Errata

Title & Document Type: **6038A/L System DC Power Supply Operating and Service Manual**

Manual Part Number: **06038-90001**

Revision Date: **November 1964**

About this Manual

We've added this manual to the Agilent website in an effort to help you support your product. This manual provides the best information we could find. It may be incomplete or contain dated information, and the scan quality may not be ideal. If we find a better copy in the future, we will add it to the Agilent website.

HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, life sciences, and chemical analysis businesses are now part of Agilent Technologies. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A. We have made no changes to this manual copy.

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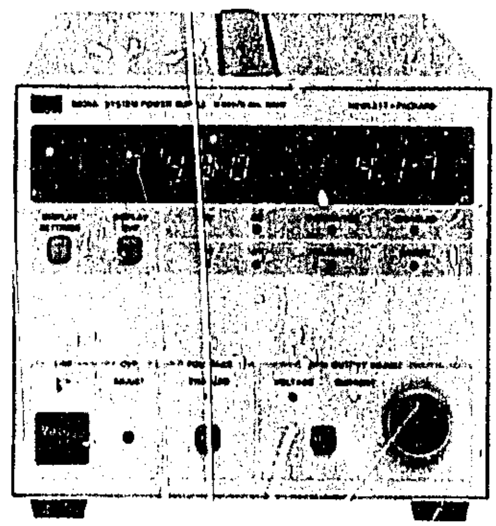
Search for the model number of this product, and the resulting product page will guide you to any available information. Our service centers may be able to perform calibration if no repair parts are needed, but no other support from Agilent is available.

Agilent Technologies

HP 6038A

OPERATING AND SERVICE MANUAL

HP 6038A/6038L
SYSTEM DC POWER SUPPLY



HEWLETT PACKARD

HP 6038A/L

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CERTIFICATION

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the Bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.

WARRANTY

This Hewlett-Packard instrument product is warranted against defects in material and workmanship for a period of one year from date of shipment. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by HP. Buyer shall prepay shipping charges to HP and HP shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to HP from another country.

HP warrants that its software and firmware designated by HP for use with an instrument will execute its programming instructions when properly installed on that instrument. HP does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

LIMITATION OF WARRANTY

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HP SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

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THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES. HP SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

ASSISTANCE

Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard products.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

HEWLETT PACKARD

AUTORANGING
SYSTEM DC POWER SUPPLY
HP MODEL 6038A/6038L*

OPERATING AND SERVICE MANUAL FOR
HP 6038A WITH SERIAL NUMBERS
2451A-00101 AND ABOVE
AND
HP 6038L WITH SERIAL NUMBERS
2446-00101 AND ABOVE

For instruments with higher Serial Numbers
a change page may be included.

*Reference Appendix C for 6038L documentation.

HP Part No. 06038-90001
Microfiche Part No. 06038-90002

Printed: November, 1984

SAFETY SUMMARY

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements.

BEFORE APPLYING POWER.

Verify that the product is set to match the available line voltage and the correct fuse is installed.

GROUND THE INSTRUMENT.

This product is a Safety Class 1 instrument (provided with a protective earth terminal). To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument must be connected to the ac power supply mains through a three-conductor power cable, with the third wire firmly connected to an electrical ground (safety ground) at the power outlet. For instruments designed to be hard-wired to the ac power lines (supply mains), connect the protective earth terminal to a protective conductor before any other connection is made. Any interruption of the protective (grounding) conductor or disconnection of the protective earth terminal will cause a potential shock hazard that could result in personal injury. If the instrument is to be energized via an external autotransformer for voltage reduction, be certain that the autotransformer common terminal is connected to the neutral (earthed pole) of the ac power lines (supply mains).

INPUT POWER MUST BE SWITCH CONNECTED.

For instruments without a built-in line switch, the input power lines must contain a switch or another adequate means for disconnecting the instrument from the ac power lines (supply mains).

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE.

Do not operate the instrument in the presence of flammable gases or fumes.

KEEP AWAY FROM LIVE CIRCUITS.

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified service personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power, discharge circuits and remove external voltage sources before touching components.

DO NOT SERVICE OR ADJUST ALONE.

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT EXCEED INPUT RATINGS.

This instrument may be equipped with a line filter to reduce electromagnetic interference and must be connected to a properly grounded receptacle to minimize electric shock hazard. Operation at line voltages or frequencies in excess of those stated on the data plate may cause leakage currents in excess of 5.0 mA peak.

SAFETY SYMBOLS.

⚠ Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual (refer to Table of Contents).

ϟ Indicates hazardous voltages.

⏚ or ⊥ Indicate earth (ground) terminal.

WARNING The WARNING sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.

CAUTION The CAUTION sign denotes a hazard. It calls attention to an operating procedure, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product. Do not proceed beyond a CAUTION sign until the indicated conditions are fully understood and met.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT.

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Hewlett-Packard Sales and Service Office for service and repair to ensure that safety features are maintained.

Instruments which appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.

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HP 6038L

Section 1
GENERAL INFORMATION

1-1 INTRODUCTION

1-2 This operating and service manual contains a description of the HP Model 6038A System Power Supply, including specifications, installation and operating instructions, theory of operation, maintenance procedures and schematics. Programming Note, part number 5952-4119, provides programming instructions and examples for the Hewlett-Packard series 200 computers (9816, 9920, 9826, 9836/ 9836C). Description and information pertaining to HP 6038L is referenced in Appendix C.

1-3 DESCRIPTION

1-4 The HP 6038A is a 200 W autoranging HP-IB power supply with maximum ratings of 60 V and 10 A. It uses power MOSFETs in a 20 kHz switching converter to provide an autoranging output characteristic with laboratory performance. Output voltage and current are continuously indicated on individual meters. LED indicators show the complete operating state of the unit. Front-panel controls allow the user to set output voltage, current and overvoltage protection trip level. Overvoltage protection (OVP) protects the user's load by quickly and automatically interrupting energy transfer if a preset trip voltage is exceeded. Foldback protection can be selected to disable the power supply output if the unit switches from Constant Voltage (CV) to Constant Current (CC) mode or vice-versa.

1-5 The HP 6038A can be programmed directly to output volts and amps. The HP Power Supply can be both a listener and talker on the HP-IB and status can be read back to the controller over the HP-IB. The power supply can be programmed directly in volts and amps. Power supply status can be read over the HP-IB, and the power supply can be instructed to request service for any of nine conditions. Upon command, the power supply will measure its output voltage, output current, or OVP trip voltage and put the value on the HP-IB. New output values can be put on hold and triggered later, allowing the controller to synchronize multiple units at one time.

1-6 The following parameters and features can be controlled via the HP-IB:

- Output voltage setting (12 bits)
- Output current setting (12 bits)
- Trigger (update output)
- Output disable/enable
- OVP reset
- "Soft" voltage and current limits
- Status reporting
- Service request capability
- Foldback protection
- Output voltage measurement (12 bits)
- Output current measurement (12 bits)
- OVP setting measurement
- Machine state initialization
- 16 machine state presets
- Self test

1-7 Output connections are made to rear-panel screw-on terminals. Either the positive or negative output terminal may be grounded or the output may be floated up to +240 Vdc (including output voltage) from chassis ground. Output voltage can be locally or remotely sensed.

1-8 The HP 6038A is considerably smaller, lighter and more efficient than older-design supplies with similar output power capability. The unit is fan cooled and is packaged in a Hewlett-Packard System II-compatible modular enclosure which is sturdy, attractive and provides easy access for servicing.

1-9 SAFETY CONSIDERATIONS

1-10 This product is a Safety Class 1 instrument (provided with a protective earth terminal). The instrument and this manual should be reviewed for safety markings and instructions before operation. Refer to the Safety Summary page at the beginning of this manual for a summary of general safety information. Safety information for specific procedures is located at appropriate places in this manual.

1-11 SPECIFICATIONS

1-12 Instrument specifications are listed in Table 1-1. These specifications are the peformance standards or limits against which the instrument is tested. Supplemental information is also listed in Table 1-1, including typical but non-warranted characteristics.

1-13 OPTIONS

1-14 Options are standard factory modifications or accessories that are delivered with the instrument. The following options are available with the HP 6038A. Note lower output power specifications for Option 100, which is described in Appendix A.

Option	Description
001	Blank Front Panel for line Options 120, 220, and 240 Vdc
100	Input power: 100 Vac +6%, −10%; 48-63 Hz single phase. Output power: 150 W, 60 V, 10 A.
120	Input power: 120 Vac +6% −13%; 48-63 Hz single phase.
220	Input power: 220 Vac +6%, −13%; 48-63 Hz, single phase.
240	Input power: 240 Vac +6%, −13%; 48-63 Hz, single phase.
800	Rack mount Kit for two units side by side.
908	Single side rack mounting kit with half-module width extension adaptor.
910	One additional Operating and Service Manual for each Option 910 ordered.

1-15 ACCESSORIES

1-16 The System-II cabinet accessories and service accessories listed below may be ordered with the power supply or separately from your local Hewlett-Packard Sales and Service Office (see list of addresses at rear of this manual).

HP Part No.	Description
5061-0060	Rack mounting adapter kit for side mounting one 7-inch high cabinet, includes one rack flange and one half-module width extension adapter. (Will be shipped with instrument if ordered as Option 908).
5061-0061	Rack mounting adapter kit for center mounting one 7-inch high cabinet, includes one rack flange and one quarter-module width extension adapter (two kits required), there will be surplus of hardware.
5061-0078	Rack flange kit for 7-inch high cabinet. Must be used with another half-module width unit of equal depth with lock link kit 5061-0094. (Will be shipped if instrument is ordered as Option 800).
5061-0094	Lock link kit for joining units of equal depth, contains hardware for three side-by-side joints (four units) and two over-under joints (three units). Locking cabinets together horizontally in a configuration wider than one full module is not recommended. 5061-0078 and 5061-0094 will be shipped if Option 800 is ordered.
5061-0090	Front handle kit for 7-inch high cabinets. Corresponding flange kit is 5061-2072.
5061-2072	Flange kit to be used with front handle kit 5061-0090.
5061-0084	Rack mounting flange kit with handles for 7-inch high cabinet. Must be used with another half-module width unit of equal depth with lock link kit 5061-0094.
5061-2003	Bail handle kit for carrying 7-inch high, half-module width cabinet.
1460-1345	Tilt stand (1) snaps into standard foot on instrument, must be used in pairs.
5061-0098	Support shelf kit for mounting one or more 7-inch high cabinets of any depth to 20 inches.
5061-2027	Front filler panel, half-module width, for 7-inch high cabinet on support shelf.
1494-0041	Slide kit for 5061-0098 support shelf.
06033-60005	Service kit, includes extenders for control and power mesh boards, three cables to allow HP-IB and PSI boards to lie on table outside unit, and control board test connector.
5060-0138	HP-IB connector non-metric to metric conversion kit.
5060-2860	FET service kit, includes FETs and all components that should be replaced with FETs.

1-17 INSTRUMENT AND MANUAL IDENTIFICATION

1-18 Hewlett-Packard power supplies are identified by a two-part serial number. The first part is the serial number prefix, a number-letter combination that denotes the date of a significant design change and the country of manufacture. The first two digits indicate the year (24 = 1984, 25 = 1985, etc), the second two digits indicate the week, and "A" designates the U.S.A. The second part of the serial number is a different sequential number assigned to each power supply, starting with 00101.

1-19 If the serial number on your instrument does not agree with those on the title page of this manual, a yellow Manual Changes sheet supplied with the manual defines the difference between your instrument and the instrument described by this manual. The change sheet may also contain information for correcting errors in the manual.

1-20 HP-IB INTERCONNECTION CABLES AND CONNECTORS

1-21 Cables for interconnecting HP-IB devices are available in four different lengths. The connector block at both ends of each HP-IB cable has a plug on one side and a matching receptacle on the other, so that several cables may be connected in parallel, thus simplifying system interconnection. Lock screws provide secure mounting of each connector block to an HP-IB instrument, or to another cable connector block. All connectors supplied since 1975 use metric hardware (colored black). Accessories table lists kit for converting one non-metric (colored silver) cable and one or two instruments to metric hardware. The 10833 series of cables features improved shielding, compared to the older 10631 series, to help improve overall RFI levels in many systems. The 10631 and 10833 series cables are functionally compatible with one another, but the 10631 series cables will interrupt the continuity of the 10833 series shielding.

Model

10833A HP-IB Cable, 1 m (3.3 ft.)
10833B HP-IB Cable, 2 m (6.6 ft.)
10833C HP-IB Cable, 4 m (13.2 ft.)
10833D HP-IB Cable, 0.5 m (1.6 ft.)
10834A HP-IB Connector Extender

1-22 The 10834A extender was designed to help in cases where rear panel space results in difficult cabling situations. The extender provides clearance by extending the first connector block 2.3 cm away from the rear panel of the instrument.

1-23 ORDERING ADDITIONAL MANUALS

1-24 One manual is shipped with each power supply. Additional manuals may be purchased directly from your local Hewlett-Packard Sales office. Specify the model number instrument serial number prefix, and the manual part number provided on the title page. (When ordered at the same time as the power supply, additional manuals may be puchased by adding Option 910 to the order and specifying the number of additional manuals desired).

1-25 RELATED DOCUMENTS

1-26 The following documents may be useful for designing HP-IB systems. The HP documents can be ordered from your local HP Sales Office.

Programming Note, Introductory Operating Guide, HP System Power Supplies, HP Part Number 5952-4119

Programming Note, Quick Reference Guide, HP System Power Supplies, HP Part Number 5952-4118.

Condensed Description of the Hewlett-Packard Interface Bus, HP Part Number 59401-90030. March, 1976, 18 pages.

Tutorial Description of the Hewlett-Packard Interface Bus, HP Part Number 59300-90007, November, 1980, 92 pages.

IEEE Std 488-1978 Digital Interface for Programmable Instrumentation, corrected edition July 25, 1980, or later, available from:

IEEE
345 East 47th Street
New York NY 10017

1-27 HP-IB COMPATABILITY

1-28 The 6038A implements the following HP-IB interface functions:

SH1 (Source Handshake)
AH1 (Acceptor Handshake)
T1 (Talker)
L1 (Listener)
SR1 (Service Request)
RL1 (Remote Local)
PP1 (Parallel Poll)
DC1 (Device Clear)
DT1 (Device Trigger)

Table 1-1. Specifications and Supplemental Characteristics

All performance specifications are at rear terminals with a resistive load. All specifications apply over the full operating temperature range unless otherwise specified.

AC Input

Two internal switches and one internal jumper permite operation from 120, 220, or 240 Vac (−13%, +6%, 48-63 Hz). 100 Vac operation is a factory set option only.

Input Current:

100 Vac: 6.0 A
120 Vac: 6.6 A
220 Vac: 3.8 A
240 Vac: 3.6 A

850 VA Maximum
375 W Maximum

Input Fuse Ratings:

The AC input is protected by a rear panel mounted fuse; 8 A for 100 Vac and 120 Vac, 4 A for 220 Vac and 240 Vac.

Peak Inrush Current:

20 A maximum at any line or temperature.

DC Output

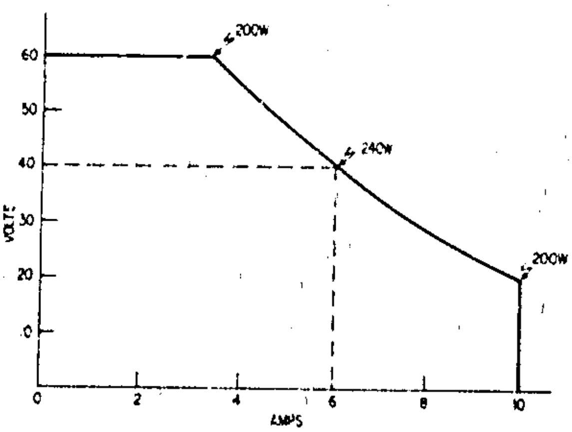
Voltage and current can be programmed via HP-IB, front panel control or remote analog control over the following ranges:

Voltage: 0 to 60 V
Current: 0 to 10 A

See graph and table for maximum output power.

OUTPUT BOUNDARY SPECIFICATION

Voltage (V)	Current (A)	Power (W)	Current (A)	Voltage (V)	Power (W)
20	10.0	200	3.3	60	200
25	8.5	212	4.0	54	216
30	7.6	228	5.0	46	232
35	6.7	234	6.0	40	240
40	6.0	240	7.0	34	238
45	5.3	237	8.0	29	232
50	4.6	232	9.0	24	217
55	4.1	226	10.0	20	200
60	3.3	200			



Load Effect

For a load change equal to the maximum available current rating of the supply at the set voltage (CV) or maximum available voltage rating at the set current (CC):

Voltage: 0.01% +3 mV
Current: 0.01% +5 mA

Source Effect

For a line change within rating:

Voltage: 0.01% +2 mV
Current: 0.01% +2 mA

DC Output Isolation

Either output terminal may be floated up to ±240 Vdc (including output voltage) from earth ground.

PARD (Ripple and Noise)

RMS/pk-pk 20Hz-20 MHz:

Voltage: 3 mV/30 mV
Current: 5 mA
Common mode current: 1 mA/40 mA typical

Temperature Coefficient:

Change in output per °C after a 30-minute warmup.

Voltage: 50 ppm +3 mV
Current: 90 ppm + 0.3 mA

Drift (Stability)

Change in output over an 8-hr interval under constant line, load and ambient temperature after 30-minute warmup.

Voltage: 0.02% +2 mV
Current: 0.03% +3 mA

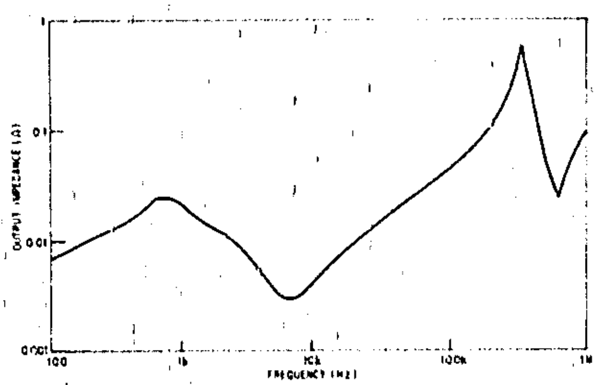
Load Transient Recovery Time

The time required for the output voltage to recover within a band around the nominal voltage following a 10% or 50% change in load current.

10% load current change: 1 ms to within 75 mV
50% load current change: 2 ms to within 200 mV

Output Imepdance (Typical)

See graph:



Programming Resolution

Voltage: 15 mV
Current: 2.5 mA

Programming Accuracy (25 ±5 °C)

Voltage: 0.035% +40 mV
Current: 0.065% +10 mA

Both channels are monotonic over the operating temperature range.

Programming Response Time

Maximum time for output voltage to change from 0 to 60 V or 60 V to 2 V and settle within 15 mV of final value.

Up:	Full load (18 ohms)	225 ms
	Light load (400 ohms)	225 ms
	No load	225 ms
Down:	Full load (18 ohms)	400 ms
	Light load (400 ohms)	750 ms
	No load	1500 ms

Typical programming response time data for changes other than full-scale excursions:

	full load 18 ohms	light load 400 ohms	no load
Up: 0 - 60 V	150 ms	120 ms	120 ms
0 - 30 V	120 ms	100 ms	100 ms
20 - 60 V	120 ms	100 ms	100 ms
Down: 60 - 2 V	150 ms	400 ms	850 ms
60 - 10 V	110 ms	210 ms	350 ms
60 - 30 V	160 ms	340 ms	500 ms

Typical output voltage overshoot:

Final value	Overshoot
<3 V	3 V
>3 V	0.1 V

Readback (25 ±5 °C)

Voltage: Resolution: 15 mV
Accuracy: 0.07% +50 mV
TC: 30 ppm +1 mV /°C

Current: Resolution: 2.5 mA
Accuracy: 0.20% +11 mA
TC: 70 ppm +0.5 mA /°C

OVP: Resolution: 37.5 mV
Accuracy: 0.25% +300 mV
TC: 100 ppm +5 mV

Table 1-1. Specifications and Supplemental Characteristics (continued)

Front Panel Meters (25 ±5 °C):

VOLTS

Range	Resolution	Accuracy
2 V	15 mV	0.07% + 50 mV
20 V	15 mV	0.07% + 55 mV
200 V	100 mV	0.07% + 100 mV

TC: Same as voltage readback

AMPS

Range	Resolution	Accuracy
20 A	10 mA	0.20% + 11 mA

TC: Same as current readback

OVP
Range: 200 V
Resolution: 100 mV
Accuracy: 0.3% + 300 mV
TC: Same as OVP readback

Overvoltage Protection:

Trip voltage adjustable via front panel control.

Range: 0-63 V
Resolution: 100 mV
Accuracy: 0.25% + 300 mV (Set using DISPLAY OVP function)
TC: 100 ppm + 5 mV/°C

Minimum setting above output voltage to avoid nuisance tripping is 1.5 V.

Remote Analog Programming (25 ±5 °C):

Resistance Programming:

0 to 4 k provides zero to maximum rated output voltage or current. The resulting scale factor is 1 ohm/LSB for a 12-bit system, which corresponds to 200 ohms/volt and 133 ohms/amp.

Voltage:
Accuracy: 0.42% + 30 mV
TC: 50 ppm + 3 mV

Current:
Accuracy: 0.8% + 20 mA
TC: 100 ppm + 0.3 mA

Voltage Programming:

0 to 5 V provides zero to maximum rated output voltage or current.

Voltage:
Accuracy: 0.25% + 30 mV
TC: 10 ppm + 3 mV

Current:
Accuracy: 0.15% + 20 mA
TC: 70 ppm + 0.3 mA

The programming inputs are protected against input voltages up to ±40 V.

Voltage and Current Monitor Outputs (25 ±5 °C):

0 to 5 V output indicates zero to maximum rated output. All accuracy specifications are referred to the output of the supply.

Voltage:
Accuracy: 0.25% + 10 mV
TC: 10 ppm + 2 mV/°C
Output impedance: 10.2 k Ω ±5%

Current:
Accuracy: 0.15% + 6 mA
TC: 70 ppm + 0.3 mA/°C
Output impedance: 10.2 k Ω ±5%

Remote Sensing:

Meets load-effect specification at load by correcting for load-lead drop of up to 0.5 V per lead with sense wire resistance of less than 0.2 ohms per sense lead and lead lengths of less than 5 metres.

Operation with up to 2V drop per load lead is possible; load-effect specification depends on sense-wire resistance. Refer to Section III.

Reverse Voltage Protection:

Maximum permissible current caused by reverse voltage impressed across output terminals:

10 A with AC power on
10 A with AC power off

Temperature Ratings:

Operating: 0 to +55°C
Storage: −40 to +75°C

Certification:

Unit complies with the following requirements:

IEC 348-Safety Requirements for Electronic Measuring Apparatus.

CSA 556B-Electronic Instruments and Scientific Apparatus for Special Use and Applications.

VDE 0411-Electronic Measuring Instruments and Automatic Controls.

VDE 0871/6.78 level B- RFI Suppression

Dimensions: See Figure 2-1

Weight:

Net: 9.6 kg (21 lb)
Shipping: 11.4 kg (25 lb)

INSTALLATION

Section II
INSTALLATION

2-1 INTRODUCTION

2-2 This section contains instructions for checking and repacking the unit, bench or rack mounting, connecting the unit to ac input power, and converting the unit from one line voltage to another if required. Instructions for connecting load and HP-IB cables, and for setting the HP-IB address are given in Section III

2-3 INITIAL INSPECTION

2-4 Before shipment, this instrument was inspected and found to be free of mechanical and electrical defects. As soon as the instrument is unpacked, inspect for any damage that may have occurred in transit. Save all packing materials until the inspection is completed. If damage is found, file claim with carrier immediately. The Hewlett-Packard Sales and Service office should be notified as soon as possible.

2-5 Mechanical Check

2-6 This check should confirm that there are no broken knobs or connectors, that the cabinet and panel surfaces are free of dents and scratches, and that the meter face and rear-panel terminal block covers are not scratched or cracked.

2-7 Electrical Check

2-8 Section V contains complete verification procedures for this instrument. Section III contains an abbreviated check which can be used quickly to place the unit into operation. Refer to the inside front cover of the manual for Certification and Warranty statements.

2-9 PREPARATION FOR USE

2-10 In order to be put into service, the power supply must be connected to an appropriate ac input power source. Also,

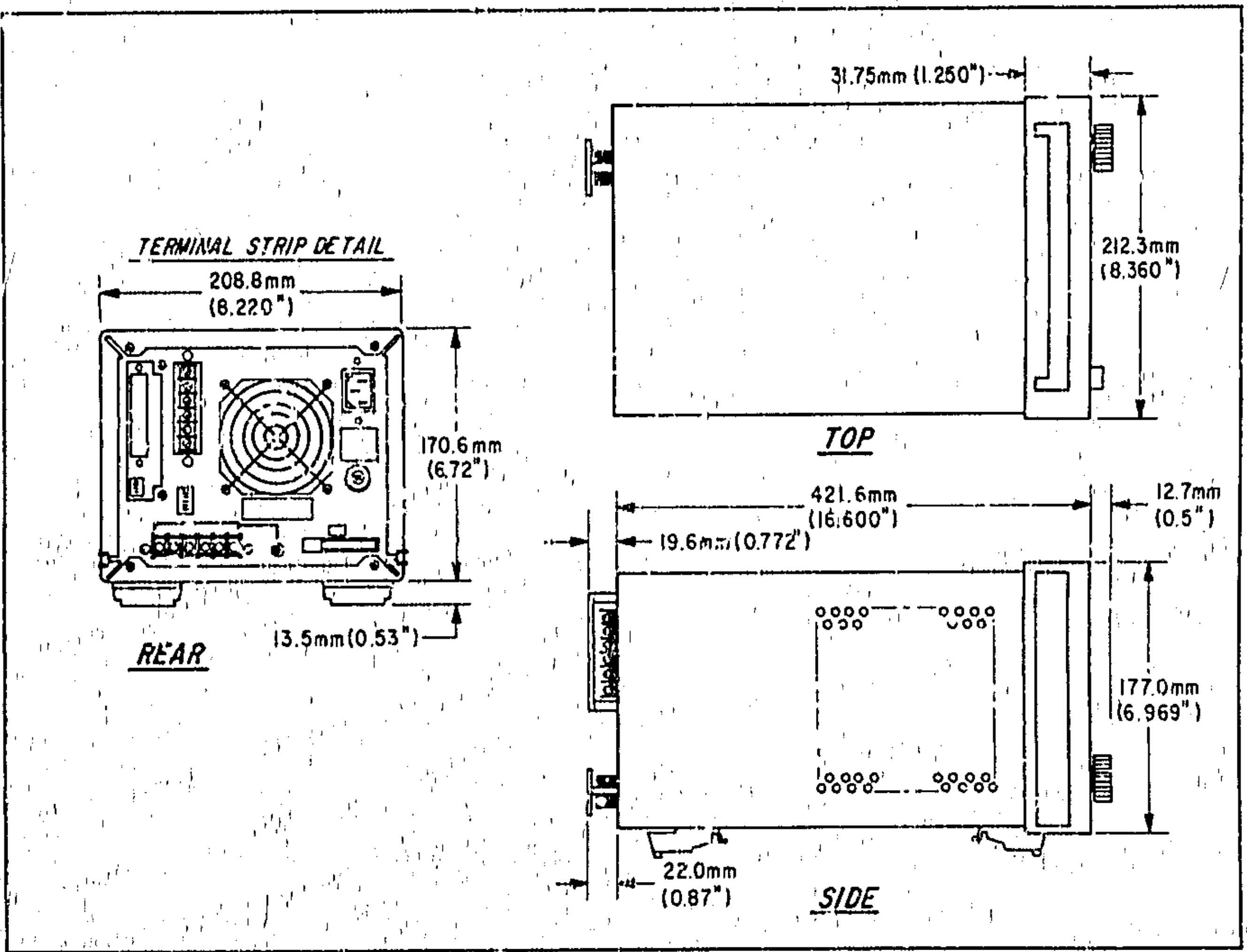


Figure 2-1. Outline Diagram

the line voltage for which the unit is set and the rear-panel fuse must be checked. Additional steps may include line voltage conversion and rack mounting. Do not apply power to the instrument before reading paragraph 2-19.

2-11 Location and Cooling

2-12 The instrument is fan cooled and must be installed with sufficient space in the rear and on sides for air flow. Either side (but not both) may be restricted to have as little as 1/4 inch (6mm) space. It should be used in an area where the ambient temperature, measured at the fan intake, does not exceed +55°C.

2-13 Outline Diagram

2-14 Figure 2-1 illustrates the outline shape and dimensions of the cabinet.

2-15 Bench Operation

2-16 The instrument cabinet has plastic feet, which are shaped to ensure self aligning when stacked with other Hewlett-Packard System II cabinets.

2-17 Rack Mounting

2-18 The unit can be mounted in a standard 19-inch rack panel or enclosure. Rack mounting accessories for this unit are listed in the ACCESSORIES paragraph in Section I. Complete installation instructions are included with each rack mounting kit.

2-19 Input Power Requirements

2-20 This supply may be operated from a nominal 100 V, 120 V, 220 V or 240 V single-phase ac power source (48-63 Hz). The input voltage range and input current required for each of the nominal inputs are listed below. The maximum input power (at high line, full load) required for any input is 375 watts. A label on the rear panel indicates the nominal line voltage for which the instrument was set at the factory. If necessary, the user can convert the instrument from one line voltage option to another by following the instructions in Paragraph 2-25.

Nominal Voltage	Line Voltage Range	Maximum Input Current
100 V	87-106	6.0 A rms
120 V	104-127	6.5 A rms
220 V	191-233	3.8 A rms
240 V	208-250	3.6 A rms

2-21 Power Cable

2-22 The power supply is shipped from the factory with a power-cord plug appropriate for the user's location. Figure 2-2 illustrates the standard configuration of power-cord plugs used by Hewlett-Packard. With each drawing is the HP Part Number for a replacement power cord equipped with a plug

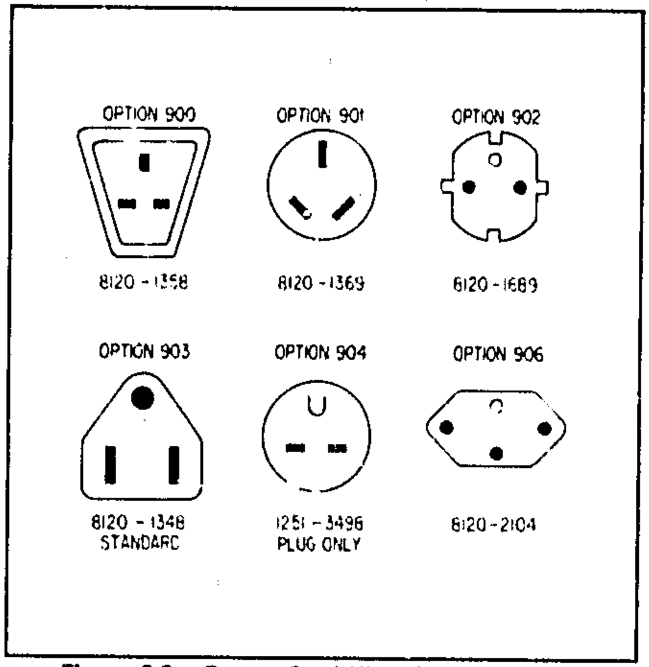


Figure 2-2. Power-Cord Plug Configurations

of that configuration. If a different power cord is required, contact the nearest Hewlett-Packard Sales and Service office.

2-23 To protect operating personnel, the National Electrical Manufacturers Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument is equipped with a three-conductor power cable; the third conductor is the ground conductor. When the cable is plugged into an appropriate receptacle the instrument is grounded. In no event shall this instrument be operated without an adequate cabinet ground connection.

2-24 The offset pin on the standard power cable three-prong connector is the ground connection. If a two-contact receptacle is encountered, it must be replaced with a properly grounded three-contact receptacle in accordance with the National Electrical Code, local codes and ordinances. The work should be done by a qualified electrician.

NOTE

Generally, it is good practice to keep the ac input lines separated from signal lines.

2-25 LINE VOLTAGE OPTION CONVERSION

CAUTION

Conversion to or from 100 V operation requires recalibration and replacement of internal components in addition to the line voltage components, and is to be done only at the factory. Failure to reconfigure and recalibrate the power supply may result in damage to the unit.

2-26 Line voltage conversion is accomplished by adjusting three components; the two-section line select switch A1S2, line-voltage jumper A1W5, and rear-panel line fuse F1. To convert the supply from one line voltage option to another, proceed as follows:

WARNING

Some components and circuits are at ac line voltage even with the switch off. To avoid electric shock hazard, disconnect line cord and load before removing cover.

a. Remove top cover from instrument by removing two screws that secure cover to rear panel; remove only rear screw on carrying handle; slide cover to rear and lift off.
b. The line voltage select switch is located in the front left corner of the instrument (see Figure 2-3). Use a small-blade screwdriver to set the two switch sections to match the pattern silkscreened on p.c. main board as shown in Figure 2-3. For example, to set switches for 120 V operation (as illustrated), move forward switch section so that its white slot is toward front of instrument and move rearward switch section so its white slot is toward rear of instrument.
c One end of A1W5 is soldered to motherboard; the other end has a female right-angle quick-connect terminal that fits onto one of two terminals soldered to motherboard. For 100 V or 120 V operation, A1W5 must be connected to terminal closer to center of instrument; for 220 V or 240 V operation, A1W5 must be connected to terminal closer to side of instrument. Be certain that jumper is firmly mated with terminal on motherboard. Do not grip jumper insulation with pliers; either grip jumper wire by hand or grip jumper terminal with pliers.
d. Check rating of fuse F1 installed in rear-panel fuseholder and replace with correct value if necessary. Do not use slow-blow fuses. For 120 V operation, use 8 A fuse, HP Part Number 2110-0383. For 220 V or 240 V operation, use 4A fuse, HP Part Number 2110-0055.
e. Replace covers and mark the supply clearly with a tag or label indicating correct line voltage and fuse to be used.

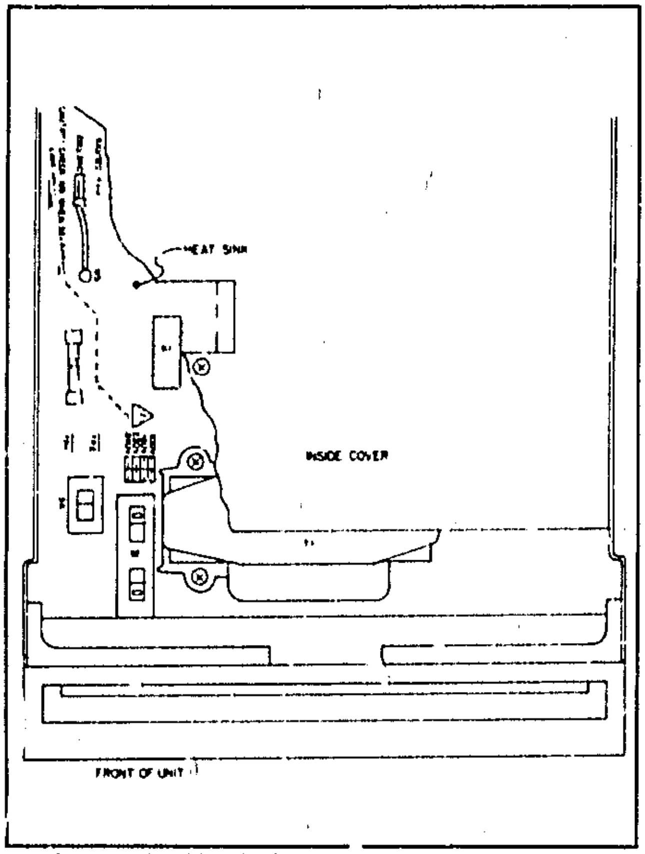


Figure 2-3. Line Voltage Selection Components

2-27 REPACKAGING FOR SHIPMENT

2-28 To insure safe shipment of the instrument, it is recommended that the package designed for the instrument be used. The original packaging material is reusable. If it is not available, contact your local Hewlett-Packard Sales and Service office to obtain the materials. This office will also furnish the address of the nearest service office to which the instrument can be shipped. Be sure to attach a tag to the instrument specifying the owner, model number, full serial number, and service required or a brief description of the trouble.

OPERATION

Section III
OPERATING INSTRUCTIONS

3-1 INTRODUCTION

3-2 This section describes the operating controls and indicators, turn-on checkout procedures, and operating procedures and considerations for the HP 6038A. Local (front-panel) and remote (via HP-IB) operation are described separately, but the user should become familiar with both methods of operation. Information in this section through paragraph 3-64 applies to both local and remote operation. Programming examples for specific Hewlett-Packard computers are given in the Introductory Operating Guide, HP P/N 5952-4119. The Quick Reference Guide, HP P/N 5952-4118, is useful for operators who are already familiar with the operation of the HP 6038A power supply. More theoretical descriptions regarding the operational features of power supplies in general are given in the DC Power Supply Handbook, Application Note 90B (available at no charge from your local Hewlett-Packard Sales Office).

WARNING

Before the instrument is turned on, all protective earth terminals, extension cords, and devices connected to the power supply should be connected to a protective earth ground. Any interruption of the protective earth grounding will cause a potential shock hazard that could result in personal injury. For continued protection against fire hazard, use only a 250 Vac fuse with required current rating. Do not use slow-blow fuses. Do not use short circuited fuseholders. To do so could cause a fire and shock hazard.

3-3 CONTROLS AND INDICATORS

3-4 The front-panel controls and indicators are shown in Figure 3-1 and described in Table 3-1. Table 3-1 also lists the paragraphs in which use of the controls and indicators is described.

3-5 OUTPUT RANGE FOR AN AUTORANGING POWER SUPPLY

3-6 The HP 6038A can operate as a constant voltage (CV) or constant current (CC) source over a wide range of output voltage and current combinations. The specifications table contains a graph showing the overall output range of the power supply. Figure 3-2 shows a rectangular operating locus that is defined by voltage and current settings of the power supply. The point on that locus at which the power supply actually

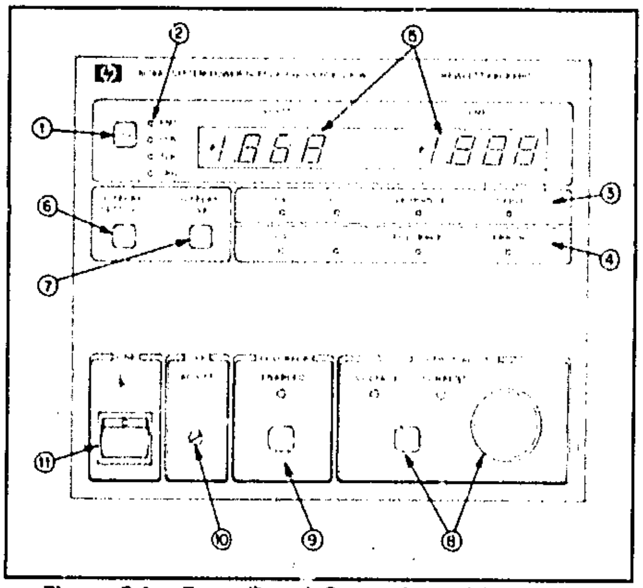


Figure 3-1. Front-Panel Controls and Indicators

operates is determined by the load resistance. Three load-resistance lines are shown on Figure 3-2. The line representing load resistance A, the highest load resistance shown on the graph, crosses the operating locus at point 1. Point 1 is on the part of the operating locus defined by the voltage setting, so the power supply operates in CV mode.

3-7 Similarly, the line representing load resistance C, the lowest load resistance shown on the graph, crosses the operating locus at point 3. Point 3 is on the part of the operating locus defined by the current setting, so the power supply operates in CC mode.

3-8 Load Resistance B equals the crossover resistance for the particular combination of voltage and current settings shown on the graph. Either the CV or CC LED, or both, will light. If the load resistance increases, the voltage setting decreases, or the current setting increases, the power supply will operate in CV mode. Conversely, if the load resistance decreases, voltage setting increases, or current decreases, the power supply will operate in CC mode.

3-9 In Figure 3-2 the entire rectangular operating locus falls within the output range of the power supply. Figure 3-3 shows a situation in which the voltage and current settings are high enough that the rectangular operating locus is cut off by the maximum output power boundary of the power supply. For the load resistance A, the power supply operates in CV mode at the voltage and current values for point 1. Similarly, for load resistance D the power supply operates in CC mode at point 4.

Table 3-1. Controls and Indicators

Number	Controls/Indicators	Description	Paragraph
1	LCL Pushbutton	Returns unit to local control (unless local lockout has been received via HP-IB). In local, power supply remains subject to remotely programmed soft limits and delays. When held in for one second, LCL causes HP-IB address to be displayed for up to two seconds or until LCL switch is released.	3-73—3-75,3-94
2	HP-IB Status Indicators These four LEDs indicate the status of the power supply on the HP-IB.	RMT (green) indicates that power supply is under remote (HP-IB) control. LSN (green) indicates that power supply is addressed to listen. TLK (green) indicates that power supply is addressed to talk. SRQ (green) indicates that power supply is requesting service from controller.	3-68, 3-74 3-79 3-79 3-80—3-83
3	Power Supply Status Indicators (Primary) These four LEDs indicate the operating state of the power supply. Usually only one LED is on, but both CV and CC can be on together if unit is operating at crossover point between CV and CC.	CV (green) indicates that the power supply is regulating its output at a constant voltage. CC (green) indicates that the power supply is regulating its output at a constant current. OVERRANGE (yellow) indicates that the power supply is operating beyond its maximum output power specification and that the output is not regulated. DISABLED (yellow) indicates that the power supply output has been turned off for one of these reasons: a. command from controller b. overvoltage protection c. overtemperature protection d. foldback protection e. low or high ac input voltage	3-17d 3-17j 3-10—3 11,3-58 3-59
4	Power Supply Status Indicators (Secondary) These four LEDs indicate the state of protective circuits within the power supply.	OV (yellow) indicates that the overvoltage protection circuit has disabled the output and is latched. OT (yellow) inidcates that the overtemperature protection circuit has disabled the output. FOLDBACK (yellow) indicates that the foldback protection circuit has disabled the output and is latched. ERROR (yellow) indicates that the power supply has detected a programming error.	3-17g, 3-60 3-61 3-35—3-39, 3-63, 3-145 3-17f,l,3-64 3-183—3-185

Table 3-1. Controls and Indicators (continued)

Number	Controls/Indicators	Description	Paragraph
		If user attempts to exceed soft limits locally (using RPG), ERROR will light while RPG is being rotated and will remain on for approximately 1 second after rotation stops. For remote programming error, ERROR will turn off when error query is received.	
5	Numeric Display	Two 3-1/2 digit alphanumeric displays with automatically positioned decimal point that ordinarily indicate output VOLTS and AMPS (items 6 & 7). When power supply is turned on all segments light for approximately 1 second. During an error condition, power supply output may exceed display range; displays will indicate +OL or −OL.	3-13—3-16, 3-17b-l,3-94
6	DISPLAYS SETTINGS Pushbutton Switch	Causes numeric displays to indicate programmed voltage and current values, rather than actual output values; allows both settings to be made without the necessity of opening or shorting load.	3-17b, d, j, 3-67
7	DISPLAY OVP Pushbutton Switch	Causes VOLTS display to indicate OVP trip voltage, AMPS display is blanked; allows setting to be made without changing output settings or load connections.	3-33
8	OUTPUT ADJUST Controls	OUTPUT ADJUST knob functions either as a voltage control or a current control, as determined by the pushbutton switch and indicated by whichever (green) indicator, VOLTAGE or CURRENT is on. Knob functions as a two-speed device; faster rotation causes greater rate of change per rotation. OUTPUT ADJUST controls operate only when unit is under local control.	3-17d-l,3-66
9	FOLDBACK Control	The pushbutton switch toggles foldback protection on and off in local operation; has no effect if power supply is not in CV or CC (ERROR LED flashes), or in remote. Switch also resets foldback protection circuit if it has disabled power supply output. FOLDBACK ENABLED LED (green) operates in either local or remote.	3-63,3-68e, 3-72e
10	OVP ADJUST	The recessed, single-turn screwdriver control sets the overvoltage protection trip voltage.	3-33
11	LINE Switch	Turns ac power on and off.	3-17a

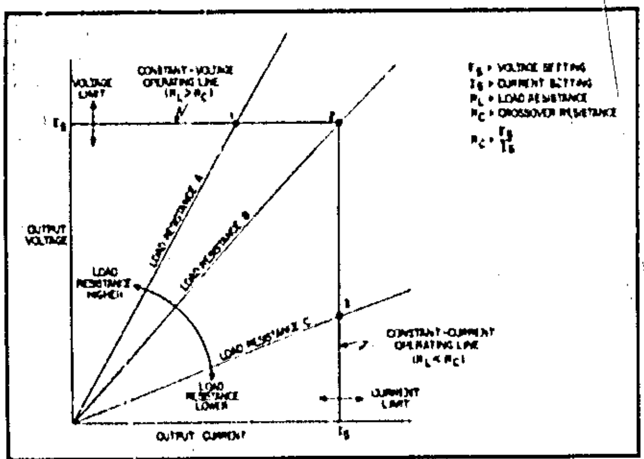


Figure 3-2. Determining Operating Point

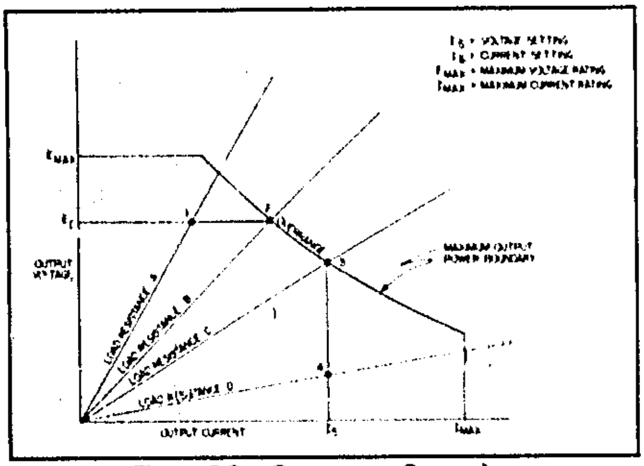


Figure 3-3. Overrange Operation

3-10 For load resistances between B and C, the operating point will be on the maximum output-power boundary between points 2 and 3, and the OVERANGE LED will be on. The VOLTS and AMPS displays will indicate the voltage and current being supplied to the output. (The product of the two readings will exceed rated output power of the supply.) Note that the actual boundary is beyond the specified minimum boundary. The OVERRANGE LED will light only if the actual boundary is exceeded.

3-11 The supply can operate in the overrange region for sustained periods without being damaged. However, the supply is not guaranteed to meet specifications in overrange. Output ripple increases substantially and regulation is seriously degraded.

NOTE

Under certain conditions of line and load, it is possible for the supply to provide more than rated output power and still maintain regulation. If this occurs, the unit will operate normally and the OVERRANGE indicator will be off. However, the slightest change in either line or load may cause the unit to go out of regulation. Operation of the unit beyond the rated-output-power boundary is not recommended under any circumstances.

3-12 TURN-ON CHECKOUT PROCEDURE

3-13 The power supply performs a series of self tests each time power is turned on. All front-panel LEDs, including all meter segments, are also turned on. The tests take approximately one second to complete, and all indicators remain on while the tests are running. This alerts the operator that self tests are running, and allows the operator to note if any indicators are inoperative.

3-14 After the self tests are completed all front-panel indicators are turned off for one-half second, allowing the operator to note if any are stuck on. If the operator suspects that any indicator may be malfunctioning he should turn power off and back on again while observing that indicator.

3-15 Once the all-indicators-off period is over, the HP-IB address switch setting is displayed on the meter displays for one second. For example, if the address switches were set for address 5, the display would be:

Adr 5

3-16 If the unit fails any of the self tests, an error code is displayed on the meter displays. The unit will not respond to any commands, either from the front panel or HP-IB, and it should be removed for service.

NOTE

Because the power supply is testing itself, it is not possible to guarantee that the unit will provide an unambiguous indication of all possible failures. For example, a failure in the core of the microcomputer or in the hardware used to light the front-panel display may prevent the unit from indicating that it has failed a test. Refer to the troubleshooting procedures in Section V if there is any reason to suspect that the unit may be malfunctioning.

3-17 The following procedure ensures that the unit is operational, and may be used as an incoming inspection check. Refer to Section V for more extensive performance tests to determine that the unit meets specifications. Ensure that the rear-panel MODE switches are set as shown in Figure 3-4, and that

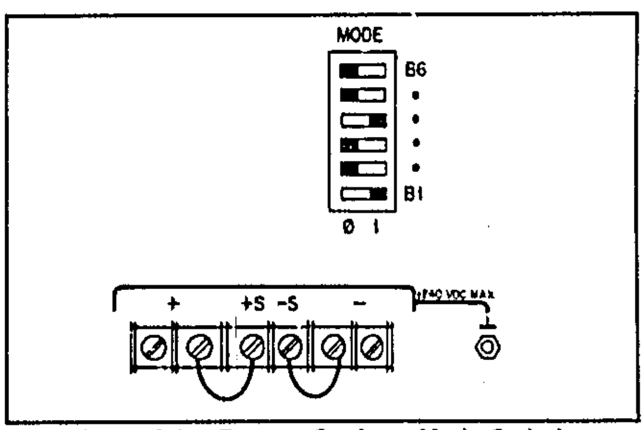


Figure 3-4. Factory Settings, Mode Switch and Sensing Leads

the sensing jumpers are tightened securely. Check that the rear-panel label indicates that the unit is set for the line voltage to be used. There should be no cables connected to the rear panel HP-IB connector. Check that the recessed OVP ADJUST control on the front panel is fully clockwise. The HP-IB address switches may be set to any address from 0 to 30 for this procedure.

a. Press top of LINE rocker switch to turn unit on. Fan should operate. Check that display shows HP-IB address set by rear-panel switches. After address display, CURRENT indicator should remain on and either CV or CC indicator should remain on. (SRQ indicator will remain on if rear-panel PON SRQ switch has been set to 1.)

b. Press momentary-contact DISPLAY SETTINGS pushbutton switch and check that VOLTS display indicates 0.00 and AMPS display indicates 0.00.

c. Press momentary-contact DISPLAY OVP pushbutton switch and check that VOLTS display indicates 65 ±2 V.

d. Turn OUTPUT ADJUST knob clockwise, press DISPLAY SETTINGS switch, and check that AMPS setting has increased. CV indicator should be on and CC indicator should be off.

e. Press momentary-contact OUTPUT ADJUST pushbutton switch once; VOLTAGE indicator should turn on and CURRENT indicator should turn off.

f. Turn OUTPUT ADJUST knob clockwise and check that output voltage increases from zero to full output voltage as indicated on VOLTS display. Continued clockwise rotation may cause VOLTS display to indicate +OL, and ERROR indicator will light (turns off one second after clockwise rotation stops).

g. Check overvoltage protection circuit by turning OVP ADJUST control counterclockwise until OVP circuit trips. Output should drop to 0 V, CV indicator turns off, and DISABLED and OV indicators turn on (SRQ and VOLTAGE indicators remain on).

h. Reset OVP circuit by turning OVP ADJUST control fully clockwise and turning unit off and back on. Output voltage should come on at 0 volts.

i. To check constant current circuit, turn power supply off and connect a wire (AWG#16, 1 mm² or larger) across + and − terminals on rear panel.

j. Turn power supply on and press OUTPUT ADJUST switch once to turn on VOLTAGE indicator. Turn OUTPUT ADJUST knob clockwise, press DISPLAY SETTINGS switch, and check that VOLTS setting has increased. CC indicator should be on and CV indicator should be off.

k. Press OUTPUT ADJUST switch once; CURRENT indicator should turn on and VOLTAGE indicator should turn off.

l. Turn OUTPUT ADJUST knob clockwise and check that output current increases from zero to full output current as indicated on AMPS display. Continued clockwise rotation may cause AMPS display to indicate +OL, and ERROR indicator light (turns off one second after clockwise rotation stops).

m. Turn off power supply, remove short from output, and read following instructions before connecting load to supply.

3-18 INITIAL SETUP AND INTERCONNECTIONS

WARNING

Turn off input ac power before changing any rear-panel connection and make certain all wires and straps are properly connected and terminal block screws are securely tightened before reapplying power. Be certain to replace both terminal block cover before reapplying power.

3-19 Connecting the Load

3-20 Load connections to the power supply are made at the + and − terminals on the rear panel. Two factors must be considered when selecting wire size for load connections, conductor temperature and voltage drop.

3-21 To satisfy safety requirements, the wires to the load should be at least heavy enough not to overheat while carrying the power supply output current that would flow if the load were shorted. Stranded AWG#16 copper wire 1 mm² cross-section area) is rated for 13.5 amps at 105°C conductor temperature. (The maximum allowable conductor temperature is based on +60°C ambient temperature plus 45°C temperature rise because of continuous dc current). This rating is based on use of a twisted pair to connect the load to the supply. If the wire insulation is rated for less than 105°C or if the wires are located such that heat build up is a factor, larger wire sizes must be used. The minimum load wire size is AWG #16 (1mm²).

3-22 The wires must be properly terminated with connectors securely attached. Do not connect unterminated wires to the power supply.

3-23 The minimum wire size required to prevent overheating will not usually be large enough to provide a good voltage regulation at the load. For proper regulation the load wires should be large enough to limit the voltage drop to no more than 0.5 volts per lead. Table 3-2 lists resistivity for various wire sizes and the maximum lengths that may be used to limit voltage drop to 0.5 volts for various currents. Lengths are given in metres and (feet).

3-24 To determine maximum lengths (in metres or feet) for currents not listed, use the formula:

$$\text{maximum length} = \frac{500}{\text{current x resistivity}}$$

where current is expressed in amps and resistivity is expressed in ohms/kilometer or ohms/1000 feet. If load regulation is critical, use remote voltage sensing (paragraph 3-40).

WARNING

Remember while calculating load wire size that the wire must be large enough not to overheat while carrying the current that would flow if the load were shorted.

3-25 Table 3-3 lists current-carrying capacity (ampacity) for various sizes of stranded copper wire.

3-26 The terminal blocks are protected by impact-resistant plastic covers, which are secured to the unit with two M4 x 8 screws each. Be certain to replace the covers after making connections.

3-27 If multiple loads are connected to one supply, each load should be connected to the supply's output terminals using separate pairs of connecting wires. This minimizes mutual coupling effects and takes full advantage of the supply's low output impedance. Each pair of connecting wires should be as short as possible and twisted or shielded to reduce noise pickup and radiation.

3-28 If load considerations require the use of output distribution terminals that are located remotely from the supply, then the power supply output terminals should be connected to the remote distribution terminals by a pair of twisted or shielded wires and each load should be separately connected to the remote distribution terminals. Remote voltage sensing is required under these circumstances (paragraph 3-40). Sense either at the remote distribution terminals, or (if one load is more sensitive than the others) directly at the most critical load.

Table 3-2. Maximum Wire Lengths To Limit Voltage Drops

Wire Size		Resistivity		Maximum Length In Metres (Feet) To Limit Voltage Drop To 0.5V Or Less			
AWG	Cross-Section Area In mm^2	Ω/kft	Ω/km	5A	10A	20A	30A
22		16.15		(6)	(3)	(1.5)	(1)
	0,5		40,1	2,5	1.2	0,6	0,4
20		10.16		(9.5)	(4.5)	(2)	(1.5)
	0,75		26,7	3,7	1,9	0,9	0,6
18		6.388		(15.5)	(7.5)	(3.5)	(2.5)
	1		20,0	5,0	2,5	1,3	0,8
16		4.018		(24.5)	(12)	(6)	(4)
	1,5		13,7	7,3	3,6	1,8	1,2
14		2.526		(39.5)	(19.5)	(9.5)	(6.5)
	2,5		8,21	12,2	6,1	3,0	2,0
12		1.589		(62.5)	(31)	(15.5)	(10.5)
	4		5,09	19,6	9,8	4,9	3,3
10		0.9994		(100)	(50)	(25)	(17)
	6		3,39	29	14,7	7 4	4,9
8		0.6285		(159)	(79)	(39.5)	(27)
	10		1,95	51	25	12,8	8,5
6		0.3953		(252)	(126)	(63)	(4)
	16		1,24	80	40	20	13,4
4		0.2486		(402)	(201)	(100)	(68)
	25		0,795	125	62	31	20
2		0.1564		(639)	(319)	(159)	(108)
	35		0,565	176	88	44	29
	50		0,393	254	127	63	42
0		0.09832		(1020)	(509)	(254)	(173)

Wire sizes of AWG #14 ($2,5mm^2$) or smaller are normally used only for sense leads.

Table 3-3. Stranded Copper Wire Ampacity

Wire Size			
AWG	Cross Section Area in mm²	Ampacity	NOTES:
22		5.0	
20		8.33	
	0,75	10	
18		15.4	
	1	13.5	
16		19.4	
	1,5	16	
14		31.2	
	2,5	25	
12		40	
	4	32	
10		55	
6		40	
8		75	
	10	63	
6		100	
4		135	
2		180	
0		245	

NOTES:

1. Ratings for AWG-sized wires are derived from MIL-W-5088B. Ratings for metric-sized wires are derived from IEC Publication 335-1.
2. Ampacity of aluminum wire is approximately 84% of that listed for copper wire.
3. When two or more wires are bundled together, ampacity for each wire must be reduced to the following percentages:

   2 conductors 94%
   3 conductors 89%
   4 conductors 82%
   5 conductors 76%

4. Maximum temperatures: Ambient, 55°C; Conductor, 105°C

3-29 Either positive or negative voltages can be obtained from the supply by grounding one of the output terminals. It is best to avoid grounding the output at any point other than the power supply output terminals to avoid noise problems caused by common-mode current flowing through the load leads to ground. Always use two wires to connect the load to the supply regardless of where or how the system is grounded. Never ground the system at more than one point. This supply can be operated with either output terminal up to ±240 volts dc (including output voltage) from ground.

3-30 The PARD specifications in Table 1-1 apply at the power supply output terminals. However, noise spikes induced in the load leads at or near the load may affect the load although the spikes are inductively isolated from the power supply. To minimize voltage spikes at the load, connect a bypass capacitor as shown in Figure 3-5. With this setup, peak-to-peak noise at the load can actually be reduced to a level well below the value specified at the power supply output terminals.

3-31 Overvoltage Protection (OVP)

3-32 The overvoltage trip point is adjusted at the front panel. The approximate trip voltage range is from zero volts to 65 volts. When the OVP circuit trips, the power supply output is disabled and delivers no output power, and the OVP and DISABLED indicators turn on.

3-33 **Adjustment.** OVP is set by the recessed single-turn OVP ADJUST potentiometer on the front panel. Rotating the control clockwise sets the trip voltage higher. (It is set to maximum at the factory.) When adjusting the OVP trip point, the possibility of false tripping must be considered. If the trip voltage is set too close to the supply's operating voltage, a transient in the output would falsely trip the OVP. For this reason it is recommended that the OVP trip voltage be set higher than the output voltage by at least 1 volt (see NOTE following Paragraph 3-42). To adjust the OVP trip voltage, proceed as follows:

a. Turn on supply and hold DISPLAY OVP pushbutton in.
b. Insert a small-blade screwdriver through hole in front panel and adjust OVP trip voltage to desired level.

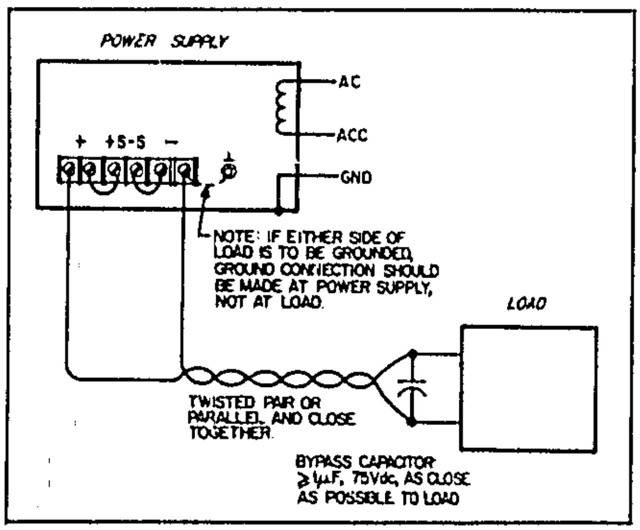


Figure 3-5. Connecting a Bypass Capacitor

3-34 **OVP Reset.** To reset OVP locally, turn the LINE switch off and then back on. OVP can also be reset via HP-IB by sending RST. The cause of the overvoltage must be removed before the OVP circuit is reset or the circuit will trip again immediately. If the OVP circuit trips continuously check the load and the trip voltage.

3-35 Foldback Protection

3-36 In some applications either CV or CC mode may be regarded as an error condition. The foldback protection feature protects sensitive loads by disabling the power supply output if the unit switches to the prohibited mode.

3-37 In local control, foldback protection is toggled on or off by the FOLDBACK pushbutton switch. The output will be disabled if the power supply switches from whichever mode (CV or CC) is in operation when foldback is enabled to the other mode. In addition to turning foldback protection on and off, the FOLDBACK pushbutton switch also resets the foldback protection circuit if it has tripped. The conditions which caused foldback should be corrected before the circuit is reset, or the foldback protection circuit will trip again after reset. To turn off foldback protection if the foldback protection circuit has tripped, press the FOLDBACK switch twice in rapid succession, once to reset the foldback protection circuit and the second time to turn off foldback protection.

3-38 The green FOLDBACK ENABLED LED lights to indicate that foldback protection is enabled; the yellow FOLDBACK LED lights to indicate that the foldback protection circuit has tripped. Note the ERROR will light if an attempt is made to turn on foldback protection while the power supply is not in CV or CC mode.

3-39 When enabled via HP-IB foldback protection can be enabled for either mode, regardless of the operating state of the power supply when the command is received.

3-40 Remote Voltage Sensing

3-41 Because of the unavoidable voltage drop developed in the load leads, the strapping pattern shown in Figure 3-4 will not provide the best possible voltage regulation at the load. The remote sensing connections shown in Figure 3-6 improve the voltage regulation at the load by monitoring the voltage there instead of at the supply's output terminals. Remote sensing allows the power supply to automatically increase the output voltage and compensate for the voltage drops in the load leads. This improves the voltage regulation at the load, and is especially useful for CV operation with loads that vary and have significant load-lead resistance. Note that with remote sensing, voltage readback is at the load. Remote sensing has no effect during CC operation. When using remote sensing, turn off the power supply before changing the rear-panel straps, sense leads, or load leads. Connect the unit for remote voltage sensing by connecting load leads from +OUT and −OUT terminals to the load, disconnecting straps between +Out and +S and between −Out and −S, and connecting sense leads from the +S and -S terminals to the load as shown in Figure 3-6.

NOTE

Sensing is independent of other power supply functions; either local or remote sensing can be used regardless of how the power supply is programmed.

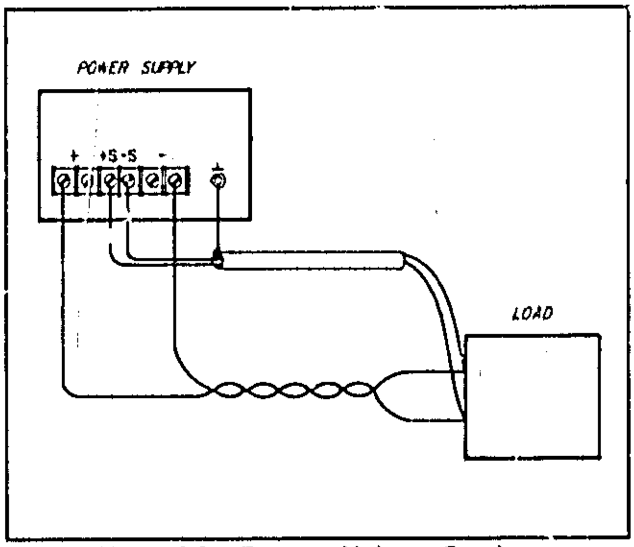


Figure 3-6. Remote Voltage Sensing

3-42 The load leads should be of the heaviest practical wire gauge, at least heavy enough to limit the voltage drop in each lead to 0.5 volts. The power supply has been designed to minimize the effects of long load-lead inductance, but best results will be obtained by using the shortest load leads practical.

NOTE

Remote voltage sensing compensates for a voltage drop of up to 0.5 V in each lead, and there may be up to a 0.12 V drop between the output terminal and the internal sensing resistor, at which point the OVP circuit is connected. Therefore, the voltage sensed by the OVP circuit could be as much as 1.12 V more than the voltage being regulated at the load. It may be necessary to readjust the OVP trip voltage when using remote sensing.

3-43 Because the sensing leads carry only a few milliamperes, the wires used for sensing can be much lighter than the load leads. Each sense lead should have no more than 0.2 ohms resistance. Use the resistivity columns in Table 3-2 to determine the minimum wire size for the length of sense leads being used. The sense leads should be a shielded, twisted pair to minimize the pickup of external noise. Any noise picked up on the sensing leads will appear at the supply's output, and CV load regulation may be adversely affected. The shield should be grounded at the power supply end only, and should not be used as one of the sensing conductors. The sensing leads should be connected as close to the load as possible.

3-44 If slightly degraded CV load regulation can be tolerated, the power supply will provide remote voltage sensing with up to 2 Vdc drop in each load lead and with more than 0.2 ohms resistance in each sense lead. As the voltage drop in the load leads increases, the load voltage error due to sense-lead resistance increases according to the formula:

$$\frac{(2Rs + 0.5)\ VI}{1000}$$

where Rs is the resistance in ohms of each sense lead and Vl is the voltage drop in each load lead. For example, if the resistance in each sense lead is 1 ohm and the voltage drop in each load lead is 2 Vdc, the load voltage is about (2(1) +0.5)2/1000 = 1.25 mVdc less than with zero sense-lead resistance.

3-45 The sensing leads are part of the supply's programming circuits, so they should be connected in such a way as to make it unlikely that they might inadvertently become open circuited. If the sense leads open during operation, the voltage at the load may rise above its programmed value.

NOTE

The power supply includes protection resistors which reduce the effect of open sense leads during remote-sensing operation. If the +S lead opens, the output voltage increases about 4% and is sensed between the +OUT terminal and the negative side of the load. If the −S lead opens the output voltage increases about 1% and is sensed between the positive side of the load and −OUT. If both sense leads open, the output voltage increases about 4.8% and is sensed locally.

3-46 Mode Switches

3-47 Table 3-4 shows six switches on the rear panel that configure the power supply for digital programming (either HP-IB or front-panel RPG) or analog programming (resistance or voltage). (Note that front panel programming is digital; the RPG produces pulses that are monitored by the microprocessor, which then raises or lowers the digital input to the DACs that control the power supply output.) Table 3-4 shows the proper switch settings for each programming mode. When shipped from the factory the switches are set for HP-IB/front-panel-RPG programming, which is the normal operating mode for this power supply. The two analog programming modes are available for use in special circumstances.

3-48 Typically, only one programming mode is used for both output parameters (voltage and current). However, the mode switches allow voltage and current to be programmed independently. For example, voltage could be programmed digitally, either via HP-IB or front panel, while current is resistance programmed. Note that only one programming mode can be used for each parameter at one time. (For example, it is not permissible to superimpose an analog programming voltage on the digital programming signal. To do so could cause programming errors.)

Table 3-4. Mode Switches

Mode Switches	Programming Mode		
	HP-IB/RPG	Voltage	Resistance
CV Circuits B6	0	0	1
CV Circuits B5	0	0	0
CV Circuits B4	1	0	0
CC Circuits B3	0	0	1
CC Circuits B2	0	0	0
CC Circuits B1	1	0	0

3-49 HP-IB

3-50 Connections between the power supply and the HP-IB are made via the HP-IB connector on the rear panel. Figure 3-7 shows the signals at each of the HP-IB connector pins. The HP-IB connectors table in Section 1 lists cables and cable accessories that are available from HP. The HP-IB connector uses metric threads, which are colored black. Cables manufactured prior to 1975 have non-metric fasteners, which are colored silver. Do not attempt to mate non-metric (silver) fasteners with metric (black) fasteners (see accessories table for conversion kit).

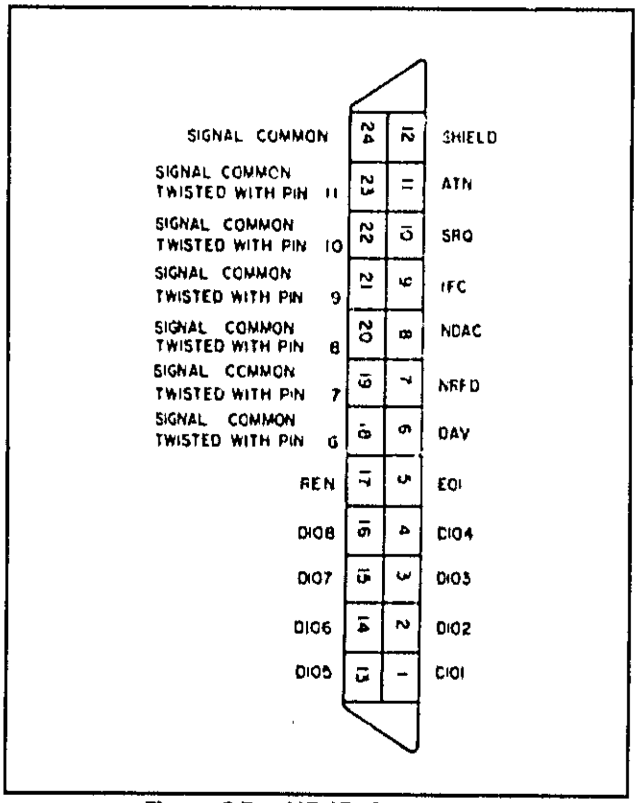


Figure 3-7. HP-IB Connector

3-51 An HP-IB system may be connected together in any configuration (star, linear or combination) as long as the following rules are followed:

1. The total number of devices is no more than 15.
2. The total length of all the cables used is no more than two metres times the number of devices connected together, up to an absolute maximum of 20 metres. (The length between adjacent devices is not critical as long as the total accumulated cable length is no more than the maximum allowed.)

NOTE

IEEE Std 488-1978 states that caution should be taken if individual cable length exceeds 4m.

3-52 It is recommended that no more than three connector blocks be stacked together, as the resultant leverage can exert excessive force on the mounting panels. Be certain that all connectors are full seated and that the lock screws are firmly finger tightened. Do not use a screwdriver. The screwdriver slots in the lock screws are provided for removal only.

3-53 Paragraph 3-75 provides information for operating the power supply in an HP-IB system. The Tutorial Description of the Hewlett-Packard Interface Bus and other documents listed in Section 1 provide additional information that may be helpful when designing an HP-IB system.

3-54 Monitor Signals

3-55 Amplified and buffered voltage and current monitor output signals are available at the rear-panel terminal strip. These signals can be connected to remote meters to indicate output voltage and current. The signals vary from 0 to 5 volts to indicate a zero to full-scale output. Both monitor-output terminals are referenced to the monitor-common terminal. Output impedance of the monitor terminals is 10.2 k ± 5%; a load of 1 megohm will maintain 1% reading accuracy.

3-56 Protective Circuits

3-57 Protective circuits within the power supply may limit or turn off the output in case of abnormal conditions. The cause of the protective action can be determined by observing the front panel indicators (lights and meters).

3-58 **Overrange.** If an overrange condition exists (load tries to draw more power than the supply can deliver), the OVERRANGE indicator turns on and both the CV and CC indicators are off. The product of the VOLTS and AMPS displays will exceed the maximum output power of the supply.

3-59 **Disabled.** If the power supply output is disabled, either by a command from HP-IB or by protective circuits within the power supply, the power supply output drops to zero and the DISABLED indicator turns on. The power supply can be disabled by overvoltage, overtemperature, or foldback (indicated by front-panel LEDs), by low or high ac line (mains) voltage, or by command from the controller (see Paragraph 3-141).

3-60 **Overvoltage.** If the voltage across the power supply output terminals rises above a preset level, possibly because of a hardware malfunction, the overvoltage protection (OVP) circuit will trip. If this occurs, the power supply will be disabled and the OV indicator turned on. To reset the OVP circuit, first ensure that the condition that caused the overvoltage is corrected. Then turn the power supply off and back on, or reset OVP via the HP-IB.

3-61 **Overtemperature.** If the overtemperature protection circuit trips, the power supply will be disabled and the OT indicator turned on. The overtemperature circuit will reset automatically and the power supply output will be restored when the temperature drops sufficiently for safe operation.

3-62 **AC Line Over/Under Voltage.** If the ac line (mains) input voltage increases or decreases beyond the range for safe operation the power supply output will be disabled. The power supply output will be restored when the input voltage is within range.

3-63 **Foldback.** If foldback protection is enabled (FOLDBACK ENABLED LED on) and the power supply switches to the prohibited mode (CV or CC), the power supply output will be disabled and the FOLDBACK indicator turned on. Press the FOLDBACK pushbutton switch to reset the foldback protection circuit and restore the power supply output. Unless the conditions (voltage setting, current setting, load resistance) that caused foldback are changed, the circuit will trip again when the output is restored. Pressing the FOLDBACK switch quickly a second time after resetting foldback will turn off foldback protection if desired.

3-64 **Error.** If the power supply receives an invalid command (syntax error, out of range), either locally or via HP-IB, the ERROR indicator turns on. The power supply ignores the invalid command and remains at previously set values. If the error was an attempt to exceed output limits using the front-panel OUTPUT ADJUST control (RPG), ERROR will turn off one second after RPG rotation stops.

3-65 LOCAL OPERATION

3-66 The power supply is configured for local operation when the unit is turned on. Output voltage and current are both set to zero, and the OUTPUT AJDUST knob is configured to adjust output current (CURRENT indicator is on). Pressing the OUTPUT ADJUST pushbutton switch alternately configures the OUTPUT ADJUST knob to adjust output voltage and current, as indicated by the VOLTAGE and CURRENT indicators. Note that the OUTPUT ADJUST knob to adjust output voltage the OUTPUT ADJUST knob will vary whichever output parameter, voltage or current, is indicated by the VOLTAGE and CURRENT indicators, even when the other parameter is limiting the output.

3-67 By pressing the DISPLAY SETTINGS pushbutton switch the operator can observe the setting (limits) of both output parameters, rather than the actual output values. This allows the operator to set the current limit when the power supply is operating in CV mode, or set the voltage limit while in CC mode, without the necessity of disconnecting or adjusting the load.

3-68 When the power supply is under remote control (RMT indicator on), neither the VOLTAGE or CURRENT indicator is on and the OUTPUT ADJUST knob has no effect.

3-69 Constant Voltage Operation

3-70 To set up the power supply for constant voltage operation:

a. With power supply turned off, connect load to output terminals.
b. Turn on power supply. Ensure that CURRENT indicator is on, hold DISPLAY SETTINGS pushbutton switch in, and rotate OUTPUT ADJUST knob to set desired current limit.
c. Press OUTPUT ADJUST switch once so that OUTPUT ADJUST knob controls voltage, and adjust output voltage to desired level.
d. Hold in DISPLAY OVP pushbutton switch and set OVP ADJUST potentiometer for desired OVP trip voltage.
e. If foldback protection is desired, press FOLDBACK pushbutton switch to enable this feature.
f. If a load change causes the current limit to be exceeded, the power supply automatically crosses over to constant current operation and the output voltage drops proportionately. If foldback protection is enabled, mode crossover causes the power supply output to be disabled. In setting the current limit, make adequate allowance for high current peaks that could cause unwanted mode crossover.

3-71 Constant Current Operation

3-72 To set up the power supply for constant current operation:

a. With power supply turned off, connect load to output terminals.
b. Turn on power supply. Press OUTPUT ADJUST pushbutton switch once so that VOLTAGE indicator turns on, hold DISPLAY SETTINGS pushbutton switch in, and rotate OUTPUT ADJUST knob to set desired voltage limit.
c. Press OUTPUT ADJUST switch once so that OUTPUT ADJUST knob controls current, and adjust output current to desired level.
d. Hold in DISPLAY OVP pushbutton switch and set OVP ADJUST potentiometer for desired OVP trip voltage. In CC mode the voltage setting will limit output voltage under quiescent conditions, and the OVP circuit provides added protection against hardware faults.
e. If foldback protection is desired, press FOLDBACK pushbutton switch to enable this feature.
f. If a load change causes the voltage limit to be exceeded, the power supply automatically crosses over to constant voltage operation and the output current drops proportionately. If foldback protection is enabled, mode crossover causes the power supply output to be disabled. In setting the voltage limit, make adequate allowance for voltage peaks that could cause unwanted mode crossover.

3-73 Return to Local

3-74 If the power supply is under remote control (RMT indicator on) and local lockout has not been sent (see Paragraph 3-88), pressing the LCL pushbutton switch will return the unit to local (front panel) control. Holding the LCL switch in will prevent the power supply from returning to remote control for as long as the LCL switch is held in or until local lockout is sent.

3-75 If the power supply has been disabled via HP-IB (DISABLED indicator on), the LCL switch will not restore the output. The only way to eliminate disable locally is to turn the LINE switch off and then back on. The OUTPUT ADJUST controls continue to operate in local control even if the power supply is disabled.

NOTE

Once the soft limits have been set by the controller via HP-IB, the OUTPUT ADJUST knob cannot obtain an output above these limits. This condition is true for both local and HP-IB control.

3-76 HP-IB OPERATION

3-77 Interface Functions

3-78 The power supply implements the following HP-IB interface functions, which are defined by IEEE standard 488:

SH1 (Source Handshake)
AH1 (Acceptor Handshake)
T1 (Talker)
L1 (Listener)
SR1 (Service Request)
RL1 (Remote Local)
PP1 (Parallel Poll)
DC1 (Device Clear)
DT1 (Device Trigger)

3-79 **Multiline Message Control Functions.** The Acceptor Handshake, Source Handshake, Listener, and Talker functions are implemented by the interface circuits of the power supply and the controller and require no action by the user. The LSN or TLK indicators turn on when the power supply is addressed to listen or talk. (The talker function includes serial poll, see paragraph 3-84.)

3-80 **Service Request.** Service request is a uniline message that can be asserted by the power supply to interrupt the controller. Service request can be generated by a power supply fault condition. The operator defines which of eight power supply conditions are defined as faults. Enabling or disabling a condition from asserting service request does not affect the condition within the power supply, nor does it affect the front-panel status indicators. Paragraphs 3-168 through 3-179 provide instructions for unmasking service request capability.

3-81 A service request can also be generated at power on (PON), depending on the setting of the rear-panel PON SRQ switch. Therefore, with PON SRQ enabled, if a momentary power dropout causes the power supply memory to lose its programmed values, PON alerts the operator that the power supply has been initialized (see Paragraph 3-100).

3-82 If the power supply fails self test at power on it will not respond to serial poll or any other commands on HP-IB. The user should include a time-out in his program after which the controller will not wait for the power supply to respond. If the time-out occurs, the power supply can be assumed to be malfunctioning and should be removed for service.

3-83 The SRQ indicator turns on whenever the power supply is requesting service from the controller, and remains on until the controller conducts a serial poll. Serial poll resets the SRQ bit and turns off the SRQ indicator, regardless of whether the fault that caused service request continues to exist.

3-84 **Serial Poll.** In a serial poll the controller polls each device on the bus, one at a time. The power supply responds by placing the contents of the eight-bit serial poll register on the HP-IB data lines. Table 3-5 defines each of the bits in the serial poll register and defines what causes each bit to be set and reset. Bit positions 0 through 7 are placed on DIO lines 1 through 8. Note that the serial poll register represents only the power supply connected to the HP-IB, not other power supplies that may be slaved to the HP-IB connected unit.

3-85 **Parallel Poll.** Parallel poll allows the controller to receive one bit of data from each of many or all instruments on the bus at the same time. In Hewlett-Packard power supplies this bit corresponds to bit 6, the RQS bit, of the serial poll register. Because the controller can receive this bit from at least eight instruments at one time, the controller can determine quickly which of a number of instruments on the bus requested service. The controller can then query that instrument to determine the cause of the service request. Parallel poll does not reset the service request bit in the power supply. The power supply's response to parallel poll can be configured remotely from the controller, or it can be configured locally.

NOTE

IEEE-488 does not define what data an instrument should put on the bus in response to parallel poll. Many instruments, such as Hewlett-Packard power supplies, indicate the state of their RQS bit, but the operator should not assume that all instruments on the bus respond to parallel poll with their RQS bit.

Table 3-5. Serial Poll Register

Bit Position	7	6	5	4	3	2	1	0
Bit Weight	128	64	32	16	8	4	2	1
Condition	-	RQS	ERR	RDY	-	-	PON	FAU

RQS Requesting Service
ERR Remote Programming Error
RDY Ready to Process Commands
PON Power On Reset
FAU Fault Condition

RQS is set when power supply generates a service request, and is reset immediately after a serial poll is conducted.

ERR follows ERR bit in Status Register, which is set whenever power supply detects a remote programming error. ERR is reset by ERR? query.

RDY is set whenever power supply finishes processing a command, and is reset when power supply starts to process a new command. Note that power supply input buffer can accept new commands via HP-IB even while unit is busy processing previously received commands.

PON is set when ac input power is turned on and is reset by CLR command or Device Clear interface message. PON is set in serial poll register regardless of whether PON SRQ is enabled by rear-panel switch.

FAU is set when any bit is set in Fault Register and is reset by FAULT? query.

3-86 Unless configured remotely, the power supply responds to a parallel poll with a "1" on one of the DIO lines (if requesting service), as determined by the setting of its address switches. Addresses 0 through 7 correspond to DIO lines 1 through 8 (decimal weight 2^0 through 2^7). If the address switches are set to 8 or higher, the power supply will not respond to a parallel poll unless the unit is configured remotely. The power supply can not return a "0" to indicate it was requesting service unless it has been configured remotely.

3-87 The power supply can be configured remotely to respond to a parallel poll with either a "1" or a "0" on one of the DIO lines if the unit is requesting service. Configuration statements with a decimal value of 0 through 7 will configure the unit to respond with a "0" on one of the DIO lines 1 through 8; decimal values of 8 through 15 configure the unit to respond with a "1" on one of DIO lines 1 through 8. By configuring the power supply remotely, the address switches may be set to any address from 0 through 30 without affecting the parallel poll response. The capability to configure either a "0" or "1" response allows the user to AND or OR two or more instruments on one DIO line.

3-88 **Remote/Local.** The remote/local function allows the power supply to operate in either local (front panel) or remote (via HP-IB) control. The user can send Local Lockout to the power supply via HP-IB to disable the front-panel LCL switch only. With Local Lockout, the controller determines if the unit operates in local or remote control; this enables the controller to prevent anyone else from returning the power supply to local control.

3-89 **Device Clear.** Device Clear is implemented in the power supply as Clear (see Paragraph 3-180). The difference between Clear and Device Clear is that Device Clear can be an unaddressed or addressed command. Device Clear is typically used in systems to send all devices in the system to a known state with a single command (which could be generated by a "panic" button).

3-90 **Device Trigger.** Device Trigger is implemented in the power supply as Trigger (see Paragraph 3-153). Each device that is to respond to Device Trigger must be addressed. Device Trigger is typically used in systems to synchronize the operation of a number of addressed devices.

3-91 HP-IB Address Selection

3-92 The five HP-IB address switches are located on the rear panel. The HP-IB address is set in binary, with A1 the least significant bit and A5 the most significant bit. Figure 3-8 shows the factory-set address of "5" (binary 00101). Any address from 00 to 30 decimal (00000 to 11110 binary) is a valid HP-IB address. The power supply will operate on whatever valid address is set on the address switches. Address 31 will cause a self-test error.

3-93 The operator should be aware that some other instruments on the HP-IB may initialize at a particular address although they can be programmed subsequently to respond to a different address. If the system includes instruments with this characteristic and they are programmed for addresses other than their initialized address, a momentary input power dropout may cause them to re-initialize their address. If another instrument, such as the power supply, is hardware set to that address, the system will not function properly. Therefore, the system program should be written to monitor any re-initialization. Any programmed data, such as addresses, that may have been lost will then have to be reset.

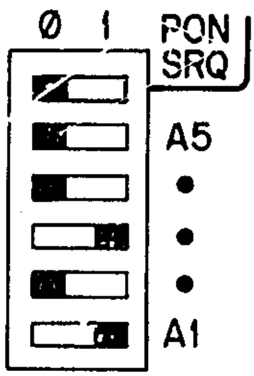


Figure 3-8. HP-IB Address/PON SRQ Switches

3-94 Holding the LCL switch in for one second causes the power supply's HP-IB address to be displayed on the front panel until the switch is released or two seconds elapse.

3-95 The address switches are also used during troubleshooting to select which self tests are run in test mode. If the power supply has been serviced be certain to check the HP-IB address switches.

3-96 Note that the top switch in the six-switch package is not an HP-IB address switch. Be careful to use the bottom five switches for setting the HP-IB address. The following paragraph provides instructions for setting the top switch.

3-97 Power-On Service Request

3-98 The power supply can request service from the controller when power is turned on. Power-on service request (PON SRQ) is enabled or disabled by the rear-panel PON SRQ switch, and cannot be controlled by commands via HP-IB. The service request bit is reset by a serial poll, regardless of whether set by power-on or some other cause.

3-99 To enable power-on to request service, set the PON SRQ switch to "1", as shown in Figure 3-8. If enabled, PON SRQ will request service when the power supply is turned on or any time a momentary input power dropout causes the power supply to re-initialize.

3-100 Initial Conditions

3-101 The power supply initializes at power on programmed with the values listed in Table 3-6.

Table 3-6. Initial Conditions

Voltage	0 Volts
Current	0 Amps
OUTPUT ADJUST control	adjusts CURRENT
OVP Trip Voltage	determined by setting of OVP ADJUST potentiometer on front panel
Soft Voltage Limit	61.425 volts
Soft Current Limit	10.2375 amps
Delay	0.5 seconds
Foldback Protection	off
Output	on
Unmask	none
Hold	off
Store/Recall	all storage registers loaded with initial conditions of unit (output on/off is not stored)

3-102 Programming Syntax

3-103 The following paragraphs describe how to program the power supply via the HP-IB. These instructions concern device-dependent messages, such as setting output voltage. Interface management messages, such as serial poll, have been described previously under Paragraph 3-77, Interface Functions.

3-104 Table 3-7 lists each of the device-dependent commands, the range of each parameter sent to the power supply or the response of the power supply to a query from the controller, and a brief description of each command. Also included is the number of the paragraph in which each command is described more fully. If no unit is specified where appropriate in data sent to the power supply, the power supply selects S.I. units (V,A,s). Paragraphs 3-105 through 3-122 provide general rules that apply to all commands.

NOTE

Lower-case alpha characters sent to the power supply are treated as upper-case alpha characters.

3-105 **Numbers Sent to Power Supply.** Numbers can be sent to the power supply either with implicit or explicit decimal point notation, and with or without a scale factor (scientific notation), allowing use with controllers having a wide variety of output formats.

3-106 Numbers written in implicit point notation do not contain a decimal point; for example, 123 for one hundred twenty three. Numbers written in explicit point notation contain a decimal point, such as 1.23.

3-107 In scientific notation the letter "E" stands for "10 raised to". For example, 1.23E4 would be read as 1.23 times 10^4, which equals 12,300.

3-108 Plus and minus signs are considered numeric characters. All numeric data fields may contain an optional plus or minus sign on both the number itself and the scale factor, such as +1.23E-2.

3-109 All numeric data fields may contain leading spaces, and embedded spaces will be accepted between optional signs and digits, digits and E, decimal point and E, and E and optional sign. The following two examples contain one embedded space in each position in which they are allowed:

+ 1.23 E + 4   + 123. E + 4

Embedded spaces will not be accepted between digits or between digits and decimal point.

3-110 At least one digit must precede E. For example, 1E +4 is correct, E +4 is incorrect. Lower case e is treated the same as upper case E.

3-111 **Numbers Returned To Controller.** The format of numbers returned to the controller depends upon the type of data requested, and is given in Table 3-8.

3-112 Leading zeroes are sent as spaces, except that the first digit to the left of a decimal point is never sent as a space.

3-113 All numeric data sent to the controller are preceded by a header consisting of alpha characters that identify the type of data, such as VOUT or ISET. The header consists of upper case characters only, with no embedded spaces. No suffixes are attached to numeric data.

3-114 **Separators For Data Sent To Power Supply.** Separators are used by the power supply to break up commands into pieces, called tokens, which it can interpret. Separation of commands into tokens is accomplished either explicitly by the insertion of separator characters or implicitly by noting a change from one class of input to another.

3-115 The explicit separators are commas and spaces. An explicit separator is required between tokens consisting of alpha characters. For example, SRQ ON is correct, SRQON is not correct. Commas are used only to separate parameters in commands containing more than one parameter. UNMASK is the only command for which more than one parameter may be sent. Only one comma is allowed, and it may be preceded or followed by any number of spaces. For example, both these commands are correct:

UNMASK CC,OR,FOLD

UNMASK CC, OR, FOLD

but this command is incorrect:

UNMASK CC OR FOLD

Spaces are used in all other cases requiring explicit separators. Any number of consecutive spaces is treated as one space.

Table 3-7. HP-IB Commands

Command	*Range or **Response to Query	Description	Paragraph
VSET x VSET xV VSET xMV	*0–61.425 V *0–61425 MV	Any of these commands is used to program output voltage. Initial Condition: 0 V	3-123–3-124
ISET x ISET xA ISET xMA	*0–10.2375A *0–10237.5MA	Any of these commands is used to program output current. Initial Condition: 0 A	3-127–3-128
VSET? ISET?	**VSET xx.xxx **ISET xx.xxx	Used to read voltage and current settings.	3-125, 3-129
VOUT? IOUT?	**VOUT xx.xxx **IOUT xx.xxx	Used to measure and read output voltage or current.	3-126, 3-130
OVP?	**OVP xx.xx	Causes power supply to measure OVP setting (which is hardware set at front panel).	3-131
VMAX x VMAX xV VMAX xMV	*0–61.425V *0–61425MV	Any of these commands is used to program an upper limit (soft limit) on the voltage programming value that the power supply will accept. Initial Condition: 61.425V	3-132, 3-133
IMAX x IMAX xA IMAX xMA	*0–10.2375A *0–10237.5MA	Any of these commands is used to program an upper limit (soft limit) on the current programming value that the power supply will accept. Initial Condition: 10.2375A	3-132, 3-133
VMAX? IMAX?	**VMAX xx.xxx **IMAX xx.xxx	Used to read voltage and current limits (soft limits).	3-134
DLY x DLY xS DLY xMS	*0–31.999S *0–31999MS	Any of these commands is used to program the delay time after a new output voltage or current is implemented, or RST or OUT ON command is received. During delay time power supply disables CV, CC, and OR conditions from being labeled as faults, and disables foldback protection. Initial Condition: 0.5 s	3-135–3-138
DLY?	**DLY xx.xxx	Used to read delay time setting.	3-139
OUT OFF OUT 0 OUT ON OUT 1		Enables or disables power supply output. Power supply remains able to implement commands even while output is disabled. Initial Condition: OUT ON	3-141–3-143

Table 3-7. HP-IB Commands (continued)

Command	*Range or **Response to Query	Description	Paragraph
OUT?	**OUT 0 or **OUT 1	Used to read OUTPUT ON/OFF setting.	3-144
{FOLD OFF FOLD 0 {FOLD CV FOLD 1 {FOLD CC FOLD 2		Enables or disables foldback protection, which will disable power supply output if power supply switches to whichever mode, CV or CC, is defined as the fold (error) condition. Foldback protection is inhibited during DELAY period. Initial Condition: FOLD OFF.	3-145—3-147
FOLD?	**FOLD 0 or **FOLD 1 or **FOLD 2	Used to read FOLDBACK setting.	3-148
RST		Used to reset power supply if output is disabled by overvoltage or foldback protection circuits. Power supply resets to present voltage and current settings (values can be changed while unit is disabled).	3-149—3-150
{HOLD OFF HOLD 0 {HOLD ON HOLD 1		Determine if certain newly received commands are implemented by power supply upon receipt or are held for later implementation while power supply continues to operate with previously received values. HOLD ON can be used to synchronize power supply changes with actions taken by other devices on the HP-IB. See TRG command. Initial Condition: HOLD OFF	3-151—3-158
HOLD?	**HOLD 0 or **HOLD 1	Used to read HOLD setting.	3-154
{T TRG		Used to implement commands that have been sent to and held by the power supply (power supply continues to operate with previous values until trigger command is received). See HOLD command. The device trigger interface message performs the same function.	3-155
STO x RCL x	*0—15	Cause power supply to store and recall up to 16 sets of the complete machine state except for output on/off. Machine state consists of: programmed voltage (first and second rank), programmed current (first and second rank), soft voltage limit, soft current limit, delay time, service request on/off, foldback (first and second rank), mask (first and second rank), and hold. Initial Condition: Each storage register is initialized to the turn-on values.	3-159—3-160

Table 3-7. HP-IB Commands (continued)

Command	*Range or **Response to Query	Description	Paragraph
STS?	**STS xxx	Used to read the contents of the status register, which maintains the present status of the power supply. See Table 3-9 for a description of each bit in the status register, and the bit weight for each condition.	3-161—3-164
ASTS?	**ASTS xxx	Used to read the contents of the accumulated-status register, which stores any bit that was entered in the status register since the accumulated-status register was last read, regardless of whether the condition still exists. The bit descriptions and weights are the same as in the status register, see Table 3-9.	3-165—3-167
UNMASK mnemonics UNMASK xxx		Determines which conditions are capable of setting bits in the FAULT register; therefore, allows operator to define which conditions are fault conditions. Conditions can be enabled either by sending a string of mnemonics after the command UNMASK, or by sending the decimal equivalent of the total bit weight for all conditions to be enabled. The mnemonics and bit weights are the same as in the status register, see Table 3-9. Mnemonics are separated from each other by commas, and may be sent in any combination and in any order. The command UNMASK NONE disables all conditions from setting bits in fault register. Initial Condition: UNMASK NONE	3-168—3-172
UNMASK?	**UNMASK xxx	Used to read which bits in the status register have been enabled to set bits in the fault register (i.e.,which power supply conditions are defined as faults). xxx is decoded using bit weights in Table 3-9.	3-173
FAULT?	**FAULT xxx	Used to read which bits have been set in the fault register. A bit is set in the fault register when the corresponding bit in the status register changes from inactive to active AND the corresponding bit in the mask register is set. Bits in the fault register are reset only after the fault register is read. xxx is decoded using bit weights in Table 3-9.	3-174—3-175
SRQ OFF SRQ 0 SRQ ON SRQ 1		Enable or disable power supply's ability to request service from the controller for fault conditions. UNMASK command defines which power supply conditions SRQ are defined as faults. Initial Condition: SRQ OFF	3-176—3-177

Table 3-7. HP-IB Commands (continued)

Command	*Range or **Response to Query	Description	Paragraph
SRQ?	**SRQ 0 or **SRQ 1	Used to read SRQ setting.	3-178
CLR		Used to initialize power supply to power-on state; also resets the PON bit in the serial poll register. The device clear interface message performs the same function.	3-180—3-182
ERR?	**ERR xx	Used to determine type of programming error detected by power supply. A remote programming error will set the ERR bit in the status register, which can be enabled by UNMASK to request service. See Table 3-10 for descriptions of error codes.	3-183—3-185
TEST?	**TEST xx	Causes power supply to run self tests and report any failures. Type of tests run depends on whether power supply output is on or off.	3-186--3-192
ID?	**HP6038A or **HP6038A, OPT 100	Causes power supply to report its model number and any options that affect the unit's output capability.	
ROM?	**ROM xx.xx	Causes power supply to report the date code of HP-IB ROM.	

[Bracketed commands are equivalent.
x = any digit (within range)
MV = millivolt
MA = milliamp
MS = millisecond
** Query causes power supply to clear output buffer, gather requested data, and store it in output buffer. Data will be put on HP-IB when power supply is addressed to talk and ATN goes false. Only most recently requested data is stored, and it is not saved after being put on HP-IB.

3-116 Implicit separation occurs when the received characters change from upper or lower case alpha (A...Z, a...z) to numeric (+, −,0...9). Spaces may also be used where implicit separation takes places. For example, both the following commands are correct:

VSET 5 V   VSET5V

The question mark is implicitly separated from alpha characters, for example:

VMAX?   VMAX ?

are both correct.

3-117 **Terminators for Data Sent to Power Supply.** Terminators mark the end of a command string, and they instruct the power supply that the command it has just received should be executed. The terminator characters are the line feed and semicolon.

3-118 Line feed is sent by all HP controllers automatically after wrt or OUTPUT statements unless deliberately suppressed, so the user need not include a terminator when only one command is sent per line. If the user wishes to send more than one command per line the commands must be separated by semicolons.

3-119 Any number of consecutive terminators is treated as one. A terminator may be preceded or followed by any number of spaces, for example:

VOUT 15V;IOUT 5A

VOUT 15V ; IOUT 5A

are both correct.

3-120 The carriage return character by itself is not sufficient to terminate a command, but it will be accepted without error in all cases where a terminator or separator is expected.

Table 3-8. Format of Numbers Sent from Power Supply

For these query commands:

VSET?	ISET?	DLY?
VOUT?	IOUT?	
VMAX?	IMAX?	

the response consists of a header followed by a space* followed by 5 decimal digits with an embedded decimal point, in this format:

<header> < space >d.dddd
to
<header>space>dddd.d

The header consists of the query alpha characters without the question mark. Leading zeroes are sent as spaces, except that the first digit to the left of the decimal point is never sent as a space.

*A minus sign can be sent instead of a space for VOUT, IOUT, and OVP.

For these query commands:

STS?	FAULT?
ASTS?	ERR?
UNMASK?	TEST?

the response consists of a header followed by a space followed by three decimal digits with an implicit decimal point, in this format:

<header> <space>ddd

The header consists of the query alpha characters without the question mark. Leading zeroes are sent as spaces.

For these query commands:

FOLD?	HOLD?
OUT?	SRQ?

the response consists of a header followed by a space followed by a single digit, in this format:

<header>space>d

The header consists of the query alpha characters without the question mark.

3-121 Command may also be terminated by asserting EOI on the HP-IB concurrently with the last character of the command. For example:

VSET 1.23
E
O
I

requires no semicolon or linefeed. Asserting EOI in conjunction with a terminator will have no adverse effect.

3-122 **Termination for Data Sent to Controller.** All data returned to the controller are terminated by a carriage return character followed immediately by a linefeed character. EOI is asserted concurrently with linefeed.

3-123 **Voltage Setting.** Voltage is programmed in either volts or millivolts using any of the following codes (the value 5 is used as an example):

VSET 5

VSET 5 V

VSET 5 MV

3-124 The programmed voltage is the actual output if the power supply is in CV mode, or the voltage limit if the power supply is in CC mode.

3-125 The voltage setting may be read by sending:

VSET?

and addressing the power supply to talk.

3-126 The power supply can be instructed to measure its actual output voltage by sending:

VOUT?

The results are placed on the HP-IB when the power supply is addressed to talk, in this format (using 20 as an example):

VOUT 20.000

NOTE

The programming resolution (LSB) for the VSET and ISET commands are 15 mV and 2.5 mA respectively. The power supply will round off settings received to the nearest multiple of these values.

3-127 **Current Setting.** Current is programmed in either amps or milliamps using any of the following codes (the value 10 is used as an example):

ISET 10

ISET 10A

ISET 10MA

3-128 The programmed current is the actual output if the power supply is in CC mode, or the current limit if the power supply is in CV mode.

3-129 The current setting may be read by sending:

ISET?

and addressing the power supply to talk.

3-130 The power supply can be instructed to measure its actual output current by sending:

IOUT?

The results are placed on the HP-IB when the power supply is addressed to talk, in this format (using 10 as an example):

IOUT 10.000

3-131 **OVP Measurement.** OVP trip voltage is hardware set at the power supply front panel. The power supply can be instructed to measure the OVP trip voltage by sending:

OVP?

The results are placed on the HP-IB when the power supply is addressed to talk, in this format (using 60 as an example):

OVP 60.000

3-132 **Soft Limits.** The power supply can be sent soft limit values that place maximum limits on the voltage and current programming values that will be accepted. If the power supply receives a programming value that exceeds the soft limit, it will ignore the command, turn on the ERROR indicator, and set the ERR bits in the status register and in the serial poll register. The power supply will not accept soft limit values that are lower than present output values or values that are being held. The largest soft limit values which can be sent are 61.425 V and 10.2375 A. These values also define the initial condition.

3-133 Soft limits are programmed using any of the following codes (the values 15 and 10 are used as examples):

VMAX 15	IMAX 10
VMAX 15V	IMAX 10A
VMAX 15MV	IMAX 10MA

3-134 The soft limits may be read by sending:

VMAX? IMAX?

and addressing the power supply to talk. The response from the power supply is in this format (using 15 and 10 as examples):

VMAX 15.000 IMAX 10.000

3-135 **Delay.** The power supply output may switch modes or be unregulated momentarily after a new output value is programmed or the output is reset from zero. In most cases this temporary condition would not be considered a fault, and foldback or a service request would be a nuisance. Delay operates to mask CV, CC, and OR conditions from the fault register for a specific period after a new output value is programmed. The delay is initiated after the following commands:

OUT ON

RST

T, TRG, or Device Trigger

VSET OR ISET if hold is off

3-136 The power supply initializes with a delay of 0.5 seconds, which is appropriate in most cases. In some cases a longer or shorter delay may be required. For example, when up-programming output voltage with a very low current limit, CC mode may persist longer than 0.5 seconds.

3-137 Factors that influence how long the mode change or unregulated condition may last include: difference between old output value and new output value, current or voltage limit, and output (load) capacitance (for CV mode) or output inductance (for CC mode). The delay required must be determined empirically; the programming-response times in the specifications table, Section I, can be used as guidelines.

3-138 Delay can be programmed in 1 ms increments using either of the following codes (31999 used as an example):

DLY 31.999S

DLY 31999MS

3-139 Delay value may be read by sending:

DLY?

and addressing the power supply to talk. The response from the power supply is in this format (using 0.5 as an example):

DLY 0.500

3-140 Note that during the delay period CV and CC are masked from the foldback protection feature also. Delay does not affect the setting of the CV, CC, or OR bits in the status register or astatus register; delay affects only the setting of those bits in the fault register. Delay does not affect conditions other than CV, CC, or OR that may cause service request, nor will delay affect CV, CC, or OR if they occur at any time other than after a programmed output change.

3-141 **Output On/Off.** The power supply output can be turned on and off using these commands:

OUT OFF or OUT 0

OUT ON or OUT 1

3-142 OUT OFF does not affect the voltage and current settings. OUT ON enables the power supply and returns the output to the present voltage and current settings, which can be changed while the output is off. OUT ON will not reset OVP or foldback protection.

3-143 Output on/off is particularly useful when storing values for later recall. (Note that output on/off is the only programmable state that is not stored.) With the output off, the user can set up and store as many as 16 versions of the complete machine state without having the output change to a particular set of values until that setup is required.

3-144 The state of the output on/off function may be read by sending:

OUT ?

and addressing the power supply to talk. The response from the power supply is in this format:

OUT 0 or OUT 1

in which 0 indicates that the power supply output is off, and 1 indicates it is on.

3-145 **Foldback Protection.** As described in Paragraph 3-35, foldback protection can be enabled to turn off the power supply output if the power supply switches from the protected operating mode (either CV or CC) to the other mode. If the power supply changes to the specified mode, the output will be turned off and the DISABLED and FOLDBACK indicators will turn on. To prevent nuisance tripping while the output is being reprogrammed, foldback protection is inhibited during the delay period.

3-146 Foldback protection is programmed using these codes:

FOLD OFF or FOLD 0
FOLD CV or FOLD 1
FOLD CC or FOLD 2

3-147 FOLD CV means that the power supply should be operating in CC Mode, and foldback protection will turn off the output if the power supply switches to CV mode. FOLD CC means that foldback occurs if the power supply switches to CC mode.

3-148 The state of the foldback protection function may be read by sending:

FOLD?

and addressing the power supply to talk. The response from the power supply is in this format:

FOLD 0 or FOLD1 or FOLD2

in which 0 indicates that foldback protection is off, 1 indicates that foldback protection will trip if the power supply switches to CV mode, and 2 indicates that foldback protection will trip if the power supply switches to CC mode.

3-149 **Reset.** Reset restores the power supply output if it has been disabled by OVP or foldback. The output returns to the present voltage and current settings; the values may be changed while the output is disabled. The power supply is reset with the command:

RST

3-150 Note that if the condition which caused OVP or foldback remains, the power supply output will be disabled again after reset. If the power supply output is disabled repeatedly, check that the OVP setting and delay time are appropriate for the application.

3-151 **Hold and Trigger.** The power supply contains first-rank and second-rank storage registers for values of voltage setting, current setting, foldback, and mask. The operating values are stored in the second rank, but the first rank can receive and hold different values for later implementation. With hold turned on, values in first rank are moved to second rank only upon receipt of a trigger or device trigger command.

3-152 This feature allows synchronization of multiple instruments on the HP-IB, and also ensures that new values are implemented at the same time within a single instrument. With hold turned off, values are loaded into both first and second rank when received.

3-153 Hold is turned on and off using these codes:

HOLD OFF or HOLD 0

HOLD ON or HOLD 1

3-154 The state of the hold on/off function may be read by sending:

HOLD?

and addressing the power supply to talk. The response from the power supply is in this format:

HOLD 0 or HOLD 1

in which 0 indicates that hold is turned off, and 1 indicates that hold is turned on.

3-155 Values that are held in first rank can be shifted to second rank (operating values) using either of these commands.

TRG or T

The device trigger interface command will also shift data from first rank to second rank.

3-156 Voltage and current values are compared to soft limits before being loaded into either first or second rank, and new soft limits are compared to values already programmed in both first and second rank. Any discrepancy between first and second rank voltage or current settings and voltage or current soft limits will result in an error condition.

3-157 The power supply has been designed to allow it to enforce sequential device command processing, which means that a second instrument on the HP-IB will not begin to receive commands until the power supply has finished processing its commands. The power supply can accept data much faster than it can process data. Therefore, if a second instrument had less data to process than the first had, the second instrument could start changing its output before the first instrument output started changing, even though the first instrument may have accepted all of its data before the second instrument began to receive its data. When using device trigger (an HP-IB interface function), the HP-IB interface circuit in the power supply will not finish the handshake of the GET message (Group Execute Trigger) until all commands have been processed and the trigger action has been completed. The controller cannot send commands to a second instrument until the handshake is completed with the first. Therefore, sending device trigger after sending a command assures that the second instrument cannot begin to receive commands until the first instrument has processed its commands.

3-158 For example, assume the following commands are sent to four power supplies assigned to addresses called PS1, PS2, PS3, and PS4:

OUTPUT PS1; "HOLD ON; ISET 10A"
OUTPUT PS2; "HOLD ON; ISET 1A"
TRIGGER PS1
TRIGGER PS2
OUTPUT PS3; "HOLD OFF; ISET 5A"
TRIGGER PS3
OUTPUT PS4; "HOLD OFF; ISET 5A"

Power supply 2 will start to change only after power supply 1 has started to change, and power supply 4 will start to change only after power supply 3 has started to change. Note that this feature concerns only the processing of the HP-IB command, the time required for the power supplies to settle at their new values depends on the load and on the direction and amount of change.

3-159 **Store/Recall.** The power supply can store up to 16 complete power supply states except for output on/off. This allows the operator to preset frequently used values, which can then be recalled when needed with a single command. Preset values are stored and recalled using these codes (3 and 11 used as examples):

STO 3
RCL 11

3-160 Sending a store command causes a "snapshot" of the present machine state to be stored. The power supply can then be programmed with new values. Note that only those values to be changed need be reprogrammed. For example, if the following command strings were sent in listed order to the power supply, the string stored in register 1 would include a current setting of 2A and CC foldback in addition to a voltage setting of 8V. The string stored in register 2 would include a voltage setting of 8V in addition to a current setting of 10A and CV foldback. Note that the power supply output would not change while the three preset states were being stored because the output was turned off. The store/recall designators need not be assigned in consecutive order, but they must be in the range of 0 to 15.

OUT OFF
VSET 5V; ISET 2A; FOLD CC; STO 0
VSET 8V; STO 1
ISET 10A; FOLD CV; STO 2

3-161 **Status Register.** The power supply maintains an 8-bit status register that reflects the present state of the unit. Each of the eight bits represents a separate condition; when the condition is true the corresponding bit is 1. Bits are assigned as shown in Table 3-9.

3-162 The status register can be read by sending:

STS?

and addressing the power supply to talk. The response from the power supply is in this format:

STS xxx

where xxx is a string of ASCII decimal digits. These digits specify an integer which is equal to the sum of the bit weights of the true conditions.

3-163 For example, if bits for both ERR (128) and CC (2) are set, the power supply would send ASCII digits 1 3 0 (128 +2 = 130).

3-164 Bits remain set in the status register as long as the corresponding conditions are true.

Table 3-9. Status Register

Bit Position	7	6	5	4	3	2	1	0
Bit Weight	128	64	32	16	8	4	2	1
Condition	ERR	FOLD	AC	OT	OV	OR	CC	CV

CV	Constant Voltage Mode
CC	Constant Current Mode
OR	Overrange
OV	Overvoltage Protection Circuit Tripped
OT	Overtemperature Protection Circuit Tripped
AC	AC Line Dropout or Out of Range
FOLD	Foldback Protection Circuit Tripped
ERR	Remote Programming Error

3-165 **Accumulated Status Register.** Reading the status register provides the controller only the state of the power supply at the time STS? was received. A condition that lasts only momentarily may not be observed even with frequent polling of the status register. To ensure that a temporary change can be noted by the controller, the power supply maintains an accumulated status (astatus) register. Table 3-9 describes the astatus register as well as the status register. A bit in the astatus register will be 1 if the corresponding bit in the status register has been 1 at any time since the astatus register was last read.

3-166 The astatus register can be read by sending:

ASTS?

and addressing the power supply to talk. The response from the power supply is in this format:

ASTS xxx

where xxx is decoded the same way as in the status register readback.

3-167 The astatus register is reset to the present value of the status register immediately after it is read by the ASTS? query.

3-168 **Mask and Fault Registers.** The power supply has two additional registers, the mask register and the fault register, both of which are arranged like the status register (Table 3-9).

The mask register is maintained by the user, and is used to specify which bits in the status register are enabled (unmasked) to set bits in the fault register. A bit is set in the fault register when the corresponding bit in the status register changes from 0 to 1 and the corresponding bit in the mask register is 1. Whenever any bit is set in the fault register the FAU bit is set in the serial poll register.

3-169 Note that bits can be set in the fault register only when there is a change in either the status register or the mask register. Therefore, if a bit is set in the mask register (unmasked) after the corresponding condition becomes true in the status register, the associated bit will also be set in the fault register.

3-170 Bits may be set in the mask register (conditions unmasked) in either of two ways. The UNMASK command may be followed by mnemonics which specify which conditions are unmasked (enabled to set bits in the fault register), or the UNMASK command may be followed by a decimal number that is the sum of the weights of the bits to be set. The mnemonics and bit weights are the same as in Table 3-9. The mnemonic NONE or decimal number 0 will clear all bits in the mask register.

3-171 Bits are set in the mask register with either of the following codes (ERR/128, OR/4, and CC/2 used as examples):

UNMASK CC, OR, ERR

or

UNMASK 134

3-172 Mnemonics may be sent in any order, and they must be seperated by commas. Note that the mask register does not affect the status register, it simply determines which bits in the status register can set bits in the fault register.

3-173 The mask register may be read by sending:

UNMASK?

and addressing the power supply to talk. The response from the power supply will be in this format (using 134 as an example):

UNMASK 134

3-174 The fault register may be read by sending:

FAULT?

and addressing the power supply to talk. The response from the power supply will be in this format (using 134 as an example):

FAULT 134

3-175 The fault register is cleared immediately after it is read by the FAULT? query.

3-176 **Service Request.** In some applications it may be desirable to interrupt the controller when a power supply fault condition occurs. The power supply interrupts the controller by asserting the service request (SRQ) line on the HP-IB. The ability to generate service requests for fault conditions can be turned on and off using the following commands:

SRQ OFF or SRQ 0

SRQ ON or SRQ 1

3-177 The service request function allows use of either polling or interrupt programming. With SRQ on, the SRQ line will be asserted true whenever the FAU bit in the serial poll register changes from 0 to 1. Therefore, the mask register, in addition to specifying which conditions set the FAU bit, also determines which conditions can generate service requests. Use of the FAULT? query will tell the user which condition caused the service request (except for PON).

3-178 The state of the service request on/off function may be read by sending:

SRQ?

and addressing the power supply to talk. The response from the power supply is in this format:

SRQ 0 or SRQ 1

in which 0 indicates that service request capability is disabled, and 1 indicates it is enabled.

3-179 Note that service request capability for power on is controlled by the rear-panel PON SRQ switch, the setting of which will not be indicated in response to an SRQ? query.

3-180 **Clear.** The power supply can be returned to its power-on state with the command:

CLR

or by sending a device clear interface command. Clear is typically used to initialize the power supply to a known state at the beginning of a program. Clear also resets the PON bit in the serial poll register.

3-181 The clear command does not complete until the power supply control circuits have had time to settle. This prevents perturbations on the power supply output, regardless of the state before the clear command was sent. The clear command takes about 500 ms to execute.

3-182 Note that stored preset states (as many as 16) are not changed by the clear command.

3-183 **Error.** When the power supply detects a remote programming error it sets the ERR bit in the status register, which can be unmasked to request service, and it turns on the front-panel ERROR indicator. Programming errors are usually the result of misspelled words or forgotten separators. When the power supply detects a programming error it dumps whatever portion of the command it has received and ignores all further characters until a terminator is received.

3-184 The type of error detected can be determined by sending:

ERR?

and addressing the power supply to talk. The response from the power supply is in this format:

ERR x

where x is a decimal digit from 0 to 8.

3-185 Table 3-10 lists the error codes with descriptions of each.

3-186 **Test.** The power supply runs a series of self tests when it is turned on, and selected tests can be run for troubleshooting (see Section V). Either of two subsets of the self tests can be run by command from the controller. Self tests can be invoked via the HP-IB by sending the command:

TEST?

3-187 The type of self test performed depends on whether the power supply output is turned on or off. See Section V for a description of each of the self tests.

3-188 If the power supply output is disabled (OUT OFF command has been sent), the following tests are performed:

RAM Test #2
ROM Test
Real-Time Clock Test
Serializer Test
PSI Digital I/O Test
PSI DAC/ADC Test

3-189 If the power supply output is enabled (output is on), only these tests are performed:

RAM Test #2
ROM Test
Real-Time Clock Test
Serializer Test

3-190 When the power supply is addressed to talk after TEST? has been received, it responds in this format:

TEST x

where x is a decimal number from 0 to 22. See Section V for a listing of test-failure codes. TEST 0 indicates that all tests passed.

3-191 The test command does not complete until the power supply control circuits have had time to settle. This prevents perturbations on the power supply output. The test command takes about 500 ms to execute.

Table 3-10. Error Codes

Error #	Description
0	**No Errors**
1	**Unrecognized Character** — A character like ! " # was received.
2	**Improper Number** — A numeric character (+ —, 0...9) was received but the following characters did not represent a proper number. For example, + —5 V or .V or +V. Examples of errors that are not error 2 are: E+04 is error 3 because E is not a numeric character and is not used in any command; 12. 34E-01 is error 4 because it is treated as 12 followed by 3.4, and no commands have two numbers separated by spaces.
3	**Unrecognized String** — A string of consecutive alpha characters that could not be found in the table of command words was received. Cause could be a spelling error or missing separator. For example, **OUTON** would be seen as one word, and would be an error.
4	**Syntax Error** — A word, number, terminator, or separator was incorrectly placed. For example, **ON OUT UNMASK,CC,** or **VOUT 5 V IOUT 5A.** A syntax error will also result if more than the maximum number of parameters are specified in the **UNMASK** mnemonic-form command
5	**Number Out Of Range** — A number was received that is too large for the command with which it was received, for example, **VOUT 5E+5, RCL 200,** or **DLY 100S.** Any negative number will also cause error 5. Note that soft limit errors are error 6.
6	**Attempt To Exceed Soft Limits** — An attempt was made to program a voltage or current greater than the soft limit, for example, **VMAX 10 V; VSET 11 V.** Note that if the programmed voltage or current is greater than the maximum rating of the supply, error 5 will result.
7	**Improper Soft Limit** — An attempt was made to program a soft limit less than the associated output value in either first or second rank. Note that if an attempt is made to program a soft limit greater than the maximum soft limit of the power supply, error 5 will result.
8	**Data Requested Without A Query Being Sent** — A query command, for example **VOUT?**, instructs the power supply to ready data for transmission to the controller. A query command must precede each request for data by the controller. If the controller requests data from the power supply (with an **INPUT** or red statement) without first having sent a query, error 8 will result.

3-192 Note that the test command in no way changes the programmed state or the output of the power supply.

CAUTION

The TEST? command software contains a bug which can affect overvoltage protection. If TEST? is sent with OUT OFF (output disabled), overvoltage protection will be disabled until the power supply receives an RST or CLR command or ac power is cycled off and back on. To restore overvoltage protection after TEST? command, be certain to send an RST or CLR command before sending the OUT ON command. RST is recommended, because CLR will reset all power supply parameters to the power-on state; RST resets only OVP.

Note that if OVP is tripped, RST or CLR will reset the OVP circuit in addition to restoring overvoltage protection.

Overvoltage protection is not affected if the power supply output has not been disabled for self test (i.e., if OUT OFF command is not send with TEST?).

3-193 **Model Identification.** The power supply model number can be determined from the controller by sending the command:

ID?

and addressing the power supply to talk. The response from the power supply will be either:

ID HP6038A
or
ID HP6038A, OPT100

with the option 100 identification indicating that the power supply has a reduced output-power capability.

3-194 ANALOG PROGRAMMING

3-195 The output voltage and/or current of the power supply can remotely programmed by an external resistance or voltage. The power supply is configured for analog programming with rear-panel slide switches; the analog programming signals are connected to rear-panel screw-on terminals.

3-196 For resistance programming, internal CV and CC current sources supply 1.5 mA currents through the programming resistors to create programming voltages for the power supply. Resistances of 0 to 4 kilohms program the output from 0 to full scale. A variable resistor can control the output over its entire range. Or, a variable resistor connected in series and/or parallel with a fixed resistor can have its control restricted to a limited portion of the output range. Alternatively, a switch can be used to select fixed values of programming resistance to obtain a set of discrete voltages or currents.

NOTE

The switching configuration used may require make-before-break contacts to avoid producing the output voltage transients caused by momentarily opening the programming terminals.

3-197 To maintain the temperature and stability specifications of the power supply, any resistors used for programming must be stable, low-noise resistors with a temperature coefficient of less than 25ppm per °C and a power rating of at least ½ watt.

3-198 Both voltage and current outputs can also be controlled by a voltage source. A voltage of 0 to 5 volts programs the output from zero to full scale. Voltage sources of more than 5 volts can be scaled down to the proper range.

3-199 Setting the power supply for analog programming of voltage and/or current disables digital programming (front-panel or HP-IB) for that parameter.

3-200 The following paragraphs discuss in greater detail the methods of remotely programming the output voltage or current using either a resistance or voltage input. Whichever method is used, the wires connecting the programming device must be shielded to reduce noise pickup. The outer shield of the cable should not be used as a conductor, and should be connected to ground at one end only.

3-201 Refer to Table 3-4 for mode-switch settings for voltage or resistance programming.

3-202 Although the following setup drawings (Figure 3-9 through 3-13) show the supply strapped for local sensing, analog programming and remote voltage sensing do not interact and may be used simultaneously.

3-203 **Constant Voltage Output, Resistance Control.** The setup shown in Figure 3-9 allows the output voltage to be varied by using an external resistor to program the power supply. A programming resistor variable from 0 to 4000 ohms produces a proportional output voltage from zero to full scale. Note that fixed resistors may be connected in series and/or parallel with the variable programming resistor to set lower and/or upper output voltage limits. The resultant programming resistance is the sum of the series/parallel resistor combination, and must be between 0 and 4000 ohms. For example, a 2000 ohm resistor connected in series with the variable programming resistor will set the lower limit for output voltage at one-half full scale.

NOTE

If the programming terminals (VP to ⏚ P) become open circuited during resistance programming, the output voltage will tend to rise above rating. The supply will not be damaged if this occurs, but the overvoltage trip point should be properly adjusted to protect the user's load.

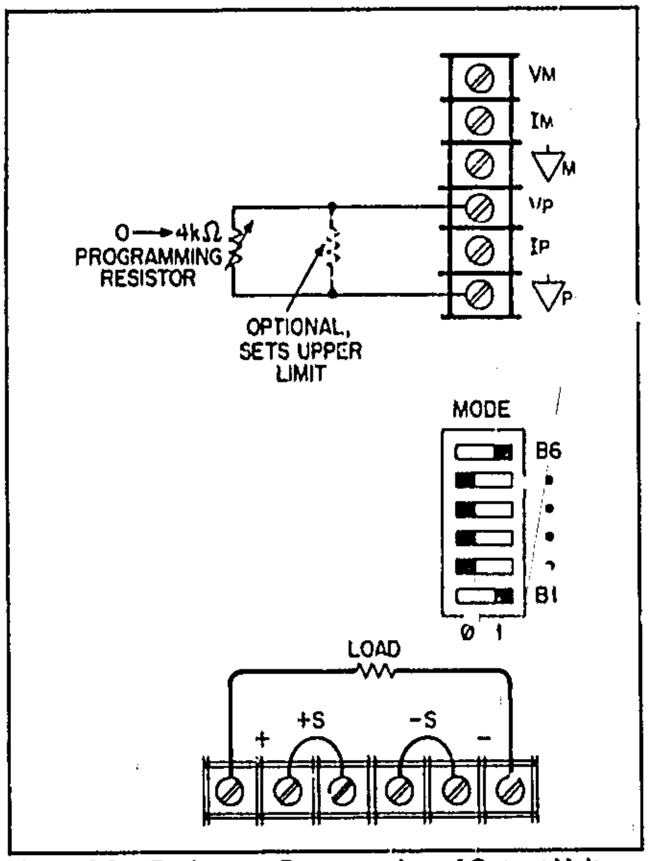


Figure 3-9. Resistance Programming of Output Voltage

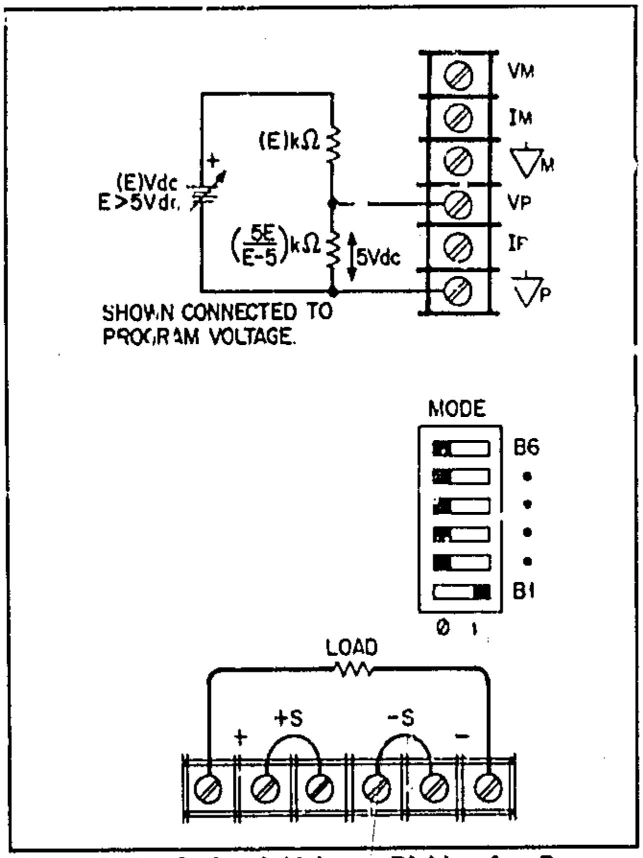


Figure 3-11. Optional Voltage Divider for Program Source

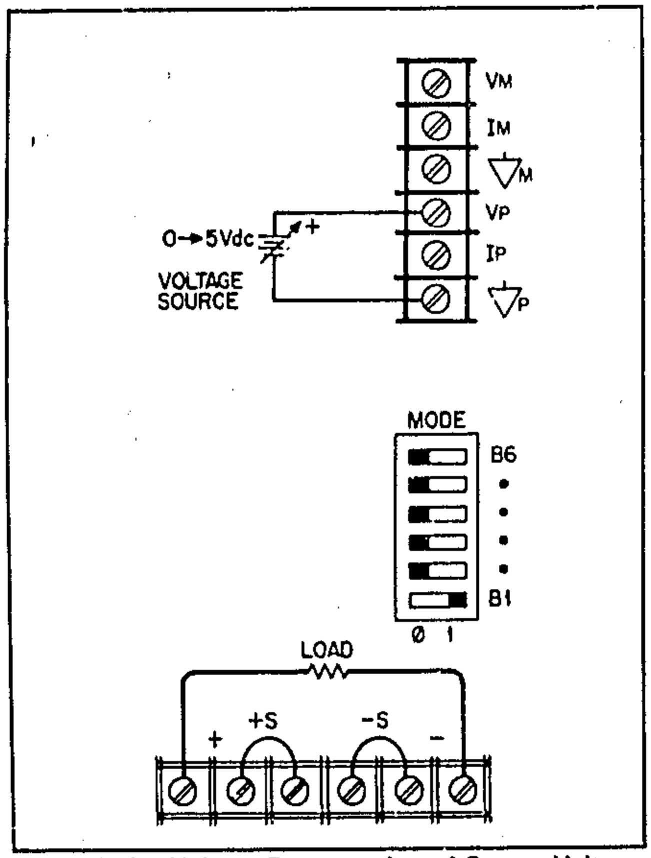


Figure 3-10. Voltage Programming of Output Voltage

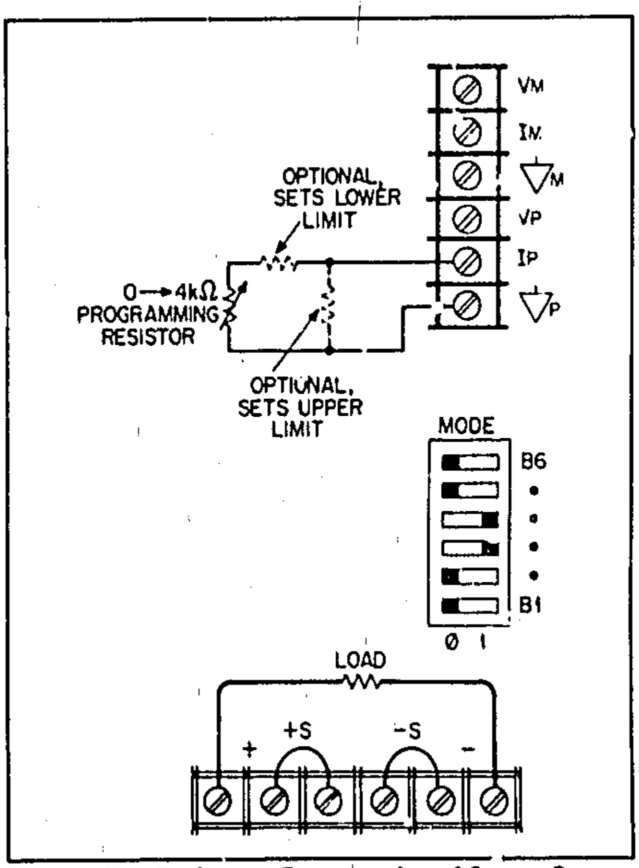


Figure 3-12. Resistance Programming of Output Current

3-204 **Constant Voltage Output, Voltage Control.** The setup shown in Figure 3-10 allows the output voltage to be varied by using an external voltage source to program the supply. A voltage source variable from 0 to +5 volts produces a proportional output voltage from zero to full scale. The static load on the programming voltage source is less than 5μA. A source resistance of less than 10 k is necessary to avoid degradation of offset and drift specifications.

NOTE

If external resistors are used to limit the remote-programming voltage to 5 Vdc, the resulting high programming-source resistance can degrade the power supply's programming speed, offset and drift performance. Limit the equivalent source resistance to 10 k ohm maximum. Figure 3-11 shows a convenient way to calculate suitable voltage-divider resistance values for a 5 k ohm source resistance.

3-205 **Constant Current Output, Resistance Control.** The setup shown in Figure 3-12 allows the output current to be varied by using an external resistor to program the supply. The discussion in Paragraph 3-203 for constant voltage operation also applies for constant current operation.

CAUTION

If the programming terminals (IP to ⏚ P) become open circuited during resistance programming, the output current will tend to rise above rating. The power supply will not be damaged if this occurs, but the user's load may be damaged. If there is a possibility that the programming leads may be opened, it is suggested that the optional resistor be connected directly across terminals IP and ⏚ P, as shown in Figure 3-12. The value of this resistor should be selected to limit the output current to the maximum that the load can handle without damage. For example, if the load can handle half the full current rating of the power supply, a 2000 ohm resistor should be connected from IP to ⏚ P. Of course, if this resistor is used, the resistance value actually programming the supply is the parallel combination of the programming resistor and the optional resistor.

3-206 **Constant Current Output, Voltage Control.** The setup shown in Figure 3-13 allows the output current to be varied by using an external voltage current to program the supply. The discussions in paragraphs 3-201 through 3-203 also apply for constant current operation. The note following paragraph 3-204 applies also to programming output current

3-207 MULTIPLE-SUPPLY OPERATION

3-208 The power supply can be operated in combination with other power supplies to provide increased output capability. Connecting the outputs of two or more power supplies in series can provide an output voltage of up to 240 volts. Auto-parallel operation of two power supplies can provide output current of up to 20 amps. Other multiple-supply combinations are possible. Contact Hewlett-Packard, New Jersey Division for specific application assistance.

3-209 Auto-Parallel Operation

3-210 Two units can be connected in an auto-parallel combination to provide twice the output current capability. One of the power supplies, the master, is programmed normally via the HP-IB. The other power supply, the slave, is analog programmed by the master. The slave may be connected to the HP-IB for readback, status, etc., but the MODE switches of the slave must be set so that the slave is analog programmed by the master.

NOTE

Proportional currents from auto-paralleled units require equal load-lead voltage drops. Connect each unit to the load using separate pairs of wire with length and gauge chosen to provide equal voltage drops from pair to pair. If this is not feasible, connect each unit to a pair of distribution terminals using equal-voltage-drop wire pairs, and then connect the distribution terminals to the load with a single pair of leads.

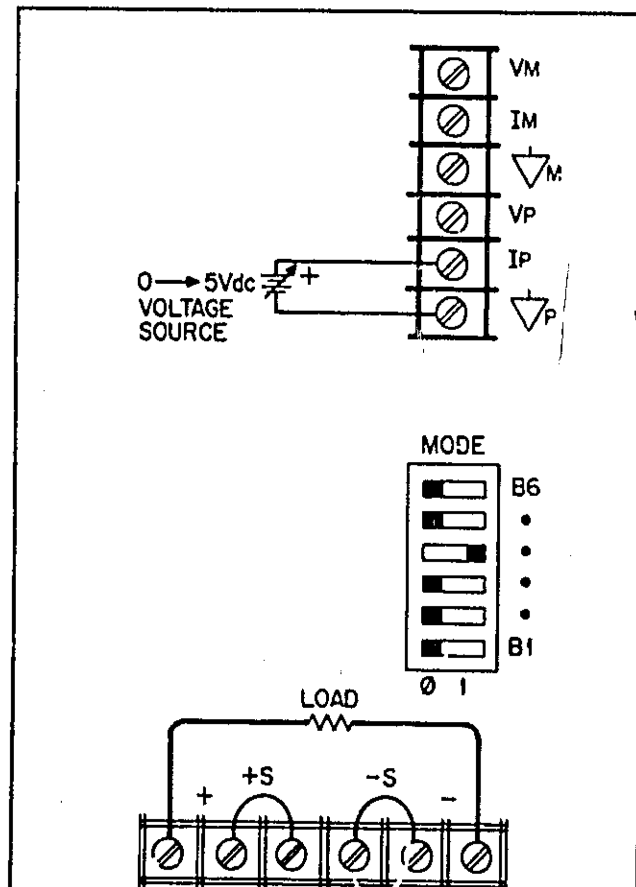


Figure 3-13. Voltage Programming of Output Current

3-211 Foldback protection, if desired, may only be used with the master power supply.

3-212 Figure 3-14 shows the rear-panel MODE switch settings and terminal connections for auto-parallel operation. This configuration provides 0 to 60 Vdc at an output current of up to 20 Adc.

3-213 **Setting Voltage and Current.** Program the slave unit's output voltage above the master's to avoid interference with master-unit CV control. The slave unit's MODE switches disable the slave unit's current setting from having any effect in auto-parallel operation. Program the master unit to the desired output voltage and current. Verify that the slave is in CC operation.

3-214 When in CV operation, the master unit's voltage setting is the output voltage of the auto-parallel combination. The output current is the total current from all units. The fraction of total current that each unit provides is the same as the ratio of that unit's output current capability to the total output current capability of the auto-parallel combination. For example, if a 30 A unit and a 10 A unit were auto-paralleled (total current capability = 40 A), the 30 A unit would provide 3/4 of the total output current (30 A/40 A = 3/4), and the 10 A unit would provide 1/4 of the total output current.

3-215 In CC operation, the user must add up the current outputs from each unit and adjust the master until the total equals the desired load current.

3-216 **Overvoltage Protection.** Adjust the desired OVP shutdown limit using the master unit's OVP ADJUST control. Set the slave unit's OVP limit above the master's. When the master unit shuts down, the master programs the slave unit to zero voltage output. If a slave unit shuts down (because its OVP shutdown limit is set lower than the master's), it shuts down only itself, and the other unit supplies all the load current. The shut-down slave unit will draw some current through its down programming circuit. The extra current required from the master unit may cause the master to switch from CV to CC mode.

3-217 **Remote Sensing.** To remove sense with auto-parallel operation, connect remote-sense leads only to the master unit according to the remote sensing instructions in paragraph 3-40.

3-218 **Remote Programming.** To remove program with auto-parallel operation, set up only the master unit for remote programming.

NOTE

Down-programming speed is slower with auto-parallel operation because only the master unit's down programmer operates.

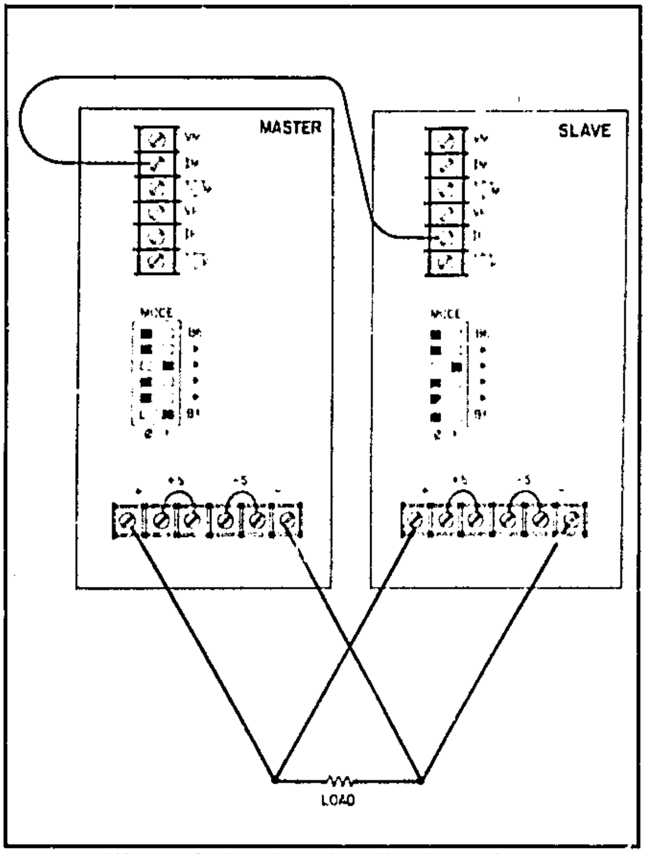


Figure 3-14. Auto-Parallel Operation

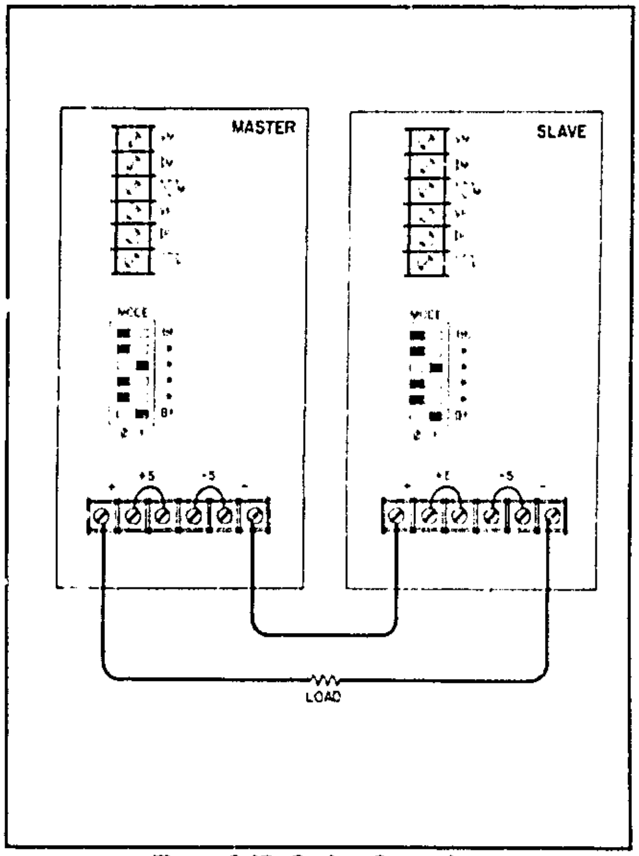


Figure 3-15. Series Operation

3-219 Series Operation

3-220 Two or more power supplies can have their outputs connected in series to provide increased output voltage. Each power supply is programmed via HP-IB with hold on, and then all units are tirggered at once. Multiple loads may be connected in series, and the combination may be grounded at any one point to provide both positive and negative outputs. Regardless of whether or where the load is grounded, no point may be more than +240 volts from ground.

3-221 Figure 3-15 shows the rear-panel MODE switch settings and terminal connections for series operation of two power supplies. To connent more power supplies in series, simply connect the − output of one to the + output of the next.

3-222 Add the voltage settings of each power supply together to determine the total output voltage. Set the current limits for each power supply to the maximum that the load can handle without damage.

THEORY

Section IV
PRINCIPLES OF OPERATION

4-1 INTRODUCTION

4-2 This section contains block diagrams, simplified schematics, and related descriptions of the power supply. The instrument can be thought of as comprising two major sections: the HP-IB, microcomputer, and interface circuitry; and the power mesh and control circuits. Three block diagrams represent the HP-IB board, the power supply interface (PSI) board, and the front panel. A block diagram and simplified schematic represent the power mesh and control board. The descriptions associated with these block diagrams explain the function of each block without describing how individual components within the circuit accomplish that function. Detailed descriptions are provided only for those individual circuits whose operation may not be obvious to the user.

4-3 The circuit names and layouts of the block diagrams and simplified schematic are the same as used on the complete schematics in Section VII; however, some items, such as bias supplies, are left off the block diagrams for clarity. In general, circuits are described as they appear on the diagrams from left to right. Signal names that appear on the drawings are printed in capitals in the descriptions, as are front-panel labels for indicators and controls. Signal names that describe an operating mode or condition are active when that condition exists. For example, OT is high and $\overline{OT}$ is low if an overtemperature condition exists. Signal flow is from left to right and top to bottom, unless arrows indicate otherwise. A notable exception is the input port to the microcomputer, and the CV and CC control circuits. Signals that lead off the edge of one block diagram pick up in the same relative position on the next block diagram.

4-4 Overview

4-5 Figure 4-1 shows the overall relationship of the major circuit groups in the power supply. Circuits on the HP-IB board maintain communications between the power supply and the HP-IB, and the microcomputer on the HP-IB board sends commands to and receives data from the power mesh and front panel. The front panel contains controls, indicators, and associated circuits that provide local control of the power supply. Circuits on the power supply interface (PSI) board convert digital values from the microcomputer to analog programming inputs for the control board and power mesh, and convert analog readings from the control board and power mesh to digital inputs for the microcomputer. Other PSI circuits pass status and control signals between the control board and microcomputer. The power mesh, converts ac input power to dc output power. Circuits on the control board monitor and control operation of the power mesh.

4-6 The following paragraphs describe the HP-IB board, power supply interface (PSI) board, and the front-panel board. These circuits provide the interface between the power mesh circuits and the controller and/or operator. The HP-IB and front-panel boards are referenced to earth common; the PSI board is referenced to the power supply negative output. Isolation is achieved by optical isolators on the PSI board. Data is sent between boards serially.

4-7 HP-IB BOARD

4-8 The HP-IB board, see Figure 4-2, contains HP-IB interface circuits, a microprocessor and memory, and parallel-to-serial and serial-to-parallel converter circuits. Other circuits include address switches, test LEDs, and bias voltage and start-up circuits. Most of the circuit blocks are connected to the microprocessor via the address bus and data bus, and the microprocessor addresses each block as if it were a memory location. The microprocessor always drives the address bus, which specifies where data goes to or comes from (i.e., identifies what is on data bus). All data on the data bus either comes from or goes to the microprocessor; no other two circuits on the data bus communicate with each other.

4-9 HP-IB Transceivers and Interface Circuits

4-10 This circuit contains the bus connector and transceivers and an HP-IB talker/listener chip. All HP-IB (IEEE-488) functions except for controller are implemented by the HP-IB chip, which handles data transfer between the microprocessor and HP-IB handshake protocol, and talker/listener addressing procedures. The HP-IB chip is connected to the data bus and appears as a memory location to the microprocessor.

4-11 Microprocessor and Clock Circuits

4-12 This circuit contains a high performance 8-bit microprocessor and associated clock circuits. The microprocessor operates on a 1 MHz cycle, which it derives from a 4 MHz oscillator. Two 1 MHz clock signals, Q and E, are generated by the microprocessor for use by other circuits. Addresses on the address bus are stable during the Q pulse, which leads the E pulse by 90 degrees.

4-13 A 1 kHz (approx) clock signal applied to the microprocessor interrupt input enables the microprocessor to keep track of real time. This enables the microprocessor to ensure that tasks are performed in timely fashion, without any

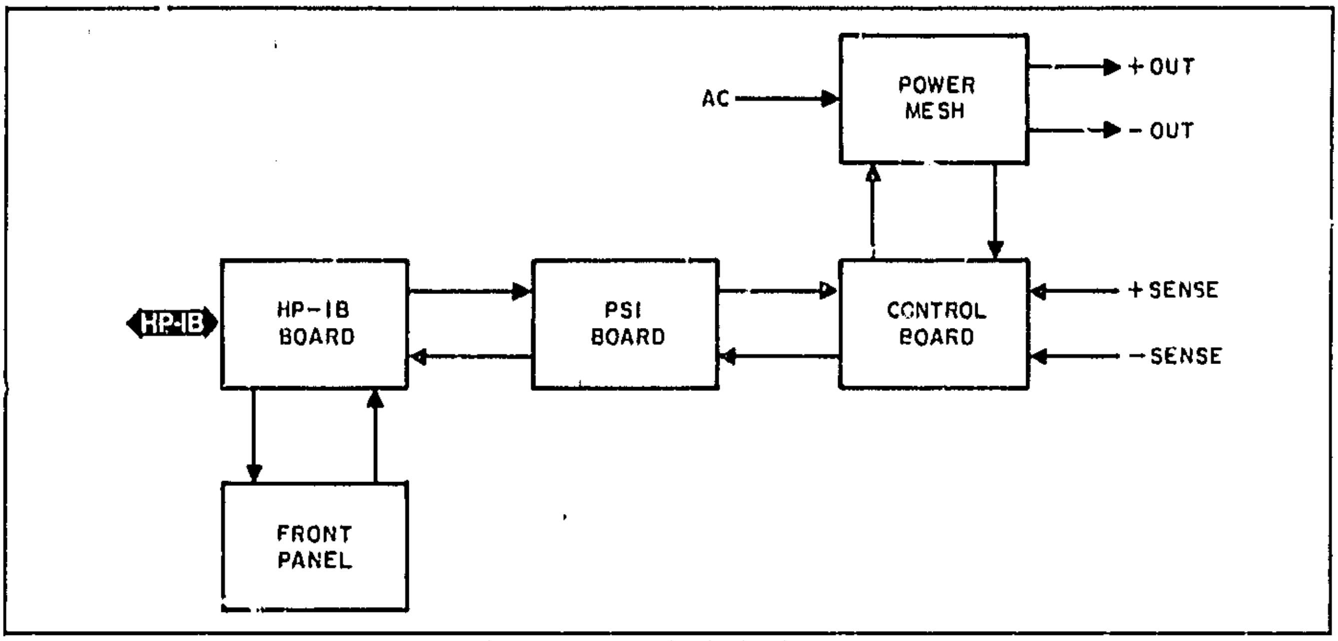


Figure 4-1. Overall Block Diagram

one task monopolizing the program. The real-time clock signal is also used to keep track of the time that has elapsed since the output was last changed, so the microcomputer can determine if a CV/CC mode change exists after the selected delay time. The clock signal is also used to determine the rate at which the front-panel RPG is being rotated.

4-14 The read/$\overline{\text{write}}$ (R/$\overline{\text{W}}$) output from the microprocessor indicates the direction of data flow on the data bus, either to or from the microprocessor.

4-15 Data Bus Latches and Free-Run Jumper

4-16 The timing sequence of the microprocessor is such that circuits providing data for the microprocessor to read are deselected (address disappears) before the microprocessor can read the data. This circuit latches data to be read by the microprocessor, and is updated on every falling Q pulse. Data put on the data bus by the microprocessor goes around the latches through buffers.

4-17 Note that the data bus is connected to the microprocessor through a jumper pack. For signature analysis of the microcomputer kernal (microprocessor, ROM, RAM) the data bus is broken and a no-op op code (NOP) is connected directly to the microprocessor data inputs. When the microprocessor performs the NOP instruction, which does not contain an address for the next instruction, the microprocessor automatically goes to the next highest address. Therefore, the address bus looks like a 16-bit counter that continuously rolls over and starts at zero. The *contents* of each address appear sequentially on the data bus (other side of the break).

4-18 Address Decoding

4-19 The microprocessor has 16 address lines, allowing it to address approximately 65,000 locations. Address decoding allows each addressable circuit to look at a shorter address. Each circuit decodes the address supplied to it only when that chip is selected by the decoding of higher-order address bits. For example, each RAM can recognize only 1024 addresses. Therefore, in order to write to or read from a particular RAM location, the RAM must not only decode 10 address lines, but the RAM must also be enabled by a chip-select line.

4-20 In addition to the chip-select lines, the address decoding circuits produce signals that control the direction of data flow between the HP-IB board and other circuits.

4-21 Memory Circuits

4-22 This unit contains both ROM devices (which contain the operating program) and RAM devices (which store variables such as voltage to be programmed, output current readback, etc). Jumpers in the address decoding circuit allow the unit to be configured with various capacity ROMs.

4-23 Each of the two RAM devices is four bits wide and stores half an eight-bit data byte. Each RAM address enables the same locations in both RAMs; one RAM stores bits D0 through D3, and the other RAM stores bits D4 through D7.

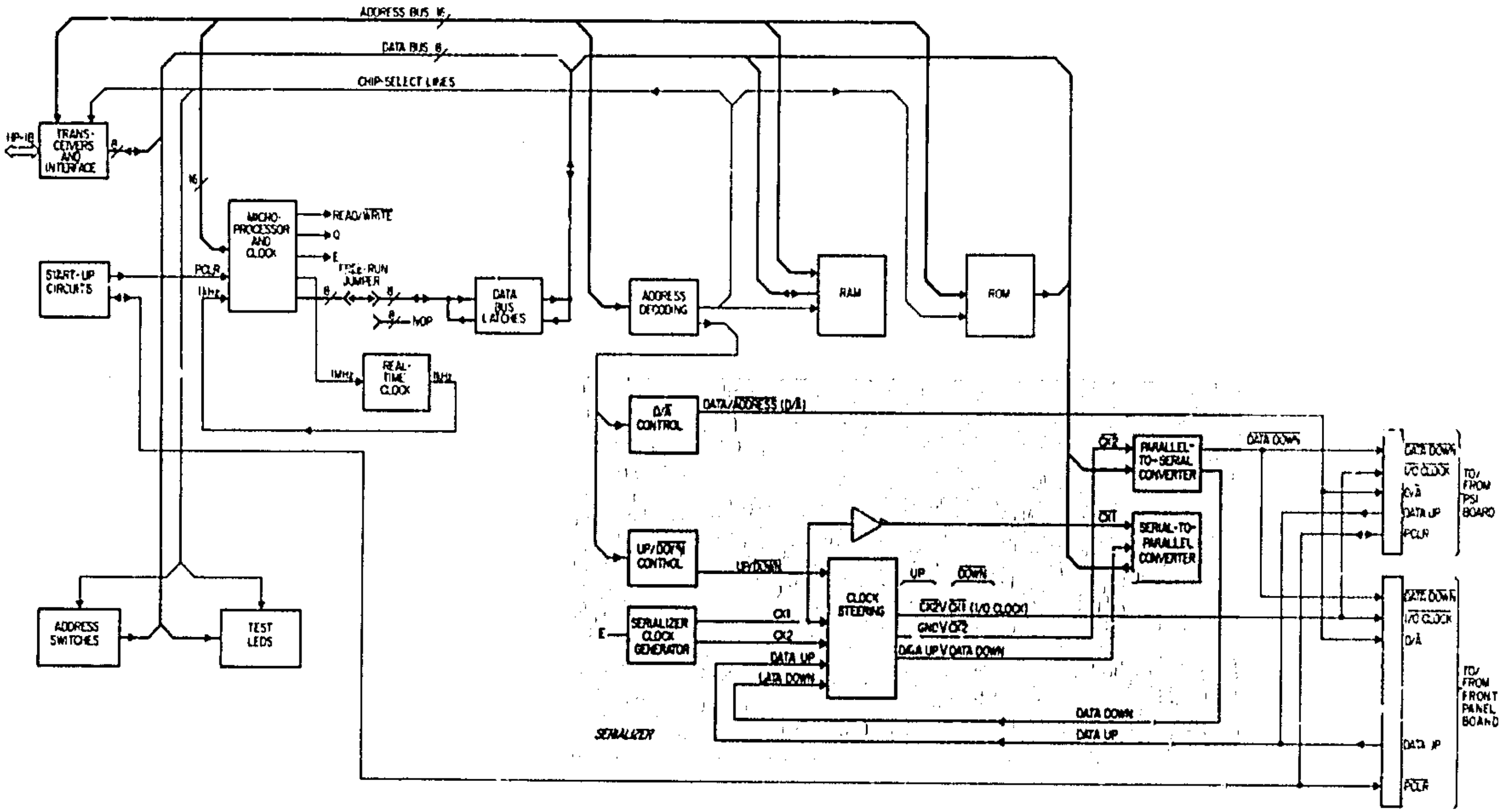


Figure 4-2. HP-IB Board Block Diagram

4-24 Start-Up Circuits

4-25 Start-up circuits monitor the voltage levels of the bias-voltage circuits, and hold various circuits reset until the bias voltages have stabilized. The start-up circuits on the HP-IB board are interlocked with similar circuits in the other bias-voltage supplies, so that all critical circuits in the unit will be disabled until all bias voltages are stabilized.

4-26 Address Switches

4-27 The five rear-panel address switches are connected via the data bus to the microprocessor, which sends the address to the HP-IB talker/listener chip. A sixth rear-panel switch connected through the same input port is user set to tell the microprocessor whether or not to request service from the controller when power is turned on.

4-28 Also connected through the same input port is one bit that indicates if jumper W5 is connected for diagnostic mode. With the unit in diagnostic mode, the rear-panel address switches select the tests to be run by the microprocessor.

4-29 Test LEDs

4-30 Six test LEDs on the HP-IB board are driven by the microprocessor to indicate which self test has failed, either at power on or in diagnostic mode. The test LEDs display, in binary, the same information as is displayed on the front panel. However, a failure may affect circuits that drive the front panel display. Therefore, the test LEDs, which are driven by the microprocessor through fewer circuits than the front-panel display, provide a redundant means to determine what self tests have failed.

4-31 Real-Time Clock

4-32 The real-time clock consists of a 14-stage (only 10 used) ripple counter that divides the 1 MHz E clock signal from the microprocessor to produce a 1 kHz (approx) clock pulse. The real-time clock is used by the microprocessor to schedule its jobs at regular intervals.

4-33 Serializer

4-34 The serializer converts the eight parallel bits on the microprocessor data bus to serial data to be shifted to the PSI board and front-panel board, and it converts serial data from the PSI board or front panel board to parallel data that is read by the microprocessor from the data bus. Shifting data serially reduces the number of isolators required between the HP-IB board and the PSI board. The signal repesenting serial data from the microprocessor to other circuits is DATA DOWN and the signal representing serial data toward the microprocessor is DATA UP. The serializer consists of circuits described in the following paragraphs.

4-35 **Serializer Clock.** The serializer clock circuit produces two clock signals, CK1 and CK2, that are derived from the 1 MHz E clock signal. Both CK1 and CK2 are half the E signal frequency, but CK1 leads CK2 by 90 degrees. These clock signals are used by the serializer to shift data serially either to or from the HP-IB board.

4-36 The parallel-to-serial and serial-to-parallel converters that shift data to and from the HP-IB board require just eight clock pulses to load or unload their data. The serializer clock circuit includes a counter that resets the clock divider to zero after eight pairs of clock pulses (CK1 & CK2) have been generated.

4-37 **Data/Address Control.** This circuit decodes outputs from the address decoders to produce the DATA/$\overline{\text{ADDRESS}}$ signal (D/$\overline{\text{A}}$). When the microprocessor sends data to the PSI or front-panel boards, it must first identify the location for which the data is intended. The address and data are both sent serially via DATA DOWN, so the D/$\overline{\text{A}}$ signal identifies to the receiving circuits if the DATA DOWN bits represent an address (D/$\overline{\text{A}}$ signal low) or data (D/$\overline{\text{A}}$ signal high).

4-38 **Up/Down Control.** This circuit decodes outputs from the address decoders to produce the UP/$\overline{\text{DOWN}}$ signal, which indicates the direction of data flow. The signal goes low to indicate data flow down (from the microprocessor) and goes high to indicate data flow up (toward microprocessor).

4-39 **Clock Steering.** This circuit connects CK1 to I/O CLOCK to shift data down, and CK2 to I/O CLOCK to shift data up. The data shifting sequence is as follows. When shifting data down, the eight data bits are first parallel loaded into the parallel-to-serial converter; one bit is then available at the serial output. The first I/O CLOCK (CK1) pulse shifts that first bit into the receiving circuit (on PSI board or front-panel board). The first CK2 pulse then shifts the next data bit out of the parallel-to-serial converter, and the sequence continues until all eight bits have been shifted out of the parallel-to-serial converter and into the receiving circuit. To shift data up, the first bit from the sending circuit is shifted into the serial-to-parallel converter by CK1, and then I/O CLOCK (CK2) causes the next bit to be shifted out of the sending circuit.

4-40 The clock steering circuit also selects whether $\overline{\text{DATA DOWN}}$ or DATA UP is shifted into the serial-to-parallel converter. For the microcomputer to read in data from the PSI or front-panel boards, DATA UP is shifted into the serial-to-parallel converter, whose eight output lines are read by the microcomputer on the data bus. When the microcomputer sends DATA DOWN to the PSI and front-panel boards, DATA DOWN is also connected back through clock steering to the serial-to-parallel converter. During self tests, this enables the microprocessor to parallel load eight bits into the serializer, shift the bits through the converters, and then read the data out of the serializer, thereby testing the serializer independently of circuits on other boards.

4-41 **Parallel-to-Serial Converter.** This circuit consists of an eight-bit shift register with two complementary serial outputs. One output is connected through buffers to the PSI and front panel boards, and the other output is connected to the clock steering circuit as part of a self test I/O loop.

4-42 **Serial-to-Parallel Converter.** This circuit consists of an eight-bit bidirectional shift register with common I/O pins. In this circuit the device is used as a serial-in/parallel-out, shift left-to-right register (Mode 1 on the schematic symbol).

4-43 POWER SUPPLY INTERFACE (PSI) BOARD

4-44 The PSI board, see Figure 4-3, contains the output voltage and current digital-to-analog converters (DACs), a readback analog-to-digital converter (ADC), associated input and output ports for the microprocessor, and isolation components. The DACs provide reference voltages to which the power mesh output-control circuits compare the power supply output. The DAC inputs are supplied to latches via the data down signal from the microprocessor. The readback ADC uses successive approximation to convert analog voltages representing output voltage and current, programmed voltage and current, and OVP level to a digital value for transmission to the microprocessor via DATA UP. The microprocessor stores those values in RAM to drive the front-panel display and to transmit to the controller via HP-IB if requested.

4-45 Input and output ports provide access by the microprocessor, via DATA UP and DATA DOWN, to power supply status lines, readback values, power-supply-type identification lines, and control lines.

4-46 Optical isolators on the PSI board provide isolation between the HP-IB board circuits, which are referenced to earth common, and the PSI board and power mesh circuits, which are referenced to the power supply negative output.

4-47 Isolation

4-48 Optical isolators transmit data between the PSI board and HP-IB board, while maintaining electrical isolation between circuits referenced to different commons.

4-49 Control Lines Output Port

4-50 This circuit is the output port for the $\overline{\text{INHIBIT}}$ and $\overline{\text{OVCLEAR}}$ control lines sent by the microprocessor to the power mesh. This port also provides an address to select the input to the ADC, and it provides the START signal for the successive approximation registers in the ADC.

4-51 Address Latches and Decoders

4-52 This circuit decodes addresses sent by the microprocessor, and selects which circuit receives or sends data by steering I/O CLOCK to only one register. Both data and addresses from the microprocessor are shifted to the PSI board via DATA DOWN. The microprocessor sends the 8-bit address first, and then either sends 8 bits of data or reads in 8 bits of data. The microprocessor controls the D/$\overline{\text{A}}$ line to tell the PSI whether a byte from data down represents an address (D/$\overline{\text{A}}$ low) or data (D/$\overline{\text{A}}$ high). If the D/$\overline{\text{A}}$ line is low, the sole destination for the bits is the address latch.

4-53 Once the 8-bit address has been received, the D/$\overline{\text{A}}$ line goes high. If data is being sent down, data bits are sent to all output registers on the PSI board. However, only the circuit receiving clock signals from the address decoder enters the data into its register or shifts data out to DATA UP.

4-54 Output Latches

4-55 This circuit contains three 8-bit shift registers that store the 12 input bits for each of the output-signal DACs. One shift register stores the 8 least-significant bits for the current DAC, the second shift register stores the 4 most significant bits for each of the two DACs, and the third shift register stores the 8 least-significant bits for the voltage DAC. Each shift register has two ranks of storage. Data is shifted serially into the first rank without affecting the outputs. After all 12 bits are loaded into the first rank, a strobe pulse parallel shifts the data to the second rank, which drives the DAC inputs.

4-56 Note that one of the shift registers has 4 output lines connected to the current DAC, and 4 lines connected to the voltage DAC. When the microprocessor sends new data to one DAC, it reloads the existing four bits for the other DAC.

4-57 Current and Voltage DACs

4-58 Output current and voltage are programmed by two 12-bit DACs which are controlled by the microprocessor via data down. The digital inputs to the DACs are derived either from the HP-IB or the front panel rotary pulse generator (RPG), depending on whether the unit is in remote or local control. The DAC circuits also include buffers and compensation amplifiers.

4-59 The DAC outputs are the programming voltages to which the power supply output voltage and current are compared to produce a control voltage. The DAC outputs are also connected to the analog multiplexer on the PSI board for self tests.

4-60 Analog Multiplexer

4-61 The analog multiplexer selects one of five inputs to be applied to the ADC for readback by the microprocessor. The five analog inputs are: CV PROGRAM and CC PROGRAM, which represent the programmed values of output voltage and current (used only for self test); OVP MONITOR, which represents the voltage at which the OVP circuit will trip; and I-MON and V-MON, which represent the measured values of output current and voltage.

4-62 Analog-To-Digital Converter (ADC)

4-63 The ADC circuit contains two cascaded successive approximation registers (SARs) and clock, a 12-bit DAC, and a comparator. The unknown voltage is connected to the non-inverting input of the comparator, and the DAC output is con-

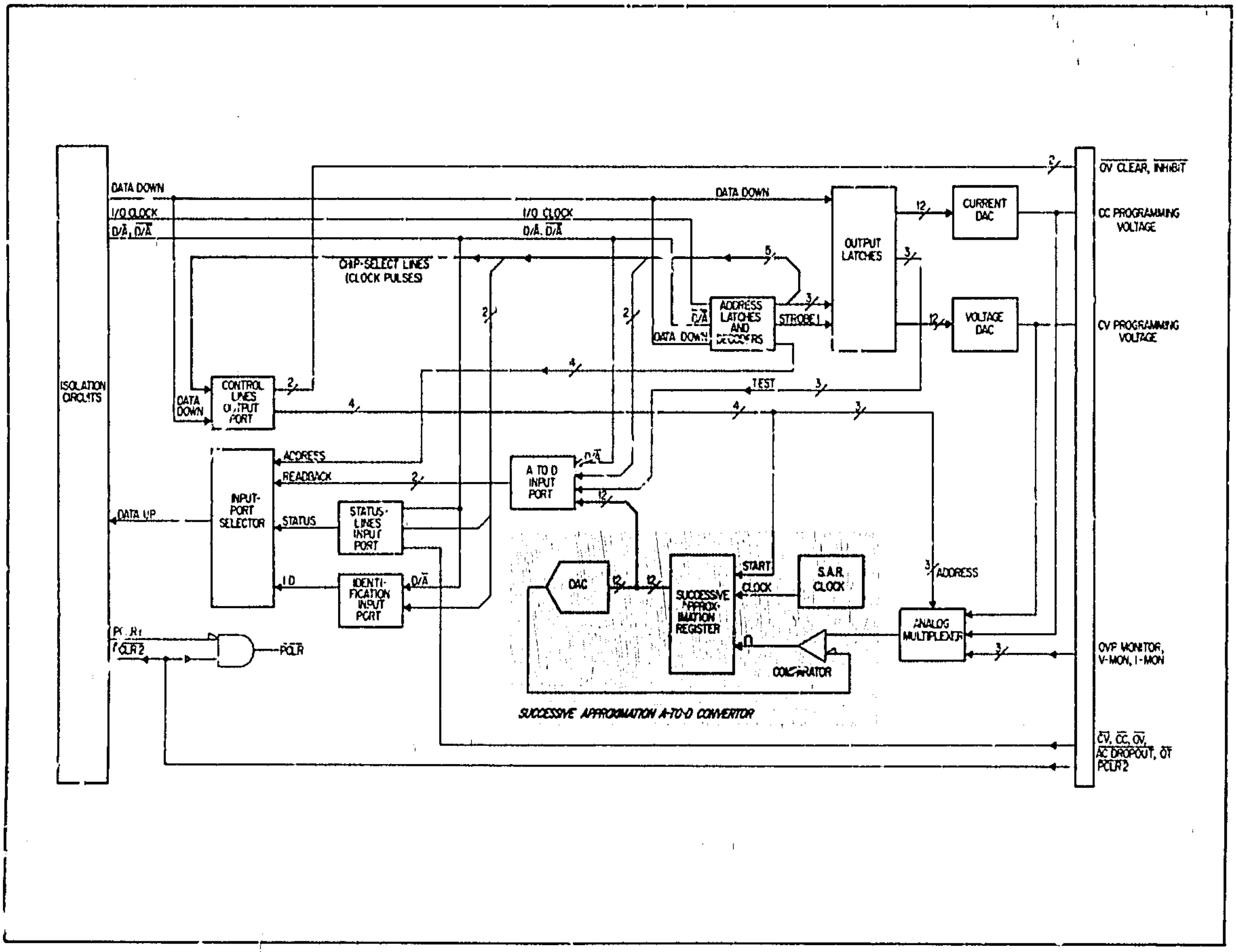


Figure 4-3. Power Supply Interface Board Block Diagram

nected to the inverting input. The comparator output is strobed into the SARs by the clock. Upon receipt of a START signal, the SARs set a mid-range value on the DAC input. The DAC output is compared to the unknown voltage, and the comparator output is strobed into the SARs by the next clock pulse. The comparator determines if the unknown voltage is greater or less than the DAC value, and the SARs raise or lower the DAC value in the direction of the unknown voltage. The SARs continue to raise or lower the DAC value in progressively smaller steps until the DAC output equals the unknown voltage. At this point the 12-bit DAC input represents the analog voltage being measured, and the SARs produce an end-of-conversion (EOC) signal. When the microprocessor looks at the digital value it also checks EOC to ensure that the digital value is valid. EOC should always be true when the microprocessor takes a reading, because after telling the SARs to start a conversion, the microprocessor does not read in the digital value until sufficient time has elapsed to allow the SARs to complete a worst-case conversion.

4-64 A-To-D Input Port

4-65 This circuit converts the 12 parallel bits from the ADC to serial data for transmission to the microprocessor via DATA UP. Included with the 12 readback bits are EOC and one bit from each of the three output latches. These three bits are used by the microprocessor for self test.

4-66 Data is parallel loaded into the input ports whenever D/ $\overline{A}$ is low (microprocessor sending any address). Therefore, if the input port address is decoded by the address decoder, the data loaded while D/ $\overline{A}$ was low will be shifted out when D/ $\overline{A}$ goes high and clock pulses are steered by the address decoder to the input port.

4-67 Status Lines Input Port

4-68 This port supplies power supply status to the microprocessor. As in the A-to-D input port, data is loaded while the D/ $\overline{A}$ line is low, and is shifted out when the D/ $\overline{A}$ line is high if the address decoder steers clock pulses to the circuit. R-S flip-flops store $\overline{CV}$ $\overline{CC}$, $\overline{AC\ FAULT}$, and $\overline{OT}$ so that a temporary status change will not be lost if the condition disappears before the microprocessor reads status. The $\overline{INHIBIT}$ signal, which comes from the microprocessor via the control lines output port, is returned to the microprocessor via the status lines input port for self test of both ports.

4-69 Identification Input Port

4-70 Because the interface circuits have been designed for use in a number of power supplies, this circuit identifies to the microprocessor the type of power supply so the microprocessor knows which calibration constants and scale factors to use from memory. The microprocessor reads this register only at turn-on.

4-71 Input Port Selector

4-72 This circuit controls which input port is connected to DATA UP.

4-73 Power Clear

4-74 $\overline{PCLR2}$, from the power mesh bias supplies, is connected across isolation on the PSI board to the HP-IB board, and is also connected to power clear circuitry on the PSI board. Circuits on the PSI board will be held reset by PCLR until both PCLR1 and $\overline{PCLR2}$ disappear.

4-75 FRONT PANEL BOARD

4-76 The front-panel board, see Figure 4-4, contains the VOLTS and AMPS display circuits, the rotary pulse generator (RPG) and RPG decoders, five pushbutton switches, mode indicators, and the OVP ADJUST potentiometer. Data from the microprocessor is shifted to the display circuits via $\overline{DATA\ DOWN}$ and data from the front-panel controls circuits is shifted to the microprocessor via DATA UP. Data transfer between the front-panel board and the microprocessor on the HP-IB board is similar to that between the PSI and HP-IB boards, except that the front-panel circuits are not isolated from the HP-IB circuits. Circuits on the front-panel board operate from bias voltages supplied from the HP-IB board, and are referenced to the same common as the HP-IB board (earth ground). The OVP ADJUST potentiometer is part of the power mesh control circuitry (referenced to power supply negative output), and is not connected to any circuits on the front-panel board.

4-77 Address Latches and Decoders

4-78 The address latches and decoders on the front-panel board operate similarly to those on the PSI board, described earlier. DATA DOWN bits received while D/ $\overline{A}$ is low are latched and decoded in this circuit, which then steers clock pulses to the addressed circuit when D/ $\overline{A}$ goes high.

4-79 Volts and Amps Output Ports and Displays

4-80 These circuits display values sent by the microprocessor via DATA DOWN. Normally, these are the actual output voltage and current readings as measured by the ADC on the PSI board. Pressing the DISPLAY SETTINGS switch causes the microprocessor to send the voltage and current values that have been set by the controller (remote) or RPG (local). If the unit is in CV mode, the voltage display should show the same reading for actual and set values; the current display will switch from the actual value to the current limit. In CC mode, the current readings will be the same and the voltage display will switch from actual value to the voltage limit. Pressing the DISPLAY OVP switch causes the voltage display to show the OVP trip voltage that has been set.

4-81 The microprocessor also uses the readout to display the HP IB address switch settings, self test error messages, and readback ADC overrange conditions.

4-82 RPG and Latches

4-83 When rotated, the RPG produces two pulse trains that are 90 degrees phase shifted from each other, with the phase

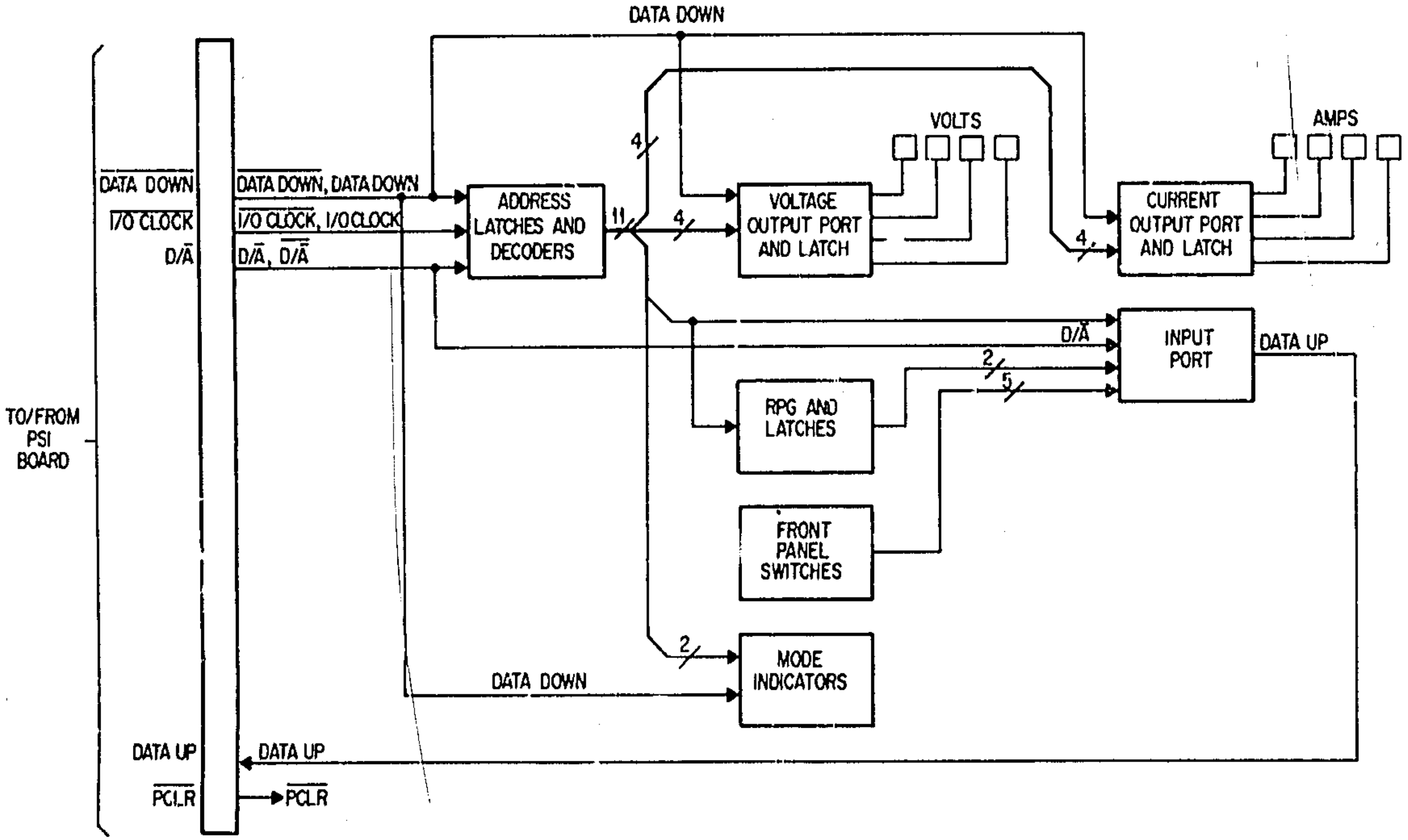


Figure 4-4. Front Panel Board Block Diagram

relationship determined by the direction of rotation. This circuit contains two flip-flops that monitor the RPG outputs. The output of one flip-flop goes low to indicate that the RPG has been rotated, and the output of the other goes low to indicate CW rotation or high to indicate CCW rotation. These data are loaded into an input port when D/ $\overline{A}$ is low, and the flip-flops are set back to their quiescent state by clock pulses from the address decoder when the input port is addressed.

4-84 Because the microprocessor reads the input approximately every millisecond, it can determine if the RPG is being turned rapidly (for a large change) or slowly (for fine adjustment), and the microprocessor varies the rate it changes the DAC inputs accordingly.

4-85 Front-Panel Controls Input Port

4-86 Five front-panel pushbutton switches plus the two RPG flip-flop outputs are connected to this input port. Data is loaded when D/ $\overline{A}$ is low, and is shifted out by clock pulses from the address decoders. The microprocessor reads data in via DATA UP approximately every millisecond, and checks the switches every 10 ms, thereby ensuring that even rapid switch operations will be captured.

4-87 Mode Indicators

4-88 The front-panel mode indicators are controlled by the microprocessor via DATA DOWN and the mode indicator output ports and latches. DATA DOWN signals are shifted in by clock pulses from the address decoders.

4-89 OVP Adjust Control

4-90 The OVP ADJUST potentiometer sets the voltage level at which the overvoltage protection (OVP) circuit trips.

4-91 Power Clear

4-92 The power clear signal ($\overline{PCLR}$)from the HP-IB board goes low when the unit is turned on, and remains low until the bias power supplies have stabilized. This low level resets the display-circuit latches on the front panel board, causing all indicators and display segments to turn on and remain on until the microprocessor updates the display (approximately one second).

4-93 POWER MESH AND CONTROL BOARD

4-94 The basic operating concepts of the the power mesh and control circuits are described in the following paragraphs. The beginning paragraphs describe the basic difference between an autoranging power supply and a conventional CV/CC power supply in terms of the available output, and provide an overview of the basic theory of operation. Later paragraphs describe the functions of the individual circuits on the power mesh and control board.

4-95 AUTORANGING POWER

4-96 The basic difference between an autoranging power supply and conventional types of Constant Voltage/Constant Current (CV/CC) power supplies can be seen by comparing the maximum-output-power characteristics of each. A conventional CV/CC power supply can provide maximum output power at only one combination of output voltage and current, as shown in Figure 4-5a. The range of a power supply can be extended by designing an instrument with two or more switch-selectable voltage/current ranges within the maximum power-output capability, as shown in Figure 4-5b. An autoranging power supply provides maximum output power over a wide and continuous range of voltage and current combinations, as shown in Figure 4-5c, without the operator having to select the proper output range.

4-97 BLOCK DIAGRAM OVERVIEW

4-98 This section is an overview. Using the block diagram, Figure 4-6, it explains how the unit works, how major circuits are interconnected and what signals are called. The next section, beginning at paragraph 4-106, explains more thoroughly how major circuits operate and uses the simplified schematic, Figure 4-8.

4-99 Power flows from the ac power line at the left of the block diagram through circuit blocks connected by heavy lines to the load on the output terminals at the right. The down programmer lowers the output voltage when required by the CV

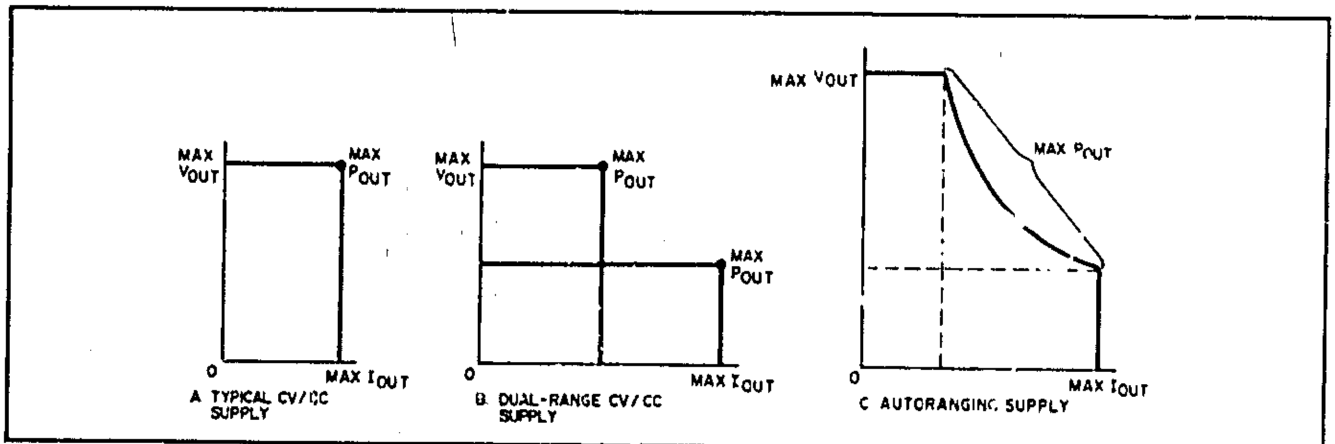


Figure 4-5. Output Characteristics; Typical, Dual-Range, And Autoranging Supplies

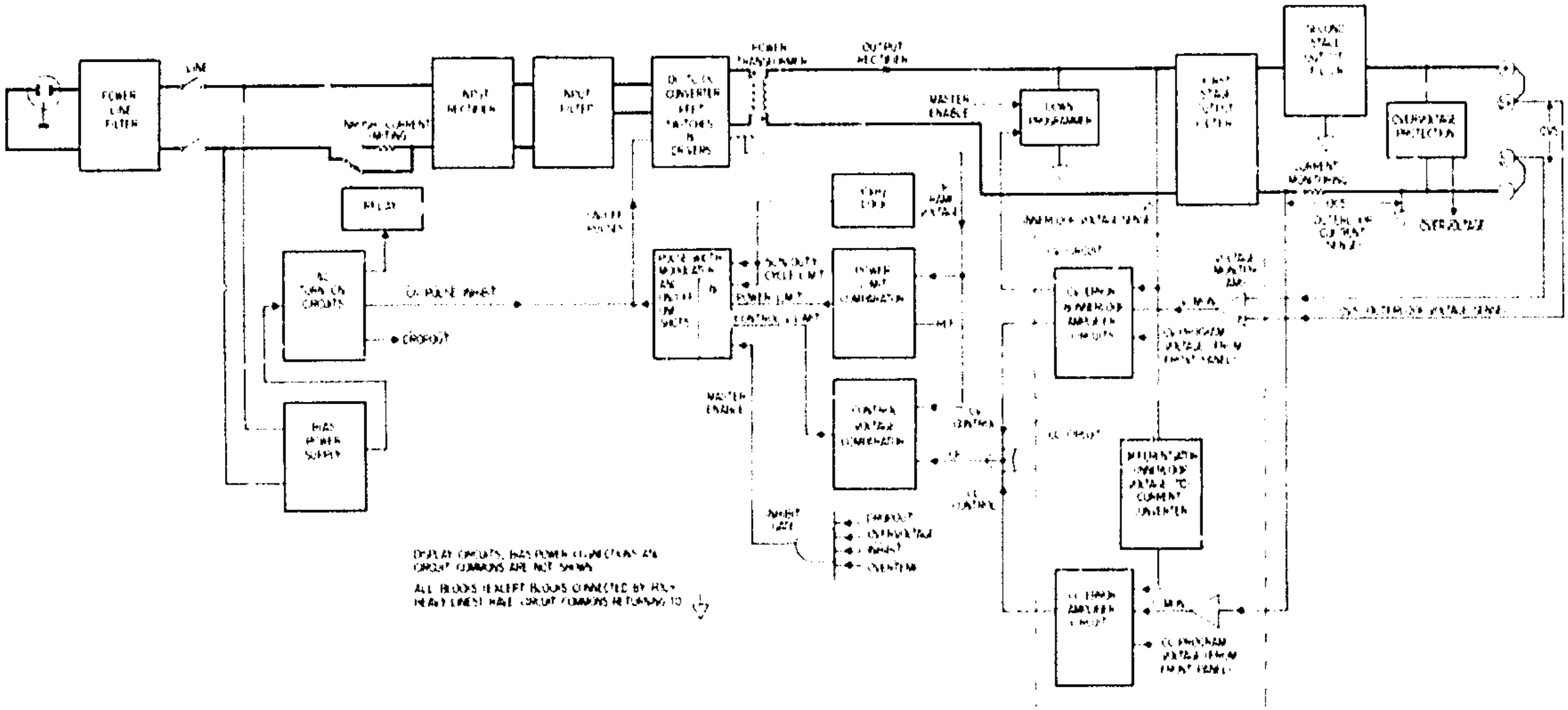


Figure 4-6. Power Mesh and Control Board Block Diagram

circuit. Overvoltage protection senses the output and shuts down the unit by inhibiting the pulse width modulator (PWM) through the master enable input when an overvoltage is detected. Other protection circuits (not shown) also can inhibit the PWM through the inhibit gate.

4-100 Control signals flow from right to left with separate circuits for constant-voltage, constant-current and power-limit control. These three control circuits jointly provide the autoranging characteristic of Figure 4-5c. AC turn-on circuits limit inrush current to the input filter and assure transient-free turn-on. Internal bias supplies provide five bias and two reference voltages to the unit's circuits and provide input signals to the AC turn-on circuits.

4-101 The unit is a flyback switching power supply. The power transformer stores energy in its magnetic field while current flows in its primary, and energy transfers to the secondary when current flow in the primary turns off. A pair of PFET switches in series with the primary turns on and off at a 20 kHz rate controlling the current flow; and the PWM varies the on-time of the PFET switches to regulate the output voltage or current. In CV or CC operation the PWM turns the PFET switches on at each clock pulse and turns them off when Ip-RAMP VOLTAGE exceeds CP CONTROL-PORT voltage. The Ip-RAMP VOLTAGE is derived from a sensing transformer in series with the power transformer primary and is proportional to the primary current. The CP CONTROL-PORT voltage is determined by the CV control circuit when the unit is in constant-voltage operation and is determined by the CC control circuit when in constant-current operation.

4-102 Follow the block diagram from right to left to see how the output voltage is regulated during CV mode of operation. The output voltage is monitored both at the output sense terminals +S and −S (OVS OUTERLOOP VOLTAGE) and also before the two stages of output filter (IVS INNERLOOP VOLTAGE). Sensing with output sense terminals provides accurate load-voltage control, and sensing before the output filter stabilizes the supply and permits it to power highly reactive loads. The CV monitor amplifier buffers the OVS OUTERLOOP VOLTAGE to produce the V-MON output monitoring voltage. A buffer amplifier (not shown) monitors the voltage before the output filter to produce the IVS INNERLOOP VOLTAGE. CV error and innerloop amplifiers compare V-MON and IVS with the CV PROGRAM VOLTAGE—which comes from the PSI board— to develop CV CONTROL VOLTAGE. When CV CONTROL VOLTAGE is lower than CC CONTROL VOLTAGE, CV determines CP and regulates the output voltage by controlling the turn-off of the PWM.

4-103 While the PWM turns off when any of the four inputs shown go low, in CV and CC operation it is controlled by the CONTROL V LIMIT input from the control voltage comparator. When Ip-RAMP VOLTAGE exceeds CP, CONTROL V LIMIT goes low and the PWM turns off the PFET switches. The next clock pulse causes the PWM to turn on the PFET switches, and thus the cycle repeats at a 20 kHz rate. Power is transferred through the transformer as required to produce the output voltage determined by the CV PROGRAM VOLTAGE.

4-104 When in CC operation, the output current is regulated in a similar manner. Output current is sensed as the OCS outer loop voltage across a current monitoring resistor. OCS is buffered to produce I-MON. IVS is differentiated to produce an innerloop current-sensing voltage; and CC error amplifier compares these to the CC PROGRAM VOLTAGE from the PSI board to develop the CC CONTROL VOLTAGE.

4-105 SIMPLIFIED SCHEMATIC

4-106 The simplified schematic, Figure 4-8, shows the basic operating circuits of the unit. Detailed descriptions follow for major circuits and components in clockwise order. The circuit names and layout of the simplified schematic are the same as used on the complete schematic in Section VII. The heavy lines are the path of power flow through the unit.

4-107 AC Turn-On Circuits

4-108 Primary power comes to the input rectifier through a resistor which limits turn-on inrush current to the input filter. Jumper A1W5 connects the input rectifier and filter as a voltage doubler for 100/120 Vac power lines. This jumper is not used for 220/240 Vac; thus the input filter develops a dc bus voltage of about 300 Vdc for either 100/120 or 220/240 Vac power line voltages. Primary power also comes through line-voltage select switches to the bias power supplies, which provide the internal operating voltages for the power supply. The line-voltage select switches connect the primary windings of the bias-supplies transformer for operation at 100, 120, 220, or 240 Vac.

4-109 The unit checks that the +5 Vdc bias voltage and the ac power line voltage are within acceptable limits as part of its turn-on sequence. When +5 Vdc comes up, the bias voltage detector resets the overvoltage protection circuit, enables the on-pulse driver for the PFET switches, and with the ac-surge-&-dropout detector starts the 1-second-delay circuit. After one second, relay A1K1 bypasses the inrush-current-limiting resistor. After 0.1 seconds more, the 1-Second-Delay circuit enables the PWM through the $\overline{\text{DROPOUT}}$ signal. The power supply can then provide output power.

4-110 When the ac-surge-&-dropout detector detects high or low line voltage, the unit shuts down until an acceptable power-line voltage returns. Then it repeats the above turn-on sequence. This protects the unit from damage from power-line surges and brownouts.

4-111 DC-to-DC Converter

4-112 PFET switches A4Q3 and A4Q4 control current flow from the Input Filter through power transformer T1. The PWM creates on- and off-pulses for the PFETs. A train of on pulses comes through diodes A4CR4 and A4CR3 to the PFETs' gates to turn on the PFETs. The PFETs' input capacitances hold the PFETs on between on pulses. Off pulses turn on transistors A4Q1 and A4Q2 which then short the PFETs' input capacitances and turn off the PFETs.

4-113 The on-pulse one-shot A2U15B and off-pulse oneshot A2U15A generate the on and off pulses. A2U15A produces a train of 160 kHz on pulses during the PWM output pulse. Off pulse one-shot A2U15A triggers an off pulse at each trailing edge of the PWM output pulses. Figure 4-7 shows the timing. Driver circuits increase the current-drive capability before applying the pulses to pulse transformers A4T1 and A4T2.

4-114 When the PFETs turn on, current flows through the primary of power transformer A1T1 and primary-current monitor transformer A4T3. The output rectifier A4CR7 is reverse biased and blocks current flow in the A1T1 secondary. Consequently, the A1T1 transformer stores energy. When the PFETs apply the dc bus voltage to the primary, the primary current ramps up, storing more and more energy. The A4T3 transformer senses the A1T1 primary current, and the secondary of A4T3 develops the Ip-RAMP VOLTAGE across resistor A2R108. This linearly increasing voltage predicts the correction in the supply's output voltage or current which will occur when the PFETs are turned off. Comparators monitoring the Ip-RAMP VOLTAGE signal the PWM to turn off the PFETs when Ip RAMP VOLTAGE exceeds either the CP CONTROL-PORT voltage or the POWER-LIMIT reference voltage.

4-115 When the PFETs turn off, the collapsing magnetic field reverses the polarity of the voltages across the A1T1 primary and secondary, and current flows from the A1T1 secondary through output rectifier A4CR7 to charge output capacitors A1C8, A1C9 and A1C10. When the PFETs turn off, the leakage inductance of T1 forces the current to continue to flow in the primary. Flyback Diodes A4CR13 and A4CR14 protect the PFETs from excess reverse voltage by conducting this current around the PFETs and back to the input filter.

4-116 Down Programmer

4-117 This circuit allows the output voltage to be lowered rapidly when required. In order to lower the output voltage it is necessary to discharge the output filter capacitors (typically, through the load). In situations that require the output voltage to drop more rapidly than can be accomplished through the load, the Down Programmer discharges the capacitors and pulls the output line low. Five conditions can trigger down programming: programming of a lower output voltage, overvoltage, overtemperature, remote disable, or primary power failure. The Down Programmer turns on when either MASTER ENABLE is low or the CV ERROR VOLTAGE is more negative than about −6 Vdc.

4-118 The +8.9 Vdc bias supply for the Down Programmer stores enough energy in its input capacitor to operate the Down Programmer after loss of primary power. This ensures that the Down Programmer will be able to discharge the output circuit completely when primary power is turned off.

4-119 Bleeder Circuit

4-120 This circuit enables the output capacitor to discharge faster by providing ample bleed current at various output levels, (thereby improving Down Programming times). The path for the bleed current is provided by one of two transistors, A1Q1 or A1Q2. At output voltages below 13 to 15.5 Vdc, transistor A1Q2 is turned on to supply milliamperes of bleed current. When the output voltage is above 13 to 15.5 Vdc, transistor A1Q1 is turned on, turning off A1Q2.

4-121 Fuse A1F3 provides protection to internal components should A1Q2 short and draw excessive current. Down programming response time at no load will be considerably longer if components malfunction in the bleeder circuit or if fuse A1F3 is blown.

4-122 Constant-Voltage (CV) Circuit

4-123 The constant-voltage circuit compares the output voltage to the user-set CV PROGRAM VOLTAGE to produce CV CONTROL VOLTAGE. Two comparison amplifier loops accomplish the comparison. In the outerloop, CV error amplifier A2U8 compares V-MON, a buffered fraction of the sensed output voltage OVS, to the programming voltage from the PSI board, to create the CV ERROR VOLTAGE. Then in the innerloop, amplifier A2U10A compares this error voltage to IVS, a buffered fraction of the innerloop output voltage, to produce the CV CONTROL VOLTAGE. The CV ERROR VOLTAGE is also diode-OR connected through diode A2CR21 as an input to the down programmer.

4-124 V-MON also connects through protective circuitry to rear-panel terminal VM for remote monitoring of the output voltage. As output varies from zero to full scale, V-MON varies from 0 to +5 volts.

4-125 Settings of the CV programming switches--the B6, B5 and B4 MODE switch settings—allow the CV PROGRAM VOLTAGE to come from the PSI board, from an external voltage applied between rear-panel terminals VP and ⏚ P, or from an external resistor between VP and ⏚ P. When using an external resistor, current from the CV constant-current source flows through the applicable resistance to develop the CV PROGRAM VOLTAGE.

4-126 In CV mode the CV CONTROL VOLTAGE varies between about −0.5 Vdc and about +1.0 Vdc. It is most negative when the load is drawing no power. As the load draws more power, the voltage becomes more positive. The CV CONTROL VOLTAGE is at the cathode of diode A2CR24, part of the diode-OR input to the control-voltage comparator. Diode A2CR20 prevents voltage overshoots during transient load changes and program changes.

4-127 Constant-Current (CC) Circuit

4-128 The constant-current circuit compares the output current to the user-set CC PROGRAM VOLTAGE to produce CC CONTROL VOLTAGE. As with the CV Circuit, two comparison amplifier loops accomplish the comparison. OCS is the voltage across current-monitoring resistors A1R27 & A1R28, and it senses the output current for the outerloop. To compensate for the fraction of the output current which flows through the unit's output-voltage sensing resistors, CC monitor amplifier A2U1 adds a fraction of V-MON to OCS. It amplifies both to produce the outerloop current-sense voltage, I-MON.

4-129 I-MON also connects through protective circuitry to rear-panel terminal IM for remote monitoring of the output current. As output varies from zero to full scale. V-MON varies from 0 to +5 volts.

4-130 Differentiation of IVS develops a current-proportional voltage which senses the innerloop current flowing into the capacitive output filter. CC error amplifier A2U2B sums this differentiated innerloop voltage with I-MON and compares the sum to the CC PROGRAM VOLTAGE to produce CC CONTROL VOLTAGE. In CC mode the CC CONTROL VOLTAGE varies between about −0.5 Vdc and about +1.0 Vdc at the cathode of diode A2CR19. CC clamp A2U2A limits CC PROGRAM VOLTAGE to about 5.6 peak volts.

4-131 Settings of the rear-panel CC programming switches—the B3, B2 and B1 MODE switch settings—allow the CC PROGRAM VOLTAGE to come from the PSI board, from an external voltage applied between terminals IP and ♢P, or from an external resistor between IP and ♢P. When using an external resistor, current from the CC constant-current source flows through the resistance to develop CC PROGRAM VOLTAGE.

4-132 Overvoltage Protection (OVP) Circuit

4-133 The OVP circuit monitors the power supply output voltage and compares it to a preset limit determined by a front-panel OVP ADJUST potentiometer. If the output voltage exceeds the limit, the OVP Circuit initiates a PWM OFF pulse, which also triggers the Down Programmer. The OVP Circuit latches itself until it receives OV CLEAR or ac power is turned off. The bias voltage detector resets the OVP at turn-on of the unit.

4-134 Power-Limit Comparator

4-135 Two comparisons with Ip-RAMP VOLTAGE provide POWER LIMIT and CONTROL V LIMIT, two of the four inputs for the PWM. Power Limit is the output of the Power-Limit Comparator A2U14A. The comparator compares Ip-RAMP VOLTAGE with the power-limit reference voltage of about 1.0 Vdc. The reference is adjustable with the POWER LIMIT calibration trim pot A2R25. POWER LIMIT sets the maximum primary current in power transformer A1T1 by going low and turning off the PWM when Ip-RAMP VOLTAGE exceeds the reference.

4-136 Primary current is approximately proportional to output power, and POWER LIMIT turns off the PWM when the CONTROL V LIMIT would otherwise allow the unit to deliver more than about 200 watts. This occurs during transient load increases, step increases in CV PROGRAM VOLTAGE and when the combination of the CV PROGRAM VOLTAGE and the CC PROGRAM VOLTAGE calls for more than 200 watts. The power-limit comparator produces the power-limited portion of the unit's output characteristic curve in Figure 4-4 and is the essence of the unit's autoranging characteristic.

4-137 Control-Voltage Comparator

4-138 The control-voltage comparator A2U16 produces the CONTROL V LIMIT input to the PWM by comparing Ip-RAMP VOLTAGE to CP CONTROL-VOLTAGE. In CV or CC operation CP is one diode-drop more than the lower of the CV and CC CONTROL VOLTAGE. CONTROL V LIMIT goes low and turns off the PWM when Ip-RAMP VOLTAGE exceeds CP. The A2R113-A2R114 voltage divider steers control of CP by its connection at the anodes of series diodes A2CR19 and A2CR24. The A2R113-A2R114 voltage divider sets the maximum CP voltage to +1.5 Vdc and assures that the diode with the lower control voltage will be forward biased when its control voltage is less than +1.5 Vdc. As an illustration of CV-CC selection, suppose the unit is in CV operation and diode A2CR24 is forward biased by a low CV CONTROL VOLTAGE: then CV sets CP to less than +1.5 Vdc. CV keeps diode A2CR19 reverse biased and prevents CC control until the CC CONTROL VOLTAGE is even lower.

4-139 The lower of the control voltages varies between about −0.5 Vdc and +1.0 Vdc regulating the unit's output. The higher control voltage has no effect on the output and increases in response to the error voltage in its circuit. When higher, the CC CONTROL VOLTAGE limits at about 6 Vdc. When higher, the CV CONTROL VOLTAGE increases only slightly. In CV or CC mode CP remains one diode drop more than the lower control voltage and varies form about 0.0 to +1.5 Vdc. In UNREGULATED mode CP is +1.0 Vdc.

4-140 Initial-Ramp Circuit

4-141 The control voltage and ramp voltage waveforms in Figure 4-7 show that there is a time delay between when the control voltage is exceeded and when the PFETS turn off. This cumulative circuit delay cuases the PFETS to deliver power even when no power is requested by the control circuits. to eliminate the delay, the initial-ramp circuit adds a ramp voltage to Ip-RAMP VOLTAGE at the input to the control voltage comparator. The added ramp voltage starts with the 20 kHz clock pulse and causes the combined-ramp voltage to exceed the control voltage earlier, thereby essentially eliminating the PFET turn-off delay. A two-state RC integrating network consisting of resistors A2R116 and A2R117 and capacitors A2C59 and A2C61 creates the initial ramp by shaping the 20 kHz clock pulses.

4-142 Pulse-Width Modulator (PWM)

4-143 The PWM generates 20 kHz repetition-rate pulses which vary in length according to the unit's output requirements. The pulses start 1.5μs after each 20 kHz clock pulse and turn off when any of these four inputs go low: The output of the control-voltage comparator (CONTROL V LIMIT), the output of the power-limit comparator (POWER LIMIT), the 20 kHz clock pulse (50% duty cycle limit), or the output of the inhibit gate A2U19A (MASTER ENABLE). As discussed in paragraph 4-112, the PFETs turn on during and turn off at the trailing edges, respectively, of PWM output pulses.

4-144 The PWM generates pulses as follows: a 20 kHz clock pulse holds the 1.5μs-delay flipflop A2U13B reset; 1.5μs after the trailing edge of the 20 kHz pulse, the next pulse from the 320 kHz clock oscillator clocks the output of A2U13B high, and this initiates the PWM pulse from PWM flipflop A2U13A. When

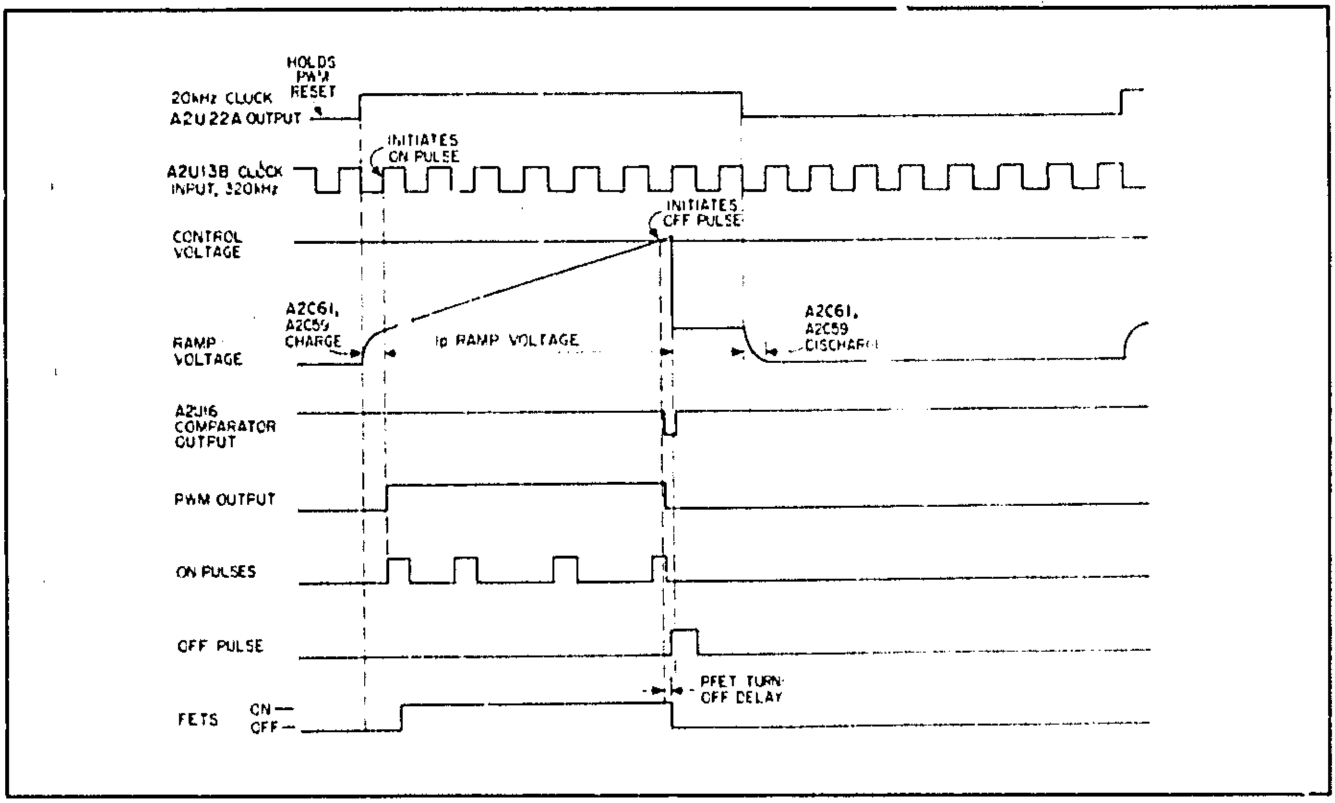


Figure 4-7. PFET Control Signals Timing Diagram

one of the above four inputs to AND-gate A2U19B goes low, A2U19B resets A2U22A, and the PWM pulse turns off.

4-145 Bias Voltage Detector

4-146 The bias voltage detector prevents spurious operation which might occur at turn-on of the unit if circuits tried to operate before the +5 Vdc bias voltage is at the clock, PWM, and logic circuits. After turn-on, as the output of the +5 Vdc bias supply rises from 0 Vdc through about 1 Vdc, three transistor switches in the Bias Voltage Detector turn on. They inhibit the Relay Driver and the On-Pulse Driver, and they create the power-clear signal, $\overline{PCLR2}$. The transistors inhibit the circuits and hold $\overline{PCLR2}$ low until the unregulated input to the +5 Vdc bias supply is greater than about 11 Vdc, an input voltage sufficient to assure +5 Vdc bias output. $\overline{PCLR2}$ resets the OVP at turn-on.

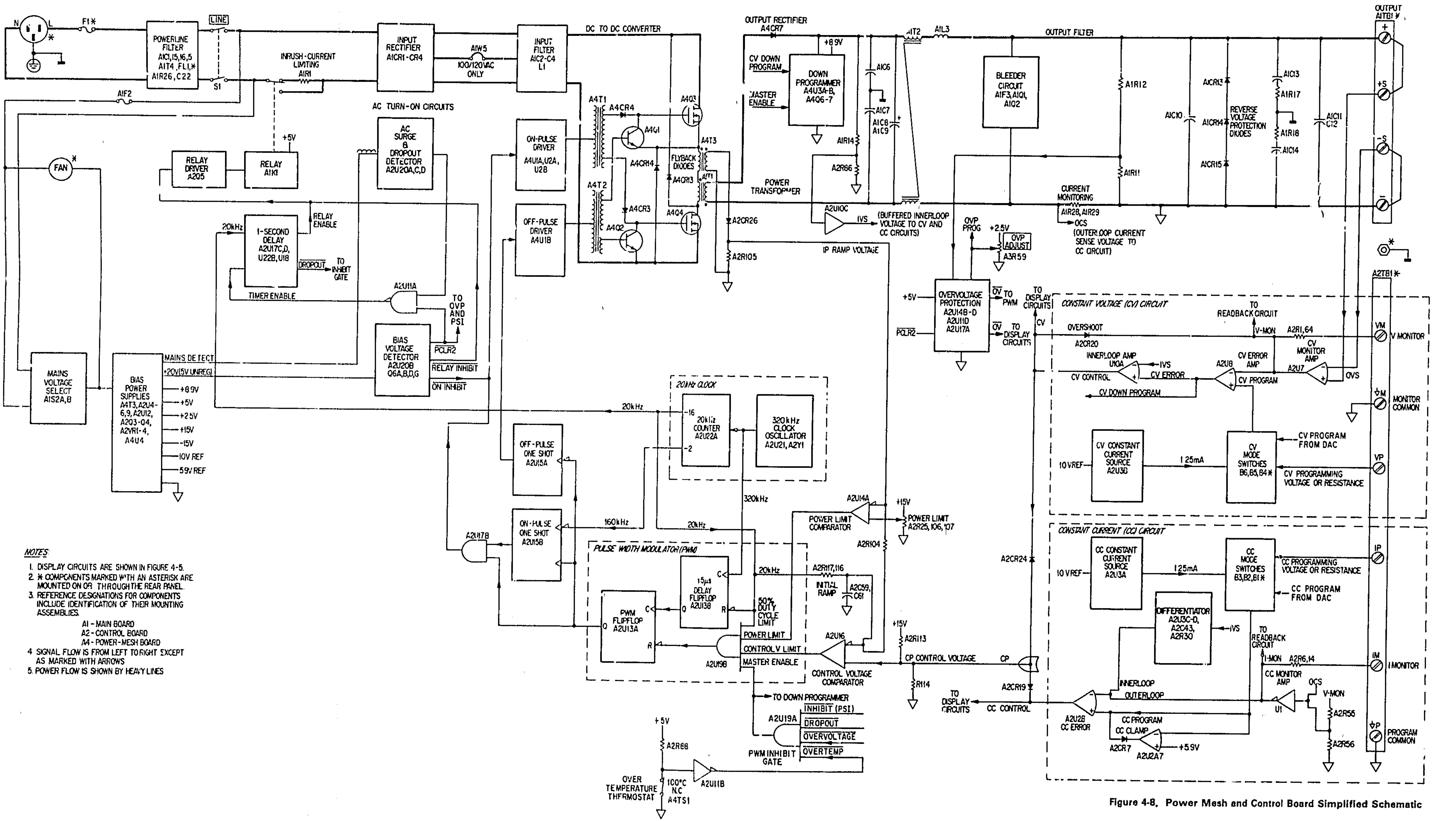
4-147 AC-Surge-&-Dropout Detector

4-148 The ac-surge-&-dropout detector protects the unit from damage from power line voltage surges and dropouts by shutting down the unit when there is either a 40% overvoltage or a 20 ms voltage interruption in the ac power line voltage. The detector shuts down the unit by inhibiting the PWM through the $\overline{DROPOUT}$ signal from the 1-Second-Delay circuit. Line Detect signal, which is fullwave-rectified ac from the +5 Vdc secondary of the bias-supplies transformer, senses the power line voltage.

4-149 The dropout detector, including comparators A2U20A an A2U20D, operates by enabling a capacitor-timing ramp when LINE DETECT ceases. Comparator A2U20C monitors the amplitude of LINE DETECT to provide highline voltage detection.

4-150 1-Second-Delay Circuit

4-151 The 1-second delay circuit is the heart of the unit's controlled turn on. It causes relay A1K1 to bypass inrush-current-limiting resistor A1R1 one second after turn on, and it enables the PWM 0.1 seconds later. When either the output of the ac-surge-&-dropout detector or $\overline{PCLR2}$ is low, NAND gate A2U11A holds the circuit reset. The circuit starts counting at 1/16 the clock frequency (1.25 kHz) when both inputs to A2U11A are high and causes RELAY ENABLE to go high in 1.0 seconds and $\overline{DROPOUT}$ to go high in 1.1 seconds. When $\overline{DROPOUT}$ goes high, it stops the count, and it enables the PWM.



NOTES:

1. DISPLAY CIRCUITS ARE SHOWN IN FIGURE 4-5.
2. * COMPONENTS MARKED WITH AN ASTERISK ARE MOUNTED ON OR THROUGH THE REAR PANEL.
3. REFERENCE DESIGNATIONS FOR COMPONENTS INCLUDE IDENTIFICATION OF THEIR MOUNTING ASSEMBLIES.
   A1 - MAIN BOARD
   A2 - CONTROL BOARD
   A4 - POWER-MESH BOARD
4. SIGNAL FLOW IS FROM LEFT TO RIGHT EXCEPT AS MARKED WITH ARROWS
5. POWER FLOW IS SHOWN BY HEAVY LINES

Figure 4-8. Power Mesh and Control Board Simplified Schematic

MAINTENANCE

Section V
MAINTENANCE

5-1 INTRODUCTION

5-2 This section provides test and calibration procedures, and troubleshooting and repair information. The operation-verification tests comprise a short procedure to verify that the unit is performing properly, without testing all specified parameters. After troubleshooting and repair of a defective power supply you can usually verify proper operation with the functional-test procedure in Section III. Repairs to the A1 main board, the A2 control board and the A7 PS; board can involve circuits which, although functional, may prevent the unit from performing within specified limits. So, after A1, A2 or A7 board repair, decide if recalibration and operation verification tests are needed according to the faults you discover. Use the calibration procedure both to check repairs and for regular maintenance.

5-3 TEST EQUIPMENT REQUIRED

5-4 Table 5-1 lists the equipment required to perform the tests of this section. You can separately identify the equipment for performance tests, calibration and troubleshooting using the USE column of the table.

5-5 OPERATION VERIFICATION TESTS

5-6 To assure that the unit is performing properly, without testing all specified parameters, perform the following procedure.

a. Perform turn-on checkout procedure given in Section III. This includes a series of power-on self tests.

b. Perform the following performance tests, provided in this section.

Voltage Programming And Readback Accuracy
Current Programming And Readback Accuracy
CV Load Effect
CC Load Effect

5-7 CALIBRATION PROCEDURE

5-8 Calibrate the unit twice per year and when required during repair. The following calibration procedures should be performed in the sequence given. Table 5-3 lists values to which each adjustment should be made. References in the calibration procedures correspond to reference numbers in Table 5-3.

NOTE

Some of the calibration procedures for this instrument can be performed independently, and some procedures must be performed together and/or in a prescribed order. If a procedure contains no references to other procedures, you may assume that it can be performed independently.

To return a serviced unit to specifications as quickly as possible with minimal calibration, the technician need only perform calibration procedures that affect the repaired circuit. Table 5-2 list various power supply circuits with calibration procedures that should be performed after those circuits are serviced. Circuits are identified by schematic designators; either the tinted circuit block and/or specific circuit area within a tint block, or the reference designator of specific components. In both cases, the printed-circuit board containing the circuit is also listed.

Table 5-1. Test Equipment Required

TYPE	REQUIRED CHARACTERISTICS	USE	RECOMMENDED MODEL
Oscilloscope	Sensitivity: 1 mV Bandwidth: 20 MHz & 100 MHz Input: differential, 50 Ω & 10 MΩ	P,T	HP1740A
RMS Voltmeter	True rms, 10 MHz bandwidth Sensitivity: 1 mV Accuracy: 5%	P	HP3400A
Logic Pulser	4.5 to 5.5Vdc @ 35 mA	T	HP546A

Table 5-1. Test Equipment Required (continued)

Type	Required Characteristics	Use	Recommended Model
Multimeter	Resolution: 100 nV Accuracy: 0.0035%, 6½ digit	P,C,T	HP3456A
Signature Analyzer	—	T	HP5004A
HP-IB Controller	Full HP-IB capabilities	C,T,P	HP85, 9816, 9826, 9836
CC PARD Test Current Probe	No saturation at 10 Adc Bandwidth: 20 Hz to 20 MHz	P	Tektronix P6303 Probe/AM503 Amp/ TM500 Power Module
Electronic Load	Voltage range: 60 Vdc Current range: 10 Adc Power range: 250 watts Open and short switches	P,C*	Transistor Devices, Model DLP 130-1E 750
CC PARD Test	Value: 2.3Ω, >200 W Accuracy: 1% Rheostat or Resistor Bank	P	
Current Monitoring Resistor	Value: 100 mV @ 10 A (10 mΩ) Accuracy: 0.02% ** TC: 20 ppm /°C	P,C	
Calibration and Test Resistors	Value: 100 Ω, 5%, 1 W 1 Ω, 5%, ½ W 1 kΩ, 5%, ¼ W 5 kΩ, 5%, ¼ W 2 kΩ, 0.01%, ¼ W	C,T	
Terminating Resistors (2)	Value: 50 Ω ±5%, noninductive	P	
Blocking Capacitors (2)	Value: 0.01 μF, 100 Vdc	P	
Common-mode Toroidal Core	≥3.7μH/turn² ≈ 23mm I.D.	P	Ferrox-Cube 500T600-3C8, HP 9170-0031
Switch	SPST, 10 A @ 60 Vdc	P	
DC Power Supply	Voltage range: 0-60 Vdc Current range: 0-3 Adc	C,T	HP6024A

P = performance testing C = calibration adjustments T = troubleshooting

* For calibration, either the electronic load or the load resistor is required.

** Less accurate, and less expensive, current-monitor resistors can be used, but the accuracy to which current programming and readback can be checked must be reduced accordingly.

Table 5-2. Guide to Recalibration After Repair

Printed Circuit Board	Block Name	Circuit Within Block	Reference Designator	Perform These Procedures *
A1 Main Board			R3	5-18,5-19
A1 Main Board			T1	5-20
A4 Power Mesh Board			T3	5-20
A4 Power Mesh Board			CR7	5-20
A2 Control Board	Constant Voltage (CV) Circuit	All Except Current Source	All	5-10,5-11,5-12, 5-13,5-14,5-15
A2 Control Board	Constant Votlage (CV) Circuit	Current Source	All	5-21
A2 Control Board	Constant Current (CC) Circuit		All	5-16,5-17,5-18 5-19
A2 Control Board	Power Limit Comparator		All	5-20
A2 Control Board	Bias Power Supplies	+ & −15 V Supplies	All	5-10—5-21
A7 PSI Board	Voltage Monitor Buffer		All	5-10,5-12,5-13 5-14,5-15
A7 PSI Board	Analog Multiplexer		All	5-12,5-13,5-14, 5-15
A7 PSI Board	Successive Approximation A/D Converter		All	5-12,5-13,5-14, 5-15
A7 PSI Board	Voltage DAC		All	5-12.5-13,5-14, 5-15
A7 PSI Board	Current DAC		All	5-17,5-19
A7 PSI Board			U43	5-12,5-13,5-14, 5-15,5-19

*Paragraph numbers of Calibration Procedures to be performed

5-10 Voltage Monitor Zero Calibration
5-11 Common Mode Calibration
5-12 Remote Readback Zero Calibration
5-13 Constant Voltage Full Scale Calibration
5-14 Voltage Monitor and Remote Readback Full Scale Calibration
5-15 Constant Voltage Zero Calibration
5-16 Current Monitor Zero Calibration
5-17 Constant Current Zero Calibration
5-18 Current Monitor Full Scale Calibration
5-19 Constant Current Full Scale Calibration
5-20 Power Limit Calibration
5-21 Resistance Programming Full Scale Calibration

Table 5-3. Calibration Values

Reference Number	Calibration Procedure	Ref Des	DVM Connection (– to +)	Correct Value And Tolerance
1	Voltage Monitor Zero	A2R22	⏚M to A2J3-3	0 V ±20 µV
2	Common Mode	A2R21	⏚M to A2J3-3	Initial Reading ±20 µV
3	p/o Remote Readback Zero	A7R40	⏚M to A2J3-3	625 µV ±30 µV
4	p/o Remote Readback Zero	A7R51	–	Toggles between 0 and 15 mV
5	Constant Voltage Full Scale	A7R58	–S to +S	60.0075 V ±1.82 mV
6	p/o Voltage Monitor And Remote Readback Full Scale	A7R75	⏚M to A2J3 3	5.000625 V ±100 µV
7	p/o Voltage Monitor And Remote Readback Full Scale	A7R61	–	Toggles between 60 V and 60.015 V
8	Constant Voltage Zero	A7R40	–S to +S	0 V ±120 µV
9	Current Monitor Zero	A2R8	⏚M to IM	0 V ±25 µV
10	Constant Current Zero	A7R29	Across Rm	0 V ±350 µV
11	Current Monitor Full Scale	A2R9	Across Rm	0.002) X (Initial Reading) ±100 µV
12	Constant Current Full Scale	A7R55	Across Rm	100 mV ±10 µV
13	Resistance Programming Full Scale	A2R23	⏚P to VP	2.5 V ± 4 mV

5-9 Initial Setup

a. Unplug the line cable and remove the top cover by removing three screws; the rear handle screw and the two top-rear-corner screws. Do not remove the front handle screw as the retaining nut will fall into the unit.

b. Slide the cover to the rear.

c. Plug a control board test connector A2J3 onto the A2J3 card-edge fingers.

d. Turn OVERVOLTAGE ADJUST control A3R59 fully clockwise.

e. Disconnect all loads from output terminals.

f. Connect power supply for local sensing, and ensure that MODE switches are set as shown in Figure 3-4.

g. Connect an HP-IB controller to the power supply.

h. Reconnect line cable and turn on ac power.

i. Allow unit to warm up for 30 minutes.

j. When attaching the DVM, the minus lead of the DVM should be connected to the first node listed, and the plus lead should be connected to the second node listed.

k. At the beginning of each calibration procedure, the power supply should be in its power-on state (turn ac power off and back on), with no external circuitry connected except as instructed.

l. The POWER LIMIT adjustment (A2R25) must be adjusted at least coarsely before many of the calibration procedures can be performed. If you have no reason to suspect that the Power Limit circuit is out of adjustment, do not disturb its setting.

Otherwise, center A2R25 before you begin to calibrate the power supply.

m. Turn off ac power when making or removing connections to the power supply.

WARNING

Maintenance described herein is performed with power supplied to the instrument, and protective covers removed. Such maintenance should be performed only by service trained personnel who are aware of the hazards involved (for example, fire and electrical shock). Where maintenance can be performed without power applied, the power should be removed.

5-10 Voltage Monitor Zero Calibration

a. Send string "OUT OFF".
b. Short power supply output terminals.
c. Attach the DVM from ∇M on the rear panel to A2J3 pin 3 (VMONT).
d. Adjust A2R22 (V-MON ZERO) to Table 5-3 reference #1.

5-11 Common Mode Calibration

a. Send string "OUT OFF".
b. Short power supply sense terminals (+S to −S) at rear panel.
c. Attach the DVM from ∇M on the rear panel to A2J3 pin 3 (VMONT).
d. Take initial reading from DVM.
e. Remove both local sensing straps from rear-panel terminal block, and connect a 1-volt external power supply with its + lead to −S and its − lead to −Out. See Figure 5-1.
f. Adjust A2R21 (CV LOAD REG) to Table 5-3 reference #2.
g. Replace local sense straps after removing external power supply.

5-12 Remote Readback Zero Calibration

NOTE

This procedure and the following three procedures must be done as a set, without omitting any of the four procedures. Also, the following four procedures require that V-MON ZERO (A2R22) be adjusted within specifications. If it is not, perform the Voltage Monitor Zero Calibration before proceeding.

a. Connect an external supply to the power supply as shown in Figure 5-2.

b. Send string "VSET 0; ISET 5; OUT ON".

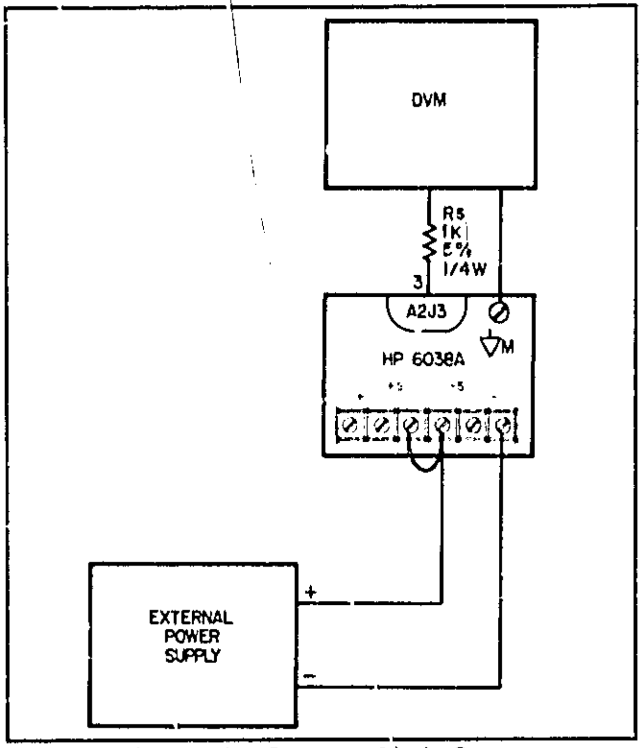


Figure 5-1. Common Mode Setup

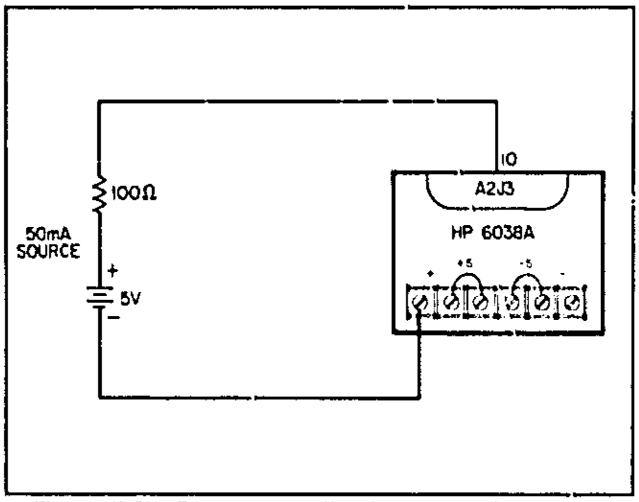


Figure 5-2. Remote Readback Zero And CV Zero Calibration Setup

c. Attach the DVM from ∇M on the rear panel to A2J3 pin 3 (VMONT).
d. Adjust A7R40 (CV PROG ZERO) to Table 5-3 reference #3.
e. Remove the DVM.
f. Enter and run the following program and begin noting the controller's display:

```
10 OUTPUT 705; "VOUT?"
10 ENTER 705; A
30 DISP A
40 GOTO 10
50 END
```

g. Adjust A7R51 (READBACK ZERO) until the value displayed on the controller toggles between the values listed in Table 5-3 reference #4.
h. After adjusting A7R51 you must continue the calibration procedure through to the completion of Constant Voltage Zero Calibration, or CV Zero will be off by 7.5 mV. Remember to disconnect external power supply and resistor.

5-13 Constant Voltage Full Scale Calibration

NOTE

Perform this procedure only after completing Remote Readback Zero Calibration.

a. Remove all external test circuits.
b. Send string "VSET 60; ISET 5".
c. Attach the DVM from −S to +S terminals on rear panel.
d. Adjust A7R58 (CV PROG F.S.) to Table 5-3 reference #5.
e. After adjusting A7R58 you must continue the calibration procedure through to the completion of Constant Voltage Zero Calibration, or the zero will be off by 7.5 mV.

5-14 Voltage Monitor and Remote Readback Full Scale Calibration

NOTE

Perform this procedure only after completing Constant Voltage Full Scale Calibration.

a. Attach the DVM from ▽ M on the rear panel to A2J3 pin 3 (VMONT). See DVM connection in Figure 5-1.
b. Send string "VSET 60; ISET 5; OUT ON".
c. Adjust A7R75 (V-MON F.S.) to Table 5-3 reference #6.
d. Disconnect the DVM.
e. Enter and run the following program and begin noting the controller's display.

```
10 OUTPUT 705; "VOUT?"
10 ENTER 705; A
30 DISP A
40 GOTO 10
50 END
```

f. Adjust A7R61 (READBACK F.S.) until the value displayed on the controller toggles between the values listed in Table 5-3 reference #7.
g. After adjusting A7R61 you must continue the calibration procedure through to the completion of Constant Voltage Zero Calibration.

5-15 Constant Voltage Zero Calibration

NOTE

Perform this procedure only after completing Voltage Monitor and Remote Readback Full Scale Calibration.

a. Send string "VSET 0; ISET 5; OUT ON".
b. Connect an external supply to the power supply as shown in Figure 5-2.
c. Attach the DVM from −S to +S on the rear panel.
d. Adjust A7R40 (CV PROG ZERO) to Table 5-3 reference #8.

5-16 Current Monitor Zero Calibration

a. Send string "VSET 0; ISET 0; OUT OFF".
b. Connect a short across power supply output terminals.
c. Attach the DVM from ▽ M to IM on the rear panel.
d. Allow several minutes (3 or more) to ensure thermal settling.
e. Adjust A2R8 (I-MON ZERO) to Table 5-3 reference #9.

5-17 Constant Current Zero Calibration

a. Connect the test setup shown in Figure 5-3.
b. Send string "VSET 2; ISET 5; OUT ON".
c. Allow several minutes (3 or more) to ensure thermal settling.
d. Adjust A7R29 (CC PROG ZERO) to Table 5-3 reference #10.

5-18 Current Monitor Full Scale Calibration

NOTE

This procedure requires that I-MON ZERO (A2R8) be adjusted within specifications. If it is not, perform the Current Monitor Zero Calibration before proceeding.

a. Connect Rm current-monitoring shunt (10 milliohm, 0.05% or better) across power supply output terminals.
b. Send string "VSET 5; ISET 10; OUT ON".
c. Attach DVM from ▽M to IM on the rear panel. Use six-digit display on HP 3456A DVM.
d. Take initial reading from DVM.
e. Attach DVM across Rm. Allow several minutes (3 or more) to ensure thermal settling. This can be noted as a stable reading on the DVM.
f. Adjust A2R9 (I-MON F.S.) to Table 5-3 reference #11.

5-19 Constant Current Full Scale Calibration

NOTE

This procedure requires that CC PROG ZERO (A2R29) and I-MON F.S. (A2R9) be adjusted within specifications. If they are not, perform Constant Current Zero and/or Current Monitor Full Scale Calibration before proceeding.

a. Connect Rm current-monitoring shunt (10 milliohm, 0.05% or better) across power supply output terminals.
b. Send string "VSET 5; ISET 10".
c. Attach DVM across Rm. Allow several minutes (3 or more) to ensure thermal settling.
d. Adjust A7R55 (CC PROG F.S.) to Table 5-3 reference #12.

5-20 Power Limit Calibration

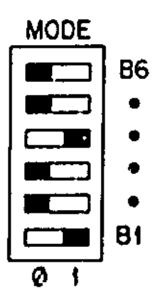
NOTE

This procedure requires that CC PROG F.S. (A7R55) be adjusted within specifications. If it is not, perform Constant Current Full Scale Calibration before proceeding.

a. Connect the power supply to the ac power line through a variable autotransformer which is set to the minimum for your line voltage (e.g., 104 V for nominal 120 V line).
b. Turn A2R25 (POWER LIMIT) fully counterclockwise.
c. Connect an electronic load across the output terminals. (A 2.3 ohm resistor can be used).
d. Set the electronic load for 10 amperes in the constant Current mode.
e. Turn on power supply and send string "VSET 23; ISET 10.2".
f. Adjust A2R25 (Power Limit) clockwise until CV LED on front panel turns on.
g. Power Supply output shall be 23 ±0.3 volts and 10 amperes.

5-21 Resistance Programming Full Scale Calibration

a. Send string "OUT OFF".
b. Connect a 2-kilohm calibration resistor from ⏚ P to VP on rear panel.
c. Set rear-panel MODE switches for resistance programming:



d. Attach the DVM from ⏚ P to VP on the rear panel.
e. Adjust A2R23 (R-PROG F.S.) to Table 5-3 reference #13.
f. Remember to reset MODE switches to original settings.

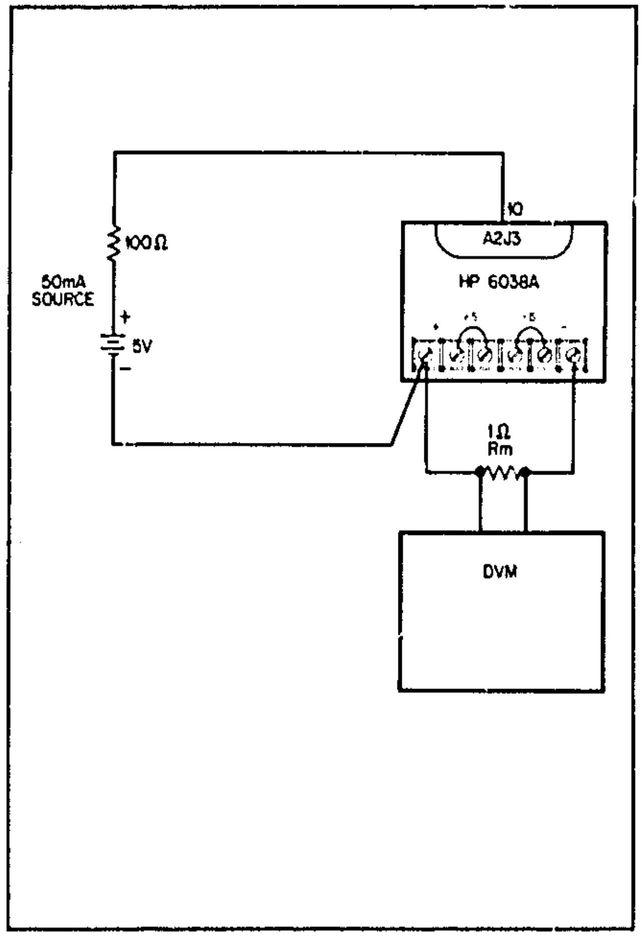


Figure 5-3. CC Zero Calibration Setup

5-22 PERFORMANCE TESTS

5-23 The following paragraphs provide test procedures for verifying the unit's compliance with the specifications of Table 1-1. Please refer to CALIBRATION PROCEDURE or TROUBLESHOOTING if you observe out-of-specification performance.

5-24 Measurement Techniques

5-25 **Setup For All Tests.** Measure the DC output voltage directly at the +S and -S terminals. Connect unit for local sensing, and ensure that MODE switches are set as shown in Figure 3-4. Select an adequate wire gauge for load leads using the procedures given in Section III for connecting the load.

5-26 **Electronic Load.** The test and calibration procedures use an electronic load to test the unit quickly and accurately. If an electronic load is not available, you may substitute a 18 Ω load resistor, capable of safely dissipating 200 watts, for the electronic, load in these tests:

CV Source Effect (Line Regulation)
CC Load Effect (Load Regulation)

You may substitute a 2 Ω, 200 W or more, load resistor in these tests:

CV Load Effect (Load Regulation)
CV PARD (Ripple and Noise)
CC Source Effect (Line Regulation)
CC PARD (Ripple and Noise)

The substitution of the load resistor requires adding a load switch and making minor changes to the procedures. The load transient recovery time test procedure is not amenable to modification for use with load resistors.

5-27 An electronic load is considerably easier to use than a load resistor. It elminates the need for connecting resistors or rheostats in parallel to handle the power, it is much more stable than a carbon-pile load, and it makes easy work of switching between load conditions as is required for the load regulation and load transient-response tests.

5-28 **Current-Monitoring Resistor.** To eliminate output-current measurement error caused by voltage drops in the leads and connections, connect the current-monitoring resistor between −OUT and the load as a four-terminal device. Figure 5-4 shows correct connections. Connect the current-monitoring test leads inside the load-lead connections directly at the monitoring resistor element. Select a resistor with stable characteristics: 10 mΩ, 0.02% accuracy, 20 ppm/°C or lower temperature coefficient and 10 A current rating.

NOTE

A current-monitoring resistor with 1% accuracy is suitable for all tests except current programming accuracy and current readback accuracy. For these tests, use a 0.02% shunt as listed in Table 5-1.

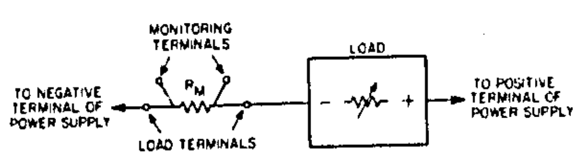


Figure 5-4. Current-Monitoring Resistor Setup

5-29 **HP-IB Controller.** Most performance tests can be performed using only front-panel controls. However, an HP-IB controller is required to perform the voltage and current programming accuracy tests and the voltage and current readback accuracy tests.

5-30 Constant Voltage (CV) Tests

5-31 **CV Setup.** If more than one meter or a meter and an oscilloscope are used, connect each to the +S and −S terminals by a separate pair of leads to avoid mutual coupling effects. Connect only to +S and -S because the unit regulates the output voltage between +S and −S, not between +OUT and −OUT. Use coaxial cable or shielded 2-wire cable to avoid pickup on test leads. For all CV tests set the output current at full output to assure CV operation.

5-32 **Voltage Programming And Readback Accuracy.** This procedure verifies that the voltage programming and readback functions are within specifications. An HP-IB controller must be used for this test.

a. Connect digital voltmeter between +S and −S.
b. Turn on ac power to the power supply.
c. Send string "VSET 0.09; ISET 10".
d. The DVM reading should be in the range 0.075 to 0.105 Vdc. Note the reading.
e. Enter and run the following program:

```
10 OUTPUT 705; "VOUT?"
20 ENTER 705;A
30 DISP A
40 GOTO 10
50 END
```

f. The value displayed by the controller should be the value noted in step d ±0.015 Vdc.
g. Send string "VSET 60; ISET 10".
h. The DVM reading shuld be in the range 59.939 to 60.061 Vdc. Note the reading.
i. Run the program listed in step e. The value displayed by the controller should be the value noted in step h ±0.092 Vdc.

5-33 **Load Effect (Load Regulation).** Constant-voltage load effect is the change in dc output voltage (Eo) resulting from a load-resistance change from open-circuit to full-load. Full-load is the resistance which draws the maximum rated output current at voltage Eo. Proceed as follows:

a. Connect the test equipment as shown in Figure 5-5. Operate the load in constant resistance mode (Amps/Volt) and set resistance to maximum.
b. Turn the unit's power on, and, using DISPLAY SETTINGS pushbutton switch, turn up current setting to full output.
c. Turn up output voltage to 20.0 Vdc as read on the digital voltmeter.
d. Reduce the resistance of the load to draw an output current of 10 Adc (0.1 Vdc across Rm). Check that the unit's CV LED remains lighted.

e. Record the output voltage at the digital voltmeter.
f. Open-circuit the load.
g. When the reading settles, record the output voltage again. Check that the two recorded readings differ no more than ±0.005 Vdc.

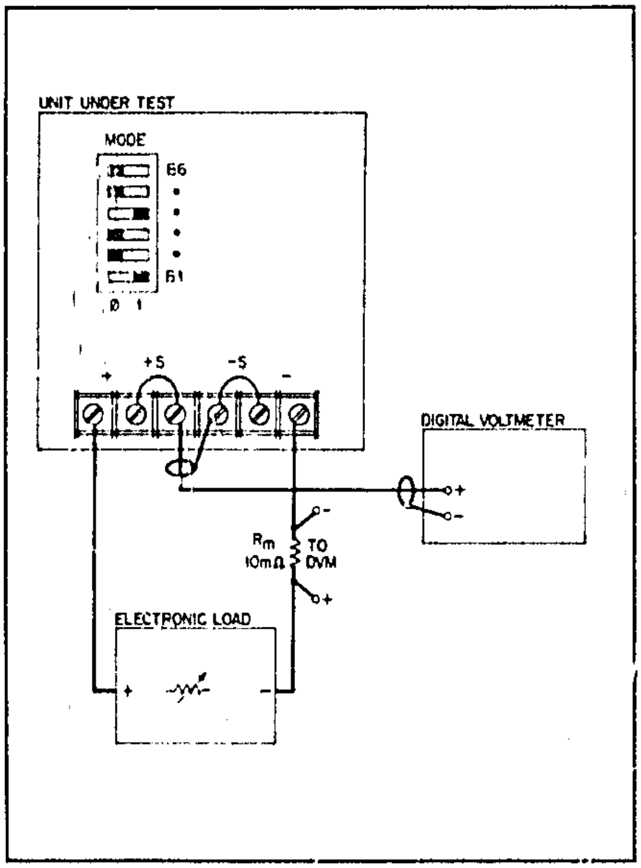


Figure 5-5. Basic Test Setup

5-34 **Source Effect (Line Regulation).** Source effect is the change in dc output voltage resulting from a change in ac input voltage from the minimum to the maximum value as specified in Input Power Requirements in the Specifications Table, Section I. Proceed as follows:

a. Connect the test equipment as shown in Figure 5-5. Operate the load in constant resistance mode (Amps/Volt) and set resistance to maximum.
b. Connect the unit to the ac power line through a variable autotransformer which is set for nominal line voltage.
c. Turn on power supply and allow it to warm up for 30 minutes. Using DISPLAY SETTINGS pushbutton switch, turn up current setting to full output.
d. Turn up output voltage to 60.0 Vdc as read on the digital voltmeter.
e. Reduce the resistance of the load to draw an output current of 0.053 Adc (0.010 Vdc across Rm). Check that the unit's CV LED remains lighted.
f. Adjust autotransformer to the minimum for your line voltage.
g. Record the output voltage at the digital voltmeter.
h. Adjust autotransformer to the maximum for your line voltage.
i. When the reading settles record the output voltage again. Check that the two recorded readings differ no more than ±0.008 Vdc.

5-35 **PARD (Ripple And Noise).** Periodic and random deviations (PARD) in the unit's output—ripple and noise—combine to produce a residual ac voltage superimposed on the dc output voltage. Constant-voltage PARD is specified as the root-mean-square (rms) or peak-to-peak (pp) output voltage in a frequency range of 20 Hz to 20 MHz.

5-36 **RMS Measurement Procedure.** Figure 5-6 shows the interconnections of equipment to measure PARD in Vrms. To ensure that there is no voltage difference between the voltmeter's case and the unit's case, connect both to the same ac power outlet or check that the two ac power outlets used have the same earth-ground connection.

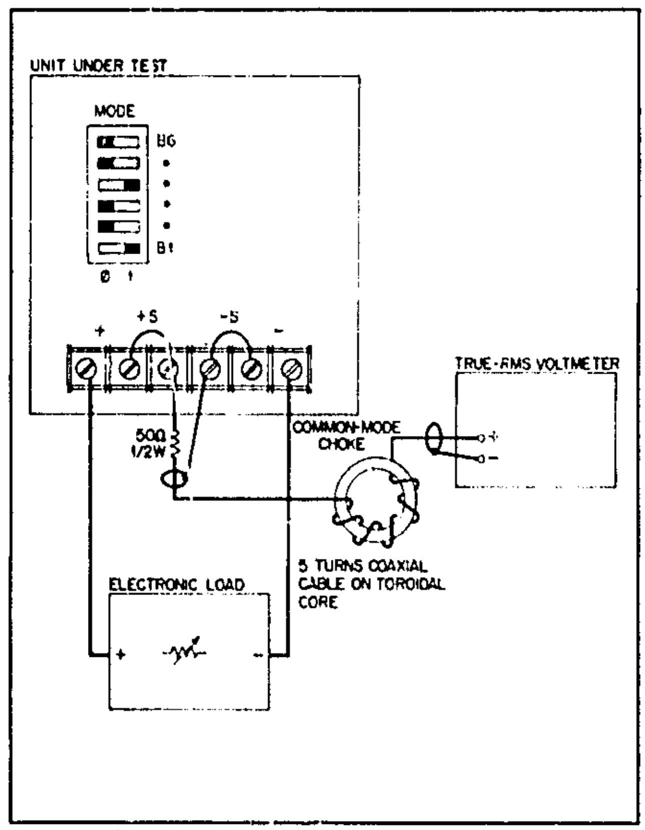


Figure 5-6. RMS Measurement Test Setup, CV PARD Test

5-37 Use the common-mode choke as shown to reduce ground-loop currents from interfering with measurement. Reduce noise pickup on the test leads by using 50 Ω coaxial cable, and wind it five turns through the magnetic core to form the common-mode choke. Proceed as follows:

a. Connect the test equipment as shown in Figure 5-6. Operate the load in constant resistance mode (Amps/Volt) and set resistance to maximum.
b. Turn the unit's power on, and, using DISPLAY SETTINGS pushbutton switch, turn up current setting to full output.
c. Turn up output voltage to 20 Vdc.
d. Reduce the resistance of the load to draw an output current of 10 Adc. Check that the unit's CV LED remains lighted.
e. Check that the rms noise voltage at the true rms voltmeter is no more than 3.0 mV rms.

5-38 **Peak-To-Peak Measurement Procedure.** Figure 5-7 shows the interconnections of equipment to measure PARD in Vpp. The equipment grounding and power connection instructions of Paragraph 5-36 apply to this setup also. Connect the oscilloscope to the +OUT and −OUT terminals through 0.01 μF blocking capacitors to protect the oscilloscope's input from the unit's output voltage. To reduce common-mode noise pickup, set up the oscilloscope for a differential, two-channel voltage measurement. To reduce normal-mode noise pickup, use twisted, 1 metre or shorter, 50 Ω coaxial cables with shields connected to the oscilloscope case and to each other at the other ends. Proceed as follows:

a. Connect the test equipment as shown in Figure 5-7. Operate the load in constant resistance mode (Amps/Volt) and set resistance to maximum.

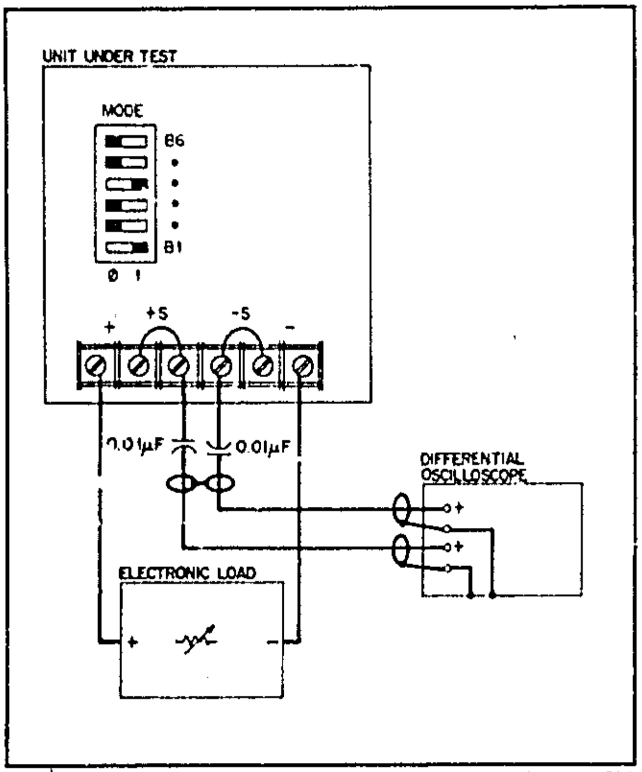


Figure 5-7. Peak-To-Peak Measurement Test Setup, CV PARD Test

b. Turn the unit's power on, and, using DISPLAY SETTINGS pushbutton switch, turn up current setting to full output.
c. Turn up output voltage to 20 Vdc.
d. Reduce the resistance of the load to draw an output current of 10 Adc. Check that the unit's CV LED remains lighted.
e. Set the oscilloscope's input impedance to 50 Ω and bandwidth to 20 MHz. Adjust the controls to show the 20 kHz and higher frequency output-noise waveform of Figure 5-8.
f. Check that the peak-to-peak is no more than 30 mV.

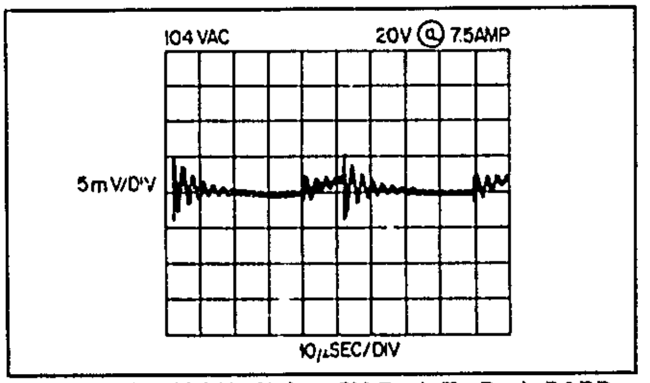


Figure 5-8. 20 kHz Noise, CV Peak-To-Peak PARD

5-39 **Load Transient Recovery Time.** Specified for CV operation only; load transient recovery time is the time for the output voltage to return to within a specified band around its set voltage following a step change in load.

5-40 Use the equipment setup of Figure 5-5 to display output voltage transients while switching the load between either 10% I or 50% I with the output set at 20 Vdc. Proceed as follows:

a. Connect the test equipment as shown in Figure 5-5. Operate the load in constant-current mode and set for minimum current.
b. Turn the unit's power on, and, using DISPLAY SETTINGS pushbutton switch, turn up current setting to full output.
c. Turn up output voltage to 20.0 Vdc as read on the digital voltmeter.
d. Set the load to vary the load current between 9 Adc and 10 Adc at a 30 Hz rate for the 10% RECOVERY TEST, or between 5 Adc and 10 Adc at a 30 Hz rate for the 50% RECOVERY TEST.
e. Set the oscilloscope for ac coupling, internal sync and lock on either the positive or negative load transient.
f. Adjust the oscilloscope to display transients as in Figure 5-9.
g. For 10% RECOVERY TEST check that the pulse width, of the transients at 75 mV is no more than 1 ms and for a 50% RECOVERY TEST that the pulse width of the transients at 200 mV is no more than 2 ms.

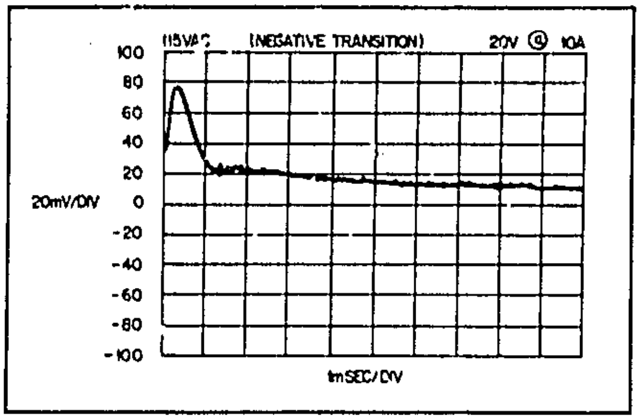


Figure 5-9. Load Transient Recovery Waveform

5-41 **Temperature Coefficient.** Temperature coefficient (TC) is the change in output voltage for each degree Celsius change in ambient temperature with constant ac line voltage, constant output-voltage setting and constant load resistance.

5-42 Measure temperature coefficient by placing the unit in an oven, varying temperature over a range within the unit's operating temperature range, and measuring the change in output voltage. Use a large, forced-air oven for even temperature distribution. Leave the unit at each measurement temperature for one half hour to allow it to stabilize before taking output-voltage measurements. Measure the output voltage with a stable digital voltmeter located outside the oven so voltmeter drift does not affect the measurement accuracy. To measure gain TC, proceed as follows:

a. Connect DVM between +S and −S.
b. Place the power supply in oven, and set temperature to 30°C.
c. Turn the unit's power on, and, using DISPLAY SETTINGS pushbutton switch, turn up current setting to full output.
d. Turn up output voltage to 60.0 Vdc as read on the digital voltmeter.
e. After 30 minutes stabilization record the temperature (T1) to the nearest 0.1°C.
f. Record the output voltage (E1) at digital voltmeter.
g. Set oven temperature to 50°C.
h. After 30 minutes stabilization, record the temperature (T2) to the nearest 0.1°C.
i. Record the output voltage (E2).
j. Check that the magnitude of the output-voltage change is no greater than 0.120 V.

To measure offset TC, repeat above procedure with output voltage set to 0.10 Vdc. The magnitude should be <3.1 mV.

5-43 **Drift (Stability).** Drift is the change in output voltage beginning after a 30-minute warmup during eight-hours operation with constant ac input line voltage, constant load resistance and constant ambient temperature.

5-44 Measure drift by monitoring the unit's output voltage over an eight-hour period following the 30-minute warmup. Use a digital voltmeter and record the output at intervals, or use a strip-chart recorder to provide a continuous record. Check that the voltmeter's or chart recorder's specified drift during the eight hours will be no more than 0.001%. Place the unit in a location with constant air temperature—preferably a large, forced-air oven set to 30°C—and verify that the ambient temperature does not change by monitoring with a thermometer near the unit. (Typically the drift during 30-minute warmup is greater than the drift during the eight-hour test.) Proceed as follows:

a. Connect DVM between +S and −S.
b. Turn the unit's power on, and, using DISPLAY SETTINGS pushbutton switch, turn up current setting to full output.
c. Turn up output voltage to 60.0 Vdc as read on the digital voltmeter.
d. After a 30-minute warmup, note reading on DVM.
e. The output voltage should not deviate more than 0.014 V from the reading obtained in step d over a period of 8 hours.

To measure offset drift, repeat above procedure with output voltage set to 0.105 Vdc. The magnitude should be <3.1 mV.

5-45 Constant Current (CC) Tests

5-46 **CC Setup.** Constant-current tests are analogous to constant-voltage tests, with the unit's output short circuited and the voltage set to full output to assure CC operation. Follow the general setup instructions of paragraphs 5-23 through 5-28.

5-47 **Current Programming And Readback Accuracy.** This procedure verifies that the current programming and readback functions are within specifications. An HP-IB controller must be used for this test. The accuracy of the current shunt resistor (Rm) must be 0.02% or better. Proceed as follows:

a. Connect test setup shown in Figure 5-5, except replace the load with a short circuit.
b. Turn on ac power to the power supply.
c. Send string "VSET 60; ISET 0.5".
d. Check that the voltage across Rm is in the range 5.15 to 4.85 mVdc. Note the reading.
e. Enter and run the following program:

```
10 OUTPUT 705; "IOUT?"
20 ENTER 705; A
30 DISP A
40 GOTO 10
50 END
```

f. The value displayed by the controller should be the actual output current (value noted in step d times 100) ± 0.025 Adc.

g. Send string "VSET 60; ISET 10".
h. Check that the voltage across Rm is in the range 0.10019 to 0.09982 Vdc. Note the reading.
i. Run the program listed in step e.
j. The value displayed by the controller should be the actual output current (value noted in step h times 100) ± 0.031 Adc.

5-48 Load Effect (Load Regulation). Constant-current load effect is the change in dc output current (Io) resulting from a load-resistance change from short-circuit to full-load, or full-load to short-circuit. Full-load is the resistance which develops the maximum rated output voltage at current Io. Proceed as follows:

a. Connect the test equipment as shown in Figure 5-5. Operate the load in constant resistance mode (Amps/Volt) and set resistance to minimum.
b. Turn the unit's power on, and, using DISPLAY SETTINGS pushbutton switch, turn up voltage setting to full output.
c. Turn up output current to 3 Adc (0.030 Vdc across Rm).
d. Increase the load resistance until the output voltage at +S and −S increases to 60 Vdc. Check that the CC LED is still lit.
e. Short-circuit the load and allow the voltage across Rm to stablize.
f. Record voltage across Rm.
g. Disconnect short across load.
h. When the reading settles (≈10 s), record the voltage across Rm again. Check that the two recorded readings differ no more than ±53 μVdc.

5-49 Source Effect (Line Regulation). Constant-current source effect is the change in dc output current resulting from a change in ac input voltage from the minimum to the maximum values listed in the Specifications Table in Section I. Proceed as follows:

a. Connect the test equipment as shown in Figure 5-5. Operate the load in constant resistance mode (Amps/Volt) and set resistance to minimum.
b. Connect the unit to the ac power line through a variable autotransformer set for nominal line voltage.
c. Switch the unit's power on and turn up output voltage setting to full output.
d. Turn up output current to 10 Adc (0.10 Vdc across Rm).
e. Increase the load resistance until the output voltage between +S and −S decreases to 20.0 Vdc. Check that the CC LED is still on.
f. Adjust autotransformer to the minimum for your line voltage.
g. Record the voltage across Rm.
h. Adjust autotransformer to the maximum for your line voltage.
i. When the reading settles record the voltage across Rm again. Check that the two recorded readings differ no more than ±30 μV.

5-50 PARD (Ripple And Noise). Periodic and random deviations (PARD) in the unit's output (ripple and noise) combine to produce a residual ac current as well as an ac voltage super-imposed on the dc output. The ac voltage is measured as constant voltage PARD, paragraph 5-35. Constant-current PARD is specified as the root-mean-square (rms) output current in a frequency range 20 Hz to 20 MHz with the unit in CC operation. To avoid incorrect measurements caused by the impedance of the electronic load at noise frequencies, use a 2 Ω load resistor that is capable of safely dissipating 200 watts. Proceed as follows:

a. Connect the test equipment as shown in Figure 5-10.
b. Switch the unit's power on and turn the output voltage all the way up.
c. Turn up output current to 10.0 Adc. Check that the unit's CC LED remains lighted.
d. Check that the rms noise current measured by the current probe and rms voltmeter is no more than 5 mA rms.

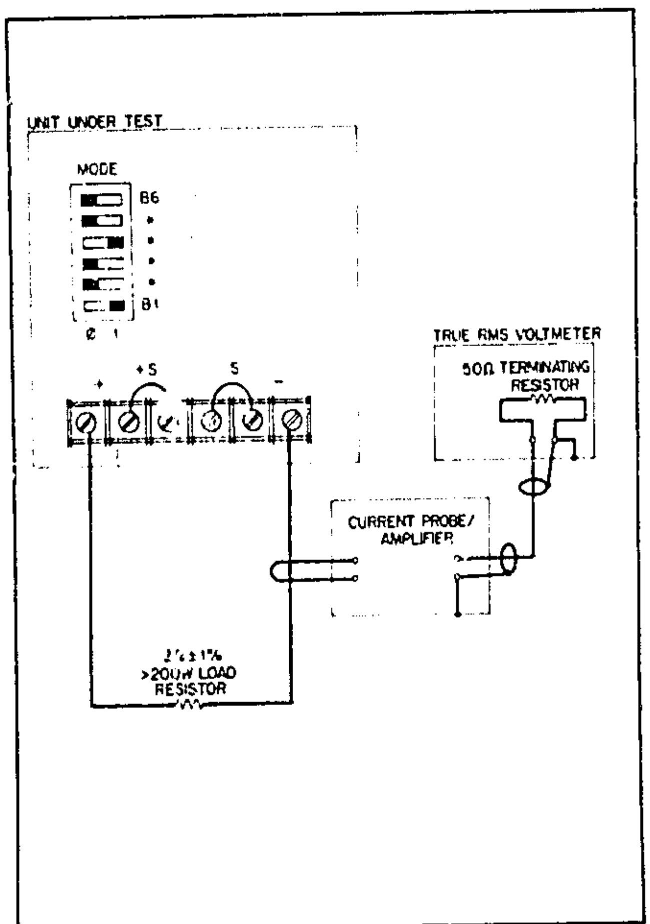


Figure 5-10. CC PARD Test Setup

Table 5-9 HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

5-51 TROUBLESHOOTING

WARNING

Maintenance described herein is performed with power supplied to the instrument, and protective covers removed. Such maintenance should be performed only by service-trained personnel who are aware of the hazards involved (for example, fire and electrical shock). Where maintenance can be performed without power applied, the power should be removed.

5-52 Before attempting to troubleshoot this instrument, ensure that the fault is with the instrument itself and not with an associated circuit. The performance test enables this to be determined without having to remove the covers from the supply.

5-53 The most important aspect of troubleshooting is the formulation of a logical approach to locating the source of trouble. A good understanding of the principles of operation is particularly helpful, and it is recommended that Section IV of this manual be reviewed before attempting to troubleshoot the unit. Often the user will then be able to isolate a problem simply by using the operating controls and indicators. Once the principles of operation are understood, refer to the following paragraphs.

5-54 Section VII contains schematic diagrams and information concerning the voltage levels and waveforms at many of the important test points. Most of the test points used for troubleshooting the supply are located on the control board test "fingers", which are accessible close to the top of the board, see Table 5-10. Other test points are available on the Power Supply Interface board as shown in Table 5-8.

5-55 If a component is found to be defective, replace it and re-conduct the performance test. When a component is replaced, refer to Calibration Procedure in this section. It may be necessary to perform one or more of the adjustment procedures after a component is replaced.

5-56 Initial Troubleshooting Procedures

5-57 If a problem occurs, follow the steps below in sequence:

a. Check that input power is available, and check the power cord and rear-panel line fuse. When replacing line fuse, be certain to select fuse of proper rating for line voltage being used.
b. Check that the settings of MODE switch A2S1 are correct for the desired mode of operation (see Table 3-4).
c. Check that all connections to the power supply are secure and that circuits between the supply and external devices are not interrupted.
d. Check that the rear-panel HP-IB address switch A8S1 is properly set.
e. If the power supply fails turn-on self-test or gives any other indication of malfunction, remove the unit from the operating system before proceeding with further testing.

WARNING

Some circuits on the power mesh are connected directly to the ac power line. Exercise extreme caution when working on energized circuits. Energize the supply through an isolation transformer to avoid shorting ac energized circuits through the test instrument's input leads. The isolation transformer must have a power rating of at least 1 kVA. During work on energized circuits, the safest practice is to disconnect power, make or change the test connections, and then re-apply power.

Make certain that the supply's ground terminal (⊥) is securely connected to an earth ground before applying power. Failure to do so will cause a potential shock hazard that could result in personal injury.

5-58 Electrostatic Protection

5-59 The following caution outlines important precautions which should be observed when working with static sensitive components in the power supply.

CAUTION

This instrument uses components which can be damaged by static charges. Most semiconductors can suffer serious performance degradation as a result of static charges, even though complete failure may not occur. the following precautions should be observed when handling static-sensitive devices

a. Always turn power off before removing or installing printed-circuit boards.
b. Always stored or transport static-sensitive devices (all semiconductors and thin-film devices) in conductive material. Attach warning labels to the container or bag enclosing the device.
c. Handle static-sensitive devices only at static-free work stations. These work stations should include special conductive work surfaces (such as HP Part No. 9300-0797) grounded through a one-megohm resistor. Note that metal table tops and highly conductive carbon-impregnated plastic surfaces are too conductive; they can act as large capacitors and shunt charges too quickly. The work surfaces should have distributed resistance of between 10^6 and 10^{12} Ω per square.
d. Ground all conductive equipment or devices that may come in contact with static-senstive devices or subassemblies containing same.
e. Where direct grounding of objects in the work area is impractical, a static neutralizer should be used (ionized-air blower directed at work). Note that this method is considerably less effective than direct grounding and provides less protection for static-sensitive devices.

f. While working with equipment on which no point exceeds 500 volts, use a conductive wrist strap in contact with skin. The wrist strap should be connected to ground through a one-megohm resistor. A wrist strap with insulated cord and built-in resistor is recommended, such as 3M Co. No. 1066 (HP Part No. 9300-0969 [small] and 9300-0970 [large]).

WARNING

Do not wear a conductive wrist strap when working with potentials in excess of 500 volts; the one-megohm resistor will provide insufficient current limiting for personal safety.

g. All grounding (device being repaired, test equipment, soldering iron, work surface, wrist strap, etc.) should be done to the same point.
h. Do not wear nylon clothing. Keep clothing of any kind from coming within 12 inches of static-sensitive devices.
i. Low-impedance test equipment (signal generators, logic pulsers, etc.) should be connected to static-sensitive inputs only while the components are powered.
j. Use a mildly activated rosin core solder (such as Alpha Metal Reliacor No. 1, HP Part No. 8090-0098) for repair. The flux residue of this type of solder can be left on the printed-circuit board. Generally, it is safer not to clean the printed-circuit board after repair. Do not use Freon or other types of spray cleaners. If necesary, the printed-circuit board can be brushed using a natural-bristle brush only. Do not use nylon-bristle or other synthetic-bristle brushes. Do not use high-velocity air blowers (unless ionized).
k. Keep the work area free of non-conductive objects such as Styrofoam-type cups, polystyrene foam, polyethylene bags, and plastic wrappers. Non-conductive devices that are necesary in the area can be kept from building up a static charge by spraying them with an anti-static chemical (HP Part No. 8500-3397).
l. Do not allow long hair to come in contact with static-sensitive assemblies.
m. Do not exceed the maximum rated voltages specified for the device.

5-60 Repair And Replacement

5-61 Repair and replacement of most components in the power supply require only standard techniques that should be apparent to the technician. The following paragraphs provide instructions for removing certain assemblies and components for which the procedure may not be obvious upon inspection.

WARNING

To avoid the possibility of personal injury, remove the power supply from operation before opening the cabinet. Turn off ac power and disconnect the line cord, HP-IB plug, load, and remote sense leads before attempting any repair or replacement.

CAUTION

When replacing any heatsink-mounted components except thermostat smear a thin coating of heatsink compound between the component and heatsink. If a mica insulator is used, smear a thin coating of heatsink compound on both sides of the mica insulator.

Do not use any heatsink compound containing silicone, which can migrate and foul electrical contacts elsewhere in the system. An organic zinc oxide cream, such as American Oil And Supply Company Heatsink Compound #100, is recommended.

CAUTION

Most of the attaching hardware in this unit is metric. The only non-metric (sometimes called English or inch) fittings are listed below. Be careful when both types of screws are removed not to get them mixed up.

a. lock-link/shelf-mounting blocks (4 on rear panel, one at each corner)
b. rear-panel fuse holder
c. rear-panel ground binding post
d. strap-handle screws (2)
e. screws that secure side chassis to front-frame casting (8, 4 on each side)
f. screws that secure front panel to front-frame casting (4, 2 on top and 2 on bottom)

5-62 Top Outside Cover Removal. Remove three screws—the rear handle screw (phillips, 10x32) and the two top-rear-corner screws (Pozidriv, M4x.7) using a Size 1, Pozidriv screwdriver. A phillips head screwdriver does not fully seat into Pozidriv screws and risks stripping the heads. (Do not remove the front handle screw, as the retaining nut will fall into the unit.) Remove the top cover by sliding it to the rear and lifting at the front.

5-63 Bottom Cover Removal. Remove only for repair of main board. Remove two bottom-rear-corner screws (Pozidriv, M4x.7), and remove the bottom cover by sliding it to the rear. You don't need to remove the unit's feet.

5-64 Inside Top Cover Removal. The unit includes an inside cover which secures the vertical board assemblies. Remove the inside cover for repair but not for calibration.

5-65 Remove the six mounting screws (Pozidriv, M4x.7)—three on each side—and the five board-fastening screws (Pozidriv, M4x.7)—all on top. Remove the inside cover by lifting at the front edge.

5-66 When installing the inside cover, insert it first at the right side. While holding it tilted up at the left, reach through the cutouts in the cover and fit the top tabs of the A8 HP-IB board into the mating slots in the cover. Then repeat the process for the A7 PSI board tabs and slots, and finally for the

A2 control board tabs and slots. With the top cover in place reach through the cutout above the A3 power mesh board align the board-fastening screw holes, and replace the rear-most screw to secure the A3 board. Press the inside cover down firmly while tightening screws that secure cover to chassis. Complete the installation by replacing the remaining ten screws.

5-67 Be careful when replacing printed-circuit assemblies and covers not to bend any boards or components.

5-68 A2 Control Board Removal

5-69 After removing the inside cover, unplug the W5 and W6 ribbon cables at the top edge of the A2 control board. Remove the A2 board by lifting first at the front edge and then pulling it up and out of the unit. Two connectors hold the A2 board at its bottom edge.

5-70 When installing the A2 board, insert it first at the rear of the unit. While holding it tilted up at the front fit the A2TB1 terminal strip into the mating cutout in the rear panel. Then lower the A2 board's bottom connectors into the mating connectors on the main board. Press the A2 board into the connectors, and reinstall the W5 and W6 ribbon cables.

5-71 A4 Power Mesh Board Removal

5-72 After removing the inside cover, remove the A4 power mesh board by lifting using the large aluminum heatsink as a handle. Two connectors hold the A4 board at its bottom edge.

5-73 When installing the A4 power mesh board, lower it vertically into its connectors and press in place.

5-74 A7 PSI Board/A8 HP-IB Board Removal

5-75 Remove the A7 PSI board and the A8 HP-IB board together, as they are clipped together by plastic spacers. Follow this procedure:

a. Remove the two screws (Pozidriv, M3x.5) which attach the A8 HP-IB board to the rear panel. Remove the single screw (Posidriv, M4x.7) that secures the HP-IB board to the side frame near the bottom front corner.
b. After removing the inside cover, unplug the W5 and W6 ribbon cables at the top edge of the A7 PSI board.
c. Unplug two cables from the A8 HP-IB board: the W2 3-wire cable from connector A8J2 and the W1 ribbon cable from connector A8J1.
d. Remove both the A7 board and the A8 board by lifting the two boards straight up.
e. Unplug the W4 ribbon cable connecting A7J3 to A8J3 and separate the two boards by gently pulling apart at the four spacers. Note that the spacers are attached to the PSI board and snap into the HP-IB board.

5-76 Install the A7 and A8 boards by reversing the above steps. Lower the rear sides of the clipped-together boards into the unit first and fit the bottom tabs into their mating slots.

5-77 A3 Front-Panel Board Removal

5-78 Remove the A3 front-panel board by first removing the entire front panel assembly. You don't need to remove the top cover. Follow this procedure:

a. Remove the top plastic insert by prying up with a flat-blade screwdriver, and remove the front feet by lifting the tabs and sliding toward the front of the unit.
b. Remove the four front-panel assembly mounting screws (phillips 6-32) on the top and bottom at the corners.
c. Gently pull the front-panel assembly away from the unit as far as permited by the connecting cables.
d. Remove the ground-wire screw (Pozidriv, M4x.7) holding the green-yellow ground wire.
e. Note the locations of the four power-wire connections to the power switch, and then unplug the quick-connect plugs.
f. Unplug the W3 3-wire cable from connector A1J3 on the A1 main board, and unplug the W1 ribbon cable from connector A8J1 on the A8 HPIB board.
g. Remove the A3 board from the front-panel assembly by removing the five mounting screws (Pozidriv, M4x.7).

5-79 Install the A3 board by reversing the above steps. Connect the power switch wires in the exact locations from which they were removed.

5-80 A1 Main Board Removal

5-81 Removing the A1 main board requires removing the rear panel, all boards except the A3 front-panel board, and 17 A1-board mounting screws, two standoffs, and interface bracket. Component-access cutouts in the bottom inside cover allow unsoldering most A1-board components for repair without removing the rear panel and the A1 board.

5-82 To remove the A1 board proceed as follows:

a. Remove the A2, A4, A7 and A8 boards according to the above instructions.
b. Detach the rear panel by removing the four mounting screws (Pozidriv, M4x.7)—two on each side. Gently pull the rear panel away from the unit as far as permitted by the four wires connected to the A1 board.
c. Remove the A7/A8 bracket by removing three screws (Pozidriv, M4x.7)—two on bracket, one on side of the unit.
d. Unplug the W2 3-wire ribbon cable from connector A1J2, and unplug the W3 3-wire cable from connector A1J3.
e. Remove the A1 board by removing the 17 mounting screws (Pozidriv, M4x.7).
f. Note locations and then unplug the two ac power wires and the two fan wires to the A1 board.

5-83 Install the A1 board by reversing the above steps. Plug the two ac-power wires onto the two spade terminals in the left-rear corner of the A1 board. Use the table below to choose the correct terminal for each wire.

AC POWER WIRE from	color	PLUG ONTO TERMINAL designated	located
F1 fuse	wht/brn/gry	L	left-rear corner
FL1 line module	white/gray	N	right of above

Plug the fan wires, ignoring color codes if any, onto the remaining pair of terminals.

5-84 Troubleshooting Procedure

5-85 The overall troubleshooting scheme for the unit consists of sectionalizing the various circuits of the supply into blocks which are troubleshot individually. The blocks associated with the HP-IB/microprocessor related circuits will be structured somewhat differently from those which make up the power supply section. The boards which contain the former are the A3 (front panel), the A7 (PSI) and the A8 (HP-IB) boards. They will be refered to collectively as the HP-IB section. The power supply circuits are on the A1 (main), the A2 (control) and the A4 (power mesh) boards. They will be referred to as the power section.

5-86 Tables 5-5, 5-9, 5-11, and 5-12 give various power supply symptoms which identify the corresponding board, circuit block or components which may have caused that symptom. Tables 5-5 and 5-9 are associated with the HP-IB circuits while Tables 5-11 and 5-12 are used for the power section.

5-87 Using the Symptom Tables

5-88 It is generally a good idea to examine all the symptoms and perform all the tests in the symptom tables starting with Table 5-5. If the tests in Table 5-5 check out positive, then proceed to either Table 5-11 (Performance Failures) or Table 5-12 (No-Output Failures). One should be chosen depending on the failure mode of the power supply.

5-89 Using the HP-IB Section Symptom Table

5-90 The HP-IB section symptom Table 5-5 lists trouble symptoms for problems in that section. Each symptom references a particular block to begin troubleshooting with. The main table is subdivided into smaller tables which are arranged in the most useful order for troubleshooting. The user should therefore start at the top of the list and work through sequentially. It is not a good idea to start in the middle.

Table 5-4. Self Test Error Codes

Error Code	Description	Error Code	Description
GENERAL		SERIALIZER TEST	
Err 1	Address switch setting out of range in self-test mode	Err 9	Serializer malfunction
RAM TEST #1		PSI DIGITAL I/O TEST	
Err 2	RAM failure, lower nibble	Err 10	Port 0 into port 5 failure
Err 3	RAM failure, upper nibble	Err 11	Port 1 into port 5 failure
RAM TEST #2		Err 12	Port 2 into port 5 failure
Err 4	RAM failure	PSI DAC/ADC TEST	
ROM TEST		Err 13	EOC occurred too early
Err 5	ROM #1 checksum error	Err 14	EOC occurred too late
Err 6	ROM #2 checksum error	Err 15	CV-reference F.S. out of range
GPIB CHIP TEST		Err 16	CC-reference zero out of range
Err 7	GPIB chip malfunction	Err 17	CV-reference zero out of range
REAL-TIME CLOCK TEST		Err 18	CC-reference F.S. out of range
Err 8	Real-time clock malfunction	GENERAL	
		Err 19	ID jumper set out of range
		Err 20	HP-IB address switch set to 31
		Err 21	Inhibit not low at power on
		Err 22	Can't set inhibit high

5-91 The table is divided into an OBSERVATION and a GOTO column. The OBSERVATION column describes the symptom while the GOTO column gives the corresponding block. If the GOTO entry is TAB X.X, that block is part of Table 5-5. If the GOTO entry is A X.X, that block is part of Table 5-9.

5-92 Many observations require the user to perform an action or provide a stimulus such as shorting the output or pressing a front panel switch. Symptoms which may be ambiguous are not included in the table as they are not very useful in isolating problems. The table should not be disregarded simply because the observation does not match one that is given. The user should try to make the supply exhibit a given symptom by performing the tests given in the table then proceeding to the appropriate block. If none of the above is possible, go to the observation described as OTHER and follow the procedure in the GOTO column.

5-93 Some observations concern self-test failures. The unit performs a rigorous self-test of its digital circuits at power-on. These tests check the kernel (microprocessor, ROM, RAM), the power mesh interface circuits (I/O ports, DACs), real-time clock, and operational switch settings. If the unit fails any test, the front-panel VOLTS and AMPS readouts will display an error number corresponding to the test that failed. For example:

Err 3

The test LEDs will also flash on/off displaying the same error number in binary code. A8DS1A through DS1E have weights of 1 through 16. Table 5-4 gives a summary of the error codes.

5-94 HP-IB Section Troubleshooting

5-95 Table 5-5 lists trouble symptoms which might be observed if a problem exists on the HP-IB, PSI or front panel boards. As stated above, these boards have been divided into functional circuit blocks for troubleshooting. Table 5-9 gives detailed troubleshooting information for the circuit blocks.

5-96 The troubleshooting procedure for these blocks is made up of input, output and internal checks of circuit nodes in the block. The first tests to be performed should be the input tests. If the results are positive, then the outputs should be checked. If any output test fails then the internal tests nodes of the block have to be verified before proceeding.

5-97 In general, an input to one block is the output of another block. Therefore, if an input test fails then the the next step is to go to the block which provides that input to the test block. The SOURCE column will give the appropriate block.

Table 5-5. HP-IB/PSI Symptom Chart

Cycle power to unit. Observe the Test LEDs (A8DS1A-DS1E):	
OBSERVATION	GOTO
No test LEDs, front panel LED indicators or digits ever light.	A8.1
All test LEDs turn on and remain lit.	A8.4 A8.5
Each test LED lights in sequence. No error code is displayed.	TAB 1.1
Each test LED lights in sequence, then an error code is displayed.	TAB 2.1
One or more of the test LEDs does not light at turn on, but others go through turn on sequence (flash on/off).	A7.2
Unrecognized pattern displayed on test LEDs.	A8.4 A8.5
TAB 1.1 Front-Panel Board Symptoms	
OBSERVATION	GOTO
All front panel LED indicators, digit segments and decimal points should turn on for ≈ 1 second, then off for ≈ ½ second when power is turned on. Note any displays which remain lit or never turn on at this time.	A3-2
No control with front panel switches or RPG.	A3.3

Table 5-5. HP-IB/PSI Sympton Chart (continued)

TAB 1.1 Front-Panel Board Symptoms (continued)	
Front panel meters always display settings, not actual voltage and current.	A3-3
OVP trip level is always displayed. Current display is blank.	A3.3
Output current setting rapidly climbs to full scale value when unit is first turned on. ERROR LED lights when setting reaches full scale.	A3.3
Output increases regardless of the direction in which RPG is rotated.	A3.3
OTHER	TAB 1.2
TAB 1.2 HP-IB Board Symptoms	
OBSERVATION	GOTO
HP-IB address displayed at turn-on disagrees with HP-IB address switch setting.	A8.7
Unit always turns on in diagnostic mode (Display shows "run").	A8.7
Unit will not enter diagnostic mode.	A8.7
SRQ LED lights at turn-on when rear-panel PON SRQ switch is set to 0.	A8.7
SRQ LED does not light at turn-on when PON SRQ switch is set to 1.	A8.7
Cannot get GATE signal on signature analyzer when unit is in setup B1, B2, B3, B5, B6, B7 or B8	A8.8
Controller hangs up when HP-IB command is sent.	A8.12
Controller hangs up when it attempts to read a response to a query command.	A8.12
ERROR LED turns on when valid command is sent.	A8.12
Garbage data is returned in response to a query command.	A8.12
Device Clear, Device Trigger, Serial Poll or Parallel Poll do not function properly.	A8.12
OTHER	TAB 1.3
TAB 1.3 PSI Board Symptoms	
OBSERVATION	GOTO
OVP will not reset when "RST" command is received, but will reset when power is cycled.	A7.2
Output current changes erratically as RPG control is rotated while unit is in CC.	A7.4
Output voltage changes erratically as RPG control is rotated while unit is in CV.	A7.5
Unit responds with the wrong model number or option to the "ID?" command.	A7.7
Full scale values of front panel voltage and/or current SETTINGS disagree with the ratings of the unit.	A7.7

Table 5.5 HP-IB/PSI Sympton Chart (continued)

DISABLED, OV or OT LEDs remain on, even though output voltage or current can be adjusted.	A7.8
Output voltage drops to zero when OVP trip level is exceeded, but OVP and DISABLED LEDs do not light.	A7.8
OVERRANGE LED lights when output terminals are open circuit and output current is set >0, or output terminals are shorted and output voltage is set >0.	A7.8
CV LED does not light when output terminals are open circuit and output current is set >0.	A7.8
CC LED does not light when output terminals are shorted and output voltage is set >0.	
Front panel voltage display changes erractically as RPG control is rotated. Actual output voltage agrees with voltage setting.	A7.10
Value displayed when DISPLAY OVP button is depressed is not consistent with OVP trip level, but OVP ADJUST control varies the trip level over the full range.	A7.10
OTHER	see A2
TAB 2.1 Self-Test Failures	
OBSERVATION	GOTO
Err 1, but A8S1 setting is in range of 1 to 13	A8.7
Err 2, 3 or 4	A8.6
Err 5 or 6	A8.5
Err 7	A8.12
Err 8	A8.9
Err 9	A8.10 A8.11
Err 10	A8.11
Err 11 or 12	A7.6
Err 13 or 14	A7.9
Err 15 or 17 Skip self tects (setup S). Output voltage significantly disagrees with voltage setting.	A7.5
Err 15 or 17 otherwise	A7.10
Err 16 or 18 Skip self tests (setup S). Output current significantly disagrees with current setting.	A7.4
Err 16 or 18 otherwise.	A7.10
Err 19	A7.7
Err 20 but HP-IB address switch not set to 31	A8.7
Err 21 or 22	A7.8

5-98 In general, the troubleshooting scheme for each block is structured as follows:

1. INPUT TESTS
2. OUTPUT TESTS
3. INTERNAL TESTS

Each block is structured as shown in Figure 5-11.

5-99 Each group of tests is presented in tabular form, where test nodes, expected measurements and the next block to be troubleshot are given. Measurement nodes are divided into related groups by blank lines. An example of a circuit block is given in Table 5-6. Some data has been excluded for conciseness.

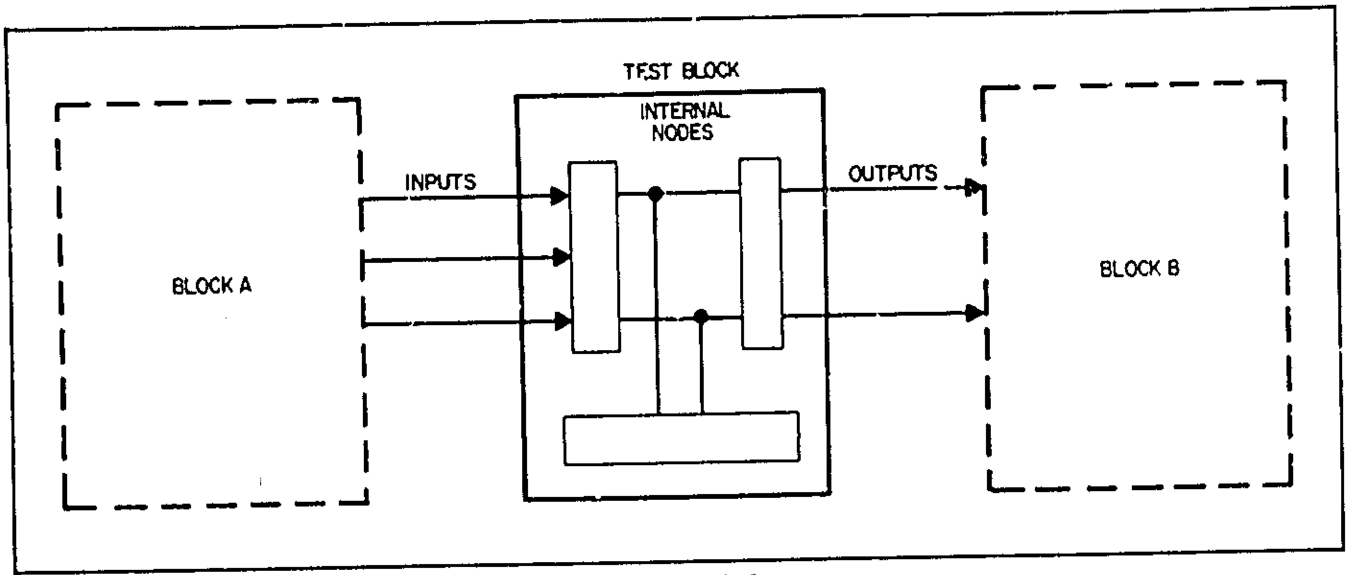


Figure 5-11. Block Structure

Table 5-6. HP-IB Troubleshooting Example

(1) **BLOCK #A7.5 Voltage Output Ports, Latches and DAC**

Serial data generated by the processor is clocked into shift registers A7U20 and A7U21. The outputs of these registers drive 12-bit current-output DAC A7U23. Op amp A7U27 provides an additional stage of inversion and compenstates for voltage drops in the ground tracks. The output of A7U27 provides the reference input to the CV error amplifier on the A2 control board.

(2) REF. DES.	DESCRIPTION
A7U20,21	MC14094 8-BIT SHIFT/STORE REGISTER

(3) **INPUTS:**

NODE	SETUP	MEASUREMENT	SOURCE
A7U20,21-1	B1	7P9A	A7.1
.	.	.	.

(4) **OUTPUTS:**

NODE	SETUP	MEASUREMENT
A7U27-6 (TP 5)	S: output voltage set to 0 volts	0V
	S: output voltage set to 60 volts	5 V

Table 5-6. HP-IB Troubleshooting Example (continued)

(5) **PROCEDURE**

NOTE	SETUP	MEASUREMENT
A7U21-4	B1	7H2P
.	.	.
.	.	.
.	.	.
A7U25-2 wrt A7U25-3	S	−1 mV to +1 mV
.	.	.
.	.	.

EXPLANATION:

(1) **BLOCK #A7.5** (description): Each block will have an alphanumeric code which identifies the circuit board and the block number. Code A7.5 indicates the A7 PSI board block 5.

(2) **REF. DES./DESCRIPTION:** The reference designators for all ICs in the circuit block as well as a description for each are listed in this section.

(3) **INPUTS:** The input measurements are listed in this seciton. If all inputs are correct proceed to the output tests.

NODE: This column gives all the test nodes to be measured.

SETUP: Each node being tested will require a particular test setup in order to take the measurement. All setups are outlined in Table 5-13 at the end of Section V. A setup may be given as "B1", for example; it corresponds to that setup in Table 5-13. Setups will sometimes have additional requirements and will be stated, for example, as:

B1: A2Q2 base to the test block.

(4) **OUTPUT:** Output tests are performed if all input tests are positive. The explanations for the associated columns, SETUP etc., are the same as the INPUTS above.

(5) **PROCEDURE:** This section lists the measurements for the internal nodes of the test block. The tests in this group should be done if an output measurement has an incorrect value. Troubleshooting information will be left implicit in this section and tests should be performed in the order given. Because each node has an expected measurement, an incorrect result can be localized to a few components. Wrt means "with respect to".

5-100 SIGNATURE ANALYSIS

5-101 The easiest and most efficient method of troubleshooting microprocessor-based instruments is signature analysis. Signature analysis is similar to signal tracing with an oscilloscope in linear circuits. Part of the microcomputer memory is dedicated to signature analysis and a known bit stream is generated to stimulate as many nodes as possible within the circuit. However, because it is virtually impossible to analyze a bit stream with an oscilloscope a signature analyzer is used to compress the bit stream into a four-character signature that is unique for each node. By comparing signatures of the unit under test to the correct signatures for each node, faults can usually be isolated to one or two components. Note that signature analysis provides only go/no-go information; *the signature provides absolutely no diagnostic information.*

5-102 Instructions in the troubleshooting chart direct the user to a specific block of circuits to commence troubleshooting. If necessary, that block will include signatures and indicate the correct signature analyzer setup for taking those signatures. (The user should refer to the signature analyzer instruction manual for complete instructions on use of the signature analyzer.)

5-103 The following general notes apply to signature analysis of the power supply.

1. Be certain to use the correct setup for the signature being examined.
2. Most signatures are taken on the HP-IB, PSI and front panel assemblies
3. Note the signatures for Vcc and ground on the I.C. being examined. If an incorrect signature is the same as that of Vcc

or ground, that point is probably shorted to Vcc or ground.

4. If two pins have identical signatures, they are probably shorted together. If two signatures are similar, it is only coincidence. For example, if the signature at a certain point should be 65C4, a signature of 65C3 is not "almost right". No diagnostic information can be inferred from an incorrect signature.
5. If a signature is incorrect at an input pin, but is correct at its source (output of previous I.C.), check for printed circuit and soldering discontinuity.
6. An incorrect signature at an output could be caused by a faulty component producing that output; or, a short circuit in another component or on the board could be loading down that node.

5-104 HP-IB and PSI Board Test Setup

5-105 The following setup allows easy access to components on the HP-IB and PSI boards for troubleshooting. The completed set-up is shown in Figure 5-12.

WARNING

Be careful not to touch any components underneath the insulating material.

a. Remove top cover and the inside metal cover of the unit as outlined in Paragraphs 5-62 and 5-64. Remove both screws holding the HP-IB board to the rear panel, and remove the screw holding the HP-IB board to the side panel.
b. Disconnect both ends of cables W5 and W6 joining the control board and the PSI board.
c. Lift out HP-IB and PSI boards and separate both boards by pulling apart at the four plastic spacers.
d. Lay out boards as shown. Place a piece of insulating material between the boards and the power supply.
e. Replace connectors W5 and W6.

CAUTION

Failure to use an insulating material between the boards and the power supply can cause malfunctions and possible damage to the supply.

f. Alternatively, the boards can be placed alongside the unit by using extender cables provided in service kit P/N 06033-60005.

NOTE

PSI test connector A7J4 is designed for factory use. Table 5-8 describes the signals at each of the test points for use by technicians who are familiar with the unit and who may wish to check specific signals.

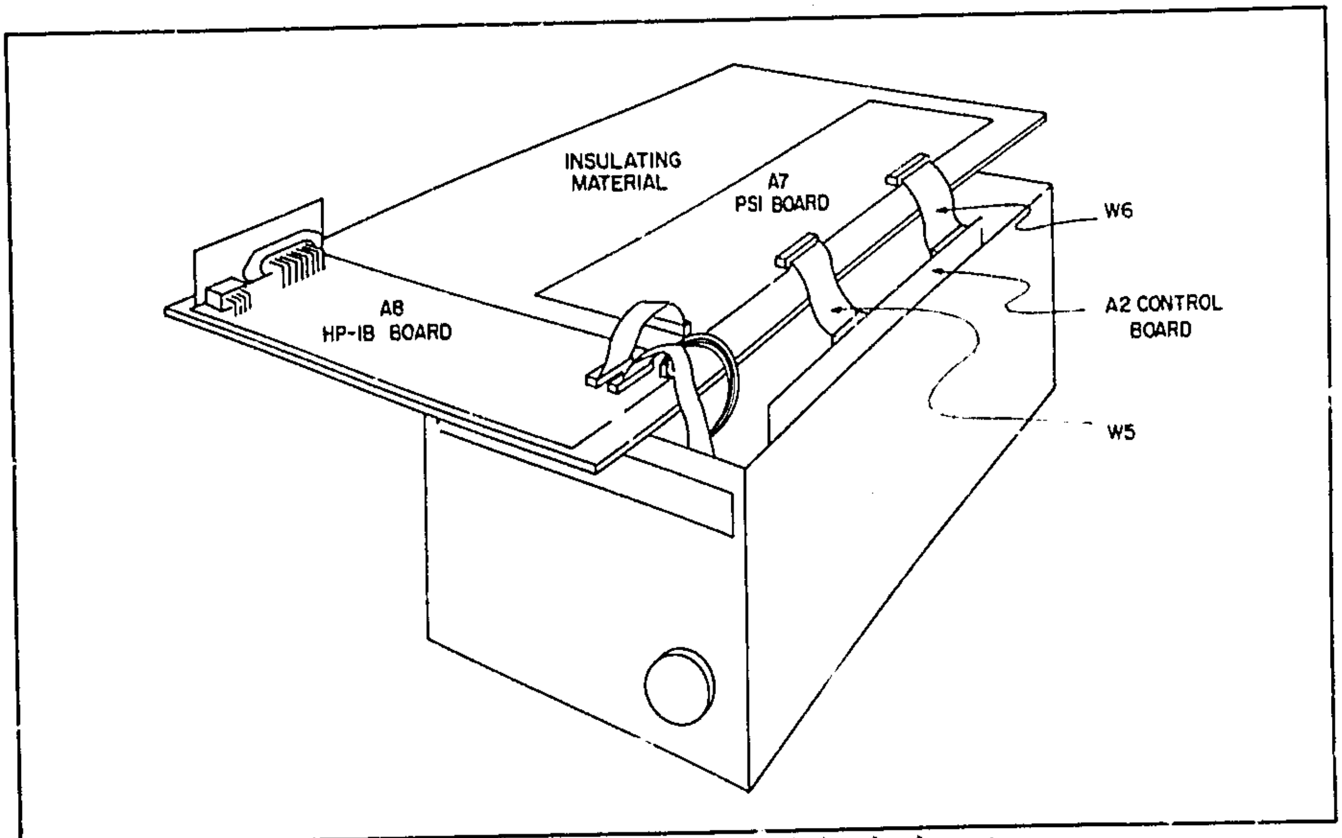


Figure 5-12. HP-IB/PSI Board Troubleshooting Layout

5-106 The following notes apply to the setups provided in Table 5-13.

a. The appropriate setup for performing each procedure in Table 5-9 is given by a letter or letter/number combination, such as B6. Setups are listed in Table 5-13 in alphanumeric order.
b. A8W4 is a 16-pin jumper pack located on the HP-IB board. *J6* means that the W4 jumper pack is plugged into the 16 pins of J6; *between J5 and J6* means that W4 is connected between J5 and pins 1 through 8 of J6. See Figures 5-13 and 7-7. To move A8W4, first turn off the unit. Use an I.C. removal tool, or, using a small-blade screwdriver, first pry up one end and then the other end of the jumper pack a little at a time. Be careful not to bend the pins. Be especially careful that all pins are properly located in the socket before pressing the jumper pack down in place.
c. A8W5 is a 2-pin jumper used to short A8J7 pins 15 and 16 together, which puts unit into diagnostic mode. A8J7 is the 16 pin test connector located on the HP-IB board. A8W5 is normally plugged onto pins 13 and 14. See Figure 5-14.
d. A8S1 is the 6-section HP-IB address switch mounted on the HP-IB board and accessible at the rear panel. A8S1 determines which diagnostic program is run when A8W5 is in the diagnostic position. Table 5-7 lists the tests performed for each combination of switch settings.
e. A8S2 is a 6-section switch mounted on the HP-IB board. A8S2 controls various signals on the HP-IB board and is used to help isolate problems. Be certain to reset A8S2 to normal setting before returning power supply to service.
f. Any conditions following colon after setup designation must be fulfilled in addition to the standard setup. For example:

   B1: A8 U2/4 shorted to GND

   means that after setting the unit to setup B1 you should connect a short between I.C. A8U2 pin 4 and ground.

g. Don't Care means that the setting of that component will not affect any procedures using that setup.
h. Component reference designators and pin numbers are identified as in the following examples:

   A8 U7/16
   refers to pin 16 of component U7 on assembly A8, the HP-IB board.
   A3 U11/2, U12/4,10
   refers to pin 2 of component U11 and pins 4 and 10 of component U12, both on assembly A3, the front-panel board.

i. The signature for +5 V for each setup is given to help locate nodes that are shorted to +5 V.

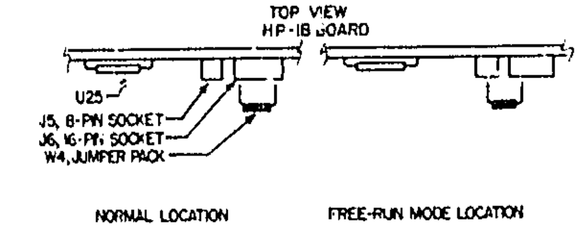


Figure 5-13. Free-Run Mode Jumper Pack

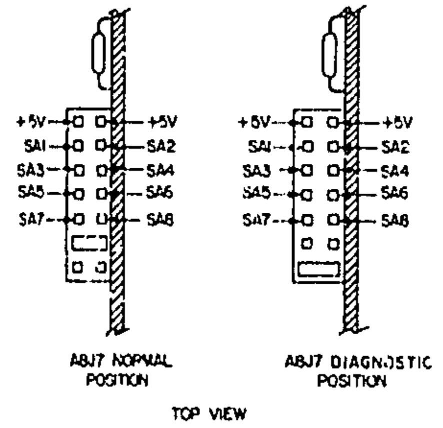


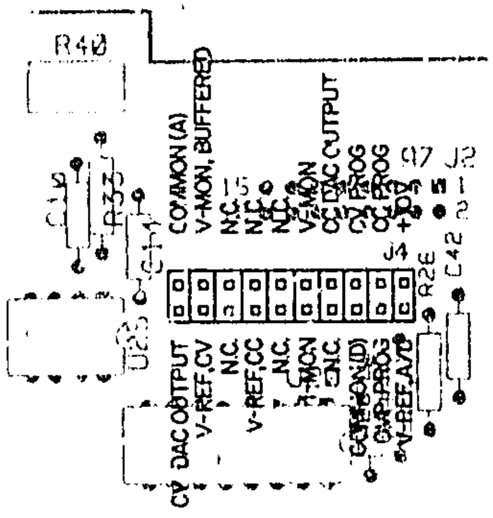
Figure 5-14. Diagnostic Jumper On A8J7

Table 5-7. Self-Test Address-Switch Settings

Address Switches	Function
00001 (1)	All self tests
00010 (2)	All microcomputer tests: RAM test #1 and #2 ROM test GPIB chip test Real-time clock test Serializer test
00011 (3)	Skip self tests
00100 (4)	RAM test #1
00101 (5)	RAM test #2
00110 (6)	ROM test
00111 (7)	GPIB chip test
01000 (8)	Real-time clock test
01001 (9)	Serializer test
01010 (10)	PSI digital I/O test
01011 (11)	PSI DAC/ADC test
01100 (12)	Signature-analysis stimulus

Table 5-8. PSI Board Test Connector A7J4

Pin #	Signal	Description
1	+10 V	Regulated +10 volt reference
2	V-REF 3	Buffered +10 V reference for readback DAC A7U31
3	CC PROG	CC programming voltage, 0 to 5 V = 0 to full scale
4	OVP PROG	OVP programming voltage, 0 to 2 V = 0 to full scale
5	CV PROG	CV programming voltage, 0 to 5 V = 0 to full scale
6	D Common	PSI common
7	CC DAC Output	0 to −10 V produces 0 to full scale output
8	(not used)	
9	V-MON	Output voltage monitor, 0 to 5 V = 0 to full scale
10	I-MON	Output current monitor, 0 to 5 V = 0 to full scale
11	(not used)	
12	(not used)	
13	(not used)	
14	V-REF 1	Buffered +10 V reference for CC DAC A7U22
15	(not used)	
16	(not used)	
17	Buffered V-MON	0 to 5 V = 0 to full scale output voltage
18	V-REF 2	Buffered +10 V reference for CV DAC A7U23
19	A Common	PSI common
20	CV DAC Output	0 to −10 V produces 0 to full scale output



BLOCK # A3.1 Front Panel Address Latches and Decoders

When the D-A line is in the ADDRESS state, Serial data is clocked into shift register A3 U15.

When the D-A line is in the DATA state, The data in A3 U15 steers the clock through decoders A3 U13 and A3 U14 to the register being addressed.

REF. DES.	DESCRIPTION
A8 U25	74LS367 HEX BUS DRIVER
A3 U17	74LS04 HEX INVERTER
A3 U16	74LS00 QUAD 2-INPUT NAND GATE
A3 U15	74LS164 8-BIT PARALLEL OUTPUT SHIFT REGISTER
A3 U14,13	74LS138 3-TO-8 LINE DECODER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U25/14	B1:	U147	A8.10
A8 U25/12	B1:	5544	A8.10
A8 U25/6	B1:	10FF	A8 10
A3 U15/9	X: cycle power to unit.	LO to HI after ≈ 160 ms	A8.3

OUTPUTS:

NODE	SETUP	MEASUREMENT
A3 U17/9	B1:	5544
A3 U17/2	B1:	002A
A3 U14/15	B1:	U861
A3 U14/14	B1:	A6H8
A3 U14/13	B1:	AUPU
A3 U13/15	B1:	5577
A3 U13/14	B1:	F384
A3 U13/13	B1:	99PC
A3 U13/12	B1:	15CU
A3 U13/11	B1:	UHU2
A3 U13/10	B1:	7FA8
A3 U13/9	B1:	2FHH
A3 U13/7	B1:	H515

PROCEDURE:

NODE	SETUP	MEASUREMENT
A8 U25/13	B1:	U147
A8 U25/11	B1:	5544
A8 U25/7	B1:	10FF
A3 U17/10	B1:	P1A1
A3 U17/8	B1:	A429
A3 U17/2	B1:	002A
A3 U16/11	B1:	H736

PROCEDURE: (continued)

NODE	SETUP	MEASUREMENT
A3 U15/10	B1:	8AU9
A3 U15/6	B1:	F22H
A3 U15/5	B1:	AU3F
A3 U15/4	B1:	U33H
A3 U15/3	B1:	9PPC
A3 U17/12	B1:	3340
A3 U16/6	B1:	1H44
A3 U16/3	B1:	97CH
A3 U17/9	B1:	5544
A3 U17/2	B1:	002A
A3 U14/15	B1:	U861
A3 U14/14	B1:	A6H8
A3 U14/13	B1:	AUPU
A3 U13/15	B1:	5577
A3 U13/14	B1:	F384
A3 U13/13	B1:	99PC
A3 U13/12	B1:	15CU
A3 U13/11	B1:	UHU2
A3 U13/10	B1:	7FA8
A3 U13/9	B1:	2FHH
A3 U13/7	B1:	H515

BLOCK # A3.2 LED Displays and Indicators Drivers

Serial data generated by the processor is clocked into shift registers A3 U1 through A3 U10. The outputs of these registers drive the 7 segment LED displays and LED indicators. Resistors A3 R1 through A3 R58 and resistor networks A3 R61 and A3 R62 limit the LED current to approx. 8 mA.

Note: Most problems in this block will involve only one of the displays or a block of LED indicators. Use the schematic to determine which register is driving the faulty display. It will usually be necessary to perform only that portion of the procedure which pertains to the faulty display.

REF. DES.	DESCRIPTION
A3 U1-10	74LS164 8-BIT PARALLEL OUTPUT SHIFT REGISTER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A3 U1-10/1	B1:	002A	
A3 U1-10/9	X: cycle power to unit.	LO to HI after ≈160ms	A3.1 A8.3
A3 U1/8	B1:	5577	
A3 U2/8	B1:	F384	A3.1
A3 U3/8	B1:	99PC	"
A3 U4/8	B1:	15CU	"
A3 U5/8	B1:	UHU2	"
A3 U6/8	B1:	7FA8	"
A3 U7/8	B1:	2FHH	"
A3 U8/3	B1:	P615	"
A3 U9/8	B1:	U861	"
A3 U10/8	B1:	A6H8	"

OUTPUTS:

NODE:	SETUP	MEASUREMENT
All display segments and LED indicators	X: cycle power to unit.	All display segments, decimal points and LED indicators will turn on for ≈1 second, then off for ≈1/2 second.
	B1:	All display segments, decimal points and LED indicators will be lit.

Note: This measurement is not conclusive. This block should be checked anytime unrecognizable patterns appear on the displays or LED indicators.

A3 U1/3	B1:	H36A
A3 U1/4	B1:	1AA2
A3 U1/5	B1:	A3PU
A3 U1/6	B1:	08U5
A3 U1/10	B1:	3578
A3 U1/11	B1:	6FP1
A3 U1/12	B1:	FCCP
A3 U1/13	B1:	3UHC

Table 5-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

PROCEDURE: (continued)

NODE	SETUP	MEASUREMENT
A3 U2/3	B1:	64FH
A3 U2/4	B1:	688C
A3 U2/5	B1:	22HA
A3 U2/6	B1:	FAC2
A3 U2/10	B1:	UFHC
A3 U2/11	B1:	P81C
A3 U2/12	B1:	1123
A3 U2/13	B1:	6U50
A3 U3/3	B1:	085C
A3 U3/4	B1:	AU6F
A3 U3/5	B1:	H1C1
A3 U3/6	B1:	FP1P
A3 U3/10	B1:	1C08
A3 U3/11	B1:	4703
A3 U3/12	B1:	9HC8
A3 U3/13	B1:	06HA
A3 U4/3	B1:	U067
A3 U4/4	B1:	54AH
A3 U4/5	B1:	U51A
A3 U4/6	B1:	PP4P
A3 U4/10	B1:	1F74
A3 U5/3	B1:	64U6
A3 U5/4	B1:	7UH8
A3 U5/5	B1:	U9P2
A3 U5/6	B1:	969H
A3 U5/10	B1:	8F22
A3 U5/11	B1:	787A
A3 U5/12	B1:	HPHA
A3 U5/13	B1:	425F
A3 U6/3	B1:	4959
A3 U6/4	B1:	7HCU
A3 U6/5	B1:	462P
A3 U6/6	B1:	6C53
A3 U6/10	B1:	6A48
A3 U6/11	B1:	39U7
A3 U6/12	B1:	F40P
A3 U6/13	B1:	48P3
A3 U7/3	B1:	760C
A3 U7/4	B1:	H0H6
A3 U7/5	B1:	CFAH
A3 U7/6	B1:	8P7H
A3 U7/10	B1:	8H82
A3 U7/11	B1:	5330
A3 U7/12	B1:	2P80
A3 U7/13	B1:	20HA
A3 U8/3	B1:	993P
A3 U8/4	B1:	F1C2
A3 U8/5	B1:	3H85
A3 U8/6	B1:	3044
A3 U8/10	B1:	ACP5

PROCEDURE: (continued)

NODE	SETUP	MEASUREMENT
A3 U9/3	B1:	546F
A3 U9/4	B1:	55F0
A3 U9/5	B1:	1U12
A3 U9/6	B1:	1C47
A3 U9/10	B1:	73F9
A3 U9/11	B1:	083U
A3 U9/12	B1:	4F97
A3 U9/13	B1:	H2F9
A3 U10/3	B1:	F275
A3 U10/4	B1:	F449
A3 U10/5	B1:	C913
A3 U10/6	B1:	66H7
A3 U10/10	B1:	HP7U
A3 U10/11	B1:	8124
A3 U10/12	B1:	0C54
A3 U10/13	B1:	60U5
A3 DS1-DS3 pins 1,2,6,7 A3 DS1-DS3 pins 8,10 A3 DS1-DS3 pins 11,13 A3 DS5-DS7 pins 1,2,6,7 A3 DS5-DS7,10 pins 8,10 A3 DS5-DS7 pins 1,13 A3 DS4,DS8 pins 1,4,5 A3 DS4,DS8 pins 10,11	B1: Setup scope for: 1 V/div, 5 µs/div, Auto trigger.	Nodes should toggle between ≈5 V and ≈3 V. The waveform is unimportant.
A3 R61, R62 pins 2-9 or anodes of DS9-23	B1: Setup scope for: 1 V/div, 5 µs/div, Auto trigger.	Nodes should toggle between ≈2.5 V and ≈5 V. The waveform is unimportant.

BLOCK # A3.3 RPG Latches and Front-Panel-Controls Input Port.

Flip flop A3 U12 decodes the output of the RPG. The processor reads the status of the RPG and front panel switches through shift register A3 U11.

REF. DES.	DESCRIPTION
A3 U11	74LS165 PARALLEL LOAD 8-BIT SHIFT REGISTER
A3 U12	74LS00 QUAD 2-INPUT NAND
A3 U16	74LS74 DUAL D-TYPE FLIP-FLOP

INPUTS:

NODE	SETUP	MEASUREMENT	DRIVES
A3 U11/1	B1:	5544	A3.1
A3 U11/2,U12/4,10 B1:	AUPU	A3.1	
A3 U16/10	B1:	8AU9	A3.1

OUTPUTS:

NODE	SETUP	MEASUREMENT	DRIVES
A3 U16/5	B1:	U16H	A8.11
	B1: A3 S1 depressed	3535	
	B1: A3 S2 depressed	P00H	
	B1: A3 S3 depressed	C4PF	
	B1: A3 S4 depressed	P76A	
	B1: A3 S5 depressed	A970	
	B1: while rotating A3 G1 (RPG) CW slowly	AFP3	
	B1: while rotating A3 G1 (RPG) CCW slowly	407C	
A3 U11/5	X: A3 S5 depressed	LO	
	X: A3 S5 released	HI	
A3 U11/4	X: A3 S4 depressed	LO	
	X: A3 S4 released	HI	
A3 U11/3	X: A3 S3 depressed	LO	
	X: A3 S3 released	HI	
A3 U11/14	X: A3 S2 depressed	LO	
	X: A3 S2 released	HI	
A3 U11/13	X: A3 S1 depressed	LO	
	X: A3 S1 released	HI	
	B1: Set up scope for dual trace operation:Connect channel A to A3 U12/3, channel B to A3 U12/2. 2 V/div, 10ms/div, normal triggering , positive edge on channel A.		

PROCEDURE: (continued)

NODE	SETUP	MEASUREMENT
A3 U12/3	Rotate RPG briskly CW	
A3 U12/2	Rotate RPG briskly CW	
A3 U12/3	Rotate RPG briskly CCW	
A3 U12/2	Rotate RPG briskly CCW	
A3 U12/5	B1:	Node will toggle when RPG is rocked back and fourth.
A3 U12/9	B1:	Node will toggle when RPG is rotated in either direction.
A3 U11/7	B1:	0000
	B1: A3 S1 depressed	F458
	B1: A3 S2 depressed	1160
	B1: A3 S3 depressed	4581
	B1: A3 S4 depressed	1607
	B1: A3 S5 depressed	581H
	B1: while rotating A3 G1 (RPG) CW slowly	5H53
	B1: while rotating A3 G1 (RPG) CCW slowly	C116
A3 U16/8	B1:	U16H
	B1: A3 S1 depressed	3535
	B1: A3 S2 depressed	P00H
	B1: A3 S3 depressed	C4PF
	B1: A3 S4 depressed	P76A
	B1: A3 S5 depressed	A970
	B1: while rotating A3 G1 (RPG) CW slowly	AF3P
	B1: while rotating A3 G1 (RPG) CCW slowly	407C

PSI Board Procedures

BLOCK # A7.1 PSI Address Latches and Decoders

When the D/A line is in the ADDRESS state, serial data is clocked into shift register A7 U13. When the D/A line is in the DATA state, the data in A7 U13 steers the CLOCK line through decoders A7 U16 and A7 U17 to the register being addressed. Optical couplers A7 U3-6 isolate the microprocessor circuits (referenced to earth) from the power supply control circuits (referenced to the negative output terminal).

REF. DES.	DESCRIPTION
A8 U25	74LS367 HEX BUS DRIVER
A7 U3-5	HPCL-2601 OPTICAL COUPLERS
A7 U13	74LS164 8-BIT PARALLEL OUTPUT SHIFT REGISTER
A7 U14	74LS00 QUAD 2-INPUT NAND
A7 U15	74LS14 HEX SCHMITT TRIGGER INVERTER
A7 U16,17	74LS138 3-TO-8 LINE DECODER
A7 U18	74LS04 HEX INVERTER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U25/2	B1:	U147	A8.10
A8 U25/4	B1:	10FF	A8.10
A8 U25/10	B1:	5544	A8.10
A8.10 A7 U13/9	X: cycle power to unit.	LO to HI after ≈ 160ms	A8.3

OUTPUTS:

NODE	SETUP	MEASUREMENT
A7 U13/10	B1:	8AU9
A7 U15/2	B1:	002A
A7 U16/9	B1:	8CFU
A7 U17/15	B1:	7H0F
A7 U17/14	B1:	9760
A7 U17/13	B1:	636C
A7 U17/12	B1:	A9U6
A7 U17/11	B1:	1039
A7 U17/10	B1:	8629
A7 U17/9	B1:	392H
A7 U17/7	B1:	2P00
A7 U18/13	B1:	7P9A

PROCEDURE:

NODE	SETUP	MEASUREMENT
A8 U25/3	B1:	U147
A8 U25/5	B1:	10FF
A8 U25/9	B1:	5544
A8 U3/6	B1:	U147
A7 U4/6	B1:	10FF
A7 U5/6	B1:	5544

Table 5-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

PROCEDURE: (continued)

NODE	SETUP	MEASUREMENT
A7 U15/2	B1:	002A
A7 U15/4	B1:	P1A1
A7 U15/6	B1:	A429
A7 U14/11	B1:	H736
A7 U14/6	B1:	3697
A7 U13/3	B1:	9PPC
A7 U13/4	B1:	U33H
A7 U13/5	B1:	AU3F
A7 U13/6	B1:	F22H
A7 U13/10	B1:	8AU9
A7 U18/11	B1:	3340
A7 U17/7	B1:	2P00
A7 U17/9	B1:	392H
A7 U17/10	B1:	8629
A7 U17/11	B1:	1039
A7 U17/12	B1:	A9U6
A7 U17/13	B1:	636C
A7 U17/14	B1:	9760
A7 U17/15	B1:	7H0F
A7 U16/7	B1:	8UU7
A7 U16/9	B1:	8CFU
A7 U18/13	B1:	7P9A

BLOCK # A7.2 Control Lines Output Port

Serial data generated by the processor is clocked into shift register A7 U28. Register A7 U29 buffers the shift register outputs so that stable data will be available while the shift register is being loaded. The outputs of A7 U29 provide control signals for the power supply and the A/D converter.

REF. DES.	DESCRIPTION
A7 U28	74LS164 8 BIT PARALLEL OUTPUT SHIFT REGISTER
A7 U29	74LS273 OCTAL D TYPE FLIP FLOP

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A7 U28/2	B1:	002A	A7.1
A7 U28/3	B1:	1039	A7.1
A7 U29/11	B1:	8CFU	A7.1
A7 U29/1	X: cycle power to unit	LO to HI after ≈ 160mS	A8.3

OUTPUTS:

NODE	SETUP	MEASUREMENT
A7 U29/2	B1:	UHFF
A7 U29/5	B1:	9A2H
A7 U29/6	B1:	CHU7
A7 U29/9	B1:	154A
A7 U29/15	B1:	6C99
A7 U29/16	B1:	7C1H
A7 U29/19	B1:	272C

PROCEDURE:

NODE	SETUP	MEASUREMENT
A7 U28/4	B1:	2AAH
A7 U28/5	B1:	H104
A7 U28/6	B1:	0CF6
A7 U28/7	B1:	C8CA
A7 U28/14	B1:	49HF
A7 U28/13	B1:	6CC0
A7 U28/12	B1:	HCH7
A7 U28/11	B1:	4F92
A7 U29/2	B1:	UHFF
A7 U29/5	B1:	9A2H
A7 U29/6	B1:	CHU7
A7 U29/9	B1:	154A
A7 U29/15	B1:	6C99
A7 U29/16	B1:	7C1H
A7 U29/19	B1:	272C

BLOCK # A7.3 DAC Voltage Reference

A7 U43 provides a stable 10V reference for the D/A converters and the A/D converter. Op amps A7 U34 buffer this reference and provide an individual voltage trim for each converter.

REF. DES.	DESCRIPTION
A7 U43	LH0070-1 PRECISION 10V REFERENCE
A7 U34	LM324 QUAD OP AMP

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A7 U43/1	X:	14.5 V to 15.5 V	A2 Control Board

OUTPUTS:

NODE	SETUP	MEASUREMENT
A7 U34/1	X: R55 fully CW	10.3 V
	X: R55 fully CCW	10.0 V
A7 U34/7	X: R58 fully CW	10.3 V
	X: R58 fully CCW	10.0 V
A7 U34/8	X: R61 fully CW	10.3 V
	X: R61 fully CCW	10.0 V

PROCEDURE:

NODE	SETUP	MEASUREMENT
A7 U43/2	X:	10V ±30 mV
A7 U34/2 wrt A7 U34/3	X:	−5mV to +5mV
A7 U34/5 wrt A7 U34/6	X:	−5 mV to +5 mV
A7 U34/10 wrt U34/9	X:	−5 mV to +5 mV
A7 U34/1	X: R55 fully CW	10.3 V
	X: R55 fully CCW	10.0 V
A7 U34/7	X: R58 fully CW	10.3 V
	X: R58 fully CCW	10.0 V
A7 U34/8	X: R61 fully CW	10.3 V
	X: R61 fully CCW	10.0 V

BLOCK # A7.4 Current Output Ports, Latches and DAC

Serial data generated by the processor is clocked into shift registers A7 U19 and A7 U20. The outputs of these registers drive 12 bit current output D/A A7 U22. Op amp A7 U24 is an inverting current to voltage converter. Op amp A7 U26 provides an additional stage of inversion and comensates for voltage drops in the ground tracks. The output of A7 U26 provides the reference input to the CC error amplifier on the A2 (control) board.

REF. DES.	DESCRIPTION
A7 U19,20	MC14094 8-BIT SHIFT/STORE REGISTER
A7 U22	12 BIT M-DAC
A7 U24,26	LM308 OP AMP

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A7 U19,20/1	B1:	7P9A	A7.1
A7 U19,20/2	B1:	002A	A7.1
A7 U19/3	B1:	636C	A7.1
A7 U20/3	B1:	9760	A7.1
A7 U22/17	X:	10.0V to 10.3V	A7.3

OUTPUTS:

NODE	SETUP	MEASUREMENT
A7 U26/6 (TP3)	S: output current set to 0A.	≈0 V
	S: output current set to 10A.	≈5 V

PROCEDURE:

NODE	SETUP	MEASUREMENT
A7 U20/14	B1:	9961
A7 U20/13	B1:	3U6U
A7 U20/12	B1:	8A07
A7 U20/11	B1:	7571
A7 U19/4	B1:	198H
A7 U19/5	B1:	8613
A7 U19/6	B1:	364F
A7 U19/7	B1:	2U21
A7 U19/14	B1:	05H5
A7 U19/13	B1:	F2U9
A7 U19/12	B1:	5C66
A7 U19/11	B1:	5C66
A7 U24/2 wrt A7 U25/3	S:	−1 mV to +1 mV
A7 U24/6	S: output current set to 0A.	≈0 V
	S: output current set to 10A.	≈ −10 V

Table 6-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

PROCEDURE (continued)

NODE	SETUP	MEASUREMENT
A7 U26/2 wrt wrt A7 U26/3	S:	−1 mV to +1 mV
measure voltage across R26	S: A7 R29 fully CW	+32 mV
	S: A7 R29 fully CCW	−32 mV
A7 U26/3	S: A7 R29 fully CW	+11 mV
	S: A7 R29 fully CCW	−11 mV
A7 U26/6	S: output current set to 0A	≈0 V
	S: output current set to 10A	≈5 V

BLOCK # A7.5 Voltage Output Ports, Latches and DAC

Serial data generated by the processor is clocked into shift registers A7 U20 and A7 U21. The outputs of these registers drive 12 bit current output D/A A7 U23. Op amp A7 U25 is an inverting current to voltage converter. Op amp A7 U27 provides an additional stage of inversion and comensates for voltage drops in the ground tracks. The output of A7 U27 provides the reference input to the CV error amplifier on the A2 (control) board.

REF. DES.	DESCRIPTION
A7 U20,21	MC14094 8-BIT SHIFT/STORE REGISTER
A7 U23	12 BIT M-DAC
A7 U25,27	LM308 OP AMP

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A7 U20,21/1	B1:	7P9A	A7.1
A7 U20,21/2	B1:	002A	A7.1
A7 U20/3	B1:	9760	A7.1
A7 U21/3	B1:	7H0F	A7.1
A7 U22/17	X:	10.0 V to 10.3 V	A3.1

OUTPUTS:

NODE	SETUP	MEASUREMENT
A7 U27/6	S: output voltage set to 0 V.	≈0 V
A7J4-5	S: output voltage set to 60 V.	≈5V

PROCEDURE:

NODE	SETUP	MEASUREMENT
A7 U21/4	B1:	7H2P
A7 U21/5	B1:	1P9U
A7 U21/6	B1:	C7P0
A7 U21/7	B1:	A668
A7 U21/14	B1:	PA20
A7 U21/13	B1:	U01H
A7 U21/[illegible]	B1:	062U
A7 U21/11	B1:	862F
A7 U20/4	B1:	HCPH
A7 U20/5	B1:	7C87
A7 U20/6	B1:	1AF3
A7 U20/7	B1:	6707
A7 U25/2 wrt A7 U25/3	S:	−1 mV to +1 mV
A7 U25/6	S: output voltage set to 0 V.	≈0 V
	S: output voltage set to 60 V.	≈ −10 V

Table 5-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

PROCEDURE (continued)

NODE	SETUP	MEASUREMENT
A7 U25/2 wrt A7 U25/3	S:	−1 mV to +1 mV
measure voltage across R37	S: A7 R40 fully CW	+6 mV
	S: A7 R40 fully CCW	−6 mV
A7 U27/3	S: A7 R40 fully CW	+2 mV
	S: A7 R40 fully CCW	−2 mV
A7 U27/6	S: output voltage set to 0 V	≈0 V
	S: output voltage set to 60 V	≈5 V

BLOCK # A7.6 Input Port Selector

Multiplexer A7 U9 connects the shift register being read by the processor to the DATA UP line.

REF. DES.	DESCRIPTION
A7 U9	74LS251 DATA SELECTOR/MULTIPLEXER
A7 U15	74LS14 HEX SCHMITT TRIGGER INVERTER
A7 U18	74LS367 HEX BUS DRIVER
A7 U6	HPCL-2601 OPTICAL COUPLER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A7 U9/7	B1:	8AU9	A7.1
A7 U9/9	B1:	AU3F	A7.1
A7 U9/10	B1:	U33H	A7.1
A7 U9/11	B1:	9PPC	A7.1
A7 U9/12	B3:	131H	A7.7
A7 U9/13	B3:	HF9F	A7.8
A7 U9/14	B3:	CF18	A7.9
A7 U9/1	B3:	1603	A7.9

OUTPUTS:

NODE	SETUP	MEASUREMENT	DRIVES
A7 U6/6	B3:	2735	A8.11

PROCEDURE:

NODE	SETUP	MEASUREMENT
A7 U9/5	B3:	toggling
A7 U15/8	B3:	P120
A7 U18/3	B3:	104H
A7 U6/6	B3:	2735

BLOCK # A7.7 ID Switch Input Port

The processor reads the unit identification code through shift register A7 U12. This code informs the processor of the full scale voltage and current ratings of the power supply.

REF. DES.	DESCRIPTION
A7 U12	74LS165 PARALLEL LOAD 8-BIT SHIFT REGISTER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A7 U12/6	X:	LO	
A7 U12/5	X:	LO	
A7 U12/4	X:	LO	
A7 U12/3	X:	LO	
A7 U12/14	X:	LO	
A7 U12/13	X:	LO	
A7 U12/12	X:	HI	
A7 U12/11	X:	LO	
A7 U12/1	B1:	5544	
A7 U12/2	B1:	2P00	

OUTPUTS:

NODE	SETUP	MEASUREMENT	DRIVES
A7 U12/9	B1:	131H	A7.6

BLOCK # A7.8 Status-Lines Input Port

The processor reads the power supply status signals through shift register A7 U10. Latch A7 U11 holds momentary occurrences of the CV, CC AC and OT signals between processor reads.

REF. DES.	DESCRIPTION
A7 U10	74LS165 PARALLEL LOAD 8-BIT SHIFT REGISTER
A7 U11	74LS279 QUAD SR LATCH

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A7 U11/1	S: output open circuit, output current limit set >0.	LO	see A2
	S: output shorted, output voltage limit set >0.	HI	
A7 U11/5	S: output short circuit, output voltage limit set >0.	LO	
	S: output open circuit, output current limit set >0.	HI	
A7 U11/10	S: supply at nominal line voltage.	HI	
	S: line voltage reduced to ≈40 VAC.	LO	
A7 U11/14	S:	HI	
	S: one lead disconnected from thermal switch A4 TS1 on PM board.	LO	
A7 U10/14	S: OVP ADJUST fully CW, power to unit cycled.	HI	
	S: output open circuit, output voltage set >1, OVP ADJUST fully CCW.	LO	
A7 U10/11	B1:	UHFF	A7.1
A7 U11/2,6	B1:	392H	A7.1
A7 U11/11,15			
A7 U10/2	B1:	392H	

Table 5-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

OUTPUTS:

NODE	SETUP	MEASUREMENT	DRIVES
A7 U10/9	B3:	HF9F	A7.6
	B3: A7 U11/1 shorted to GND	3238	
	B3: A7 U11/5 shorted to GND	U0F7	
	B3: A7 U11/10 shorted to GND	178A	
	B3: A7 U11/14 shorted to GND	AP59	
	B3: A7 U10/14 shorted to GND	402H	

PROCEDURE:

NODE	SETUP	MEASUREMENT
A7 U11/4	B3:	U16H
	B3: A7 U11/1 shorted to GND	F840
A7 U11/7	B3:	U16H
	B3: A7 U11/5 shorted to GND	F840
A7 U11/9	B3:	U16H
	B3: A7 U11/10 shorted to GND	F840
A7 U11/13	B3:	U16H
	B3: A7 U11/14 shorted to GND	F840
A7 U10/9	B3:	U16H
	B3: A7 U11/1 shorted to GND	3238
	B3: A7 U11/5 shorted to GND	U0F7
	B3: A7 U11/10 shorted to GND	178A
	B3: A7 U11/14 shorted to GND	AP59
	B3: A7 U10/14 shorted to GND	402A

BLOCK # A7.9 A/D Successive Approximation Registers and Input Port

Successive approximation registers A7 U36 and A7 U37 drive D/A converter A7 U31 based on the output of comparator A7 U36. The processor reads the output of SAR through shift registers A7 U38 and A7 U39.

REF. DES.	DESCRIPTION
A7 U38,39	74LS165 PARALLEL LOAD 8-BIT SHIFT REGISTER
A7 U36	MC14549 SUCCESSIVE APPROXIMATION REGISTER
A7 U37	MC14559 SUCCESSIVE APPROXIMATION REGISTER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A7 U36,37/6	X: A7 U35/3 shorted to GND and A7 U35/2 shorted to +5 V	HI	A7.10
	X: A7 U3 3 shorted to +5 V and A ' U35/2 shorted to GND.	LO	
			A7.1
A7 U38,39/1	B1:	5544	A7 1
A7 U38/2	B1:	A9U6	A7.1
A7 U39/2	B1:	8629	A7.2
A7 U37/9	B1:	CHU7	
A7 U36/10	B1:	CHU7	
A7 U37/7	X:	1 kHz, 50% duty cycle square wave, TTL levels	A7 U41

OUTPUTS:

NODE	SETUP	MEASUREMENT	DRIVES
A7 U38/9	B3:	1603	A7.6
A7 U39/9	B3:	CF18	A7.6

PROCEDURE:

NODE	SETUP	MEASUREMENT
A7 U37/4	B3:	AHAF
A7 U37/3	B3:	550C
A7 U37/2	B3:	UU73
A7 U37/1	B3:	23H2
A7 U36/4	B3:	17FH
A7 U36/3	B3:	908A
A7 U36/2	B3:	2369
A7 U36/1	B3:	1PP4
A7 U36/15	B3:	4U46
A7 U36/14	B3:	C9F3
A7 U36/13	B3:	0152
A7 U36/12	B3:	9PF5
A7 U36/11	B3:	52C1
A7 U38/9	B3:	1603
A7 U39/9	B3:	CF18

BLOCK # A7.10 Analog Multiplexer and Successive Appoximation A/D Converter

A7 U31 is a 12-bit current output D/A converter. It is driven by the successive approximation registers. Op amp A7 U32 serves as an inverting current to voltage converter. Op amp A7 U33 provides an additional stage of inversion and compensates for voltage drops in ground tracks. A7 U35 compares the D/A converter output to the signal being measured. The output of this comparator drives the SAR. Multiplexer A7 U40 connects one of 8 signals to the A/D converter.

REF. DES.	DESCRIPTION
A7 U31	12 BIT M-DAC
A7 U30,32,33	LM308 OP AMP
A7 U40	ANALOG MULTIPLEXER
A7 U35	uA734 COMPARATOR

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A7 U31/4	B3:	AHAF	A7.9
A7 U31/5	B3:	550C	"
A7 U31/6	B3:	UU73	"
A7 U31/7	B3:	23H2	"
A7 U31/8	B3:	17FH	"
A7 U31/9	B3:	908A	"
A7 U31/10	B3:	2369	"
A7 U31/11	B3:	1PP4	"
A7 U31/12	B3:	4U46	"
A7 U31/13	B3:	C9F3	"
A7 U31/14	B3:	0152	"
A7 U31/15	B3:	9PF5	"
A7 U40/1	B3:	6C99	A7.2
A7 U40/16	B3:	7C1H	A7.2
A7 U40/15	B3:	272C	A7.2
A7 U31/17	X:	10.0 V to 10.3 V	A7.3
A7 U40/9	S: output terminals open circuit, output current set >0:		
	output voltage set to 0 V.	≈0 V	
	output voltage set to 60 V.	≈5 V	
A7 U40/10	S: output terminals shorted, output voltage set >0:		
	output current set to 0A.	≈0 V	
	output current set to 10A.	≈5 V	
A7 U30/3	S: output voltage set to 0 V.	≈0 V	
	output voltage set to 60 V.	≈5 V	
A7 U40/5	S: output current set to 0 A	≈0 V	
	output current set to 10 A.	≈5 V	

INPUTS: (continued)

NODE	SETUP	MEASUREMENT	SOURCE
A7 U40/11	X: OVP ADJUST fully CCW OVP ADJUST fully CW	≈ 0 V ≈2.4 V	

OUTPUTS:

NODE	SETUP	MEASUREMENT
A7 U35/7	There is no single measurement which can completely verify the output of this block.	

PROCEDURE:

NODE	SETUP	MEASUREMENT
A7 U30/6 (A7J4-17)	S: output terminals open circuit and output current set >0: output voltage set to 0 V. output voltage set to 60 V.	 ≈0 V ≈5 V

The following portion of this procedure verifies every channel of the multiplexer. If a particular channel appears to be faulty, test that channel first. If all channels appear faulty, test one channel; if it works, go to the next troubleshooting area.

NODE	SETUP	MEASUREMENT
A7 U40/8 (TP1)	S: send "DSP OFF" command or tape down DISPLAY SETTINGS switch.	
VMON, Buffered	output terminals open circuit. output current set >0. send "VOUT?" command. output voltage set to 0 V. output voltage set to 60 V.	 ≈0 V ≈5 V

WARNING

Output should be at 0 V before shorting output terminals.

NODE	SETUP	MEASUREMENT
IMON	output terminals shorted, output voltage set >0. sent "IOUT?" command. output current set to 0A. output current set to 10A.	 ≈0 V ≈5 V
CV PROG	send "VPROG?" command. output voltage set to 0 V. output voltage set to 60 V.	 ≈0 V ≈5 V
CC PROG	send "IPROG?" command. output current set to 0A. output current set to 10A.	 ≈0 V ≈5 V
OVP PROG	send "OVP?" command. OVP ADJUST fully CCW. OVP ADJUST full CW. send "ZERO?" command.	 ≈0 V ≈2.1 V ≈0 V

Table 5-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

PROCEDURE:

NODE	SETUP	MEASUREMENT
A7 U32/2 wrt A7 U32/3	S: send "DSP OFF" command or tape down the DISPLAY SETTINGS switch. Set OVP ADJUST fully CW. Short A7 C18. send "OVP?" command.	−1 mV to +1 mV
A7 U32/6	"	≈ −10 V
A7 U33/2 wrt A7 U33/3	"	−1 mV to +1 mV
measure voltage across A7 R48	" and A7 R51 fully CW " and A7 R51 fully CCW	+0 V −32 mV
A7 U33/3	" and A7 R51 fully CW " and A7 R51 fully CCW	+11 mV −11 mV
A7 U33/6	"	≈5 V
A7 U32/6	S: send "DSP OFF" command or tape down the DISPLAY SETTINGS switch. Short A7 U35/6 to GND	≈0 V
A7 U33/6	"	≈0 V
A7 U36/6	X: A7 U36/1 shorted to +5 V and A7 U36/10 shorted to GND.	LO
	X: A7 U36/1 shorted to GND and A7 U36/10 shorted to +5 V	HI

For a more complete test of the comparator, continue in the following procedure.

NODE	SETUP	MEASUREMENT
A7 U35/7	S: send "DSP OFF" command or tape down the DISPLAY SETTINGS switch. Short A7 C18. Use RPG control to increase the output voltage to ≈1 V. Send "VOUT?" command.	
	Remove short from A7 C18. Using clip leads, connect a 5 k 1/4 W resistor across A7 R47.	LO
	With unit in local control, use RPG control to increase output past mid scale (30 V).	HI
A7 U35/3 wrt A7 U35/2	Slowly adjust RPG control until A7 U36/6 just changes state.	−1 mV to +1 mV

BLOCK # A8.1 5 V Bias Supply

The PWM A8U28 includes a clock generator (45 kHz set by A8R21 and A8C21) and a current limit (4 Adc maximum set by 0.15 Vdc across A8R33). It turns off each output pulse using the difference between the voltage at voltage divider A8R29-A8R30 and the 2.5 Vdc set by voltage regulator A8U29.

REF. DES.	DESCRIPTION
A8 U28	SG3524J PWM
A8 U29	MC1403U 2.5V voltage regulator

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8CR1 anode	X:	≈ 20 Vdc	A8CR1, CR2

OUTPUTS

NODE	SETUP	MEASUREMENT
A8U28/6	X:	≈ 2 to 4 Vdc sawtooth, 45 kHz
A8U28/12,13	"	≈ 19 Vpk, 15 μs pulses, 45 kHz
A8Q2 emitter	"	≈ 20 Vpk, 5 μs pulses, 45 kHz
A8U29/2	"	2.5 Vdc
across A8CR3	"	≈ 0 V > −0.07 Vdc
across A8R30	"	2.5 Vdc

To check if load on +5 V is shorted, remove jumper A8W3.

BLOCK # A8.2 Power Clear (1)

This block generates a signal which indicates when the unregulated DC input voltage to the 5V bias supply on the HP-IB board is sufficent for the supply to function properly. A delay is also provided so that the processor will have time to start up.

When the unit is first turned on, the unregulated DC input will begin to rise. Transistor A8 Q3 will be starved of base drive until zener VR1 breaks down. By the time VR1 breaks down, there is sufficient voltage for comparator U30 to operate. A8 U30A will keep A8 C28 from charging and A8 U30B will sink base current from A8 Q3 until the unregulated input reaches ≈11V. Then A8 U30A will allow A8 C28 to charge up. When the voltage across A8 C28 reaches ≈3.3V, A8 U30A will allow A8 Q3 to turn on.

REF. DES.	DESCRIPTION
A8 U30	LM383 DUAL COMPARATOR

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 VR1 cathode	X:	15 V to 25 V	A8.1

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 Q3 collector	X: cycle power to unit	HI to LO after ≈160 ms

PROCEDURE:

NODE	SETUP	MEASUREMENT
A8 U30/3	X: cycle power to unit	−6.5 V with respect to VR1 cathode
A8 U30/2	"	≈40% of V at VR1 cathode
A8 U30/1	"	≈0 V charging up to ≈5 V
A8 U30/6	"	≈3.3 V
A8 CR4 anode	"	≈0 V to ≈1.4V after ≈160 ms. no glitches
A8 Q3 collector	"	HI to LO after ≈160 ms. no glitches

Table 6-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

BLOCK # A8.3 Power Clear (2)

All measurements listed in this block are changes from one level to another. When making these measurements, cycle the power to the unit and observe the signal with a scope. The first level specified should be stable within ≈ 10 ms. During the first ≈ 10 ms, glitching may occur. The signal will change to the second level after specified time.

REF. DES.	DESCRIPTION
A3 U17	74LS04 HEX INVERTER
A7 U14	74LS00 QUAD 2-INPUT NAND GATE
A7 U15	74LS14 HEX SCHMITT-TRIGGER INVERTER
A7 U18	74LS368 HEX BUS DRIVER
A8 U11	74LS32 QUAD 2-INPUT NOR GATE
A8 U27	74LS14 HEX SCHMITT-TRIGGER INVERTER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U11/1	X: cycle power to unit	HI to LO after ≈ 160 ms no glitches.	A8.2
A7 U18/4	"	LO to HI after ≈ 15 ms	see A2
A7 U14/10	"		

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 U27/7	"	HI to LO after ≈ 160 ms
A8 U27/6	"	LO to HI after ≈ 160 ms
A3 U17/6	"	"
A7 U18/7	"	"

PROCEDURE:

NODE	SETUP	MEASUREMENT
A7 U18/5	"	HI to LO after ≈ 15 ms
A7 U7/6	"	HI to LO after ≈ 15 ms
A8 U11/3	"	HI to LO after ≈ 160 ms
A8 U27/6	"	LO to HI after ≈ 160 ms
A8 U27/4	"	HI to LO after ≈ 160 ms
A8 U27/12	"	LO to HI after ≈ 160 ms
A3 U17/4	"	HI to LO after ≈ 160 ms
A3 U17/6	"	LO to HI after ≈ 160 ms
A7 U8/6	"	HI to LO after ≈ 160 ms
A7 U15/10	"	LO to HI after ≈ 160 ms
A7 U14/8	"	HI to LO after ≈ 160 ms
A7 U18/7	"	LO to HI after ≈ 160 ms

Table 5-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

BLOCK # A8.4 Microprocessor, Microprocessor Clock and Address Decoding

Oscillator A8 U4 provides the clock to A8 U10, the microprocessor. The processor drives the address and the address decoder, A8 U12. Inverters A8 U5 buffer the processor timing and control signals.

REF. DES.	DESCRIPTION
A8 U4	4 MHZ OSCILLATOR
A8 U5	74LS04 HEX INVERTER
A8 U10	6809 MICROPROCESSOR
A8 U12	74LS138 3-TO-8 LINE DECODER
A8 U26	74LS08 QUAD 2-INPUT AND GATE

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U10/37	X: cycle power to unit.	LO to HI after ≈160 ms	A8.3
A8 U10/2	A1:	HI	A8 S2E
A8 U10/38	X:	4MHz, 50% duty cycle square wave, TTL levels	A8 U4

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 U10/34 (E)	A1:	1 MHz, 50% duty cycle square wave, TTL levels
A8 U5/10	A1:	"
A8 U5/8	A1:	"
A8 U10/35 (Q)	A1:	"
A8 U5/12	A1:	"
A8 U10/32	A1:	HI
A8 U5/4	A1:	LO
A8 U5/6	A1:	HI
A8 U10/8	A1:	UUUU
A8 U10/9	A1:	FFFF
A8 U10/10	A1:	8484
A8 U10/11	A1:	P763
A8 U10/12	A1:	1U5P
A8 U10/13	A1:	0356
A8 U10/14	A1:	U759
A8 U10/15	A1:	6F9A
A8 U10/16	A1:	7791
A8 U10/17	A1:	6321
A8 U10/18	A1:	37C5
A8 U10/19	A1:	6U28
A8 U10/20	A1:	4FCA
A8 U10/21	A1:	4868
A8 U10/22	A1:	9UP1
A8 U10/23	A1:	0002
A8 U12/15	A1:	H21U
A8 U12/14	A1:	3714
A8 U12/13	A1:	3H02
A8 U12/12	A1:	47PC
A8 U12/11	A1:	C7HA
A8 U12/9	A1:	147P
A8 U12/7	A1:	26UU
A8 U26/11	A1:	3282

BLOCK # A8.5 ROM and Data Bus Latch

ROM A8 U8 stores the programs which the processor executes. Latch A8 U19 holds the data bus data between the time when the ROMs are deselected and the processor reads the data bus.

REF. DES.	DESCRIPTION
A8 U8	64K ROM
A8 U19	74LS374 OCTAL D-TYPE FLIP-FLOP

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U8/20,22	A1:	3282	A8.4
A8 U19/11	X:	1 MHz, 50% duty cycle square wave, TTL levels	
A8 U19/1	A1:	LO	A8.4
A8 U8/10	A1:	UUUU	A8.4
A8 U8/9	A1:	FFFF	"
A8 U8/8	A1:	8484	"
A8 U8/7	A1:	P763	"
A8 U8/6	A1:	1U5P	"
A8 U8/5	A1:	0356	"
A8 U8/4	A1:	U759	"
A8 U8/3	A1:	6F9A	"
A8 U8/25	A1:	7791	"
A8 U8/24	A1:	6321	"
A8 U8/21	A1:	37C5	"
A8 U8/23	A1:	6U28	"
A8 U8/2	A1:	4FCA	"

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 U8/11	A2:	U63P
A8 U8/12	A2:	1363
A8 U8/13	A2:	0827
A8 U8/15	A2:	53U4
A8 U8/16	A2:	794C
A8 U8/17	A2:	50UF
A8 U8/18	A2:	C5C4
A8 U8/19	A2:	9[illegible]71
A8 U19/2	A2:	625U
A8 U19/5	A2:	10U1
A8 U19/6	A2:	9H53
A8 U19/9	A2:	30CA
A8 U19/12	A2:	A5P5
A8 U19/15	A2:	C13P
A8 U19/16	A2:	F39A
A8 U19/19	A2:	5178

The continuity of the data bus jumper, A8 W4, can be checked by inserting it in A8 J6, the normal position. Use a logic probe to determine whether lines A8 U10/24-31 are toggling.

BLOCK # A8.6 RAM and Data Bus Buffers

RAMs A8 U6 and A8 U7 store data which changes during course of program execution. Buffer A8 U14 is used to bypass latch A8 U19 when the processor writes data.

REF. DES.	DESCRIPTION
A8 U6,7	1 K x 4 STATIC RAM
A8 U14	74LS244 OCTAL BUFFER
A8 U5	74LS04 HEX INVERTER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U14/2	C1:	96PF	A8 U10
A8 U14/4	C1:	725C	"
A8 U14/6	C1:	P5PH	"
A8 U14/8	C1:	5CP0	"
A8 U14/11	C1:	7P25	"
A8 U14/13	C1:	85FA	"
A8 U14/15	C1:	77F7	"
A8 U14/17	C1:	6PCP	"
A8 U5/3	C2:	6FAF	A8 U10
A8 U6/5,U7/5	A1:	UUUU	A8.4
A8 U6/6,U7/6	A1:	FFFF	"
A8 U6/7,U7/7	A1:	8484	"
A8 U6/4,U7/4	A1:	P763	"
A8 U6/3,U7/3	A1:	1U5P	"
A8 U6/2,U7/2	A1:	0356	"
A8 U6/1,U7/1	A1:	U759	"
A8 U6/17,U7/17	A1:	6F9A	"
A8 U6/16,U7/16	A1:	7791	"
A8 U6/15,U7/15	A1:	6321	"
A8 U6/8,U7/8	A1:	H21U	A8.4

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 U14/18	C1:	96PF
A8 U14/16	C1:	725C
A8 U14/14	C1:	P5PH
A8 U14/12	C1:	5CPO
A8 U14/9	C1:	7P25
A8 U14/7	C1:	85PA
A8 U14/5	C1:	77F7
A8 U14/3	C1:	6PCP
A8 U5/4	C2:	6PFP
A8 U5/6	C2:	6FAF

Table 5-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

OUTPUTS: (continued)

Note: If all output measurements are correct and Err 2, 3, or 4 persists, U6 or U7 is at fault.

NOTE: If the +5 V signature for setups C1 or C2 is not correct, use the following procedure to troubleshoot gate and clock signals.

NODE	SETUP	MEASUREMENT	SOURCE
A8 U13/1	A1:	UUUU	A8.4
A8 U13/2	A1:	FFFF	"
A8 U13/3	A1:	8484	"
A8 U13/4	A1:	3H02	"

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 U13/9	A1:	P8PH
A8 U22/11	A1:	CC33

PROCEDURE

NODE	SETUP	MEASUREMENT
A8 U13/14	A1:	CC30
A8 U13/13	A1:	PPFU
A8 U13/9	A1:	P8PH
A8 U26/6	A1:	H5.[illegible]
A8 U22/11	A1:	CC33

BLOCK # A8.7 Address Input Port

The processor reads the HP-IB address switch and the diagnostic mode jumper position through buffer A8 U15. S1 A1 through S1 A5 and PON SRQ refer to rear-panel switch sections.

REF. DES.	DESCRIPTION
A8 U15	74LS244 OCTAL BUFFER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U15/1,19	A1:	47PC	A8.4
A8 U15/11	X: S1 A1 = 1 X: S1 A1 = 0	LO HI	-
A8 U15/15	X: S1 A2 = 1 X: S1 A2 = 0	LO HI	-
A8 U15/13	X: S1 A3 = 1 X: S1 A3 = 0	LO HI	-
A8 U15/8	X: S1 A4 = 1 X: S1 A4 = 0	LO HI	-
A8 U15/6	X: S1 A5 = 1 X: S1 A5 = 0	LO HI	-
A8 U15/4	X: S1 PON SRQ = 1 X: S1 PON SRQ = 0	LO HI	-
A8 U15/17	X: W5 in NORMAL position X: W5 in DIAGNOSTIC position.	HI LO	-

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 U15/9	A3: S1 A1 = 1 A3: S1 A1 = 0	0000 1180
A8 U15/5	A3: S1 A2 = 1 A3: S1 A2 = 0	0000 1180
A8 U15/7	A3: S1 A3 = 1 A3: S1 A3 = 0	0000 1180
A8 U15/12	A3: S1 A4 = 1 A3: S1 A4 = 0	0000 1180
A8 U15/14	A3: S1 A5 = 1 A3: S1 A5 = 0	0000 1180
A8 U15/16	A3: S1 PON SRQ = 1 A3: S1 PON SRQ = 0	0000 1180
A8 U15/2	A3: W5 in NORMAL position A3: W5 in DIAGNOSTIC position	1180 0000

BLOCK # A8.8 Test LEDs and Output Port

The processor writes data into latch A8 U16 to drive the TEST LEDs control lines for the real time clock and signature analyzer.

REF. DES.	DESCRIPTION
A8 U16	74LS273 OCTAL D-TYPE FLIP-FLOP

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U16/3	C1:	96PF	A8.6
A8 U16/4	C1:	725C	"
A8 U16/7	C1:	P5PH	"
A8 U16/8	C1:	5CP0	"
A8 U16/13	C1:	7P25	"
A8 U16/14	C1:	85PA	"
A8 U16/17	C1:	77F7	"
A8 U16/18	C1:	5FCP	"
A8 U16/1	X: cycle power to unit	LO to HI after 160 ms	A8.3
A8 U16/11	A1:	C7HA	A8.4

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 U16/2	B1:	3657
A8 U16/5	B1:	U16H
A8 U16/6	B1:	P0C2
A8 U16/9	B1:	132U
A8 U16/12	B1:	1291
A8 U16/15	B1:	HH63
A8 U16/16	B1:	301A
DS1/A-E	B1: Cycle power to unit.	Each LED will light in sequence. Then DS1/D and DS1/C should remain on.

BLOCK # A8.9 Real-Time Clock

A8 U17 divides one of the microprocessor timing signals down to approximately 1 kHz. This signal interrupts the processor to provide a real-time clock.

REF. DES.	DESCRIPTION
A8 U17	MC14020B 14 BINARY COUNTER
A8 U27	74LS04 HEX INVERTER
A8U5	74LS04 HEX INVERTER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U17/10	X:	1 MHz, 50% duty cycle square wave, TTL levels	A8.4
A8 U27/1	B1:	3657	A8.8

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 U10/2	B1: close A8 S2E	1 kHz, 50% duty cycle square wave, TTL levels

PROCEDURE:

NODE	SETUP	MEASUREMENT
A8 U27/2	B1:	F73A
A8 U17/14	B1:	1 kHz, 50% duty cycle square wave, TTL levels.
A8 U5/2	B1:	"
A8 U10/2	B1: close A8 S2E	"

BLOCK # A8.10 Serializer (1)

The processor loads data into shift register A8 U23. This data is in turn shifted out of A8 U23 into a receiving register on the PSI or front panel boards. Counter A8 U20 and flip flop A8 U18 derive the shift register clock signals from a processor timing signal. Selector A8 U21 is used to steer the clock signals to the appropriate register or interface line. The processor generates control signals for the interface with decoder A8 U13 and gates A8 U22 and A8 U26.

REF. DES.	DESCRIPTION
A8 U13	74LS138 3-TO-8 LINE DECODER
A8 U18	74LS74 DUAL D-TYPE FLIP-FLOP
A8 U20	74LS293 4-BIT BINARY COUNTER
A8 U21	74LS158 QUAD 2-TO-1 LINE SELECTOR
A8 U22	74LS00 QUAD 2-INPUT NAND
A8 U23	74LS165 PARALLEL LOAD 8-BIT SHIFT REGISTER
A8 U26	74LS08 QUAD 2-INPUT AND
A8 U27	74LS04 HEX SCHMITT TRIGGER INVERTER

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U18/11	X:	1MHz, 50% duty cycle square wave, TTL levels	A8.4
A8 U13/1	A1:	UUUU	A8.4
A8 U13/2	A1:	FFFF	"
A8 U13/3	A1:	8484	"
A8 U13/4	A1:	3H02	"
A8 U18/1	X: cycle power to unit	LO to HI after 160 ms	A8.3
A8 U23/11	C1:	96PF	A8.6
A8 U23/12	C1:	725C	"
A8 U23/13	C1:	P5PH	"
A8 U23/14	C1:	5CP0	"
A8 U23/3	C1:	7P25	"
A8 U23/4	C1:	85PA	"
A8 U23/5	C1:	77F7	"
A8 U23/6	C1:	6PCP	"

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 U22/3	B1:	5544
A8 U23/9	B1:	002A
A8 U23/7	B1:	U147
A8 U27/6	B1:	CA5H
A8 U21/4	B1:	10FF

Table 5-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

PROCEDURE:

NODE	SETUP	MEASUREMENT
A8 U13/10	B8:	H839
A8 U13/11	B8:	H664
A8 U13/12	B8:	63C7
A8 U13/13	B8:	CPC9
A8 U13/14	B8:	2019
A8 U13/15	B8:	260P
A8 U26/3	B8:	6UFH
A8 U26/6	B8:	FF63
A8 U22/3	B8:	C93P
A8 U22/6	B8:	4853
A8 U22/8	B8:	434F
A8 U22/11	B8:	C221
A8 U18/6	B2:	81P9
A8 U20/8	B2:	UP36
A8 U27/10	B2:	0U5C
A8 U20/9	B2:	C834
A8 U27/8	B2:	4959
A8 U18/9	B2:	HF1A
A8 U21/4	B1:	10FF
A8 U21/7	B1:	3285
A8 U23/7	B1:	U147
A8 U23/9	B1:	002A

BLOCK # A8.11 Serializer (2)

Serial data from the PSI and front panel boards is clocked into shift register A8 U24. This data is then read by the processor. Selector A8 U21 allows data shifted out of shift register A8 U23 to be shifted into A8 U24 for self test.

REF. DES.	DESCRIPTION
A8 U21	74LS158 QUAD 2-TO-1 LINE SELECTOR
A8 U24	74LS299 8-BIT BIDIRECTIONAL SHIFT REGISTER)
A8 U26	74LS26 QUAD 2-INPUT AND GATE

INPUTS:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U24/2	B8:	H664	A8.10
A8 U24/12	B1:	CA5H	"
A8 U21/1	B1:	50FC	"
A8 U21/11	B1:	002A	"
A8 U26/9	B3:	2375	A7.6
A8 U26/10	B1:	U16H	A3.3
A8 U24/9	X: cycle power to unit		A8.3

OUTPUTS:

NODE	SETUP	MEASUREMENT
A8 U24/4	B6:	H746
A8 U24/5	B6:	6081
A8 U24/6	B6:	5AA1
A8 U24/7	B6:	A000
A8 U24/13	B6:	H607
A8 U24/14	B6:	683F
A8 U24/15	B6:	7AH9
A8 U24/16	B6:	2F88

PROCEDURE:

NODE	SETUP	MEASUREMENT
A8 U26/8	B3:	104H
A8 U21/9	B3:	6F28
A8 U21/12	B3:	9H45
A8 U24/4	B6:	H746
A8 U24/5	B6:	6081
A8 U24/6	B6:	5AA1
A8 U24/7	B6:	A000
A8 U24/13	B6:	H607
A8 U24/14	B6:	683F
A8 U24/15	B6:	7AH9
A8 U24/16	B6:	2F88

BLOCK # A8.12 HP-IB Transceivers and Interface

A8 U3 performs most of the HP-IB interface functions. A8 U3 appears to the processor as a group of memory locations. Reading from and writing to these locations controls the exchange of data on the bus. Transceivers A8 U1 and A8 U2 provide the loading and drive required by the HP-IB.

REF. DES.	DESCRIPTION
A8 U1	75160 BUS TRANSCEIVER
A8 U2	75161 BUS TRANSCEIVER
A8 U3	8291 GPIB TALKER/LISTENER
A8 U11	74LS32 QUAD 2-INPUT OR GATE

This block does not lend itself well to defining inputs and outputs. Please use the following procedure in the sequence presented. Since the procedure involves testing bi-directional signal lines, the circuit driving the line will be noted whenever it is not obvious. A logic pulser is required to troubleshoot this block.

PROCEDURE:

NODE	SETUP	MEASUREMENT	SOURCE
A8 U3/8	A1:	3714	A8.4
A8 U11/5,10	A1:	3714	
A8 U3/21	A1:	UUUU	A8.4
A8 U3/22	A1:	FFFF	"
A8 U3/23	A1:	8484	"
A8 U11/4	C2:	6PFP	A8.6
A8 U11/9	C2:	6FAF	"
A8 U11/8	B8	88P6	A8 U11
A8 U11/6	B8	0496	"
A8 U3/12	B7:	64F4	A8 U3
A8 U3/13	"	5931	
A8 U3/14	"	964F	
A8 U3/15	"	A593	
A8 U3/16	"	2964	
A8 U3/17	"	0A59	
A8 U3/18	"	0295	
A8 U3/19	"	40A6	

At this point, it has been verified that the processor can read and write data to the internal serial-poll-mode register of A8U3.

NODE	SETUP	MEASUREMENT	SOURCE
A8 U3/1	S:	LO	A8 U3
A8 U2/19	S: pulse A8 U2/3	toggling	A8 U2
A8 U2/18	pulse A8 U2/3	"	"
A8 U2/14	pulse A8 U2/7	"	"
A8 U2/13	pulse A8 U2/8	"	"

Table 5-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

PROCEDURE: (continued)

NODE	SETUP	MEASUREMENT	SOURCE
A8 U2/16	S: Short A8 U2/8 to GND		
	pulse A8 U2/6	toggling	A8 U2
A8 U3/37	same as above	"	A8 U3
A8 U2/5	same as above	"	A8 U2
A8 U3/38	same as above	"	A8 U3
A8 U2/4	same as above	"	A8 U2
A8 U11/11	same as above	HI	A8 U11
A8 U1/19	S: pulse A8 U1/2	toggling	A8 U1
A8 U1/18	S: pulse A8 U1/3	"	"
A8 U1/17	S: pulse A8 U1/4	"	"
A8 U1/16	S: pulse A8 U1/5	"	"
A8 U1/15	S: pulse A8 U1/6	"	"
A8 U1/14	S: pulse A8 U1/7	"	"
A8 U1/13	S: pulse A8 U1/8	"	"
A8 U1/12	S: pulse A8 U1/9	"	"
A8 U3/1	B1:	HI	A8 U3
A8 U2/17	B1: pulse A8 U2/4	toggling	A8 U2
A8 U3/36	B1: pulse	"	A8 U3
A8 U2/6	B1: pulse	"	A8 U2
	B1: A8 U2/4 shorted to GND	LO	A8 U3
	B1: A8 U2/5 shorted to GND	HI	A8 U3
A8 U3/28	B1:	toggling	A8 U3
A8 U3/29	B1:	"	
A8 U3/30	B1:	"	"
A8 U3/31	B1:	"	"
A8 U3/32	B1:	"	"
A8 U3/33	B1:	"	"
A8 U3/34	B1:	"	"
A8 U3/35	B1:	"	"
A8 U1/2	B1:	toggling	A8 U1
A8 U1/3	B1:	"	"
A8 U1/4	B1:	"	"
A8 U1/5	B1:	"	"
A8 U1/6	B1:	"	"
A8 U1/7	B1:	"	"
A8 U1/8	B1:	"	"
A8 U1/9	B1:	"	"

Set unit up for normal operation, with HP-IB address set to 5. Connect controller to instrument and run the programs given for the tests that follow.

Enter Program:

```
10 OUTPUT 705 USING "#,K";"VSET 8",END
20 LOCAL 7
30 ABORT 7
40 WAIT 0.1
50 GOTO 10
60 END
```

Table 5-9. HP-IB, PSI, Front Panel Troubleshooting Blocks (continued)

PROCEDURE: (continued)

NODE	SETUP	MEASUREMENT	SOURCE
LSN LED		toggling	A8 U3
RMT LED		toggling	"
VOLTS display	with DISPLAY SETTINGS switch depressed	8.00	"

Enter Program:

```
10 OUTPUT 705; "UNMASK ERR; SRQ ON; X; CLR"
20 X=PPOLL(7)
30 GOTO 10
40 END
```

NODE	SETUP	MEASUREMENT	SOURCE
A8 U3/27		toggling	A8 U3
A8 U2/9		"	A8 U2
A8 U11/11		"	A8 U11

5-107 Power Section Troubleshooting

5-108 Table 5-10 describes the signals at each of the control board test points. The test connector provided in service kit P/N 06033-60005 allows easy connection to each test point. The measurements given here include bias and reference voltages as well as power supply status signals. It provides conditions for these measurements and gives the components which are the sources of the signals. Tables 5-11 and 5-12 describe possible symptoms in the power section. Both give lists of circuit blocks or components which can cause the symptoms shown. The appropriate board is also given.

5-109 If the supply exhibits a symptom given in Table 5-11 or 5-12, go to the block which pertains to that symptom. If the exact symptom seen is not in Table 5-11 or 5-12, start with the symptom that seems to be closest to the one observed. The blocks are given in the Power Section Blocks section starting in Paragraph 5-117. Troubleshooting information for each block will include a brief description of the circuit. The columns provided are as follows:

NODE: This column lists the nodes where the measurements should be taken. In some cases this will be stated as NODE(+) and NODE(−) where the first is the test node and the second is the reference.

SETUP: If a certain setup is required for the measurement, it will be given in this column.

MEASUREMENT: This column indicates what the expected measurement is for the given node.

SOURCE: If applicable, the components which generate the signal will be provided in this column.

5-110 To troubleshoot the power supply the A4 power mesh board and A2 control board can be raised out of the unit using extender boards and cables provided in service kit P/N 06033-60005.

5-111 Main Troubleshooting Setup

5-112 Figure 5-15 shows the troubleshooting setup for trouble shooting all of the unit except the front panel and initial no-output failures (see Paragraph 5-116). The external power supply provides the unit's internal bus voltage. The ac mains cord connects directly to the unit's A1T3 bias transformer thereby energizing the bias supplies, but it does not connect to the input rectifier and filter because that would create the bus voltage. With the external supply the unit operates as a dc-to-dc converter. The supply biases the A4Q3 and A4Q4 PFETs with a low voltage rather than the 320 Vdc bus voltage. This protects the PFETs from failure from excess power dissipation if the power-limit comparator or the off-pulse circuitry are defective. It also reduces the possibility of electrical shock to the troubleshooter.

WARNING

An isolation transformer provides ac voltage that is not referenced to earth ground, thereby reducing the possibility of accidently touching two points having high ac potential between them. Failure to use an isolation transformer as shown in Figure 5-15 will cause the ac mains voltage to be connected directly to many components and circuits within the power supply, including the FET heatsinks, as well as to the terminals of the external dc power supply. Failure to use an isolation transformer is a definite personal-injury hazard.

The troubleshooting setup of Figure 5-15 connects high ac voltage to relay K1, fan B1, fuseholder A1F1, and other components and circuits along the front of the A1 main board.

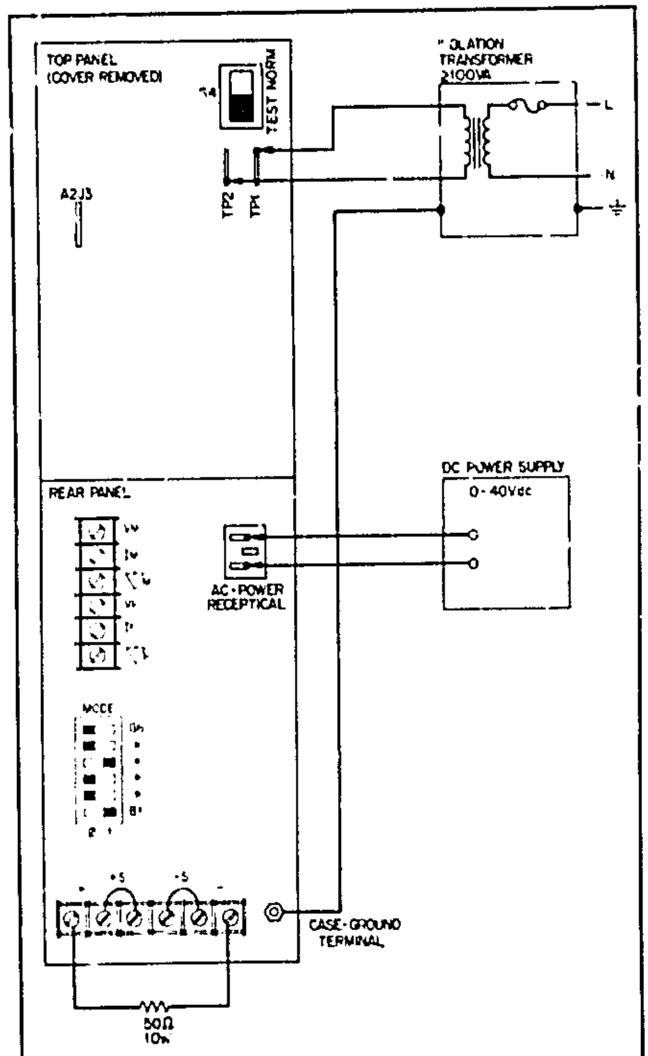


Figure 5-15. Main Troubleshooting Setup

5-113 As a convenience in implementing the troubleshooting setup, modify a spare mains cord set as shown in Figure 5-16. This facilitates connecting the unit's power receptacle to the external supply and connecting the bias transformer to the ac mains.

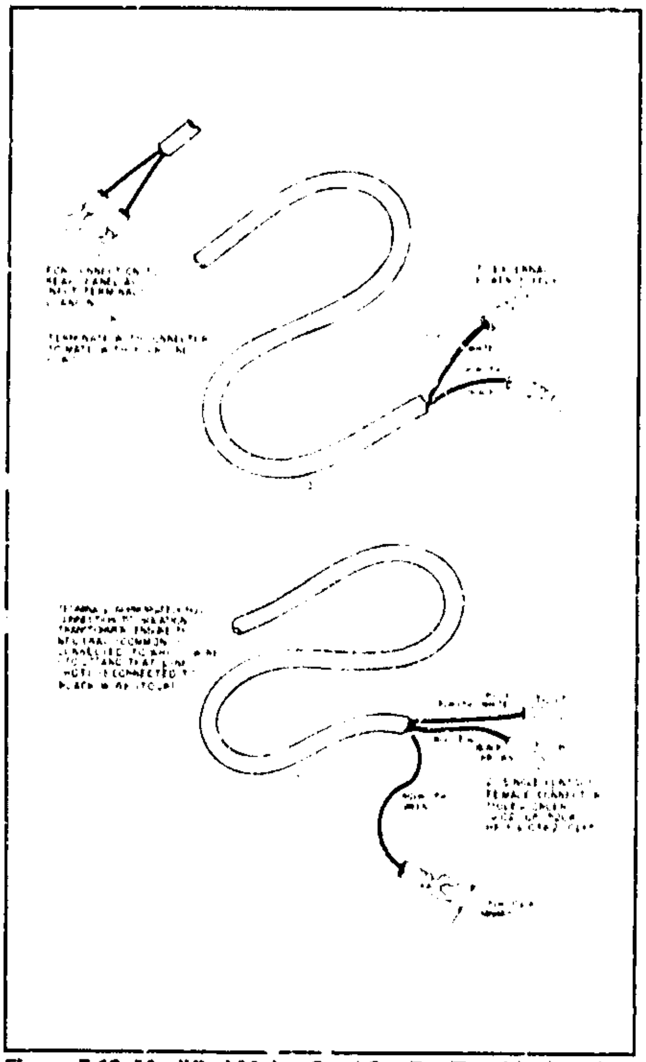


Figure 5-16. Modified Mains Cord Set For Troubleshooting

5-114 With the mains cord unplugged proceed as follows:

a. Remove the top cover and the inside cover per Paragraphs 5-62 and 5-64. Set switch S4 (front-left corner of the A1 main board) in the TEST position.

WARNING

Failure to set switch S4 in the TEST position will result in damage to the power supply, damage to the external power supply, and is an electrical shock hazard to you.

b. Install control board test connector onto the A2J3 card-edge fingers.
c. Connect a 50 Ω, 10 W, load resistor to the unit's output terminals.
d. With the LINE switch off connect an external dc power supply to the outside prongs of the unit's power receptacle. Ignore polarity as the unit's input rectifying diodes steer the dc power to the correct nodes.
e. Complete the setup of Figure 5-16 by attaching an ac mains cord to test points TP1 (L, black wire) and TP2 (N, white wire) and connect the green ground wire to the unit's case ground terminal or a suitably grounded cabinet screw. TP1 and TP2 are accessible through the cutout on the left side of the unit and are at the left edge of the A1 main board.

5-115 Troubleshooting No-Output Failures

5-116 No-output failures often include failure of the A4Q3 and A4Q4 PFETs and their fuses, A4F1 and A4F2. When either the off-pulses or the power-limit comparator fails, the PFETs can fail from excessive power dissipation. The strategy for localizing no-output failures is to check the voltages and waveforms at the control board test connector to predict if that circuit failure would cause the the PFETs to fail. This makes it possible to develop your troubleshooting approach without an extensive equipment setup. Proceed as follows:

a. With the mains cord unplugged remove the A4 power mesh board per Paragraph 5-71. Plug in the mains cord and switch on power.
b. Using Table 5-10 check the bias voltages, the PWM-OFF, PWM-ON and Ip MONITOR Control signal and other signals of interest at the A2 control board test fingers, A2J3.
c. Check for the presence of program voltages, VP and IP, at the rear panel.
d. Check for presence of the 320 Vdc rail voltage between the cathodes of diodes A1CR1 and A1CR2 and the anode of diodes A1CR3 and A1CR4. If there is no rail voltage, check diodes A1CR1 through A1CR4.

WARNING

Diodes A1CR1 through A1CR4 connect to the ac mains voltage. Use a voltmeter with both input terminals floating to measure the rail voltage.

e. Select the functional circuit for troubleshooting based on your measurements and Table 5-12, which provides direction based on the status of the PWM OFF and PWM ON signals.

5-117 Power Section Blocks

5-118 This section contains the blocks referenced in Tables 5-11 and 5-12.

5-119 Troubleshooting AC-Turn-On Circuits

5-120 Relay A1K1 closes at 1.0 seconds and DROPOUT goes high at 1.1 seconds after 20 V (5 V UNREG) reaches about 11 Vdc. DROPOUT high enables the PWM if OVERVOLTAGE, INHIBIT, and OVERTEMP are also high.

5-121 **Circuits Included.** AC-Surge-&-Dropout Detector, Bias Voltage Detector, U11A, 1-Second Delay and Relay Driver-all on A2 Control board.

Table 5-10. Control Board Test Connector, A2J3

PIN NO.	SIGNAL NAME	Vdc	WAVEFORM/CONDITIONS	SOURCE
Digital-Circuits Bias & Reference Voltages				
1	+5 V	5.0		A2Q3 (emitter)
22	+20 V(5 V UNREG)	20.0	with 120 Hz & 45 kHz ripple	A1CR6, A1CR7
14	2.5 V ref	2.50		A2U9 (OUT)
6	0.5V ref	0.50		A2R79, A2R80
Analog-Circuits Bias Voltages				
2	+15 V	15.0		A2U12 (OUT)
21	−15 V	−15.0		A2U4 (OUT)
Status Signals				
17	CV	TTL lo	if in CV operation	A2Q6C-7 (collector)
16	CC	TTL lo	if in CC operation	A2Q6F-14(collector)
13	OV	TTL hi	if not OVP shutdown	A2U11D-11
11	DROPOUT	TTL hi	if ac mains okay	A2U17D-11
12	OT	TTL hi	if not overtemp shutdown	A2U11B-6
Control Signals				
25	PWM OFF		1.7 µs TTL pulses, 20kHz	U1A-5
26	PWM ON		1.7 µs TTL pulses, 20 kHz	U2B-6
18	Ip MONITOR		1 V pk, * ½ sawtooth, 20 kHz	A2CR26 (cathode)
8	INHIBIT	TTL hi	if not remotely inhibited	A2R185C,U19A-2
15	DOWN PROGRAM	1.2-3.0	while not down programming	A2CR21, A2CR27
7	OVP PROGRAM	1/30 OVP	e.g.: 2 Vdc if OVP set to 60	A3R6 (wiper)
5	OV CLR	+5V	inverted OV reset line	A7U29-5
19	FCLR 2	+5V	*at full power only	A2Q60-9
Commons & Current-Monitor				
4	L COMMON	0.0	common return for all bias voltages and status and control signals	A2C20(−), A2R50, A2U6-4
9	M COMMON	0.0	common return for 2.5V ref and 0.5V ref	A2R83, A2*-20
10	I-TEST	≈0.055(Iout)	inboard-side monitoring res.	A1R27 & A1R28, A1T2
3	V-MONT	V-OUT/12	trimmed V-MON for readback	A7U30-6

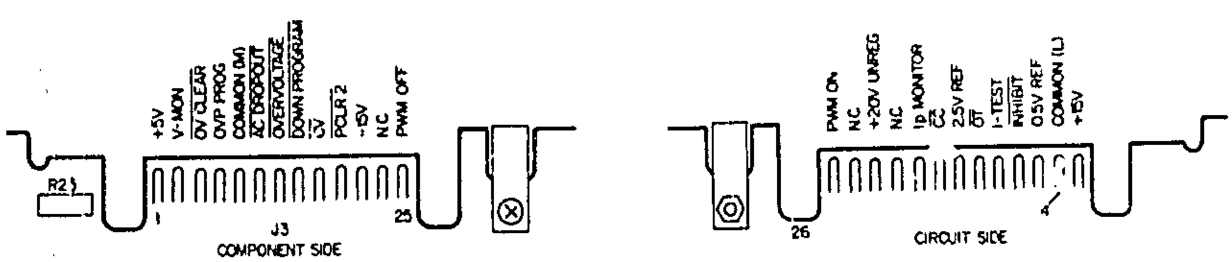


Table 5-11. Performance Failure Symptons

SYMPTOMS	DEFECTIVE BOARD	CHECK FUNCTIONAL CIRCUITS
unexplained OVP shutdowns	A2	OVP Circuit, CV Circuit
no current limit	A2	CC Circuit
max current < 10 Adc	A2	CC Clamp, CC Circuit
max power < specified	A2, A1	Power Limit, 20 kHz clock, transformer A1T1
max voltage < 60 Vdc	A2, A1	CV Circuit, diodes A1CR1-CR4
cycles on & off randomly	A2, A1	AC-Surge-&-Dropout Detector, Mains Voltage Select switch A1S2
CV overshoots	A2	A2U10A, A2CR20, A2R94
output noise (<1 kHz)	A2, A1	CV Circuit, Input Filter
output noise (>1 kHz)	A1, A4	transformer A1T1, Output Filter, snubbers A4R7/R8/C5/CR5, A4R13/R14/C6/CR6, A4R33/C13
CV regulation, transient response, programming time	A2, A1	wrong sensing (paragraph 3-40), low ac mains voltage, CV Circuit
CC regulation	A2	low ac mains voltage, CC circuit
CV oscillates with capacitive loads	A2	A2U10, A2C51, A2R95, A2R96, A2R86, A2C47, A2R71, A2C36
CC oscillates with inductive loads	A2	A2U10, A2R86, A2C47, A2C43, A2R77, A2U3D, A2R30, A2C44, A2R76, A2R75, A2C42, A2C41, A2R16

Table 5-12. No-Output Failures
(Bias supplies and AC turn-on circuit functioning)

Status of PFET On/Off-Pulses			
PWM-ON A2J3-26	PWM-OFF A2J3-25	DEFECTIVE BOARD	CHECK FUNCTIONAL CIRCUITS
lo	lo	A2	Control ckts: CV & CC thru On- & Off-Pulse Oneshots *
lo	hi	A2&A4	PWM and DC-to-DC Converter: A4Q3 and A4Q4 probably failed
hi	lo	A2&A4	PWM and DC-to-DC Converter: A4Q3 and A4Q4 probably failed
hi	hi	A2&A4	PWM and DC-to-DC Converter: A4Q3 and A4Q4 probably failed
lo	N	A2	A2U17B,On-Pulse Oneshot and A2Q6A
N	lo	A2&A4	Off-Pulse Oneshot and DC-to-DC: A4Q3 and A4Q4 probably failed
hi	N	A2&A4	A2U17B, On-Pulse Oneshot & DC-to-DC: A4Q3 and A4Q4 probably failed
N	hi	A2&A4	Off-Pulse Oneshot and DC-to-DC: A4Q3 and A4Q4 probably failed
N	N	A2&A4	Power-Limit Comparator and DC-to-DC: A4Q3 and A4Q4 probably failed

lo = TTL low hi = TTL high N = normal 20 kHz pulse train, TTL levels

* Decide which to troubleshoot—the CV Circuit, the CC Circuit, or the PWM and Off-Pulse & On-Pulse Oneshots—by measuring the CV CONTROL (A2CR24, cathode) and the CC CONTROL (A2CR19 cathode) voltages. Troubleshoot whichever is negative, and if neither is negative, troubleshoot the PWM. Make these voltage measurements after you have implemented the Main Troubleshooting Setup.

5-122 **Setup.** The Main Troubleshooting Setup, Paragraph 5-111. Apply the ac mains voltage to the isolation transformer, and set the external supply to 0 Vdc.

5-123 **Inputs:**

NODE	SETUP	MEASUREMENT	SOURCE
A2J3-1	wait 2 s	5.0 Vdc	A2Q3 (emit.)
A2J3-22	20 Vdc	A1CR6,A1CR7	
A2U20-8,13		f.w.rect.,1-2 V pk	A1CR8,A1CR9
A2U22-13		TTL sq wave,20 kHz	A2U22-6

5-124 **Outputs:**

NODE	SETUP	MEASUREMENT
A2U20-5	cycle power	≈ 13.5 Vdc
A2U20-2	cycle power	≈ 1.4 Vdc
A2Q6-1	cycle power	transition 0 to 5.0 to 0.3 Vdc
A2Q6-8	cycle power	transition 0 to 0.3 to 5.0 Vdc
A2U20-6	wait 2 s	<0.25 Vdc
A2U20-1,14	wait 2 s	hi (5 Vdc)
A2U11-3	cycle power	transition lo to hi to lo
A2U18-10	cycle power	burst 1.25 kHz sq. wave, 1.1 s
A2U18-13	cycle power	five 100 ms pulses then hi
A2U18-12	cycle power	two 200 ms pulses then hi
A2U18-15	cycle power	transition lo to hi at 800 ms
A2U17-8	cycle power	transition lo to hi at 1.0 s
A2U17-11 (DROPOUT)	cycle power	transition lo to hi at 1.1 s
A2Q5 (base) (RELAY ENABLE)	cycle power	transition 5.0 to 0.3 Vdc at 1.0 s

5-125 Troubleshooting DC-To-DC Converter

5-126 Parallel NOR gates A4U2A, A4U2B and A4U1A act as drivers and switch on PFETs A4Q3 and A4Q4 through pulse transformer A4T1. NOR gate A4U1B turns off the PFETs through pulse transformer A4T2 and transistors A4Q1 and A4Q2.

5-127 **Circuits Included.** On-Pulse Driver, Off-Pulse Driver, PFET Switches and Drivers on A4 power mesh board.

5-128 **Setup.** The Main Troubleshooting Setup, Paragraph 5-111. Apply the ac mains voltage to the isolation transformer, set the external supply to 40 Vdc, and switch on the LINE switch. Set the unit's output voltage to 60 Vdc and current to above 1 Adc. Verify that the OVERRANGE LED lights. See Figure 5-17 for waveforms

5-129 **Inputs:**

NODE (+)	NODE (−)	MEASUREMENT	SOURCE
A2J3-26 (PWM-ON)	⏚M	waveform #1	A2U17-6,A2P1-7, A4P1-24,C
A2J3-25 (PWM-OFF)	⏚M	waveform #2	A2U15-5,A2P1-13 A4P1-26,A
A4Q3-D	A4Q4-S	39 Vdc	A1C4(+),A4P1-10,A,C A1C4(-),A4P1-4,A,C

5-130 **Outputs:**

NODE (+)	NODE (−)	MEASUREMENT
A4Q3-G	A4Q3-S	waveform #3
A4Q4-G	A4Q4-S	waveform #3
A4Q3-D	A4Q3-S	waveform #4
A4Q4-D	A4Q4-S	waveform #4
A2J3-18	A2J3-4	waveform #5

NOTE

The Gate (G) and Source (S) leads of PFETs A4Q3 and A4Q4 can be accessed from the circuit side of the board and used as test points. The Drain (D) of A4Q3 can be picked up at its case or from the cathode of A4CR13. The Drain of A4Q4 can be picked up at its case or from the anode of A4CR14.

5-131 If all the INPUT measurements are correct but the OUTPUT Vgs waveform (3) is incorrect, the problem may be caused by weak PFETs. Two 6800pF capacitors (HP PN 0160-0159) can be substituted for the PFETs (G to S) to check waveform 3. If the waveform is still incorrect, the problem may be located in the drive components. If you replace the PFETs, replace both the PFETs and associated drive components as furnished in PFET Service Kit, HP Part No. 5060-2860.

CAUTION

The PFETs are static sensitive and can be destroyed by relatively low levels of electrostatic voltage. Handle the A4 power mesh board and the PFETs only after you, your work surface and your equipment are properly grounded with appropriate resistive grounding straps. Avoid touching the PFET's gate and source pins.

5-132 Troubleshooting Bias Supplies

5-133 **+5 V On A2 Control Board.** The PWM A2U6 includes a clock generator (45 kHz set by A2R53 and A2C26) and a current limit (2 Adc set by 0.15 Vdc across A2R50). It turns off each output pulse using the difference between the voltage at voltage divider A2R46-A2R47 and the 2.5 Vdc set by voltage regulator A2U5.

5-134 **Circuit Included.** +5 Vdc bias supply circuitry from connector pin A2P1-15 through jumper A2W3 on A2 control board.

5-135 **Setup.** The Main Troubleshooting Setup, paragraph 5-111. Apply the ac mains voltage to the isolation transformer, and set the external supply to 0 Vdc.

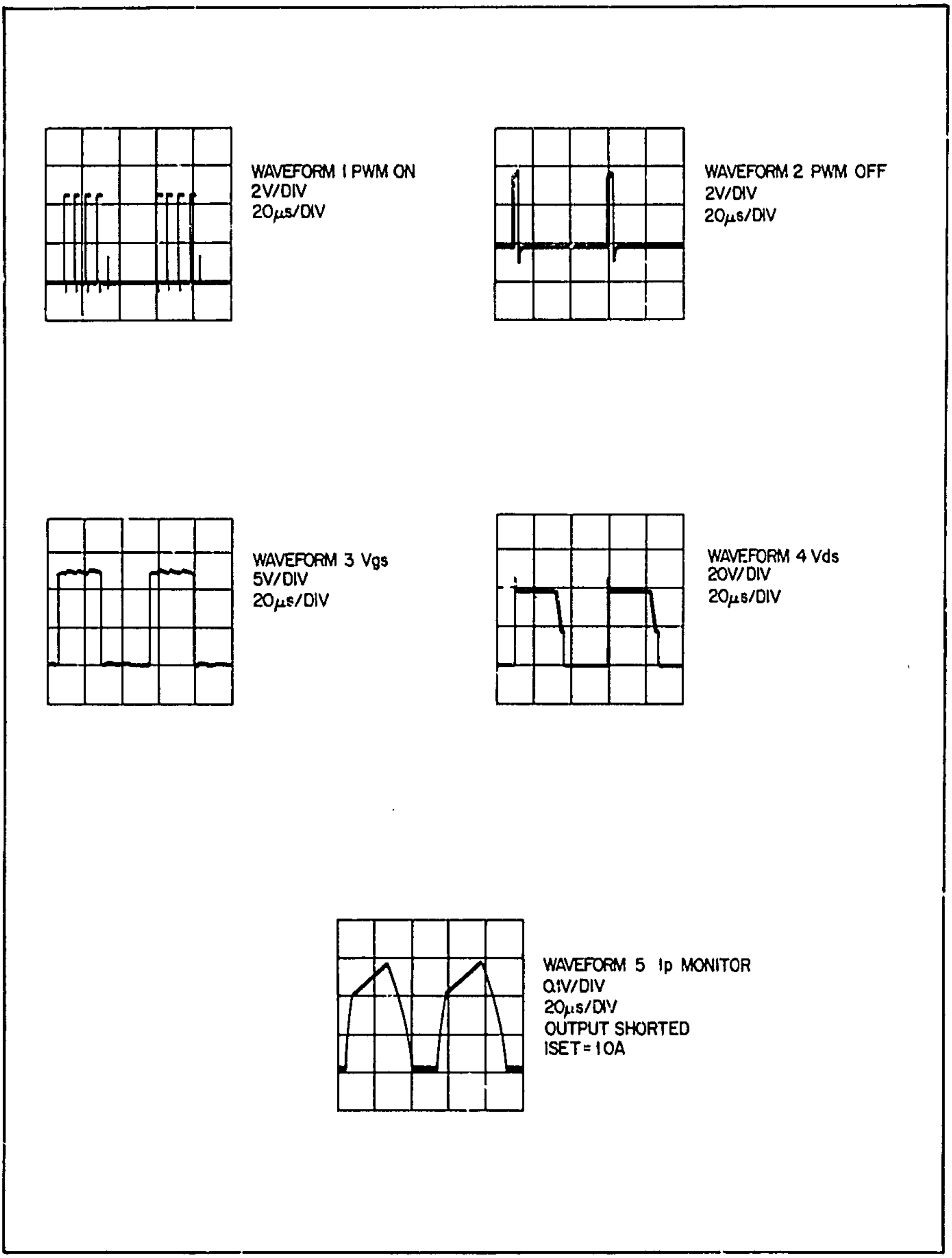


Figure 5-17. Waveforms

5-136 **Input:**

NODE	MEASUREMENT	SOURCE
A2J3-22	≈20 Vdc	A1CR6,A1CR7

5-137 **Outputs:**

NODE	MEASUREMENT
A2U6-6	≈2 to 4 Vdc sawtooth, 45 kHz
A2U6-12,13	≈19 Vpk, 15 μs pulses, 45 kHz
A2Q3 (emit.)	20 Vpk, 5 μs pulses, 45 kHz
A2U5 (OUT)	2.5 Vdc
A2R50, A2CR11 (anode)	≈0 >V >.0.007 Vdc
A2R46, A2R47	2.5 Vdc

5-138 To check if load on +5 V is shorted, remove jumper A2W3.

5-139 **+15 V On A2 Control Board.** Voltage regulator A2U12 regulates the voltage across resistor A2R29 to be 1.25 Vdc. That sets the current through zener diode A2VR1 at 7.5 mAdc. The output voltage is 1.25 Vdc plus 11.7 Vdc across A2VR1 plus the voltage across A2R34.

5-140 **Circuit Included.** +15 Vdc bias supply circuitry from connector pin A2P1-27 through test point A2J3-2 on A2 control board.

5-141 **Setup.** The Main Troubleshooting Setup, paragraph 5-111. Apply the ac mains voltage to the isolation transformer, and set the external supply to 0 Vdc.

5-142 **Input:**

NODE	MEASUREMENT	SOURCE
A2U12(IN), A2C17(+)	≈24 Vdc	A1U1, A1C1 (+)

5-143 **Outputs:**

NODE (+)	NODE (-)	MEASUREMENT
A2U12(OUT)	A2U12(ADJ)	1.25 Vdc
A2U12(cath.)	A2U12(anode)	11.7 Vdc
A2VR1(anode)	A2R34,A2R33	2.05 Vdc
A2VR3(cath.)	A2VR3(anode)	6.2 Vdc

5-144 To check if load on +15 V is shorted, remove jumper A2W1.

5-145 **−15 V On A2 Control Board.** Voltage regulator A2U4 regulates the voltage across resistor A2R32 to be 1.25 Vdc.

5-146 **Circuit Included.** −15 Vdc bias supply circuitry from connector pin A2P1-30 through test point A2J3-21 on A2 control board.

5-147 **Setup.** The Main Troubleshooting Setup, paragraph 5-111. Apply the ac mains voltage to the bias transformer, and set the external supply to 0 Vdc.

5-148 **Input:**

NODE	MEASUREMENT	SOURCE
A2U4(IN), A2C16(-)	≈ −24 Vdc	A1U1, A1C1(+)

5-149 **Outputs:**

NODE (+)	NODE (−)	MEASUREMENT
A2U4(ADJ)	A2U4(OUT)	1.25 Vdc
A2VR2(cath.)	A2VR2(anode)	11.7 Vdc
A2R33,A2R34	A2VR2(cath.)	2.05 Vdc

5-150 To check if load on −15 V is shorted, remove jumper A2W3.

5-151 Refer to Down Programmer, paragraph 5-152, for the +8.9 V bias supply, and refer to OVP Circuit, paragraph 5-170, for the +2.5 V bias supply.

5-152 Troubleshooting Down Programmer

5-153 The down programmer loads the output when either MASTER ENABLE is low or CV ERROR is more negative than about -6 Vdc. Comparator A4U3B triggers down programming when the voltage at A4U3B-5 is less than about 3 Vdc. The collector-emitter current through transistor A4Q6 increases as the output voltage decreases because of feedback from voltage divider A4R24-A4R27 at A4U3A-2.

5-154 **Circuit Included.** Down programmer and +8.9V bias supply on A4 power mesh board.

5-155 **Setup.** The Main Troubleshooting Setup, paragraph 5-111, except connect the external supply to the unit's +OUT (+) and −OUT (−) terminals. Apply the ac mains voltage to the isolation transformer. Set the external supply (EXTERNAL) and adjust the unit's voltage setting (INTERNAL) as instructed below.

5-156 **Outputs:**

NODE	Set Voltage (Vdc) External	Internal	Setup	Measurement
A4U4(OUT)	–	–		8.9 Vdc
A4U3B-7	0	2	unplug TS1	0 Vdc
A4U3B-7	10	0	reconnect TS1	0 Vdc
A4U3B-7	0	2		7.8 Vdc
A4U3A-2	0	2	unplug TS1	0.43 Vdc
A4R26	5	2		≈0.41 Vdc
A4Q6 (base)	20	2		1.0 Vdc
A4U3A-1	20	2		4.0 Vdc
A4R26	20	2		≈0.34 Vdc

5-157 Troubleshooting CV Circuit

5-158 V-MON, the output of CV Monitor Amp A2U7, is the voltage between +S and −S. CV Error Amp A2U8 compares V-MON to CV PROGRAM. Innerloop Amp A2U10A stabilizes the CV loop with IVS input from A2U10C. The measurements below verify that the operational amplifier circuits provide expected positive and negative dc voltage excursion when the CV loop is open and the power mesh shut down.

5-159 **Circuits Included.** Constant Voltage (CV) Circuit and buffer amplifier A2U10C.

5-160 **Setup.** The Main Troubleshooting Setup, paragraph 5-111. Apply the ac mains voltage to the isolation transformer, and disconnect the external supply. Remove the +S jumper and connect A2J3-2 (+15 V) to +S. Set MODE switch settings B4, B5 and B6 all to 0. Set VP to 0 Vdc by connecting to ⏚P or set VP to +5 Vdc by connecting to A2J3-1 according to SETUP below.

5-161 **Outputs:**

NODE	SETUP	MEASUREMENT
VM		3.75 Vdc
A2U10C-8		4.7 Vdc
A2U8-6	VP=0	−14 Vdc
A2U10A-1	VP=0	−14 Vdc
A2U8-6	VP=5	4.7 Vdc
A2U10A-1	VP=5	5.1 Vdc

5-162 If the failure symptoms include output voltage oscillation, check if the CV Error Amp circuit is at fault by shorting A2U8-6 to A2U8-2. If oscillations stop, the CV Error Amp circuit is probably at fault.

5-163 Troubleshooting CC Circuit

5-164 I-MON, output of CC Monitor Amp A2U1, in volts is 1/6 the output current in amperes. CC Error Amp A2U2B compares I-MON to CC PROGRAM. Differentiator circuit, A2U3D and A2U3C, differentiates the inboard voltage sense to stablize the CC loop. Its output is summed with IMON at CC Error Amp A2U2B.

5-165 The measurements below verify that the operational amplifier circuits provide expected positive and negative dc voltage gain when the CC loop is open and the power mesh shut down.

5-166 **Circuits Included.** Constant Current (CC) Circuit on A2 control board.

5-167 **Setup.** The Main Troubleshooting Setup, Paragraph 5-111, except connect the external supply with polarity reversed to the unit's +OUT (−) and −OUT (+) terminals. Apply the ac mains voltage to the isolation transformer. Set mode switches B1, B2, and B3 all to 0. Set the external supply to 3.0 Adc constant current with a voltage limit in the range 5 to 20 Vdc. Set IP to 0 Vdc by connecting to ⏚P or set IP to +5 Vdc by connecting to A2J3-1 according to the following SETUP.

5-168 **Outputs:**

NODE	SETUP	MEASUREMENT
IM	0.50 Vdc	
A2U2B-7	IP=0	−14 Vdc
A2U2B-7	IP=5	6.0 Vdc
A2U3D-13	+0.015 Vdc	
A2U3C-8	+0.015 Vdc	
A2U3C-8	+0.25 Vdc	

5-169 If the failure symptoms include output current oscillation, check if the differentiator circuit is at fault by removing resistor A2R16 (3.3 MΩ). If oscillations stop, the differentiator is probably at fault.

5-170 Troubleshooting OVP Circuit

5-171 Comparator A2U14D sets, and gate A2U17A resets, flipflop A2U14B-A2U14C. TTL low at A2U14-1,8,13 inhibits the PWM.

5-172 **Circuit Included.** OVP Circuit and 2.5V bias supply on A2 control board.

5-173 **Setup.** The Main Troubleshooting Setup, Paragraph 5-111, except connect the external supply to the unit's +OUT (+) and −OUT (−) terminals. Apply the ac mains voltage to the isolation transformer. Adjust the unit's OVP limit to 15 Vdc. Set the external supply (EXTERNAL) as instructed below.

5-174 **Outputs:**

NODE	SET VOLTAGE External (Vdc)	Setup	Measurement
A2U9(OUT)	–		2.5 Vdc
A2U14-10	10		1.0 Vdc
A2U14-11	–		1.5 Vdc
A2J3-13	10		hi
A2J3-13	20		lo
A2J3-13	10		lo
A2J3-13	10	cycle power	hi

NOTE

Connecting a test probe to either input of either comparator in the OV Flipflop (pins A2U14-1,6,7,8,9,14 or A2U11-13) may cause the flipflop to change states and cause the probed input to be low.

5-175 Troubleshooting PWM & Clock

5-176 The inputs to Inhibit Gate A2U19A and PWM gate A2U19B are the keys to PWM troubleshooting. The 20 kHz Clock starts each PWM output pulse, and the pulse stops when any of the inputs to A2U19A or A2U19B goes low. The PWM is inhibited and prevented from initiating output pulses as long as any of the eight inputs are low.

5-177 Circuits included. Pulse Width Modulator (PWM), Inhibit Gate A2U19A, Off-Pulse Oneshot, On-Pulse Oneshot, A2U17B, 20 kHz Clock.

5-178 **Setup.** The Main Troubleshooting Setup, Paragraph 5-111. Apply the ac mains voltage to the bias transformer and switch on the LINE switch. Adjust the unit's current setting above 1.0 Adc. Set the external supply (EXTERNAL) and adjust the unit's voltage setting (INTERNAL) as instructed below. Use the DISPLAY SETTINGS switch to adjust the unit's current or voltage setting.

5-179 **Inputs:**

NODE	SETUP	MEASUREMENT	SOURCE
A2J3-1		5.0 Vdc	A2Q3(emitter)
A2U19-1		hi	A2U17D-11
A2U19-2		hi	remote inhibit
A2U19-4		hi	A2U14-1,8
A2U19-5		hi	A2U11B-6
A2U19-10		hi	A2U16-7
A2U19-12	POWER LIMIT fully CCW	lo	A2U14-2
A2U19-12	POWER LIMIT fully CW	hi	A2U14-2

5-180 **Outputs:**

NODE	SET VOLTAGE (Vdc) EXT.	INT.	SETUP	MEASUREMENT
A2U21-7	0	0		TTL sq wave, 320 kHz
A2U22-3	0	0		TTL sq wave, 160 kHz
A2U22-6	0	0		TTL sq wave, 20 kHz
A2U13-5	0	0		23.5 μs TTL pulses, 20 kHz
A2U13-8	0	0		23.5 μs TTL pulses, 20 kHz
A2U14-2	40	0	POWER LIMIT fully CCW	lo
A2U19-8	40	0		lo
A2U13-9	40	0		lo
A2U17-6	40	0		lo
A2U15-13	40	0		lo
A2U15-5	40	0		lo
A2U17-6	40	0	POWER LIMIT fully CW	groups of 4 pulses, 1.7 μs, TTL, 20 kHz
A2U15-5	40	0		1.7 μs TTL pulses, 20 kHz
+OUT	40	15		≈ 12.2 Vdc (OVERRANGE)
+OUT	40	2		2.0 Vdc (CV)
+OUT	40	2	short A2J3-4 to A2J3-6	0.0 Vdc

SETUP: X—Don't care. Tests requiring this setup can be performed in any mode.

SETUP: A1

µP in free-run mode—Used for testing µP address bus.

A8W4: between J5 and J6

A8W5: don't care

A8S1 A5: don't care
A4: "
A3: "
A2: "
A1: "

A8S2 A: closed
B: open
C: closed
D: open
E: open

Signature Analyzer:

	NODE	EDGE
START	SA1 (A8J7/3)	_/‾
STOP	SA2 (A8J7/4)	_/‾
CLOCK	SA5 (A8J7/7)	_/‾

+5 V signature is 0003

SETUP: A2

µP in free-run mode—Used for testing A8 U8 while it is driving the data bus.

A8W4: between J5 and J6

A8W5: don't care

A8S1 A5: don't care
A4: "
A3: "
A2: "
A1: "

A8S2 A: closed
B: open
C: closed
D: open
E: open

Signature Analyzer:

	NODE	EDGE
START	SA8 (A8J7/10)	‾_
STOP	A8 U12/15	‾_
CLOCK	SA6 (A8J7/8)	‾_

+5 V signature is 1180

SETUP: A3

µP in free-run mode—Used for testing data bus when A8 U15 (input port for S1 and W5) is doing the driving.

A8W4: Between J5 and J6

A8W5: don't care

A8S1 A5: don't care
A4: "
A3: "
A2: "
A1: "

A8S2 A: closed
B: open
C: closed
D: open
E: open

Signature Analyzer:

	NODE	EDGE
START	SA1 (A8J7/3)	‾_
STOP	SA2 (A8J7/4)	‾_
CLOCK	A8 U12/12	_/‾

+5 V signature is 1180

SETUP: B1

SA mode—general testing.

A8W4: J6

A8W5: Diagnostic (A8J7/15 shorted to A8J7/16)

run 12 (SA mode) is displayed on front panel

Short A8J7/11 to A7TP2

A8S1 A5: 0
A4: 1
A3: 1
A2: 0
A1: 0

A8S2 A: closed
B: open
C: closed
D: open
E: open

Signature Analyzer:

	NODE	EDGE
START	SA3 (A8J7/5)	_/‾
STOP	SA4 (A8J7/6)	‾_
CLOCK	SA6 (A8J7/8)	_/‾

+5 V signature is U16H

SETUP: B2

SA mode—Used for testing serializer clock generator.

A8 W4: J6

A8W5: diagnostic (A8J7/15 shorted to A8J7/16)

Short A8J7/11 to A7TP2

A8S1 A5: 0
A4: 1
A3: 1
A2: 0
A1: 0

A8S2 A: closed
B: open
C: open
D: closed
E: open

Signature Analyzer:

	NODE	EDGE
START	SA3 (A8J7/5)	_/‾
STOP	SA4 (A8J7/6)	‾_
CLOCK	SA6 (A8J7/8)	_/‾

+5 V signature is U16H

SETUP: B3

SA mode—Used for testing data read from the A7 (PSI) board.

A8W4: J6

A8W5: Diagnostic (A8J7/15 shorted to A8J7/16)

Short A8J7/11 to A7TP2

A8S1 A5: 0
A4: 1
A3: 1
A2: 0
A1: 0

A8S2 A: closed
B: open
C: closed
D: open
E: open

Signature Analyzer:

	NODE	EDGE
START	SA3 (A8J7/5)	_/‾
STOP	SA4 (A8J7/6)	‾_
CLOCK	SA6 (A8J7/8)	_/‾

+5 V signature is U16H

Additional requirements:

A2 R20 shorted
A2 R99 shorted
A7 C30 shorted
A7 TP4 jumpered to A7 TP5
A7 TP6 jumpered to A7 TP2

SETUP: B6

SA mode—Used for testing A8 U24 (DATA UP shift register) while it is driving the data bus.

A8W4: J6

A8W5: Diagnostic (A8J7/15 shorted to A8J7/16)

A8S1 A5: 0
A4: 1
A3: 1
A2: 0
A1: 0

A8S2 A: closed
B: open
C: closed
D: open
E: open

Signature Analyzer:

	NODE	EDGE
START	SA3 (A8J7/5)	_/‾
STOP	SA4 (A8J7/6)	‾_
CLOCK	A8 U13/11	_/‾

+5 V signature is P545

Additional Requirements:

A2 R20 shorted
A2 R99 shorted
A7 C30 shorted
A7 TP4 jumpered to A7 TP5
A7 TP6 jumpered to A7 TP2

SETUP: B7

SA mode—Used for testing A8 U3 (GPIB chip) while it is driving the data bus.

W4: J6

W5: Diagnostic (A8J7/15 shorted to A8J7/16)

S1 A5: 0
A4: 1
A3: 1
A2: 0
A1: 0

S2 A: closed
B: open
C: closed
D: open
E: open

Signature Analyzer:

	NODE	EDGE
START	SA3 (A8J7/5)	_/‾
STOP	SA4 (A8J7/6)	‾_
CLOCK	A8 U12/14	_/‾

+5 V signature is FP54

SETUP: B8

SA mode—Used for testing A8 U3 (GPIB chip)

A8W4: J6

A8W5: Diagnostic (A8J7/15 shorted to A8J7/16)

A8S1 A5: 0
A4: 1
A3: 1
A2: 0
A1: 0

A8S2 A: closed
B: open
C: closed
D: open
E: open

Signature Analyzer:

	NODE	EDGE
START	SA3 (A8J7/5)	_/‾
STOP	SA4 (A8J7/6)	‾_
CLOCK	SA5 (A8J7/7)	_/‾

+5 V signature is U16H

SETUP: C1

SA mode—Used for testing A8 U14 (data bus buffer).

A8W4: J6

A8W5: Diagnostic (A8J7/15 shorted to A8J7/16)

A8S1 A5: 0
A4: 1
A3: 1
A2: 0
A1: 1

A8S2 A: closed
B: open
C: closed
D: open
E: open

Signature Analyzer:

	NODE	EDGE
START	A8 U22/11	_/‾
STOP	A8 U22/11	‾_
CLOCK	A8 U13/9	_/‾

+5 V signature is CC34

SETUP: C2

SA mode

A8W4: J6

A8W5: Diagnostic (A8J7/15 shorted to A8J7/16)

A8S1 A5: 0
A4: 1
A3: 1
A2: 0
A1: 1

A8S2 A: closed
B: open
C: closed
D: open
E: open

Signature Analyzer:

	NODE	EDGE
START	A8 U22/11	_/‾
STOP	A8 U22/11	‾_
CLOCK	SA5 (A8J7/7)	_/‾

+5 V signature is 0262

SETUP: S

Unit will skip all self tests. Front panel meters will display unscaled readings of all monitor signals. 60 V or 10 A will correspond to a meter reading of 5.00. HP-IB address will be 5, even though address switch is set to 3.

A8W4: J6

A8W5: Diagnostic (A8J7/15 shorted to A8J7/16)

A8S1 A5: 0
A4: 0
A3: 0
A2: 1
A1: 1

A8S2 A: closed
B: open
C: closed
D: open
E: closed

NOTE:
In these setups, Ground for the HP-IB Board is A8J7 11, 13, 14 or 15.

Table 5-13. Test Setups

PARTS LIST

Section VI
REPLACEABLE PARTS

6-1 INTRODUCTION

6-2 This section contains information for ordering replacement parts. Table 6-4 lists parts in alpha-numeric order by reference designators and provides the following information:

a. Reference Designators. Refer to Table 6-1.
b. Hewlett-Packard Part Number.
c. Total Quantity (TQ) used in that assembly (given the first time the particular part number appears).
d. Description. Refer to Table 6-2 for abbreviations.
e. Manufacturer's Federal Supply Code Number. Refer to Table 6-3 for manufacturer's name and address.
f. Manufacturer's Part Number or Type.

6-3 Parts not identified by reference designator are listed at the end of Table 6-4 under Mechanical and/or Miscellaneous.

Table 6-1. Reference Designators

A	Assembly
B	Blower
C	Capacitor
CR	Diode
DS	Signaling Device (light)
F	Fuse
FL	Filter
G	Pulse Generator
J	Jack
K	Relay
L	Inductor
Q	Transistor
R	Resistor
RT	Thermistor Disc
S	Switch
T	Transformer
TB	Terminal Block
TS	Thermal Switch
U	Integrated Circuit
VR	Voltage Regulator (Zener diode)
W	Wire (Jumper)
X	Socket*
Y	Oscillator

*Reference designator following "X" (e.g. XA2) indicates assembly or device mounted in socket.

6-4 ORDERING INFORMATION

6-5 To order a replacement part, address order or inquiry to your local Hewlett-Packard sales office (see lists at rear of this manual for addresses). Specify the following information for each part: Model, complete serial number, and any Option or special modification (J) numbers of the instrument; Hewlett-Packard part number; circuit reference designator; and description. To order a part not listed in Table 6-4, give a complete description of the part, its function, and its location.

Table 6-2. Description Abbreviations

ADDR	Addressable
ASSY	Assembly
AWG	American Wire Gauge
BUFF	Buffer
CER	Ceramic
COMP	Carbon Film Composition
CONV	Converter
DECODER/DEMULTI	Decoder/Demultiplexer
ELECT	Electrolytic
EPROM	Eraseable Programmable Read-Only Memory
FET	Field Effect Transistor
FF	Flip-Flop
FXD	Fixed
IC	Integrated Circuit
INP	Input
LED	Light Emmiting Diode
MET	Metalized
MOS	Metal-Oxide Silicon
OP AMP	Operational Amplifier
OPTO	Optical
OVP	Over Voltage Protection
PCB	Printed Circuit Board
PORC	Porcelain
POS	Positive
PRIOR	Priority
ROM	Read-Only Memory
RAM	Random Access Memory
RECT	Rectifier
REGIS	Register
RES	Resistor
TBAX	Tube Axial
TRIG	Triggered
UNI	Universal
VAR	Variable
VLTG REG	Voltage Regulator
WW	Wire Wound

Table 6-3. Code List of Manufacturers

Code	Manufacturer	Address
00853	Sangamo Electric Company	Pickens, Sc
01121	Allen Bradley Company	Milwaukee, WI
01295	Texas Instruments Inc, Semicon Comp Div.	Dallas, TX
03508	G.E. Company, Semicon Prod Dept.	Auburn, N.Y.
04713	Motorola Semiconductor Products	Phoenix, AZ
07263	Fairchild Semiconductor Div.	Hicksville, N.Y.
14936	General Instruments Corp, Semicon Prod	Hicksville, N.Y.
16299	Corning Glass Works, Component Division	Raleigh, NC
19701	Mepco/Electra Corporation	Mineral Wells, TX
20940	Micro-Ohm Corporation	El Monte, CA
24546	Corning Glassworks	Bradford, PA
27014	National Semiconductor Corporation	Santa Clara, CA
27167	Corning Glassworks	Wilmington NC
28480	Hewlett-Packard	Palo Alto, CA
32997	Bourns Inc.	Riverside, CA
55576	Synertek	Santa Clara, CA
56289	Sprague Electric Company	North Adams, MA
71400	Bussman Division of McGraw Edison Co.	St. Louis, MO
75042	TRW Inc, Philadelphia Division	Philadelphia, PA
82877	Rotron Inc	Woodkstock, N.Y.
IB546	Varo Semiconductor Inc	Garland, TX
3L585	RCA Corporation, Solid State Div	Somerville, N.J.
H9027	Schurter AGH	Luzern, Switzerland
S0545	Nippon Electric Company	Tokyo, Japan

Table 6-4. Replaceable Parts List

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
	06038-60021	1	A1 Main Board Assembly	28480	
C1	0160-4962	2	fxd cer 1uf +10% 50Vac	28480	
C2,3	0180-3426	2	fxd elect 590uf +50-10% 400V	28480	
C4	0180-3427	1	fxd cer 300uf +50-10% 200V	28480	
C5	0160-4962		fxd cer 1uf +20% 250V	28480	
C6,7	0160-5933	4	fxd cer .022uf 10% 1500V	28480	
C8-10	0180-3548	3	fxd elect 1700uf 75V	28480	
C11,12	0160-6167	2	fxd cer 2.2uf 100V	28480	
C13,14	0160-5933		fxd cer .022uf 10% 1500V	28480	
C15,16	0160-4355	2	fxd met ppr .01uf +10% 250V	28480	
C17	0160-4834	1	fxd cer .047uf +20% 100V	28480	
C18,19			NOT USED		
C20,21	0180-3428	2	fxd elect 1000uf 50V	28480	
C22,23	0160-4439	2	fxd met ppr 4700pf +20% 250V	28480	
C24,25	0160-4281	2	fxd met 2200pf 20% 250V	28480	
C26	0160-4323	1	fxd met 0.047 20% 250V	28480	
CR1	1901-1087	2	pwr rect 600V 3A 200ns	04713	MR856
CR2	1901-0759	2	pwr rect 600V 3A	14936	1N5406
CR3	1901-1087		pwr rect 600V 3A 200ns	04713	MR856
CR4	1901-0759		pwr rect 600V 3A	14936	1N5406
CR5			NOT USED		
CR6,7	1901-0731	5	pwr rect 400V 1A	28480	
CR8,9	1901-0050	2	switching 80V 200mA	28480	
CR10-12			NOT USED		
CR13-15	1901-0731		pwr rect 400V 1A	28480	
F1			NOT USED		
F2	2110-0007	1	fuse 1A 250V	75915	313001
F3	2110-0343	1	fuse .25A 125V	28480	
J1	1251-5927	1	connector, post type 26-cont	28480	
J2	1251-5384	1	connector, post type 3-cont	28480	
J3	1251-8676	1	connector, post type 5-cont	28480	
K1	0490-1417	1	relay, DPST		
L1	06024-80094	1	choke, RFI, 3A (used with magnetic core 9170-0721)		
L2			NOT USED		
L3	9140-0987	1	choke, output, 3uH	28480	
Q1	1854-0067	1	NPN SI	28480	
Q2	1854-0799	1	NPN SI	01295	TIP41C
R1	0811-3667	1	fxd ww 20 5% 7W	28480	
R2	0811-1865	2	fxd ww 2K 1% 5W	28480	
R3			NOT USED		
R4	0683-1025	2	fxd comp 1K 5% 1/4W	01121	CB1025
R5	7175-0057	5	wire, tinned copper, AWG 22	28480	
R6	0683-1025		fxd comp 1K 5% 1/4W	01121	CB1025
R7	0699-1210		fxd film 80.K .1% .1W	28480	
R8	0699-0118		fxd film 20K .1% .1W	28480	
R9	7175-0057		wire, tinned copper, AWG 22		
R10	0698-6359		fxd film 80K .1% 1/8W	28480	
R11	0698-6322	1	fxd film 4K 0.1% 1/8W	28480	
R12	0698-8695	1	fxd film 36K 0.1% 1/8W	28480	
R13			NOT USED		
R14	0698-3572	1	fxd film 60.4 1% 1/8W	28480	

Table 6-4. Replaceable Parts List (cont.)

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
R15	0757-0270	1	fxd film 249K 1% 1/4W	24546	CT4-1/8-T0-2493-F
R16			NOT USED		
R17,18	0683-1005	2	fxd comp 10 5% 1/4W	01121	CB1005
R19	0683-1055	1	fxd comp 1M 5% 1/4W	01121	CB1055
R20,21	0811-1867	2	fxd ww 15K 5% 5W	28480	
R22,23	0686-1065	2	fxd comp 10M 5% 1/2W	01121	EB1055
R24,25	0686-1035	2	fxd comp 10K 5% 1/2W	01121	EB1035
R26	0683-3315	1	fxd comp 330 5% 1/4W	01121	CB3315
R27A,28B	0811-1865	2	fxd ww .2 1% 5W	28480	
R29	0686-3335	1	fxd comp 33K 5% 1/2W	01121	EB3335
R30	0811-1865	1	fxd ww 2K 1% 5W	28480	
R31	0812-0098	1	fxd ww 135 5% 5W	28480	
R32	0683-1035	1	fxd film 10K 5% 1/4W	01121	CB1035
R33	0683-4745	1	fxd film 470 5% 1/4W	01121	CB4745
R34	0683-2035	1	fxd film 20K 5% 1/4W	01121	CB2035
S1	3101-0402	1	switch, DPST rocker (mounted on front chassis)	28480	
S2	3101-1914	1	switch 2-DPDT, slide	28480	
S3			NOT USED		
S4	3101-2046	1	switch DPDT, slide	28480	
T1	06038-80090	1	Transformer, Power		
T2	9170-1264	1	core, magnetic (used with primary wire 06023-80004)	28480	
T3	5080-1982	1	transformer, bias	28480	
T4	5080-1984	1	choke, line 2mH	28480	
TP1,2	1251-5613	2	connector, single contact	28480	
U1	1906-0006	1	rectifier bridge 400V 1A	18546	VE48
VR1,2	1902-1377	1	zener 6.19V 2%	28480	
W1,2	06023-80003	2	jumper, output 10 AWG	28480	
XA2P1	1251-8665	1	connector, post type 30-cont	28480	
XA2P2	1251-8667	1	connector, post type 20-cont	28480	
XA4P1,2	1251-8806	2	connector, DIN type 32-cont	28480	
	06038-60023	1	A2 Control Board Assembly	28480	
C1	0160-5469	3	fxd film 1uf 10% 50V	28480	
C2	0160-5422	22	fxd cer 0.047uf 20% 50V	28480	
C3	0160-4812	2	fxd cer 220PF 5%	28480	
C4-6			NOT USED	28480	
C7	0160-5422	23	fxd cer 0.047uf 20% 50V	28480	
C8	0160-4812	6	fxd cer 220pf 5% 100V	28480	
C9	0160-5377	1	fxd cer 2.2uf 10% 63V	28480	
C10,11	0160-5469		fxd film 1uf 10% 50V	28480	
C12,13	0160-5422		fxd cer 0.047uf 20% 50V	28480	
C14	0180-0291	3	fxd elect 1uf 10% 35V	56289	150D105X9035A2
C15	0180-1731	1	fxd elect 4.7uf 10% 50V	56289	150D475X9050B2
C16,17	0180-0230	2	fxd elect 1uf 20% 50V	56289	150D105X0050A2
C18,19	0180-0291		fxd elect 1uf 10% 35V	56289	150D105X9035A2
C20	0180-2624	1	fxd elect 2000uf +75-25% 10V	28480	
C21	0160-5098	2	fxd cer 0.22uf 10% 50V	28480	
C22	0160-4832	2	fxd cer 0.01uf 10% 100V	28480	
C23	0180-3407	1	fxd elect 2200uf +50-10% 35V	28480	

Table 6-4. Replaceable Parts List (cont.)

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
C24	0160-5098		fxd cer 0.22uf 10% 50V	28480	
C25	0160-4833	1	fxd cer 0.022uf 10% 100V	28480	
C26	0160-0154	1	fxd poly 2200pf 10% 200V	28480	
C27,28	0160-5422		fxd cer 0.047uf 20% 50V	28480	
C29	0160-4812		fxd cer 220pf 5% 100V	28480	
C30	0160-4830	1	fxd 2200PF 10% 100V	28480	
C31,32	0160-4801	5	fxd cer 100pf 5% 100V	28480	
C33-35	0160-5422		fxd cer 0.047uf 20% 50V	28480	
C36	0160-4833	2	fxd cer 0.022uf 10% 100V	28480	
C37	0160-5422		fxd cer 0.047uf 20% 50V	28480	
C38	0160-4803	1	fxd cer 68pf 5% 100V	28480	
C39,40	0160-5422		fxd cer 0.047uf 20% 50V	28480	
C41	0160-4835	1	fxd cer 0.1uf 10% 50V	28480	
C42	0160-4805	2	fxd cer 47pf 5% 100V	28480	
C43	0160-5422		fxd cer 0.047uf 20% 50V	28480	
C44	0160-4805		fxd cer 47pf 5% 100V	28480	
C45	0160-4810	1	fxd cer 330pf 5% 100V	28480	
C46	0160-4807	1	fxd cer 33pf 5% 100V	28480	
C47	0160-4822	1	fxd cer 1000pf 5% 100V	28480	
C48	0160-5422		fxd cer 0.047uf 20% 50V	28480	
C49	0160-4833		fxd cer 0.022uf 10% 100V	28480	
C50	0160-0168	1	fxd poly 0.1uf 10% 200V	28480	
C51	0160-4801		fxd cer 100pf 5% 100V	28480	
C52,53	0160-4831		fxd cer 4700pf 10% 100V	28480	
C54	0160-5422		fxd cer 0.047uf 20% 50V	28480	
C55,56	0160-4801		fxd cer 100pf 5% 100V	28480	
C57,58	0160-5422		fxd cer 0.047uf 20% 50V	28480	
C59	0160-4812	4	fxd cer 220pf 5% 100V	28480	
C60	0160-5422		fxd cer 0.047pf 20% 50V	28480	
C61	0160-4812		fxd cer 220pf 5% 100V	28480	
C62	0160-5422		fxd cer 0.047pf 20% 50V	28480	
C63	0180-0116	1	fxd elect 6.8uf 10% 35V	28480	
C64,65	0160-5422		fxd cer 0.047uf 20% 50V	28480	
C66	0180-0376	1	fxd elect 0.47uf 10% 35V	56289	150D105X9035A2
C67,68	0160-4812		fxd cer 220pf 5% 100V	28480	
C69	0160-4832		fxd cer 0.01uf 10% 100V	28480	
C70	0180-1980	1	fxd elect 1uf 5% 35V	28480	
C71,72	0160-5422		fxd cer 0.047pf 20% 50V	28480	
CR1,2	1901-0033	12	gen prp 180V 200mA	28480	
CR3	1901-0050	15	switching 80V 200mA	28480	
CR5-7	1901-0033		gen prp 180V 200mA	28480	
CR8-10	1901-0050		switching 80V 200mA	28480	
CR11	1901-0992	1	pwr rect 40V 3A	28480	
CR12-16	1901-0033		gen prp 180V 200mA	28480	
CR17			NOT USED	28480	
CR18	1901-0033		gen prp 180V 200mA	28480	
CR19	1901-0050		switching 80V 200mA	28480	
CR20	1901-0033		gen prp 180V 200mA	28480	
CR21-30	1901-0050		switching 80V 200mA	28480	
J1,2	1251-8417	2	connector, post type 16-cont	28480	
L1	06023-80090	1	choke, bias, 820uH	28480	
L2			NOT USED	28480	
P1	1251-8664	1	connector, post type 30-cont	28480	
P2	1251-8666	1	connector, post type 20-cont	28480	
Q1,2	1855-0413	2	J-FET P-chan D-mode SI	27014	2N5116

Table 6-4. Replaceable Parts List (cont.)

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
Q3	1854-0635	1	NPN SI	03508	D44H5
Q4	1853-0012	1	PNP SI	01295	2N2904A
Q5	1854-0823	1	NPN SI	28480	
Q6	1858-0023	1	transistor array, 16pin	3L585	CA3081E
Q7	1854-0087	1	NPN SI	28480	
R1	0683-5125	6	fxd comp 5.1K 1/2W	01121	EB5125
R2	0757-0419	1	fxd film 681 1% 1/8W	24546	CT4-1/8-T0-681R-F
R3	0698-6797	1	fxd film 660 1% 1/8W	28480	
R4	0683-1035	7	fxd comp 10K 5% 1/4W	01121	CB1035
R5	0699-0774	1	fxd film 6.65K 1% 1/8W	28480	
R6	0683-5125	4	fxd comp 5.1K 5% 1/4W	01121	CB5125
R7	0683-4745	1	fxd comp 470K 5% 1/4W	01121	CB4745
R8	2100-3353	2	trmr 20K 10% 1-turn side adj	28480	
R9	2100-3349	1	trmr 100 10% 1-turn side adj	28480	
R10	0757-0427	1	fxd film 1.5K 1% 1/8W	24546	CT4-1/8-T0-1501-F
R11,12	0683-1025	3	fxd comp 1K 5% 1/4W	01121	CB1025
R13	0683-2735	3	fxd comp 27K 5% 1/4W	01121	CB2735
R14	0686-5125		fxd comp 5.1K 1/2W	01121	EB5125
R15	0683-2015	5	fxd comp 200 5% 1/4W	01121	CB2015
R16	0683-2255	1	fxd film 2.2M 5% 1/4W	01121	CB2255
R17	0757-0289	1	fxd film 13.3K 1% 1/8W	28480	
R18,19	0757-0449	4	fxd film 20K 1% 1/8W	24546	CT4-1/8-T0-2002-F
R20	0683-1035		fxd comp 10K 5% 1/4W	01121	CB1035
R21	2100-3273	2	trmr 2k 10% 1-turn side adj	28480	
R22	2100-3353		trmr 20K 10% 1-turn side adj	28480	
R23	2100-3273		trmr 2K 10% 1-turn side adj	28480	
R24	2100-3350	1	trmr 200 10% 1-turn side adj	28480	
R25	2100-3207	1	trmr 5K 10% 1-turn side adj	28480	
R26	0683-1045	4	fxd comp 100K 5% 1/4W	01121	CB1045
R27	0698-6322	2	fxd film 4K 0.1% 1/8W	28480	
R28	0683-1045		fxd comp 100K 5% 1/4W	01121	CB1045
R29	0698-4416	2	fxd film 169 1% 1/8W	24546	CT4-1/8-T0 169R-F
R30	0683-7545	2	fxd comp 750K 5% 1/4W	01121	CB7545
R31	0698-6322		fxd film 4K 0.1% 1/8W	28480	
R32	0698-4416		fxd film 169 1% 1/8W	24546	CT4-1/8-T0-169R-F
R33	0698-4447	1	fxd film 280 1% 1/8W	24546	CT4-1/8-T0-280R-F
R34	0757-0404	1	fxd film 130 1% 1/8W	24546	CT4-1/8-T0-131-F
R35	0698-4608	1	fxd film 806 1% 1/8W	24546	CT4-1/8-T0-806R-F
R36	0757-0438	2	fxd film 5.11K 1% 1/8W	24546	CT4-1/8-T0-5111-F
R37,38	0683-1035		fxd comp 10K 5% 1/4W	01121	CB1035
R39	0686-2005	1	fxd comp 20 5% 1/2W	01121	EB2005
R40	0683-1005	4	fxd comp 10 5% 1/4W	01121	CB1005
R41,42	0686-6215	2	fxd comp 620 5% 1/2W	01121	EB6215
R43	0683-1515	1	fxd comp 150 5% 1/4W	01121	CB1515
R44	0757-0434	1	fxd film 3.65K 1% 1/8W	24546	CT4-1/8-T0-3651-F
R45	0757-0442	7	fxd film 10K 1% 1/8W	24546	CT4-1/8-T0-1002-F
R46,47	0757-0283	2	fxd film 2K 1% 1/8W	24546	CT4-1/8-T0-2001-F
R48,49	0686-1315	2	fxd comp 130 5% 1/2W	01121	EB1315
R50	0811-3174	1	fxd ww 0.07 5% 5W	28480	
R51	0698-6076	1	fxd film 39K 1% 1/8W	24546	CT4-1/8-T0-3901-F
R52	0757-0280	2	fxd film 1K 1% 1/8W	24546	CT4-1/8-T0-1001-F
R53	0698-4121	1	fxd film 11.3K 1% 1/8W	24546	CT4-1/8-T0-1132-F
R54	0683-2015		fxd comp 200 5% 1/4W	01121	CB2015
R55	0683-1055	2	fxd comp 1M 5% 1/4W	01121	CB1015

Table 6-4. Replaceable Parts List (cont.)

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
R56	0757-0269	1	fxd film 270 1/4W	24546	
R57	0683-2015		fxd film 200 5% 1/4W	01121	CB2015
R58	0683-1045		fxd comp 100K 5% 1/4W	01121	CB1045
R59	0698-8816	1	fxd film 2.15 1% 1/8W	28480	
R60	0757-0199	1	fxd film 21.5K 1% 1/8W	24546	CT4-1/8-T0-2152-F
R61	0698-6360	2	fxd film 10K 0.1% 1/8W	28480	
R62	8159-0005	1	wire, 22 AWG	28480	
R63	0698-6360		fxd film 10K 0.1% 1/8W	28480	
R64	0683-5125		fxd comp 5.1K 5% 1/4W	01121	CB5125
R65	0699-1210	1	fxd film 80K 0.1% 0.1W	28480	
R66	0699-1211	1	fxd film 95K 0.1% 0.1W	28480	
R67,68	0686-5125		fxd comp 5.1K 5% 1/2W	01121	EB5125
R69	0683-2225	7	fxd comp 2.2K 5% 1/4W	01121	CB2225
R70	0683-2015		fxd comp 200 5% 1/4W	01121	CB2015
R71	0698-5089	1	fxd comp 33K 1% 1/8W	24546	CB2735
R72	0757-0470	1	fxd film 162K 1% 1/8W	24546	CT4-1/8-T0-1003-F
R73,74	0757-0452	3	fxd film 27.4K 1% 1/8W	24546	CT4-1/8-T0-2742-F
R75	0683-7545		fxd comp 750K 5% 1/4W	01121	CB7545
R76	0757-0446	1	fxd film 15K 1% 1/8W	24546	CT4-1/8-T0-1502-F
R77	0757-0469	1	fxd film 150K 1% 1/8W	24546	CT4-1/8-T0-1503-F
R78	0698-4014	1	fxd film 787 1% 1/8W	24546	CT4-1/8-T0-787R-F
R79	0698-6983	1	fxd film 20.4K 0.1% 1/8W	19701	MF4C1/2-T9-2042B
R80	0698-6320	1	fxd film 5K 0.1% 1/8W	03888	PME551/8T95001B
R81	0757-0459	1	fxd film 56.2K 1% 1/8W	24546	CT4-1/8-T0-5622-F
R82	0683-3325	1	fxd comp 3.3K 5% 1/4W	01121	CB3325
R83	0757-0270	1	fxd film 249K 1% 1/8W	24546	CT4-1/8-T0-2493-F
R84	0757-0442	7	fxd film 10K 1% 1/8W	24546	CT4-1/8-T0-1002-F
R85	0698-3450	1	fxd film 42.2K 1% 1/8W	24546	CT4-1/8-T0-4222-F
R86	0757-0452	1	fxd film 27.4K 1% 1/8W	24546	CT4-1/8-T0-2742-F
R87	0683-2715	2	fxd comp 270 5% 1/8W	01121	CB2715
R88,89	0683-2225		fxd comp 2.2K 5% 1/4W	01121	CB2225
R90	0683-2715		fxd comp 270 5% 1/4W	01121	CB2715
R91	0683-2225		fxd comp 2.2K 5% 1/4W	01121	CB2225
R92	0683-2015		fxd comp 200 5% 1/4W	01121	CB2015
R93	0683-5125		fxd comp 5.1K 5% 1/4W	01121	CB5125
R94	0683-1035		fxd comp 10K 5% 1/4W	01121	CB1035
R95	0757-0472	1	fxd film 200K 1% 1/8W	24546	CT4-1/8-T0-2003-F
R96	0757-0455	1	fxd film 36.5K 1% 1/8W	24546	CT4-1/8-T0-3652-F
R97	0683-5125		fxd comp 5.1K 5% 1/4W	01121	CB5125
R98	0683-2735		fxd comp 27K 5% 1/4W	01121	CB2735
R99	0683-1035		fxd comp 10K 5% 1/4W	01121	CB1035
R100,101	1810-0365	4	res network 6-SIP 2.2K x 5	01121	206A222
R102,103	0757-0449	2	fxd film 20K 1% 1/8W	24546	CT4-1/8-T0-2002-F
R104	0757-0280		fxd film 1K 1% 1/8W	24546	CT4-1/8-T0-1001-F
R105	0698-3430	1	fxd film 21.5K 1% 1/8W	03888	PME551/8T021R5F
R106	0698-3449	1	fxd film 28.7K 1% 1/8W	24546	CT4-1/8-T0-2872-F
R107	0698-3153	1	fxd film 3.38K 1% 1/8W	24546	CT4-1/8-T0-3831-F
R108	0683-2035		fxd comp 20K 5% 1/4W	01121	CB2035
R109	0683-2225		fxd comp 2.2K 5% 1/4W	01121	CB2225
R110	0683-4725	6	fxd comp 4.7K 5% 1/4W	01121	CB4725
R111	0683-2025	2	fxd comp 2K 5% 1/4W	01121	CB2025
R112	0683-1125	3	fxd comp 1.1K 5% 1/4W	01121	CB1125
R113	0757-0442		fxd film 10K 1% 1/8W	24546	CT4-1/8-T0-1002-F
R114	0757-0424	1	fxd film 1.1K 1% 1/8W	24546	CT4-1/8-T0-1101-F

Table 6-4. Replaceable Parts List (cont.)

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
R115	0683-1015	1	fxd comp 100 5% 1/4W	01121	CB1015
R116	0698-3498	1	fxd film 8.66K 1% 1/8W	24546	CT4-1/8-T0-8661-F
R117	0757-0438		fxd film 5.11K 1% 1/8W	24546	CT4-1/8-T0-5111-F
R118	1810-0365		res network 6-SIP 2.2K x 5	01121	206A222
R119	0757-0288	1	fxd film 9.09 1% 1/8W	19701	MF4C1/8-T0-9091-F
R120	0683-1005		fxd comp 10 5% 1/4W	01121	CB1005
R121	0757-0442		fxd film 10K 1% 1/8W	24546	CT4-1/8-T0-1002-F
R122	0683-5135	1	fxd film 51K 5% 1/4W	19701	(CR-25)1-4-5P-51
R123-126	0683-4725		fxd comp 4.7K 5% 1/4W	01121	CB4725
R127	0683-1855	1	fxd comp 1.8M 5% 1/4W	01121	CB1855
R128	0683-6835	1	fxd comp 68K 5% 1/4W	01121	CB6835
R129	0757-0439	1	fxd film 6.8K 1% 1/8W	24546	CT4-1/8-,0-6811-F
R130	0683-1055	1	fxd comp 1M 5% 1/4W	01121	CB1055
R131	0683-3335	1	fxd comp 33K 5% 1/4W	01121	CB3335
R132	0683-2225		fxd comp 2.2K 5% 1/4W	01121	CB2225
R133	0683-2735		fxd comp 27K 5% 1/4W	01121	CB2735
R134	0757-0466	1	fxd film 110K 1% 1/8W	24546	CT4-1/8-T0-1103-F
R135,136	0757-0442		fxd film 10K 1% 1/8W	24546	CT4-1/8-T0-1002-F
R137	0698-3455		fxd film 261K 1% 1/8W	24546	CT4-1/8-T0-2613-F
R138	0683-2045		fxd comp 200K 5% 1/8W	01121	CB2045
R139	0757-0442		fxd film 10K 1% 1/8W	24546	CT4-1/8-T0-1002-F
R140	0698-3160		fxd film 31.6K 1% 1/8W	24546	CT4-1/8-T0-3162-F
R141	0683-1025		fxd comp 1K 5% 1/4W	01121	CB1025
R142	0683-2225		fxd comp 2.2K 5% 1/4W	01121	CB2225
R143	0683-1045		fxd comp 100K 5% 1/4W	01121	CB1045
R144	0683-4725		fxd comp 4.7K 5% 1/4W	01121	CB4725
R145	0683-4715		fxd comp 470 5% 1/4W	01121	CB4715
R146,147	0683-1125		fxd comp 1.1K 5% 1/4W	01121	CB1125
R148	0683-3925		fxd comp 3.9K 5% 1/4W	01121	CB3925
R149	1810-0365		res network 6-SIP 2.2K x 5	01121	206A222
R150,151	0683-1815	2	fxd comp 180 5% 1/4W	01121	CB1815
R152	0683-1025		fxd film 1K 5% 1/4W	01121	CB1025
R153	0683-1035		fxd film 10K 5% 1/4W	01121	CB1035
R154			NOT USED		
R155	0683-1005		fxd film 10 5% 1/4W	01121	CB1005
R156,157			NOT USED		
R158	0683-1005		fxd film 10 5% 1/4W	01121	CB1005
S1	3101-2097	1	switch 6-1A slide assy	28480	
U1	1826-0493	3	IC op amp L-bias H-impd	04713	MLM308AP1
U2	1826-0346	1	IC op amp GP dual	27014	LM358N
U3	1826-0161	2	IC op amp GP Quad	04713	MLM324P
U4	1826-0527	1	IC voltage regulator 1.2/37V neg.	27014	LM337T
U5	1826-0544	2	IC 2.5V voltage reference	04713	MC1403U
U6	1826-0428	1	IC modulator	01295	SG3524J
U7,8	1826-0493		IC op amp L-bias H-impd	04713	MLM308AP1
U9	1826-0544		IC 2.5 voltage reference	04713	MC1403U
U10	1826-0161		IC op amp GP quad	04713	MLM324P
U11	1820-1209	1	IC BFR TTL LS NAND quad	01295	SN74LS38N
U12	1826-0393	1	IC voltage regulator 1.2/37V pos.	27014	LM317T
U13	1820-1112	1	IC FF TTL LS D-type pos-edge-trig	01295	SN74LS74AN
U14	1826-0138	2	IC comparator GP quad	01295	LM339N

Table 6-4. Replaceable Parts List (cont.)

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
U15	1820-1437	1	IC MV TTL LS monostbl dual	01295	SN74LS221N
U16	1826-0065	2	IC comparator PRCN	01295	SN72311P
U17	1820-1246	1	IC gate TTL LS AND quad	01295	SN74LS09N
U18	1820-0935	1	IC CTR CMOS BIN neg-edge-trig	3L585	CD4020BE
U19	1820-1205	1	IC gate TTL LS AND dual	01295	SN74LS21N
U20	1826-0138		IC comparator QUAD	01295	LM339N
U21	1826-0065		IC comparator PRCN	01295	LM339N
U22	1820-2096	1	IC SHF-RGTR CMOS	3L585	CD4006BE
VR1,2	1902-0018	2	zener 11.7V 5%	04713	1N941
VR3	1902-0777	1	zener 6.2V 5%	04713	1N825
VR4	1902-3110	1	zener 5.9V 2%	28480	
VR5	1902-0575	1	zener 6.5V 2%	28480	
W1-3	7175-0057	3	jumpers wire 22	28480	
Y1	0960-0586	1	cer resonator 320KHZ	28480	
	06038-60022		A3 Front Panel Board	28480	
C1,2	0180-0374	2	fxd elect 10uf 10 20V	56289	150D106X9020B2
C3-14	0160-5422	12	fxd cer 0.047uf 20% 50V	28480	
DS1-8	1990-0985	1	numeric display pack, 8-char	28480	
DS9,10	1990-0835	9	LED	28480	
DS11-16	1990-0831	6	LED		
DS17-23	1990-0835		LED		
G1	0960-0683	1	pulse generator		
J1	1251-8417	1	connector, post type 16-cont	28480	
J2,3	1251-8675	2	connector, post type 5-cont		
L1	9100-1618	1	coil 5.6uH 10%	28480	
R1-58	0683-4715	58	fxd comp 470 5% 1/4W	01121	CB4715
R59	2100-1775	1	trmr 5k 5% 1-turn top adj	28480	
R60	0683-1015	1	fxd film 100 5% 1/4W	01121	CB1015
R61,62	1810-0272	2	res network 10-SIP 330 x 9	01121	210A331
R63	1810-1231	1	res network 8-SIP 2.2k x 7	01121	208A222
S2-5	5060-9436	5	switch, pushbutton	28480	
U1-10	1820-1433	11	IC SHF-RGTR TTL LS R-S serial-in PRL-out	01295	SN74LS164N
U11	1820-1975	1	IC SHF-RGTR TTL LS neg-edge-trig PRL-in	01295	SN74LS165N
U12	1820-1112	1	IC FF LS D-type pos-edge-trig	01295	SN74LS74AN
U13,14	1820-1216	2	IC DCDR TTL LS 3-to-8 line	01295	SN74LS138N
U15	1820-1433		IC SHF-RGTR TTL LS R-S serial-in PRL-out	01295	SN74LS164N
U16	1820-1197	1	IC gate TTL LS NAND quad	01295	SN74LS00N
U17	1820-1199	1	IC INV TTL LS hex	01295	SN74LS04N
			A4 Power Mesh Assembly		
C1	0160-5091	1	fxd met 0.47uF +10% 630V	28480	
C2	0160-5422	1	fxd cer .047uF +20% 50V	28480	
C3,4			NOT USED		
C5,6	0160-4960	2	fxd film 2200pF +10% 1.6kV	56289	715P222916LD3
C7	0180-0155	1	fxd elect 2.2uF +20% 20V	56289	150D225X0020A2

Table 6-4. Replaceable Parts List (cont.)

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
C8	0160-0127	1	fxd cer 1uF +20% 25V	28480	
C9	0180-2780	1	fxd elect 470uF +75-10% 16V	28480	
C10	0160-4834	1	fxd cer .047uF +10% 100V	28480	
C11,12	0160-4835	2	fxd cer 0.1uF +10% 50V	28480	
C13	0160-5022	1	fxd poly 2200pf 10% 600Vac	28480	
CR1-4	1901-0050	6	switching 80V 200mA	28480	
CR5,6	1901-1065	2	pwr rect 400V 1A	14936	1N4936
CR7	1901-0887	1	diode pwr rectifier 300V 50A	28480	
CR8,9			NOT USED		
CR10,11	1901-0050		switching 80V 200mA	28480	
CR12			NOT USED		
CR13,14	1901-1087	2	pwr rect 600V 3A	04713	MR856
F1,2	2110-0671	2	axial lead, 1/8A	28480	
F3	2110-0447	1	fuse, 3A	28480	
L1,2			NOT USED		
L3	06024-80096	1	inductor, 3A	28480	
L4	06024-80097	1	inductor, 12A	28480	
[illegible]	1251-8807	2	connector, DIN type 32-cont F	28480	
Q1,2	1854-0477	2	NPN SI	04713	2N2222A
Q3,4	1855-0547	2	PFET	28480	
Q5			NOT USED		
Q6	1854-1017	1	NPN SI	04713	2N3715
Q7	1855-0549	1	PFET	28480	
R1,2	0686-0275	2	fxd comp 2.7 5% 1/2W	01121	EB0275
R3	0683-3915	2	fxd comp 390 5% 1/4W	01121	CB3915
R4	0683-1015	2	fxd comp 100 5% 1/4W	01121	CB1015
R5	0683-4705	2	fxd comp 47 5% 1/4W	01121	CB4705
R6	0683-1045	2	fxd comp 100k 5% 1/4W	01121	CB1045
R7	0811-1857	2	fxd ww 400 5% 5W	28480	
R8	0698-3601	3	fxd met ox 10 5% 2W	27167	FP42-2-T00-10R0J
R9	0683-3915		fxd comp 390 5% 1/4W	28480	
R10	0683-1015		fxd comp 100 5% 1/4W	01121	CB1015
R11	0683-4705		fxd comp 47 5% 1/4W	01121	CB4705
R12	0683-1045		fxd comp 100k 5% 1/4W	01121	CB1045
R13	0811-1857		fxd ww 400 5% 5W	28480	
R14	0698-3601		fxd met ox 10 5% 2W	27167	FP42-2-T00-10R0J
R15	0757-0403	1	fxd film 121 1% 1/8W	24546	CT4-1/8-T0-121R-F
R16	0683-3305	3	fxd comp 33 5% 1/4W	01121	CB3305
R17	0683-1025	1	fxd comp 1k 5% 1/4W	01121	CB1025
R18	0683-0475	3	fxd comp 4.7 5% 1/4W	01121	CB0475
R19	0683-2025	1	fxd comp 2k 5% 1/4W	01121	CB2025
R20	0683-0275	1	fxd comp 2.7 5% 1/4W	01121	CB0275
R21,22	0683-0475		fxd comp 4.7 5% 1/4W	01121	CB0475
R23	0683-2725	1	fxd comp 2.7k 5% 1/4W	01121	CB2725
R24	0757-0476	1	fxd film 301k 1% 1/8W	28480	
R25	0686-3005	1	fxd comp 30 5% 1/2W	01121	EB3005
R26	0811-2994	1	.27 3% 5W	28480	
R27	0698-3225	1	fxd film 1.43k 1% 1/8W	24546	CT4-1/8-T0-1431-F
R28	0757-0279	1	fxd film 3.16k 1% 1/8W	24546	CT4-1/8-T0-3161-F
R29	0698-3159	1	fxd film 26.1k 1% 1/8W	24546	CT4-1/8-T0-2612-F
R30	0698-3202	1	fxd film 1.74k 1% 1/8W	24546	CT4-1/8-T0-1741-F
R31	0698-4046	1	fxd film 732 1% 1/8W	24546	CT4-1/8-T0-732R-F
R32	0757-0442	1	fxd film 10k 1% 1/8W	24546	CT4-1/8-T0-1002-F
R33	0698-3628		fxd met 220 5% 2W	27167	FP42-2-T00-10R0J

Ref Desig	HP Part No	Qty	Description	Mfr Code	Mfr Part No
R34	0698-4484	1	fxd film 19.1k 1% 1/8W	24546	CT4-1/8-T0-1912-F
R35,36	0683-3305		fxd comp 33 5% 1/4W	01121	CB3305
R37	0683-3325	1	fxd comp 3.3k 5% 1/4W	01121	CB3325
R38	0757-0465		fxd film 100k 1% 1/8W	28480	
R39	0683-1055	1	fxd comp 1M 5% 1/4W	01121	CB1055
T1,2	5080-1983	2	transformer, FET driver	28480	
T3	9100-4350	1	transformer, current	28480	
TS1	3103-0116	1	switch, thermal 100 C	28480	
TP1-4	1251-0646	4	contact connector, post type	28480	
U1,2	1820-1050	2	IC DRVR TTL NOR dual	01295	SN75454BP
U3	1826-0346	1	IC op amp GP dual	27014	LM358N
U4	1826-0393	1	IC voltage regulator 1.2/37V pos	27014	LM317T
VR1			NOT USED		
VR2	1902-3002	1	zener 2.37V 5%	28480	
VR3	1902-0057	1	zener 6.49V 5%	28480	
VR4	1902-0575	1	zener 6.5V 2%	28480	
	5060-2832		A7 PSI Board	28480	
C1,2	0160-5469	4	fxd film 1uF +10% 50V	28480	
C3-6	0160-4835	4	fxd cer 0.1uF +10% 50V	28480	
C7,8	0160-5422	21	fxd cer .047uF +20% 50V	28480	
C9-11	0160-4801	4	fxd cer 100pF +5% 100V	28480	
C12-16	0160-4807	6	fxd cer 33pF +5% 100V	28480	
C17	0160-4801		fxd cer 100pF +5% 100V	28480	
C18,19	0160-4820	2	fxd cer 1800pf +5% 100V	28480	
C20-22	0160-5422		fxd cer .047uF +20% 50V	28480	
C23			NOT USED		
C24-29	0160-5422	6	fxd cer. .047uF +20% 50V	28480	
C30	0160-4832	1	fxd cer .01uF +10% 100V	28480	
C31	0160-5422		fxd cer .047uF +20% 50V	28480	
C32	0160-4807		fxd cer 33pF +5% 100V	28480	
C33-37	0160-5422		fxd cer .047uF +20% 50V	28480	
C38,39	0180-0116	2	fxd elect 6.8uF +10% 35V	56289	150D685X9035B2
C40	0180-0374	1	fxd elect 10uF +10 20V	56289	150D106X9020B2
C41-43	0160-5422		fxd cer .047uF +20% 50V	28480	
C44,45	0160-5469		fxd film +10% 50V	28480	
C46	0160-5422		fxd cer .047uF +20% 50V	28480	
CR1	1901-0050	1	switching 80V 200mA	28480	
J1-3	1251-8417	3	connector, post type,16 cont	28480	
J4	1251-5240	1	connector, post type,20 cont	28480	
R1,2	0698-3558	8	fxd film 4.02k 1% 1/8W	24546	CT4-18-T0-4021-F
R3-5	0683-1015	3	fxd comp 100 5% 1/4W	01121	CB1015
R6	0683-1025	4	fxd comp 1k 5% 1/4W	01121	CB1025
R7	0683-2225	6	fxd comp 2.2k 5% 1/4W	01121	CB2225
R8-10	0683-3915	4	fxd comp 390 5% 1/4W	01121	CB3915
R11	0683-2715	1	fxd comp 270 5% 1/4W	01121	CB2715
R12	0683-3915		fxd comp 390 5% 1/4W	01121	CB3915
R13	0683-2015	2	fxd comp 200 5% 1/4W	01121	CB2015
R14	0683-1025		fxd comp 1k 5% 1/4W	01121	CB1025
R15	0683-2015		fxd comp 200 5% 1/4W	01121	CB2015
R16	0683-2225		fxd comp 2.2k 5% 1/4W	01121	CB2225
R17	0757-0123	1	fxd film 34.8k 1% 1/8W	28480	
R18	0757-0443	1	fxd film 11k 1% 1/8W	24546	CT4-1/8-T0-1102-F

Table 6-4. Replaceable Parts List (cont.)

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
R19	0757-0452	1	fxd film 27.4K 1% 1/8W	24546	CT4-1/8-T0-4742-F
R20	0757-0288	1	fxd film 9.09k 1% 1/8W	19701	MF4C1/8-T0-9091F
R21,22	0683-3315	2	fxd comp 330 5% 1/4W	01121	CB3315
R23	0757-0316	3	fxd film 42.2 1% 1/8W	24546	CT4-1/8-T0-42R2-F
R24	0699-0642	3	fxd film 10k 0.1% 0.1W	28480	
R25	0699-0059	3	fxd film 5k 0.1% 0.1W	28480	
R26	0757-0401	6	fxd film 100 1% 1/8W	24546	CT4-1/8-T0-101-F
R27	0698-6360	3	fxd film 10k 0.1% 1/8W	28480	
R28	0757-0457	2	fxd film 47.5k 1% 1/8W	19701	CT4-1/8-T0-4752-F
R29	2100-3353	3	trmr 20k 10% 1-turn side adj	28480	
R30	0698-6320	3	fxd film 5k 0.1% 1/8W	03888	PME551/8T95001B
R31	0757-0400	3	fxd film 90.9 1% 1/8W	24546	CT4-1/8-T0-90R9-F
R32,33	0757-0401		fxd film 100 1% 1/8W	24546	CT4-1/8-T0-101-F
R34	0757-0316		fxd film 42.2 1% 1/8W	24546	CT4-1/8-T0-42R2-F
R35	0699-0642		fxd film 10k 0.1% 0.1W	28480	
R36	0699-0059		fxd film 5k 0.1% 0.1W	28480	
R37	0757-0401		fxd film 100 1% 1/8W	24546	CT4-1/8-T0-101-F
R38	0698-6360		fxd film 10k 0.1% 1/8W	28480	
R39	0757-0270	1	fxd film 249k 1% 1/8W	24546	CT4-1/8-T0-2493-F
R40	2100-3353		trmr 20k 10% 1-turn side adj	28480	
R41	0698-6320		fxd film 5k 0.1% 1/8W	03888	PME551/8T95001B
R42	0757-0400		fxd film 90.9 1% 1/8W	24546	CT4-1/8-T0-90R9-F
R43	0757-0401		fxd film 100 1% 1/8W	24546	CT4-1/8-T0-101-F
R44	0683-2225		fxd comp 2.2k 5% 1/4W	01121	CB2225
R45	0757-0316		fxd film 42.2 1% 1/8W	24546	CT4-1/8-T0-42R2-F
R46	0699-0642	1	fxd film 10K 0.1%, 0.1W	28480	
R47	0699-0059		fxd film 5k 0.1% 0.1W	28480	
R48	0757-0401		fxd film 100 1% 1/8W	24546	CT4-1/8-T0-101-F
R49	0698-6360		fxd film 10k 0.1% 1/8W	28480	
R50	0757-0457		fxd film 47.5k 1% 1/8W	19701	CT4-1/8-T0-4752F
R51	2100-3353		trmr 20k 10% 1-turn side adj	28480	
R52	0698-6320		fxd film 5k 0.1% 1/8W	03888	PME551/8T95001B
R53	0757-0400		fxd film 90.9 1% 1/8W	24546	CT4-1/8-T0-90R9-F
R54	0683-2225		fxd comp 2.2k 5% 1/4W	01121	CB2225
R55	2100-3732	3	trmr 500 10% 17-turn side adj	28480	28480
R56	0698-3156	4	fxd film 14.7k 1% 1/8W	24546	CT4-1/8-T0-1472-F
R57	0683-2225		fxd comp 2.2k 5% 1/4W	01121	CB2225
R58	2100-3732		trmr 500 10% 17-turn side adj	28480	
R59	0698-3156		fxd film 14.7k 1% 1/8W	24546	CT4-1/8-T0-1472-F
R60			NOT USED		
R61	2100-3732		trmr 500 10% 17-turn side adj	28480	
R62	0698-3156		fxd film 14.7k 1% 1/8W	24546	CT4-1/8-T0-1472-F
R67	0757-0451	1	fxd film 24.3k 1% 1/8W	24546	CT4-1/8-T0-2432-F
R68	0757-0199	1	fxd film 21.5k 1% 1/8W	24546	CT4-1/8-T0-2152-F
R69	0698-3156		fxd film 14.7k 1% 1/8W	24546	CT4-1/8-T0-1472-F
R70-74	0698-3558		fxd film 4.02k 1% 1/8W	24546	CT4-1/8-T0-4021-F
R75	2100-3273	1	trmr 2k 10% 1-turn side adj	28480	
R76,77			NOT USED		
R78,79	0683-1025		fxd comp 1k 5% 1/4W	01121	CB1025
R80	0683-2225		fxd comp 2.2k 5% 1/4W	01121	CB2225
R81,82			NOT USED		
R83,84	0698-3455	2	fxd film 261k 1% 1/8W	24546	CT4-1/8-T0-2613-F
R85	0757-0280	1	fxd film 1k 1% 1/8W	24546	CT4-1/8-T0-1001-F
R86	1810-0280	1	res network 10-SIP 10K x 9	01121	210A103

Table 6-4. Replaceable Parts List (cont.)

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
R87	1810-0231	1	res network 8-SIP 2.2k x 7	56289	256CH222X2PD
R88	0683-1035	1	fxd comp. 10K 5% 1/4W	01121	CB1035
S1	3101-2371	1	switch, slide assy.	28480	
TP1-6	0360-0124	6	connector single contact	28480	
U1,2			NOT USED		
U3-6	1990-0602	4	IC opto-isolator	28480	
U7,8	1990-0494	2	IC opto-isolator	28480	
U9	1820-1298	1	IC MUXR/data-sel TTL LS 2-to-1 line	01295	SN74LS251N
U10	1820-1975	4	IC SHF-RGTR TTL LS neg-edge-trig PRL-in	01295	SN74LS165N
U11	1820-1440	1	IC LCH TTL LS quad	01295	SN74LS279N
U12	1820-1975		IC SHF-RGTR TTL LS neg-edge-trig PRL-in	01295	SN74LS165N
U13	1820-1433	1	IC SHF-RGTR TTL LS R-S serial-in PRL-out	01295	SN74LS164N
U14	1820-1197	1	IC gate TTL LS NAND quad	01295	SN74LS00N
U15	1820-1416	1	IC schmitt-trig TTL LS INV hex	01295	SN74LS14N
U16,17	1820-1216	2	IC DCDR TTL LS 3-to-8 line	01295	SN74LS138N
U18	1820-1492	1	IC BFR TTL LS INV hex	01295	SN74LS368AN
U19-21	1820-1662	4	IC SHF-RGTR CMOS serial-in PRL-out	3L585	CD4094BE
U22,23	1826-1158	3	IC DAC		
U24-27	1826-0493	7	IC op amp L-bias H-impd	04713	MLM308AP1
U28	1820-1662		IC SHF-RGTR CMOS serial-in PRL-out	3L585	CD4094BE
U29	1820-1730	1	IC FF TTL LS D-type pos-edge-trig com	01295	SN74LS273N
U30	1826-0493		IC op amp L-bias H-impd	04713	MLM308AP1
U31	1826-1158		IC DAC		
U32,33	1826-0493		IC op amp L-bias H-impd	04713	MLM308AP1
U34	1826-0161	1	IC op amp GP quad	04713	MLM324P
U35	1826-0098	1	IC comparator PRCN	27014	LM211H
U36	1820-1721	1	IC RGTR CMOS	04713	MC14549BCP
U37	1820-1722	1	IC RGTR CMOS	04713	MC14559BCP
U38,39	1820-1975		IC SHF-RGTR TTL LS neg-edge-trig PRL-in	01295	SN74LS165N
U40	1826-0609	1	IC multiplexer analog switch	06665	MUX08FQ
U41	1826-0412	1	IC comparator PRCN dual	27014	LM393N
U42			NOT USED		
U43	1826-0316	1	IC 10V voltage reference	27014	LH0070-1H
	5060-2831		A8 HP-IB Board	28480	
C1,2			NOT USED		
C3-19	0160-4835	29	fxd cer 0.1uF +10% 50V	28480	
C20	0180-3423	1	fxd elect 3300uF	28480	
C21	0160-0154	1	fxd poly 2200pF +10% 200V	28480	
C22	0160-4833	1	fxd cer .022uF +10% 100v	28480	
C23	0160-4835		fxd cer 0.1uF +10% 50V	28480	
C24	0160-4832	1	fxd cer .01uF +10% 100V	28480	
C25,26	0160-5098	2	fxd cer 0.22uF +10% 50V	28480	

Table 6-4. Replaceable Parts List (cont.)

Ref. Desig.	HP Part No.	TQ	Description	Mfr. Code	Mfr. Part No.
C27	0180-3424	1	fxd elect 2000uF +75-10% 10V	28480	
C28	0180-0405	1	fxd elect 1.8uF +10% 20V	56289	150D185X9020A2
C29	0180-0116	1	fxd elect 6.8uF +10% 35V	56289	150D685X9035B2
C30-34	0160-4835		fxd cer 0.1uF +10% 50V	28480	
C35	0180-0374	1	fxd elect 10uF +10 20V	56289	150D106X9020B2
C36-39	0160-4835		fxd cer 0.1uF +10% 50V	28480	
C40	0160-54_2	1	fxd cer .047uF +20% 50V	28480	
C41,42	0160-4835		fxd cer 0.1uF +10% 50V	28480	
CR1,2	1901-0759	2	pwr rect 600V 3A	14936	1N5406
CR3	1901-0992	1	pwr rect 40V 3A	28480	
CR4	1901-0050	1	switching 80V 200mA	28480	
DS1	1990-0998	1	LED	28480	
J1	1251-4927	2	connector, post type	28480	
J2	1251-538_	1	connector, 3-pin M post type	28480	
J3	1251-4927		connector, post type	28480	
J4	1251-7162	1	connector, 24-pin F	28480	
J5	1200-0940	1	socket, multi-contact	28480	
J6	1200-0607	1	socket, IC 16-contact	28480	
J7	1251-8417	1	connector, post type	28480	
L1	06023-80090	1	bias choke	28480	
Q1	1853-0012	1	PNP SI	01295	2N2904A
Q2	1854-0635	1	NPN SI	28480	
Q3	1854-0823	1	NPN SI	28480	
R1-5	0683-4715	5	fxd comp 470 5% 1/4W	01121	CB4715
R6			NOT USED		
R7,8	0683-4725	8	fxd comp 4.7k 5% 1/4W	01121	CB4725
R9-11	0683-1515	4	fxd comp 150 5% 1/4W	01121	CB1515
R12-14	0683-4725		fxd comp 4.7k 5% 1/4W	01121	CB4725
R15	0757-0401	1	fxd film 100 1% 1/8W	24546	CT4-1/8-T0-101-F
R16	0683-4725		fxd comp 4.7k 5% 1/4W	01121	CB4725
R17			NOT USED		
R18	0698-6076	1	fxd film 39k 1% 1/8W	24546	CT4-1/8-T0-3902-F
R19	0757-0280	1	fxd film 1k 1% 1/8W	24546	CT4-1/8-T0-1001-F
R20			NOT USED		
R21	0698-4121	1	fxd film 11.3k 1% 1/8W	24546	CT4-1/8-T0-1132-F
R22	0683-1515		fxd comp 150 5% 1/4W	01121	CB1515
R23,24	0686-6215	2	fxd comp 620 5% 1/2W	01121	EB6515
R25	0683-1005	2	fxd comp 10 5% 1/4W	01121	CB1005
R26	0686-2005	1	fxd comp 20 5% 1/2W	01121	EB2005
R27	0757-0434	1	fxd film 3.65k 1% 1/8W	24546	CT4-1/8-T0-3651-F
R28	0757-0442	4	fxd film 10k 1% 1/8W	24546	CT4-1/8-T0-1002-F
R29,30	0757-0283	2	fxd film 2k 1% 1/8W	24546	CT4-1/8-T0-2001-F
R31,32	0686-1315	2	fxd comp 130 5% 1/2W	01121	EB1315
R33	0811-1826	1	fxd ww .05 10% 3W	28480	
R34	0683-1535	1	fxd comp 15k 5% 1/4W	01121	CB1535
R35	0698-4479	1	fxd film 14k 1% 1/8W	24546	CT4-1/8-T0-1402-F
R36	0757-0442		fxd film 10k 1% 1/8W	24546	CT4-1/8-T0-1002-F
R37	0757-0465	1	fxd film 100k 1% 1/8W	24546	CT4-1/8-T0-1003-F
R38	0757-0442		fxd film 10k 1% 1/8W	24546	CT4-1/8-T0-1002-F
R39	0757-0446	1	fxd film 15k 1% 1/8W	24546	CT4-1/8-T0-1502-F
R40	0683-1055	1	fxd comp 1M 5% 1/4W	01121	CB1055
R41	0757-0442		fxd film 10k 1% 1/8W	24546	CT4-1/8-T0-1002-F
R42	0683-4725		fxd comp 4.7k 5% 1/4W	01121	CB4725
R43	0757-0437	1	fxd film 4.75k 1% 1/8W	19701	CT4-1/8-T0-4751-F

Table 6-4. Replaceable Parts List (cont.)

Ref Desig	HP Part No	Qty	Description	Mfr Code	Mfr Part No
R44	0683-4725		fxd comp 4.7k 5% 1/4W	01121	CB4725
R45	0683-1005		fxd comp 10 5% 1/4W	01121	CB1005
R46	1810-0279	1	res network 10-SIP 4.7 x 9	01121	210A472
S1	3101-2097	1	switch, 6-1A slide assy	28480	
S2	3101-2372	1	switch, 5-1A slide assy	28480	
U1	1820-3431	1	IC RCVR TTL LS bus octal	27014	DS75160AN
U2	1820-3513	1	IC RCVR TTL LS bus octal	27014	DS75161AN
U3	1820-2549	1	IC 8291A HPIB	28480	
U4	0960-0464	1	IC crystal oscillator	28480	
U5	1820-1199	1	IC INV TTL LS hex	01295	SN74LS04N
U6,7	1818-0443	2	IC NMOS 4k stat ram	S0545	UPD2114LC-1
U8	1818-3386	1	IC MASKED ROM	28480	
U9			NOT USED		
U10	1820-2490	1	IC MPU Support Chip		
U11	1820-1208	1	IC gate TTL LS OR quad	01295	SN74LS32N
U12,13	1820-1216	2	IC DCDR TTL LS 3-to-8 line	01295	SN74LS138N
U14,15	1820-2024	2	IC DRVR TTL LS line DRVR octl	01295	SN74LS244N
U16	1820-1730	1	IC FF TTL LS D-type pos-edge-trig com	01295	SN74LS273N
U17	1820-0935	1	IC CTR CMOS BIN neg-edge-trig	3L585	CD4020BE
U18	1820-1112	1	IC FF LS D-type pos-edge-trig	01295	SN74LS74AN
U19	1820-1997	1	IC FF TTL LS D-type pos-edge-trig PRL-in	01295	SN74LS374N
U20	1820-1443	1	IC CNTR TTL LS BIN asynchro	01295	SN74LS293N
U21	1820-1428	1	IC MUXR/data-sel TTL LS 2-to-1 line quad	01295	SN74LS158N
U22	1820-1197	1	IC gate TTL LS NAND quad	01295	SN74LS00N
U23	1820-1975	1	IC SHF-RGTR TTL LS neg-edge-trig PRL-in	01295	SN74LS165N
U24	1820-1987	1	IC SHF-RGTR TTL LS com clear stor 8-bit	01295	SN74LS299N
U25	1820-1491	1	IC BFR TTL LS non-INV hex	01295	SN74LS367AN
U26	1820-1201	1	IC gate TTL LS AND quad	01295	SN74LS08N
U27	1820-1416	1	IC schmitt-trig TTL LS	01295	SN74LS14N
U28	1826-0428	1	IC modulator	01295	SG3524J
U29	1826-0544	1	IC 2.5V voltage reference	04713	MC1403U
U30	1826-0412	1	IC comparator PRCN dual	27014	LM393N
VR1	1902-0575	1	zener 6.5V 2%	28480	
W1-3	7175-0057	5	wire, 22 AWG	28480	
W4	1251-4787	1	shunt, DIP 8-position	28480	
W5	1258-0189	1	connector, jumper	28480	
W6,7	7175-0057		wire, 22 AWG	28480	
XS1	1200-0485	1	socket, IC 14-contact	28480	
			Chassis Electrical		
	3160-0343	1	fan, axial tube	28480	
	9135-0223	1	line filter, IEC	28480	
	2110-0383	1	fuse 8A 250V	75915	312008

Table 6-4. Replaceable Parts List (cont.)

Ref Desig	HP Part No	Qty	Description	Mfr Code	Mfr Part No
			Cabling		
W1	8120-4355	1	Ribbon Cable, (Connects A8 and A5 Boards)	28480	
W2	8120-4352	1	Ribbon Cable, (Connects A1 and A8 Boards)	28480	
W3	8120-4351	1	3 Wire Cable (Connects A1 and A8 Boards)	28480	
W4	8120-4354	1	Ribbon Cable (Connects A7 and A8 Boards)	28480	
W5,6	8120-4356	2	Ribbon Cable, (Connects A2 and A7 Boards)	28480	
			A1 Board Mechanical Parts		
	1251-0600	4	single contact connector (Ref.fan)	28480	
	1251-5613	2	single contact connector	28480	
	1480-0552	1	pin, escutcheon (Ref. L1)	28480	
	2110-0269	2	fuseholder, clip type (Ref. F2)	28480	
	0360-2190	2	jumper, barrier block (ref. A1TB1)	28480	
A1TB1	0360-1833	1	barrier block 6 pos.	28480	
			A2 Board Mechanical Parts		
	1200-0485	1	socket, IC 14-contact (Ref. S1)	28480	
	1205-0282	3	heatsink (Ref. Q2, U15, U16)	28480	
	1531-0309	2	clevis (A2 Board,Tapped Cover Mount)	28480	
A2TB1	0360-2195	1	barrier block	28480	
	1200-0181	1	Insulator, (Ref. Q4)	28480	
			A3 Board Mechanical Parts		
	4040-1615	15	STDF LED (Ref DS9-23)	28480	
			A4 Board Mechanical Parts		
	1205-0256	2	heatsink (Ref. Q3, Q4)	28480	
	1205-0282	1	heatsink (Ref. Q7)	28480	
	06023-20001	1	heatsink (Ref. CR7)	28480	
	0380-1679	4	standoff, hex (Ref. Q3, Q4)	28480	
	1531-0309	3	Clevis (A4 Board Tapped Cover Mount)	28480	
			A8 Board Mechanical Parts		
	0380-1332	2	HP-IB connector mounting (Ref. J4A, J4B)	28480	
	1200-0181	1	insulator (Ref. Q1)	28480	
	1205-0282	1	heatsink (Ref. Q2)	28480	

Table 6-4. Replaceable Parts List (cont.)

Ref Desig	HP Part No	Qty	Description	Mfr Code	Mfr Part No
			Chassis Mechanical Parts		
	0370-1303	1	knob, base	28480	
	0403-0282	6	bumper feet	28480	
	1510-0044	1	binding post, single	28480	
	2110-0564	1	fuseholder body	19027	031.1657
	2110-0565	1	fuseholder cap	28480	
	2110-0569	1	fuseholder nut	28480	
	3160-0309	1	finger guard	28480	
	4040-1954	1	window, display	28480	
	5001-0440	2	trim, side	28480	
	5020-8817	1	frame front	28480	
	5040-7201	4	foot	28480	
	5040-7203	1	strip, top trim	28480	
	5040-7219	1	retainer, strap handle	28480	
	5040-7220	1	retainer, strap handle	28480	
	5041-0309	3	key cap, quarter	28480	
	5041-2089	1	key, quarter	28480	
	5060-9803	1	assembly, handle strap	28480	
	7120-1254	1	nameplate	28480	
	8120-4383	1	cable assembly	28480	
	06023-00001	1	chassis	28480	
	06023-00002	1	cover, top	28480	
	06023-00003	1	cover, bottom	28480	
	06023-00004	1	bracket, upper	28480	
	06023-00009	1	cover, bar block	28480	
	06023-00011	1	rear panel, screened	28480	
	06033-00006	1	panel, sub frnt	28480	
	06033-00002	1	bracket, lower	28480	
	06033-00003	1	plate, HP-IB	28480	
	06038-00001	1	frnt panel screened	28480	
	06038-90001	1	operating and service manual	28480	
	0380-1489	1	snap-in spacer	28480	

SCHEMATIC DIAGRAMS

SECTION VII
COMPONENT LOCATION ILLUSTRATIONS AND CIRCUIT DIAGRAMS

7-1 This section contains component location diagrams, schematics, and other drawings useful for maintenance of the power supply. Included in this section are:

a. Component location illustrations (Figures 7-1 through 7-7), showing the physical location and reference designators of almost all electrical parts. (Components located on the rear panel are easily identified.)

b. Notes (Table 7-1) that apply to all schematic diagrams

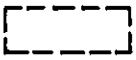
c. Schematic diagrams (Figures 7-8 through 7-11). Logic symbols used on the schematics are described in Appendix B.

WARNING

AC line voltage is present on the A1 Main Board Assembly whenever the power cord is connected to an ac power source.

Table 7-1. Schematic Diagram Notes

1.  denotes front-panel marking.

2.  denotes rear-panel marking.

3. Complete reference designator consists of component reference designator prefixed with assembly number (e.g.: A2R14).

4. Resistor values are in ohms. Unless otherwise noted, resistors are either 1/4 W, 5% or 1/8 W, 1%. Parts list provides power rating and tolerance for all resistors.

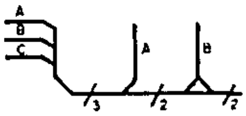
5. Unless otherwise noted, capacitor values are in microfarads.

6. Square p.c. pads indicate one of the following:
   a. pin 1 of an integrated circuit.
   b. the cathode of a diode or emitter of a transistor.
   c. the positive end of a polarized capacitor.

7. In schematic symbols drawn to show right-to-left signal flow, blocks of information are still read left to right. For example:

left to right — right to left

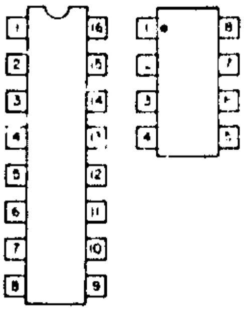
→ indicates shift away from control block (normally down and to right), ← indicates shift toward control block (normally up and to left).

8. 

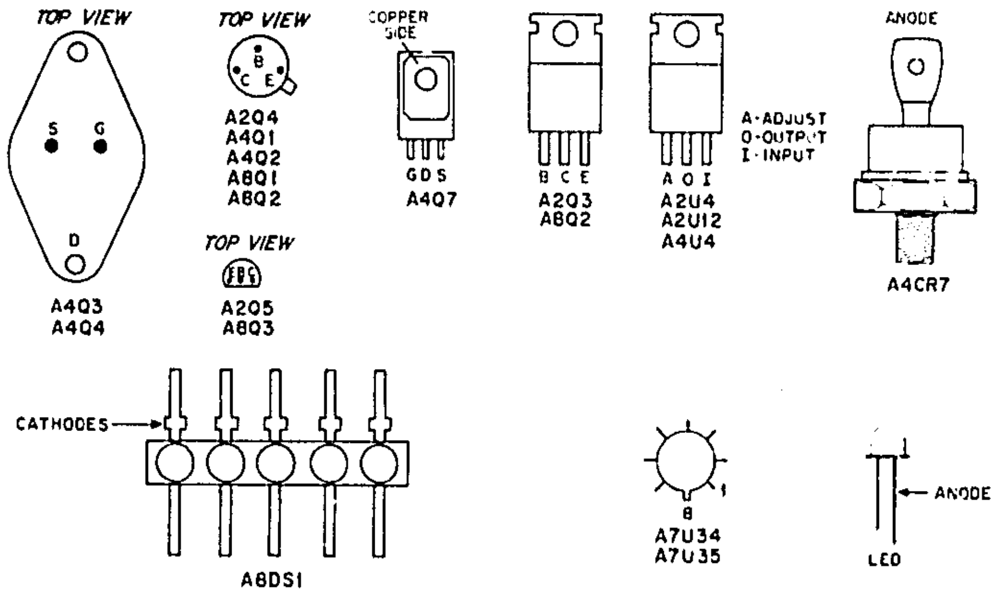
Indicates multiple paths represented by only one line. Reference designators with pin numbers indicate destination, or signal names identify individual paths. Numbers indicate number of paths represented by the line.

9. Inter-board commons have letter identifications (e.g.: L); commons existing on a single assembly have number identifications (e.g.: 2).

10. For single in-line resistor packages, pin 1 is marked with a dot. For dual in-line integrated circuit packages, pin 1 is either marked with a dot, or pin 1 is to the left (as viewed from top) of indentation at end of integrated circuit package, e.g.:



Pin locations for other semi-conductors are shown below:



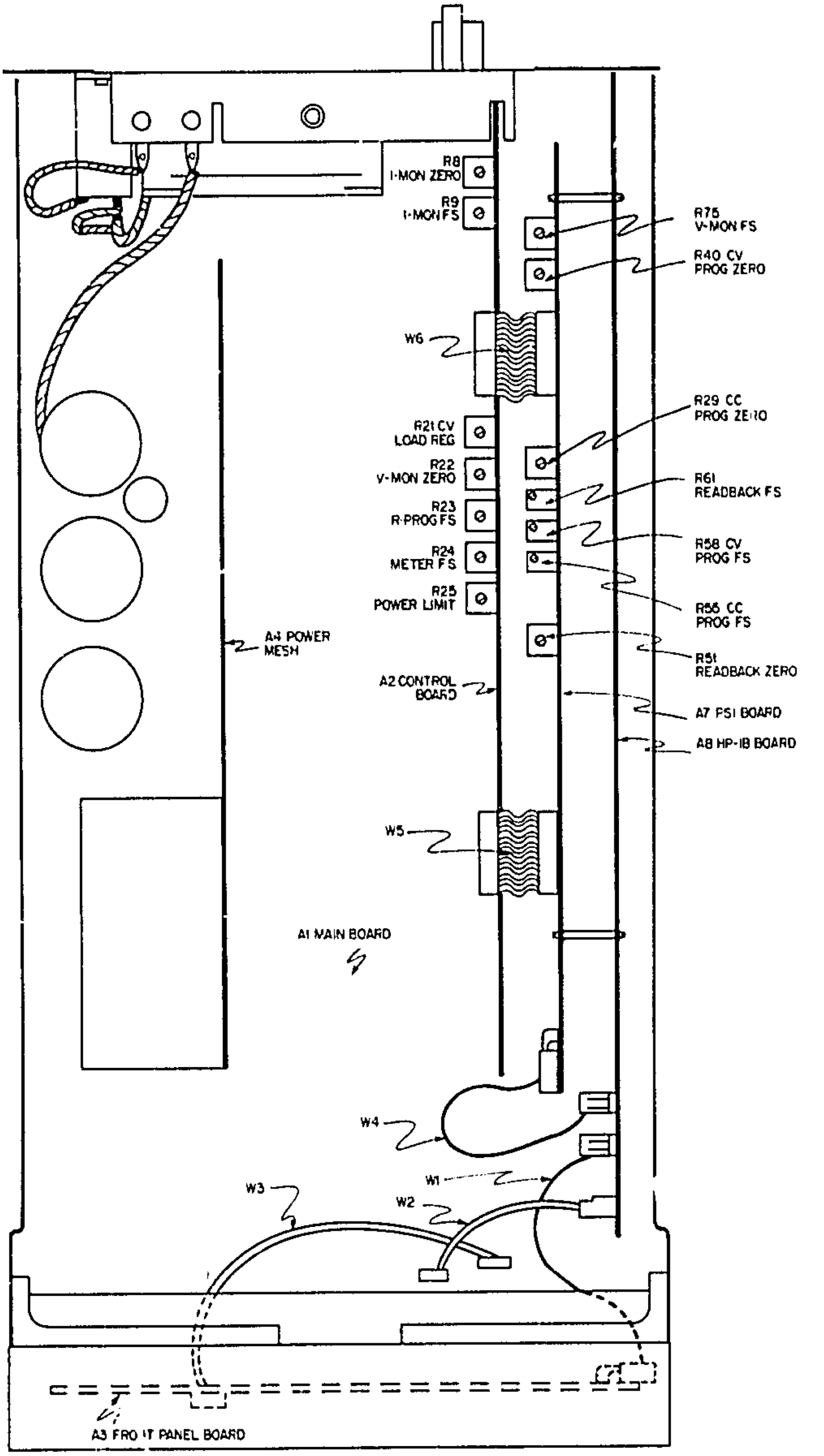


Figure 7-1. Top View, Top Covers Removed

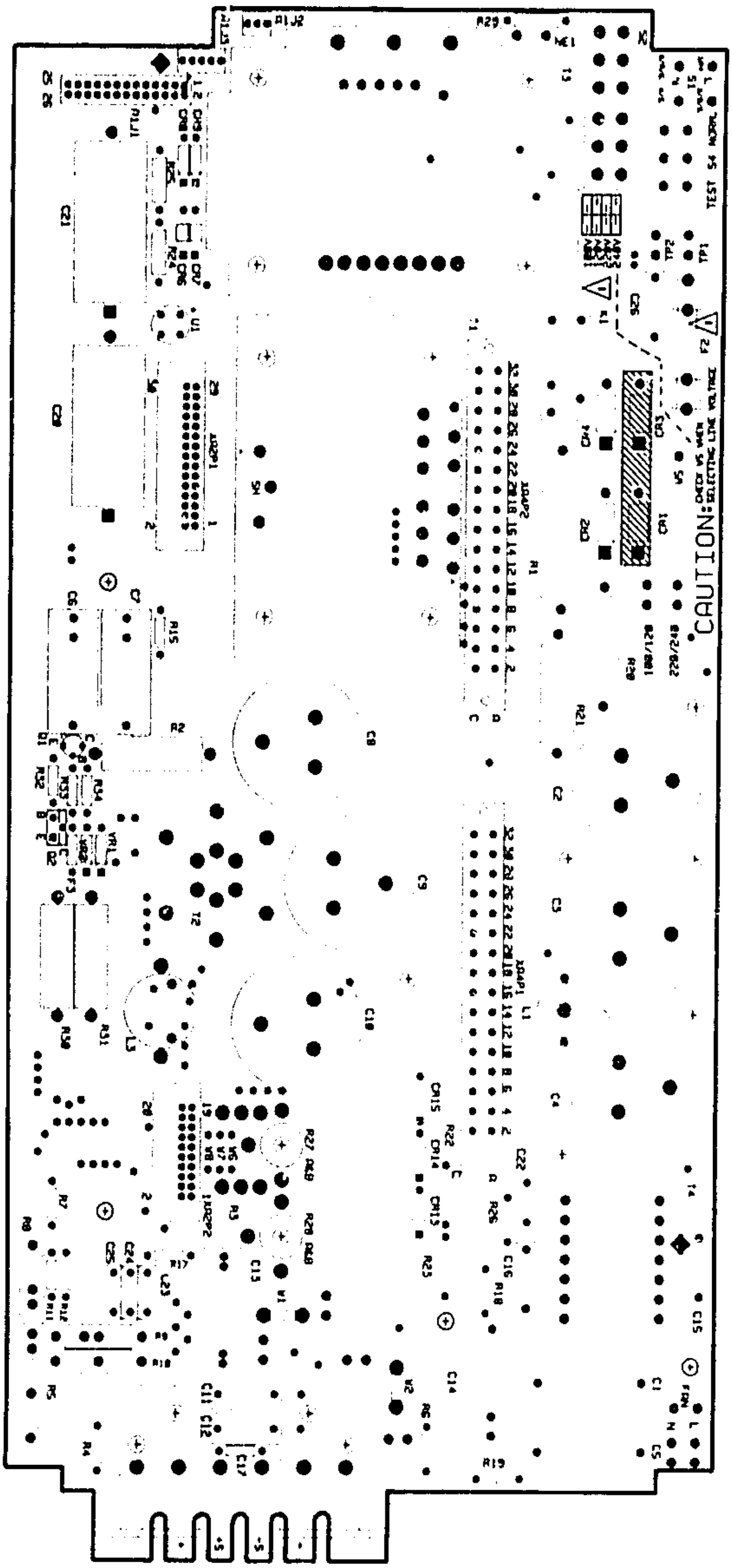


Figure 7-2. Main Board (A1) Component Location

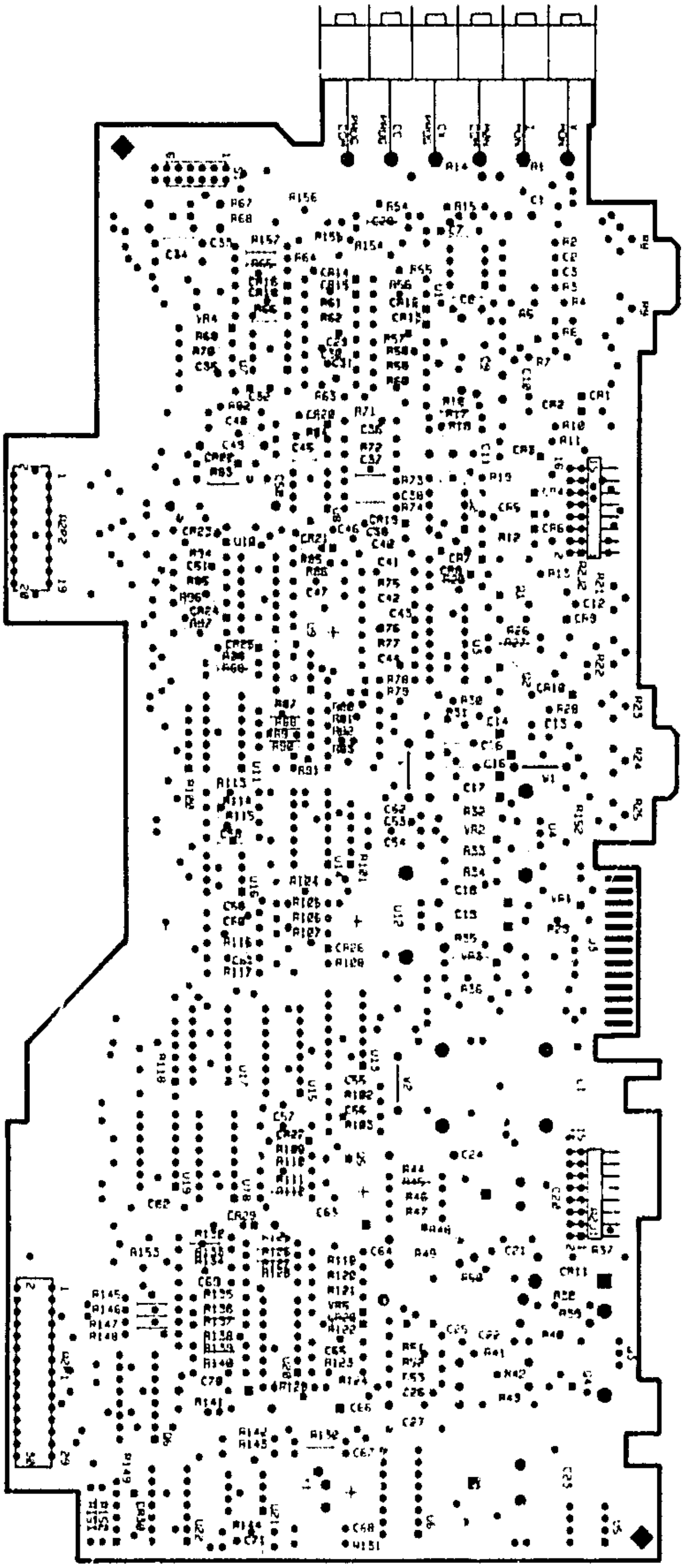


Figure 7-3. Control Board (A2) Component Location

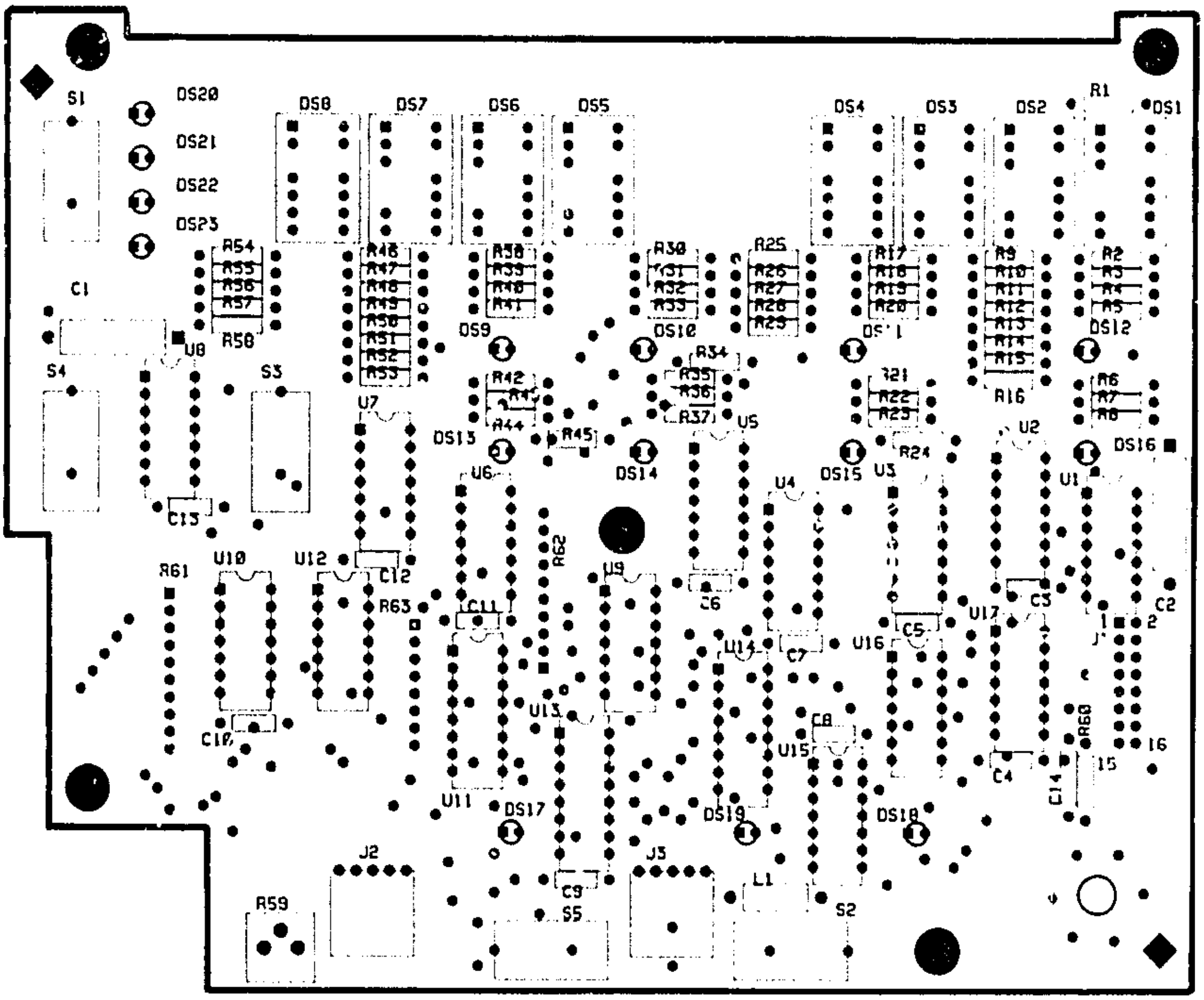


Figure 7-4. Front Panel Board (A3) Component Location

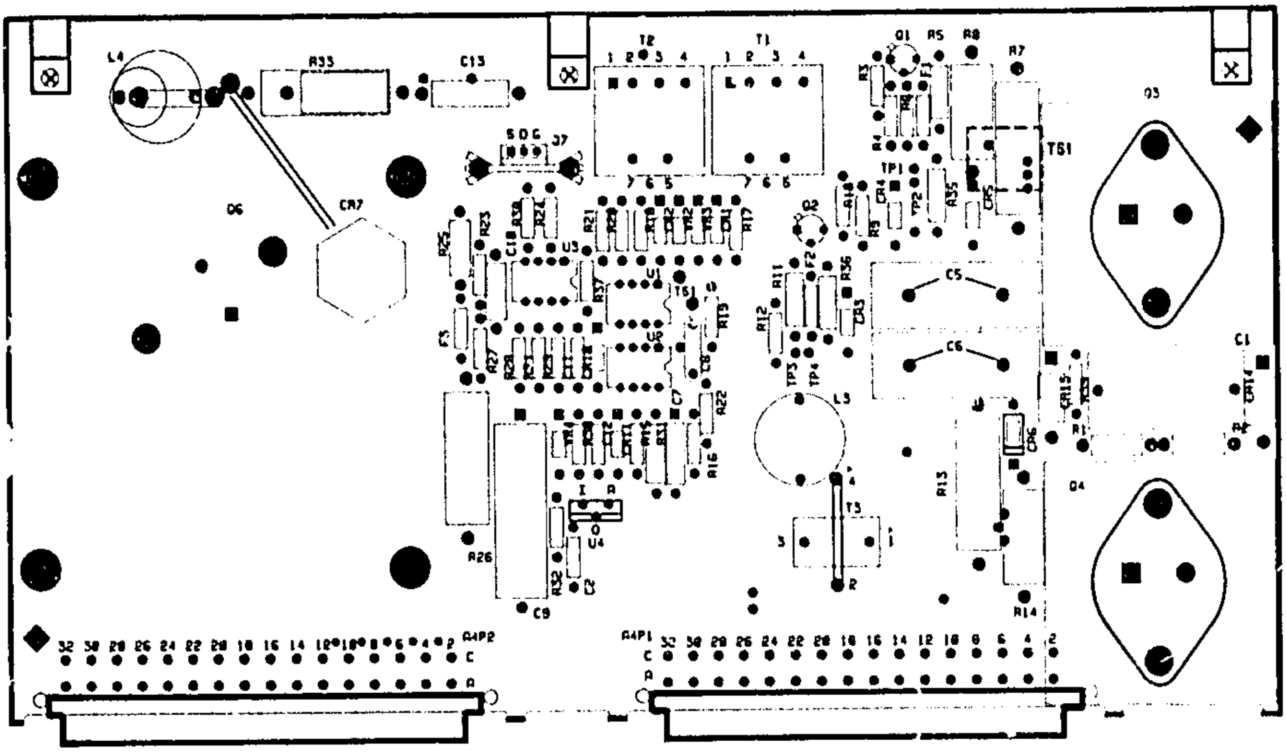


Figure 7-5. Power Mesh Board (A4) Component Location

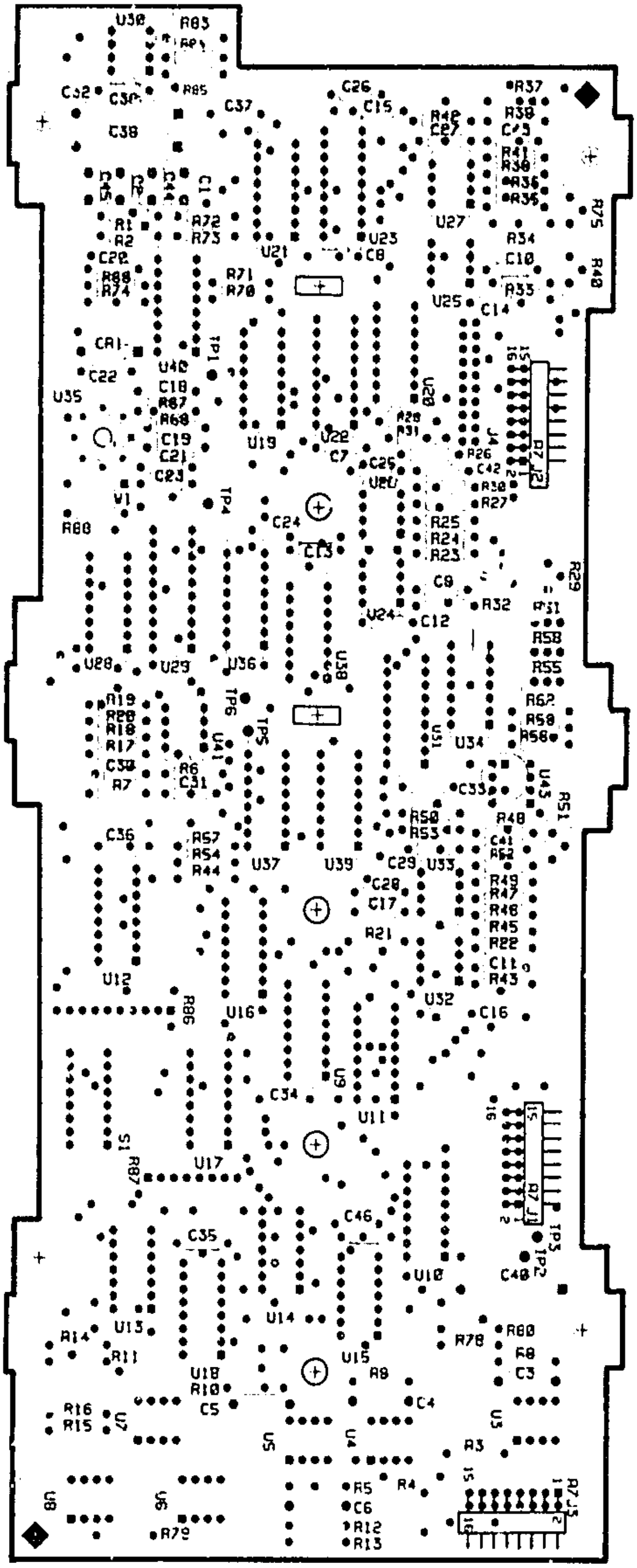


Figure 7-6. Power Supply Interface (PSI) Board (A7) Component Location

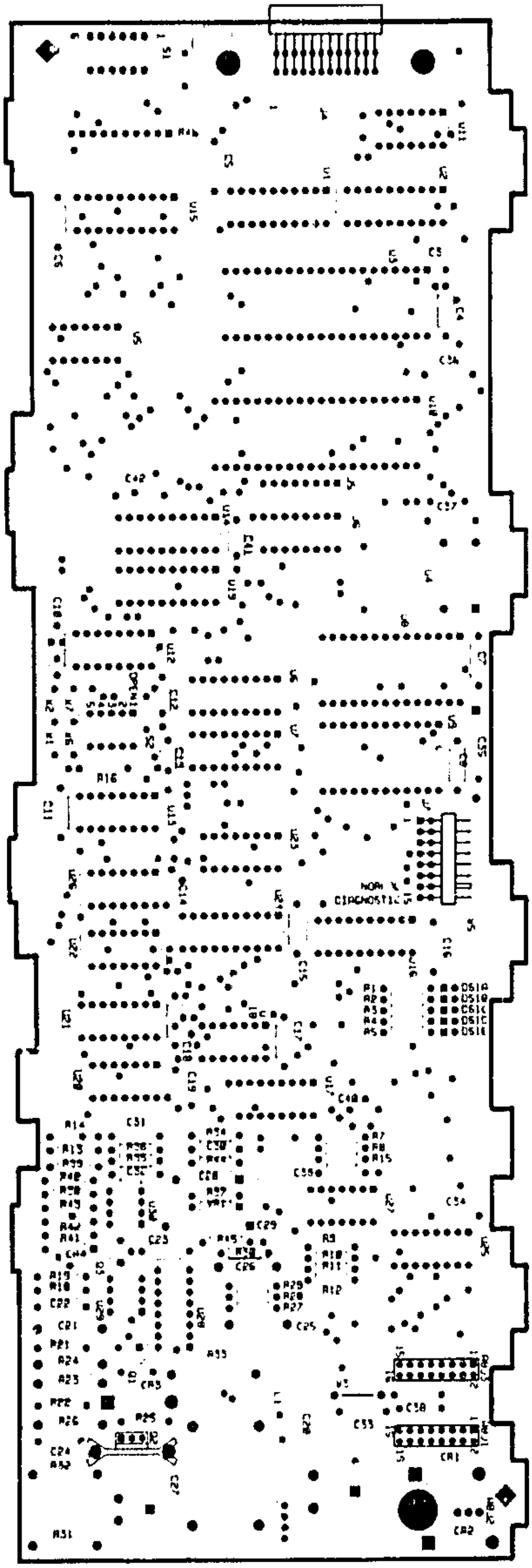


Figure 7-7. HP-IB Board (A8) Component Location

Power Mesh/Control Board Schematic Notes

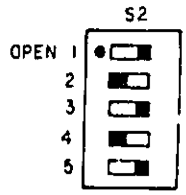
1. Line voltage select switch S2 is shown set for 120 Vac input. Jumper W5 is shown set for 100 Vac or 120 Vac input.

2. MODE switches are shown set for front-panel/HP-IB operation.

Figure 7-8. Power Mesh and Control Board Schematic Diagram

HP-IB Board Schematic Notes

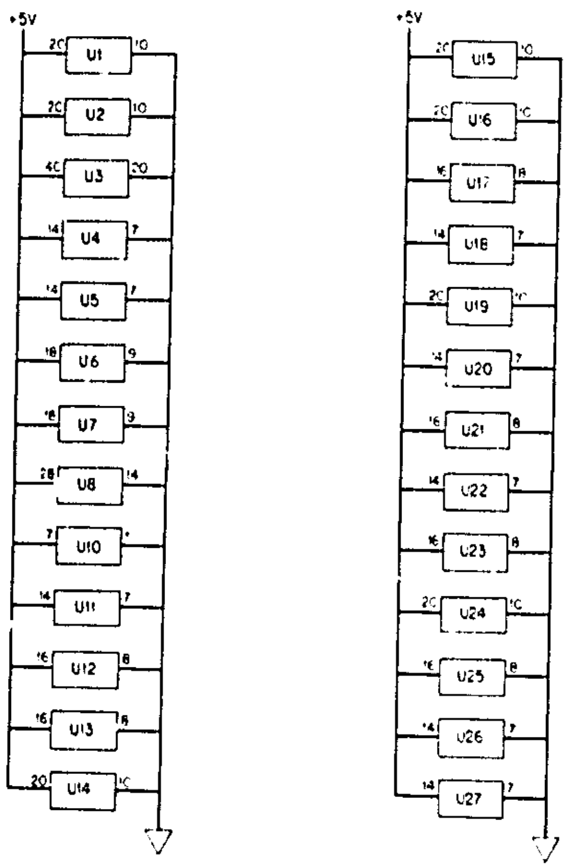
1. Switch S2 sections are shown set for normal operation:



2. Free-run jumper W4 and Diagnostic jumper W5 are shown set for normal operation.

3. Signal names followed by a prime symbol (e g.: R/$\overline{W}$') have been processed by circuits subsequent to the generation of the original signal.

4. Digital integrated circuit Vcc and Gnd connections are as follows:



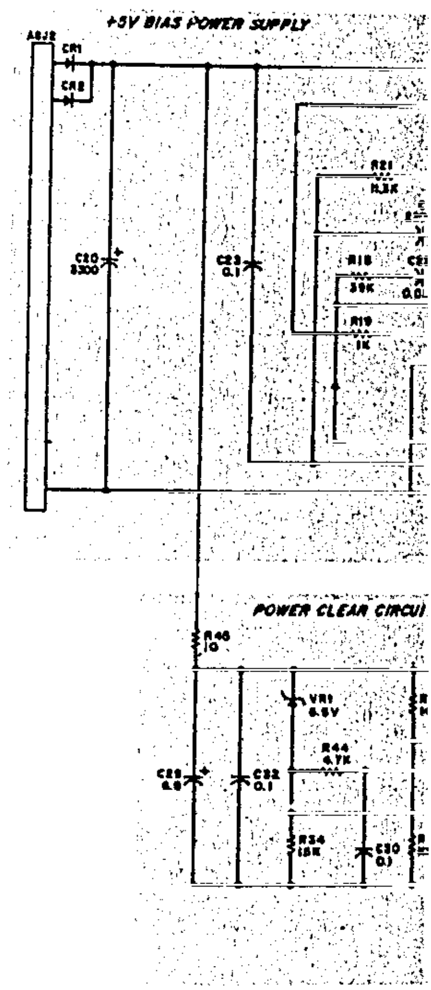
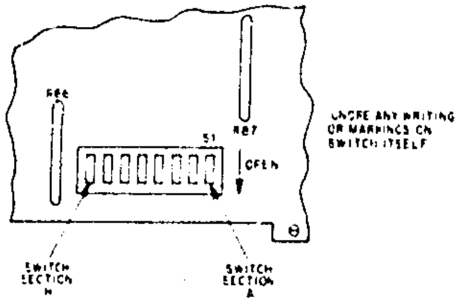


Figure 7-9. HP-IB Board Schematic Diagram

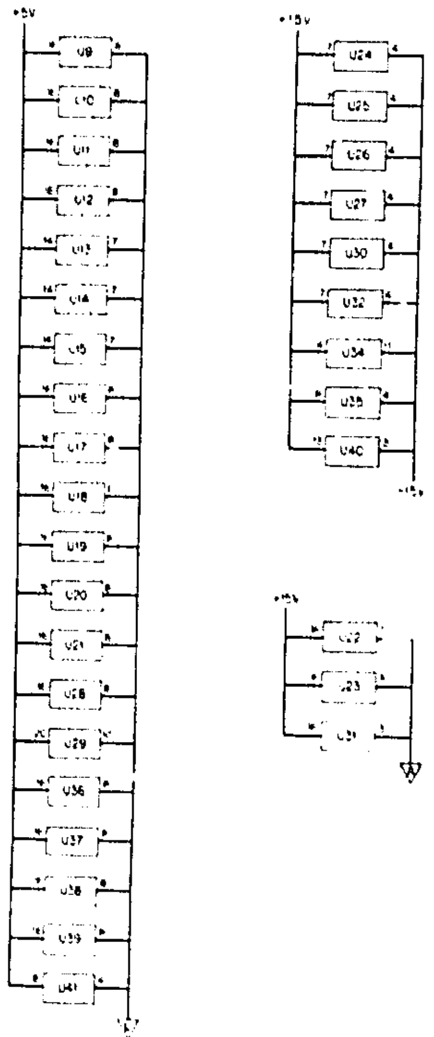
PSI Board Schematic Notes

1. Identification switch S1 sections are set as follows

A	B	C	D	E	F	G	H
closed for 120, 220, or 240 Vac; open for Option 100	closed	closed	closed	closed	closed	open	closed



2. Digital integrated circuit Vcc and Gnd connections are as follows:



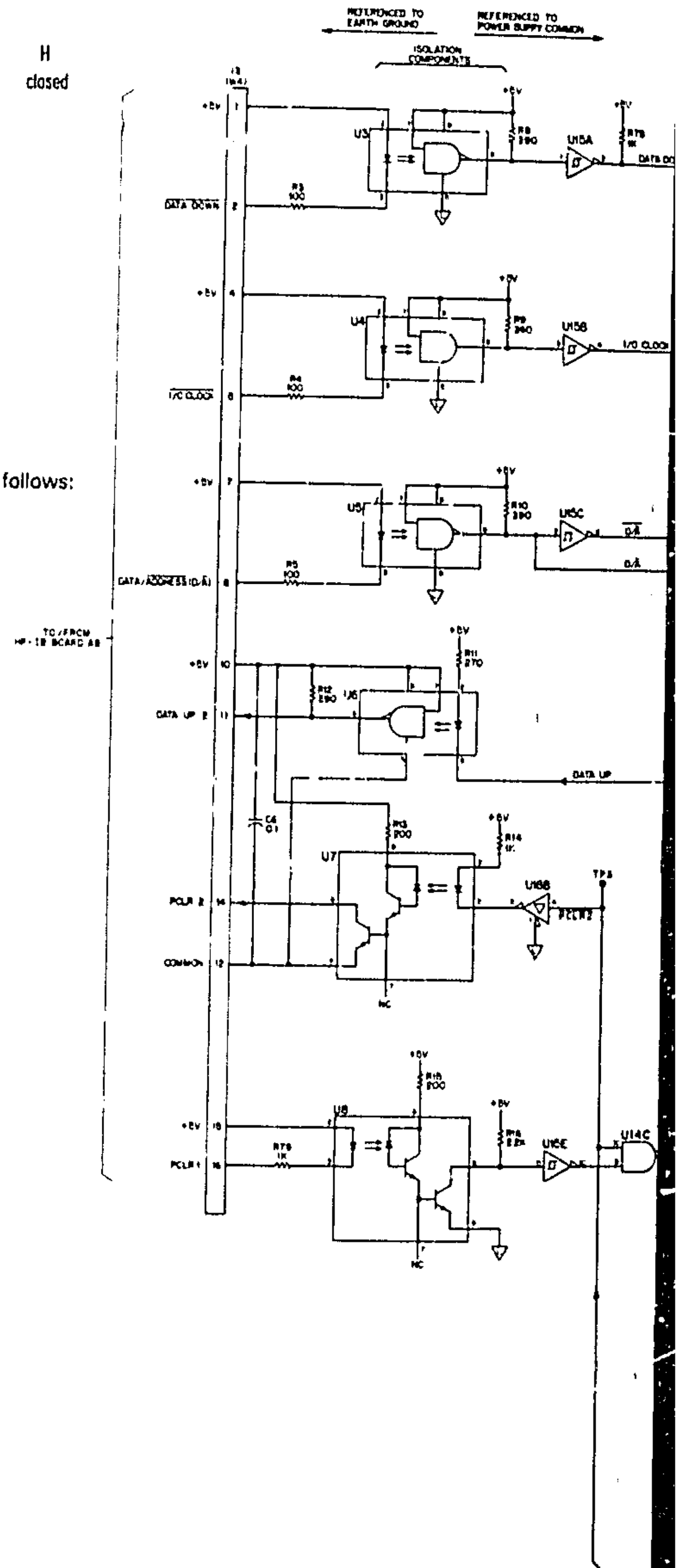


Figure 7-10. Power Supply Interface (PSI) Board Schematic Diagram

Front Panel Board Schematic Notes

1. Digital integrated circuit Vcc and Gnd connections are as follows:

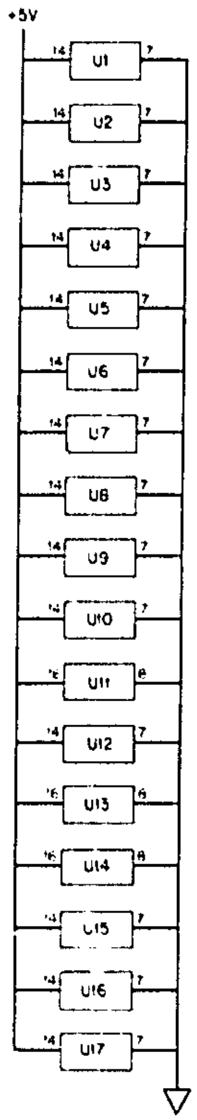


Figure 7-11. Front Panel Board Schematic Diagram

APPENDIX

A

Appendix A
100 Vac INPUT POWER OPTION 100

A-1 GENERAL INFORMATION

A-2 Description

A-3 Option 100 is a modification of HP 6038A that involves changing a resistor in the A2 OVP circuit, recalibrating the supply, and changing the Front Panel. These changes allow the unit to operate at a lower line voltage of 87 to 106 Vac, while operating on the same line frequency of 48 to 63 Hz. The reduced input voltage limits the output power to 150 W and the output voltage from 0 to 50 V, while retaining the standard unit's output current rating. Other specifications that change due to Option 100 include Programming Response Time, Overvoltage Protection and Remote Analog Programming.

A-4 Scope of Appendix A

A-5 This appendix contains all the information necessary to support HP 6038A power supplies that are equipped with Option 100. The appendix describes only the changes pertaining to Option 100 and how they affect the other portions of this manual. Unless otherwise specified in Appendix A, all other portions of the manual apply to both the standard unit and the Option 100 unit.

A-6 Suggestions for Using Appendix A

A-7 The Option 100 changes are listed sequentially, starting with Section I in the main body of the manual and working back through Section VII. It is recommended that the user mark all the necessary changes directly into his manual. This will update the manual for Option 100 and eliminate the need for constant referrals back to Appendix A.

A-8 Section I Manual Changes

A-9 In paragraph 1-4 change the output power from **200 watts to 150 watts.**

A-10 Specifications Changes

A-11 Table A-1 provides all the specifications changes for Option 100. Specification not listed in Table A-1 are the same as those in the main specifications Table 1-1.

A-12 INSTALLATION

A-13 Section II Manual Changes

A-14 **Line Voltage Option Conversion.** In paragraph 2-26, b; the line Voltage Select Switch, A1S2 is preset at the factory for 100 V operation. In paragraph 2-26, c; jumper A1W5 is already connected at the factory for 100 V operation. In paragraph 2-26, d; An 8A fuse is already installed and can be used for 100 volt operation. It is possible to convert the Option 100 unit to other line voltages by following the directions in paragraph 2-26, but the unit will maintain its derated 150 W, 50 V output.

WARNING

No attempt should be made by the user to uprate the Option 100 unit above its calibrated output voltage and power limits. To do so could result in severe damage to the unit and a fire hazard.

A-15 OPERATING INSTRUCTIONS

A-16 Section III Manual Changes

A-17 In paragraph 3-17, c; change **65 ±2 V** to **54 V ±1.4 V.**

A-18 In paragraph 3-32 change **65 volts** to **54 volts.**

A-19 In paragraph 3-55 change **Zero to 5 volts** to **0 to 4.167 volts.**

A-20 In Table 3-7, under Range or Response to Query, in the 1st box change **0 - 61.425 V** to **0 - 51.495 V** also change **0 - 61425 MV** to **0 - 51495 MV.** Make this same change in the 6th box of the same column. The initial condition of VMAX is 51.495 V.

A-21 In paragraph 3-196 change the second sentence to read: **Resistances of 0 to 3.333 kilohms program the output voltage from 0 to full scale.**

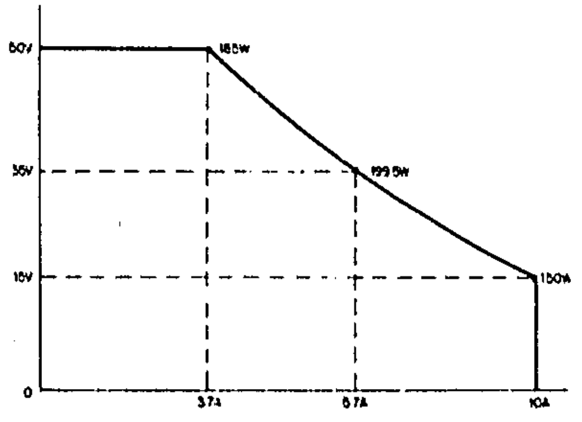
Table A-1. Specifications and Supplemental Characteristics

Input Current:

850 VA Maximum
325 W Maximum at 150 W output.

DC Output: Voltage and current can be programmed via HP-IB or front panel control over the following ranges:

Voltage: 0 - 50 V **Current:** 0 - 10 A. See graph and Table for maximum output power.



Programming Response Time: Maximum time for output voltage to change from 0 to 50 V or 50 V to 2 V and settle within 15 mV of final value.

		full load 18 ohms	light load 400 ohms	no load
Up:	0 - 50 V	225 ms	225 ms	225 ms
Down:	50 - 2 V	400 ms	750 ms	1500 ms

Typical programming response time data for changes other than full scale excursions:

		full load 18 ohms	light load 400 ohms	no load
Up:	0 - 50 V	150 ms	120 ms	120 ms
	0 - 30 V	120 ms	100 ms	100 ms
	20 - 50 V	120 ms	100 ms	100 ms
Down:	50 - 2 V	150 ms	400 ms	850 ms
	50 - 10 V	110 ms	210 ms	350 ms
	50 - 30 V	160 ms	340 ms	500 ms

Output Boundary Specification

Voltage (V)	Current (A)	Power (W)	Current (A)	Voltage (V)	Power (W)
15	10	150	4	48	192
20	8.5	170	5	40	200
25	7.5	187.5	6	33	198
30	6.5	195	7	28	196
35	5.7	199.5	8	23	184
40	5	200	9	19	171
45	4.3	194	10	15	150
50	3.7	185			

Overvoltage Protection: Trip voltage adjustable via front panel control.

Range: 0-54 V
Resolution: 100 mV
Accuracy: 0.25% +300 mV (Set using DISPLAY OVP function)
TC: 100 ppm +5 mV/°C

Minimum setting above output voltage to avoid nuisance tripping is 1.5 V.

Remote Analog Programming (25 ±5°C)

Resistance programming: 0 to 3.33 k provides zero to maximum rated output voltage. The resulting scale factor is 66.67 ohm/volt or 1 ohm/LSB. The current scale factor remains the same as the standard unit.

Voltage programming: 0 to 4.167 V provides zero to 50 V. The current scale factor is the same as the standard unit.

Voltage and Current Monitor Outputs (25 ±5°C)
0 to 4.167 V output indicates zero to maximum rated output voltage. Current monitor output scale factor remains the same as the standard unit.

A-22 In paragraph 3-198 change the second sentence to read: A voltage of 0 to 4.167 volts programs the output voltage from zero to full scale.

A-23 In paragraph 3-203 change 0 to 4000 ohms to 0 to 3.33 k ohms.

A-24 In Figure 3-9 change the programming Resistor to 0→3.33 kΩ (CV), 0→4 k (CC).

A-25 In paragraph 3-204 change 0 to 5 volts to 0 to 4.167 volts.

A-26 In Figure 3-10 change VOLTAGE SOURCE to 0→4.167 Vdc.

A-27 In Figure 3-11 change the Program Voltage E>5 Vdc to E>4.167 Vdc.

A-28 In paragraph 3-212 change 0 to 60 Vdc to 0 - 50 Vdc.

A-29 PRINCIPLES OF OPERATION

A-30 Section IV Manual Changes

A-31 In paragraph 4-124 change 5 Vdc to 4.167 Vdc.

A-32 In paragraph 4-136 wherever 200 watts is mentioned change to 150 watts.

A-33 MAINTENANCE

A-34 Section V Manual Changes

A-35 In Table 5-3 change under the heading, Correct Value and Tolerance, 60.0075 V ±1.82 mV to 50.0175 V ±1.52 mV, 5.000625 V ± 100 μV to 4.168125 V ± 80μV, and Toggles between 60 V and 60.015 V to Toggles between 50.01 V and 50.025 V.

A-36 In paragraphs 5-14 and 5-13, b; change VSET 60 to VSET 50.

A-37 In paragraph 5-20, e; change VSET 23 to VSET 21. For step d; change 10 amperes to 9.2 amperes. For step g; change 23± .05 volts to 22± 0.5 volts.

A-38 In paragraph 5-32, g; change VSET 60 V to VSET 50 V, h; change 59.93[illegible] [illegible] 60.061 to 49.9375 and 50.0621.

A-39 In paragraph 5-34, d; change 60.0 Vdc to 50 Vdc, i; change ±0.003 Vdc to ±.007 Vdc.

A-40 In paragraph 5-42, d; change 60.0 Vdc to 50 Vdc, j; change .120 V to .110 V.

A-41 In paragraph 5-44, c; change 60.0 Vdc to 50 Vdc e; change .014 V to .012 V.

A-42 In paragraph 5-47, c; change VSET 60 to VSET 50, g; change VSET 60 to VSET 50.

A-43 In paragraph 5-48, d; change 60 Vdc to 50 Vdc.

A-44 In paragraph 5-49, e; change 20 Vdc to 15 Vdc.

A-45 In Table 5-6, step (4) under SETUP, change 60 volts to 50 volts and under MEASUREMENT change 5 V to 4 167 V.

A-46 In Table 5-8, Pin #9, change 0 to 5 V to 0 to 4.16625 V, Pin #17 change 0 to 5 V to 0 to 4.16625 V, Pin #20, change −10 V to −8.3325 V, Pin #5, change 0 to 5 V to 0 to 4.16625 V.

A-47 In Table 5-9, Block #A7-5, outputs A7J4-5 changed 60 [illegible] 50 Vand under MEASUREMENT change, ≈5 V to ≈4.16625 V; under OUTPUTS NODE A7 U25/6 change 60 V to 50 V and under MEASUREMENT change ≈ −10 V to ≈ −8.3325 V. Under OUTPUT NODE A7 U27/6, change 60 V to 50 V and under MEASUREMENT change ≈5 V to ≈4.16625 V.

A-48 In Table 5-9, Block #A7.10, under INPUTS NODE A7 U40/9, change 60 V to 50 V and ≈5 V to ≈4.16625 V, make this same change to NODE A7 U30/3. Under NODE A7 U40/11 change ≈2.4 V to ≈1.8 V. Under PROCEDURE NODE A7 U30/6, change 60 V to 50 V, and ≈5 V to ≈4.16625 V, make this same change to NODE A7 U40/8 VMONT and CVPROG. Under OVP PROG change ≈2.1 V to ≈ 1.8 V. Under NODE A7 U35/7, In the last step change 30 V to 25 V.

A-49 In the WARNING of paragraph 5-114, change 320 Vdc to 250 Vdc.

A-50 In Table 5-11, under SYMPTONS, change Max Voltage <60 Vdc to max voltage<50 Vdc.

A-51 In paragraph 5-128 change 60 Vdc to 50 Vdc.

A-52 In paragraph 5-167 change 60 Vdc to 50 Vdc.

A-53 In Table 5-13, under SETUP S, change the third sentence to read: 50 V will correspond to a meter reading of 4.167 and 10 A will correspond to a meter reading of 5.00.

A-54 REPLACEABLE PARTS/SCHEMATIC DIAGRAMS

A-55 Section VI and VII Manual Changes

A-56 In the replaceable parts list and on the schematic diagram make the changes as indicated below:

DESCRIPTION
1. A2 board to HP P/N 05038-60024
a. A2R78 to HP P/N 0757-0415.
b. Option 100 Label (A2 board) HP P/N 9320-4957.
2. Front Panel to HP P/N 06038-00003.
3. Line voltage label (rear panel) to HP P/N 06023-81004.

APPENDIX

B

Appendix B
LOGIC SYMBOLOGY

The logic symbols used in this manual are based on ANSI/IEEE Std 91-1982 (or later), which is a revision of ANSI Y32.14. The following paragraphs and illustrations provide a brief description of the symbology to aid in interpreting the symbols. When referring to the symbols, it should be remembered that:

1. Power supply and ground connections usually are not shown on the symbols, but are listed separately on the schematic.
2. Items in brackets [ ] are not part of the symbol, but are included to help the user interpret the symbol.
3. Unless arrows indicate otherwise, inputs are on left, outputs are on right, and signal flow is from left to right.
4. In an array of two or more identical elements, only the first (top) element is shown in full detail.
5. When shown individually on a schematic rather than as part of an array, basic logic gates (AND, OR, buffer) are shown by distinctive-shape outlines (see Figure B-1).

Qualifier and Functional Labels. Figure B-2 shows qualifiers and functional labels. Qualifiers denote basic logic functions. For example, "&" denotes the AND function. Functional labels, such as DEMUX for a demultiplexer, identify complex devices.

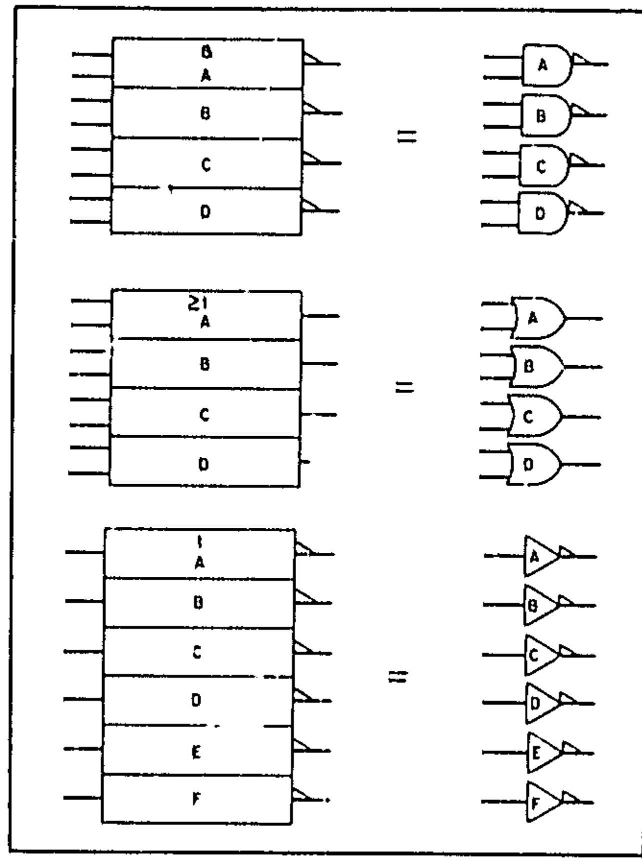


Figure B-1. Distinctive-Shape Outlines

Symbol	Description
FF	**Flip-Flop**- Binary element with two states, set and reset. When the flip-flop is set, its outputs will be in their active states. When the flip-flop is reset, its outputs will be in their inactive states.
&	**AND** - All inputs must be active for the output to be active.
≥1	**OR** - One or more inputs being active will cause the output to be active.
=1	**EXCLUSIVE OR** - Output will be active when one (and only one) input is active.
1	**Buffer or Inverter** - Without special amplification.
=m	**m and only m** - Output will be active when m (and only m) inputs are active (m is replaced with a number).
=	**Logic Identity** - Output will be active only when all or none of the inputs are active (i.e., when all inputs are identical, output will be active).
▷	**Amplifier** - The output will be active only when the input is active (can be used with polarity or logic indicator at input or output to signify inversion).
X/Y	**Signal Level Converter or Code Converter** Input level(s) are different than output level(s), or input code (X) is converted to output code (Y) per weighted values or table.
CTR	**Counter**- Produces one output pulse each time it receives a specific number of input pulses.
MUX	**Multiplexer** - The output is dependent only on the selected input.
DEMUX	**Demultiplexer** - Only the selected output is a function of the input.
REG	**Register** - Array of unconnected flip-flops that form a simple register or latch.
SRG*	**Shift Register** - Register in which data can be shifted from one stage to the next, the asterisk indicates the number of stages.
COMP	**Comparator** - The active output indicates which of two or more sets of inputs is of greatest magnitude.
1⎍	**Monstable (One-Shot) Multivibrator** - Output becomes active when the input becomes active. Output remains active (even if the input becomes inactive) for a period of time that is characteristic of the device and/or circuit.
BIN/OCT	**Binary-to-Octal Decoder** - Converts a three-line binary code to eight-line octal code.
HPRI/BIN	**High-Priority-to-Binary Encoder** - Encodes the address of the highest active of eight inputs to three line binary code.
#/∩	**Digital-to-Analog Converter** - Output current is a linear product of a digital word.
RAM	**Random Access Memory** - Addressable memory with read-in and read-out capability
ROM	**Read Only Memory** - Addressable memory with read-out capability only.
EPROM	**Erasable Programmable Read Only Memory** - Similar to a ROM in normal use, but can be erased and programmed with special equipment.

Figure B-2. Qualifiers and Functional Labels

Indicator Symbols. Indicator symbols identify the active state of a device's input or output, as shown in Figure B-3.

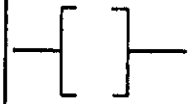
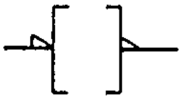
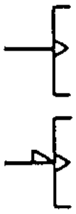
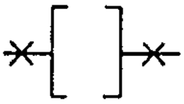
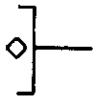
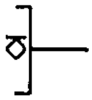
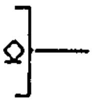
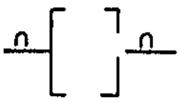
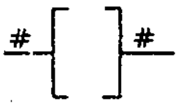
Symbol	Description
	**Implied Indicator** - Absence of polarity indicator (see below) implies that the active state is a relative high voltage level.
	**Polarity Indicator** - The active state is a relatively low voltage level.
	**Dynamic Indicator** - The active state is a transition from a relative low to a relative high voltage level, or from a high to a low voltage level if a polarity indicator is shown outside symbol.
	**Non-Logic Indicator** - Input or output does not carry logic information (e.g., RC inputs to a one-shot multivibrator).
	**Open-Circuit Output, general symbol**.
	**Open-Circuit Output, H Level** - NPN open emitter, PNP open collector, P-channel FET open drain, N-channel FET open source.
	**Open-Circuit Output, L Level** - NPN open collector, PNP open emitter, P-channel FET open source, N-channel FET open drain.
	**Analog Input or Output** - Used only when necessary to distinquish analog signals.
	**Digital Input or Output** - Used only when necessary to distinguish digital signals.
D	**Data Input** - Always enabled by another input (generally a C input-see Dependency Notation). Any D input is associated with storage.
→ m	**Shift Right (Down) Input** - When active, causes the contents of a shift register to shift to the right or down "m" places (m is replaced with a number). **NOTE** *If m = 1, it is omitted.*
	**Postponed Output** - Output delayed until input returns to its initial state.
▽	**Three-State Output** - Indicates outputs that can have a high-impedance (disconnect) state in addition to the normal binary logic states.
	**Bithreshold Input** - Input characterized by hysteresis; one threshold for positive-going signals and a different threshold for negative-going signals.
>	**Greater-Than** Input or Output of a magnitude comparator.
<	**Less-Than** Input or Output of a magnitude comparator.
=	**Equal Input or Output** of a magnitude comparator.
E	**Extension Input or Extender Output** - Connected between devices to extend the number of inputs.
	**Multiplier Input** - Analog input used to control a variable characteristic of a function (e.g., range).
CT	**Content** - Indicates the value of an input or output when active.
	**Binary Grouping** - m is highest power of 2.
	**Input Line Grouping** - Two or more terminals implement a single logic input.

Figure B-3. Input and Output Indicators

Contiguous Blocks. Two symbols may share a common boundary parallel or perpendicular to the direction of signal flow. Note that in the examples shown in Figure B-4 there is generally no logic connection across a horizontal line, but there is always an implied logic connection across a vertical line. Notable exceptions to this rule are the horizontal lines beneath control blocks and between sections of shift registers and counters.

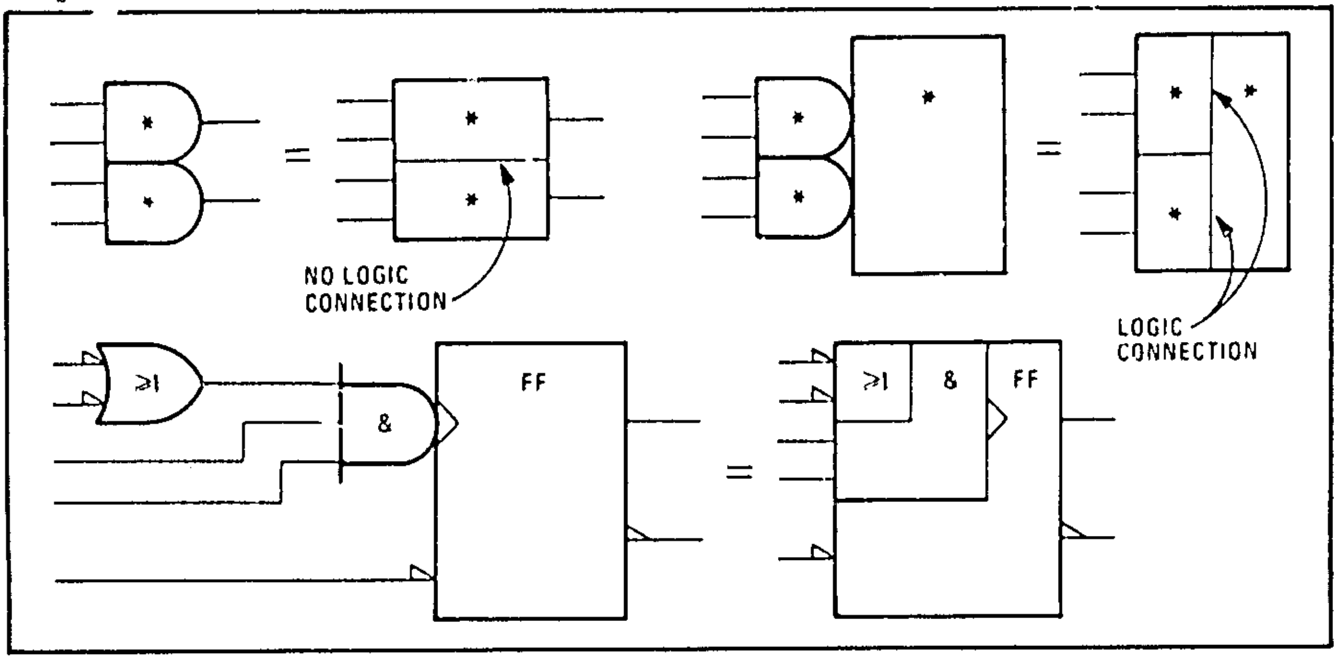


Figure B-4. Contiguous Blocks

Common Control Block. The Control block is used in conjunction with an array of related symbols in order to group common logic lines. Figure B-5 shows how the Control block is usually represented. Figure B 6 shows a quad D type flip flop with reset. This can be redrawn as shown in Figure B 7. Note that the more complex representation shown in Figure B 6 can be used when the flip-flops are functionally scattered around the schematic (i.e., not used as a quad unit).

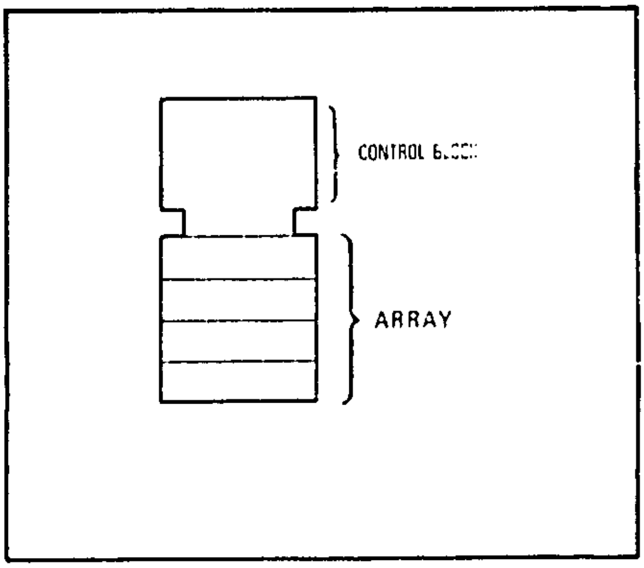


Figure B-5. Common Control Block

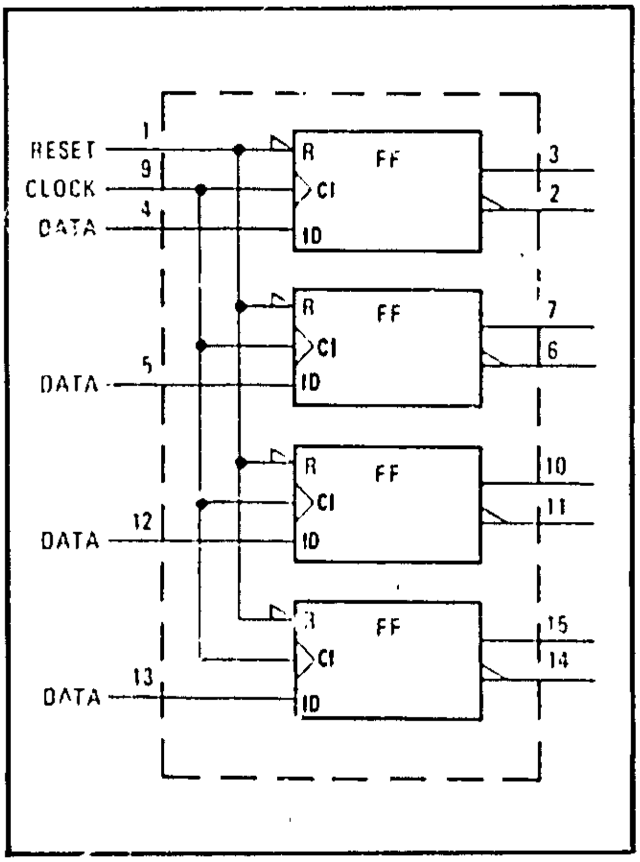


Figure B-6. Quad D-Type Latch (Individual)

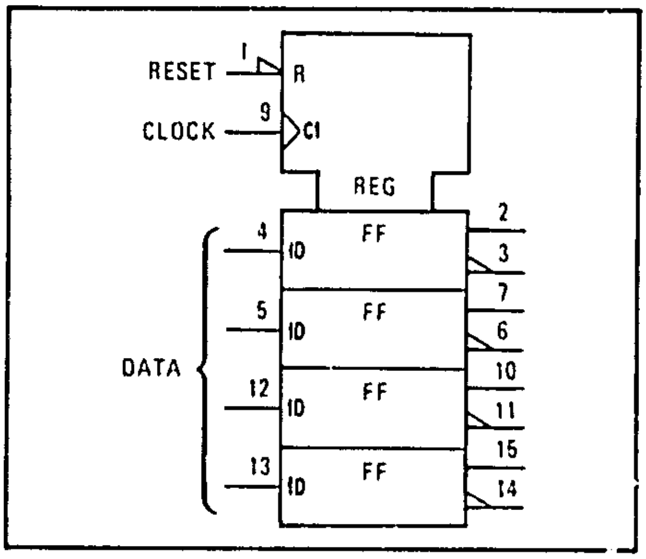


Figure B-7. Quad D-Type Latch (Combined)

Dependency Notation. Dependency notation simplifies symbols for complex integrated circuit elements by defining the interdependencies of inputs or outputs without actually showing all the elements and interconnections involved. (See Figure B-8 and B-9 for examples of AND dependency and enable dependency.)

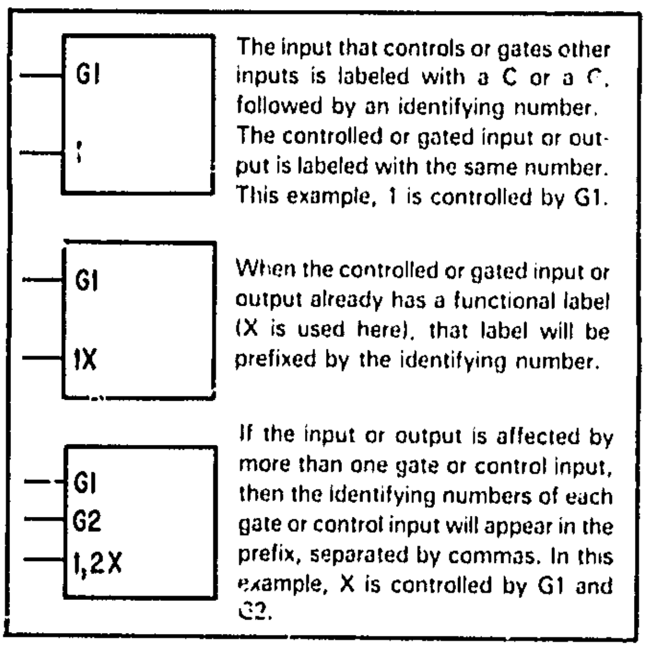


Figure B-8. AND Dependency Notation

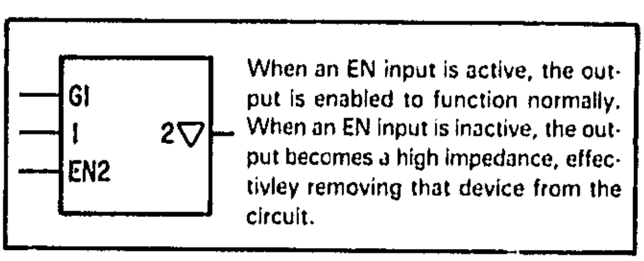


Figure B-9. Enable Dependency Notation

Application of dependency notation is accomplished by:

1. labelling the input affecting other inputs or outputs with the letter symbol denoting the relationship involved followed by an appropriately chosen identifying number, and
2. labelling each input or output affected by the affecting input with that same number.

If it is the complement of the internal logic state of the affecting input or output that does the affecting, a bar is placed over the identifying number at the affected input or output.

If the affected input or output requires a label to denote its function, this label shall be prefixed by the identifying number of the affecting input.

If an input or output is affected by more than one affecting input, the identifying numbers of each of the affecting inputs shall appear in the label of the affected one separated by commas. The left-to-right reading order of these identifying numbers is the same as the sequence of the affecting relationships.

Two affecting inputs labelled with different letters shall not have the same identifying number, unless one of the letters is A.

If two affecting inputs have the same letter and the same identifying number, they stand in an OR relationship to each other.

If the labels denoting the functions of affecting inputs or outputs must be numbers (e.g., outputs of a coder), the identifying numbers to be associated with both affecting inputs and affected inputs or outputs shall be replaced by another character selected to avoid ambiguity (e.g., Greek letters).

An affecting input affects only the corresponding affected inputs and outputs of the symbol.

Note that dependency notation is usually indicated by numbers. The numbers themselves have no value; they simply relate two or more points having the same number. However, sometimes an input or output has a weighted value (e.g., 1,2,4,8); in these cases a non-numeric symbol (e.g.,∝) may be used to avoid confusion between a weighted value and the dependency notation.

Eleven types of dependencies are defined, as listed below:

A **Address** - Identifies the address inputs of a memory.

C **Control** - Identifies an input, such as a timing or clock input, that produces action, and indicates which other inputs are controlled by it. Used for sequential elements (flip-flops, registers), and may imply more than a simple AND relationship.

EN **Enable** - Identifies an input that enables outputs, and indicates which outputs are affected by it. Acts as a connect switch when active, and a disconnect switch when inactive.

G **Gate (AND)** - Identifies an input having an AND relationship with other inputs or outputs having the same identifier number (or symbol).

M **Mode** - Identifies an input that selects the mode of operation, and indicates which inputs and outputs depend on that mode.

N **Negate** - Identifies an input that when active, complements other inputs or outputs, and identifies which inputs and outputs are affected.

R **Reset** - When active, causes a flip-flop to reset.

S **Set** - When active, causes a flip-flop to set.

V **OR** - Identifies an input having an OR relationship with other inputs or outputs having the same identifier number (or symbol).

X **Transmission** - Identifies an input that makes or breaks bidirectional connections between affected input/output ports.

ℓ **Interconnection** - Identifies a point that is internally connected to another input, output, internal input, or internal output having the same identifier number (or symbol).

Connections to Discrete Components. Discrete components that are a functional part of the logic device connect to pins marked as shown in Figure B-10.

[B]	Bias components
[C]	Current - Monitor components
[D]	Divider components
[E]	External components, miscellaneous
[F]	Frequency, Frequency Compensation, Timing components
[G]	Gain-Determining components
[N]	Null components
[T]	Terminating components
[d]	Differentiating components
[∫]	Integrating components

Figure B-10. Connections to Discrete Components

Miscellaneous Terms and Symbols. Figure B-11 shows miscellaneous terms and symbols that are used in conjunction with the logic symbols, function tables, and truth tables used in this section.

H	**High** - The more positive algebraic value.
L	**Low** - The more negative algebraic value.
Q_0	The level of Q (output) before steady-state input.
Q_n	The level of Q (output) before control-signal transition
↑	Transition from low to high.
↓	Transition from high to low.
↔	Bidirectional signal flow.
I	**Internal Connection** - Connection between two circuit areas within a device.
Active	**Active State** - A binary physical or logical state that corresponds to the true state of an input, an output, or a function. The opposite of the inactive state.
Enable	**Enabled Condition** - A logical state that occurs when dependency conditions are satisfied. Functions are assumed to be enabled when their behavior is described. A convenient way to think of it is as follows: A function becomes active when: 1 Its external stimulus (e.g., voltage level) enters the active state. 2. Its external stimulus (e.g., voltage level) enters the active sta'. .

Figure B-11. Miscellaneous Terms and Symbols

Basic Logic Symbols. Figure B-12 shows the symbols for each of the basic logic devices used in this instrument. Also included are the HP part number, the part number of the device from a typical manufacturer, and the reference designators for each use of the device in this instrument.