and turn on supply.

d. Adjust CURRENT control until front panel meter reads exactly the maximum rated output current.

e. Read and record voltage indicated on differential voltmeter.

f. Short out load resistor (R_y) by closing switch S1.

g. Reading on differential voltmeter should not vary from reading recorded in step e by more than the following:

Model No.	6253A, 6284A	6255A, 6289A
Variation (mVdc)	±0.183	±0.265

Model No.	6281A	6294A
Variation (mVdc)	±0.5	±0.35

5-36 Line Regulation. To check the line regulation proceed as follows:

a. Utilize test setup shown in Figure 5-4 leaving switch S1 open throughout test.

b. Connect variable auto transformer between input power source and power supply power input.

c. Adjust auto transformer for 105Vac input.

d. Turn VOLTAGE control(s) fully clockwise.

e. Set METER switch to highest current range and turn on supply.

f. Adjust CURRENT controls until front panel meter reads exactly the maximum rated output current.

g. Read and record voltage indicated on differential voltmeter.

h. Adjust variable auto transformer for 125 Vac input.

i. Reading on differential voltmeter should not vary from reading recorded in step g by more than the following:

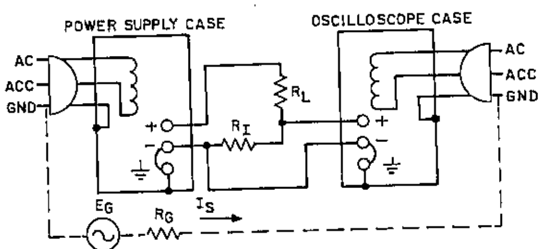
Model No.	6253A, 6284A	6255A, 6289A
Variation (mVdc)	±0.183	±0.265

Model No.	6281A	6294A
Variation (mVdc)	±0.15	±0.35

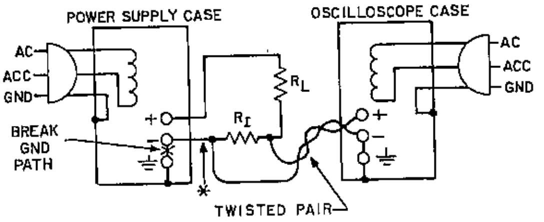
5-37 Ripple and Noise. Most of the instructions pertaining to the ground loop and pickup problems associated with constant voltage ripple and noise measurement also apply to the measurement of constant current ripple and noise. Figure 5-12 illustrates the most important precautions to be observed when measuring the ripple and noise of a constant current supply. The presence of a 120 cycle waveform on the oscilloscope is normally indicative of a correct measurement method. A waveshape having 60 Hz as its fundamental component is typically associated with an incorrect measurement setup.

5-38 Ripple and Noise Measurement. To check the ripple and noise, proceed as follows:

a. Connect the oscilloscope or RMS voltmeter as shown in Figures 5-12B or 5-12C.

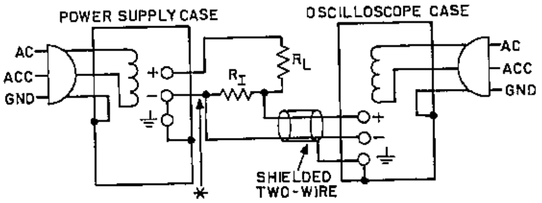


A. INCORRECT METHOD – GROUND CURRENT I_S PRODUCES 60 CYCLE DROP IN NEGATIVE LEAD WHICH ADDS TO THE POWER SUPPLY RIPPLE DISPLAYED ON SCOPE.



* LENGTH OF LEAD BETWEEN R_I AND OUTPUT TERMINAL OF POWER SUPPLY MUST BE HELD TO ABSOLUTE MINIMUM.

B. A CORRECT METHOD USING A SINGLE-ENDED SCOPE. OUTPUT FLOATED TO BREAK GROUND CURRENT LOOP, TWISTED PAIR REDUCES STRAY PICKUP ON SCOPE LEADS.



* LENGTH OF LEAD BETWEEN R_I AND GROUNDED OUTPUT TERMINAL OF POWER SUPPLY MUST BE HELD TO ABSOLUTE MINIMUM.

C. A CORRECT METHOD USING A DIFFERENTIAL SCOPE WITH FLOATING INPUT. GROUND CURRENT PATH IS BROKEN; COMMON MODE REJECTION OF DIFFERENTIAL INPUT SCOPE IGNORES DIFFERENCE IN GROUND POTENTIAL OF POWER SUPPLY & SCOPE, SHIELDED TWO-WIRE FURTHER REDUCES STRAY PICKUP ON SCOPE LEAD.

MODEL	6253A	6255A	6281A	6284A	6289A	6294A
R_I (OHMS)	0.33	0.66	0.20	0.33	0.66	1.0
R_L (OHMS)	6	26	1.0	6	26	59

Figure 5-12. CC Ripple and Noise Test Setup

b. Rotate the VOLTAGE control fully cw.

c. Set METER switch to highest current range and turn on supply.

d. Adjust CURRENT control until front panel meter reads exactly the maximum rated output current.

e. The ripple and noise indication should be less than the following:

Model	6253A,6284A	6255A,6289A	6281A	6294A
mA rms	2	0.5	4	0.5

5-39 TROUBLESHOOTING

5-40 Components within Hewlett-Packard power supplies are conservatively operated to provide maximum reliability. In spite of this, parts within a supply 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.

5-41 TROUBLE ANALYSIS

5-42 General. Before attempting to troubleshoot this instrument, ensure that the fault is with the instrument and not with an associated circuit. The performance test (Paragraph 5-10) enables this to be determined without having to remove the instrument from the cabinet.

5-43 Once it is determined that the power supply is at fault, check for obvious troubles such as 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.

5-44 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 boards).

5-45 Table 5-2 includes the symptoms and probable causes of many possible troubles. If either high or low output voltage is a symptom, there are two methods of isolating the fault. The first is a simplified procedure that involves only measuring voltages; the second is a more thorough approach requiring that transistor stages be opened or shorted. Both methods are described as follows:

1. First, the reference, bias, and filtered dc voltages as given in Table 5-3 should be checked. Then the voltage levels at critical points (base and collector) in the feedback loop should be measured and compared to the normal voltages given on the overall schematic diagram at the rear of the manual. This method of troubleshooting a feedback loop is not always conclusive; a better method is described in (2).

2. First, measure the reference, bias, and filtered dc voltages as given in Table 5-3. Then, drive each stage in the feedback loop into conduction or cutoff by either shorting or opening the previous stage as indicated in Tables 5-4 or 5-5.

Table 5-2. Common Troubles

Symptom	Probable Cause
Low output or no output voltage	Refer to Table 5-3, then 5-4.
High output voltage	Refer to Table 5-3, then 5-5.
High ripple	a. Check operating setup for ground-refer to Paragraph 5-18. b. If output floating, connect 1µf capacitor between output and ground. c. Check for excessive internal ripple; refer to Table 5-3. d. Ensure that supply is not in constant-current operation under loaded conditions. To prevent this condition turn CURRENT control fully clockwise. e. Check for low voltage across C14, C12, or C10.

Table 5-2. Common Troubles (Continued)

Symptom	Probable Cause
Poor line regulation	a. Improper measuring technique; refer to Paragraph 5-3. b. Check reference circuit voltages, Table 5-3. c. Check reference circuit adjustment, Paragraph 5-62.
Poor load regulation (Constant Voltage)	a. Improper measuring technique; refer to Paragraph 5-3. b. Check the regulation characteristics of Zener diode VR1 as follows: (1) Connect differential voltmeter across VR1 (2) Connect appropriate load resistor (RY), given in Figure 5-4, across (+) and (-) output terminals (3) Perform steps b through f of Paragraph 5-16 (4) If the differential voltmeter reading varies by more than 0.5mV, replace VR1. c. Ensure that supply is not in constant-current operation under loaded conditions. To prevent this condition turn CURRENT control fully clockwise.
Poor load regulation (Constant Current)	a. Improper measuring technique; refer to Paragraph 5-3. b. Check the regulation characteristics of Zener diode VR2 as follows: (1) Connect differential voltmeter across VR2 (2) Connect appropriate load resistor (RY), given in Figure 5-4, across (+) and (-) output terminals (3) Perform steps b through f of Paragraph 5-35 (4) If the differential voltmeter reading varies by more than 0.5mV, replace VR2. c. C19, C20, and CR34 leaky. d. Check clamp circuit, Q10, CR30, VR3, and CR32. e. Ensure that supply is not crossing over into constant voltage operation. To prevent this condition, load the supply and turn the VOLTAGE control fully clockwise.
Oscillates	a. Check C5 open. Adjustment of R30; refer to Paragraph 5-64. b. Check R21 and C3 in current input circuit.
Poor stability (Constant Voltage)	a. Check +6.2Vdc reference voltage (Table 5-3). b. Noisy programming resistor R10. c. CR1, CR2 leaky. d. Check R1, R12, R13, and C2 for noise or drift. e. Stage Q1 defective.
Poor stability (Constant Current)	a. Check -6.2Vdc reference voltage (Table 5-3). b. Noisy programming resistor R16. c. CR5, CR34, C19, C3 leaky. d. Check R18, R19, R20, R21, R54, and R55 for noise or drift. e. Stage Q2 defective.
Poor transient recovery	a. Check R30 and C5. Refer to adjustment procedure Paragraph 5-64.

Table 5-3. Reference, Bias, and filtered DC Troubleshooting

Meter Common	Meter Positive	Normal Vdc	Normal Ripple (P-P)	Probable Cause
31	+S	6.2 ✓ 6.44	0.5mV	VR2
+S	33	6.2 6.18	0.5mV	VR1
+S	37	12.4 12.42 ✓	5mV	Q8, Q9
34	37	24 ✓ 24.78	1.4V	C10, CR22, CR23, T1
41	23	4.4 ✓ 4.46	20mV	VR4
41	38	28V(6253A) 53V(6255A) 12V(6281A) 28V(6284A) 53V(6289A) 80V(6294A) 52.2 ✓	3V 1V 2V 3V 1V 1V	C12, CR24, CR25, T1
- Out	27	38V(6253A) 62V(6255A) 21V(6281A) 38V(6284A) 62V(6289A) 90V(6294A) 61.5	0.4V 0.6V 0.2V 0.4V 0.5V 0.8V	C14, C16, CR26, CR27, R49, T1

Table 5-4. Low Output Voltage Troubleshooting

Step	Action	Response	Probable Cause
1	Turn the VOLTAGE control fully clockwise and disconnect the load		
2	To eliminate the constant current circuit as a cause of the malfunction, remove CR4 cathode or anode lead	a. Output increases b. Output remains low	a. Stage Q2 defective b. Reconnect CR4 and proceed to step 3
3	Check conduction of Q6 and Q7 by connecting a jumper between Q4 emitter (22) and base (18)	a. Output remains low b. Output increases	a. Q6, Q7, CR11 or associated parts defective b. Remove jumper and proceed to step 4
4	Check turnoff of Q4 by shorting Q5 emitter to base	a. Output remains low b. Output increases	a. Q4, CR17, R38 defective b. Remove jumper and proceed to step 5
5	Check turnoff of Q5 by shorting Q3 emitter to collector	a. Output remains low b. Output increases	a. Q5, R31 or associated components defective b. Remove short across Q3 and proceed to step 6

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

Step	Action	Response	Probable Cause
6	Check conduction of Q3 by shorting Q1A emitter to collector	a. Output remains low	a. Stage Q3 or Q16 defective
		b. Output increases	b. Remove short and proceed to step 7
7	Remove CR32 anode or cathode lead	a. Output increases	a. Voltage clamp circuit is defective
		b. Output remains low	b. Reconnect CR32. Stage Q1 defective. Check R10, C1 for short and R12, R13 for open.

Table 5-5. High Output Voltage Troubleshooting

Step	Action	Response	Probable Cause
1	Turn the VOLTAGE control to approximately mid-range and disconnect the load. If the output voltage should rise to an excessive value with the VOLTAGE control turned ccw, the control could be damaged.		
2	Check turnoff of Q6 and Q7 by shorting collector of Q5 to emitter of Q4	a. Output remains high	a. Q6, Q7, CR11, R23, R27, R34 defective VR5
		b. Output decreases	b. Remove short across Q4 and proceed to step 3
3	Check conduction of Q4 by shorting Q5 emitter to collector	a. Output remains high	a. Q4, CR17, R38 defective
		b. Output decreases	b. Remove short across Q5 and proceed to step 4
4	Open Q3 collector lead Check conduction of Q5 by shorting R33	a. Output remains high	a. Q5, R31 or associated components defective
		b. Output decreases	b. Remove short and proceed to step 5
5	Check turnoff of Q3 by shorting Q3 base to emitter	a. Output remains high	a. Stage Q3 or Q17 defective
		b. Output decreases	b. Remove short and proceed to step 6
6	Remove CR32 anode or cathode	a. Output decreases	a. Voltage clamp circuit is defective
		b. Output remains high	b. Reconnect CR32 and proceed to step 7
7	On rear terminal board, short A6 to (-)	a. Output remains high	a. Stage Q1 defective
		b. Output decreases	b. Remove short across terminals A6 and (-). Check R10 for open and R12, R13 for short.

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

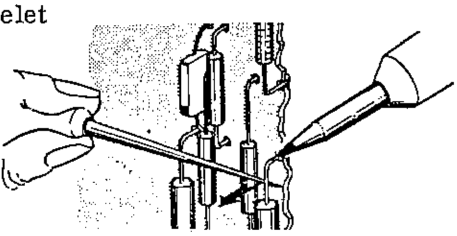
A break in the copper should be repaired by soldering a short length of tinned copper wire across the break.

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

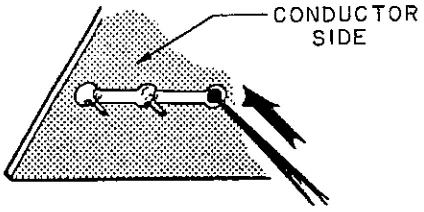
When replacing components with multiple mounting pins such as tube sockets, electrolytic capacitors, and potentiometers, it will be necessary to lift each pin slightly, working around the components several times until it is free.

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

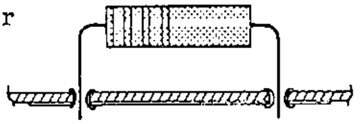
1. Apply heat sparingly to lead of component to be replaced. If lead of component passes through an eyelet in the circuit board, apply heat on component side of board. If lead of component does not pass through an eyelet, apply heat to conductor side of board.



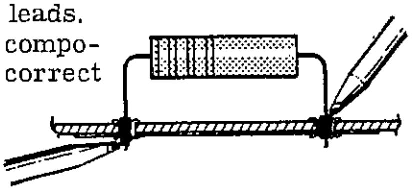
2. Reheat solder in vacant eyelet and quickly insert a small awl to clean inside of hole. If hole does not have an eyelet, insert awl or a #57 drill from conductor side of board.



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

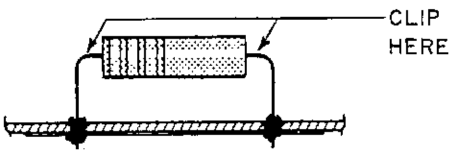


4. Hold part against board (avoid overheating) and solder leads. Apply heat to component leads on correct side of board as explained in step 1.

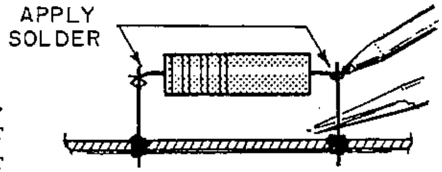


In the event that either the circuit board has been damaged or the conventional method is impractical, use method shown below. This is especially applicable for circuit boards without eyelets.

1. Clip lead as shown below.



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



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

Figure 5-13. Servicing Printed Wiring Boards

5-46 REPAIR AND REPLACEMENT

5-47 Before servicing a printed wiring board, refer to Figure 5-13. Section VI of this manual contains a list of replaceable parts. Before replacing a semiconductor device, refer to Table 5-6 which lists the special characteristics of selected semiconductors. If the device to be replaced is not listed in Table 5-6, the standard manufacturers part number listed in Section VI is applicable. After replacing a semiconductor device, refer to Table 5-7 for checks and adjustments that may be necessary.

Table 5-6. Selected Semiconductor Characteristics

Reference Designator	Characteristics	Stock No.	Suggested Replacement
Q1, 2, 11	Matched differential amplifier. NPN Si Planar. 70 (min.) h_{FE} $i_c = 1$ ma. $V_{CE} = 5V$. I_{co} 0.01μa @ $V_{cbo} = 5V$.	1854-0229	2N2917 G. E.
Q6, 7 (16)	NPN Power. $h_{FE} = 35$ (min.) @ $I_c = 4A$, $V_{CE} = 4V$.	1854-0228	2N3055 R. C. A.
CR1-5, 19, 20, 30, 32	Si. rectifier, 200ma, 200prv	1901-0033	1N485B Sylvania
VR3	Diode, zener, 4.22V, 400mW	1902-3070	1N749 Motorola
VR4, 5	Diode, zener, 4.3V, 1W	1902-0797	1N3824 Motorola

Table 5-7. Checks and Adjustments After Replacement of Semiconductor Devices

Reference	Function	Check	Adjust
Q1	Constant voltage differential amplifier	Constant voltage (CV) line and load regulation. Zero volt output.	R6 or R8
Q2	Constant current differential amplifier	Constant current (CC) line and load regulation. Zero current output.	R25 or R28
Q3, Q16	Mixer amplifier	CV/CC load regulation. CV transient response.	R30.
Q4, Q5	Error amplifiers and driver	CV/CC load regulation.	
Q6, Q7	Series regulator	CV/CC load regulation.	
Q8, Q9	Reference regulator	Reference circuit line regulation.	R46
Q10	Clamp circuit	CC load regulation.	
Q11-Q15	Meter circuit	Meter zero. Voltmeter/ammeter tracking.	R63, R72 R56
CR1, CR2	Limiting diodes	CV load regulation.	
CR3, CR4, CR5	OR-gate diodes and limiting diode	CV/CC load regulation.	

Table 5-7. Checks and Adjustments After Replacement of Semiconductor Devices (Continued)

Reference	Function	Check	Adjust
CR8-CR10	Forward bias regulator	Voltage across each diode 0. 6 to 0. 9 volts.	
CR22-CR27	Rectifier diodes	Voltage across appropriate filter capacitor.	
CR34	Protection diode	Output voltage	
VR1	Positive reference voltage	Positive reference voltage (+6. 2V).	
VR2	Negative reference voltage	Negative reference voltage (-6. 2V).	
VR4	Bias voltage	4. 4V	

Table 5-8. Calibration and Adjustment Summary

Adjustment or Calibration	Paragraph	Control Device
Meter Zero	5-50	Pointer
Voltmeter Tracking	5-52	R63 and R72
Ammeter Tracking	5-54	R56
"Zero" Volt Output	5-57	R6 or R8
"Voltage" Programming Current	5-58	R13
"Zero" Current Output	5-60	R25 or R28
"Current" Programming Current	5-61	R19
Reference Circuit Line Voltage Adjustment	5-63	R46
Negative Reference Load Adjustment	5-64	Replace VR2
Positive Reference Load Adjustment	5-65	Replace VR1
Transient Response	5-66	R30

5-48 ADJUSTMENT AND CALIBRATION

5-49 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 5-8 summarizes the adjustments and calibrations contained in the following paragraphs.

5-50 METER ZERO

5-51 The meter pointer must rest on the zero calibration mark on the meter scale when the instrument is at normal operating temperature, resting in its normal operating position, and the instrument is turned off. To zero-set the meter proceed as follows:

a. Turn on instrument and allow it to come up to normal operating temperature (about 20 minutes).

b. Turn the instrument off. Wait two minutes for power supply capacitors to discharge completely.

c. Rotate adjustment screw on front of meter clockwise until the meter pointer is to the left of zero and further clockwise rotation will move the pointer upscale towards zero.

d. Turn the adjustment screw clockwise until the pointer is exactly over the zero mark on the scale. If the screw is turned too far, repeat steps c and d.

e. Turn meter adjustment screw counterclockwise about 15 degrees to break contact between adjustment screw and pointer mounting yoke, but not far enough to move the pointer back downscale. If screw is turned too far, as shown by the needle moving, repeat the procedure. The meter is now zero-set for best accuracy and mechanical stability.

5-52 VOLTMETER TRACKING

5-53 To calibrate voltmeter tracking, proceed as follows:

a. To electrically zero meter, set METER switch to highest current position and, with supply on and no load connected, adjust R63 until front panel meter reads zero.

b. Connect differential voltmeter across supply, observing correct polarity.

c. Set METER switch to highest voltage range and turn on supply. Adjust VOLTAGE control until differential voltmeter reads exactly the maximum rated output voltage.

d. Adjust R72 until front panel meter also indicates maximum rated output voltage.

5-54 AMMETER TRACKING

5-55 To calibrate ammeter tracking proceed as follows:

a. Connect test setup shown on Figure 5-4 leaving switch S1 open.

b. Turn VOLTAGE control fully clockwise and set METER switch to highest current range.

c. Turn on supply and adjust CURRENT controls until differential voltmeter reads 1. 0Vdc.

d. Adjust R56 until front panel meter indicates exactly the maximum rated output current.

5-56 CONSTANT VOLTAGE PROGRAMMING CURRENT

5-57 To calibrate the zero volt programming accuracy, proceed as follows:

a. Connect differential voltmeter between +S and -S terminals.

b. Short out voltage controls by connecting jumper between terminals A6 and -S.

c. Rotate CURRENT controls fully clockwise and turn on supply.

d. Observe reading on differential voltmeter.

e. If it is more positive than 0 volts, shunt resistor R6 with decade resistance box.

f. Adjust decade resistance until differential voltmeter reads zero, then shunt R6 with resistance value equal to that of the decade resistance.

g. If reading of step d is more negative than 0 volts, shunt resistor R8 with the decade resistance box.

h. Adjust decade resistance until differential voltmeter reads zero then shunt R8 with resistance value equal to that of the decade box.

5-58 To calibrate the constant voltage programming current, proceed as follows:

a. Connect a 0. 1%, $\frac{1}{2}$ watt resistor between terminals -S and A6 on rear barrier strip. Resistor value to be as follows:

Model	6253A,6284A	6255A,6289A	6281A	6294A
Resistance	4KΩ	8KΩ	1. 5KΩ	18KΩ

b. Disconnect jumper between A6 and A8 (leaving A6 and A7 jumpered) on rear terminal barrier strip.

c. Connect a decade resistance in place of R13.

d. Connect a differential voltmeter between +S and -S and turn on supply.

e. Adjust decade resistance box so that differential voltmeter indicates maximum rated output voltage within the following tolerances:

Model No.	6253A, 6284A	6255A, 6289A
Tolerance (Vdc)	±0. 4	±0. 8

Model No.	6281A	6294A
Tolerance (Vdc)	±0. 15	±1. 2

f. Replace decade resistance with resistor of appropriate value in R13 position.

5-59 CONSTANT CURRENT PROGRAMMING CURRENT

5-60 To calibrate the zero current programming accuracy, proceed as follows:

a. Connect differential voltmeter between +S and -S terminals.

b. Short out current controls by connecting jumper between terminals A1 and A5.

c. Rotate VOLTAGE control(s) fully clockwise and turn on supply.

d. Observe reading on differential voltmeter.

e. If it is more positive than 0 volts, shunt resistor R25 with a decade resistance box.

f. Adjust decade resistance until differential voltmeter reads zero, then shunt R25 with resistance value equal to that of decade resistance.

g. If reading of step d is more negative than 0 volts, shunt resistor R28 with decade resistance.

h. Adjust decade resistance until differential voltmeter reads zero, then shunt R28 with resistance value equal to that of decade box.

5-61 To calibrate the constant current programming current, proceed as follows:

a. Connect power supply as shown in Figure 5-4.

b. Remove strap between A3 and A4 (leaving A4 and A5 jumpered).

c. Connect a 0. 1%, $\frac{1}{2}$watt resistor between A1 and A5. Resistor value to be as follows:

Model No.	6253A, 6284A	6255A, 6289A
Resistance	1. 5KΩ	750Ω

Model No.	6281A	6294A
Resistance	1KΩ	1KΩ

d. Connect decade resistance box in place of R19.

e. Set METER switch to highest current range and turn on supply.

f. Adjust the decade resistance so that the differential voltmeter indicates 1. 0 ± 0. 01 Vdc.

g. Replace decade resistance with appropriate value resistor in R19 position.

5-62 REFERENCE CIRCUIT ADJUSTMENTS

5-63 Line Regulation. To adjust the line regulation capabilities of the instrument proceed as follows:

a. Connect the differential voltmeter between +S (common) and 33 (positive).

b. Connect variable voltage transformer between supply and input power source.

c. Adjust line to 105 Vac.

d. Connect decade resistance in place of R46.

e. Turn on supply and adjust VOLTAGE control(s) for maximum rated output voltage.

f. Adjust decade resistance so that voltage indicated by differential voltmeter does not change more than the following as input line voltage is varied from 105 to 125Vac:

Model No.	6253A, 6284A	6255A, 6289A
Variation (mVdc)	0.95	0.81
Model No.	6281A	6294A
Variation (mVdc)	1.24	0.75

g. Replace decade resistance with appropriate value resistor in R46 position.

5-64 CONSTANT VOLTAGE TRANSIENT RESPONSE

5-65 To adjust the transient response, proceed as follows:

a. Connect test setup as shown in Figure 5-8.

b. Repeat steps a through e as outlined in Paragraph 5-31.

c. Adjust R30 so that the transient response is as shown in Figure 5-9.