

DC POWER SUPPLY
HVR SERIES, MODEL 6522A
SERIAL NUMBER PREFIX 5J

Printed: July, 1966
Stock Number: 06522-90001

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HVR

MANUAL CHANGES

Model 6522A DC Power Supply
Manual HP Part No. 06522-90001

Make all corrections in the manual according to errata below, then check the following table for your power supply serial number and enter any listed change(s) in the manual.

SERIAL		MAKE CHANGES
Prefix	Number	
All	—	Errata
5J	0290 - 0369	1
7H	0370 - 0479	1, 2
7H	0480 - 0500	1, 2, 3
7H	0501 - 0644 *	1, 2, 3, 4
7H	0645 - 0674	1 thru 5
7H	0675 - 0694	1 thru 6
7H	0695 - 0734	1 thru 7
7H	0735 - 0790	1 thru 8
1152A	0791 - 0805	1 thru 9
1152A	0806 - 0850	1 thru 10
1152A	0851 - 1012	1 thru 11
1503A	1013 - 1117	1 thru 12
1634A	1118 - 1177	1 thru 13
1716A	1178 - 1222	1 thru 14
1817A	1223 - 1237	1 thru 15
1820A	1238 - 1267	1 thru 16
1903A	1268-up	1 thru 17

ERRATA:

Page 1-1, Paragraph 1-9, change last sentence to read:
"The power supply is insulated to permit operation up to 2,000Vdc off ground, i. e., the maximum potential between either output terminal and ground shall not exceed 2kV above the maximum rated output."

Page 1-2, change Constant Voltage Temperature Coefficient to "0.012% plus 1mV".

Page 1-2, under "Calibration Accuracy", delete the word "full".

Page 3-1, Paragraph 3-4, change last sentence to read:
"It is not recommended that the power supply be floated above 300Vrms at frequencies below 500Hz".

Page 3-2, Paragraph 3-10, add the following statement:
"The mating connectors for the output terminals are of the UG-932 type, HP Part No. 1250-0927, and the cable type is RG-59/U, HP Part No. 8120-0019. Due to the high output voltage of the supply, it is important that only this type cable be used".

Page 4-5, Paragraph 4-42 change "F1" to "F3". Also change "approximately 160 volts" to "approximately 320 volts".

Page 5-3, Paragraph 5-9, add steps e and f as follows:

e. Reset front panel VOLTAGE controls until controls indicate exactly the maximum rated output voltage.

f. The differential voltmeter should indicate:

Model	6521A	6522A	6525A
Volts dc	10 ±0.1	20 ±0.2	40 ±0.4

Page 5-4, Paragraph 5-16, add new Step a, as follows:

"Step a. Connect supply as given in Paragraph 5-15(a)".
Change existing steps "a" through "d" to "b" through "e", respectively.

Page 5-6, Paragraph 5-32, at end of paragraph add:

NOTE

Under no circumstances should fuse F3 be replaced with a regular or slo-blo fuse.

Page 5-7, Paragraph 5-37, step f-3: Change to read "Waveform across test points 60 (positive lead) and 53 (waveform shown on schematic diagram)".

Page 5-7, Paragraph 5-37, step f-4: Change to read "Waveform across test points 56 (positive lead) and 53 (waveform shown on schematic diagram)".

In the replaceable parts table, make the following changes:

C28: fxd, paper 1μF, 400Vdc, HP Part No. 0160-2580.
CR1, 70-72, 74-78: Change to Rect. Si. 500mA 200prv 1N3253, RCA, HP Part No. 1901-0389.

F3: Add "fast blow, ceramic body" to description; add HP Part No. 2110-0227.

L1: Add HP Part No. 9100-1892.

L2, 3: Add HP Part No. 9100-1893.

L4A: Add HP Part No. 9100-1891.

M1: Meter Type 673/S movement 200μA @ 1000Ω
F. S. Plastic Pointer 0-100mA, 09182, HP Part No. 1120-1348.

M2: Meter Type 673/S movement 200μA @ 1000Ω
F. S. Plastic Pointer 0-2kV, 09182, HP Part No. 1120-1345.

R15: Change to fxd, ww, 200Ω, ±5%, 5W, 243E2015, Sprague, HP Part No. 0811-1204.

R19: Add resistor R19, 200 ohms, ±5%, 1/2W, AB., HP Part No. 0686-2015.

R126: Change to fxd, ww, 15kΩ, ±5%, 5W, Type 5XM, W. L., HP Part No. 0811-1867.

S1: Add HP Part No. 3101-0984.

T1: Add HP Part No. 9100-1887.

Manual Changes

Model 6522A HP Part No. 06522-90001

Page - 2 -

T2: Add HP Part No. 9100-1889.

T3: Add HP Part No. 9100-1890.

In the replaceable parts table, delete listings under S2 for R200, R201-209, R211-219, R221, R222, S201-203 and replace them with the following breakdown:

<u>Ref. Desig.</u>	<u>Description</u>	<u>HP Part No.</u>
S2	Thumbwheel Assembly (See items marked with *)	06522-60001
	* Deck 1 (L to R) H-V Board	06522-60003
	* R221, R222 1 Meg, 1W	0698-5506
	* Deck 2 (L to R) P. C. Board	5060-6113
	* R211-R219 200k, 1W	0698-5505
	* Deck 3 (L to R) P. C. Board	5060-6112
	* R201-R209 20k, 1W	0698-5522
	* Deck 4 (L to R) Pot Board (R200)	06522-60002

The waveforms shown on the attached sheet should be pasted down on the apron of the schematic diagram.

On the schematic diagram at the rear of the manual, make the following corrections:

Reverse the polarity of capacitor C32. The positive side of the capacitor should now be connected to the junction of the cathodes of CR20 and CR21.

Change the voltage between test points 52 and 53 to 160 ±10Vdc.

Add test point 55 at the cathode of CR18.

Change the test point at the cathode of CR17 from 53 to 55.

Reverse polarity of C27. The negative side of the capacitor should now be connected to the emitter of Q16.

Change reference designator of diode connected in +OUT lead from CR27 to CR72.

Change reference designator of diode in base circuit of Q13 from CR5 to CR6.

Reverse the polarity of diode CR3. Cathode should now be connected to the base of Q1A.

Change voltage at test point 18 to 12.4 ±0.6Vdc.

Change voltage at test point 17 to 6.2 ±0.3Vdc.

Change voltage at test point 9 to -0.65Vdc (referenced to +S terminal).

Change voltage at test point 11 to -1.8Vdc (referenced to +S terminal).

In the "NOTES", add the following to Note 5:
CURRENT control set fully clockwise.

In the "NOTES", add the following:
Note 7. Under no circumstances should fuse F3 be replaced with a regular or slo-blo fuse.

CHANGE 1:

In the replaceable parts table make the following additions:
CR1, 70-72, 74-78: Change to Rect. Si. 500mA 200prv, 1N3253, RCA, HP Part No. 1901-0389.
R19: Add resistor R19, fxd, comp 200Ω ±5% 1/2W, EB-2015, A. B., HP Part No. 0686-2015.
VR2: Diode zener 6.2V ±5%, 250mW, 1N825, Transitron, HP Part No. 1902-1221.

On the schematic at the rear of the manual add resistor R19 (200Ω) in series with the lead connecting the + output terminal to the shield (surrounding the lead between R200 and T.P. 2).

CHANGE 2:

On the title page, change Serial Number Prefix from "5J" to "7H".

In the replaceable parts table, make the following changes:
CR15, CR16: Change to SCR 35A 400prv, HP Part No. 1884-0058.

R4: Change to fxd, ww, 3k, ±5%, 3W, 242E3025, Sprague, HP Part No. 0812-0010.

Boron Nitride Insulators: Add 2; HP Part Nos. 0340-0175, and 9; HP Part Nos. 0340-0452.

Teflon Bushing: Add 2 bushings, HP Part No. 0340-0415.

CHANGE 3:

In the replaceable parts table, change R16 to fxd, ww, 39Ω, ±5%, 2W, Type BWH, IRC, HP Part No. 0811-2244.

CHANGE 4:

* This change is applicable to Serial Numbers 7H0540-up and to units with the following Serial Numbers: 7H0501, 7H0510, 7H0514, 7H0515, 7H0517, 7H0518, 7H0521, 7H0523-7H0525, 7H0529, 7H0531, 7H0533, 7H0534, 7H0535, 7H0537, and 7H0538.

In the replaceable parts table, make the following changes:
C41: Change to 0.1μF, 200V, HP Part No. 0160-0168.
R100: Change to 510Ω, ±5%, 1/2W, A. B. EB-5115, HP Part No. 0686-5115.
CR68: Add diode, Si, I. T. T., S270, HP Part No. 1901-0050.

R111: Add fxd, comp, 1.2kΩ, ±5%, 1/2W, A. B., EB-1225, HP Part No. 0686-1225.

Add Voltage Doubler Circuit as follows:

P. C. Board (Includes Components), HP Part No. 652528.

C35, 36: 1μF, 450V, HP Part No. 0180-1845.

CR13, 14: Rect. Si., G. E., HP Part No. 1901-0388.

R28: fxd, ww, 30kΩ, ±5%, 10W, Sprague, Type 247E, HP Part No. 0811-1918.

R29: fxd, comp 100Ω, ±5%, 1/2W, A. B., EB-1015, HP Part No. 0686-1015.

All of Change 4 is shown on the schematic on the separate

page. For convenience, this schematic may be pasted down on top of the existing schematic at the rear of the manual.

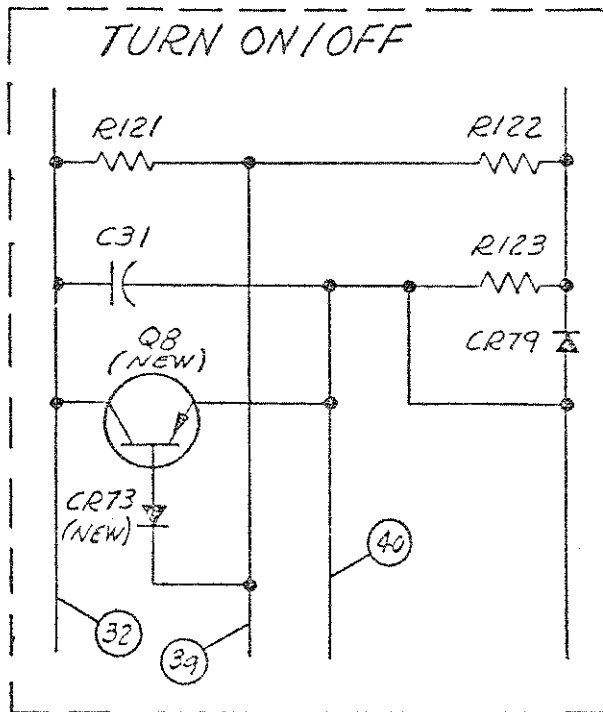
Note that all applicable changes listed under ERRATA have also been made on this paste-down schematic.

CHANGE 5:

In the replaceable parts table, make the following changes:

- C29: Change to 200 μ F, 65V, HP Part No. 0180-1884.
- Q8: Add A8, Si, PNP, HP Part No. 1853-0099.
- CR73: Add CR73, Si, Rect. HP Part No. 1901-0033.

On the schematic diagram, add new transistor and diode as shown in the following sketch. Q8 prevents F3 from blowing when unit is turned on and off rapidly.



CHANGE 6:

In the replaceable parts table, change HP Part No. 1250-0735 for HV BNC connector to HP Part No. 1250-1267

CHANGE 7:

In the replaceable parts table and on the schematic, make the following changes:

- C20: Change to 0.022 μ F, 400V, HP Part No. 0160-3892.
- R46: Change to 200 Ω , 5W, HP Part No. 0811-1204.

CHANGE 8:

In the replaceable parts table, and on the schematic, make the following changes in the pulse width modulator:

- R17: Change to 43 Ω , 2W, HP Part No. 0698-3614.
- R46: Change to 400 Ω , 5W, HP Part No. 0811-1857.
- R47: Change to 43 Ω , 2W, HP Part No. 0698-3614.
- Add R133: In parallel with R46, 400 Ω , 5W, HP Part No. 0811-1857.
- Add R134, R135: In parallel with R17 and R47, respectively. Both are 43 Ω , 2W, HP Part No. 0698-3614.

CHANGE 9:

On the title page, change the serial number prefix from "7H" to "1152A".

In the replaceable parts table and on the schematic diagram, make the following changes:

- F3: Change to 6A, 250V normal blo, HP Part No. 2110-0056.
- CR17, 18, 19: Change to HP Part No. 1901-0660.
- CR20, 21, 22, 23: Change to HP Part No. 1901-0314.

CHANGE 10:

The standard colors for this instrument are now mint gray (for the front panel) and olive gray (for all other surfaces). Option X95 designates use of the former color scheme of light gray and blue gray. Option A85 designates use of a light gray front panel with olive gray used for all other external surfaces. New part numbers are shown below:

CHANGE 11:

In the parts list on page 6-7, delete line cord 8120-0852, and add line cord 8120-1348 and ac receptacle 1251-2357. In the color change table on the change sheet in the Standard and Option A85 columns, change the rear chassis part number to 06525-00019.

ERRATA:

Change thyristors CR15 and CR16 to 1884-0058. This is

DESCRIPTION	HP PART NO.		
	STANDARD	OPTION A85	OPTION X95
Front Panel, Complete	06525-00017	06525-00014	06525-00014
Cover, Side (1)	06525-00016	06525-00016	06525-00002
Cover, Side (2)	06525-00015	06525-00016	06525-00013
Chassis, Rear	06525-00018	06525-00018	06525-00003
Heat Sink	06525-20007	06525-20007	06525-20004

a direct replacement for all previous 6522A supplies.

Insert the following note ahead of Paragraph 5-44.

NOTE

When zeroing the meters, be sure to follow the instructions in Paragraph 5-44 exactly. This method avoids leaving the pin on the zero adjust screw in contact with the upper meter spring where it could affect the meter sensitivity and cause the zero adjustment to drift.

CHANGE 12:

In the parts list, change the part number of C28 to 0160-4117, and change C24 to 0160-4119. These new capacitors are to be used for field replacement in all previously built instruments. The new C24 requires a new capacitor clamp, part number 06522-00004.

CHANGE 13:

On page 6-5, change the HP Part Number of CR15 to 1884-0254. This 35A 400V SCR is more reliable in this application. The 1884-0254 is electrically equivalent to a 2N3658.

ERRATA:

Change paragraph 3-13 (parallel operation) to read as follows: Two power supplies can be connected in parallel to obtain a combined output current greater than that available from one supply. The total output current is the sum of the output currents from each individual supply. Since the inputs to the supplies' error amplifiers are not available, the two supplies must be connected in straight parallel with one supply operating as a constant voltage (CV) source and the other supply operating as a constant current (CC) source. To protect the supplies' input voltage amplifiers, diodes CR1 and CR2 are added between the + output terminals and the load as shown in Figure 3-2. If the diodes are not added, damage may occur when one supply is turned off with the voltage controls set for zero volts or to some low value.

To operate the two supplies in parallel, proceed as follows:

- With both supplies turned off, connect the load and the protection diodes as shown in Figure 3-2.
- Turn on the CC supply (leaving the CV supply off), set the CC supply's voltage controls for maximum and adjust its current control for one-half the desired output current.
- Turn on the CV supply and with its current control set to maximum, adjust the CV supply's voltage controls for the desired output voltage.

NOTE

The CV supply's output voltage will be slightly higher than the voltage across the load by an amount equal to the drop across diode CR1 plus the drop in the load connecting wires.

Change the CAUTION notice after paragraph 3-15 to read as follows:

CAUTION

Under no circumstances shall the voltage between any output terminal and ground exceed 2kV plus the output rating of the supply; otherwise, the power supply may be damaged.

In the parts list on page 6-6, change the R22 description to read: Selected, 7.5k, (HP Part No. 0686-7525) or 8.2k (HP Part No. 0686-8225).

Change the part number of pilot light DS1 to 1450-0566.

This new light is more reliable than the former one.

Add the part number for C19 to the parts list. It is 0160-2570.

Add the following CAUTION ahead of step (a) in paragraph 5-12.

CAUTION

Oscilloscope may be damaged unless its controls are set for dc input coupling.

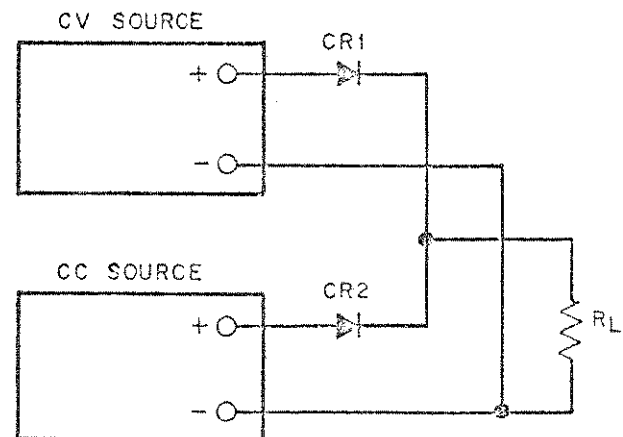


Figure 3-2. Paralleling Two Supplies

CHANGE 16:

ERRATA:

To improve personnel safety and reduce the risk of test equipment damage, the Figure 5-4 test setup for the constant-current tests of par. 5-18 through 5-25 has been changed as shown below. Shorting switch S1 has been replaced by a high-voltage relay, R_L has been moved to the negative output line, and a high stability X10 multiplier resistor and a spark gap have been added to protect the voltmeter. The positive output of the power supply must be grounded to the chassis as shown.

Change T2, power transformer part no. to HP Part No. 5080-1912.

CHANGE 17:

In the parts list and schematic:

Change zener diode VR4 to 9V, 0.005% TC, HP Part No. 1902-0785.

Change resistor R 22 to 6.8K, 0.5W, HP Part No. 0686-6825.

Note that the above changed parts are not interchangeable in units with serial prefixes earlier than 1903A unless both (VR4 and R22) are changed at the same time.

CHANGE 14:

On page 6-7, change the HP Stock No. of R117 to 2100-3210.

ERRATA:

In paragraph 5-12, change (a) to read, "Disconnect the 100:1 divider and connect the 20,000 ohm load resistor to the power supply output". Also, change (f) to read, "The oscilloscope should indicate less than 500mV p-p".

CHANGE 15:

On page 6-5, change capacitor C1 to HP Part No. 0160-4763. Add: Insulated standoff posts, HP Part No. 0380-0701, machine screw HP Part No. 2515-0003, hex nut, HP Part No. 2580-0005, solder lug, HP Part No. 0360-0621, high voltage wire, HP Part No. 8150-3078.

The parts added are used to mount the new capacitor on the high voltage box rear and to connect the capacitor to resistor R15 (see 6522A schematic).

ERRATA:

For all instruments delivered on or after July 1, 1978, change the HP Part No. for fuseholder from 1400-0084 to fuseholder body 2100-0564 and fuseholder carrier 2100-0565. Change the HP Part No. for fuseholder nut from 2950-0038 to 2110-0569. If old fuseholder must be replaced for any reason, replace complete fuseholder and nut with new fuseholder parts. Do not replace new parts with old parts.

10-9-79

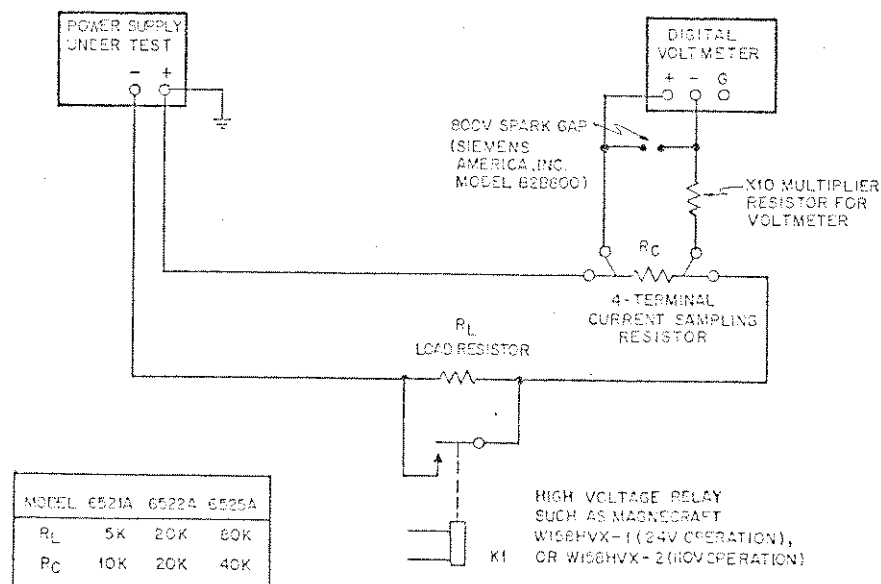


Figure 5-4. Constant-Current Test Setup Diagram

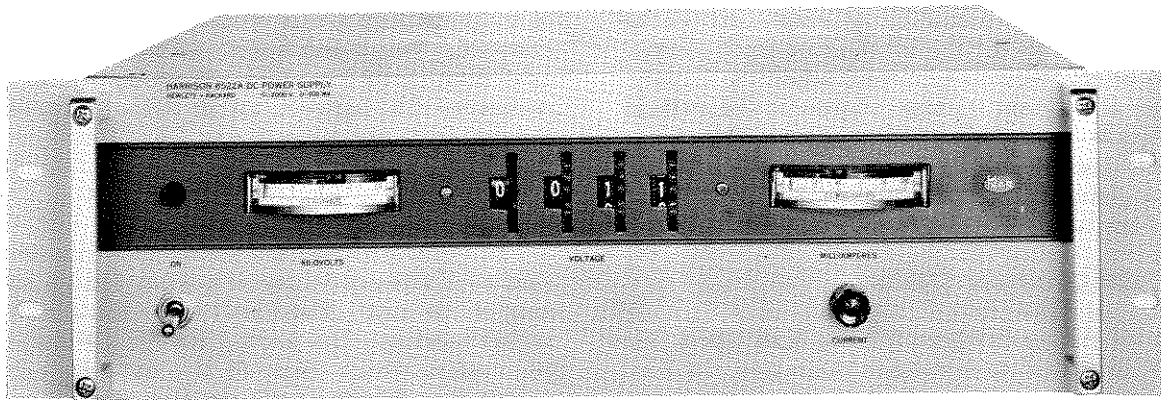


Figure 1-1. DC Power Supply, Model 6522A

SECTION I
GENERAL INFORMATION

1-1 DESCRIPTION

1-2 The HVR (High Voltage Rack) Series of DC Power Supplies (Figure 1-1) are all semiconductor, compact, well-regulated, constant voltage/constant current models suitable for either bench or rack operation. A three-wire five-foot input power cord is provided. The output is continuously variable between zero and the maximum rating of the supply. The continuously variable current control may be used to set the maximum output current (overload or short-circuit current) when the supply is used as a constant voltage source or the voltage control may be used to set the maximum output voltage (voltage ceiling) when the power supply is used as a constant current source. Detailed specifications are given in Table 1-1.

1-3 OVERLOAD PROTECTION

1-4 A crossover feature protects both power supply and load in constant voltage operation. Automatic crossover circuitry switches the power supply from constant voltage to constant current operation if the output current exceeds a preset limit. This crossover circuitry also protects the load from over-voltage during constant current operation by automatically switching the power supply into constant voltage operation if the output voltage exceeds the preset limit. The user can adjust the crossover point via the front panel controls (Paragraph 3-1).

1-5 The power supply is protected from reverse voltage (positive voltage applied to negative terminal) by an internal protection diode and the diode bridge network that shunts current across the output terminals when this condition exists, clamping the reverse voltage. Protection from reverse current (current forced into the power supply in the direction opposite to the output current) must be provided by preloading the power supply (Paragraph 3-29). The power supply cannot accept reverse current without damage.

1-6 COOLING

1-7 Convection cooling is used. No fan is required. The power supply has no moving parts (except for meter movement).

1-8 OUTPUT TERMINALS

1-9 Output power is available via two UG-931/U connectors at the rear of the power supply. Mating connectors (UG-932/U) are supplied with the unit. The output terminals are isolated from the chassis and either the positive or the negative terminal may be connected to the chassis by shorting the center pin and case of the applicable UG-931/U connector, or by grounding a wire from the connector to the chassis. The power supply is insulated to permit operation up to 2,000 vdc off ground, i. e. the maximum potential between either output terminal and ground shall not exceed 3 KV DC.

1-10 INSTRUMENT IDENTIFICATION

1-11 Hewlett-Packard power supplies are identified by a three-part serial number tag located on the rear of the unit. The first part is the power supply model number. The second part is the serial number prefix, which consists of a number-letter combination that denotes the date of a significant design change. The number designates the year, and the letter, A through L, designates the month, January through December respectively. The third part is the power supply serial number.

1-12 If the serial number prefix on your power supply does not agree with the prefix on the title page of this manual, change sheets are included to update the manual. Where applicable, backdating information is given in an appendix at the rear of the manual.

1-13 ORDERING ADDITIONAL MANUALS


1-14 One manual is shipped with each power supply. Additional manuals may be purchased from your local Hewlett-Packard field office (see list at rear of this manual for addresses). Specify the model number, serial number prefix, and  stock number provided on the title page.

Table 1-1. Specifications

<p>INPUT: 105-125 Vac, 50-500 cps., 4A, 270W.</p> <p>OUTPUT: 0-2000 Vdc, 0-100 mA.</p> <p>LOAD REGULATION: <u>Constant Voltage:</u> Less than 0.002% plus 10 mV for a full load to no load change in output current. <u>Constant Current:</u> Less than 2% or 1 mA for a full load to no load change in output voltage.</p> <p>LINE REGULATION: For a change in line voltage from 105 to 125 (or 125 to 105) at any output voltage and current within rating <u>Constant Voltage:</u> Less than 0.001% plus 10 mV. <u>Constant Current:</u> Less than 1 mA.</p> <p>RIPPLE AND NOISE: At any line voltage and under any load condition within rating <u>Constant Voltage:</u> Less than 1 mV rms. <u>Constant Current:</u> Less than 1 mA rms.</p> <p>TRANSIENT RECOVERY TIME: Less than 50 μsec is required for output voltage recovery to within 0.005% or 20 mV, whichever is greater, following a full load to no load or no load to full load change in output current.</p> <p>TEMPERATURE RATINGS: Operating: 0 to 50°C Storage: -20 to 70°C.</p> <p>TEMPERATURE COEFFICIENT: Output change per degree centigrade change in ambient following 30 minutes warm-up <u>Constant Voltage:</u> 0.012% plus 1 mV. <u>Constant Current:</u> 0.2% plus 0.1 mA.</p>	<p>STABILITY: Under constant ambient conditions, total drift for 8 hours following 60 minutes warm-up <u>Constant Voltage:</u> 0.036% plus 3 mV. <u>Constant Current:</u> 0.25% plus 0.25 mA.</p> <p>CONTROLS: Voltage controls consist of a three decade thumbwheel switch plus a thumbwheel vernier with 0.002% resolution. A single turn potentiometer controls output current.</p> <p>METERS: Zero to 2 kV and 0-100 mA front panel meters are included. They provide accuracy of 2% full scale.</p> <p>CALIBRATION ACCURACY: One percent of the voltage control setting.</p> <p>OUTPUT IMPEDANCE: DC to 100 Hz (cps.) -- less than 0.01Ω. 100 Hz to 1 kHz -- less than 0.02Ω. 1 kHz to 100 kHz -- less than 0.5Ω. 100 kHz to 1 MHz -- less than 3Ω.</p> <p>SIZE: 5$\frac{1}{4}$" H x 18" D x 19" W (standard rack width).</p> <p>WEIGHT: 50 lbs. net, 60 lbs. shipping.</p> <p>FINISH: Light gray front panel with dark gray case.</p>
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SECTION II INSTALLATION

2-1 INITIAL INSPECTION

2-2 Before shipment, the power supply was inspected and found free of mechanical and electrical defects. If damage to the shipping carton is evident, ask that the carrier's agent be present when the power supply is unpacked. As soon as the power supply is unpacked, inspect it for any damage that may have occurred in transit. Also check the cushioning material for signs of severe stress (may be indication of internal damage). Save all packing materials until the inspection is completed. If damage is found, proceed as instructed in the Claim for Damage in Shipment notice on the inside of the back cover of this manual.

2-3 MECHANICAL CHECK

2-4 Check that there are no broken knobs or connectors, that the external surface is not scratched or dented, that the meter face is not damaged, that all controls move freely, and that the fuses (at rear of power supply) are in place and of the correct rating (two 8 ampere and one 5 ampere, type 3AB). Any external damage may be an indication of internal damage.

2-5 ELECTRICAL CHECK

2-6 Check the electrical performance of the power supply as soon as possible after receipt. A performance check that is suitable for incoming inspection is given in Paragraphs 5-6 through 5-22.

2-7 INSTALLATION DATA

2-8 The power supply is shipped ready for bench or standard 19 inch relay rack operation.

2-9 LOCATION

2-10 Because the power supply is cooled by convection, there must be enough space along the sides and rear of the power supply to permit free

flow of cooling air. The power supply should be located in an area where the ambient temperature does not exceed 50°C.

2-11 POWER REQUIREMENTS

2-12 The power supply is operated from a 105 to 125 Vac, 50 to 500 Hz (cps.) power source. The power supply is shipped from the factory wired for operation at 115 volts (nominal), unless otherwise ordered. At 115 volts, 60 Hz (cps.), the full load requirement is 270 watts at 4.0 amperes.

2-13 POWER CABLE

2-14 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 and when the cable is plugged into an appropriate receptacle, the instrument is grounded. The offset pin on the power cable three-prong connector is the ground connection.

2-15 To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adaptor and connect the green lead on the adaptor to ground.

2-16 REPACKAGING FOR SHIPMENT

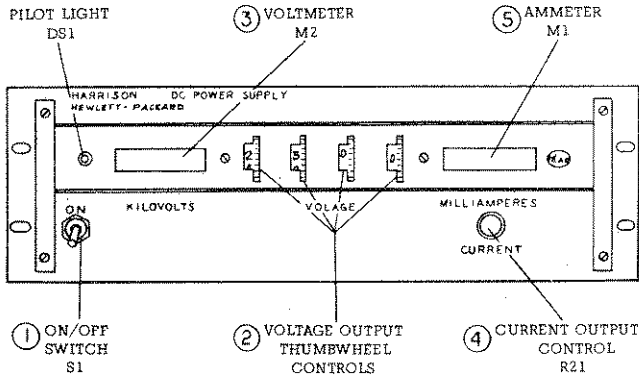
2-17 To insure safe shipment of the instrument, it is recommended that the package designed for the instrument be used. The original packaging material is reusable. If it is not available, contact your Hewlett-Packard field office for packing materials and information.

2-18 Attach a tag to the instrument which specifies the owner, model number, full serial number, and service required or a brief description of the trouble.

SECTION III
OPERATING INSTRUCTIONS

3-1 CONTROLS AND INDICATORS

3-2 The controls and indicators are illustrated in Figure 3-1.



TURN-ON SEQUENCE

1. TURN SUPPLY ON
2. USE VOLTAGE OUTPUT THUMBWHEEL CONTROLS TO SELECT OUTPUT VOLTAGE
3. VOLTMETER INDICATES VOLTAGE
4. SHORT CIRCUIT OUTPUT TERMINALS AT REAR AND ADJUST CURRENT OUTPUT CONTROL TO SELECT CONSTANT CURRENT LIMIT
5. AMMETER INDICATES CURRENT (REMOVE SHORT AND CONNECT LOAD TO REAR OUTPUT TERMINALS)

Figure 3-1. Front Panel Controls and Indicators

3-3 OPERATION

3-4 The power supply can be operated as a single unit (normal operation), in parallel, or in series. No provisions for remote programming or remote sensing has been made due to their limited use and insulation problems at 1,000 Vdc. For safety, ensure that the power supply chassis is grounded (either through power cord or by other means). The operator can ground either output terminal or operate the power supply up to 2,000 Vdc off ground (floating). It is not recommended that the power supply be floated above 300 vrms at low audio frequencies.

WARNING

Serious injury to personnel can occur if the power supply chassis is ungrounded. The warranty is void if the chassis is ungrounded during operation.

NOTE

With the unit on and no load connected, the transformer will make an audible ticking noise. This is perfectly normal for this unit and should not be a cause for rejection.

3-5 NORMAL

3-6 Constant Voltage. To select a constant voltage output, proceed as follows:

a. Turn-on power supply and adjust VOLTAGE thumbwheel controls for desired output voltage (output terminals open).

b. Short output terminals and adjust CURRENT control for maximum output current allowable (current limit), as determined by load conditions. If a load change causes the current limit to be exceeded, the power supply will automatically crossover to constant current output at the preset current limit and the output voltage will drop proportionately. In setting the current limit, allowance must be made for high peak currents which can cause unwanted crossover. (Refer to Paragraph 3-17).

3-7 Constant Current. To select a constant current output, proceed as follows:

a. Short output terminals and set CURRENT control for desired output current.

b. Open output terminals and set VOLTAGE thumbwheel controls for maximum output voltage allowable (voltage limit), as determined by load conditions. If a load change causes the voltage limit to be exceeded, the power supply will automatically crossover to constant voltage output at the preset voltage limit and the output voltage will drop proportionately. In setting the voltage limit, allowance must be made for high peak voltages which can cause unwanted crossover. (Refer to Paragraph 3-17).

CAUTION

High output current surges are possible even though supply is in constant current operation, because of charge on output capacitors.

3-8 CONNECTING LOAD

3-9 Output terminals are provided at the rear of the power supply. The terminals are marked + and -. The positive or negative output terminal may be grounded by shorting the center pin and case of the applicable UG-931/U plug or by grounding the wire from the plug to the chassis, or neither grounded (floating operation; permitted to 2,000 Vdc off ground).

WARNING

To avoid injury to personnel due to arcing, turn-off the power supply before connecting or disconnecting the load connectors.

3-10 Each load should be connected to the power supply output terminals using separate pairs of connecting wires. This will minimize mutual coupling effects between loads and will retain full advantage of the low output impedance of the power supply. Each pair of connecting wires should be as short as possible to reduce noise pickup; in addition, a 0.1 to 1.0 μf capacitor should be connected between one terminal and the chassis, if the supply is floated off of ground.

3-11 If load considerations require that the output power distribution terminals be remotely located from the power supply, then the power supply output terminals should be connected to the remote distribution terminals via a pair of twisted or shielded wires and each load separately connected to the remote distribution terminals. A 0.1 to 1 μf capacitor should be connected across the remote distribution terminals to reduce high frequency coupling and noise.

NOTE

It is recommended that the voltage drop in the connecting wires not exceed 2V. If a larger drop must be tolerated, please consult a Hewlett-Packard field representative.

3-12 PARALLEL

3-13 Two or more power supplies can be connected in parallel to obtain a total output current greater than that available from one power supply. The total output current is the sum of the output currents of the individual power supplies. Each power supply can be turned on or off separately. The output current control of each power supply can be separately set. The output voltage control of one power supply (master) should be set to the desired output voltage; the other power supply (slave) should be set for a slightly larger output voltage

(3%). The master will act as a constant voltage source; the slave will act as a constant current source, dropping its output voltage to equal the master's.

3-14 SERIES. Two or more power supplies can be connected in series to obtain a total output voltage higher than that available from one power supply. The total output voltage is the sum of the output voltages of the individual power supplies. A single load can be connected across the series-connected power supplies or a separate load can be connected across each power supply. The power supply is internally protected against reverse polarity voltage if the load is short-circuited or if one power supply is turned off while its series partners are on.

3-15 The output current control of each power supply is operative and the current limit is equal to the lowest control setting. If any output current control is set too low, the series power supplies will automatically crossover to constant current operation and the output voltage will drop until the supply in constant current operation drops to zero.

CAUTION

If the load is grounded, no output terminal must be allowed to be 3,000Vdc or more with respect to ground; otherwise, the power supply may be damaged.

3-16 OPERATING CONSIDERATIONS

3-17 PULSE LOADING

3-18 The power supply will automatically crossover from constant voltage to constant current operation, or the reverse, in response to an increase (over the preset limit) in the output current or voltage, respectively. Although the preset limit may be set higher than the average output current or voltage, high peak currents or voltages (as occur in pulse loading) may exceed the preset limit and cause crossover to occur. To avoid this unwanted crossover, the preset limit must be set for the peak requirement and not the average.

3-19 OUTPUT IMPEDANCE

3-20 In constant current operation, the voltage programming resistance (VOLTAGE thumbwheel controls) effectively shunt the output terminals. Thus, the output impedance at dc is approximately equal to the voltage programming coefficient (2,000 ohms per volt) times the voltage setting. Thus, for a 500 Vdc setting the output impedance is approximately 1 megohm. As the frequency increases, the output capacitance of the power supply lowers the output impedance. In constant voltage operation, the output impedance is low (see specifications Table 1-1).

3-21 OUTPUT CAPACITANCE

3-22 A capacitor (internal) across the output terminals of the power supply, helps to supply high-current pulses of short duration during constant-voltage operation. Any capacitance added externally will improve the pulse current capability, but will decrease the safety provided by the constant current circuit. A high-current pulse may damage load components before the average output current is large enough to cause the constant current circuit to operate.

3-23 The effects of the output capacitor during constant-current operation are as follows:

a. The output impedance of the power supply decreases with increasing frequency.

b. The rise time of the output voltage may be increased.

c. A large surge current causing a high power dissipation in the load occurs when the load impedance is reduced rapidly.

3-24 TURN-ON AND TURN-OFF

3-25 There is no overshoot at turn-on or turn-off of the power supply. However, it is recommended that the load be capable of withstanding a maximum

charge rate of 3,000 volts per second and a maximum discharge rate of 10,000 volts per second.

3-26 NEGATIVE VOLTAGE LOADING

3-27 If a negative voltage (reverse voltage) is applied to the output terminals (positive voltage applied to negative terminal), the internal protection diode and the diode network will conduct, shunting current across the output terminals and limiting the voltage to the forward voltage drop of the diodes (approximately 5 volts).

3-28 NEGATIVE CURRENT LOADING

3-29 Certain types of loads may cause current to flow into the power supply in the direction opposite to the output current. This reverse current cannot be tolerated by the power supply and therefore preloading will be necessary. For example; if the load delivers 50 milliamperes to the power supply with the power supply output voltage at 500 Vdc, a resistor equal to 10,000 ohms ($500/50 \times 10^{-3}$) should be connected across the output terminals. Thus, the 10,000-ohm resistor shunts the reverse current across the power supply. For more information on preloading, refer to Paragraph C4 in the Harrison Division Application Manual. This manual can be obtained from your local Hewlett-Packard Field Sales Office (Refer to list at rear of manual).

SECTION IV
PRINCIPLES OF OPERATION

4-1 BLOCK DIAGRAM DESCRIPTION (See Figure 4-1.)

4-2 The ac input power is applied to auxiliary power transformer T2 and to the line-voltage bridge and storage capacitor circuit. The auxiliary power transformer provides isolation and power for the turn-on/turn-off circuit and for the 20 Vdc and 40 Vdc bias supplies. The line-voltage bridge and storage capacitor circuit full-wave rectifies and filters the ac input to provide a dc power source for the pulse-width modulator.

4-3 The high-voltage bridge and storage capacitor circuit in series with the 40 Vdc bias supply and the series regulator provide the dc output voltage. The series regulator is controlled by either the voltage or current input circuits. Diode gate CR11-CR12 assures that only one input circuit is used at a time.

4-4 The voltage input circuit differential amplifier detects an error voltage that is proportional to the difference between the voltage across its programming resistors and the dc output voltage. The error signal is passed through the diode gate, amplified, and applied to the series regulator. The amplified error signal causes the series regulator to increase or decrease the output current as required to maintain a constant dc output voltage that is equal to the programmed voltage.

4-5 The current input circuit differential amplifier detects an error voltage that is proportional to the difference between the voltage across its programming resistor (R21) and the voltage across current monitoring resistor R20. The voltage across the current monitoring resistor is proportional to the load current. The series regulator responds to the amplified error voltage by increasing or decreasing the output current as required to maintain a constant load current.

4-6 The current through the programming resistors must be held constant. The feedback loop of each input circuit strives to maintain a zero difference voltage at the input to its differential amplifier. Therefore, the programming current is equal to the applied reference circuit voltage divided by the resistance of R22 (current input) or by R4-R5 in parallel plus R6 in series (voltage input). Capacitor C29 is the storage capacitor that powers the reference circuit. Diode CR78 prevents C29 from discharging back into the turn-on/turn-off circuit.

4-7 When the voltage across the series regulator falls below a predetermined level, the Schmitt trigger pulses (via pulse transformer T3) the pulse-width modulator which produces an approximately rectangular voltage pulse. The width of the pulse produced by the pulse-width modulator is primarily determined by the dc output voltage level and to a lesser extent by the line voltage amplitude. High line voltage corresponds to a narrower pulse width; high output voltage to a wider pulse width. The pulse from the pulse-width modulator is stepped up in voltage by high-voltage transformer T1, rectified by the high-voltage bridge, and provides a charging current to the high-voltage storage capacitor.

4-8 The voltage across the series regulator rises exactly as the voltage rises across the high-voltage storage capacitor. When the voltage across the series regulator rises above a predetermined level, the Schmitt trigger sends another pulse to the pulse-width modulator to end the pulse output of the pulse-width modulator. Thus, the charging of the high-voltage storage capacitor ceases.

4-9 To summarize; the series regulator maintains the output voltage or current constant in response to error signals from the voltage or current input circuits. However, the voltage across the series regulator is kept within predetermined limits by the action of the Schmitt trigger and pulse-width modulator.

4-10 If the output of the power supply is shorted, internal protection diode CR72 becomes forward biased and the charge on the high-voltage storage capacitor is conducted to the output via CR72 (R120 limits surges). This protects the series regulator which otherwise would have to take almost the full output voltage that existed at the time the power supply was shorted. The 40 Vdc bias supply assures that CR72 is reverse biased during normal operation; and also provides operating bias for the series regulator. It should be noted that the 40 Vdc bias supply and the series regulator with its control and reference circuits forms a complete regulated 0 to 40 Vdc at 0 to 200 mA power supply.

4-11 To allow the power supply circuits to stabilize before power is delivered to the output, the turn-on circuit provides a time delay by clamping the series regulator via CR81. To permit rapid turn-off (delayed by the various storage capacitors), the turn-off circuit clamps the series regulator via CR82 to prevent the high-voltage

storage capacitor from conducting charge to the output.

4-12 CIRCUIT DESCRIPTION (See overall schematic at back of manual.)

4-13 AC INPUT

4-14 The 105 to 125 Vac, single phase, 50 to 500 Hz (cps.) input is applied to auxiliary power transformer T2 and to the line-voltage bridge and storage capacitor. Each side of the line input has an eight-ampere fuse for protection. A pilot lamp is connected across the primary of T2. Each of the three secondary windings of T2 is center-tapped for full-wave rectification.

4-15 20 VDC BIAS SUPPLY

4-16 The 20 Vdc bias supply consists of diodes CR74 and CR75 which provide full-wave rectification, and capacitor C27 which provides filtering. The 20 Vdc is used by both the Schmitt trigger and the series regulator.

4-17 40 VDC BIAS SUPPLY

4-18 The 40 Vdc bias supply consists of diodes CR70 and CR71 which provide full-wave rectification, and capacitor C26 which provides filtering. The 40 Vdc is used by the series regulator.

4-19 VOLTAGE INPUT

4-20 The voltage input circuit is basically a differential amplifier (Q1A-Q1B) that detects any voltage difference between the programmed output voltage and the actual output voltage. The differential amplifier output voltage varies in proportion to the power supply output voltage variation. Transistors Q1A and Q1B are a matched pair in a single package to ensure that both are at the same temperature and thus improve stability.

4-21 There are two inputs to the base of Q1A; one determined by the programmed voltage (VOLTAGE thumbwheel controls S201, 202, and 203) and the other by the collector voltage of Q3 (negative feedback). The base input of Q1B is determined by the positive output voltage. The collectors of Q1A and Q1B are connected directly to the bases of Q2 and Q3, respectively. Transistors Q2 and Q3 comprise a differential amplifier that provides required voltage gain. The negative feedback from the collector of Q3 via C6 and R7 to the base of Q1A extends the combined frequency response of both differential amplifiers to well beyond 100 kHz (kc) and reduces the high frequency gain in order to

prevent power supply oscillation. The collector output of Q3 is coupled to the diode gate (CR11).

4-22 At high frequencies, capacitors C3, C4, and C5 bypass the base of Q1B, the emitters of Q2 and Q3, and the collector of Q1B (base of Q2), respectively. Thus, Q1A operates as an emitter-follower that drives Q1B (common-base) and Q3 is a common-emitter driven by Q1B; Q2 is effectively bypassed from the circuit. This bypassing at high frequencies compensates for the Miller effect capacitances and thus maintains high-frequency gain approximately equal to the low-frequency gain.

4-23 Diodes CR3 and CR4 protect Q1A from excessive voltage in either direction by clamping the base to approximately 0.8 volts. Resistor R3 protects the programming resistors (VOLTAGE thumbwheel controls) from surge currents that result when the voltage controls are programmed up or down rapidly. The surge current is caused by the voltage difference between the output voltage and the newly programmed voltage, and flows through either CR3 or CR4 depending on whether the programming is up or down, respectively.

4-24 Capacitor C1 couples high-frequency transient and ripple voltages in the negative output to the base of Q1A (via C2 and R2). The voltage across C1 is large because it is connected between the negative output bus and the base of Q1A which is approximately at the positive bus potential. Due to rapid down programming or shorting the output of the power supply, heavy discharge currents from C1 occur. R15 limits the magnitude of these currents and CR1 provides a path to the output terminals. R1 is used to bleed off any D. C. leakage current of C1 and thus prevent a voltage build-up at point (1). C2 prevents the D. C. leakage current of C1 from reaching the base of Q1A thus improving the D. C. stability of the power supply. R2 limits the amount of high-frequency coupling to the base of Q1A via C2, R15, and C1. CR2 couples C1 to the base of Q1A via R15 and R2 to assure a safe rate of voltage rise across the output when the supply is turned on.

4-25 CURRENT INPUT

4-26 The current input circuit is basically a differential amplifier (Q4-Q5) that detects any current difference between the programmed output current (proportional to voltage across CURRENT control R21) and the actual output current (proportional to voltage across current monitoring resistor R20). The differential amplifier output voltage varies in proportion to the output current variation.

4-27 The input to the differential amplifier (across bases of Q4-Q5) is the voltage difference across CURRENT control R21 (programming resistor) and current monitoring resistor R20). Because the programming current is constant in constant current operation, the voltage input to the differential amplifier varies as the load current through R21 (error voltage). Capacitor C10 provides gain roll-off at high frequencies for stability. Diode CR9 fixes the collector voltage of Q5 to eliminate the Miller effect capacitance which is pronounced at high frequencies. Voltage divider R23-R24 biases the base of Q5 slightly positive to ensure that the output current can be programmed to zero. The collector output of Q4 is coupled to the diode gate (CR12).

4-28 DIODE GATE

4-29 Diode gate CR11-CR12 provides an output to the error amplifier (base of Q6) that is determined by either the voltage or current input circuit. In constant voltage operation, CR11 is forward biased and CR12 is reverse biased; the reverse is true in constant current operation. Resistor R33 provides a small current path for the forward biased diode so that the diode is properly biased when the error signal is small.

4-30 ERROR AMPLIFIER

4-31 The two-stage (Q6 and Q7) error amplifier provides gain for the voltage and current error signals from the diode gate. Stage Q6 is an emitter-follower to eliminate the Miller effect. Zener diode VR1 provides a 6.2 Vdc bias. The emitter output of Q6 is coupled via R38 and C13 to the base of Q7. For low frequencies, coupling is via R38; for high frequencies, coupling is via C13. Thus, the impedance seen looking to the right of the base of Q7 remains low at high frequencies to reduce the Miller effect capacitance of Q7. Resistor R36 forms a voltage divider with R38 across VR1 to provide proper base bias for Q7. For stability, negative feedback is provided from the collector of Q7 via C12 and R34 to the base of Q6. The collector output of Q7 is coupled to the series regulator driver (base of Q10) via R37.

4-32 SERIES REGULATOR

4-33 The series regulator (Q11) controls the output current in response to the voltage and current error signals. Transistor Q10 is the driver for Q11. In constant voltage operation, the output voltage is adjusted so that it remains constant for changing loads. In constant current operation, the output current is maintained constant for changing loads and the output voltage is allowed to vary.

Capacitor C16 eliminates the Miller effect capacitance of Q10. Transistor Q17 is a current bleed for the series regulator and serves to rapidly discharge output capacitor C28. The voltage across Q11 is monitored by the Schmitt trigger.

4-34 SCHMITT TRIGGER

4-35 The Schmitt trigger (Q15-Q16) pulses the pulse-width modulator via pulse transformer T3 when the voltage (collector-to-emitter) across series regulator Q11 falls below a predetermined level. When the voltage across Q11 rises above another (higher) predetermined level, the pulse from the Schmitt trigger ends. Initially, both Q15 and Q16 are off by virtue of the bias provided from the collector of Q11 (voltage above lower predetermined level) via R95.

4-36. When the collector-to-emitter voltage of Q11 falls below the lower predetermined level, Q15 is forward biased by R97. Transistor Q15 conducts and causes Q16 to turn-on. The collector of Q16 goes negative and current via R98 and R99 biases the base of Q15 in the forward direction. The primary of pulse transformer T3 is connected to the collector of Q16 via CR67 and R102. The resulting current through T3 causes the pulse-width modulator to initiate the action required to raise the voltage across Q11. The voltage across Q11 must rise to a level that is higher than the level that was required to forward bias Q15 in order to overcome the rigid forward bias established at the base of Q15 by the current through R98 and R99. When this higher voltage level is reached, Q15 becomes reverse biased thus returning both transistors to their non-conducting state.

4-37 Zener diode VR5 and diodes CR64, CR65, and CR66 provide reference voltages. Capacitor C40 is a bypass. Capacitor C46 acts as a bypass and to assure that when the power supply is turned on, the voltage across VR5 does not rise faster than the voltage across Q11; to prevent Q15 from being forward biased instead of reverse biased. Diodes CR62 and CR63 are a protective clamp in the forward direction for Q15. Diode CR60 provides clamping action to assure that the rigid bias established at the base of Q15 by the collector of Q16 is not sensitive to ac input (line) voltage variations; (line voltage variations affect the collector voltage of Q16).

4-38 Capacitor C45 and R103 in parallel with R106 form a speed-up network to assure rapid turn-on and turn-off of Q16. Capacitor C42 and R101 in parallel with R102 form a speed-up network to assure that sharp pulses are developed in pulse transformer T3. Capacitor C39 and R96 in parallel with R95

provide compensation for the voltage rise rate across Q11; too fast a rate may cause overshoot in the output of the power supply. Capacitor C41 in series with R100 prevent the Schmitt trigger from producing pulse widths less than approximately 120 microseconds and from having pulses closer than approximately 500 microseconds. The 120 microsecond minimum time is required to allow the pulse-width modulator commutating circuit to stabilize; the 500 microsecond minimum time is required to avoid saturation of high-voltage transformer T1 under transient overload conditions.

4-39 LINE-VOLTAGE BRIDGE AND STORAGE CAPACITOR

4-40 The ac input voltage is full-wave rectified by bridge rectifier CR20 through CR23. Storage capacitor C32 is charged to the peak rectified voltage and supplies charge to the pulse-width modulator when called upon. Two filter networks (L4A and C33; L4B and C34) reduce voltage spikes.

4-41 PULSE-WIDTH MODULATOR

4-42 The pulse-width modulator is a gate circuit that opens and closes in response to pulses from the Schmitt trigger and transfers charge from the line-voltage bridge and storage capacitor to the high-voltage bridge and storage capacitor. Initially, C19 is charged to approximately 160 volts by the line-voltage storage capacitor via R45, CR17 and F1. The first pulse from the Schmitt trigger gates CR15 on. Current flows from the line-voltage storage capacitor through high-voltage transformer T1, CR17, L3, and CR15. The voltage across T1 appears as a step function; the current is ramp shaped.

4-43 When CR15 was gated on, it effectively clamped test point 56 to test point 53 (neglecting small voltage drops across CR15 and L3). Thus, the positive side (right side) of C19 is pulled down to test point 53. Because the voltage across a capacitor cannot change instantaneously, the negative side (left side) of C19 must fall a corresponding amount with respect to test point 53. This forward biases CR18 which begins charging C19 through L1 in the opposite direction. Due to the energy storage of L1, C19 is charged to approximately -160 volts (CR18 prevents C19 from discharging back into L1). The time required to charge C19 to -160 volts is approximately 120 microseconds.

4-44 The next pulse from the Schmitt trigger gates CR16 on. The positive side (left side) of C19 is clamped to test point 53 and the negative side (right side) falls a corresponding amount to reverse bias CR15. With CR15 cutoff and CR16 on, the current

through T1 flows through C19 (charging it in opposite direction) and CR16. When C19 is charged to approximately 160 volts (equal to line-voltage storage capacitor) the polarity across T1 reverses and maintains the current flow into C19. The voltage across T1 now builds up in the reverse direction and is coupled to the second primary winding which is phase reversed from the first winding. When the voltage across the second primary winding reaches approximately 160 volts, CR19 is forward biased and the voltage across T1 is clamped to the line-voltage capacitor (160 volts), because the voltage across T1 can no longer increase, the current through the first primary winding of T1 falls to zero and CR16 is cut off. At this point C19 has been charged to 320 volts (right side is positive; CR17 prevents C19 from discharging back into T1). The current through the second primary winding of T1 falls toward zero as the energy stored in the leakage inductance and core of the transformer is returned to the line-voltage storage capacitor. The 320 volts across C19 remains until the next pulse from the Schmitt trigger causes the action to repeat. Thus, at the time of the first pulse C19 was charged to 160 volts; thereafter, the initial condition for C19 is 320 volts. It should be noted that if the line voltage were high, the rise rate for the voltage across T1 (to reach clamping level; CR19 forward biased) would be faster and therefore the pulse width would be narrower. High output voltage, however, causes the pulse width to be wider because the current in T1 is smaller for high output voltages.

4-45 The following networks suppress voltage spikes that occur primarily because of the SCR switching: C20 and R46, L2 and R16, L3 and R17, and C22. Capacitor C21 and R47 suppress ringing in T1. Diodes CR25 and CR26 are clamps to prevent the SCR gates from pulling T3 negative with respect to test point 53; otherwise, heavy current would flow through T3 and the applicable SCR gate causing possible disturbances to the circuit.

4-46 HIGH-VOLTAGE BRIDGE AND STORAGE CAPACITOR

4-47 The high-voltage bridge, connected across the third winding of T1, full-wave rectifies the output of the pulse-width modulator (after voltage step-up by T1) and charges high-voltage storage capacitor C24. Diode CR72 provides internal protection if the power supply output is shorted. This diode will then conduct charge directly from high-voltage storage capacitor C24 to the output; thus protecting the series series regulator. Resistor R120 limits surges. Capacitor C28 is the output capacitor.

4-48 TURN-ON/TURN-OFF CIRCUIT

4-49 The input voltage from T2 is full-wave rectified by CR76 and CR77. When the power supply is turned on, C31 charges slowly through R123 and C30 charges rapidly. Diode CR81 clamps the base of series regulator driver Q10 until C31 is charged. This prevents the series regulator from delivering current to the output before the power supply circuits have stabilized. Diode CR80 and R124 clamp the voltage across C31 to approximately 15 volts; otherwise, C31 would charge to approximately 40 volts.

4-50 When the power supply is turned off, C30 discharges rapidly through R121 and R122, and C31 discharges rapidly through CR79. Diode CR82 clamps the base of Q10 immediately after an interruption of the line voltage to shut down the series regulator and thus preventing any possibility of the circuit going into an unstable state before the bias supplies discharge.

4-51 REFERENCE CIRCUIT

4-52 The reference circuit provides +12.4 Vdc operating voltage for the error amplifier and voltage and current differential amplifiers, and +6.2 and -9.4 Vdc reference voltages for the voltage and current programming currents. The reference circuit is powered by C29 (charged to approximately 40 Vdc via full-wave rectifier CR76-CR77).

4-53 Differential amplifier Q12-Q13 detects the voltage difference (error) between the +6.2 volts (zener diode VR2) at the base of Q13 and the voltage at the center of voltage divider R88-R89 (+12.4 volts across divider; resistors are equal). The amplified error across the collectors of Q12 and Q13 is the base-emitter bias of reference series regulator Q14. In response to the error signal, the reference series regulator adjusts the +12.4 Vdc so that it remains constant. Potentiometer R91 is a line compensation adjustment. Zener diode VR3 provides bias for Q14. Zener diodes VR2 and VR4 maintain the +6.2 and -9.4 Vdc for the voltage and current programming currents, respectively. Diode CR5 clamps the voltage across R4-R5 when the voltage programming resistance is turned down rapidly. (If the voltage programming resistance is reduced to zero rapidly, R6 would be connected directly to the negative output which might be at 1,000 Vdc; R6 limits the programming current.)

4-54 METER CIRCUIT

4-55 The ammeter is connected across current monitoring resistor R20. The voltage across R20 is proportional to the output current plus the voltage programming current. Resistors R118 and R119 (variable) calibrate the ammeter. The voltmeter is connected across R20 and the power supply output. This prevents the voltmeter current from flowing through R20. Resistors R127 and R117 (variable) calibrate the voltmeter; R116 drops most of the output voltage.

SECTION V
MAINTENANCE

5-1 GENERAL

5-2 Table 5-1 lists the type of test equipment, its required characteristics, use, and a recommended model for performing the instructions given in this section. Upon receipt of the power supply, the performance check should be made. This check is suitable for incoming inspection. Additional specification checks are given in Paragraphs 5-23 through 5-25. If a fault is detected in the power supply while making the performance check or during normal operation, proceed to the trouble-

during normal operation, proceed to the troubleshooting procedures. After troubleshooting and repair, perform any necessary adjustments and calibrations. Before returning the power supply to normal operation, repeat the performance check to ensure that the fault has been properly corrected and that no other faults exist. Before doing any maintenance checks, turn the power supply on, allow a half-hour warm-up, and read the measurement techniques discussed in the following paragraph.

Table 5-1. Test Equipment

Type	Required Characteristics	Use	Recommended Model
AC Voltmeter	Accuracy: 2%. Sensitivity: 1mv full scale (min.).	Measure AC voltages	Ⓢ 403 B
Variable Voltage Transformer	Range: 90-130 volts. Equipped with voltmeter accurate within 1 volt, 1 KW rating.	Vary and measure AC input voltage	-----
Oscilloscope	Sensitivity: 1 mv/cm (min.).	Measure ripple and transient response	Ⓢ 140 A plus 1400 A Plug-in.
Differential Voltmeter	Sensitivity: 1mv full scale (min.).	Measure regulation; Calibrate meter	Ⓢ 3420
Repetitive Load Switch	Rate: 60-400 Hz, 2μsec rise and fall time, 250V, 1A.	Measure transient response	See Figure 5-1
Resistive Loads	<u>Model</u> 6521A 5,000 Ω , \pm 5%, 200 W 6522A 20,000 Ω , \pm 5%, 200 W 6525A 80,000 Ω , \pm 5%, 200 W	Power supply load	-----
Current Sampling Resistor	\pm 1%, 20 W, 20ppm temp. coeff., 4 terminals <u>Model</u> <u>Value</u> 6521A 10 Ω 6522A 20 Ω 6525A 40 Ω	Measure current; calibrate meter	-----
Resistor	1K Ω , \pm 1% 2 W non-inductive.	Measure impedance	-----

Table 5-1. Test Equipment (Continued)

Type	Required Characteristics	Use	Recommended Model
Capacitor	500 μ fd, 50 vdcw	Measure impedance	-----
Resistor	2,000 ohms, \pm 5%, 20 W	Measure impedance	-----
Audio Oscillator	5 cps - 600 Kc. Accuracy: 2%. Output: 10 vrms	Measure impedance	Φ 200 CD
Shorting Switch	-----	Constant current load regulation	-----
Controlled-Temperature Oven	0-50°C	Measure temperature stability	-----
Resistance Box	0-100K Ω . Accuracy: 0.1% + 1 Ω . Make-before-break contacts.	Measure programming coefficients	Φ Model 6931A
Capacitor	01 μ fd, 4000 wvdc	Measure ripple and noise	-----
Voltage Divider	100:1, up to 4KV, 0.01% Accuracy	Load regulation. Line regulation.	Keithley Instruments, Inc. Model 6601A

5-3 MEASUREMENT TECHNIQUES

5-4 All measurements given in this manual are with a negative power supply output (positive terminal grounded to chassis). When measuring performance of the power supply it is important that the connection to the output terminal does not introduce additional resistance. For voltage measurements, use a T-connector at the positive output terminal and connect the load to one output of the T-connector and the measuring device to the other output of the T-connector. For current measurements, connect a four-terminal current monitoring resistor in series with the load resistor and connect both to one output of the T-connector. Connect the measuring device across the current monitoring resistor.

5-5 When using an oscilloscope, ground the case at the same ground point as the grounded terminal of the power supply. Make certain that the case is not also grounded by some other means (power cord).

Connect both oscilloscope input leads to the power supply ground and check that the oscilloscope is not exhibiting a ripple or transient due to ground loops, pick-up or other means.

5-6 PERFORMANCE TEST

5-7 The performance check is made using a 115-volt, 60-Hz (cps), single-phase input power source. The performance check is normally made at a constant ambient room temperature. The temperature range specification can be verified by doing the performance check (except temperature stability check) at a controlled temperature of 0°C and at a controlled temperature of 50°C. If the correct result is not obtained for a particular check, do not adjust any controls; proceed to troubleshooting.

5-8 CONSTANT VOLTAGE TESTS

5-9 Rated Output, Meter, and Output Controls Accuracy. Proceed as follows:

a. Connect the load resistance (value shown in Figure 5-1), 100:1 voltage divider, and the differential voltmeter to the T-connector.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Turn front-panel VOLTAGE controls until front-panel voltmeter indicates the maximum rated output voltage.

d. The differential voltmeter should indicate:

Model	6521A	6522A	6525A
Volts dc	10 ± 0.2	20 ± 0.4	40 ± 0.8

5-10 Line Regulation. Proceed as follows:

a. Turn front-panel CURRENT control fully clockwise (maximum).

b. Connect the variable voltage transformer between the input power source and the power supply power input. Adjust the variable voltage transformer to 105 VAC.

c. Turn front-panel VOLTAGE controls until the differential voltmeter indicates maximum rated output.

d. Adjust the variable voltage transformer to 125 VAC.

e. Differential voltmeter indication should change by less than:

Model	6521A	6522A	6525A
MVDC	0.2	0.3	0.5

5-11 Load Regulation. Proceed as follows:

a. Turn front-panel CURRENT control fully clockwise (maximum).

b. Turn front-panel VOLTAGE controls until the differential voltmeter indicates maximum rated output.

c. Disconnect load resistance.

d. Differential voltmeter indication should change by less than 0.6 mvdc.

5-12 Ripple and Noise. Proceed as follows:

a. Disconnect the 100:1 divider and connect the 5000 ohm load resistance to the power supply output.

b. Connect the oscilloscope (in series with the 0.01μf capacitor rated at 4000 wvdc) to the power supply output.

c. Turn front-panel CURRENT control fully clockwise (maximum).

d. Connect the variable voltage transformer between the input power source and the power supply power input. Adjust the variable voltage transformer to 125 VAC.

e. Turn front-panel VOLTAGE control until front-panel voltmeter indicates maximum rated voltage output.

f. The oscilloscope should indicate less than 1.4V P-P.

5-13 Transient Response. Proceed as follows:

a. Connect test setup shown in Figure 5-1.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Adjust front-panel VOLTAGE controls until front-panel voltmeter indicates 200vdc.

d. Energize the repetitive load switch from 115-volt, 60-Hz (cps), single-phase power source.

e. Recovery time on the oscilloscope display should not exceed 50μs as shown in Figure 5-2.

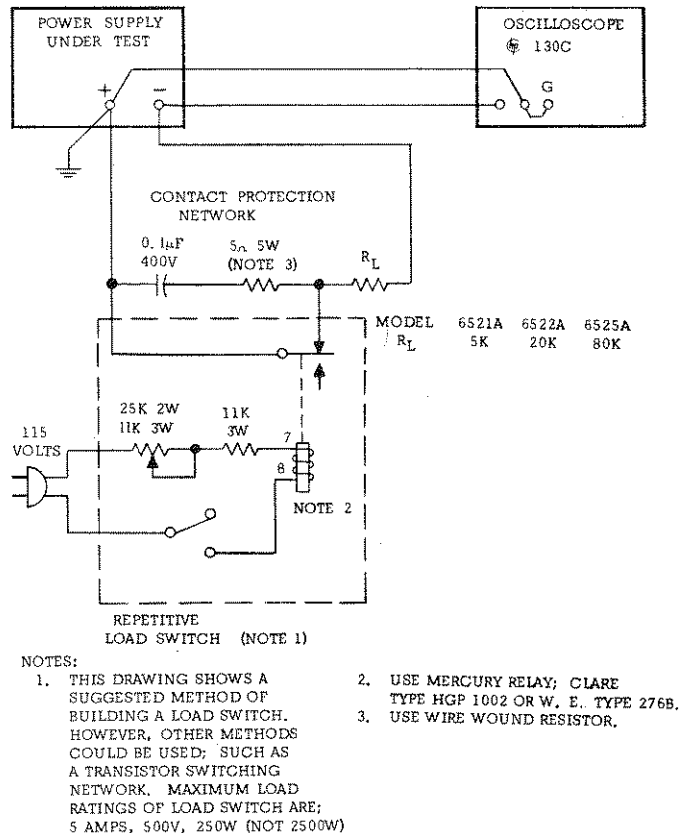


Figure 5-1. Transient Recovery Time Test Setup

5-14 ADDITIONAL CONSTANT VOLTAGE SPECIFICATION CHECK

5-15 Temperature Coefficient. Proceed as follows:

a. Connect the load resistance (value shown in Figure 5-1), 100:1 voltage divider, and the differential voltmeter to the T-connector.

b. Turn front-panel CURRENT control fully clockwise (maximum).

c. Turn front-panel VOLTAGE controls until the differential voltmeter indicates maximum rated voltage output.

- d. Insert the power supply into the controlled-temperature oven (differential voltmeter remains outside oven). Set the temperature to 30°C and allow a half-hour warm-up.
- e. Record the differential voltmeter indication.
- f. Raise the temperature to 40°C and allow a half-hour warm-up.
- g. Differential voltmeter indication should change by less than 20 mvdc from indication recorded in step e.

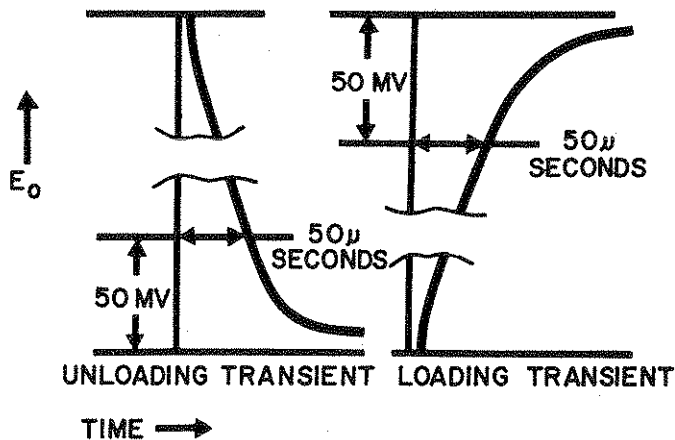


Figure 5-2. Transient Recovery Waveform Diagram

5-16 Output Stability. Proceed as follows:

- a. Turn front-panel CURRENT control fully clockwise (maximum).
- b. Turn front-panel VOLTAGE controls until the differential voltmeter indicates maximum rated output voltage.
- c. Allow a half-hour warm-up and then record the differential voltmeter indication.
- d. After eight hours, differential voltmeter indication should change by less than 3.6 mvdc from indication recorded in step d.

5-17 Output Impedance. Proceed as follows:

- a. Connect test setup shown in Figure 5-3.
- b. Turn front-panel CURRENT control fully clockwise (maximum).
- c. Adjust front-panel VOLTAGE controls until front-panel voltmeter indicates 200.0 vdc.
- d. Adjust the audio oscillator for a 10-vrms (E_{in}), 5-Hz (cps) output.
- e. Calculate and record the output impedance using the following formula:

$$Z_{out} \approx \frac{E_o R}{E_{in}} \quad \text{since } Z_{out} \ll R$$

$R = 1,000$ ohms; E_o measured across power supply front terminals using the AC voltmeter; E_{in} measured across audio oscillator output terminals using the AC voltmeter.

f. Using the formula given in step e, calculate and record the output impedance for audio oscillator frequencies of 100 Hz (cps), 1000 Hz, and 600 kHz at 10 vrms.

g. The output impedances calculated and recorded in steps e and f should fall into the following ranges:

- (1) DC to 100 Hz (cps); less than 0.01 ohm.
- (2) 100 Hz to 1 kHz; less than 0.02 ohm.
- (3) 1 kHz to 100 kHz; less than 0.5 ohm.
- (4) 100 kHz to 1 MHz; less than 3 ohms.

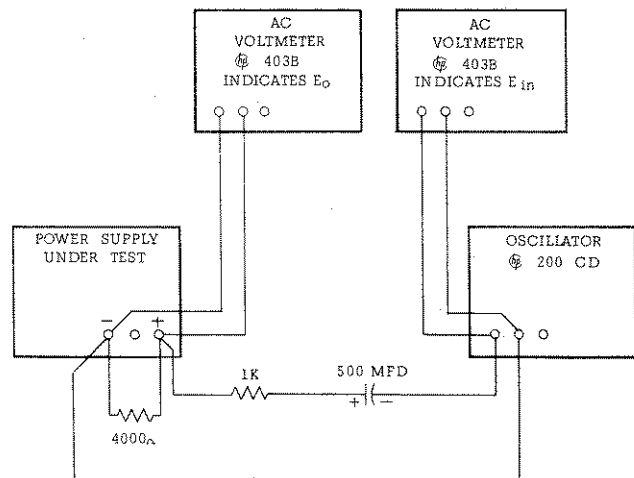


Figure 5-3. Output Impedance, Test Setup Diagram

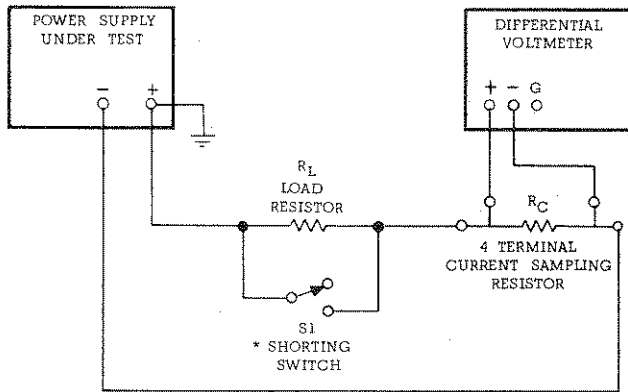
5-18 CONSTANT CURRENT OPERATION

5-19 Rated Output and Meter Accuracy. Proceed as follows:

- a. Connect test setup shown in Figure 5-4.
- b. Turn front-panel VOLTAGE controls to maximum rated output.
- c. Turn front-panel CURRENT control until front-panel ammeter indicates 0.20 ampere.
- d. The differential voltmeter should indicate 2 ± 0.04 vdc.

5-20 Line Regulation. Proceed as follows:

- a. Connect test setup shown in Figure 5-4.
- b. Turn front-panel VOLTAGE controls for maximum rated output.
- c. Connect the variable voltage transformer between the input power source and the power supply power input. Adjust the variable voltage transformer to 105 VAC.



MODEL	6521A	6522A	6525A
RL	5K	20K	80K
RC	10 Ω	20 Ω	40 Ω

* SHORTING SWITCH
USED ONLY FOR
CONSTANT CURRENT
LOAD REGULATION
CHECK AND +6.2 VOLT
REFERENCE CIRCUIT
LOAD REGULATION
ADJUSTMENT.

Figure 5-4. Constant Current Test Setup Diagram

d. Turn front-panel CURRENT control until the differential voltmeter indicates 2.0 vdc.

e. Adjust the variable voltage transformer to 125 VAC.

f. Differential voltmeter indication should change by less than 10.0 mvdc.

5-21 Load Regulation. Proceed as follows:

a. Connect test setup shown in Figure 5-4. Close shorting switch.

b. Turn front-panel VOLTAGE controls to maximum.

c. Turn front-panel CURRENT control until the differential voltmeter indicates 2.0 vdc.

d. Open the shorting switch.

e. Differential voltmeter indication should change by less than 10.0 mvdc.

5-22 Ripple and Noise. Proceed as follows:

a. Connect test setup shown in Figure 5-4 except replace the differential voltmeter with the AC voltmeter.

b. Turn front-panel VOLTAGE controls to maximum rated output voltage.

c. Connect the variable voltage transformer between the input power source and the power supply power input. Adjust the variable voltage transformer to 125 VAC.

d. Turn front-panel CURRENT control until front-panel ammeter indicates:

Model	MVDC
6521A	200
6522A	100
6525A	50

e. The AC voltmeter should indicate less than 20 mv rms.

5-23 ADDITIONAL CONSTANT CURRENT PERFORMANCE TESTS

5-24 Temperature Coefficient. Proceed as follows:

a. Connect test setup shown in Figure 5-4.

b. Turn front-panel VOLTAGE controls to maximum rated output voltage.

c. Turn front-panel CURRENT control until the differential voltmeter indicates 2.0 vdc.

d. Insert the power supply into the controlled-temperature oven (differential voltmeter remains outside oven). Set the temperature to 30°C and allow a half-hour warm-up.

e. Record the differential voltmeter indication.

f. Raise the temperature to 40°C and allow a half-hour warm-up.

g. Differential voltmeter indication should change by less than 60.0 mvdc, from indication recorded in step e.

5-25 Output Stability. Proceed as follows:

a. Connect test setup shown in Figure 5-4.

b. Turn front-panel VOLTAGE controls to maximum rated output voltage.

c. Turn front-panel CURRENT control until the differential voltmeter indicates 2.0 vdc.

d. Allow a half-hour warm-up and then record the differential voltmeter indication.

e. After eight hours, differential voltmeter indication should change by less than 10.0 mvdc from indication recorded in step d.

5-26 COVER REMOVAL

WARNING

Make certain power supply is off and high voltage capacitors are discharged (allow five minutes) before removing covers. The high voltage present in this power supply can cause injury.

5-27 The top and bottom covers are removed by removing both sets of six attaching screws.

5-28 TROUBLESHOOTING

5-29 If a fault in the power supply is suspected, remove the covers and visually inspect for broken connections, burned components, etc. If the fault is not detected visually, proceed to trouble analysis. If the fault is detected visually or via trouble

analysis, correct it and then perform the performance check (Paragraph 5-6). If a part is replaced, refer to repair and replacement Paragraph 5-39 and to adjustments and calibrations Paragraph 5-41.

5-30 TROUBLE ANALYSIS

5-31 Before attempting trouble analysis, a good understanding of the principles of operation should be acquired by reading Section IV of this manual. Once the principles of operation are understood, logical application of this knowledge in conjunction with significant waveforms and normal voltage information should suffice to isolate a fault to a part or small group of parts. Normal voltages and tolerances are provided on the overall schematic diagram at the rear of the manual. The voltages are positioned adjacent to test points (numbered balloons printed on the schematic diagrams and printed wiring boards). In addition waveform photographs taken at significant test points are provided on the apron of the schematic diagram.

5-32 In most cases a fault will manifest itself as either excessive voltage output or low voltage output (less than 40 volts). The latter is, by far, more common since the pulse-width modulator requires a series of trigger pulses at the proper intervals and sequence and the skipping of a pulse or an excessively long "on" interval will cause the transformer T1 to saturate and blow fuse F3. Thus the pulse-width modulator ceases to function causing no high-voltage to appear at the output.

5-33 With the exception of a component failure in the Line Voltage Bridge-Storage Capacitor circuit, the Pulse-width Modulator, the High-voltage Transformer, or the High-voltage Bridge-Storage Capacitor circuit all failures can be isolated to the "Piggy-back" power supply system. This allows a great deal of trouble shooting to be done with the pulse-width modulator inoperative so that the maximum voltage on the unit is the "Piggy-back" power supply which does not exceed 40 volts.

5-34 In addition to the normal voltages and waveforms, procedures are included for isolating common troubles as follows:

a. Procedure for checking the reference circuit. Trouble in this circuit should show up in many ways because it supplies internal operating voltages for the power supply.

b. Procedures for checking the voltage feedback loop for the two most common troubles; high or low output voltage (Table 5-2 and 5-3, respectively).

NOTE

Check the input power source for low or high voltage before assuming that the power supply is at fault. The turn-on-turn-off circuit will cause output to have excessive ripple and poor regulation if the line voltage is low.

c. Table 5-4 which gives the probable causes for some common troubles.

5-35 REFERENCE CIRCUIT. Turn the front-panel VOLTAGE and CURRENT controls fully clockwise (maximum). Ground +OUTPUT to chassis. Turn-on power supply (no load connected) and proceed as follows:

a. Using the differential voltmeter, check the +40 vdc between test points 16 and 37. If the voltage indication is not $+40 \pm 2$ vdc, diode CR70, CR71, or capacitor C26 is defective.

b. Using the differential voltmeter, check the +12.4 vdc between test points 18 and +out. If the voltage indication is not $+12.4 \pm 1.0$ vdc, transistor Q12, Q13, or Q14 is probably defective.

c. Using the differential voltmeter, check the +6.2 vdc between test points 17 and +out. If the voltage indication is not $+6.2 \pm 0.30$ vdc, diode VR2 is probably defective.

d. Using the differential voltmeter, check the -9.4 vdc between test points 32 and +out. If the voltage indication is not -9.4 ± 0.40 vdc, diode VR4 is probably defective.

e. Using the differential voltmeter, check the 20 vdc between test points 28 and 27. If the indication is not 19 ± 1 vdc, CR74, CR75 or C27 is probably defective.

5-36 HIGH OUTPUT VOLTAGE. Proceed as follows:

a. Turn front-panel CURRENT control fully clockwise (maximum).

b. Turn-on power supply (no load connected).

c. Turn front-panel VOLTAGE controls to 500.0 vdc.

d. Using the differential voltmeter, proceed as instructed in Table 5-2.

Table 5-2. High Output Voltage Troubleshooting

Step	Meter		Response	Probable Cause
	+	-		
1	16	13	+0.1 vdc 18 to 20 vdc	Q10 or Q11 shorted. Proceed to Step 2.
2	7	14	6 vdc 1 to 1.1 vdc.	CR11 or R32 open. Proceed to Step 3.
3	7	18	More positive than +6.8 vdc. 6.2 to 6.8 vdc.	a. Q1A or Q3 shorted. b. Q1B, Q2, or R13 open. Proceed with Step 4.
4	2	+out	More positive than 0 vdc. 0 vdc.	a. R5 shorted. b. Q1A shorted. Resistor in voltage control circuit open. If not, proceed with Step 5.
5	59	53	0.7 ± 0.2	CR15 shorted or other defect in pulse-width modulator. Use waveforms and normal voltages on schematic to locate.

5-37 LOW OUTPUT VOLTAGE. Check F3; if blown proceed as follows:

- a. Turn front-panel CURRENT control fully clockwise (maximum).
- b. Disconnect anode or cathode of diode CR12.
- c. Turn-on power supply (no load connected).
- d. Turn front-panel VOLTAGE controls to see if the 1,000 vdc output can be obtained. If it can, the probable cause of the low output voltage is one or more of the following:
 - (1) CR12 shorted.
 - (2) Q4 shorted.
 - (3) Q5 shorted.
 - (4) R26 shorted.
 - (5) R22 shorted.
- e. If the 1,000 vdc output cannot be obtained in step d, reconnect diode CR12 and turn the front-panel VOLTAGE controls to 500.0 vdc.
- f. Using the differential voltmeter and oscilloscope, check the following:

- (1) Waveform across test points 22 (positive lead) and 27 (waveform shown on schematic diagram). If waveform is incorrect, the Schmitt trigger circuit may be defective. Use standard troubleshooting techniques in conjunction with the normal voltages given on the schematic diagram to isolate the defect. If no waveform indication is observed, the 20 vdc bias supply (CR74, CR75, and C27) may be defective.

- (2) Voltages across test points 52 and 53. If voltage is not 160 ± 10 vdc, CR20 through CR23 or C32 may be defective.

- (3) Waveform across test points 60 (positive lead) and 55 (waveform shown on schematic diagram) If waveform is incorrect, CR25 through CR28, R48, R49, or T3 may be defective.

- (4) Waveform across test points 56 (positive lead) and 55 (waveform shown on schematic diagram). If waveform is incorrect, the pulse-width modulator may be defective. Use standard troubleshooting techniques in conjunction with the normal voltages and waveforms shown on the schematic diagram to isolate the defect.

- g. Using the differential voltmeter, proceed as instructed in Table 5-3.

Table 5-3. Low Output Voltage Troubleshooting

Step	Meter		Response	Probable Cause
	+	-		
1	16	13	More positive than 20 vdc. 18 to 20 vdc.	Q10 or Q11 open. Proceed with Step 2.
2	7	14	Less than 1 vdc 1 to 1.1 vdc	CR11 or R32 shorted. Proceed with Step 3.
3	18	7	Less than 6.2 vdc. 6.2 to 6.8 vdc.	a. Q1A or Q3 open. b. Q1B, Q2, or R13 shorted. Proceed with Step 4.
4	2	+out	More negative than 0 vdc. 0 vdc.	a. R3 open. b. Q1A open. Resistor in voltage control circuit shorted.

5-38 COMMON TROUBLES Table 5-4 gives the symptoms, checks, and probable causes for common troubles. The checks should be made using a

115-volt, 60-Hz (cps), single-phase power input and the test equipment listed in Table 5-1.

Table 5-4. Common Troubles

Symptom	Checks and Probable Causes
Poor Line Regulation	a. Check reference circuit (Paragraph 5-35). Refer to Paragraph 5-51 for adjustment. b. Check 20 and 40 vdc bias supplies.
Poor Load Regulation (Constant Voltage)	a. Check reference circuit (Paragraph 5-35). Refer to Paragraphs 5-53 and 5-55 for adjustments. b. Power supply going into current limit. Check constant current input circuit. c. Constant voltage loop oscillates. Check adjustment of R7 (Paragraph 5-58).
Poor Load Regulation (Constant Current)	a. Check reference circuit (Paragraph 5-35). Refer to Paragraphs 5-53 and 5-55 for adjustments. b. Power supply going into voltage limit. Check constant voltage input circuit. c. Constant current loop oscillates. Check C10.

Table 5-4. Common Troubles (Continued)

Symptom	Checks and Probable Causes
High Ripple	<ul style="list-style-type: none"> a. Check operating setup for ground loops. b. If output is floating (ungrounded) connect 1μf capacitor between output and ground (unless particular application prohibits this). c. Line compensation. Check adjustment of R91 (Paragraph 5-52).
Poor Stability (Constant Voltage)	<ul style="list-style-type: none"> a. Check reference circuit (Paragraph 5-35). b. Check adjustment of R7 (Paragraph 5-57). c. Noisy programming resistors. d. CR3 or CR4 leaky. e. R4, R5, R6, or R86 noisy or drifting. f. Q1, Q2, or Q3 defective.
Poor Stability (Constant Current)	<ul style="list-style-type: none"> a. Check reference circuit (Paragraph 5-35). b. Noisy programming resistor (R21). c. R22 noisy or drifting. d. Q4 or Q5 defective. e. CR9 leaky.
Oscillates (Constant Voltage)	Check adjustment of R7 (Paragraph 5-57).
Oscillates (Constant Current)	Check C10.
Output Voltage Does Not Go To Zero	Check voltage programming resistors and input circuit.
Output Current Does Not Go To Zero	Check R23 and R24.

5-39 REPAIR AND REPLACEMENT

5-40 Before servicing a printed wiring board, refer to Figure 5-5. When replacing semiconductor devices, make certain that a mica washer and a good silicone grease (Dow Corning silicone grease #3 or equivalent) are used for mounting in order to provide good heat conduction to the chassis.

Before replacing a semiconductor device, refer to Table 5-5 which lists the characteristics of each device and the suggested commercial replacement. After replacing a semiconductor device, refer to Table 5-6 for checks and adjustments that may be necessary. If a check indicates a trouble, refer to Paragraph 5-28. If an adjustment is necessary, refer to Paragraph 5-41.

Excessive heat or pressure can lift the copper strip from the board. Avoid damage by using a low power soldering iron (50 watts maximum) and following these instructions. Copper that lifts off the board should be cemented in place with a quick drying acetate base cement having good electrical insulating properties.

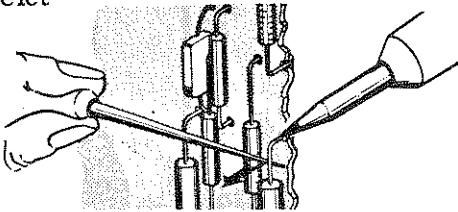
A break in the copper should be repaired by soldering a short length of tinned copper wire across the break.

Use only high quality rosin core solder when repairing etched circuit boards. NEVER USE PASTE FLUX. After soldering, clean off any excess flux and coat the repaired area with a high quality electrical varnish or lacquer.

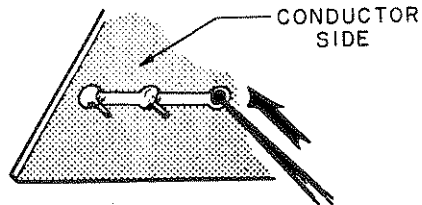
When replacing components with multiple mounting pins such as tube sockets, electrolytic capacitors, and potentiometers, it will be necessary to lift each pin slightly, working around the components several times until it is free.

WARNING: If the specific instructions outlined in the steps below regarding etched circuit boards without eyelets are not followed, extensive damage to the etched circuit board will result.

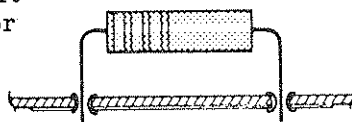
1. Apply heat sparingly to lead of component to be replaced. If lead of component passes through an eyelet in the circuit board, apply heat on component side of board. If lead of component does not pass through an eyelet, apply heat to conductor side of board.



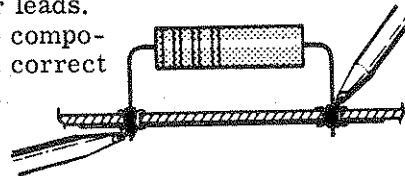
2. Reheat solder in vacant eyelet and quickly insert a small awl to clean inside of hole. If hole does not have an eyelet, insert awl or a #57 drill from conductor side of board.



3. Bend clean tinned lead on new part and carefully insert through eyelets or holes in board.

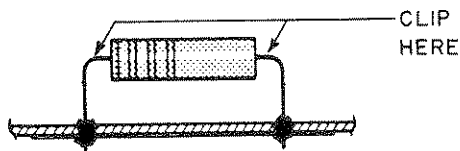


4. Hold part against board (avoid overheating) and solder leads. Apply heat to component leads on correct side of board as explained in step 1.

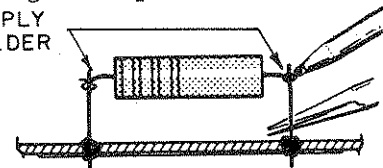


In the event that either the circuit board has been damaged or the conventional method is impractical, use method shown below. This is especially applicable for circuit boards without eyelets.

1. Clip lead as shown below.



2. Bend protruding leads upward. Bend lead of new component around protruding lead. Apply solder using a pair of long nose pliers as a heat sink.



This procedure is used in the field only as an alternate means of repair. It is not used within the factory.

Figure 5-5. Servicing Printed Circuit Wiring Boards

Table 5-5. Selected Semiconductor Characteristics

Reference Designator	Characteristics	Ⓢ Stock Number	Suggested Replacement
Q1	Matched differential amplifier.	1854-0221	2N4045 Union Carbide
Q2 - Q7, Q10, Q12, Q13	NPN Si planar, $70 h_{FE}$, $i_C = 2 \text{ ma}$, $V_{CE} = 1 \text{ V}$.	1854-0027	2N2714 G. E.
Q11, Q17	NPN power, $h_{FE} = 35$ (min.) at $I_C = 4 \text{ A}$, $V_{CE} = 4 \text{ V}$.	1854-0225	233055 R. C. A.
Q14, Q16	NPN, Si, $h_{FE} = 60$ (min.) at $I_C = 1 \text{ ma}$; $V_{CE} = 1 \text{ V}$.	1854-0244	2N2195 G. E.
CR9, CR25, CR26, CR61 - CR66, CR80	Si rectifier, 200 ma, 10 prv	1901-0461	1N4828
VR1, VR3, VR5	Zener diode, 6.19 V, 400 mw	1902-0049	1N753 Motorola

Table 5-6. Checks and Adjustments After Replacement of Semiconductor Devices

Reference	Function	Check	Adjust
Q1, Q2, Q3	Constant voltage differential amplifier	Constant voltage load regulation	-----
Q4, Q5	Constant current differential amplifier	Constant current load regulation	-----
Q6, Q7	Error amplifier	Constant voltage/constant current load regulation	-----
Q10, Q11, Q17	Series regulator	Constant voltage/constant current line and load regulation	-----
Q12, Q13	Reference circuit amplifier	Constant voltage/constant current line regulation	R91
Q14	Reference circuit series regulator	Constant voltage/constant current line regulation	R91
Q15, Q16	Schmitt Trigger	Load regulation	-----

Table 5-6. Checks and Adjustments After Replacement of Semiconductor Devices (Continued)

Reference	Function	Check	Adjust
CR3, CR4, CR72	Protection diodes	Constant voltage load regulation	-----
CR15, CR16	SCR's	Constant voltage/constant current regulation	-----
CR20—CR23	Bridge rectifier	Voltage across C32	-----
CR70, CR71	Full-wave rectifier	Voltage across C26	-----
CR74, CR75	Full-wave rectifier	Voltage across C27	-----
CR76, CR77	Full-wave rectifier	Voltage across C30	-----
CR30 — CR41	Bridge rectifier	Voltage across C24	-----
CR30 — CR47 (6525A ONLY)	Bridge rectifier	Voltage across C24	-----
VR1, VR5	(+6.2 vdc) bias	Constant voltage/constant current line and load regulation	-----
VR2, VR3	Positive reference voltage (+6.2 vdc)	Line and load regulation of +6.2 vdc	R91
VR4	Negative reference voltage (-9.4 vdc)	Line and load regulation of -9.4 vdc	-----

5-41 ADJUSTMENTS AND CALIBRATIONS

5-42 Adjustments and calibrations may be required after performance testing, troubleshooting, or repair and replacement. Test points called out in the procedures are identified on the overall sche-

matic diagram. If an adjustment or calibration cannot be performed, troubleshooting is required. Table 5-7 summarizes the adjustments and calibrations. The adjustments and calibrations are performed using a 115-volt, 60-Hz (cps), single-phase power input to the power supply.

Table 5-7. Adjustment and Calibration Summary

Adjustment or Calibration	Paragraph Reference	Control Device
Meter Zero	5-43	Meter Spring
Voltmeter Tracking	5-45	R117
Ammeter Tracking	5-47	R119
Constant Voltage Programming Current	5-49	R4, R5
Output Voltage Line Regulation	5-51	R91
-9.4 VDC Reference Load Regulation	5-53	Replace VR4
+6.2 VDC Reference Load Regulation	5-55	Replace VR2
Voltage Output Stability	5-57	R7

5-43 METER ZERO

5-44 Proceed as follows:

- a. Turn-off power supply and allow five minutes for all capacitors to discharge.
- b. Remove top cover (Paragraph 5-26).
- c. Rotate meter zero set screw (located behind front panel at top of meter) clockwise until the front-panel meter pointer is to the right of zero and moving to the left towards zero. Stop when pointer is on zero. If the pointer overshoots zero, continue rotating clockwise and repeat this step.
- d. When the pointer is exactly on zero, rotate the zero set screw approximately 15 degrees counterclockwise to free the screw from the meter suspension. If pointer moves, repeat steps c and d.

5-45 VOLTMETER TRACKING

5-46 Proceed as follows:

- a. Connect the differential voltmeter and the 100:1 voltage divider to the T-connector.
- b. Turn front-panel VOLTAGE controls until the differential voltmeter indicates maximum rated voltage output of power supply.
- c. Adjust R117 until front-panel voltmeter indicates:

Model	6521A	6522A	6525A
Kilovolts DC	1	2	4

5-47 AMMETER TRACKING

5-48 Proceed as follows:

- a. Connect test setup shown in Figure 5-4.
- b. Turn front-panel VOLTAGE controls to maximum.
- c. Turn front-panel CURRENT control until differential voltmeter indicates 2.0 vdc.
- d. Adjust R119 until front-panel ammeter indicates maximum rated output current of the supply.

5-49 CONSTANT VOLTAGE PROGRAMMING CURRENT

5-50 Proceed as follows:

- a. Using the differential voltmeter, check voltage across test points 17 and +OUT. If voltage is greater than 6.2 vdc, R4 should be 3,000 ohms; if voltage is less than 6.2 vdc, R4 should be 2,600 ohms.
- b. Connect the differential voltmeter and the 100:1 voltage divider to the T-connector.
- c. Connect the resistance box (set to 100,000 ohms) in place of R5.

- d. Turn front-panel VOLTAGE controls to 1,000 vdc.
- e. Adjust the resistance box until the differential voltmeter indication is $1,000 \pm 5.0$ vdc.
- f. Choose R5 equal to the resistance value required in step e. R5 must be greater than 30K if carbon composition, 10K if metal film with a temperature coefficient of ± 100 ppm.

5-51 OUTPUT VOLTAGE LINE REGULATION

5-52 Proceed as follows:

- a. Connect the differential voltmeter to the T-connector.
- b. Connect the variable voltage transformer between input power source and power supply power input.
- c. Turn front-panel VOLTAGE controls until the differential voltmeter indicates 1,000 vdc.
- d. Adjust variable voltage transformer to

105 volts.

- e. Adjust R91 so that the voltage indicated by the differential voltmeter does not change more than 50.0 mvdc as the variable voltage transformer is varied from 105 to 125 volts. This may be easily achieved by noting value at 105 then setting adjust to return to this value at 125. Repeat several times.

5-53 VOLTAGE OUTPUT STABILITY

5-54 Proceed as follows:

- a. Connect the oscilloscope to the T-connector.
- b. Connect the resistance box (set to 24,000 ohms) in place of R7.
- c. Turn front-panel VOLTAGE OUTPUT controls to 1,000 vdc.
- d. Adjust the resistance box until there are no oscillations detected on the oscilloscope.
- e. Choose R7 equal to the resistance value required in step d.

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. Description. Refer to Table 6-2 for abbreviations.
- c. Total Quantity (TQ). Given only the first time the part number is listed except in instruments containing many sub-modular assemblies, in which case the TQ appears the first time the part number is listed in each assembly.
- d. Manufacturer's Part Number or Type.
- e. Manufacturer's Federal Supply Code Number. Refer to Table 6-3 for manufacturer's name and address.
- f. Hewlett-Packard Part Number.
- g. Recommended Spare Parts Quantity (RS) for complete maintenance of one instrument during one year of isolated service.
- h. Parts not identified by a reference designator are listed at the end of Table 6-4 under Mechanical and/or Miscellaneous. The former consists of parts belonging to and grouped by individual assemblies; the latter consists of all parts not immediately associated with an assembly.

6-3 ORDERING INFORMATION

6-4 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 6-1. Reference Designators

A = assembly	E = miscellaneous
B = blower (fan)	electronic part
C = capacitor	F = fuse
CB = circuit breaker	J = jack, jumper
CR = diode	K = relay
DS = device, signaling (lamp)	L = inductor
	M = meter

Table 6-1. Reference Designators (Continued)

P = plug	V = vacuum tube, neon bulb, photocell, etc.
Q = transistor	VR = zener diode
R = resistor	X = socket
S = switch	Z = integrated circuit or network
T = transformer	
TB = terminal block	
TS = thermal switch	

Table 6-2. Description Abbreviations

A = ampere	mfr = manufacturer
ac = alternating current	mod. = modular or modified
assy. = assembly	mtg = mounting
bd = board	n = nano = 10^{-9}
bkt = bracket	NC = normally closed
°C = degree Centigrade	NO = normally open
cd = card	NP = nickel-plated
coef = coefficient	Ω = ohm
comp = composition	obd = order by description
CRT = cathode-ray tube	OD = outside diameter
CT = center-tapped	p = pico = 10^{-12}
dc = direct current	P.C. = printed circuit
DPDT = double pole, double throw	pot. = potentiometer
DPST = double pole, single throw	p-p = peak-to-peak
elect = electrolytic	ppm = parts per million
encap = encapsulated	pvr = peak reverse voltage
F = farad	rect = rectifier
°F = degree Fahrenheit	rms = root mean square
fxd = fixed	Si = silicon
Ge = germanium	SPDT = single pole, double throw
H = Henry	SPST = single pole, single throw
Hz = Hertz	SS = small signal
IC = integrated circuit	T = slow-blow
ID = inside diameter	tan. = tantalum
incnd = incandescent	Ti = titanium
k = kilo = 10^3	V = volt
m = milli = 10^{-3}	var = variable
M = mega = 10^6	ww = wirewound
μ = micro = 10^{-6}	W = Watt
met. = metal	

Table 6-3. Code List of Manufacturers

CODE NO.	MANUFACTURER	ADDRESS
00629	EBY Sales Co., Inc.	Jamaica, N. Y.
00656	Aerovox Corp.	New Bedford, Mass.
00853	Sangamo Electric Co.	
	S. Carolina Div.	Pickens, S. C.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	
		Beverly Hills, Calif.
01281	TRW Semiconductors, Inc.	
		Lawndale, Calif.
01295	Texas Instruments, Inc.	
	Semiconductor-Components Div.	
		Dallas, Texas
01686	RCL Electronics, Inc.	Manchester, N. H.
01930	Amerock Corp.	Rockford, Ill.
02107	Sparta Mfg. Co.	Dover, Ohio
02114	Ferroxcube Corp.	Saugerties, N. Y.
02606	Penwal Laboratories	Morton Grove, Ill.
02660	Amphenol Corp.	Broadview, Ill.
02735	Radio Corp. of America, Solid State and Receiving Tube Div.	Somerville, N. J.
03508	G. E. Semiconductor Products Dept.	
		Syracuse, N. Y.
03797	Eldema Corp.	Compton, Calif.
03877	Transitron Electronic Corp.	
		Wakefield, Mass.
03888	Pyrofilm Resistor Co. Inc.	
		Cedar Knolls, N. J.
04009	Arrow, Hart and Hegeman Electric Co.	
		Hartford, Conn.
04072	ADC Electronics, Inc.	Harbor City, Calif.
04213	Caddell & Burns Mfg. Co. Inc.	
		Mineola, N. Y.
04404	*Hewlett-Packard Co. Palo Alto Div.	
		Palo Alto, Calif.
04713	Motorola Semiconductor Prod. Inc.	
		Phoenix, Arizona
05277	Westinghouse Electric Corp.	
	Semiconductor Dept.	Youngwood, Pa.
05347	Ultronix, Inc.	Grand Junction, Colo.
05820	Wakefield Engr. Inc.	Wakefield, Mass.
06001	General Elect. Co. Electronic Capacitor & Battery Dept.	Irmo, S. C.
06004	Bassik Div. Stewart-Warner Corp.	
		Bridgeport, Conn.
06486	IRC Div. of TRW Inc.	
	Semiconductor Plant	Lynn, Mass.
06540	Amatom Electronic Hardware Co. Inc.	
		New Rochelle, N. Y.
06555	Beede Electrical Instrument Co.	
		Penacook, N. H.
06666	General Devices Co. Inc.	
		Indianapolis, Ind.
06751	Semcor Div. Components, Inc.	
		Phoenix, Arizona
06776	Robinson Nugent, Inc.	New Albany, Ind.
06812	Torrington Mfg. Co., West Div.	
		Van Nuys, Calif.
07137	Transistor Electronics Corp.	
		Minneapolis, Minn.

CODE NO.	MANUFACTURER	ADDRESS
07138	Westinghouse Electric Corp.	
	Electronic Tube Div.	Elmira, N. Y.
07263	Fairchild Camera and Instrument Corp. Semiconductor Div.	
		Mountain View, Calif.
07387	Birtcher Corp., The	Los Angeles, Calif.
07397	Sylvania Electric Prod. Inc.	
	Sylvania Electronic Systems Western Div.	Mountain View, Calif.
07716	IRC Div. of TRW Inc.	Burlington Plant Burlington, Iowa
07910	Continental Device Corp.	
		Hawthorne, Calif.
07933	Raytheon Co. Components Div. Semiconductor Operation	
		Mountain View, Calif.
08484	Breeze Corporations, Inc.	Union, N. J.
08530	Reliance Mica Corp.	Brooklyn, N. Y.
08717	Sloan Company, The	Sun Valley, Calif.
08730	Vemaline Products Co. Inc.	Wyckoff, N. J.
08806	General Elect. Co. Minia- ture Lamp Dept.	Cleveland, Ohio
08863	Nylomatic Corp.	Norrisville, Pa.
08919	RCH Supply Co.	Vernon, Calif.
09021	Airco Speer Electronic Components	
		Bradford, Pa.
09182	*Hewlett-Packard Co. New Jersey Div.	
		Berkeley Heights, N. J.
09213	General Elect. Co. Semiconductor Prod. Dept.	Buffalo, N. Y.
09214	General Elect. Co. Semiconductor Prod. Dept.	Auburn, N. Y.
09353	C & K Components Inc.	Newton, Mass.
09922	Burndy Corp.	Norwalk, Conn.
11115	Wagner Electric Corp.	
	Tung-Sol Div.	Bloomfield, N. J.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of Cal. Inc.	
		So. Pasadena, Calif.
11502	IRC Div. of TRW Inc.	Boone Plant Boone, N. C.
11711	General Instrument Corp Rectifier Div.	Newark, N. J.
12136	Philadelphia Handle Co. Inc.	
		Camden, N. J.
12615	U. S. Terminals, Inc.	Cincinnati, Ohio
12617	Hamlin Inc.	Lake Mills, Wisconsin
12697	Clarostat Mfg. Co. Inc.	Dover, N. H.
13103	Thermalloy Cp.	Dallas, Texas
14493	*Hewlett-Packard Co. Loveland Div.	
		Loveland, Colo.
14655	Cornell-Dubilier Electronics Div. Federal Pacific Electric Co.	
		Newark, N. J.
14936	General Instrument Corp. Semicon- ductor Prod. Group	Hicksville, N. Y.
15801	Fenwal Elect.	Framingham, Mass.
16299	Corning Glass Works, Electronic Components Div.	Raleigh, N. C.

*Use Code 28480 assigned to Hewlett-Packard Co., Palo Alto, California

Table 6-3. Code List of Manufacturers (Continued)

CODE NO.	MANUFACTURER	ADDRESS
16758	Delco Radio Div. of General Motors Corp.	Kokomo, Ind.
17545	Atlantic Semiconductors, Inc.	Asbury Park, N. J.
17803	Fairchild Camera and Instrument Corp Semiconductor Div. Transducer Plant	Mountain View, Calif.
17870	Daven Div. Thomas A. Edison Industries McGraw-Edison Co.	Orange, N. J.
18324	Signetics Corp.	Sunnyvale, Calif.
19315	Bendix Corp. The Navigation and Control Div.	Teterboro, N. J.
19701	Electra/Midland Corp.	Mineral Wells, Texas
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.
22229	Union Carbide Corp. Electronics Div.	Mountain View, Calif.
22753	UID Electronics Corp.	Hollywood, Fla.
23936	Pamotor, Inc.	Pampa, Texas
24446	General Electric Co.	Schenectady, N. Y.
24455	General Electric Co. Lamp Div. of Con- sumer Prod. Group	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
24681	LTV Electrosystems Inc Memcor/Com- ponents Operations	Huntington, Ind.
26982	Dynacool Mfg. Co. Inc.	Saugerties, N. Y.
27014	National Semiconductor Corp.	Santa Clara, Calif.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
28520	Heyman Mfg. Co.	Kenilworth, N. J.
28875	IMC Magnetics Corp.	New Hampshire Div. Rochester, N. H.
31514	SAE Advance Packaging, Inc.	Santa Ana, Calif.
31827	Budwig Mfg. Co.	Ramona, Calif.
33173	G. E. Co. Tube Dept.	Owensboro, Ky.
35434	Lectrohm, Inc.	Chicago, Ill.
37942	P. R. Mallory & Co. Inc.	Indianapolis, Ind.
42190	Muter Co.	Chicago, Ill.
43334	New Departure-Hyatt Bearings Div. General Motors Corp.	Sandusky, Ohio
44655	Ohmite Manufacturing Co.	Skokie, Ill.
46384	Penn Engr. and Mfg. Corp.	Doylestown, Pa.
47904	Polaroid Corp.	Cambridge, Mass.
49956	Raytheon Co.	Lexington, Mass.
55026	Simpson Electric Co. Div. of American Gage and Machine Co.	Chicago, Ill.
56289	Sprague Electric Co.	North Adams, Mass.
58474	Superior Electric Co.	Bristol, Conn.
58849	Syntron Div. of FMC Corp.	Homer City, Pa.
59730	Thomas and Betts Co.	Philadelphia, Pa.
61637	Union Carbide Corp.	New York, N. Y.
63743	Ward Leonard Electric Co.	Mt. Vernon, N. Y.

CODE NO.	MANUFACTURER	ADDRESS
70563	Amperite Co. Inc.	Union City, N. J.
70901	Beemer Engrg. Co.	Fort Washington, Pa.
70903	Belden Corp.	Chicago, Ill.
71218	Bud Radio, Inc.	Willoughby, Ohio
71279	Cambridge Thermionic Corp.	Cambridge, Mass.
71400	Bussmann Mfg. Div. of McGraw & Edison Co.	St. Louis, Mo.
71450	CTS Corp.	Elkhart, Ind.
71468	I. T. T. Cannon Electric Inc.	Los Angeles, Calif.
71590	Globe-Union Inc.	Milwaukee, Wis.
71700	General Cable Corp. Cornish Wire Co. Div.	Williamstown, Mass.
71707	Coto Coil Co. Inc.	Providence, R. I.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71785	Cinch Mfg. Co. and Howard B. Jones Div.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro Motive Mfg. Co. Inc.	Willimantic, Conn.
72619	Dialight Corp.	Brooklyn, N. Y.
72699	General Instrument Corp.	Newark, N. J.
72765	Drake Mfg. Co.	Harwood Heights, Ill.
72962	Elastic Stop Nut Div. of Amerace Esna Corp.	Union, N. J.
72982	Erie Technological Products Inc.	Erie, Pa.
73096	Hart Mfg. Co.	Hartford, Conn.
73138	Beckman Instruments Inc. Helipot Div.	Fullerton, Calif.
73168	Fenwal, Inc.	Ashland, Mass.
73293	Hughes Aircraft Co. Electron Dynamics Div.	Torrance, Calif.
73445	Amperex Electronic Corp.	Hicksville, N. Y.
73506	Bradley Semiconductor Corp.	New Haven, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73734	Federal Screw Products, Inc.	Chicago, Ill.
74193	Heinemann Electric Co.	Trenton, N. J.
74545	Hubbell Harvey Inc.	Bridgeport, Conn.
74868	Amphenol Corp. Amphenol RF Div.	Danbury, Conn.
74970	E. F. Johnson Co.	Waseca, Minn.
75042	IRC Div. of TRW, Inc.	Philadelphia, Pa.
75183	*Howard B. Jones Div. of Cinch Mfg. Corp.	New York, N. Y.
75376	Kurz and Kasch, Inc.	Dayton, Ohio
75382	Kilka Electric Corp.	Mt. Vernon, N. Y.
75915	Littlefuse, Inc.	Des Plaines, Ill.
76381	Minnesota Mining and Mfg. Co.	St. Paul, Minn.
76385	Minor Rubber Co. Inc.	Bloomfield, N. J.
76487	James Millen Mfg. Co. Inc.	Malden, Mass.
76493	J. W. Miller Co.	Compton, Calif.

*Use Code 71785 assigned to Cinch Mfg. Co., Chicago, Ill.

Table 6-3. Code List of Manufacturers (Continued)

CODE NO.	MANUFACTURER	ADDRESS
76530	Cinch	City of Industry, Calif.
76854	Oak Mfg. Co. Div. of Oak	
77068	Electro/Netics Corp.	Crystal Lake, Ill.
	Bendix Corp., Electrodynamics Div.	
		No. Hollywood, Calif.
77122	Palnut Co.	Mountainside, N.J.
77147	Patton-MacGuyer Co.	Providence, R. I.
77221	Phaostron Instrument and Electronic Co.	
		South Pasadena, Calif.
77252	Philadelphia Steel and Wire Corp.	
		Philadelphia, Pa.
77342	American Machine and Foundry Co.	
	Potter and Brumfield Div.	Princeton, Ind.
77630	TRW Electronic Components Div.	
		Camden, N.J.
77764	Resistance Products Co.	Harrisburg, Pa.
78189	Illinois Tool Works Inc. Shakeproof Div.	
		Elgin, Ill.
78452	Everlock Chicago, Inc.	Chicago, Ill.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78526	Stanwyck Winding Div.	San Fernando
	Electric Mfg. Co. Inc.	Newburgh, N.Y.
78553	Tinnerman Products, Inc.	Cleveland, Ohio
78584	Stewart Stamping Corp.	Yonkers, N.Y.
79136	Waldes Kohinoor, Inc.	L. I. C., N.Y.
79307	Whitehead Metals Inc.	New York, N.Y.
79727	Continental-Wirt Electronics Corp.	
		Philadelphia, Pa.
79963	Zierick Mfg. Co.	Mt. Kisco, N.Y.
80031	Mepco Div. of Sessions Clock Co.	
		Morristown, N.J.
80294	Bourns, Inc.	Riverside, Calif.
81042	Howard Industries Div. of Msl Ind. Inc.	
		Racine, Wisc.
81073	Grayhill, Inc.	La Grange, Ill.
81483	International Rectifier Corp.	
		El Segundo, Calif.
81751	Columbus Electronics Corp.	Yonkers, N.Y.
82099	Goodyear Sundries & Mechanical Co. Inc.	
		New York, N.Y.
82142	Airco Speer Electronic Components	
		Du Bois, Pa.
82219	Sylvania Electric Products Inc.	
	Electronic Tube Div. Receiving	
	Tube Operations	Emporium, Pa.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Metals and Controls Inc. Control	
	Products Group	Attleboro, Mass.
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Calif.
83058	Carr Fastener Co.	Cambridge, Mass.
83186	Victory Engineering Corp.	
		Springfield, N.J.
83298	Bendix Corp. Electric Power Div.	
		Eatontown, N.J.
83330	Herman H. Smith, Inc.	Brooklyn, N.Y.
83385	Central Screw Co.	Chicago, Ill.
83501	Gavitt Wire and Cable Div. of	
	Amerace Esna Corp.	Brookfield, Mass.

CODE NO.	MANUFACTURER	ADDRESS
83508	Grant Pulley and Hardware Co.	
		West Nyack, N.Y.
83594	Burroughs Corp. Electronic	
	Components Div.	Plainfield, N.J.
83835	U. S. Radium Corp.	Morristown, N.J.
83877	Yardeny Laboratories, Inc.	
		New York, N.Y.
84171	Arco Electronics, Inc.	Great Neck, N.Y.
84411	TRW Capacitor Div.	Ogallala, Neb.
86684	RCA Corp. Electronic Components	
		Harrison, N.J.
86838	Rummel Fibre Co.	Newark, N.J.
87034	Marco & Oak Industries a Div. of Oak	
	Electro/netics Corp.	Anaheim, Calif.
87216	Philco Corp. Lansdale Div.	Lansdale, Pa.
87585	Stockwell Rubber Co. Inc.	
		Philadelphia, Pa.
87929	Tower-Olschan Corp.	Bridgeport, Conn.
88140	Cutler-Hammer Inc. Power Distribution	
	and Control Div. Lincoln Plant	
		Lincoln, Ill.
88245	Litton Precision Products Inc, USECO	
	Div. Litton Industries	Van Nuys, Calif.
90634	Gulton Industries Inc.	Metuchen, N.J.
90763	United-Car Inc.	Chicago, Ill.
91345	Miller Dial and Nameplate Co.	
		El Monte, Calif.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat, Inc.	Attleboro, Mass.
91637	Dale Electronics, Inc.	Columbus, Neb.
91662	Elco Corp.	Willow Grove, Pa.
91929	Honeywell Inc. Div. Micro Switch	
		Freeport, Ill.
92825	Whitso, Inc.	Schiller Pk., Ill.
93332	Sylvania Electric Prod. Inc. Semi-	
	conductor Prod. Div.	Woburn, Mass.
93410	Essex Wire Corp. Stemco	
	Controls Div.	Mansfield, Ohio
94144	Raytheon Co. Components Div.	
	Ind. Components Oper.	Quincy, Mass.
94154	Wagner Electric Corp.	
	Tung-Sol Div.	Livingston, N.J.
94222	Southco Inc.	Lester, Pa.
95263	Leecraft Mfg. Co. Inc.	L. I. C., N.Y.
95354	Methode Mfg. Co.	Rolling Meadows, Ill.
95712	Bendix Corp. Microwave	
	Devices Div.	Franklin, Ind.
95987	Weckesser Co. Inc.	Chicago, Ill.
96791	Amphenol Corp. Amphenol	
	Controls Div.	Janesville, Wis.
97464	Industrial Retaining Ring Co.	
		Irvington, N.J.
97702	IMC Magnetics Corp. Eastern Div.	
		Westbury, N.Y.
98291	Sealectro Corp.	Mamaroneck, N.Y.
98410	ETC Inc.	Cleveland, Ohio
98978	International Electronic Research Corp.	
		Burbank, Calif.
99934	Renbrandt, Inc.	Boston, Mass.

Reference Designator	Description	Quantity	Mfr. Part # or Type	Mfr.	Mfr. Code	Stock No.	RS
C1	paper film glasscase .1 μ f 4KV	1	268P10	Sprague	56289	-	1
C2, 42	fxd, film .22 μ f 80vdc	2	192P2249R8	Sprague	56289	0160-2453	1
C3, 4, 10	fxd, film .1 μ f 200vdc	3	192P10492	Sprague	56289	0160-0168	1
C5, 6	fxd, mica 510 μ f	2	RCM15E 511J	Arco	04062	0140-0047	1
C7-9, 11, 15, 17, 18, 23, 25, 35, 36, 38	NOT ASSIGNED	-	-	-	-	-	-
C12, 16	fxd, film .01 μ f 200vdc	2	192P10392	Sprague	56289	0160-0161	1
C13	fxd, film .0047 μ f 200vdc	1	192P47292	Sprague	56289	0160-0157	1
C14	NOT USED	-	-	-	-	-	-
C19	2.3 μ f 400vdc SPECIAL	1	3S3420	HLAB	09182	-	1
C20-22	fxd, paper .047 μ f 400vdc	3	191P4730454	Sprague	56289	0160-2479	1
C24	non-elect. 8 μ f 2000vdc	1	DCP49993	Sprague	56289	0160-2582	1
C26, 27	fxd, elect 1450 μ f 45vdc	2	D39532	Sprague	56289	0180-1893	1
C28	non-elect 1 μ f 4000vdc	1	DCP49991	Sprague	56289	0160-2580	1
C29	fxd, elect 100 μ f 50vdc	1	D32218	Sprague	56289	0180-1852	1
C30	fxd, elect 20 μ f 50vdc	1	30D206G050DC4	Sprague	56289	0180-0049	1
C31	fxd, elect 100 μ f 25vdc	1	30D107G025DH4	Sprague	56289	0180-0094	1
C32	fxd, elect 3300 μ f 200vdc	1	32D332F200DE6A	Sprague	56289	0180-1840	1
C33, 34	fxd, paper .1 μ f 400vdc	2	160P10494	Sprague	56289	0160-0013	1
C37, 40	fxd, elect 20 μ f 15vdc	2	30D206G015BB4	Sprague	56289	0180-0300	1
C39, 41, 45	fxd, film .033 μ f 200vdc	3	192P33392	Sprague	56289	0160-0163	1
C43, 44	fxd, ceramic .01 μ f 500wvdc	2	29C9B5	Sprague	56289	0150-0081	1
C46	fxd, elect 75 μ f 15vdc	1	30D756G015CC2	Sprague	56289	0180-1838	1
CR1, 70-72, 74-78	rect. Si. 500ma 200prv	9	1N3253	R. C. A.	02735	1901-0026	6
CR2-4, 6, 11, 12, 27, 28, 60, 67, 79, 81, 82	rect. Si.	13	1N485B	Sylvania	93332	1901-0033	7
CR5, 7, 8, 10, 13, 14, 24, 29, 42-59, 68, 69, 73	NOT ASSIGNED	-	-	-	-	-	-
CR9, 25, 26, 61-66, 80	rect. Si. 200ma 10prv	10		HLAB	09182	1901-0461	6
CR15, 16	SCR 8A 400v	2	MCR-2305-6	Motorola	04713	1884-0022	2
CR17, 18	rect. Si. 12A 100prv (select for 660 min. PIV)	2	1N1206A	R. C. A.	02735	1901-0314	2
CR19	Select for 860 min. PIV	1	1N1206A	R. C. A.	02735	1901-0314	1
CR20-23	Select for 250 PIV min.	4	1N1200A	R. C. A.	02735	1901-0002	4
CR30-41	rect. Si. 400ma 800prv	12	1N3256	R. C. A.	02735	1901-0388	7
DS1	Indicator light neon	1	599-124	Drake	72765	1450-0048	1
F1, 2	Fuse cartridge 8A	2	312008	Littlefuse	75915	2110-0036	10
F3	Fuse cartridge 5A - 3AB	1	314005	Littlefuse	75915	2110-0227	5
L1	Choke 780 μ h 6A	1	652595	HLAB	09182	-	1
L2, 3	Choke 10 μ h 6A	2	652596	HLAB	09182	-	1
L4A, L4B	Choke 400 μ h 4A	2	652594	HLAB	09182	-	1
M1	Meter, 0-100ma Type 673/S	1	100204	HLAB	09182	-	1
M2	Meter, 0-2KV Type 673/S	1	100203	HLAB	09182	-	1
Q1	SS NPN diff. amp. si.	1	BD1148	HLAB	09182	1854-0221	1
Q2-7, 10, 12, 13	SS NPN si.	9	4JX16B533	HLAB	09182	1854-0027	6
Q8, 9	NOT ASSIGNED	-	-	-	-	-	-

Reference Designator	Description	Quantity	Mfr. Part # or Type	Mfr.	Mfr. Code	Stock No.	RS
Q11, 17	Power NPN si.	2	36616	HLAB	09182	1854-0225	2
Q14, 16	SS NPN si.	2	4JX11C710	HLAB	09182	1854-0244	2
Q15	SS PNP si.	1	40362	R. C. A.	02735	1853-0041	1
R1	fxd, comp 3.9 meg Ω \pm 5% $\frac{1}{2}$ w	1	EB-3955	A. B.	01121	0686-3955	1
R2, 32, 95	fxd, comp 10 $\mu\Omega$ \pm 5% $\frac{1}{2}$ w	3	EB-1035	A. B.	01121	0686-1035	1
R3, 6	fxd, ww 10K Ω \pm 5% 5w 30ppm	2	Type K-47212-10K	HLAB	09182	0811-1866	1
R4	fxd, comp SELECTED \pm 5% $\frac{1}{2}$ w	1	Type EB	A. B.	01121	-	-
R5	fxd, ww 2.6K Ω \pm 5% 3w 2ppm	1	242E2625	Sprague	56289	0811-1808	1
R7, 13	fxd, comp 24K Ω \pm 5% $\frac{1}{2}$ w	2	EB-2435	A. B.	01121	0686-2435	1
R8, 9	fxd, film 432K Ω \pm 1% 1/8w	2	Type MF5C T-O	Electra	19701	0757-0480	1
R10	fxd, film 221K Ω \pm 1% 1/8w	1	Type MF5C T-O	Electra	19701	0757-0473	1
R11, 127	fxd, comp 22K Ω \pm 5% $\frac{1}{2}$ w	2	EB-2235	A. B.	01121	0686-2235	1
R12, 123	fxd, comp 15K Ω \pm 5% $\frac{1}{2}$ w	2	EB-1535	A. B.	01121	0686-1535	1
R14	fxd, film 27.4K Ω \pm 1% 1/8w	1	Type MF5C T-O	Electra	19701	0757-0452	1
R15	fxd, ww 200 Ω \pm 5% 5w WW	1	Type 5XM	W. L.	63743	0811-1205	1
R16	fxd, comp 43 Ω \pm 5% $\frac{1}{2}$ w	1	EB-4305	A. B.	01121	0686-4305	1
R17, 47	fxd, film 22 Ω \pm 5% 2w	2	Type C42S	Corning	16299	0698-3609	1
R18, 19, 28-31, 41-44, 50-52, 65-76, 78-83, 111, 112	NOT ASSIGNED	-	-	-	-	-	-
R20	fxd, comp .18 Ω \pm 5% $\frac{1}{2}$ w	1	GB-1805	A. B.	01121	0689-1805	1
R21	var. ww 2K Ω \pm 5% 20ppm	1	(With Delrin shaft)	HLAB	09182	2100-1884	1
R22, 118	fxd, comp 7.5K Ω \pm 5% $\frac{1}{2}$ w	2	EB-7525	A. B.	01121	0686-7525	1
R23, 85, 96, 105	fxd, comp 3.3K Ω \pm 5% $\frac{1}{2}$ w	4	EB-3325	A. B.	01121	0686-3325	1
R24	fxd, comp 240K Ω \pm 5% $\frac{1}{2}$ w	1	EB-2445	A. B.	01121	0686-2445	1
R25, 98	fxd, comp 3.6K Ω \pm 5% $\frac{1}{2}$ w	2	EB-3625	A. B.	01121	0686-3625	1
R26	fxd, comp 6.2K Ω \pm 5% $\frac{1}{2}$ w	1	EB-6225	A. B.	01121	0686-6225	1
R27, 97	fxd, comp 4.7K Ω \pm 5% $\frac{1}{2}$ w	2	EB-4725	A. B.	01121	0686-4725	1
R33	fxd, comp 160K Ω \pm 5% $\frac{1}{2}$ w	1	EB-1645	A. B.	01121	0686-1645	1
R34	fxd, comp 51K Ω \pm 5% $\frac{1}{2}$ w	1	EB-5135	A. B.	01121	0686-5135	1
R35, 99	fxd, comp 1.5K Ω \pm 5% $\frac{1}{2}$ w	2	EB-1525	A. B.	01121	0686-1525	1
R36, 100	fxd, comp 1.2K Ω \pm 5% $\frac{1}{2}$ w	2	EB-1225	A. B.	01121	0686-1225	1
R37, 92, 124	fxd, comp 5.1K Ω \pm 5% $\frac{1}{2}$ w	3	EB-5125	A. B.	01121	0686-5125	1
R38	fxd, comp 1.8K Ω \pm 5% $\frac{1}{2}$ w	1	EB-1825	A. B.	01121	0686-1825	1
R39	fxd, comp 3.9K Ω \pm 5% $\frac{1}{2}$ w	1	EB-3925	A. B.	01121	0686-3925	1
R40	NOT USED	-	-	-	-	-	-
R45	fxd, ww 30K Ω \pm 5% 10w	1	Type 10XM	W. L.	63743	0811-1918	1
R46	fxd, film 135 Ω 5w WW	1	Type 5XM	W. L.	63743	0812-0098	1
R48, 49, 109	fxd, film 560 Ω \pm 5% $\frac{1}{2}$ w	3	EB-5615	A. B.	01121	0686-5615	1
R53-64	fxd, comp 1.8 meg Ω \pm 5% 1w	12	GB-1855	A. B.	01121	0689-1855	3
R77	fxd, ww 7.5K Ω 3w	1	242E7525	Sprague	56289	0811-1815	1
R84	fxd, comp 62 Ω \pm 5% $\frac{1}{2}$ w	1	EB-6205	A. B.	01121	0686-6205	1
R86	fxd, comp 750 Ω \pm 5% $\frac{1}{2}$ w	1	EB-7515	A. B.	01121	0686-7515	1
R87-89	fxd, ww 3K Ω \pm 5% 3w \pm 20ppm	3	242E3025	Sprague	56289	0812-0010	1
R90	fxd, comp 1 meg Ω \pm 5% $\frac{1}{2}$ w	1	EB-1055	A. B.	01121	0686-1055	1
R91	var. ww 5K Ω	1	Type 110-F4	C. T. S.	11236	2100-1824	1
R93, 122	fxd, comp 1K Ω \pm 5% 1w	2	GB-1025	A. B.	01121	0689-1025	1
R94	fxd, comp 330 Ω \pm 5% $\frac{1}{2}$ w	1	EB-3315	A. B.	01121	0686-3315	1
R101	fxd, comp 51 Ω \pm 5% $\frac{1}{2}$ w	1	EB-5105	A. B.	01121	0686-5105	1
R102	fxd, ww 75 Ω \pm 5% 5w	1	Type 5XM	W. L.	63743	0812-0097	1
R103	fxd, comp 470 Ω \pm 5% $\frac{1}{2}$ w	1	EB-4715	A. B.	01121	0686-4715	1
R104, 106	fxd, comp 1K Ω \pm 5% $\frac{1}{2}$ w	2	EB-1025	A. B.	01121	0686-1025	1
R107	fxd, comp 680 Ω \pm 5% $\frac{1}{2}$ w	1	EB-6815	A. B.	01121	0686-6815	1
R108	fxd, film 270 Ω \pm 5% 2w	1	Type C42S	Corning	16299	0698-3629	1
R110	fxd, comp 27K Ω \pm 5% $\frac{1}{2}$ w	1	EB-2735	A. B.	01121	0686-2735	1
R113	fxd, comp 150 Ω \pm 5% $\frac{1}{2}$ w	1	EB-1515	A. B.	01121	0686-1515	1

Reference Designator	Description	Quantity	Mfr. Part # or Type	Mfr.	Mfr. Code	Stock No.	RS
R114	fxd, comp 2K Ω \pm 5% $\frac{1}{2}$ w	1	EB-2025	A. B.	01121	0686-2025	1
R115	fxd, comp 18K Ω \pm 5% $\frac{1}{2}$ w	1	EB-1835	A. B.	01121	0686-1835	1
R116	fxd, film 8.1 meg Ω \pm 10% 4w	1	Type EFQ	Resis. Prod.	77764	0698-5502	1
R117	var. comp 10K Ω Series 70	1		HLAB	09182	2100-0092	1
R119	var. ww 3K Ω (Modify)	1	Type 110-F4	C. T. S.	11236	2100-1823	1
R120	fxd, ww 20 Ω 10w	1	Type 10XM	W. L.	63743	0811-1898	1
R121	fxd, comp 750 Ω \pm 5% 1w	1	GB-7515	A. B.	01121	0689-7515	1
R125	fxd, comp 33K Ω \pm 5% $\frac{1}{2}$ w	1	EB-3335	A. B.	01121	0686-3335	1
R126	fxd, ww 15K Ω \pm 5% 5w	1	Type 5XM	W. L.	63743	0815-0045	1
S1	Switch SPST	1	2FA53-73XSCOL	Carling	73559	-	1
S2	Thumbwheel Assembly (See Parts Listed Below Marked With An *)						
*R200	var. ww 20K Ω (SPECIAL)	1	100209-1	HLAB	09182	2100-1885	1
*R201-209	met film 20K Ω \pm 1% 1w 50ppm	9	421E2002FC3	Sprague	56289	0698-5522	2
*R211-219	met film 200K Ω \pm 1% 1w 50ppm	9	421E2003FC3	Sprague	56289	0698-5505	2
*R221, 222	met film 1 meg Ω \pm 1% 1w 50ppm	2	421E1004FC3	Sprague	56289	0698-5506	1
*S201, 202	rotary switch, 10 pos. SPKEL-F2	2	253225-FV	Oak	81716	3100-1902	1
*S203	rotary switch, 4 pos. SPKEL-F1	1	244909-FV	Oak	81716	3100-1901	1
	*P. C. Board ass'y, pot.	1		HLAB	09182	06522-60002	1
	*P. C. Board ass'y, thumbwheel	2	C2230	HLAB	09182	-	1
	*Thumbwheel stamping	3		HLAB	09182	4040-0047	1
	*Thumbwheel stamping	1		HLAB	09182	4040-0048	1
	*Gear and shaft	4		HLAB	09182	4040-0049	1
	*Stop pin	4	R62-2	Bead Chain	70892	1251-1984	1
T1	Power Transformer	1	652291	HLAB	09182	-	1
T2	Auxillary Transformer	1	652592	HLAB	09182	-	1
T3	Pulse Transformer	1	652593	HLAB	09182	-	1
VR1, 3, 5	diode, zener 6.19v \pm 5% 400mw	3		HLAB	09182	1902-0049	3
VR2	diode, zener 6.2v \pm 5% 250mw	1	1N825	Transitron	83877	1902-0777	1
VR4	diode, zener 9.4v \pm 5% 500mw	1	1N2163	U. S. Semcor	06751	1902-0762	1
	Mica insulator 6 mills 3/4 dia.	9	100371	HLAB	09182	2190-0498	2
	Mica insulator 4 mills 3/4 dia.	1	734	Reliance	08530	0340-0174	1
	Transistor socket	12	3305	Elco	91662	1200-0708	3
	Fuse holder	3	342014	Littlefuse	75915	1400-0048	1
	Insulator, transistor pin	2		HLAB	09182	0340-0166	1
	Insulating bushing	2		HLAB	09182	0340-0168	1
	Trim strip extrusion	1		HLAB	09182	7200-0308	1
	Bushing insulator, Teflon	9	100370	HLAB	09182	0340-0176	2
	Connector receptacle, H. V. -						
	BNC bulkhead mtg. jack rec.	2		HLAB	09182	1250-0735	2
	Strain relief bushing	1	SR-6P3-4	Heyco	28520	0400-0098	1
	Knob, black, 5/8 dia.	1		HLAB	09182	0370-0084	1
	Pilot light fastener	1	C17373-012-24B	Tinnerman	89032	0510-0123	1
	Line cord, plug PH151 7 $\frac{1}{2}$ ft.	1	HK4629	Beldon	70903	8120-0852	1
	Capacitor clamp 3-1/16" dia.	1	4586-2A	Sprague	56289	-	1
	Capacitor clamp, footed bkt.	5	3-36-132D	Sprague	56289	-	2
	Captive fastener #6-32	13	C8091-632-4	Tinnerman	89032	-	3
	Ext. heat sink, 4 $\frac{1}{2}$ 5/8" lg.	1		HLAB	09182	7200-0084	1
	Ext. tee, 9" lg.	1		HLAB	09182	7200-0085	1
	Phenolic spacer	3	9261PH 171	Amatom	06540	0380-0703	2
	Alum. spacer	4	9323A 171	Amatom	06540	0380-0706	1
	Alum. spacer	4	9325A 171	Amatom	06540	0380-0145	1
	Swage standoff	5	110221	Fed. Scr.	73734	-	2
	Alum. Pem nut, #8-32	2	CLA-832-2	Penn Eng.	46384	-	1
	Captive fastener, #6-32	4	C8022-632-4	Tinnerman	89032	-	1
	Captive fastener, #6-32	6	C11228-632-4	Tinnerman	89032	-	2
	Captive fastener, #6-32	4	C8082-632-4	Tinnerman	89032	-	1
	Delrin standoff, #8-32	16		HLAB	09182	0380-0701	4

