

HEWLETT-PACKARD

DC POWER SUPPLY

STB SERIES, MODEL 6110A

SERIAL NUMBER PREFIX 6E  
FOR REFERENCE PURPOSES ONLY

Printed: May, 1967

Ⓢ Stock Number: 06110-90001

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## MANUAL CHANGES

Model 6110A DC Power Supply  
Manual HP Part No. 06110-90001

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	
6E	0213 - 0512	1
6E	0513 - 0667	1, 2
ALL	-	Errata
6E	0668 - 0717	1, 2, 3
6E	0718 - 0742	1, 2, 3, 4
6E	0743 - 0842	1 thru 5
1145A	0843 - 0932	1 thru 6
1145A	0933 - 1447	1 thru 7
1723A	1448 - 1507	1 thru 8
1831A	1508 - up	1 thru 9

### CHANGE 1:

In the Replaceable Parts Table, change R76 from 8.2K $\Omega$  to 4.3K $\Omega$ ,  $\pm 5\%$ ,  $\frac{1}{2}W$ , HP Part No. 0686-4325, A. B. 01121.

### CHANGE 2:

In Replaceable Parts List, make the following changes:

C19: Change to HP Part No. 0180-2256.

R201 thru R209: Change to 1K $\Omega$ ,  $\pm 1\%$ ,  $\frac{1}{4}W$ , HP Part No. 0811-2770.

P.C. Board: Change to HP Part No. 06110-60005.

R19: Change to 1K $\Omega$ ,  $\pm 1\%$ ,  $\frac{1}{4}W$ , HP Part No. 0811-2770.

T2: Change to HP Part No. 5080-7129.

Option 05: T2; Delete. (Transformer need not be changed.)

Option 18: T2; change to HP Part No. 5080-7130.

### ERRATA:

Q7, 8: Change to 2N2907A, Sprague, 56289, HP Part No. 1853-0099. SS PNP Si.

In Replaceable Parts Table, make the following change:

Q11: Change to 2N4240, RCA, HP Part No. 1854-0311.

On Page 6-8, under Manual Backdating Changes, change the second sentence to read:

To adapt the manual to serial numbers prior to 6F0161, make the following changes.

On the Schematic Diagram, change the value of capacitor C14 to 20 $\mu F$ .

In the Replaceable Parts Table, make the following changes:

Change CR11, 24-28, and 32 to: Rect. Si. 750mA 200prv, quantity 7, 1N5059, GE 03508, HP Part

No. 1901-0327, RS 6.

Change CR29 and CR30 to: Rect. Si. 750mA 800prv, quantity 2, 1N5062, GE 03508, HP Part No. 1901-0330, RS 2.

### CHANGE 3:

In the Replaceable Parts Table, change the HP Part No. of switch S1 to 3101-1244. This switch requires new front panel lettering.

### CHANGE 4:

In the replaceable parts table, change the HP Part No. of switch S1 to 3101-1248.

### CHANGE 5:

In the Replaceable Parts Table, delete the listing for BNC-HV Cable Plug and associated hardware and add new listing:

BNC-HV Connector, HP Part No. 1250-1267.

### ERRATA:

In Table 5-2, Step 5 (Page 5-9), change the Meter Common connection to "VR2 anode."

In the Replaceable Parts Table, add the following:  
Oven heating element, HP Part No. 8110-0189.  
(Installation and calibration instructions for oven are covered in Service Note P-5060-6125.)

### ERRATA:

In Table 1-1 and page 5-5, paragraph 5-31, step c., change the ripple and noise specification to: "Less than 2mVrms and 5mV p-p."

### CHANGE 6:

The Serial Prefix of this unit has been changed to 1145A. This is the only change.

### CHANGE 7:

In the Replaceable Parts Table and on the schematic, change R9 to 120 $\Omega \pm 5\%$ , 1/2W, HP Part No. 0686-1215.

The standard colors for this instrument are now mint gray (for front and rear panels) and olive gray (for all top, bottom, side, and other external 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:

DESCRIPTION	HP PART NO.		
	STANDARD	OPTION A85	OPTION X95
Front Panel	06110-00002	06110-00001	↑ See Manual Parts List ↓
Side Chassis, Right	5060-7950	←	
Side Chassis, Left	5060-7949	←	
Rear Chassis - ass'y	5000-9482	←	
Cover, (2)	5000-9421	←	

#### ERRATA:

Make the following changes to the parts list on page 6-8:

Option 05: Delete T1 (Transformer need not be changed).

Option 18: Add R55, 120K 5% 1/2W, 0686-1245.

Options 05 and 18: Add R55, same as Option 18 above; change HP Part No. of T2 to 5080-7130.

Change part number of rubber bumper from 0403-0088 to 0403-0002.

On page 6-5 and on the schematic, change C27 and C28 to 1 $\mu$ F 2000V HP Part No. 0160-4121.

Add to the parts list the replacement lamp for illuminated switch 3101-1248, which is used in those supplies that include Change 4. The HP Part No. of the type A1H lamp is 2140-0244.

Add to the parts list the mating plugs for the front panel output connectors. They are type BNC-HV male coaxial plugs, HP Part No. 1250-0927. Two are provided.

Effective January 1, 1977, Options 005 (50Hz ac input) and 018 (230 Vac input) are no longer available separately as standard options for this model. These two options have been replaced by a new standard option, Option 019, which combines the modifications of Options 005 and 018 for use with a 230 Vac $\pm$ 10%, 50 $\pm$ 0.3Hz input. After January 1, Model 6110A instruments for use with a 115Vac 50Hz input or a 230Vac 60Hz input must be ordered as special factory modifications. Make the necessary corrections wherever Option 005 or 018 is mentioned in the manual.

#### ERRATA:

Under the heading Controls in Table 1-1, change the resolution specification to 20 millivolts.

The blue gray meter bezel has been replaced by a black one, HP Part No. 4040-0414.

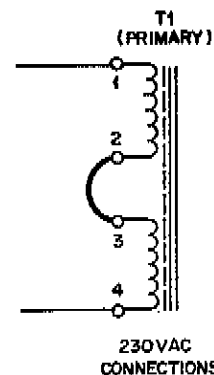
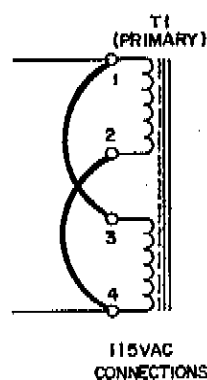
#### CHANGE 8:

Make the following changes to the schematic and the parts list; change R71 in the overvoltage protection circuit to 20k, 10%, HP Part No. 2100-0558; change R25 and R67 in the meter circuit to 100k, 10%, HP Part No. 2100-3214.

#### CHANGE 9:

Change power transformer T1 to HP Part No. 5080-1910. The primary of the new transformer can be strapped for 115Vac or 230Vac input as shown below. Change rear chassis to HP Part No. 5000-3148. Replace capacitor clamp HP Part No. 5000-6023 with capacitor bracket HP Part No. 1210-0006.

Change zener diode VR2 to 9V, 0.005% T. C., HP Part No. 1902-0785. Note that the old zener diode (1902-0763) should not be used for a replacement at any time.



► ERRATA:

In Table 1 -1, change the Transient Recovery Time Specification to read as follows:

Less than 50µsec is required for output voltage recovery to within 50mV of the nominal output voltage following a change in output current equal to the current rating of the supply, when the input line voltage is at 115Vac or 230Vac.

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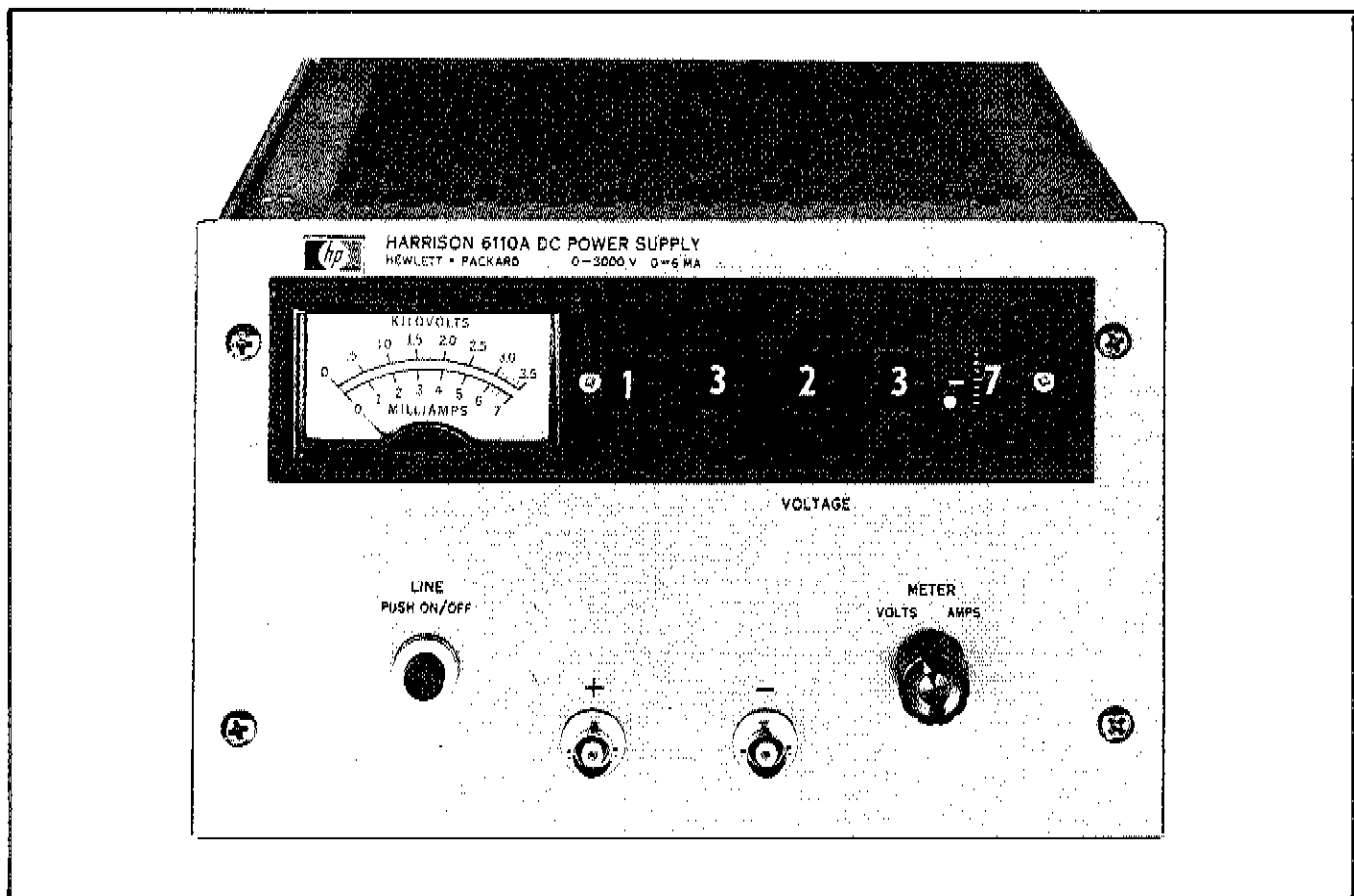


Figure 1-1. DC Power Supply, Model 6110A



SECTION I  
GENERAL INFORMATION

1-1 DESCRIPTION

1-2 This instrument (Figure 1-1) is an all semiconductor high voltage supply suitable for either bench or relay rack operation. It is a compact, well-regulated, Constant Voltage/Current Limited supply that will furnish 3,000 volts at 6 milliamps or can be adjusted throughout the output voltage range. It is designed for applications requiring extreme stability, regulation, and insensitivity to ambient temperature variations.

1-3 This supply utilizes a series regulated "piggy-back" circuit technique that consists of placing a well-regulated low voltage power supply in series with a less well-regulated supply having a greater voltage capability. The well-regulated "piggy-back" supply continuously compensates for any ripple, load regulation, or line regulation deficiencies of the main power source and adjusts the voltage across its series regulator so that the total output voltage remains constant despite disturbances in the main voltage source.

1-4 OVERLOAD PROTECTION

1-5 The voltage thumbwheel switches select the constant voltage level; an internal potentiometer selects the current limit level. The supply will automatically crossover from constant voltage to current limit operation and vice versa if the output current or voltage exceeds these preset levels. Detailed characteristics of the output current limiting are given in Paragraph 3-5.

1-6 The power supply is protected from reverse voltage (positive voltage applied to negative terminal) by an internal protection diode 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 3-15). The power supply cannot accept reverse current without damage.

1-7 COOLING

1-8 Convection cooling is used; no fan is required. The power supply has no moving parts except for the meter movement.

1-9 OUTPUT TERMINALS

1-10 Output power is available via two UG-931/U connectors mounted on the front panel of the 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 to the 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 1,000 volts dc off ground, i. e. the maximum potential between either output terminal and ground shall not exceed 4KVdc.

1-11 SPECIFICATIONS

1-12 Detailed specifications for the power supply are given in Table 1-1.

1-13 OPTIONS

1-14 Options are factory modifications of a standard instrument that are requested by the customer. The following options are available for the instrument covered by this manual. Where necessary, detailed option information (operation, alignment, etc.) is included throughout the manual.

Option No.    Description

05            50Hz Input Modification. Factory modification includes the substitution of 60Hz with 50Hz magnetic component as indicated at the end of the parts list in Section VI. In addition, the overvoltage protection adjustment is rechecked, refer to Section V.

18            230Vac ±10%, Single-Phase Input. Factory modification includes the installation of a 230 volt input transformer to replace the standard 115 volt transformers as indicated at the rear of the parts list in Section VI.

1-15 ACCESSORIES

1-16 The accessories listed in the following chart may be ordered with the power supply or separately

from your local  $\text{\textcircled{H}}$  sales office. (Refer to list at rear of manual for addresses.) Additional information on accessories is given in Section II.

<u><math>\text{\textcircled{H}}</math> Part No.</u>	<u>Description</u>
14515A	Rack Kit for Mounting one $5\frac{1}{4}$ " H supply in a standard 19" EIA rack. (Refer to Section II for details.)
14525A	Rack Kit for mounting two $5\frac{1}{4}$ " H supplies in a standard 19" EIA rack. (Refer to Section II for details.)

#### 1-17 INSTRUMENT IDENTIFICATION

1-18 Hewlett-Packard power supplies are identified by a three-part serial number tag. 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; a different sequential number is assigned to each power supply.

1-19 If the serial number prefix on your power supply does not agree with the prefix on the title page of this manual, use the change page that is included to update the manual to the proper serial number. Where applicable, backdating information is given in an appendix at the rear of the manual.

#### 1-20 ORDERING ADDITIONAL MANUALS

1-21 One manual is shipped with each power supply. Additional manuals may be purchased from your local  $\text{\textcircled{H}}$  sales office (see list at rear of this manual for addresses). Specify the model number, serial number prefix, and  $\text{\textcircled{H}}$  stock number provided on the title page.

Table 1-1. Specifications

<p><b>OUTPUT:</b> 0-3000Vdc, 0-6 milliamperes.</p>	<p>no load and full load voltage.</p>
<p><b>INPUT:</b> 115Vac <math>\pm</math>10%, single phase, 57-63Hz, 1A, 50W.</p>	<p><b>OVERLOAD PROTECTION:</b> An all electronic, continuously acting current limit protects the power supply for all overloads regardless of how long imposed, including a direct short circuit across the output terminals.</p>
<p><b>LOAD REGULATION:</b> Less than 0.001% (10ppm) plus 100<math>\mu</math>V for a full load to no load change in output current.</p>	<p><b>CONTROLS:</b> An in-line 5-digit (thumbwheel) voltage programmer permits control of the output voltage with an accuracy of 0.1% plus 100mV of the output voltage; resolution is 1mV.</p>
<p><b>LINE REGULATION:</b> Less than 0.001% (10ppm) output voltage change for a 10% change in line voltage.</p>	<p><b>METER:</b> The front panel meter can be used as either a 0-3500V voltmeter or as a 0-7mA ammeter.</p>
<p><b>RIPPLE AND NOISE:</b> Less than 400<math>\mu</math>Vrms, 1mV p-p.</p>	<p><b>OUTPUT TERMINALS:</b> The dc output of the supply is floating; thus, the supply can be used as either a positive or negative source. Terminals for +OUT, -OUT, and GND are provided on the front of the supply.</p>
<p><b>TEMPERATURE RANGES:</b> Operating: 0 to 50<math>^{\circ}</math>C. Storage: -20 to +85<math>^{\circ}</math>C.</p>	<p><b>COOLING:</b> Convection cooling is employed. The supply has no moving parts.</p>
<p><b>TEMPERATURE COEFFICIENT:</b> Less than 0.001% (10ppm) plus 50<math>\mu</math>V output voltage change per <math>^{\circ}</math>C after 30 minute warm-up.</p>	<p><b>SIZE:</b> 8<math>\frac{1}{2}</math>" W x 5<math>\frac{1}{4}</math>" H x 16" D</p>
<p><b>STABILITY:</b> Less than 0.01% plus 500<math>\mu</math>V total drift for 8 hours (less than 0.012% plus 600<math>\mu</math>V for 1 month) after 30 minute warm-up and with 3<math>^{\circ}</math>C ambient variation.</p>	<p><b>WEIGHT:</b> 19 lbs. net, 23 lbs. shipping. Two of the units can be mounted side by side in a standard 19" relay rack.</p>
<p><b>OUTPUT IMPEDANCE:</b> At 3000V, less than 50 ohms from DC to 1000Hz. At 3V, less than 0.05 ohm from DC to 100Hz.</p>	<p><b>FINISH:</b> Light gray front panel with dark gray case.</p>
<p><b>TRANSIENT RECOVERY TIME:</b> Less than 50<math>\mu</math> seconds is required for output voltage to recover to within 10 millivolts of the nominal output voltage following a full load change in output current. Less than 100<math>\mu</math> seconds is required for output voltage recovery to within the load regulation specification. The nominal output voltage is defined as the mean between the</p>	<p><b>POWER CORD:</b> A 3-wire 5-foot power cord is provided with each unit.</p>

## SECTION II INSTALLATION

### 2-1 INITIAL INSPECTION

2-2 Before shipment, this instrument was inspected and found to be free of mechanical and electrical defects. As soon as the instrument is unpacked, inspect for any damage that may have occurred in transit. Save all packing materials until the inspection is completed. If damage is found, proceed as described in the Claim for Damage in Shipment section of the warranty page at the rear of this manual.

### 2-3 MECHANICAL CHECK

2-4 This check should confirm that there are no broken knobs or connectors, that the cabinet and panel surfaces are free of dents and scratches, and that the meter is not scratched or cracked.

### 2-5 ELECTRICAL CHECK

2-6 The instrument should be checked against its electrical specifications. Section V includes an "in-cabinet" performance check to verify proper instrument operation.

### 2-7 INSTALLATION DATA

2-8 The instrument is shipped ready for bench operation. It is necessary only to connect the instrument to a source of power and it is ready for operation.

### 2-9 LOCATION

2-10 This instrument is air cooled. Sufficient space should be allotted so that a free flow of cooling air can reach the sides and rear of the instrument when it is in operation. It should be used in an area where the ambient temperature does not exceed 55°C.

### 2-11 RACK MOUNTING

2-12 This instrument may be rack mounted in a standard 19 inch rack panel either alongside a similar unit or by itself. Figures 2-1 and 2-2 show how both types of installations are accomplished.

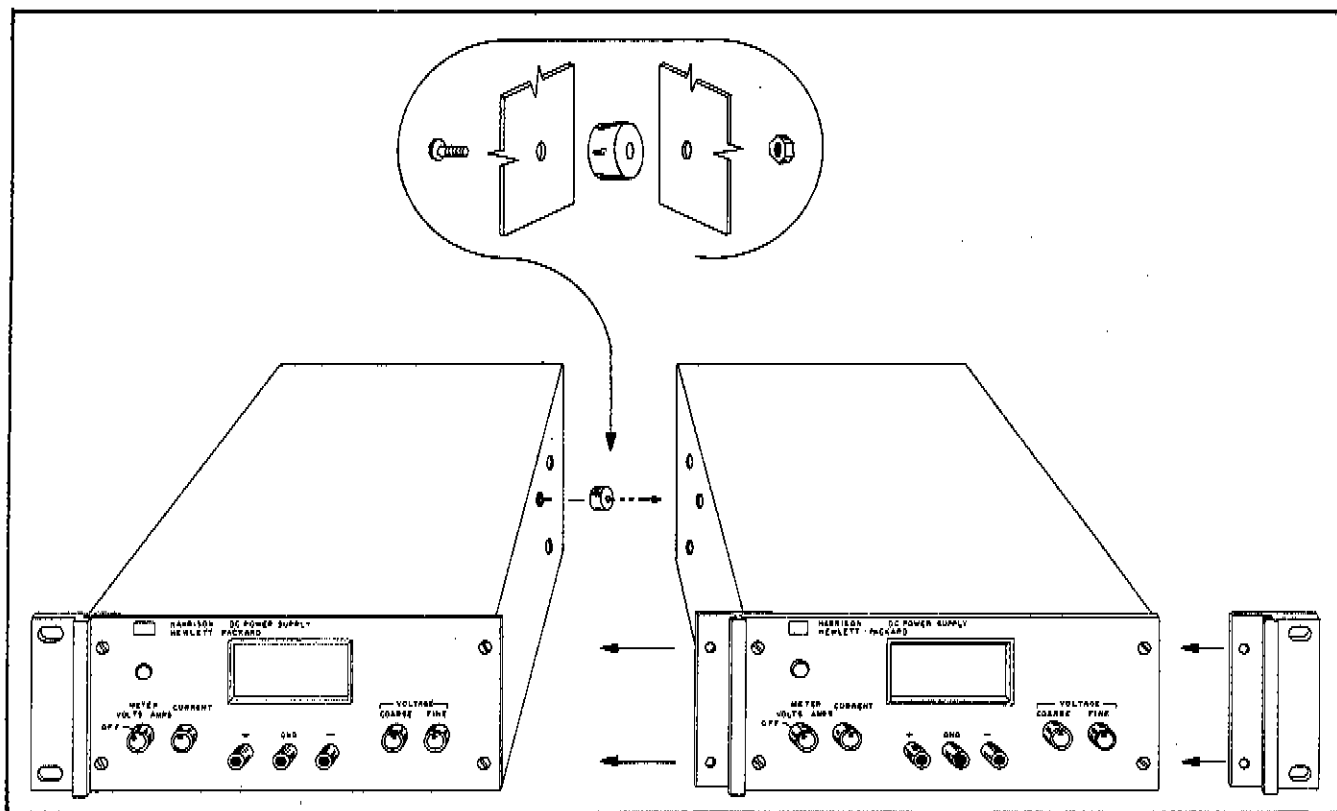


Figure 2-1. Rack Mounting, Two Units

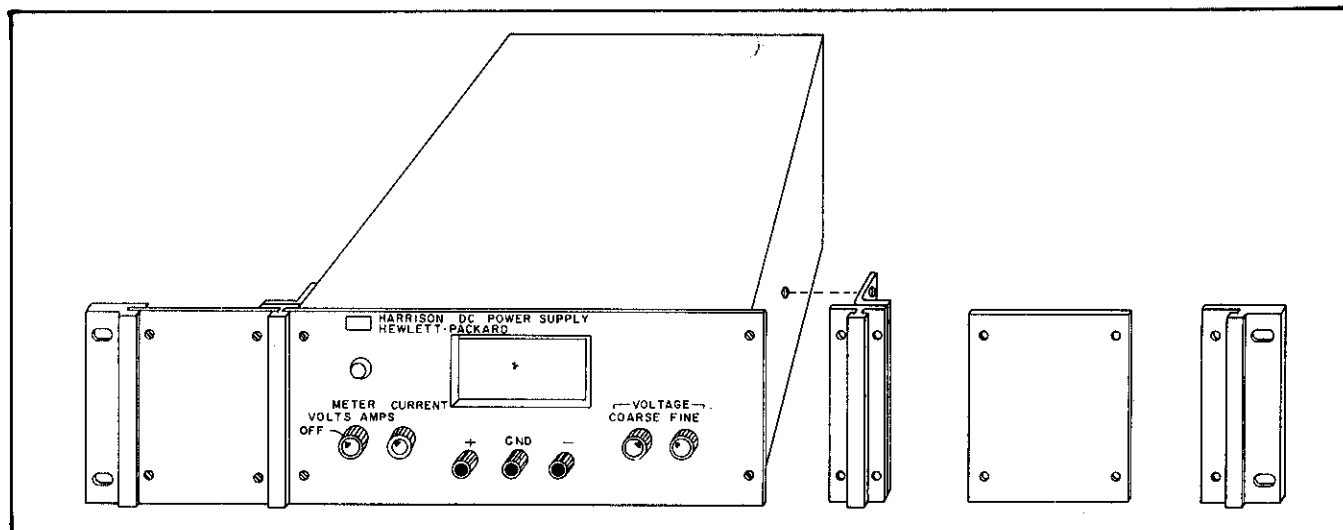


Figure 2-2. Rack Mounting, One Unit

2-13 To mount two units side-by-side, proceed as follows:

- a. Remove the four screws from the front panels of both units.
- b. Slide rack mounting ears between the front panel and case of each unit.
- c. Slide combining strip between the front panels and cases of the two units.
- d. After fastening rear portions of units together using the bolt, nut, and spacer, replace panel screws.

2-14 To mount a single unit in the rack panel, proceed as follows:

- a. Bolt rack mounting ears, combining strips, and angle brackets to each side of center spacing panels. Angle brackets are placed behind combining strips as shown in Figure 2-2.
- b. Remove four screws from front panel of unit.
- c. Slide combining strips between front panel and case of unit.
- d. Bolt angle brackets to front sides of case and replace front panel screws.

#### 2-15 INPUT POWER REQUIREMENTS

2-16 This power supply is operated from a nominal 115 volt 60 Hz power source. The input power required when operated from a 115 volt 60 Hz power source at full load is:

Model 6110A 60 Watts  
 Model 6516A 40 Watts

#### 2-17 POWER CABLE

2-18 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.

2-19 To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green lead on the adapter to ground.

#### 2-20 REPACKAGING FOR SHIPMENT

2-21 To insure safe shipment of the instrument, it is recommended that the package designed for the instrument be used. The original packaging material is reusable. If it is not available, contact your local Hewlett-Packard field office to obtain the materials. This office will also furnish the address of the nearest service office to which the instrument can be shipped. Be sure to attach a tag to the instrument 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 TURN-ON CHECK OUT PROCEDURE

3-2 The following procedure describes the use of the front panel controls and indicators illustrated in Figure 3-1 and insures that the power supply is operational.

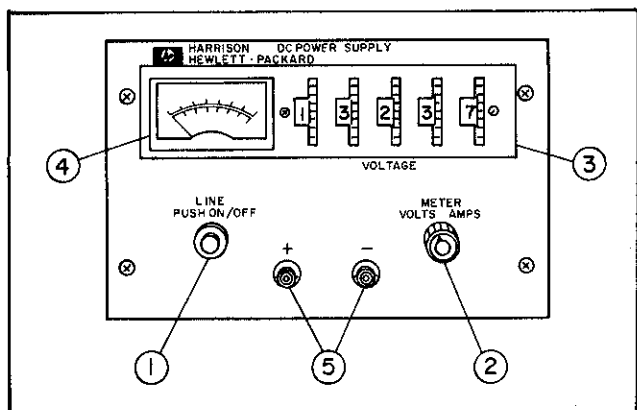


Figure 3-1. Front Panel Controls and Indicators

- a. Push ON/OFF switch-indicator (1); indicator should light.
- b. Set METER switch (2) to VOLTS position (6110A only).
- c. Adjust voltage thumbwheel switches for desired output voltage as indicated on meter.
- d. Attach a multimeter to the output and set the voltage decadal control to at least 200 volts. Check that the current indication on the multimeter does not exceed 7.5mA.
- e. Remove meter and connect load to output terminals.

3-3 OPERATION

3-4 The power supply can be operated as a single unit (normal operation) or in parallel. No provisions for remote programming or remote sensing have been made due to their limited use and insulation problems at 3,000Vdc. For safety, insure that the power supply chassis is grounded (either via power cord or by other means). The operator can ground either output terminal or operate the power supply up to 1,000 volts dc off ground (floating). It is not recommended that the power supply be floated above 300 volts rms at low audio frequencies (less than 500Hz).

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

This supply emits a ticking sound which is characteristic of normal operation. It in no way indicates that the power supply is malfunctioning.

3-5 CURRENT LIMIT PROVISIONS

3-6 The current limiting feature is designed to protect the power supply and the load. It is factory adjusted by selecting resistor R20 so that the short-circuit output current will not exceed approximately 8mA.

3-7 OPERATION OF SUPPLY BEYOND RATED OUTPUT

3-8 The shaded area on the front panel meter face indicates the amount of output voltage that is available in excess of the normal rated output. Although the supply can be operated in this shaded region without being damaged, it cannot be guaranteed to meet all its performance specifications. However, if the line voltage is maintained above 115Vac, the power supply will probably operate within its specifications.

3-9 LOAD CONNECTION

3-10 Output terminals are provided on the front panel of the power supply; mating connectors are UG-932 and cable type is RG-59/U. The positive or negative output terminal may be grounded by shorting the center pin and case of the applicable UG-931/U jack; or both output terminals ungrounded (floating operation). Floating operation is permitted to 1,000 volts dc off ground; neither output terminal should exceed 4,000 volts dc. The best ripple-free results are obtained when one output jack is grounded and the load is connected to the other output jack by the appropriate cable and connector.

WARNING

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

3-11 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 $\mu$ f capacitor should be connected between one terminal and the chassis, if the supply is floated off of ground.

3-12 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 shielded wires and each load connected separately to the remote distribution terminals. A 0.1 to 1.0 $\mu$ f capacitor should be connected across the remote distribution terminals to reduce high frequency coupling and noise.

### 3-13 OUTPUT CAPACITANCE

3-14 An internal capacitor, 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 cur-

rent limiting circuit. A high current pulse may damage load components before the average output current is large enough to cause the current limiting circuit to operate.

### 3-15 REVERSE CURRENT LOADING

3-16 Active loads connected to the power supply may actually deliver a reverse current to the power supply during a portion of its operating cycle. An external source cannot be allowed to pump current into the supply without loss of regulation and possible damage to the output capacitor. To avoid these effects, it is necessary to preload the supply with a "dummy" load so that the power supply delivers current through the entire operating cycle of the load device.

### 3-17 REVERSE VOLTAGE LOADING

3-18 A diode is connected across the output terminals. Under normal operating conditions, the diode is reverse biased (anode connected to negative terminal). If a reverse voltage is applied to the output terminals (positive voltage applied to negative terminal), the diode will conduct, shunting current across the output terminals and limiting voltage to the forward voltage drop of the diode. This diode protects the series transistors and the output electrolytic capacitors.

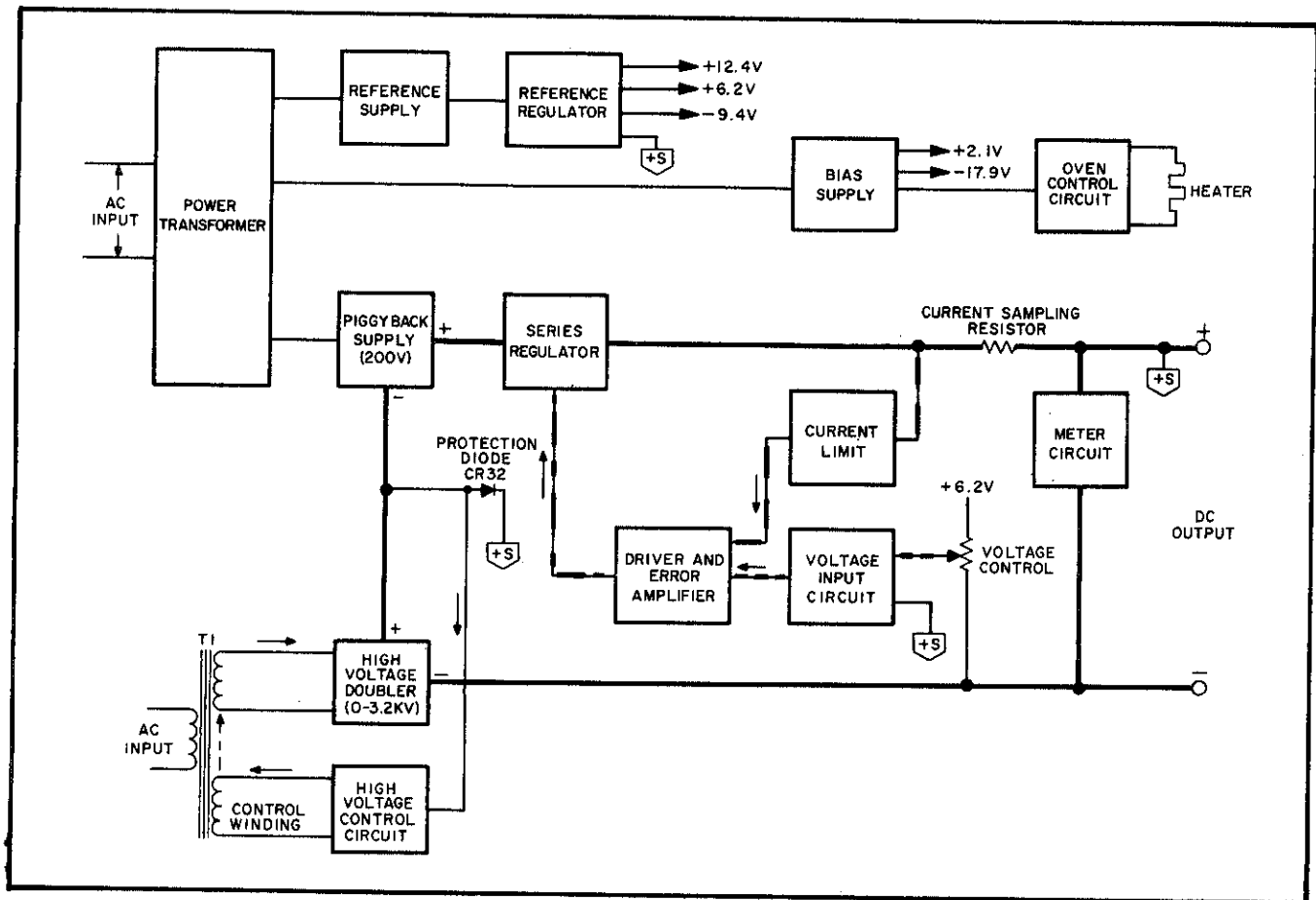


Figure 4-1. Overall Block Diagram



## SECTION IV PRINCIPLES OF OPERATION

### 4-1 OVERALL BLOCK DIAGRAM DISCUSSION (Figure 4-1)

4-2 Models 6110A and 6516A, as illustrated in Figure 4-1, are constant voltage/current limited power supplies that utilize a "piggy-back" regulator design. This design extends the usefulness of the series regulating transistors rated for approximately 30 volts to short-circuit-proof power supplies rated for 3,000 volts. The basic technique consists of placing the well-regulated low-voltage "piggy-back" supply in series with a less well-regulated high voltage doubler. Notice, however, that the amplified error signal from the voltage input circuit is dependant upon the total output voltage—not just the output of the "piggy-back" supply alone. Thus, the well-regulated "piggy-back" supply continuously compensates for any ripple, load regulation, or line regulation deficiencies of the high voltage doubler, and adjusts the voltage across the series regulator so that the total output voltage remains constant despite disturbances in the high voltage doubler.

4-3 For purposes of discussion the voltage values of Model 6110A are used in the following paragraphs, however, the theory pertains equally well to both Models 6110A and 6516A. The "piggy-back" supply develops 200 volts, and the high voltage doubler supply is capable of providing a maximum of 3200 volts. With 30 volts normally dropped across the series regulator, the maximum output of this supply is 3370 volts; 170 volts from the "piggy-back" supply and 3200 volts from the high voltage doubler. Thus, the series regulator of the "piggy-back" supply has a voltage range for accomplishing the dynamic changes necessary to compensate for the variations of the power source. Short-circuit protection for the series regulator in the "piggy-back" supply is provided by the protection diode, which provides a discharge path from the positive side of the power supply to the positive side of the high voltage doubler shunting the short circuit current around the series regulator. Whenever the load resistance decreases to a value such that  $+S$  becomes greater than  $-200$  volts, the protection diode conducts. This prevents the output terminals of the "piggy-back" supply from ever reversing polarity, and the series regulator will never be called upon to withstand a voltage strain greater than 200 volts from its own rectifier.

4-4 The ac input line voltage is raised to the proper level and coupled to the "piggy-back" sup-

ply. This supply converts the ac input to raw dc which is fed to the positive terminal via the series regulator and current sampling resistor network. The regulator, part of the feedback loop, is made to alter its conduction to maintain a constant output voltage or limit the output current. Voltage developed across the current sampling resistor is the input to the current limiting circuit. If the output current that passes through the sampling network exceeds a certain predetermined level, the current limiting circuit applies a feedback signal to the series regulator which alters the regulator's conduction so that the output current does not exceed the predetermined limit.

4-5 The voltage input circuit obtains its input by sampling the output voltage of the supply at the voltage control. Any changes in output voltage are detected in the constant voltage input circuit, amplified by the error amplifier and driver, and applied to the series regulator in the correct phase and amplitude to counteract the change in output voltage. The reference regulator circuit provides stable reference voltages which are used by the constant voltage input circuit and the current limiting circuit for comparison purposes.

4-6 The high voltage control circuit monitors the voltage across the "piggy-back" supply, and alters the conduction of transformer T1 so that the output of the high voltage doubler can be varied between 0 and 3.2 kilovolts. For instance, if the high voltage control is adjusted for an output voltage in excess of the voltage supplied by the "piggy-back" supply, the input to the high voltage control circuit becomes more negative. The high voltage control circuit opens the control winding, and all the energy appearing at the ac input of transformer T1 is coupled to the secondary which is connected to the high voltage doubler. The result is that the output voltage of the high voltage doubler increases. If the voltage control is adjusted for an output which is less than the "piggy-back" supply, the input to the high voltage control circuit becomes less negative. The control winding of transformer T1 becomes shorted impeding the transfer of energy from the ac input to the secondary which is connected to the high voltage doubler. Thus, the output voltage of the high voltage doubler decreases.

4-7 In Model 6110A, an oven houses the temperature sensitive components in the supply to provide a low temperature coefficient which results in excellent stability. The oven control circuit maintains the oven temperature at 65°C.

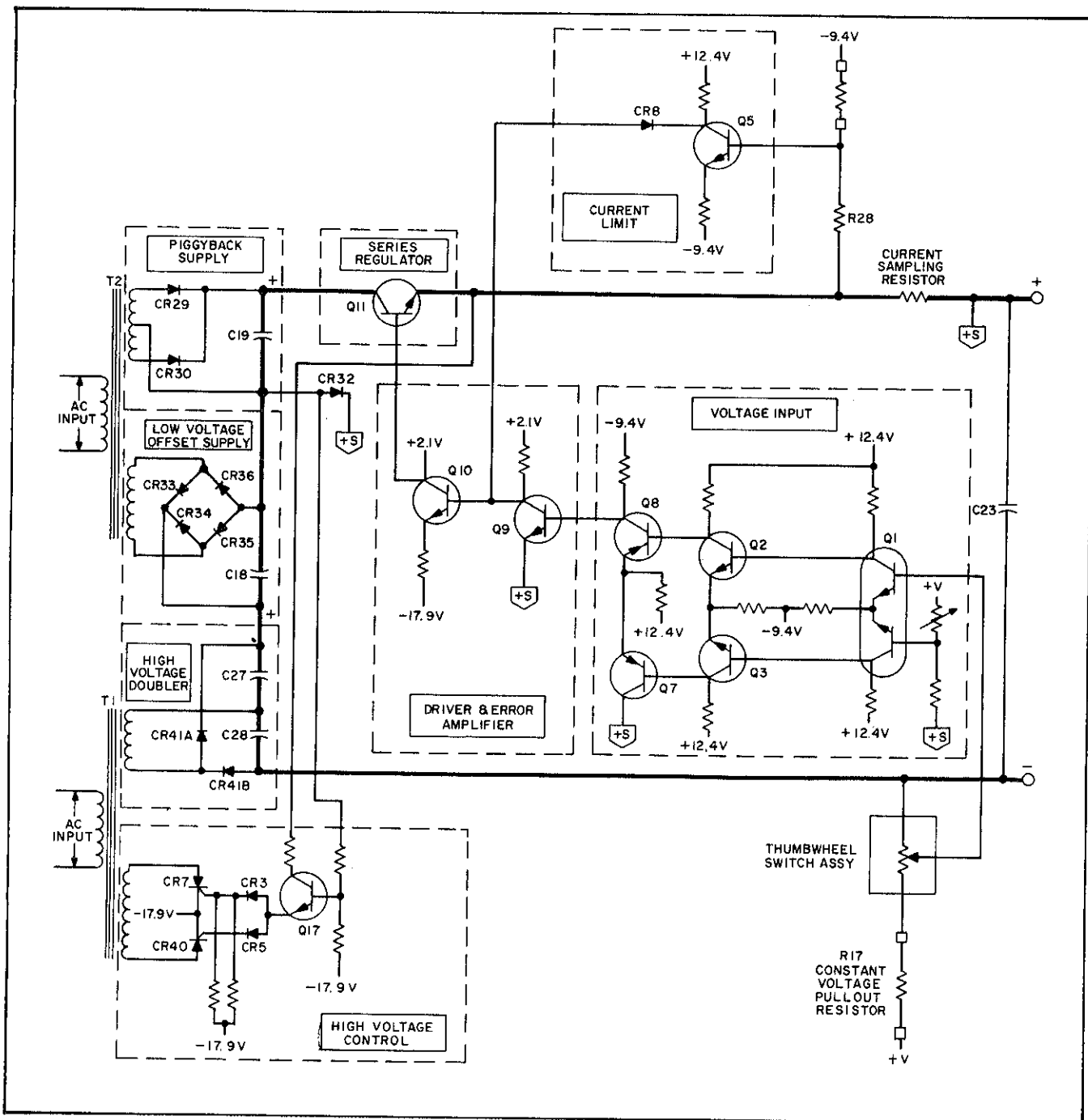


Figure 4-2. Simplified Schematic Diagram

4-8 SIMPLIFIED SCHEMATIC DISCUSSION  
(Figure 4-2)

4-9 The regulating feedback loop, consisting of the thumbwheel switch assembly (programming resistors), voltage input circuit, driver and error amplifier, series regulator, and high voltage control circuit, function continuously to maintain the output voltage constant during constant voltage operation and the output current at a safe limit during current limit operation.

4-10 The voltage input circuit differential amplifier, Q1, detects an error voltage that is proportional to the difference between the voltage across its programming resistors (thumbwheel switch assembly) and the dc output voltage. The error signal is amplified by differential amplifiers, Q2-Q3 and Q7-Q8. The amplified error signal is further amplified by Q9 and Q10, and applied to the series regulator. The series regulator increases or decreases the output current as required to maintain a constant dc output voltage that is equal to the

programmed voltage. The high voltage control circuit, transformer T1, and the high voltage doubler maintain the voltage across the series regulator within a limited range. When the voltage across the series regulator falls below a predetermined level, Q17 turns on, forward biasing diodes CR3 and CR5. SCR's CR7 and CR40 begin firing on each cycle, and the voltage across C27 and C28 decays. When the voltage across the series regulator rises above a predetermined level, Q17 turns off, reverse biasing diodes CR3 and CR5. SCR's CR7 and CR40 stop firing and the voltage across C27 and C28 rises.

4-11 The current limit circuit protects the load and the series regulator against excessive currents. If the external load resistance is decreased to a point where the load current exceeds the value selected by resistor R20, the negative voltage on the collector of Q5 forward biases CR8. Thus, the collector of Q9 is clamped and the output current is maintained at a constant safe maximum. Any further decreases in load resistance cause the output voltage to decrease proportionally.

4-12 DETAILED CIRCUIT ANALYSIS (Refer to overall schematic at rear of manual)

#### 4-13 SERIES REGULATOR

4-14 The series regulator consists of transistor stage Q11. The regulator serves as a series control element by altering its conduction so that the output voltage and current limit is never exceeded. The conduction of Q11 is controlled by the feedback voltage obtained from driver Q10.

#### 4-15 CONSTANT VOLTAGE INPUT CIRCUIT

4-16 This circuit consists of voltage decade control R200 through R235, voltage calibrate potentiometer R16, and differential amplifiers Q1, Q2-Q3, and Q7-Q8. Q1 consists of two transistors having closely matched characteristics in a single transistor package. This package insures that both transistors will operate at essentially the same temperature, minimizing drift due to thermal differentials. Q1, Q2, and Q3 are enclosed in a constant-temperature oven to further minimize effects of changing ambient temperature.

4-17 The constant voltage input circuit continuously compares a fixed reference voltage with a portion of the output voltage and, if a difference exists, produces an error voltage whose amplitude and phase is proportional to the difference. The error output is fed back to the series regulator, through the error and driver amplifiers. The error voltage changes the conduction of the series regulator which, in turn, alters the output voltage so that the difference between the two input voltages

applied to the differential amplifier is reduced to zero. The above action maintains the output voltage constant.

4-18 The base of Q1A is connected to the junction of the programming resistors and the current pull-out resistor, R17, through a current limiting resistor R1. Diodes CR1 and CR2 limit voltage excursions on the base of Q1A. R1 limits the current through the programming resistors under the condition of rapid voltage turn-down. Capacitors C4 and C9 shunt the programming resistors to increase the high frequency gain of the amplifier. The programming current is determined primarily by the reference voltage and the pull-out resistor, R17.

4-19 The base of Q1B is connected to ground through R2. Variable current can be injected at this point through R13 which serves to compensate for fixed voltage offsets in Q1.

4-20 Negative feedback is coupled from the output of differential amplifier Q7-Q8 to the input of Q1 by network R30 and C6. This feedback provides high frequency roll-off in the loop gain to stabilize the feedback loop.

#### 4-21 DRIVER AND ERROR AMPLIFIER

4-22 The driver and error amplifier circuit raises the level of the error signal from the constant voltage input circuit to a sufficient level to drive the series regulator. Common emitter amplifier Q10 also receives a current limiting input when CR8 becomes forward biased.

#### 4-23 CURRENT LIMIT CIRCUIT

4-24 The output current flows through R23 producing a voltage drop of 1 volt for 7 milliamps output current. The positive voltage appearing on R23 causes a current flow through R28 and selectable resistor R20. When the output current reaches 7 milliamps, Q5 conducts, forward biasing diode CR8. The base of Q10 becomes sufficiently negative to turn-off Q10 and series regulator Q11; thus, limiting the output current. R27 and CR4 provide a -0.7 volt bias for the emitter of Q5. The value of resistor R20 determines the level at which the output current will be limited. This value is normally selected for 7 milliamps output current. Capacitor C5 and resistor R29 prevent oscillation in the current limit mode of operation.

#### 4-25 HIGH VOLTAGE CONTROL AND DOUBLER CIRCUITS

4-26 This circuit controls the voltage output of the high voltage doubler as a function of the voltage across the series regulator and resistor R54. When the voltage across the series regulator rises

to a predetermined value, CR39 becomes forward biased and Q17 conducts. Diodes CR3 and CR5 are forward biased and on alternate half-cycles SCR's CR7 and CR40 fire shorting the control winding of transformer T1. This action decreases the voltage on the secondary of T1 thus reducing the charge on capacitors C27 and C28. This, in turn, reduces the voltage drop across the series regulator.

4-27 When the voltage drop across the series regulator decreases to a predetermined amount, diode CR39 becomes reverse biased and Q17 turns off. This action reverse biases diodes CR3 and CR5 and the SCR's cease firing on alternate half-cycles. The output of the high voltage doubler rises until Q17 again begins to conduct.

4-28 Diodes CR3 and CR5 form an OR-gate that prevents the interaction of SCR's CR7 and CR40. For example, when CR7 fires positive pulse appears on its gate, back biasing CR3 and preventing this positive pulse from tripping CR40. Two RFI filters in the control winding of transformer T1 prevent spikes from being transferred to the high voltage doubler and the ac input line. These filters consist of C29, R61, L4, C26, R74, and L5. Diode CR39 protects the base of transistor Q7 from the negative output voltage of the "piggy-back" supply. This voltage can go as far negative as -187 volts.

#### 4-29 PROTECTION CIRCUIT

4-30 This circuit prevents the high voltage doubler from exceeding approximately 4kV which might occur if the feedback loop were to malfunction. Diodes CR37 and CR38 are connected directly across the control winding and rectify (monitor) the voltage across this winding. The rectified voltage charges capacitor C24, and when it exceeds a predetermined level, neon tube VR3 fires. The resulting positive going voltage turns on Q17 which in turn shorts the control winding of transformer T1, thus, reducing the output of the high voltage doubler. Overvoltage control R71 determines the level at which VR3 will fire and, therefore, controls the maximum output voltage of the high voltage doubler.

#### 4-31 OVEN CONTROL CIRCUIT

4-32 The oven temperature is sensed by thermistor R57. If the temperature is too low, the resistance of R57 will be high enough to bias the emitter of unijunction transistor Q16 sufficiently positive for it to act as a free running pulse generator. These pulses are coupled through CR6 and R52 to the gate of the silicon controlled rectifier CR31. The first pulse in any half-cycle of line voltage will cause CR31 to conduct and remain conducting until the end of the half-cycle. When CR31 is conducting, current flows through the oven heater

winding raising the temperature. When the temperature is high enough, the voltage developed across R57 will have decreased sufficiently to lower the emitter bias of Q16, stopping its output pulses and turning CR31 off.

#### 4-33 REFERENCE CIRCUIT

4-34 The reference circuit is a feedback power supply similar to the main supply. It provides stable reference voltages which are used throughout the unit. The reference voltages are all derived from raw dc obtained from the full wave rectifier (CR24 and CR25) and filter capacitor C16. The +6.2 and -9.4 voltages, which are used in the constant voltage input circuit for comparison purposes, are developed across temperature compensated Zener diodes VR1 and VR2. Resistor R49 limits the current through the zener diodes to establish an optimum bias level.

4-35 The reference circuit is a closed loop feedback regulator which acts to maintain the voltage at test point 16 at 12.4 volts regardless of line voltage variation. Any difference between the zener reference diode VR1 and 1/2 of the 12.4 volt bus as sampled by R47 and R48 is amplified by Q14 and Q15 connected as a differential amplifier. The error is further amplified by Q13 and is applied to the base of series regulator Q12 which controls the output voltage of the reference circuit.

4-36 Zener diode VR2 is added in series with the reference outputs to provide a -9.4 volt bias output. The main reference voltage is the 6.2 volt zener diode VR1. The 12.4 volt output is used as a stable bias source. Diode CR19 provides initial start-up for the reference circuit when the power supply is first turned on.

#### 4-37 METER CIRCUIT

4-38 The meter circuit provides continuous indications of output voltage or current on a single meter. The meter can be used as either a voltmeter or an ammeter depending upon the position of METER switch S2 on the front panel of the supply. In the VOLTS position, R68 and R21 form a 38 to 1 voltage divider, and the meter is connected through voltage calibrate potentiometer R67. Voltage calibrate potentiometer R67 is adjusted for proper full scale meter deflection in the voltage range.

4-39 With meter switch S2 in the AMPS position, the meter is connected through R66 and R65 across the current sampling resistor R23. After the meter has been mechanically zeroed and with the power supply turned off, current zero potentiometer R25 is adjusted until the meter needle rests on zero. Current calibrate potentiometer R65 is adjusted for full scale meter deflection in the current range.

## SECTION V MAINTENANCE

### 5-1 INTRODUCTION

5-2 Upon receipt of the power supply, the performance check (Paragraph 5-11) should be made. This check is suitable for incoming inspection. If a fault is detected in the power supply while making the performance check or during normal operation, proceed to the troubleshooting procedures (Paragraph 5-51). After troubleshooting and repair (Paragraph 5-59), perform any necessary adjustments and calibrations (Paragraph 5-62). 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-on power supply, allow a half-hour warm-up, and read the general information regarding measurement techniques (Paragraph 5-6).

### 5-3 HIGH VOLTAGE PRECAUTIONS

5-4 With the supply operating normally and neither output grounded to the chassis, there are many high voltage points within the chassis that are dangerous to personnel. The potentials vary from several hundred to 3000 volts and are dependent on the setting of the VOLTAGE thumbwheel switches. Therefore, always observe the following caution:

#### CAUTION

Connect the positive output to ground (chassis) before removing the covers to perform maintenance. This reduces the number of internal points with dangerous potentials.

5-5 With the positive terminal connected to chassis, only the points illustrated in Figure 5-1 are at a high potential with respect to the chassis.

### 5-6 MEASUREMENT TECHNIQUES

5-7 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

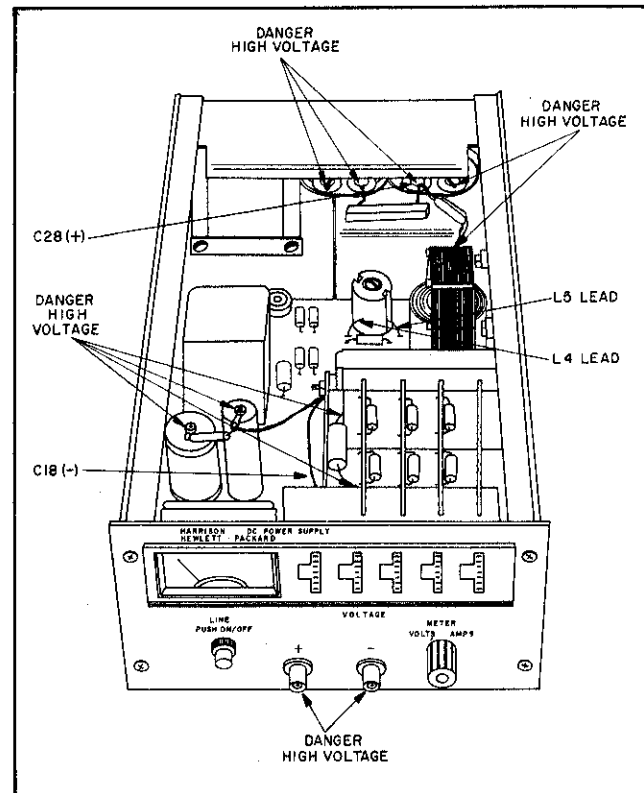


Figure 5-1. High Voltage and Troubleshooting Location Diagram

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.

5-8 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 (powercord). 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.

### 5-9 TEST EQUIPMENT REQUIRED

5-10 Table 5-1 lists the test equipment required to perform the various procedures described in this section.

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: 100 $\mu$ V/cm. Differential Input	Measure ripple and transient response	Ⓢ 140 A plus 1400 A Plug-in. 1402A Plug-in for spike measurement only.
Differential Voltmeter	Sensitivity: 1mV full scale (min.).	Measure regulation; Calibrate meter	Ⓢ 3420 See Note
Repetitive Load Switch	Rate: 60-400 Hz, 2 $\mu$ sec rise and fall time, 250V, 1A.	Measure transient	See Figure 5-7
Resistive Load	500K, 18W	Power supply load	---
Resistor	1 K $\Omega$ , $\pm$ 1% 2W non-inductive.	Measure impedance	---
Multimeter	Accuracy 1%	Measure output current and DC voltages	Ⓢ 412 A
Capacitor	500 $\mu$ fd, 50vdcw	Measure impedance	---
Resistor	200K, 1/2W	Measure impedance	---
Oscillator	5 Hz - 600 kHz. Accuracy: 2% Output: 10vrms	Measure impedance	Ⓢ 200 CD
Controlled-Temperature Oven	0-50 $^{\circ}$ C	Measure temperature stability	---
Resistance Box	0-100K $\Omega$ . Accuracy: 0.1% + 1 $\Omega$ . Make-before-break contacts.	Measure programming coefficients	Ⓢ Model 6931A
Capacitor	1 $\mu$ f, 1600wvdc	Measure ripple and noise	---
Voltage Divider	100: 1, up to 4KV, 0.01% Accuracy	Load regulation. Line regulation	Keithley Instruments, Inc. Model 6601A

## NOTE

A satisfactory substitute for a differential voltmeter is to arrange a reference voltage source and null detector as shown in Figure 5-2. The reference voltage source is adjusted so that the voltage difference between the supply being measured and the reference voltage will have the required resolution for the measurement being made. The voltage difference will be a function of the null detector that is used. Examples of satisfactory null detectors are: Ⓢ 419A null detector, a dc coupled oscilloscope utilizing differential input, or a 50mV meter movement with a 100 division scale. For the latter, a 2mV change in voltage will result in a meter deflection of four divisions.

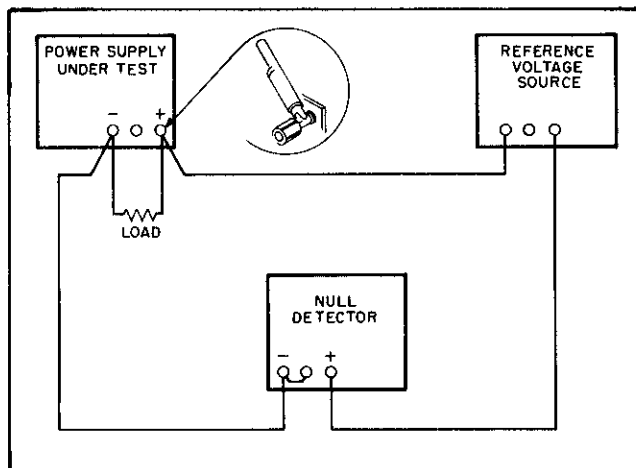


Figure 5-2. Differential Voltmeter Substitute Test Setup

**CAUTION**

Care must be exercised when using an electronic null detector in which one input terminal is grounded to avoid ground loops and circulating currents.

**5-11 PERFORMANCE TEST**

5-12 The following test can be used as an incoming inspection check and appropriate portions of the test can be repeated either to check the operation of the instrument after repairs or for periodic preventive maintenance tests.

5-13 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.

**5-14 RATED OUTPUT, METER, AND OUTPUT CONTROLS ACCURACY**

5-15 Voltage. To check the accuracy of the output voltage, front panel voltmeter, and front panel voltage controls, proceed as follows:

- a. Connect the differential voltmeter, load resistor, and the attenuator to the power supply as illustrated in Figure 5-3. Load resistance is approximately 500K ohms, 18 watts.
- b. Turn the front panel VOLTAGE thumbwheel controls until the front panel voltmeter indicates exactly 3000Vdc.

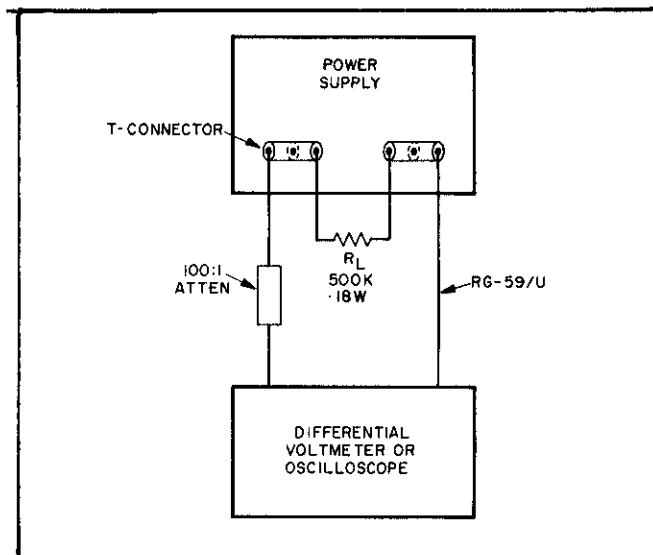


Figure 5-3. Line and Load Regulation, Test Setup

- c. The differential voltmeter should indicate  $30 \pm 0.6$ Vdc.

5-16 Current. To check the output current capability of the supply, proceed as follows:

- a. Connect the multimeter (set to the 10mA position) or another milliammeter in series with a 500K, 18W load resistance, and attach the series combination to the output terminals.
- b. Adjust the VOLTAGE thumbwheel controls until the front panel voltmeter indicates 3000Vdc.
- c. The multimeter should indicate 6mA.

**5-17 LOAD REGULATION**

Definition: The change  $\Delta E_{OUT}$  in the static value of DC output voltage resulting from a change in load resistance from open circuit to a value which yields maximum rated output current (or vice versa).

5-18 To check constant voltage load regulation, proceed as follows:

- a. Connect differential voltmeter, load resistor and attenuator to the power supply as illustrated in Figure 5-3.
- b. Turn the front panel VOLTAGE thumbwheel controls until the front panel voltmeter indicates exactly 3000 volts.
- c. Read and record voltage indicated on differential voltmeter.
- d. Disconnect load resistor.
- e. Reading on differential voltmeter should not vary from reading recorded in step c by more than 0.3mV.

### 5-19 LINE REGULATION

Definition: The change,  $\Delta E_{OUT}$ , in the static value of DC output voltage resulting from a change in AC input voltage over the specified range from low line (usually 105 volts) to high line (usually 125 volts), or from high line to low line.

5-20 To check constant voltage line regulation, proceed as follows:

- Connect variable auto-transformer between input power source and power supply power input.
- Connect differential voltmeter, load resistor, and attenuator as illustrated in Figure 5-3.
- Adjust variable auto-transformer for 105 Vac input.
- Adjust front panel VOLTAGE thumbwheel controls until the front panel voltmeter indicates exactly 300Vdc.
- Read and record voltage indicated on differential voltmeter.
- Adjust variable auto transformer for 125 Vac input.
- Reading on differential voltmeter should not vary from reading recorded in step e by more than 0.3mV.

### 5-21 RIPPLE AND NOISE

Definition: The residual AC voltage which is superimposed on the DC output of a regulated power supply. Ripple and noise may be specified and measured in terms of its RMS or (preferably) peak-to-peak value.

5-22 Ripple and noise measurement can be made at any input AC line voltage combined with any DC output voltage and load current within rating.

5-23 The amount of ripple and noise that is present on the power supply output is measured either in terms of the RMS or (preferably) peak-to-peak value. The peak-to-peak measurement is particularly important for applications where noise spikes could be detrimental to a sensitive load, such as logic circuitry. The RMS measurement is not an ideal representation of the noise, since fairly high output noise spikes of short duration could be present in the ripple and not appreciably increase the RMS value.

5-24 The technique used to measure high frequency noise or "spikes" on the output of a power supply is more critical than the low frequency ripple and noise measurement technique; therefore the former is discussed separately in Paragraph 5-32.

5-25 Ripple and Noise Measurements. Figure 5-4A shows an incorrect method of measuring p-p ripple. Note that a continuous ground loop exists from the third wire of the input power cord of the supply to the third wire of the input power cord of the oscilloscope via the grounded power supply case, the wire between the negative output terminal of the power supply and the vertical input of the scope, and the grounded scope case. Any ground current circulating in this loop as a result of the difference in potential  $E_G$  between the two ground points causes an IR drop which is in series with the scope input. This IR drop, normally having a 60Hz line frequency fundamental, plus any pickup on the unshielded leads interconnecting the power supply and scope, appears on the face of the CRT. The magnitude of this resulting noise signal can easily be much greater than the true ripple developed between the plus and minus output terminals of the power supply, and can completely invalidate the measurement.

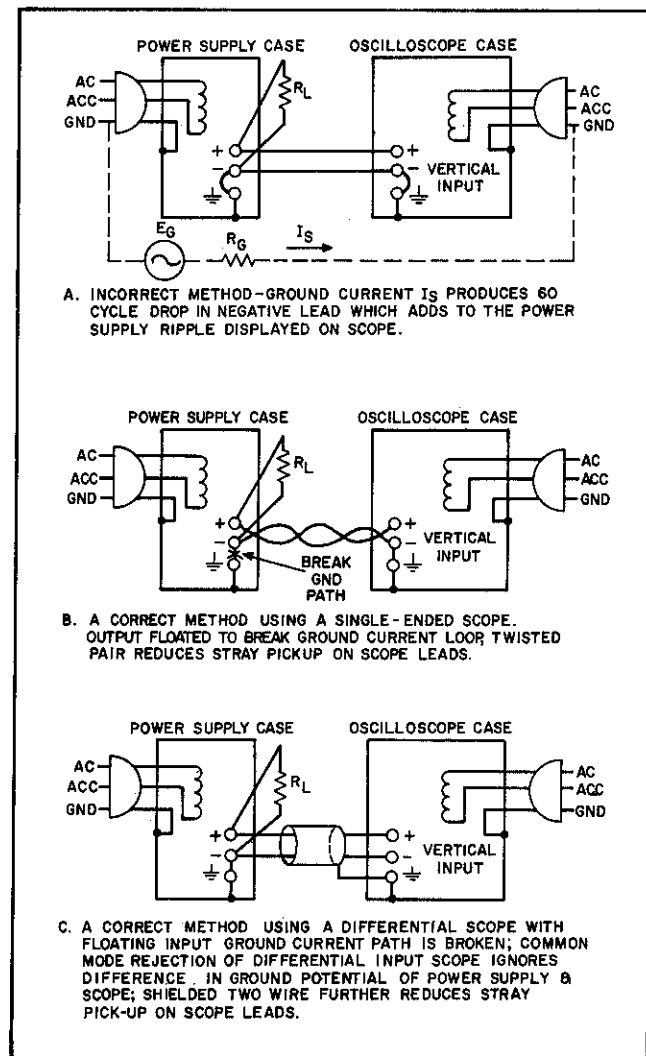


Figure 5-4. Ripple and Noise Test Setup



5-26 The same ground current and pickup problems can exist if an RMS voltmeter is substituted in place of the oscilloscope in Figure 5-4. However, the oscilloscope display, unlike the true RMS meter reading, tells the observer immediately whether the fundamental period of the signal displayed is 8.3 milliseconds (1/120 Hz) or 16.7 milliseconds (1/60 Hz). Since the fundamental ripple frequency present on the output of an AC supply is 120 Hz (due to full-wave rectification), an oscilloscope display showing a 120 Hz fundamental component is indicative of a "clean" measurement setup, while the presence of a 60 Hz fundamental usually means that an improved setup will result in a more accurate (and lower) value of measured ripple.

5-27 Figure 5-4B shows a correct method of measuring the output ripple of a constant voltage power supply using a single-ended scope. The ground loop path is broken by floating the power supply output. Note that to ensure that no potential difference exists between the supply and the oscilloscope, it is recommended that whenever possible they both be plugged into the same AC power buss. If the same buss cannot be used, both AC grounds must be at earth ground potential.

5-28 Either a twisted pair or (preferably) a shielded two-wire cable should be used to connect the output terminals of the power supply to the vertical input terminals of the scope. When using a twisted pair, care must be taken that one of the two wires is connected to the grounded input terminal of the oscilloscope. When using shielded two-wire, it is essential for the shield to be connected to ground at one end only so that no ground current will flow through this shield, thus inducing a noise signal in the shielded leads.

5-29 To verify that the oscilloscope is not displaying ripple that is induced in the leads or picked up from the grounds, the (+) scope lead should be shorted to the (-) scope lead at the power supply terminals. The ripple value obtained when the leads are shorted should be subtracted from the actual ripple measurement.

5-30 In most cases, the single-ended scope method of Figure 5-4B will be adequate to eliminate non-real components of ripple and noise so that a satisfactory measurement may be obtained. However, in more stubborn cases it may be necessary to use a differential scope with floating input as shown in Figure 5-4C. If desired, two single conductor shielded cables may be substituted in place of the shielded two-wire cable with equal success. Because of its common mode rejection, a differential oscilloscope displays only the difference in signal between its two vertical input terminals, thus ignoring the effects of any common mode signal introduced because of the

difference in the AC potential between the power supply case and scope case. Before using a differential input scope in this manner, however, it is imperative that the common mode rejection capability of the scope be verified by shorting together its two input leads at the power supply and observing the trace on the CRT. If this trace is a straight line, the scope is properly ignoring any common mode signal present. If this trace is not a straight line, then the scope is not rejecting the ground signal and must be realigned in accordance with the manufacturer's instructions until proper common mode rejection is attained.

5-31 To check the ripple and noise output, proceed as follows:

a. Connect the oscilloscope or RMS voltmeter as shown in Figures 5-4B or 5-4C. In addition, connect the high voltage protection network, illustrated in Figure 5-5, in series with the power supply output. In this network, the diodes clamp the input to the oscilloscope in the event that the power supply is rapidly turned up or down. The 50 ohm resistor limits the current through the diodes. The 5Meg resistor is a bleeder to discharge the 0.1µf capacitor which is a 3000Vdc blocking capacitor. A good quality 3000Vdc blocking capacitor can be used in place of the protection network; however, if the capacitor becomes leaky or in cases where the power supply output voltage is rapidly increased or decreased, the oscilloscope input could be damaged.

b. Adjust VOLTAGE control until front panel meter indicates maximum rated output voltage.

c. The observed ripple and noise should be less than 400µV RMS and 1mV p-p.

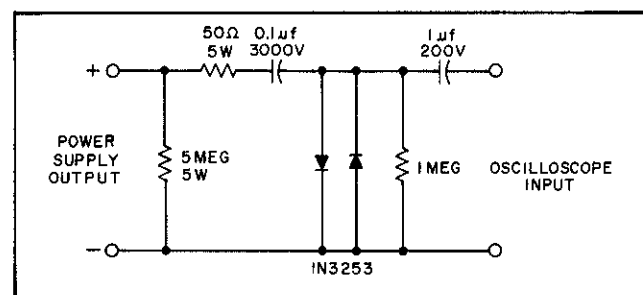


Figure 5-5. High Voltage Protection Network

5-32 Noise Spike Measurement. When a high frequency spike measurement is being made, an instrument of sufficient bandwidth must be used; an oscilloscope with a bandwidth of 20 MHz or more is adequate. Measuring noise with an instrument that has insufficient bandwidth may conceal high frequency spikes detrimental to the load.

5-33 The test setups illustrated in Figures 5-4A and 5-4B are generally not acceptable for measuring spikes; a differential oscilloscope is necessary. Furthermore, the measurement concept of Figure 5-4C must be modified if accurate spike measurement is to be achieved:

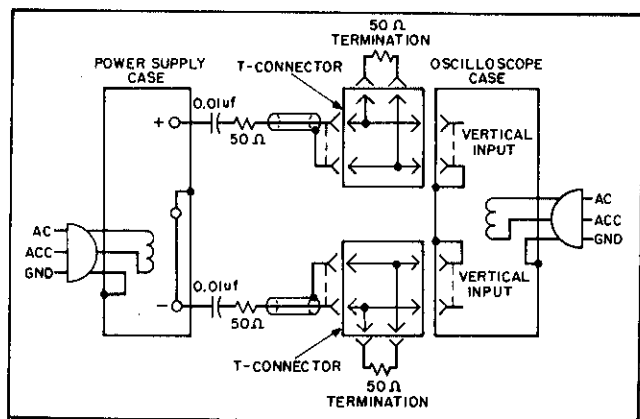


Figure 5-6. Noise Spikes Test Setup

1. As shown in Figure 5-6, two coax cables, must be substituted for the shielded two-wire cable. In addition a high voltage protection network (Figure 5-5) as described in paragraph 5-31 should be connected in series with the power supply output.

2. Impedance matching resistors must be included to eliminate standing waves and cable ringing, and the capacitors must be connected to block the DC current path.

3. The length of the test leads outside the coax is critical and must be kept as short as possible; the blocking capacitor and the impedance matching resistor should be connected directly from the inner conductor of the cable to the power supply terminals.

4. Notice that the shields of the power supply end of the two coax cables are not connected to the power supply ground, since such a connection would give rise to a ground current path through the coax shield, resulting in an erroneous measurement.

5. The measured noise spike values must be doubled, since the impedance matching resistors constitute a 2-to-1 attenuator.

6. The noise spikes observed on the oscilloscope should be less than 0.5mV p-p.

5-34 The circuit of Figure 5-6 can also be used for the normal measurement of low frequency ripple and noise; simply remove the four terminating resistors and the blocking capacitors and substitute a higher gain vertical plug-in in place of the wide-band plug-in required for spike measurements. Notice that with these changes, Figure 5-6 becomes a two-cable version of Figure 5-4C.

### 5-35 TRANSIENT RECOVERY TIME

Definition: The time "X" for output voltage recovery to within "Y" millivolts of the nominal output voltage following a "Z" amp step change in load current—where:

"Y" is specified separately for each model but is generally of the same order as the load regulation specification. The nominal output voltage is defined as the DC level half way between the static output voltage before and after the imposed load change, and "Z" is the specified load current change, normally equal to the full load current rating of the supply.

5-36 Transient recovery time may be measured at any input line voltage combined with any output voltage and load current within rating.

5-37 Reasonable care must be taken in switching the load resistance on and off. A hand-operated switch in series with the load is not adequate, since the resulting one-shot displays are difficult to observe on most oscilloscopes, and the arc energy occurring during switching action completely masks the display with a noise burst. Transistor load switching devices are expensive if reasonably rapid load current changes are to be achieved.

A mercury-wetted relay, as connected in the load switching circuit of Figure 5-7 should be used for loading and unloading the supply. When this load switch is connected to a 60 Hz AC input, the mercury-wetted relay will open and close 60 times per second. Adjustment of the 25K control permits adjustment of the duty cycle of the load current switching and reduction in jitter of the oscilloscope display.

5-38 To check the transient recovery time, proceed as follows:

- Connect test setup as shown in Figure 5-7.
- Set the VOLTAGE thumbwheel switches for 90Vdc.
- Close the line switch on the repetitive load switch setup.
- Set the oscilloscope for internal sync and lock on either the positive or negative load transient spike.
- Set the vertical input of the oscilloscope for AC coupling so that small DC level changes in the output voltage of the power supply will not cause the display to shift.
- Adjust the vertical centering on the scope so that the tail ends of the no load and full load waveforms are symmetrically displaced about

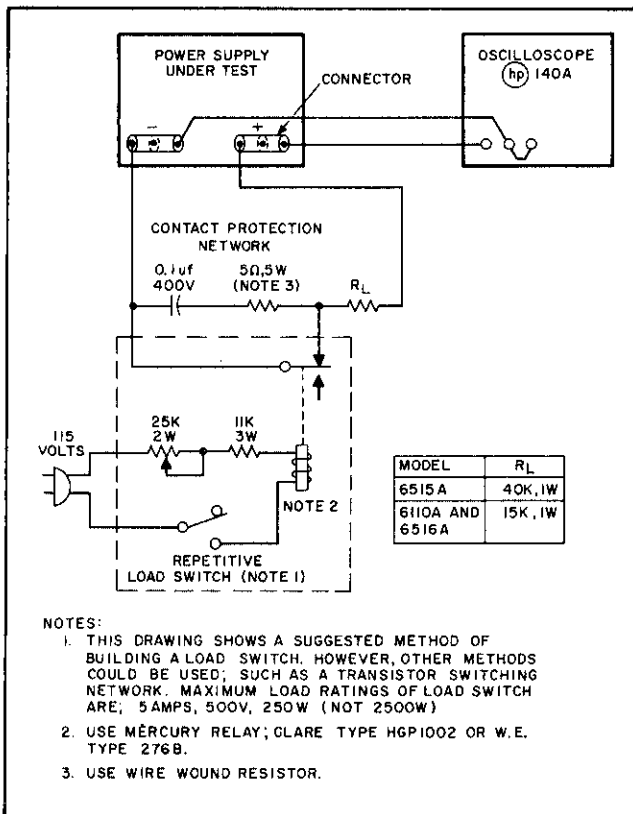


Figure 5-7. Transient Recovery Time, Test Setup

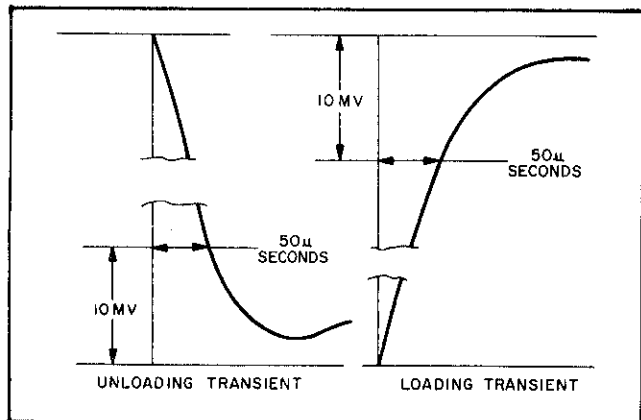


Figure 5-8. Transient Recovery Time, Waveforms

the horizontal center line of the oscilloscope. This center line now represents the nominal output voltage defined in the specification.

g. Adjust the horizontal positioning control so that the trace starts at a point coincident with a major graticule division. This point is then representative of time zero.

h. Increase the sweep rate so that a single transient spike can be examined in detail.

i. Adjust the sync controls separately for the positive and negative going transients so that

not only the recovery waveshape but also as much as possible of the rise time of the transient is displayed.

j. Starting from the major graticule division representative of time zero, count to the right 50  $\mu$ sec and vertically 10mV. Recovery should be within these tolerances as illustrated in Figure 5-8.

### 5-39 OUTPUT IMPEDANCE

Definition: At any given frequency of load change,  $\Delta E_{OUT}/\Delta I_{OUT}$ . The definition applies only for a sinusoidal load disturbance, unless, of course, the measurement is made at zero frequency (DC). The output impedance of an ideal constant voltage power supply would be zero at all frequencies, while the output impedance for an ideal constant current power supply would be infinite at all frequencies.

5-40 The output impedance of a power supply is normally not measured, since the measurement of transient recovery time reveals both the static and dynamic output characteristics with just one measurement. The output impedance of a power supply is commonly measured only in those cases where the exact value at a particular frequency is of engineering importance.

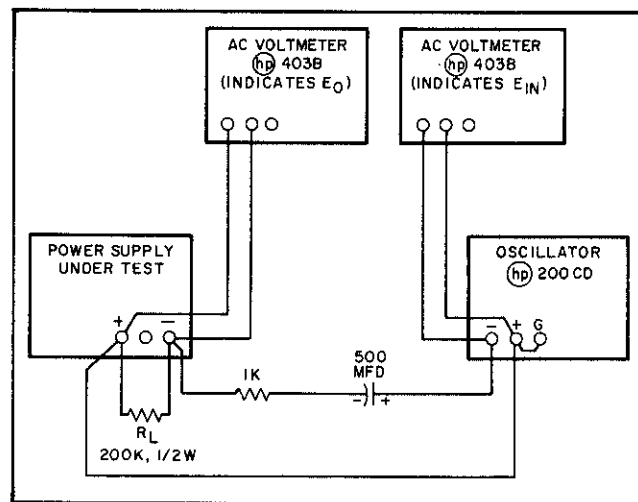


Figure 5-9. Output Impedance, Test Setup

5-41 To check the output impedance, proceed as follows:

a. Connect the test setup shown in Figure 5-9. The best method of connecting the load resistor, oscillator, and AC voltmeter to the power supply is

with two tee connectors on each power supply terminal. Clip lead connections can be used in lieu of the tee connectors providing that all connections are made directly to the power supply and lead lengths are short.

b. Adjust front panel VOLTAGE thumbwheel switches until the front panel voltmeter indicates 200Vdc.

c. Set AMPLITUDE control on oscillator to 10 volts ( $E_{IN}$ ), and FREQUENCY control to 1000 Hz (cps).

d. Record voltage across output terminals of the supply ( $E_O$ ) as indicated on AC voltmeter.

e. Calculate the output impedance by the following formula:

$$Z_{out} = \frac{E_{OR}}{E_{in} - E_O}$$

where  $E_O$  = rms voltage across power supply output terminals

$R = 1000$  ohms

$E_{in} = 10$  volts

f. The output impedance ( $Z_{out}$ ) should be less than 50 ohms.

#### 5-42 TEMPERATURE COEFFICIENT

Definition: The change in output voltage per degree Centigrade change in the ambient temperature under conditions of constant input AC line voltage, output voltage setting, and load resistance.

5-43 The temperature coefficient of a power supply is measured by placing the power supply in an oven and varying it over any temperature span within its rating. (Most  $\phi$  power supplies are rated for operation from 0°C to 50°C.) The power supply must be allowed to thermally stabilize for a sufficient period of time at each temperature of measurement.

5-44 The temperature coefficient specified is the maximum temperature-dependent output voltage change which will result over any 5°C interval. The differential voltmeter or digital voltmeter used to measure the output voltage change of the supply should be placed outside the oven and should have a long term stability adequate to insure that its drift will not affect the overall measurement accuracy.

5-45 To check the temperature coefficient, proceed as follows:

a. Connect the load resistance, attenuator, and differential voltmeter as illustrated in Figure 5-3.

b. Adjust front panel VOLTAGE thumbwheel switches until the front panel voltmeter indicates 3000 Vdc.

c. Insert the power supply into the temperature — controlled oven (differential voltmeter remains outside oven). Set the temperature to 30°C and allow 30 minutes warm-up.

d. Record the differential voltmeter indication.

e. Raise the temperature to 40°C and allow 30 minutes warm-up.

f. The differential voltmeter indication should change by less than 0.35mV from indication recorded in step d.

#### 5-46 OUTPUT STABILITY

Definition: The change in output voltage for the first eight hours following a 30 minute warm-up period. During the interval of measurement all parameters, such as load resistance, ambient temperature, and input line voltage are held constant.

5-47 This measurement is made by monitoring the output of the power supply on a differential voltmeter or digital voltmeter over the stated measurement interval; a strip chart recorder can be used to provide a permanent record. A thermometer should be placed near the supply to verify that the ambient temperature remains constant during the period of measurement. The supply should be put in a location immune from stray air currents (open doors or windows, air conditioning vents); if possible, the supply should be placed in an oven which is held at a constant temperature. Care must be taken that the measuring instrument has a stability over the eight hour interval which is at least an order of magnitude better than the stability specification of the power supply being measured. Typically, a supply may drift less over the eight hour measurement interval than during the 1/2 hour warm-up period.

Stability measurement can be made while the supply is remotely programmed with a fixed wire-wound resistor, thus avoiding accidental changes in the front panel setting due to mechanical vibration or "knob-twiddling."

5-48 To check the output stability, proceed as follows:

a. Connect the load resistance, attenuator, and differential voltmeter as illustrated in Figure 5-3.

b. Adjust front panel VOLTAGE RANGE switch and VERNIER until the differential voltmeter indicates 30Vdc.

c. Allow 30 minutes warm-up then record the differential voltmeter indication.

d. After 8-hours, differential voltmeter should change by less than 3.5mV from indication recorded in step c.

5-49 CURRENT LIMIT

5-50 To check the current limiting characteristics of the supply, proceed as follows:

- a. Connect a milliammeter across the output of the supply.
- b. Turn on the supply and increase the output voltage until the milliammeter indicates 6mA.
- c. Check that the supply is not in current limit by examining the output ripple. The ripple will be very high — much greater than 400µV — if the supply is in current limit.
- d. Increase the output voltage to 3000V and ensure that the output current does not exceed 8mA.

5-51 TROUBLESHOOTING

5-52 Before attempting to troubleshoot this instrument, ensure that the fault is with the instrument and not with an associated circuit. The performance test (Paragraph 5-11) enables this to be determined without having to remove the instrument from the cabinet.

5-53 A good understanding of the principles of operation is a helpful aid in troubleshooting, and it is recommended that the reader review Section IV of the manual before attempting to troubleshoot the unit in detail. Once the principles of operation are understood, refer to the overall troubleshooting procedures in paragraph 5-55 to locate the symptom and probable cause.

NOTE

The normal voltages shown on the schematic diagram at the rear of the

manual are positioned adjacent to the applicable test points (identified by encircled numbers on the schematic and printed wiring boards).

5-54 Once the defective component has been located (by means of visual inspection or trouble analysis) correct it and re-conduct the performance test. If a component is replaced, refer to the repair and replacements and adjustment and calibration paragraphs in this section.

5-55 OVERALL TROUBLESHOOTING PROCEDURE

5-56 To locate the cause of trouble follow steps 1, 2, and 3 in sequence.

CAUTION

Connect the positive output to ground (chassis) before troubleshooting with the supply turned on. This reduces the number of internal points with dangerous potentials to those indicated in Figure 5-1.

(1) Check for obvious troubles such as open fuse, defective power cord, input power failure, or defective voltage or current meter. Next remove the top and bottom covers (each held by four retaining screws) and inspect for open connections, charred components, etc. If the trouble source cannot be detected by visual inspection, proceed with step 2

(2) In almost all cases, the trouble can be caused by the DC bias or reference voltages; thus, it is a good practice to check voltages in Table 5-2, before proceeding with step 3

Table 5-2. Bias, Reference, and Rectifier Voltages  
(Refer to Figure 5-10 for test point locations)

Step	Meter Common	Meter Positive	Normal Vdc	Normal Ripple (P-P)	Probable Cause
1	15	24	17.5	1V	CR26, CR27, CR28 C17
2	+S(C14,neg.)	24	+2.1	50 mV	CR10, R41
3	+S(C14,neg.)	C14 positive	15	less than 200µV	Q12, Q13, Q14
4	+S(C14,neg.)	30	6.2	less than 50µV	VR1, R49
5	VR2 cathode	C14 negative	9.4	less than 100µV	VR2
6	34	R43	26	0.4V	CR24, CR25, C16
7	36	11	170	1V	CR29, CR30, C19 R54
8	36	22	325	6V	CR33-CR36, C18, R40

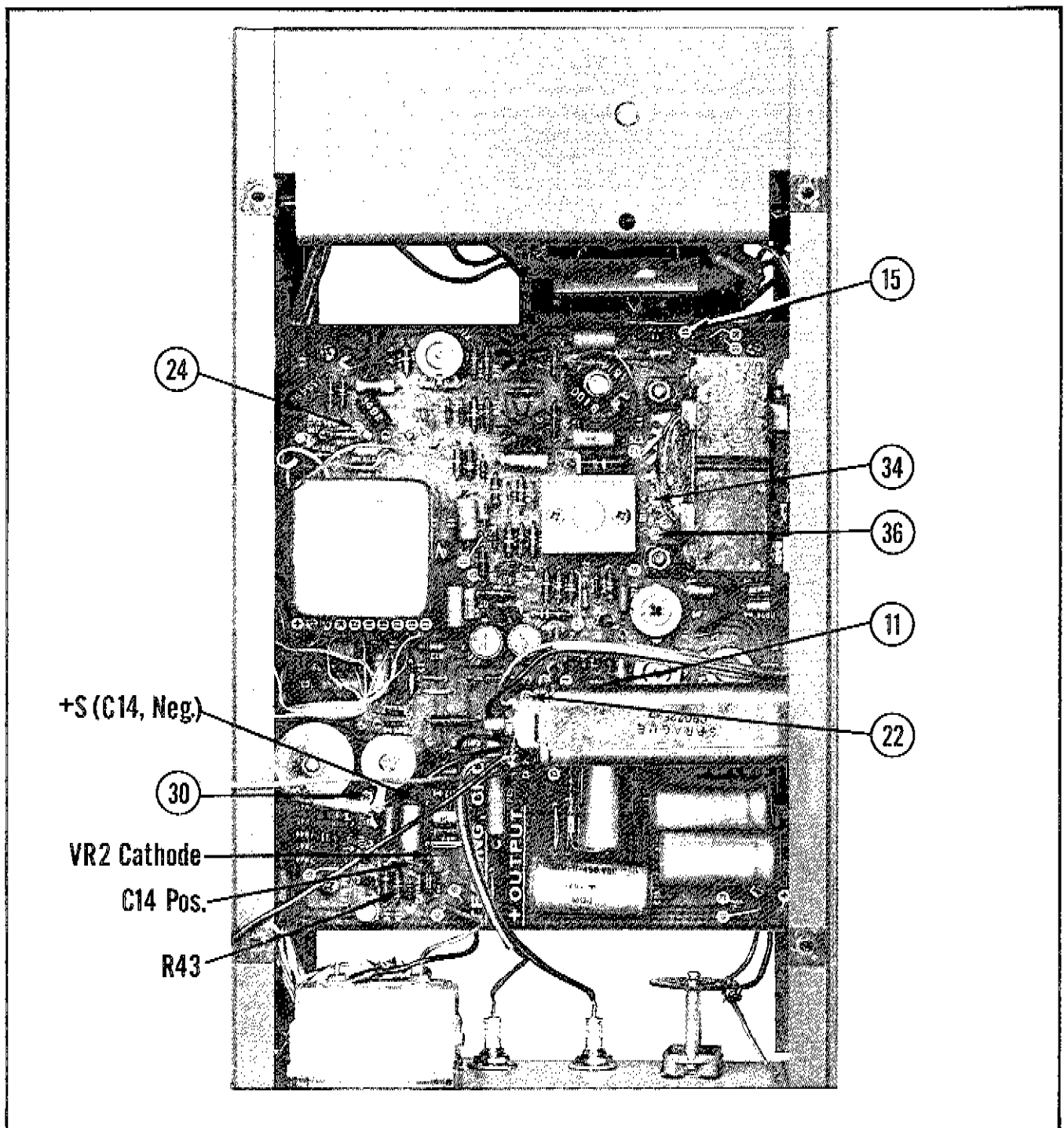


Figure 5-10. Printed Circuit Board Location Diagram

(3) Examine the following list to determine your symptom, then check the probable cause.

Symptom	Probable Cause
Low output or no output voltage	Insure that the front panel meter is not defective, then refer to paragraph 5-57.
High output voltage	Insure that the front panel meter is not defective, then refer to paragraph 5-57.

#### CAUTION

Never set the output voltage controls to zero volts when there is high or low output voltage; damage to the voltage controls could result.

Erratic output voltage. (The needle on the output voltage meter wavers slightly, or an oscilloscope connected to the output displays erratic ripple).	Same as low output symptom; refer to paragraph 5-57.
Inability to reach zero output voltage $\pm 1\text{mV}$ .	a. Check output voltage zero adjustment, paragraph 5-63. b. Output voltage control R200 defective c. Differential amplifier Q1 defective
Oscillates	C6, C3, C8, C1, C2, C7, C13 or C14 defective
Meter needle pegs in current position	CR19 defective or short between +12.4V and +2.1V supplies test point (16) to (24)
Slow drift	a. Measuring equipment b. Reference diode VR1 c. Q1, Q2, Q3 d. Insufficient warm-up time (should be 30 minutes) e. Oven control circuit defective or misadjusted (refer to paragraph 5-75)
Random instability a. Large output voltage transients (output reductions of 1V or more)	High voltage control circuit defective. Refer to Table 5-3 step 9

b. Large output voltage transients (output increases of 1V or more).

c. Small output voltage transients (output changes of 10-30 mV).

High Ripple

Poor Transient Recovery Time

Output Voltage Inaccuracy

5-57 Regulating Loop Troubles. If the voltages in Table 5-2 have been checked to eliminate the reference, bias and rectifier circuits as a source of trouble; the malfunction is caused by either the low or high voltage regulating loops. If any component in a feedback loop is defective, measurements made anywhere in the loop may appear abnormal. Under these circumstances it is very difficult to separate cause from effect with the loop closed. As described in Tables 5-3 and 5-4, the trouble is isolated to either the high or low voltage regulating loop. The loop is opened, and the conduction and cutoff capability of each stage is checked as follows:

High voltage control circuit defective. Refer to Table 5-4, step 9.

VR1 defective, voltage thumbwheel switches noisy, 1V thumbwheel control R200 noisy

a. Check operating set-up for ground loops.  
b. If output floating, connect 1 $\mu\text{f}$  capacitor between output and ground  
c. Check for excessive internal ripple; refer to Table 5-2.  
d. Ensure that supply is not current limiting under loaded conditions. Check that test point (21) is approx +12V. Current limit circuit defective or misadjusted (refer to paragraph 5-77)

C6, C3, C8, C1, C2, C9 C13 or C14 defective.

a. Set output voltage controls to zero. Output voltage should read  $0\text{V} \pm 10\text{mV}$ ; if not, perform adjustment given in paragraph 5-63.  
b. Slowly rotate each thumbwheel switch a step at a time, and record the output voltage. The step changes should be within  $\pm 0.1\%$ . A deviation in any step indicates that the associated resistor is defective.

1. Shorting the emitter to collector of a transistor simulates saturation, or the full ON condition.

2. Shorting the emitter to base of a transistor cuts it off, and simulates an open circuit between emitter and collector.

5-58 Although a logical first choice might be to break the loop somewhere near its mid-point, and then perform successive subdividing test, it is more useful to trace the loop from the series regulator backwards a stage at a time, since loop failures occur more often at the higher power levels.

Table 5-3. Low Output Voltage Troubleshooting

Step	Action	Response	Probable Cause
1	To isolate the fault to either the high voltage circuits or the low voltage feedback loop, measure the voltage between the collector (case) of Q11 and +S	a. Approximately 160V b. Approximately 0V	a. Low voltage feedback loop. Proceed to step 2 b. High voltage circuits. Proceed to step 9
2	Once it is determined that the low voltage loop is defective, the high voltage control circuit should be disabled by connecting a jumper between L4 and L5 as illustrated in Figure 5-1.. Since this places a reverse voltage across capacitors C27 and C28, a jumper must be connected from the (-) lead of C18 to the (-) lead of C28 as illustrated in Figure 5-1.. The low voltage loop should be checked as follows:		
3	To check the operation of the current limit, measure the voltage at test point (21)	a. Less than 2V	a. Current limit circuit faulty. Check CR8, Q5 and associated components
4	Check turn-on of Q11 by connecting a jumper between the emitter and collector of Q10	b. Approximately 12V a. Output remains low b. Output increases (≈150V)	b. Proceed to step 3 a. Q11 defective b. Remove jumper from Q10 and proceed to step 5
5	Check turn-on of Q10 by opening the collector lead of Q9	a. Output remains low b. Output increases	a. Q10 or associated components defective b. Reconnect Q9 and proceed to step 6
6	Check turn-off of Q9 by shorting base to emitter	a. Output remains low b. Output increases	a. Q9 or associated components defective b. Reconnect Q8 and proceed to step 7
7	Check turn-off of Q8 and turn on of Q7 by shorting Q8 base to emitter	a. Output remains low b. Output increases	a. Q8, Q7 or associated components defective b. Reconnect Q8 and proceed to step 8
8	Turn off the supply and check the resistance from test point 19 to (-) output	a. Approximately zero ohms b. Approximately 200K ohms	a. Short in R1 or R200-R235 network b. Check Q1, Q2, Q3, or associated
9	To check the high voltage control circuit, set the output VOLTAGE controls to 900V and remove the jumpers from L4-L5 and C18-C28. Proceed with step 10.		



Table 5-3. Low Output Voltage Troubleshooting (Continued)

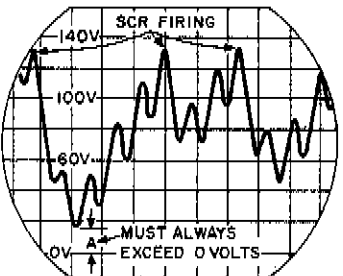
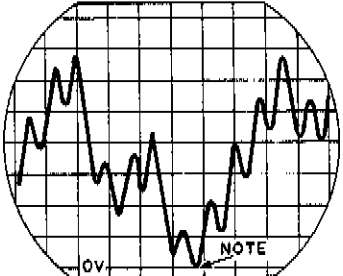
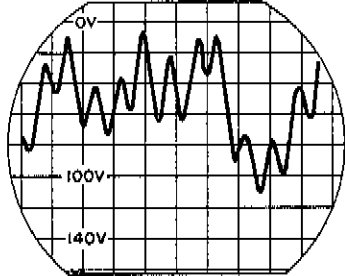
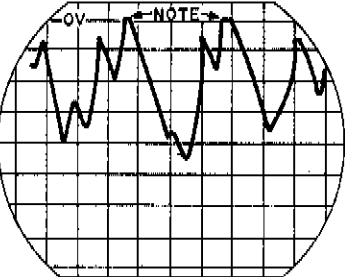
Step	Action	Response	Probable Cause
10	<p>Connect the oscilloscope between test point 11 and +out. Set the oscilloscope for dc coupled input</p>	<p style="text-align: center;">NOTE</p> <p>Waveforms that indicate normal operation of the high voltage control circuit under various line and load conditions are shown on the schematic diagram at the rear of the manual.</p> <div style="text-align: center;">  <p>T.P. (11) TO (+) 20V/CM 10ms/CM</p> </div> <p>The waveform above indicates a normal condition. Note that the lowest peak does not reach zero volts</p> <div style="text-align: center;">  <p>T.P. (11) TO (+) 20V/CM 10ms/CM</p> </div> <p>The waveform above is indicative of poor regulation and erratic output in addition to slightly low output voltage. Note that the lowest peak touches 0V. If the output is very low, the waveform is compressed toward 0V.</p>	<ul style="list-style-type: none"> <li>a. If VR3 is on or blinking, OVERVOLTAGE control R71 should be adjusted (see paragraph 5-73)</li> <li>b. Q17 leaky or shorted</li> <li>c. CR7 or CR40 shorted or leaky</li> <li>d. CR3 or CR5 shorted</li> <li>e. CR41 open or shorted</li> <li>f. T1 or L3 defective.</li> </ul>

Table 5-4. High Output Voltage Troubleshooting

Step	Action	Response	Probable Cause
1	Turn the thumbwheel voltage controls from zero to 600 volts	a. Output voltage is high up to 300V then becomes normal above 300V b. Output voltage is high throughout voltage range	a. Low Voltage Offset circuit defective b. Proceed to step 2
2	To isolate the fault to either the high voltage circuits or the low voltage feedback loop, set the output voltage to 100.0V and disable the high voltage control circuit as described in Table 5-4, step 2	a. Approximately 160V b. Approximately 0V	a. Low voltage feedback Proceed to step 3 b. High voltage circuits Proceed to step 7
3	Check turn-off of Q11 and Q10 by connecting a jumper between Q9 collector and emitter	a. Output remains high b. Output decreases to 0V	a. Q10, Q11 or associated components defective b. Remove jumper on Q9 and proceed to step 4
4	Check turn-on of Q9 by connecting a jumper between Q8 collector and emitter	a. Output remains high b. Output decreases to 0V	a. Q9 or associated components defective b. Remove jumper on Q8 and proceed to step 5
5	Check turn-on of Q8 and turn-off of Q7 by connecting a jumper between Q7 base and emitter	a. Output remains high b. Output decreases to 0V	a. Q7, Q8 or associated components defective b. Reconnect Q7 and proceed to step 6
6	Turn off the supply and remove lead from test point 23. Check the resistance from that lead to (-) output	a. More than $100\Omega \pm 1\%$ b. $100\Omega \pm 1\%$	a. Open in R1 or R200-R235 network b. Check Q1, Q2, Q3, or associated circuitry inside oven housing
7	To check the high voltage control circuit, set the output VOLTAGE controls to 900V and remove the jumpers from L4-L5 and C18-C28. Proceed with step 8		
NOTE			
Waveforms that indicate normal operation of the high voltage control circuit under various line and load conditions are shown on the schematic diagram at the rear of the manual.			

Table 5-4. High Output Voltage Troubleshooting (Continued)

Step	Action	Response	Probable Cause
8	Connect the oscilloscope between test point 36 and + out. Set the oscilloscope for dc coupled input	 <p data-bbox="806 711 1111 860">The waveform above indicates a normal condition. Note that the highest peak does not reach zero volts</p>  <p data-bbox="806 1320 1111 1595">The waveform above is indicative of high output voltage. Note that the peaks reach and are clipped at zero volts. Extremely high output voltage produces a waveform that is compressed at zero volts</p>	<ul style="list-style-type: none"> <li>a. CR39 or R77 open</li> <li>b. CR3 or CR5 open</li> <li>c. T1 control winding terminals 5-7 open. Resistance between collect of CR7 and T1 term 6 should be 25<math>\Omega</math>. Resistance between collector of CR40 and T1 term 6 should be 25<math>\Omega</math>.</li> <li>d. R76 or Q17 open</li> <li>e. CR7 or CR40 not firing.</li> </ul>

5-59 REPAIR AND REPLACEMENT

5-60 Before servicing a printed wiring board,

refer to Figure 5-11, which describes the basic techniques in replacing components on a printed wiring board.

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.

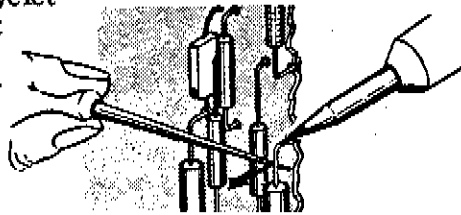
Use only high quality rosin core solder when repairing etched circuit boards. NEVER USE PASTE FLUX. After soldering, clean off any excess flux and coat the repaired area with a high quality electrical varnish or lacquer.

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.

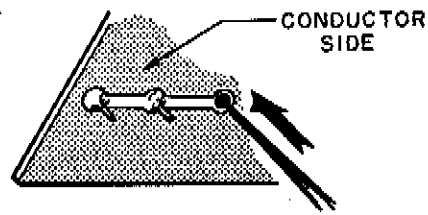
1. Apply heat sparingly to lead of component to be replaced. If lead of component passes through an eyelet

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.

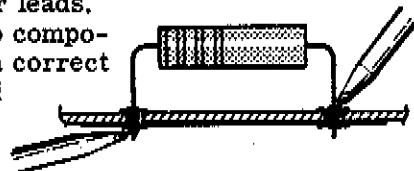


3. Bend clean tinned lead on new part and carefully insert through eyelets or holes in board.



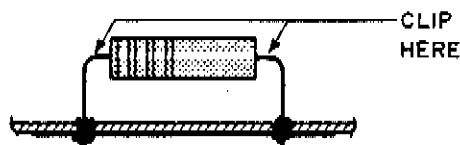
4. Hold part against board (avoid overheating) and solder leads.

Apply heat to component leads on correct side of board as explained in step 1.

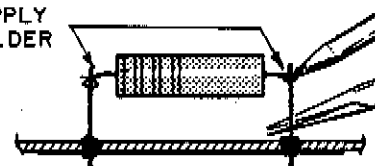


In the event that either the circuit board has been damaged or the conventional method is impractical, use method shown below. This is especially applicable for circuit boards without eyelets.

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 5-11. Servicing Printed Wiring Boards

## 5-61 ADJUSTMENT AND CALIBRATION

5-62 Adjustment and calibration may be required after performance testing, troubleshooting, or repair and replacement. Perform only those adjustments that affect the operation of the faulty circuit and no others.

## 5-63 OUTPUT VOLTAGE ZERO AND TRACKING

5-64 To adjust the output voltage so that it tracks the setting of the VOLTAGE controls from zero to 3000V, proceed as follows:

- a. Set the VOLTAGE controls for 0Vdc and turn off the supply.
- b. Connect the differential voltmeter directly across the output of the power supply.
- c. Disconnect the lead from the thumbwheel assembly at test point (23). Connect a precision 100K, .01% resistor between the lead and test point 23.
- d. Set potentiometers R14 and R16 to mid-range.
- e. Connect a 1% decade resistance box set to 300 ohms in place of R17.
- f. Turn on the supply and allow a 15-minute warm-up.
- g. Connect a jumper across the 100K resistor and adjust the output to zero volts using ZERO ADJ potentiometer R14.
- h. Remove the jumper across the 100K resistor and adjust the decade resistance until the front panel meter indicates 100Vdc.
- i. Select R17 according to the following list, and solder into place:

Decade Resistance	Wirewound Resistor $\frac{1}{4}$ W, 1%	Stock No.
0-50 $\Omega$	0 $\Omega$	---
50-150 $\Omega$	98 $\Omega$	0811-1923
150-250 $\Omega$	197 $\Omega$	0811-1925
250-350 $\Omega$	297 $\Omega$	0811-1929
350-450 $\Omega$	400 $\Omega$	0811-1930
450-550 $\Omega$	505 $\Omega$	0811-1932
550-up $\Omega$	612 $\Omega$	0811-1933

- j. Adjust R16 until differential voltmeter indicates 100 volts.

## 5-65 METER MECHANICAL ZERO

5-66 Proceed as follows to zero meter:

- a. Turn off instrument (after it has reached normal operating temperature) and allow 30 seconds for all capacitors to discharge.
- b. Insert sharp pointed object (pen point or awl) into the small hole at top of round black plastic disc located directly below meter face.

- c. Rotate plastic disc clockwise (cw) until meter reads zero, then rotate ccw slightly in order to free adjustment screw from meter suspension. If pointer moves, repeat steps b and c.

## 5-67 VOLTMETER TRACKING

5-68 To calibrate the voltmeter tracking, proceed as follows:

- a. Set the METER switch to VOLTS position and turn on the supply.
- b. Adjust the power supply VOLTAGE controls for 3000Vdc.
- c. Adjust VOLT CAL control R67 until the meter indicates exactly 3000Vdc.

## 5-69 AMMETER ZERO

5-70 To electrically zero the ammeter, proceed as follows:

- a. Set the METER switch to AMPS position and turn on the supply.
- b. Adjust the power supply VOLTAGE controls for 3000Vdc.
- c. Adjust CURRENT ZERO control R25 for zero output current on front panel meter.

## 5-71 AMMETER TRACKING

5-72 To calibrate the ammeter tracking, proceed as follows:

- a. Connect 500K, 18W load resistor across the power supply output terminals.
- b. Set the METER switch to AMPS position and turn on the supply.
- c. Adjust the power supply VOLTAGE controls for 3000Vdc.
- d. Adjust the CURRENT CAL control R65 until the front panel ammeter indicates 6mA.

## 5-73 OVERVOLTAGE PROTECTION

5-74 To adjust the overvoltage protection feature so that the output voltage will not exceed 3000V under any circumstances, proceed as follows:

- a. Connect a 500K, 18W load resistor to the output of the supply and connect a Variac to the input.
- b. Turn on the power supply and adjust the Variac for 127Vac.
- c. Set the output VOLTAGE controls for 3000Vdc.
- d. Turn overvoltage potentiometer R71 clockwise until neon light VR3 is on; then turn R71 slowly counterclockwise until VR3 extinguishes.

#### 5-75 OVEN CONTROL CIRCUIT

5-76 To calibrate the oven control circuit so that it maintains the proper oven temperature, proceed as follows:

- a. Disconnect the jumper between test points (51) and (15).
- b. Connect a 14.9K,  $\pm 1\%$  resistor across test points (52) and (15).
- c. Set a decade resistance box to 10K and connect in place of R56.
- d. Connect an oscilloscope across the heater, test points 53 and 54.
- e. Adjust the oscilloscope for 2mS/cm and 5V/cm, and ensure that the oscilloscope terminals are not grounded.
- f. Observe the oscilloscope to determine if the heater is on or off. If the heater is on, a multiple square wave will appear; however if the heater is off a dc line will appear on the oscilloscope.
- g. If the heater is off, decrease the decade resistance until it turns on. If the heater is on, increase the decade resistance until it turns off. The decade resistance should be between 5K and 15K.
- h. Solder the nearest value  $\frac{1}{2}$  watt carbon composition resistor, determined in step g, across the R56 terminals.

- i. Reconnect the jumper to test points (51) and (15).

- j. Check the oven cycling rate. Each on and off period should be approximately 10 to 15 seconds as observed on the oscilloscope.

#### 5-77 CURRENT LIMIT ADJUSTMENT

5-78 The following procedure determines the value of the short circuit output current limit:

- a. Adjust the output VOLTAGE thumbwheel switches for 2V.
- b. Connect a decade resistance box in place of resistor R20, and set the resistance to 500K.
- c. Short the output terminals and turn on the supply.
- d. Adjust the decade resistance slightly to eliminate oscillations (singing).
- e. Solder nearest value  $\frac{1}{2}$  watt carbon composition resistor determined in step i across R20 terminals. After cooling, recheck to ensure no oscillations (singing).
- f. To check the current limit level, connect a multimeter or milliammeter to the output terminals and turn on the supply. The meter indication should be approximately 8mA.

## 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	
R = resistor	VR = zener diode
S = switch	X = socket
T = transformer	Z = integrated circuit or network
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	CODE NO.	MANUFACTURER	ADDRESS
00629	EBY Sales Co., Inc.	Jamaica, N. Y.	07138	Westinghouse Electric Corp.	
00656	Aerovox Corp.	New Bedford, Mass.		Electronic Tube Div.	Elmira, N. Y.
00853	Sangamo Electric Co.		07263	Fairchild Camera and Instrument Corp.	Semiconductor Div.
	S. Carolina Div.	Pickens, S. C.			Mountain View, Calif.
01121	Allen Bradley Co.	Milwaukee, Wis.	07387	Birtcher Corp., The	Los Angeles, Calif.
01255	Litton Industries, Inc.	Beverly Hills, Calif.	07397	Sylvania Electric Prod. Inc.	
				Sylvania Electronic Systems	
01281	TRW Semiconductors, Inc.	Lawndale, Calif.		Western Div.	Mountain View, Calif.
			07716	IRC Div. of TRW Inc.	Burlington Plant
01295	Texas Instruments, Inc.				Burlington, Iowa
	Semiconductor-Components Div.		07910	Continental Device Corp.	
		Dallas, Texas			Hawthorne, Calif.
01686	RCL Electronics, Inc.	Manchester, N. H.	07933	Raytheon Co. Components Div.	
01930	Amerock Corp.	Rockford, Ill.		Semiconductor Operation	
02107	Sparta Mfg. Co.	Dover, Ohio			Mountain View, Calif.
02114	Ferroxcube Corp.	Saugerties, N. Y.	08484	Breeze Corporations, Inc.	Union, N. J.
02606	Fenwal Laboratories	Morton Grove, Ill.	08530	Reliance Mica Corp.	Brooklyn, N. Y.
02660	Amphenol Corp.	Broadview, Ill.	08717	Sloan Company, The	Sun Valley, Calif.
02735	Radio Corp. of America, Solid State and Receiving Tube Div.	Somerville, N. J.	08730	Vemaline Products Co. Inc.	Wyckoff, N. J.
03508	G. E. Semiconductor Products Dept.		08806	General Elect. Co. Minia- ture Lamp Dept.	Cleveland, Ohio
		Syracuse, N. Y.	08863	Nylomatic Corp.	Norrisville, Pa.
03797	Eldema Corp.	Compton, Calif.	08919	RCH Supply Co.	Vernon, Calif.
03877	Transitron Electronic Corp.	Wakefield, Mass.	09021	Airco Speer Electronic Components	
					Bradford, Pa.
03888	Pyrofilm Resistor Co. Inc.	Cedar Knolls, N. J.	09182	*Hewlett-Packard Co. New Jersey Div.	
					Berkeley Heights, N. J.
04009	Arrow, Hart and Hegeman Electric Co.	Hartford, Conn.	09213	General Elect. Co. Semiconductor Prod. Dept.	Buffalo, N. Y.
04072	ADC Electronics, Inc.	Harbor City, Calif.	09214	General Elect. Co. Semiconductor Prod. Dept.	Auburn, N. Y.
04213	Caddell & Burns Mfg. Co. Inc.	Mineola, N. Y.	09353	C & K Components Inc.	Newton, Mass.
04404	*Hewlett-Packard Co. Palo Alto Div.	Palo Alto, Calif.	09922	Burndy Corp.	Norwalk, Conn.
			11115	Wagner Electric Corp.	
04713	Motorola Semiconductor Prod. Inc.	Phoenix, Arizona		Tung-Sol Div.	Bloomfield, N. J.
05277	Westinghouse Electric Corp. Semiconductor Dept.	Youngwood, Pa.	11236	CTS of Berne, Inc.	Berne, Ind.
05347	Ultronix, Inc.	Grand Junction, Colo.	11237	Chicago Telephone of Cal. Inc.	
05820	Wakefield Engr. Inc.	Wakefield, Mass.			So. Pasadena, Calif.
06001	General Elect. Co. Electronic Capacitor & Battery Dept.	Irmo, S. C.	11502	IRC Div. of TRW Inc.	Boone Plant
06004	Bassik Div. Stewart-Warner Corp.	Bridgeport, Conn.			Boone, N. C.
			11711	General Instrument Corp Rectifier Div.	Newark, N. J.
06486	IRC Div. of TRW Inc. Semiconductor Plant	Lynn, Mass.	12136	Philadelphia Handle Co. Inc.	
06540	Amatom Electronic Hardware Co. Inc.	New Rochelle, N. Y.			Camden, N. J.
06555	Beede Electrical Instrument Co.	Penacook, N. H.	12615	U. S. Terminals, Inc.	Cincinnati, Ohio
			12617	Hamlin Inc.	Lake Mills, Wisconsin
06666	General Devices Co. Inc.	Indianapolis, Ind.	12697	Clarostat Mfg. Co. Inc.	Dover, N. H.
			13103	Thermalloy Cp.	Dallas, Texas
06751	Semcor Div. Components, Inc.	Phoenix, Arizona	14493	*Hewlett-Packard Co. Loveland Div.	Loveland, Colo.
06776	Robinson Nugent, Inc.	New Albany, Ind.			
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.	14655	Cornell-Dubilier Electronics Div. Federal Pacific Electric Co.	Newark, N. J.
07137	Transistor Electronics Corp.	Minneapolis, Minn.	14936	General Instrument Corp. Semicon- ductor Prod. Group	Hicksville, N. Y.
			15801	Fenwal Elect.	Framingham, Mass.
			16299	Coming 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	CODE NO.	MANUFACTURER	ADDRESS
16758	Delco Radio Div. of General Motors Corp.	Kokomo, Ind.	70563	Amperite Co. Inc.	Union City, N.J.
17545	Atlantic Semiconductors, Inc.	Asbury Park, N.J.	70901	Beemer Engrg. Co.	Fort Washington, Pa.
17803	Fairchild Camera and Instrument Corp	Semiconductor Div. Transducer Plant	70903	Belden Corp.	Chicago, Ill.
17870	Daven Div. Thomas A. Edison Industries	McGraw-Edison Co. Orange, N.J.	71218	Bud Radio, Inc.	Willoughby, Ohio
18324	Signetics Corp.	Sunnyvale, Calif.	71279	Cambridge Thermionic Corp.	Cambridge, Mass.
19315	Bendix Corp. The Navigation and Control Div.	Teterboro, N.J.	71400	Bussmann Mfg. Div. of McGraw & Edison Co.	St. Louis, Mo.
19701	Electra/Midland Corp.	Mineral Wells, Texas	71450	CTS Corp.	Elkhart, Ind.
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.	71468	I. T. T. Cannon Electric Inc.	Los Angeles, Calif.
22229	Union Carbide Corp. Electronics Div.	Mountain View, Calif.	71590	Globe-Union Inc.	Centralab Div. Milwaukee, Wis.
22753	UID Electronics Corp.	Hollywood, Fla.	71700	General Cable Corp. Cornish Wire Co. Div.	Williamstown, Mass.
23936	Pamotor, Inc.	Pampa, Texas	71707	Coto Coil Co. Inc.	Providence, R. I.
24446	General Electric Co.	Schenectady, N. Y.	71744	Chicago Miniature Lamp Works	Chicago, Ill.
24455	General Electric Co. Lamp Div. of Consumer Prod. Group	Nela Park, Cleveland, Ohio	71785	Cinch Mfg. Co. and Howard B. Jones Div.	Chicago, Ill.
24655	General Radio Co.	West Concord, Mass.	71984	Dow Corning Corp.	Midland, Mich.
24681	LTV Electrosystems Inc Memcor/Components Operations	Huntington, Ind.	72136	Electro Motive Mfg. Co. Inc.	Willimantic, Conn.
26982	Dynacool Mfg. Co. Inc.	Saugerties, N. Y.	72619	Dialight Corp.	Brooklyn, N. Y.
27014	National Semiconductor Corp.	Santa Clara, Calif.	72699	General Instrument Corp.	Newark, N. J.
28480	Hewlett-Packard Co.	Palo Alto, Calif.	72765	Drake Mfg. Co.	Harwood Heights, Ill.
28520	Heyman Mfg. Co.	Kenilworth, N. J.	72962	Elastic Stop Nut Div. of Amerace Esna Corp.	Union, N. J.
28875	IMC Magnetics Corp.	New Hampshire Div. Rochester, N. H.	72982	Erie Technological Products Inc.	Erie, Pa.
31514	SAE Advance Packaging, Inc.	Santa Ana, Calif.	73096	Hart Mfg. Co.	Hartford, Conn.
31827	Budwig Mfg. Co.	Ramona, Calif.	73138	Beckman Instruments Inc.	Helipot Div. Fullerton, Calif.
33173	G. E. Co. Tube Dept.	Owensboro, Ky.	73168	Fenwal, Inc.	Ashland, Mass.
35434	Lectrohm, Inc.	Chicago, Ill.	73293	Hughes Aircraft Co. Electron Dynamics Div.	Torrance, Calif.
37942	P. R. Mallory & Co. Inc.	Indianapolis, Ind.	73445	Amperex Electronic Corp.	Hicksville, N. Y.
42190	Muter Co.	Chicago, Ill.	73506	Bradley Semiconductor Corp.	New Haven, Conn.
43334	New Departure-Hyatt Bearings Div.	General Motors Corp. Sandusky, Ohio	73559	Carling Electric, Inc.	Hartford, Conn.
44655	Ohmite Manufacturing Co.	Skokie, Ill.	73734	Federal Screw Products, Inc.	Chicago, Ill.
46384	Penn Engr. and Mfg. Corp.	Doylestown, Pa.	74193	Heinemann Electric Co.	Trenton, N. J.
47904	Polaroid Corp.	Cambridge, Mass.	74545	Hubbell Harvey Inc.	Bridgeport, Conn.
49956	Raytheon Co.	Lexington, Mass.	74868	Amphenol Corp. Amphenol RF Div.	Danbury, Conn.
55026	Simpson Electric Co. Div. of American Gage and Machine Co.	Chicago, Ill.	74970	E. F. Johnson Co.	Waseca, Minn.
56289	Sprague Electric Co.	North Adams, Mass.	75042	IRC Div. of TRW, Inc.	Philadelphia, Pa.
58474	Superior Electric Co.	Bristol, Conn.	75183	*Howard B. Jones Div. of Cinch Mfg. Corp.	New York, N. Y.
58849	Syntron Div. of FMC Corp.	Homer City, Pa.	75376	Kurz and Kasch, Inc.	Dayton, Ohio
59730	Thomas and Betts Co.	Philadelphia, Pa.	75382	Kilka Electric Corp.	Mt. Vernon, N. Y.
61637	Union Carbide Corp.	New York, N. Y.	75915	Littlefuse, Inc.	Des Plaines, Ill.
63743	Ward Leonard Electric Co.	Mt. Vernon, N. Y.	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	CODE NO.	MANUFACTURER	ADDRESS
76530	Cinch	City of Industry, Calif.	83508	Grant Pulley and Hardware Co.	West Nyack, N. Y.
76854	Oak Mfg. Co. Div. of Oak		83594	Burroughs Corp. Electronic	
77068	Electro/Netics Corp.	Crystal Lake, Ill.		Components Div.	Plainfield, N. J.
	Bendix Corp., Electrodynamics Div.		83835	U. S. Radium Corp.	Morristown, N. J.
		No. Hollywood, Calif.	83877	Yardeny Laboratories, Inc.	
77122	Painut Co.	Mountainside, N. J.			New York, N. Y.
77147	Patton-MacGuyer Co.	Providence, R. I.	84171	Arco Electronics, Inc.	Great Neck, N. Y.
77221	Phaotron Instrument and Electronic Co.	South Pasadena, Calif.	84411	TRW Capacitor Div.	Ogallala, Neb.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.	86684	RCA Corp. Electronic Components	Harrison, N. J.
77342	American Machine and Foundry Co.		86838	Rummel Fibre Co.	Newark, N. J.
	Potter and Brumfield Div.	Princeton, Ind.	87034	Marco & Oak Industries a Div. of Oak	
77630	TRW Electronic Components Div.			Electro/netics Corp.	Anaheim, Calif.
		Camden, N. J.	87216	Philco Corp. Lansdale Div.	Lansdale, Pa.
77764	Resistance Products Co.	Harrisburg, Pa.	87585	Stockwell Rubber Co. Inc.	
78189	Illinois Tool Works Inc. Shakeproof Div.	Elgin, Ill.			Philadelphia, Pa.
78452	Everlock Chicago, Inc.	Chicago, Ill.	87929	Tower-Olschan Corp.	Bridgeport, Conn.
78488	Stackpole Carbon Co.	St. Marys, Pa.	88140	Cutler-Hammer Inc. Power Distribution	
78526	Stanwyck Winding Div.	San Fernando		and Control Div. Lincoln Plant	Lincoln, Ill.
	Electric Mfg. Co. Inc.	Newburgh, N. Y.	88245	Litton Precision Products Inc. USECO	
78553	Tinnerman Products, Inc.	Cleveland, Ohio		Div. Litton Industries	Van Nuys, Calif.
78584	Stewart Stamping Corp.	Yonkers, N. Y.	90634	Gulton Industries Inc.	Metuchen, N. J.
79136	Waldes Kohinoor, Inc.	L. I. C., N. Y.	90763	United-Car Inc.	Chicago, Ill.
79307	Whitehead Metals Inc.	New York, N. Y.	91345	Miller Dial and Nameplate Co.	
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.			El Monte, Calif.
79963	Zierick Mfg. Co.	Mt. Kisco, N. Y.	91418	Radio Materials Co.	Chicago, Ill.
80031	Mepco Div. of Sessions Clock Co.		91506	Augat, Inc.	Attleboro, Mass.
		Morristown, N. J.	91637	Dale Electronics, Inc.	Columbus, Neb.
80294	Bourns, Inc.	Riverside, Calif.	91662	Elco Corp.	Willow Grove, Pa.
81042	Howard Industries Div. of Msl Ind. Inc.		91929	Honeywell Inc. Div. Micro Switch	
		Racine, Wisc.			Freeport, Ill.
81073	Grayhill, Inc.	La Grange, Ill.	92825	Whitso, Inc.	Schiller Pk., Ill.
81483	International Rectifier Corp.		93332	Sylvania Electric Prod. Inc. Semi-	
		El Segundo, Calif.		conductor Prod. Div.	Woburn, Mass.
81751	Columbus Electronics Corp.	Yonkers, N. Y.	93410	Essex Wire Corp. Stemco	
82099	Goodyear Sundries & Mechanical Co. Inc.			Controls Div.	Mansfield, Ohio
		New York, N. Y.	94144	Raytheon Co. Components Div.	
82142	Airco Speer Electronic Components			Ind. Components Oper.	Quincy, Mass.
		Du Bois, Pa.	94154	Wagner Electric Corp.	
82219	Sylvania Electric Products Inc.			Tung-Sol Div.	Livingston, N. J.
	Electronic Tube Div. Receiving		94222	Southco Inc.	Lester, Pa.
	Tube Operations	Emporium, Pa.	95263	Leecraft Mfg. Co. Inc.	L. I. C., N. Y.
82389	Switchcraft, Inc.	Chicago, Ill.	95354	Methode Mfg. Co.	Rolling Meadows, Ill.
82647	Metals and Controls Inc. Control		95712	Bendix Corp. Microwave	
	Products Group	Attleboro, Mass.		Devices Div.	Franklin, Ind.
82866	Research Products Corp.	Madison, Wis.	95987	Weckesser Co. Inc.	Chicago, Ill.
82877	Rotron Inc.	Woodstock, N. Y.	96791	Amphenol Corp. Amphenol	
82893	Vector Electronic Co.	Glendale, Calif.		Controls Div.	Janesville, Wis.
83058	Carr Fastener Co.	Cambridge, Mass.	97464	Industrial Retaining Ring Co.	
83186	Victory Engineering Corp.				Irvington, N. J.
		Springfield, N. J.	97702	IMC Magnetics Corp. Eastern Div.	
83298	Bendix Corp. Electric Power Div.				Westbury, N. Y.
		Eatontown, N. J.	98291	Sealelectro Corp.	Mamaroneck, N. Y.
83330	Herman H. Smith, Inc.	Brooklyn, N. Y.	98410	ETC Inc.	Cleveland, Ohio
83385	Central Screw Co.	Chicago, Ill.	98978	International Electronic Research Corp.	
83501	Gavitt Wire and Cable Div. of				Burbank, Calif.
	Amerace Esna Corp.	Brookfield, Mass.	99934	Renbrandt, Inc.	Boston, Mass.

Reference Designator	Description	Quantity	Mfr. Part # or Type	Mfr.	Mfr. Code	Stock No.	RS
C1	fxd, elect 1 $\mu$ f 35vdc	1	150D105X9035A2	Sprague	56289	0180-0291	1
C2, 8, 26,							
29	fxd, film 0.1 $\mu$ f 200vdc	4	192P10492	Sprague	56289	0160-0168	1
C3, 13, 21	fxd, film 0.033 $\mu$ f 200vdc	3	192P33392	Sprague	56289	0160-0163	1
C4	fxd, film paper glass case, 0.1 $\mu$ f 4,000vdc	1	268P10	Sprague	56289	0160-2596	1
C5	fxd, film 0.022 $\mu$ f 200vdc	1	192P22392	Sprague	56289	0160-0162	1
C6	fxd, elect 0.0047 $\mu$ f 200vdc	1	192P47292	Sprague	56289	0160-0157	1
C7	fxd, elect 0.068 $\mu$ f 200vdc	1	192P68392	Sprague	56289	0160-0166	1
C9	fxd, film 0.22 $\mu$ f 80vdc	1	192P2249R8	Sprague	56289	0160-2453	1
C10	fxd, elect 20 $\mu$ f 15vdc	1	D28708	Sprague	56289	0180-0300	1
C11	fxd, film 0.001 $\mu$ f 200vdc	1	192P10292	Sprague	56289	0160-0153	1
C12	NOT ASSIGNED	-	-	-	-	-	-
C14	fxd, elect 20 $\mu$ f 50vdc	1	30D206G050DC4	Sprague	56289	0180-0049	1
C16, 17	fxd, elect 325 $\mu$ f 35vdc	2	D34656	Sprague	56289	0180-0332	1
C18	fxd, elect 10 $\mu$ f 450vdc	1	D38267	Sprague	56289	0180-1944	1
C19	fxd, elect 20 $\mu$ f 200vdc	1	34D206F200FJ4	Sprague	56289	0180-0367	1
C20, 24	fxd, film 0.0022 $\mu$ f 200vdc	2	192P22292	Sprague	56289	0160-0154	1
C23	fxd, elect 1 $\mu$ f 4000vdc	1	P49991	Sprague	56289	0160-2580	1
C25	fxd, ceramic 0.02 $\mu$ f 600vdc	1	ED-.02	Erie	72982	0150-0024	1
C27, 28	fxd, paper 1 $\mu$ f 2000vdc	2	264P90	Sprague	56289	0160-2483	1
CR1-5, 8, 9, 12, 14, 16, 19, 39	Rect. si. 200ma 180prv	12	1N485	Sylvania	93332	1901-0033	7
CR6	Diode	1	1N4828	G. E.	03508	1901-0461	1
CR10, 13, 20	Rect. si. $V_f = 2.4V @ 100 MA$	3	1N483B	G. E.	03508	1901-0460	3
CR11, 24-28, 32	Rect. si. 500ma 200prv	7	1N3253	R. C. A.	02735	1901-0389	6
CR15, 17, 18, 21-23	NOT ASSIGNED	-	-	-	-	-	-
CR29, 30	Rect. si. 400ma 800prv	2	1N3256	R. C. A.	02735	1901-0388	2
CR31	SCR 50prv 50fbv	1	C6F	G. E.	03508	1884-0033	1
CR33-38	Rect. si. 900ma 400prv	6	1N5060	G. E.	03508	1901-0328	6
CR40, 7	SCR 150pri 150fbv	2	C6G	G. E.	03508	1884-0038	2
CR41	Voltage Doubler si.	1		HLAB	09182	1901-0084	1
DS1	Lamp - neon part of si, ass'y	Ref		HLAB	09182	2140-0244	1
F1	Fuse cartridge 2A @ 250v 3AG	1	312002	Littlefuse	75915	2110-0002	5
J1	STRAP	1					
L1, 2	Coil	2	635492	HLAB	09182	9100-1854	1
L3	Line inductor	1		HLAB	09182	9100-1813	1
L4	Inductor pair	1		HLAB	09182	9100-1814	1
Q1	Diff. Amp. NPN (oven ass'y)	1	2N4045	Union Carbide	22229	1854-0221	1
Q2, 3	SS NPN si. (oven ass'y)	2	4JX16A1014	G. E.	03508	1854-0071	2
Q4, 6	NOT ASSIGNED	-	-	-	-	-	-
Q5, 9, 13-15, 17	SS NPN si.	6	2N3391	G. E.	03508	1854-0071	6
Q7, 8	SS PNP si.	2	MPS6517	Motorola	04713	1853-0099	2
Q10	SS NPN si.	1	2N3417	G. E.	03508	1854-0087	1
Q11	MP NPN si.	1	40422	R. C. A.	02735	1854-0253	1
Q12	SS PNP si.	1	40362	R. C. A.	02735	1853-0041	1
Q16	Uni Junction si.	1	2N2646	G. E.	03508	1855-0010	1

Reference Designator	Description	Quantity	Mfr. Part # or Type	Mfr.	Mfr. Code	Stock No.	RS
R1, 2	fxd, ww 1K $\Omega$ $\pm$ 5% 3w	2	242E1025	Sprague	56289	0813-0001	1
R3	fxd, met. film 221K $\Omega$ $\pm$ 1% 1/8w (oven ass'y)	1	Type CEA T-O	I. R. C.	07716	0757-0473	1
R4	fxd, met. film 27.4K $\Omega$ $\pm$ 1% 1/8w (oven ass'y)	1	Type CEA T-O	I. R. C.	07716	0757-0452	1
R5, 6	fxd, met. film 432K $\Omega$ $\pm$ 1% 1/8w (oven ass'y)	2	Type CEA T-O	I. R. C.	07716	0757-0480	1
R7, 8	fxd, met. film 43K $\Omega$ $\pm$ 1% 1/8w (oven ass'y)	2	Type CEA T-O	I. R. C.	07716	0698-5090	2
R9	fxd, comp 30 $\Omega$ $\pm$ 5% 1/2w	1	EB-3005	A. B.	01121	0686-3005	1
R10-12, 42, 50, 51	NOT ASSIGNED	-	-	-	-	-	-
R13, 15	fxd, film 1 MEG $\Omega$ $\pm$ 1% 1/2w	2	Type MF6C T-O	Electra	19701	0757-0344	1
R14, 16	var. ww 15K $\Omega$ $\pm$ 5% 1W @ 50 $^{\circ}$ C	2	Model 100	I. R. C.	07716	2100-0896	1
R17	fxd, ww 297 $\pm$ 1% 1/2w TC 20ppm	1		HLAB	09182	0811-1929	1
R18	fxd, ww 4.9K $\pm$ 1% $\pm$ 5ppm/ $^{\circ}$ C	1		HLAB	09182	0811-1942	1
R19	fxd, ww 1K $\Omega$ $\pm$ 1% 1/2w 5ppm	1	Type E20	R. C. L.	01686	0811-1976	1
R20, 56	fxd, comp SELECTED $\pm$ 5% 1/2w	2	Type EB	A. B.	01121		1
R21	fxd, comp 31 MEG 10% 4w	1	Type EFQ	R. P. C.	77764	0698-5680	1
R22	fxd, met. film 562K $\pm$ 1% 1/8w	1	MF5C T-O	Electra	19701	0757-0483	1
R23	fxd, met. film 143 $\Omega$ $\pm$ 1% 1/2w	1	MF6C T-O	Electra	19701	0757-0167	1
R24	fxd, comp 82K $\pm$ 5% 1/2w	1	EB-8235	A. B.	01121	0686-8235	1
R25, 67	var. ww 100K $\Omega$	2	Series 70	C. T. S.	11236	2100-0095	1
R26	fxd, comp 220K $\Omega$ $\pm$ 5% 1/2w	1	EB-2245	A. B.	01121	0686-2245	1
R27, 29, 33, 62, 63, 70, 75	fxd, comp 1K $\Omega$ $\pm$ 5% 1/2w	7	EB-1025	A. B.	01121	0686-1025	2
R28, 32, 43	fxd, comp 10K $\Omega$ $\pm$ 5% 1/2w	3	EB-1035	A. B.	01121	0686-1035	1
R30	fxd, comp 5.1K $\Omega$ $\pm$ 5% 1/2w	1	EB-5125	A. B.	01121	0686-5125	1
R31	fxd, comp 3.9K $\Omega$ $\pm$ 5% 1/2w	1	EB-3925	A. B.	01121	0686-3925	1
R34	fxd, comp 7.5K $\pm$ 5% 1/2w	1	EB-7525	A. B.	01121	0686-7525	1
R35	fxd, comp 15K $\Omega$ $\pm$ 5% 1/2w	1	EB-1535	A. B.	01121	0686-1535	1
R36	fxd, comp 100K $\Omega$ $\pm$ 5% 1/2w	1	EB-1045	A. B.	01121	0686-1045	1
R37	fxd, comp 10 $\Omega$ $\pm$ 5% 1/2w	1	EB-1005	A. B.	01121	0686-1005	1
R38	fxd, comp 3K $\Omega$ $\pm$ 5% 1/2w	1	EB-3025	A. B.	01121	0686-3025	1
R39	fxd, met. ox 300 $\Omega$ $\pm$ 5% 2w	1	Type C425	Corning	16299	0698-3630	1
R40	fxd, ww 30K $\Omega$ $\pm$ 5% 10w	1	Type 10XM	W. L.	63743	0811-1918	1
R41, 52, 61, 74	fxd, comp 200 $\Omega$ $\pm$ 5% 1/2w	4	EB-2015	A. B.	01121	0686-2015	1
R44	fxd, comp 4.3K $\Omega$ $\pm$ 5% 1/2w	1	EB-4325	A. B.	01121	0686-4325	1
R45	fxd, comp 1.5K $\Omega$ $\pm$ 5% 1/2w	1	EB-1525	A. B.	01121	0686-1525	1
R46	fxd, comp 2.7K $\Omega$ $\pm$ 5% 1/2w	1	EB-2725	A. B.	01121	0686-2725	1
R47, 48	fxd, met. film 1.5K $\Omega$ $\pm$ 1% 1/8w	2	MF5C T-O	Electra	19701	0757-0427	1
R49	fxd, ww 714 $\Omega$ $\pm$ 1% 1/2w TC 20ppm	1		HLAB	09182	0811-1935	1
R53, 60	fxd, comp 510 $\Omega$ $\pm$ 5% 1/2w	2	EB-5115	A. B.	01121	0686-5115	1
R54	fxd, comp 100K $\Omega$ $\pm$ 5% 1w	1	GB-1045	A. B.	01121	0689-1045	1
R55, 72	fxd, comp 33K $\Omega$ $\pm$ 5% 1/2w	2	EB-3335	A. B.	01121	0686-3335	1
R57	Thermistor 100K $\pm$ 10% (oven ass'y)	1	51TG4	Gulton	90634	0837-0026	1
R58	fxd, comp 2K $\Omega$ $\pm$ 5% 1/2w	1	EB-2025	A. B.	01121	0686-2025	1
R59	fxd, comp 680 $\Omega$ $\pm$ 5% 1/2w	1	EB-6815	A. B.	01121	0686-6815	1
R64	fxd, comp 3.6 MEG $\pm$ 5% 1/2w	1	EB-3645	A. B.	01121	0686-3645	1
R65	var. ww 1K $\Omega$ (Modify)	1	Type 110-F4	C. T. S.	11236	2100-0391	1
R66	fxd, met. film 7.50K $\Omega$ $\pm$ 1% 1/8w	1	Type MF5C T-O	Electra	19701	0757-0440	1
R68	fxd, met. film 390K $\Omega$ $\pm$ 1% 1/8w	1	Type MF5C T-O	Electra	19701	0698-5093	1
R69, 79	fxd, ww 50 $\Omega$ $\pm$ 5% 5w	2	Type 5XM	W. L.	63743	0811-1854	1
R71	var. ww 25K $\Omega$	1	Series 70	C. T. S.	11236	2100-1534	1

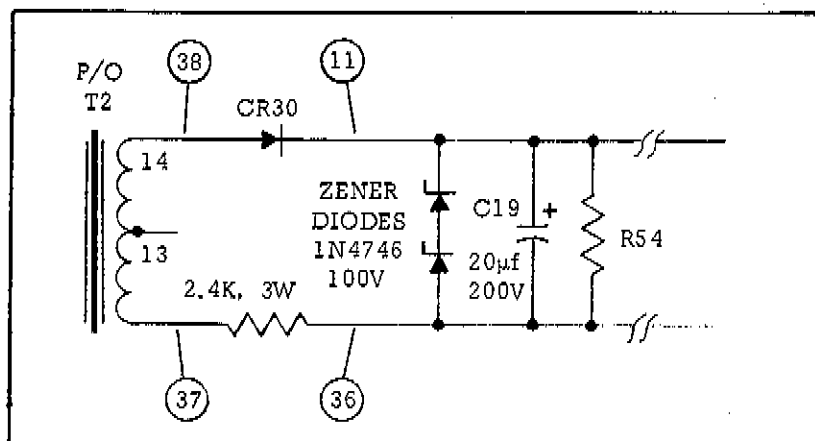
Reference Designator	Description	Quantity	Mfr. Part # or Type	Mfr.	Mfr. Code	Stock No.	RS
R73	fxd, comp 51K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w	1	EB-5135	A. B.	01121	0686-5135	1
R76	fxd, comp 8.2K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w	1	EB-8225	A. B.	01121	0686-8225	1
R77,78	fxd, comp 200K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w	2	EB-2045	A. B.	01121	0686-2045	1
S1	Switch, pilot lt. (red) COMB.	1	54-61681-26 A1H	Oak	87034	3101-0100	1
S2	Switch - Rotary	1		HLAB	09182	3100-1906	1
S3	Thumbwheel Assembly	1	See parts listed below marked with an *			06110-60001	1
	*High Voltage Board	1		HLAB	09182	06110-60003	
	*231-234						
	fxd, ww 500K $\Omega$ $\pm$ .1% 5 ppm/ $^{\circ}$ C	4	310A	Ultronik	05347	0811-1981	1
	*P. C. Board Ass'y. No. 2 (L to R)	1		HLAB	09182	5060-6107	
	*R221-R229						
	fxd, ww 100K $\Omega$ $\pm$ .1% 5 ppm/ $^{\circ}$ C	9	7010	R. C. L.	01686	0811-1997	2
	*P. C. Board Ass'y. No. 3 (L to R)	1		HLAB	09182	5060-6106	
	*R211-R219						
	fxd, ww 10K $\Omega$ $\pm$ .1% 5 ppm/ $^{\circ}$ C	9	E30	R. C. L.	01686	0811-1994	2
	*P. C. Board Ass'y. No. 4 (L to R)						
	*R201-R209						
	fxd, ww 1K $\Omega$ $\pm$ .1% 5 ppm/ $^{\circ}$ C	9	E20	R. C. L.	01686	0811-1976	2
	*Pot. Board Ass'y. (Deck No. 5, L to R)	1		HLAB	09182	06110-60002	
T1	Power Transformer	1		HLAB	09182	9100-1811	1
T2	Bias Transformer	1		HLAB	09182	9100-1812	1
VR1	Zener 6.2V $\pm$ 5% 250MW (oven ass'y)	1	1N825	Transitron	03877	1902-1221	1
VR2	Diode zener 9.4V 500MW	1	1N2163A	Semcor	06751	1902-0763	1
VR3	Neon	1	NE 76	G. E.	03508	2140-0019	1
	Front Panel	1		HLAB	09182	06110-00001	
	Side chassis right - ass'y	1		HLAB	09182	5060-6103	
	Side chassis right	1		HLAB	09182	5000-6020	
	Side chassis left - ass'y	1		HLAB	09182	5060-6102	
	Side chassis left	1		HLAB	09182	5000-6021	
	Rear chassis - ass'y	1		HLAB	09182	5000-6022	
	Capacitor clamp	1		HLAB	09182	5000-6023	
	Print circuit board bracket	4		HLAB	09182	5000-6024	
	Trim strip	1		HLAB	09182	5000-6026	
	Heat Sink "U" type	1		HLAB	09182	5000-6025	
	Cover	2		HLAB	09182	5000-6027	
	Assembly P. C. Bd.	1		HLAB	09182	06110-60020	
	Board, printed circuit	1		HLAB	09182	06110-20020	
	Meter $2\frac{1}{2}$ " DUAL SCALE 0-3.5KV 0-7 MIL. AMP.	1		HLAB	09182	1120-1126	1
	Spring	4		HLAB	09182	1460-0720	1
	Bezel 1/6 MOD	1		HLAB	09182	4040-0295	1
	Lock washer	2	1920-02-00-2480	Shakeproof	78189	2190-0016	1
	Knob $\frac{1}{2}$ insert pointer	1		HLAB	09182	0370-0084	1
	Heat Sink	3	NF-207	Wakefield	05820	1205-0033	1

Reference Designator	Description	Quantity	Mfr. Part # or Type	Mfr.	Mfr. Code	Stock No.	RS
	Line cord plug PH 151 7½'	1	KH-4096	Beldon	70903	8120-0050	1
	Strain relief bushing	1	SR-5P-1	Heyco	28520	0400-0013	2
	BNC-HV Cable Plug (Body Assembly Only)	1	12651-1	Dage	95712	1250-0741	1
	Center Contact	1	1-026-9	Dage	95712	1250-0742	1
	Clamp Nut	1	834-32	Dage	95712	1250-0142	1
	Clamp Washer	1	832-2	Dage	95712	1250-0143	2
	Clamp Gasket	1	833-13	Dage	95712	1250-0145	1
	Flat Washer	1	2053-6	Dage	95712	1250-0146	1
	Lockwasher	1	1224-08	Shakeproof	78189	2190-0037	1
	Nut	1	903-12	Littlefuse	75915	2950-0038	1
	Rubber bumper	1	4072	Stockwell	87575	0403-0086	1
	Rubber bumper	4	MB 50	Stockwell	87575	0403-0088	1
	Fastener	8	C8091-632-24B	Tinnerman	89032	0510-0275	2
	Fastener	2	C8022-632-4	Tinnerman	89032		1
	Cable Clamp	3	T4-4	Whitehead	79307	1400-0330	1
	Fastener	4	C-8082-832-1	Tinnerman	89032		2
OPTION 05							
L3	Line-Inductor	1		HLAB	09182	9100-2148	1
OPTION 18							
L3	Line Inductor	1		HLAB	09182	9100-2149	1
R55	fxd, comp 120K <sub>Ω</sub> ±5% ½W	1	EB-1245	A. B.	01121	0686-1245	1
T1	Power Transformer	1		HLAB	09182	9100-2138	1
T2	Bias Transformer	1		HLAB	09182	9100-2139	1
OPTIONS 05 AND 18							
L3	Line Inductor	1		HLAB	09182	9100-2140	1
R55	fxd, comp 120K <sub>Ω</sub> ±5% ½W	1	EB-1245	A. B.	01121	0686-1245	1
T1	Power Transformer	1		HLAB	09182	9100-2138	1
T2	Bias Transformer	1		HLAB	09182	9100-2140	1

APPENDIX I  
MANUAL BACKDATING CHANGES

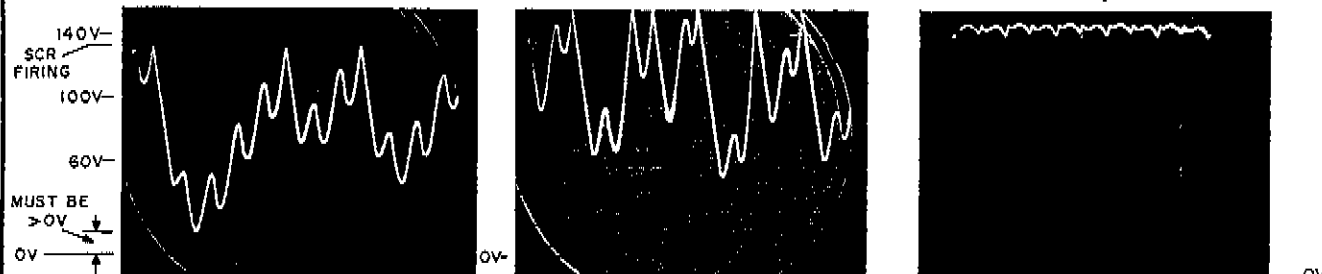
Manual backdating changes describe changes necessary to adapt this manual to earlier instruments. To adapt the manual to serial numbers prior to 6E0183, make the following changes:

CHANGE 1: On the schematic, remove CR29 and center tap connection at terminal 13 in the secondary of T2 and add new resistor and zener diodes as shown on the sketch below.



# HIGH VOLTAGE CONTROL CIRCUIT WAVEFORMS

## NORMAL WAVEFORMS



TP(11) TO (+)  
20V/CM  
10MS/CM

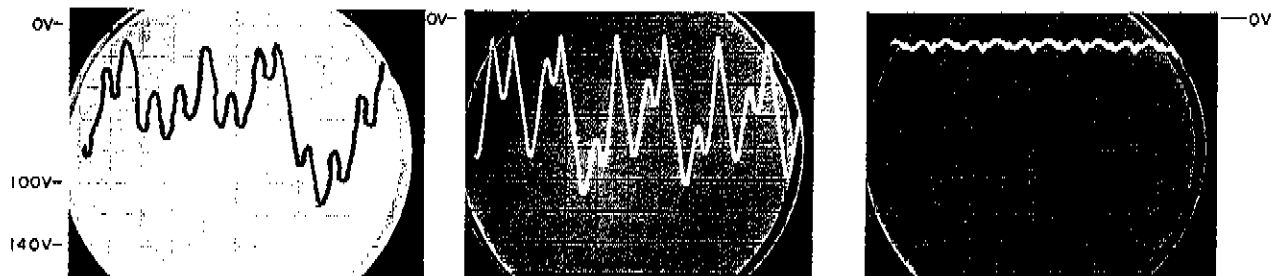
115VAC INPUT  
3000V/6MA OUTPUT

TP(11) TO (+)  
20V/CM  
10MS/CM

115VAC INPUT  
1500V/6MA OUTPUT

TP(11) TO (+)  
20V/CM  
10MS/CM

115VAC INPUT  
0V/0MA OUTPUT



TP(36) TO (+)  
20V/CM  
10MS/CM

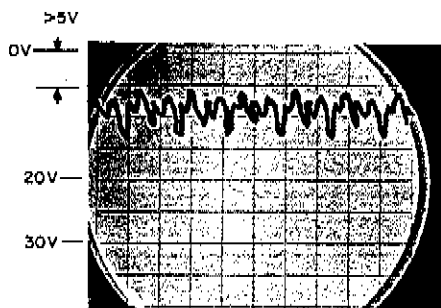
115VAC INPUT  
3000V/6MA OUTPUT

TP(36) TO (+)  
20V/CM  
10MS/CM

115VAC INPUT  
1500V/6MA OUTPUT

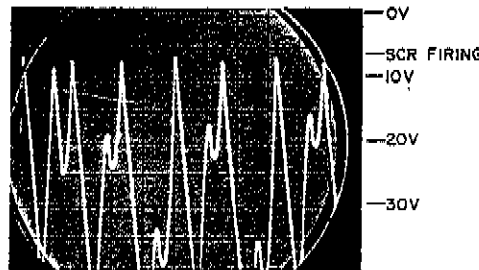
TP(36) TO (+)  
20V/CM  
10MS/CM

115VAC INPUT  
0V/0MA OUTPUT



TP(36) TO (+)  
5V/CM  
10MS/CM

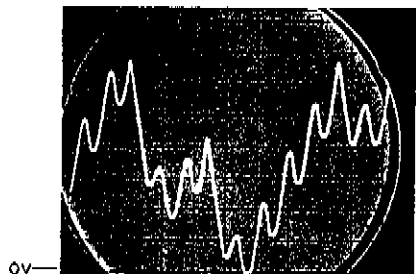
105VAC INPUT  
0V/0MA OUTPUT



TP(36) TO (+)  
5V/CM  
10MS/CM

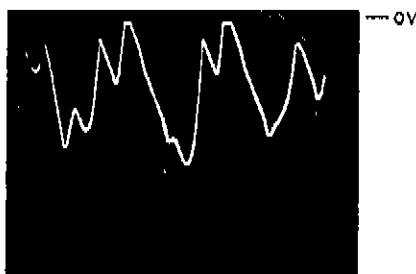
105VAC INPUT  
500V/2MA OUTPUT

## TYPICAL TROUBLES



TP(11) TO (+)  
20V/CM  
10MS/CM

115VAC INPUT  
3000V/6MA OUTPUT



TP(36) TO (+)  
20V/CM  
10MS/CM

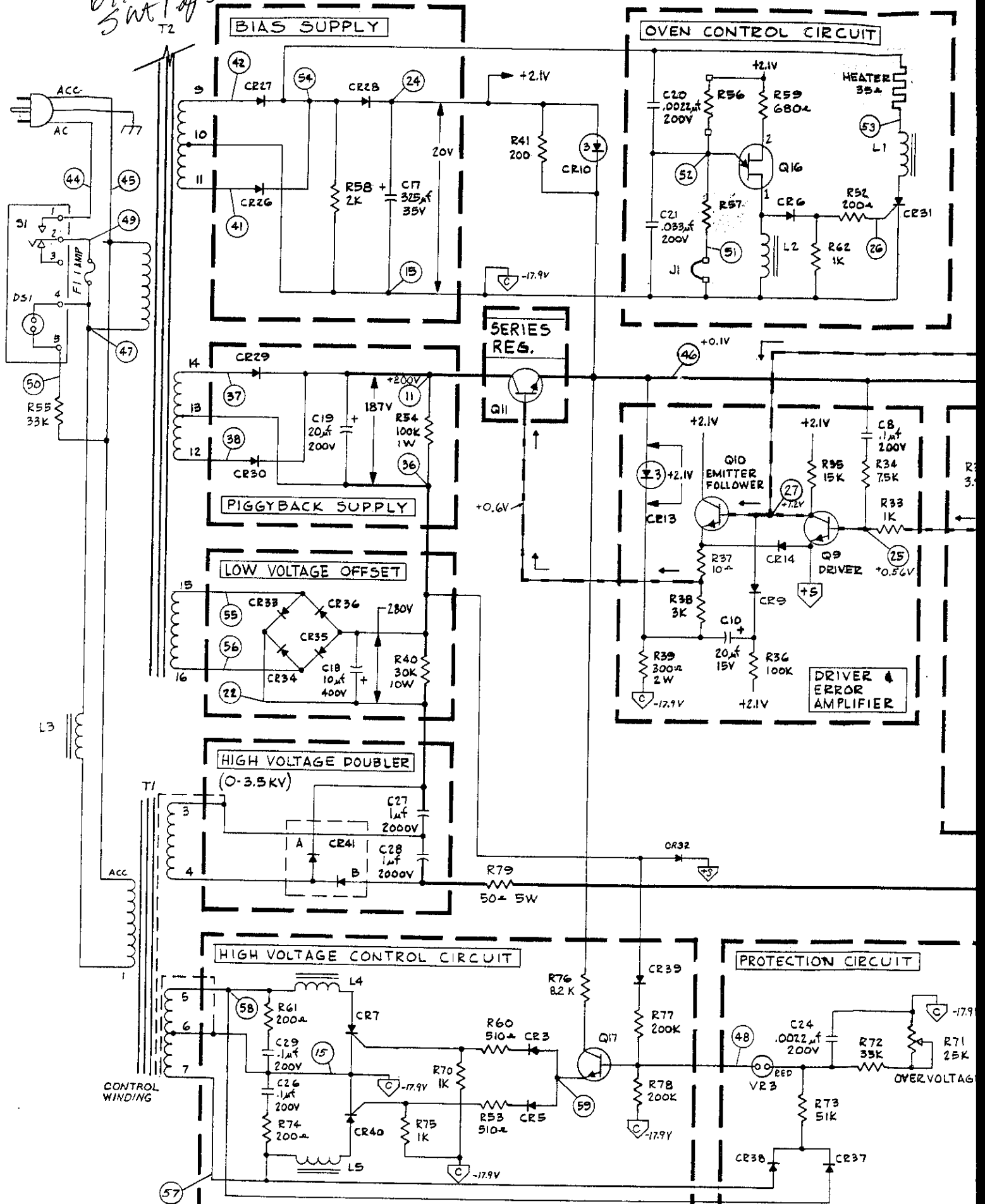
115VAC INPUT  
3000V/6MA OUTPUT

WAVEFORM INDICATES MISADJUSTMENT OF PROTECTION CIRCUIT. NOTE THAT NEGATIVE PEAK IS TOUCHING 0V BASE LINE.

WAVEFORM INDICATES ONE SCR (CR7 OR CR40) NOT FIRING. NOTE POSITIVE PEAKS TOUCH 0V BASE LINE.

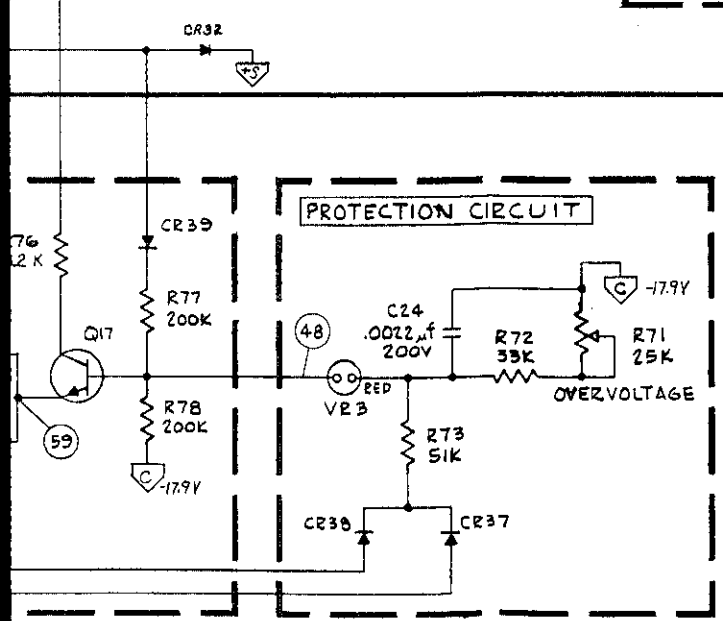
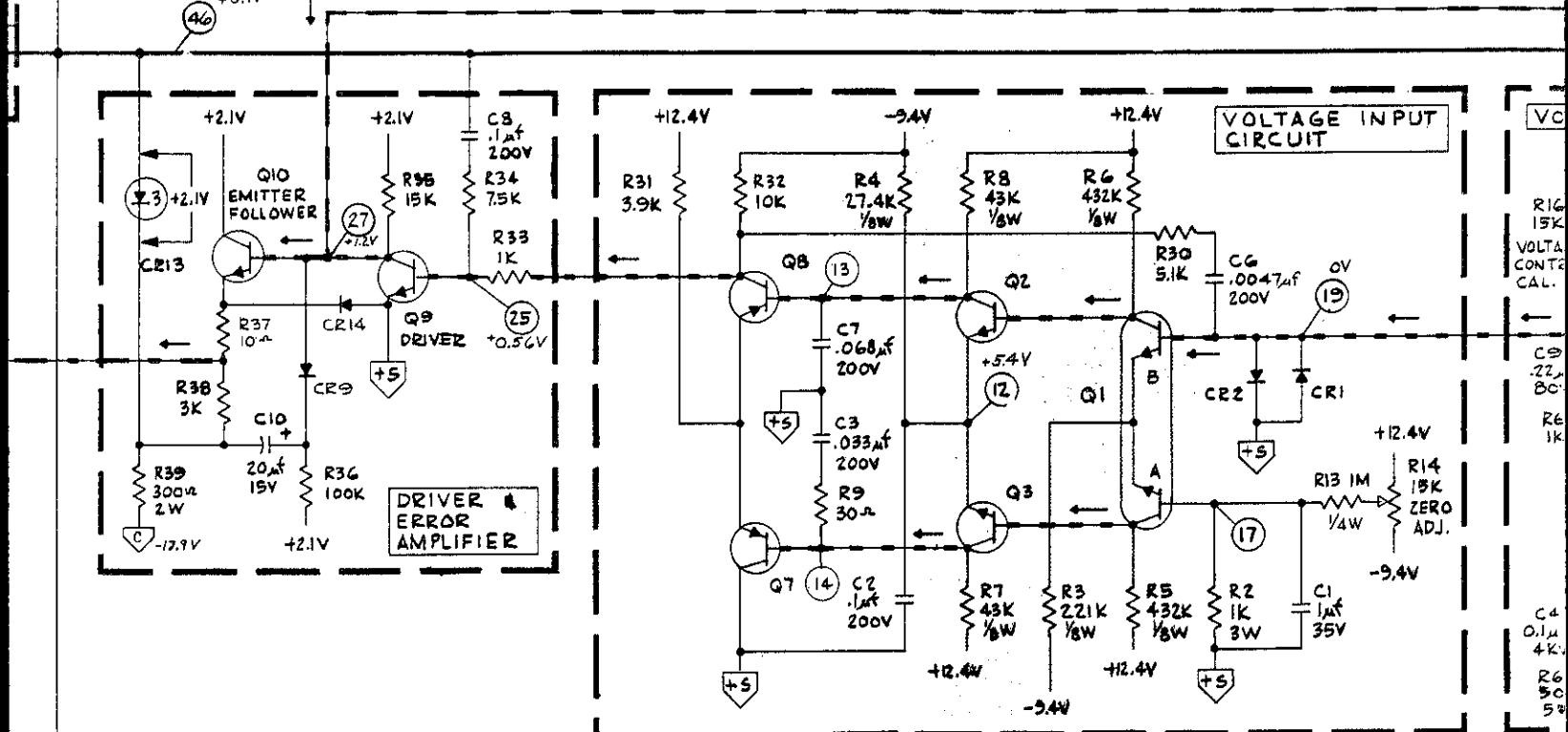
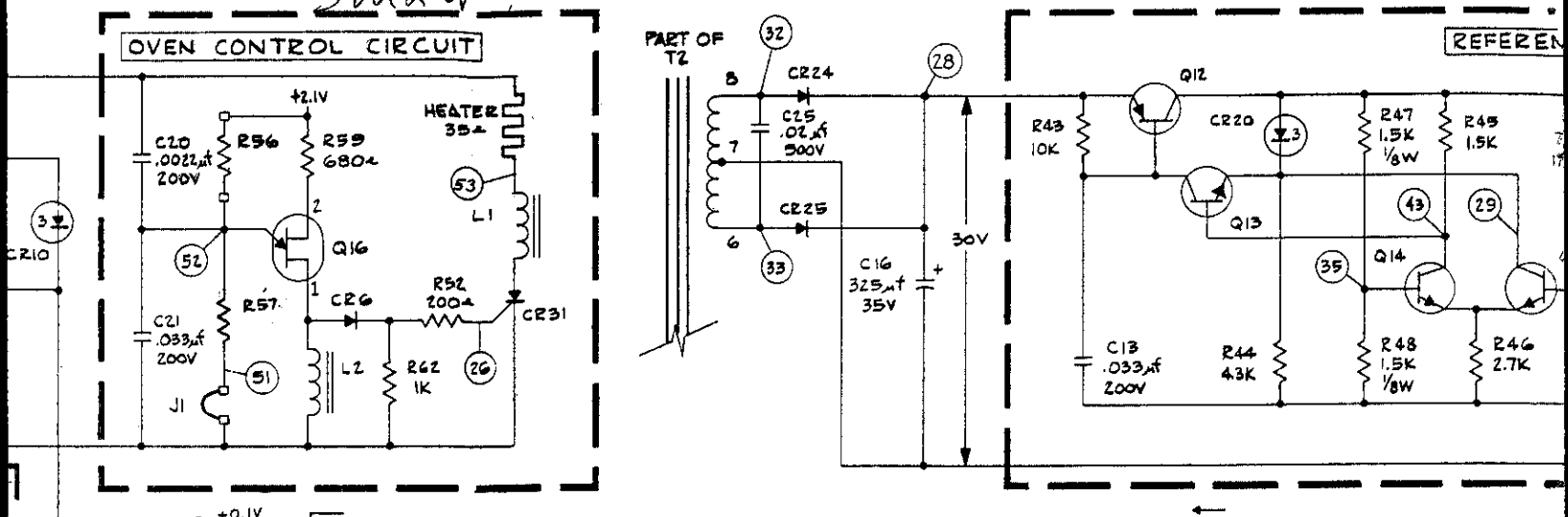
NOTE: ALL WAVEFORMS ARE DC COUPLED.

6110A  
3 W 1 of 3  
T2



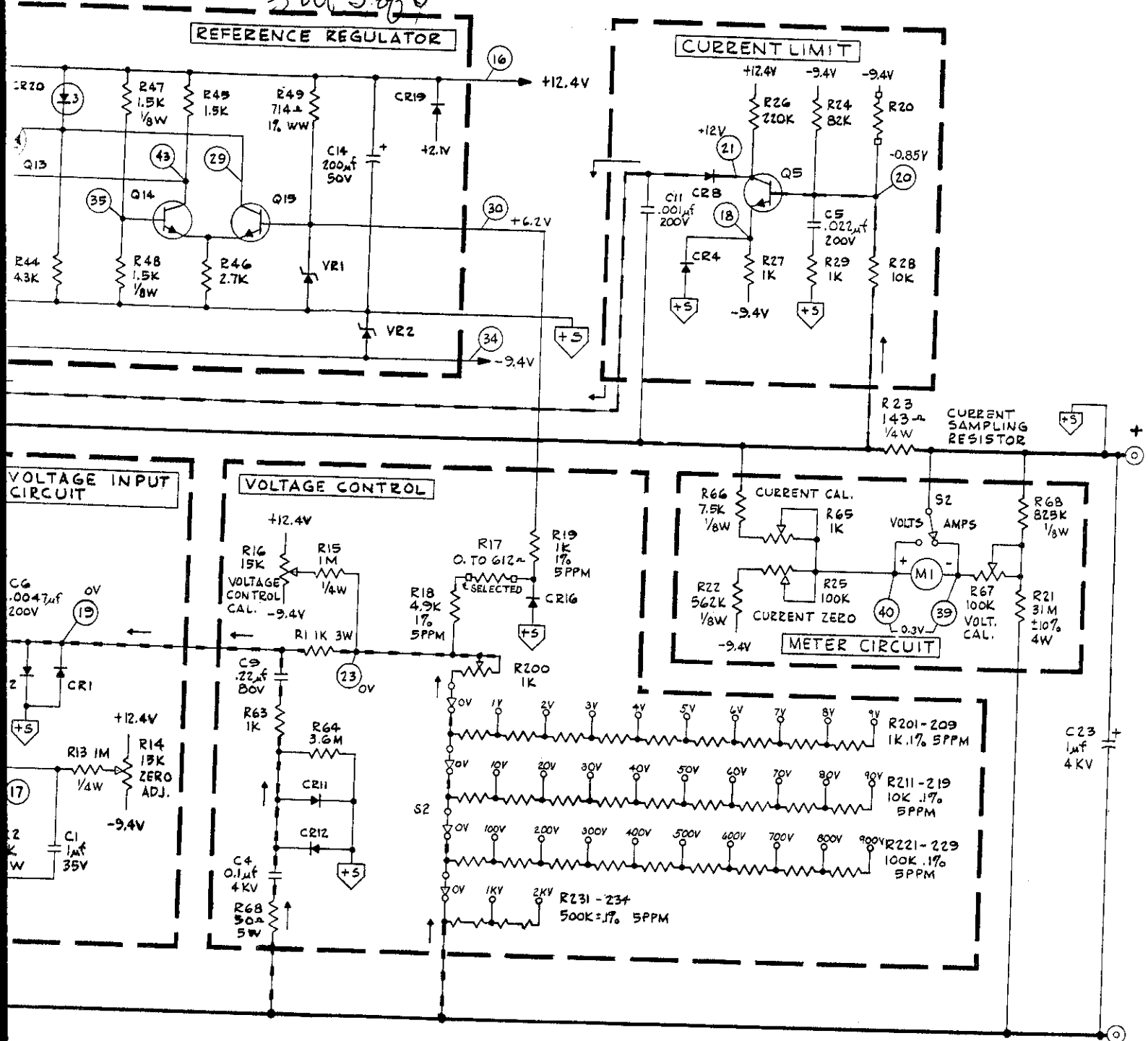


6110A  
SW 2 of 3



- NOTES:
1. ALL RESISTORS ARE 1/2W. 5% UNLESS OTHERWISE SPECIFIED.
  2. ALL 1/4W & 1/8W RESISTORS ARE 1% IN TOLERANCE.
  3. ——— DENOTES VOLTAGE FEEDBACK SIGNAL.
  4. ——— DENOTES CURRENT FEEDBACK SIGNAL.
  5. D.C. VOLTAGES WERE MEASURED UNDER THE FOLLOWING CONDITIONS:
    - A. SIMPSON MODEL 260 OR EQUIVALENT.
    - B. 115VAC INPUT.
    - C. VOLTAGES REFERENCED TO +5 UNLESS OTHERWISE SPECIFIED.
    - D. VOLTAGES ARE TYPICAL, ±10% UNLESS OTHERWISE SPECIFIED.
  6. OVEN ASSEMBLY COMPONENTS ARE IDENTICAL TO 6110A.

6110A  
 5 of 3



W. 5% UNLESS OTHERWISE NOTED.  
 ARE 1% IN TOLERANCE.  
 VOLTAGE FEEDBACK SIGNAL.  
 CURRENT FEEDBACK SIGNAL.  
 MEASURED UNDER THE FOLLOWING CONDITIONS.  
 50 OR EQUIVALENT.  
 CONNECTED TO +5 UNLESS OTHERWISE NOTED.  
 CAL. ±10% UNLESS OTHERWISE NOTED.  
 COMPONENTS ARE IDENTIFIED BY SHADED AREAS.

Model 6110A, Schematic Diagram