

## Errata

**Title & Document Type:** 6824A Power Supply / Amplifier Operating and Service Manual

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**Agilent Technologies**

POWER SUPPLY/AMPLIFIER

PS/A SERIES, MODEL 6824A

SERIAL NUMBER PREFIX 6F

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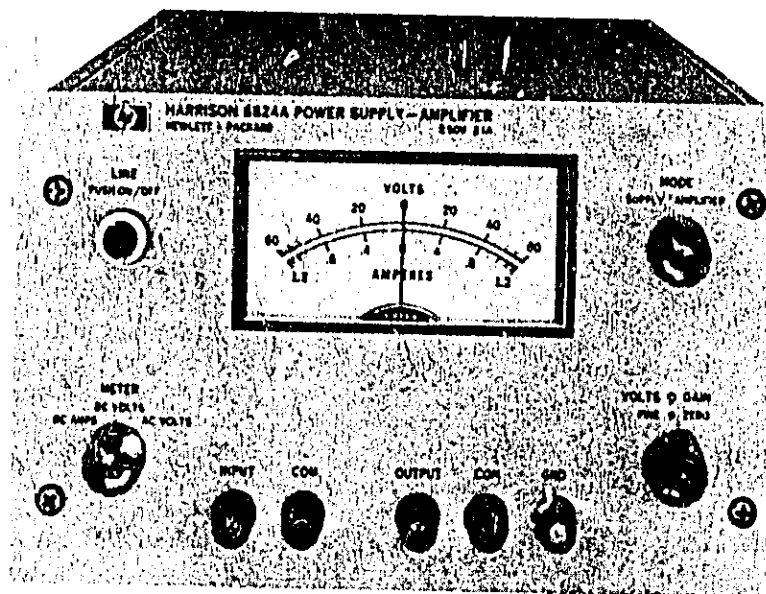


Figure 1-1. DC Power Supply/Amplifier, Model 6824A

## SECTION I GENERAL INFORMATION

### 1-1 DESCRIPTION

1-2 The Power Supply/Amplifier (PS/A) shown on Figure 1-1, is a general purpose instrument useful in any laboratory engaged in research and development of electronic systems or components. The PS/A can be operated in one of two basic operating modes; power supply or amplifier. Terminals on the rear barrier strip permit access to various control points within the unit to further expand the operating capabilities of the instrument. The resulting flexibility lends the PS/A to an almost unlimited number of applications. Some of these applications are outlined in Section III of this manual; but a more comprehensive description of the features and applications of the PS/A are included in Application Note 82 published by the Harrison Division. A copy of Application Note 82 can be obtained from your local Hewlett-Packard field office. The following paragraphs describe some of the features of the PS/A both as a power supply and an amplifier.

### 1-3 POWER SUPPLY FEATURES

1-4 The unit can be made to function as a regulated dc power supply by setting the front panel MODE switch to the SUPPLY position. The supply can furnish either a Constant Voltage output or a Constant Current output (with the addition of an external current sampling resistor). The dc output is bi-polar and is continuously adjustable from its maximum rated positive value to an equal negative value; smoothly through zero with no polarity switch. Both the supply and the load are protected against overloads by a fixed current limit which is set by means of an internal adjustment.

1-5 The supply can be programmed (controlled) at a very high rate of speed (less than 50  $\mu$ sec for output voltage change over the entire voltage span). The supply can be programmed locally; by means of the front panel control, or remotely; by means of a resistance, voltage, or current source.

1-6 A single meter is used to measure dc output voltage or current. A front panel METER switch allows the dual purpose selection.

### 1-7 AMPLIFIER FEATURES

1-8 As a power amplifier the unit has a high signal-to-noise ratio (80 db at full output) and an adjustable gain of from 0 to 10 (20 db). The output distortion is low — less than 0.02% at 1 KHz. The amplifier contains a push-pull output stage that can furnish either a Constant Voltage output or a Constant Current output (with the addition of an external current sampling resistor). The external input can be from either a voltage or a current source. The bandwidth of the amplifier is from dc to 20KHz ( $\pm 3$ db).

1-9 The ac component of the output signal can be measured with the front panel meter (Model 6824A only).

### 1-10 SPECIFICATIONS

1-11 Detailed specification for the PS/A are given in Table 1-1.

### 1-12 OPTIONS

1-13 Options are factory modifications of a standard instrument that are requested by the customer. The following option is available for the instrument covered by this manual.

| <u>Option No.</u> | <u>Description</u> |
|-------------------|--------------------|
|-------------------|--------------------|

|    |  |
|----|--|
| 28 | Rewire For 230V AC Input: Supply as normally shipped is wired for 115 Vac input. Option 28 consists of reconnecting the input transformer for 230 Vac operation. |
|----|--|

### 1-14 ACCESSORIES

1-15 The applicable accessories listed in the following chart may be ordered with the instrument or

separately from your local Hewlett-Packard field sales office (refer to list at rear of manual for addresses).

| <u>Part No.</u> | <u>Description</u>  |
|-----------------|---|
| 14513A          | Rack Kit for mounting one 3½" -high unit. (Refer to Section II for details.)  |
| 14523A          | Rack Kit for mounting two 3½" -high units. (Refer to Section II for details.) |
| 14515A          | Rack Kit for mounting one 5¼" -high unit. (Refer to Section II for details.)  |
| 14525A          | Rack Kit for mounting two 5¼" -high units. (Refer to Section II for details.) |

#### 1-16 INSTRUMENT IDENTIFICATION

1-17 Hewlett-Packard instruments are identified by a three-part serial number tag. The first part is

the unit 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 instrument serial number.

1-18 If the serial number prefix on your unit does not agree with the prefix on the title page of this manual, change sheets are included to update the manual. Where applicable, backdating information is given in an appendix at the rear of the manual.

#### 1-19 ORDERING ADDITIONAL MANUALS

1-20 One manual is shipped with each instrument. Additional manuals may be purchased from your local Hewlett-Packard field office (see list at rear of this manual for addresses). Specify the model number, serial number prefix, and  $\text{Ⓢ}$  stock number provided on the title page.

Table 1-1. Specifications

| DC POWER SUPPLY  | POWER AMPLIFIER  |
|--|--|
| <p><b>OUTPUT:</b><br/>-50 to +50 Vdc @ 0 to 1.0 amp.</p> <p><b>LOAD REGULATION:</b><br/>Less than 0.02% plus 5 mV for a full load to no load, change in output current.</p> <p><b>LINE REGULATION:</b><br/>Less than 0.02% plus 5 mV for any line voltage change within the input rating.</p> <p><b>RIPPLE AND NOISE:</b><br/>Less than 10 mVrms.</p> <p><b>REMOTE PROGRAMMING:</b><br/>Remote programming of the output at approximately 500 ohms per volt is made available at the rear terminals.</p> <p><b>PROGRAMMING SPEED:</b><br/>Less than 50 <math>\mu</math>sec are required to program between -50V and +50V. Typically, about 15 <math>\mu</math>sec is required to program between 10% and 90% of the maximum voltage span.</p> <p><b>TRANSIENT RECOVERY TIME:</b><br/>Less than 100 <math>\mu</math>sec for output recovery to within 5 mV plus 0.02% following a full load current change in the output.</p>   | <p><b>OUTPUT:</b><br/>100 volts peak-peak @ 0 to 1.0 amp.</p> <p><b>VOLTAGE GAIN:</b><br/>Gain is variable, 0 to 10 (20db). Output is inverted.</p> <p><b>FREQUENCY RESPONSE:</b><br/>DC to 20 kHz (<math>\pm</math>3db) at full output.</p> <p><b>DISTORTION:</b><br/>Output distortion is less than 0.02% at 1 kHz and maximum rated output.</p> <p><b>INPUT IMPEDANCE:</b><br/>Approximately 2K ohms.</p> <p><b>MAXIMUM PHASE SHIFT:</b></p> <p>At dc       — 180°<br/>At 100 Hz   — 180.7°<br/>At 10 kHz   — 205°<br/>At 20 kHz   — 225°</p> |
| <p><b>INPUT:</b> 105-125/210-250 Vac, single phase, 50-60 Hz; 1.3 Amp, 96 Watts maximum.</p> <p><b>STABILITY:</b> Less than 0.075% +5 mV total drift for 8 hours after an initial warm-up of 30 minutes at constant line voltage with ambient temperature variations held to <math>\pm</math>3°C.</p> <p><b>TEMPERATURE RANGES:</b> Operating: 0 to 50°C. Storage: -20 to +85°C.</p> <p><b>TEMPERATURE COEFFICIENT:</b> Less than 0.015% plus 1 mV per degree Centigrade.</p> <p><b>OUTPUT IMPEDANCE:</b> Less than 0.03 ohm from dc to 100 Hz. Less than 0.3 ohm from 100 to 1000 Hz. Less than 3 ohms from 1000 Hz to 100 kHz.</p> <p><b>OVERLOAD PROTECTION:</b> A continuously acting current limiting circuit protects the unit for all overloads including a direct short placed across the output terminals.</p> <p><b>METER:</b> The front panel meter is triple purpose. It can be used as a -60 Vdc to +60 Vdc voltmeter, a -1.2 Amp to +1.2 Amp dc Ammeter, or as a 0 to 60 Vac rms voltmeter.</p> <p><b>SIZE:</b> 5½" H x 8¼" W x 14 5/8" D. Two units can be rack mounted side-by-side in a standard rack panel.</p> <p><b>WEIGHT:</b> 17 lbs. net, 21 lbs. shipping.</p> <p><b>FINISH:</b> Light gray front panel with dark gray case.</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 power 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 cooled with forced air from the cooling fan. However, it should not be used in an area where the ambient temperature may exceed 50°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.

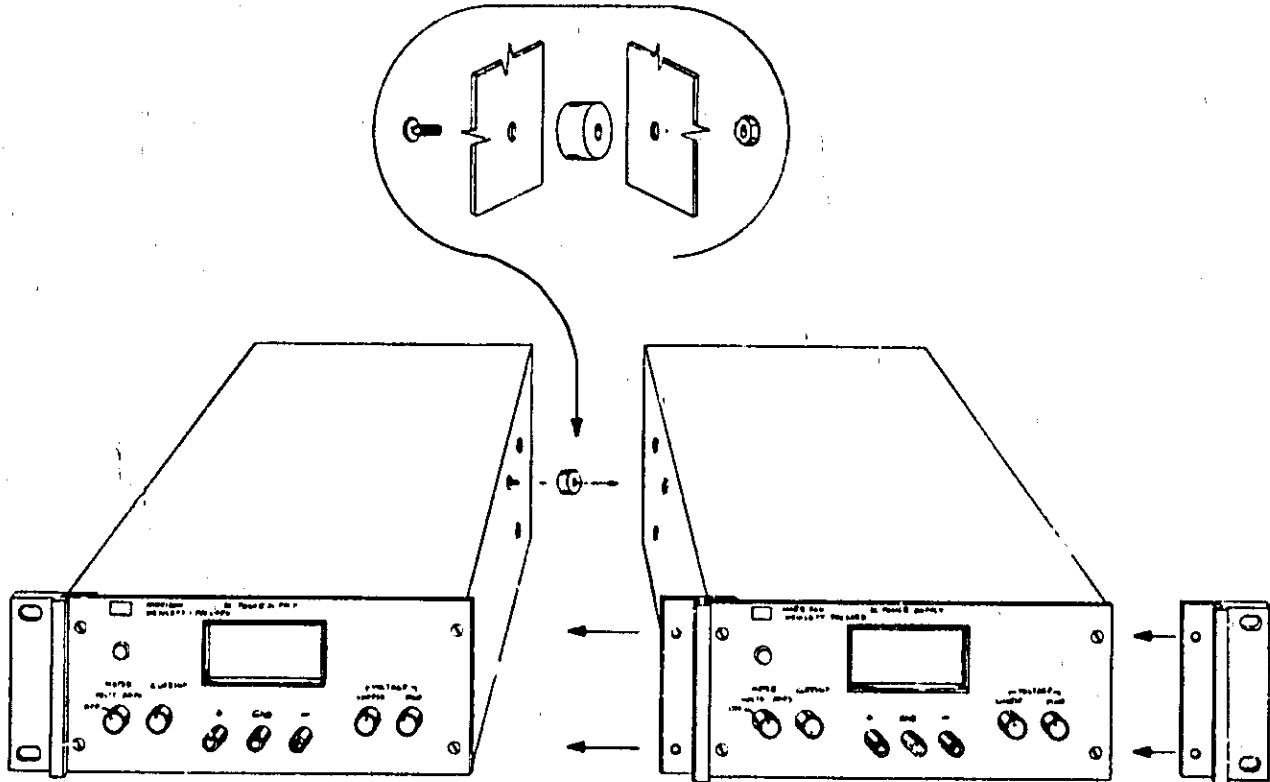


Figure 2-1. Rack Mounting, Two Units

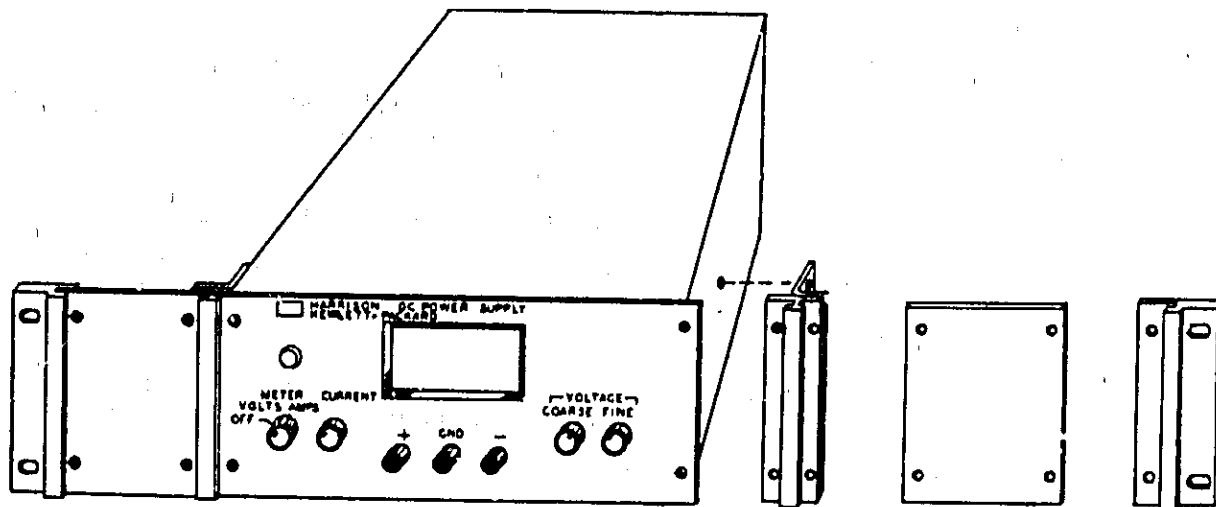


Figure 2-2. Rack Mounting, One Unit

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 straps, and angle brackets to each side of center spacing panels. Angle brackets are placed behind combining straps 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 may be operated from either a nominal 115 volt or 230 volt 50-60 cycle power source. The unit, as shipped from the factory, is wired for 115 volt operation. The input power required when operated from a 115 volt 60 cycle power source at full load is 96 watts and 1.3 amperes.

### 2-17 CONNECTIONS FOR 230 VOLT OPERATION (Figure 2-3)

2-18 Normally, the two primary windings of the input transformer are connected in parallel for operation from 115 volt source. To convert the

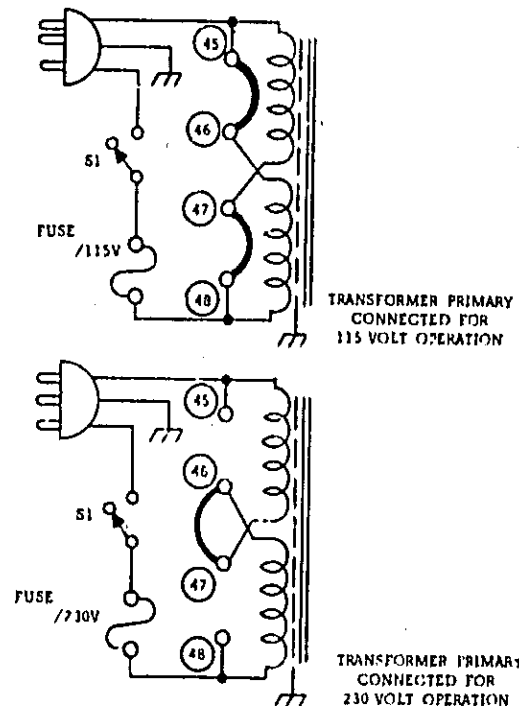


Figure 2-3. Primary Connections

power supply to operation from a 230 volt source, the power transformer windings are connected in series as follows:

- a. Unplug the line cord and remove the top and bottom covers from the unit.
- b. Break the printed wiring between 45 and 46 and also between 47 and 48 on the printed circuit board. These are shown in Figure 2-3, and are labeled on printed side of the circuit board.
- c. Connect a strap between 46 and 47.
- d. Replace existing fuse with 1.5 ampere, 230 volt fuse. Replace covers and operate unit normally.

## 2-19 POWER CABLE

2-20 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.

2-21 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.

## 2-22 REPACKAGING FOR SHIPMENT

2-23 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.

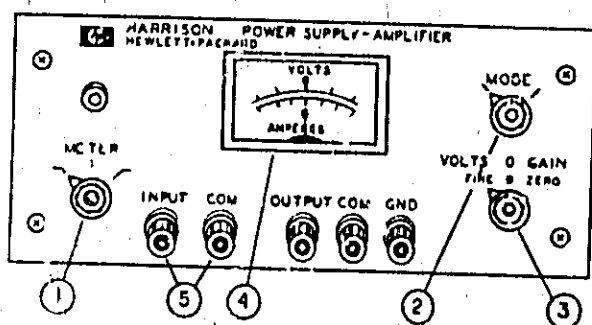
**OPERATION**

**THEORY**

## SECTION III OPERATING INSTRUCTIONS

### 3-1 OPERATING CONTROLS AND INDICATORS

3-2 The front panel controls and indicators, together with the normal turn-on sequences, for both power supply and amplifier operation are shown on Figure 3-1. These turn-on procedures are performed utilizing the normal rear terminal strapping connections as received from the factory.



#### TURN-ON SEQUENCE - POWER SUPPLY

1. SET AC LINE SWITCH TO ON AND OBSERVE THAT PILOT LIGHT GOES ON.
2. SET METER SWITCH (1) TO DC VOLTS.
3. SET MODE SWITCH (2) TO SUPPLY.
4. ADJUST VOLTS/GAIN CONTROL (3) CLOCKWISE OR COUNTERCLOCKWISE UNTIL DESIRED POSITIVE OR NEGATIVE OUTPUT VOLTAGE, RESPECTIVELY, IS INDICATED ON FRONT PANEL METER (4). CONCENTRIC FINE/ZERO CONTROL (3) PERMITS FINE CONTROL OF THE OUTPUT VOLTAGE.
5. SHORT CIRCUIT OUTPUT TERMINALS; SET METER SWITCH TO AMPS AND OBSERVE SHORT CIRCUIT OUTPUT CURRENT ON METER. CURRENT LIMIT IS FACTORY ADJUSTED SO THAT METER SHOULD INDICATE FULL SCALE DEFLECTION.
6. REMOVE SHORT AND CONNECT LOAD TO OUTPUT TERMINALS (FRONT OR REAR).

#### TURN-ON SEQUENCE - AMPLIFIER

1. TURN ON UNIT AND SET MODE SWITCH (2) TO AMPLIFIER.
2. CONNECT INPUT SIGNAL SOURCE TO INPUT (5) TERMINALS (FRONT OR REAR).
3. ADJUST VOLTS/GAIN CONTROL (3) FOR DESIRED GAIN (0 TO 10). CONCENTRIC FINE/ZERO CONTROL PERMITS AVERAGE OUTPUT TO BE ADJUSTED TO ZERO.
4. MEASURE OUTPUT VOLTAGE WITH EXTERNAL VOLTMETER FOR 6823A UNITS OR FOR 6824A UNITS. SET METER SWITCH (1) TO AC VOLTS AND READ OUTPUT DIRECTLY ON FRONT PANEL METER.
5. CONNECT LOAD TO OUTPUT TERMINALS (FRONT OR REAR).

Figure 3-1. Front Panel Controls and Indicators

### 3-3 OPERATING MODES

3-4 The position of the front panel MODE switch determines whether the instrument will be used as a power supply or an amplifier. Terminals on the

rear barrier strip, which connect into various control points within the unit, allow strapping connections to be made which enable the power supply or amplifier to be utilized in an almost unlimited number of applications. The following paragraphs describe the procedures for utilizing some of the features which will suggest many related applications.

3-5 However, the configurations shown in the succeeding paragraphs by no means exhaust the various modes in which the PS/A can be used. The reader is encouraged to consider this instrument in terms of operational amplifier techniques; this viewpoint will suggest and facilitate many other areas of application. Many such possibilities are suggested by handbooks on operational amplifiers (e. g., "Handbook of Operational Amplifier Applications" - Burr-Brown Research Corporation, Copyright 1963).

3-6 Such handbooks suggest how operational amplifiers can be used as integrators, differentiators, ramp function generators, etc.; with the PS/A, these techniques are extended to previously unattained power levels.

3-7 An alternate viewpoint is to consider the PS/A as a general-purpose DC coupled precision power transducer capable of accepting either resistance, voltage, or current input (AC and/or DC) and delivering a power output, Constant Voltage or Constant Current, AC and/or DC.

3-8 Application Note 82, published by the Harrison Division, presents a more detailed approach concerning the operational features and related applications of the PS/A unit. A copy of this note can be obtained from your local Hewlett-Packard field office.

### 3-9 GENERAL NOTES AND OPERATING CONSIDERATIONS

#### 3-10 DIAGRAMS

3-11 All of the following diagrams show the necessary barrier strip connections, as well as a simplified circuit diagram showing how the major internal components of the unit are connected for that strapping arrangement. The diagrams also

include all components which must be added externally to the unit. The barrier strip portion of each diagram is correct for all PS/A Series instruments, but when implementing these strapping patterns, check whether the terminal locations are the same as shown in the following diagrams, which are based specifically on the Model 6823A. In any case, the terminal designations are correct for all PS/A Series instruments and should be followed regardless of their location.

**3-12** Unless otherwise indicated, the configurations shown have been selected so that operation is independent of whether the front panel MODE switch is in the power SUPPLY or AMPLIFIER position.

**3-13 EXTERNAL RESISTORS**

**3-14** External resistors and potentiometers should be wire-wound and have a temperature coefficient of less than 20ppm/°C. They should operate at less than 1/30th (preferably 1/100th) of their wattage rating in order to minimize short term "bobble" associated with elevated surface temperature.

**3-15 CONNECTING LEADS**

**3-16** Shielded leads should be used for all barrier strip connections, except that twisted leads may be used from the "Common" and "Output" terminals to the load. The outer sheath of the shielded wire should never be used as a conductor, but should be connected at the unit end only to the terminal designated "Common".

**3-17** Best high speed programming and wide band amplifier operation will be achieved when the load is connected at the rear terminals rather than at the front. Any capacitance in parallel with the load device should be minimized, since this capacitance will limit the high frequency bandwidth.

**3-18** Ensure that the screws on the rear terminals are tightened securely before power is applied to the unit.

**3-19 FINE/ZERO CONTROL**

**3-20** The front panel Fine/Zero control is operable for all modes. In the power supply mode, it acts as a fine control on the DC output. In remote programming and amplifier modes, it provides a DC "offset" adjustment of approximately 1% of the maximum rated output voltage. Thus, this control permits the accurate setting of zero output voltage with zero ohms programming.

**3-21 GROUND LOOPS**

**3-22** If excessive 60 Hz component exists on output, check for ground loops. The system in which the PS/A is employed should have one ground point only. See the Harrison Division's power supply Application Manual, Sections D1a (6) and D1d, for further discussion of typical ground loop problems.

**3-23 REVERSE CURRENT LOADING**

**3-24** An active load connected to the unit may actually deliver a reverse current during a portion of its operating cycle. An external source cannot be allowed to pump current into the instrument without the risk of possible damage. To avoid damage it is necessary to preload the unit with a dummy load resistor so that it will deliver current through the entire operating cycle of the load device.

**3-25** In general, the load resistor that is added should draw a current equal to the peak current which otherwise would be forced back into the PS/A. This means that the current rating of the PS/A instrument used must be equal to, or greater than, the sums of the absolute values of the output and reverse currents.

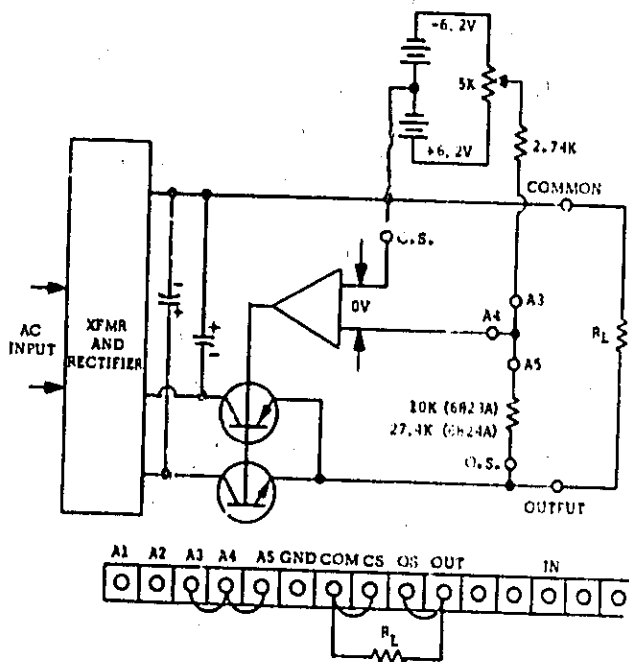


Figure 3-2. Standard Power Supply Operation (CV)

### 3-26 CONSTANT VOLTAGE OPERATING MODES

### 3-27 NORMAL OPERATING MODES

3-28 Figure 3-2 shows the circuit configuration and normal rear barrier strip strapping pattern for standard power supply operation. The front panel MODE switch is in the SUPPLY position. The DC output is continuously adjustable from its maximum rated positive value to an equal negative value — smoothly through zero with no polarity switch.

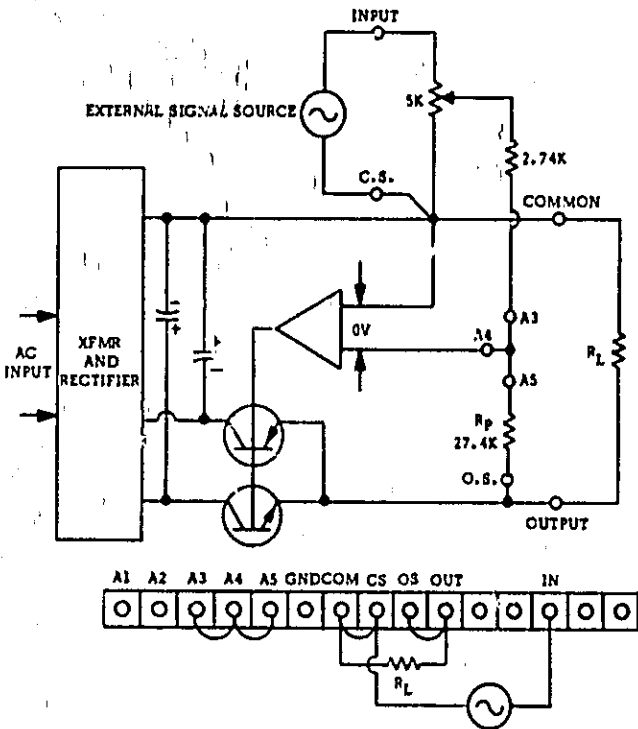


Figure 3-3. Standard Amplifier Operation (CV)

3-29 Similarly, Figure 3-3 shows the circuit configuration and strapping pattern for standard amplifier operation. The external oscillator must have a voltage output which is at least 1/10th of the peak output voltage desired; its current capability must be at least 600 $\mu$ a for each volt input — in other words, the oscillator faces an input impedance of approximately 1.7K. The front panel gain control permits the amplifier gain to be set anywhere from zero to X10, although the gain setting will not be a linear function of control rotation. The front panel FINE/ZERO control permits the dc component of the output to be adjusted approximately 1% of the voltage rating of the instrument, thus enabling the average output value to be adjusted exactly to zero (assuming the input signal has either no dc component or only a small dc component). If desired, a coupling

capacitor can be added to block any large input dc components, although in many applications this capacitor will be omitted so that the PS/A can amplify all input signal components, both dc and ac.

### 3-30 REMOTE SENSING

3-31 In normal operation, a power supply develops an IR drop in the leads connecting it to the load. This reduces the output voltage actually present at the load terminals and also degrades the load regulation performance.

3-32 Sensing terminals permit the feedback amplifier to sense at the load terminals instead of at the PS/A output terminals. This configuration is shown in Figure 3-4 and is applicable for all Constant Voltage modes of operation, both power supply and amplifier. Moreover, the strapping pattern shown in Figure 3-4 can be combined with any of the Constant Voltage diagrams shown elsewhere in the manual in order to achieve optimum performance at the load terminals.

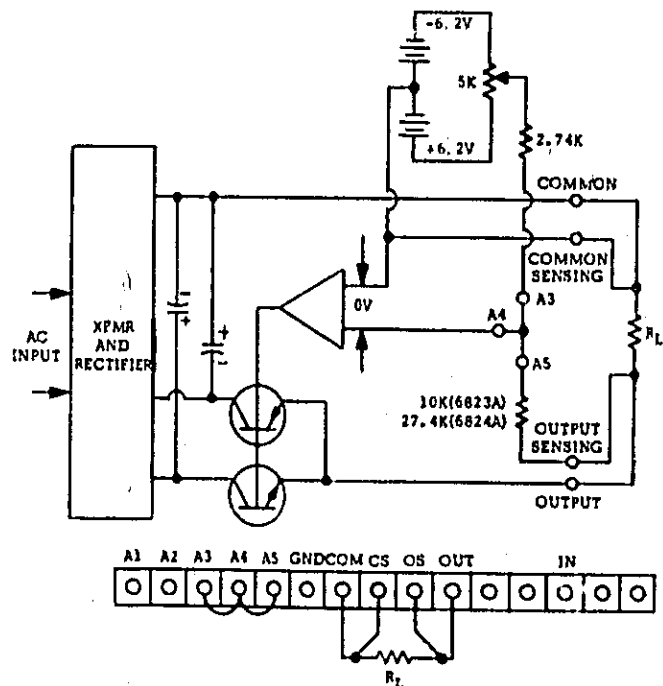


Figure 3-4. Remote Error Sensing

3-33 This does not mean that remote sensing can be used to compensate for an unlimited IR drop between the Common and Output terminals and the load. Any voltage lost in this way detracts directly from the output voltage available for the load. Furthermore, proper operation of the PS/A is insured only if the IR drop in the Common lead is less than, or equal to, one volt.

3-34 If external switching schemes are employed in conjunction with remote sensing, care must be taken that each sensing lead is not momentarily open circuited with respect to the corresponding output terminal. Such open circuit conditions can result in the power supply delivering excessive voltage and/or current to the load, risking damage to both the PS/A and the load device. If it is impossible to insure that an open sensing lead condition will not occur, it is recommended that a 100 ohm, 1/2 watt resistor be connected from "Common" to "Common Sensing", and a similar resistor from "Output" to "Output Sensing". This will minimize voltage and current transients if the sensing leads should accidentally become open circuited. All sensing leads should be shielded.

### 3-35 REMOTE PROGRAMMING, POSITIVE OUTPUT

3-36 Figure 3-5 shows the strapping pattern and associated circuit configuration for remote programming Power Supply / Amplifiers for positive Constant Voltage DC output at the rate of 500 ohms/volt. The programming control  $R_p$  should be wire-wound and selected in accordance with paragraph 3-13. Its dissipation can be computed by remembering that the current through  $R_p$  is 2 MA.

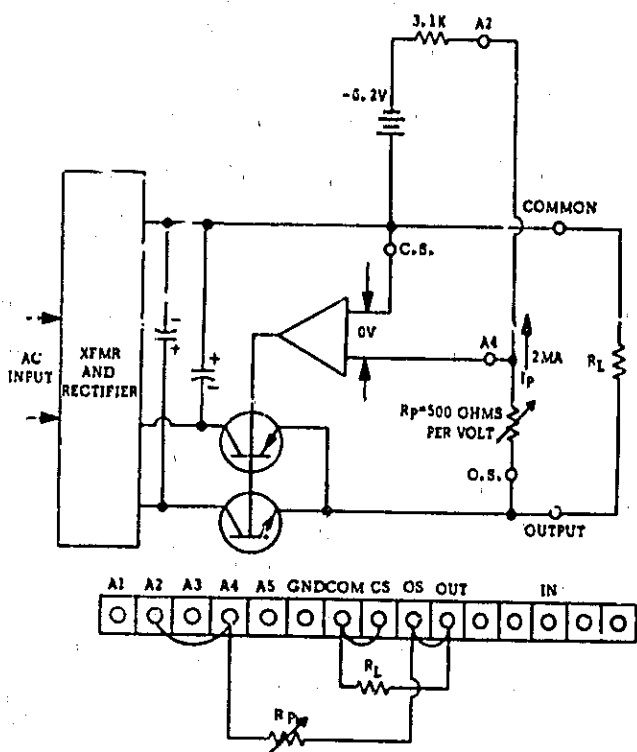


Figure 3-5. Remote Resistance Programming, Positive Output

3-37 Figure 3-6 shows two resistance programming characteristics which are typical (although somewhat exaggerated) of the performance without programming alignment. The output voltage with zero programming always will differ from zero, being either positive (V) or negative (A), and the maximum output voltage will be achieved with a value of programming resistance not predicted by the programming coefficient.

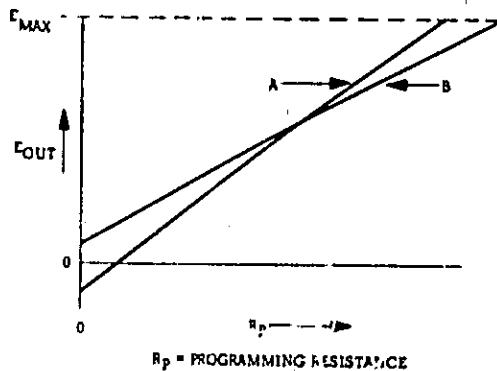


Figure 3-6. Unaligned Resistance Programming Characteristics

3-38 Notice, however, that even with an unaligned instrument the typical characteristics of A and B are extremely linear — that is, there is no curvature. To convert either of the characteristics of Figure 3-6 to the desired programming characteristic of Figure 3-7, it is necessary to adjust both the zero crossing and the angle of slope of the programming characteristic.

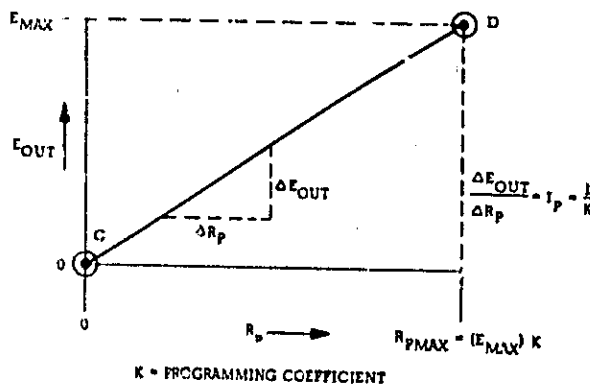


Figure 3-7. Aligned Resistance Programming Transfer Function

3-39 In the PS/A Series the zero crossing is adjusted by means of the front panel FINE/ZERO knob, while the slope of the programming function



is adjusted by means of an internal control, R<sub>38</sub>. First the zero crossing is adjusted; then a programming resistance, which according to the programming coefficient (500 ohms/volt) should yield the maximum rated output voltage for the instrument, is connected to the programming terminals, and R<sub>38</sub> is adjusted until the output voltage is exactly equal to the maximum rated value. Since the two adjustments are mildly interdependent, it is necessary to repeat this procedure once.

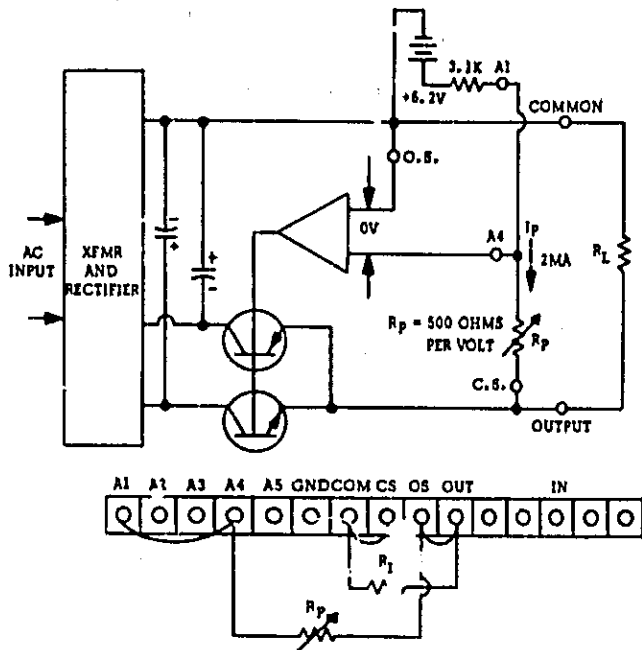


Figure 3-8. Remote Resistance Programming, Negative Output

### 3-40 REMOTE PROGRAMMING, NEGATIVE OUTPUT

3-41 Figure 3-8 is the same as Figure 3-5 except that the linearly programmed output voltage is negative. The internal programming slope adjustment for a negative output is R<sub>39</sub>.

### 3-42 REMOTE PROGRAMMING, BIPOLAR OUTPUT

3-43 The circuits of Figures 3-5 and 3-8 can be combined to yield a power supply which is programmable in either direction, depending upon the position of switch S<sub>1</sub> (see Figure 3-9). One obtains a linearly programmed negative DC output when switch S<sub>1</sub> is connected to A<sub>1</sub>; and a positive output when connected to A<sub>2</sub>. Switch S<sub>1</sub> must be a break-before-make switch.

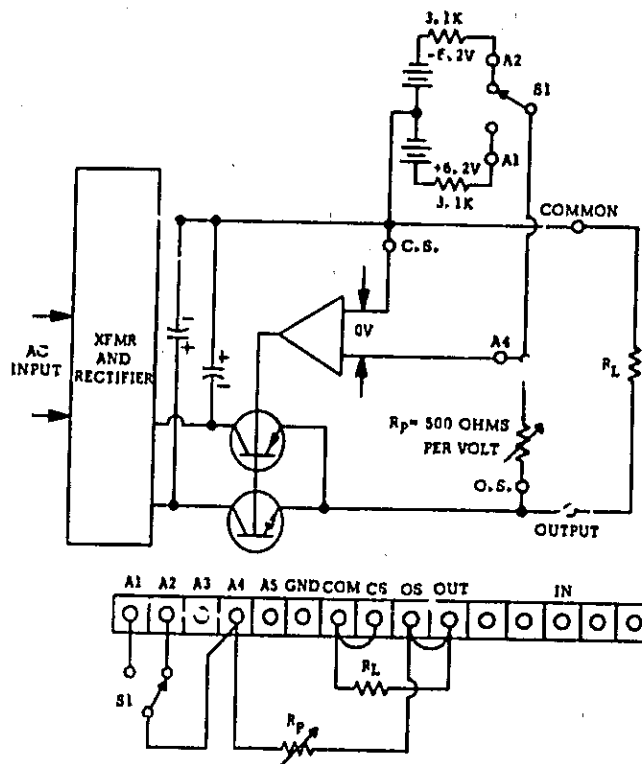


Figure 3-9. Remote Resistance Programming, Bi-Polar Output (CV)

3-44 The advantage of the configuration of Figure 3-9 is that the output is linearly programmed in both directions. The disadvantage is that a switch must be used in order to reverse the output polarity.

3-45 If it is desired to achieve accurate programming reproducibility, or if it is necessary to repeatedly set the power supply output to specific voltage values, either of the substitute arrangements suggested by Figure 3-10(B) and 3-10(C) may be employed in place of the rheostat R<sub>p</sub>. Suppose, for example, it is decided to set the power supply over the span from 0-20V. If continuous adjustment is required, the best choice would be a 10K rheostat (since the programming coefficient is 500 ohms/volt). But if specific tests must be made at 0, 5, 10, 15, and 20V, the arrangement shown in Figure 3-10(B) should be employed, using a make-before-break switch. If the same voltage values are desired, but not in ascending or descending sequence, the terminals from the resistor string can be connected to the switch in any desired sequence, as suggested by Figure 3-10(C).

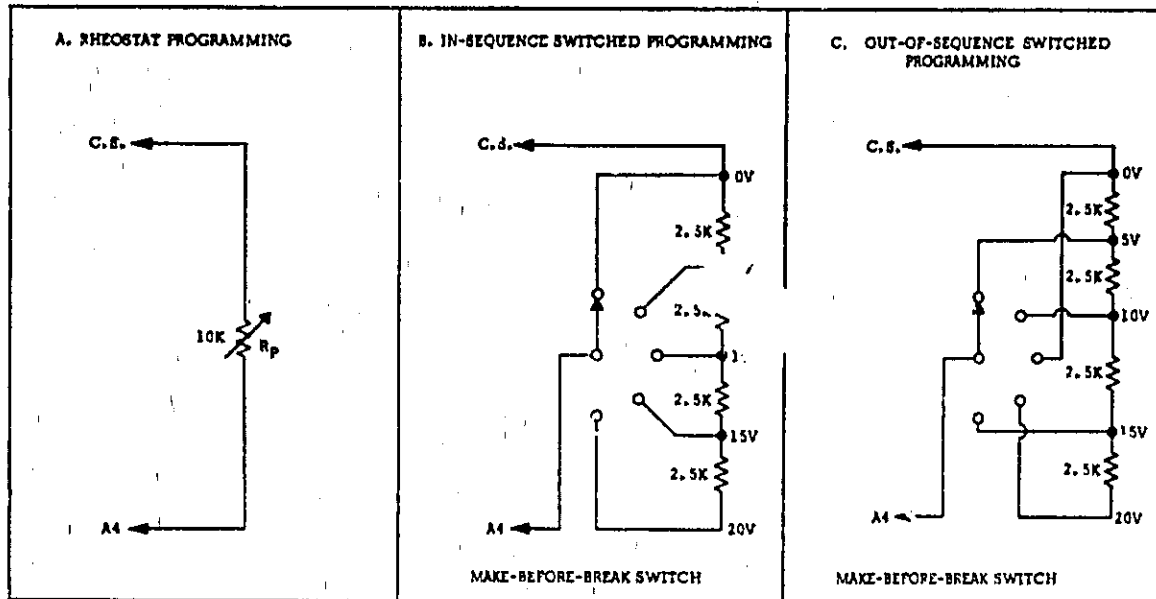


Figure 3-10. Switched Resistor Substitutes

3-46 These substitute configurations for  $R_p$  can be employed with any of the diagrams in this section. In all such applications a make-before-break switch must be used so that output voltage transients will not occur during the switching interval. Such transients can lead to damage to both the load and the power supply.

### 3-47 SWITCHLESS BIPOLAR PROGRAMMING

3-48 Figure 3-11 shows how to resistance program a PS/A for continuously variable output dc voltage, remotely controlled, without need for a polarity switch. Clockwise rotation of the 10K potentiometer will result in a positive output equal to the maximum voltage capability of the instrument.

3-49 The advantage of Figure 3-11 is that the output is continuously variable through zero with one control. The disadvantage is that the output is not a linear function of the rotation of potentiometer  $R_Q$ . Note, however, that in many applications it is not necessary that the programming function be linear, just reproducible. The power supply can be switched readily to positive or negative values (and later reset precisely at these same values) by substituting a switched resistor network for  $R_Q$ . The switch must be a break-before-make type.

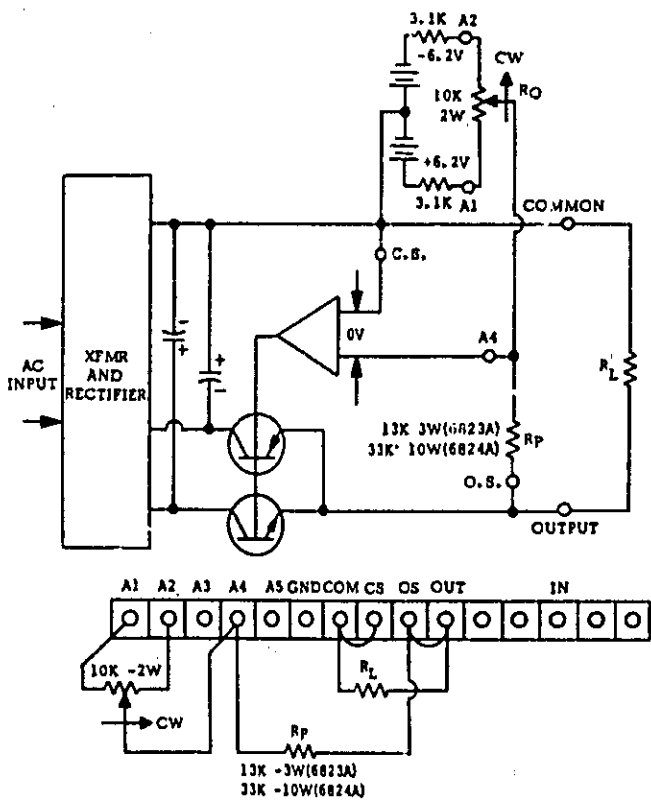


Figure 3-11. Bi-Polar Programming (Constant Voltage)

### 3-50 POWER SUPPLY WITH SUPERIMPOSED AC OUTPUT

3-51 In some applications it is desirable to add an AC component to the adjustable DC output of a Constant Voltage power supply. Figure 3-12 shows how this can be done.

3-52 The PS/A is operated as a normal power supply from the front panel with the MODE switch in the SUPPLY position. The amplitude of the added AC component is controlled by adjusting  $R_y$ . The value of this resistor should be greater than the minimum load resistance which the external signal source is suited to drive, since the impedance looking into terminals C.S. and A4 is virtually zero ohms.

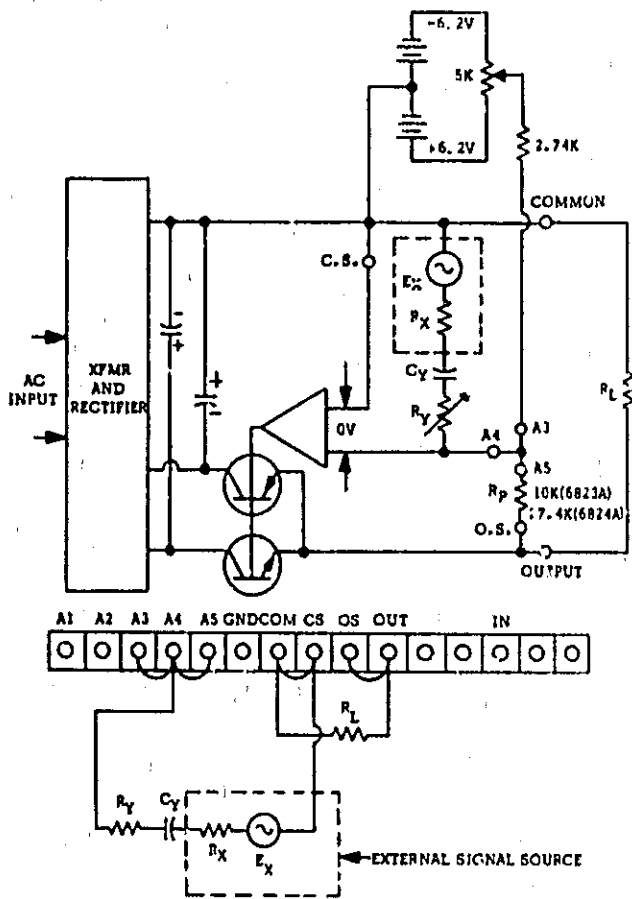


Figure 3-12. Constant Voltage Supply With Superimposed AC Output

3-53 The amplitude of the ac Output component is given by  $E_{AC} = E_X (R_p / R_X + R_y)$ , where  $R_X$  is the internal (Thevenin equivalent) source resistance. The capacitor  $C_y$  is added in order to block the DC current path through the oscillator, and must

be selected large enough to pass the lowest frequency of interest. The low frequency 3 db down point will be at  $f = \frac{1}{2\pi(R_X + R_y) C_y}$

### 3-54 CONSTANT VOLTAGE AMPLIFIER WITH REMOTE GAIN CONTROL

3-55 The PS/A can be used as a power amplifier with Constant Voltage output that can be remotely controlled in a linear manner if the strapping arrangement shown on Figure 3-13 is employed. With this configuration, the gain is a linear function of control rotation, and the gain control is external to the PS/A.  $E_X$  and  $R_X$  are the equivalent (open circuit) voltage and output resistance looking back into the external signal source.  $R_y$  must be selected to have a value at least as large as the minimum load resistance which the external signal source can feed without overloading or distorting.  $C_y$  is inserted in order to block any small DC currents which otherwise might flow from the oscillator, producing a DC component on the output.  $C_y$  must be selected large enough to pass the lowest frequency of interest; the 3 db down frequency is

$$f = \frac{1}{2\pi (R_X + R_y) C_y}$$

3-56 If it is desired to amplify a DC signal, or one which has both a DC and AC component, then the capacitor  $C_y$  must be eliminated from the circuit.

3-57 The output voltage is given by the equation

$$E_O = E_X \frac{R_p}{R_X + R_y}$$

Proper impedance levels will be maintained if approximately 2 mA is allowed to flow through  $R_y$  and  $R_p$ . Thus wherever possible,  $R_y$  should be selected so that

$$R_y = \frac{E_X}{2 (10^{-3})} - R_X$$

where the  $E_X$  for this equation is the maximum peak value which will be amplified. This equation, of course, assumes that the external signal source is capable of delivering 2 mA without overloading or distorting, and should be altered if less current is available.

3-58 Current Input. Actually, the components  $E_X$ ,  $R_X$ , and  $R_y$  of Figure 3-13 comprise a current source feeding the summing point A4 and the gain control  $R_p$ . A current source can be substituted in place of these components, and the output voltage

will be  $V_{OUT} = I_X R_P$ , where  $I_X$  is the current source connected between CS and A4, as shown in Figure 3-13. The capacitor  $C_Y$  should also be added in series if it is desired to suppress any DC component present in the input signal source.

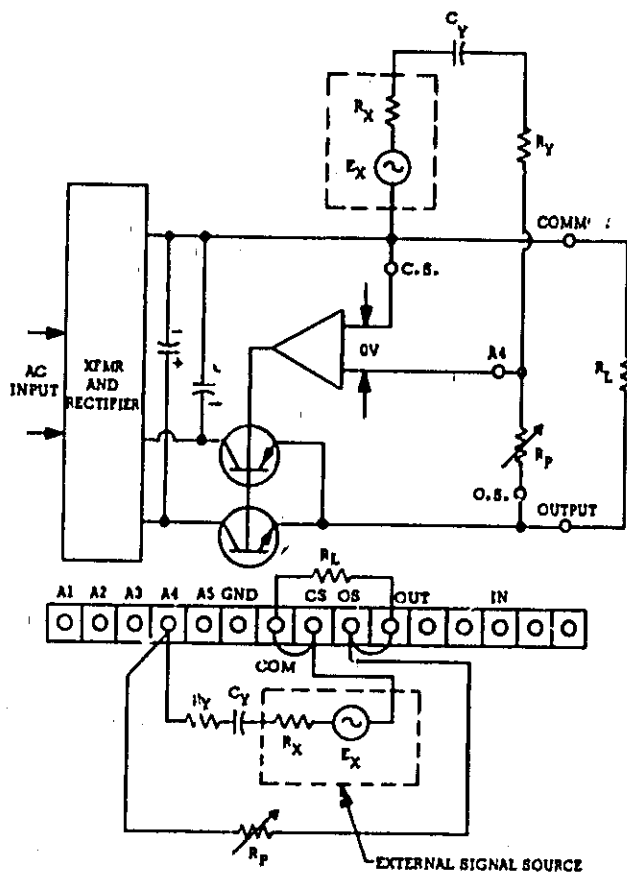


Figure 3-13. Constant Voltage Amplifier With Linear Remote Gain Control

3-59 Two or More Inputs. The concept of Figure 3-13 is readily adapted, using standard operational amplifier techniques, to the simultaneous amplification of two or more signals. Figure 3-14 shows the manner in which two voltage inputs can be mixed and amplified; additional inputs can be added in parallel without limit, and current input signals can be substituted for voltage input signals, as discussed in the previous paragraph. The capacitors  $C_Y$  and  $C'_Y$  are only included when it is desired to:

- Prevent the DC input level of the signal from affecting the DC level of the output, or
- Prevent the DC level of the PS/A from being fed back into the output terminals of the signal source.

3-60 The output for two (or more) inputs is given by:

$$L_O = E_X \frac{R_P}{R_X + R_Y} + E_{X'} \frac{R_P}{R_{X'} + R_{Y'}} + \dots$$

Thus  $R_Y$ ,  $R_{Y'}$  can be made variable and used as relative level controls while  $R_P$  functions as a master gain control. Notice that any of the signal inputs which are to be mixed and amplified may be ac, dc, or both.

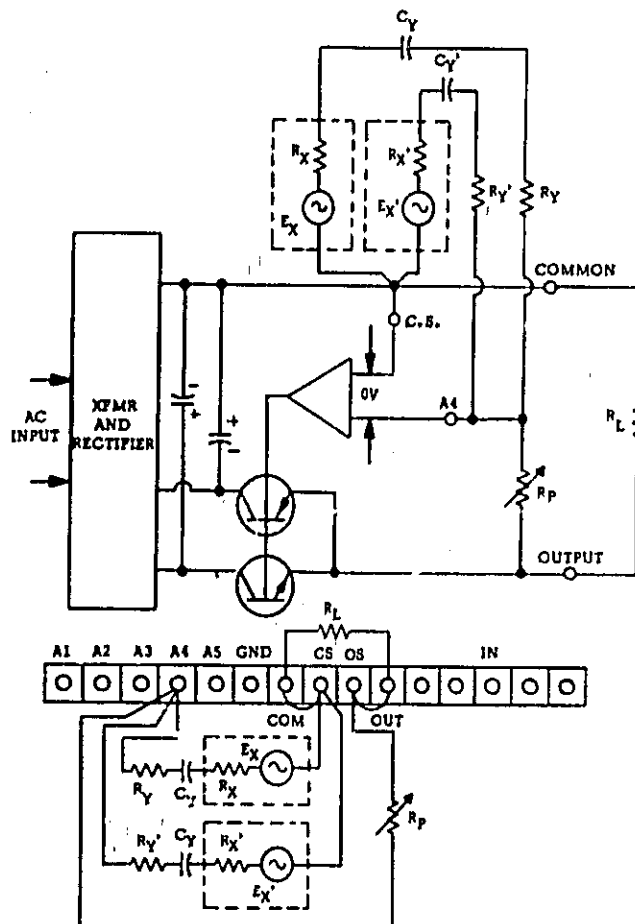


Figure 3-14. Constant Voltage Amplifier, Two Inputs

### 3-61 CONSTANT CURRENT OPERATING MODES

3-62. In order to achieve constant current operation, it is necessary to utilize an external current sampling resistor which yields a voltage drop that is proportional to the output current. This voltage drop can then be applied to the comparison amplifier in the input circuit and compared with a fraction of the reference voltage (or input voltage). The output of the comparison amplifier is then fed back to the regulator/output amplifier in a manner identical to that occurring during constant voltage operation. Hence, the only conceptual difference

between Constant Current operation and Constant Voltage operation is that the voltage which is sensed by the comparison amplifier is taken across the current sampling resistor rather than across the load.

3-63 The regulator ripple, temperature coefficient, and stability of Constant Current Power Supply/Amplifier performance can be predicted by dividing the corresponding Constant Voltage specification by the ohmic value of  $R_S$ . For example, the use of a 2 ohm current sampling resistor converts the 2 mV rms Constant Voltage ripple and noise specification of the 6823A to 1 MA, etc. In the case of temperature coefficient and stability, it is also necessary to add in the percentage effect due to any change in ohmic value of the monitoring resistor  $R_S$ .

3-64 The output impedance of the Constant Current source at DC is given by the relationship  $Z_O = (\Delta E_L / \Delta I_L)$ , where  $\Delta E_L$  is the change in load voltage associated with a load resistance change, and  $\Delta I_L$  is the small resulting output current change. The fact that the PS/A has a high loop gain and no output capacitor means that the PS/A used in a Constant Current mode will have a high output impedance. In fact, it can be shown that the impedance at any frequency for a Constant Current source of this type will be approximately equal to  $R_M (AB)$ , where AB is the loop gain of the feedback amplifier within the power supply at the frequency of interest. Since the PS/A has a bandwidth in excess of 20 KHz, this output impedance will remain quite high over a wide frequency band. Stated in terms of the time domain, the PS/A will respond quickly to changes in load resistance — the load current transient will be short.

### 3-65 SELECTING $R_S$

3-66 Particular care must be paid to the manner in which the current sampling resistor,  $R_S$ , is selected and employed. Constant Current operation, on a percentage basis, can be no better than this resistor.

3-67  $R_S$  is selected to yield a 1 volt drop at the maximum current rating of the instruments; its

maximum dissipation is 1/2 watt for the Model 6823A and 1 watt for the Model 6824A. It is therefore recommended that a minimum 30 watt wire-wound resistor be used for the former and 60 watt for the latter. This ensures that the surface temperature of the resistor will not be high compared to the ambient, and therefore subject to long-term warm-up effects and short-term variations resulting in output "bobble". In any case, the temperature coefficient of the resistor should be 20 ppm/°C or less.

3-68 If it is intended to use the PS/A at less than maximum rated output current, proportionately higher values of  $R_S$  may be chosen. This will result in better performance at low currents. It should be remembered, however, that the resistor  $R_S$  cannot be increased in ohmic value indiscriminately for two reasons:

- a. It soon becomes impractical to increase the wattage rating of  $R_S$  by the necessary amount.
- b. The IR drop which occurs across  $R_S$  detracts directly from the power supply voltage rating available to the load device.

3-69 Resistor  $R_S$  should be a four terminal device connected as shown on Figure 3-15. Note that for convenience and clarity, the remaining Constant Current diagrams do not show this connection pattern explicitly.

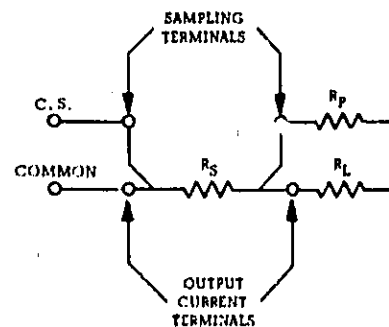


Figure 3-15. Current Sampling Resistor, Connection Method

### 3-70 NORMAL OPERATING MODES

3-71 Figure 3-16 shows the connection pattern and associated circuit configuration for operating the S/A as a continuously variable, reversible  $\Gamma$ , Constant Current source. This is the Constant Current counterpart of the Constant Voltage mode of operation shown in Figure 3-2. The MODE switch is in the SUPPLY position.

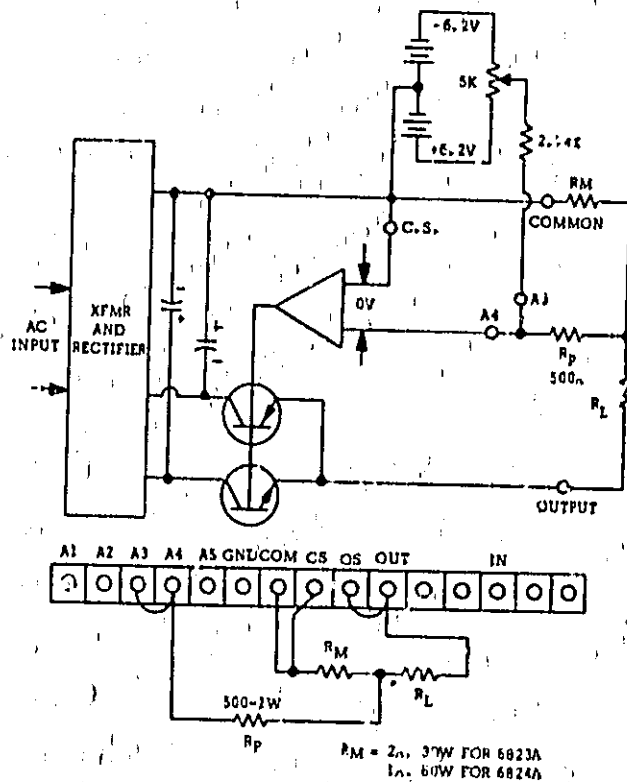


Figure 3-16. Standard Constant Current Power Supply

3-72 Figure 3-17 shows the simplest way of operating the PS/A as a Constant Current output amplifier with continuously variable gain. The front panel FINE/ZERO control should be adjusted for zero dc output current (assuming the input source has no dc input component). With the values given in Figure 3-17, the external oscillator must have a voltage output of 1.5 volts/peak in order to drive the power amplifier to its full output current capability. The impedance seen by this external voltage source will be approximately 1.7K.

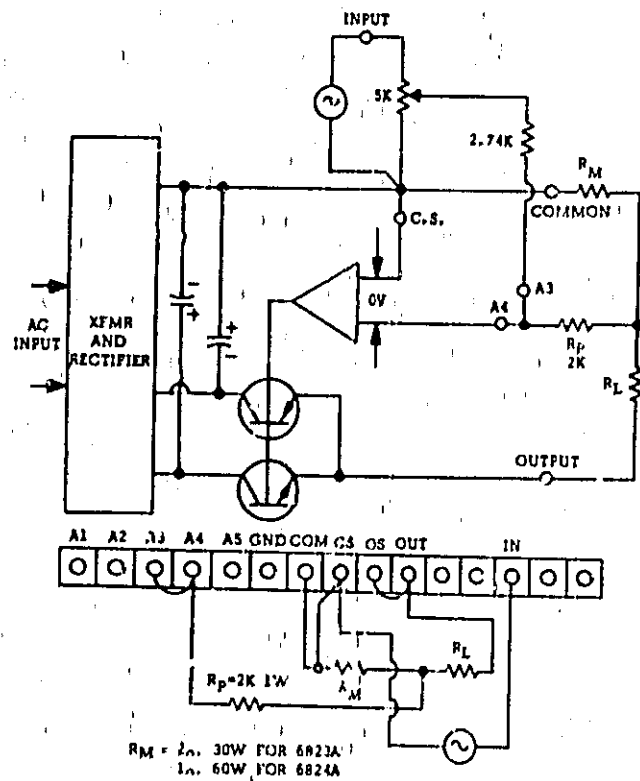


Figure 3-17. Standard Constant Current Amplifier

### 3-73 REMOTE PROGRAMMING, BIPOLAR OUTPUT

3-74 Figure 3-18 shows one method of controlling the output of the PS/A as a remote programmed Constant Current power supply. Switch S1 causes the output current to be either positive or negative. If it is desired to achieve only a positive or only a negative output current (unipolar output), then S1 must be eliminated. Terminal A4 is strapped directly to A2 for a positive output, or directly to A1 for a negative output.

3-75 The front panel FINE/ZERO control permits the output current to be adjusted to zero when Rp is set to zero, while the slope of the programming coefficient is adjusted by means of R38 (positive output) and R39 (negative output). Either of the switched resistance schemes of Figure 3-10 may be substituted for a variable Rp in this or any other Constant Current diagrams which follow. The advantage of the circuit of Figure 3-18 is that the output current is a linear function of the programming resistance; the disadvantage is that a switch must be used in order to accomplish polarity reversing.

### 3-76 SWITCHLESS BIPOLAR PROGRAMMING

3-77 Figure 3-19 shows the method of connecting the PS/A for Constant Current bipolar programming without the necessity for polarity switching. The 680 ohm resistor should be wire-wound with a temperature coefficient of less than 20 ppm/°C. Switched resistances can be substituted for resistor  $R_Q$  in Figure 3-19. The disadvantage of this mode lies in the non-linear (but accurately reproducible) programming characteristic.

### 3-78 CONSTANT CURRENT SUPPLY WITH SUPERIMPOSED AC OUTPUT

3-79 Figure 3-20 shows the method of adding an AC component on top of the adjustable DC output current. The dc level is controlled in the normal fashion from the front panel. The amplitude of the added ac component is determined by the value of  $R_Y$ , which, however, should not have a value less than the minimum load resistance which the external signal source is capable of driving without overloading or distorting.

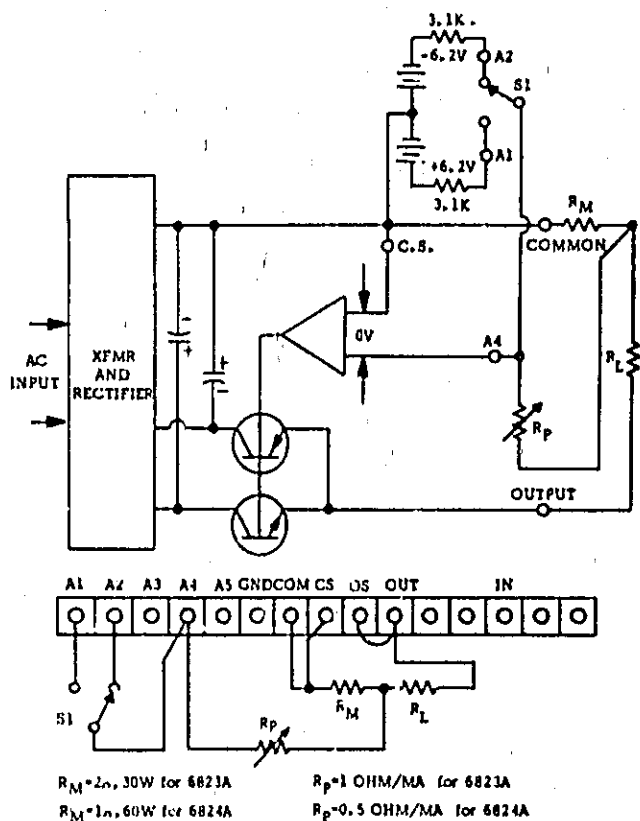


Figure 3-18. Remote Resistance Programming, Bipolar Output (CC)

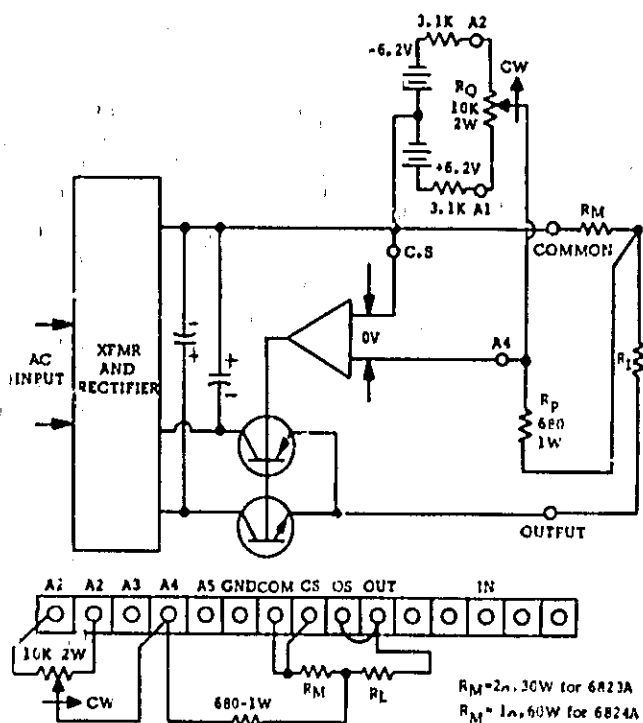


Figure 3-19. Switchless Bipolar Programming (CC)

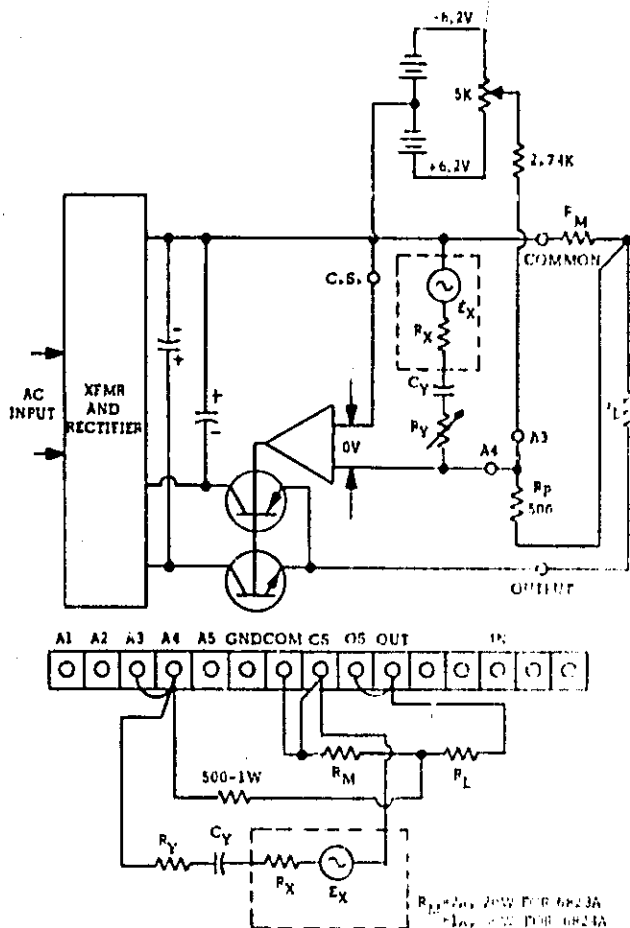


Figure 3-20. CC Power Supply With Superimposed AC Output

3-80 The peak voltage  $E_X$  which is necessary to achieve a peak output current equal to the maximum rating of the instrument, equals  $(R_X + R_Y) / R_P$ . The capacitor  $C_Y$  is added to block the DC current path through the oscillator.  $C_Y$  must be selected large enough to pass the lowest frequency of interest; the low frequency 3 db down point will be at

$$f = \frac{1}{2\pi (R_X + R_Y) C_Y}$$

where  $R_X$  is the internal (Thevenin equivalent) source resistance. Of course, capacitor  $C_Y$  is not employed if it is desired for the Constant Current output to respond to the DC component of the external signal source.

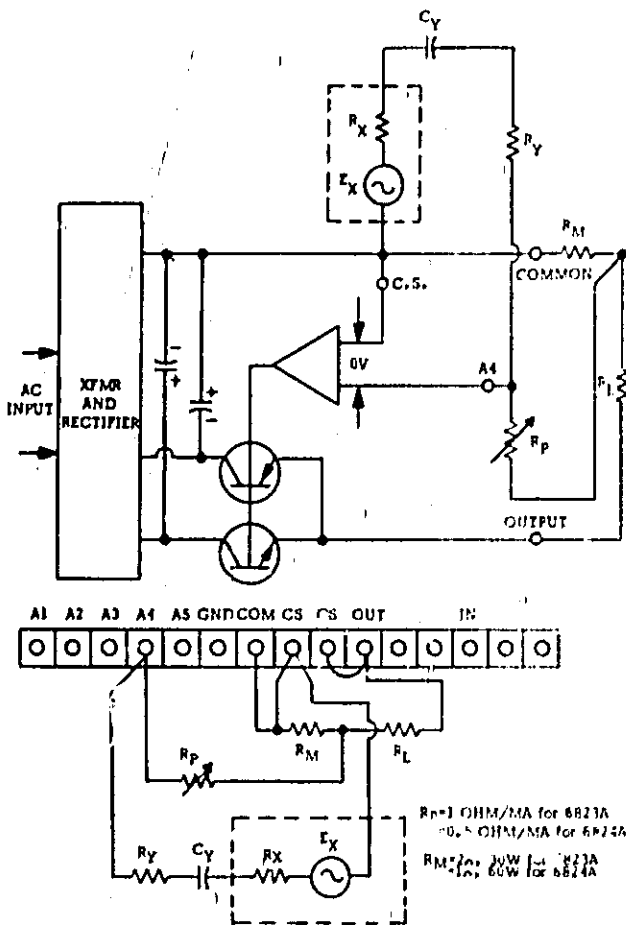


Figure 3-21. CC Amplifier With Linear Remote Gain Control

### 3-81 CONSTANT CURRENT AMPLIFIER WITH REMOTE GAIN CONTROL

3-82 Figure 3-21 shows the method of connecting an external voltage source with a PS/A to obtain Constant Current output with linear remote gain control. Using the recommended values for  $R_S$ , the output current is given by:

$$I_O = (E_X / R_M) \cdot R_P / (R_X + R_Y)$$

It is recommended that  $R_Y$  be selected so that at the peak input voltage  $E_X$  the current flowing through  $R_X$ ,  $R_Y$ , and  $R_P$  is 2 MA. With this choice,  $R_P = 500$  ohms results in an output current equal to the maximum rating of the instrument.

3-83  $C_Y$  is chosen large enough to pass the lowest frequency of interest and is omitted if it is desired to have the output current responsive to the DC (as well as AC) component of the input voltage  $E_X$ .

3-84 Care should be taken that  $R_Y$  is chosen to be more than the minimum load resistance which the external signal source can feed without overload or distortion. However,  $R_Y$  should not be chosen too large, or the current flowing through  $R_P$  will be influenced by the current into the comparison amplifier. Thus it is undesirable to select  $R_Y$  so that the current flowing through it with full input signal is less than 1 MA.

3-85 Current Input. The combination of components  $E_X$ ,  $R_X$ , and  $R_Y$  can always be replaced by a Constant Current source. If this is done, the current gain of the configuration of Figure 3-21 is:

$$\frac{I_{OUT}}{I_{IN}} = \frac{R_P}{R_M}$$

3-86 Two or More Inputs. If desired, the circuit of Figure 3-22 can be used to add the effect of two or more signals. All the equations given in this section hold true for each of the multiple inputs, with no interaction.

$$I_O = \frac{E_X}{R_M} \frac{R_P}{R_X + R_Y} + \frac{E_X'}{R_M} \frac{R_P}{R_X' + R_Y'} + \dots$$

### 3-87 SERIES AND PARALLEL OPERATING MODES

3-88 The following paragraphs include methods for combining separate PS/A's in series and parallel combinations. These methods are employed whenever it is required to extend the voltage or current capability beyond that available from one instrument alone. In all of the following diagrams the strapping pattern and circuit configuration for slave units have been shown in complete detail. In several of the diagrams, however, the strapping pattern and circuit configuration have not been completed for the Master unit. This was done because the configuration chosen for the Master is determined by the manner in which it is desired for the ensemble of units to operate, and may be selected from any of the diagrams already given in this Section. Whether a combination acts as a power supply or amplifier, Constant Voltage or Constant Current source, locally or remotely controlled by resistance, voltage, or current, depends entirely on the connection mode selected for the Master Unit.



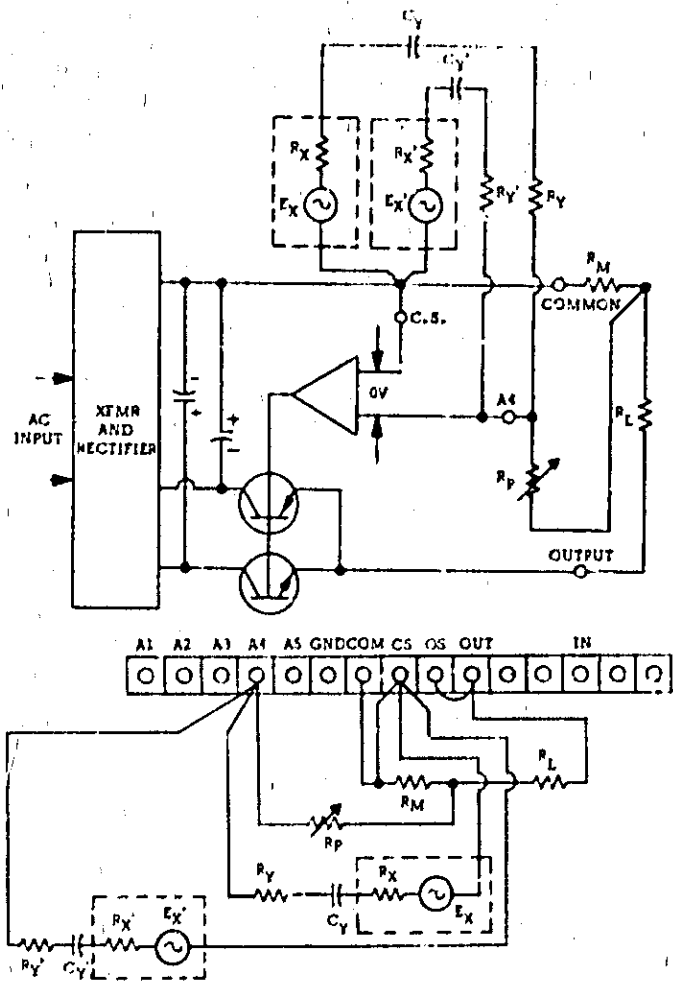


Figure 3-22. CC Amplifier With Two Inputs

3-89 Any PS/A instrument may be master or slave, depending only on the strapping pattern chosen. Units may be connected in series up to 300V off ground. They need not be the same model number, but should all be PS/A Series instruments. Similarly, units may be connected in parallel, without any limit, except that all instruments must be

PS/A Series and employ an external sampling resistor which develops a 1 volt drop.

### 3-90 COORDINATED SERIES OPERATION

3-91 Auto-Series, Two Units, Single Ended Output. To increase the voltage output, two units can be connected in Auto-Series as shown on Figure 3-23. The front panel switch position of the slave is not significant, but the front panel position and barrier strip wiring of the master unit depends upon the operating mode desired for the system of two power supplies, and should be selected from one of the previous alternatives.

3-92 For instantaneous equal voltage sharing,  $R_1$  and  $R_2$  must be equal. However, if it is desired for the slave to have a voltage, which although always proportional to the output of the master supply, is greater than or less than the output of the master supply, then  $R_2$  should be selected according to the relation  $E_S = E_M (R_2/R_1)$  where  $E_S$  and  $E_M$  are the output voltage of the Slave and Master instruments respectively.

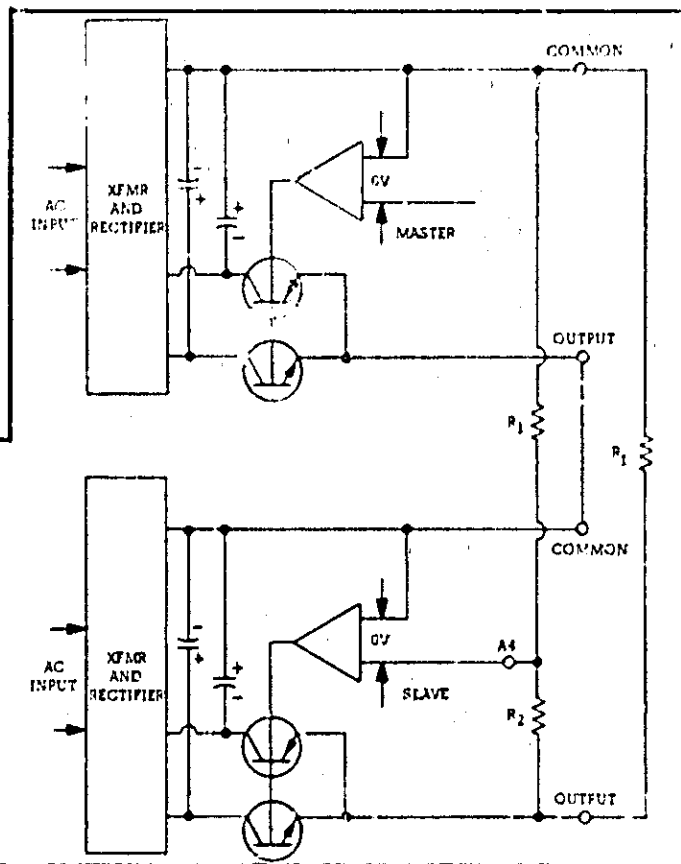
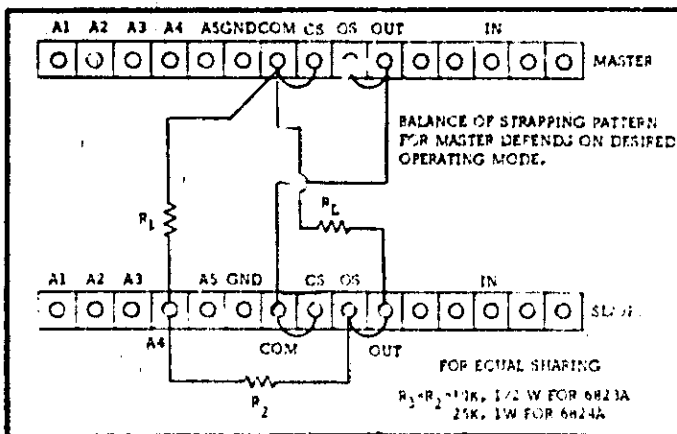


Figure 3-23. Auto-Series Operation, Two Units



3-93 Auto-Series, Three or More Units. The concept of the previous paragraphs is easily extended to three supplies as shown in Figure 3-24. If un-

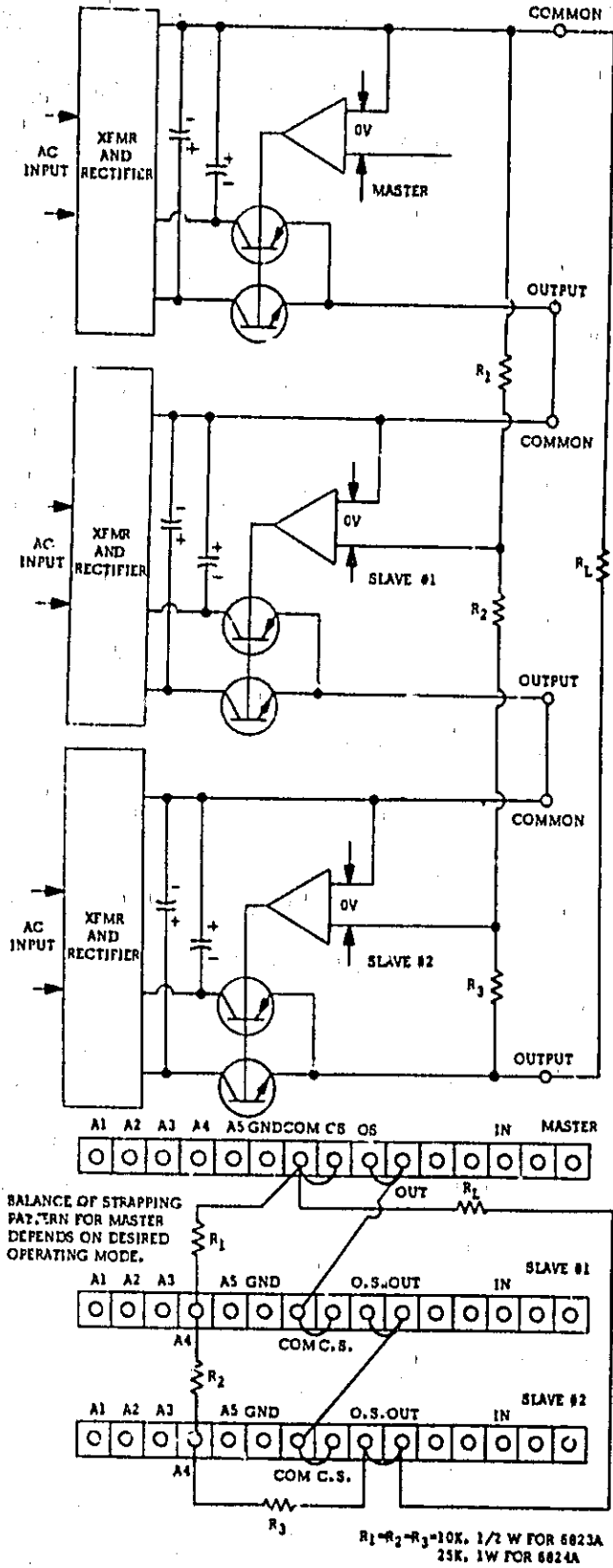


Figure 3-24. Auto-Series Operation, Two Units

equal voltage contributions are desired, the output of Slave #1 is given by  $E_{S1} = E_M (R_2/R_1)$ ; for Slave #2,  $E_{S2} = E_M (R_3/R_1)$ .

3-94 The concept of Figure 3-24 is easily extended to series combinations involving more than three units by merely iterating that portion of the circuit configuration which is bounded by the two horizontal dotted lines.

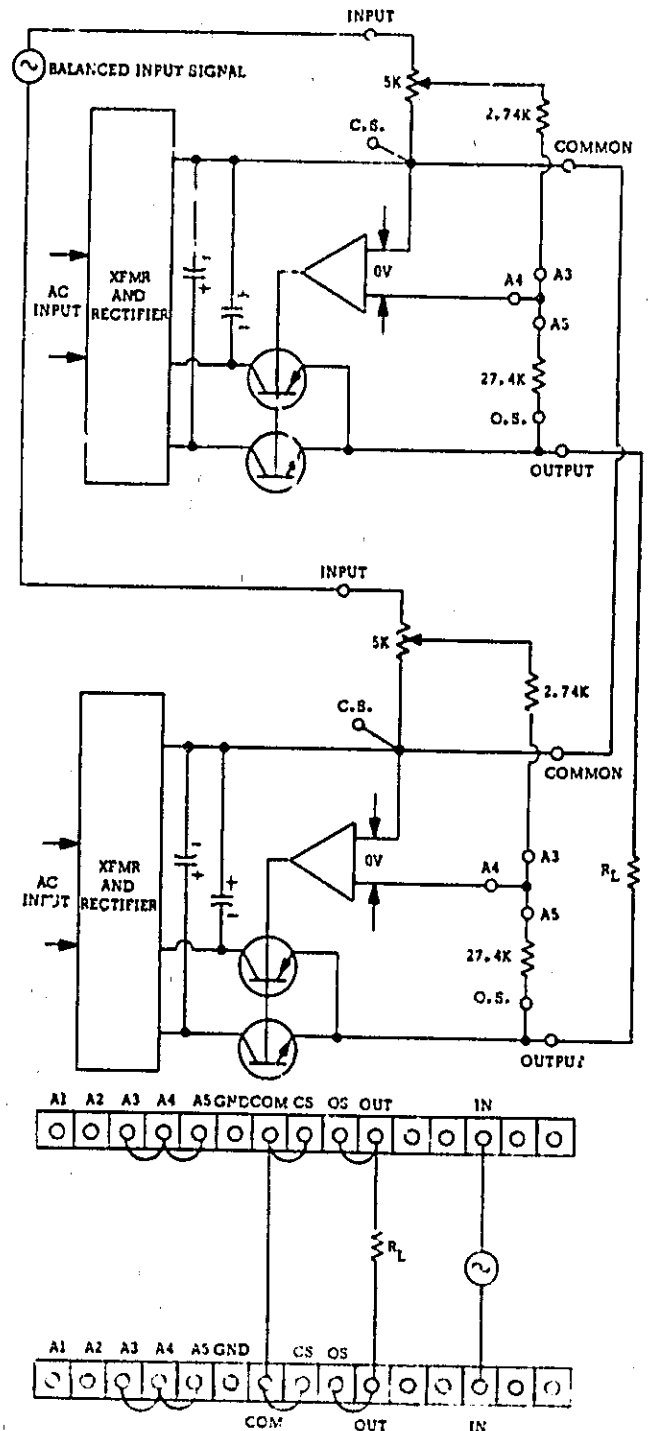


Figure 3-25. Balanced Input/Output Series Operation, Two Units

3-95 Series Operation, Balanced Output. The previous Auto-Series configurations are accomplished with single-ended input and single ended output having a common terminal. In some applications, however, it is necessary to employ an amplifier with input and output signals balanced about ground. Figure 3-25 shows the circuit configuration and strapping pattern for this mode of operation.

3-96 Since this mode is more likely to be employed as an amplifier rather than as a power supply, the diagram shows an oscillator input. The voltage input to this circuit must be at least 1/10th the desired voltage output; the input impedance seen by the oscillator is approximately 3.4K.

3-97 The balanced input concept can be extended to even higher voltages if voltage Slaves are added to each side. Figure 3-26 shows this configuration, which has an output voltage capability four times that of one unit alone, as well as a balanced input and a balanced output. The input oscillator must have a voltage capability of at least 1/20th of the output voltage desired, and faces an input impedance of 3.4K.

3-98 AUTO PARALLEL OPERATION

3-99 Constant Voltage Output. Figure 3-27 shows the correct method of connecting two PS/A's in parallel for increased output current in Constant Voltage operation. Although the terminal configuration has been completed for the Slave unit, the remainder of the connections to the Master unit are dependent upon desired operating mode. Thus the Master can be connected in any of the patterns shown in Section III, and the Auto-Parallel system will behave accordingly.

3-100 For equal current sharing, the leads from common to  $R_M$  and  $R_M$  to  $R_L$  should be short and have equal resistance for the two supplies. Greater current capability can be obtained by connecting more Slaves to the Master unit.

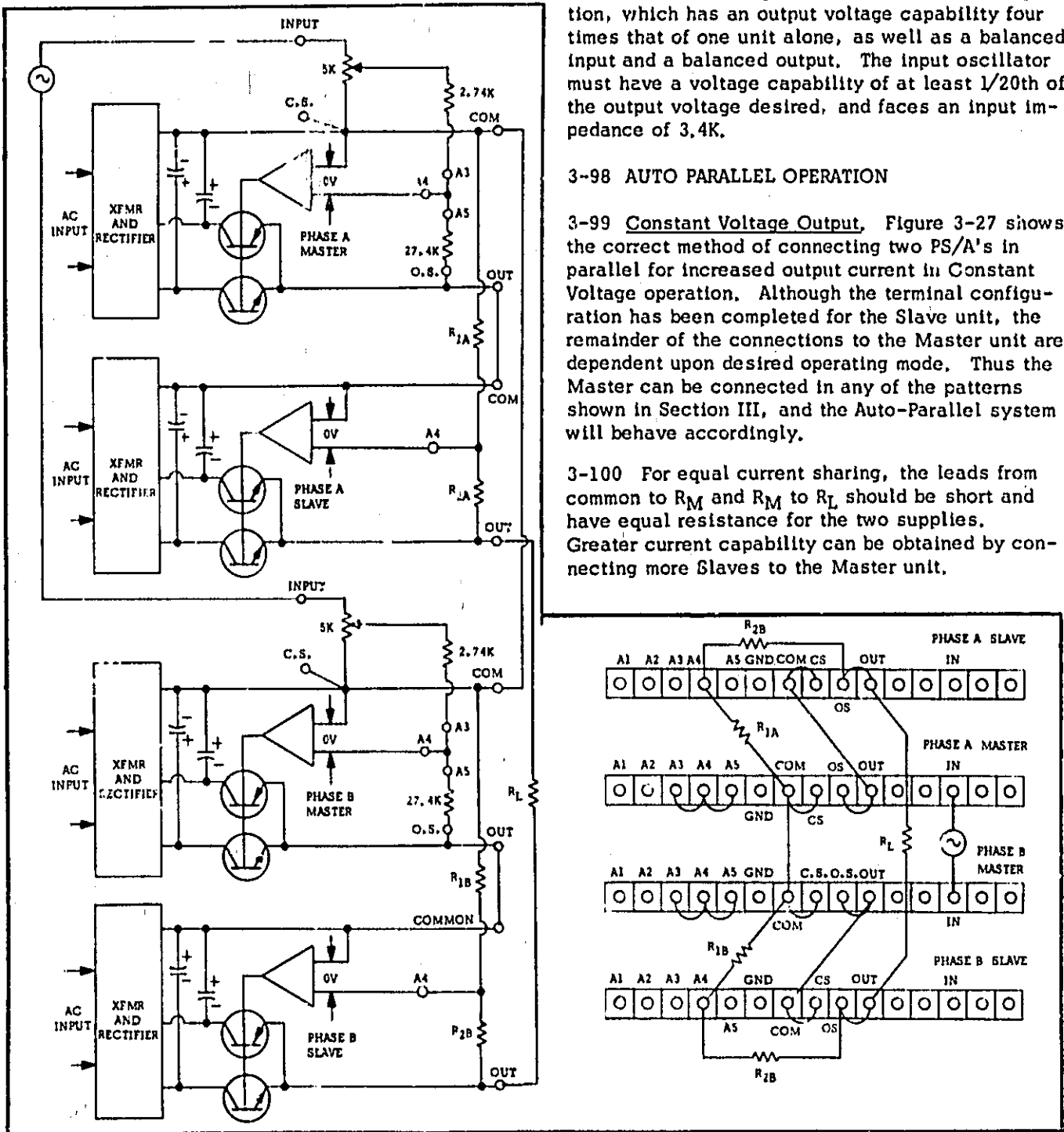


Figure 3-26. Balanced Input/Output Series Operation, Four Units

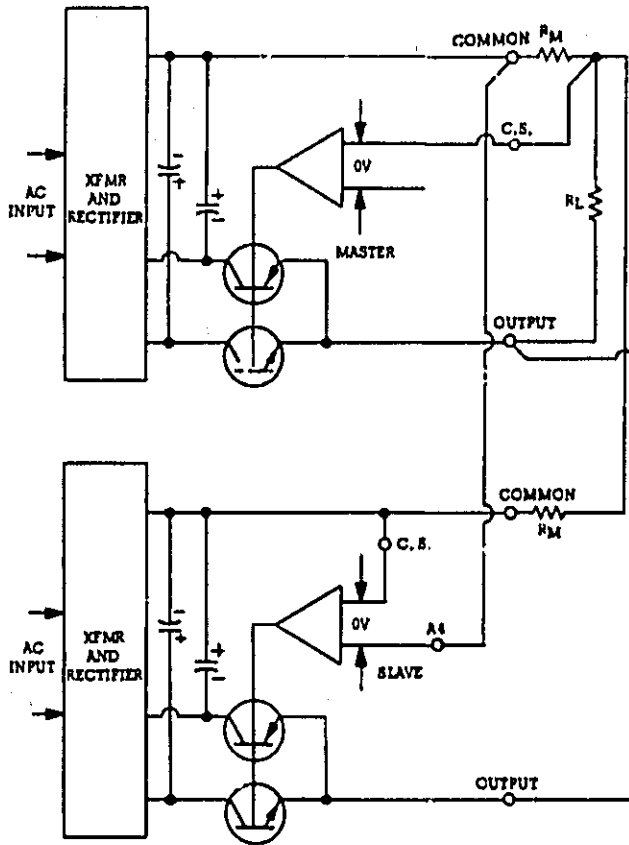


Figure 3-27. Auto-Parallel Operation, Constant Voltage Output

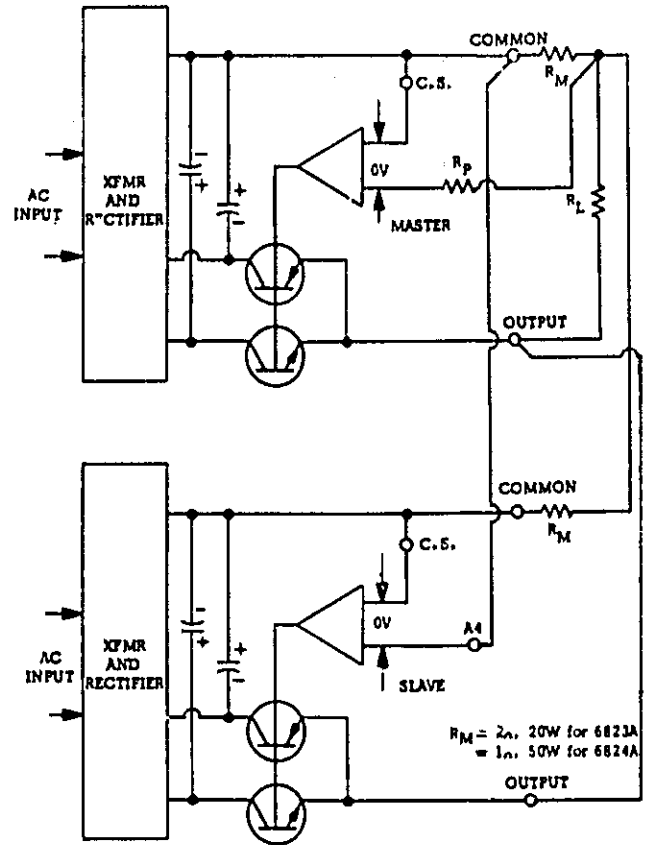
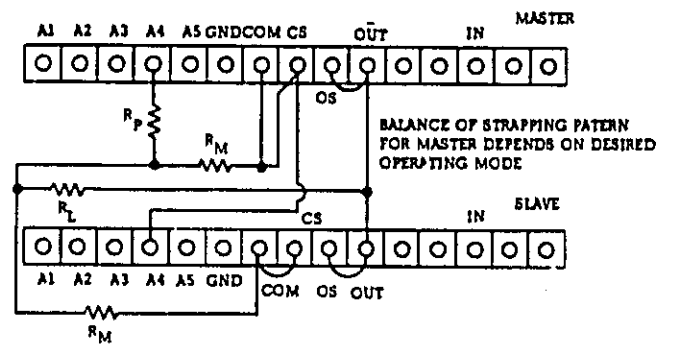
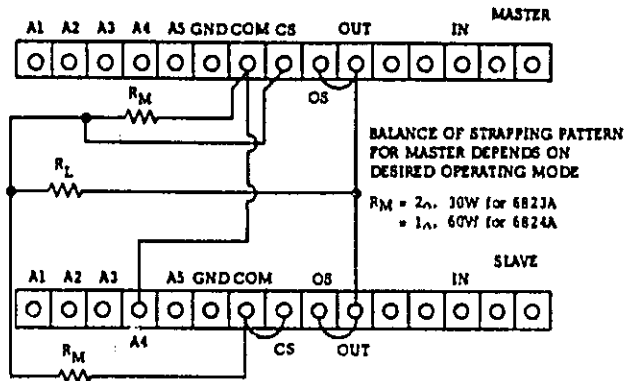


Figure 3-28. Auto-Parallel Operation, Constant Current Output



3-101 **Constant Current Output.** Figure 3-28 shows the correct method of connecting two supplies in Auto-Parallel for Constant Current output. The strapping configuration and circuit diagram for the master unit are not complete but can be wired

in accordance with any of the diagrams given in Section III and the Auto-Parallel combination will behave accordingly. Still greater current output can be accomplished by adding any desired number of slaves to the master in the same way.

## SECTION IV PRINCIPLES OF OPERATION

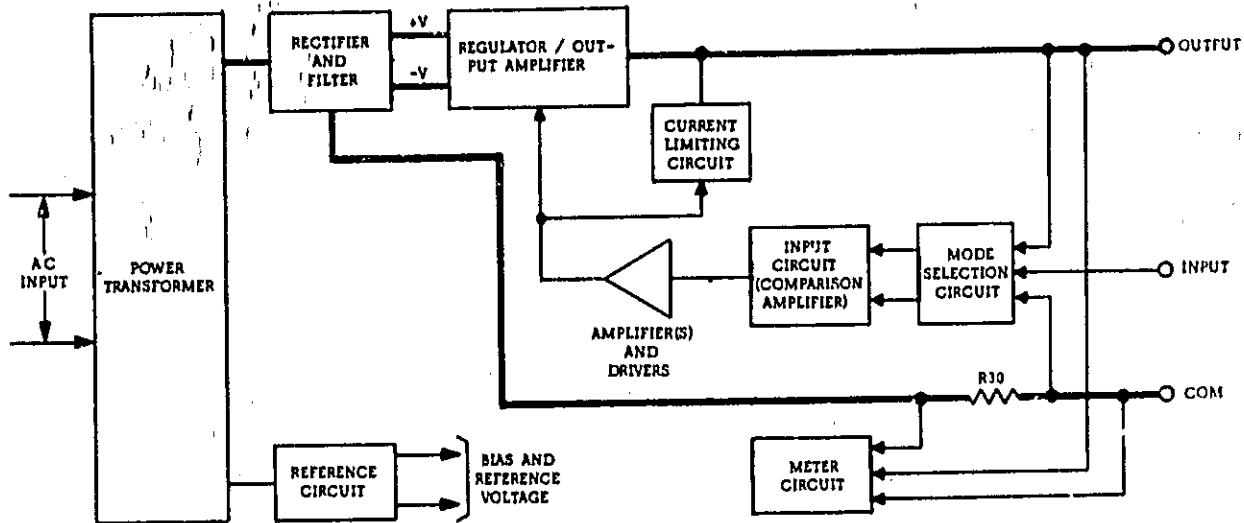


Figure 4-1. Overall Block Diagram

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

4-2 The Power Supply/Amplifier (PS/A) can be operated as either a power supply or a power amplifier. The operating mode is determined by the mode selection circuit which couples to the input circuit; either the voltage across the output terminals (during power supply operation) or the voltage across the input terminals (during amplifier operation).

### 4-3 POWER SUPPLY OPERATION

4-4 During power supply operation, the PS/A functions as a well-regulated dc power supply capable of furnishing a bi-polar, Constant Voltage output. Constant Current operation can also be achieved by connecting an external current sampling resistor to the unit.

4-5 The ac line voltage is reduced to the proper level by the power transformer and coupled to the rectifier and filter. The rectifier-filter converts the ac input to raw dc which is fed to the regulator/output amplifier circuit in both positive and negative form. The regulator/output amplifier acts as a series regulator during power supply operation. Its conduction is altered in accordance with the feedback control signals received from the driver

amplifiers, thus maintaining the output voltage (or current) constant. The feedback control signals also determine the polarity of the output voltage. For positive power supply output voltages the regulator circuit receives a positive input and for negative output voltages it receives a negative input. Hence, the dc output voltage can be continuously adjusted from its maximum rated positive value to an equal negative value.

4-6 The current limiting circuit monitors the output current passing through the regulator. If this current exceeds a certain preset limit, the limiting circuit conducts, shunting input current away from the regulator and thus keeping the output current constant.

4-7 The input circuit serves as the first "link" in the feedback circuit. It detects any changes in the output voltage and sends a feedback control signal to the series regulator via the amplifier-drivers. The feedback signal is of the correct phase and amplitude to counteract the change in output voltage. Notice that the supply can also be used as a Constant Current source as outlined in Section III of this manual. Under these conditions, the input circuit monitors the voltage dropped across an externally connected current sampling resistor and, in this manner develops the feedback error signals necessary to maintain the output current constant.

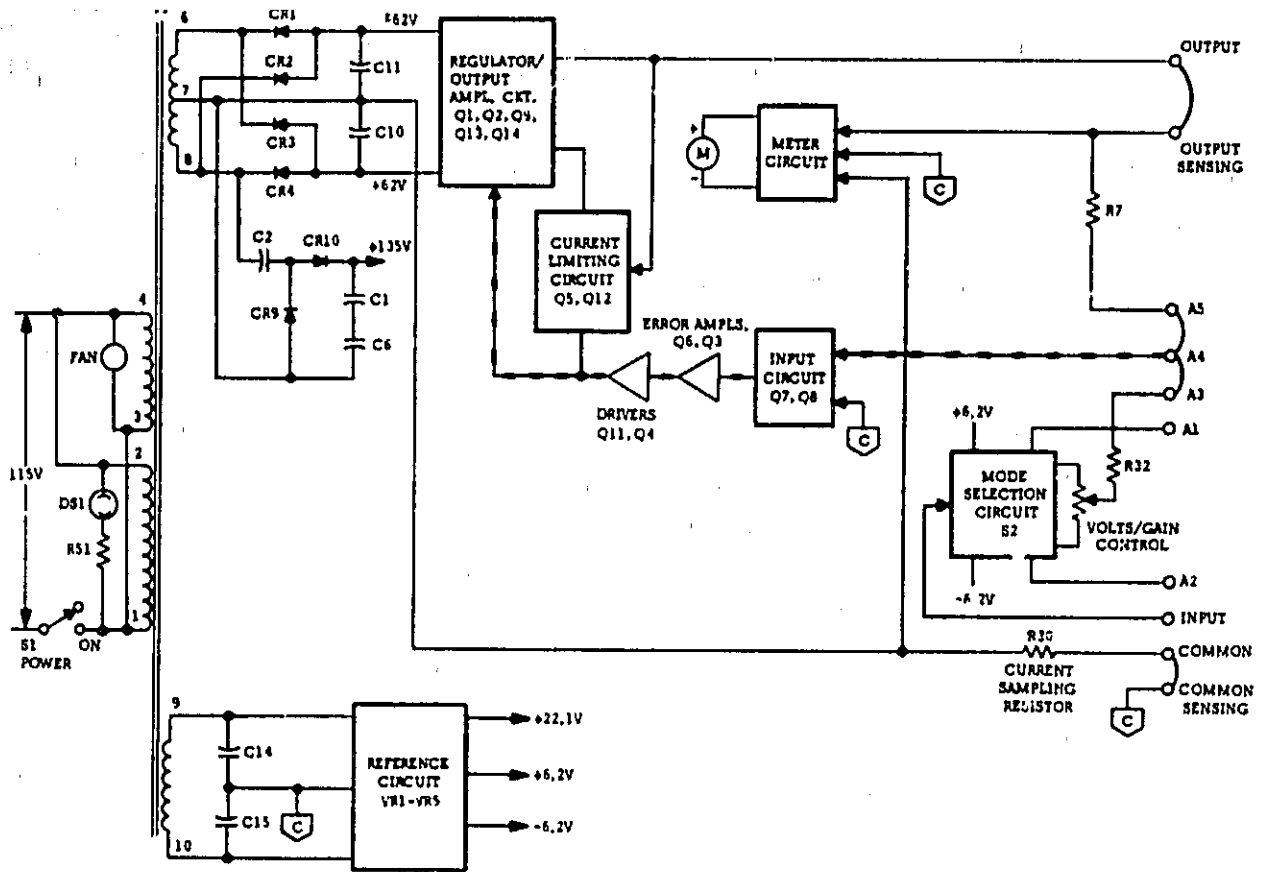


Figure 4-2. Simplified Schematic

4-8. The reference circuit provides stable reference voltages which are used throughout the unit for biasing and comparison purposes. The meter circuit provides indications of dc output voltage or current. When measuring voltage it is connected across the output of the supply; when measuring current it is connected across an internal current sampling resistor, R30.

#### 4-9 AMPLIFIER OPERATION

4-10 During amplifier operation, the unit acts as a power amplifier with a single-ended, push-pull output stage. It furnishes either a Constant Voltage output or a Constant Current output (with the addition of an external current sampling resistor). It is capable of amplifying both ac and dc input signals over a bandwidth of dc to 20 kHz.

4-11 Input signals are received from the external source via the input and common terminals. The input circuit and amplifier-drivers amplify the signal and forward it to the regulator/output amplifier circuit. This circuit functions as a push-pull output amplifier during amplifier operation, although note that no internal connections are necessary in the regulator/output amplifier circuit in order to accomplish this.

4-12 The current limiting circuit is operable in the amplifier mode and serves to protect both the amplifier and the load by preventing the output current from exceeding the preset current limit.

4-13 In a manner similar to that used during power supply operation, the input circuit generates the error signals necessary to keep the output voltage (or current) constant despite variations in the load or line circuits. The meter circuit for Model 6824A units is capable of indicating ac output voltage during amplifier operation, while Model 6823A meter circuits can measure dc output voltage only.

#### 4-14 SIMPLIFIED SCHEMATIC

4-15 A simplified schematic of the PS/A is shown in Figure 4-2. It shows the internal sources of bias and reference voltages and their nominal magnitudes with an input of 115Vac and under full load. It also shows some of the operating controls; the off-ON pushbutton (S1) and the VOLTS/GAIN control (R52A). METER switch S3, included in the meter circuit block on Figure 4-2, permits the meter to read dc output voltage or current, or ac output voltage. Rectifier diodes CR1 through CR4, and filter capacitors C10 and C11 provide

+62Vdc and -62Vdc to the regulator/output amplifier circuit. These voltages are also fed to the error amplifiers and drivers for biasing purposes. Another bias voltage (+140V) is obtained from a voltage doubler network composed of CR9, CR10, C1, C2, and C6.

4-15 MODE switch S2, in the mode selection circuit, connects the VOLTS/GAIN potentiometer between a bi-polar reference source (+6.2V and -6.2V) during power supply operation, or across the external input signal path during amplifier operation. Hence, the position of the VOLTS/GAIN potentiometer determines the polarity and magnitude of the output voltage in the power supply mode or the gain of the PS/A in the amplifier mode.

4-17 Note that the PS/A does not have the large output capacitor connected across most power supplies to insure feedback loop stability. This capacitor has been removed to ease the bandwidth limitation during amplifier operation. Removal of the output capacitor has the additional advantage of greatly enhancing the programming speed during power supply operation. Alternate methods of insuring feedback loop stability are employed throughout the PS/A feedback circuit to offset the absence of this capacitor.

4-18 DETAILED CIRCUIT ANALYSIS (See schematic at rear)

#### 4-19 INPUT CIRCUIT

4-20 The input circuit consists basically of a differential amplifier stage (Q7 and Q8), and the FINE/ZERO and VOLTS/GAIN controls (R52A and R52B). Note that for simplicity's sake, R52A has been included in the mode selection circuit on the schematic.

4-21 The input circuit controls the conduction of the series regulator/output amplifier transistors. To accomplish this, the circuit continuously compares a fraction of the output voltage (or current) with a fixed reference 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 regulator/output amplifier, via the error and driver amplifiers. The feedback voltage alters the conduction of the regulator/output amplifier transistors which, in turn, alter the output voltage (or current) so that the difference between the two differential amplifier input voltages is reduced to zero. The above action not only maintains a constant output regardless of line or load variations; but establishes output levels in accordance with the setting of the VOLTS/GAIN control.

4-22 Stage Q7 of the differential amplifier is connected to a voltage divider consisting of R40, R52B, R47, and R48. The FINE/ZERO control, R52B, permits the bias at the base of Q7 to be adjusted slightly above or below the common sensing (C) point. During power supply operation the FINE/ZERO control provides a fine adjustment of the dc output voltage or current and during amplifier operation it provides a dc "offset" adjustment of approximately 1% of the maximum rated output. Hence, the average value of an ac output signal can be adjusted exactly to zero with this control.

4-23 Stage Q8 is connected to the voltage (or current) summing point (A4) at the junction of the VOLTS/GAIN control and resistor R7. The potential at the summing point will instantaneously change if the output voltage/current attempts to change or if the voltage that is picked off by R52A changes. Output variations affect the voltage dropped across R7 thus changing the summing point potential. Similarly, moving the VOLTS/GAIN control arm affects the summing point potential. During power supply operation, this control is connected across a bi-polar reference source. Moving the control toward the positive end of the potentiometer causes the summing point to go positive resulting in a more negative output. Conversely, moving the control toward the negative end results in a more positive output. During amplifier operation the external input signal is applied across R52A and moving the control arm varies the amount of signal that is picked off.

4-24 Summing point variations are felt at the base of the Q8 which varies its conduction in accordance with the polarity and magnitude of the change at the summing point. The resulting error voltage is taken from the collector of Q8 and ultimately alters the conduction of the regulator/amplifier transistors.

4-25 Feedback network C8, R25 helps stabilize the feedback loop. Diodes CR25 through CR28 form a limiting network which prevent excessive voltage excursions from over-driving stage Q8. Resistor R45 in series with the base of Q8 is a current limiting resistor.

#### 4-26 MODE SELECTION CIRCUIT

4-27 The mode selection circuit consists basically of MODE switch S2 which determines the operating mode of the instrument. As mentioned previously, S2 connects the VOLTS/GAIN control between a bi-polar reference source in the SUPPLY position and across the input signal path in the AMPLIFIER position. In the AMPLIFIER position S2 also connects a load resistor (R57) between the bi-polar reference voltages to prevent loading down the reference circuit.

#### 4-28 ERROR AND DRIVER AMPLIFIERS

4-29 The error and driver amplifiers amplify the error signal from the input circuit to a level sufficient to drive the regulator/amplifier transistors. Amplifier stages Q6 and Q3 each contain a stabilization network (C5-R24 and C7-R14, respectively) which provides for roll off in the loop gain. Diode CR11 clamps the emitter of Q6 to a stable reference voltage, +22.1V. Emitter follower Q4 drives the regulator/amplifier transistors Q1, Q2, Q9, Q13, and Q14.

#### 4-30 REGULATOR/OUTPUT AMPLIFIER CIRCUIT

4-31 During power supply operation, transistors Q1, Q9 and Q2, Q13, Q14 serve as series control elements in the positive and negative output lines, respectively. The conduction of the series transistors is controlled by the feedback voltage from Q4. Note that when the feedback voltage is negative, PNP transistors Q2, Q13 and Q14 are conducting and NPN transistors Q1 and Q9 are cut-off. Under these conditions, the supply furnishes a negative output voltage. The reverse is true when the feedback voltage is of positive polarity. Transistor Q10 furnishes a constant bias current to the bases of the series transistors. At zero volts output, both banks of series transistors are conducting slightly because of the base current provided by Q10. Diodes CR18 and CR19 provide the voltage drop necessary to forward bias each regulator bank simultaneously. This eliminates any "dead spots" when the output voltage is programmed away from zero. Note, however, that as soon as the output voltage is driven away from zero, one bank of transistors remains in conduction while the other is cutoff.

4-32 During amplifier operation, the transistors serve as a single-ended, push-pull, output amplifier. Although the schematic at the rear of the manual shows Q1, Q2, Q9, Q13, and Q14 drawn as a conventional series regulator, a closer inspection will reveal that the circuit could be redrawn as a push-pull amplifier without changing any of the connections. The output amplifiers are biased for class AB operation and connected in a complementary configuration, as described in the previous paragraph, thus obviating the need for center-tapped input and output transformers.

#### 4-33 CURRENT LIMITING CIRCUIT

4-34 The current limiting circuit consists of transistors Q5 and Q12 and associated resistors.

These transistors keep the output current from exceeding the current limit established by the setting of potentiometers R5 and R6. PNP transistor Q5 limits the current in the negative line and NPN transistor Q12 limits the current in the positive line. Under increased current demands, the current through the PNP regulator/amplifier transistors increases, increasing the voltage drop across R6 and driving the base of Q5 in a negative direction. The conduction of Q5 limits the base current of the PNP transistors and, hence, the output current. Operation of current limiting transistor Q12 is similar; except that the base current of the NPN transistors is limited further back in the feedback loop at the input of Q4.

#### 4-35 REFERENCE CIRCUIT

4-36 The reference circuit is an auxiliary supply which provides stable reference voltages used throughout the instrument for biasing and comparison purposes. The reference voltages are developed across temperature compensated Zener diodes VR1 through VR5. The reference voltages are all derived from smoothed positive and negative dc obtained from full wave rectifiers CR5, CR6 and CR7, CR8 and filter capacitors C12 and C13.

#### 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 a dc voltmeter or ammeter or as an ac voltmeter depending upon the position of METER switch S3. With S3 in the dc VOLTS position the meter is connected in series with R31 and R33 across the output of the supply. Resistor R31 permits dc voltage calibration of the meter to compensate for slight resistance variations.

4-39 With S3 in the DC AMPS position, the meter is connected across current sampling resistor R30, whose voltage drops varies in proportion to the output current. Current calibrate potentiometer, R35 is adjusted for full scale deflection in the current range.

4-40 In the AC VOLTS position, the meter indicates the rms output voltage of the amplifier. Rectification of the ac output voltage is accomplished by diodes CR13 through CR16.

4-41 The meter movement used in this instrument, can withstand a current overload of many times the maximum rated output without damage.



# MAINTENANCE

## SECTION V MAINTENANCE

### 5-1 INTRODUCTION

5-2 Upon receipt of this instrument, the performance check (Paragraph 5-10) should be made. This check is suitable for incoming inspection. If a fault is detected in the unit while making the performance check or during normal operation, proceed to the troubleshooting procedures (Paragraph 5-24). After troubleshooting and repair (Paragraph 5-34), perform any necessary adjustments and calibrations (Paragraph 5-36). Before returning the PS/A 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 5-3).

### 5-3 GENERAL MEASUREMENT TECHNIQUES

5-4 The measuring device must be connected across the sensing leads of the unit or as close to the output terminals as possible when measuring the output impedance, transient response, regulation, or ripple of the power supply in order to achieve valid measurements. A measurement made across the load includes the impedance of the leads to the load and such lead lengths can easily have an impedance several orders of magnitude greater than the supply impedance, thus invalidating the measurement.

5-5 The monitoring device should be connected to the OS and CS terminals or as shown in Figure 5-1. The performance characteristics should never be measured at the front terminals if the load is connected across the rear terminals. Note that when measurements are made at the front terminals, the monitoring leads are connected at A, not B; as shown in Figure 5-1. Failure to

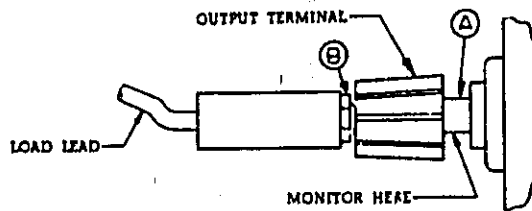


Figure 5-1. Front Panel Terminal Connections

connect the measuring device at A will result in a measurement that includes the resistance of the leads between the output terminals and the point of connection.

5-6 For output current measurements, the current sampling resistor should be a four-terminal resistor. The four terminals are connected as shown in Figure 3-15. In addition, the resistor should be of the low noise, low temperature coefficient (20ppm/°C or less) type and should be used at no more than 5% of its rated power so that its temperature rise will be minimized.

5-7 When using an oscilloscope, ground the common terminal of the PS/A and then ground the case of the oscilloscope to this same point. Make certain that the case is not also grounded by some other means (such as the power line). Connect both oscilloscope input leads to the PS/A ground terminal and check that the oscilloscope is not exhibiting a ripple or transient due to ground loops, pick-up, or other means.

### 5-8 TEST EQUIPMENT REQUIRED

5-9 Table 5-1 lists the test equipment required to perform the various procedures described in this Section.

Table 5-1. Test Equipment Required

| Type                         | Required Characteristics  | Use   | Recommended Model            |
|------------------------------|---|---|------------------------------|
| Differential Voltmeter       | Sensitivity: 1 mv full scale (min.), Input impedance: 10 megohms (min.),        | Measure DC voltages; calibration procedures   | Ⓢ 3420 (See Note)            |
| Variable Voltage Transformer | Range: 90-130 volts. Equipped with voltmeter accurate within 1 volt.            | Vary AC Input                                 | -----                        |
| AC Voltmeter                 | Accuracy: 2%. Sensitivity: 1 mv full scale deflection (min.),                   | Measure AC voltages and ripple.               | Ⓢ 403 B                      |
| Oscilloscope                 | Sensitivity: 10 $\mu$ v/cm. Differential input.                                 | Peak-to-peak measurements. Waveform displays. | Ⓢ 140 A plus 1400 A plug in. |
| Oscillator                   | Range: 5 Hz to 600KHz<br>Accuracy: 2%   | Impedance Checks, amplifier input source      | Ⓢ 200 CD                     |
| Square Wave Generator        | Rise time: 0.02 $\mu$ sec<br>Frequency: 1 Hz to 1 MHz                           | Measure programming speed                     | Ⓢ 211 A                      |
| Repetitive Load Switch       | Rate: 50-400 Hz, 2 $\mu$ sec rise and fall time.                                | Measure transient response                    | See Figure 5-5               |
| Resistor                     | Value: See Paragraph 5-13 and Figure 5-3, $\pm$ 5%, 75 watts                    | Load Resistor                                 | -----                        |
| Resistor                     | Value: See Figure 5-3. 1%, 30 watts (6823A) 60 watts (6824A) 20ppm, 4-Terminal. | Current sampling                              | -----                        |
| Resistor                     | 1 K $\Omega$ $\pm$ 1%, 2 watt non-inductive                                     | Measure impedance                             | -----                        |
| Resistor                     | 100 ohms, $\pm$ 5%, 10 watt   | Measure impedance                             | -----                        |
| Capacitor                    | 500 $\mu$ f, 50 wvdc  | Measure impedance                             | -----                        |

## 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 50 mv meter movement with a 100 division scale. For the latter, a 2 mv change in voltage will result in a meter deflection of four divisions.

## 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.

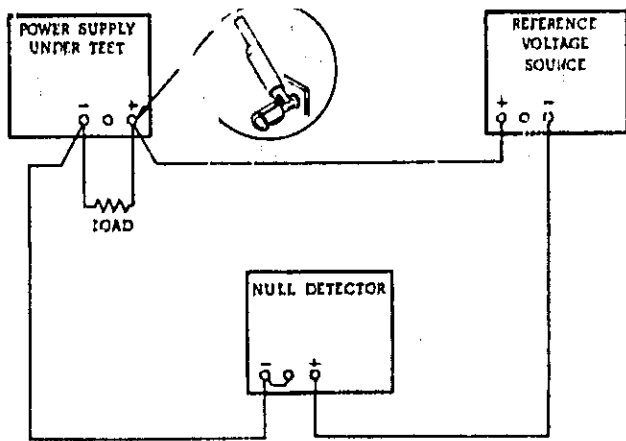


Figure 5-2. Differential Voltmeter Substitute, Test Setup

### 5-10 PERFORMANCE TEST

5-11 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 maintenance tests. The tests are performed using a 115-VAC 60 Hz, single phase input power source. They test the performance of the unit both as a power supply and as a power amplifier. If the correct result is not obtained for a particular check, do not adjust any controls; proceed to troubleshooting (Paragraph 5-24).

### 5-12 POWER SUPPLY TESTS

5-13 Rated Output and Meter Accuracy. To check the output voltage, proceed as follows:

- a. Connect 40 ohm load resistor (50 ohms for Model 6824A) across rear output terminals of supply.
- b. Connect differential voltmeter across OS and CS terminals of supply observing correct polarity.
- c. Set METER switch to VOLTS and MODE switch to SUPPLY.
- d. Adjust VOLTS/GAIN control clockwise (cw) until front panel meter indicates exactly the maximum rated positive output voltage.
- e. Differential voltmeter should indicate maximum rated positive output voltage within  $\pm 2\%$ .
- f. Adjust VOLTS/GAIN control in ccw direction until front panel meter reads maximum rated negative output voltage.

g. Reverse position of input polarity switch on differential voltmeter. Voltmeter should indicate maximum rated negative output voltage within  $\pm 2\%$ .

5-14 To check the output current, proceed as follows:

- a. Connect test setup shown in Figure 5-3.

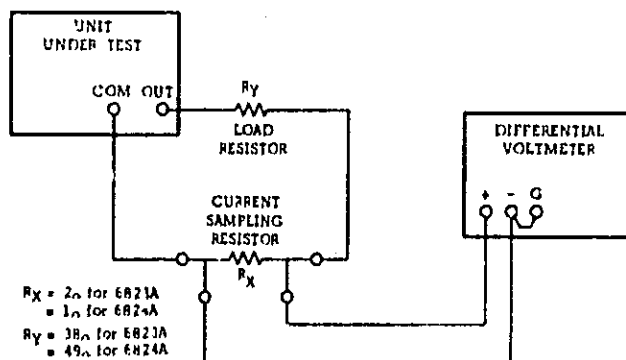


Figure 5-3. Output Current, Test Setup

- b. Set METER switch to AMPS.
- c. Turn on supply and adjust VOLTS/GAIN control cw until front panel meter indicates exactly maximum rated positive current.
- d. Differential voltmeter should read  $1 \pm 0.02$  Vdc.
- e. Reverse polarity switch on differential voltmeter and adjust VOLTS/GAIN control ccw for maximum rated negative current.
- f. Differential voltmeter should again read  $1 \pm 0.02$  Vdc.

5-15 Load Regulation. To check the Constant Voltage load regulation, proceed as follows:

- a. Connect test setup as shown in Figure 5-4.
- b. Set METER switch to VOLTS.
- c. Turn on supply and adjust VOLTS/GAIN control cw until front panel meter indicates maximum rated positive output voltage.
- d. Read and record voltage indicated on differential voltmeter.
- e. Disconnect load resistor.

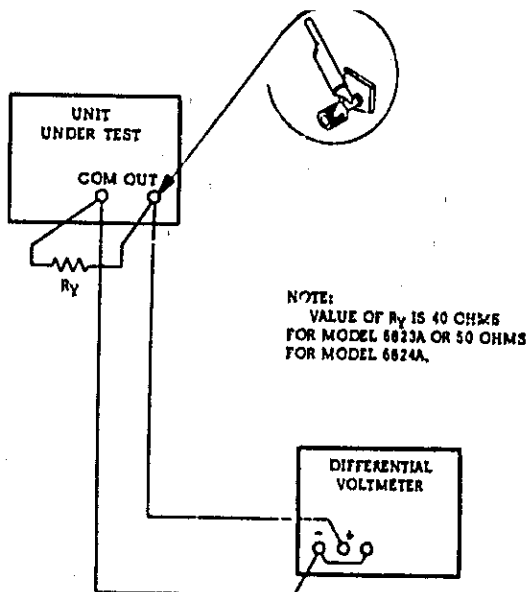


Figure 5-4. Load Regulation, Test Setup

f. Reading on differential voltmeter should not vary from reading recorded in step d by more than 9 mVdc for Model 6823A or 15 mVdc for Model 6824A.

g. Set input polarity switch to appropriate position. Rotate VOLTS/GAIN control ccw and repeat steps c through f for maximum rated negative output voltage.

5-16 Line Regulation. To check the Constant Voltage line regulation, proceed as follows:

a. Connect variable auto transformer between input power source and PS/A power input.

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

c. Adjust variable auto transformer for 105 or 210 Vac input.

d. Turn on supply and rotate VOLTS/GAIN control cw until front panel meter indicates exactly the maximum rated positive output voltage.

e. Read and record voltage indicated on differential voltmeter.

f. Adjust variable auto transformer for 125 or 250 Vac input.

g. Reading on differential voltmeter should not vary from reading recorded in step e by more than 9 mVdc for Model 6823A units or 15 mVdc for Model 6824A units.

h. Rotate VOLTS/GAIN control ccw to obtain maximum negative voltage and repeat steps d through g.

5-17 Ripple and Noise. To check ripple and noise, proceed as follows:

a. Retain test setup used for previous line regulation test except connect AC voltmeter (Model 403B) across output terminals instead of differential voltmeter.

b. Adjust variable auto transformer for 125 Vac input.

c. Turn on supply and adjust VOLTS/GAIN control cw until front panel meter indicates exactly the maximum rated positive output voltage.

d. AC voltmeter should read less than 2 mV rms (Model 6823A) or 10 mV rms (Model 6824A).

e. Reverse polarity of input to ac voltmeter and repeat steps c and d for maximum rated negative output voltage.

5-18 Transient Recovery Time. To check the transient recovery time of the supply, proceed as follows:

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

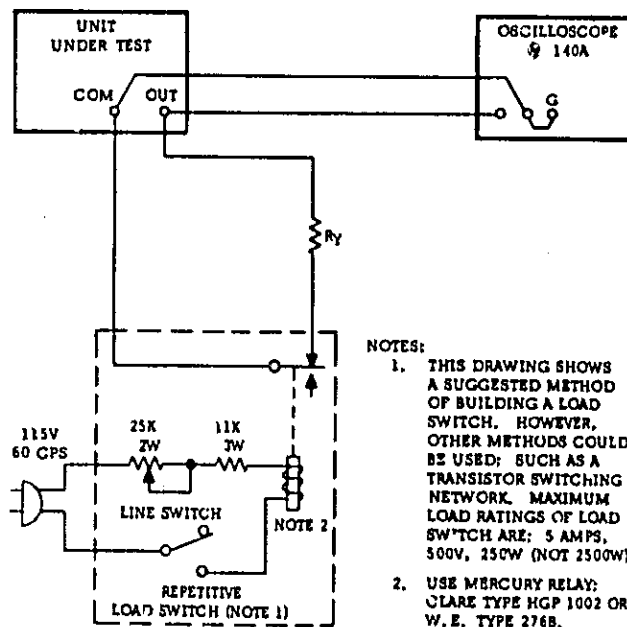


Figure 5-5. Transient Response, Test Setup

b. Rotate VOLTS/GAIN control cw to obtain maximum rated positive output.

c. Close line switch on repetitive load switch setup.

d. Adjust 25K potentiometer until a stable display is obtained on oscilloscope. Waveform should be within the tolerances shown in Figure 5-6 (output should return to within 5 mv of original value in less than 100 microseconds).

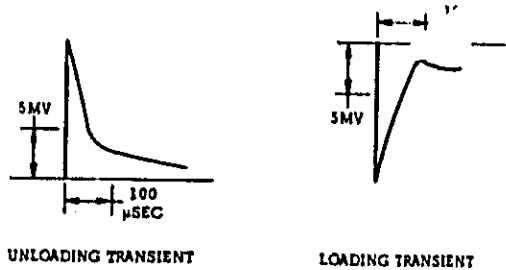


Figure 5-6. Transient Response Waveforms

e. Reverse input connections to oscilloscope and repeat steps c and d for maximum rated negative output.

5-19 Programming Speed. To check the unit's programming speed, a square wave is applied to the unit and it is operated in the amplifier mode. This has the same effect as rapidly programming the unit, up and down, in the power supply mode. To make this test, proceed as follows:

a. Connect test setup shown in Figure 5-7.

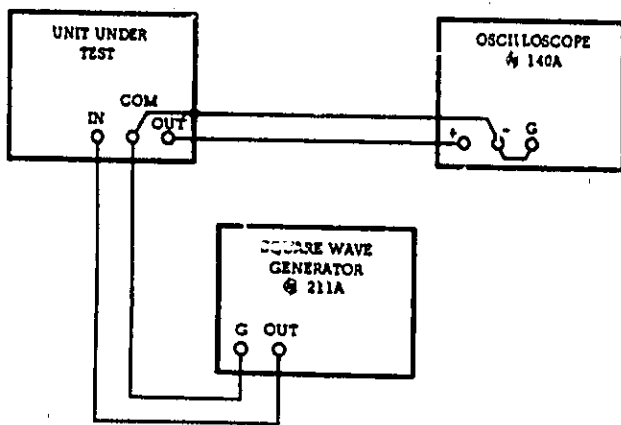


Figure 5-7. Programming Speed, Test Setup

b. Set MODE switch to AMPLIFIER and turn on unit.

c. Rotate VOLTS/GAIN control fully clockwise.

d. On pulse generator, set input frequency to about 2 kHz and adjust amplitude to obtain maximum rated peak-to-peak output signal on oscilloscope (-20V to +20V on Model 6823A and -50V to +50V on Model 6824A).

e. Adjust oscilloscope to observe rise time of one square wave. The wave shape should be within the tolerances shown on Figure 5-8 (output should change from maximum rated negative value to maximum rated positive value in less than 50 microseconds).

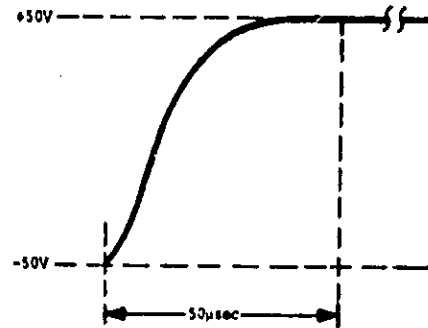


Figure 5-8. Typical Programming Speed Waveforms

f. Check the fall time of one square wave. It should be almost identical to the rise time except for inversion.

5-20 Output Impedance. To check the output impedance, proceed as follows:

a. Connect test setup shown in Figure 5-9.

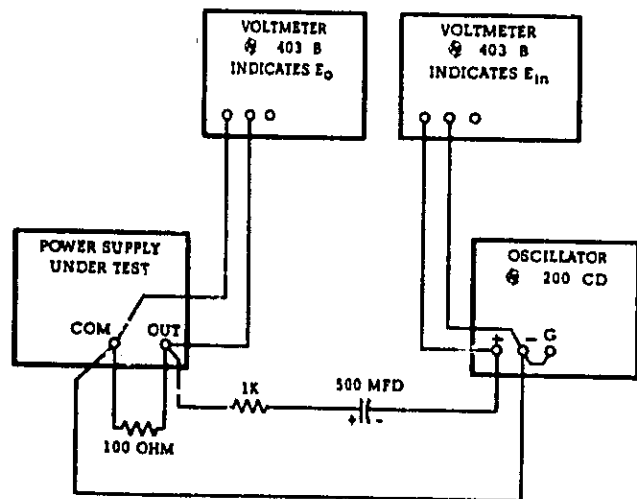


Figure 5-9. Output Impedance, Test Setup

b. Turn on supply and adjust VOLTS/GAIN control until front panel meter reads +10 volts (+20 volts for Model 6824A).

c. Set AMPLITUDE control on Oscillator to 10 volts ( $E_{in}$ ), and FREQUENCY control to 100Hz.

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

e. Calculate the output impedance by the following formula:

$$Z_{out} = \frac{E_o R}{E_{in} - E_o}$$

$E_o$  = rms voltage across power supply output terminals.

$R = 1000$

$E_{in} = 10$  volts

f. The output impedance ( $Z_{out}$ ) should be less than 0.03 ohm.

g. Using formula of step e calculate output impedance at frequencies of 500Hz and 100KHz. Values should be less than 0.3 ohm and 3.0 ohms, respectively.

#### 5-21 AMPLIFIER TESTS

5-22 Gain and Frequency Response. To check the gain and frequency response of the amplifier, proceed as follows:

a. Connect test setup shown in Figure 5-10.

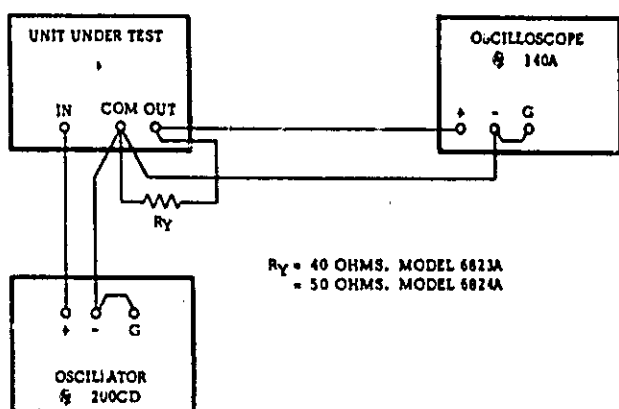


Figure 5-10. Gain and Frequency Response, Test Setup

b. Set MODE switch to AMPLIFIER.

c. Set oscillator frequency at 2KHz and output at 4 Vac, peak-to-peak (Model 6823A) or 10 Vac, peak-to-peak (Model 6824A).

d. Adjust VOLTS/GAIN control on amplifier to obtain 40 volt peak-to-peak (Model 6823A) or 100 volt peak-to-peak (Model 6824A) reading on

oscilloscope. Reading should be within  $\pm 2\%$  tolerance.

e. Adjust oscillator frequency to 20 KHz while maintaining same oscillator output voltage.

f. Waveform on oscilloscope should not be less than 29 volts peak-to-peak (Model 6823A) or 71 volts peak-to-peak (Model 6824A).

5-23 AC Meter Accuracy (Model 6824A Only). The front panel meter on Model 6824A units is capable of measuring ac output voltages. To check its accuracy, proceed as follows:

a. Retain test setup of Figure 5-10.

b. Repeat steps b through d of Paragraph 5-22.

c. METER switch to AC VOLTS position.

d. Front panel meter should indicate rms value of peak output voltage indicated on oscilloscope ( $E_o$  pk.  $\times 0.707 = E_o$  rms).

#### 5-24 TROUBLESHOOTING

5-25 Components within Hewlett-Packard instruments are conservatively operated to provide maximum reliability. In spite of this, parts within a unit may fail. Usually the instrument must be immediately repaired with a minimum of "down time" and a systematic approach as outlined in succeeding paragraphs can greatly simplify and speed up the repair.

#### 5-26 TROUBLE ANALYSIS

5-27 General. Before attempting to trouble shoot this instrument, ensure that the fault is with the instrument and not with an associated circuit. The performance test (Paragraph 5-10) enables this to be determined without having to remove the instrument from the cabinet.

5-28 Once it is determined that the PS/A is at fault, check for obvious troubles such as an open fuse, a defective power cable, or an input power failure. 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, follow the detailed procedure outlined in succeeding paragraphs. 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 replacement and adjustment and calibration paragraphs in this section.

5-29 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, logical application of this knowledge used in conjunction with the normal voltage readings shown on the schematic and the additional procedures given in the following paragraphs should suffice to isolate a fault to a component or small group of components. The normal voltages shown on the schematic are positioned adjacent to the applicable test points (identified by encircled numbers on the schematic and printed wiring board). Additional test procedures that will aid in isolating troubles are as follows:

- a. Reference circuit check (Paragraph 5-31). This circuit provides critical operating voltages for the instrument and faults in the circuit could affect the overall operation in many ways.
- b. Feedback loop checks (Paragraph 5-32).
- c. Procedures for dealing with common troubles (Paragraph 5-33).

5-30 Note that the above mentioned procedures are applicable to both power supply and amplifier operation except in a few cases which are noted in the procedures. Generally speaking, very few

troubles that are encountered will affect the operation of the PS/A in only one of its operating modes.

5-31 Reference Circuit. To check the reference circuit, proceed as follows:

- a. Turn VOLTS/GAIN control fully clockwise and set MODE switch to SUPPLY.
- b. Turn-on unit with no load connected.
- c. Proceed as instructed in Table 5-2.

5-32 Feedback Circuit. Generally, malfunction of the feedback circuit is indicated by high or low output voltages. If one of these situations occur, disconnect the load and proceed as instructed in the applicable table (5-3 through 5-6). Note that the cooling fan in Model 6824A may interfere with some voltage readings recommended in the following tables. If this occurs, the fan may be electrically disconnected in order to take the reading in question. However, the fan must be reconnected immediately after the reading has been taken, as operation of the unit without benefit of the cooling fan will cause overheating and probable damage.

5-33 Common Troubles. Table 5-7 provides a tabular list of the symptoms, checks, and probable causes for common troubles.

Table 5-2. Reference Circuit Troubleshooting

| Step | Meter Common | Meter Positive | Normal Indication | Action   |
|------|--------------|----------------|-------------------|--|
| 1    | C            | 30             | +22.1 ± 2 Vdc     | If normal, proceed to Step 2. If abnormal, check R4, C12, R17, CR5, and CR6. |
| 2    | C            | 11             | +6.2 ± 0.3 Vdc    | If abnormal, check VR2, R36, R56, VR5.                                       |
| 3    | C            | 10             | -6.2 ± 0.3 Vdc    | If abnormal, check VR1, VR3, C13, R37, R60, CR7, and CR8.                    |



Table 5-3. High Positive Output Voltage Troubleshooting

| Step | Measure                           | Response   | Probable Cause   |
|------|-----------------------------------|--|--|
| 1    | Check fuse F2                     | a. Blown<br>b. Not Blown                         | a. Q2, Q13, or Q14 shorted, CR21, CR22 or CR24 open.<br>b. Proceed to Step 2.  |
| 2    | Voltage between 23 (+) and 25 (-) | a. Less positive than +5.4V<br>b. +5.4V to +5.7V | a. CR21, or CR22, or CR24 shorted, R61 open.<br>b. Check Q10 or R22 for open. Check Q1 or Q9 for short. Proceed to Step 3. |
| 3    | Voltage between C and 16          | a. More negative than -60V<br>b. -56V to -60V    | a. Q8 open, Q7 shorted, Q6 open.<br>b. Proceed to Step 4.  |
| 4    | Voltage between C and 17          | a. More positive than +60V<br>b. +54V to +60V    | a. Q3 open, R44 shorted.<br>b. Check Q4 for short. Check Q11 for open, CR12 for short.                                     |

Table 5-4. High Negative Output Voltage Troubleshooting

| Step | Measure                            | Response   | Probable Cause   |
|------|------------------------------------|--|--|
| 1    | Voltage between 23 (+) and 25 (-)  | a. More positive than +5.7V<br>b. +5.4V to +5.7V | a. CR21, CR22, or CR24 open.<br>b. Proceed to Step 2.            |
| 2    | Voltage between 19 and 7, 8, and 9 | a. 0V or positive<br>b. More negative than 0V    | a. Q2, Q13 or Q14 shorted, Q10 shorted.<br>b. Proceed to Step 3. |
| 3    | Voltage between C and 16           | a. Less negative than -45V<br>b. -45V to -50V    | a. Q8 shorted, Q7 open, Q6 shorted.<br>b. Proceed to Step 4.     |
| 4    | Voltage between C and 17           | a. More negative than -55V                       | a. Q3 shorted, R64 shorted.                                      |

Table 5-5. Low Positive Output Voltage Troubleshooting

| Step | Measure                 | Response  | Probable Cause  |
|------|-------------------------|---|---|
| 1    | Remove Q12 from circuit | a. Normal positive output voltage<br>b. Low positive output voltage | a. Q12 shorted R5 or R3 open or high resistance.<br>b. Reconnect Q12 and check Q1 or Q9 for open. If normal, proceed to Step 2. |

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

|   |                          |   |  |
|---|--------------------------|---|--|
| 2 | Voltage between C and 16 | <ul style="list-style-type: none"> <li>a. Less negative than -56V</li> <li>b. -56V to -60V</li> </ul> | <ul style="list-style-type: none"> <li>a. Open strap between A3 -A4. Check -6.2V reference for low voltage. Check R13 for open. Check R52A for open.</li> <li>b. Proceed to Step 3.</li> </ul> |
| 3 | Voltage between C and 17 | <ul style="list-style-type: none"> <li>a. Less positive than +54V</li> </ul>                          | <ul style="list-style-type: none"> <li>a. Check R44 or R55 for open or high resistance. Check Q4 for open.</li> </ul>  |

Table 5-6. Low Negative Output Voltage Troubleshooting

| Step | Measure                  | Response  | Probable Cause  |
|------|--------------------------|---|---|
| 1    | Remove Q5 from circuit   | <ul style="list-style-type: none"> <li>a. Normal negative output voltage</li> <li>b. Low negative output voltage</li> </ul> | <ul style="list-style-type: none"> <li>a. Q5 shorted. R6 or R19 open or high resistance.</li> <li>b. Reconnect Q5 and check Q2, Q13, or Q14 for open. If normal proceed to Step 5.</li> </ul>           |
| 2    | Voltage between C and 16 | <ul style="list-style-type: none"> <li>a. More negative than -50V</li> <li>b. -45V to -50V</li> </ul>                       | <ul style="list-style-type: none"> <li>a. Open strap between A3-A4. Check R52A for open. Check +6.2V reference for low voltage. Check R13 for low resistance.</li> <li>b. Proceed to Step 4.</li> </ul> |
| 3    | Voltage between C and 17 | <ul style="list-style-type: none"> <li>a. Less negative than -45V</li> </ul>  | <ul style="list-style-type: none"> <li>a. Check R4 or R55 for open or high resistance. Check Q11 for short, Q4 for open.</li> </ul>   |

Table 5-7. Common Troubles

| Symptom                         | Checks and Probable Causes   |
|---------------------------------|--|
| High ripple                     | <ul style="list-style-type: none"> <li>a. Check operating setup for ground loops.</li> <li>b. Ensure that unit is not crossing over to current limiting operation under loaded conditions. (This will be characterized by ripple in the power supply mode and clipping of the positive and negative peaks in the amplifier mode).</li> </ul> |
| Oscillation (power supply mode) | <ul style="list-style-type: none"> <li>a. Check feedback networks; C8-R25, C5-R24, and C7-R14.</li> </ul>  |
| Distortion (amplifier mode)     | <ul style="list-style-type: none"> <li>a. Ensure that unit is not going into current limit operation.</li> <li>b. If high frequency component of output signals are distorted, check feedback networks; C8-R25, C5-R24, and C7-R14.</li> </ul>   |

Table 5-7. Common Troubles (Continued)

|                                     |  |
|-------------------------------------|--|
| Poor Stability                      | <ul style="list-style-type: none"> <li>a. Check reference voltages (Table 5-2).</li> <li>b. Noisy VOLTS/GAIN control (R52A).</li> <li>c. CR25 through CR28 leaky.</li> <li>d. Stage Q7 or Q8 defective.</li> </ul> |
| Unit programs in only one direction | <ul style="list-style-type: none"> <li>a. R38 or R39 open</li> <li>b. No +6.2V or -6.2V reference source.</li> </ul>   |
| Zero Output                         | <ul style="list-style-type: none"> <li>a. R32 or R52A open</li> <li>b. S2 open</li> </ul>  |

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.

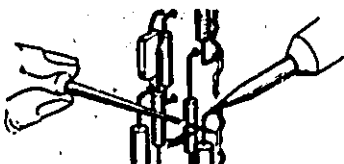
A break in the copper should be repaired by soldering a short length of tinned copper wire across the break.

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.

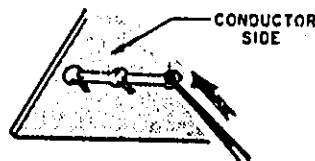
When replacing components with multiple mounting pins such as tube sockets, electrolytic capacitors, and potentiometers, it will be necessary to lift each pin slightly, working around the components several times until it is free.

**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.

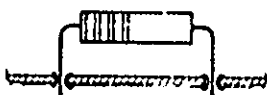
1. Apply heat sparingly to lead of component to be replaced. If lead of component passes through an eyelet in the circuit board, apply heat on component side of board. If lead of component does not pass through an eyelet, apply heat to conductor side of board.



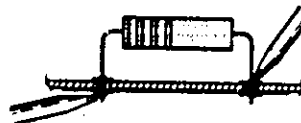
2. Reheat solder in vacant eyelet and quickly insert a small awl to clean inside of hole. If hole does not have an eyelet, insert awl or a #57 drill from conductor side of board.



3. Bend clean tinned leads 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

Table 5-8: Selected Semiconductor Characteristics

| Reference Designator | Characteristics   | Stock No. | Suggested Replacement |
|----------------------|---|-----------|-----------------------|
| Q1, 4, 9, 10         | NPN Si Power. $h_{fe} = 35$ (min.) @ $I_C = 1A$ ; $V_{CE} = 4V$ . $V_{CE}$ (sat.) = 1V (max.) @ $I_C = 1A$ ; $I_b = 0.1A$ . $V_{BE} = 1.5V$ (max.) @ $I_C = 1A$ ; $V_{CE} = 4V$ . Power rating test $V_{CE} = 130V$ ; $I_C = 500mA$ for 1 second. | 1854-0250 | 2N3442 R. C. A.       |
| Q2, 13, 14           | PNP Ger Power. $h_{fe} = 40$ (min.) @ 8A. $BV_{CEO} = 160V$ . Pwr-Diss. = 150w. FT (max.) = 400 kHz.  | 1850-0407 | B213002 Bendix        |
| CR5-10, 19           | Si rectifier, 500ma, 200prv   | 1901-0026 | 1N3253 R. C. A.       |
| CR11, 12, 22, 25-28  | Si rectifier 200ma, 15prv   | 1901-0461 | 1N4828 G. E.          |
| CR13-16              | Si rectifier, 200ma, 200prv   | 1901-0033 | 1N279 Transistron     |
| VR3-5                | Zener Diode, 22.1V $\pm 5\%$ , 1W.  | 1902-0562 | 1N3028 Motorola       |

5-34 REPAIR AND REPLACEMENT

5-35 Before servicing a printed wiring board, refer to Figure 5-11. Section VI of this manual contains a tabular list of the instruments replaceable parts. Before replacing a semiconductor device, refer to Table 5-8 which lists the special

characteristics of selected semiconductors. If the device to be replaced is not listed in Table 5-8, the standard manufacturers part number listed in Section VI is applicable. After replacing a semiconductor, refer to Table 5-9 for checks and adjustments that may be necessary.

Table 5-9. Checks and Adjustments After Replacement of Semiconductor Devices

| Reference            | Function                          | Check  | Adjust                    |
|----------------------|-----------------------------------|--|---------------------------|
| Q1, Q2, Q9, Q13, Q14 | Regulator/Output Amplifier        | Load regulation (Power Supply)<br>Gain/frequency response (Amplifier)<br>Current limit<br>Ammeter/Voltmeter tracking | R5 and R6<br>R35/R31, R43 |
| Q3, Q4, Q6, Q11      | Error and driver amplifiers       | Load regulation  |                           |
| Q7, Q8               | Differential Amplifier            | Line and load regulation<br>Programming current  | R38 and R39               |
| Q5, Q12              | Current limiting transistors      | Current limit  | R5 or R6                  |
| CR1-CR10             | Rectifier diodes                  | Voltage across appropriate filter capacitor  |                           |
| VR1-VR5              | Develop stable reference voltages | Positive and negative reference voltages<br>Line regulation  |                           |

Table 5-10. Calibration Adjustment Summary

| Adjustment or Calibration | Paragraph | Control Device |
|---------------------------|-----------|----------------|
| Meter Zero                | 5-38      | Pointer        |
| DC Voltmeter Tracking     | 5-41      | R31            |
| AC Voltmeter Tracking     | 5-42      | R43            |
| DC Ammeter Tracking       | 5-43      | R35            |
| Programming Current       | 5-45      | R38 and R39    |
| Current Limit             | 5-47      | R5 and R6      |

### 5-36 ADJUSTMENT AND CALIBRATION

5-37 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. Table 5-10 summarizes the adjustments and calibrations contained in the following paragraphs.

#### 5-38 METER ZERO

5-39 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 indentation near 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.

#### 5-40 VOLTMETER TRACKING

5-41 To calibrate dc voltmeter tracking, proceed as follows:

- a. Connect differential voltmeter across output. Connect positive lead to common terminal on rear of PS/A.
- b. Set METER switch to VOLTS and MODE switch to SUPPLY. Adjust VOLTS/GAIN control ccw until differential voltmeter reads exactly the maximum rated negative output voltage.

c. Adjust R31 until front panel meter also indicates maximum rated output voltage.

5-42 To calibrate ac voltmeter tracking, proceed as follows:

- a. Connect test setup shown in Figure 5-10 except remove load resistor  $R_L$ .
- b. Set MODE switch to AMPLIFIER and oscillator frequency to 2 kHz.
- c. Adjust VOLTS/GAIN control for 100 volt peak-to-peak reading on oscilloscope.
- d. Set METER switch to AC VOLTS and adjust R43 to obtain 35.35 volt rms reading on front panel meter.

#### 5-43 AMMETER TRACKING

5-44 To calibrate ammeter tracking proceed as follows:

- a. Connect test setup shown on Figure 5-3.
- b. Set METER switch to AMPS.
- c. Turn on supply and adjust VOLTS/GAIN control cw until differential voltmeter reads 1.0 Vdc.
- d. Adjust R35 until front panel meter indicates exactly the maximum rated positive output current.

#### 5-45 PROGRAMMING CURRENT

5-46 To calibrate the programming current, proceed as follows:

- a. Connect differential voltmeter across output terminals.
- b. Set MODE switch to SUPPLY and turn on unit.
- c. Set VOLTS/GAIN control fully cw and FINE/ZERO control to mid-position.
- d. Adjust R38 so that differential voltmeter reads +20.2 Vdc (Model 6823A) or +52 Vdc (Model 6824A).
- e. Set polarity switch for minus input and rotate VOLTS/GAIN control fully ccw.
- f. Adjust R39 so that differential voltmeter reads -20.2 Vdc (Model 6823A) or -52 Vdc (Model 6824A).

#### 5-47 CURRENT LIMIT ADJUSTMENT

5-48 To adjust the current limit so that the unit can be used to furnish maximum rated output cur-

rent, proceed as follows:

- a. Connect test setup shown in Figure 5-3 except connect variable transformer between input source and PS/A.
- b. Short out load resistor (R<sub>L</sub>).
- c. Set MODE switch to SUPPLY. Adjust variable transformer for 105 Vac input (low line).
- d. Turn on supply and rotate VOLTS/GAIN controls fully clockwise.
- e. Adjust R5 until differential voltmeter indicates +1.5 Vdc for Model 6823A or +1.2 Vdc for Model 6824A. Set position of input polarity switch for minus input and rotate VOLTS/GAIN control fully ccw.
- f. Adjust R6 until differential voltmeter indicates -1.5 Vdc for Model 6823A units or -1.2 Vdc for Model 6824A units.

**PARTS**

**LIST**

## SECTION VI REPLACEABLE PARTS

### 6-1 INTRODUCTION

6-2 This section contains information for ordering replacement parts. Table 6-4 lists parts in alphanumeric 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 electronic part |
| B  | = blower (fan)             | F | = fuse                          |
| C  | = capacitor                | J | = jack, jumper                  |
| CB | = circuit breaker          | K | = relay                         |
| CR | = diode                    | L | = inductor                      |
| DS | = device, signaling (lamp) | M | = meter                         |

Table 6-1. Reference Designators (Continued)

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

Table 6-2. Description Abbreviations

|       |                             |      |                             |
|-------|-----------------------------|------|-----------------------------|
| A     | = ampere                    | mfr  | = manufacturer              |
| ac    | = alternating current       | mod. | = modular or modified       |
| assy. | = assembly                  | mtg  | = mounting                  |
| bd    | = board                     | n    | = nano = 10 <sup>-9</sup>   |
| 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 <sup>-12</sup>  |
| 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 <sup>3</sup>    | V    | = volt                      |
| m     | = milli = 10 <sup>-3</sup>  | var  | = variable                  |
| M     | = mega = 10 <sup>6</sup>    | ww   | = wirewound                 |
| μ     | = micro = 10 <sup>-6</sup>  | W    | = Watt                      |
| met.  | = metal                     |      |                             |

### MANUAL CHANGES Model 6824A DC Power Supply Manual HP Part No. 06824-90001

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

| SERIAL |        | MAKE CHANGES |
|--------|--------|--------------|
| Prefix | Number |              |
| ALL    | —      | Errata       |

Knob: HP Part No. 0373-0137.  
Modified Front Panel: HP Part No. 06824-60002.  
Under OUTPUT IMPEDANCE on Page 1-3, change the  
last sentence to read as follows:



Table 6-3. Code List of Manufacturers

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

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

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

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

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

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

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

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

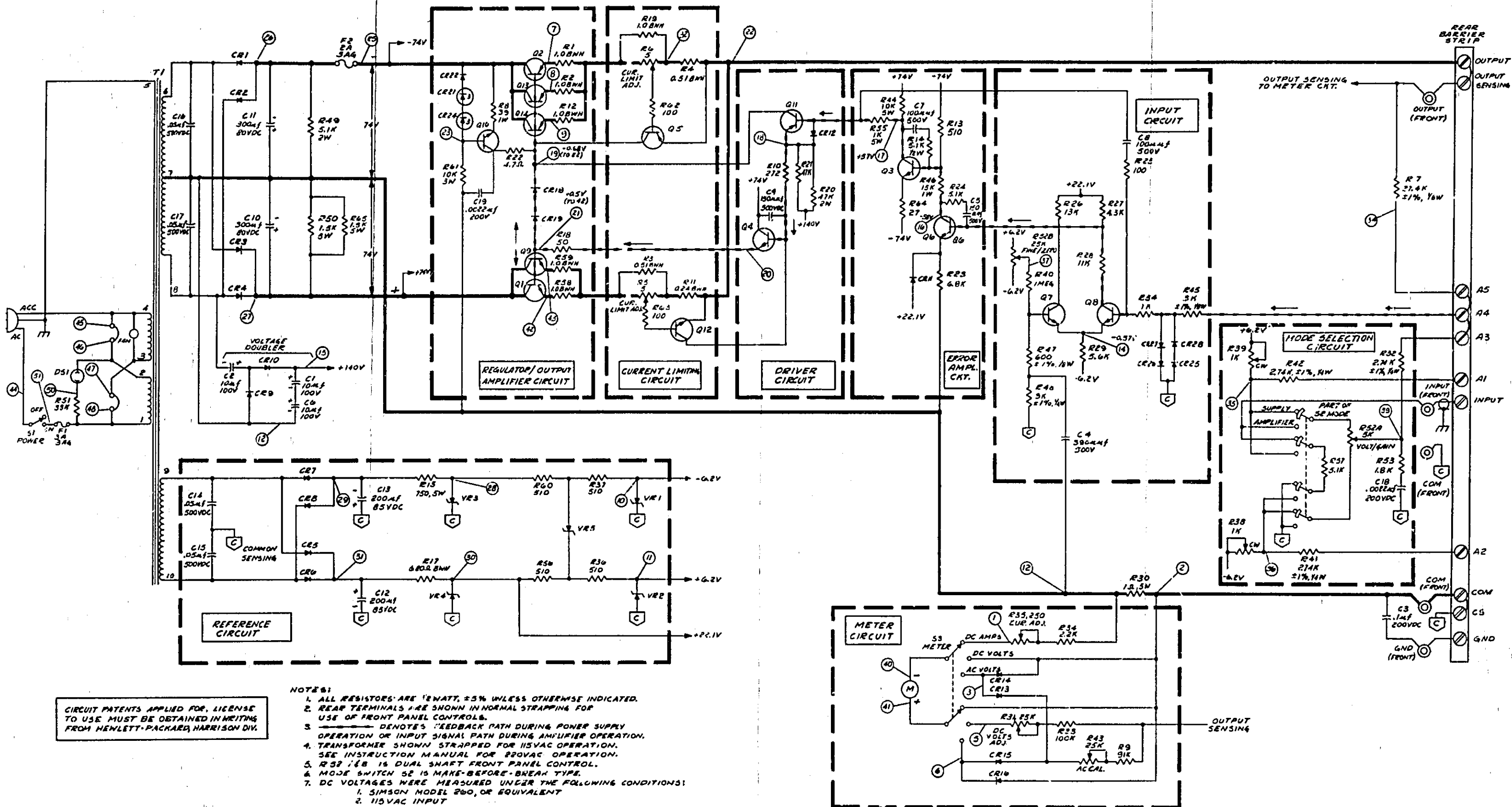
| CODE NO. | MANUFACTURER                               | ADDRESS                  |
|----------|--|--------------------------|
| 76530    | Cinch                                      | City of Industry, Calif. |
| 76854    | Oak Mfg. Co. Div. of Oak                   |                          |
| 77068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

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

| Reference Designator  | Description                                      | Quantity | Mfr. Part # or Type | Mfr.       | Mfr. Code | Stock No. | RS |
|-----------------------|--|----------|---------------------|------------|-----------|-----------|----|
| C1, 2, 6              | fxd, elect 10 $\mu$ f 100vdc                     | 3        | 30D106F100 DC2      | Sprague    | 56289     | 0180-0091 | 1  |
| C3                    | fxd, film .1 $\mu$ f 200vdc                      | 1        | 192P10492           | Sprague    | 56289     | 0160-0168 | 1  |
| C4                    | fxd, Mica 390 $\mu$ f 500vdc                     | 1        | RCM15E391J          | Arco       | 04062     | 0140-0037 | 1  |
| C5, 9                 | fxd, Mica 150 $\mu$ f 500vdc                     | 2        | RCM15E151J          | Arco       | 04062     | 0140-0067 | 1  |
| C7, 8                 | fxd, Mica 100 $\mu$ f 500vdc                     | 2        | RCM15E101J          | Arco       | 04062     | 0140-0041 | 1  |
| C10, 11               | fxd, elect 3000 $\mu$ f 80vdc                    | 2        | D42492              | HLAB       | 09182     | 0180-1987 | 1  |
| C12, 13               | fxd, elect 200 $\mu$ f 85vdc                     | 2        | D31642              | HLAB       | 09182     | 0180-1854 | 1  |
| C14, 15, 16, 17       | fxd, ceramic .05 $\mu$ f 500vdc                  | 4        | 33C17A              | Sprague    | 56289     | 0150-0052 | 1  |
| C18, 19               | fxd, film .0022 $\mu$ f 200vdc                   | 2        | 192P22292           | Sprague    | 56289     | 0160-0154 | 1  |
| CR1-4                 | Rect. si. 3A 200prv                              | 4        | MR1032B             | Motorola   | 04713     | 1901-0416 | 4  |
| CR5-10, 19            | Rect. si. 500ma 200prv                           | 7        | 1N3253              | R. C. A.   | 02735     | 1901-0389 | 6  |
| CR11, 12, 22, 25-28   | Rect. si. 200ma 15prv                            | 7        |                     | HLAB       | 09182     | 1901-0461 | 6  |
| CR13-16               | Rect. si. 200ma 200prv                           | 4        |                     | HLAB       | 09182     | 1901-0033 | 4  |
| CR18                  | Rect. si. 70V 100prv                             | 1        | 1N91                | G. E.      | 03508     | 1911-0001 | 1  |
| CR21, 24              | Rect. si. 2.4V 150ma                             | 2        |                     | HLAB       | 09182     | 1901-0460 | 2  |
| DS1                   | Lamp, Neon part of S1 ass'y Ref.                 |          |                     | HLAB       | 09182     | 2140-0244 | 1  |
| F1                    | Fuse Cartridge (AC)<br>3A @ 250V 3AG             | 1        | 312003              | Littlefuse | 75913     | 2110-0003 | 5  |
| F2                    | Fuse Cartridge (DC)<br>2A @ 250V 3AG             | 1        | 312002              | Littlefuse | 75913     | 2110-0002 | 5  |
| Q1, 4, 9, 10          | Power NPN si.                                    | 4        |                     | HLAB       | 09182     | 1854-0250 | 4  |
| Q2, 13, 14            | Power PNP Ger.                                   | 3        |                     | HLAB       | 09182     | 1850-0407 | 3  |
| Q3                    | SS NPN si.                                       | 1        | 40422               | R. C. A.   | 02735     | 1854-0253 | 1  |
| Q5, 11                | SS PNP si.                                       | 2        | 2N2907A             | Sprague    | 56289     | 1853-0099 | 2  |
| Q6                    | SS PNP si. SELECTED for<br>BVCEP $\geq$ 100V     | 1        | 40362               | R. C. A.   | 02735     | 1853-0041 | 1  |
| Q7, 8, 12             | SS NPN si.                                       | 3        | 2N3417              | G. E.      | 03508     | 1854-0087 | 3  |
| R1, 2, 12, 19, 58, 59 | fxd, ww 1.0 $\Omega$ $\pm$ 5%                    | 6        | Type BWH            | I. R. C.   | 07716     | 0811-1672 | 2  |
| R3, 4                 | fxd, ww .51 $\Omega$ $\pm$ 5%                    | 2        | Type BWH            | I. R. C.   | 07716     | 0811-0929 | 1  |
| R5, 6                 | var, ww 5 $\Omega$                               | 2        | Type 110-F4         | C. T. S.   | 11236     | 2100-1821 | 1  |
| R7                    | fxd, film 27.4K $\pm$ 1% 1/8w                    | 1        | Type MF5C T-O       | Electra    | 19709     | 0757-0452 | 1  |
| R8                    | fxd, ww 39 $\Omega$ $\pm$ 5%                     | 1        | Type BWH            | I. R. C.   | 07716     | 0811-2244 | 1  |
| R9                    | fxd, comp 91K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w  | 1        | EB-9135             | A. B.      | 01121     | 0686-9135 | 1  |
| R10, 64               | fxd, comp 27 $\Omega$ $\pm$ 5% $\frac{1}{2}$ w   | 2        | EB-2705             | A. B.      | 01121     | 0686-2705 | 1  |
| R11                   | fxd, ww .24 $\Omega$ $\pm$ 5%                    | 1        | Type BWH            | I. R. C.   | 07716     | 0811-1758 | 1  |
| R13, 36, 37, 56, 60   | fxd, comp 510 $\Omega$ $\pm$ 5% $\frac{1}{2}$ w  | 5        | EB-5115             | A. B.      | 01121     | 0686-5115 | 1  |
| R14, 24, 57           | fxd, comp 5.1K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w | 3        | EB-5125             | A. B.      | 01121     | 0686-5125 | 1  |
| R15, 17, 55           | fxd, ww 1K $\pm$ 5% 5w                           | 3        | Type 5XM            | W. L.      | 63743     | 0812-0099 | 1  |
| R16                   | NOT ASSIGNED                                     | -        | -                   | -          | -         | -         | -  |
| R18                   | fxd, comp 50 $\Omega$ $\pm$ 5% 5w                | 1        | 243E5005            | Sprague    | 56289     | 0811-1854 | 1  |
| R20, 21               | fxd, met. ox 47K $\Omega$ $\pm$ 5% 2w            | 2        | Type C42S           | Corning    | 16299     | 0764-0031 | 1  |
| R22                   | fxd, comp 4.7 $\Omega$ $\pm$ 5% $\frac{1}{2}$ w  | 1        | Type EB             | A. B.      | 01121     | 0698-0001 | 1  |
| R23                   | fxd, comp 6.8K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w | 1        | EB-6825             | A. B.      | 01121     | 0686-6825 | 1  |
| R25, 62, 63           | fxd, comp 100 $\Omega$ $\pm$ 5% $\frac{1}{2}$ w  | 3        | EB-1015             | A. B.      | 01121     | 0686-1015 | 1  |
| R26                   | fxd, comp 13K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w  | 1        | EB-1335             | A. B.      | 01121     | 0686-1335 | 1  |
| R27                   | fxd, comp 4.3K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w | 1        | EB-4325             | A. B.      | 01121     | 0686-4325 | 1  |
| R28                   | fxd, comp 11K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w  | 1        | EB-1135             | A. B.      | 01121     | 0686-1135 | 1  |
| R29                   | fxd, comp 5.6K $\Omega$ $\pm$ 5% $\frac{1}{2}$ w | 1        | EB-5625             | A. B.      | 01121     | 0686-5625 | 1  |

| Reference Designator | Description                  | Quantity | Mfr. Part # or Type | Mfr.       | Mfr. Code | Stock No.   | RS |
|----------------------|------------------------------|----------|---------------------|------------|-----------|-------------|----|
| R30                  | fxd. ww 1K ±5% 5w            | 1        | Type 5XM            | W. L.      | 63743     | 0811-1340   | 1  |
| R31, 43              | var. comp .25K Series 70     | 2        |                     | HLAB       | 09182     | 2100-1534   | 1  |
| R32, 41, 42          | fxd, met. film 2.74K ±1% ½w  | 3        | Type MF6-C T-O      | Electra    | 19707     | 0757-0742   | 1  |
| R33                  | fxd, comp 100K ±5% ½w        | 1        | EB-1045             | A. B.      | 01121     | 0686-1045   | 1  |
| R34                  | fxd, comp 2.2K ±5% ½w        | 1        | EB-2225             | A. B.      | 01121     | 0686-2225   | 1  |
| R35                  | var. ww 250K                 | 1        | Type 110-F4         | C. T. S.   | 11236     | 2100-0439   | 1  |
| R38, 39              | var. ww 1K                   | 2        | Type 110-F4         | C. T. S.   | 11236     | 2100-0391   | 1  |
| R40                  | fxd, comp 1 MEG ±5% ½w       | 1        | EB-1055             | A. B.      | 01121     | 0686-1055   | 1  |
| R44                  | fxd. ww 10K ±1% 5w           | 1        |                     | HLAB       | 09182     | 0811-1866   | 1  |
| R45                  | fxd, met. film 3K ±1% 1/8w   | 1        | Type CEA T-O        | I. R. C.   | 07716     | 0757-1093   | 1  |
| R46                  | fxd, comp 15K ±5% 1w         | 1        | GB-1535             | A. B.      | 01121     | 0689-1535   | 1  |
| R47                  | fxd, met. film 600K ±1% 1/8w | 1        | Type CEA T-O        | I. R. C.   | 07716     | 0757-1100   | 1  |
| R48                  | fxd, met. film 3.01K ±1% ½w  | 1        | Type MF6-C T-O      | Electra    | 19709     | 0757-0339   | 1  |
| R49                  | fxd, met. ox 5.1K ±5% 2w     | 1        | Type C42S           | Corning    | 16299     | 0690-3644   | 1  |
| R50, 65              | fxd. ww 1.5K ±5% 5w          | 2        | 243E1525            | Sprague    | 56289     | 0811-1863   | 1  |
| R51                  | fxd, comp 33K ±5% ½w         | 1        | EB-3335             | A. B.      | 01121     | 0686-3335   | 1  |
| R52                  | var. ww DUAL 5K -25K         | 1        |                     | HLAB       | 09182     | 2100-1805   | 1  |
| R53                  | fxd, comp 1.8K ±5% ½w        | 1        | EB-1825             | A. B.      | 01121     | 0686-1825   | 1  |
| R54                  | fxd, comp 1K ±5% ½w          | 1        | EB-1025             | A. B.      | 01121     | 0686-1025   | 1  |
| R61                  | fxd. ww 10K ±5% 3w           | 1        | 242E1035            | Sprague    | 56289     | 0811-1816   | 1  |
| S1                   | Switch (Pilot Lite) ON/OFF   | 1        | 54-61681 - 26 A1H   | Oak        | 87034     | 3101-0100   | 1  |
| S2                   | Switch, Wafer Mode           | 1        |                     | HLAB       | 09182     | 3100-1917   | 1  |
| S3                   | Switch, Wafer-Meter          | 1        |                     | HLAB       | 09182     | 3100-1916   | 1  |
| T1                   | Power Transformer            | 1        |                     | HLAB       | 09182     | 9100-1895   | 1  |
| VR1, 2               | Diode zener 6 2V ±5%         | 2        | 1N821               | N. A.      | 06486     | 1902-0761   | 2  |
| VR3, 4, 5            | Diode zener 22.1V ±5% 1w     | 3        |                     | HLAB       | 09182     | 1902-0562   | 3  |
|                      | Chassis-side formed (right)  | 1        |                     | HLAB       | 09182     | 06824-00001 |    |
|                      | Chassis-side formed (left)   | 1        |                     | HLAB       | 09182     | 06824-00002 |    |
|                      | Panel - front                | 1        |                     | HLAB       | 09182     | 06824-00003 |    |
|                      | Chassis - rear               | 1        |                     | HLAB       | 09182     | 06824-00004 |    |
|                      | Heat sink                    | 1        |                     | HLAB       | 09182     | 06824-20002 |    |
|                      | Bracket - P. C. Board        | 2        |                     | HLAB       | 09182     | 06824-00005 |    |
|                      | Cover                        | 2        |                     | HLAB       | 09182     | 5000-6092   |    |
|                      | Angle Guard                  | 1        |                     | HLAB       | 09182     | 06824-20001 |    |
|                      | 5 Way binding post (maroon)  | 2        | DF21 Mn.            | HLAB       | 09182     | 1510-0040   | 1  |
|                      | 5 Way binding post (black)   | 3        | DF 21 BC            | Superior   | 58474     | 1510-0039   | 1  |
|                      | Line cord plug PH151 7½ ft.  | 1        | KH-4096             | Beldon     | 70903     | 8120-0050   | 1  |
|                      | Strain relief bushing        | 1        | SR-5P-1             | Heyco      | 28520     | 0400-0013   | 1  |
|                      | Knob ¼ insert pointer        | 2        |                     | HLAB       | 09182     | 0370-0084   | 1  |
|                      | Knob 17/64 insert pointer    | 1        |                     | HLAB       | 09182     | 0370-0101   | 1  |
|                      | Knob 3/16                    | 1        |                     | HLAB       | 09182     | 0370-0179   | 1  |
|                      | Jumper                       | 4        | 422-13-11 013       | Cinch      | 71785     | 0360-1143   | 1  |
|                      | Barrier strip                | 1        |                     | HLAB       | 09182     | 0360-1285   | 1  |
|                      | Rubber bumper                | 4        | MB50                | Stockwell  | 87575     | 0403-0088   | 1  |
|                      | Rubber bumper                | 6        | 4072                | Stockwell  | 87575     | 0403-0086   | 1  |
|                      | Delrin standoff ½ Dia.       |          |                     |            |           |             |    |
|                      | 5/8 long 8-32 tap            | 3        |                     | HLAB       | 09182     | 0380-0701   | 1  |
|                      | Phenolic standoff ½ Dia.     |          |                     |            |           |             |    |
|                      | 5/8 long 6-32 thread         | 2        | 8694-PH 0632        | Amatom     | 06540     | 0380-0702   | 1  |
|                      | Bezel ¼ MOD                  | 1        |                     | HLAB       | 09182     | 4040-0294   | 1  |
|                      | Fuse holder                  | 2        | 342014              | Littlefuse | 75915     | 1400-0084   | 1  |
|                      | Lockwasher                   | 1        | 1224-08             | Shakeproof | 78189     | 2190-0037   | 1  |
|                      | Nut                          | 1        | 903-12              | Littlefuse | 75915     | 2950-0038   | 1  |

| Reference Designator | Description               | Quantity | Mfr. Part # or Type | Mfr.        | Mfr. Code | Stock No. | RS |
|----------------------|---------------------------|----------|---------------------|-------------|-----------|-----------|----|
|                      | Meter H/P 3½" size        |          |                     |             |           |           |    |
|                      | 0-60V 0-1.2A zero center  | 1        |                     | HLAB        | 09182     | 1120-1124 | 1  |
|                      | Spring                    | 4        |                     | HLAB        | 09182     | 1460-0256 | 2  |
|                      | Fan Motor                 | 1        |                     | HLAB        | 09182     | 3140-0010 | 1  |
|                      | Fan Blade 4 inch dia.     | 1        | 4RHB183B            | P. M. Motor | NONE      | 3160-0028 | 1  |
|                      | Fastener                  | 10       | C8091632-24B        | Tinnerman   | 89032     | 0510-0275 | 2  |
|                      | Captive nut               | 10       | CLA-832-2           | Penn. Eng.  | 46384     | 0590-0395 | 2  |
|                      | Spacer (br. cad. pl)      | 2        | #6 x ¼ Lg           | HLAB        | 09182     | 0380-0716 | 1  |
|                      | Swage nut (Ni Pl          |          |                     |             |           |           |    |
|                      | 6-32 x 3/16 Lg)           | 4        | 110211              | Fed. Scr    | 73734     | 0380-0390 | 1  |
|                      | Mica insulator            | 2        | 734                 | Reliance    | 08530     | 0340-0174 | 1  |
|                      | Insulator, Transistor pin | 10       |                     | HLAB        | 09182     | 0340-0166 | 2  |
|                      | Insulator                 | 10       |                     | HLAB        | 09182     | 0340-0168 | 2  |
|                      | Transistor Socket         | 5        |                     | HLAB        | 09182     | 1200-0044 | 5  |



CIRCUIT PATENTS APPLIED FOR. LICENSE TO USE MUST BE OBTAINED IN WRITING FROM HEWLETT-PACKARD, HARRISON DIV.

- NOTES:
1. ALL RESISTORS ARE 1/2WATT, ±5% UNLESS OTHERWISE INDICATED.
  2. REAR TERMINALS ARE SHOWN IN NORMAL STRAPPING FOR USE OF FRONT PANEL CONTROLS.
  3. --- DENOTES FEEDBACK PATH DURING POWER SUPPLY OPERATION OR INPUT SIGNAL PATH DURING AMPLIFIER OPERATION.
  4. TRANSFORMER SHOWN STRAPPED FOR 115VAC OPERATION. SEE INSTRUCTION MANUAL FOR 220VAC OPERATION.
  5. R52 1/8 IS DUAL SHAFT FRONT PANEL CONTROL.
  6. MODE SWITCH S2 IS MAKE-BEFORE-BREAK TYPE.
  7. DC VOLTAGES WERE MEASURED UNDER THE FOLLOWING CONDITIONS:
    1. SIMSON MODEL 200, OR EQUIVALENT
    2. 115VAC INPUT
    3. VOLTAGES REFERENCED TO C6 UNLESS OTHERWISE INDICATED
    4. VOLTAGES ARE TYPICAL ±10% UNLESS OTHERWISE INDICATED
    5. ALL READINGS TAKEN WITH UNIT IN POWER SUPPLY OPERATION AT MAXIMUM RATED POSITIVE OUTPUT WITH NO LOAD CONNECTED. UNDER LOADED CONDITIONS VOLTAGES SHOULD DECREASE BY APPROXIMATELY 10%.

Model 6824A, Schematic Diagram

# MANUAL CHANGES



**MANUAL CHANGES**  
**Model 6824A DC Power Supply**  
**Manual HP Part No. 06824-90001**

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

| SERIAL |             | MAKE CHANGES    |
|--------|-------------|-----------------|
| Prefix | Number      |                 |
| ALL    | —           | Errata          |
| 6F     | 0361-0710   | 1               |
| 6F     | 0711-0760   | 1,2             |
| 6F     | 0761-0880   | 1,2,3           |
| 6F     | 0881-1060   | 1,2,3,4         |
| 6F     | 1061-1100   | 1 thru 5        |
| 6F     | 1101-1140   | 1 thru 6        |
| 1026A  | 1105, 1123  | 1 thru 6, and 9 |
|        | 1128, 1135, |                 |
|        | *136, 1137  |                 |
| OC     | 1141-1180   | 1 thru 7        |
| 1026A  | 1181-1220   | 1 thru 8        |
| 1027A  | 1221-1360   | 1 thru 9        |
| 1027A  | 1361-1540   | 1 thru 10       |
| 1027A  | 1541-1570   | 1 thru 11       |
| 1027A  | 1571-1660   | 1 thru 12       |
| 1027A  | 1661-2340   | 1 thru 13       |
| 1027A  | 2341-2400   | 1 thru 14       |
| 1706A  | 2401-2430   | 1 thru 15       |
| 1716A  | 2431-2700   | 1 thru 16       |
| 1914A  | 2701-2709   | 1 thru 18       |
| 1914A  | 2710-2730   | 1 thru 17       |
| 1932A  | 2731-2790   | 1 thru 18       |
| 1946A  | 2791-2820   | 1 thru 19       |
| 2001A  | 2821- 3190  | 1 thru 20, 21*  |
| 2205A  | 3191-3220   | 1-21, 22†       |
| 2227A  | 3221-up     | 1-22            |

**ERRATA:**

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

**C5, 11:** Change to SS PNP Si., HP Part No. 1853-0099.

**R10:** Change value on schematic to 27Ω. Value in parts list is correct.

**R1, 2, 12, 19, 58, 59:** Change to HP Part No. 0811-1666. Value remains unchanged.

**Rubber Bumper:** Change total quantity from 6 to 4.

In Paragraph 1-13, add Option 07: Finer Volts Gain Control. Allows greater accuracy in setting the supply/amplifier output. The option consists of changes in the following parts (1 each):

**R52A (Volts Gain):** 5kΩ, ±5%, 10-turn HP Part No. 2100-1865.

**R52B (Fine Zero):** 25kΩ, ±5%, HP Part No. 2100-1862.

Knob: HP Part No. 0370-0137.

Modified Front Panel: HP Part No. 06824-60002.

Under OUTPUT IMPEDANCE on Page 1-3, change the last sentence to read as follows:

"Less than 3Ω from 1kHz to 10kHz and less than 30Ω from 10kHz to 100kHz."

On Page 5-3, change the caption of Figure 5-2 to read:

Differential Voltmeter Substitute Test Setup.

In Table 1-1, make the following changes:

**PROGRAMMING SPEED:**

Less than 50μsec are required to program between -25V +25V. Less than 17μsec are required to program between 10% and 90% of the half-voltage span.

Less than 125μsec are required to program between -50V and +50V. Less than 25μsec are required to program between 10% and 90% of the maximum voltage span.

**FREQUENCY RESPONSE:**

DC to 20kHz (±3dB) at half-rated output (±25V, 50V p-p).

DC to 10kHz (±3dB) at full output.

**DISTORTION:**

Output distortion is less than 0.02% at 1kHz and half-rated output.

**MAXIMUM PHASE SHIFT (at Half-Rated Output):**

(No further changes.)

**CHANGE 1:**

In the replaceable parts table, make the following changes:

**Q6:** Change to SS PNP Si., SS2109, Motorola, HP Part No. 1853-0037.

**Fan Motor:** Change to Howard 1175-06-4155, HP Part No. 3140-0406.

**Fan Blade:** Change to Howard 6-129-125, HP Part No. 3160-0098.

**CHANGE 2:**

In the replaceable parts table make the following changes:

**C10,11:** Change to HP Part No. 0180-2193.

**Clamp (C10,C11):** Add 2, HP Part No. 0160-2149.

**CHANGE 3:**

In Section II of the manual, add the following note to the instructions for rack mounting two units:

**NOTE**

When rack mounting two units, attach the sides of the units together using the 6-32 screw (supplied with the 14525A rack kit) and the threaded insert nut attached to the right side of each unit under the heat sink. Disregard the 6-32 hex nut/washer supplied with the rack mounting kit.

**CHANGE 4:**

In the replaceable parts table make the following changes:

**Q3:** Change to 2N4240, RCA, HP Part No. 1854-0311.

**CHANGE 5:**

In the replaceable parts table and on the schematic

diagram, make the following changes:  
 R20, R21: Change to 36k, 2W,  $\pm 5\%$  HP Part No. 0698-3651.

**CHANGE 6:**

In the replaceable parts table and on the schematic diagram, make the following changes:  
 R35: Change to 500 ohms, HP Part No. 2100-0328.

**CHANGE 7:**

The serial number prefix of the instrument has been changed from "6F" to "0C,"  
 In the replaceable parts table and on the schematic diagram, make the following changes:  
 R40: Change to 510k, HP Part No. 0686-5145.  
 CR11: Change to HP Part No. 1901-0460.

**CHANGE 8:**

In the replaceable parts list and on the schematic diagram, make the following changes:  
 R38, 39: Change to 390 $\Omega$ ,  $\pm 5\%$ , 3W, HP Part No. 0811-1799.  
 R66, 67: Add, selected value,  $\pm 1\%$ , 1/8W, connected in parallel with R38 and R39 respectively.  
 R32: Change to 2.67k $\Omega$ ,  $\pm 1\%$ ,  $\frac{1}{4}$ W, HP Part No. 0811-1941.  
 R41, 42: Change to 2.43k $\Omega$ ,  $\pm 1\%$ ,  $\frac{1}{4}$ W, HP Part No. 0811-1937.  
 R27: Change to 15k $\Omega$ ,  $\pm 1\%$ , 1/8W, HP Part No. 0757-0446.  
 R28: Delete and replace with jumper.  
 R24: Change to nominal value 100 $\Omega$ ,  $\pm 5\%$ ,  $\frac{1}{4}$ W, HP Part No. 0 93-1015.  
 C5: Change to 510pF, 500Vdc, HP Part No. 0140-0047.  
 CR11: Replace with zener diode (anode connected to emitter of Q6) VR6, 6.19V, 400mW, HP Part No. 1902-0049.  
 CR29: Add, cathode connected to emitter of Q6 and anode connected to base of Q6; 15prv, 400mW, HP Part No. 1901-0461.  
 Q7, 8: Change to single-housing dual differential amplifier, HP Part No. 1854-0221.  
 VR1, 2: Change to 6.2V,  $\pm 5\%$ , 250mW, HP Part No. 1902-1221.  
 R23: Change to 5.6k $\Omega$ ,  $\pm 5\%$ ,  $\frac{1}{4}$ W, HP Part No. 0686-5625.  
 F2: Replace with short circuit.  
 Fuse Holder, HP Part No. 1400-0084: Delete.

Lockwasher, HP Part No. 2190-0037: Delete.  
 Nut, HP Part No. 2950-0038: Delete.  
 Chassis, rear: Change to HP Part No. 06824-00007.  
 Serial ID Plate: Add, HP Part No. 7120-1111.

**CHANGE 9:**

In the replaceable parts list, make the following change:  
 P.C. Board Assembly: Add HP Part No. 06824-60021. Assembly omitted from original parts list in manual; this new P.C. Board Assembly number reflects changes 1 through 9 inclusive.  
 Fan Motor: Change to HP Part No. 3140-0745.

**CHANGE 10:**

In the replaceable parts list and on the schematic diagram make the following changes:  
 R20, 21: Change to 15k $\Omega$ ,  $\pm 5\%$ , 5W, HP Part No. 0811-1867.  
 S1: Change to new type pushbutton switch, HP Part No. 3101-1248.  
 R61: Change to 10k $\Omega$ ,  $\pm 5\%$ , 1W, HP Part No. 0689-1035.

**CHANGE 11:**

In the replaceable parts list and on the schematic, make the following change:  
 C8: Change to 56pF, HP Part No. 0140-0191.

**CHANGE 12:**

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.

**CHANGE 13:**

In the replaceable parts list and on the schematic, make the following change:  
 R33: Change to 110k $\Omega$   $\pm 1\%$ , 1/8W, HP Part No. 0757-0466.

| DESCRIPTION             | HP PART NO. |             |             |
|-------------------------|-------------|-------------|-------------|
|                         | STANDARD    | OPTION A85  | OPTION X95  |
| Front Panel             | 06824-00010 | 06824-00003 | ←           |
| Chassis, Right Side     | 06824-00008 | ←           | 06824-00001 |
| Chassis, Left Side      | 06824-00009 | ←           | 06824-00002 |
| Chassis, Rear           | 06824-00011 | ←           | 06824-00007 |
| Cover                   | 5000-9419   | ←           | 5000-6016   |
| Rack Kit, 1 unit (accy) | 14515A      | 14515A-A85  | ←           |
| Rack Kit, 2 units "     | 14525A      | 145 -A85    | ←           |

**ERRATA:**

Add to the parts list the replacement lamp for illuminated switch 3101-1248, which is used in those supplies that include Change 10. The HP Part No. of the type A1H lamp is 2140-0244.

**CHANGE 14:**

Add to paragraph 2-18 and to the parts list the correct fuse (F1) for Option 028 (230Vac) instruments. Fuse F1 should be a 1A slow-blow type HP Part No. 2110-0007.

**ERRATA:**

Effective January 1st, 1977, Option 007 (10-turn volts-gain control) has been redesignated Option 009. Make this change wherever Option 007 is mentioned in the manual.

**CHANGE 15:**

Add to the parts list on page 6-7 one fuseholder spacer, HP Part No. 5020-2568. This plastic spacer had been added to fuseholder 1400-0084 outside the rear panel to increase the distance between primary and secondary circuits for increased safety.

**CHANGE 16:**

On page 6-6, and on the schematic, change the resistance value for R31 and R43 (in the meter circuit) to  $20k \pm 1$  change their HP Stock No. to 2100-0558.

**CHANGE 17:**

On page 6-8, change the HP part numbers for the front panel + and - binding posts to: 1510-0091, red, qty 2. Change the HP part number for the front panel GND binding post to 1510-0107, black, qty 1. Add the HP part number for nylon nuts: 2950-0144, qty 3.  
4-9-79

**CHANGE 18:**

In the replaceable parts list and on the schematic, delete Q2 and R1. Change Q13 and Q14 to silicon transistors, HP Part No. 1853-0485; change CR18 to silicon, 1901-0327; change R8 to 30 ohm  $\pm 5\%$ , 2W, 0764-0041; change R61 to 7.5k  $\pm 5\%$ , 3W, 0811-1815.

**CHANGE 19:**

In the replaceable parts list, change switch S1 to HP Part No. 3101-2287. On the schematic diagram, change switch S1 to show two switch sections, one which breaks the AC line (as shown).  
The other breaks the ACC line.

**CHANGE 20:**

In the replaceable parts list, change C3 to 0.1 $\mu$ F, 500Vdc, HP Part No. 0160-0269. Add C.S.A. (Canadian Standards Association) identification label, HP Part No. 7120-8572. The Model 6824A is now C.S.A. certified for laboratory equipment.

**ERRATA:**

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

In the replaceable parts list, page 6-5, change Q2,13,14 to HP Part No. 1853-0485.

► On page 1-3, change the Output Impedance specification to read as follows: "Less than 30 ohms from 1000Hz to 100kHz." On page 5-6, change paragraph 5-20g to read as follows: "Values should be less than 0.3 ohm and 30 ohms respectively."

**CHANGE 21:**

In the replaceable parts list, page 6-5, add C22, 56pf, 300V, Mica, HP Part No. 0140-0191, qty. 1. On the schematic, C22 is added between the base and collector of Q12.

\*This change also applies to the following serial numbers:

|            |            |
|------------|------------|
| 2001A 3149 | 2001A 3173 |
| 3153-3155  | 3178,3179  |
| 3157       | 3181-3188  |
| 3162,3163  | 3190       |
| 3171       | 3198       |

**CHANGE 22:**

In the replaceable parts list, page 6-5, change C22 (added in CHANGE 21) to 270pf, 300V, Mica, HP Part No. 0140-0210, qty. 1.

†This change also applies to the following serial numbers: 2205A 3211-3220

9-24-82

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Tel: 72057  
Telex: 0155-459  
Cable: BLUEFROST  
A,E

Blue Star Ltd.  
T.C. 7/603 Poomina  
Maruthankuzhi  
TRIVANURUM 695 013  
Tel: 65799  
Telex: 0884-259  
Cable: BLUESTAR  
E

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BERCA Indonesia P.T.  
P.O. Box 496/JKT.  
J. Abdul Muis 62  
JAKARTA  
Tel: 373009  
Telex: 46748 BERSAL IA  
Cable: BERSAL JAKARTA  
P

BERCA Indonesia P.T.  
Wisma Antara Bldg., 17th floor  
JAKARTA  
A,CS,E,M  
BERCA Indonesia P.T.  
P.O. Box 174/SBY.  
J. Kutei No. 11  
SURABAYA  
Tel: 68172  
Telex: 31146 BERSAL SB  
Cable: BERSAL-SURABAYA  
A\*,E,M,P

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Hewlett-Packard Trading S.A.  
Service Operation  
Al Mansoor City 98/3/7  
BAGHDAD  
Tel: 551-49-73  
Telex: 212-455 HEPARAO IK  
CH,CS

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Hewlett-Packard Ireland Ltd.  
82/83 Lower Leeson St.  
DUBLIN 2  
Tel: (1) 60 68 00  
Telex: 30439  
A,CH,CM,CS,E,M,P  
Cardiac Services Ltd.  
Kilmore Road  
Artane  
DUBLIN 6  
Tel: (01) 35 1820  
Telex: 30439  
M

**ISRAEL**  
Eidan Electronic Instrument Ltd.  
P.O. Box 1270  
JERUSALEM 91000  
16, Ohalev St.  
JERUSALEM 94487  
Tel: 533 221, 553 242  
Telex: 25231 AB/PAKRO IL  
A

Electronics Engineering Division  
Motorola Israel Ltd.  
18 Kramenski Street  
P.O. Box 25018  
TEL-AVIV 67999  
Tel: 3-338973  
Telex: 33569 Moll IL  
Cable: BASTEL Tel-Aviv  
CH,CM,CS,E,M,P

**ITALY**  
Hewlett-Packard Italiana S.p.A.  
Traversa 99C  
Via Giulio Patroni, 19  
I-70124 BARI  
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M

Hewlett-Packard Italiana S.p.A.  
Via Martin Luther King, 38/111  
I-40132 BOLOGNA  
Tel: (051) 402394  
Telex: 511650  
CH,E,MS

Hewlett-Packard Italiana S.p.A.  
Via Principe Niccolò 43G/C  
I-95126 CATANIA  
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Telex: 970291  
C,P

Hewlett-Packard Italiana S.p.A.  
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I-80131 NAPLES  
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Telex: 710698  
A,CH,E

Hewlett-Packard Italiana S.p.A.  
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I-16156 GENOVA PEGLI  
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E,C

Hewlett-Packard Italiana S.p.A.  
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Telex: 430315  
A,CH,E,MS

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I-00144 ROMA  
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Telex: 610514  
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CH,E

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CM,C\*,E

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KOBE, 650, Hyogo  
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C,E

Yokogawa-Hewlett-Packard Ltd.  
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KUMAGAYA, Saitama 360  
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Yokogawa-Hewlett-Packard Ltd.  
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4-7 Hanabata-cho  
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CH,E

Yokogawa-Hewlett-Packard Ltd.  
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CH,E

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CH,CM,E

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NAGOYA, 450 Aichi  
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CH,CM,CS,E,MS

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Yodogawa-ku  
OSAKA, 532  
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Telex: YHPOSA 523-3624  
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Telex: 21456 SABCO JO  
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NAIROBI  
Tel: 331955  
Telex: 22639  
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Kangnam-Ku  
C.P.O. Box 2775  
SEOUL  
Tel: 555-7555, 555-5447  
Telex: K27364 SAMSAN  
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P.O. Box 270 Safat  
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Telex: 22747 Malin-KT  
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Achrafieh  
P.O. Box 165.167  
BEIRUT  
Tel: 290293  
MP\*\*

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Woluwe-dal  
B-1200 BRUSSELS  
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Telex: 23-494 paloben bru  
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American  
Jalan Semantan, Damansara Heights  
KUALA LUMPUR 23-03  
Tel: 943022  
Telex: MA31011  
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Protel Engineering  
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P.O. Box 1917  
Kuching, SARAWAK  
Tel: 53544  
Telex: MA 70904 FROMAL  
Cable: PROTELENG  
A,E,M

**MALTA**  
Philip Toledo Ltd.  
Notable Rd.  
MREHET  
Tel: 447 47, 455 66  
Telex: 649 Media MH  
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Hewlett-Packard Mexicana, S.A. de  
C.V.  
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Tepic, Jalisco  
MEXICO D.F. 16020  
Tel: 676-4600  
Telex: 17-74-507 HEWPACK MEX  
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Effective November 1, 1982:  
Hewlett-Packard Mexicana, S.A. de  
C.V.  
Ejercito Nacional #570  
Colonia Granada  
11560 MEXICO, D.F.  
CH\*\*

Hewlett-Packard Mexicana, S.A. de  
C.V.  
Rio Volga 600  
Pte. Colonia del Valle  
MONTERREY, N.L.  
Tel: 78-42-93, 78-42-40, 78-42-41  
Telex: 038-2410 HPMTY ME  
CH  
Effective Nov. 1, 1982  
Ave. Colonia del Valle #409  
Col. del Valle  
Municipio de garza garcia  
MONTERREY, N.V.  
ECISA  
Talle 229, Piso 10  
Polanco MEXICO D.F. 11570  
Tel: 250-5391  
Telex: 17-72755 ECE ME  
M

**MOROCCO**  
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81 rue Karachi  
CASABLANCA  
Tel: 3041-82, 3068-39  
Telex: 23051, 22822  
E  
Gerep  
2 rue d'Agadir  
Boite Postale 156  
CASABLANCA  
Tel: 272093, 272095  
Telex: 23 739  
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P.O. Box 667  
NL 1180 AR AMSTELVEEN  
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Telex: 13 216  
A,CH,CM,CS,E,M,P

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NL 2900 AA CAPELLE, IJssel  
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Telex: 21261 HEPAC NL  
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Epsom, AUCKLAND  
Tel: 687-150  
Cable: HEWPACK Auckland  
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Hewlett-Packard (N.Z.) Ltd.  
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Kilbirnie, WELLINGTON 3  
P.O. Box 9443  
Courtenay Place, WELLINGTON 3  
Tel: 877-199  
Cable: HEWPACK Wellington  
CH,CM,E,P

Northrop Instruments & Systems  
Ltd.  
369 Khyber Pass Road  
P.O. Box 8602  
AUCKLAND  
Tel: 794-091  
Telex: 60605  
A,M

Northrop Instruments & Systems  
Ltd.  
110 Mandeville St.  
P.O. Box 5388  
CHRISTCHURCH  
Tel: 486-928  
Telex: 4203  
A,M

Northrop Instruments & Systems  
Ltd.  
Surdlee House  
85-87 Ghuznee Street  
P.O. Box 2406  
WELLINGTON  
Tel: 850-091  
Telex: NZ 3380  
A,M

**NORTHERN IRELAND**  
Cardiac Services Company  
95A /inaghy Road South  
BELFAST BT 10 0BY  
Tel: (0232) 625-566  
Telex: 747626  
M

**NORWAY**  
Hewlett-Packard Norge A/S  
Folke Bernadottel vei 50  
P.O. Box 3558  
N-5033 FYLLINGSDALEN (Bergen)  
Tel: (05) 16-55-40  
Telex: 16621 hpnas n  
CH,CS,E,MS

Hewlett-Packard Norge A/S  
Ostendalen 18  
P.O. Box 34  
N-1345 ØSTERAS  
Tel: (02) 17-11-80  
Telex: 16621 hpnas n  
A,CH,CM,CS,E,M,P

**OMAN**  
Khajil Ramdes  
P.O. Box 19  
MUSCAT  
Tel: 722225, 745001  
Telex: 3289 BROKER MI, MUSCAT  
P



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Arranged Alphabetically by Country

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P.O. Box 169  
MUSCAT  
Tel: 734 201-3  
Telex: 3274 BAHWAN MB

**PAKISTAN**  
Mushko & Company Ltd.  
1-B, Street 43  
Sector F-8/1  
ISLAMABAD  
Tel: 26875  
Cable: FEMUS Rawalpindi  
A,E,M

Mushko & Company Ltd.  
Osman Chambers  
Abdullah Haroon Road  
KARACHI 0302  
Tel: 511027, 512927  
Telex: 2894 MUSKO PK  
Cable: COOPERATOR Karachi  
A,E,M,P

**PANAMA**  
Electrónico Balboa, S.A.  
Calle Samuel Lewis, Ed. Alta  
Apartado 4929  
PANAMA S  
Tel: 64-2700  
Telex: 3483 ELECTRON PG  
A,C,M,E,M,P  
Foto Internacional, S.A.  
Colon Free Zone  
Apartado 2068  
COLON J  
Tel: 45-2333  
Telex: 6626 IMPORT PG  
P

**PERU**  
Cía Electro Médica S.A.  
Los Flamencos 145, San Isidro  
Casilla 1030  
LIMA I  
Tel: 41-4323, 41-3703  
Telex: Puz, Booth 25306  
A,C,M,E,M,P

**PHILIPPINES**  
The Online Advanced Systems  
Corporation  
Rico House, Amorao Cor. Herrera  
Street  
Lagassi Village, Makati  
P.O. Box 1510  
Metro MANILA  
Tel: 85-35-81, 85-34-91, 85-32-21  
Telex: 3274 ONLINE  
A,C,H,C,S,E,M  
Electronic Specialists and  
Proprietors Inc.  
690-B Epitacio de los Santos  
Avenue  
Cubao, QUEZON CITY  
P.O. Box 2649 Manila  
Tel: 98-96-81, 98-96-82  
Telex: 40018, 42000  
MACKAY BOOTH  
P

**PORTUGAL**  
Mundiner  
Intercambio Mundial de Comércio  
S.a.r.l.  
P.O. Box 2781  
Av. Antonio Augusto de Aguiar 138  
P-LISSON  
Tel: (19) 53-21-31, 53-21-37  
Telex: 16691 mundin p  
M

**Soquimica**  
Av. de Libertad, 220-2  
1298 LISBON Codes  
Tel: 56 21 81/2/3  
Telex: 13316 SABASA P  
Teletra-Empresa Técnica de  
Equipamentos Eléctricos S.a.r.l.  
Rua Rodrigo de Fonseca 103  
P.O. Box 2531  
P-LISSON 1  
Tel: (19) 68-60-72  
Telex: 12598  
CH,C,S,E,P

**PUERTO RICO**  
Hewlett-Packard Puerto Rico  
P.O. Box 4407  
CANOLINA, Puerto Rico 00628  
Calle 272 Edificio 203  
Urb. Country Club  
RIO Piedras, Puerto Rico 00924  
Tel: (809) 762-7255  
A,C,H,CS

**QATAR**  
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DOHA  
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Telex: 4439 NASSER DH  
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Computearbia  
P.O. Box 2750  
DOHA  
Tel: 883555  
Telex: 4838 CHPARB  
P

Eastern Technical Services  
P.O. Box 4747  
DOHA  
Tel: 329 993  
Telex: 4156 EASTEC DH

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Modern Electronic Establishment  
Hewlett-Packard Division  
P.O. Box 281  
Thuqbah  
AL-KHOBAR  
Tel: 864-46 78  
Telex: 671 106 HPMEEK SJ  
Cable: ELECTA AL-KHOBAR  
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Hewlett-Packard Division  
P.O. Box 1228  
Redec Plaza, 6th Floor  
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Tel: 644 38 48  
Telex: 402712 FARNAS SJ  
Cable: ELECTA JEDDAH  
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Modern Electronic Establishment  
Hewlett-Packard Division  
P.O. Box 2728  
RIYADH  
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Telex: 202049 MEERY I SJ  
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Royal Bank Buildings  
Swan Street  
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CH  
Hewlett-Packard Ltd.  
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Cable: HEWPACK, Singapore  
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Kolek Ayer Industrial Estate  
SINGAPORE 1334  
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Telex: RS 26283  
CM

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PORT ELIZABETH 6001  
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CH

Hewlett-Packard So Africa (Pty.) Ltd.  
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Constantia Park Ridge Shopping  
Centre  
Constantia Park  
PRETORIA  
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Telex: 32183  
CHE

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Hewlett-Packard Española S.A.  
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A,C,S,M,S,P

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C/Ramon Gordillo, 1 (Entlo.3)  
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Hewlett-Packard (Schweiz) AG  
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CH-3018 BERN  
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CH-1202 GENEVA  
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CH,CM,CS

Hewlett-Packard (Schweiz) AG  
19 Chemin Châteaue Bloc  
CH-1219 LE LIGNON-Geneva  
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Cable: HEWPACKAG Geneva  
A,E,M,S,P

Hewlett-Packard (Schweiz) AG  
Allmend 2  
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Tel: (57) 31 21 11  
Telex: 33833 hpag ch  
Cable: HPAG CH  
A,C,H,CM,C,S,E,M,S,P

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General Electronic Inc.  
Nuri Basha  
P.O. Box 5781  
DAMASCUS  
Tel: 33-24-87  
Telex: 11216 ITKAL SY  
Cable: ELECTROBOR DAMASCUS  
E

**Middle East Electronics**  
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Boite Postale 2308  
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M,P

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Telex: 84439 Simonco TH  
Cable: UNIMESA Bangkok  
A,C,H,C,S,E,M  
Bangkok Business Equipment Ltd.  
5/5-5 Dejo Road  
BANGKOK  
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Telex: 87669-BEQUPT TH  
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Tunis Electronique  
31 Avenue de la Liberté  
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Corema  
1 ter. Av. de Carthage  
TUNIS  
Tel: 253-821  
Telex: 12319 CABAM TN  
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Teknim Company Ltd.  
Iran Caddesi No. 7  
Kavaklıdere, ANKARA  
Tel: 275800  
Telex: 42155 TKNM TR  
E  
E.M.A.  
Medina Etem Sokak No.41/8  
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M

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Telex: 68136 Emtac SH  
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Hewlett-Packard Co.  
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Hewlett-Packard Co.  
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55th Floor  
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WOODBURY, NY 11797  
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**Hewlett-Packard Co.**  
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GREENSBORO, NC 27450  
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**Hewlett-Packard Co.**  
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**Hewlett-Packard Co.**  
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**Hewlett-Packard de Venezuela C.A.**  
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**END**