

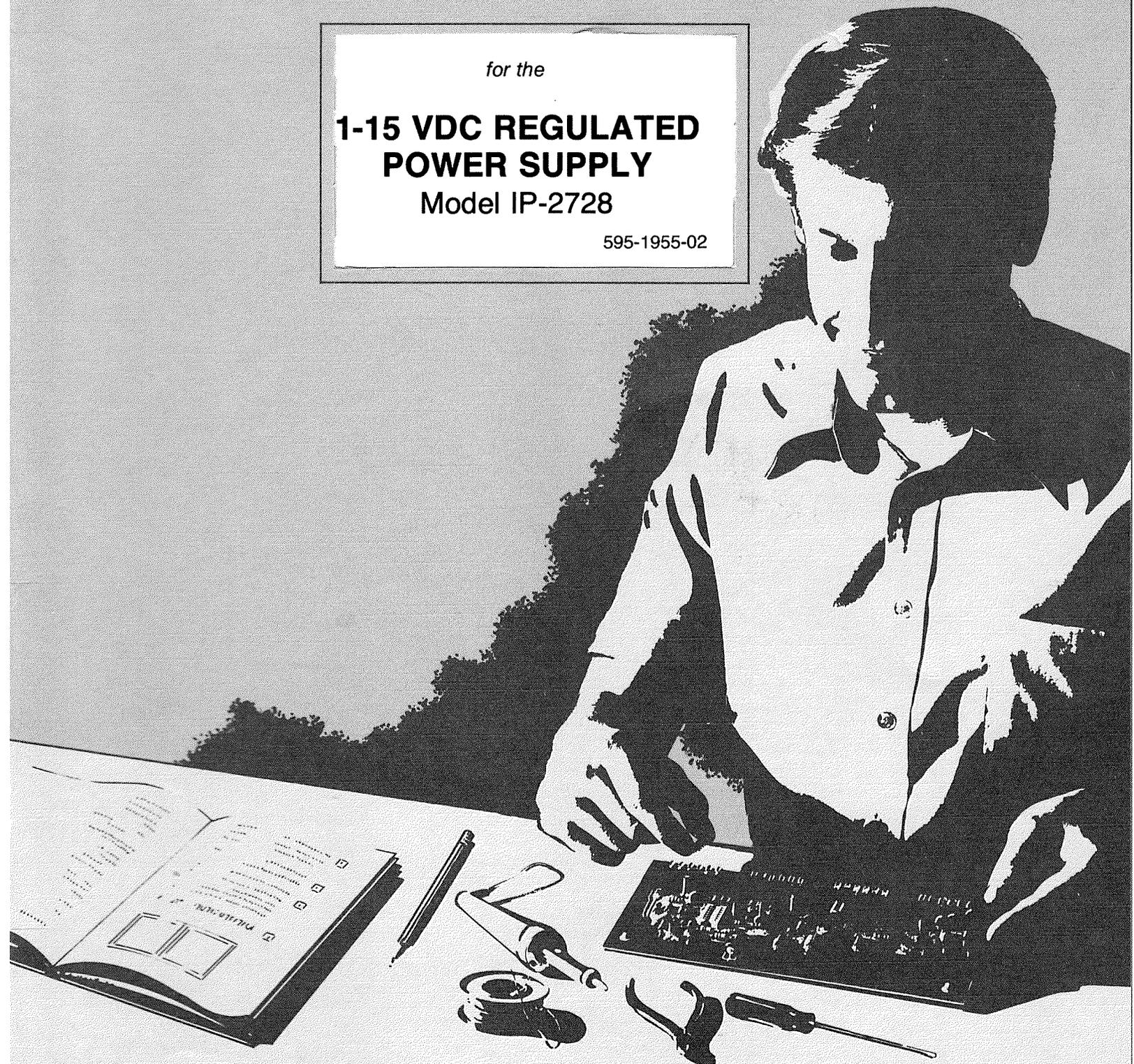
HEATHKIT[®] MANUAL

for the

**1-15 VDC REGULATED
POWER SUPPLY**

Model IP-2728

595-1955-02



HEATH COMPANY • BENTON HARBOR, MICHIGAN

Heathkit® Manual

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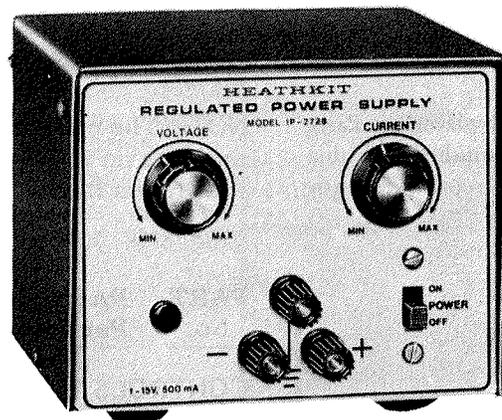
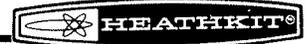


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HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

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INTRODUCTION

The Heathkit Model IP-2728 1-15 VDC Regulated Power Supply is a convenient source of voltage-regulated and current-controlled DC power. It will furnish DC voltages between 1 and 15 volts at up to 500 milliamperes of current.

Among the features of the Power Supply are all-solid-state design and circuit board construction for compact size, reliability, and ease of assembly. The output voltage and current are adjustable from the front panel, and the "floating" ground system enables the Supply to furnish either positive or negative output voltages.

The Programming terminals on the rear of the cabinet enable you to use an AC or DC voltage

from another source to control the output voltage of this Power Supply. The 3-wire line cord protects you from the danger of electrical shock due to a "hot" chassis.

This handy, compact Regulated Power Supply will fill most of your low voltage power supply needs. You will find it especially useful as a DC power source for the design, testing, and repair of solid-state devices.

Refer to the "Kit Builders Guide" for information on tools, wiring, soldering, resistors, and capacitors.

PARTS LIST

To order replacement parts, refer to the Replacement Parts Price List and use the Parts Order Form furnished with this kit. For pricing information, refer to the separate "Heath Parts Price List."

NOTE: The numbers in parentheses are keyed to the numbers on the Parts Pictorial (located in the sheet illustration included with this Manual).

<u>PART No.</u>	<u>PARTS Per Kit</u>	<u>DESCRIPTION</u>	<u>PART No.</u>	<u>PARTS Per Kit</u>	<u>DESCRIPTION</u>
RESISTORS			CONTROLS		
(1) 1-9	1	1000 Ω (brown-black-red) 1/2 watt	(5) 10-250	1	100 Ω
1-93	1	1800 Ω (brown-gray-red) 1/2 watt	10-249	1	5000 Ω
1-14	1	3300 Ω (orange-orange-red) 1/2 watt			
1-23	1	27 k Ω (red-violet-orange) 1/2 watt			
(2) 1-3-1	1	3300 Ω (orange-orange-red) 1 watt			
(3) 1-13-2	1	220 Ω (red-red-brown) 2 watt	(6) 25-145	1	25 μF
3-6-2	1	.51 Ω (green-brown-silver-gold) 2 watt (same size as 1 watt)	25-126	1	50 μF
(4) 3-20-5	1	5 Ω , 5 watt	25-146	1	100 μF
			25-273	1	250 μF
			(7) 25-154	1	2500 μF
					ELECTROLYTIC CAPACITORS



PART No.	PARTS Per Kit	DESCRIPTION
DIODES-TRANSISTORS-LAMP		
(8)56-26	1*	Germanium diode (brown-white-brown)
(9)57-65	3*	Silicon diode
(10)56-45	1*	Zener diode
(11)417-109	1**	2N3566 transistor
(12)417-118	2	2N3393 transistor
(13)417-140	1**	Field-effect transistor (FET)
(14)417-162	1	Power transistor
(15)412-15	1	NE-2H neon lamp

*Appearance of diodes may vary. Check part number carefully.

**Transistors may appear as one of the two types illustrated in the chart on the Parts Pictorial. When identifying each transistor, look for the part number or type number printed on the case. EXAMPLE: Transistor number 417-109 may be marked 417-109, 2N3566, or 417-109/2N3566 (or in this last case, where 417-109 is also on the transistor, another number may be used in place of 2N3566).

HARDWARE

#6 Hardware

(16)250-56	7	6-32 x 1/4" screw
(17)250-26	2	6-32 x 5/8" screw
(18)250-8	6	#6 x 3/8" sheet metal screw
(19)252-3	9	6-32 nut
(20)254-1	8	#6 lockwasher
(21)259-1	3	#6 solder lug
(22)254-27	1	#6 internal-external lockwasher

#8 Hardware

(23)250-137	2	8-32 x 3/8" screw
(24)252-4	2	8-32 nut
(25)254-2	4	#8 lockwasher (1 spare)

PART No.	PARTS Per Kit	DESCRIPTION
Other Hardware		
(26)259-25	1	Double solder lug
(27)252-32	1	Speednut
(28)252-7	2	Control nut
(29)253-10	2	Control flat washer
(30)255-1	2	1/8" spacer
(31)255-74	2	1/16" spacer
(32)255-89	2	Control spacer
MISCELLANEOUS		
(33)54-212	1 ✓	Power transformer
(34)60-1	1 ✓	Slide switch
(35)75-17	5 ✓	Binding post bushing
(36)427-3	3 ✓	Binding post base
(37)100-16-2	1 ✓	Black binding post cap
100-16-18	1 ✓	Red binding post cap
100-699	1 ✓	Green binding post cap
(38)75-71	1 ✓	Strain relief (flat cord)
75-30***	1 ✓	Strain relief (round cord)
(39)75-52	1 ✓	Switch insulator
(40)75-60	1 ✓	Mica insulator
(41)75-88	1 ✓	Transistor case insulator
(42)434-336	1 ✓	Transistor socket
85-1642-1	1 ✓	Circuit board
(43)204-9	1 ✓	L bracket
(44)259-20	25 ✓	Solder pins (4 extra)
(45)431-8	1 ✓	Terminal strip (3-lug screw-type)
(46)413-10	1 ✓	Neon lamp lens
(47)455-619	2 ✓	Knob bushing
(48)462-920	2 ✓	Knob
(49)261-49	4 ✓	Plastic foot
(50)90-402-4	1 ✓	Top cabinet shell
(51)90-1149-3	1 ✓	Bottom cabinet shell
346-6	1	Large sleeving
346-44	1	Small sleeving
344-56	1 ✓	Blue wire
89-23	1 ✓	Line cord
(52)421-40	1 ✓	3/16 ampere slow-blow fuse
391-34	1 ✓	Blue and white label
390-362	1 ✓	Fuse label
(53)490-5	1 ✓	Nut starter
490-168	1 ✓	End wrench, 1/4"
597-260	1	Parts Order Form
597-308	1	Kit Builders Guide
	1	Manual (See front cover for part number.)
		Solder

*** This strain relief is supplied to be used in areas mainly outside the U.S. where round line cords are required.

STEP-BY-STEP ASSEMBLY

Before you begin to assemble the Power Supply, read the "Kit Builders Guide" for information on wiring and soldering.

Components will be installed on the circuit board by following the steps on Pictorials 1 through 3. Position all parts as shown in the Pictorials. All resistors will be called out by only the resistance value (in Ω or $k\Omega$) and the color code for color-coded resistors. Use 1/2 watt resistors unless the step directs otherwise. Capacitors will be called out by the capacitance value and type.

START



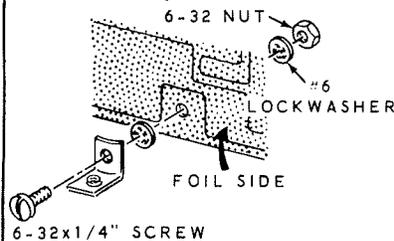
() Position the circuit board (#85-1642-1) lettered side up as shown in Pictorial 1. Then perform the following steps. Do not solder or cut off any leads until you are directed to do so.

() Germanium diode (#56-26) (brown-white-brown). Position the cathode end as shown.

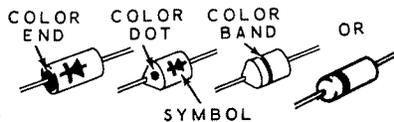


() 1800 Ω (brown-gray-red).

() L bracket. Be sure to install it on the foil side of the board and to use the unthreaded hole. Do not overtighten.



NOTE: When installing silicon diodes, be sure to place the cathode end as directed. The cathode end is marked with a color dot, color end, or color band.

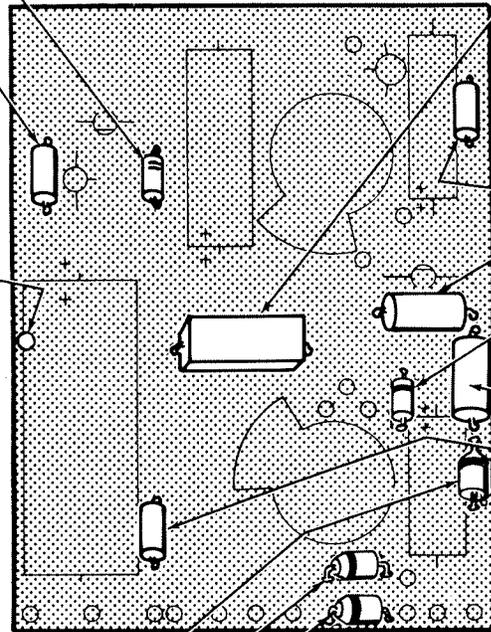


() Silicon diode (#57-65). Note cathode lead.

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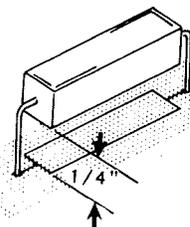
() Solder all connections and cut off the excess lead lengths.



CONTINUE



() 5 Ω 5 watt. Position 1/4" above the circuit board as shown.



() 3300 Ω (orange-orange-red).

() .51 Ω 2 watt (green-brown-silver-gold).

() Zener diode (#56-45). Note cathode lead.

() 3300 Ω 1 watt (orange-orange-red).

() 27 $k\Omega$ (red-violet-orange).

() Solder all connections and cut off the excess lead lengths. Save two 1" lengths of bare wire for use in the 120 or 240 volt wiring steps.

PROCEED TO PICTORIAL 2.

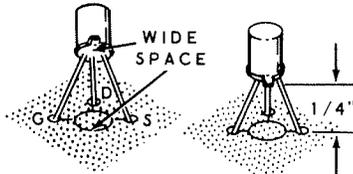
PICTORIAL 1

START

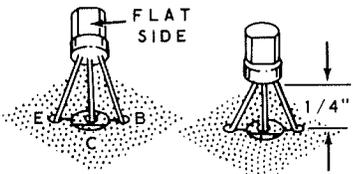
CONTINUE

The transistors will be installed in the following steps. Position the transistors 1/4" above the circuit board. Solder all leads after each transistor is installed; then clip off the excess lead lengths. Save two 1" lengths of bare wire for use in the 120 or 240 volt wiring steps.

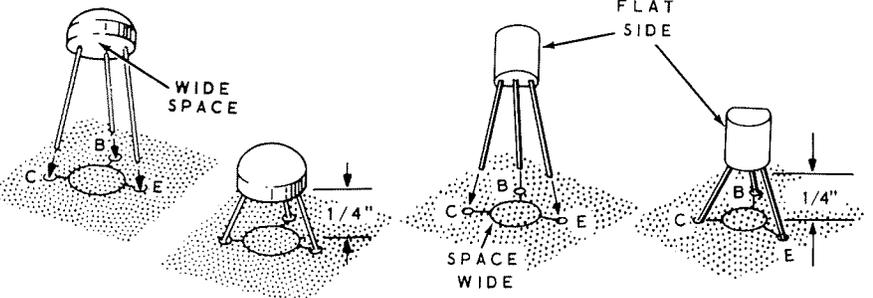
() Install the FET (#417-140) at Q1. Place the source (S), drain (D), and gate (G) leads in their proper holes as shown below.



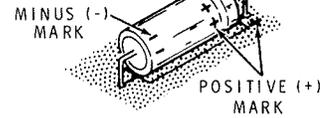
() Install 2N3393 (#417-118) transistors at Q4 and Q5. Match the flat side of each transistor with the outline of the flat on the circuit board; then insert the emitter (E), base (B), and collector (C) leads into their proper holes.



() Install transistor #417-109 at Q2. NOTE: Identify the transistor by its part number or type number printed on the case. Identify the transistor type and position it as shown below. Then insert the emitter (E), base (B), and collector (C) leads into their proper holes.

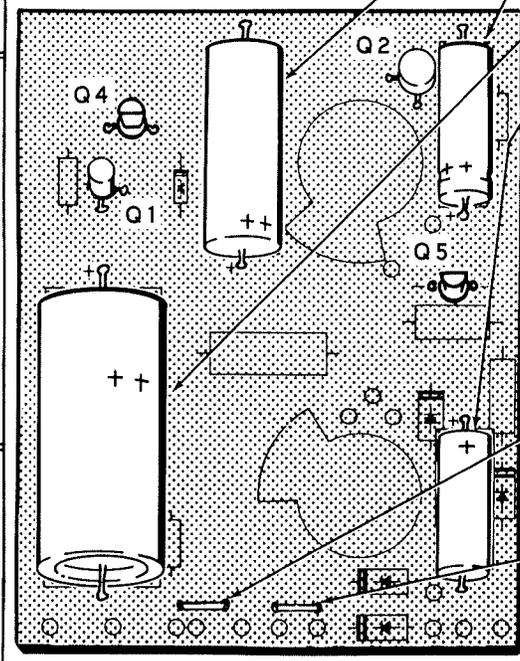


NOTE: Before you install an electrolytic capacitor, look at it and identify the leads. One lead will have a plus (+) mark or a minus (-) mark near it. Be sure to install the positive lead in the positive-marked hole. Be careful; only the negative lead may be marked.



- () 250 μ F electrolytic. Position the positive (+) end as shown.
- () 100 μ F electrolytic. Position the positive (+) end as shown.
- () 2500 μ F electrolytic. Position the positive (+) end as shown.
- () 50 μ F electrolytic. Position the positive (+) end as shown.

NOTE: The Power Supply can be wired for use with 120 volts AC power or 240 volts AC power. Follow either the 120 VOLT WIRING steps or the 240 VOLT WIRING step, whichever corresponds to the line voltage in your area.



120 VOLT WIRING

- () 1" bare wire. Use excess lead cut from the circuit board previously. Note the measuring scale on the fold-out from Page 4.
- () 1" bare wire.

240 VOLT WIRING

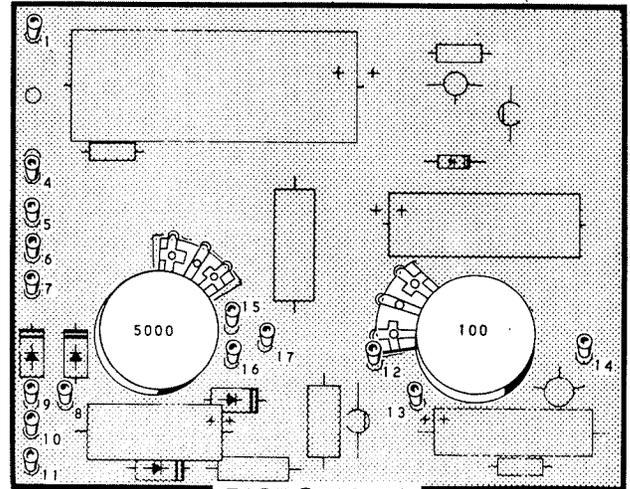
- () 1" bare wire.
- () Solder all connections and cut off the excess lead lengths.

PICTORIAL 2

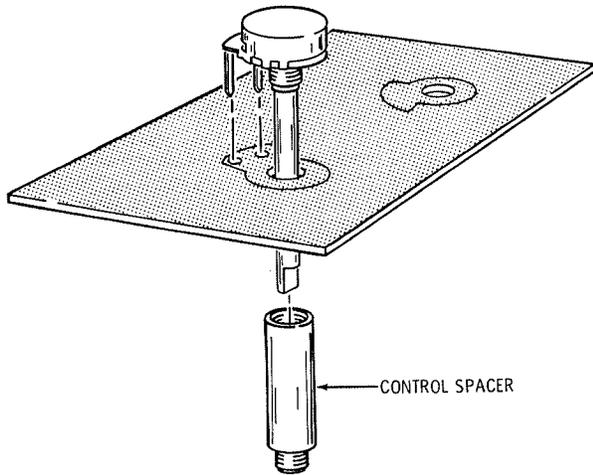
Refer to Pictorial 3 for the following steps.

NOTE: Do not solder the control lugs until you are directed to do so.

- () Refer to Detail 3A and install the 5000 Ω control (#10-249) on the circuit board at the control location shown. Insert the control shaft and lugs through the board from the lettered side. Then install a control spacer on the control bushing. Solder the three lugs to the foil.
- () In a like manner, install the 100 Ω control at the remaining control location on the circuit board. Solder the control lugs to the foil.



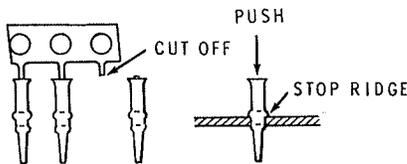
PICTORIAL 3



Detail 3A

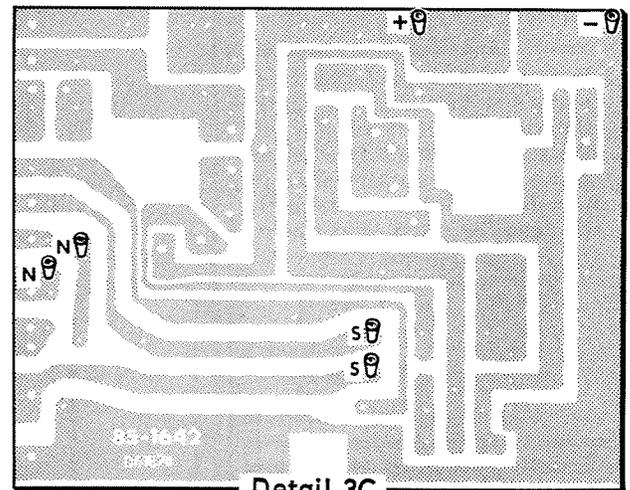
CAUTION: In the following step, there will be a sharp metal edge where each solder pin is cut off. Watch your fingers!

- () Refer to Detail 3B. Then cut off and install solder pins in the following numbered holes on the lettered side of the circuit board; do NOT solder the pins yet: 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 and 17.



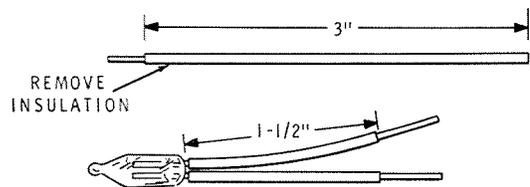
Detail 3B

- () Refer to Detail 3C and in a like manner, install solder pins in holes "-", "+", S, S, N, N, and N on the foil side of the circuit board.

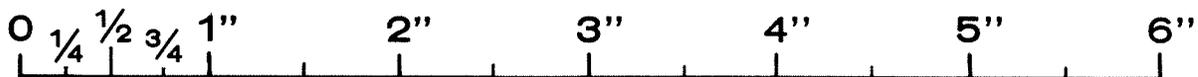


Detail 3C

- () Refer to Detail 3D and cut a 3" length of blue wire. Remove the insulation in one piece. Cut this piece into two 1-1/2" lengths, and place one length on each lead of the neon lamp.



Detail 3D



Refer to Detail 3E for the following steps.

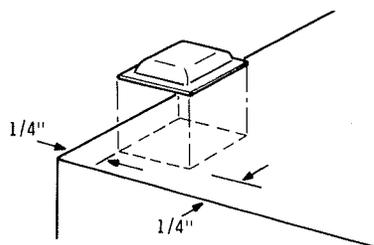
- () Connect one lead of the neon lamp to either one of the solder pins N. Solder this lead to the solder pin and the solder pin to the foil.
- () In a like manner, connect and solder the other neon lamp lead to the remaining solder pin N.
- () Cut a 2" length of blue wire and remove 1/4" of insulation from each end of the wire.
- () Refer to Detail 3E and connect one end of the 2" blue wire to the top solder pin S. Simultaneously, solder the wire to the pin and the pin to the foil.
- () Cut a 1-1/4" length of small sleeving.
- () Bend one lead of the 3/16-ampere fuse 90 degrees to the fuse body; then place the 1-1/4" sleeving on this lead.
- () Connect the prepared fuse lead to the lower pin S on the circuit board as shown. Then solder the pin and the lead to the circuit board foil.

Set the circuit board aside temporarily.

PARTS MOUNTING

Refer to Pictorial 4 (located in the illustration sheet included with this Manual) for the following steps.

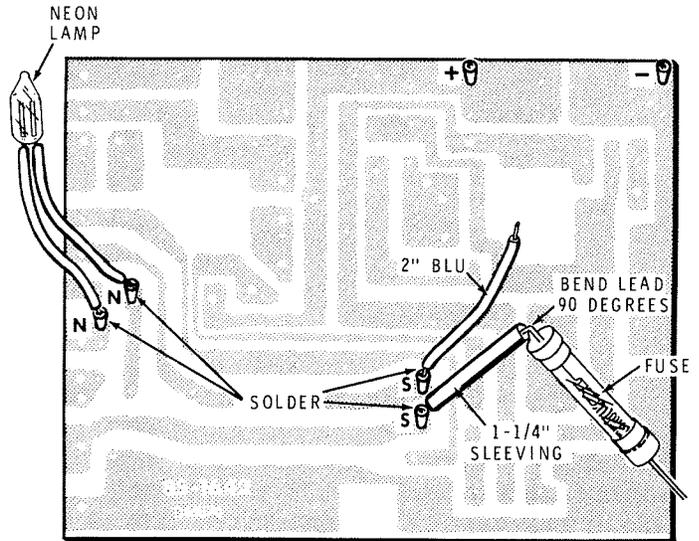
- () Refer to Detail 4A and install the four plastic feet on the bottom cabinet shell by peeling away the protective paper from the adhesive and pressing the feet into position. The feet are difficult to move if not positioned correctly before they contact the shell.



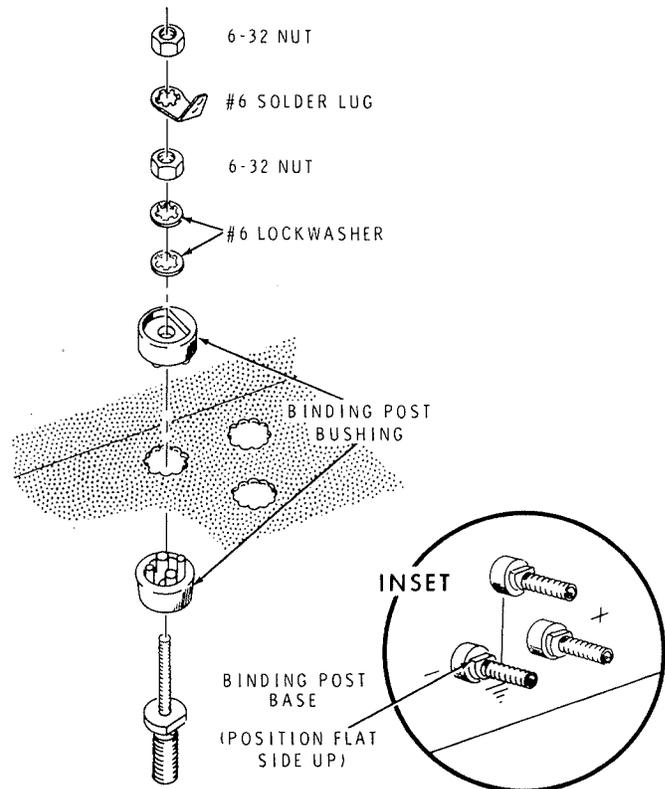
Detail 4A

NOTE: The Heath Company has provided a plastic nut starter with this kit. Use the nut starter to hold and start 6-32 nuts on screws. Refer to the Kit Builders Guide for further information.

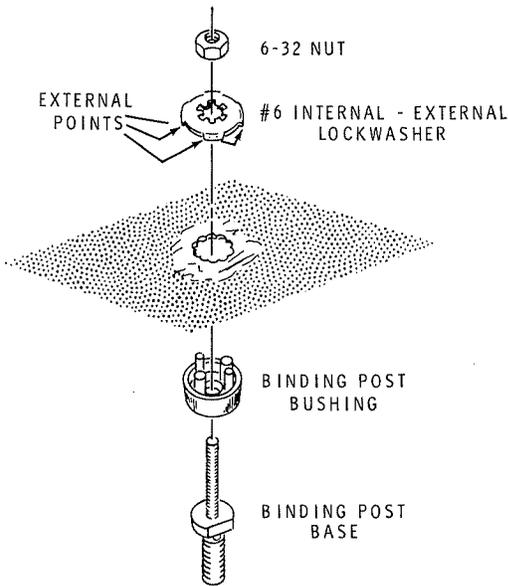
- () Refer to Detail 4B and install binding post bases at A and C on the cabinet bottom shell. Use two binding post bushings, two #6 lockwashers, two 6-32 nuts, and a #6 solder lug for each. Position the flat side of each binding post base as shown. Use the wrench provided to tighten the first nut before you install the solder lug and second nut on each binding post.



Detail 3E



Detail 4B

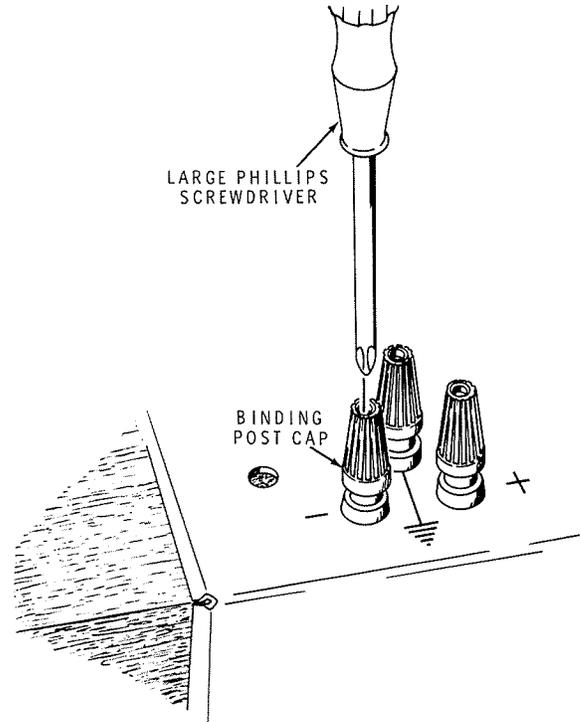


Detail 4C

- () Refer to Pictorial 4 and Detail 4C and scrape the paint away at location B at the inside of the front panel.
- () Install a binding post base at B as shown in Detail 4C. Use a binding post bushing, a #6 internal-external lockwasher, and a 6-32 nut. The eight external points of the #6 internal-external lockwasher must dig into the sheet metal of the front panel. Position the flat side of the binding post base as before.
- () Install the black binding post cap on binding post A (-), the green cap on B (ground), and the red cap on C (+).

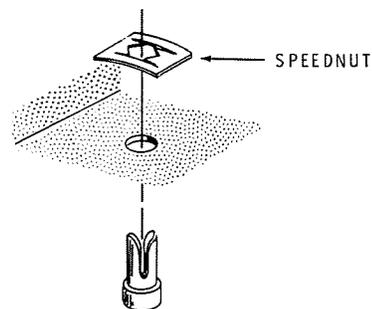
NOTE: In the following two steps, (optional), use a phillips screwdriver to expand the end of the metal binding post base so the cap will not come off of the binding post. The screwdriver tip must be large enough so it will not go inside of the binding post base.

- () Refer to Detail 4D and place the tip of a large phillips screwdriver through the opening in the end of each binding post cap and against the hollow end of the binding post base. Support the binding post base with a block of wood or a thick magazine to avoid bending the panel.

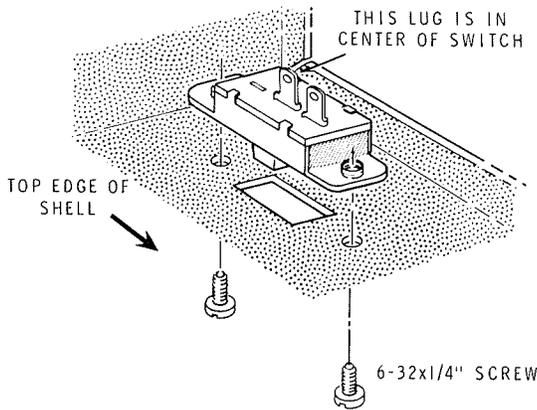


Detail 4D

- () Now tap the handle end of the phillips screwdriver sharply with a small hammer to expand the hollow end of the binding post base. The binding post base should be expanded only enough to prevent the caps from coming off.
- () Refer to Detail 4E and install the neon lamp lens with a speednut at D.

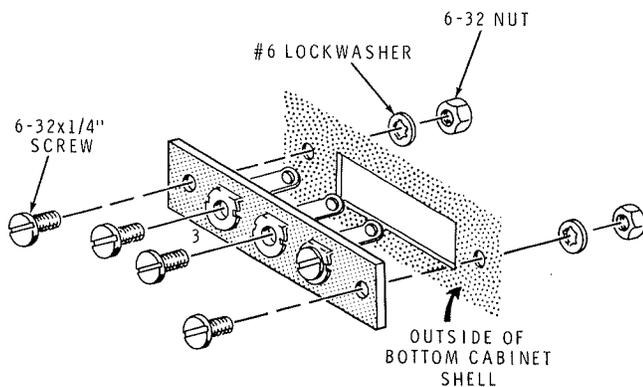


Detail 4E

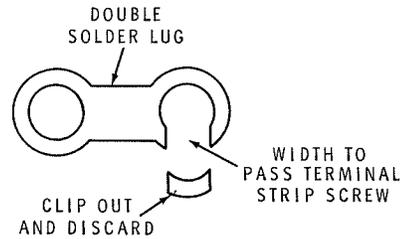


Detail 4F

- () Refer to Detail 4F and install the slide switch at E. Use 6-32 x 1/4" screws and be sure to position the switch lugs as shown in the Pictorial.
- () Install the terminal strip at F on the outside of the bottom cabinet shell as shown in Detail 4G. Use 6-32 x 1/4" screws, #6 lock-washers, and 6-32 nuts. Be sure to position the solder lugs of the terminals as shown.
- () Temporarily remove screw 3 from terminal strip F, and loosen screw 2.



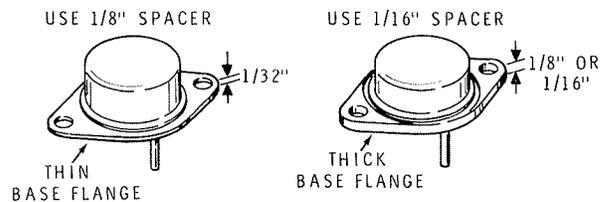
Detail 4G



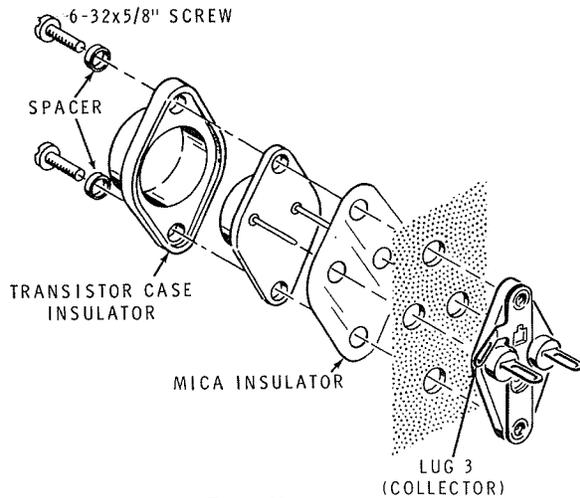
Detail 4H

- () Refer to Detail 4H and prepare the double solder lug as shown. Use diagonal cutters to clip out enough of the lower edge of one lug to allow it to pass freely over the threaded portion of one of the terminal strip screws.
- () Mount the uncut end of this double solder lug on the screw at 3 and the cut end on the other screw at 2 of terminal strip F.

NOTE: Refer to Detail 4J and determine whether the power transistor (#417-162) included in your kit has a thick or a thin base flange. Use 1/8" spacers if the transistor has a thin base flange. Use 1/16" spacers if the transistor has a thick base flange.



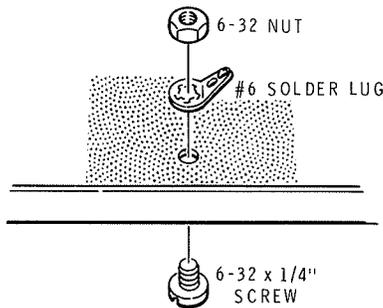
Detail 4J



Detail 4K

() Refer to Detail 4K and install the power transistor at G with 6-32 x 5/8" screws, two spacers, a transistor case insulator, a mica insulator and a transistor socket. Note that lug 3 is up. Be sure the socket is fully seated in the mounting holes; then tighten the screws securely. Tighten until the screw heads are fully seated in the recessed holes on the insulator.

() Refer to Detail 4L and mount a #6 solder lug at L as shown. Use a 6-32 x 1/4" screw and a 6-32 nut. Position the solder lug as shown in the Pictorial.



Detail 4L

PRELIMINARY WIRING

Refer to Pictorial 5 for the following steps.

NOTES:

1. In the following step, you will be directed to "prepare" wires for use. To prepare a wire, cut it to the stated length and then remove 1/2" of insulation from one end and 1/4" of insulation from the other. The wires are listed in the order in which they are used.
2. In the following steps, (NS) means not to solder because the other wires will be added later. "S-" with a number, such as (S-3), means to solder the connection. The number following the "S" tells how many wires are at the connection.

() Prepare the following lengths of blue wire:

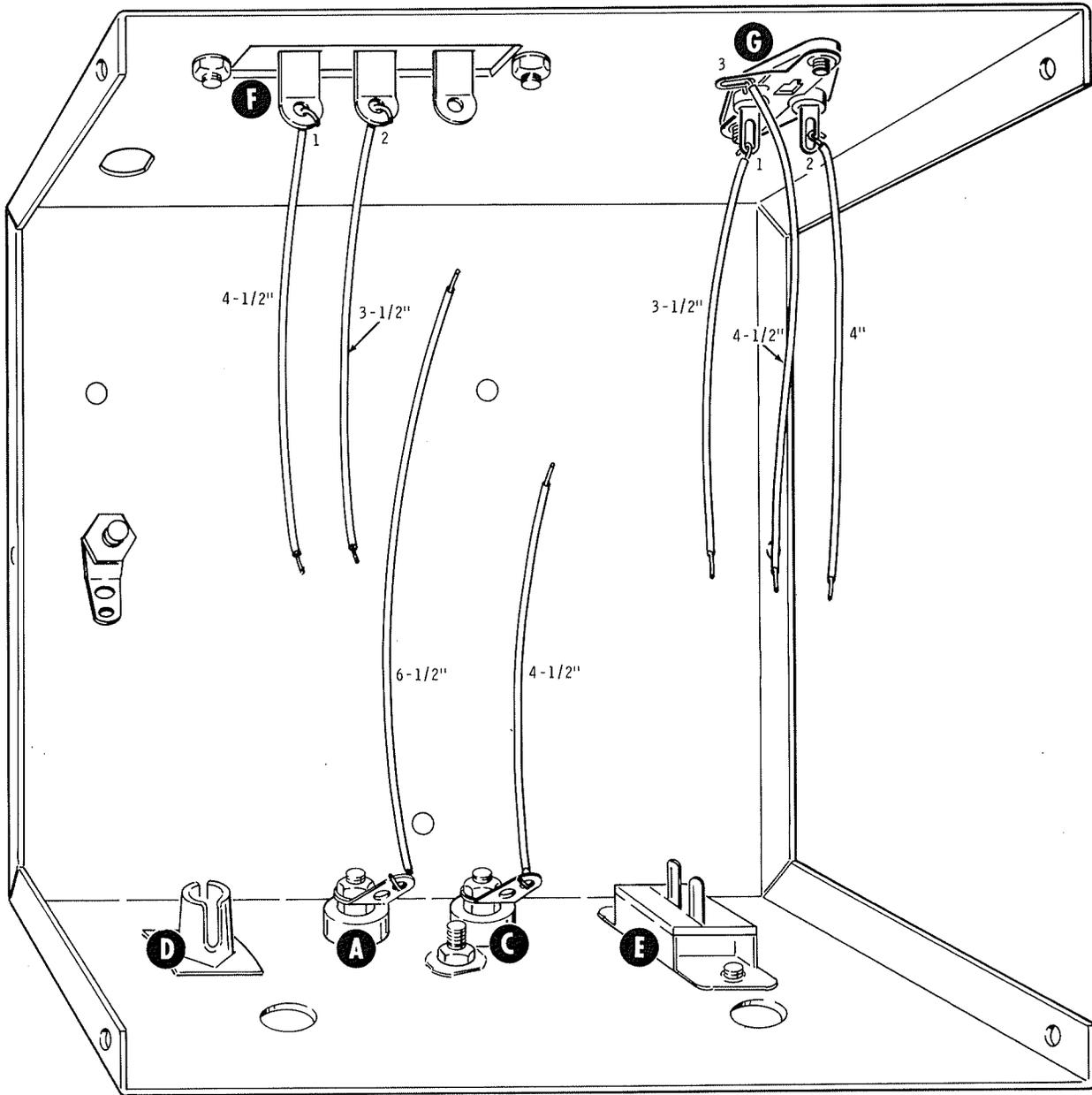
6-1/2"	3-1/2"
4-1/2"	4"
4-1/2"	4-1/2"
3-1/2"	

NOTE: Most wire lengths are longer than needed. To do a neater wiring job, it is recommended that you use square corners (90 degree bends) when positioning the wires.

Connect only the 1/4" bared end of the prepared wires as directed in the following steps. The other end of each wire will be connected later.

- () 6-1/2" to binding post A (S-1).
- () 4-1/2" to binding post C (S-1).
- () 4-1/2" to lug 1 of terminal strip F (NS).
- () 3-1/2" to lug 2 of terminal strip F (S-1).
- () 3-1/2" to lug 1 of socket G (S-1).
- () 4" to lug 2 of socket G (S-1).
- () 4-1/2" to lug 3 of socket G (S-1).



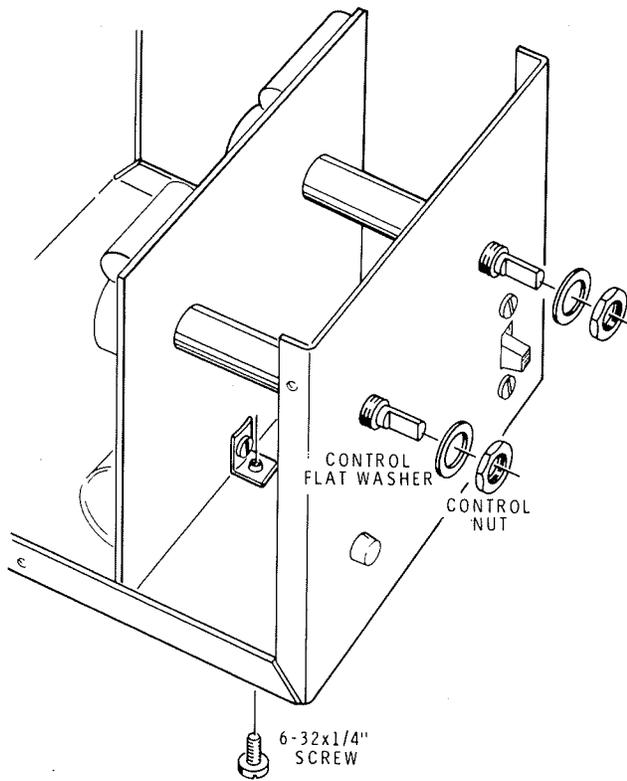


PICTORIAL 5

CIRCUIT BOARD INSTALLATION AND WIRING

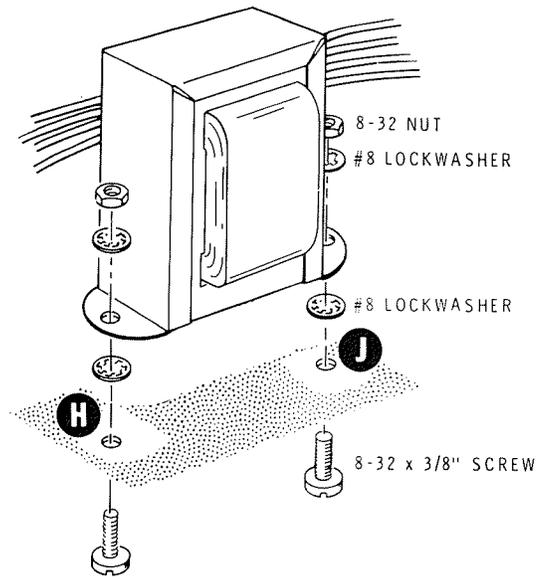
Refer to Pictorial 6 (located in the illustration sheet included with this Manual) for the following steps. Route all wires as shown.

- () Refer to Detail 6A and install the circuit board in the cabinet bottom shell. Use control nuts, control flat washers, and a 6-32 x 1/4" screw. As you mount the circuit board, insert the neon lamp into the rear of the lamp lens at D on the cabinet bottom shell. Push it in as far as possible.



Detail 6A

- () Temporarily place the power transformer over chassis holes H and J. Mark the outline of the mounting feet of the transformer and put the transformer aside. Scrape the paint from the chassis inside the two outlined locations.
- () Install the power transformer as shown in Detail 6B. Use an 8-32 x 3/8" screw, two #8 lockwashers, and an 8-32 nut at H and J. Be sure the transformer leads are positioned as shown in the Pictorial.



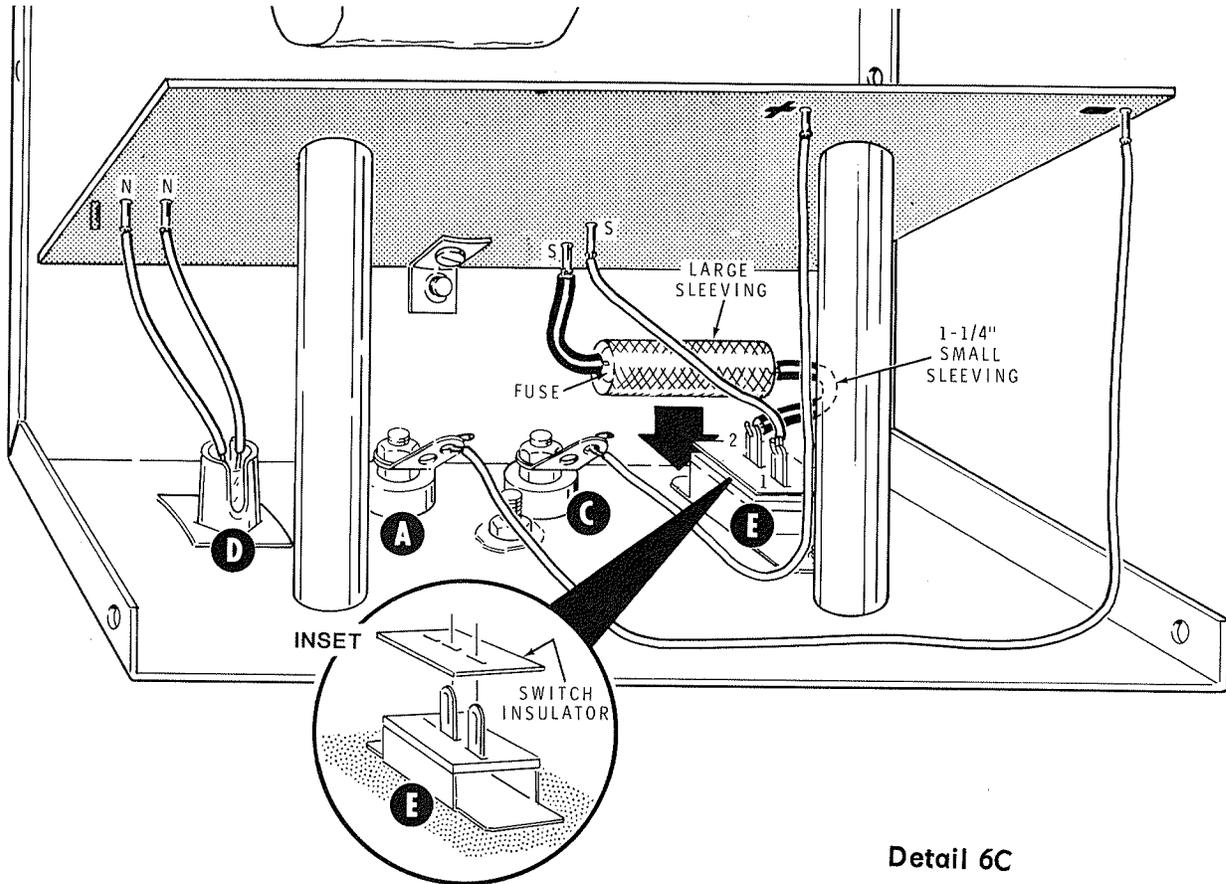
Detail 6B



NOTE: In the following steps, twist together the wires in each group of leads coming from the transformer before connecting the ends of the leads. This will keep the wires together and improve the appearance of the wiring.

In the following steps, push each wire into the solder pin at the designated hole until the tip of the wire appears at the other end of the pin. Then solder the wire to the pin and the pin to the foil in one operation. After the solder has cooled, pull on each wire to make sure you have a good solder connection.

<u>COLOR</u>	<u>COMING FROM</u>	<u>CONNECT TO HOLE</u>
() Red-yellow	transformer	1 (S-1).
() Black	transformer	4 (S-1).
() Black-green	transformer	5 (S-1).
() Black-yellow	transformer	6 (S-1).
() Black-red	transformer	7 (S-1).
() Either red	transformer	8 (S-1).
() Other red	transformer	9 (S-1).
() Either green	transformer	10 (S-1).
() Other green	transformer	11 (S-1).
() Blue	lug 2 of socket G	12 (S-1).
() Blue	lug 3 of socket G	13 (S-1).
() Blue	lug 1 of socket G	14 (S-1).
() Blue	lug 2 of terminal strip F	15 (S-1).
() Blue	lug 1 of terminal strip F	17 (S-1).



Detail 6C

Refer to Detail 6C for the following steps. Connect the indicated wires to the terminals on the foil side of the circuit board as follows:

<u>COLOR</u>	<u>COMING FROM</u>	<u>CONNECT TO</u>
() Blue	binding post A	"-" (S-1).
() Blue	binding post C	"+" (S-1).

- () Refer to the inset drawing on Detail 6C and place a switch insulator over the lugs of switch E as shown. NOTE: If the lugs are in the center of the switch, discard the insulator; it is not required on this type of switch.

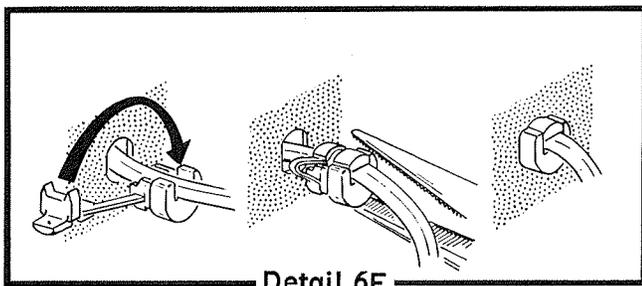
- () Place the length of large sleeving over the body of the fuse. Bend the free fuse lead 90 degrees toward switch E. NOTE: Be sure to keep the fuse leads bent as directed; this will hold the large sleeving in place around the fuse body.
- () Cut a 1-1/4" length of small sleeving. Place this sleeving on the free lead of the fuse and connect this fuse lead to lug 2 of switch E (S-1).
- () Position the body of the fuse down and under switch E as shown in the Pictorial.
- () Refer to Detail 6C and connect the blue wire coming from the upper solder pin S to lug 1 of switch E (S-1).
- () Twist together the small strands of wire at the end of each line cord lead. Then melt a small amount of solder on the end of each lead to hold the separate strands together.

Refer to Detail 6D for the following steps.

- () Insert the line cord through hole K in the rear of the cabinet bottom shell.

NOTE: Observe that the two edges of the flat line cord are different. One edge is smooth but the other edge is ribbed for identification.

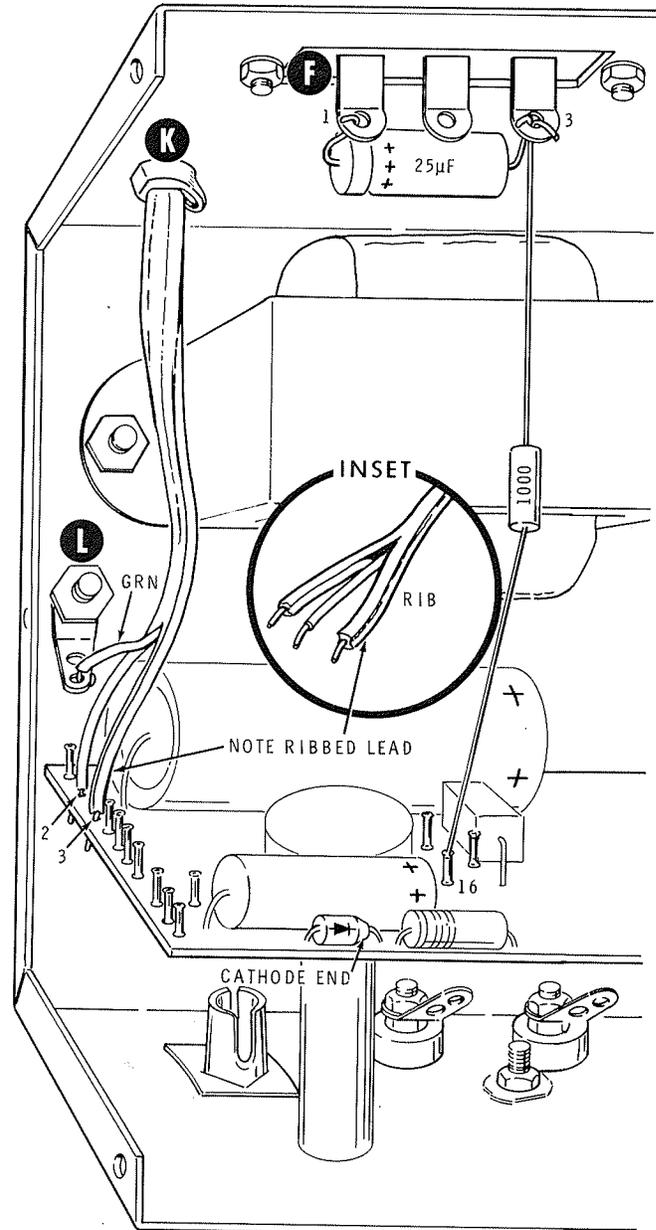
- () Connect the green (center) line cord lead to solder L (S-1).
- () Connect the ribbed line cord lead to hole 3 (S-1) and the other lead to hole 2 (S-1) on the circuit board. Refer to the inset drawing on Detail 6D.
- () Install the proper strain relief in hole K. Detail 6E shows the strain relief (#75-71) for the flat line cord supplied with the kit. If a round line cord is used, install the other strain relief.



Detail 6E

- () Connect the positive (+) marked lead of a 25 μ F electrolytic capacitor to lug 1 (S-2) and the other lead to lug 3 (NS) of terminal strip F. Keep the capacitor leads as short as possible and position the capacitor as shown.
- () Connect a 1000 Ω (brown-black-red) resistor from terminal 16 on the component side of the circuit board (S-1) to lug 3 of terminal strip F (S-2).
- () Write the fuse value, "3/16A S.B." into the space provided on the fuse label ("1/8A S.B.", if your unit is wired for 220-240 VAC operation).
- () Remove the backing from the fuse label and press the label into place on the bottom of the chassis as shown in the Pictorial.

This completes the wiring of the Power Supply. One 220 Ω (red-red-brown) resistor should remain. It will be used later.



Detail 6D

Carefully inspect your work to make sure that all connections are soldered and that there are no loose components, faulty solder connections, or solder bridges on the circuit board foil. Disregard the four unused holes. Shake out any wire clippings or solder splashes. Then proceed to the Resistance Checks if an ohmmeter is available, or directly to Final Assembly if one is not available.

RESISTANCE CHECKS

If you have an ohmmeter available, make the following resistance measurements. These measurements will help you determine if you made any construction errors. NOTE: If you do not obtain readings within 20% of the values given in the following steps, refer to the In Case Of Difficulty section on Page 24. Before doing any actual troubleshooting, however, complete all the checks. The resistance readings thus obtained may establish a pattern which will make the difficulty easier to locate.

FROM	TO	RESIST- ANCE
() Lug 1	ground (⊥) binding post	infinity (∞)
() Lug 2	ground (⊥) binding post	infinity (∞)
() Lug 3	ground (⊥) binding post	infinity (∞)
() Turn the VOLTAGE and CURRENT controls to MIN.		

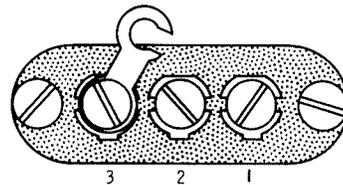
Make the following resistance tests at the power transistor socket (socket G). A reading of infinity at all three points indicates that the transistor assembly was properly installed. A reading of zero ohms at any of the points indicates a short circuit to the chassis; in this case you should remove the transistor assembly and carefully reinstall it as directed on Page 10. Then repeat the resistance checks.

Make the following resistance measurements by connecting the ohmmeter leads to the binding posts marked as shown in the Meter Leads columns. The first two checks indicate an absence of short circuits. In the third test a meter reading in the megohms range shows that there is no unintended leakage between the circuit and the metal shell of the Power Supply. Be sure the ohmmeter range switch is properly set.

Common (Negative) Meter Lead To	Plus (Positive) Meter Lead To	Ohmmeter Range	Resistance
() -	+	R x 100	Over 700 Ω
() +	-	R x 100	Over 2000 Ω
() ⊥	+ or -	R x 1 M	Infinity

IMPORTANT The letter "D" in the Resistance column of the following chart indicates that a diode is in the circuit under test. Therefore, the measured resistance can vary due to the forward current of the diode, and depending on the range setting of the ohmmeter. In some ohmmeters the battery polarity is reversed and erroneous readings will be obtained. Try reversing the ohmmeter leads if the measurements do not check out correctly the first time.

Make the following resistance measurements between the Programming terminals on the back of the bottom cabinet shell. Identify the terminal numbers from the drawing at the right. Disconnect the jumper between terminals 2 and 3 before making these measurements.



Common (Negative) Meter Lead To	Plus (Positive) Meter Lead To	Ohmmeter Range	Resistance
() 1	2	R x 100	4500 Ω
() 2	3	R x 100	*10 kΩ "D"
() 3	2	R x 10 k	*over 1 MΩ "D"

*Wait for needle to come to rest.

() Reconnect the jumper between terminals 2 and 3.

() Set the ohmmeter range switch to R x 100.

() Refer to the X-Ray View on Page 30 and connect the common lead of the meter to the soldering pin for the red-yellow transformer lead. Connect the plus lead of the meter to the positive lead of C1 and allow time for the meter needle to come to rest. The resistance should be over 3000 Ω. There is a diode in the circuit.

() Reverse the connections of the meter leads. The resistance should be 500 Ω.

() Connect the common lead of the meter to the solder pin of either green transformer lead. Connect the plus meter lead to the cathode end of D3. The meter should read over 5000 Ω.

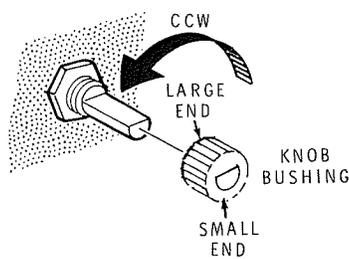
This completes the Resistance Checks.

FINAL ASSEMBLY

Refer to Pictorial 7 for the following steps.

The knobs supplied with this kit use knob bushings that provide permanent positive action without the use of setscrews.

Refer to Detail 7A and notice that the knob bushing is tapered. Be sure, in the next step, to place this bushing on the shaft with the small end facing out, or the knob will not slide onto it. (Roll the bushing on a flat surface if you are unsure about it; the bushing will gradually turn toward the small end.)

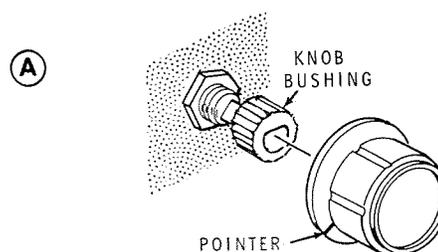


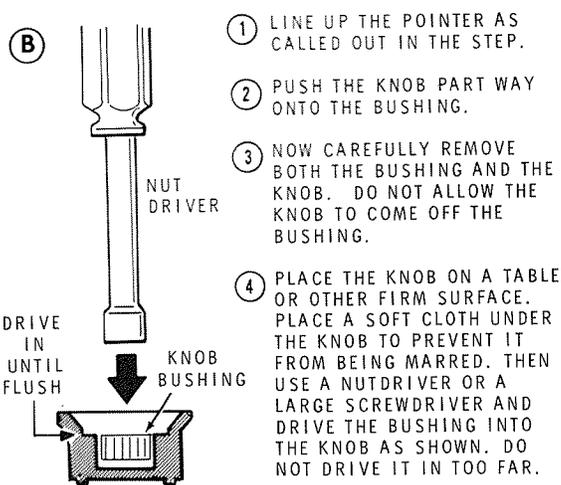
Detail 7A

- () Install a knob bushing on each control shaft.
- () Turn the shafts fully counterclockwise.

In the following steps you will install knobs on the two control shafts as shown in Detail 7B. Perform these steps carefully, since it is difficult to remove a bushing from a knob once it is fully inserted.

- () Line up the pointer of each knob with the letter N in "MIN" and install the knobs on the shafts.

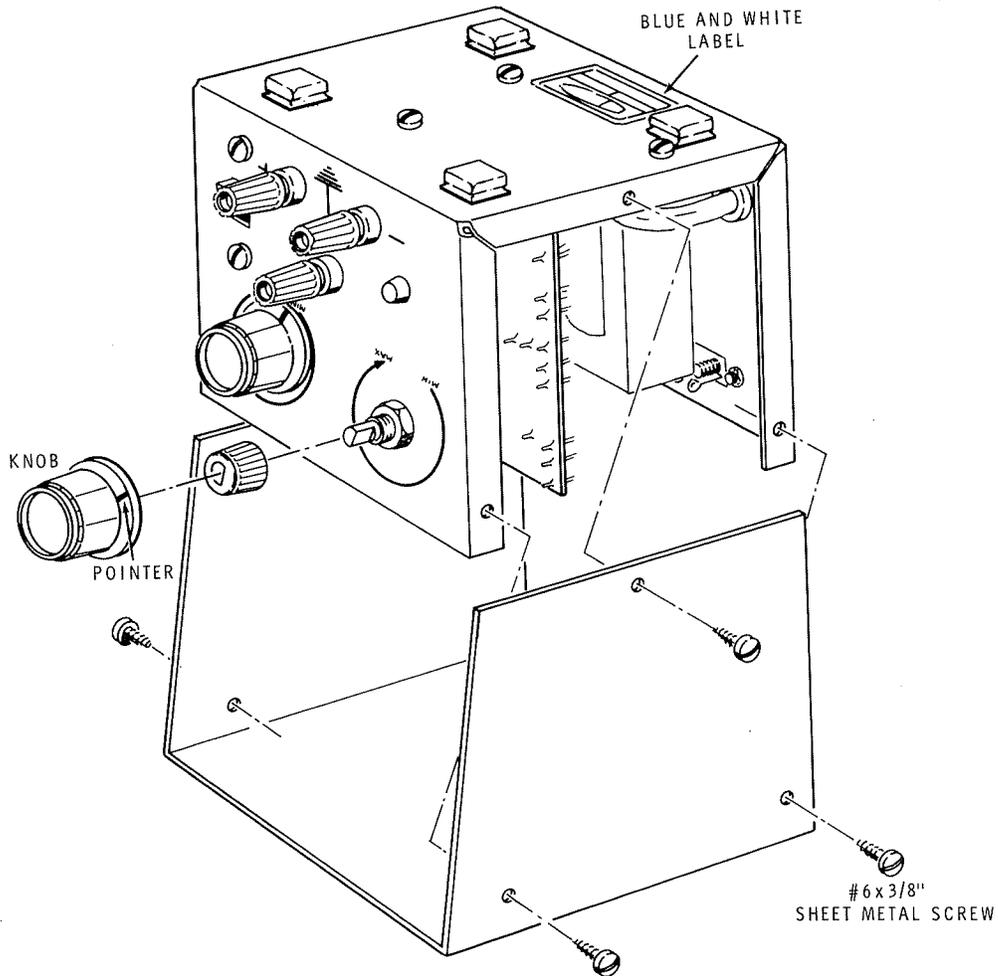


- (B)**
- 
- ① LINE UP THE POINTER AS CALLED OUT IN THE STEP.
 - ② PUSH THE KNOB PART WAY ONTO THE BUSHING.
 - ③ NOW CAREFULLY REMOVE BOTH THE BUSHING AND THE KNOB. DO NOT ALLOW THE KNOB TO COME OFF THE BUSHING.
 - ④ PLACE THE KNOB ON A TABLE OR OTHER FIRM SURFACE. PLACE A SOFT CLOTH UNDER THE KNOB TO PREVENT IT FROM BEING MARRED. THEN USE A NUTDRIVER OR A LARGE SCREWDRIVER AND DRIVE THE BUSHING INTO THE KNOB AS SHOWN. DO NOT DRIVE IT IN TOO FAR.
 - ⑤ REPLACE THE KNOB ON THE CONTROL FROM WHICH IT WAS REMOVED.

Detail 7B

- () Refer to the Pictorial and install the blue and white label on the cabinet bottom by carefully peeling away the backing paper and pressing the label into position. NOTE: Refer to the numbers on this label in any communications that you have with Heath Company concerning this kit.
- () Install the cabinet top shell. Use #6 x 3/8" sheet metal screws, and be sure to mount the top shell with the angled edge above the front panel.

This completes the assembly of the Power Supply.



PICTORIAL 7

OPERATION

Refer to Figure 1 for control functions and connecting information.

The output of this Power Supply is "floating" above chassis ground, which is brought out to a separate terminal on the front panel. This has been done so you can operate the Power Supply with circuits requiring either a positive or negative ground.

A 220 Ω , 2-watt (red-red-brown) resistor has been furnished for your use in checking out this Power Supply. Whenever you are instructed to "connect the load," connect the leads of this resistor to the - and + (the black and the red) binding posts. Make sure the leads do not touch the cabinet shell.

The jumper between the terminals marked AC on the rear of the cabinet must be connected for all types of operation except Remote Programming (described on Page 22).

CONSTANT VOLTAGE OPERATION

For use when maximum current is not important. In this type of service, only the output voltage is controlled.

1. Preset the controls as follows:

VOLTAGE MIN

CURRENT MAX

Power Switch OFF

2. Connect the load to the front panel negative (-) and positive (+) terminals.
3. Turn the Power switch on and, while watching a voltmeter, advance the VOLTAGE control until the desired voltage is reached.

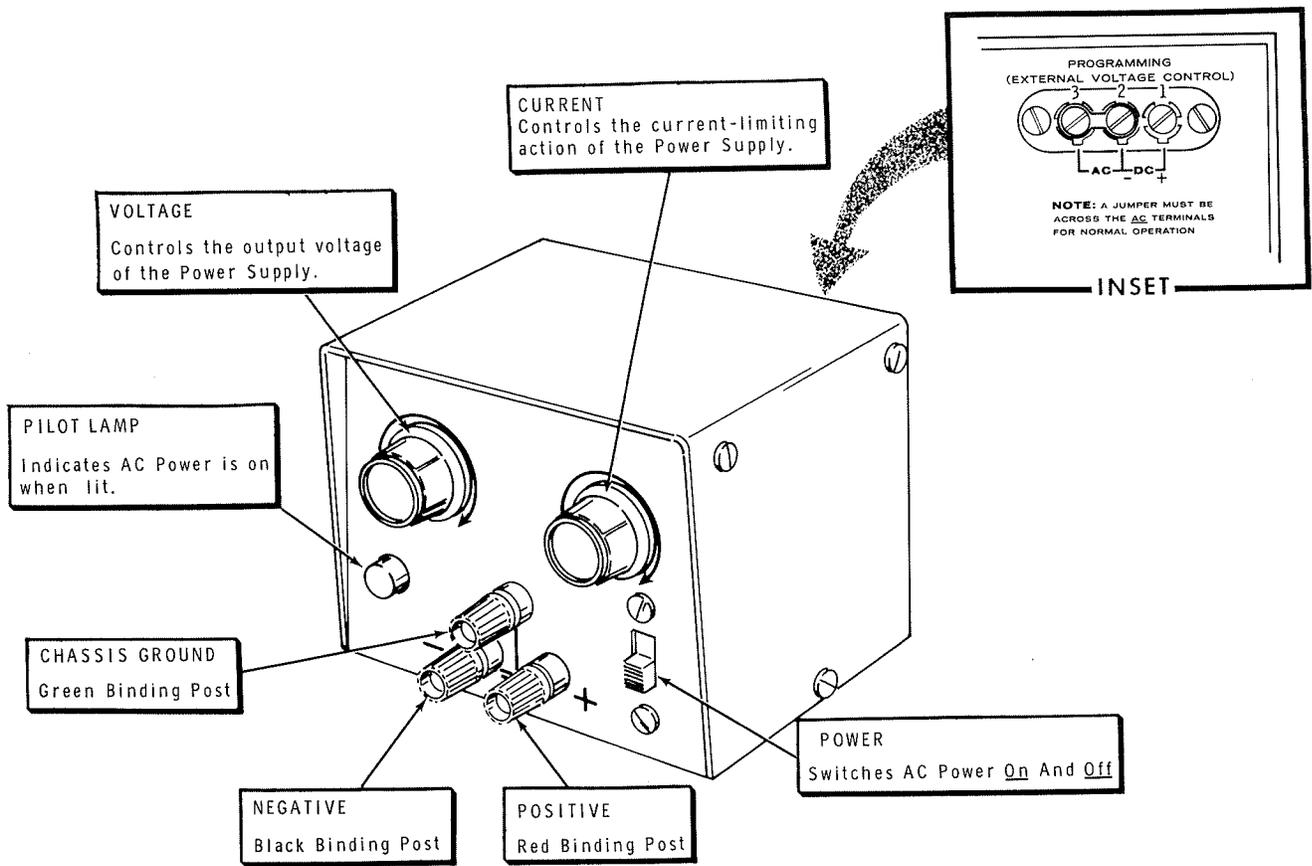


Figure 1

LIMITED CURRENT OPERATION

For use when excessive current flow would damage the circuit under test.

1. Preset the controls as follows:

VOLTAGE MIN

CURRENT MIN

Power Switch OFF

2. Turn the Power switch on and, while watching a voltmeter, set the VOLTAGE control for the desired voltage. Then turn the Power switch off.
3. Connect the load to the front panel negative (-) and positive (+) terminals.
4. Turn the Power switch on.
5. Advance the CURRENT control to a point just past where the preset voltage is obtained.

OPERATIONAL EXAMPLE

The circuit of this Power Supply provides a certain amount of built-in protection when it is adjusted to the knee of the voltage-current output curve, as directed in the following steps. For example, as the load increases (less resistance) the voltage decreases rapidly because the current is limited. If the load decreases (more resistance) the voltage remains constant, while the current decreases.

Use the 220 ohm 2-watt resistor supplied for the following demonstration:

1. Set the output voltage, without load, to 10 volts.
2. Turn the CURRENT control to its maximum clockwise position. The allowable values of voltage and current are shown in Figure 2.

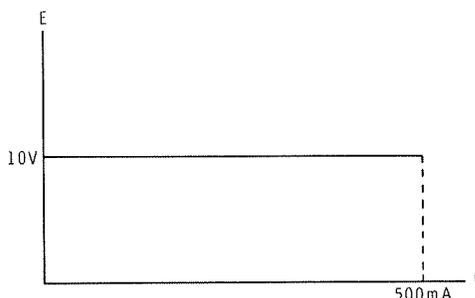


Figure 2

3. Turn the Power Supply off.
4. Connect 220 ohm load.
5. Turn the Power Supply on.
6. Turn the CURRENT control counterclockwise until the voltage just starts to decrease. (See Figure 3). The current is now limited to about $10/220 = .045A = 45 \text{ mA}$.

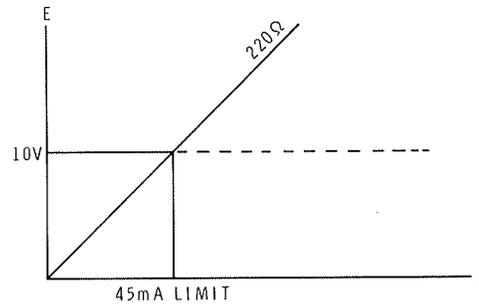


Figure 3

7. Turn the VOLTAGE control clockwise. Note that the voltage does not increase perceptibly. The supply is now current-limited, (See Figure 4).

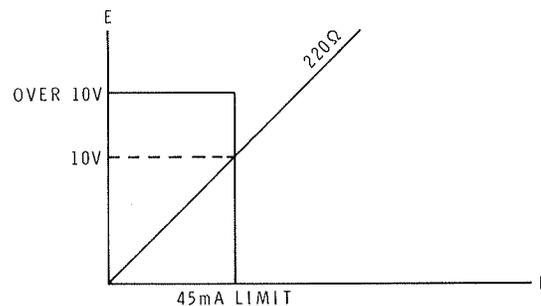


Figure 4

8. Turn the VOLTAGE control below 10 volts and note that voltage (and current) decreases (See Figure 5).

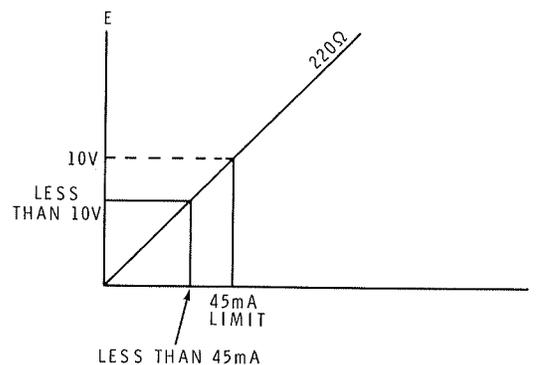


Figure 5

For heavier loads (lower resistance) the current drain will be higher than the example and the limit could be set higher, or the output voltage will drop rapidly to a value appropriate for the current limit selected. Further experiments will increase your understanding of the characteristics of this supply.

CAUTION: A load current greater than .5 ampere will result in a loss of regulation and possible overheating of the Power Supply.

REMOTE PROGRAMMING

The Programming terminals on the rear of the cabinet are connected to the reference voltage circuit in the Power Supply. These terminals make it possible for you to control the reference voltage circuit, and therefore, the output of the Power Supply, from an external DC (DC Programming) or AC (AC Programming) voltage source.

DC Programming

1. Remove the jumper from between the AC lugs on the Programming terminal strip.
2. Connect the leads supplying the desired DC control voltage to the DC terminals on the rear of the cabinet. Be sure to observe proper polarity, and do not use a control voltage which exceeds 16 VDC or damage may result.

3. Set the VOLTAGE control to MAX and the CURRENT control as described in Constant Voltage-Limited Current Operation. The output voltage will now follow the voltage applied to the DC PROGRAMMING terminals. Note that the VOLTAGE control can now be used to reduce the output voltage below the applied control voltage.

AC Programming

1. Remove the jumper from between the AC lugs on the Programming terminal strip.
2. Connect the leads supplying the desired AC control voltage to these same AC terminals.

NOTE: The AC signal source must have a low DC resistance (such as a low impedance transformer secondary) to maintain a DC output reference.

The output voltage from the Power Supply will now be varying DC, with a modulation component which approximates the waveform of the external AC control voltage. The VOLTAGE control will set the average voltage of the varying DC output. The CURRENT control operates normally.

The peak value of the AC voltage plus the DC output voltage must not exceed 16 volts.

NOTE: Be sure to reinstall the jumper between the AC terminals on the Programming terminal strip when you disconnect the external control voltage leads.

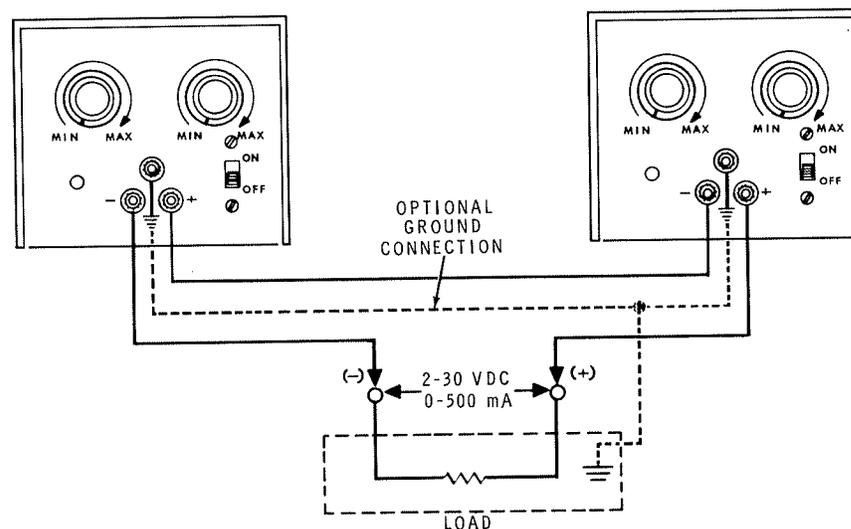


Figure 6

SERIES OPERATION

Two or more Power Supplies can be connected in series to obtain voltages greater than 15 volts. The correct method of connecting Power Supplies for series operation is shown in Figure 6. CURRENT control settings should be identical in each series unit, but VOLTAGE control settings can be distributed between the Power Supplies as desired.

PARALLEL OPERATION

For higher current loads, two or more Power Supplies can be connected in parallel, as shown in Figure 7. Use the following steps for parallel connections.

1. Determine the voltage required and, using a DC voltmeter, preadjust the VOLTAGE control of each Power Supply to this value. Do this before making any connections to any of the Power Supplies.
2. Turn the Power Supplies OFF.
3. Place a $.1 \Omega$ to $.2 \Omega$ resistor (not supplied) in series with the positive (+) lead of each Power Supply as shown. Do not connect the load at this time.
4. Connect together the negative (-) binding posts of all Power Supplies.
5. Connect the load as shown in Figure 7.

Unless current limiting is required, operate all the Power Supplies with the CURRENT controls at Maximum. If current limiting is required, set the CURRENT controls of all Power Supplies just above the point where the limiting occurs. Also remember that each time you change the voltage setting of one of the Power Supplies, you must also change the others by an equal amount. If this is not done, one Power Supply may load the others.

NOTE: It is important that approximately equal currents be drawn from each of the Power Supplies. This will occur when the voltage output of all Supplies are equal. To balance the voltage outputs, connect a DC voltmeter between the positive (+) binding posts of adjacent Supplies, and adjust the VOLTAGE control of either Supply until a zero indication is obtained. Repeat this procedure with all connected Supplies.

CAUTION: This instrument is not intended for use as a battery charger. To use it for this purpose, it is necessary to use an external circuit, such as a series connected diode, to protect the power supply from damage caused by reverse current.

REFERENCE

For information on the design of regulated DC power supplies, refer to the Kepco Power Supply Handbook by Paul Birman, published by Kepco, Inc., Flushing, New York, 11352.

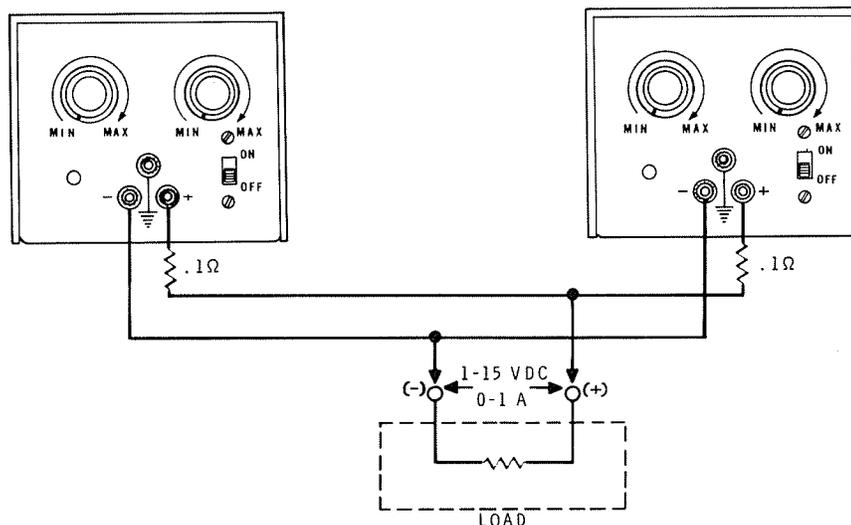


Figure 7

IN CASE OF DIFFICULTY

1. Recheck the wiring. Trace each lead in colored pencil on the Pictorial as it is checked. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something consistently overlooked by the builder.
2. About 90% of the kits that are returned for repair do not function properly due to poor connections and soldering. Therefore, you can eliminate many troubles by reheating all connections to make sure that they are soldered as described in the Kit Builders Guide.
3. Check the values of the parts. Be sure that the proper parts have been wired into each circuit, as shown in the Pictorial diagrams and as called out in the wiring instructions.
4. Check for bits of solder, wire ends or other foreign matter which may be lodged in the wiring.
5. If, after careful checks, the trouble is still not located and a voltmeter is available, check voltage readings against those shown on the Schematic Diagram. NOTE: All voltage readings were taken with an 11 megohm input voltmeter. Voltages may vary as much as $\pm 10\%$.
6. A review of the Circuit Description may help you locate the trouble.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover.

Troubleshooting Chart

SYMPTOM	POSSIBLE CAUSE
No output voltage (pilot lamp lights).	<ol style="list-style-type: none"> 1. Diodes D1 and D2 faulty. 2. Transistor Q3 faulty or shorted to chassis. If faulty, also check Q2 and Q4. 3. Capacitors C1, C2, C3, or C4 shorted or faulty. 4. Transformer T1 faulty or improperly wired. 5. F1 open.
Low output voltage (no voltage control).	<ol style="list-style-type: none"> 1. Diode D3 faulty. 2. Diode D4 shorted. 3. Diode D5 open. 4. Transistor Q4 faulty. If faulty, also check D5. 5. Transistor, Q3 faulty or shorted to chassis. If faulty, also check Q2 and Q4. 6. Transistor Q2 faulty. 7. Capacitor C2 or C5 shorted.
High output voltage (no voltage control).	<ol style="list-style-type: none"> 1. Transistor Q4 faulty. If faulty, also check D5. 2. Transistor Q2 faulty. 3. Transistor Q3 faulty or shorted to chassis. If faulty, also check Q2 and Q4.
No current output (voltage normal).	<ol style="list-style-type: none"> 1. Transistor Q5 faulty. 2. Transistor Q1 faulty. 3. Control R6 open. 4. Resistor R7 open.
Current limiting inoperative.	<ol style="list-style-type: none"> 1. Control R6 shorted. 2. Transistor Q5 faulty.
Excessive ripple.	<ol style="list-style-type: none"> 1. Capacitor C1, C2, C3, or C5 faulty.
Low output voltage with ripple.	<ol style="list-style-type: none"> 1. Diodes D1 or D2 open. 2. Capacitors C1, C2, C3, or C5 leaky.
Poor regulation.	<ol style="list-style-type: none"> 1. Diode D4 open (line regulation only). 2. Transistor Q4 faulty (load regulation only). 3. Transistor Q1 faulty (line and load regulation). 4. Transistor Q2 faulty (line and load regulation). 5. Transistor Q3 faulty (line and load regulation).

THEORY OF OPERATION

Qualifications for a perfect power supply would include zero internal resistance, a feature that is theoretically ideal but not practically possible. When a load is connected to the output terminals, the voltage tends to decrease due to the increased current flow through the internal resistance. A common example of this loss due to the internal resistance of a power supply can be seen when the lights on a car dim as the engine is being started. The automobile storage battery, which is the power supply in this case, contains enough internal resistance to present reduced voltage to the car during the heavy current drain by the starter motor. This reduced voltage causes the lights to dim.

A regulated Power Supply is designed to simulate an ideal zero internal resistance condition. This is done by using automatic correction (regulating) circuits to hold the output voltage at a constant level.

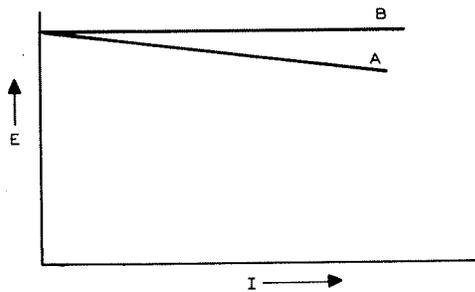


Figure 8

In Figure 8, line A represents the output of a typical unregulated power supply. As the current (I) increases, the voltage (E) decreases. Line B represents a regulated Power Supply where the voltage remains constant with increasing current.

Figure 9 shows a basic voltage regulated power supply, where E_S is a DC voltage source, and R_I is the internal resistance of the voltage source. E_{REF} is an independent reference voltage source of the same voltage as desired from the output. When a load, R_L , is applied to the output terminals, current flows. This current flow causes a voltage drop across R_I and R_R , causing the voltage between the positive (+) and negative (-) output terminals to drop.

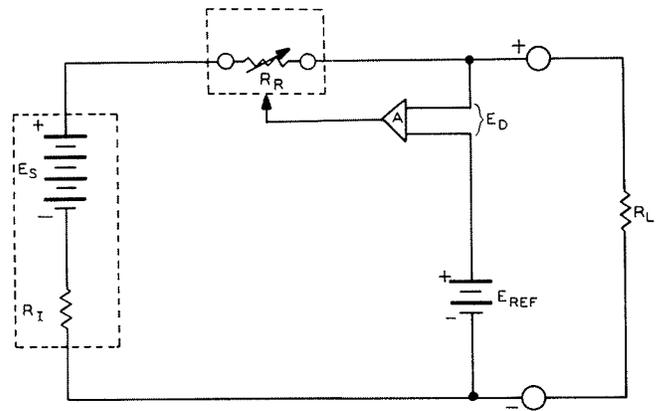


Figure 9

At the same time, the difference voltage, E_D , occurs at the input of amplifier A. This difference is amplified in A to produce a usable error signal. The error signal is then transferred to some form of variable resistance, such as a transistor (R_R), in series with the load path.

Now, when the output voltage starts to decrease, the error voltage causes resistance R_R to decrease also. This causes less voltage to be dropped across R_R and compensates for the voltage drop across R_I . Thus, when the voltage drop across R_I increases, the voltage across R_R decreases by an equal amount and the output voltage is held at the same level.

Although the foregoing is a simplified description of the regulating action, the important point to remember is that a feedback system of the correct value and speed can be made to perform the regulating function. It can also be seen that the original supply voltage must be considerably higher than the desired output voltage, in order to compensate for the voltage drop in series resistance R_R and internal resistance R_I .

It is desirable to limit the current that can be drawn from a regulated power supply in order to protect both the load and the supply. The current curve for such a condition is shown in Figure 10, where the voltage remains constant for all currents up to a predetermined value and then drops, while the current remains nearly constant.

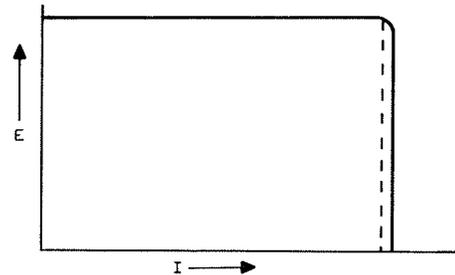


Figure 10

CIRCUIT DESCRIPTION

This Regulated Power Supply consists of four sections: the power source, the reference voltage source, regulator circuit, and the current limiter. Each of these sections will be described separately in this Circuit Description. Refer to the Schematic Diagram (on the illustration sheet) while you read this Description.

POWER SOURCE

Transformer T1 is equipped with a dual primary winding which can be wired to operate from either a 120 VAC or a 240 VAC, 50/60 Hz power source. The primary windings are connected in parallel for 120 VAC operation and in series for 240 VAC operation.

The output voltage source consists of a full wave rectifier circuit composed of diodes D1 and D2, and a pi-type filter composed of capacitors C1 and C3, and resistor R1.

REFERENCE VOLTAGE SOURCE

The reference voltage source consists of a half-wave rectifier and filter system composed of diode D3, capacitor C2, resistor R2, and a voltage-regulating zener diode, D4. Provisions are made, through the Programming terminal strip, for the substitution of an external reference voltage source, and for the use of AC programming.

REGULATOR CIRCUIT

Transistors Q2 and Q3 are directly connected in a Darlington circuit, which may be considered as a single high-power, high-gain transistor.

This transistor combination is driven by a voltage divider across the power source. One side of the divider is a constant current source composed of Q1 and R5 installed between the base of Q2 and the positive (+) side of the power source. The other side of the divider is formed by Q4 installed between the base of Q2 and the negative (-) side of the power source.

When Q4 is not turned on, the constant current source biases the pass transistor (Q2, Q3) on, producing maximum output voltage. The reference voltage, between output terminal and the base of Q4, provides base drive for Q4. Some of the constant current from Q1 is passed to the negative (-) side of the power source, leaving less drive for the pass transistor. A balanced condition will be reached, depending on the reference voltage, where the output voltage will be equal to the reference voltage plus the base-emitter drop in Q4 and the drop across D5.

Increased current drain causes the output voltage to decrease slightly, lowering the drive to Q4. Thus, more drive is available for the pass transistor, which returns the output voltage practically to the original level.

CURRENT LIMITER

The current limiter is composed of transistor Q5, Current control R6, and resistor R7, which act in conjunction with transistors Q2 and Q3.

Transistor Q5 acts as a current sensing transistor. When sufficient current flows through R6 and R7 to produce a voltage drop of .6 V, Q5 conducts and effectively shorts the base to the emitter of the Darlington pair (Q2, Q3). This lowers the output voltage to limit the output current of the Supply. The point at which this happens is determined by the setting of Current control R6 which varies the resistance of Current control R6 which varies the resistance and thus the current level where .6 V is produced.

FUNCTIONAL PARTS LIST

R1 - Part of a low-pass filter consisting of C1, C3, and R1 that is used to smooth out the rectified DC. Also acts as a current limiter.

R2 - Part of a low-pass filter consisting of C2, D4, and R2. Also acts as a voltage dropping resistor for D4.

R3, R4 - Adjustable voltage divider on output of reference voltage supply. Determines the output voltage of the Power Supply. R3 serves to limit the range of R4 (Voltage control).

R5 - Source resistor for Q1. Determines the current level in Q1.

R6, R7 - Current-limiting control and resistor. Connected in series with the output, presenting a voltage drop from the base to emitter of Q5. Current limiting starts at a voltage drop of .6 volt. R7 determines the maximum current output.

R8 - Current-limiting resistor for neon lamp PL-1.

R9 - Minimum load resistor. Maintains current flow at the output at all times.

C1, C3 - Part of a low-pass filter consisting of C1, C3, and R1 that is used to smooth out the rectified DC in the main Power Supply.

C2 - Part of a low-pass filter consisting of C2, D4, and R2 that is used to smooth out the rectified DC in the reference voltage supply.

C4 - Output filter capacitor. Lowers the output impedance of the Power Supply.

C5 - Part of a low-pass filter consisting of R3 and C5 to eliminate ripple and noise in the reference voltage supply.

D1, D2 - Silicon diodes. Connected as a full-wave rectifier for the main Power Supply.

D3 - Silicon diode. Connected as a half-wave rectifier for the reference voltage supply.

D4 - Zener diode voltage regulator for the reference voltage supply. Also simulates a capacitor in the low-pass filter consisting of C2, R2, and D4.

D5 - Germanium diode to protect Q4 against reverse base-emitter voltage.

Q1 - Field-effect transistor. Connected with R5 as a constant current source for the base of Q2.

Q2 - Driver transistor for Q3 in a Darlington circuit.

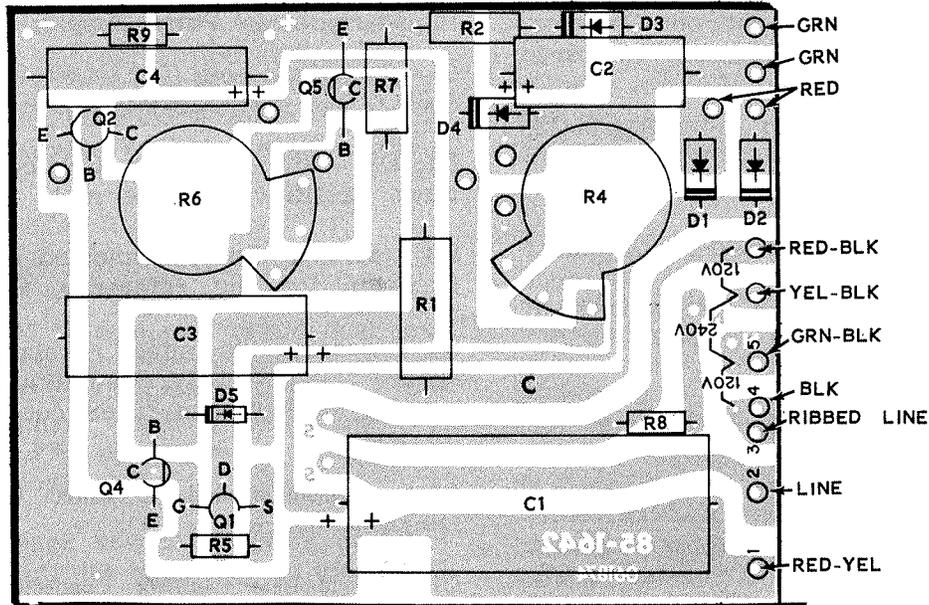
Q3 - Series regulator transistor which acts as a variable resistor to control the voltage and current output of the Power Supply.

Q4 - Error detector transistor. Senses any difference between the output voltage and the reference voltage and corrects by varying the base-bias of Q2.

Q5 - Current sensing transistor. Conducts and turns Q2 and Q3 off when sufficient current flows through R6 and R7 to develop a voltage drop of .6 volts.

CIRCUIT BOARD X-RAY VIEW

(VIEWED FROM COMPONENT SIDE)



SPECIFICATIONS

Voltage Output.	1-15 VDC, continuously adjustable.
Load Regulation.	Less than 50 mV variation from no load to full load.
Line Regulation.	Less than 50 mV variation in output voltage for a 10% change in line voltage.
Ripple And Noise.	Less than 5 mV.
Current Output.	500 mA maximum continuous load.
Current Limiting.	Adjustable from 10 mA to over 500 mA.
Transient Response.	25 μ s.
Output Impedance.5 Ω or less to 100 kHz.
Power Requirements.	105 to 125 or 210-250 VAC, 50/60 Hz, 15 watts at full load.
Dimensions.	5-1/2" wide x 4-3/8" high x 5-3/4" deep.
Net Weight.	3-1/4 lbs.

The Heath Company reserves the right to discontinue products and to change specifications at any time without incurring any obligation to incorporate new features in products previously sold.

CUSTOMER SERVICE

REPLACEMENT PARTS

Please provide complete information when you request replacements from either the factory or Heath Electronic Centers. Be certain to include the **HEATH** part number exactly as it appears in the parts list.

ORDERING FROM THE FACTORY

Print all of the information requested on the parts order form furnished with this product and mail it to Heath. For telephone orders (parts only) dial 616 982-3571. If you are unable to locate an order form, write us a letter or card including:

- Heath part number.
- Model number.
- Date of purchase.
- Location purchased or invoice number.
- Nature of the defect.
- Your payment or authorization for COD shipment of parts not covered by warranty.

Mail letters to: Heath Company
Benton Harbor
MI 49022
Attn: Parts Replacement

Retain original parts until you receive replacements. Parts that should be returned to the factory will be listed on your packing slip.

OBTAINING REPLACEMENTS FROM HEATH ELECTRONIC CENTERS

For your convenience, "over the counter" replacement parts are available from the Heath Electronic Centers listed in your catalog. Be sure to bring in the original part and purchase invoice when you request a warranty replacement from a Heath Electronic Center.

TECHNICAL CONSULTATION

Need help with your kit? — Self-Service? — Construction? — Operation? — Call or write for assistance. you'll find our Technical Consultants eager to help with just about any technical problem except "customizing" for unique applications.

The effectiveness of our consultation service depends on the information you furnish. Be sure to tell us:

- The Model number and Series number from the blue and white label.
- The date of purchase.
- An exact description of the difficulty.
- Everything you have done in attempting to correct the problem.

Also include switch positions, connections to other units, operating procedures, voltage readings, and any other information you think might be helpful.

Please do not send parts for testing, unless this is specifically requested by our Consultants.

Hints: Telephone traffic is lightest at midweek — please be sure your Manual and notes are on hand when you call.

Heathkit Electronic Center facilities are also available for telephone or "walk-in" personal assistance.

REPAIR SERVICE

Service facilities are available, if they are needed, to repair your completed kit. (Kits that have been modified, soldered with paste flux or acid core solder, cannot be accepted for repair.)

If it is convenient, personally deliver your kit to a Heathkit Electronic Center. For warranty parts replacement, supply a copy of the invoice or sales slip.

If you prefer to ship your kit to the factory, attach a letter containing the following information directly to the unit:

- Your name and address.
- Date of purchase and invoice number.
- Copies of all correspondence relevant to the service of the kit.
- A brief description of the difficulty.
- Authorization to return your kit COD for the service and shipping charges. (This will reduce the possibility of delay.)

Check the equipment to see that all screws and parts are secured. (Do not include any wooden cabinets or color television picture tubes, as these are easily damaged in shipment. Do not include the kit Manual.) Place the equipment in a strong carton with at least **THREE INCHES** of *resilient* packing material (shredded paper, excelsior, etc.) on all sides. Use additional packing material where there are protrusions (control sticks, large knobs, etc.). If the unit weighs over 15 lbs., place this carton in another one with 3/4" of packing material between the two.

Seal the carton with reinforced gummed tape, tie it with a strong cord, and mark it "Fragile" on at least two sides. Remember, the carrier will not accept liability for shipping damage if the unit is insufficiently packed. Ship by prepaid express, United Parcel Service, or insured Parcel Post to:

Heath Company
Service Department
Benton Harbor, Michigan 49022



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