REM	Power supply returns 192 decimal or C0 Hex in SRQ status byte to indicate Power On and Request Service bits had been set
REM	Set soft limits at 6 volts and 4 amps
OUTPUT	"MXV 6.000 ; MXC 4.00"
REM	Set service request for OVP condition
OUTPUT	"MSK 01"
REM	Set output for 5 volts, current limit at 4 amps, enable the output
OUTPUT	"V5.00 ; C4.00 ; R"
REM	Readback actual power supply output values
OUTPUT	"T"
INPUT	
REM	Power supply will return actual values

Battery Charging Sequence using the HPD15-20:

REM	Conduct serial poll to clear Power On SRQ
SPOLL	
REM	Power supply returns 192 decimal or C0 Hex
REM	Set output for 14.4 volts, 20 amp current limit
OUTPUT	"V14.4 ; C20"
REM	Set power supply as a current source, Enable output
OUTPUT	"MDC ; GO"
REM	Set service request for Mode Crossover event
OUTPUT	"MSK 8"
REM	Readback actual power supply output values
OUTPUT	"T"
INPUT	
REM	Power supply will return actual voltage and current values

The power supply will now request service when the mode changes from Constant Current to Constant Voltage, when the current drawn by the battery drops below 20 amps.

SECTION 3

THEORY OF OPERATION

3.1 POWER CIRCUIT (A2)

This section explains the operation of the A2 assembly switching regulator power circuit including basic switching regulator theory, basic features of the Sorensen two-transistor forward converter, and a more detailed circuit description.

3.1.1 Basic Off-Line Switching Regulator Theory

An off-line switching power supply converts AC line voltage to high voltage DC by diode rectification and then chops the DC at a high frequency. This DC switching waveform is then applied to a high frequency transformer which provides a step-down in voltage and electrical isolation on its secondary. The switching waveform on the secondary is then rectified and filtered, giving a smooth DC output voltage. Feedback from the secondary circuit is used to control the switching waveform to the primary so that output regulation is obtained. This feedback is applied to a pulse width modulator (PWM) control circuit which controls the on-time of the primary circuit, thus increasing or decreasing the voltage on the secondary. See Figure 3-1.

The use of high frequency transformers in switching power supplies has the advantage of requiring less volume, less weight, and dissipating less heat than the lower frequency transformers in conventional linear power supplies.

3.1.2 Simplified Two-Transistor Forward Converter Theory

As in the basic switching regulator scheme of Figure 3-1, the AC line voltage is first rectified to a DC voltage (Figure 3-2). Following this, an active circuit provides surge current limiting, preventing excessive power-on current surges to the main filter capacitors in the input rectification circuit. This DC voltage is applied to power-FET transistors which are gated on and off simultaneously at a 100kHz switching rate by the pulse width modulator (U8) through totem-pole drivers Q12 and Q13 and drive transformer T2. This allows current to begin flowing through the primary of T3 for the duration of the drive pulse waveform from U8, causing a current ramp in the T3 primary, which develops a voltage ramp across the primary shunt resistor. This voltage level is fed back to the pulse width modulator (U8) which terminates the on-time drive pulse when the ramp crosses an internal threshold voltage (corresponding to a peak primary current in T3). In this way, the current feedback to the PWM forms a cycle-by-cycle current mode control loop limiting the maximum output on the T3 secondary.

During the on-time of the switching transistors and the T3 primary, current flows through CR5A and inductor L2 to the output. When the T3 primary is turned off, the stored energy in inductor L2 causes current to continue to flow to the output through CR5B. (CR5 is a fast recovery switching rectifier.)

A current shunt resistor in the output return line develops a voltage dependent on the output current. This current information is compared to the setting of the current limit control in the current control circuit (U3C, U3D). The output voltage is similarly monitored and compared to the voltage adjust control in the voltage control circuit (U3A). The outputs of both of these (voltage and current) control circuits are ORed to drive power-FET Q3 to precisely regulate the output voltage or current to the level set by the voltage adjust control or the current limit control. As the output load requirements change, the voltage and current control circuits change the drive to Q3 to maintain the desired output level.

The output from T3 is pre-regulated to the level required by the linear post-regulator circuit (described in the preceding paragraph). This is accomplished by a negative feedback path through opto-isolator U5,

BASIC SWITCHING REGULATOR SCHEME

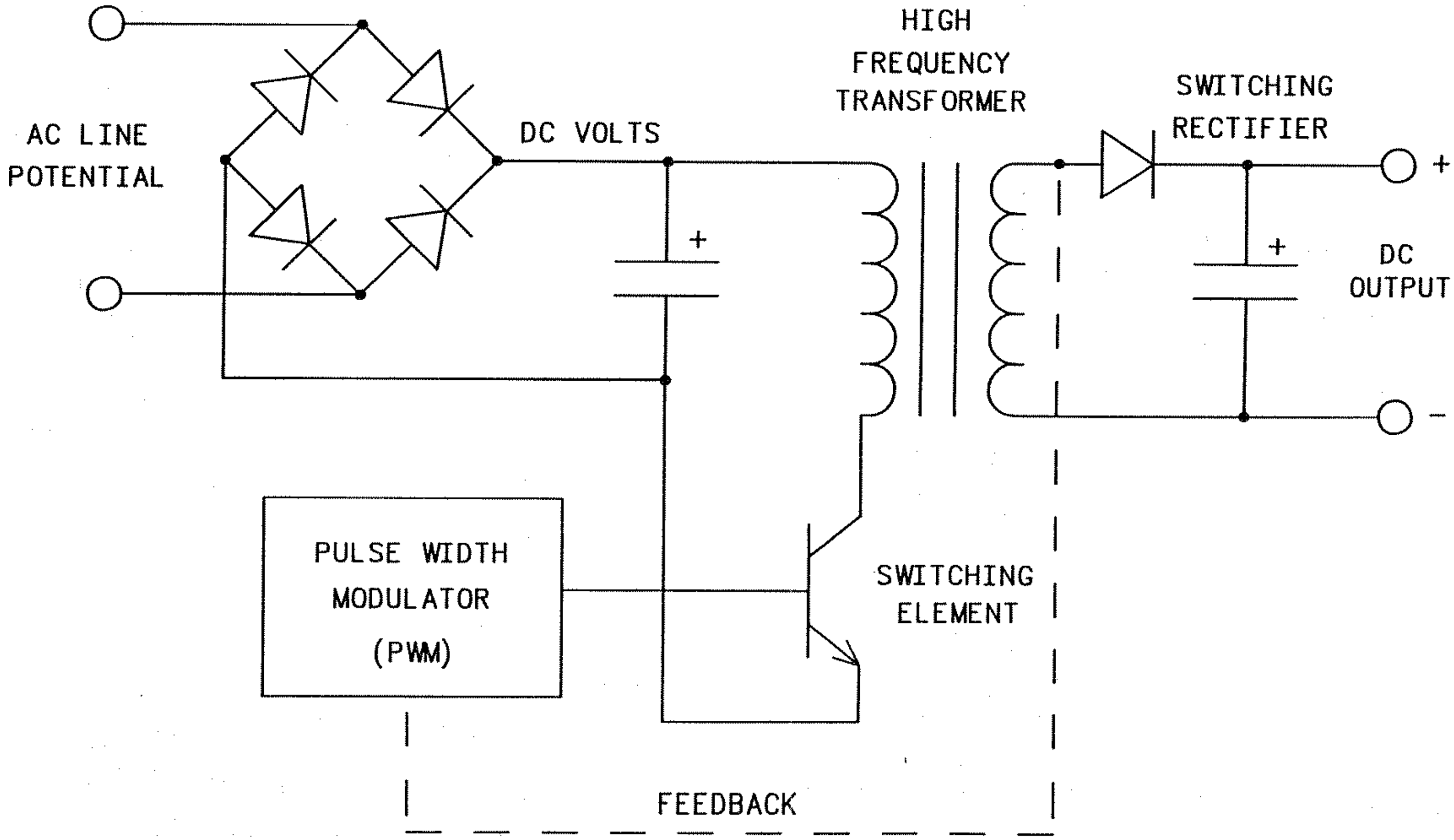


Figure 3-1

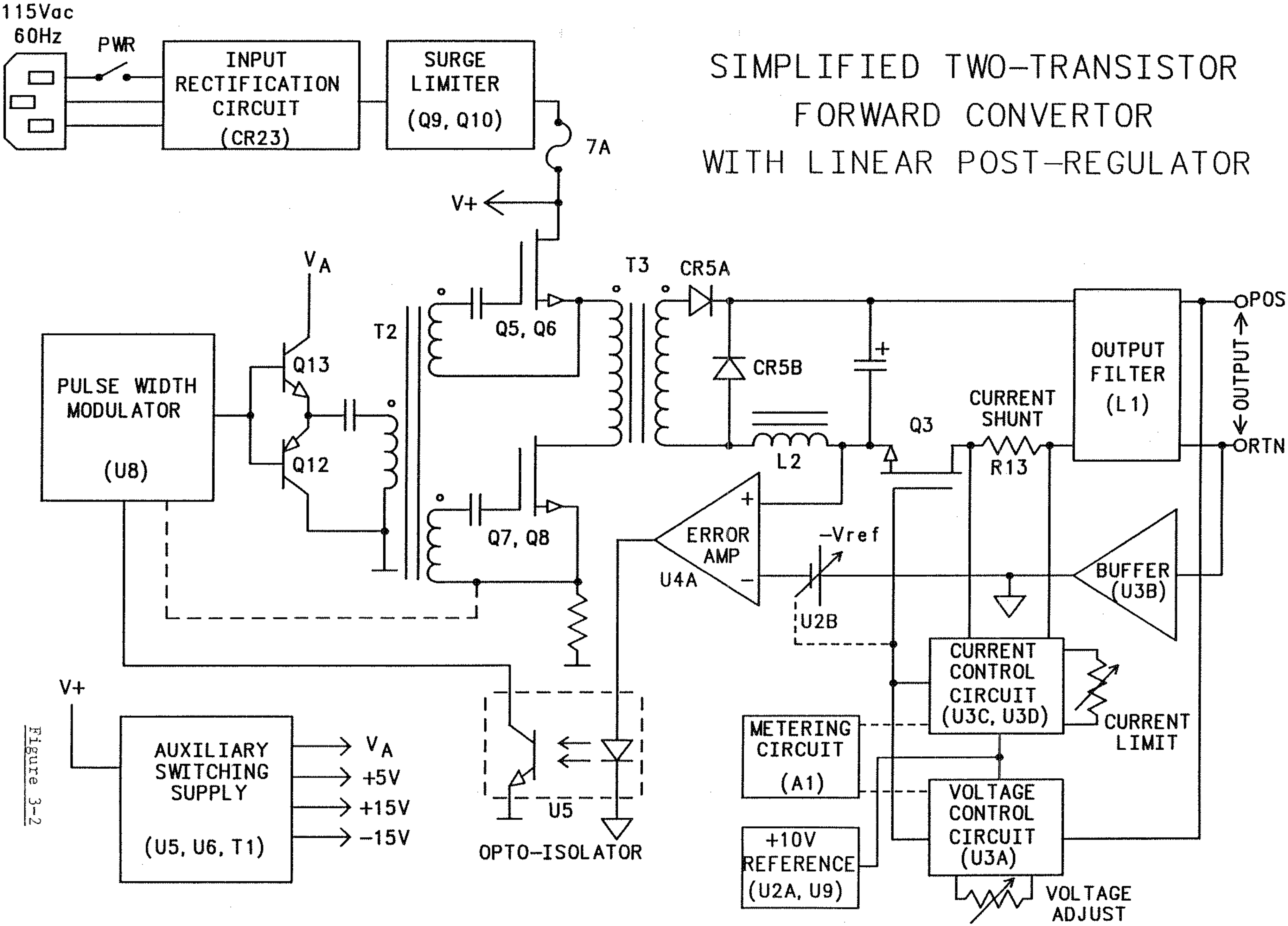

SIMPLIFIED TWO-TRANSISTOR
FORWARD CONVERTOR
WITH LINEAR POST-REGULATOR
115Vac
60Hz
PWR
INPUT
RECTIFICATION
CIRCUIT
(CR23)
SURGE
LIMITER
(Q9, Q10)
7A
V+
V_A
Q13
Q12
T2
Q5, Q6
Q7, Q8
T3
CR5A
CR5B
L2
Q3
CURRENT
SHUNT
R13
OUTPUT
FILTER
(L1)
POS
OUTPUT
RTN
PULSE WIDTH
MODULATOR
(U8)
ERROR
AMP
U4A
-Vref
U2B
BUFFER
(U3B)
CURRENT
CONTROL
CIRCUIT
(U3C, U3D)
CURRENT
LIMIT
METERING
CIRCUIT
(A1)
+10V
REFERENCE
(U2A, U9)
VOLTAGE
CONTROL
CIRCUIT
(U3A)
VOLTAGE
ADJUST
V+
AUXILIARY
SWITCHING
SUPPLY
(U5, U6, T1)
V_A
+5V
+15V
-15V
U5
OPTO-ISOLATOR

Figure 3-2

which controls PWM U8, and sets the on-time of the switching drive waveform. As more output is required by Q3, the negative reference provided by U2B biases error amplifier U3A positive, biasing the opto-isolator on, and lengthening the on-time pulse from the PWM until the output increases to the required level (at which the error amplifier output returns to zero). As the post-regulator requires more input at lower voltage and current levels, the negative reference level is also controlled by the outputs of the current and voltage control circuits.

The output voltage and current information from the current and voltage control circuits is also fed to the A1 assembly (front panel) where it is displayed on voltage and current digital readouts and bar graphs. An auxiliary switching power supply of the flyback type, operating at 200kHz, provides the necessary supply voltage for the PWM circuit as well as isolated supply voltages for the voltage and current control circuits, A3 or A4 option boards, and A1 metering board. A 10 volt reference circuit supplies the necessary reference level for the current and voltage monitoring circuits.

The isolation of transformer T3 and opto-isolator U5 provide output isolation from the line potentials in the primary circuit, PWM, and auxiliary switching supply (which also has an isolating transformer).

CAUTION: Potentially LETHAL VOLTAGES exist on the A2 circuit board on the primary side of the isolation barrier. Troubleshoot with care, preferably with power off and recognizing that filter capacitors store potentially LETHAL and DESTRUCTIVE ENERGY even for some time AFTER POWER is REMOVED. Always use an isolation transformer connected ONLY to the power supply input when making test measurements on the primary side circuits.

3.1.3 Detailed Circuit Description

This section is intended to provide further detail for troubleshooting purposes. Please read the previous section and then refer to the detailed A2 assembly schematic in Section 5 (Figure 5-3).

Input Rectifier and Surge Limiter

Power is applied through F1 to the input RFI filter consisting of C56-C58, L3, and L4. CR23 provides input rectification. The input surge limiter consists of transistors Q9, Q10, Q14 and associated components. As the main filter capacitors (C53 and C54) begin to charge, current flows through Q9, Q10 and R77. Above a nominal 20 Amps (peak) the voltage across R77 turns on Q14. This turns down the gate drive to Q9 and Q10 provided by R81, limiting the peak current to a nominal 20 Amps. As the voltage across Q9 and Q10 increases above a nominal 5 volts, Q14 is similarly turned on and Q9 and Q10 are turned off. In this way Q9 and Q10 remain within their safe operating regions as capacitors C53 and C54 charge. CR22 clamps the gate voltage to below 18 volts and C55 charges and holds Q9 and Q10 on after the charging of C53 and C54 is completed. CR24 protects Q9 and Q10 against line transient events exceeding 160 volts, and CR24A, R83 and C52 dissipate transient energy when Q9 and Q10 turn off.

Pulse Width Modulator

Pulse width modulator U8 acts as a current mode controller driving switching transistors Q5-Q8 through drive transistors Q12 and Q13 and transformer T2. Zeners CR10, CR11, CR18 and CR19 provide gate protection while components R50, CR13, C31 and R63, CR20, C38 act as snubbers limiting switching transients on the primary of T3. Current shunt R64 provides a voltage ramp which is monitored by U8 and compared to an internal threshold voltage, thus controlling the output pulse duration on U8 pin 14 depending on the T3 primary current. R62 and C50 provide filtering for this current feedback signal. U7 and associated components form a 200kHz astable oscillator from which a 200kHz pulse is taken to U8 pin 10 (sync input) via C44. This sets the output of U8 to a 100kHz frequency. The PWM IC generates a +5.1 volt reference at pin 2. R75, R76, and C51 provide a soft-start function by holding pin 1 low on power-up. U5 and R70 divide the reference voltage and, with R71 and R72, control the internal threshold voltage to which the peak T3 primary current is compared. The degree to which U5 is biased on thus controls the on-time of the pulse at U8 pin 14, and consequently the output level at the secondary of T3.

Output Rectifier Circuit

CR5A and CR5B rectify the output on the T3 secondary as previously described. R44, R45, C25 and C26 are snubber components further limiting switching transients. C5-C7 and L2 provide filtering of the pre-regulated output at this point, and C5-C7 can be rapidly discharged by Q1 whenever power-on/off or output load changes occur. Q1 maintains the voltage across Q3 at a maximum of -10 volts (set by CR29 and associated components).

Output Pre-Regulator Circuit

The circuit formed by U3B and Q15 buffers the output return sense level to provide a control ground level used by the reference and output regulating circuits. U2B is used to generate a -10 volt reference from the +10 volt reference level provided by U2A. This negative reference is divided down by R33, R34, and R37 to provide the appropriate negative reference level at the U4A error amplifier input pin 2. R37 and R34 are referenced to the current control output (U3C pin 8) and the output voltage respectively, thus making the negative reference proportional to the output current and voltage levels. The other error amplifier input (U4A pin 3) is referenced to the source of Q3. As the voltage across Q3 (source to drain) varies between -10 volts and zero, the output of U4A also varies, controlling the drive to opto-coupler U5, which in turn controls the output of the PWM and the level at the T3 secondary. This forms a negative feedback path which pre-regulates the voltage across Q3 at typically -4 volts (set by the negative reference level at U4A pin 2). In this way, enough output is supplied to Q3 for all output conditions.

Output Filter Circuit

C4, C4A, L1 and C120-C122 form the output filter. R27A provides an output pre-load and allows the output circuits to operate under low output current conditions.

Auxiliary Switching Supply

U6, U7, T1 and associated components form a multiple output flyback type switching supply operating at 200kHz. U7 (a CMOS timer IC) generates a 200kHz frequency used to drive the oscillator input of pulse width modulator U6 which generates a variable pulse width 200kHz signal to Q4. Q4 switches the primary of transformer T1 generating a current ramp monitored by U6 at pin 3 from current shunt resistor R55. R53, R54, and C41 condition this current feedback signal. R56 and R57 limit the gate drive to Q4 below 20 volts. R51, CR15, and C32 act as a snubber limiting switching transients on the T1 primary. A flyback winding provides power to U6 through CR16 and C34, and provides negative feedback to pin 2 through R66 and R67 where internal comparison to a 2.5 volt reference shortens the output pulse width for increasing flyback voltage (thus providing voltage regulation). The resulting regulation provides regulated outputs on the T1 secondaries which are rectified and filtered to provide supply voltages for the control, A1 metering, and A3/A4 option circuits. The flyback winding is also used to power the main PWM circuit (U8) via CR17 and filter capacitors C35 and C45. R12 and CR2 provide a -6.2 volt supply to the A1 circuit.

+10 Volt Reference

U2A, U9 and associated components form a well-regulated +10 volt reference circuit used in the voltage and current control circuits as well as the A1 metering circuit. U9 is a temperature-stabilized zener diode reference. Trimming R16 sets the output of U2A to the +10 volt reference level. C2 and C11 filter any noise present on the reference.

Voltage Control Circuit

The output voltage is monitored by U3A at pin 2 through the positive sense line (J2-8) and the resistor divider string R7-R10. A zero to 10 volt reference is applied in comparison to this output voltage at pin 3 of U3A from the voltage adjust control (via analog gate U1C). As the output voltage rises, pin 2 goes high with respect to pin 3 of U3A, the U3A output goes low, and the drive to Q3 is decreased through CR3. (In the voltage control mode, U3D pin 14 is high.) This decreases the output current through Q3 so that voltage regulation of the output is achieved at a voltage proportional to the set point of the voltage adjust control. The R7 to R10 divider is scaled such that 10 volts at pin 3 of U3A generates maximum output voltage. Thus the output tracks the voltage adjust control linearly from zero to maximum output voltage.

Current Control Circuit

The output current is monitored by U3C from current sense resistor R13. U3C and associated components form a differential amplifier scaled such that full scale output current corresponds to +5 volts at U3C pin 8. This level is compared to the current limit control at U3D. The current limit control supplies an adjustable zero to 10 volt signal to U1A, after which it is scaled to zero to 5 volts at U3D pin 12. As U3D pin 13 exceeds U3D pin 12 (when the output current increases above the current limit set-point), the output of U3D goes low, decreasing the drive to Q3. This limits the output current as a result, until the voltage at U3D pin 13 becomes equal to that of U3D pin 12, and precise current regulation is achieved. In this way the output current tracks the current limit control linearly from zero to maximum rated current, provided the output load is sufficient to draw such current. If the output current falls below the current limit set-point, U3D pin 14 will go high and U3A will be able to control the output in the voltage control mode by sinking current through R35 and CR3, and thus controlling the drive to Q3.

Mode Indication

U4B takes advantage of the fact that CR3 is forward-biased in voltage control mode and reverse-biased in current control mode to provide a mode indication signal at U4B pin 7. This is used to drive two back-to-back LED indicators on the front panel. In the voltage control mode, U4B pin 7 is high and the green (voltage) LED lights. In the current control mode, U4B pin 7 is low and the red (current) LED lights.

Remote Programming

The zero to 10 volt signals from the current and voltage controls may be switched out of circuit by analog gates U1C and U1A being turned off via the option connector lines P2-9 and P2-8. Lines P2-1 and P2-2 can then be used by the option boards to remotely program the voltage and current control circuits with appropriate zero to 10 volt programming levels.

Shutdown Circuit

The power circuit may be turned off with a high level on the option connector line P1-9. This turns on Q2, which turns off U1D, and removes drive current to the opto - coupler U5, turning off the power supply. When U1D turns off, U1B turns on, preventing positive saturation of U3A which would result in an output overshoot when the shutdown level is removed. A control ground or return sense line fault, causing the buffered control ground from U3B to go high, will cause a similar shutdown function through CR3A.

Metering Outputs

The R7 to R10 divider string provides two outputs proportional to the output voltage for metering purposes: a zero to 5 volt output to the option board (P2-4), and an appropriately scaled output to the A1 metering circuit (J2-7). Similarly, the resistor divider string R28, R25A, and R11 provides two outputs proportional to the output current: a zero to 5 volt output to the option board (P3-1), and an appropriately scaled output to the A1 metering circuit (J2-6).

Model Identification

The A2 board also provides model information required by the option board at connector lines P3-4, P3-5, P3-6 and P3-7. Each model is identified by a coded combination of shorted links at points A, B and C. This is decoded by logic circuitry on the option boards.

3.2 METER CIRCUIT (A1)

Refer to the schematic diagram (figure 5-2) in section 5 for the following discussion.

3.2.1 Voltage Meter

The analog input signal from the A2 power board is divided down so that 1 mV between P102-7 to P102-5 represents 1 volt at the output of the power supply. This reduced voltage is filtered by R128 and C114 to remove any noise and then input to U104, a 3 1/2 digit analog to digital converter. U104 converts the input voltage to a three digit readout of up to 999 mV on the seven segment LED displays DS104 through DS106. The conversion is performed approximately 3 times each second at a rate determined by the value of C106. The full scale accuracy of the meter is determined by the reference voltage from pin 35 to pin 36 of U104. The reference voltage is 1.0 volts and is derived from the 10 volt reference on the A2 board via the divider R132, R133, and R134. Note that any negative input will be displayed as a positive reading as there is no negative sign in the display.

The bar graph driver IC (U103) and LEDs DS117 through DS126 are used to display changes in the output voltage. The full scale reference voltage which corresponds to all 10 LEDs being lit is determined by R104 and R113.

3.2.2 Current Meter

The current meter circuit functions like the voltage meter circuit discussed in paragraph 3.2.1. The analog to digital conversion is performed by U102 and displayed by DS101 through DS103. The output current is displayed on the current bar graph LEDs DS107 through DS116 which are driven by U101.

3.2.3 Output and Sense Lines

The remote sense lines are internally connected to the main output terminals by R122 and R125. Should the sense lines be incorrectly connected to the output (eg. reversed), Q101 is biased on and raises the return sense potential. This performs a shutdown function via U3B, CR3A, and Q2 on the A2 power assembly.

3.3 OPTION CIRCUITS

The following paragraphs describe the optional features available for the HPD Series power supplies. Refer to the schematic diagrams (figures 5-4 and 5-5) in section 5, being sure to distinguish between the A3 (analog remote programming) and A4 (IEEE 488 interface) options available.

3.3.1 Over-Voltage Protection (A3 board)

The OVP control IC (U309) compares the output voltage to an internal reference voltage. The output voltage is sampled by the OVP set point potentiometer (R115) on the front panel. When the set point voltage exceeds the reference for a period longer than approximately 1 msec, U309 fires Q308, an SCR, which shorts the main output. The crowbar SCR is latched on by the current flowing through R35A and CR309. When Q308 fires, Q307 is turned on via CR325 lighting the red OVP indicator LED on the front panel (DS127). Q307 also forward biases CR308 which shuts down the power supply output.

3.3.2 Remote Voltage Programming of Output Voltage and Current (A3 board)

The zero to 10 volt external voltage programming signal is scaled and buffered by U305B and clamped by CR314 and CR316. Switch S304 selects the remote voltage programming mode by enabling U307A which connects the programming signal to the power board (A2) and disables the local voltage control potentiometer by driving the output of U306A low.

The zero to 10 volt external current programming signal is scaled and buffered by U305A and clamped by CR311 and CR315. Switch S305 selects the remote current programming mode by enabling U307B which connects the programming signal to the power board (A2) and disables the local current control potentiometer by driving the output of U306D low.

Both the remote voltage and current programming signals are referenced to a common control ground provided by the voltage follower U308B which is set at the return sense line potential. The control ground line is fused by F301 to limit current to 1/8 Amp maximum. The external programming voltage supplies, therefore, must have outputs that are floating with respect to the programmed supply output.

U306C and U306B function as a 2 Hz oscillator which is enabled when either external program control switch is closed. The oscillator drives Q305 which flashes the green program indicator LED (DS129) on the front panel.

3.3.3 TTL Compatible ON-OFF Control (A3 board)

The input lines for the ON-OFF function are fully isolated by opto-isolator U304. The external TTL control circuit can be biased up to 400Vdc with respect to the power supply ground. The power supply output is disabled when pin 15 of the rear connector J305 exceeds +3 volts with respect to pin 2 of J305. This turns on U304 which turns on Q306. When Q306 is on, it pulls the external shutdown line on J301-9 high turning off the power supply via Q2 on the power board (A2), and also lights the yellow shutdown indicator LED (DS128) on the front panel.

3.3.4 IEEE 488 Interface (A4 board)

The digital portion of the interface board (A4) is energized by an auxiliary power source from the A2 board applied between J3-8 and J3-9. This is rectified and regulated to +5V by CR3 and U7, forming a floating power supply.

U3 and U4 are bus transceivers which buffer and control the signals to and from the IEEE 488 parallel bus through rear connector J5. U6 uses these signals in conjunction with 8-bit latch U5 to control microprocessor U4. Y1 supplies a stable frequency for the microprocessor clock, C8 provides a power-on reset delay, and U1 provides model information to the microprocessor from the A2 circuit.

Using the internally stored program in its EPROM memory, the microprocessor outputs serial information and control signals to two 12-bit D to A converters (U26, U28) through opto-isolators U22, U16, U23, U21 and U15. These DACs control the output voltage and current limit of the power supply as follows. The output signal from U28 pin 1 is conditioned by operational amplifiers U27A and U27B and applied to the analog gate input of U25C. Under software control U4 outputs a high signal on pin 24 turning on the REM indicator on the front panel and turning on analog gate U25A through opto-isolator U20. This enables gates U25B and U25C and allows the conditioned DAC output from U28 to be applied to the remote voltage program line to the A2 board (J2-1). At the same time U20 pulls the remote voltage control line to the A2 low (J2-8). This sets the output of the supply to the desired remotely programmed voltage which is proportional to the U20 (DAC) output. Similarly U26, U27D and U27C control the remotely programmed current through U25B.

The OVP circuit is formed by U29, Q3, Q2 and associated components and operates similarly to the OVP circuit described in section 3.3.1. The MODE signal is applied to the microprocessor through opto-isolator U10. The output voltage and current are monitored by U24B and U24A respectively and A to D converters U10 and U17 send this information in serial form to the microprocessor through opto-isolator U18. (This read-back feature is only available on option M9). U11, U12 and U19 allow the microprocessor to control the read-back A to D converters with the appropriate control signals.

The microprocessor status is displayed by four LED indicators indicating LISTEN, TALK, SERVICE REQUEST, and REMOTE operating modes. The LISTEN and TALK indicators are provided on the rear panel for trouble-shooting purposes. An address is assigned to the power supply by switches S4 to S8 through U1 onto the microprocessor data lines. S1 tells the microprocessor to select either IEEE 488 remote control or local control by the A2 board on power-up. U24D provides a common buffered ground for the analog signal processing circuits. Opto-isolator U14 inputs an external OVP signal to U4 when the OVP circuit is activated.

The isolation provided by the opto-isolators allows the digital and analog sections to be separated by a potential of up to 400Vdc. This allows operation of multiple units in series or parallel configurations provided the maximum output potential with respect to case or line ground is less than 400Vdc.

SECTION 4

MAINTENANCE

4.1 GENERAL

This section provides troubleshooting data, and periodic servicing, calibration, and performance testing procedures. The troubleshooting data should be used in conjunction with the schematic diagrams in section 5 and with section 3 which outlines the theory of operation. Any questions pertaining to repair should be directed to Sorensen Company, 5555 N. Elston Avenue, Chicago, IL, 60630, (312) 775-0843. Include the model and serial numbers in any correspondence. Should it be necessary to return a unit to the factory for repair, prior authorization from Sorensen Company must be obtained.

4.2 PERIODIC SERVICING

Whenever a unit is removed from service, it should be cleaned, using naphtha or an equivalent solvent on painted metal surfaces, and a weak solution of soap and warm water for the front panel. Compressed air (at 5 psi) may be used to blow dust from in and around components.

4.3 TEST EQUIPMENT REQUIRED

The following test equipment may be required to service the power supply:

1. Oscilloscope, dual trace, 20-200MHz bandwidth.

2. Digital multimeter, 4 1/2 digit accuracy.

3. True RMS voltmeter (Hewlett Packard HP-3403C or Fluke 8840-09).

4. Line isolation transformer, 500VA.

4.4 TROUBLESHOOTING

CAUTION!! POTENTIALLY LETHAL VOLTAGES EXIST IN THE POWER CIRCUIT (A2). Troubleshoot with care after familiarization with circuit operation and using appropriate high voltage testing techniques. Refer servicing to experienced technical personnel only. Remember - FILTER CAPACITORS STORE POTENTIALLY DANGEROUS ENERGY EVEN FOR SOME TIME AFTER POWER IS REMOVED. Discharging of large filter capacitors with suitable resistors is necessary for safety and the protection of components during repair work. LINE POTENTIALS ARE PRESENT THROUGHOUT THE A2 CIRCUIT. ISOLATE THE POWER SUPPLY FROM THE LINE WITH AN ISOLATION TRANSFORMER WHEN USING GROUNDED TEST EQUIPMENT IN THE POWER CIRCUIT.

Fuses should always be replaced with the same type and rating as originally installed. A blown fuse almost invariably indicates other faulty components which should be identified and replaced before a new fuse is installed. If possible, troubleshoot and identify faulty components WITH POWER REMOVED. Look particularly for isolation faults in inductors and transformers, and drain-source shorts in the power-FET devices. A blown F2 fuse indicates likely failure of switching transistors Q4 to Q8 and/or output devices, while a blown F1 fuse indicates likely bridge rectifier (CR23) failure and/or failure of transistors Q9, Q10, and Q14. Replace power transistors with the same type; not substitutes.

4.4.1 Main Assembly Troubleshooting Chart
(A1 Front Panel Assembly, and A2 Power Assembly)

- Check for burnt components, poor solder connections, and loose connectors.
- Disconnect any attached option board (A3 or A4 assembly). If the problem is corrected when the board is removed, refer to the appropriate option board troubleshooting chart.
- Observe the high voltage precautions listed in section 4.4 when troubleshooting the A2 assembly. Be sure the unit is powered from an isolation transformer when using grounded test equipment (such as an oscilloscope) in the primary side of the circuit. FAILURE TO OBSERVE THESE PRECAUTIONS COULD CAUSE SERIOUS INJURY or damage to test equipment.
- All measurements are to be made with reference to P2-6 unless otherwise noted.
- All parts and test points are located on the A2 assembly unless otherwise noted.
- Under the POSSIBLE DEFECTIVE COMPONENTS column, parts are listed in order of decreasing probability of failure.

SYMPTOM	CHECK	POSSIBLE DEFECTIVE COMPONENTS AND CAUSES
NO OUTPUT AND THE DISPLAY IS BLANK	1) THAT F1 IS NOT OPEN	1) CHECK Q9, Q10, CR24, CR23, Q14, CR22 AND CR21 BEFORE REPLACING FUSE
	2) THAT F2 IS NOT OPEN	2) CHECK Q5 TO Q8, Q4, CR12, CR14, CR5, AND INSULATING WASHERS ON Q5 TO Q10 BEFORE REPLACING FUSE
	3) DC AUXILIARY VOLTAGES ARE PRESENT AND WITHIN RANGE: P2-5 = +15V +/- 1V P2-7 = -15V +/- 1V P3-3 = + 5V +/- 1V	3) IF NOT: U6, U7, Q4, T1, CR7 TO CR9
	4) REFERENCE VOLTAGE AT P1-7 IS 10V +/- 0.1V	4) IF NOT: U2, U9 OTHERWISE: REPLACE THE FRONT PANEL AND PROCEED TO NEXT TROUBLESHOOTING SECTION

NO OUTPUT BUT THE DISPLAY FUNCTIONS	1) FAST-ON CABLE CONNECTORS TO THE A1 ASSEMBLY ARE PROPERLY SEATED	1) FAST-ON CONNECTORS
	2) DC AUXILIARY VOLTAGES ARE AS LISTED IN STEP #3 OF PREVIOUS SECTION	2) IF NOT: CR7, CR8, U6, T1
	3) REFERENCE VOLTAGE IS AS IN STEP #4 OF PREVIOUS SECTION	3) IF NOT: U2, U9
	4) WITH VOLTAGE AND CURRENT CONTROLS FULLY CLOCKWISE, VOLTAGE AT ANODE OF CR3 IS GREATER THAN 5V	4) IF NOT: U3, U1, Q2, Q3, Q1 OR R122, R125 ON A1 ASSEMBLY
	5) VOLTAGE ACROSS Q3 IS LESS THAN 3 VOLTS	5) IF NOT: Q3, Q1, Q2, U1
	6) VOLTAGE AT R70, R71 JUNCTION IS LESS THAN 2V WITH REFERENCE TO P4-2	6) IF NOT: U2B, U4A, COAXIAL JUMPER W1, U5
	7) WITH AN OSCILLOSCOPE, CHECK FOR 15Vp-p SQUARE WAVE AT EMITTERS OF Q12 OR Q13 AT 100kHz +/- 5kHz WITH REFERENCE TO P4-2	7) IF NOT: U8, Q12, Q13
	8) WITH AN OSCILLOSCOPE, CHECK FOR SQUARE WAVE ON T3 SECONDARY PINS 7 TO 12	8) IF NOT: T2, Q5 TO Q8 OTHERWISE: CR5
OUTPUT REGULATION POOR OR OUTPUT NOT ADJUSTABLE OVER FULL RANGE	1) DC AUXILIARY VOLTAGES ARE PRESENT AS PREVIOUSLY DESCRIBED (SECTION 1, STEP #3)	1) IF NOT: U6, U7, Q4, T1, CR7 TO CR9
	2) DC REFERENCE VOLTAGE IS AS PREVIOUSLY DESCRIBED (SECTION 1, STEP #4)	2) IF NOT: U2, U9

	3) CONTROL GROUND VOLTAGE AT P2-3 REFERENCED TO THE NEGATIVE OUTPUT IS LESS THAN +/- 50mV	3) IF NOT: R125 ON A1 ASSEMBLY OR U3, Q15
	4) DC VOLTAGE AT U3 PIN 3 IS ADJUSTABLE FROM 0V TO 9.5V WITH FRONT PANEL VOLTAGE CONTROL	4) IF NOT: U1, U3, RIBBON CABLE CONNECTORS
	5) WITH NO LOAD ON OUTPUT, DC VOLTAGE AT Q3 SOURCE IS BETWEEN -2V AND -10V	5) IF NOT: Q1, U4A, U2B, CR29, U3
	6) CR5 AND Q3 CASE ARE ISOLATED FROM HEATSINK	6) INSULATING WASHERS ON Q3 AND CR5
	7) DC RAW SUPPLY VOLTAGE AT T1 PIN 4 REFERENCED TO P4-2 IS GREATER THAN 140V	7) IF NOT: CR23, Q9, Q10, Q14 OTHERWISE: U3, U1, U8
DISPLAY ERRATIC OR BLANK BUT OUTPUT IS FUNCTIONAL	1) RIBBON CABLE CONNECTORS TO A1 ASSEMBLY ARE PROPERLY SEATED	1) RIBBON CABLE CONNECTORS
	2) DC VOLTAGE AT P3-3 IS 5V +/- 0.5V AND AT CR2 ANODE IS -6.2V +/- 0.5V	2) IF NOT: CR9, CR2, CR8
	3) DC REFERENCE VOLTAGE AT P1-7 IS 10V +/-.1V	3) IF NOT: U2, U9 OTHERWISE: (A1 ASSEMBLY) - VOLTAGE DISPLAY: U104 - VOLTAGE BAR GRAPH: U103, R113 - CURRENT DISPLAY: U3 ON A2 ASSEMBLY, U102 - CURRENT BAR GRAPH: U3 ON A2 ASSEMBLY, U101

OUTPUT IS ABOVE THE NORMAL MAXIMUM OUTPUT VOLTAGE AND IS NOT ADJUSTABLE	1) TURN OFF THE POWER SUPPLY IMMEDIATELY AND REMOVE U8 FROM ITS SOCKET TO PREVENT FURTHER DAMAGE TO OUTPUT COMPONENTS	1) REPLACE OVER-STRESSED OUTPUT CAPACITORS C5,C6 AND C7
	2) Q3 IS FUNCTIONAL	2) IF NOT: Q3
	3) WITH POWER ON AND THE VOLTAGE CONTROL FULLY COUNTERCLOCKWISE, U3 PIN 1 IS LESS THAN ZERO VOLTS	3) IF NOT: CONNECT +SNS TO +OUTPUT AND -SNS TO -OUTPUT. IF VOLTAGE IS THEN CORRECT, REPLACE R122 AND R125 ON A1. IF STILL INCORRECT, CHECK U3B, U2, U9, U1.
	4) WITH POWER OFF, CHECK THAT RESISTANCE ACROSS W1 IS GREATER THAN 1k OHM	4) IF NOT: U5, W1 OTHERWISE: U4, U2, U8

4.4.2 Option M5 Troubleshooting Chart
(A3 Option Assembly - Analog Programming Card)

- Connect the A3 assembly in question to a power supply that is known to be operational to ensure that any problems are on the option board.
- Be sure that all connectors are properly oriented and correctly seated.
- All parts and test points are on the A3 assembly unless otherwise noted.
- All voltages are referenced to control ground at the anode of CR327 unless otherwise noted.
- Before beginning troubleshooting, check that the voltage between control ground (anode of CR327) and the negative output terminal is less than +/- 50mV. If this voltage is exceeded, replace U308.
- Parts are listed in the POSSIBLE DEFECTIVE COMPONENTS column in order of decreasing probability of failure.

SYMPTOM	CHECK	POSSIBLE DEFECTIVE COMPONENTS AND CAUSES
OVP IS ALWAYS TRIPPED (RED LED IS ON)	1) J4 CONNECTOR TO THE FRONT PANEL IS PROPERLY SEATED, OVP POT IS FULLY CLOCKWISE, AND POWER WAS CYCLED OFF/ON	1) J4 CONNECTOR, OVP POT
	2) VOLTAGE AT U309 PIN 8 IS LESS THAN 0.2V	2) IF NOT: U309 OTHERWISE: Q308, Q307
OVP WILL NOT TRIP	1) J4 CONNECTOR TO THE FRONT PANEL IS PROPERLY SEATED, OVP POT IS TURNED FULLY COUNTERCLOCKWISE, AND SUPPLY OUTPUT VOLTAGE IS SET AT GREATER THAN 3V	1) J4 CONNECTOR, OVP POT
	2) VOLTAGE AT U309 PIN 8 IS GREATER THAN 2V	2) IF NOT: U309, R115 ON A1 ASSEMBLY, F302 OTHERWISE: Q308, CR309, CR325
REMOTE SHUTDOWN IS NOT FUNCTIONAL	1) WITH 3V PRESENT FROM J305-15 (+) TO J305-2 (-) THE VOLTAGE AT ANODE OF CR307 IS GREATER THAN 10V	1) IF NOT: U304, Q306
	2) IF THE SUPPLY OUTPUT IS DISABLED	2) IF NOT: CR307, Q2 ON A2 ASSEMBLY
	3) WITH 0V PRESENT FROM J305-15 TO J305-2 THE VOLTAGE AT ANODE OF CR307 IS LESS THAN 0.2V	3) IF NOT: U304, Q306
	4) IF THE SUPPLY OUTPUT IS ENABLED	4) IF NOT: Q2, Q3 ON A2 ASSEMBLY

THE REMOTE VOLTAGE OR REMOTE CURRENT PROGRAMMING IS NOT FUNCTIONAL	1) WITH 10V APPLIED TO THE VOLTAGE PROGRAM INPUT (J305-17 & J305-5) OR TO THE CURRENT PROGRAM INPUT (J305-16 & J305-5) THE VOLTAGE AT CATHODE OF CR321 (VOLTAGE) OR CR322 (CURRENT) IS 9.5V +/- .2V	1) IF NOT: U305, F301
	2) VOLTAGE AT U307 PIN 1 (VOLTAGE PROGRAM) OR U307 PIN 3 (CURRENT PROGRAM) IS 9.5V +/- 0.2V	2) IF NOT: U307, S304, S305 OTHERWISE: U306, OR U1 ON A2 ASSEMBLY

4.4.3 Option M9 Troubleshooting Chart
(A4 Option Assembly - IEEE 488 Programming Card)

- Connect the A4 assembly in question to a power supply that is known to be operational to ensure that any problems are on the option board.
- Disconnect all unused equipment from the IEEE 488 bus and use a known good IEEE 488 cable securely seated to the rear connector.
- Check that all ICs, cables, and connectors are properly oriented and correctly seated.
- All parts and test points are on the A4 assembly unless otherwise noted.
- All voltages are referenced to control ground at U24 pin 14 in the analog section or to ground at C5 (-) in the digital section unless otherwise noted.
- Before beginning troubleshooting, check that the voltage at J1-5 is less than +/- 50mV. If this voltage is exceeded, replace U24. Also check for +5V across C5 to ensure power supply to the digital section. If this voltage is not correct, check U7 or ICs in the digital section which are abnormally warm to the touch and replace them as necessary.
- Parts are listed in the POSSIBLE DEFECTIVE COMPONENTS column in order of decreasing probability of failure.

SYMPTOM	CHECK	POSSIBLE DEFECTIVE COMPONENTS OR CAUSES
OVP IS ALWAYS TRIPPED (RED LED IS ON)	1) J4 CONNECTOR TO THE FRONT PANEL IS PROPERLY SEATED, OVP POT IS FULLY CLOCKWISE, AND POWER WAS CYCLED OFF/ON	1) J4 CONNECTOR, OVP POT
	2) VOLTAGE AT U29 PIN 8 IS LESS THAN 0.2V	2) IF NOT: U29 OTHERWISE: Q3, Q2
OVP WILL NOT TRIP	1) J4 CONNECTOR TO THE FRONT PANEL IS PROPERLY SEATED, OVP POT IS TURNED FULLY COUNTERCLOCKWISE, AND SUPPLY OUTPUT VOLTAGE IS SET AT GREATER THAN 3V	1) J4 CONNECTOR, OVP POT
	2) VOLTAGE AT U29 PIN 8 IS GREATER THAN 2V	2) IF NOT: U29, R115 ON A1 ASSEMBLY OTHERWISE: Q3, CR8, U14, CR6
SRQ LED IS OFF AFTER POWER-ON RESET	1) PGM (front), TALK AND LISTEN (rear) LEDs TURN ON MOMENTARILY DURING POWER-ON	1) DS128
	2) U4 PIN 11 HAS A FREQUENCY SIGNAL AT ABOUT 733kHz	2) IF NOT: Y1, C6, C7, C8, Q4, U4
NO RESPONSE TO A SERIAL POLL; WILL NOT LISTEN OR TALK	1) INCORRECT ADDRESS SET ON THE REAR PANEL ADDRESS SWITCHES	1) S8 TO S4 SETTINGS
	2) LISTEN AND TALK LEDs REMAIN OFF	2) U1, U5, U6, U2, U3, U4
UNIT WILL NOT GO INTO REMOTE MODE	1) S1 IS SET TO REMOTE	1) S1 SETTING
	2) U4 PIN 24 IS HIGH	2) IF NOT: Q1, U20, U25 OTHERWISE: U6, U5, U4

UNIT LISTENS BUT NO OUTPUT VOLTAGE OR CURRENT	1) COMMAND SYNTAX IS CORRECT	1) COMMAND SYNTAX ERROR
	2) CURRENT AND VOLTAGE LIMITS SET ABOVE ZERO	2) IF NOT: LIMIT SETTINGS
	3) CORRECT OUTPUT VOLTAGE IN VOLTAGE CONTROL MODE	3) IF NOT: R16, R14, U28, U23, U22, U16, U15, U27, U25, U8, U9
	4) CORRECT OUTPUT CURRENT IN CURRENT CONTROL MODE	4) IF NOT: R17, R15, U26, U21, U22, U16, U15, U27, U25, U8, U9
NO SERVICE REQUEST ON MODE TRANSITION OR OVP CONDITION	1) SRQ IS UNMASKED	1) UNMASK SRQ
DISABLE COMMAND "S" DOES NOT TURN OUTPUT OFF	1) U4 PIN 38 IS HIGH	1) IF NOT: U4 OTHERWISE: U15, U28, U26
NO VOLTAGE OR CURRENT READ-BACK	1) U10, U17 NOT MISSING	1) OPERATOR, PURCHASER
	2) SET FOR 50% OF VOLTAGE AND CURRENT. CHECK U10 PIN 2 AND U17 PIN 2 FOR ABOUT 2.3V	2) IF NOT: J2, J3, U24, R8, R9, R31, R32 OTHERWISE: U11, U18, U19, U10, U17

4.5 CALIBRATION

The HPD Series power supply is calibrated primarily with selected resistors which trim such critical parameters as the reference voltage and front panel display accuracy. These resistors are mounted in component lead sockets on 0.5" centers and are readily replaceable with the use of needle nose pliers. Some are 1% metal film resistors to ensure low temperature drift of the related parameter, and should not be replaced with standard 1/4W 5% resistors. These calibration resistors and other calibration components are listed by assembly in the following sections. Recalibration is not normally required unless entire assemblies are replaced when repairing the supply.

4.5.1 A1 Assembly Calibration Chart

CALIBRATION RESISTOR	PARAMETER AFFECTED
R103	Current bar graph full scale level
R104	Voltage bar graph full scale level
R130 or R133	Voltage and current display accuracy -adjusts both displays simultaneously

4.5.2 A2 Assembly Calibration Chart

CALIBRATION RESISTOR	PARAMETER AFFECTED
R3	Maximum output current - Set for 5% above rated output current.
R28	Current display accuracy
R24	Current display offset - Set for "0" reading with output current at zero
R16	+10 volt reference level - Set for most accurate voltage display.
C43	Switching frequency - Set for frequency of 200kHz +/- 5kHz at Q11 emitter referenced to P4-2 (Be sure to use an isolation transformer to power the supply when using grounded test equipment)

4.5.3 A4 Assembly Calibration

CALIBRATION COMPONENT	PARAMETER AFFECTED
R8 (V GAIN)	Voltage read-back full scale level - Iterative with R32.
R9 (I GAIN)	Current read-back full scale level - Iterative with R31.
R14 (V OFF)	Voltage programming offset - Adjust at 5% programmed output voltage for best linearity. Iterative with R16.
R15 (I OFF)	Current programming offset - Adjust at 5% programmed output current for best linearity. Iterative with R17.
R16 (V ADJ)	Voltage programming full scale level - Iterative with R14.
R17 (I ADJ)	Current programming full scale level - Iterative with R15.
R31 (I ZERO)	Current read-back offset - Adjust at 5% output current for best linearity. Iterative with R9.
R32 (V ZERO)	Voltage read-back offset - Adjust at 5% output voltage for best linearity. Iterative with R8.

SECTION 5

DRAWINGS AND PARTS LISTS

5.1 GENERAL

This section provides schematic drawings and parts lists for the following assemblies:

A1 - Front panel assembly
A2 - Power assembly
A3 - Option M5 assembly
A4 - Option M9 assembly
-- - Base plate Assembly, Cover, Power cord set

5.2 PARTS ORDERING

Parts may be ordered from the factory by the Sorensen part numbers listed in the following parts lists.
Order parts from:

SORENSEN COMPANY
5555 N. Elston Avenue
Chicago, IL
60630
(312) 775-0843

POWER SUPPLY INTERCONNECTION DIAGRAM

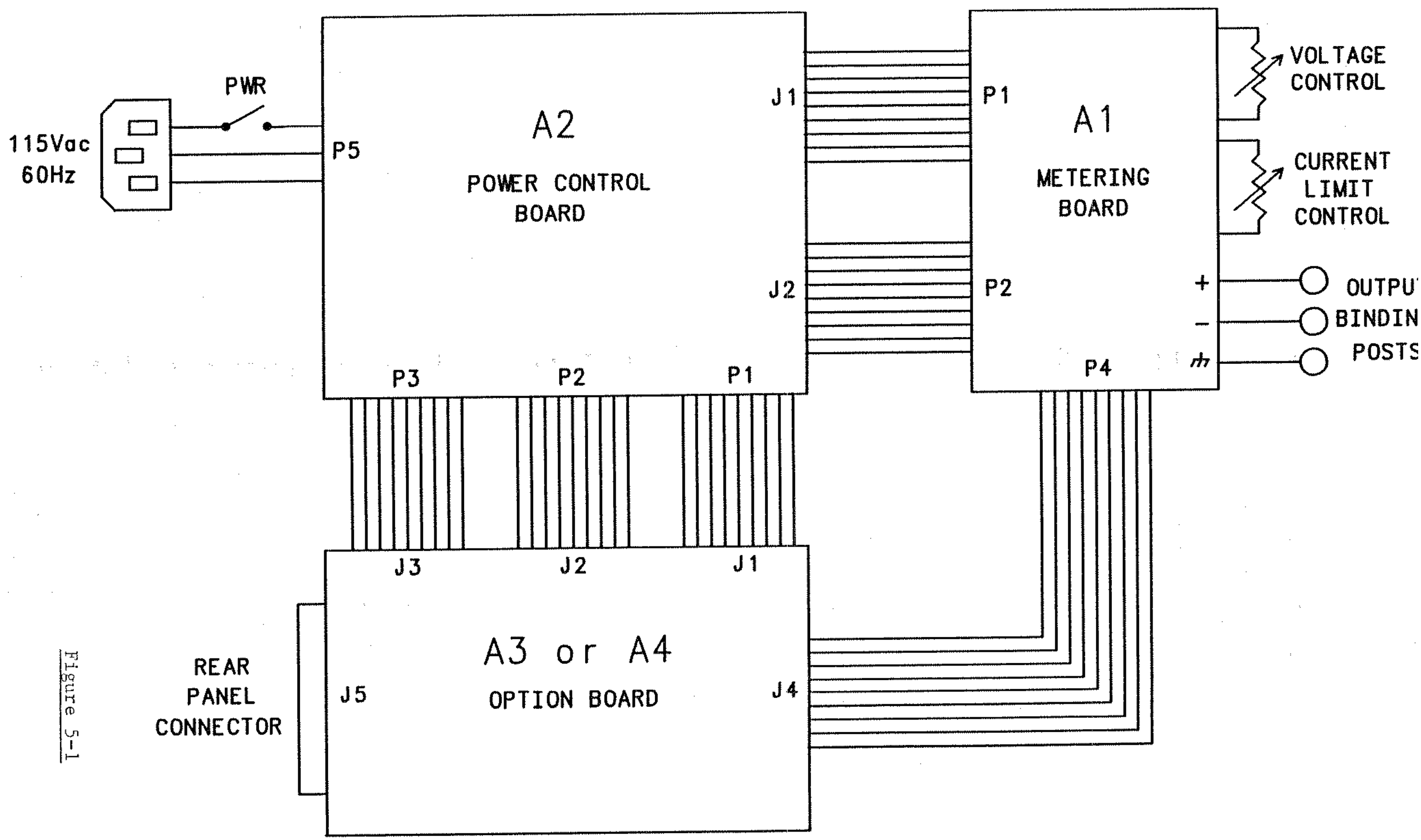
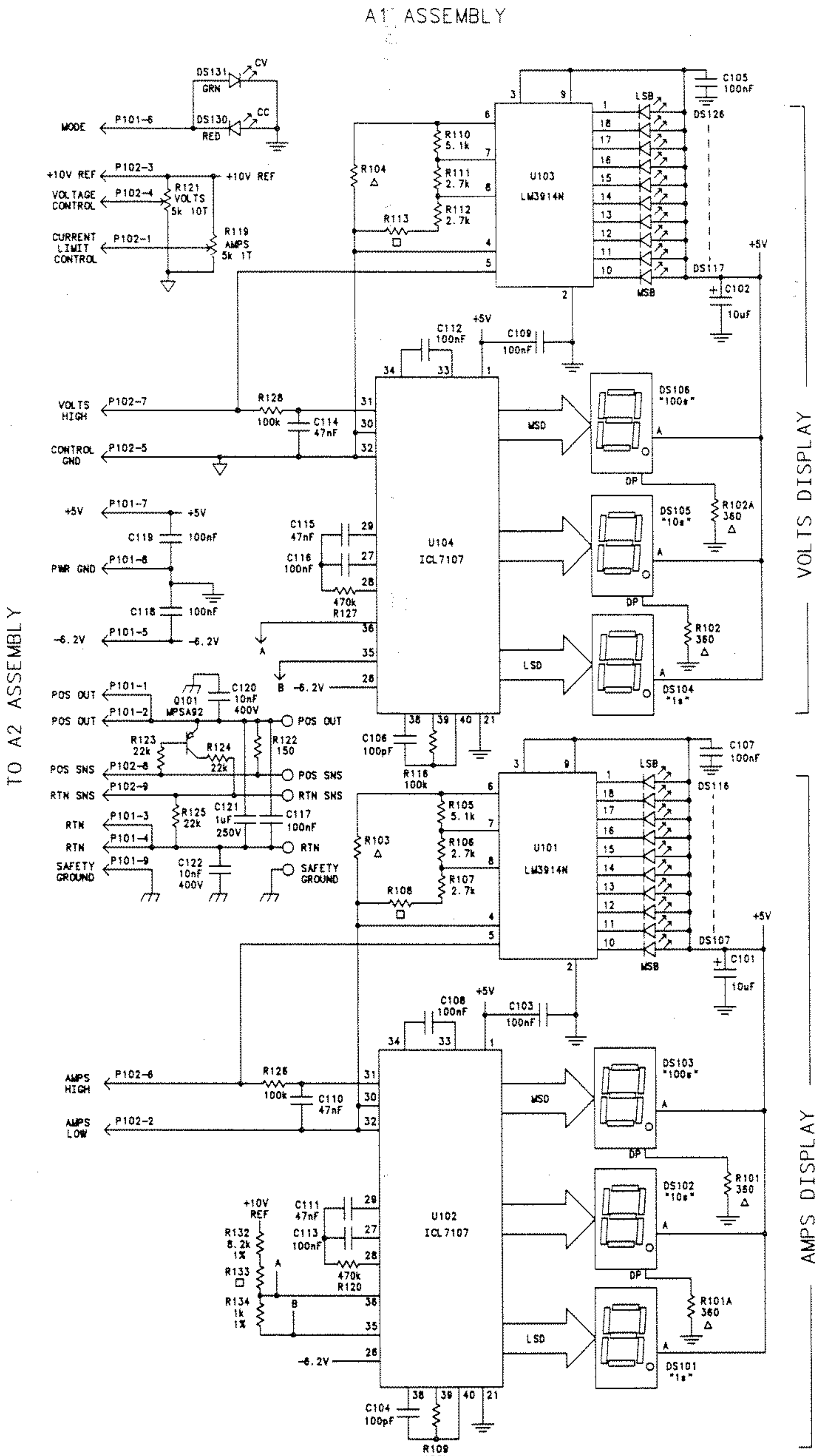


Figure 5-1



NOTE: ALL RESISTORS - 1/4W 5% EXCEPT AS NOTED
ALL CAPACITORS - uF/Vdc EXCEPT AS NOTED
△ - DENOTES MODEL DEPENDENT PART
□ - DENOTES SELECTED TRIM VALUE

Figure 5-2

5.3 A1 ASSEMBLY REPLACEMENT PARTS

Designation	Description	Part Number
C101,C102	10uF 25V EL RAD 2.5mm	1060677
C103,C105	0.1uF 50V CER RAD 2.5mm	1060736
C104,C106	100pF 100V CER RAD 2.5mm	1060825
C107-C109	0.1uF 50V CER RAD 2.5mm	1060736
C110,C111	47nF 50V CER RAD 2.5mm	1060826
C112	0.1uF 50V CER RAD 2.5mm	1060736
C113,C116	0.1uF 100V MET FILM 10mm	1060827
C114,C115	47nF 50V CER RAD 2.5mm	1060826
C117	0.1uF 100V MET FILM 10mm	1060827
C118,C119	0.1uF 50V CER RAD 2.5mm	1060736
C120,C122	10nF 400V MET FILM 10mm	1060828
C121	470nF 100V MET FILM 10mm	1060829
C123,C124	10nF 50V CER RAD 5mm	1060676
DS101-DS103	Green seven segment display	1060830
DS104-DS106	Green seven segment display	1060830
DS107-DS116	Green rectangular LED	1060831
DS117-DS126	Green rectangular LED	1060831
DS127	Red rectangular LED	1060832
DS128	Yellow rectangular LED	1060833
DS129,DS131	Green rectangular LED	1060834
DS130	Red rectangular LED	1060832
P101,P102,P104	9 Pin male connector	1060732
Q101	MPSA92 Transistor	1060835
R101 (60-5)	360 ohm 1/4W 5%	1060836
R101A (15-20,30-10)	360 ohm 1/4W 5%	1060836
R102	360 ohm 1/4W 5%	1060836
R103 (15-20)	390 ohm 1/4W 5%	1060837
R103 (30-10)	180 ohm 1/4W 5%	1060838
R103 (60-5)	1.1k 1/4W 5%	1060839
R104 (15-20)	270 ohm 1/4W 5%	1060956
R104 (30-10)	620 ohm 1/4W 5%	1060840
R104 (60-5)	1.5k 1/4W 5%	1060765
R105	5.1k 1/4W 5%	1060841
R106,R107	2.7k 1/4W 5%	1060842
R108	Selected value	-------
R109	100k 1/4W 5%	1060742
R110	5.1k 1/4W 5%	1060841
R111,R112	2.7k 1/4W 5%	1060842
R113	Selected value	-------
R114 (15-20)	16k 1/4W 5%	1060958
R114 (30-10)	7.5k 1/4W 5%	1060843
R114 (60-5)	36k 1/4W 5%	1060844
R115 (15-20,30-10)	100k 1 turn potentiometer	1060845
R115 (60-5)	1M ohm 1 turn potentiometer	1060846
R116	100k 1/4W 5%	1060742
R117	Selected value	-------

R118	Not used	-------	
R119	5k 1 turn potentiometer	1060847	R120 4
70k 1/4W 5%	1060779		
R121	5k 10 turn potentiometer	1060848	
R122	150 ohm 1/4W 5%	1060849	
R123-R125	22k 1/4W 5%	1060850	
R126,R128	100k 1/4W 5%	1060742	
R127	470k 1/4W 5%	1060851	
R129-R131	Not used (in parallel with R132-R134)	-------	
R132	8.25k 1/4W 1%	1060852	
R133	Selected value	-------	
R134	1k 1/4W 1%	1060745	
U101,U103	LM3914N IC	1060853	
U102,U104	ICL7107 IC	1060854	
	Molded plastic knob	1060855	
	Latex hose, 3/16" I.D.	1060856	
	Grey display filter	1060857	
	Molded plastic front panel	1060858	
	6-32x1/4" PPH self-tapping screw	1060859	
	A1 Printed circuit board	1060866	
	Component lead socket	1060885	
	40 Pin IC socket	1060868	
	Top label, no options	1060869	
	Top label, option M5(MODEL DEP.)	1060870	
	Top label, option M9(MODEL DEP.)	1060871	
	Bottom label, with switch	1060872	
	Bottom label, without switch	1060873	
	Model label, 15-20	1060874	
	Model label, 30-10	1060875	
	Model label, 60-5	1060876	

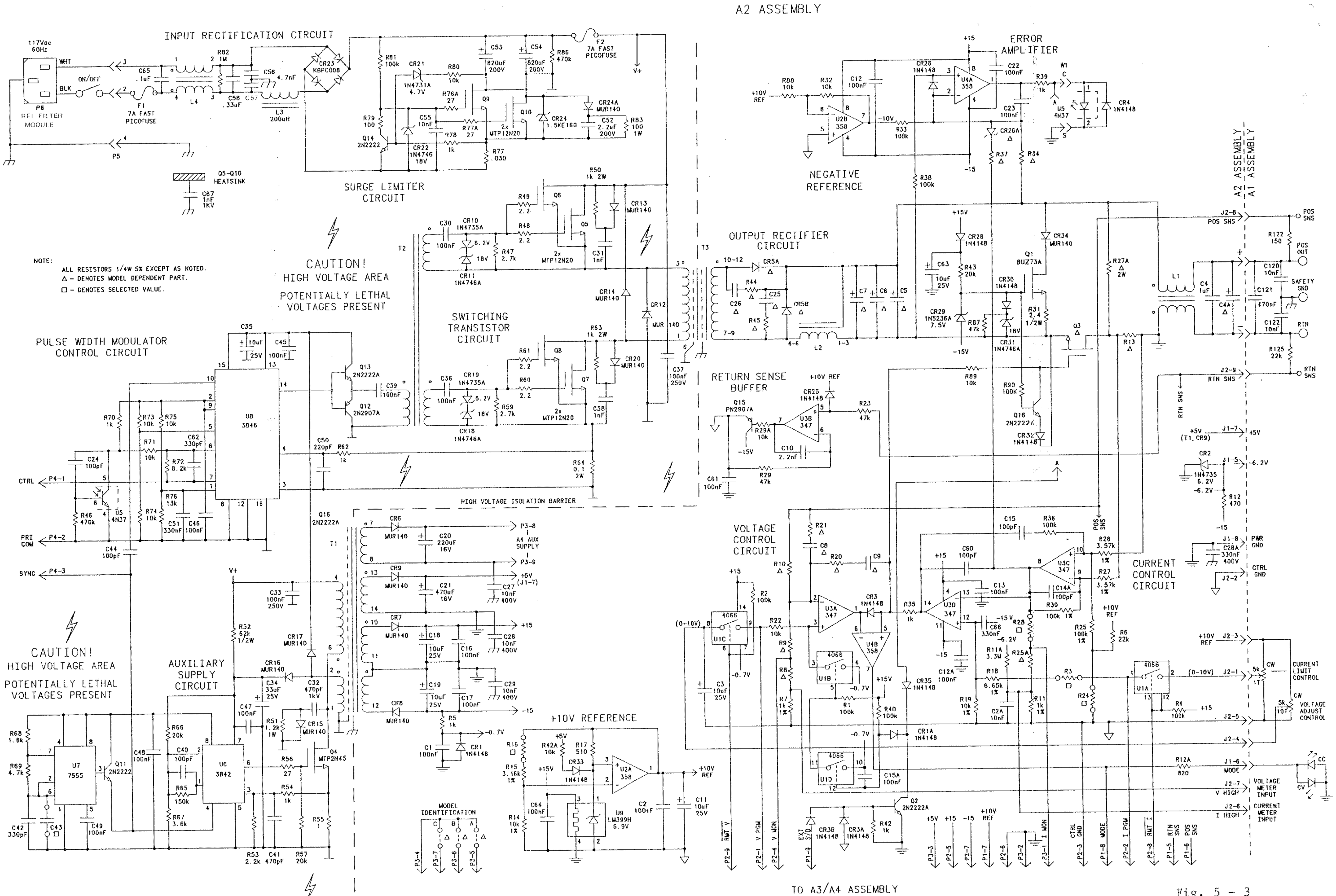

A2 ASSEMBLY
INPUT RECTIFICATION CIRCUIT
SURGE LIMITER CIRCUIT
ERROR AMPLIFIER
NEGATIVE REFERENCE
NOTE:
ALL RESISTORS 1/4W 5% EXCEPT AS NOTED.
Δ - DENOTES MODEL DEPENDENT PART.
□ - DENOTES SELECTED VALUE.
CAUTION! HIGH VOLTAGE AREA
POTENTIALLY LETHAL VOLTAGES PRESENT
OUTPUT RECTIFIER CIRCUIT
PULSE WIDTH MODULATOR CONTROL CIRCUIT
SWITCHING TRANSISTOR CIRCUIT
RETURN SENSE BUFFER
HIGH VOLTAGE ISOLATION BARRIER
VOLTAGE CONTROL CIRCUIT
CURRENT CONTROL CIRCUIT
AUXILIARY SUPPLY CIRCUIT
+10V REFERENCE
MODEL IDENTIFICATION
A2 ASSEMBLY
A1 ASSEMBLY
TO A3/A4 ASSEMBLY

Fig. 5 - 3

REV E

5.4 A2 ASSEMBLY REPLACEMENT PARTS

Designation	Description	Part Number
C1,C2	0.1uF 50V CER RAD 5mm	1060675
C2A	10nF 50V CER RAD 5mm	1060676
C3	10uF 25V EL RAD 2.5mm	1060677
C4	1uF 100V MET FILM 15mm	1060678
C4A (15-20)	220uF 25V EL RAD	1060679
C4A (30-10)	100uF 63V EL RAD	1060680
C4A (60-5)	47uF 100V EL RAD	1060681
C5-C7 (15-20)	1000uF 25V EL RAD 5mm	1060682
C5-C7 (30-10)	470uF 63V EL RAD 5mm	1060683
C5-C7 (60-5)	220uF 100V EL RAD 5mm	1060684
C8 (15-20)	2.2nF 100V CER RAD 5mm	1060685
C8 (30-10)	1nF 100V CER RAD 5mm	1060686
C8 (60-5)	1nF 100V CER RAD 5mm	1060686
C9	100pF 100V CER RAD 5mm	1060689
C10	2.2nF 50V CER RAD 5mm	1060685
C11	10uF 25V EL RAD 2.5mm	1060677
C12,C12A,C13	0.1uF 50V CER RAD 5mm	1060675
C14A	100pF 100V CER RAD 5mm	1060689
C15	100pF 100V CER RAD 5mm	1060689
C15A	0.1uF 50V CER RAD 5mm	1060675
C16,17	0.1uF 50V CER RAD 5mm	1060675
C18,C19	10uF 25V EL RAD 2.5mm	1060677
C20	220uF 16V EL RAD 5mm	1060697
C21	470uF 16V EL RAD	1060698
C22,C23	0.1uF 50V CER RAD 5mm	1060675
C24	330pF 100V CER RAD 5mm	1060699
C25,C26 (15-20)	1nF 100V CER RAD 5mm	1061161
C25,C26 (30-10)	2.2nF 100V CER RAD 5mm	1060685
C25,C26 (60-5)	470pF 250V CER RAD 5mm	1060700
C27-C29	10nF 400V MET FILM 10mm	1060701
C28A	330nF 400V FILM 22.5mm	1060702
C30	0.1uF 50V CER RAD 5mm	1060675
C31	1nF 250V CER RAD 5mm	1060700
C32	470pF 1kV CER RAD 5mm	1060703
C33	0.1uF 250V MET FILM 10mm	1060704
C34	33uF 25V EL RAD 2.5mm	1060696
C35	10uF 25V EL RAD 2.5mm	1060677
C36	0.1uF 50V CER RAD 5mm	1060675
C37	0.1uF 250V MET FILM 10mm	1060704
C38	1nF 250V CER RAD 5mm	1060700
C39	0.1uF 50V CER RAD 5mm	1060675
C40	100pF 100V CER RAD 5mm	1060689
C41	470pF 100V CER RAD 5mm	1060705
C42	330pF 100V CER RAD 5mm	1060699
C43	Selected value	-------
C44	100pF 100V CER RAD 5mm	1060689
C45-C49	0.1uF 50V CER RAD 5mm	1060675
C50	470pF 100V CER RAD 5mm	1060705
C51	0.33uF 50V CER RAD 5mm	1060706
C52	2.2uF 200V EL RAD	1060707

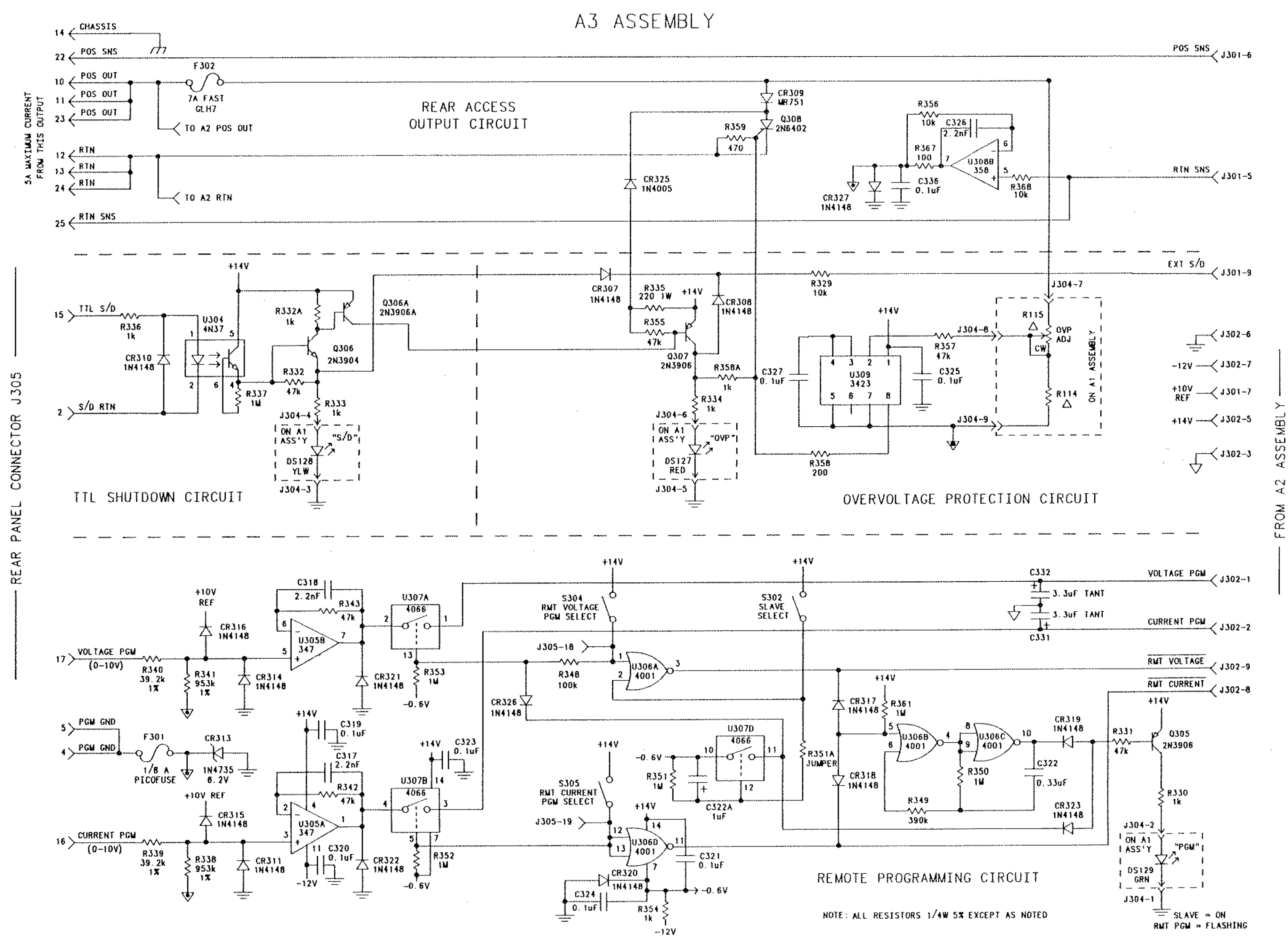
C53,C54	820uF 200V EL RAD	1060708
C55	10nF 50V CER RAD 5mm	1060676
C56,C57	4.7nF 250V MET FILM 15mm	1060709
C58	0.33uF 250Vac FILM RAD 20mm	
C59	47pF 100V CER RAD 5mm	1060710
C60	100pF 100V CER RAD 5mm	1060689
C61	0.1uF 50V CER RAD 5mm	1060675
C63	10uF 25V AL RAD 2.5mm	1060677
C64	0.1uF 50V CER RAD 5mm	1060675
C65	0.1uF 250Vac FILM 15mm	
C66 (60-5)	0.33uF 50V CER RAD 5mm	1060706
C67	1.0nF CER RAD 1KV	
CR1,CR1A	1N4148 Diode	1060711
CR2	1N4735A Zener diode	1060712
CR3,CR3A,CR3B,CR4	1N4148 Diode	1060711
CR5 (15-20)	FRM3220CC Dual rectifier	1060713
CR5 (30-10)	FRM3220CC Dual rectifier	1060713
CR5 (60-5)	MUR3040PT Dual rectifier	1060714
CR6-CR9	MUR140 Rectifier diode	1060715
CR10	1N4735A Zener diode	1060712
CR11	1N4746A Zener diode	1060716
CR12-CR17	MUR140 Rectifier diode	1060715
CR18	1N4746A Zener diode	1060716
CR19	1N4735A Zener diode	1060713
CR20	MUR140 Rectifier diode	1060715
CR21	1N4731A Zener diode	1060717
CR22	1N4746A Zener diode	1060716
CR23	KBPC804 8A Bridge rectifier	1060718
CR24	1.5KE160 Transient voltage suppressor 1060719	
CR24A	MUR140 Rectifier diode	1060715
CR25,CR26	1N4148 Diode	1060711
CR26A (60-5)	1N5240A Zener diode	1060720
CR27	Not used	-------
CR28	1N4148 Diode	1060711
CR29	1N5236A Zener diode	1060721
CR30,CR32,CR33	1N4148 Diode	1060711
CR31	1N4746A Zener diode	1060722
CR34	MUR140 Rectifier diode	1060715
CR35	1N4148 Diode	1060711
F1,F2	7A Picofuse	1060723
J1	3.5" MTA cable assembly	1060724
J2	4.5" MTA cable assembly	1060725
L1	0.5" X 0.25" Toroidal inductor	1060726
L2 (15-20)	21uH 20A Inductor	1060727
L2 (30-10)	85uH 10A Inductor	1060728
L2 (60-5)	342uH 5A Inductor	1060729
L3	213uH 6A Toroidal inductor	1060730
L4	Input common mode inductor	1060731
P1,P2,P3	9 pin Header	1060732

P4	Not used	-------
P5	4 pin MATE-N-LOK connector	1060733
Q1	RFP2N18 Transistor	1060734
Q2	2N2222A Transistor	1060735
Q3 (15-20)	MTM50N05 Transistor	1060736
Q3 (30-10)	MTM25N10 Transistor	1060737
Q3 (60-5)	MTM15N20 Transistor	1060738
Q4	MTP2N45 Transistor	1060739
Q5-Q10	RFP12N20 Transistor	1060740
Q11	2N2222A Transistor	1060735
Q12	2N2907A Transistor	1060741
Q13,Q14,Q16	2N2222A Transistor	1060735
Q15	2N2907A Transistor	1060741
R1,R2,R4	100k 1/4W 5%	1060742
R3	Selected value	-------
R5	1k 1/4W 5%	1060743
R6	20k 1/4W 5%	1060744
R7	1k 1/4W 1%	1060745
R8 (15-20)	32.4k 1/4W 1%	1060746
R8 (30-10)	15.8k 1/4W 1%	1060747
R8 (60-5)	7.32k 1/4W 1%	1060748
R9 (15-20)	30.1k 1/4W 1%	1060749
R9 (30-10)	15.0k 1/4W 1%	1060750
R9 (60-5)	7.50k 1/4W 1%	1060751
R10 (15-10)	36.5k 1/4W 1%	1060752
R10 (30-10)	68.1k 1/4W 1%	1060753
R10 (60-5)	84.5k 1/4W 1%	1060754
R11	1k 1/4W 1%	1060745
R11A	3.3M 1/4W 5%	1060755
R12	510 ohm 1/4W 5%	1060756
R12A	820 ohm 1/4W 5%	1060757
R13 (15-20)	4pcs 1.8" #20 Manganin wire	1060758
R13 (30-10)	2pcs 1.8" #20 Manganin wire	1060758
R13 (60-5)	1 pc 1.8" #20 Manganin wire	1060758
R14	10k 1/4W 1%	1060759
R15	3.16k 1/4W 1%	1060760
R16	Selected Value	-------
R17	510 ohm 1/4W 5%	1060756
R18	6.65k 1/4W 1%	1060761
R19	10k 1/4W 1%	1060759
R20	10k 1/4W 5%	1060767
R21 (15-20)	4.3k 1/4W 5%	1060764
R21 (30-10)	1.5k 1/4W 5%	1060765
R21 (60-5)	1.3k 1/4W 5%	1060766
R22	10k 1/4W 5%	1060767
R23	47k 1/4W 5%	1060768
R24	Selected value	-------
R25	100k 1/4W 1%	1060769
R25A (15-20)	24.3k 1/4W 1%	1060770
R25A (30-10)	49.9k 1/4W 1%	1060771
R25A (60-5)	9.09k 1/4W 1%	1060772
R26,R27	3.57k 1/4W 1%	1060773

R27A (15-20)	270 ohm 2W 5%	1060774
R27A (30-10)	1k 2W 5%	1060775
R27A (60-5)	3.9k 2W 5%	1060776
R28	Selected Value	-------
R29	47k 1/4W 5%	1060768
R29A	10k 1/4W 5%	1060767
R30	100k 1/4W 1%	1060769
R31	2.7 ohm 1/2W 5%	1060777
R32	10k 1/4W 5%	1060767
R33	100k 1/4W 5%	1060742
R34,R35	1k 1/4W 5%	1060743
R36,R38	100k 1/4W 5%	1060742
R37 (15-20)	75k 1/4W 5%	1060763
R37 (30-10)	120k 1/4W 5%	1060743
R37 (60-5)	47k 1/4W 5%	1060768
R39	1k 1/4W 5%	1060743
R40	100k 1/4W 5%	1060742
R41,R43	10k 1/4W 5%	1060767
R42	1k 1/4W 5%	1060743
R42A	10k 1/4W 5%	1060767
R44,R45 (15-20)	3pcs 10 ohm 1/2W 5%	1060777
R44,R45 (30-10)	3pcs 33 ohm 3W 5%	1060778
R44,R45 (60-5)	4pcs 330 ohm 3W 5%	1060955
R46	470k 1/4W 5%	1060779
R47	2.2k 1/4W 5%	1060780
R48,R49	2.2 ohm 1/4W 5%	1060781
R50	1k 2W 5%	1060775
R51	1.2k 1W 5%	1060782
R52	62k 1/2W 5%	1060783
R53	2.2k 1/4W 5%	1060780
R54	1k 1/4W 5%	1060743
R55	1 ohm 1/4W 5%	1060784
R56	27 ohm 1/4W 5%	1060785
R57	20k 1/4W 5%	1060744
R58	Not Used	-------
R59	2.2k 1/4W 5%	1060780
R60,R61	2.2 ohm 1/4W 5%	1060781
R62	1k 1/4W 5%	1060743
R63	1k 2W 5%	1060775
R64	0.1 ohm 2W 5%	1060786
R65	150k 1/4W 5%	1060787
R66	20k 1/4W 5%	1060744
R67	3.6k 1/4W 5%	1060788
R68	1.6k 1/4W 5%	1060789
R69	4.7k 1/4W 5%	1060790
R70	1k 1/4W 5%	1060743
R71	10k 1/4W 5%	1060767
R72	8.2k 1/4W 5%	1060791
R73-R75	10k 1/4W 5%	1060767
R76	20k 1/4W 5%	1060744
R76A,R77A	27 ohm 1/4W 5%	1060785
R77	1.20" #20 Manganin wire	1060758
R78	1k 1/4W 5%	1060743
R79	100 ohm 1/4W 5%	1060793

R80	10k 1/4W 5%	1060767
R81	100k 1/4W 5%	1060742
R82	1M 1/4W 5%	1060794
R83	100 ohms 1W 5%	1060795
R84,R85	Not used	-------
R86	470k 1/4W 5%	1060851
R87	47k 1/4W 5%	1060768
R88,R89	10k 1/4W 5%	1060743
R90	470k 1/4W 5%	1060851
T1	200kHz 20VA Transformer	1060796
T2	100kHz Pulse transformer	1060797
T3 (15-20)	100kHz 340VA Transformer	1060798
T3 (30-10)	100kHz 320VA Transformer	1060799
T3 (60-5)	100kHz 310VA Transformer	1060851
U1	4066 CMOS quad analog gate IC	1060852
U2,U4	LM358N Dual op amp IC	1060854
U3	LF347N Quad op amp IC	1060853
U5	4N37 Opto-coupler IC	1060855
U6	3842 PWM IC	1060856
U7	7555 CMOS timer IC	1060857
U8	3846 PWM IC	1060858
U9	LM399H 6.9V Reference IC	1060859
W1	RG174U Coaxial cable, 5"	1060860
	A2 assembly printed circuit board	1060861
	#4 Internal lock washer	1060862
	#4 Nylon shoulder washer	1060863
	4-40x5/16" PPH machine screw	1060864
	4-40x1/4" KEP nut	1060865
	#6 Internal lock washer	1060866
	#6x3/8" Flat washer	1060867
	#6x3/8" PPH self-tapping screw	1060868
	#6x5/8" PPH self-tapping screw	1060869
	6-32x5/16" PPH machine screw	1060870
	6-32x3/8" PPH machine screw	1060871
	6-32x1/2" PPH machine screw	1060872
	6-32x1/4" KEP nut	1060873
	#14 Red TEW Wire	1060874
	#14 Black TEW Wire	1060875
	#14 AWG Tinned bus wire (L1)	1060876
	#18 Teflon sleeving (R77)	1060877
	1/4" Fast-on connector, male PC	1060878
	1/4" Fast-on connector, female	1060878
	1/4" Diameter heatshrink	1060879
	1/2" Right angle bracket	1060880
	Nylon grommet, heatsink mounting	1060881
	Extruded heatsink	1060882
	Bridge rectifier heatsink plate	1060883
	TO-220 Transistor heatsink	1060884
	Component lead socket	1060885
	TO-3 Insulating washer	1060886

TO-3 Transistor socket	1060887
TO-218 Insulating washer	1060888
TO-220 Insulating washer	1060889
8 pin IC Socket	1060890
14 pin IC Socket	1060891
16 pin IC Socket	1060892
10 mil x 1.73" Nomex insulation	1060893


A3 ASSEMBLY
REAR PANEL CONNECTOR J305
FROM A2 ASSEMBLY
5A MAXIMUM CURRENT FROM THIS OUTPUT
14 CHASSIS
22 POS SNS
10 POS OUT
11 POS OUT
23 POS OUT
12 RTN
13 RTN
24 RTN
25 RTN SNS
F302 7A FAST GLH7
TO A2 POS OUT
TO A2 RTN
REAR ACCESS OUTPUT CIRCUIT
CR309 MR751
Q308 2N6402
R359 470
CR325 1N4005
R356 10k
C326 2.2nF
R367 100
U308B 358
R368 10k
C336 0.1uF
CR327 1N4148
POS SNS J301-6
RTN SNS J301-5
EXT S/D J301-9
15 TTL S/D
R336 1k
CR310 1N4148
U304 4N37
2 S/D RTN
+14V
R332A 1k
Q306 2N3904
Q306A 2N3906A
R332 47k
R337 1M
R333 1k
J304-4
ON A1 ASS'Y
"S/D"
DS128 YLW
J304-3
TTL SHUTDOWN CIRCUIT
CR307 1N4148
R335 220 1W
R355 47k
Q307 2N3906
CR308 1N4148
R329 10k
R358A 1k
R334 1k
J304-6
"OVP"
DS127 RED
J304-5
C327 0.1uF
U309 3423
C325 0.1uF
R357 47k
J304-8
J304-7
R115
OVP ADJ
CW
R114
ON A1 ASSEMBLY
J304-9
R358 200
OVERVOLTAGE PROTECTION CIRCUIT
J302-6
-12V J302-7
+10V REF J301-7
+14V J302-5
J302-3
17 VOLTAGE PGM (0-10V)
R340 39.2k 1%
R341 953k 1%
+10V REF
CR316 1N4148
CR314 1N4148
C318 2.2nF
R343 47k
U305B 347
CR321 1N4148
U307A 4066
R353 1M
-0.6V
S304 RMT VOLTAGE PGM SELECT
J305-18
R348 100k
CR326 1N4148
U306A 4001
S302 SLAVE SELECT
C332 3.3uF TANT
C331 3.3uF TANT
VOLTAGE PGM J302-1
CURRENT PGM J302-2
RMT VOLTAGE J302-9
RMT CURRENT J302-8
5 PGM GND
4 PGM GND
F301 1/8 A PICOFUSE
CR313 1N4735 6.2V
C319 0.1uF
C317 2.2nF
R342 47k
U305A 347
C320 0.1uF
-12V
16 CURRENT PGM (0-10V)
R339 39.2k 1%
R338 953k 1%
CR315 1N4148
CR311 1N4148
CR322 1N4148
U307B 4066
C323 0.1uF
R352 1M
S305 RMT CURRENT PGM SELECT
J305-19
U306D 4001
C321 0.1uF
CR320 1N4148
C324 0.1uF
R354 1k
R351 1M
C322A 1uF
U307D 4066
R351A JUMPER
CR317 1N4148
R361 1M
CR318 1N4148
U306B 4001
U306C 4001
R350 1M
R349 390k
C322 0.33uF
CR319 1N4148
CR323 1N4148
R331 47k
Q305 2N3906
R330 1k
J304-2
"PGM"
DS129 GRN
J304-1
SLAVE = ON
RMT PGM = FLASHING
REMOTE PROGRAMMING CIRCUIT
NOTE: ALL RESISTORS 1/4W 5% EXCEPT AS NOTED

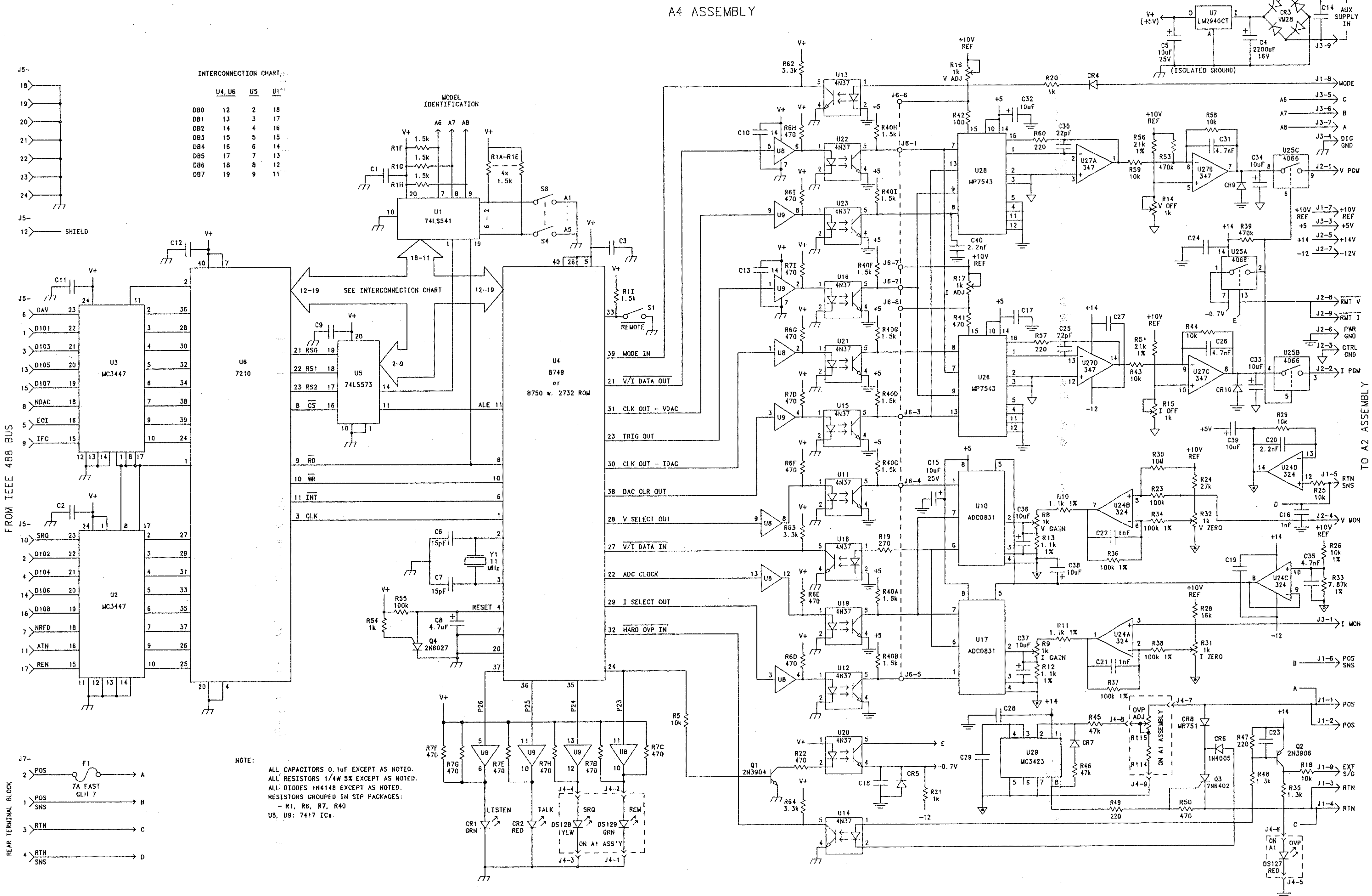

A4 ASSEMBLY
FROM IEEE 488 BUS
TO A2 ASSEMBLY
REAR TERMINAL BLOCK
INTERCONNECTION CHART
MODEL IDENTIFICATION
SEE INTERCONNECTION CHART
NOTE:
ALL CAPACITORS 0.1uF EXCEPT AS NOTED.
ALL RESISTORS 1/4W 5% EXCEPT AS NOTED.
ALL DIODES 1N4148 EXCEPT AS NOTED.
RESISTORS GROUPED IN SIP PACKAGES:
- R1, R6, R7, R40
U8, U9: 7417 ICs.

Fig. 5 - 5

5.5 A3 ASSEMBLY REPLACEMENT PARTS

Designation	Description	Part Number
C308	Not used	-------
C314	10uF 25V EL RAD 2.5mm	1060677
C317,C318	2.2nF 100V CER RAD 5mm	1060685
C319-C321	0.1uF 50V CER RAD 5mm	1060675
C322	0.33uF 50V CER RAD 5mm	1060706
C323-C325	0.1uF 50V CER RAD 5mm	1060675
C326	2.2nF 100V CER RAD 5mm	1060685
C327	0.1uF 50V CER RAD 5mm	1060675
C331,C332	3.3uF 25V TANT RAD 5mm	1060900
C333,C334,C335	Not used	-------
C336	1uF 35V TANT RAD 5mm	1060895
CR303	Not used	-------
CR307-CR309	1N4148 Diode	1060711
CR309	MR751 Rectifier diode	1060901
CR310,CR311	1N4148 Diode	1060711
CR312	Not used	-------
CR313	1N4735A Zener diode	1060902
CR314-CR324	1N4148 Diode	1060711
CR325	1N4005 Rectifier diode	1060903
CR326,CR327	1N4148 Diode	1060711
F301	1/8A Picofuse	1060905
F302	GLH 7 fuse	1060906
J301,J302,J304	3.5" MTA cable assembly	1060723
J305	25 Pin female D-Sub. connector	1060907
Q305,Q307	2N3906 Transistor	1060910
Q306	2N3904 Transistor	1060909
Q308	2N6402 SCR	1060911
R317	Not used	-------
R329	10k 1/4W 5%	1060767
R330	1k 1/4W 5%	1060743
R331,R332	47k 1/4W 5%	1060768
R333,R334	1k 1/4W 5%	1060743
R335	220 ohm 1W 5%	1060917
R336	1k 1/4W 5%	1060743
R337	1M 1/4W 5%	1060794
R338,R341	953k 1/4W 1%	1060918
R339,R340	39.2k 1/4W 1%	1060919
R342,R343	47k 1/4W 5%	1060768
R348	100k 1/4W 5%	1060742
R349	390k 1/4W 5%	1060916
R350-R353	1M 1/4W 5%	1060794
R354	1k 1/4W 5%	1060743
R355,R357	47k 1/4W 5%	1060768
R356	10k 1/4W 5%	1060767
R358	200 ohm 1/4W 5%	1060920

R358A	1k 1/4W 5%	1060743
R359	470 ohm 1/4W 5%	1060921
R360	Jumper wire	1060922
R361	1M 1/4W 5%	1060794
R365	Not used	-------
R367	100 ohm 1/4W 5%	1060793
R368	10k 1/4W 5%	1060767
S301-S308	8PST Piano DIP switch	1060923
U304	4N37 IC	1060855
U305	LF347N IC	1060853
U306	4001B IC	1060926
U307	4066B IC	1060929
U308	LM358N IC	1060927
U309	MC3423P IC	1060928
	A3 Printed circuit board	1060930
	Component lead socket	1060885
	14 pin IC socket	1060891
	8 pin IC socket	1060890
	Fuse clip	1060931
	#6x3/8" PPH self-tapping screw	1060868
	4-40x5/16" PPH machine screw	1060864
	4-40x1/4" KEP nut	1060865
	Female screw lock assembly kit	1060932
	A3 assembly sub-plate	1060933
	Magnetic shield	1060934
	Nylon grommet	1060881
	6-32x5/16" PPH machine screw	1060870
	25 Pin male D-Sub. connector	1060935

5.6 A4 ASSEMBLY REPLACEMENT PARTS

Designation	Description	Part Number
C1-C3	0.1uF 50V CER RAD 2.5mm	1060936
C4	2200uF 16V EL AXIAL 12.5x30mm	1060937
C5	10uF 25V EL RAD 2.5mm	1060677
C6,C7	15pF 100V CER RAD 5mm	1060938
C8	4.7uF 25V EL RAD 2.5mm	1060939
C9-C14	0.1uF 50V CER RAD 2.5mm	1060936
C15	10uF 25uF TANT RAD 2.5mm	1060677
C16	1nF 100V CER RAD 5mm	1060940
C17-C19	0.1uF 50V CER RAD 2.5mm	1060936
C20	2.2nF 100V CER RAD 5mm	1060685
C21,C22	1nF 100V CER RAD 5mm	1060961
C23,C24	0.1uF 50V CER RAD 5mm	1060936
C25	22pF 100V CER RAD 5mm	1060941
C26	4.7nF 100V CER RAD 5mm	1060942
C27-C29	0.1uF 50V CER RAD 2.5mm	1060936
C30	22pF 100V CER RAD 5mm	1060941
C31	4.7nF 100V CER RAD 5mm	1060942
C32,C33,C34	10uF 25V EL RAD 2.5mm	1060677
C35	4.7nF 100V CER RAD 5mm	1060942
C36-C39	10uF 25V TANT RAD 5mm	1060943
C40	2.2nF 100V CER RAD 5mm	1060685
CR1	Green T-1 3/4 LED	1060944
CR2	Red T-1 3/4 LED	1060945
CR3	VM28 Bridge rectifier	1060946
CR4,CR5	1N4148 Diode	1060711
CR6	1N4005 Rectifier diode	1060903
CR7,CR9-CR10	1N4148 Diode	1060711
CR8	MR751 Rectifier diode	1060901
F1	GLH 7 Fuse, 7 Amp fast blow	1060906
J1-J4	3.5" MTA cable assembly	1060724
J5	IEEE 488 Connector	1060947
J6	9 Pin male connector	1060732
J7	4 Position barrier strip	1060948
Q1	2N3904 Transistor	1060909
Q2	2N3906 Transistor	1060910
Q3	2N6402 SCR	1060911
Q4	2N6027 Programmable UJT	1060949
R1	1.5k x 9 SIP	1060950
R2-4	Not used	-------
R5	10k 1/4W 5%	1060767
R6,R7	470 ohm x 9 SIP	1060951
R8,R9	1k potentiometer, multi-turn	1060953
R10-R13	1.1k 1/4W 1%	1060954
R14-R17	1k potentiometer, multi-turn	1060953
R18	10k 1/4W 5%	1060767

R19	270 ohm 1/4W 5%	1060956
R20,R21	1k 1/4W 5%	1060743
R22	470 ohm 1/4W 5%	1060921
R23	100k 1/4W 5%	1060742
R24	27k 1/4W 5%	1060957
R25	10k 1/4W 5%	1060767
R26	10k 1/4W 1%	1060759
R27	Not used	-------
R28	16k 1/4W 5%	1060958
R29	10k 1/4W 5%	1060767
R30	10M 1/4W 5%	1060959
R31,R32	1k potentiometer, multi-turn	1060953
R33	7.87k 1/4W 1%	1060960
R34,R36-R38	100k 1/4W 1%	1060769
R35	1.3k 1/4W 5%	1060766
R39	470k 1/4W 5%	1060779
R40	1.5k x 9 SIP	1060950
R41	470 ohm 1/4W 5%	1060921
R42	100 ohm 1/4W 5%	1060793
R43,R44	10k 1/4W 5%	1060767
R45,R46	47k 1/4W 5%	1060768
R47,R49	220 ohm 1/4W 5%	1060961
R48	1.3k 1/4W 5%	1060766
R50	470 ohm 1/4W 5%	1060921
R51	21k 1/4W 1%	1060962
R52	Not used	-------
R53	470k 1/4W 5%	1060779
R54	1k 1/4W 5%	1060743
R55	100k 1/4W 5%	1060742
R56	21k 1/4W 1%	1060962
R57	220 ohm 1/4W 5%	1060961
R58,R59	10k 1/4W 5%	1060767
R60	220 ohm 1/4W 5%	1060961
R62-R64	3.3k 1/4W 5%	1060952
S1	8 Pos. piano DIP switch	1060923
U1	74LS541 IC	1060963
U2,U3	MC3447 IC	1060964
U4	8750 IC	1060966
U4 Piggy back	2732 IC	1060967
U5	74LS573 IC	1060968
U6	7210 IC	1060969
U7	LM2940CT IC	1060970
U8,U9	7417 IC	1060971
U10	ADC0831 IC	1060972
U11-U16	4N37 IC	1060855
U17	ADC0831 IC	1060972
U18-U23	4N37 IC	1060855
U24	LM324 IC	1060973
U25	4066B IC	1060929
U26,U28	MP7543 IC	1060974
U27	LF347 IC	1060853
U29	MC3423 IC	1060928

Y1	11MHz Crystal	1060975
	#6x3/8" Type A screw	1060868
	6-32x1/4" PPH machine screw	1060976
	6-32x1/4" KEP nut	1060873
	IEEE 488 connector hardware kit	1060977
	Fuse clip	1060931
	Barrier strip retaining clip	1060979
	TO-220 Heatsink	1060980
	A4 assembly sub-plate	1060981
	A4 printed circuit board	1060982
	6 Pin IC socket	1060983
	8 Pin IC socket	1060890
	14 Pin IC socket	1060891
	16 Pin IC socket	1060892
	20 Pin IC socket	1060984
	24 Pin IC socket	1060985
	40 Pin IC socket	1060986
	LED right angle mount	1060987
	1/4" Fast-on terminal, female	1060878
	#22 AWG Red wire	1060988
	#22 AWG Black wire	1060989
	#18 AWG Red TEW wire	1060990
	#18 AWG Black TEW wire	1060991
	Cable tie, 4"	1060992

5.7 BASE PLATE AND COVER ASSEMBLY REPLACEMENT PARTS

Description	Part Number
Cover, single	1060993
Power cord	1061000
Base plate, single	1061001
Power receptacle / RFI filter	1061003
4 Pin connector housing	1061005
Connector socket pin	1061006
4 Terminal barrier strip	1060979
Power switch	1061007
Power switch rod	1061008
Power switch bracket	1061009
4-40x1/4" PPH self-tapping screw	1061010
4-40x1/4" PFH machine screw	1061011
4-40x1/4" KEP nut	1060865
6-32x1/4" PPH machine screw	1060976
6-32x1/4" KEP nut	1060873
#6x 3/8" Flat washer	1060867
#8 Ring tongue	1061012
#8x1/2" PFH self-tapping screw	1061013
#18 Black TEW wire	1060991
#18 Green TEW wire	1061014

#18 White TEW Wire	1061015
#18 Orange TEW Wire	1061016
Cable tie, 4"	1061018
Rubber foot	1061019
Rear sub-plate, no options	1061022
Serial No. Label	1061023
Caution Label	1061024